MARINE MAMMAL MONITORING AND MITIGATION DURING A MARINE SEISMIC SURVEY BY ION GEOPHYSICAL IN THE ARCTIC OCEAN, OCTOBER–NOVEMBER 2012: 90-DAY REPORT

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LIST OF ACRONYMS AND ABBREVIATIONS

~	approximately
AKDT	Alaska Daylight Time
AMAR	Autonomous Multichannel Acoustic Recorder
BOEM	Bureau of Ocean Energy Management, Regulation
Bf	Beaufort Wind Force
BSEE	Bureau of Safety and Environmental Enforcement
C	Celsius (degrees)
cm	centimeter
CPA	Closest (Observed) Point of Approach
CTD	Conductivity, Temperature, Depth
dB	decibel(s)
DP	Dynamic Positioning
DPS	Distinct Population Segments
ESA	(U.S.) Endangered Species Act
F	Fahrenheit (degrees)
$f(0)$	sighting probability density at zero perpendicular distance from survey track; equivalently, 1/(effective strip width)
FFT	Fast Fourier Transform
ft	feet
GIS	Geographic Information System
GPS	Global Positioning System
$g(0)$	probability of seeing a marine mammal or group located directly on a survey line
h	hour(s)
Hz	Hertz (cycles per second)
IHA	Incidental Harassment Authorization (under U.S. MMPA)
in	inches
in^3	cubic inches
kHz	kilohertz
km	kilometer
km^2	square kilometers
km/h	kilometers per hour
ksps	kilo-samples per second
kt	nautical mile(s) per hour
lb	pound
LOA	Letter of Authorization (under U.S. MMPA)
µPa	micro Pascal
m	meter(s)
mi	statute mile
min	minute(s)
MMO	Marine Mammal Observer
MMPA	(U.S.) Marine Mammal Protection Act
ms	millisecond
n	sample size

NMFS	(U.S.) National Marine Fisheries Service
OBH	Ocean Bottom Hydrophone
OCS	Outer Continental Shelf
psi	pounds per square inch
PSO	Protected Species Observer
PTS	Permanent Threshold Shift
rms	Root-Mean-Square: an average, in the present context, over the duration of a sound pulse
RSL	Received Sound Level
s	seconds
s.d.	standard deviation
SEL	Sound Exposure Level: a measure of energy content, in dB re 1 $\mu Pa^2 \cdot s$
SPL	Sound Pressure Level; the SPL for a seismic pulse is equivalent to its rms level
SSV	Sound Source Verification
USFWS	United States Fish and Wildlife Service
UTC	Universal Time, Coordinated
yd	yard(s)

EXECUTIVE SUMMARY

Background and Introduction

This report summarizes the operational activities, mitigation, and monitoring efforts performed by ION Geophysical (ION) during the 2012 2D seismic survey in the Beaufort and Chukchi seas. The seismc source vessels was the M/V *Geo Arctic* and the escort icebreaker was the M/V *Polar Prince*.

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.

ION's 2D seismic survey was conducted under the jurisdiction of an Incidental Harassment Authorizations (IHA) issued by the NMFS and a Letters of Authorization (LOA) issued by the USFWS, as well asa Geological and Geophysical permit issued by the BOEM. 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 and monitoring program was implemented to avoid or minimize potential effects of ION's marine surveys on marine mammals and subsistence hunting, and to ensure that ION was in compliance with the provisions of the IHA and LOA. This required that protected species observers (PSOs) onboard the *Geo Arctic* and the *Polar Prince* detect marine mammals within or about to enter the designated safety radii, and in such cases request an immediate power down (or shut down if necessary) of the airguns. It 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 strong seismic pulses or coring sounds; and
3. determine the reactions (if any) of marine mammals to industrial sounds.

This 90-day report describes the methods and results of the monitoring conducted to meet the above primary objectives.

Seismic Survey Operations Described

The geophysical survey (seismic reflection/refraction) planned by ION Geophysical was to occur primarily in the Alaskan Beaufort and Chukchi seas from 1 October to as late as mid-December, 2012. Most of the planned survey lines were in the Alaskan Beaufort Sea; however, two survey lines extended west past Point Barrow into the Chukchi Sea and there were three short tie lines near the U.S.–Russian border in the north-central Chukchi Sea. The bathymetry along the planned survey lines ranged from

shallow (<20 m) to relatively deep (>3500 m) water over the continental shelf, the continental slope, and the abyssal plain.

The seismic survey vessel (M/V *Geo Arctic*) used a 26-airgun configuration (4380 in^3 total airgun volume; which is less than the initially proposed 4450 in^3 airgun array) for seismic data acquisition and a single 70 in^3 airgun for mitigation purposes. Due to expected ice conditions at the time of the planned survey, an icebreaker was contracted to escort the seismic survey vessel when ice conditions were present. The M/*V Geo Arctic* was escorted by the medium class (100A) icebreaker M/V *Polar Prince* during some survey operations in open-water and during most (~97%; 360 km or 224 mi) survey operations in heavily (≥80%) ice-covered waters. Detailed descriptions of these vessels and their equipment can be found in Appendix A. Protected species observers (PSOs) aboard the *Geo Arctic* and the *Polar Prince* collected data and requested mitigation measures, as necessary, during the operations.

The start of the survey was delayed due to vessel availability such that seismic survey activities did not begin until 20 Oct with the initiation of sound source measurements in the southeastern portion of the survey area. The measurements were completed on 23 Oct and seismic data collection began on 24 Oct. During survey operations on 30 Oct the two spare airguns in the array were unintentionally activated resulting in a total array discharge volume of 4880 in^3. This incident was immediately reported to the regulatory agencies. Survey activities continued in the Beaufort Sea until 9 Nov, at which time the seismic equipment was recovered and the vessels transited to the Chukchi Sea. One seismic line in the Chukchi Sea was surveyed on 14 and 15 Nov before the vessels began transiting south to Dutch Harbor.

ION collected 1844 km (1146 mi) of seismic data in the Beaufort and Chukchi seas in 2012. Periods of full array firing including periods of lead in, lead out, seismic testing, and ramp up occurred along 2408 km (1496 mi) of trackline. During turns from one seismic line to the next, testing 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 583 km (362 mi) of vessel trackline. Thus, one or more airguns were operated along 2991 km (1858 mi) of total trackline in the Beaufort and Chukchi seas in 2012.

Underwater Sound Measurements

ION's authorization and permits from regulatory agencies stipulated the measurement of underwater sound levels from certain noise-generating sources. The measurements were analyzed to determine the distances at which broadband sound levels reached the level A (auditory injury) and level B (behavioral disturbance) take criteria 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 issued by NMFS also required the distances that corresponded to sound levels from 120 to 190 dB re 1 μPa (rms) be reported in 10 dB steps.

Acoustic measurements were performed from the support vessel M/V *Polar Prince*. The sound sources characterized were a 4380 in^3 airgun array that consisted of 26 active airguns, and a single 70 in^3 airgun, used as a mitigation source. The single 70 in^3 airgun was used during turns and brief periods between full airgun array operations to discourage marine mammals from approaching and being exposed to higher-level sounds from the 4380 in^3 array when it was ramped up. This study monitored both airgun sources and vessel noise from the *Geo Arctic* and *Polar Prince*.

Sound measurements were made with JASCO's autonomous Ocean Bottom Hydrophone (OBH) recorders in two different configurations depending on the measurement location depth. Sounds from

airguns were measured at two sites: Shallow (nominal water depth 50 m, 164 ft) and Deep (nominal water depth 500 m, 1640 ft). Sounds at the Shallow site were measured using three seafloor-mounted recorders. Sounds at the Deep site were measured using one recorder tethered to the Polar Prince and deployed over the side of the vessel. The recorder was lowered to 50 m depth for the recordings and was periodically repositioned to measure sounds at different distances from the airgun sources. Each OBH recorded two channels of acoustic data sampled at 96 ksps using two types of hydrophones: a lower sensitivity Reson TC4043 and a higher sensitivity Reson TC4032. All hydrophones were calibrated by Reson. G.R.A.S. 42AC pistonphone calibrators in the field immediately before and after each measurement; calibration results are included in the Appendix to this report.

Distances to sound level thresholds from the 4380 in^3 airgun array and 70 in^3 mitigation airgun operating at both sites are given in Table ES-1. Distances to 120 dB re 1 µPa (rms) for the *Geo Arctic* and *Polar Prince* transiting at the Shallow site were 1420 (0.88 mi) and 943 m (0.59 mi), respectively. Vessel noise was not measured at the Deep site. Sounds from the *Polar Prince* conducting icebreaking activities were not measured as no ice present in the area at that time of the measurements.

Comparing SSV measurements to pre-season modeling results showed the geoacoustic environment of the survey area was not well characterized. We performed new modeling to improve the characterization; Chapter 3 includes the improved geoacoustic profiles. Future pre-season modeling studies would benefit from a sensitivity analysis of environmental parameters to characterize the uncertainty in model estimates.

Table ES-1. Threshold distances (m) for the 4380 in^3 airgun array and 70 in^3 mitigation airgun for two depth environments.

rms SPL threshold (dB re 1 µPa)	Threshold distances for the 4380 in^3 airgun array		Threshold distances for the 70 in^3 mitigation airgun	
	<100 m depth	>100 m depth	<100 m depth	>100 m depth
190	287*	395**	24*	23**
180	2 290	1 250**	94*	74**
170	9 260	2 930	362*	234**
160	18 700	6 260	1 360	741**
150	29 000*	13 400	4 690	1 990*
140	51 600	28 600*	13 400	5 100
130	78 700*	61 200*	29 600	13 000*
120	109 000*	131 000*	52 000	33 400*

*Extrapolated beyond measurement range using the 90% fit.

**Extrapolated by back-propagating the loudest measured pulse using spherical spreading (i.e., 20LogR).

Marine Mammal Monitoring

PSOs aboard the *Geo Arctic* and *Polar Prince* were on watch for a total of 5396 km (3353 mi; 606 h) during this project. Of this total, 2313 km (1437 mi; 267 h) of observation effort was from the *Geo Arctic* and 3083 km (1916 mi; 339 h) was from the *Polar Prince*. The majority of the total observation effort occurred in the Beaufort Sea (75% and 74%, respectively).

During ION's seismic survey activities in the Chukchi and Beaufort seas, PSOs observed a total of 471 sightings of 2404 marine mammals from the two survey vessels. Nearly all (96%; *n*=451) of the marine mammal sightings recorded during ION's seismic program occurred during three distinct locations over four days (Nov 11, 14-15, and 16; Fig. ES-1).

On Nov 11th during the transit from the Beaufort Sea portion of the study area to the Chukchi Sea, the PSOs on the *Geo Arctic* and *Polar Prince* observed 92 seal sightings of 125 individual seals over a 5.5 h period of time. These seal sightings accounted for 88% of the total seal sightings observed during operations in the Beaufort Sea. The seal sightings on Nov 11th ranged from 67 to 78 km (42 to 48 mi) offshore and were predominately (83%; *n*=76) in water depths ≥50 m (55 yd). During observations in the Beaufort Sea on Oct 21st when the *Geo Arctic's* airguns were off and there were similar visibility and Beaufort wind force conditions as on Nov 11th, the two vessels observed no seals while in open-water and in water depths ≥200 m (656 ft). The difference between the number of seal sightings during these two days suggest that certain habitat factors like water depth and ice conditions may have influenced the number of seals encountered on Nov 11th.

During survey operations along the southernmost seismic survey line near the U.S.–Russian border in the north-central Chukchi Sea, PSOs aboard the two vessels observed 38 sightings of 80 individual bowhead whales on Nov 14th and 15th. These sightings accounted for all but one of the bowhead whale sightings recorded during the 2012 ION survey. The majority (89%, *n* = 34) of the bowhead whale sightings observed on Nov 14th and 15th from the *Geo Arctic* and the *Polar Prince* were during periods while the airguns were operating. Most (*n* = 30) of the bowhead whale sightings observed during periods of airgun activity occurred while the full array was active on Nov 14th. The remaining four sightings occurred while the single mitigation airgun was firing on Nov 15th. The mean closest point of approach (CPA) of the bowhead whale sightings to the *Geo Arctic's* airgun array during seismic activity was 3057 m (1.90 mi; *n*=16), while the mean CPA was 3705 m (2.30 mi; *n* = 4) during non-seismic periods.

Based on results provided in the sound source measurement field report, PSOs aboard the vessels were implementing an 832 m (0.52 mi) safety zone for cetaceans in the Chukchi Sea where water depths were <100 m (328 ft). The closest approach of a whale to the operating airgun array was 870 m (0.54 mi) so no power-downs were requested by the PSOs. However, during post-season analysis of the acoustic data it was determined that the field-report results for the safety radii in shallow waters were erroneous and the ≥180 dB (rms) safety zone should have been 2290 m (1.42 mi). This meant that 7 sightings (of 10 bowhead whales) may have been exposed to received sound levels ≥180 dB (rms). No other marine mammal sightings triggered (or should have triggered, based on the final analysis of the acoustic data) a power-down or shutdown of the airgun.

After concluding the 2012 seismic survey program in the north-central Chukchi Sea on Nov 15th, the ION vessels began to transit south towards Dutch Harbor. On Nov 16th, when the vessels were just south of Point Hope, the observers aboard both vessels began to encounter many Pacific walruses. During a 5.5 h period on Nov 16th, the PSOs aboard the *Geo Arctic* and *Polar Prince* observed 179 sightings of 1728 individual Pacific walruses. Nearly all (97%; *n*=174) of these sightings were of animals in the water. Both vessels initially altered course to avoid approaching within 0.5 miles (800 m) of the walruses, as per the USFWS LOA stipulations. However, due to the large number of walruses all around the vessels it was not possible to remain 0.5 miles (800 m) distant at all times, so the vessels reduced speed from approximately 10 kts (11.5 mph) to between 4-5 kts (4.6-5.8 mph) and attempted to stay 0.5 miles (800 m) from only the larger groups of walruses. In addition, both vessels made sure to not approach within 0.5 miles (800 m) of the few individuals on ice to avoid the possibility of a stampede event.

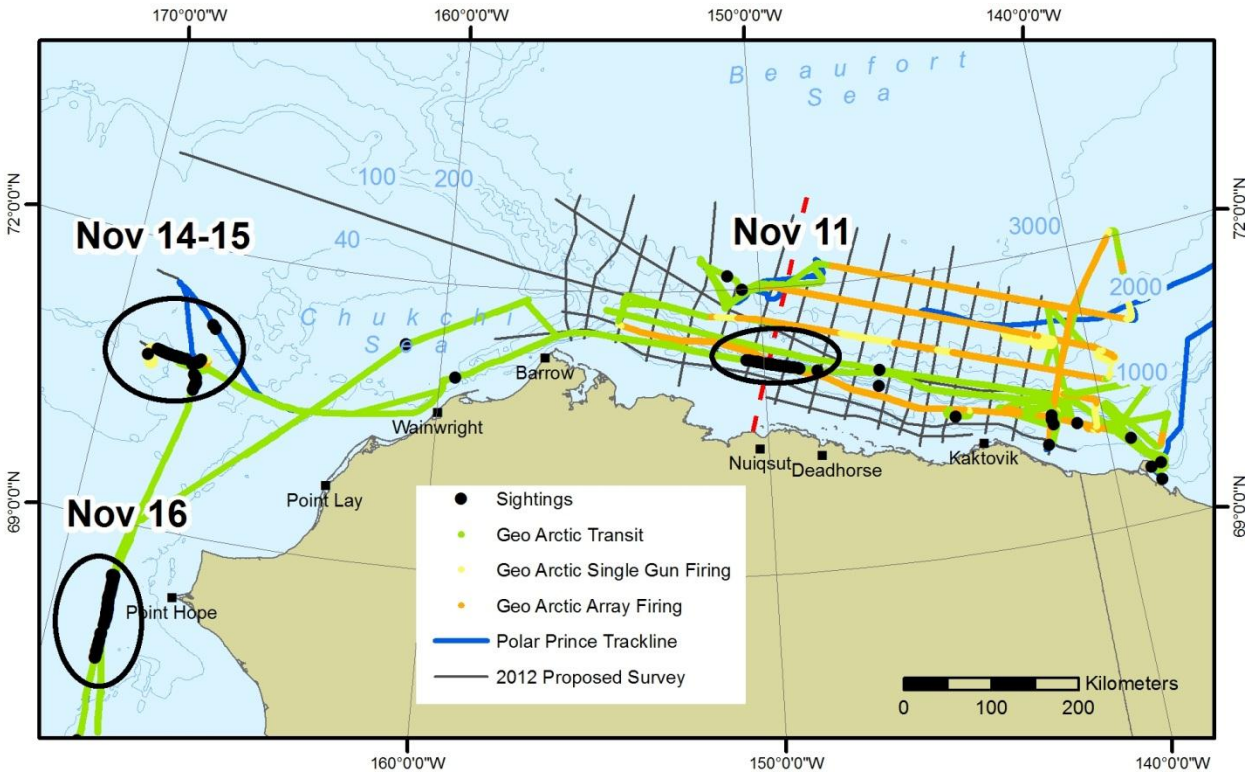

FIGURE ES-1. All marine mammal observations and vessel tracklines during ION Geophysical's seismic survey in the Beaufort and Chukchi Seas, 12 Oct – 16 Nov 2012. The three periods of concentrated marine mammal sightings noted by date on the map account for 96% of all sightings recorded during the survey.

Summary of Marine Mammals Potentially Effected

No power downs or shut downs of the airguns were requested for any marine mammals as all sighting occurred outside the safety zones provided to PSOs during the field season. Based on direct observations, 64 bowhead whales, 2 seals, and no Pacific walruses or polar bears were likely exposed to airgun sounds above the 160 dB (rms) disturbance threshold.

Based on densities calculated from observational data collected during the survey, ~3,233 bowhead whales may have been present during survey activities in the Chukchi Sea; however, this estimate may be biased somewhat high by extrapolating a density from a high concentration area over the entire area exposed to seismic sounds ≥160 dB (rms) in the Chukchi Sea. Very few cetaceans were observed in the Beaufort Sea during either seismic or non-seismic periods so the number of cetaceans estimated to have been exposed during survey activities there was likely quite small.

Only two seals were observed in the water within the ≥160 dB (rms) radius of the operating airguns during the ION survey. However, density based calculations of exposures in both the Beaufort and Chukchi seas estimate that 1000–4500 seals may have been present in the water within the ≥160 dB zone.

No polar bears were observed in the water during either seismic or non-seismic periods of the ION survey; therefore, both estimation methods results in zero polar bears being potentially exposed to seismic sounds ≥160 dB. Similarily, Pacific walruses were only observed during a single day while the vessels

transit south of Pt. Hope where no seismic activity occurred. Thus, it is unlikely that many, if any, walruses were present during the survey activities.

Night Observations

Observers on the *Polar Prince* performed routine observations at night using both a night vision device (NVD) and a forward looking thermal imaging (FLIR) camera system to test and assess their usefulness for monitoring in darkness. The NVD used was a U.S. Night Vision model AN/PVS-7B, a third generation auto-gated night vision goggle. The thermal imaging camera used was model M626L manufactured by FLIR Systems Inc. These devices were used between 2-4 h each night during twilight and darkness periods (~122 h in total).

The NVD was most useful when there was still a small amount of ambient light present. These included nights with low cloud cover (excluding fog), or no clouds and some moon light. The low cloud cover helped to reflect the vessel lights and greatly increased the ambient light in the water around the vessel. Nights with fog, no ambient light, or heavy seas made observations nearly impossible and the devices were not often used in those conditions. Additionally, the vessels exterior lights (spotlights or deck lights) and/or internal bridge lights often severely limited the usefulness of the NVD from inside the bridge. Observers on the *Polar Prince* estimated the night-vision goggles effective range to be between 10 m (11 yd) and 1000 m (0.62 mi) depending on the lighting and environmental conditions. Based on comments from the observers the NVD appeared to have a much narrower field of view than the FLIR. Where the NVD excelled was in detecting lighted sources, as in distant vessels or lighted buoys.

The infrared camera system (FLIR) used during the 2012 ION survey was able to detect the temperature differences between objects (including marine mammals) and their surrounding environment. During favorable sighting conditions, a high contrast object was easily detected on the FLIR system by the observer. The FLIR system had environmental limitations similar to NVD; ineffective in fog, heavy snow conditions, high sea state, etc., but it also had advantages. The images from the camera were displayed on a computer monitor that could be dimmed and observed for much longer periods without eye fatigue (and neck strain) than the night-vision goggles. The FLIR system was also far less sensitive to the surrounding light conditions than the night-vision goggles and could be used during daytime and night-time operations. The FLIR system was estimated by observers to have an effective range between 10 m (11 yd) and 6000 m (3.73 mi) depending on the lighting and environmental conditions.

Observers on the *Polar Prince* were able to occasionally sight birds and other objects, such as logs, if they were near the vessel and sighting conditions were good. Most of the birds and objects were first sighted by the observer using the FLIR system, and then would be confirmed by the NVD observer when they were told where the object was located. Only two marine mammal sightings were made during darkness periods. The first marine mammal sighting was of a seal on ice. The FLIR system was able to effectively detect the temperature difference between the seal and the ice and project an image on the computer monitor that was discernible enough to tell the object was a seal. The NVD observer subsequently tried to locate the seal on ice, but was unable to do so. The second sighting was of seal in water that was initially detected with the NVD and then subsequently spotted with the unaided eye. The FLIR observer attempted, but could not observe the seal in water on the monitor. In addition to those two sightings, the FLIR system was able to detect a few individual Pacific walruses in water when it was used opportunistically during the daytime on Nov 16th. The image of the Pacific walruses on the FLIR monitor was quite grainy, but the outline of their bodies in water was distinguishable.

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Geo Arctic	***Polar Prince***
Meike Holst	Joe Beland
Heather Smith	Suzanne Yin
Freddie Kaleak	Tim Burris
Colin Gordon	Spencer Mangelana
Stanley Felix	

1. BACKGROUND AND INTRODUCTION[1]

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). The effects could consist of behavioral or distributional changes, and perhaps (for animals very close to the sound source) temporary or permanent reduction in hearing sensitivity. Potential effects, however, may be reduced by marine mammals moving away from approaching sound sources (Reiser et al. 2009; Richardson et al. 1995, 1999; Stone and Tasker 2006; Gordon et al. 2004; Smultea et al. 2004). Either behavioral/distributional effects or auditory effects (if they occur) could constitute "taking" under the provisions of the U.S. Marine Mammal Protection Act (MMPA) and the U.S. Endangered Species Act (ESA), at least if the effects are considered to be "biologically significant."

A number of species of cetaceans and pinnipeds inhabit parts of the Arctic Ocean. The National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) split jurisdiction over the marine mammal species that could be encountered during offshore industrial activities in this region. Three species under NMFS jurisdiction that may occur there are listed as "Endangered" under the ESA, including bowhead whale (*Balaena mysticetus*), humpback whale (*Megaptera novaeangliae*), and fin whale (*Balaenoptera physalus*). NMFS recently initiated status reviews to determine if listing as endangered or threatened under the ESA was warranted for four other species including ringed seal (*Phoca fasciata*), spotted seal (*Phoca largha*), bearded seal (*Erignathus barbatus*), and ribbon seal (*Histriophoca fasciata*; NMFS 2008a,b). NMFS (2010a) determined that no listing action was warranted for the Bering Sea and Okhotsk populations of spotted seal. After completing a status review in 2008, NMFS (2008a,b,c) announced a finding that listing the ribbon seal under the ESA was not warranted. However, in August 2011, NMFS re-initiated a status review for the ribbon seal based on new information about the species and a determination is pending (NMFS 2011c). The Alaska stock of bearded seals, part of the Beringia distinct population segment, was proposed by NMFS for listing as threatened under the ESA (NMFS 2010b) and a final determination to list the population as threatened was released in December 2012 (NMFS 2012a). NMFS (2010c) also proposed four subspecies of ringed seal, including Arctic, Okhotsk, Baltic, and Ladoga, as threatened species and released a final determination to list them as threatened in December 2012 (NMFS 2012b). USFWS manages two marine mammal species occurring in the Chukchi and Beaufort seas, the Pacific walrus (*Odobenus rosmarus*) and polar bear (*Ursus maritimus*). The polar bear was recently listed as threatened under the ESA (USFWS 2008). A petition to list Pacific walrus as threatened or endangered was submitted to USFWS (CBD 2008). USFWS found that listing the Pacific walus under the ESA was warrented. However, USFWS believed listing the Pacific walrus was precluded by higher priority listing actions and therefore designated Pacific walrus as a candidate species on the ESA (USFWS 2011).

Because of the potential for marine mammals to be encountered during planned seismic surveys in the Beaufort and Chukchi seas during October–December 2012, ION Geophysical (ION) submitted an application to NMFS on 29 Feb 2012 for an Incidental Harassment Authorization (IHA) to authorize non-lethal "takes" of marine mammals incidental to ION's proposed activities. A notice announcing ION's request for an IHA was published in the *Federal Register* 17 August 2012 and public comments were

[1] By Lauren Bisson, Joe Beland, Darren Ireland (LGL Alaska Research Associates, Inc.)

invited (NMFS 2012c). An IHA allowing the proposed activities in the Beaufort and Chukchi seas was issued to ION by NMFS on 17 Oct 2012 which allowed operations to be conducted from 17 Oct 2012 through 15 Dec 2012 (NMFS 2012d). The IHA authorized "potential take by harassment" of various cetacean and seal species during the seismic survey described in this report.

Similarly, on 29 Feb 2012, ION requested a Letter of Authorization (LOA) from USFWS for the incidental "take" of polar bears and walrus during the seismic survey in the Beaufort and Chukchi seas in 2012. The USFWS issued a LOA on 17 Oct 2012 allowing ION to "take" small numbers of polar bears and Pacific walruses incidental to proposed activities occurring during the October-December 2012 period (USFWS 2012). The LOA was valid from 17 Oct 2012 through 31 Dec 2012.

Having received the necessary authorizations, as well as a geological and geophysical exploration permit from the Bureau of Ocean Energy Management, ION collected marine seismic data in the Beaufort and Chukchi seas. Seismic acquisition for ION was conducted using the M/V *Geo Arctic*, a seismic vessel that towed an airgun array as well as a hydrophone streamer to record seismic data. The *Geo Arctic* was assisted by the icebreaker M/V *Polar Prince.*

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 Beaufort and Chukchi seas, the methods and results of the marine mammal monitoring and mitigation program, 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, strong sounds were generated by *Geo Arctic*'s airgun array in order to collect seismic data in the Beaufort and Chukchi seas. 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 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 (e.g., NMFS 2011a,b), "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

[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 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.

pinnipeds. Those safety radii 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.

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 (Richardson et al. 1995). The NMFS assumes that marine mammals exposed to pulsed airgun sounds with received levels ≥160 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 dB (rms) criteria for pulsed sounds, but others may tolerate levels somewhat above 160 dB (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 ION authorized incidental level B harassment "takes" of one ESA-listed species, bowhead whale, as well as several non-listed species including gray whale (*Eschrichtius robustus*), Minke whale (*Balaenoptera acutorostrata*), beluga whale (*Delphinapterus leucas*), harbor porpoise (*Phocoena phocoena*), and ringed, spotted, bearded, and ribbon seals. The IHA issued by NMFS to ION also authorized incidental level A harassment takes for: one individual bowhead whale, three individual beluga whales, and four individual ringed seals.

NMFS granted the IHA to ION on the expectation that

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

The LOA issued to ION by USFWS was based on similar expectation as described for the IHA, and required ION to implement a 190 dB (rms) exclusion zone for polar bears and a 180 dB (rms) exclusion zone for walruses.

Mitigation and Monitoring Objectives

The objectives of the mitigation and monitoring program were described in detail in ION's IHA and LOA applications and in the IHA and LOA issued to ION. An explanation of the monitoring and mitigation requirements was published by NMFS in the *Federal Register* (NMFS 2012d).

The primary objectives of the monitoring program were to

- provide real–time sighting data needed to implement the required mitigation;
- estimate the numbers of marine mammals potentially exposed to strong seismic pulses; 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 Arctic Ocean are described in detail in Chapter 4.

The purpose of the mitigation program was to minimize potential effects of ION's seismic survey 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 to ensure that marine mammals were not near the airguns when operations began (see Chapter 4).

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 five chapters:

1. background and introduction (this chapter);
2. description of ION's seismic survey;
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 seismic survey vessel *Geo Arctic* and support icebreaker *Polar Prince* and estimates of potential "take by harassment";

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

A. descriptions of vessels and equipment;
B. sound source measurement results;
C. details of monitoring, mitigation, and analysis methods;
D. Beaufort wind force definitions;
E. marine mammal status and abundance in the Arctic Ocean;
F. marine mammal monitoring results during the Arctic Ocean surveys;
G. list of all marine mammal detections;

H. unidentified marine mammal detections;

I. weekly summary maps of vessel activity;

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2. OPERATIONS DESCRIBED[1]

Operating Areas and Dates

The geophysical survey (seismic reflection/refraction) planned by ION Geophysical was to occur primarily in the Alaskan Beaufort and Chukchi seas from 1 October to as late as mid-December, 2012. Most of the planned survey lines were in the Alaskan Beaufort Sea; however, two survey lines extended west past Point Barrow into the Chukchi Sea and there were three short tie lines near the U.S.–Russian border in the north-central Chukchi Sea (Fig. 2.1). The bathymetry along the planned survey lines ranged from shallow (<20 m) to relatively deep (>3500 m) water over the continental shelf, the continental slope, and the abyssal plain.

The seismic survey vessel (M/V *Geo Arctic*) used a 26-airgun configuration (4380 in^3 total airgun volume; which is less than the initially proposed 4450 in^3 airgun array) for seismic data acquisition and a single 70 in^3 airgun for mitigation purposes. Due to expected ice conditions at the time of the planned survey, an icebreaker was contracted to escort the seismic survey vessel when ice conditions were present. The M/*V Geo Arctic* was escorted by the medium class (100A) icebreaker M/V *Polar Prince* during some survey operations in open-water and during most (~97%; 360 km or 224 mi) survey operations in heavily (≥80%) ice-covered waters. Detailed descriptions of these vessels and their equipment can be found in Appendix A. Protected species observers (PSOs) aboard the *Geo Arctic* and the *Polar Prince* collected data and requested mitigation measures, as necessary, during the operations.

The start of the survey was delayed due to vessel availability such that seismic survey activities did not begin until 20 Oct with the initiation of sound source measurements in the southeastern portion of the survey area (Fig. 2.2). The measurements were completed on 23 Oct and seismic data collection began on 24 Oct. Survey activities continued in the Beaufort Sea until 9 Nov, at which time the seismic equipment was recovered and the vessels transited to the Chukchi Sea. One seismic line in the Chukchi Sea was surveyed on 14 and 15 Nov before the vessels began transiting south to Dutch Harbor. Additional details of the operations are provided in the following sub-sections.

ION collected 1844 km (1146 mi) of seismic data in the Beaufort and Chukchi seas in 2012. 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. The airguns were also firing during "lead out" periods after completion of each seismic line, before the full array was powered down to a single gun for transit to the next survey line. Periods of full array firing including periods of lead in, lead out, seismic testing, and ramp up occurred along 2408 km (1496 mi) of trackline. During turns from one seismic line to the next, testing 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 583 km (362 mi) of vessel trackline. Thus, one or more airguns were operated along 2991 km (1858 mi) of total trackline in the Beaufort and Chukchi seas in 2012.

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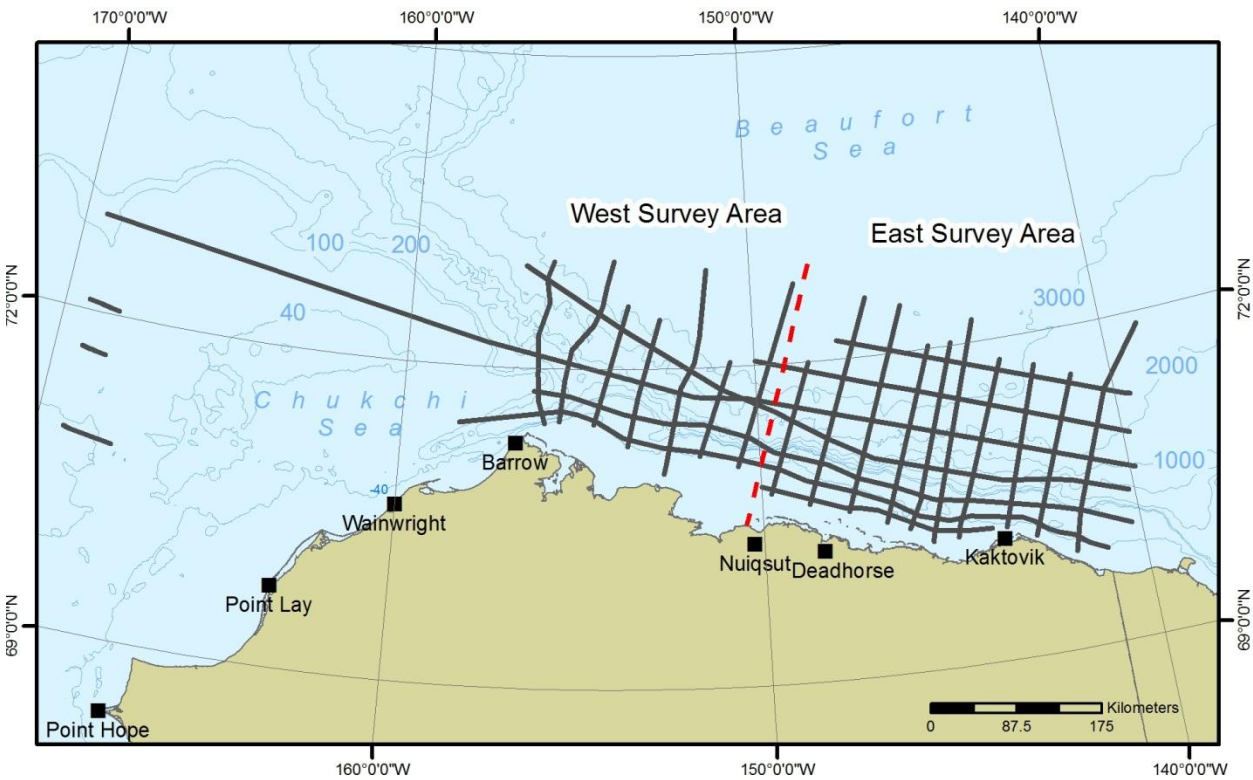

FIGURE 2.1. Planned seismic survey lines in the Beaufort and Chukchi seas.

Pre-Survey Transit

The two vessels left Nome on 11 Oct and entered the Chukchi Sea on 12 Oct. The vessels transited through the Chukchi Sea and rounded Pt. Barrow on 14 Oct, and then crossed the Alaskan Beaufort Sea and entered Canadian waters on 16 Oct. No seismic survey activities were conducted during this transit. The vessels waited out some poor weather and then took fuel from a barge near Herschel Island from 16 Oct to 18 Oct. While transiting to the eastern edge of the survey area on 19 Oct, the *Geo Arctic* began deploying and testing the airgun array while the *Polar Prince* prepared to deploy acoustic recorders as part of the sound source measurement program.

Seismic Survey

Sound Source Measurements

Sound source measurements of the full 26-airgun array and the single mitigation airgun were conducted by JASCO Applied Sciences (JASCO) from 20 to 23 Oct. The measurements required several days to complete for two primary reasons. When the *Geo Arctic* first transited along the shallow water (50 m; 164 ft water depth) SSV line, the airgun array was not operating all 26 airguns intended to be used during the survey due to an error in programming the airgun array. This error was identified at the completion of the line, so the *Geo Arctic* returned to the start of the line and re-shot the entire 100 km (62 mi) long line using the intended 26 airguns. Secondly, the survey was planned over a wide range of depths so measurements of the array were taken at two water depths, ~50 m and ~500 m (164 ft and 1640 ft; Fig. 2.2). Thus, measurements had to be repeated at the 500 m (1640 ft) water depth location. The acoustic measurements were conducted in the southeastern part of the survey area in the Beaufort 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. These radii were thereafter used by PSOs to implement mitigation measures during seismic survey activities.

Additional analyses of the acoustic data were completed after the survey and the safety and disturbance zones were revised. Based on the revised radii there were seven sightings of 10 individual bowhead whales during seismic activity in the Chukchi Sea that would have been mitigated had the updated radii been available. The reasons for the revised radii are described in Chapter 3 and detailed descriptions of those seven sightings are given in Chapter 5.

Beaufort Sea Seismic Survey

After completing the sound source measurements, the *Geo Arctic* began collecting seismic data in the Beaufort Sea on 24 Oct. The first seismic line along which the *Geo Arctic* collected data ran east to west along the shelf break from the Canadian border to Barrow. Prior to crossing the line that divides the survey area into eastern and western halves (Fig 2.2), ION received word from the AEWC (on 24 Oct) that whaling in Barrow had concluded. This allowed ION to conduct survey activities in the western half of the survey area, which it did on 27 Oct while surveying along that same east-west line. The *Geo Arctic* turned north before reaching Barrow and then began surveying east along another east-west line further offshore.

On 30 Oct, while surveying eastward, the *Geo Arctic* unintentionally activated the two spare airguns in the array resulting in 28 airguns with a total volume of 4880 in^3 firing for 6 hrs and 36 minutes. This incident was reported to the three regulatory agencies: BOEM, NMFS, and USFWS. Acoustic modeling of the larger airgun array was undertaken to assess the relative increase in acoustic impacts from that firing of the additional airguns and those results are presented in Chapter 3.

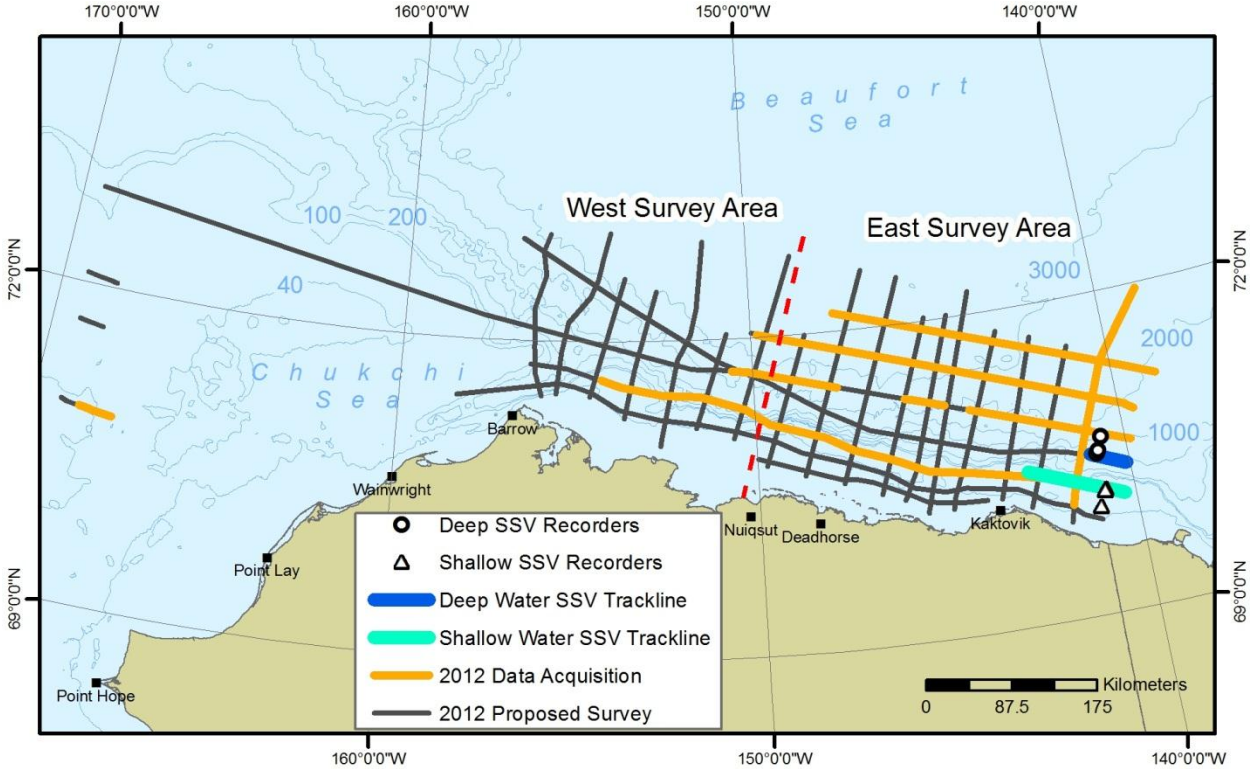

FIGURE 2.2. SSV measurement locations and seismic survey lines completed by ION during seismic operations between 20 Oct and 15 Nov.

Seismic survey activities continued in the Beaufort Sea, primarily on east-west lines, through 9 Nov. The *Polar Prince* rejoined the *Geo Arctic* on 4 Nov and began scouting ice and assisting with monitoring for marine mammals. The *Polar Prince* had been delayed near Herschel Island attempting to disembark the JASCO personnel after the sound source measurements were completed. After several days of poor weather conditions prevented the personnel transfer at that location, the *Polar Prince* transited to Sachs Harbor, NT where the personnel disembarked on 31 Oct.

The two vessels first encountered newly forming sea ice near the northern edge of the survey area on 5 Nov. There had been no ice encountered prior to that date, so most of the survey activities in the Beaufort Sea were conducted in open-water. Ice concentrations were quite variable thereafter, depending on location and time of day. After encountering some thicker ice conditions on 9 Nov, and with ice forecasts indicating heavier ice forming near Pt. Barrow, the decision was made to end seismic survey activities in the Beaufort Sea, retrieve the seismic gear, and transit to the Chukchi Sea. The transit occurred from 10 Nov through 12 Nov when the vessels passed Pt. Barrow.

Chukchi Sea Seismic Survey

After passing Pt. Barrow on 12 Nov, the vessel transited south along the Chukchi Sea coast where ice conditions were lightest. The *Geo Arctic* traveled towards the southern-most seismic line while the *Polar Prince* headed to a seismic line further north to assess ice conditions there (Fig 2.2). It was determined that ice conditions were too heavy at the more northern location, so the *Polar Prince* returned to the southern line to escort the *Geo Arctic* while it collected seismic data.

Since no other seismic survey activities would occur after completing the southern line, ION requested permission from the regulatory agencies to survey that line 4 times, each time decreasing the size of the airgun array. This would allow an assessment of the required size of an airgun array to collect quality geophysical data in the Chukchi Sea. Permission to do this was granted, and the *Geo Arctic* surveyed the line from east to west with the full 26-airgun (4380 in^3) array on 14 Nov. The vessel then turned and surveyed eastward along the line firing only 13 airguns (2190 in^3) on 15 Nov. At the conclusion of that line equipment problems were encountered that would require the airguns to be retrieved, so the survey was terminated and the vessels began transiting south towards Dutch Harbor while the seismic equipment was recovered.

Post-Survey Transit

The *Geo Arctic* and *Polar Prince* passed through the Bering Strait on 17 Nov. During their transit of the Bering Sea they remained on the east side of St. Lawrence Island and arrived in Dutch Harbor on 20 Nov. No airgun activity occurred during this transit period.

Airgun Description

The *Geo Arctic* towed an airgun array consisting of 28 Sercel G-gun airguns, 26 of which were active and had a total discharge volume of 4380 in^3. The 28 airguns were distributed in two sub-arrays with 14 airguns per sub-array. Individual airgun sizes ranged from 70 to 250 in^3. The seismic array and a single hydrophone streamer 4.5–9 km in length were towed behind the *Geo Arctic* at 8.5 and 9.5 m in depth, respectively. The shot interval was 18-20 s. Additional specifications of the airgun array are provided in Appendix A. The single 70 in^3 airgun was used as the mitigation gun and was fired between lines to discourage marine mammals from approaching the vessel.

Both vessels operated using industry standard echo sounder/fathometer instruments for continuous measurements of water depth. These instruments are used by all large vessels to provide routine water

depth information to the vessel crew. The *Geo Arctic* used one navigational echosounder; the downward facing single-beam Simrad Pulse EA600. The *Polar Prince* also used one echo sounder, an ELAC LAZ-72.

Marine Mammal Monitoring

Vessel-based marine mammal monitoring and mitigation was conducted from the *Geo Arctic* and the *Polar Prince* throughout operations in the Beaufort and Chukchi seas. Four PSOs were stationed aboard the *Polar Prince* to provide advanced notice of marine mammals to the PSOs on the survey vessel, and five PSOs were stationed aboard the *Geo Arctic* to monitor the safety zones centered on the airguns. At least two PSOs were on duty during nearly all daylight periods on both vessels. During seismic activity on the *Geo Arctic*, two PSOs were on duty for all daytime ramp ups. 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 Canon 18×50 image stabilized binoculars. During periods of darkness, PSOs occasionally scanned using generation 3 night vision goggles. On the *Polar Prince*, PSOs also used a forward looking infrared camera, night vision goggles, and the unaided eye.

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

Communication with Native Communities

While working in the Beaufort and Chukchi seas, personnel contracted by ION (most often the PSOs) aboard the *Geo Arctic* and the *Polar Prince* routinely contacted the communication center (comm. center) which was, at times, jointly funded by ION and other industry operators, and at other times fully funded by ION. These communications were intended to ensure that project activities did not interfere with subsistence hunting along the coast. Communications were made via phone or email by each vessel every 6 hours. The current vessel location and activities were reported during each call. There were no reported conflicts encountered during the survey.

Prior to the survey season, numerous contacts were made and meetings held with native villages and subsistence organizations in an effort to understand and minimize any potential impacts on subsistence hunting activities. The meetings are summarized in Table 2.1, 2.2, and 2.3.

TABLE 2.1. 2010 Meetings and Correspondence with Potentially Affected Stakeholders and Subsistence Users

Community/Stakeholder	Date	Location	Notes
NSB – Department of Wildlife Management	15 December 2009	Barrow	Met with Robert Sudam of NSB to discuss proposed project
AEWC and Village Whaling Captains	12 – 13 February 2010	Barrow	Presented the proposed project to AEWC as part of the 2010 Annual Captains' Mini-Convention
Kaktovik Leadership	16 March 2010	Anchorage	Meeting with Kaktovik mayor and president of Kaktovik Inupiat Corporation scheduled, but canceled due to illness
Nuiqsut Leadership	17 March 2010	Nuiqsut	Meeting with KSOP and Native Village of Nuiqsut. Thomas Napageak Jr., mayor of Nuiqsut was present.
NSB Planning Commission	18 March 2010	Barrow	Presented the proposed project to NSB Planning Commission. Representatives of NSB Planning Department were present.
Barrow Leadership	18 March 2010	Barrow	Meeting with NSB Dept. of Wildlife Management, ICAS, and Native Village of Barrow
NMFS Open Water Meeting	22 – 24 March 2010	Anchorage	Presented at NMFS Open Water Meeting.
NMFS Peer Review Meeting	25 March 2010	Anchorage	Presented to NMFS Peer Review Meeting
Barrow public meeting	8 April 2010	Barrow	Public meeting held at Inupiat Heritage Center from 7pm to 9pm
Kaktovik public meeting	10 April 2010	Kaktovik	Public meeting held at Kaktovik Community Center from 7pm to 9pm
Nuiqsut public meeting	17 April 2010	Nuiqsut	Public meeting held at Kisik Community Center from 7pm to 9pm
Kaktovik update	3 August 2010	Kaktovik	Public meeting held at Kaktovik Community Center from 7pm to 9pm to provide an update of the proposed project prior to beginning operations.
Nuiqsut update	4 August 2010	Nuiqsut	Public meeting held at Kisik Community Center from 7pm to 9pm to provide an update of the proposed project prior to beginning operations.
Barrow update	5 August 2010	Barrow	Public meeting held at Inupiat Heritage Center from 7pm to 9pm to provide an update of the proposed project prior to beginning operations.
NSB Planning Commission	30 September 2010	Barrow	Presented the proposed project to NSB Planning Commission. Representatives of NSB Planning Department were present.
Notice of Project Delay	30 September 2010	Barrow	Notified NSB Planning Commission, Barrow, Nuiqsut, and Kaktovik leadership, and subsistence users' groups that the 2010 BeaufortSPAN™ West Program would be delayed a year due to technical complications with the seismic vessel.
AEWC	7-8 December 2010	Barrow	Presented the proposed project to the AEWC at their 4th Quarter Meeting

Notes: AEWC = Alaska Eskimo Whaling Commission; ICAS = Inupiat Community of the Arctic Slope; NMFS = National Marine Fisheries Service; NSB = North Slope Borough; KSOP = Kuukpikmiut Subsistence Oversight Panel, Inc.; SAR = Search and Rescue

Table 2.2. 2011 Meetings and Correspondence with Potentially Affected Stakeholders and Subsistence Users

Community/Stakeholder	Date	Location	Notes
AEWC and Village Whaling Captains	18 February 2011	Barrow	Presented the proposed project to the AEWC as part of the 2011 Annual Captains' Mini-Convention.
Barrow Public Meeting	19 February	Barrow	Public meeting held at the Inupiat Heritage Center from 7pm to 9pm. Invitations to the public meeting were sent to Barrow leadership prior to the public meeting.
Nuiqsut Public Meeting	21 February 2011	Nuiqsut	Public meeting held at the Kuukpik Corporation Hotel from 7pm to 9pm. Invitations to the public meeting were sent to Nuiqsut leadership prior to the public meeting.
Kaktovik Public Meeting	22 February 2011	Kaktovik	ION attempted to host a public meeting in Kaktovik at the Kaktovik Community Center from 7pm to 9pm, but the meeting was cancelled due to weather. Invitations to the public meeting were sent to Kaktovik leadership prior to the public meeting.
NSB Planning Commission	24 February 2011	Barrow	Presented to proposed project to NSB Planning Commission. Representatives of NSB Planning Department were present.
NMFS Open Water Meeting	7-8 March 2011	Anchorage	Presented at NMFS Open Water Meeting.
NMFS Peer Review Panel	9 March 2011	Anchorage	Presented to NMFS Peer Review Panel.
NSB Planning Commission	18 April 2011	Barrow	Submitted a letter to NSB Planning Commission members addressing questions raised at the 24 February 2011 Planning Commission meeting.
Kaktovik Leadership and Public Meeting	18 April 2011	Kaktovik	Leadership and Public meeting held at the Kaktovik Community Center from 5pm to 6pm. This was a re-schedule of the planned February meeting that was canceled due to weather.
Nuiqsut Leadership Meeting	19 April 2011	Nuiqsut	ION attempted to meet with Leadership in Nuiqsut, including KSOP, the Native Village of Nuiqsut, the City of Nuiqsut, Kuukpik Corp., and the Nuiqsut Whaling Captains' Association. The meeting was cancelled due to weather.
Barrow Leadership Meeting	20 April 2011	Barrow	ION notified Barrow leadership that they would be in Barrow this day and that ION would be happy to meet with members of Barrow leadership. Due to timing (preparation for Barrow spring whale hunt), no meetings were scheduled.
Notice of Project Delay	7 July 2011	Multiple Locations	Notified Barrow, Nuiqsut, Kaktovik, and North Slope Borough leadership via a letter that the 2011 seismic program was delayed a year.

AEWC 2nd Quarter Meeting	21-22 July 2012	Fairbanks	Notified AEWC Commissioners of the project delay.
Notice of Project Delay	16 August 2011	Kaktovik	ION notified leadership in Kaktovik that the 2011 BeaufortSPAN™ West Program would be delayed a year.
Notice of Project Delay	17 August 2011	Barrow	ION notified leadership in Barrow that the 2011 BeaufortSPAN™ West Program would be delayed a year due to uncertainty in the availability of the *Polar Explorer*.
Notice of Project Delay	18 August 2011	Nuiqsut	ION notified leadership in Nuiqsut that the 2011 BeaufortSPAN™ West Program would be delayed a year.
AEWC Commissioners	12 December 2011	Barrow	Discussed 2012 Operational Plan and Conflict Avoidance Agreement

Notes: AEWC = Alaska Eskimo Whaling Commission; NMFS = National Marine Fisheries Service; KSOP = Kuukpikmiut Subsistence Oversight Panel, Inc.

Table 2.3. 2012 Meetings and Correspondence with Potentially Affected Stakeholders and Subsistence Users

Community/Stakeholder	Date	Location	Notes
Kaktovic Public Meeting	23 January 2012	Kaktovik	Review of proposed project for 2012
Barrow Public Meeting	25 January 2012	Barrow	Review of proposed project for 2012
Barrow Whaling Captains Association	25 January 2012	Barrow	Review of proposed project for 2012
2012 AEWC CAA Meeting	16-17 February 2012	Barrow	Review of proposed 2012 project, CAA language comments
Wainwright Whaling Captains' Association	20 February 2012	Wainwright	ION presented the proposed 2012 project to the Wainwright Whaling Captains' Association. The focus was on transit from the project site near Barrow through the Chukchi Sea after completion of the seismic survey
Nuiqsut Public Meeting	21 February 2012	Nuiqsut	ION presented the 2012 proposed project at a public meeting held at the Community Center
NMFS Open-Water Meeting	6-8 March 2012	Anchorage	Review of proposed project for 2012
Meeting with members of AEWC	6 March 2012	Anchorage	ION reviewed and signed the Conflict Avoidance Agreement with the AEWC
NSB Planning Commission	28 June 2012	Barrow	ION presented the proposed project to NSB Planning Commission.
Kaktovik Update	20 August 2012	Kaktovik	ION provided an update of the proposed project prior to beginning operations.
Nuiqsut Update	21 August 2012	Nuiqsut	ION provided an update of the proposed project prior to beginning operations.
Barrow Update	22 August 2012	Barrow	ION provided an update of the proposed project prior to beginning operations.

3. UNDERWATER SOUND MEASUREMENTS[1]

This chapter presents the results of an underwater acoustic study to verify the sound emissions of seismic sound sources used during ION Geophysical's seismic survey in the Beaufort and Chukchi Seas. The Sound Source Verification (SSV) study, performed by JASCO Applied Sciences, measured underwater sound pressure levels (SPLs) as a function of distance, frequency, and direction from ION's geophysical sound sources. The SSV measurements address the underwater noise monitoring requirements of ION's Incidental Harassment Authorization (IHA).

Conditions 7(d) and 8(a) of the IHA (NMFS 2012) define the monitoring and reporting requirements for sound verification measurements. Field reports were delivered within five days of the measurements as per Section 8. This chapter addresses the detailed reporting tasks of Condition 8, and provides detail about the measurements performed under Condition 7.

The SSVs were conducted north of Demarcation Bay near the Canada-U.S. border in the Beaufort Sea in October 2012. All measurements were made with calibrated sound recorders deployed on the seabed or over the side of a support vessel. The seabed-deployed recorders were JASCO Ocean Bottom Hydrophone (OBH) recorders.

The measured geophysical sources include a 70 in^3 mitigation airgun and a 4380 in^3 airgun array, which this chapter describes in detail. The distances to various root-mean-square (rms) SPL thresholds derived from the measurements are compared to the pre-season model results. Noise from the survey vessel (M/V *Geo Arctic*) and support vessel (M/V *Polar Prince*) was also measured.

Goals of the Acoustic Monitoring Study

The goals of the sound source verification program were to:

1. Determine distances from the airgun sources to rms sound pressure level thresholds between 190 and 120 dB re 1 µPa in 10 dB steps. These distances were used to define exclusion zones that were implemented in the field by Protected Species Observers onboard the survey vessels.
2. Compare the measurements to the pre-season modeled threshold distances.
3. Refine the pre-season model results to match the measured results and determine updated geoacoustic properties.
4. If possible, measure sound from the icebreaker with and without icebreaking.

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[1] By Jennifer L. Wladichuk, Jeff MacDonnell, Graham Warner, David Hannay, and Holly Sneddon (JASCO Applied Sciences).

Methods

Sound Sources Monitored

Underwater sounds from airguns and vessels were measured for this study. Two airgun configurations, a mitigation airgun (70 in^3) and an airgun array (4380 in^3), were measured in two environments. The two sources were fired alternately along each track. The full airgun array consisted of 26 active airguns and 2 inactive spare airguns. The airguns had individual volumes between 70 and 250 in^3 and were arranged in clustered pairs (Figure 3.1).

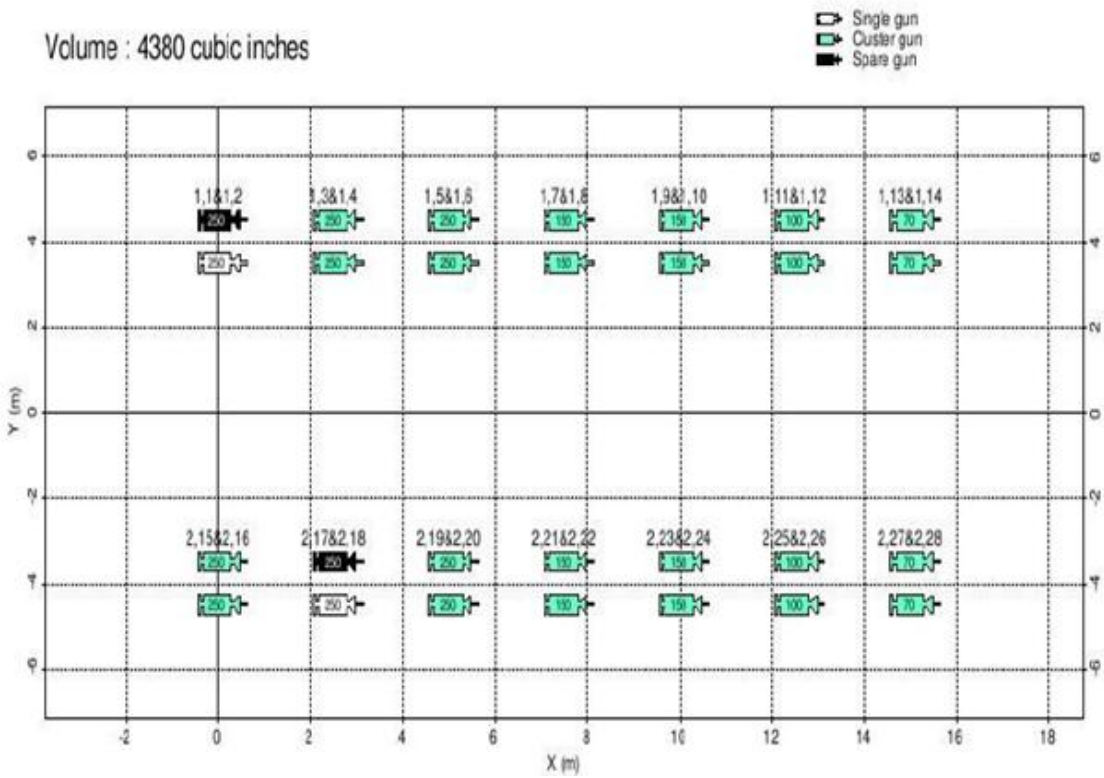

FIGURE 3.1. Geometric layout of the 4380 in^3 airgun array. The volume of each airgun is in cubic inches. Tow direction is to the right; tow depth is 8.5 m (27.9 ft).

The vessels monitored were the seismic survey vessel M/V *Geo Arctic* and the icebreaker M/V *Polar Prince*. Both vessels were measured separately as they transited at the Shallow SSV site. The *Polar Prince* did not conduct icebreaking activities during the SSV measurements as no ice was present in the area at that time.

Acoustic Monitoring Equipment

Sound sources were recorded with JASCO's autonomous Ocean Bottom Hydrophone (OBH) recorders. Signals from RESON TC4032 and TC4043 hydrophones (−170 and −201 dB re 1 V/µPa nominal sensitivities, respectively) were digitized (24-bit) and recorded on Digital Audio Recorders (Sound Devices Model 722), at a sample rate of 96 kHz. The hydrophones and recorders were powered by alkaline battery packs, providing a recording lifetime of 50–60 h with this configuration.

The recorders were calibrated using a pistonphone precision sound source (G.R.A.S. Type 42AC), which generates a 250 Hz tone with amplitude accurate to ±0.08 dB. The tone was played directly to the

hydrophone sensor via a specialized adapter. Calibrations were performed in the field immediately before each deployment and immediately after each retrieval. The pistonphone reference signal recorded by the digital recorders was analyzed to provide the end-to-end system calibration of the hydrophone, amplifiers, and digitization. See Appendix B for the recorder calibrations.

Coordinates of the deployment, vessel, and sources were obtained with a hand held Global Positioning System (GPS) receiver (Garmin GPSmap 76) or from the survey vessel logs; they are accurate to within 3 m.

Shallow SSV Site

The Shallow SSV site was at the continental shelf with 50 m (164 ft) nominal water depth. At this site, three recorders were deployed on the seabed (Figure 3.2) at various distances from the SSV track to measure the broadside and endfire sound emissions.

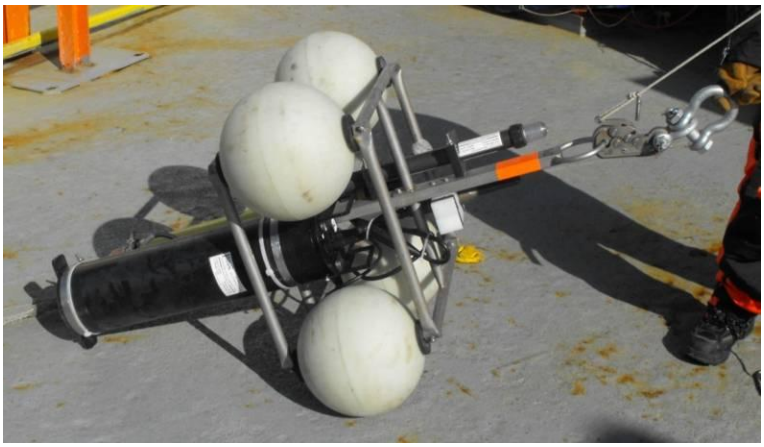

FIGURE 3.2. JASCO's ocean bottom hydrophone recorder used for the Sound Source Verification measurements.

Deep SSV Site

The Deep SSV site was at the continental slope with 500 m (1640) nominal water depth. At this site, the recorder was ballasted to be neutrally buoyant at approximately 50 m (164 ft) water depth, which lies near the axis of the sound channel (Figure 3.24) and consequently is expected to receive maximum sound levels. The depth of the recorder was verified using a Star-Oddi depth sensor. The recorder was suspended from a surface float, which had a GPS that logged the position of the recorder (Figure 3.3). The surface float was tethered to the support vessel and was allowed to drift several meters from the vessel during the SSV. The engines of the M/V *Polar Prince* were off to minimize noise pollution in the data. The vessel was periodically repositioned to the predetermined deployment location to counteract drifting.

FIGURE 3.3. Recording system used for the Deep SSV measurements. The float (right) suspended the recorder at approximately 50 m depth in approximately 500 m of water. A GPS attached to the float recorded the position of the recorder.

Field Measurements

The sound speed was determined from water temperature and salinity of the water column, which were sampled with a conductivity-temperature-depth (CTD) profiler (AML Oceanographic Minos-X). Casts were performed over the side of the support vessel, M/V *Polar Prince*, at both the Shallow and Deep SSV sites. The OBH was lowered over the side of the ship and to the seafloor at the Shallow site and to approximately 250 m (800 ft) water depth at the Deep SSV site.

Two SSVs, Shallow and Deep, were performed during ION's seismic survey (Figure 3.4). For each SSV track, the 4380 in^3 full volume array and the 70 in^3 single airgun were fired alternately. Table 3.1 shows the measurement locations for the two SSVs.

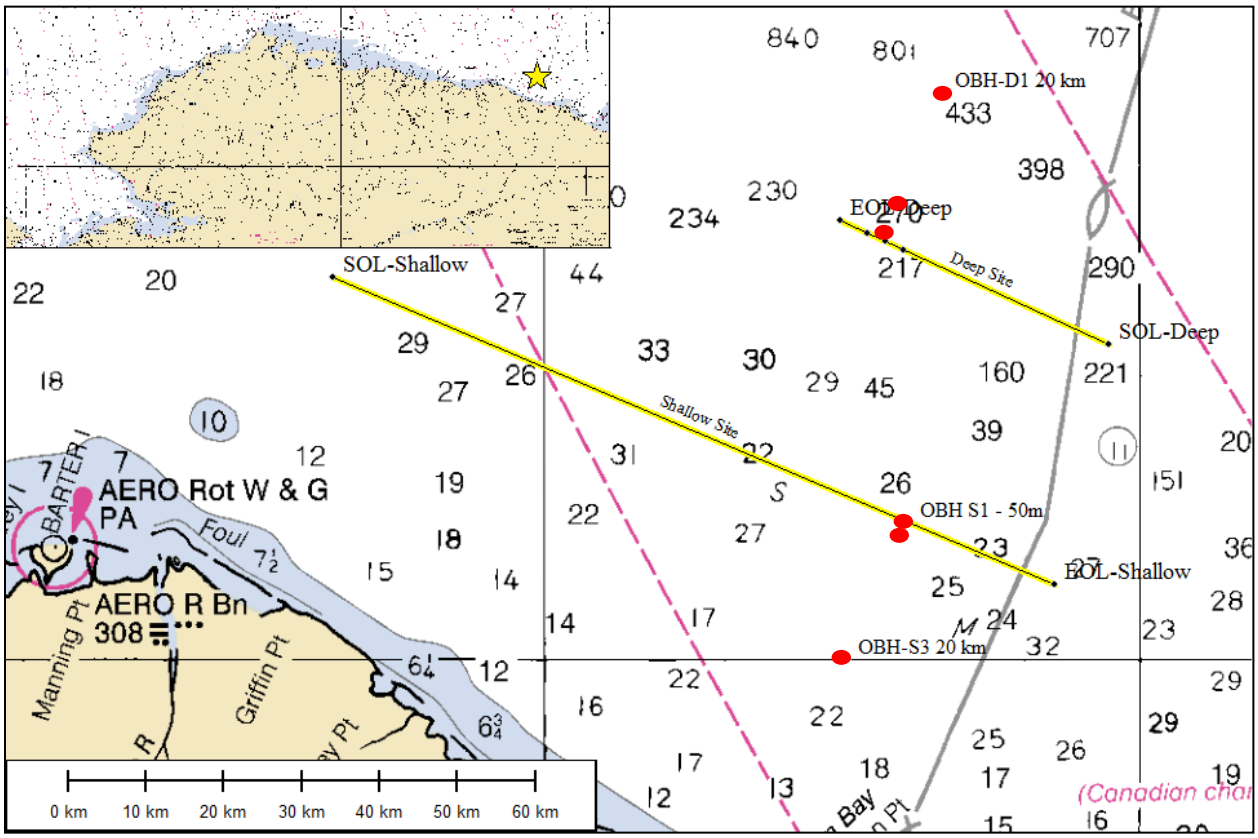

FIGURE 3.4. The Deep and Shallow SSV tracks and the respective OBH locations (●). Chart depths are in fathoms (1 fathom is 1.83 m or 6 ft).

TABLE 3.1. OBH locations (WGS-84 Datum) and deployment and retrieval times (UTC). Water depths indicate the depth at time of deployment. All ranges and the deep OBH locations are at the closest point of approach (CPA).

Location	Deployment	Retrieval	Latitude	Longitude	Water Depth (m)	CPA from Track (m)
S1	22 Oct 15:23	24 Oct 00:47	70°09.397′ N	140°46.108′ W	50	400
S2	20 Oct 22:50	24 Oct 02:33	70°08.681′ N	140°46.991′ W	49	1 843
S3	20 Oct 21:28	24 Oct 04:33	70°00.042′ N	140°58.435′ W	50	19 472
D1	23 Oct 11:04	23 Oct 16:31	70°29.658′ N	140°50.169′ W	476	2 046
D2	23 Oct 16:57	23 Oct 18:15	70°31.397′ N	140°47.022′ W	494	5 700
D3	23 Oct 19:21	23 Oct 20:50	70°38.756′ N	140°38.084′ W	1 016	20 416

Shallow SSV Site

Three recorders were deployed on the seafloor at approximately 50 m, 1.5 km, and 20 km (165 ft, 1 mi, 12 mi, respectively) from the closest point of approach (CPA), and were retrieved after the Deep and Shallow SSVs were complete. The Shallow SSV track was approximately 100 km long (~62 mi) in roughly 50 m (165 ft) water depth. Table 3.2 shows the start, end, and CPA ranges and times of the Shallow SSV.

TABLE 3.2. Times, positions, and ranges of the M/V *Geo Arctic* during the Shallow SSV, 22-23 Oct 2012. Nominal vessel speed was 4 kts.

Event	Time (UTC)	Latitude	Longitude	Range from Recorder (m)
Track start	17:51	70°26.150′ N	142°42.234′ W	79 194 (from S1)
CPA to S1	04:26	70°09.598′ N	140°45.886′ W	400
CPA to S2	04:26	70°09.598′ N	140°45.886′ W	1 844
CPA to S3	04:26	70°09.598′ N	140°45.886′ W	19 475
Track end	07:09	70°05.208′ N	140°16.868′ W	20 070 (from S1)

Deep SSV Site

An acoustic recording system was deployed over the side of the support vessel, M/V *Polar Prince*, as the M/V *Geo Arctic* traversed the Deep SSV track while alternately firing the full-volume (4380 in^3) airgun array and the 70 in^3 single airgun. To avoid the M/V *Geo Arctic*'s towed equipment colliding with the *Polar Prince*, the minimum measurement range was always more than 2 km. The first pass was of a 37 km (23 mi) survey line with the recorder positioned approximately 2 km (1.2 mi) from the CPA. The next pass was on a 5 km (3 mi) section of the same track line while the recorder was positioned approximately 6 km (mi) off the CPA. This small section was re-run with the recorder repositioned approximately 20 km (12 mi) away. The water depth along the track lines was approximately 550 m (1800 ft) and the recorder was suspended at approximately 50 m (165 ft) water depth. Table 3.3 gives the seismic vessel location at the start, end, and CPA of each Deep SSV survey line. The source-receiver distances are also given.

TABLE 3.3. Times, positions, and ranges of the M/V *Geo Arctic* during the Deep SSV, 23 Oct 2012. Nominal vessel speed was 4 kts.

Event	Time (UTC)	Latitude	Longitude	Range from Recorder (m)
Line start	11:23	70°21.550′ N	140°05.884′ W	30 530
CPA to D1	15:32	70°28.604′ N	140°51.077′ W	2 046
Line end	16:20	70°29.948′ N	140°59.895′ W	7 522
Line start	17:29	70°29.101′ N	140°54.640′ W	5 770
CPA to D2	17:32	70°29.005′ N	140°54.008′ W	5 714
Line end	18:08	70°27.928′ N	140°47.321′ W	6 648
Line start	20:01	70°27.902′ N	140°47.130′ W	20 517
CPA to D3	20:12	70°28.209′ N	140°48.997′ W	20 416
Line end	20:42	70°29.075′ N	140°54.447′ W	20 811

Data Analysis

The majority of the results in this report are based on data presented in the 2012 field report (MacDonnell and Wladichuk 2012); however, some of the data were reanalyzed to improve the accuracy of the measurements. Airgun array sound levels recorded on the high sensitivity hydrophones at distances less than 2 km were inaccurate due to a non-linear gain effect at very high SPLs. Data presented in the field report were affected by this problem because the analysis considered only the more sensitive hydrophone channel, which became distorted when the airgun array came within 2 km. Data from the low-sensitivity hydrophone properly captured the higher sound levels. Reanalysis of the SPLs for the Shallow site, using the low-sensitivity hydrophone, increased the threshold distances for the 190 and 180 dB levels from the initial values given in the field report.

The mitigation airgun data from the Deep SSV were also reanalyzed for this report. Due to a relatively low signal-to-noise ratio (SNR) and alternation of airgun configurations, the pulses were manually re-picked to verify that only sounds from the mitigation shots were selected. This reanalysis increased the threshold distances for the 190, 180, and 160 dB levels and decreased the threshold distance for the 120 dB level from the initial values given in the field report.

Acoustic Metrics

Underwater sound amplitude is measured in decibels (dB) relative to a standard reference pressure of p_o = 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 impulse, $p(t)$:

$$L_{pk} = 10\log_{10}\left(\frac{\max\left(\left|p^2(t)\right|\right)}{p_o^2}\right) \qquad (1)$$

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 pulse:

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

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

By convention, when computing airgun safety radii, T is often defined as the "90% energy pulse duration", containing the central 90% (from 5% to 95% of the total) of the cumulative square pressure (or energy) of the pulse, rather than over a fixed time window (Malme et al. 1986, Greene 1997, McCauley et al. 1998). The 90% rms SPL (L_{p90}, dB re 1 µPa) in a stated frequency band is calculated over this 90% energy time window, T_{90}:

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

The SEL (L_E, dB re 1 µPa^2·s) is the time integral of the squared pressure in a stated frequency band over a stated time interval or event. The per-pulse SEL is calculated over the time window containing the entire pulse (i.e., 100% of the acoustic energy), T_{100}:

$$L_E = 10\log_{10}\left(\int_{T_{100}} p^2(t)dt \Big/ T_o p_o^2\right) \qquad (4)$$

where T_o is a reference time interval of 1 s. The per-pulse SEL, with units of dB re 1 µPa·√s, or equivalently dB re 1 µPa^2·s, represents the total acoustic energy delivered over the duration of the acoustic event at a receiver. It is a measure of sound energy (or exposure) rather than sound pressure although it is not measured in energy units.

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 90% energy time window T_{90}:

$$L_E = L_{p90} + 10\log_{10}(T_{90}) + 0.458 \qquad (5)$$

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 pulses. The cumulative SEL (L_{EC}) can be computed by summing (in linear units) the SELs of the N individual pulses (L_{Ei}).

$$L_{EC} = 10\log_{10}\left(\sum_{i=1}^{N} 10^{\frac{L_{Ei}}{10}}\right) \qquad (6)$$

Exposure Criteria

Operational safety radii for this seismic survey were based on auditory injury criteria developed by the National Marine Fisheries Service (NMFS). NMFS has defined 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.

NMFS has also established a threshold criterion for behavioral responses (Level B harassment) to impulse noise sources. The threshold for the onset of behavioral response to seismic pulses is 160 dB re 1 µPa rms SPL, based on estimated received seismic noise levels during behavioral studies where baleen whales exhibited avoidance behavior around airgun pulses (e.g., Malme et al. 1984 and 1986). The NMFS behavioral threshold criterion was also used to estimate the number of animals potentially affected by the seismic survey.

Marine Mammal Frequency Weighting

The potential for anthropogenic noise to impact marine animals depends on how well the animal can hear the noise (Southall et al. 2007). Noises are less likely to disturb or injure animals if they are at frequencies that the animal cannot hear well. An exception is when the sound pressure is so high that it can cause physical injury. For sound levels that are too low to cause physical injury, frequency weighting based on audiograms may be applied to weight the importance of sound levels at particular frequencies in a manner reflective of an animal's sensitivity to those frequencies (Nedwell and Turnpenny 1998, Nedwell et al. 2007).

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—referred to as M-weighting functions—for five functional hearing groups of marine mammals:

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

The discount applied by the M-weighting functions for less-audible frequencies is less than that indicated by the corresponding audiograms (where available) for member species of these hearing groups. 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 curves increasingly have less rapid roll-off outside the most sensitive hearing frequency range as sound levels increase. This is why, for example, C-weighting curves for humans, used for assessing loud sounds such as blasts, are flatter than A-weighting curves, used for quiet to mid-level sounds. Additionally, out-of-band frequencies, though less audible, can still cause physical injury if pressure levels are sufficiently high. The M-weighting functions therefore are primarily intended to be applied at high sound levels where impacts such as temporary or permanent hearing threshold shifts may occur. The use of M-weighting is considered precautionary (in the sense of overestimating the potential for impact) when applied to lower level impacts such as onset of behavioral response. Figure 3.5 shows the decibel frequency weighting of the four underwater M-weighting functions.

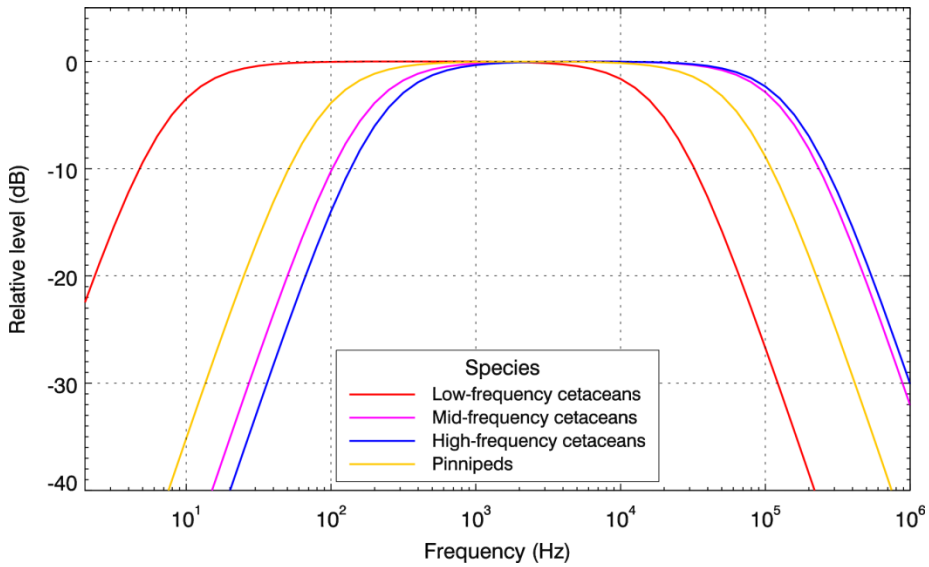

Figure 3.5. The standard M-weighting functions for the four underwater functional marine mammal hearing groups (Southall et al. 2007).

The 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 in the frequency domain of the M-weighting functions is defined by:

$$G(f) = -20\log_{10}\left[\left(1+\frac{f_{lo}^2}{f^2}\right)\left(1+\frac{f^2}{f_{hi}^2}\right)\right] \qquad (7)$$

The roll-off and passband of these functions are controlled by the parameters f_{lo} and f_{hi}, the estimated upper and lower hearing limits specific to each functional hearing group (Table 3.4).

Table 3.4 The low (flo) and high (fhi) frequency cut-off parameters of the standard M-weighting functions for the four underwater functional marine mammal hearing groups (Southall et al. 2007).

Functional hearing group	*Estimated auditory bandwidth*	
	f_{lo}	f_{hi}
Low-frequency cetaceans (LFC)	7 Hz	22000 Hz
Mid-frequency cetaceans (MFC)	150 Hz	160000 Hz
High-frequency cetaceans (HFC)	200 Hz	180000 Hz
Pinnipeds underwater (PINN)	75 Hz	75000 Hz

Cumulative SEL Exposure Criteria

The M-weighted cumulative SEL metric considers the total SEL received from multiple pulses and also accounts for frequency-dependent hearing sensitivity of different species groups. The original auditory injury cumulative SEL thresholds proposed by Southall et al. (2007) were 198 dB re 1 µPa^2-s (M-weighted) for cetaceans and 186 dB re 1 µPa^2-s (M-weighted) for pinnipeds under water.

The cumulative SEL metric proposed by Southall et al. (2007) involves summing the single pulse SELs for multiple pulses. They acknowledge that this approach is very conservative because it does not

make any allowance for the recovery of hearing between pulse exposures as is done for similar exposure thresholds applied for humans. For the purpose of this analysis we have calculated the SEL values for all airgun shots in the single survey line monitored using Equation 5 above. In practice, at least for the closest two receivers at 400 m and 1840 m off the survey line, the highest SEL contributions occur from airgun shots at closest point of approach and the majority of SEL is generated by airgun shots within a few kilometers of the recorders. Consequently, the CSEL received by an animal passing within approximately 2 km of the survey line can be estimated by determining its closest point of approach to the operating airgun array. This assumes that the animal travels more slowly than the survey vessel and that it does not swim parallel to the operating array for significant distance. The estimate can then be obtained from the interpolated CSEL value from the plots of CSEL versus fixed recorder range off the survey line.

Acoustic Signal Analysis Procedures

Per-Shot Pulse Levels

The loudness or magnitude of each recorded pulse from the airguns was quantified by computing the three noise metrics: peak SPL, 90% rms SPL, and SEL. Each pulse was analyzed as follows:

1. Converted digital recording units to micropascals (µPa) by applying hydrophone sensitivity, analogue circuit frequency response, and digital conversion gain.
2. An automated feature detection algorithm was used to pick start and end times of individual airgun pulses in the acoustic data. Automated detections were supplemented by manual picks as required.
3. Computed peak SPL (symbol L_{pk}) according to Equation 1.
4. Computed cumulative square pressure over the duration of the pulse.
5. Determined the 90% time window length (T_{90}) and computed the 90% rms SPL (L_{p90}) according to Equation 3.
6. Computed SEL (symbol L_{E}) according to Equation 4 over the duration of the pulse.

Sound Level versus Range

The noise metrics computed for each source are presented as a function of source-receiver slant range. To estimate the distance to sound level thresholds and the source level for each monitored sound source, the 90% rms SPL (L_{p90}) as a function of range (R, in meters) were fit with an empirical transmission loss function of the form:

$$L_{p90} = \mathrm{SL} - n \log R - \alpha R, \text{ or} \qquad (8)$$

$$L_{p90} = \mathrm{SL} - n \log R \qquad (9)$$

where SL is the source level (dB re 1 µPa @ 1 m), n is the geometric spreading loss coefficient, and α is an attenuation coefficient. These coefficients are determined by a least-squares fit. Equation 8 is used if excess attenuation with range is observed in the received level versus log(R) data trend; whereas Equation 9 is used if no significant excess attenuation exists.

The fits for the Deep site measurements matched the data and may be accurate for extrapolating beyond the maximum measurement range; however, for ranges closer than measured, the fits are likely inaccurate. In deep water at close range, spherical spreading (i.e., 20LogR) is expected (Jensen et al. 1994). Therefore, distances to thresholds higher than measured were extrapolated by back-propagating the loudest measured pulse using spherical spreading.

Spectral Analysis

The broadband frequency content of each source was presented in three formats: (1) spectrogram, (2) spectral density over a specified time window, and (3) 1/3-octave band levels.

For 1/3-octave band analysis of impulsive sources, the sound data were band-pass filtered into several adjacent frequency bins, and the SEL of each bin computed. The acoustics community has adopted standard 1/3-octave frequencies (ISO R 266 and ANSI S1.6-1984) to facilitate comparisons between studies; the central frequency of the *i*th standard 1/3-octave band is:

$$f_{ci} = 10^{i/10},\ i = 1, 2, 3, \ldots \qquad (8)$$

The bandwidth of a single 1/3-octave band is ~23% of the central frequency of the band. 1/3-octave band analysis was applied to both continuous and impulsive noise sources.

Noise from the M/V Geo Arctic

SPLs in consecutive 1-second windows were computed from the Shallow SSV recorder at S1. The airgun array, mitigation airgun, and M/V *Geo Arctic* vessel all contributed to the sound levels during this test. The sound energy contributed by the airgun pulses and reverberation were removed to determine the SPLs attributed only to the M/V *Geo Arctic*. The M/V *Geo Arctic* SPLs included only the lowest SPL from each airgun array shot repetition period (18 seconds).

Noise from the M/V Polar Prince

SPL versus range was computed from a recording of the support vessel at S1. The vessel was transiting away from the recording location at a constant speed of ~5 kts. Airgun activity was not present during this time. Low-pass filtering was applied to remove contamination from the vessel's 50 kHz depth sounder. The data from 15:30–16:30 22 Oct 2012 (UTC) were processed using a 1-second window length and a 0.5-second step size.

Results

Two Sound Source Verifications (SSVs), Shallow and Deep, were performed during ION's seismic survey in the Beaufort Sea. The results for each SSV are grouped by sound source. Conductivity-temperature-depth (CTD) casts were performed at both SSV sites; the resulting sound speed profiles are presented in this section.

Shallow SSV Site

Sound Speed Profile

Salinity, temperature, and sound speed were measured near S1 at 23:35 on 20 Oct 2012 (UTC), immediately after the OBH was deployed at that location (Figure 3.6). The plots show a well-mixed layer above approximately 15 m (49 ft), with salinity and temperature fairly constant, but at greater depths salinity steadily increased and temperature decreased. These conditions resulted in an overall downward refracting sound speed profile, which is expected to increase acoustic propagation loss with range due to increased bottom interactions.

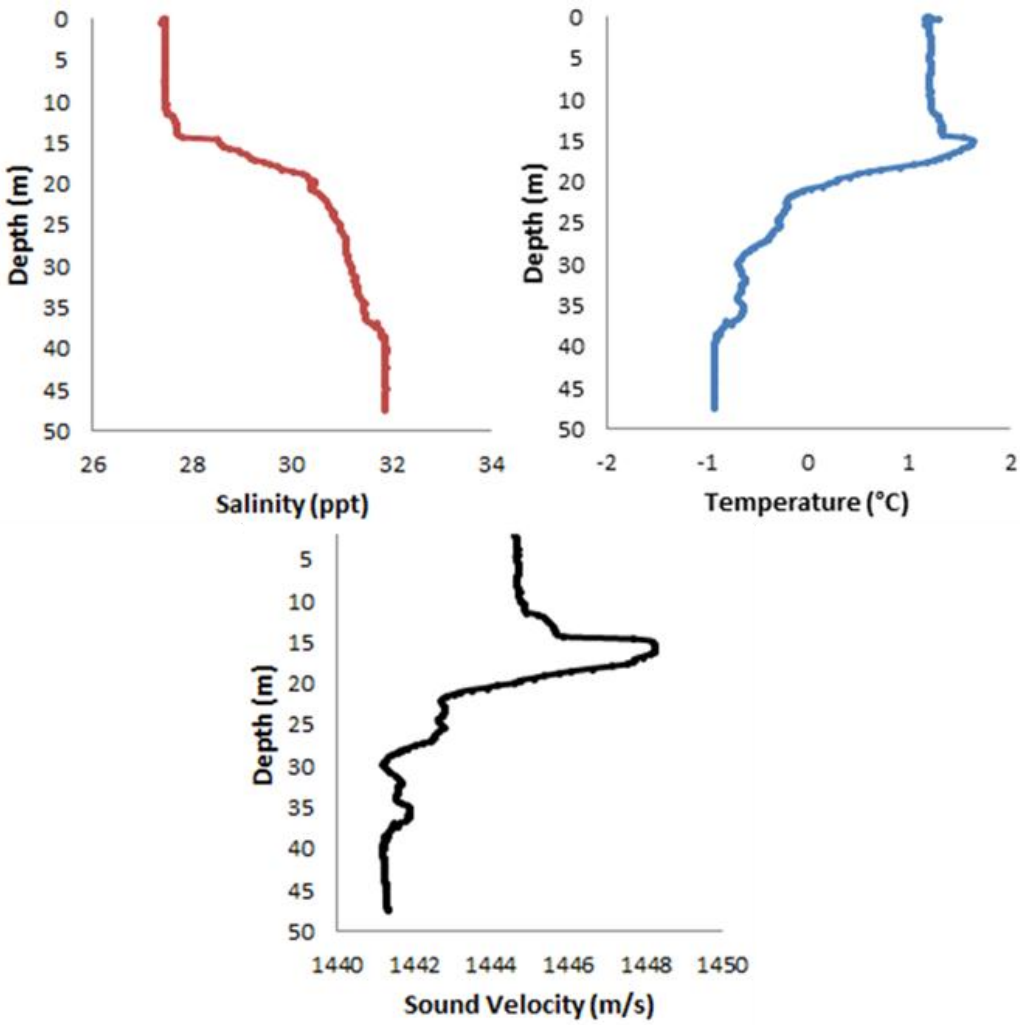

FIGURE 3.6. Measured ocean salinity and temperature profiles and the derived sound speed profile from the CTD cast at the Shallow SSV site. The cast was performed at 23:35 on 20 Oct 2012 (UTC) at 70°09.656′ N, 140°46.412′ W near S1.

Mitigation Airgun (70 in^3)

Underwater sound from the omnidirectional 70 in^3 mitigation airgun was measured at S1. Sound levels in the endfire and broadside directions were not distinguished because the 70 in^3 airgun is an omnidirectional source. The M/V *Geo Arctic* towed the airgun at approximately 8.5 m (27.9 ft) depth along the Shallow SSV track. The measurement was performed on 22 Oct 2012 as the vessel approached the recorder, and then departed. The hydrophone was approximately 3 m (10 ft) above the seafloor, with 55 m (180) nominal water depth along the track. The CPA was 400 m slant range.

Figure 3.7 shows sound levels versus range for the forward endfire direction of the 70 in^3 airgun. A curve of the form Equation 8 was fit to the data to determine resulting distances to threshold levels (Table 3.5).

Figure 3.8 shows two 70 in^3 airgun pulses, measured at the CPA and at the maximum detectable range. The M/V *Geo Arctic* is the source of tonal noise in the spectrograms. The majority of the airgun pulse energy is below 1 kHz.

Figure 3.9 shows the corresponding waveforms and spectra of the same two pulses shown in Figure 3.8. The waveforms show a lengthening of the pulse with range and the spectra reveal a decrease in frequency bandwidth with range. The 90% energy pulse duration plot in Figure 3.10 also shows an increase in pulse length with range, with a maximum pulse length of ~2 s at approximately 80 km (50 mi).

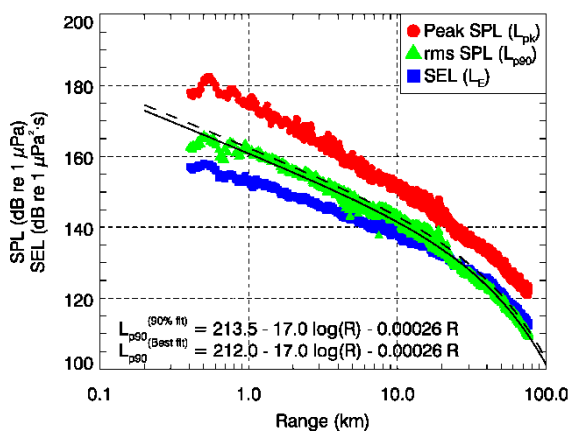

FIGURE 3.7. Mitigation airgun 70 in^3 peak SPL, 90% rms SPL, and SEL versus range at the Shallow SSV site. Solid line is best fit of the empirical function to L_{p90} values. Dashed line is the best fit shifted to exceed 90% of the L_{p90} values (90th percentile fit).

TABLE 3.5. Mitigation airgun (70 in^3) distances to sound level thresholds (50 m receiver depth) from least-squares fit (see Figure 3.7) for the Shallow SSV site.

rms SPL Threshold (dB re 1 µPa)	Endfire Direction	
	Best-fit range (m)	90th percentile-fit range (m)
190	20*	24*
180	76*	94*
170	293*	362*
160	1 110	1 360
150	3 890	4 690
140	11 550	13 400
130	26 500	29 600
120	48 200	52 000

* Extrapolated beyond minimum measurement range of 401 m.

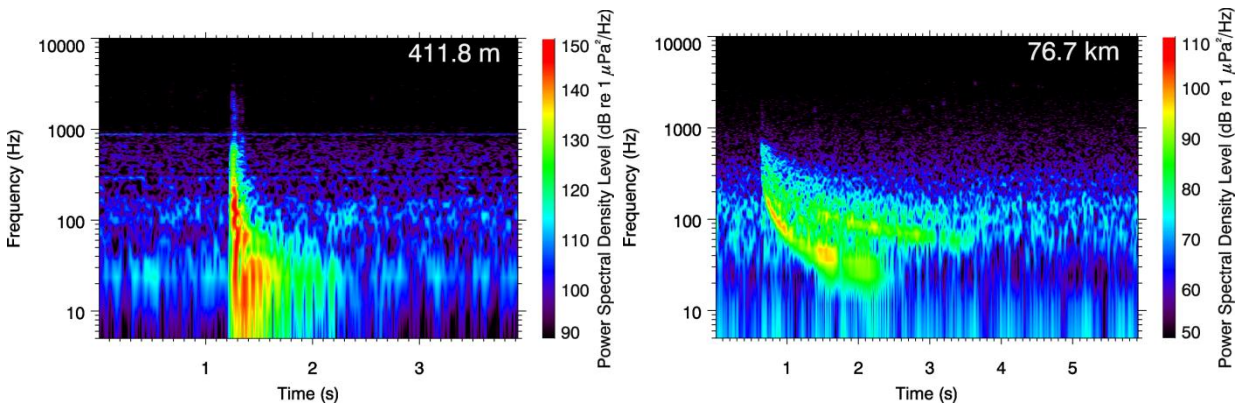

FIGURE 3.8. Spectrograms of a 70 in^3 airgun pulse at CPA (left) and at the maximum range (right) at the Shallow SSV site. 8192-pt FFT, 96 kHz sample rate, Hanning window, 1024-pt step size.

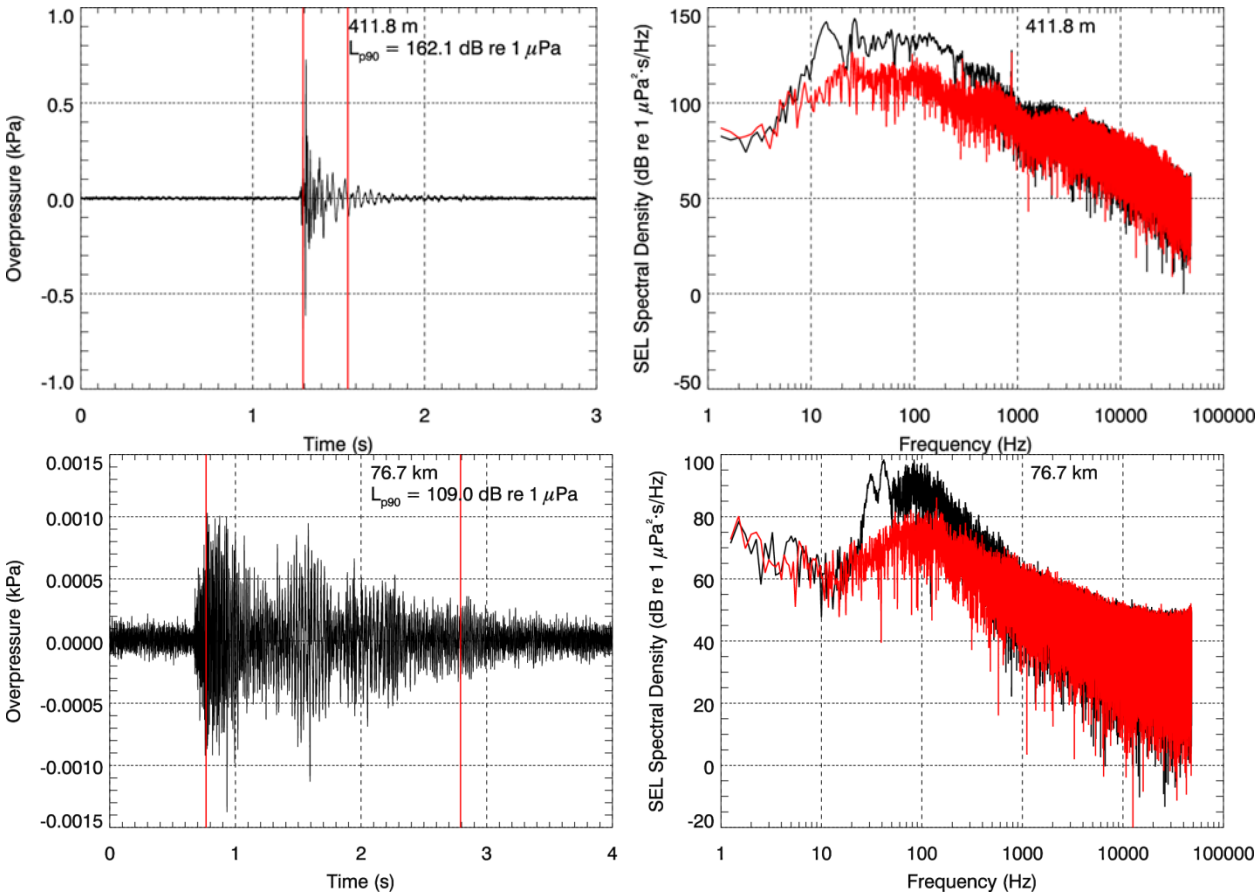

FIGURE 3.9. Waveform (left) and SEL spectral density plot (right) of the two 70 in^3 airgun pulses shown in Figure 3.8 measured at S1 near CPA (top) and at the maximum detectable range (bottom). Background noise from a same-sized window preceding the pulse is shown in red for comparison.

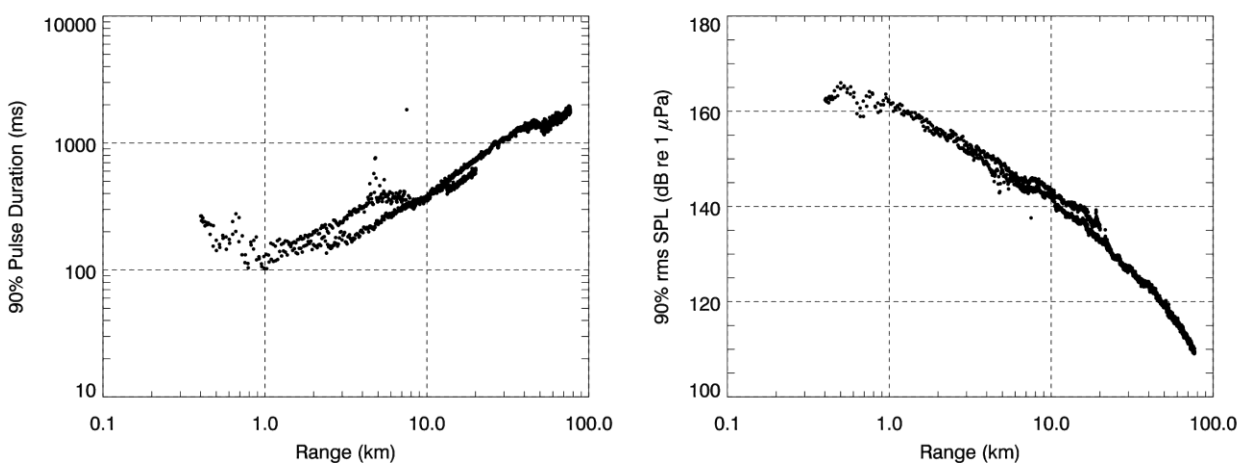

FIGURE 3.10. The 90% energy pulse duration and rms SPL as a function of range for the mitigation airgun (70 in^3) at the Shallow SSV site.

Airgun Array (4380 in^3)

Underwater sound from the 4380 in^3 airgun array was measured at S1, S2, and S3 to capture sound in both endfire and broadside directions. The measurements were performed on 22 Oct 2012 as the M/V *Geo Arctic* approached the recorders and then departed.

Figure 3.11 shows sound levels versus range for the approach of the 4380 in^3 airgun array in the endfire (left) and broadside (right) directions. Endfire data were restricted to ranges greater than 1 km (0.6 mi) to avoid lower levels between the array's endfire and broadside lobes. The broadside plot contains the 10 pulses with highest rms SPL measured on each recorder to ensure the recorder was measuring the array's broadside lobe. A curve of the form of Equation 8 was fit to the data to determine distances to threshold levels (Table 3.6).

As discussed in the Data Analysis section, these distances are more accurate than those in the field report (MacDonnell and Wladichuk 2012) because this analysis has excluded distorted measurements from the more sensitive hydrophone and included the more accurate measurements from the less sensitive hydrophone. The endfire measurements have been restricted to greater than 1 km range and only 10 broadside pulses were included for the broadside fit. These restrictions have also increased the accuracy of the directional threshold distances.

The reanalysis resulted in an increase to the 190 and 180 dB threshold distances. The lower level threshold distances are similar to those of the field report with the exception of the 120 dB threshold distance in the broadside direction. These distances are extrapolated substantially beyond the maximum measurement range so the accuracy of these results is uncertain. Table 3.7 lists threshold distances from the field report and from this reanalysis.

Figure 3.12 shows 4380 in^3 airgun array pulses measured at 1 km (0.6 mi), 10 km (6 mi), and maximum range. Figure 3.13 shows two spectrograms of full array broadside pulses measured at CPA (~400 m or ~1312 ft) and 20 km (12 mi) range at S3. The spectrograms show the majority of the pulse energy was below 1 kHz.

The waveforms (Figure 3.14) and spectra (Figure 3.12) for the endfire pulses show pulse length increased and frequency bandwidth decreased with range. Figure 3.15 shows contoured 1/3-octave band levels versus range from the endfire data. The 90% energy pulse duration and SPL versus range plots are shown in Figure 3.16.

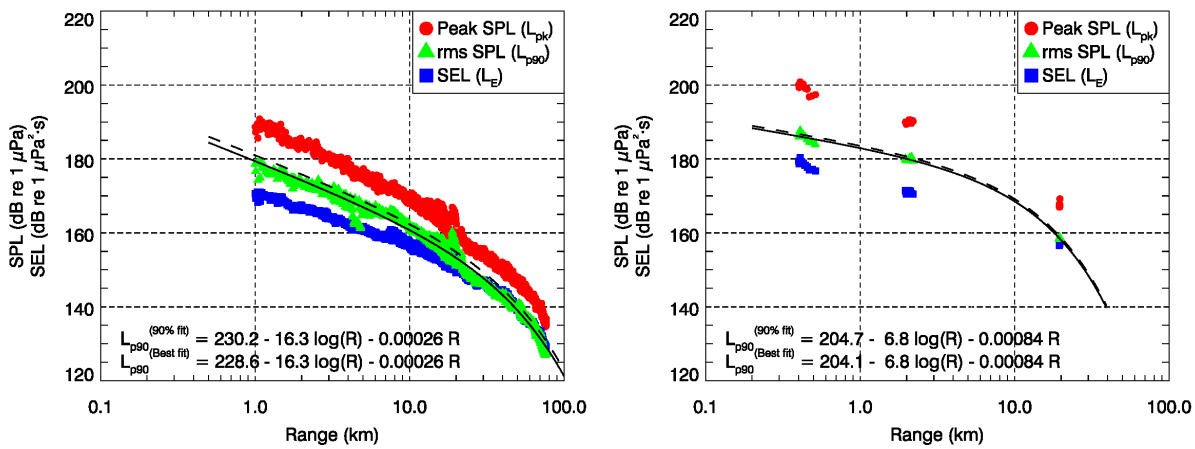

FIGURE 3.11. Airgun array 4380 in^3 peak SPL, 90% rms SPL, and SEL versus range in the forward endfire (left) and broadside (right) directions at the Shallow SSV site. Solid line is best fit of the empirical function to L_{p90} values. Dashed line is the best fit shifted to exceed 90% of the L_{p90} values (90th percentile fit).

TABLE 3.6. Airgun array 4380 in^3 distances to sound level thresholds (50 m receiver depth) from least-squares fit (see Figure 3.11) in the forward endfire and broadside directions for the Shallow SSV site.

rms SPL Threshold (dB re 1 µPa)	Forward Endfire		Broadside	
	Best-fit range (m)	90th percentile-fit range (m)	Best-fit range (m)	90th percentile-fit range (m)
190	230[a]	287[a]	115[b]	141[b]
180	917[a]	1 140	2 010	2 290
170	3430	4 190	8 730	9 260
160	10 800	12 600	18 100	18 700
150	25 700	28 800	28 300[c]	29 000[c]
140	47 600	51 600	39 100[c]	39 800[c]
130	74 200	78 700[d]	50 100[c]	50 800[c]
120	104 000[d]	109 000[d]	61 200[c]	61 900[c]

[a] Extrapolated beyond minimum measurement range of 1 km using the 90th percentile fit.
[b] Extrapolated beyond minimum measurement range of 401 m using the 90th percentile fit.
[c] Extrapolated beyond maximum measurement range of 19.6 km using the 90th percentile fit.
[d] Extrapolated beyond maximum measurement range of 76.8 km using the 90th percentile fit.

TABLE 3.7. Airgun array 4380 in^3 distances to sound level thresholds (50 m receiver depth) from the 90th percentile fits from the field report and Table 3.6 in the forward endfire and broadside directions for the Shallow SSV site.

rms SPL threshold (dB re 1 µPa)	Forward Endfire		Broadside	
	Field report	90 day report (TABLE 3.6)	Field report	90 day report (TABLE 3.6)
190	160[a]	287[b]	10[a]	141[a]
180	820	1 140	340[a]	2 290
160	12 900	12 600	18 000	18 700
120	105 000[c]	109 000[c]	90 000[d]	61 900[d]

[a] Extrapolated beyond minimum measurement range of 401 m using the 90th percentile fit.
[b] Extrapolated beyond minimum measurement range of 1 km using the 90th percentile fit.
[c] Extrapolated beyond maximum measurement range of 76.8 km using the 90th percentile fit.
[d] Extrapolated beyond maximum measurement range of 19.6 km using the 90th percentile fit.

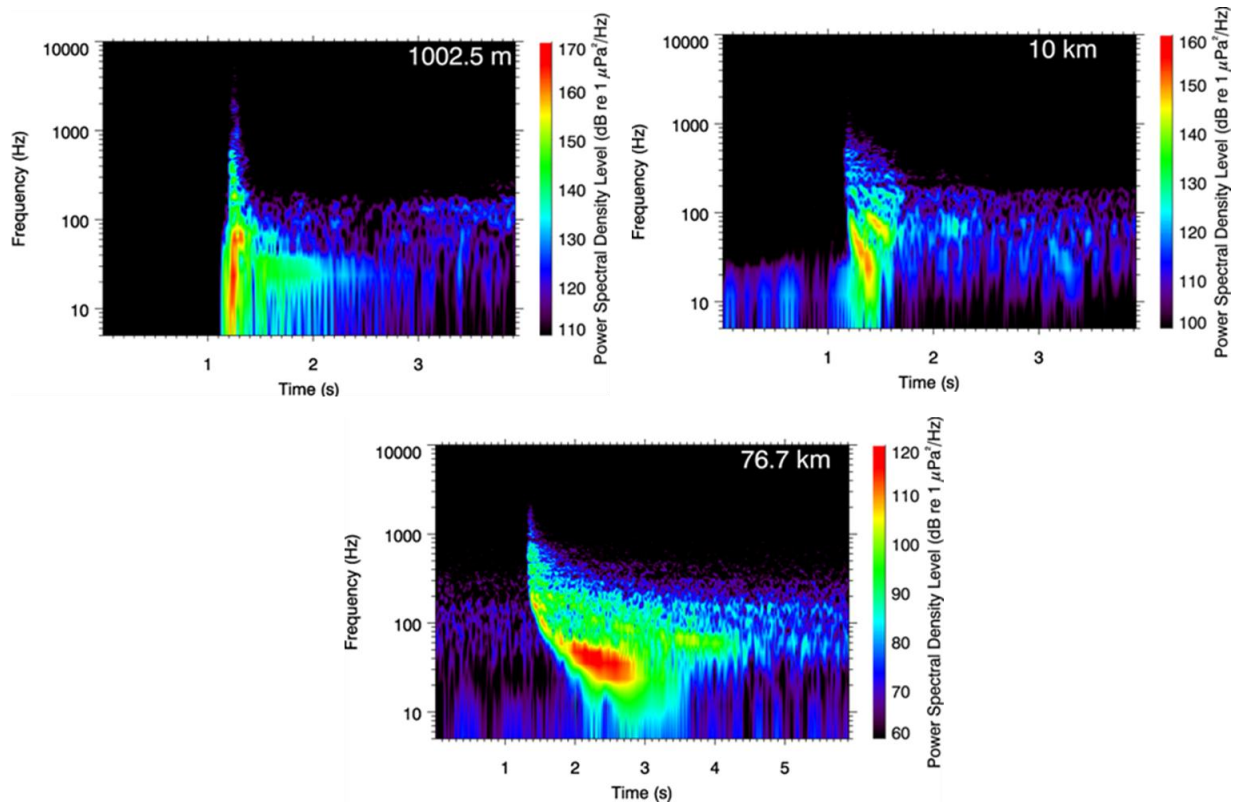

FIGURE 3.12. Spectrograms of 4380 in³ airgun array pulses measured in the endfire direction at S1. Ranges to source in top right corners of plots. 8192-pt FFT, 96 kHz sample rate, Hanning window, 1024-pt step size.

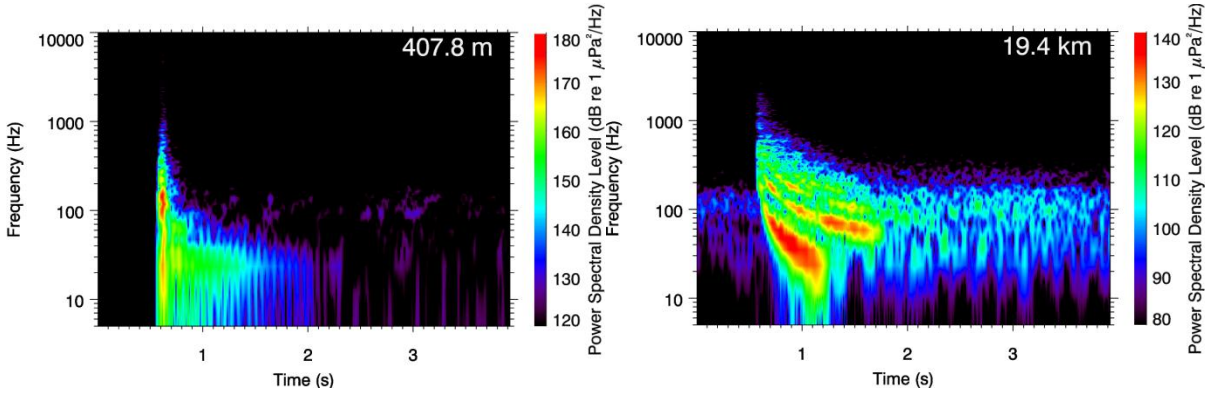

FIGURE 3.13. Spectrograms of 4380 in³ airgun array pulse measured at broadside at S1 (left) and S3 (right). Ranges to source in top right corners of plots. 8192-pt FFT, 96 kHz sample rate, Hanning window, 1024-pt step size.

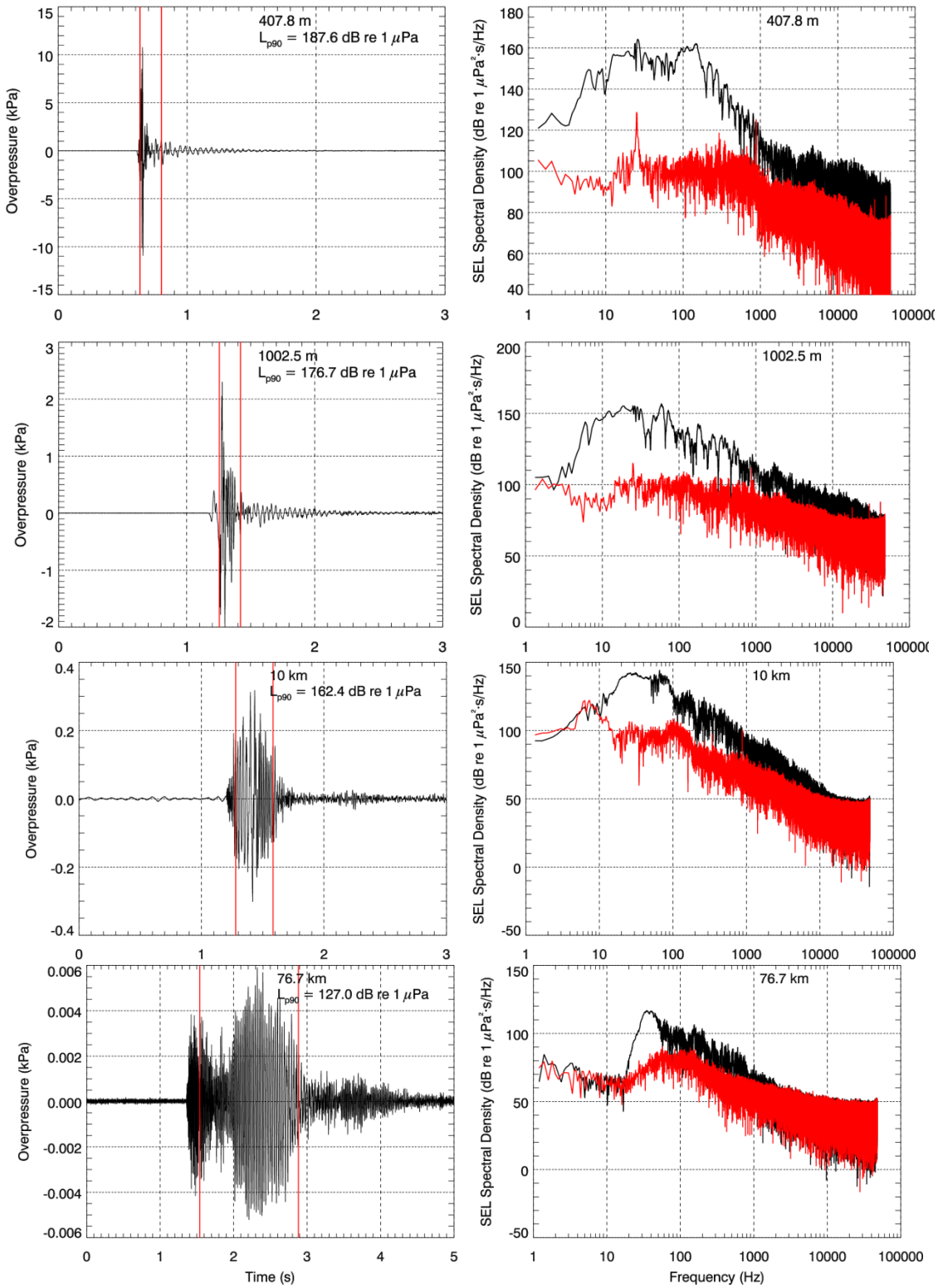

FIGURE 3.14. Waveform (left) and SEL spectral density plots (right) for the pulses in the spectrograms in Figure 3.12. Background noise from an equivalent window preceding the pulse is shown in red for comparison. Range to source noted in the plots.

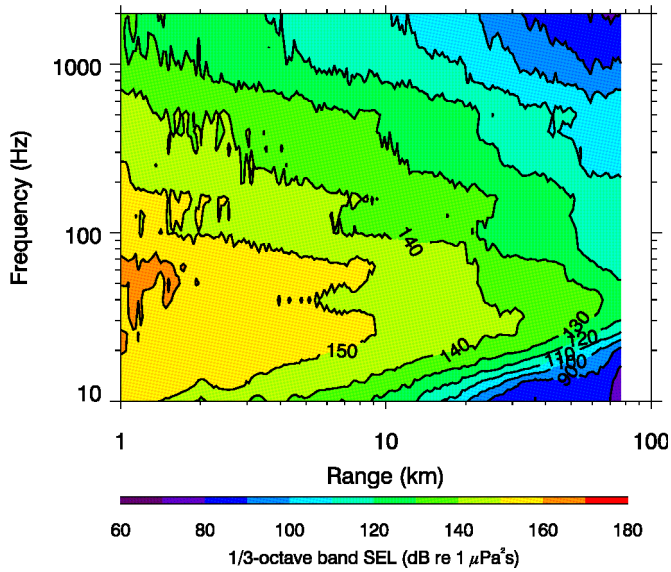

FIGURE 3.15. 1/3-octave band levels as a function of range and frequency for the 4380 in^3 airgun array configuration in the endfire direction.

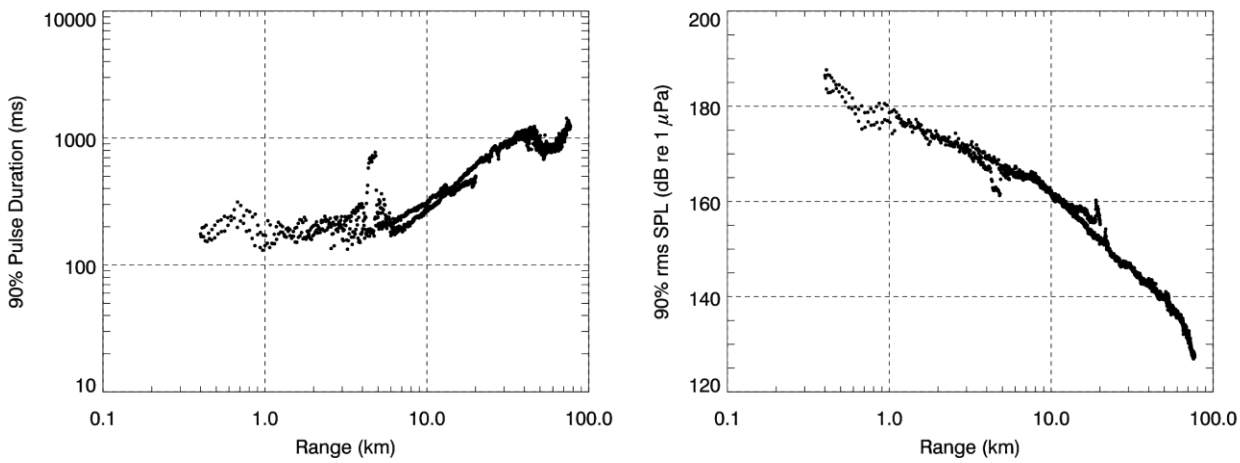

FIGURE 3.16. 4380 in^3 airgun array 90% energy pulse duration and rms SPL as a function of range.

Cumulative SEL was calculated with respect to each of S1, S2, and S3 recorders. Each pulse was M-weighted before computing and summing SEL, providing cumulative SELs specific to low- (LFC), mid- (MFC), and high-frequency (HFC) cetaceans, and pinnipeds (PINN). The cumulative flat- and M-weighted SEL at each recorder are shown in Figure 3.17 - Figure 3.19. Flat-weighted per pulse SEL was included for comparison. In aggregate, these data indicate the cumulative SEL at fixed positions at various distances from the track line, increasing with the number of recorded pulses as the track line was reversed until the line flattens out where the weak pulses travelling over long ranges have little contribution. Note that if these levels were to be used for assessing impact then one would be assuming the exposed animals remained stationary throughout the exposure (while the airguns operated along the entire track line).

The total cumulative SEL for each hearing group is listed in Table 3.8. Figure 3.20 shows the total cumulative SEL as a function of CPA distance. The total cumulative SEL did not reach the thresholds

proposed by Southall et al. (2007) at the closest measured range for cetaceans but was reached for pinnipeds. Distances to the injury criteria were calculated (see Table 3.9) using best-fit equations computed from Figure 3.20.

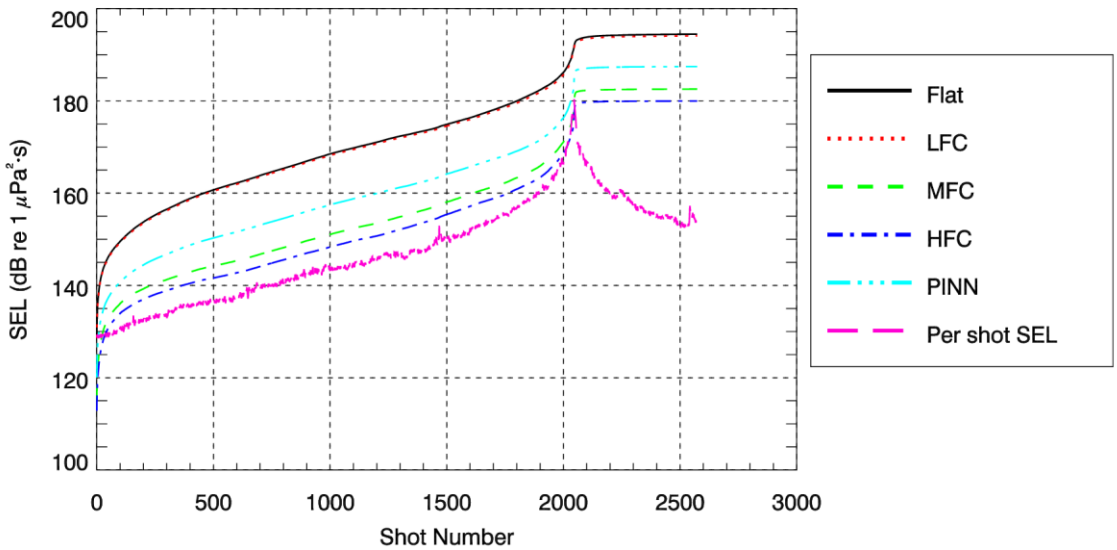

Figure 3.17. Airgun array 4380 in^3: Flat and M-weighted cumulative SEL with flat-weighted per shot SEL for OBH recorder S1 at the Shallow SSV site , with a CPA distance of 400 m.

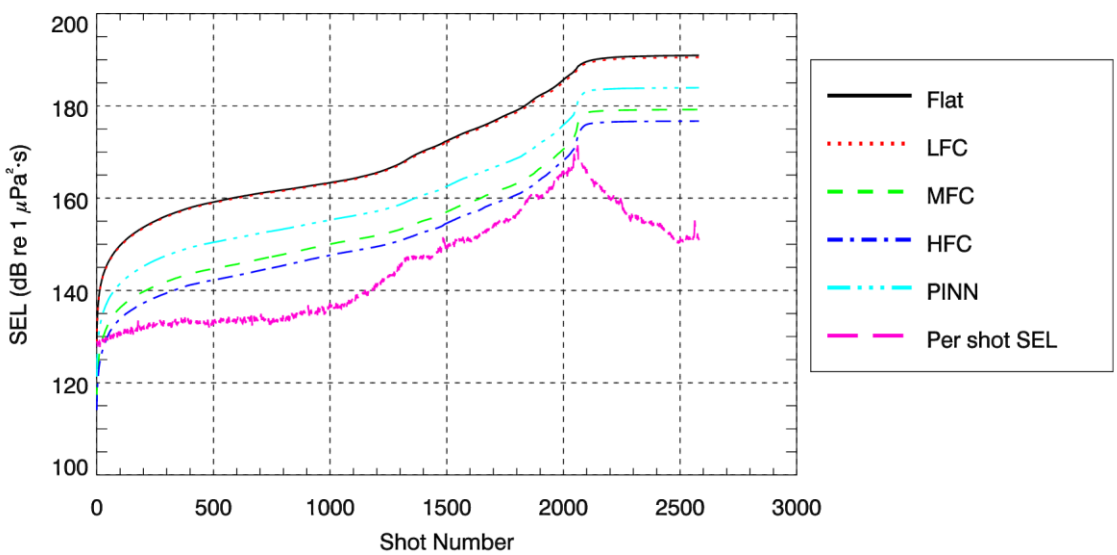

Figure 3.18. Airgun array 4380 in^3: Flat and M-weighted cumulative SEL with flat-weighted per shot SEL for OBH recorder S2 at the Shallow SSV site, with a CPA distance of 1844 m.

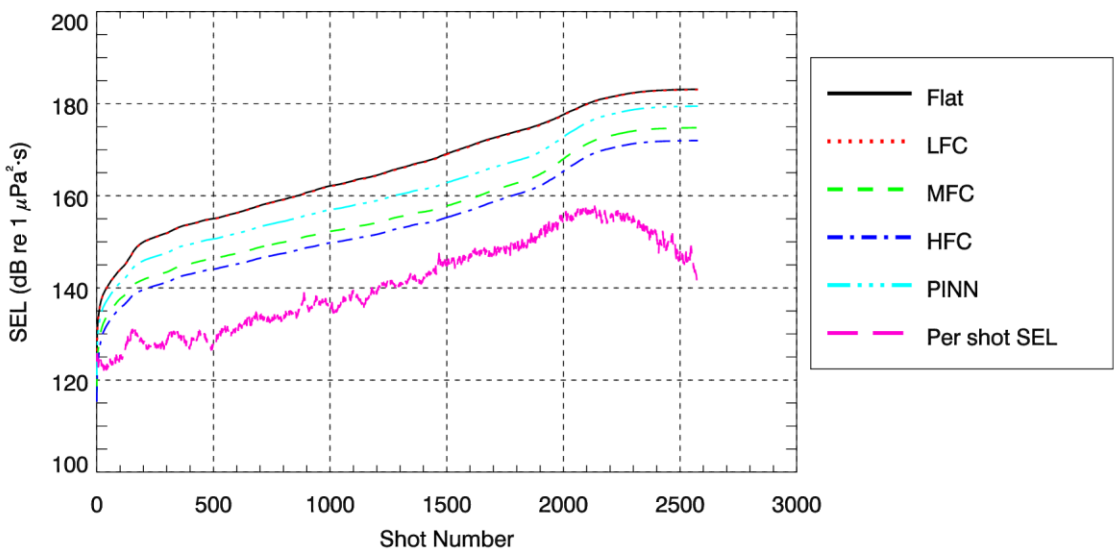

Figure 3.19. Airgun array 4380 in^3: Flat and M-weighted cumulative SEL with flat-weighted per shot SEL for OBH recorder S3 at the Shallow SSV site, with a CPA distance of 19.5 km.

Table 3.8. Total flat- and M-weighted cumulative sound exposure level (SEL) from the 4380 in^3 airgun array measured at fixed distances from the Shallow SSV track.

Distance off seismic survey line	Cumulative SEL (dB re 1 μPa^2·s)				
	Flat-Weighted	Low Frequency Cetaceans	Mid-Frequency Cetaceans	High Frequency Cetaceans	Pinnipeds Underwater
400 m	194.4	194.1	182.5	180.0	187.4
1844 m	190.9	190.5	179.2	176.7	183.9
19479 m	183.1	183.0	174.8	172.0	179.4

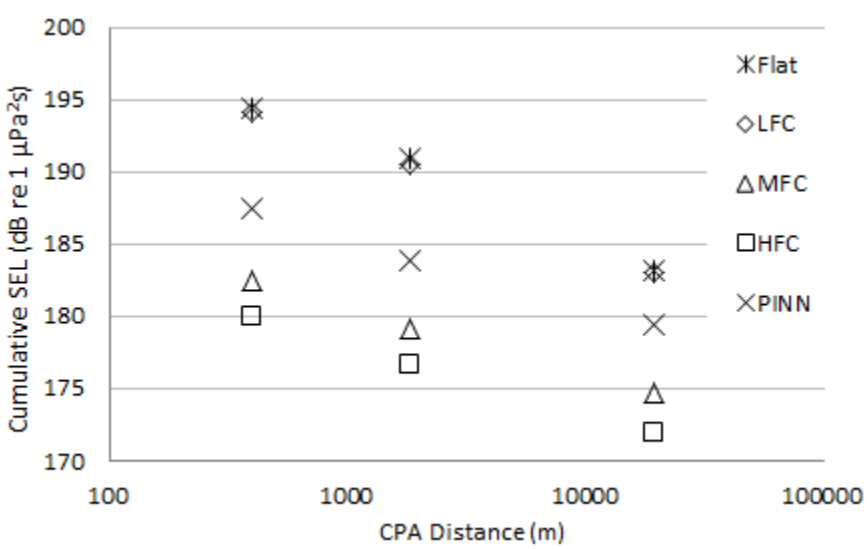

Figure 3.20. Cumulative SEL as a function of CPA distance for the 4380 in^3 airgun array measured at the Shallow SSV site.

Table 3.9. Airgun array 4380 in^3: Logarithmic best fit equations to cumulative SEL values shown in Figure 3.20 as well as distances to the Southall et al. (2007) proposed threshold criteria. All distances are extrapolated from the minimum measurement range.

Hearing Group	Equation (from Figure 3.20)	Distance to threshold (m)[a]
LFC	y = -2.872ln(x) + 211.59	114
MFC	y = -1.99ln(x) + 194.34	N/A[b]
HFC	y = -2.047ln(x) + 192.17	N/A[b]
PINN	y = -2.043ln(x) + 199.52	735

[a] LFC, MFC, and HFC use 198 dB re 1 μPa^2s threshold; PINN uses 186 dB re 1 μPa^2s.
[b] cSEL at notional source is below the threshold value.

M/V *Geo Arctic*

Noise from the M/V *Geo Arctic* contributed to background sound levels measured during the Shallow SSV. Sound levels corresponding to airgun pulses and reverberation were removed from the data to determine sound levels attributed only to the M/V *Geo Arctic*. The lowest 1-second SPL measured every 36 seconds was attributed to the vessel. The resulting SPLs versus range are shown in Figure 3.21. These data represent an upper estimate of SPLs from the M/V *Geo Arctic* as simultaneous energy from seismic reverberation was present. The trend of the SPL versus range had positive curvature and consequently could not be fit well using either Equation 8 or 9 that are linear or have downward curvature shapes. The upward curvature is likely due to energy contributions from seismic reverberation which became relatively more important as vessel noise levels decreased with range. The distances to threshold levels were computed directly from the data without using a fit function (Table 3.10); each threshold distance is the maximum distance beyond which measured SPLs were less than the threshold level. Seismic reverberation contributions are expected to have little influence on the 120 and 130 dB re 1 µPa threshold distances.

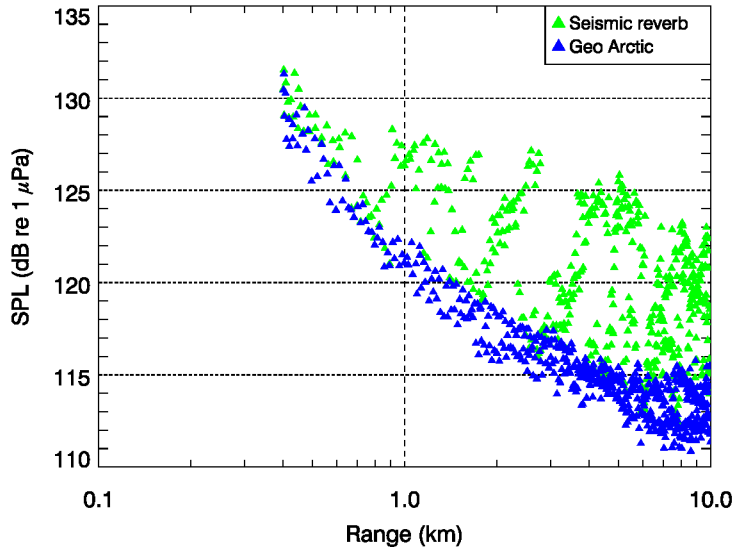

FIGURE 3.21. M/V *Geo Arctic* rms SPL (blue) and seismic reverberation (green) versus slant range. Vessel speed was approximately 4 kts.

TABLE 3.10. M/V *Geo Arctic* threshold distances for transiting at 4 kts at the Shallow SSV site. Each threshold distance is the maximum distance beyond which measured SPLs were less than the threshold level.

SPLrms Threshold (dB re 1 µPa)	Distance to Threshold (m)
130	411
120	1420

M/V Polar Prince

SPLs were computed for noise from the support vessel, M/V *Polar Prince*, as it transited away from S1. Airgun activity was not present during this time. A low-pass filter at 40 kHz was applied to eliminate any noise from the vessel's 50 kHz depth sounder.

SPLs were computed in consecutive 1-second time windows (0.5-second step size) and represent continuous noise levels as opposed to the impulsive levels from airguns. Figure 3.22 presents the rms SPLs versus slant range for the M/V *Polar Prince* vessel noise transiting at approximately 5 kts, as well as the best-fit and 90th percentile trend lines and associated equations. Data presented in these plots were recorded from the higher sensitivity TC4032 hydrophone. The ranges to the sound level thresholds of 130 to 100 dB re 1 µPa (rms SPL) for the M/V *Polar Prince* travelling at 5 kts are listed in Table 3.11.

Figure 3.23 shows contoured 1/3-octave band levels versus range and frequency for the M/V *Polar Prince* transiting at 5 kts. 1/3-octave band levels at frequencies between approximately 60 Hz and 400 Hz were highest near the vessel.

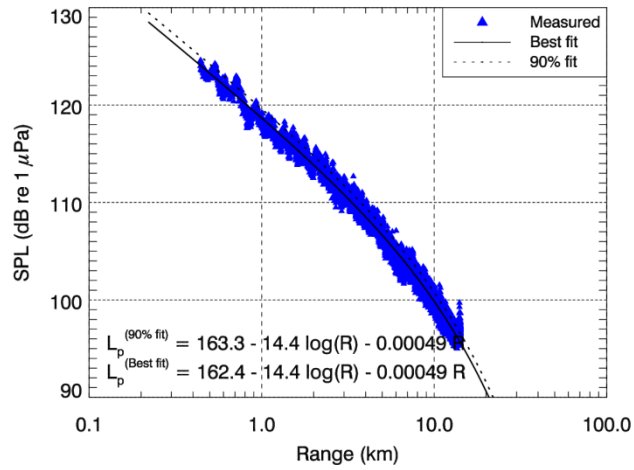

FIGURE 3.22. M/V *Polar Prince* rms SPL versus slant range in the aft direction while the vessel departed S1 at 5 kts. Solid line is the best fit of the empirical function to SPL values. Dashed line is the best fit adjusted to exceed 90% of the SPL values.

TABLE 3.11. M/V *Polar Prince* threshold distances for transiting at approximately 5 kts at the Shallow SSV site measured at S1 as determined from SPL versus distance data (Figure 3.22).

rms SPL Threshold (dB re 1 μPa)	Best-Fit Line Radius (m)	90th Percentile Radius (m)
130	175*	202*
120	820	943
110	3 330	3 740
100	9 870	10 700

* Extrapolated beyond the closest measured range of 440 m.

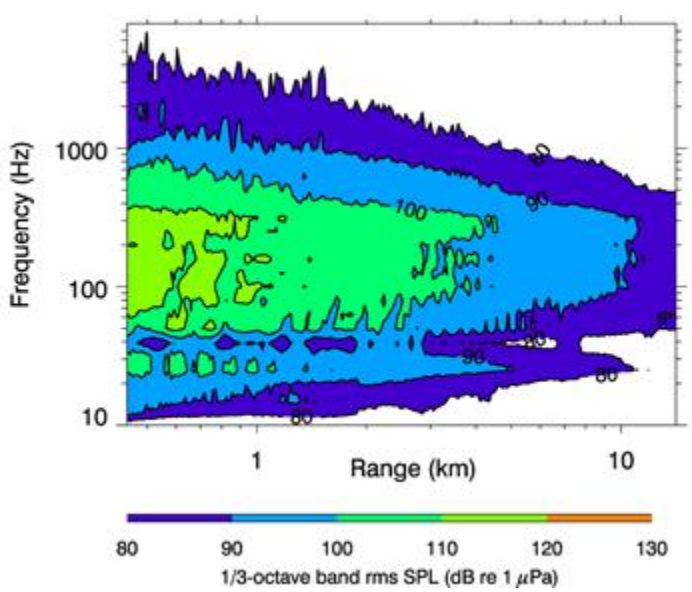

FIGURE 3.23. M/V *Polar Prince* vessel noise 1/3-octave band levels as a function of range and frequency when transiting at approximately 5 kts away from S1.

Deep SSV Site

Sound Speed Profile

Salinity, temperature, and sound speed (Figure 3.24) were measured near D2 at 18:13 on 21 Oct 2012 (UTC). Salinity steadily increased with depth whereas temperature decreased with depth until approximately 100 m, at which point temperature remained constant to approximately 170 m. Temperature increased gradually at depths greater than 170 m. The sound speed profile followed a similar trend to the temperature in that the sound speed increased until ~15 m, then decreased until ~100 m, remained constant until ~145 m, and then increased with depth. This resulted in a surface-duct profile that was expected to trap airguns sound in the upper ~200 m of the water column and enhance long-range propagation.

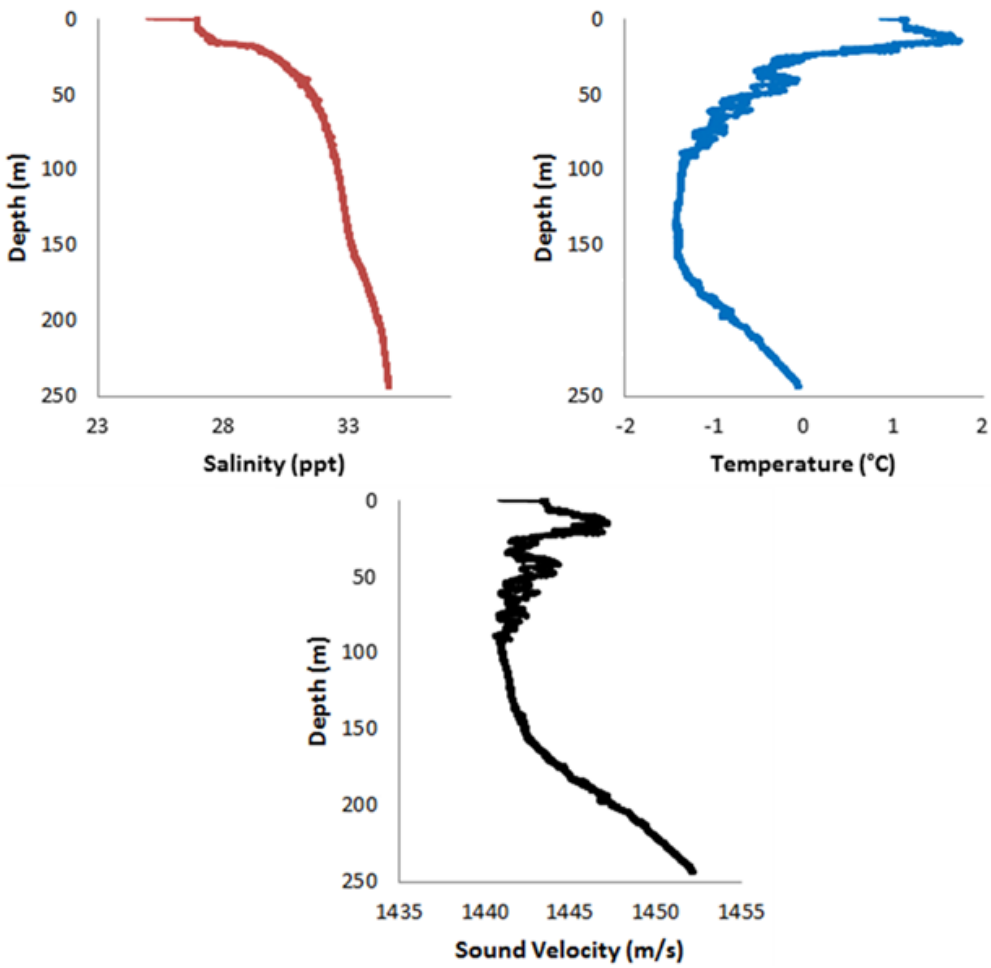

FIGURE 3.24. Measured ocean salinity and temperature profiles and the derived sound speed profile from a CTD cast at the Deep SSV site. The cast was performed 21 Oct 2012, 18:13 (UTC) at 70°28.720′ N, 140°49.854′ W near the 1 km offset location.

Mitigation Airgun (70 in^3)

Underwater sound from the 70 in^3 mitigation airgun was measured on a 50 m-deep recorder suspended from the support vessel M/V *Polar Prince*. The vessel engines were off during the SSV to minimize contaminating vessel noise. The measurement was performed on 23 Oct 2012 as the M/V *Geo Arctic* passed D1 at approximately 2 km range.

Figure 3.25 shows received sound levels versus range of the 70 in^3 airgun. A curve of the form Equation 9 was fit to the data to determine the distances to lower threshold levels (Table 3.12). For higher threshold levels, the fit did not represent spherical spreading loss (i.e., 20LogR) which is expected in deep water at close range (Jensen et al. 1994). Distances for threshold levels above 150 dB re 1 µPa were calculating by back-propagating the loudest measured pulse (150 dB re 1 µPa at 2230 m range) using spherical spreading. Though the spherically back-propagated threshold distances are less than those from the 90th percentile fit, they are expected to be more accurate for this environment. The loudest pulse was likely measured at a convergence zone so back propagating this pulse level likely results in cautionary threshold distances for a receiver at 50 m depth and may represent the maximum sound level over all depths for closer ranges.

Figure 3.26 shows two 70 in^3 airgun pulses measured at the CPA and near the maximum detectable range. Tonal noise in the spectrograms is from the vessels. The majority of the pulse energy is below approximately 500 Hz. Figure 3.27 shows the corresponding waveforms and spectra for these pulses. The spectra show relatively low signal-to-noise ratio due to high background noise levels from the M/V *Polar Prince*.

Figure 3.28 shows contoured 1/3-octave band levels for the endfire data. Figure 3.29 shows the 90% energy pulse duration and SPL versus range.

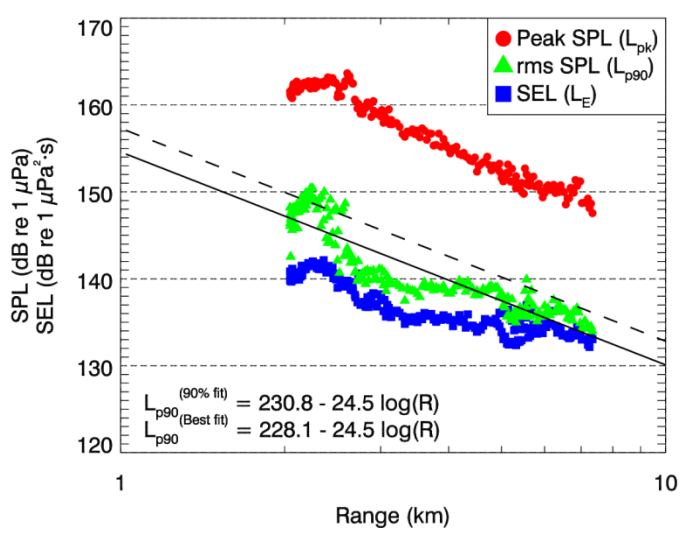

FIGURE 3.25. Mitigation airgun 70 in^3 peak SPL, 90% rms SPL, and SEL versus range at the Deep SSV site. Solid line is best fit of the empirical function to L_{p90} values. Dashed line is the best fit shifted to exceed 90% of the L_{p90} values (90th percentile fit).

TABLE 3.12. Mitigation airgun 70 in^3 distances to sound level thresholds (50 m receiver depth) from least-squares fit (see Figure 3.25) for the Deep SSV site.

rms SPL threshold (dB re 1 µPa)	90% rms SPL	
	Best-fit range (m)	90th percentile-fit range (m)
190	N/A	23[a]
180	N/A	74[a]
170	N/A	234[a]
160	N/A	741[a]
150	1 540[b]	1 990[b]
140	3 940	5 100
130	10 100[c]	13 000[c]
120	25 800[c]	33 400[c]

[a] Extrapolated by back-propagating the loudest measured pulse (150 dB re 1 µPa at 2230 m range) using spherical spreading (i.e., 20LogR).
[b] Extrapolated beyond closest measurement range of 2050 m using the 90th percentile fit.
[c] Extrapolated beyond the farthest measurement range of 7340 m using the 90th percentile fit.

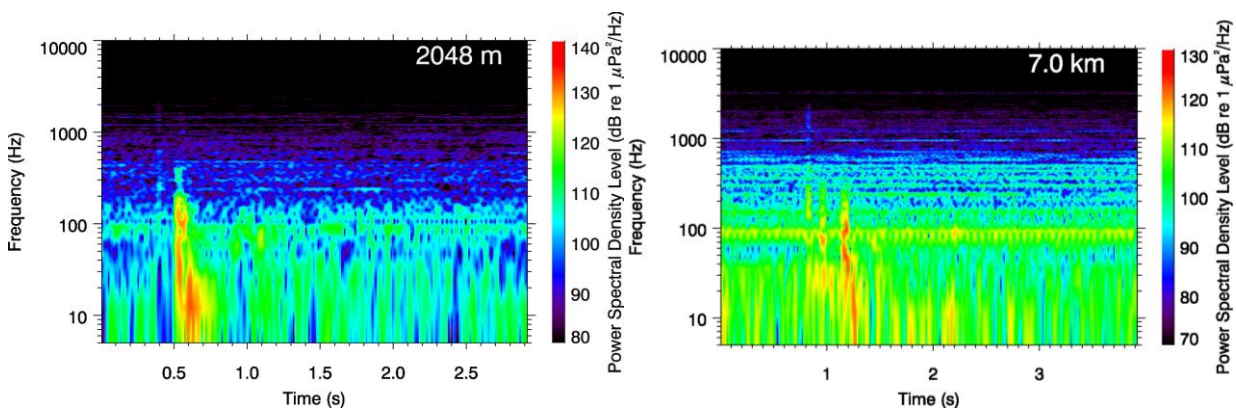

FIGURE 3.26. Spectrogram of a 70 in^3 airgun pulse at the CPA (left) and near maximum detectable range (right) at the Deep SSV site. Tonal noise is from the support vessel, although main engines were off. 8192-pt FFT, 96 kHz sample rate, Hanning window, 1024-pt step size.

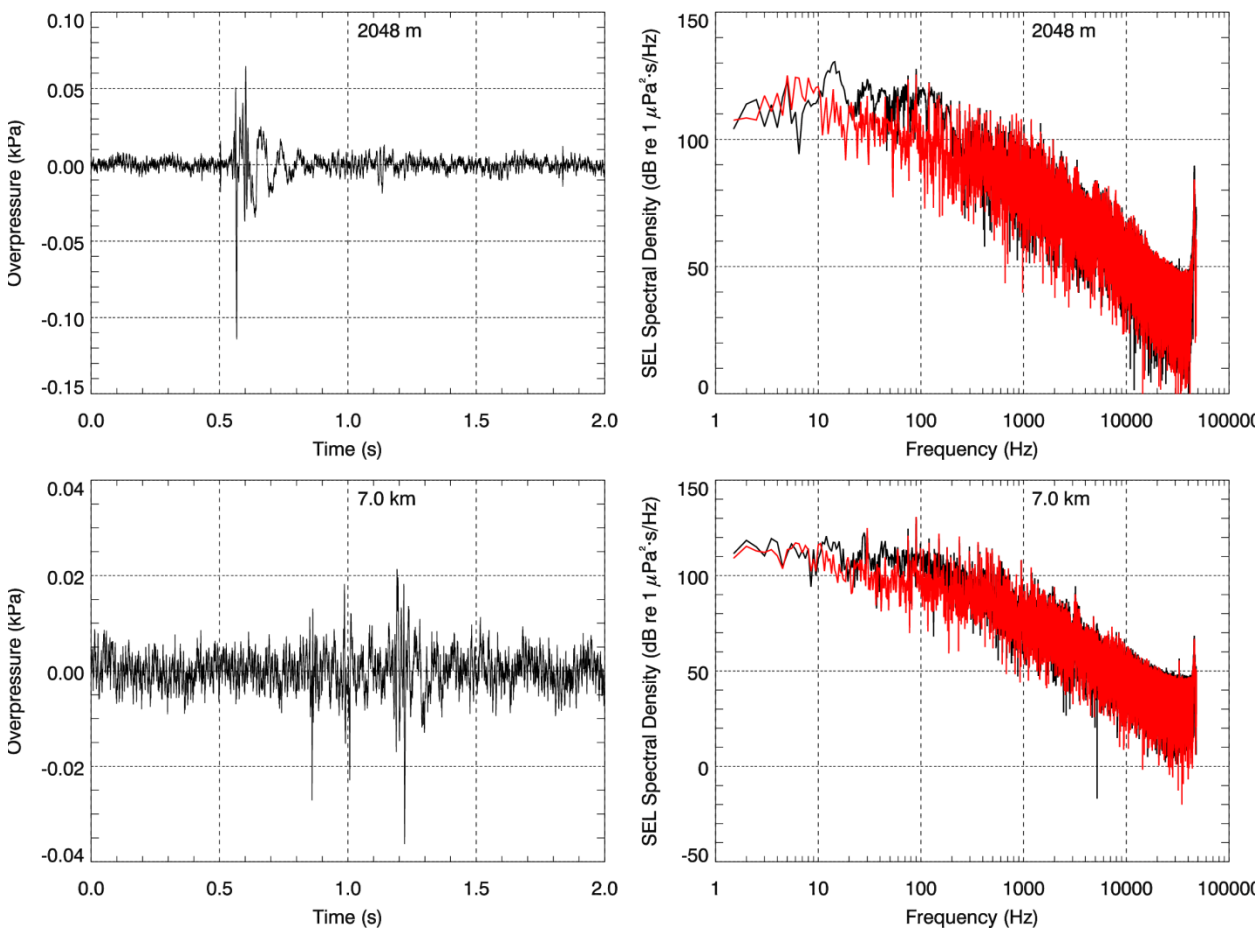

FIGURE 3.27. Mitigation airgun 70 in^3 waveforms (left column) and SEL spectral density over 200 ms (right column) of the same pulses in the spectrograms in Figure 3.26 at the Deep SSV site. Background noise from a 200 ms window preceding the pulse is shown in red for comparison.

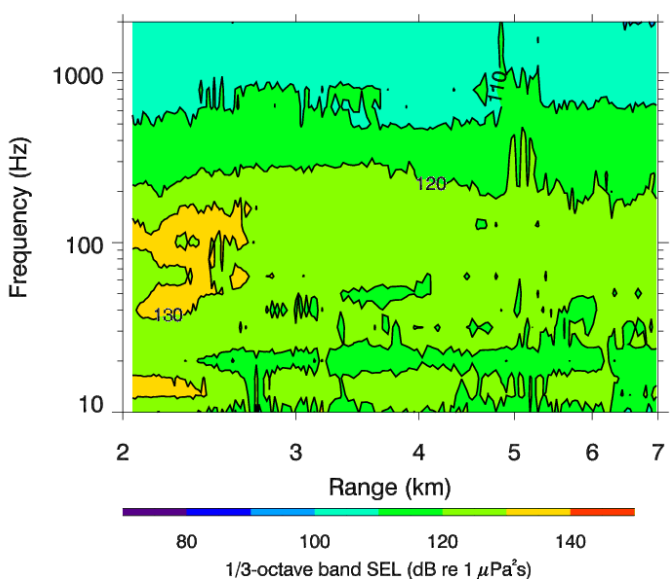

FIGURE 3.28. 1/3-octave band SEL as a function of range and frequency for the mitigation airgun 70 in^3 at the Deep SSV site.

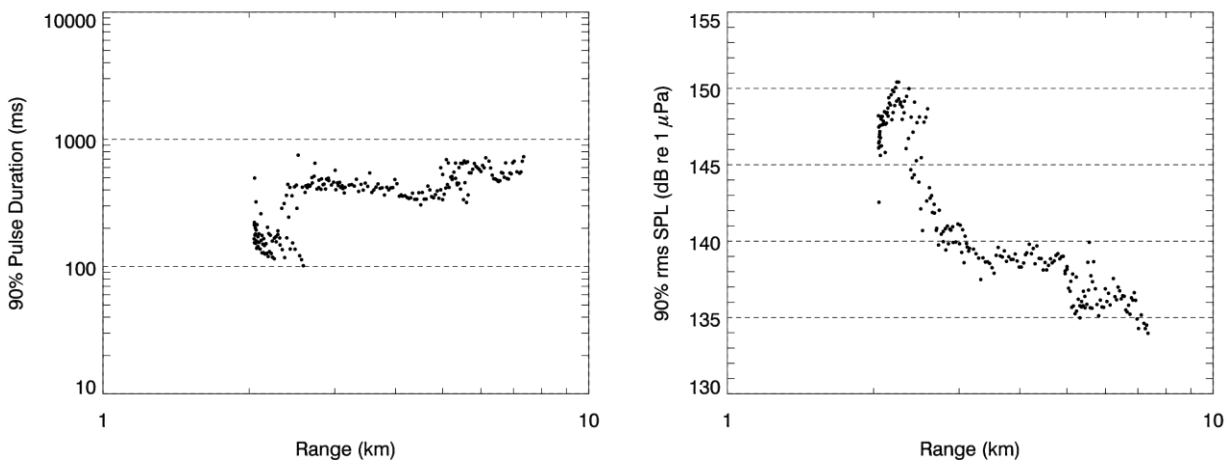

FIGURE 3.29. 70 in^3 mitigation airgun array 90% energy pulse duration and rms SPL as a function of range for the Deep SSV site.

Airgun Array (4380 in^3)

Underwater sound from the 4380 in^3 airgun array was measured on a 50 m-deep recorder suspended from the support vessel M/V *Polar Prince* at various ranges. The vessel engines were off during the SSV, but were turned on when the vessel needed to reposition itself due to drift. The measurement was performed on 23 Oct as the *Geo Arctic* passed D1 at approximately 2 km range. To obtain broadside data, a small track section was run two additional times, once with the recorder repositioned at approximately 5 km and again with the recorder at a 20 km range.

Received sound levels versus range in the forward endfire and broadside directions are shown in Figure 3.30. No endfire measurements at 20 km range were obtained because the M/V *Polar Prince* had to be repositioned when the M/V *Geo Arctic* was at that range. The broadside plot has the 10 pulses with highest rms SPL for each recorder to ensure each was recording the array's broadside lobe.

A curve of the form Equation 8 was fit to the endfire data and a curve of the form Equation 9 was fit to the broadside data. The curve fits were used to estimate distances to threshold levels beyond the maximum measurement ranges. Beyond the minimum measurement ranges, the fits did not represent spherical spreading loss (i.e., 20LogR) which is expected in deep water at close range (Jensen et al. 1994). Threshold distances were calculated by back-propagating the loudest measured pulse (159 dB re 1 µPa at 3030 m range for endfire, 175 dB re 1 µPa at 2240 m range for broadside) using spherical spreading. These back-propagated threshold distances are likely more accurate than those obtained from the 90th percentile fit. Spherically back-propagated endfire threshold distances are larger than the corresponding 90th percentile fit distances; for broadside measurements, spherically back-propagated threshold distances are less than the corresponding 90th percentile fit distances. Extrapolated broadside threshold distances from the 90th percentile fit are likely overestimated because the high 30.3LogR transmission loss value is due to long range pulse spreading which is not expected at close range for this environment. Table 3.13 lists the distances to threshold levels for both directions.

Figure 3.31 is spectrograms of three 4380 in^3 airgun array pulses measured at various distances in the endfire direction; tonal noise is from the vessels. The spectrograms show the majority of the pulse energy is below approximately 2 kHz. Figure 3.32 shows spectrograms at the three distances measured in the broadside direction. Figure 3.33 shows the waveforms and spectra for the same pulses shown in the spectrograms in Figure 3.31 and Figure 3.32. The waveforms show that, at long ranges, multipath

propagation was responsible for spreading of the airgun pulses at the Deep site. The spectra show most of the pulse energy is below 2 kHz (Figure 3.31 and Figure 3.32).

Figure 3.35 shows contoured 1/3-octave band levels for the endfire direction. The 90% energy pulse duration and SPL versus range plots are shown in Figure 3.36.

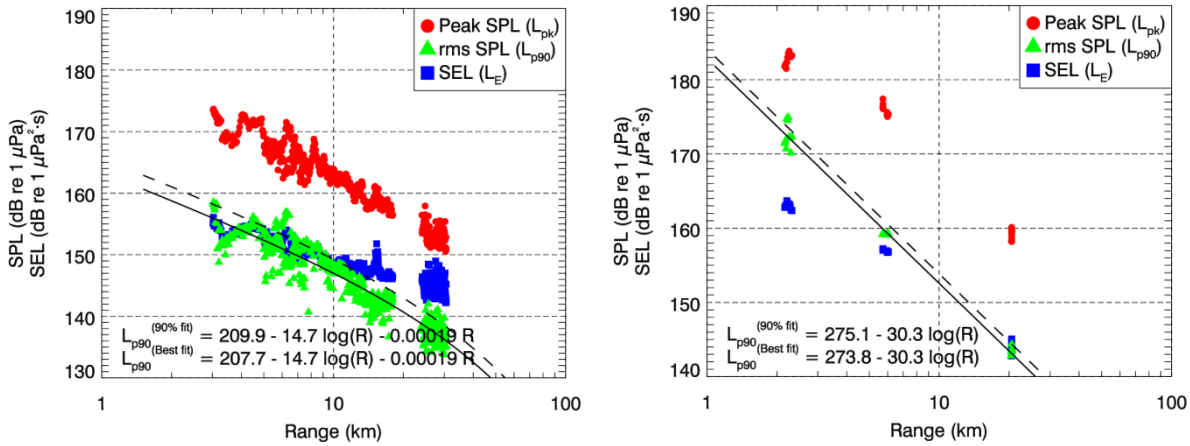

FIGURE 3.30. Airgun array 4380 in^3 peak SPL, 90% rms SPL, and SEL versus range in the forward endfire (left) and broadside (right) directions at the Deep SSV site. The gap in the endfire plot is when the recorder was retrieved while the support vessel repositioned itself to the predetermined recording location. Solid line is best fit of the empirical function to L_{p90} values. Dashed line is the best fit shifted to exceed 90% of the L_{p90} values (90th percentile fit).

TABLE 3.13. Airgun array 4380 in^3 distances to sound level thresholds (50 m receiver depth) from least-squares fit (see Figure 3.30) in the forward endfire and broadside directions for the Deep SSV site.

rms SPL threshold (dB re 1 μPa)	Endfire		Broadside	
	Best-fit range (m)	90th percentile-fit range (m)	Best-fit range (m)	90th percentile-fit range (m)
190	N/A	81[a]	N/A	395[b]
180	N/A	256[a]	N/A	1250[b]
170	N/A	810[a]	2 660	2 930
160	N/A	2 560[a]	5 690	6 260
150	6 840	9 120	12 200	13 400
140	21 400	26 400	26 000[c]	28 600[c]
130	47 600[d]	54 800[d]	55 500[c]	61 200[c]
120	82 200[d]	90 800[d]	119 000[c]	131 000[c]

[a] Extrapolated by back-propagating the loudest measured pulse (159 dB re 1 μPa at 3030 m) using spherical spreading (i.e., 20LogR).
[b] Extrapolated by back-propagating the loudest measured pulse (175 dB re 1 μPa at 2240 m) using spherical spreading (i.e., 20LogR).
[c] Extrapolated beyond the farthest measurement range of 20.5 km using the 90th percentile fit.
[d] Extrapolated beyond the farthest measurement range of 30.4 km using the 90th percentile fit.

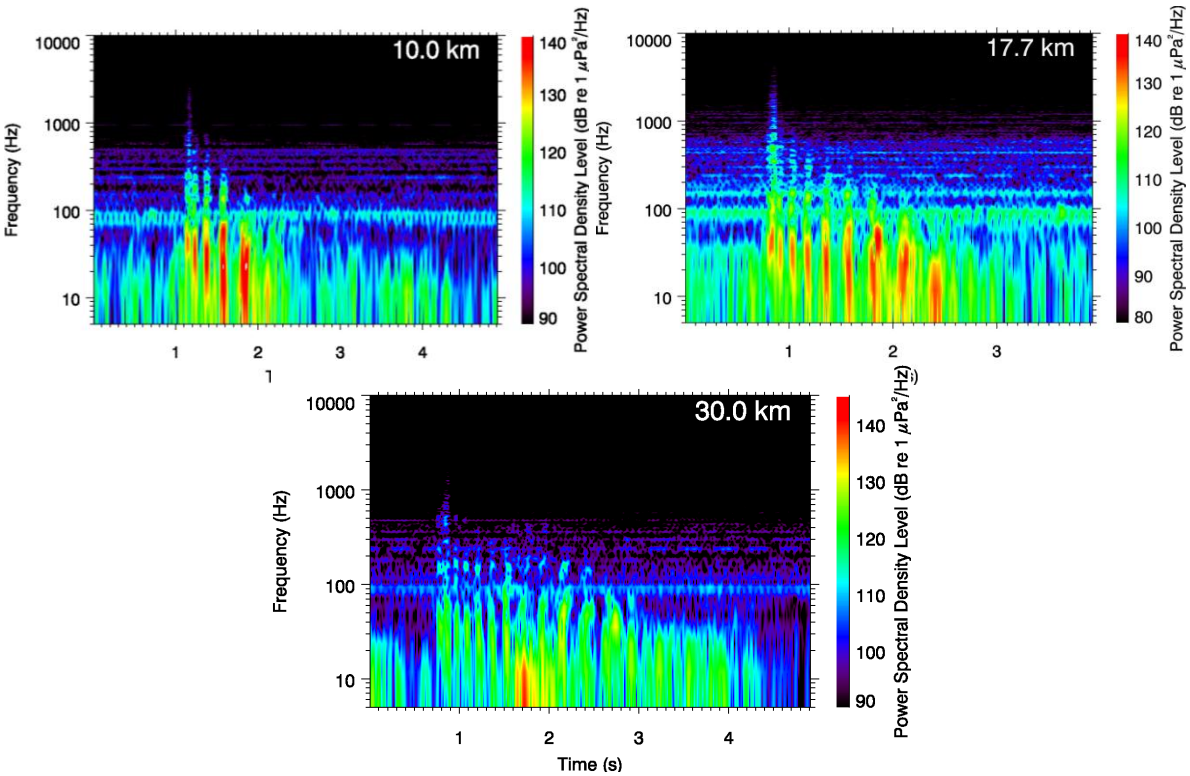

FIGURE 3.31. Spectrograms of 4380 in³ airgun array pulses measured in the endfire direction at the Deep site. Tonal noise is from the vessels. 8192-pt FFT, 96 kHz sample rate, Hanning window, 1024-pt step size.

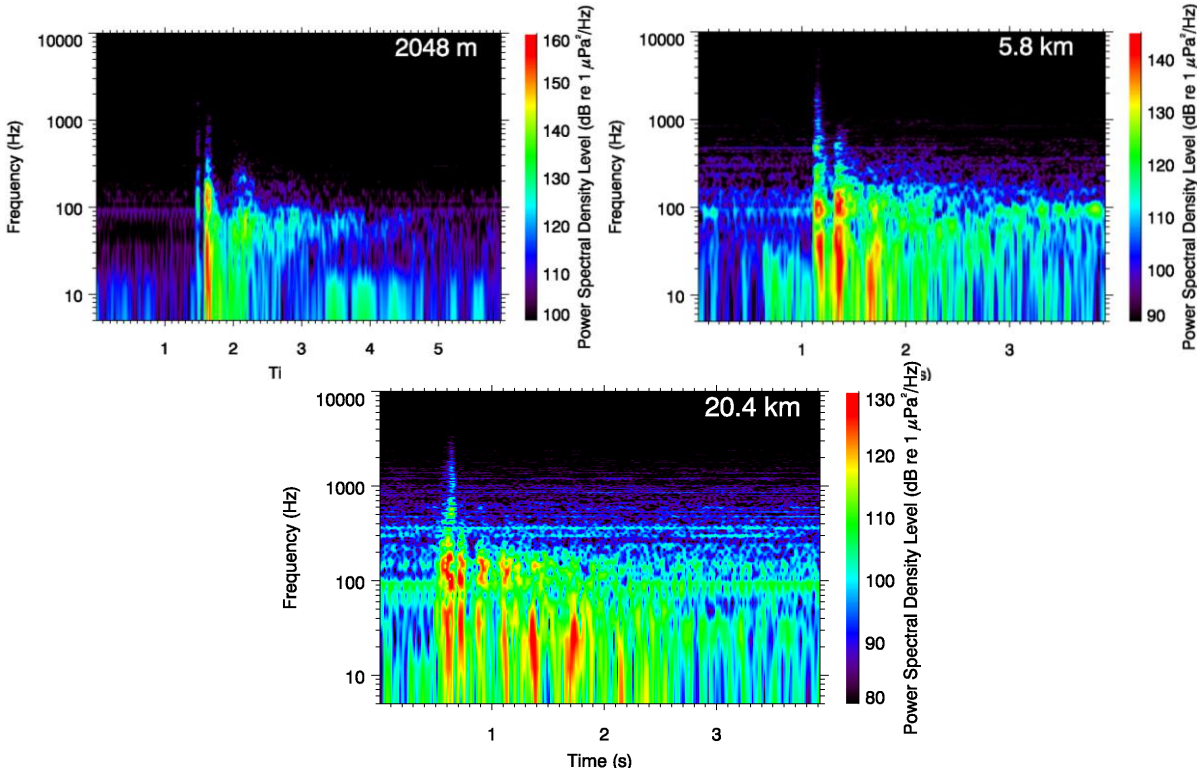

FIGURE 3.32. Spectrograms of 4380 in³ airgun array pulses measured at broadside at D1. Tonal noise is from the vessels. 8192-pt FFT, 96 kHz sample rate, Hanning window, 1024-pt step size.

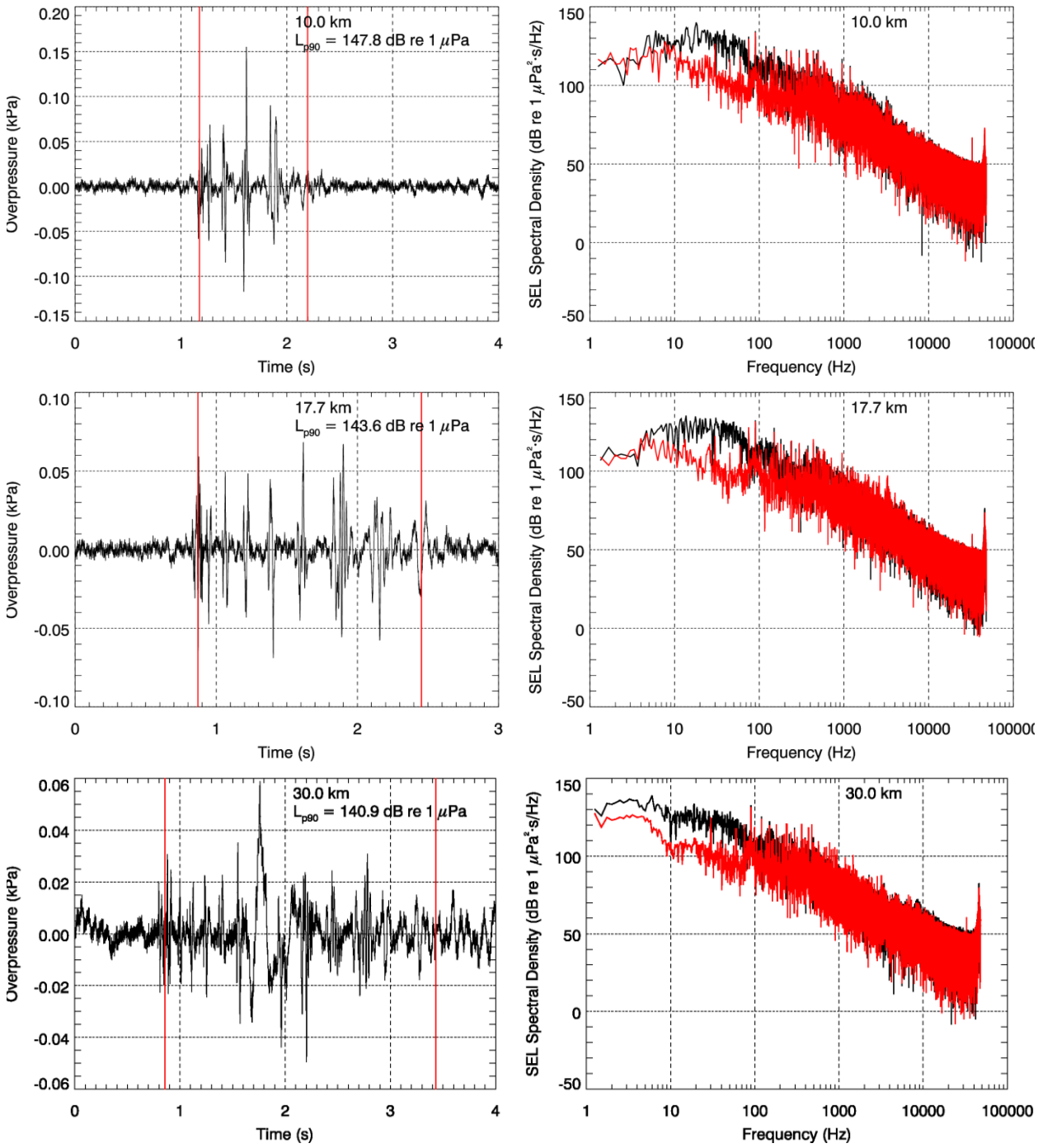

FIGURE 3.33. Airgun array 4380 in^3 waveforms (left) and SEL spectral density (right) of pulses measured in the endfire direction at various ranges to the source. These pulses are the same as shown in the spectrograms in Figure 3.31. Background noise from a preceding window of the same length is shown in red for comparison.

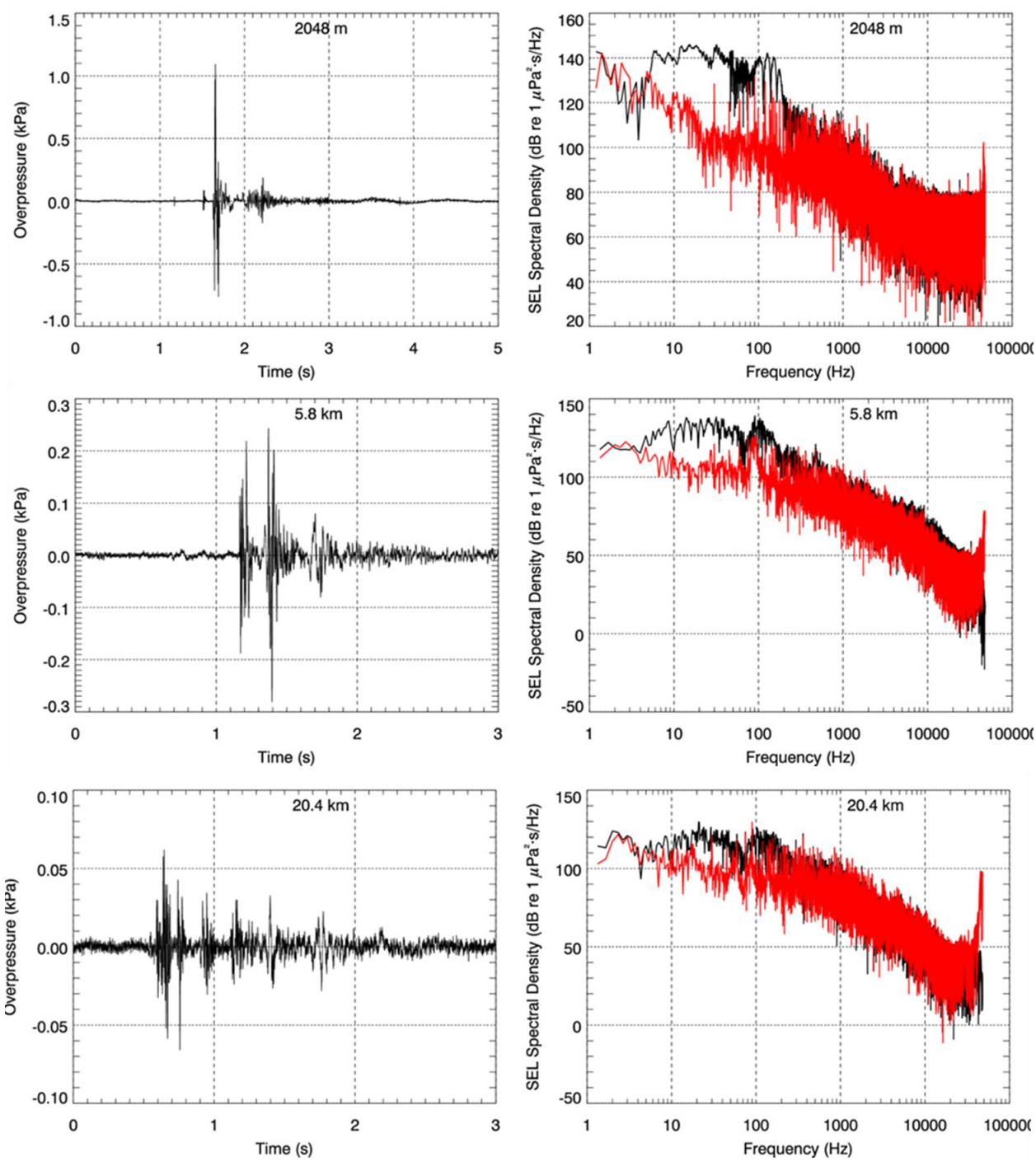

FIGURE 3.34. Airgun array 4380 in^3 waveforms (left) and SEL spectral density (right) of pulses measured at the three distances in the broadside direction. These pulses are the same as shown in the spectrograms in Figure 3.32. Background noise from a preceding window of the same length is shown in red for comparison.

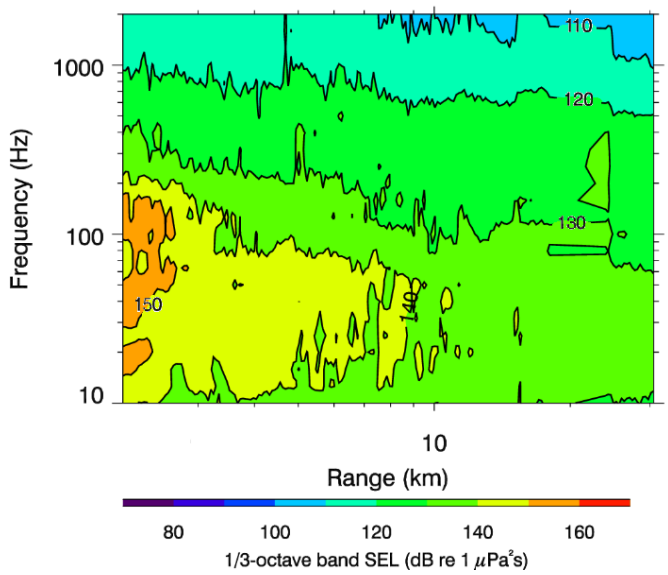

FIGURE 3.35. 1/3-octave band SEL as a function of range and frequency for the 4380 in^3 airgun array measured in the endfire direction at the Deep SSV site.

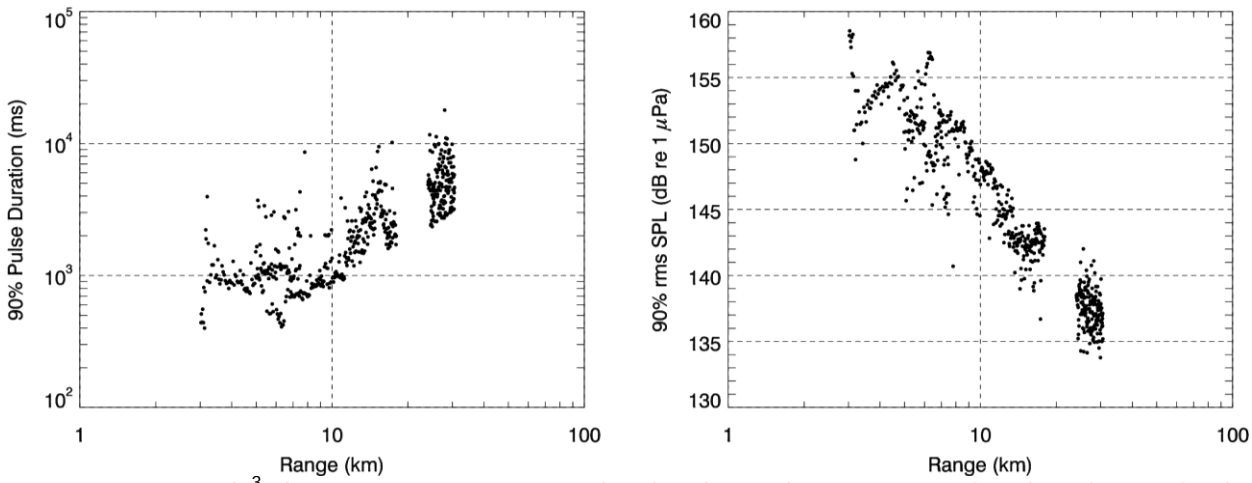

FIGURE 3.36. 4380 in^3 airgun array 90% energy pulse duration and rms SPL as a function of range for the Deep SSV endfire measurements.

Discussion

4880 in^3 Airgun Array Configuration

The primary airgun array configuration for the seismic survey used 26 active airguns with a total volume of 4380 in^3. Two additional airguns, however, operated during a ~6.5 h period, resulting in a total volume of 4880 in^3. This operation did not occur during the SSV, so the sound levels were not measured directly. Matthews and MacGillivray (2012) performed a brief modeling study to initially assess the differences in threshold distances between these two array configurations. The updated model results were considered using the new threshold distance calculations to revise the threshold distances for the 4880 in^3 array configuration. Table 3.14 lists the estimated threshold distances for the 4880 in^3 array operating at the Shallow and Deep SSV sites.

Table 3.14. Estimated $R_{95\%}$ threshold distances for the 4880 in^3 airgun array operating at the Shallow and Deep SSV sites. Distances were calculated by applying the ratio of the $R_{95\%}$ distances (4880 in^3/4380 in^3) for the 50 and 500 m depth sites (from Table 8 in Matthews and MacGillivray 2012) to the maxima of the broadside and endfire measurements of the 4380 in^3 airgun array configuration threshold distances.

rms SPL threshold (dB re 1 µPa)	Shallow SSV Site (50 m Water Depth)			Deep SSV Site (500 m Water Depth)		
	4380 in³ threshold distance (m)	Ratio of $R_{95\%}$ (4880 in^3/ 4380 in^3, %)	4880 in³ threshold distance (m)	4380 in³ threshold distance (m)	Ratio of $R_{95\%}$ (4880 in^3/ 4380 in^3, %)	4880 in³ threshold distance (m)
190	287[a]	110.39	317	395[b]	107.83	426
180	2 290	107.26	2 460	1 250[b]	107.49	1340
160	18 700	116.32	21 800	6 260	128.60	8050
120	109 000[c]	N/A	>109 000	131 000[d]	N/A	>131 000

[a] Extrapolated beyond minimum measurement range of 1 km using the 90th percentile fit.
[b] Extrapolated by back-propagating the loudest measured pulse (175 dB re 1 µPa at 2240 m) using spherical spreading (i.e., 20Log*R*).
[c] Extrapolated beyond maximum measurement range of 76.8 km using the 90the percentile fit.
[d] Extrapolated beyond the farthest measurement range of 20.5 km using the 90th percentile fit.

Comparison with IHA Threshold Distances

The sound pressure level (SPL) threshold distances derived from measurements differed from pre-season model estimates in the IHA. Table 3.15 lists the modeled threshold distances from the IHA (from Zykov et al. 2011) and the corresponding measured values. No measurements were made in water depths greater than 1000 m, so the 100–1000 m depth distances were used. The model results indicated distances should be slightly smaller for the deeper environment, so these distances are expected to provide slightly cautionary estimates for deeper water.

TABLE 3.15. Comparison between SSV and IHA sound level threshold distances. SSV distances are maximized over direction and from the 90th percentile fits. IHA distances are the maximum modeled threshold distances (R_{max}) from Zykov et al. (2011).

rms SPL threshold (dB re 1 µPa)	Exclusion and Disturbance Zones					
	Less than 100 m depth		100 m–1000 m depth		More than 1000 m depth	
	IHA[c] (m)	SSV (m)	IHA (m)	SSV (m)	IHA (m)	SSV (m)
190	600	287[a]	180	395[b]	180	395[b]
180	2850	2 290	660	1 250[b]	580	1 250[b]
160	27 800	18 700	42 200	6 260	31 600	6 260

[a] Extrapolated beyond minimum measurement range of 1 km using the 90th percentile fit.
[b] Extrapolated by back-propagating the loudest measured pulse (175 dB re 1 µPa at 2240 m) using spherical spreading (i.e., 20LogR).
[c] Zykov et al. 2011.

The pre-season modeling for the IHA (Zykov et al. 2011) was performed to estimate distances to threshold levels above 160 dB re 1 µPa and was later updated to predict threshold distances to 120 dB re 1 µPa (Li and MacGillivray 2012). The modeled 4450 in^3 airgun array is larger than the actual survey's 4380 in^3 array, and the source locations in these modeling studies were more than 100 km distant from the 2012 SSV locations. Geoacoustic parameters, bathymetry features, and water sound speed profiles were different between these locations and the noted differences between measured and modeled threshold ranges are likely partly due to these environmental differences.

The rms SPLs of the pre-season modeling estimates were calculated by adding 10 dB to the predicted SELs at all ranges. This approach was expected to overestimate rms SPLs at ranges greater than 2 km as pulse duration generally increases with range and longer durations lead to smaller differences between the rms SPL and SEL. The measured difference between the rms SPL and SEL was much less than 10 dB at ranges greater than 2 km (e.g., Figure 3.30), and this contributed to the pre-season overestimation of distances to lower level thresholds (e.g., 160 dB).

Sound Propagation

Underwater sound propagation was substantially different between the Shallow (< 100 m) and Deep (100–1000 m) SSV sites. Figure 3.37 shows examples of typical sound propagation effects observed at different water depths. The spectrograms show pulses measured from the full array at the Shallow and Deep sites at similar ranges. Waveguide propagation at the Shallow site trapped airgun pulse energy in the water column and the upper sediment layers. This resulted in strong modal propagation with associated dispersion of the airgun pulse. At the Deep site, multiple refracted propagation paths in the water column were responsible for temporal spreading of the airgun pulse.

Pulse durations differed for measurements at the Shallow and Deep sites. At the Shallow site, the 90% energy pulse duration was constant at approximately 200 ms for ranges up to 6 km and then increased to just over 1 s at the maximum measurement range (Figure 3.16). At the Deep site, the 90% energy pulse duration was highly variable and much longer than at the Shallow site, reaching 10 s at 30 km range (Figure 3.36). The variability and very long durations are attributed to higher background noise levels at the Deep site and long pulse picks; therefore, some of the longer pulse durations are influenced by non-seismic noise. The lower trend of the pulse duration versus range, however, accurately reflects 90% energy pulse duration from airgun pulses because the shorter pulse windows accurately bound the airgun pulse arrivals and exclude most background noise. The resulting variability in rms SPL is accounted for in the determination of threshold distances by using the 90th percentile fit distances in Table 3.13.

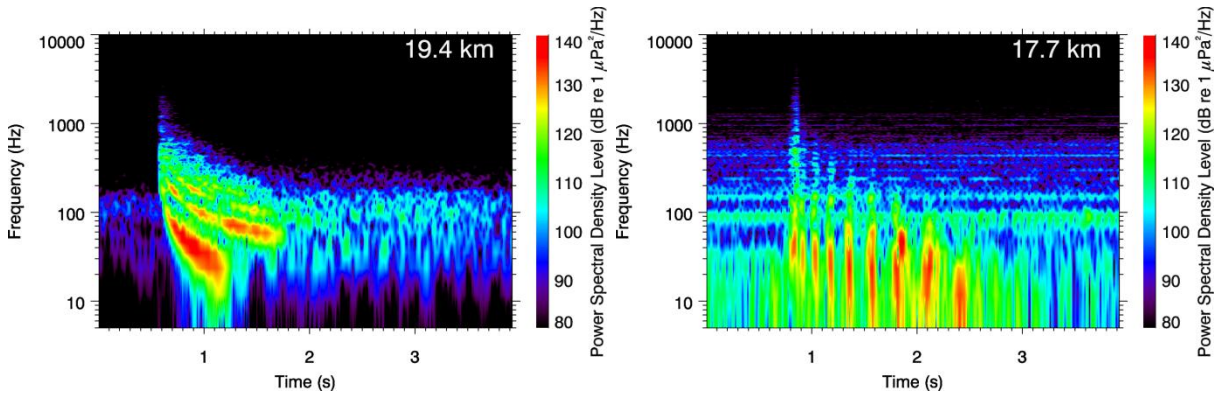

FIGURE 3.37. (Left) Spectrogram of a 4380 in³ airgun array pulse measured at approximately 19 km in the broadside direction at S3. (Right) Spectrogram of a 4380 in³ airgun array pulse measured at approximately 18 km in the endfire direction at D1. Tonal noise is from the vessels. 8192-pt FFT, 96 kHz sample rate, Hanning window, 1024-pt step size.

Model-Data Comparison

Pre-season modeling (Matthews 2012) was performed with a 4450 in^3 airgun array for the planned SSV geometry and locations with the intent of comparing modeled and measured sound levels. Because the final SSV geometry, locations, and airgun array configuration did not match the model scenarios, the model results could not be directly compared to the measured data. Therefore, new modeling was performed using the same approach as pre-season modeling, but with the model inputs that matched the SSV environment and airgun array.

The airgun array signature was modeled with JASCO's Airgun Array Source Model (AASM MacGillivray 2006) and compared to close range SSV measurements. The 4380 in^3 airgun array source signature used for this analysis is shown in Figure 3.38.

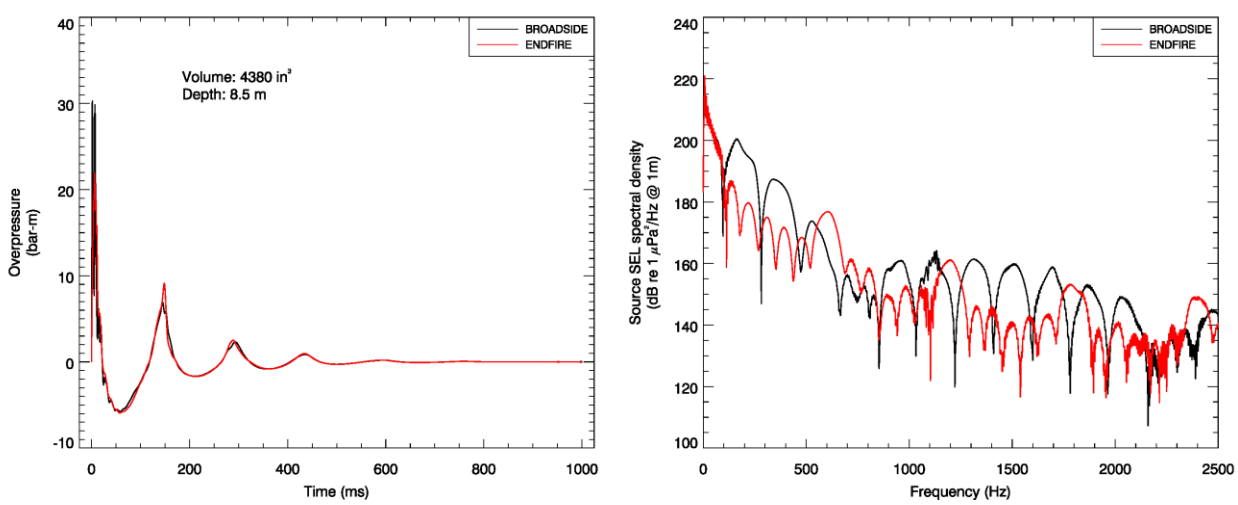

FIGURE 3.38. 4380 in^3 airgun array signatures (left) and spectra (right) in the broadside and endfire directions.

Shallow SSV Site

One shallow water model scenario was modeled for the 4380 in^3 airgun array operating along the shallow water track in the endfire direction. JASCO's Full Waveform Range-dependent Acoustic Model (FWRAM, MacGillivray and Chapman 2012) was used, as described in Section A.1 of Matthews (2012), to predict synthetic airgun pressure data up to 10 km from the array. The synthetic pressure data were used to compute rms SPL and SEL vs distance from the airguns. Figure 3.39 shows the measurements and modeled levels versus range for this scenario.

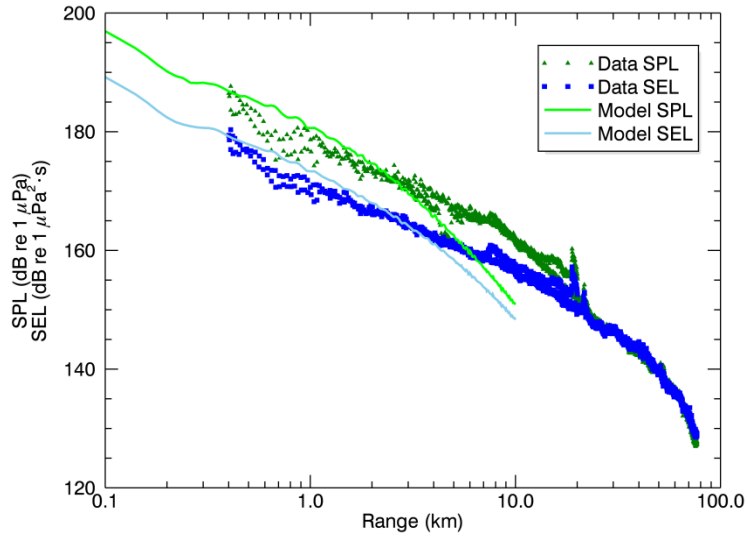

FIGURE 3.39. SPL and SEL versus range from SSV measurements and FWRAM model predictions for the Shallow SSV measurements in the endfire direction.

The agreement between measured and modeled levels is good at ranges up to approximately 3 km. Modeled levels are somewhat higher than measured because the simplified scenario for this analysis did not account for varying directivity (i.e., only forward endfire levels were modeled). Between ranges of approximately 500 and 2000 m, the OBH was neither in the endfire nor broadside lobes of the array, which resulted in lower measured levels than predicted. At ranges beyond 3 km, the transmission loss predicted by the model is too high. This discrepancy is likely due to range-dependence of the acoustic environment.

To address the deviation between the model results and measurements beyond 3 km, the seabed parameters in the model were modified at 3 km and beyond. Table 3.16 lists the range-dependent geoacoustic parameters—density (ρ), compressional wave speed and attenuation (v_p and α_p), and shear wave speed and attenuation (v_s and α_s)—that provided the best match to measurements. Figure 3.40 shows the predicted sound levels.

TABLE 3.16. Range-dependent geoacoustic parameters for the Shallow SSV site.

Depth (m)	ρ (g/cm^3)	v_p (m/s)	α_p (dB/λ)	v_s (m/s)	α_s (dB/λ)
Range ≤ 3km					
0–2	1.61–2.06	1443–1675	0.26–0.55	200	0.11
2–10	2.06	1675–1781	0.55–0.91		
10–100	2.06	1781–2118	0.91–1.71		
>100	2.06	2118	1.71		
Range > 3km					
0–2	1.61–2.06	1693–1925	0.26	200	0.11
2–10	2.06	1925–2031			
10–100	2.06	2031–2368			
>100	2.06	2368			

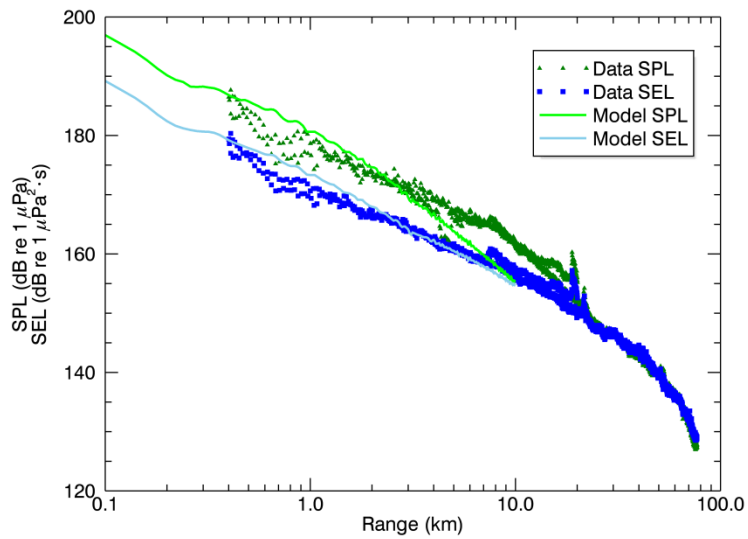

FIGURE 3.40. SPL and SEL versus range from SSV measurements and FWRAM model predictions for the Shallow SSV measurements in the endfire direction using range-dependent geoacoustics.

The revised geoacoustic model was a better match to the data, especially with SEL, but the predicted rms SPL increasingly underestimated measured SPL as distance to the source increased. The modeled SPL values are lower than the measured values beyond 4 km because the pulse duration predicted by the model is too long. The model-data mismatch at longer ranges could be better explained with a more rigorous geoacoustic inversion. For this environment, the model can predict SEL well to at least 10 km, but the rms SPL predictions are inconsistent beyond approximately 4 km.

Deep SSV Site

Model predictions for the Deep environment were generated using JASCO's Marine Operations Noise Model (MONM, Hannay and Racca 2005), since a full synthetic waveform calculation could not be completed in the time available using FWRAM. MONM calculates transmission loss, which is sufficient for modeling SEL, but it cannot directly predict rms SPL for airguns because it does not output pressure waveforms. The comparison was also limited to endfire measurements. 1/3-octave band SEL source levels were calculated for the 4380 in^3 airgun array signatures from AASM (Figure 3.38). Received levels were calculated using the source levels and transmission loss predictions for the Deep SSV survey track. The model used the measured water sound speed profile (Figure 3.24), but the geoacoustic parameters from the 100–1000 m depth category in Matthews (2012). Figure 3.41 shows the modeled and measured SELs versus range.

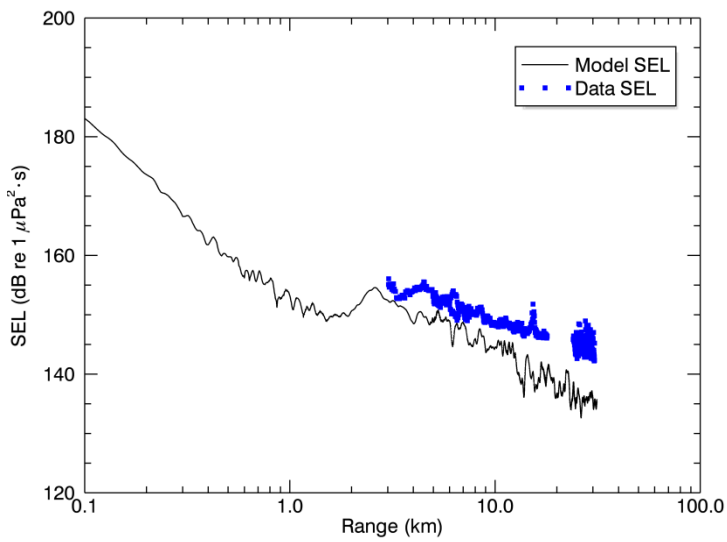

FIGURE 3.41. Modeled and measured SEL versus range for the Deep SSV in the endfire direction.

Modeled SELs are less than the measured values at corresponding ranges by 2–10 dB, and these differences increase with range. Therefore, changes to the geoacoustic parameters that would improve the match were investigated. Specifically, the compressional wave attenuation was decreased in all bottom layers as listed in Table 3.17 to decrease the acoustic energy loss for bottom-refracted acoustic paths. The SELs predicted using the modified attenuation parameters are shown in Figure 3.42.

The modified attenuation parameters reduced the SEL mismatch between the model results and the data, particularly for ranges less than 10 km. In general, the model progressively underestimated the data for ranges greater than 10 km with differences approaching 5–10 dB at 30 km. This mismatch may be due to geoacoustic parameter errors or bathymetry errors—substantial differences between bathymetry datasets have been observed for this region[2].

[2] SRTM +30, version 6.0 (Becker et al. 2009) and GINA (Lindquist et al. 2004).

TABLE 3.17. Geoacoustic parameters for the Deep SSV site.

Depth (m)	ρ (g/cm^3)	v_p (m/s)	α_p (dB/λ)		v_s (m/s)	α_s (dB/λ)
			Matthews (2012)	Modified		
0–2	1.48–1.50	1424–1471	0.14–0.36	0.14–0.2	100	0.03
2–10	1.50–1.52	1471–1527	0.36–0.60	0.2		
10–50	1.52–1.57	1527–1628	0.60–0.95			
50–100	1.57–1.63	1628–1697	0.95–1.15			
>100	1.63	1628	1.15			

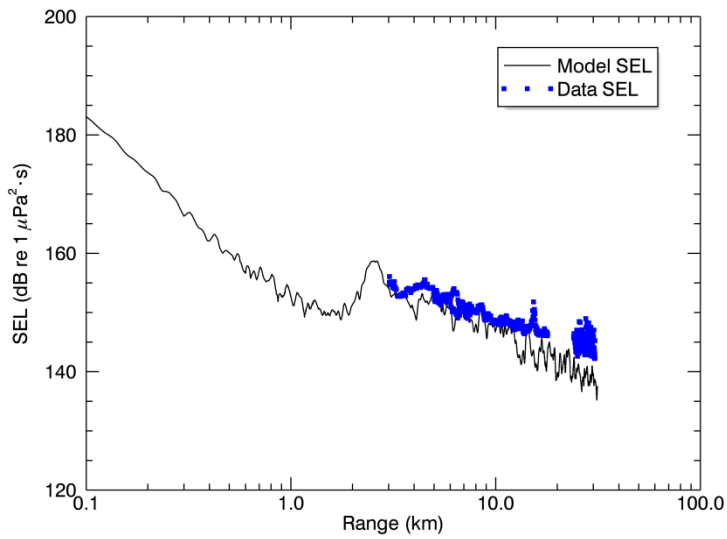

FIGURE 3.42. Modeled and measured SEL versus range for the Deep SSV site in the endfire direction. The compressional wave attenuation used for the modeling was modified from Matthews (2012) to improve the model-data mismatch.

Summary and Conclusions

This chapter presented results of the Sound Source Verification (SSV) study that measured underwater sounds from seismic sources and vessels used during ION Geophysical's 2012 seismic survey in the Beaufort and Chukchi Seas. The goals of the SSV study were to determine distances to sound level thresholds for airgun sources, compare measurements to pre-season model results, refine the geoacoustic model of the SSV sites, and quantify sound levels from vessel activities. Sounds from airguns were measured at two sites: Shallow (~50 m depth) and Deep (~500 m depth). For the Shallow site, sounds were measured with three autonomous Ocean Bottom Hydrophone (OBH) recorders. Airgun array sounds were measured in the broadside and endfire directions at ranges up to 75 km. For the Deep site, airgun array sounds in the broadside and endfire directions were measured with an OBH deployed over the side of the M/V *Polar Prince*. Sound levels were measured between ranges of 2 and 30 km.

This analysis revised and expanded preliminary results presented in the 2012 field report (MacDonnell and Wladichuk 2012). After the SSV, marine mammal safety zone distances were reduced based on the field report results. In this analysis, airgun pulses from the 4380 in^3 airgun array and the 70 in^3 airgun were analyzed in greater detail, which provided more accurate, and in some cases larger, distances to threshold levels (Table 3.18). In future measurement studies where preliminary measurements show marked differences of threshold distances to pre-season model estimates, using the larger distances is recommended until the discrepancy can be fully investigated.

The SSV geometry allowed measurements of most thresholds distances; however, for thresholds where measured data were unavailable, exclusion zone distances were extrapolated using the empirical curve fits in the sound level versus range plots (e.g., Figure 3.30) or using spherical spreading loss (i.e., 20LogR) to back-propagate the loudest measured pulse level. The extrapolations provide the best estimates of the threshold distances given the available data, but their accuracy is limited. Additional measurements or modeling is required to assess the accuracy of the extrapolated threshold distances. Future measurements in deep water would benefit from using autonomous recorders moored to the seabed with no surface float to allow close range measurements and reduce background noise.

Sound generally propagated further at the Shallow site than at the Deep site. This was due to the bottom trapping energy in the water column. The deeper water allowed sound energy to dissipate and disperse through the larger water column. Spectral analysis of close range airgun pulses at the Shallow site showed that sound energy from the 4380 in^3 airgun array was concentrated at frequencies below 1 kHz. Higher frequencies did not propagate as well as lower frequencies; beyond 10 km most energy was below 100 Hz. Deep site measurements also showed higher frequencies did not propagate as well as lower frequencies but the effect was not as pronounced.

The qualitative structure of measured pulses differed between the two sites. At the Shallow site, modal dispersion spread out the airgun pulse with increasing range. At the Deep site, multiple refracted propagation paths in the water column were responsible for temporal spreading of the airgun pulse. These two different dispersion mechanisms resulted in different 90% energy pulse durations at the two sites. The pulse durations, and therefore the difference between rms SPL and SEL, were greater at the Deep site.

TABLE 3.18. Threshold distances for the 4380 in^3 airgun array and 70 in^3 mitigation airgun for two depth environments.

rms SPL Threshold (dB re 1 µPa)	Threshold Distances (m) for the 4380 in^3 Array		Threshold Distances (m) for the 70 in^3 Mitigation Airgun	
	<100 m depth	>100 m depth	<100 m depth	>100 m depth
190	287[a]	395[b]	24[c]	23[d]
180	2 290	1 250[b]	94[c]	74[d]
170	9 260	2 930	362[c]	234[d]
160	18 700	6 260	1 360	741[d]
150	29 000[e]	13 400	4 690	1 990[f]
140	51 600	28 600[g]	13 400	5 100
130	78 700[h]	61 200[g]	29 600	13 000[i]
120	109 000[h]	131 000[g]	52 000	33 400[i]

[a] Extrapolated beyond minimum measurement range of 1 km using the 90th percentile fit.
[b] Extrapolated by back-propagating the loudest measured pulse (175 dB re 1 µPa at 2240 m) using spherical spreading (i.e., 20LogR).
[c] Extrapolated beyond minimum measurement range of 401 m using the 90th percentile fit.
[d] Extrapolated by back-propagating the loudest measured pulse (150 dB re 1 µPa at 2230 m range) using spherical spreading (i.e., 20LogR).
[e] Extrapolated beyond maximum measurement range of 19.6 km using the 90th percentile fit.
[f] Extrapolated beyond closest measurement range of 2050 m using the 90th percentile fit.
[g] Extrapolated beyond the farthest measurement range of 20.5 km using the 90th percentile fit.
[h] Extrapolated beyond maximum measurement range of 76.8 km using the 90th percentile fit.
[i] Extrapolated beyond the farthest measurement range of 7340 m using the 90th percentile fit.

Several SSV threshold distances significantly differed from pre-season estimates in ION's IHA because the distances in the IHA were based on model results (Zykov et al. 2011) that did not correspond to the SSV geometry or airgun array configuration. Additional pre-season modeling was conducted to predict more accurate sound levels for the SSV site (Matthews 2012). The SSV geometry and airgun array configuration changed again, prior to the SSV, so, to compare how well modeled levels matched measurements, the modeling was revised again for this report. The comparison showed substantial differences in levels at long ranges, indicating that previous assessments of the geoacoustic properties of the seafloor for the two measurement sites from Matthews (2012) were not accurate. To improve the model-data mismatch, the geoacoustic parameters were adjusted. The new parameters, used in this chapter, are more accurate than those from the 2012 modeling study. The revised parameters should be relevant for future modeling studies at the same sites.

At long ranges, sound propagation models are highly sensitive to environmental uncertainty. This model-data comparison showed that the environment at the SSV sites was poorly characterized. A more rigorous geoacoustic inversion would improve the characterization of the environment at the SSV sites. Future modeling studies at different locations would benefit from a sensitivity analysis to quantify uncertainty in the model estimates.

Sound levels from transiting vessels were calculated from periods when the airguns were not operating or from periods between airgun pulses. The calculated distances to the 120 dB threshold for the M/V *Geo Arctic* and M/V *Polar Prince* transiting at the Shallow site were 1420 and 943 m, respectively. The M/V *Polar Princ*e did not conduct icebreaking activities during the SSV.

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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.

90%-energy time window

The time interval over which the cumulative energy rises from 5% to 95% of the total pulse energy. This interval contains 90% of the total pulse energy. Symbol: T_{90}.

90% rms SPL

The root-mean-square sound pressure levels calculated over the 90%-energy time window of a pulse. Used only for pulsed sounds.

ambient noise

All-encompassing sound at a given place, usually a composite of sounds from many sources near and far (ANSI S1.1-1994 R1999) e.g., shipping, seismic activity, precipitation, sea ice movement, wave action, and biological activity.

attenuation

The acoustic energy loss due to absorption and scattering.

azimuth

A horizontal angle relative to a reference direction, often magnetic north or the direction of travel.

background noise

Total of all sources of interference in a system used for the production, detection, measurement, or recording of a signal, independent of the presence of the signal (ANSI S1.1-1994 R1999). Ambient noise detected, measured, or recorded with a signal is part of the background noise.

bar

Unit of pressure equal to 100 kPa, which is approximately equal to the atmospheric pressure on Earth at sea level. 1 Bar is equal to 10^6 Pa or 10^{11} $^{\mu Pa}$.

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.

compressional wave

A mechanical vibration wave where the direction of particle motion is parallel to the direction of propagation. Sometimes referred to as a primary wave, or P-wave.

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).

endfire direction

Parallel to the travel direction of a source.

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.

geoacoustic

Relating to the acoustic properties of the seabed.

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.

intermittent noise

A level of noise that abruptly drops to the background noise level several times during the observation period.

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.

peak sound pressure level (peak SPL)

The maximum instantaneous sound pressure level, in a stated frequency band, within a stated period. Also called zero-to-peak sound pressure level. Unit: decibel (dB). Symbol: L_{pk}.

peak-to-peak sound pressure level (peak-to-peak SPL)

The difference between the maximum and minimum instantaneous sound pressure levels. Unit: decibel (dB). Symbol: $L_{\mathrm{pk\text{-}pk}}$.

point source

A source that radiates sound as if from a single point (ANSI S1.1-1994 R1999).

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).

pulsed sound

Discrete sounds with durations less than a few seconds. Sounds with longer durations are called continuous sounds.

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.

See also 90% rms SPL.

shear wave

A mechanical vibration wave where the direction of particle motion is perpendicular to the direction of propagation. Sometimes referred to as a secondary wave or S-wave. Shear waves propagate only in solid media, such as sediments or rock. Shear waves in the seabed can be converted to compressional waves in water at the water-seabed interface.

signature

Pressure signal generated by a source.

sound

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

sound exposure

Time integral of squared, instantaneous frequency-weighted sound pressure over a stated time interval or event. Unit: pascal-squared second ($Pa^2 \cdot s$). Symbol: E (ANSI S1.1-1994 R1999).

sound exposure level (SEL)

A measure of the total sound energy in one or more pulses. Unit: dB re 1 μPa^2·s.

sound field

Region containing sound waves (ANSI S1.1-1994 R1999).

sound intensity

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

sound pressure level (SPL)

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

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

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

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

source level (SL)

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

spectrum

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

See also power spectrum density.

transmission loss (TL)

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

wavelength

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

zero-to-peak SPL

See peak SPL.

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

This chapter describes the marine mammal monitoring and mitigation measures implemented during ION Geophysical's (ION) 2012 seismic operations in the Beaufort and Chukchi seas. The required measures were detailed in the IHA and LOA issued to ION by the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS), respectively. It also describes the methods used to categorize and analyze the monitoring data collected by observers and reported in the following chapter.

Monitoring Tasks

The main purposes of the marine mammal monitoring program were to ensure that the provisions of the IHA and LOA issued to ION 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 seismic source vessel and icebreaker, to visually monitor the occurrence and behavior of marine mammals near the airguns when the airguns were operating and during a sample of the times when they were not;
- use the visual monitoring data as a basis for implementing the required mitigation measures;
- record (insofar as possible) the effects of the airgun operations and the resulting sounds on marine mammals;
- estimate the number of marine mammals potentially exposed to airgun sounds at specified levels.

Safety and Potential Disturbance Radii

Under current NMFS guidelines (e.g., NMFS 2000), "safety radii" for marine mammals around airgun arrays and other 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 the species under its jurisdiction (≥180 dB for walrus and ≥190 dB for polar bear, respectively) in the LOA issued to ION. These safety criteria are based on 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. 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.

ION's IHA and LOA applications described the anticipated underwater sound field around the planned 4450 in^3 airgun array with airguns towed at a depth of 8.5 m (9.3 yd) based on acoustic modeling results (Zykov et al. 2010). Field measurements of the received airgun sounds as a function of distance and aspect were acquired during the beginning of seismic data acquisition and reported in a 5-day field report (MacDonnell and Wladichuk 2012). During the 2012 field measurements and until those results were available, the modeled safety radii distances were used for mitigation purposes. The ≥190 dB and ≥180 dB safety radii provided in the field report for the full array in intermediate (100-1000 m; 0.06-0.62

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mi) and deep water areas (>1000 m; 0.62 mi) all increased compared to the modeled safety radii ("Field Report" columns in Table 4.1). However, the biggest difference between the modeled and field report ≥190 dB and ≥180 safety radii for the full array occurred in shallow water areas (<100 m, 109 yd). The field report ≥190 dB safety radius in shallow water areas was nearly three times less than the modeled ≥190 dB safety radius, and the ≥180 dB SSV field report safety radius was nearly four times less than the modeled ≥180 dB safety radius in shallow water areas ("Field Report" in Table 4.1).

More extensive analysis of the field measurements was completed after the field season as described in Chapter 3 of this report. Those analyses resulted in some refinements of the various radii ("Final Radii" columns in Table 4.1). The final analysis was not completed until after the field season; therefore the results were not available for use by the PSOs in the field. However, the revised estimates were used during processing of the monitoring data presented in Chapter 5 and to estimate the numbers of marine mammals exposed to various sound levels. The biggest difference between the field report and final ≥190 dB and ≥180 dB safety radii for the full array also occurred in shallow water areas. However, this time the ≥190 dB and ≥180 safety radii for the full array increased. The final" ≥190 dB safety radius in shallow water areas was nearly 1.5 times greater than the field report ≥190 dB safety radius, and the ≥180 final safety radius was nearly three times greater than the field report ≥180 dB safety radius in shallow water areas ("Final Radii" in Table 4.1). All other safety radii for the full array changed only slightly between the field report and final analyses (Table 4.1).

TABLE 4.1. Comparison of measurements of the ≥190, 180, and 160 (rms) distances (in km) for sound pulses from the 26-airgun, 4380 in^3 array and 70 in^3 mitigation airgun deployed from the *Geo Arctic* during ION's seismic survey, 12 Oct – 16 Nov 2012.

Water Depth and Received Level dB (rms)	Full Airgun Array			Mitigation Airgun		
	Modeled Radii	Field Report	Final Radii	Modeled Radii	Field Report	Final Radii
<100 m						
≥190	0.600	0.210	0.287	0.019	0.024	0.024
≥180	2.850	0.832	2.290	0.086	0.094	0.094
≥160	27.800	18.000	18.700	NA	NA	1.360
100-1000 m						
≥190	0.180	0.420	0.395	0.019	0.024	0.023
≥180	0.660	1.300	1.250	0.086	0.094	0.074
≥160	42.200	6.000	6.260	NA	NA	0.741
>1000 m						
≥190	0.180	0.420	0.395	0.019	0.024	0.023
≥180	0.580	1.137	1.250	0.086	0.094	0.074
≥160	31.600	7.590	6.260	NA	NA	0.741

Mitigation Measures as Implemented

ION's seismic survey incorporated both design features and operational procedures for minimizing potential impacts on marine mammals and on subsistence hunts. The location and timing of operations were planned to avoid the highest bowhead whale concentrations and subsistence hunting activities from coastal villages. During survey operations, mitigation procedures such as seismic array ramp ups, delayed ramp ups, power downs, and shut downs were in place and/or implemented as necessary. These measures are standard procedures during seismic surveys and are described in detail in Appendix C. Mitigation also included those measures specifically identified in the IHA and LOA as described below. PSOs aboard the two ION vessels also routinely contacted the whaling communication centers (while they were operational) in order to ensure that the vessels did not interfere with subsistence activities.

Location and Timing of Survey Operations

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 plan for ION's seismic operations. The operational plan was designed to avoid the majority of the fall bowhead whale migration by not beginning operations until Oct 1st and starting those operations on the eastern end of the Alaskan Beaufort Sea. In order to avoid impacts to bowhead whale subsistence hunting in this region, ION also agreed not to begin seismic survey activities in the eastern half of the survey area until after the subsistence hunts at Kaktovik and Nuiqsut were completed, even if that was after Oct 1st. The start of the ION survey was delayed by a couple weeks due to vessel availability issues, so by the time the vessels were transiting towards the survey area, both Kaktovik and Nuiqsut had successfully completed their subsistence hunts; therefore, additional delays of the survey to mitigate potential impacts to the hunt were not necessary.

In some years, bowhead whale subsistence hunting near Barrow can occur through the end of Oct or into early Nov. To mitigate potential impacts to that subsistence hunt and to avoid higher concentrations of migrating bowhead whales that may be present near Pt. Barrow, ION did not plan to operate in the eastern half of the Alaskan Beaufort Sea until after the Barrow subsistence hunt was completed or late October, whichever was later. ION conducted SSV measurements in the eastern Alaskan Beaufort Sea from Oct 20th to 23rd and began seismic data collection on Oct 24th. The AEWC informed ION that the bowhead subsistence hunt in Barrow was completed on Oct 24th. Since the Barrow subsistence hunt was over and it was late Oct, ION continued collecting seismic data along and east-west survey line that took the vessels into the eastern half of the Alaskan Beaufort Sea on Oct 27th.

Standard Mitigation Measures

Standard mitigation measures implemented during the study included the following:

- Modeled safety radii (distances used in the IHA and LOA applications) were implemented by PSOs during the initial seismic activities (Zykov et al. 2010). The safety radii distances were then revised to the results of the SSV measurements as presented in the field report (MacDonnell and Wladichuk 2012; Table 4.1).
- In order for seismic operations to begin, the entirety of the ≥180 dB (rms) safety radius, the largest safety radii to be monitored by PSOs on the vessel, 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 safety radius while the airguns were operating.
- A change in vessel course and/or speed alteration, when practicable, was implemented if a marine mammal 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. In addition, a change in vessel course or speed was implemented to avoid approaching with a ½ mile (800 m) of Pacific walruses and polar bears, as per the USFWS LOA stipulations

Protocols were in place to implement the following mitigation measures, although no marine mammal sightings required a power down or shutdown during the ION survey. The specific procedures applied during ramp-ups, power downs, and shut downs are described in Appendix C. Briefly, a ramp-up involves a gradual increase in the number of airguns operating (from no airguns or one airgun firing) usually accomplished by slowly adding airguns such that the number of airguns operating is doubled approximately every 5 min. For the *Geo Arctic*, the ramp up duration was 30 min. A power down involves reducing the number of operating airguns from the full array (4380 in^3) to a single "mitigation" airgun (70 in^3) when a marine mammal is observed approaching or already within the full airgun array safety radius. Power downs also occurred when the survey vessel is between seismic survey lines to reduce the amount of sound energy introduced into the water. A shutdown involves suspending operation of all airguns. A shutdown is implemented if a marine mammal is sighted within or approaching the safety radius of the mitigation airgun either after the full array has been powered down or upon initial observation.

Marine Mammal Monitoring Methods

Marine mammal monitoring methods were designed to meet the requirements specified in the IHA and LOA as listed above (NMFS 2012; USFWS 2012). The main purposes of PSOs aboard the seismic source vessel and icebreaker were as follows: ***(1)*** 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). ***(2)*** 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. Results of marine mammal monitoring effort are presented in Chapter 5.

The visual monitoring methods that were implemented during ION's seismic survey were similar to those used during various previous seismic cruises conducted under IHAs since 2003. The standard visual observation methods are described below and in Appendix C.

During the seismic survey, at least one PSO onboard the seismic source vessel, *Geo Arctic*, maintained a visual watch for marine mammals during all daylight hours while the airguns were in use, and during most daylight hours while the airguns were not active. 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, or Canon 18×60 image stabilized binoculars. PSOs instructed seismic operators to power down or shut down the airguns if marine mammals were sighted within or about to enter applicable safety radii.

PSOs onboard the icebreaker, *Polar Prince*, conducted watches similar to those of PSOs onboard the source vessel. However, observers on the *Polar Prince* also maintained night-watches, typically between 2-4 h a night, using night-vision goggles (NVD) and a forward looking thermal imaging (FLIR)

camera system. The *Polar Prince* was used primarily to escort the *Geo Arctic* during survey operations in heavily ice-covered waters. PSOs onboard the *Polar Prince* notified PSOs onboard the *Geo Arctic* if they observed any marine mammals while working in close proximity to the *Geo Arctic's* applicable safety radii. PSOs aboard the *Geo Arctic* then initiated any necessary mitigation measures.

Data Analysis Methods

Categorization of Data

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

Species Groups

Results are presented separately by species 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 industrial activities. Pacific walrus and polar bears are presented separately due to their management by USFWS.

Geographic Boundaries

Data were collected during the entire cruise period for both vessels including the transit between Nome and the survey area, and the transit from the survey area to Dutch Harbor. For the purposes of this report, observer sightings and effort data from vessel activities north of 68.75 °N and west of Pt. Barrow (156.45 °W) were included for analysis covering the Chukchi Sea vessel operations. Data collected east of Pt. Barrow (156.45 °W) were included for analysis covering the Beaufort Sea vessel operations.

Vessel or Survey Activity

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

The *Polar Prince* was in constant motion relative to the seismic sound source towed by the *Geo Arctic*. Therefore, sighting and effort data were categorized by received sound level (RSL) based on the distance to the seismic sound source and the results of the sound source measurements (see Chapter 3). The *Polar Prince* data were categorized into 10 dB (rms) sound level bins from >190 through <120 dB (rms). In order to keep sample sizes large enough for comparisons among RSL bins, data were grouped into three broader bins: (1) ≥160 dB (rms), (2) 159–120 dB (rms), and (3) <120 dB (rms). The ≥160 dB (rms) bin is roughly equivalent to the "full array" category in the source vessel data and the "seismic" category used in some previous seismic survey reports. The <120 dB (rms) bin is roughly equivalent to the "non-seismic" category in the source vessel data and the "non-seismic" category used in previous seismic survey reports. The 159–120 dB (rms) bin represents data collected where received sound levels were at intermediate levels. In this report, the term "seismic" refers to "full array" data from the source vessel and monitoring vessel data in the ≥160 (rms) bin while the term "non-seismic" refers to "non-seismic" data from the source vessel and the <120 dB (rms) bin from monitoring vessel data. Statistical analyses were generally limited to comparisons of the "seismic" and "non-seismic" bins where adequate effort allowed for meaningful interpretation.

Sighting Rate Calculation and Comparisons

Sighting rates (sightings/1000 km of observer effort) are presented for the *Geo Arctic* and *Polar Prince* within the analysis categories of Beaufort wind force, number of PSOs on watch, and by seismic status (for the *Geo Arctic*) or RSL (for the *Polar Prince*). Sighting rates are presented independently by species groups including cetaceans, pinnipeds (excluding walrus), and Pacific walrus. Where appropriate and sample sizes permitted, comparisons of sightings rates between categories were made using a chi-square (χ^2) test and results of a post-hoc power analysis have also been included. Power analysis of chi-square tests were completed using the G*Power software (Faul et al. 2007).

Where appropriate and sample sizes permitted, comparisons of sightings rates between categories were made using a G-test. The G-test is a likelihood ratio test, akin to the chi-square test commonly used in similar 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), operational conditions, and other vessel proximity. The criteria were intended to exclude data from periods of observation effort when conditions would have made it unlikely to detect marine mammals that were at the surface. If those data were to be included in analyses, important metrics like sightings rates and densities would be biased downward.

For previous seismic projects, those criteria included a filter that removed data collecting from a vessel when another vessel was operating within 5 km (3.1 mi) in the forward 180° of the vessel. This criterion was based on the assumption that vessel(s) operating ahead of another vessel would likely impact the distribution and behavior of marine mammals observed from the vessel in the rear (Beland et al. 2009). However, if this approach had been used for data from the 2012 ION project, approximately 15% of the total observational effort for cetaceans (336 km; 209 mi) and 11% of the total observational effort for pinnipeds and polar bears (243 km; 151 mi) from the *Geo Arctic* would have been excluded. Due to the already limited amount of overall survey effort, excluding these data would preclude some comparisons of sighting rates. Additionally, based on the number of sightings made from the *Geo Arctic* at time when the *Polar Prince* was operating directly in front of it, the assumption behind this criterion did not seem to apply in this case. Thus, data during periods when the *Polar Prince* was operating within 5 km (3.1 mi) for cetaceans and 1 km (0.6) for pinnipeds and polar bears in the forward 180° of the *Geo Arctic* were included when calculating sighting rates for the 2012 ION survey.

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 1 h for pinnipeds and polar bears, or 2 h for cetaceans, after the airguns were turned off (post-seismic period);
- 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 D 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 C. Sightings data that met these criteria are presented in Appendix F.

Distribution and Behavior

Initial Sighting Distance and Distribution

Marine mammal behavior is difficult to observe because individuals and/or groups are often at the surface only briefly, and may avoid the vessel. This causes difficulties in re-sighting those animals, and in determining whether two sightings some minutes apart are repeat sightings of the same individual(s). Limited behavioral data were collected during this project because marine mammals were often observed at distances too far from the vessel to determine behavior, and they were typically not tracked for long distances or durations while the vessel was underway.

Data collected during visual observations provided some information about behavioral responses of marine mammals to the seismic survey:

- bearings and distances of initial sightings to marine mammals from the PSO observation station;
- observed behavior of animals at the time of the initial sighting;
- animal movements relative to vessel movements; and
- reaction of animals in response to the vessel or seismic sounds.

Sightings were classified by seismic status (for the *Geo Arctic*) or RSL (for the *Polar Prince*). Sightings made during periods of good visibility and sightings made during periods of poor visibility were included in these analyses.

Closest Point of Approach

The closest point of approach (CPA) of each sighting to the observer position or airgun array was calculated in a GIS using the closest sighting record to the PSO position on the vessel and then triangulating to the airgun array. The mean CPA to the observer or airgun array was calculated separately for sightings from the *Geo Arctic* and *Polar Prince* and within the three seismic activity categories or RSL bins. Standard deviation and range of distances (m) to the observer were also calculated.

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 observational periods with 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 three seismic activity categories or RSL bins.

Initial Behavior

For each sighting, an initial behavior was recorded by the PSO. Animal behavior codes included: sink, thrash, fluking, diving, looking, logging, spyhop, swim, breach, lobtail, flipper slap, blow, bow riding, porpoising, rafting, wake riding, unknown, walking, dead, and other. Activities, or a collection of behaviors that indicate an overall behavioral state, were also included as an initial behavior if PSOs clearly observed animals exhibiting these combinations of behaviors. Activity codes included: traveling, surface active, surface active-travel, milling, feeding, mating, and resting. The initial behaviors recorded for each sighting were summarized and compared for each vessel and across the three seismic activity categories or RSL bins.

Reaction Behavior

Animal reactions in response to the vessel or the seismic source were recorded during each sighting. Reaction behavior codes included: change in direction, increase or decrease in speed, look, splash, rush, bowriding or wake riding, interactions with gear, and no reaction. The reaction behaviors of animals that fell into these categories were compared between source and monitoring vessels and across the three seismic activity or RSL bins.

Line Transect Estimation of Densities

Sightings of marine mammal in the water recorded during seismic and non-seismic periods, as well as on specific days when high concentrations of marine mammals were encountered, were used to calculate separate densities (#/km^2) of marine mammals near the vessels during those periods. Only sightings of animals that were in the water were used in the calculations since only those animals would have been exposed to seismic sounds at the distance and levels reported in Chapter 3. Densities calculated in previous survey reports typically excluded observation data from a vessel when it was operating directly behind another vessel in order to avoid biasing the density estimates downward under the assumption that few animals would be detected from the trailing vessel. However, this assumption did not appear to apply to the data collected during the ION survey. As an alternative, the sightings from a vessel when it was in a trailing position (typically the *Geo Arctic*) were used in the density estimates but only the effort from one of the vessels was included in the calculations. This effectively treated the two vessels as a single observation platform and may have biased density estimates upwards during these periods.

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 the two project vessels during the 2012 season as well as vessels of similar height that operated in the Chukchi and Beaufort seas in previous years (2006–2011). 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) and Barlow (1999). This was necessary because of the inability to assess trackline sighting probability, $g(0)$, during a project of this type. Further details on the line transect methodology used during the survey are provided in Appendix C.

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 levels of sounds exceeding 160 dB re 1 μPa rms (NMFS 2005, 2006; USFWS 2008). When calculating the number of mammals potentially affected as described below, we used the "final" ≥160 dB (rms) radii distances shown in Table 4.1.

Three 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 activities; and

(B) estimates based on pinniped and cetacean 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) during the survey operations;

(C) estimates based on pinniped and cetacean 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) during the survey operations.

As noted in the previous section, separate density estimates were calculated from data collected during seismic and non-seismic periods or locations. The use of non-seismic densities in method ***(B)*** 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 ***(C)*** 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. The actual number of individuals exposed to, and potentially affected by, seismic survey sounds was likely between the minimum and maximum estimates resulting from methods ***(A)*** and ***(C)***. Because most marine mammals sightings occurred on just a few days and locations during the ION survey, site specific densities were calculated for those periods. This severely limited the amount of observational effort that occurred during seismic or non-seismic periods on those days making interpretation of potential avoidance based on relative densities like those described above very limited.

Method ***(B)*** 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 2003; Gordon et al. 2004; Smultea et al. 2004, Funk et al. 2008). Within the ≥160 dB (rms) radii around the seismic source (i.e., 6.2–18.7 km [3.9–11.6 mi]), the distribution and behavior of cetaceans may have been altered as a result of the seismic survey. The distribution and behavior of pinnipeds may have been altered within some lesser distance. These effects could occur because of reactions to the active airgun array, or to other sound sources or other vessels working in the area.

Density estimates for each species or species group were used to estimate the number of animals potentially affected by seismic operations (methods ***(B)*** and ***(C)***). 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 calculation of ensonified areas for the ION survey did utilize the larger radii estimated for the 4880 in^3 shown in Table 3.14 during the ~6.5 hr period that it was operated on Oct 30. The ensonified area used in the above calculations did not include multiple counts of the same area of water that was exposed on multiple occasions. Areas within the survey area may have been ensonified by airgun sounds multiple times when survey lines crossed or were spaced closer together than twice the measured ≥160 dB (rms) distance. 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 in the same location throughout the duration of the survey 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).

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5. MARINE MAMMAL MONITORING[1]

Monitoring Effort and Marine Mammal Encounter Results

This section summarizes the visual observer effort from the *Geo Arctic* and the icebreaker *Polar Prince* during ION Geophysical's (ION) 2012 seismic operations in the Beaufort and Chukchi seas, and does not include effort conducted during transit from Dutch Harbor to and from the Chukchi Sea (see detailed description of the survey area in Chapter 4: *Methods*). The survey period began when the *Geo Arctic* and the *Polar Prince* entered the Chukchi Sea on 12 Oct 2012 (AKDT) and ended when the two vessels departed the Chukchi Sea on 16 Nov 2012.

Geo Arctic

The *Geo Arctic* traveled along a total of 7701 km (4785 mi) of trackline in the survey area. Of that total, 5542 km (3444 mi) of trackline was in the Beaufort Sea and 2159 km (1342 mi) of trackline was in the Chukchi Sea. Airgun operations occurred along 2991 km (1859 mi) of that trackline. Nearly all (94%; 2807 km or 1744 mi) of the seismic activity occurred in the Beaufort Sea, however, 185 km (115 mi) of airgun activity occurred in the Chukchi Sea. The full airgun array was ramping up or active along 2408 km (1496 mi) of trackline. The single mitigation airgun operated along 583 km (362 mi), including turns and power downs. The airguns did not operate along the remaining 4710 km (2927 mi) of trackline in the survey area.

Polar Prince

The *Polar Prince* traveled along a total of 7270 km (4517 mi) of trackline in the survey area. Of that total, 4921 km (3058 mi) of trackline was in the Beaufort Sea and 2350 km (1460 mi) of trackline was in the Chukchi Sea. The *Polar Prince* operated within 5 km (3 mi) of the *Geo Arctic* ~31% of the survey period (~264 h). During those times, the *Polar Prince* was within 2 km (1.2 mi) of the *Geo Arctic* ~81% of the time and was often as close as a few hundred meters of the *Geo Arctic* when sea ice was present. The proximity of the vessels to each other was variable over time and may have influenced the number and behavior of marine mammals sighted from the project vessels. Vessels other than those involved in the survey seldom passed through the project area, and PSOs observed no instances of harassment or disturbance to marine mammals due to their presence.

Observer Effort

PSOs aboard the *Geo Arctic* and *Polar Prince* were on watch for a total of 5396 km (3353 mi; 606 h). Of this total, 2313 km (1437 mi; 267 h) of observation effort was from the *Geo Arctic* and 3083 km (1916 mi; 339 h) was from the *Polar Prince* (Fig. 5.1). The majority of the total observation effort on the *Geo Arctic* and *Polar Prince* occurred in the Beaufort Sea (75% and 74%, respectively; Fig. 5.1).

The LOA and IHA required PSOs on the *Polar Prince* to observe at night (typically between 2-4 h each night) using both night-vision goggles and a forward looking infrared camera mounted on the flying bridge. Of the total observation effort on the *Geo Arctic* and *Polar Prince*, 752 km (467 mi; 81 h) occurred during darkness (Fig. 5.2). Observers on the *Polar Prince* conducted 696 km (432 mi; 75 h) of watch effort in darkness while observers on the *Geo Arctic* conducted 57 km (35 mi; 6 h; Fig. 5.2). Hereafter, effort analyses will compare the seismic source vessel, *Geo Arctic*, to the data from the *Polar Prince*.

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[1] By Joseph Beland, Darren Ireland, and Lauren Bisson

Observer Effort by Beaufort Wind Force

Observer effort from the *Geo Arctic* and *Polar Prince* occurred between Beaufort wind force (Bf) zero and Bf ≥7. In the Beaufort Sea, the majority (63%) of the observer effort on the *Geo Arctic* and *Polar Prince* occurred between Bf three and five (63% and 69%, respectively; Fig. 5.3). In the Chukchi Sea, the majority (62%) of the observer effort from the *Geo Arctic* occurred between Bf one and three, whereas 46% of the observer effort from the *Polar Prince* occurred in those conditions (Fig. 5.4). This difference is mostly a result of the *Polar Prince* departing Nome earlier than the *Geo Arctic* and encountering rougher conditions while in transit to the Beaufort Sea.

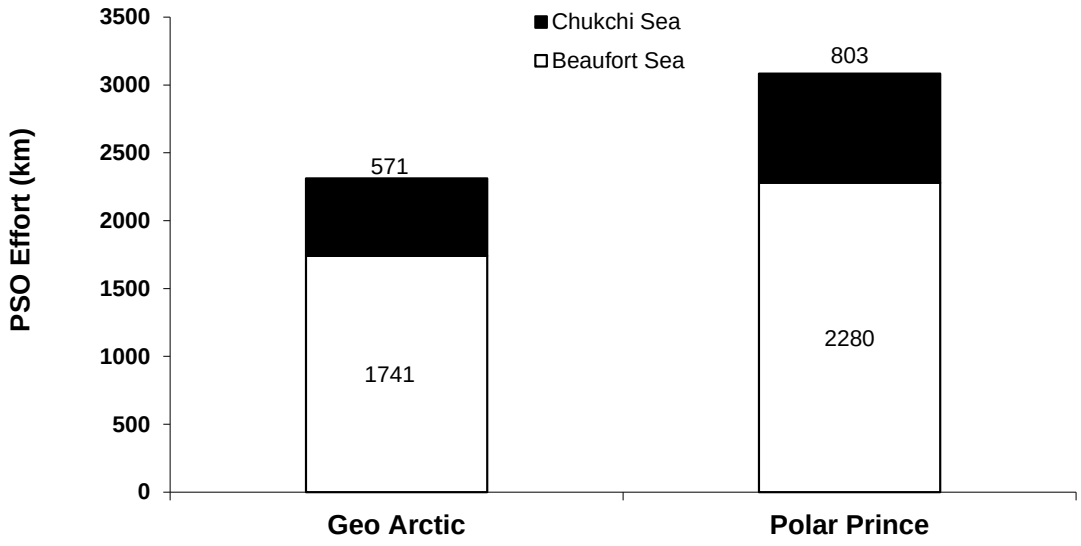

FIGURE 5.1. PSO observation effort (km) in the Beaufort Sea and Chukchi Sea during ION's seismic survey from the *Geo Arctic* and *Polar Prince*, 12 Oct – 16 Nov 2012.

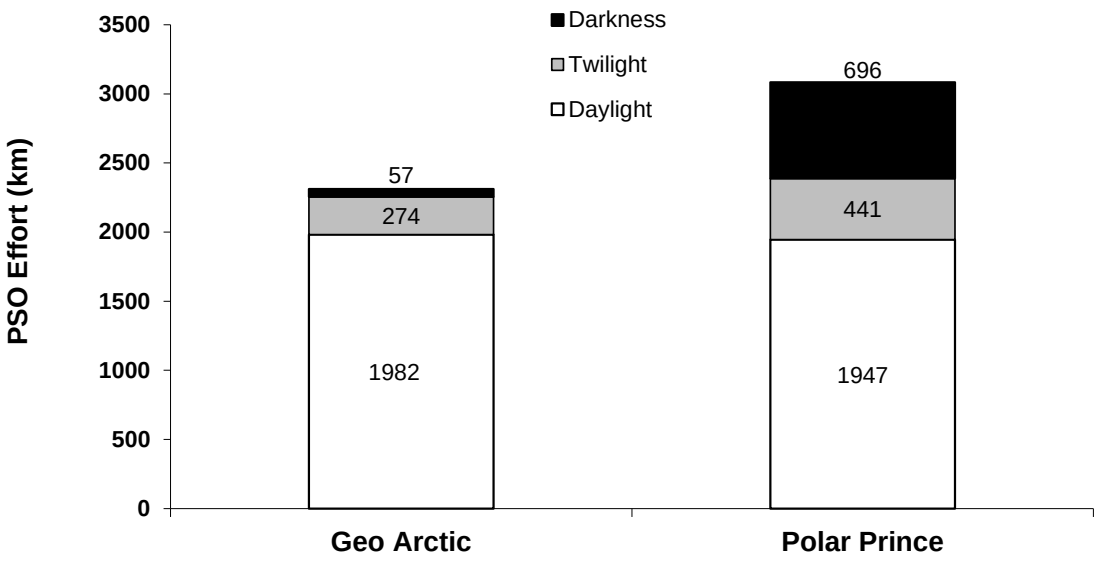

FIGURE 5.2. PSO observation effort (km) by daylight, twilight and darkness periods, during ION's seismic survey from the *Geo Arctic* and *Polar Prince*, 12 Oct – 16 Nov 2012.

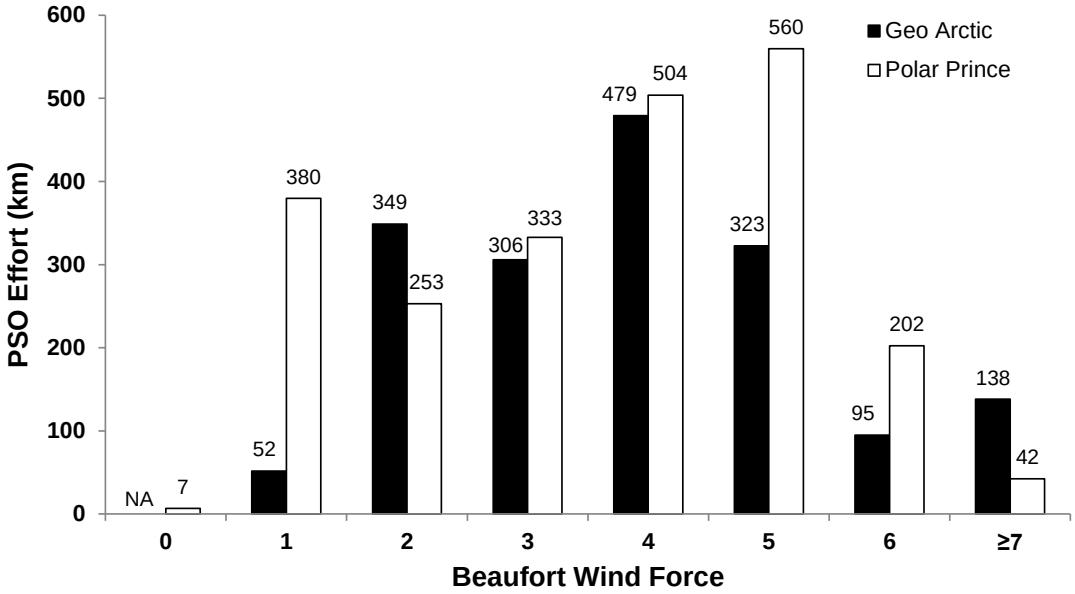

FIGURE 5.3. PSO observation effort (km) in the Beaufort Sea by Beaufort wind force from the *Geo Arctic* and *Polar Prince* during ION's seismic survey, 12 Oct – 16 Nov 2012.

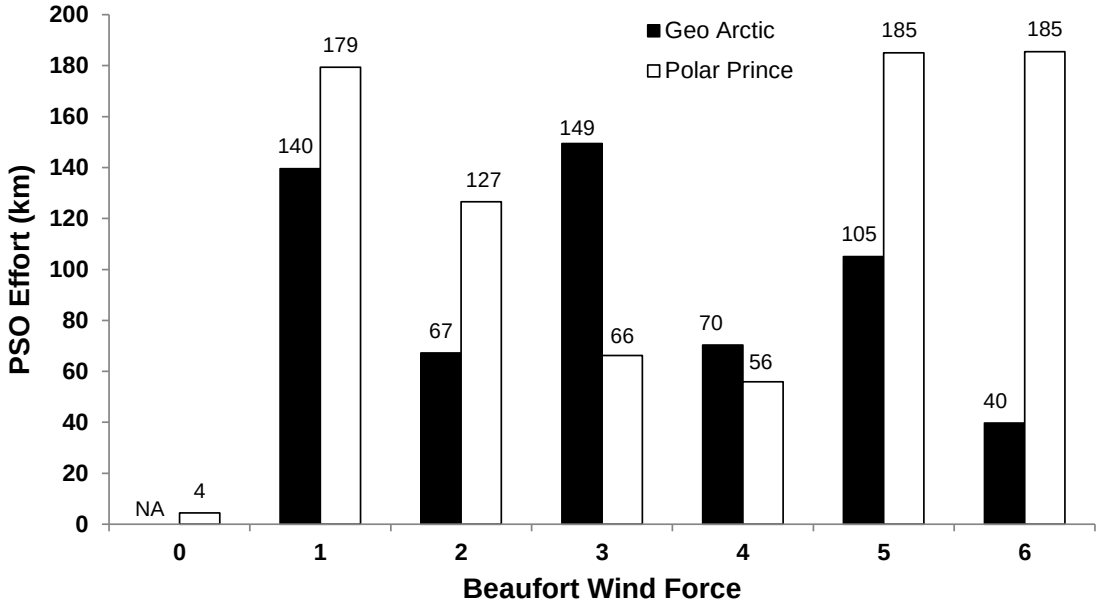

FIGURE 5.4. PSO observation effort (km) in the Chukchi Sea by Beaufort wind force from the *Geo Arctic* and *Polar Prince* during ION's seismic survey, 12 Oct – 16 Nov 2012.

Observer Effort by Number of PSOs

On the *Geo Arctic*, three PSOs were on watch during 76% of observation effort while on the *Polar Prince*, two PSOs were on watch during 89% of effort (Fig. 5.5). The lesser amount of three-person watch on the *Polar Prince* was a result of the fewer number of PSOs onboard as well as bridge space limitations. The observer effort breakdown by the number of PSOs on watch was similar for both vessels in the Beaufort and Chukchi seas.

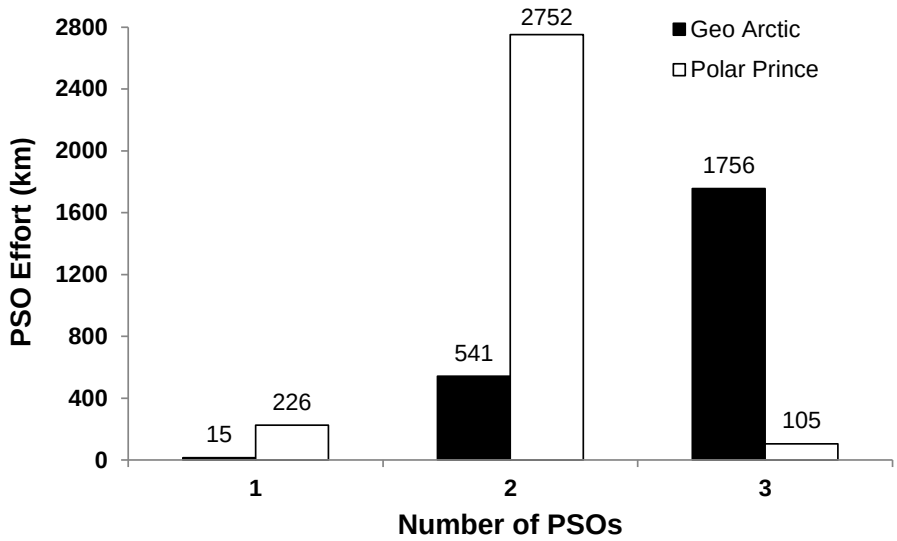

FIGURE 5.5. PSO observation effort (km) by number of PSOs, during ION's seismic survey from the *Geo Arctic* and the *Polar Prince*, 12 Oct – 16 Nov 2012.

Observer Effort by Seismic Status and Received Sound Level

Overall, slightly more than half of observer effort from the *Geo Arctic* (56%) occurred while the airguns were not active. However, in the Beaufort Sea, 44% of observer effort occurred while the full array was active and 11% while the mitigation airgun was active (Fig. 5.6). In the Chukchi Sea, 8% of observer effort occurred while the full array was active and only 4% while the mitigation airgun was active (Fig. 5.6).

Most observer effort from the *Polar Prince* occurred where RSLs were 159-120 dB or <120 dB (rms) in both the Beaufort and Chukchi seas (69% and 89%, respectively; Fig. 5.7). In the Beaufort Sea, this was because the *Polar Prince* spent a considerable amount of time disembarking personnel at the start of seismic operations and was therefore away from the seismic source. The very limited amount of survey activity in the Chukchi Sea in general resulted in a small percentage of total effort from that region occurring where RSLs were ≥160 dB (rms) even though the *Polar Prince* escorted the *Geo Arctic* during all survey activities there (Fig. 5.7).

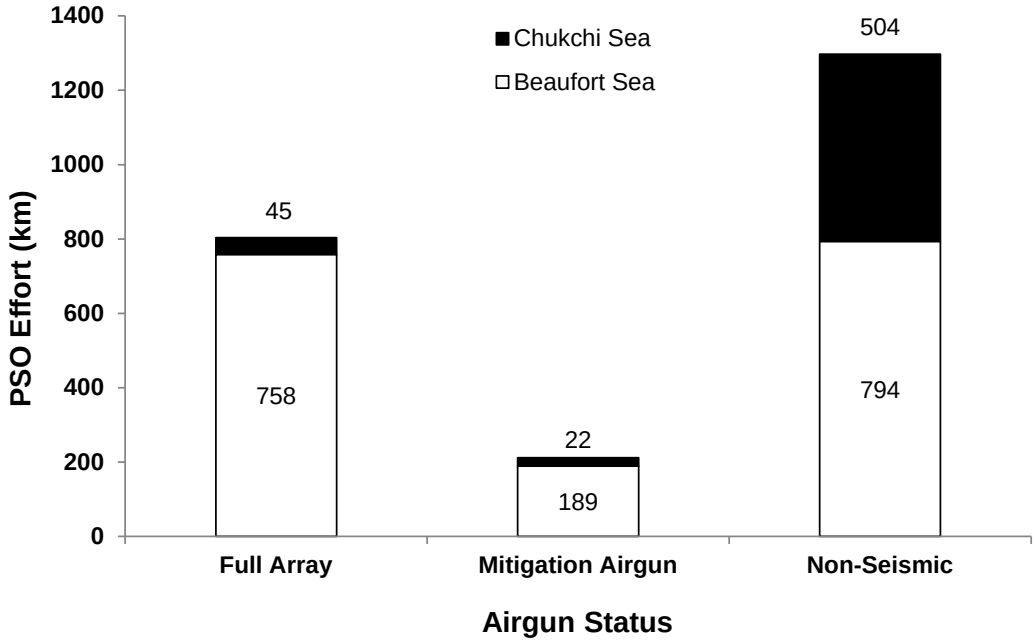

FIGURE 5.6. PSO observation effort (km) for the *Geo Arctic* by seismic status during ION's seismic survey, 12 Oct – 16 Nov 2012. The full airgun array operated at 4380 in^3 and the mitigation airgun operated at 70 in^3.

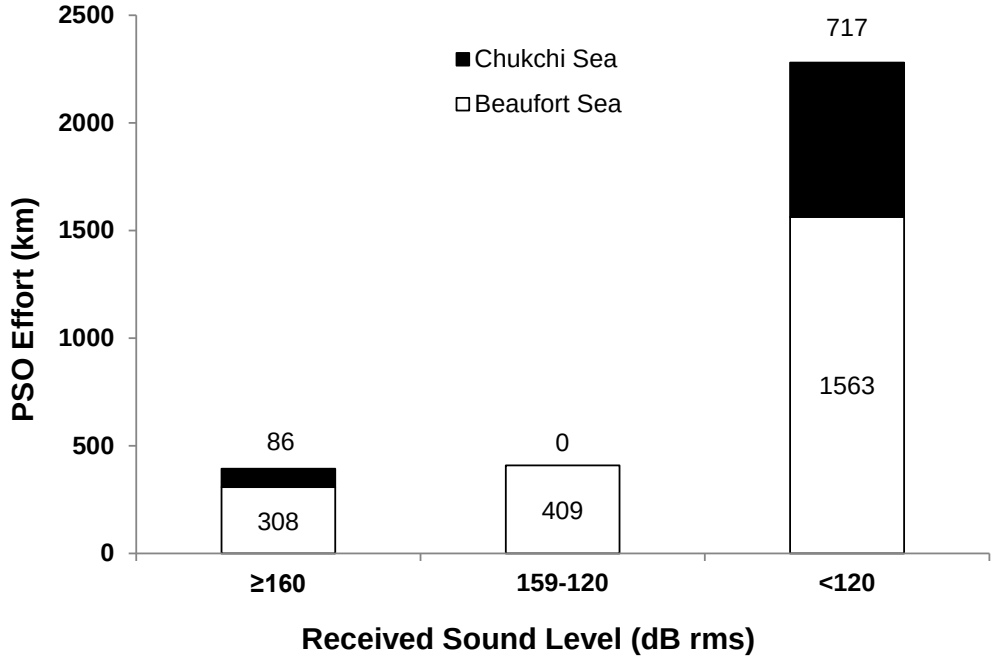

FIGURE 5.7. PSO observation effort (km) from the *Polar Prince* by received sound level during ION's seismic survey, 12 Oct – 16 Nov 2012.

Night Observations

Observers on the *Polar Prince* performed routine observations at night using both a night vision device (NVD) and a forward looking thermal imaging (FLIR) camera system to test and assess their usefulness for monitoring in darkness. The NVD used was a U.S. Night Vision model AN/PVS-7B, a third generation auto-gated night vision goggle. The PVS-7B is a dual eye configuration night vision device that amplifies ambient light making observation of low light areas possible. It has a 40° field of view, a 3X optical magnifier, and has a focal range from 25 cm to infinity. The device can either be held up to the eyes or it can be worn over the eyes 'hands-free' with the use of a head strap. The thermal imaging camera used was model M626L manufactured by FLIR Systems Inc. The FLIR system detects thermal contrasts and has the ability to sense these differences independent of daylight. The camera was mounted on the flying bridge of the *Polar Prince* and was connected to a joystick control unit (JCU) and a display monitor that was located on the bridge. The FLIR-PSO manually controlled the view that was displayed by adjusting the pan (360° continuous pan) and tilt (+/-90° tilt) settings using the JCU.

Observers on the *Polar Prince* used these devices between 2-4 h each night during twilight and darkness periods (~122 h in total). Two different search methods were implemented for FLIR and NVD monitoring. The first method involved a back-and-forth panning motion and the second focused on a fixed swath ahead and to one side of the vessel track. Both devices were used in conjunction with one another, and the observer on one device would replicate the monitoring methodology being employed by the observer on the other device. The typical darkness observation session on the *Polar Prince* was 30 minutes in length for each method. The observers on duty would switch devices after 30 minutes, and observations typically would switch between port and starboard side of the vessel every hour.

The NVD was most useful when there was still a small amount of ambient light present. These included nights with low cloud cover (excluding fog), or no clouds and some moon light. The low cloud cover helped to reflect the vessel lights and greatly increased the ambient light in the water around the vessel. Nights with fog, no ambient light, or heavy seas made observations nearly impossible and the devices were not often used in those conditions. Additionally, the vessels exterior lights (spotlights or deck lights) and/or internal bridge lights often severely limited the usefulness of the NVD from inside the bridge. These light sources often obscured certain areas around the vessel by causing moderate to severe reflection on the bridge windows and required the observer to focus only on those areas least obscured by the various sources of light. Observers on the *Polar Prince* estimated the night-vision goggles effective range to be between 10 m (11 yd) and 1000 m (0.62 mi) depending on the lighting and environmental conditions. Based on comments from the observers the NVD appeared to have a much narrower field of view than the FLIR. Where the NVD excelled was in detecting lighted sources, as in distant vessels or lighted buoys. On several occasions, vessels were clearly detected by the NVD 30 km (18 mi) away, but were not sighted by the FLIR. Obviously this does not assist in the detection of protected species, but may help in locating instrumented scientific gear.

Conditions for using the NVD effectively depend on a large number of factors, many of which are common to all types of visual observations, but a number of these factors are specific to the NVDs. These factors include number and location of lighted instruments on the bridge, tilt and tinting (polarized, etc.) of the bridge windows and sources of reflection such as the railing on the bridge wings. Outdoor observations with the NVD to remove the reflection problem from the windows was not possible due to safety concerns with the cold temperatures, and the potential hazard of having an observer outside alone (potential for slipping, falling overboard). Other factors that influence the NVDs effectiveness included cloud cover and location, moon phase and location, precipitation (e.g. snow, hail) and number and location of deck and running lights.

The infrared camera system (FLIR) used during the 2012 ION survey was able to detect the temperature differences between objects (including marine mammals) and their surrounding environment. During favorable sighting conditions, a high contrast object was easily detected on the FLIR system by the observer. The FLIR system had environmental limitations similar to NVD; ineffective in fog, heavy snow conditions, high sea state, etc., but it also had advantages. The images from the camera were displayed on a computer monitor that could be dimmed and observed for much longer periods without eye fatigue (and neck strain) than the night-vision goggles. The FLIR system was also far less sensitive to the surrounding light conditions than the night-vision goggles and could be used during daytime and night-time operations. The FLIR system was estimated by observers to have an effective range between 10 m (11 yd) and 6000 m (3.73 mi) depending on the lighting and environmental conditions. This is six times farther than what the observers estimated the night-vision goggles could see under optimal observation conditions. However, no reliable ground-truthing was able to be performed to determine actual distances.

Observers on the *Polar Prince* were able to occasionally sight birds and other objects, such as logs, if they were near the vessel and sighting conditions were good. Most of the birds and objects were first sighted by the observer using the FLIR system, and then would be confirmed by the NVD observer when they were told where the object was located. Only two marine mammal sightings were made during darkness periods. The first marine mammal sighting was of a seal on ice. The FLIR system was able to effectively detect the temperature difference between the seal and the ice and project an image on the computer monitor that was discernible enough to tell the object was a seal. The NVD observer subsequently tried to locate the seal on ice, but was unable to do so. The second sighting was of seal in water that was initially detected with the NVD and then subsequently spotted with the unaided eye. The FLIR observer attempted, but could not observe the seal in water on the monitor. In addition to those two sightings, the FLIR system was able to detect a few individual Pacific walruses in water when it was used opportunistically during the daytime on Nov 16th. The image of the Pacific walruses on the FLIR monitor was quite grainy, but the outline of their bodies in water was distinguishable. The FLIR system was not used frequently during daytime because visual observations were far more effective with binoculars and the unaided eye.

A recommended next step in evaluating these two technologies would be to determine actual effective ranges for the FLIR and NVD, rather than using observer estimates, possibly by using static targets (preferably with no additional lighting, as this would increase the detectability of the object by the NVD) or by increasing the number of possible detections. Testing the NVD and FLIR out in high marine mammal density areas, where there are a larger number of possible targets, would allow for a better comparison between the two methods. However, many of the factors mentioned above would need to be addressed (deck lighting, window type, reliability of the FLIR when scanning, etc). It would also be beneficial to have a way of determining actual distances to a target, such as having reticles for the NVD or using the ‘rings’ around the ship on the FLIR screen to depict where the FLIR camera is directed. Additionally, having the capability of the FLIR system to record all or segments of the video stream coming from the camera would be a useful function for retrospective analysis and comparison to optical observations. It is also important to increase the robustness, durability and reliability of the FLIR system as there were numerous issues with the software interface, the screen resolution and the knob on the joystick control unit being used to rotate the camera during scans. The FLIR system should be installed by a licensed system technician along with the engineers on the vessel prior to the start of the survey to make sure that everything is functioning properly.

Marine Mammal Sightings

During ION's seismic survey activities in the Chukchi and Beaufort seas, PSOs observed a total of 348 sightings of 1425 marine mammals from the *Geo Arctic* and 123 sightings of 979 marine mammals from the *Polar Prince* (Fig 5.8). Nearly all (~96%; *n*=451) of the marine mammal sightings recorded during ION's seismic program occurred during four days of operations (Nov 11 and Nov 14-16). These four days will be broken down into three distinct survey periods (*Transit through the Beaufort Sea study area*, *Chukchi Sea survey operations*, and *Transit through the Southern Chukchi Sea*) and discussed in detail below. All marine mammal sightings data, including those observed during the three aforementioned survey periods, will then be presented and analyzed by species groups: cetaceans, seals, polar bears and Pacific walruses. Details of each marine mammal sighting observed within the survey area are available in Appendix G.

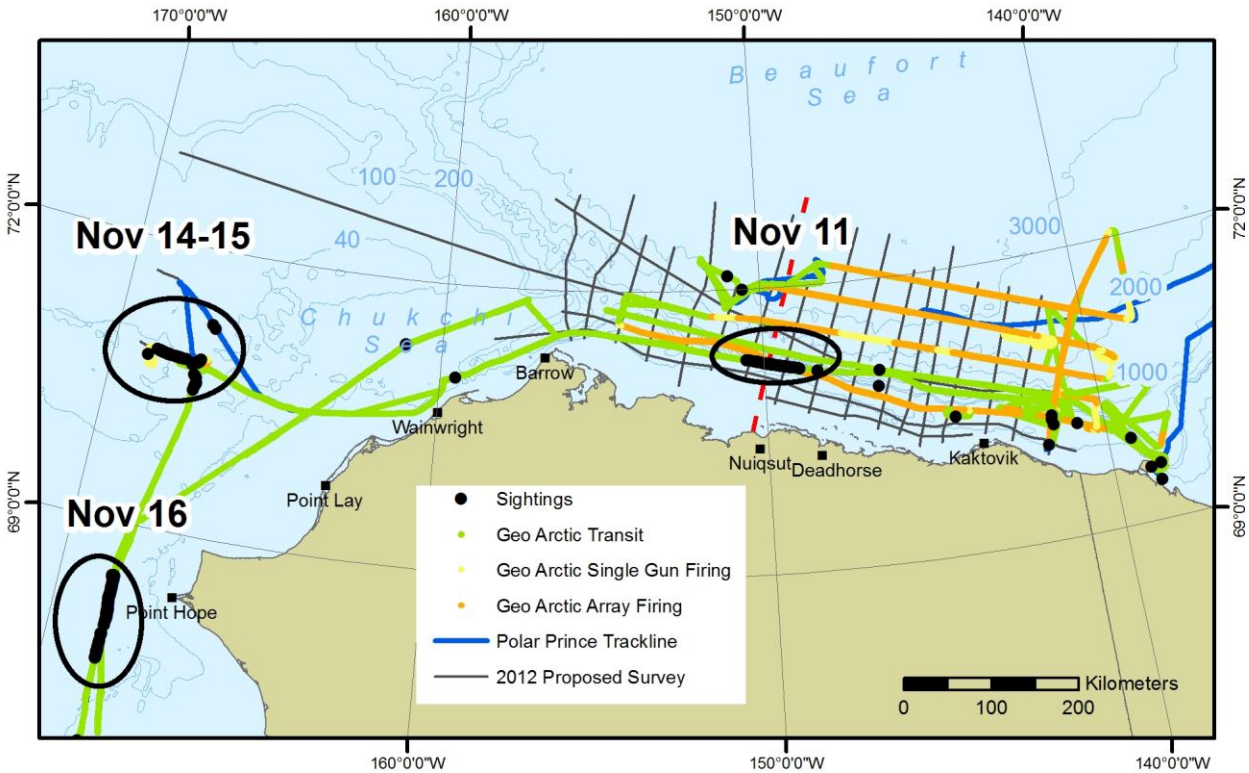

FIGURE 5.8. All marine mammal observations and vessel tracklines during ION Geophysical's seismic survey in the Beaufort and Chukchi Seas, 12 Oct – 16 Nov 2012.

Transit through the Beaufort Sea Study Area

During the transit from the Beaufort Sea portion of the study area to the Chukchi Sea, the PSOs on the *Geo Arctic* and *Polar Prince* observed 92 seal sightings of 125 individual seals during a 5.5 h period on Nov. 11th (Table 5.1 and Fig 5.9). These seal sightings accounted for approximately 88% of the total seal sightings observed during operations in the Beaufort Sea. However, this observation period accounted for only a small percentage (~2%) of the total time the *Geo Arctic* and *Polar Prince* spent in the Beaufort Sea. The large number of seals observed on Nov. 11th can be at least partially attributed to the favorable observation conditions, as the Beaufort sea state was ≤2 throughout the day and the majority (76%) of observation effort occurred during visibility conditions ≥7 km. Habitat factors like water depth

and ice conditions also likely influenced the number of seals present. The water depth ranged from 40 to 206 m (131 to 676 ft) during observations on Nov 11th, with slightly more than half (~56%) of the observational effort in water depths ≤100 m (328 ft). The area was also largely covered (averaged 90% coverage) by new and small pancake ice allowing animals to be hauled out and more visible to observers. In addition, there was no seismic activity occurring during the transit.

The seal sightings on Nov 11th ranged from 67 to 78 km (42 to 48 mi) offshore and were predominately (83%; *n*=76) in water depths ≥50 m (164 ft). The high seal sighting rate (532.0 sightings/1000 km; 856.4 sightings/1000 mi) in water depths ≤200 m (656 ft) on Nov 11th is consistent with previous aerial surveys conducted during springtime in the central Alaskan Beaufort Sea, where estimated seal densities were higher in shallow areas than in deeper areas (Frost et al. 2004, Moulton et al. 2002, Moulton et al. 2005). In the eastern Canadian Beaufort Sea, ringed seal densities were also generally high in waters with similar depths (50-100 m or 50-150 m; 164-328 ft or 164-492 ft; Stirling et al. 1982 and Kingsley 1990). During observations in the Beaufort Sea on Oct 21st when the *Geo Arctic's* airguns were off and there were similar visibility and Beaufort wind force conditions as on Nov 11th, the two vessels observed no seals while in open-water and in water depths ≥200 m (656 ft). The difference between the number of seal sightings during these two days suggest that certain habitat factors like water depth and ice conditions may have influenced the number of seals encountered on Nov 11th, although temporal and weather factors may have also played a role. However, with this limited dataset conclusions cannot be drawn regarding which factor(s) played the most influential role, but as future projects are conducted in the same area around a similar time period certain trends may become evident.

The majority of the seal sightings observed on Nov. 11th could not be identified (~74%; *n*=68) to species. Of the seal sightings that were able to be identified to the species level, approximately 80% were of ringed seals and the remaining 20% were of bearded seals. Most seal sightings were of animals in the water (77%; *n*=71), however, as the vessels traveled further west and the ice thickness appeared to increase, the number of seal sightings on ice also increased. Seals in water were observed as close as 100 m (109 yd) and as far as 3000 m (1.86 mi) from the vessel. Seals on ice were observed as close as 523 m (572 yd) and as far away as 5000 m (3.11 mi). The mean closest point of approach (CPA) distance of seal sightings in the water was more than 3.5 times lower than the mean CPA of seal sightings observed on ice (640 m vs. 2335 m; 0.40 mi vs. 1.45 mi, respectively). However, most seal sightings (67%) were observed within a ½ mile (800 m) of the vessels. Even though the vessels approached relatively close to the majority of seal sightings, very few of the seal sightings exhibited a reaction (<10%) to the vessels as they transited through the area. One seal on ice (out of 21 observed on ice) moved off the ice and into the water as the vessels approached within a distance of 755 m (0.47 mi). There were three other sightings of seals on ice were closer to the vessels than 755 m (0.47 mi) and none of them reacted to the boats. The other sightings of seals on ice were at distances of >1 km (0.62 mi) and also showed no reaction to the passing vessels. Seals in the water that exhibited a reaction were usually recorded as having looked at the vessels.

TABLE 5.1. Marine mammal observations from the *Geo Arctic* and *Polar Prince* on Nov 11th, 2012.

Species	Number of Sightings	Number of Individuals	% of Survey Sightings Total	Mean CPA Distance (m)[a]
Seals in Water				
Bearded Seal	2	2	22	359
Ringed Seal	14	26	48	444
Unidentified Seal	55	62	73	700
Total Seals in Water	***71***	***90***	***62***	***640***
Seals on Ice				
Bearded Seal	3	4	12	3296
Ringed Seal	5	16	36	1970
Unidentified Seal	13	15	16	2253
Total Seals on Ice	***21***	***35***	***17***	***2335***
Total of Seal Sightings	***92***	***125***	***39***	***1027***

[a] For both vessels this value is the marine mammal's closest point of approach to the PSO position on the vessel.

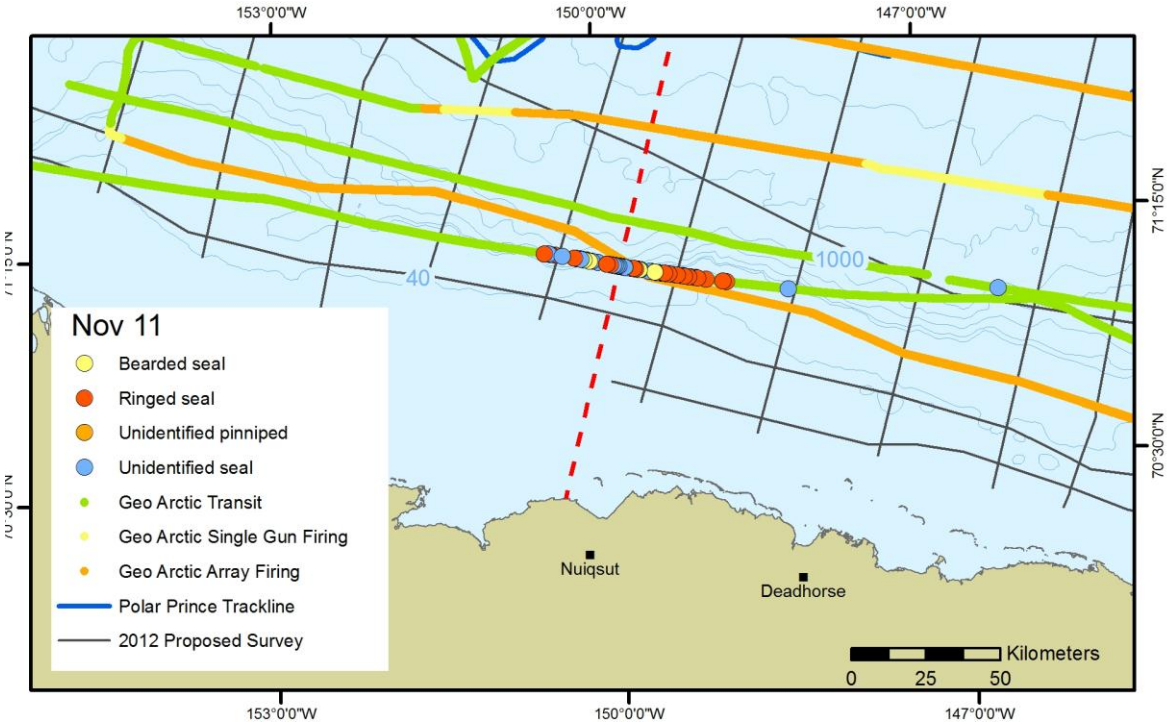

FIGURE 5.9. Marine mammal observations from the *Polar Prince* and *Geo Arctic* on Nov 11th, 2012.

Chukchi Sea Survey Operations

During survey operations along the southernmost east-west tie line near the U.S.–Russian border in the Chukchi Sea, the PSOs aboard the *Geo Arctic* and the *Polar Prince* observed 38 sightings of 80 individual bowhead whales on Nov 14th and 15th (Fig 5.10). These sightings accounted for all but one of the bowhead whale sightings recorded during the 2012 ION survey. Group size ranged from one to six individuals, however nearly half (47%; *n*=18) of the sightings were of a single individual. All of the bowhead whale sightings on Nov 14th and 15th were observed between 110 km (68 mi) and 158 km (98 mi) northeast of Herald Shoal (70° 30' N, 171° 30' W; Ljungblad et. al 1986) and may have been part of a "pulse" of bowhead whales migrating westward towards Russia. This is consistent with observations from previous aerial surveys conducted in late September to early Nov when most migrating bowhead whales in the Chukchi Sea were observed on headings to the west-southwest and were believed to cross the northern Chukchi Sea near Herald Shoal (Quakenbush et. al 2010, Ljungblad et. al 1986). However, satellite tagged bowhead whales spent an unusual amount of time in the north-central Chukchi Sea earlier in the year (late September through the end of Oct) and were presumably feeding there at that time. Although, by the time ION's vessels entered the Chukchi Sea in mid-Nov, the two remaining animals with active satellite tags had moved south to the Russian coast near the Bering Strait (ADF&G 2012).

The majority (89%, *n* = 34) of the bowhead whale sightings observed on Nov 14th and 15th from the *Geo Arctic* and the *Polar Prince* were during periods while the airguns were operating. Most (*n* = 30) of the bowhead whale sightings observed during periods of airgun activity occurred while the full array was active on Nov 14th. The remaining four sightings occurred while the single mitigation airgun was firing on Nov 15th. The mean closest point of approach (CPA) of the bowhead whale sightings to the *Geo Arctic's* airgun array during seismic activity was 3057 m (1.90 mi; *n*=16), while the mean CPA was 3705 m (2.30 mi; *n*=4) during non-seismic periods. The closest bowhead sighting during seismic activity was 870 m (951 yd) from the *Geo Arctic's* airguns. The mean CPA of bowhead whale sightings during periods of seismic activity was slightly closer (2839 m; 1.76 mi; *n*=14) to the *Polar Prince* than to the *Geo Arctic*, which was to be expected due the *Polar Prince* operating at a greater distance from the airguns.

The majority (~95%) of whales were initially observed swimming, fluking, and showing typical surface behavior (e.g. blowing at the surface). The only other initial behaviors observed were of an individual bowhead whale breaching out of the water ~4 km (2.49 mi) ahead of the *Polar Prince*, and a sighting of two individuals in an apparent resting state at the surface. None of the bowhead whales exhibited any noticeable avoidance reactions to the airguns or the vessels themselves.

The sighting conditions on Nov 14th and 15th were very favorable with a Beaufort sea state of predominately ≤2 (73% of the time) and visibility conditions ≥8 km for the majority of the observation effort (81% of the time). The area was covered by variable amounts of new and small pancake ice, ranging from 5% to 100% ice-cover over the course of the two days. The percentage of ice-cover and ice thickness (between 4-8 inches thick) increased as the vessels travelled west along the survey line on Nov 14th. The sea ice was pushed eastward by the wind and currents overnight and resulted in more of the survey line being ice covered on Nov 15th. Many of the bowhead whale sightings on Nov 14th and 15th were observed surfacing in the polynyas within the ice, and when the leads in the ice closed the whales were occasionally seen breaking through thin patches of ice to surface for air. The favorable observation conditions on Nov 14th and 15th helped enable the PSOs to spot whales as far away as 5463 m (3.40 mi), through 25x150 binoculars mounted on the flying bridge of the *Polar Prince*.

TABLE 5.2. Marine mammal observations from the *Geo Arctic* and *Polar Prince* on Nov 14th and 15th.

Species	Number of Sightings	Number of Individuals	% of Survey Sightings Total	Mean CPA Distance[a]
Cetaceans				
Bowhead Whale	38	80	97	3018
Total Cetaceans	***38***	***80***	***97***	***3018***
Seals in Water				
Unidentified Pinniped	1	1	50	886
Unidentified Seal	5	6	7	668
Total Seals in Water	***6***	***7***	***5***	***704***
Seals on Ice				
Bearded Seal	5	14	20	3022
Ringed Seal	1	1	7	4013
Unidentified Seal	7	7	9	2811
Total Seals on Ice	***13***	***22***	***11***	***2985***
Polar Bears				
On Ice	12	13	92	2993
Total Polar Bears	***12***	***13***	***92***	***2993***
Grand Total of Sightings	***69***	***122***	***15***	***2806***

[a] For both vessels this value is the marine mammal's closest point of approach to the PSO position on the vessel.

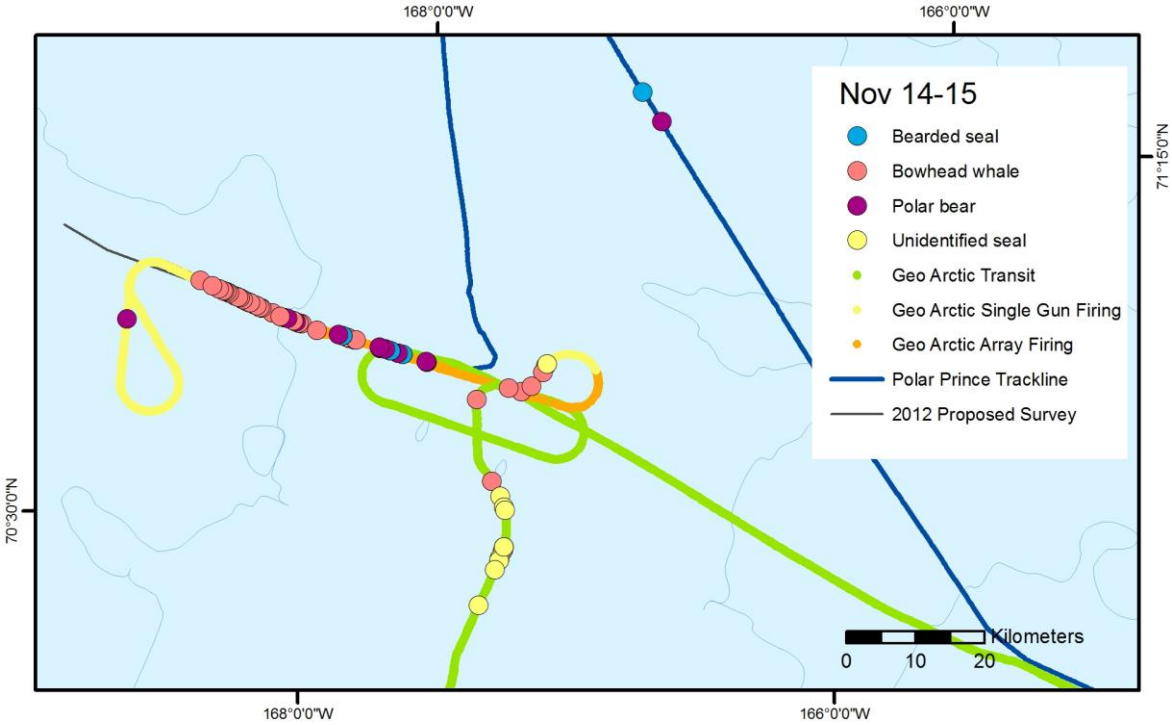

FIGURE 5.10. Marine mammal observations from the *Geo Arctic* and *Polar Prince* on Nov 14th and 15th.

In addition to the bowhead whale sightings on Nov 14th and 15th, there were 31 sightings of 42 other marine mammals observed during those two days. Of those sightings, 18 sightings were able to be identified to species level and included 12 sightings of 13 individual polar bears (*see Polar Bear Sightings section*), five sightings of 14 bearded seals, and one sighting of an individual ringed seal. Twelve sightings of 13 individual unidentified seals and one sighting of an individual unidentified pinniped were also recorded. Similar to the Nov 11th sighting event, the large number of marine mammal sightings on Nov 14th and 15th was likely influenced by temporal and weather factors, as well as by habitat factors such as ice conditions and perhaps food availability.

Transit through the Southern Chukchi Sea

After concluding the 2012 seismic survey program in the north-central Chukchi Sea on Nov 15th, the ION vessels began their transit south towards Dutch Harbor. On Nov 16th, when the vessels were just south of Point Hope, the observers aboard both vessels began to encounter large groups of Pacific walruses. During a 5.5 h period on Nov 16th, the PSOs aboard the *Geo Arctic* and *Polar Prince* observed 179 sightings of 1728 individual Pacific walruses (Fig. 5.11). Nearly all (97%; *n*=174) of these sightings were of Pacific walruses in the water. The percent ice-cover within close proximity (2 km; 1.2 mi) of the vessels on Nov 16th ranged from 0-100%. However, the ice did not appear to be as thick as that which had been observed a day prior in the north-central Chukchi Sea, and the majority of the ice likely would not have been able to support the weight of a walrus.

The observation conditions on Nov 16th were very favorable with a Beaufort sea state of predominately 1 (76% of the time) and visibility conditions ≥10 km for nearly the entire day (91% of the time). The Pacific walrus sightings on Nov 16th ranged from 68 to 110 km (42 to 68 mi) offshore and were almost exclusively (99%; *n*=177) in water depths between 50-60 m (164-197 ft). It is suspected that this "patch" of walruses was moving southward ahead of the newly forming pack ice (Buckley 1958, Fay 1982).

Both vessels initially altered course to avoid approaching with a ½ mile (800 m) of the walruses, as per the USFWS LOA stipulations. However, due to the large number of walruses all around the vessels it was impossible to keep a ½ mile (800 m) distance at all times, so the vessels reduced speed from approximately 10 kts (11.5 mph) to between 4-5 kts (4.6-5.8 mph) and attempted to stay a ½ mile (800 m) from only the larger groups of walruses. In addition, both vessels made sure to not approach within a ½ mile (800 m) of the few individuals on ice to avoid the possibility of a stampede event. The overall mean closest point of approach (CPA) of Pacific walruses observed in the water from the *Geo Arctic* and the *Polar Prince* was 1333 m (0.83 mi). The mean CPA distance of the five Pacific walruses on ice was slightly higher than the overall mean CPA of Pacific walruses in the water (1469 m; 0.91 mi). Pacific walruses were observed as close as 246 m (269 yd) and as far as 2984 m (1.85 mi) from the vessels. Even though the vessels approached within a ½ mile (800 m) of ~32% (*n*=58) of the Pacific walrus sightings, very few of the sightings exhibited a reaction (~16%) to the vessels. The majority of Pacific walrus sightings (65%) that exhibited a reaction to the vessels were observed splashing in response to the vessel. Looking at the vessel was the next most commonly observed reaction (28%). The only other observed Pacific walrus reactions to the vessels were increasing speed (*n*=1) and changing direction (*n*=1) in response to the vessel. All of the Pacific walruses observed on ice showed no reaction to the vessel.

TABLE 5.3. Marine mammal observations from the *Geo Arctic* and *Polar Prince* on Nov 16th, 2012.

Species	Number of Sightings	Number of Individuals	% of Survey Sightings Total	Mean CPA Distance[a]
Cetaceans				
Bowhead Whale	1	6	3	2725
Total Cetaceans	***1***	***6***	***3***	***2725***
Seals in Water				
Bearded Seal	5	9	56	853
Ringed Seal	10	13	34	596
Unidentified Pinniped	1	4	50	1687
Unidentified Seal	13	14	17	852
Total Seals in Water	***29***	***40***	***25***	***793***
Seals on Ice				
Bearded Seal	15	60	60	1963
Ringed Seal	6	11	43	1384
Unidentified Seal	60	113	73	2767
Total Seals on Ice	***81***	***184***	***67***	***2062***
Pacific Walruses				
In the Water	174	1701	100	1333
On Ice	5	27	100	1469
Total Pacific Walruses	***179***	***1728***	***100***	***1337***
Grand Total of Sightings	***290***	***1918***	***62***	***1617***

[a] For both vessels this value is the marine mammal's closest point of approach to the PSO position on the vessel.

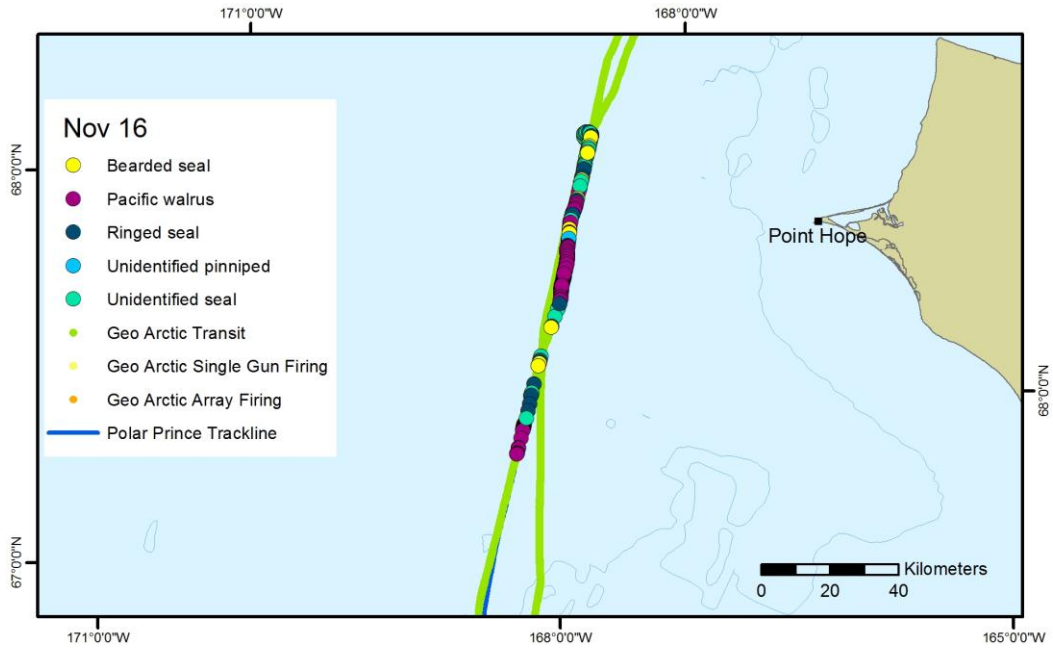

FIGURE 5.10. Marine mammal observations from the *Geo Arctic* and *Polar Prince* on Nov 16th, 2012.

During previous seismic surveys in the Chukchi Sea in 2007 and 2010, large numbers of Pacific walruses were also encountered. In 2007, there were 143 sightings of 1050 individual Pacific walruses observed in a 24-hr period on 24 August (UTC), and in 2010, there were 250 sightings of 823 individual Pacific walruses observed between 28 and 31 August. Both of these other events occurred in the summer months when the Pacific walruses were moving from the receding ice edge towards land. However, together with this sighting event, it suggests that in the Chukchi Sea, most Pacific walruses are likely to be encountered in concentrated periods of time and specific locations associated with migratory movements.

In addition to the Pacific walrus sightings on Nov 16th, there were 111 sightings of 230 other marine mammals observed. Nearly two-thirds (*n*= 73) of the other marine mammals sightings observed on Nov 16th were of unidentified seals. Of the remaining 38 marine mammal sightings, there were 20 sightings of 69 bearded seals, 16 sightings of 24 ringed seals, one sighting of four unidentified pinnipeds, and one sighting of six bowhead whales. Similarly to the other sighting events, the large number of marine mammal sightings on Nov 16th was likely influenced by temporal and weather factors, as well as by habitat factors such as the ice conditions and food availability.

Cetacean Sightings

PSOs observed 43 sightings of 216 cetaceans from the *Geo Arctic* and *Polar Prince* combined (Table 5.1). The majority (91%) of the cetacean sightings were of bowhead whales. Of the remaining cetacean sightings, three were unable to be identified to species and one was of a group of 125 beluga whales (Table 5.4). Only two cetacean sightings occurred in the Beaufort Sea during ION's 2012 survey, one beluga whale sighting in the Canadian Beaufort and one unidentified mysticete whale sighting. The sighting of 125 beluga whales observed in the Canadian Beaufort were spread from the 11 o'clock position to the 2 o'clock position from the *Polar Prince* at a distance of approximately 4 km (2.5 mi) from the PSOs. The whales were travelling in a direction perpendicular to the vessels trackline, and were estimated to have a closest point of approach (CPA) of 2725 m (1.7 mi) to the PSOs aboard the *Polar Prince*. None of the beluga whales approached the *Polar Prince* or exhibited any noticeable reaction to the vessel. Eleven of the 27 bowhead whale sightings were recorded by PSOs on both vessels and these duplicate sightings have only been counted once for all analyses.

Cetacean Sighting Rates

Cetacean sighting rates will not be presented separately by sea due to the limited number of cetacean sightings (*n*=1) in the Beaufort Sea that met the data analysis criteria. Cetacean sighting rates were calculated using only the periods of effort that met the criteria for being able to reliably detect cetaceans (See Chapter 4 and Appendix C) and the sightings that occurred during those periods. For previous seismic projects, those criteria included a filter that removed data collecting from a vessel when another vessel was operating within 5 km (3.1 mi) in the forward 180° of the vessel. This criterion was based on the assumption that vessel(s) operating ahead of another vessel would likely impact the distribution and behavior of marine mammals observed from the vessel in the rear (Beland et al. 2009). However, if this approach had been used for with data from the 2012 ION project, approximately 15% of the total observational effort (336 km; 209 mi) from the *Geo Arctic* would be excluded. Due to the already limited amount of overall survey effort, excluding these data would preclude some comparisons of cetacean sighting rates. Additionally, based on the number of sightings made from the *Geo Arctic* at times when the *Polar Prince* was operating directly in front of it, the assumption behind this criterion did not appear to apply in this case. Thus, data during periods when the *Polar Prince* was operating within 5 km (3.1 mi) in the forward 180° of the *Geo Arctic* were included when calculating cetacean sighting rates for the 2012 ION survey. Data that met these criteria are presented in Appendix F.

TABLE 5.4. Number of cetacean sightings (number of individuals) from the *Geo Arctic* and *Polar Prince* during ION's seismic survey, 12 Oct – 16 Nov 2012.

Species	*Geo Arctic*	*Polar Prince*	*Total*
Cetaceans			
Beluga Whale	0	1 (125)	***1 (125)***
Bowhead Whale	23 (43)	16 (43)	***39 (86)***
Unidentified Mysticete Whale	1 (2)	2 (3)	***3 (5)***
Total Cetaceans	***24 (45)***	***19 (171)***	***43 (216)***

Cetacean Sighting Rates by Beaufort Wind Force – Cetacean sighting rates from both vessels were greatest during periods of Beaufort wind force (Bf) two (Fig. 5.8). Although this result makes intuitive sense, it is also heavily biased by the fact that all but three of the cetacean sightings occurred on just two days (Nov 14th and 15th) when Bf conditions were predominately two. This resulted in the combined cetacean sighting rate for both vessels being significantly higher during periods of Bf 2 than all the other Bf periods combined (χ^2 = 98.61, *df* = 1, *p* = <0.0001, power [1-β] = 0.26). The single cetacean sighting observed in the Beaufort Sea from the *Polar Prince* also occurred during a period of Bf two.

Cetacean Sighting Rates by Number of PSOs – Most often there were three observers on duty aboard the *Geo Arctic* and two observers on duty board the *Polar Prince*. In order to partially mask these biases, the effort and sightings from both vessels were combined in order to compare sighting rates between periods with different numbers of PSOs on watch (Fig. 5.9). Once the data were combined, cetacean sighting rates were greatest with three PSOs on watch. This sighting rate was nearly four times greater than periods when two PSOs were on watch and the difference was statistically significant (χ^2 = 15.40, df = 1, p = <0.0001, power [1-β] = 0.19). The highest sighting rate was during periods when three PSOs were on watch aboard the *Polar Prince* (115.3 sightings/1000 km; 185.5 sightings/1000 mi). However, further complicating this entire analysis is the fact that the number of observers on duty aboard the Polar Prince was increased from two to three in response to the increased presence of cetaceans. There was a very limited amount observer effort (~54 km; 34 mi) during periods when only one PSO was on watch and no sightings were recorded. This precluded any meaningful comparison of sightings rates from periods with one observer on duty.

Cetacean Sighting Rates by Received Sound Level – Cetacean sighting rates from the *Geo Arctic* were over seven times higher when the full array was active than during non-seismic periods. Cetacean sighting rates from the *Polar Prince* were also higher in areas where RSLs were ≥160 dB (rms) than in areas where RSLs were <120 dB (rms). Not surprisingly, when effort and sightings from the *Geo Arctic* and the *Polar Prince* were pooled, the sighting rate was significantly higher in areas where RSLs were ≥160 dB (rms) than in areas where RSLs were <120 dB (rms; χ^2 = 53.73, *df* = 1, *p* = <0.0001, power [1-β] = 0.16; Fig. 5.10). However, this whole analysis is heavily biased due to the vast majority (~81%) of cetacean sightings occurring on one day (Nov 14th) during which the *Geo Arctic's* full array was active. The single cetacean sighting observed in the Beaufort Sea from the *Polar Prince* occurred while the *Geo Arctic's* airguns were off.

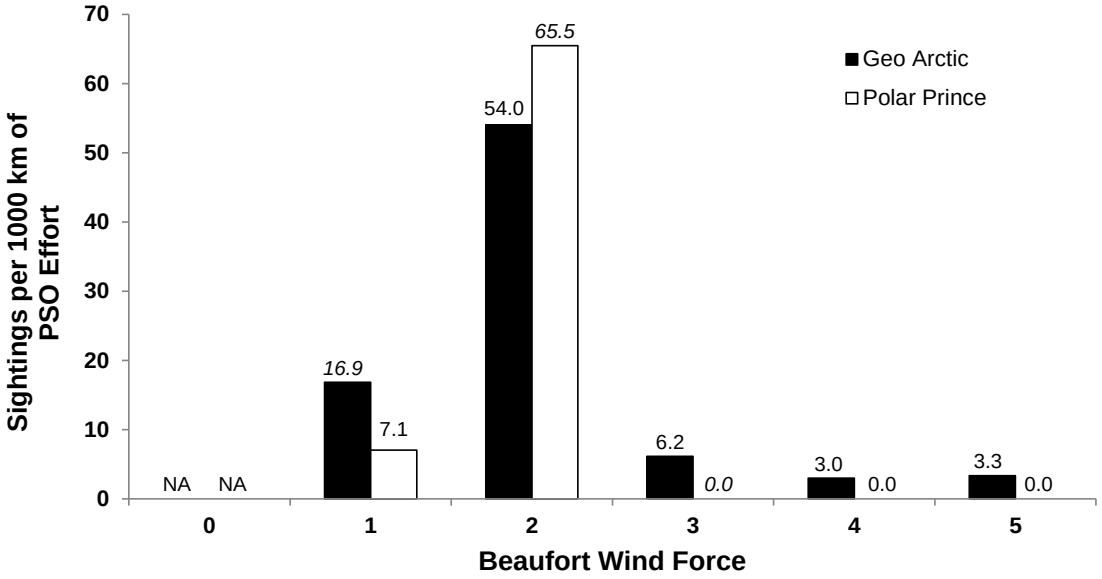

FIGURE 5.8. Cetacean sighting rates during Beaufort wind force conditions 0 through 5 during ION's seismic survey, 12 Oct – 16 Nov 2012. Italics indicate a marginal level of effort was available for calculating the sighting rate (<250 km; 155 mi). NA indicates a Bf category where a sighting rate could not be calculated due to lack of effort (<100 km; 62 mi).

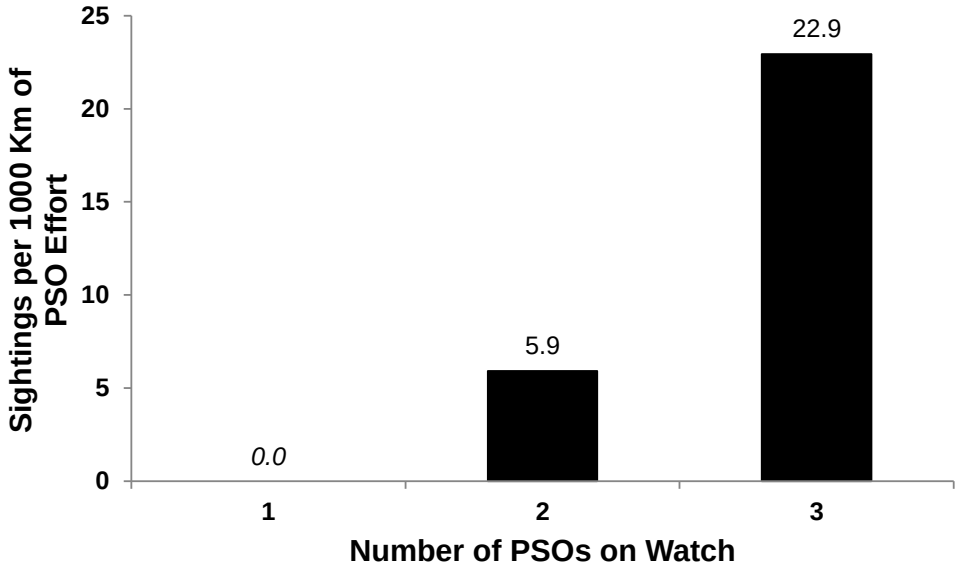

FIGURE 5.9. Cetacean sighting rates by number of PSOs on watch from both vessels combined during ION's seismic survey, 12 Oct – 16 Nov 2012. Italics indicate a marginal level of effort was available for calculating the sighting rate (<250 km; 155 mi).

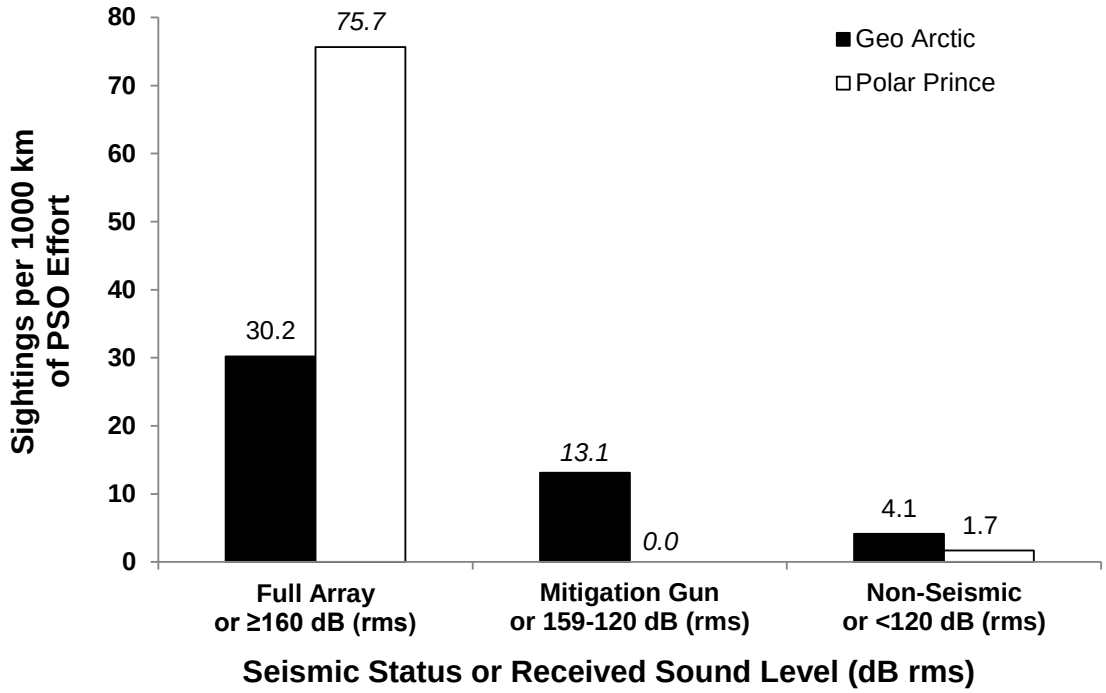

FIGURE 5.10. Cetacean sighting rates from the *Geo Arctic* by airgun activity level (seismic status) and from the *Polar Prince* by received sound level during ION's seismic survey, 12 Oct – 16 Nov 2012. Seismic status labels (full array, mitigation airgun, and non-seismic) describe the sighting rate categories from the *Geo Arctic*, while received sound level labels (≥160 dB, 159-120 dB, and <120 dB) describe the sighting rate categories from the *Polar Prince*. Italics indicate a marginal level of effort was available for calculating the sighting rate (<250 km; 155 mi).

Seal Sightings

There were 236 seals sightings of 446 individuals by PSOs on the *Geo Arctic* and *Polar Prince* (Table 5.5). Ringed seal was the most frequently identified seal species in the Beaufort and Chukchi seas, although over two-thirds of the seals could not be identified to species. The majority (75%) of seal sightings in the Beaufort Sea were in the water, whereas the majority (~73%) of seal sightings were on ice in the Chukchi Sea. There were six sightings of 12 unidentified seals and one sighting of an individual bearded seal that were recorded by PSOs on both the *Geo Arctic* and the *Polar Prince*. These duplicate sightings have only been counted once for all analyses.

TABLE 5.5. Number of sightings (number of individuals) of seals in the Beaufort and Chukchi seas during ION's seismic survey from the *Geo Arctic* and *Polar Prince*, 12 Oct – 16 Nov 2012.

Species	*Geo Arctic*	*Polar Prince*	*Total*
Beaufort Sea			
Seals in Water			
Bearded Seal	1 (1)	3 (3)	***4 (4)***
Ringed Seal	5 (5)	13 (25)	***18 (30)***
Unidentified Seal	52 (59)	5 (5)	***57 (64)***
Seals on Ice			
Bearded Seal	1 (1)	3 (4)	***4 (5)***
Ringed Seal	2 (8)	5 (63)	***7 (71)***
Unidentified Seal	10 (12)	5 (5)	***15 (17)***
Total Beaufort Sea Seals	***71 (86)***	***34 (105)***	***105 (191)***
Chukchi Sea			
Seals in Water			
Bearded Seal	2 (4)	3 (5)	***5 (9)***
Ringed Seal	2 (2)	9 (12)	***29 (44)***
Unidentified Seal	14 (16)	4 (4)	***18 (20)***
Unidentified Pinniped	1 (1)	1 (4)	***2 (5)***
Seals on Ice			
Bearded Seal	10 (37)	11 (38)	***21 (75)***
Ringed Seal	2 (3)	5 (9)	***7 (12)***
Unidentified Seal	60 (102)	7 (18)	***67 (120)***
Total Chukchi Sea Seals	***91 (165)***	***40 (90)***	***131 (255)***

Seal Sighting Rates

Seal sighting rates were calculated using only the periods of effort that met the criteria for being able to reliably detect seals (See Chapter 4 and Appendix C) and the sightings that occurred during those periods. Both seal sightings in the water and on ice were used during calculations of sighting rates. For previous seismic projects, those criteria included a filter that removed data collecting from a vessel when another vessel was operating within 1 km (0.62 mi) in the forward 180° of the vessel. This criterion was based on the assumption that vessel(s) operating ahead of another vessel would likely impact the distribution and behavior of marine mammals observed from the vessel in the rear (Beland et al. 2009). However, if this approach had been used for with data from the 2012 ION project, approximately 11% of the total observational effort (243 km; 151 mi) from the *Geo Arctic* would be excluded. Due to the already limited amount of overall survey effort, excluding these data would preclude some comparisons of seal sighting rates. Additionally, based on the number of sightings made from the *Geo Arctic* at times when the *Polar Prince* was operating directly in front of it, the assumption behind this criterion did not appear to apply in this case. Thus, data during periods when the *Polar Prince* was operating within 1 km

(0.62 mi) in the forward 180° of the *Geo Arctic* were included when calculating seal sighting rates for the 2012 ION survey.

Seal Sighting Rates by Beaufort Wind Force – As would be expected, seal sighting rates from the *Geo Arctic* and *Polar Prince* decreased with increasing Beaufort wind force (Fig. 5.11). In the Beaufort Sea, approximately 96% of the seal sightings occurred during periods of Bf 2 (317.5 sightings/1000 km; 511.1 sighting/1000 mi) from the *Geo Arctic*, whereas approximately 87% of the seal sightings occurred during periods of Bf 1 (134.2 sightings/1000 km; 215.9 sightings/1000 mi) from the *Polar Prince*. In the Chukchi Sea, the majority of the sightings from both the *Geo Arctic* and the *Polar Prince* were during periods of Bf 1 (80% and 66%, respectively). When the effort and sightings data from the Beaufort and Chukchi seas were combined, seal sighting rates were greatest during periods of Bf 1 for both vessels (Fig. 5.11).

Seal Sighting Rates by Number of PSOs – Most often there were three observers on duty aboard the *Geo Arctic* and two observers on duty board the *Polar Prince*. In order to partially mask these biases, the effort and sightings from both vessels were combined to compare sighting rates between periods with different numbers of PSOs on watch (Fig. 5.12). Seal sighting rates with one PSO on watch were greater than with two or three PSOs on watch. However, only 54 km (34 mi) of effort occurred when there was only one PSO on watch, so that comparison is not very meaningful. However, seal sighting rates were significantly greater with three PSOs on watch than with two PSOs on watch (χ^2 = 98.21, *df* = 1, *p* = <0.0001, power [1-β] = 0.19).

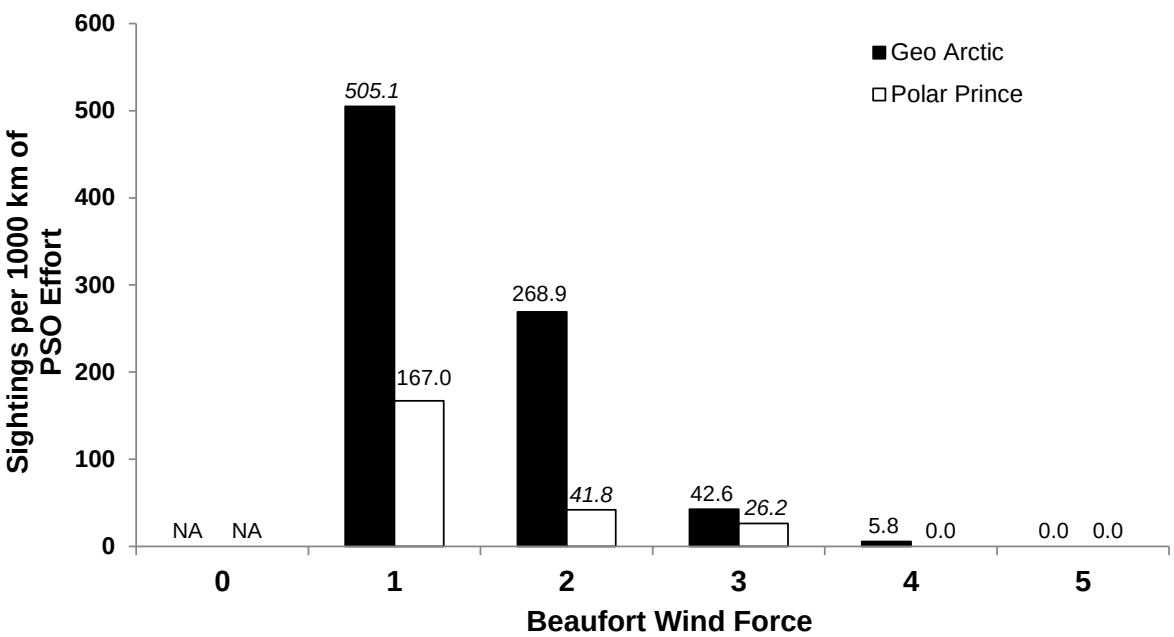

FIGURE 5.11. Seal sightings by Beaufort wind force during ION's seismic survey from the *Geo Arctic* and *Polar Prince*, 12 Oct – 16 Nov 2012. Italics indicate a marginal level of effort was available for calculating the sighting rate (<250 km; 155 mi). NA indicates a level where a sighting rate could not be calculated (<100 km; 62 mi).

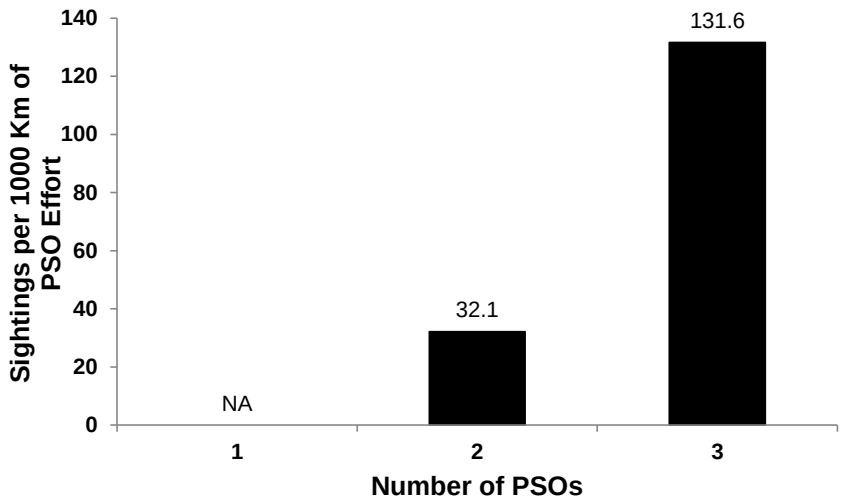

FIGURE 5.12. Seal sighting rates by number of PSOs from the *Geo Artic* and *Polar Prince* combined during ION's seismic survey, 12 Oct – 16 Nov 2012. NA indicates a level where a sighting rate could not be calculated (<100 km; 62 mi).

Seal Sighting Rates by Received Sound Level – The seal sighting rate from the *Geo Arctic* was highest during non-seismic periods in both the Beaufort and Chukchi seas (Fig. 5.13). The sighting rate during non-seismic periods was nearly two times greater than during full array airgun activity in the Chukchi Sea. In the Beaufort Sea, there were no seal sightings during either full array or mitigation gun activity from the *Geo Arctic*, whereas there were 70 seal sightings during non-seismic periods (156.5 sightings/1000 km; 251.8 sightings/1000 mi). When the effort and sightings data from the *Geo Arctic* in the Beaufort and Chukchi seas were combined, the difference between sighting rates during non-seismic periods and full array activity was statistically significant (χ^2 = 87.13, *df* = 1, *p* = <0.0001, power [1-β] = 0.19).

The sighting rates from the *Polar Prince* were highest in areas where RSLs were <120 dB (rms) in both the Beaufort and Chukchi seas. The sighting rate in areas where the RSLs were <120 dB (rms) was nearly 1.5 times greater than in areas where the RSLs were ≥160 dB in the Chukchi Sea. In the Beaufort Sea, there were no seal sightings from the *Polar Prince* in areas where RSLs were ≥160 dB (rms). When the effort and sightings data from the *Polar Prince* in the Beaufort and Chukchi seas were combined, there was a significant difference between sighting rates in areas where the RSLs were <120 dB (rms) and in areas where the RSLs were 159–120 dB (rms; χ^2 = 6.53, *df* = 1, *p* = 0.010, power [1-β] = 0.16). However, there was not a significant difference between sighting rates in areas where the RSLs were <120 dB (rms) and in areas where the RSLs were ≥160 dB dB (rms; χ^2 = 4.89, *df* = 1, *p* = 0.027, power [1-β] = 0.16). Sighting rate comparisons from the *Polar Prince* should be interpreted with caution due to the marginal amount of effort in areas where RSLs were ≥160 dB (rms) and 159–120 dB (rms).

As was the case for cetacean sightings, the interpretation of seal sighting rates relative to airgun activity aboard the *Geo Arctic* (or received sound levels near the *Polar Prince*) must be done while keeping in mind the very patchy nature of marine mammal sightings during this survey. The few areas of high seal numbers were generally encountered on days when the airguns were not active; leading to the higher seal sighting rates during "non-seismic" periods and a possible interpretation that seals avoided the seismic airgun activity. However, these higher sighting rates may have simply resulted from the chance distribution of concentrated areas of seals being located in areas where seismic activity did not occur.

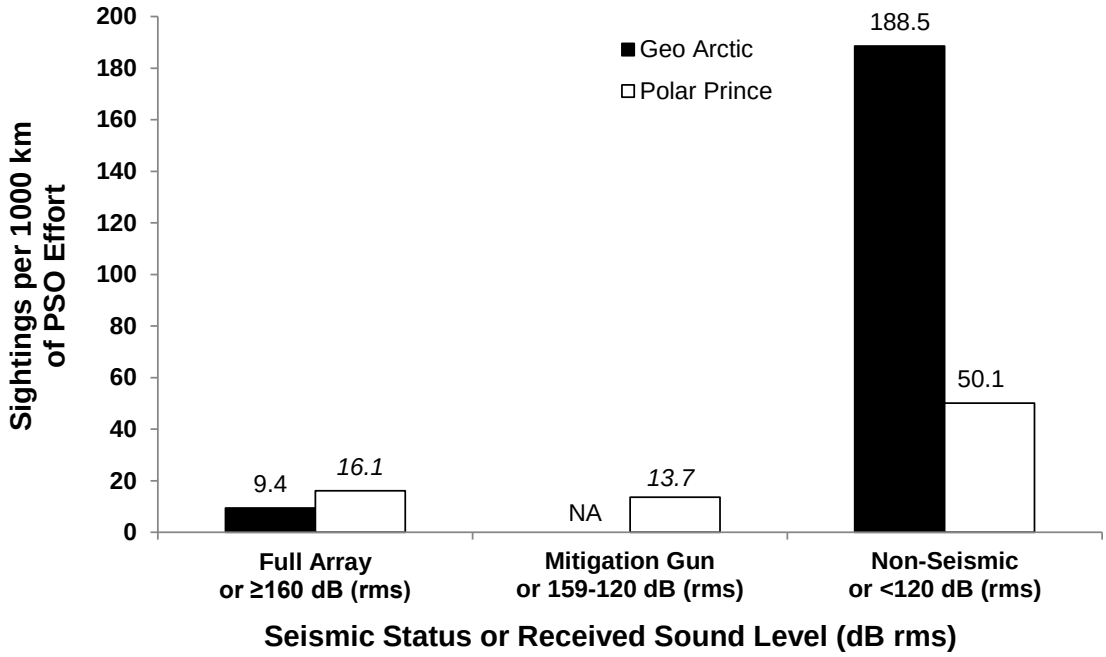

FIGURE 5.13. Seal sighting rates from the *Geo Arctic* by airgun activity level (seismic status) and from the *Polar Prince* by received sound level during ION's seismic survey, 12 Oct – 16 Nov 2012. Seismic status labels (full array, mitigation airgun, and non-seismic) describe the sighting rate categories from the *Geo Arctic*, while received sound level labels (≥160 dB, 159-120 dB, and <120 dB) describe the sighting rate categories from the *Polar Prince*. Italics indicate a marginal level of effort was available for calculating the sighting rate (<250 km; 155 mi). NA indicates a level where a sighting rate could not be calculated (<100 km; 62 mi).

Polar Bear Sightings

There were 12 polar bear sightings of 13 individuals by PSOs on the *Geo Arctic* and *Polar Prince* during survey operations in the Chukchi Sea (Table 5.6). There were also three observations of polar bear tracks on ice in the Chukchi Sea. No sightings of polar bears occurred in the Beaufort Sea. All of the polar bear sightings were observed on ice between 13 and 15 Nov 2012 (Table 5.3).

TABLE 5.6. Number of sightings (number of individuals) of polar bears during ION's seismic survey from the *Geo Arctic* and *Polar Prince*, 12 Oct – 16 Nov 2012.

Species	*Geo Arctic*	*Polar Prince*	*Total*
Polar Bears			
In Water	0	0	***0***
On Ice/land	6 (6)	6 (7)	***12 (13)***
Total Polar Bears	***6 (6)***	***6 (7)***	***12 (13)***

Polar Bear Sighting Rates

Polar bear sighting rates were calculated using only the periods of effort *in the Chukchi Sea* (since there were no polar bear sightings in the Beaufort Sea) that met the criteria for being able to reliably detect polar bears (See Chapter 4 and Appendix C) and the sightings that occurred during those periods. For previous seismic projects, those criteria included a filter that removed data collecting from a vessel when another vessel was operating within 1 km (0.62 mi) in the forward 180° of the vessel. This criterion was based on the assumption that vessel(s) operating ahead of another vessel would likely impact the distribution and behavior of marine mammals observed from the vessel in the rear (Beland et al. 2009). However, if this approach had been used for with data from the 2012 ION project, approximately 11% of the total observational effort (243 km; 151 mi) from the *Geo Arctic* would be excluded. Due to the already limited amount of overall survey effort, excluding these data would preclude some comparisons of polar bear sighting rates. Additionally, based on the number of sightings made from the *Geo Arctic* at times when the *Polar Prince* was operating directly in front of it, the assumption behind this criterion did not appear to apply in this case. Thus, data during periods when the *Polar Prince* was operating within 1 km (0.62 mi) in the forward 180° of the *Geo Arctic* were included when calculating polar bear sighting rates for the 2012 ION survey. Data that met these criteria are presented in Appendix F.

Polar Bear Sighting Rates by Beaufort Wind Force – The majority (80%) of the polar bear sightings from the *Geo Arctic* and *Polar Prince* were during periods of Bf one and two. Sighting rates from the *Geo Arctic* during periods of Bf two were slightly greater than during periods of Bf one. Conversely, sighting rates from the *Polar Prince* during periods of Bf one were slightly greater than during periods of Bf two (Fig. 5.14). However, the limited amount of effort within the Bf one category from both vessels precludes any meaningful interpretation of these comparisons.

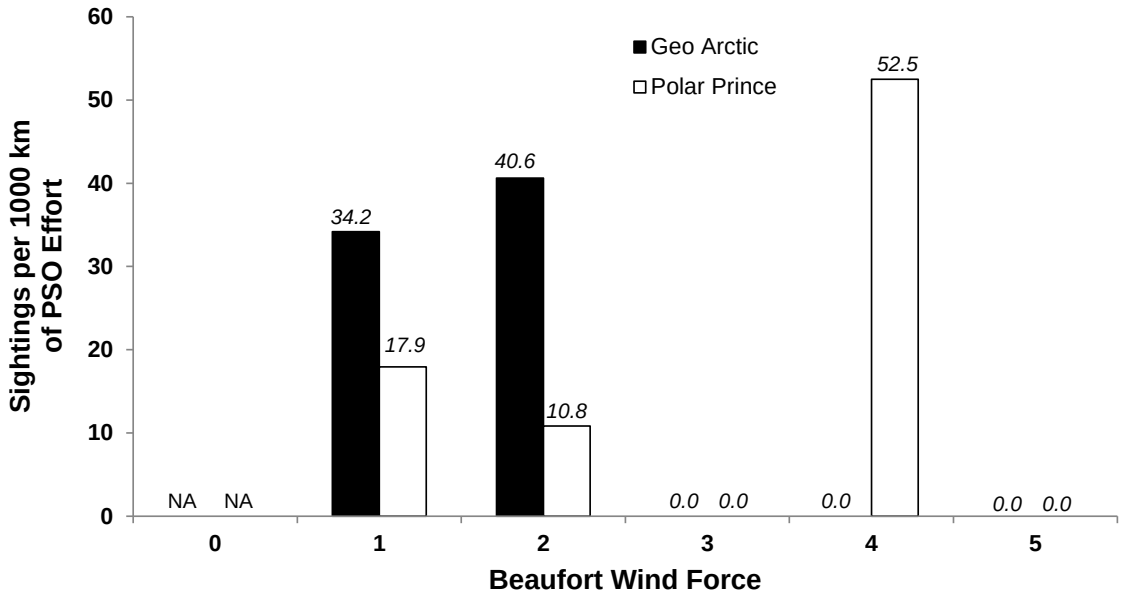

FIGURE 5.14 Polar bear sightings by Beaufort wind force during ION's seismic survey from the *Geo Arctic* and the *Polar Prince*, 12 Oct – 16 Nov 2012. Italics indicate a marginal level of effort was available for calculating the sighting rate (<250 km; 155 yd). NA indicates a level where a sighting rate could not be calculated (<10 km; 6.2 mi).

Polar Bear Sighting Rates by Number of PSOs – All of the polar bear sightings from the *Geo Arctic* were during periods when three PSOs were on watch (22.3 sightings/1000 km; 35.9 sightings/1000 mi). In contrast, all polar bear sightings from the *Polar Prince* were during periods when two PSOs were on watch (13.7 sightings/1000 km; 22.0 sightings/1000 mi).

Polar Bear Sighting Rates by Received Sound Level – All polar bear sightings from the *Geo Arctic* occurred while the full array was active (126.5 sightings/1000 km; 203.6 sightings/1000 mi). Polar bear sighting rates from the *Polar Prince* were also higher in areas where RSLs were ≥160 dB (rms) than in areas where RSLs were <120 dB (rms). When effort and sightings from the *Geo Arctic* and the *Polar Prince* were combined, the sighting rates were significantly higher in areas where RSLs were ≥160 dB (rms) than in areas where RSLs were <120 dB (rms; $\chi^2 = 64.48$, $df = 1$ $p = <0.0001$, power [1-β] = 0.16; Fig. 5.15). However, this was entirely because all but one of the polar bear sightings occurred on Nov 14th in the Chukchi Sea while the airgun array was active. All polar bear sightings were observed on ice in the Chukchi Sea, and likely were not exposed to RSLs ≥160 dB (rms).

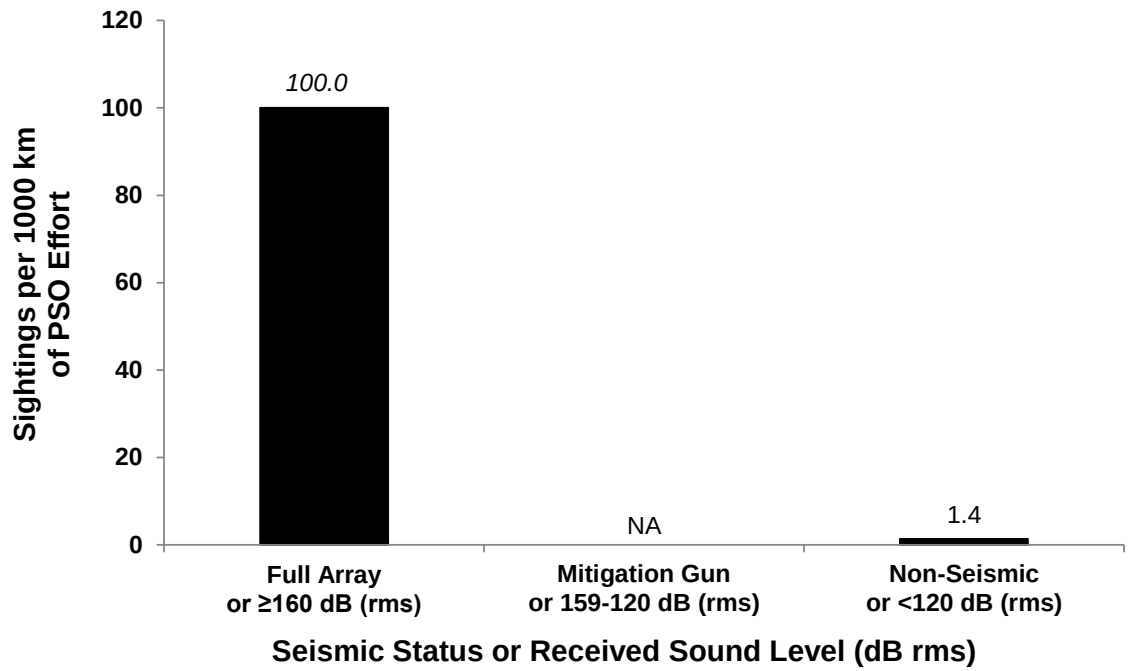

FIGURE 5.15. Sighting rates from the *Geo Arctic* by airgun activity level (seismic status) and from the *Polar Prince* by received sound level during ION's seismic survey, 12 Oct – 16 Nov 2012. Seismic status labels (full array, mitigation airgun, and non-seismic) describe the sighting rate categories from the *Geo Arctic*, while received sound level labels (≥160 dB, 159-120 dB, and <120 dB) describe the sighting rate categories from the *Polar Prince*. Italics indicate a marginal level of effort was available for calculating the sighting rate (<250 km; 155 mi). NA indicates a level where a sighting rate could not be calculated (<100 km; 62 mi).

Pacific Walrus Sightings

There were 179 Pacific walrus sightings of 1728 individuals by PSOs on the *Geo Arctic* and the *Polar Prince* (Table 5.7). All of the Pacific walrus sightings were observed on 16 Nov south of Point Hope in the Chukchi Sea and after seismic survey activities had concluded.

TABLE 5.7. Number of sightings (number of individuals) of Pacific walruses during ION's seismic survey from the *Geo Arctic* and *Polar Prince*, 12 Oct – 16 Nov 2012.

Species	*Geo Arctic*	*Polar Prince*	*Total*
Pacific Walruses			
In Water	156 (1123)	18 (578)	***174 (1701)***
On Ice/land	0	5 (27)	***5 (27)***
Total Pacific Walruses	***156 (1123)***	***23 (605)***	***179 (1728)***

Pacific Walrus Sighting Rates

Pacific walrus sighting rates were calculated using only the periods of effort *in the Chukchi Sea* (since there were no Pacific walrus sightings in the Beaufort Sea) that met the criteria for being able to reliably detect walruses (See Chapter 4 and Appendix C) and the sightings that occurred during those periods. For previous seismic projects, those criteria included a filter that removed data collecting from a vessel when another vessel was operating within 1 km (0.62 mi) in the forward 180° of the vessel. This criterion was based on the assumption that vessel(s) operating ahead of another vessel would likely impact the distribution and behavior of marine mammals observed from the vessel in the rear (Beland et al. 2009). However, if this approach had been used for with data from the 2012 ION project, approximately 11% of the total observational effort (243 km; 151 mi) from the *Geo Arctic* would be excluded. Due to the already limited amount of overall survey effort, excluding these data would preclude some comparisons of Pacific walrus sighting rates. Additionally, based on the number of sightings made from the *Geo Arctic* at times when the *Polar Prince* was operating directly in front of it, the assumption behind this criterion did not appear to apply in this case. Thus, data during periods when the *Polar Prince* was operating within 1 km (0.62 mi) in the forward 180° of the *Geo Arctic* were included when calculating Pacific walrus sighting rates for the 2012 ION survey. Data that met these criteria are presented in Appendix F.

Pacific Walrus Sighting Rates by Beaufort Wind Force – All Pacific walrus sightings (n=160) from the *Geo Arctic* and the *Polar Prince* occurred on Nov 16th in the Chukchi Sea during periods of Bf one (802.8 sightings/1000 km; 1292.4 sightings/1000 mi).

Pacific Walrus Sighting Rates by Number of PSOs and Vessel – During the period of high Pacific walrus sightings both vessels had three observers on the bridge, but in both cases one of the observers spent the majority of their time entering data and only occasionally was free to scan for animals. The *Geo Arctic* had a significantly higher Pacific walrus sighting rate (377.7 sightings/1000 km) than the *Polar Prince* (48.9 sighting/1000 km) in the Chukchi Sea (χ^2 = 115.23, df = 1 p = <0.0001, power [1-β] = 0.26), despite the two vessel travelling within close proximity of one another when the Pacific walruses were observed. The difference in sighting rates between the two vessels could partially be attributed to differing counting methodologies (e.g. the lumping of some loosely aggregated individuals into a single group versus counting all individuals as separate sightings), as well as the bridge on the *Geo Arctic* being a preferable observation platform.

Pacific Walrus Sighting Rates by Received Sound Level – All Pacific walrus sightings from the *Geo Arctic* and *Polar Prince* occurred while the *Geo Arctic's* airguns were off.

Distribution and Behavior of Marine Mammals

Marine mammal behaviors and reactions were difficult to observe because individuals and/or groups typically spent most of their time below the water surface and could not be observed for extended periods. Additionally, the PSO's primary duty is mitigation rather than collecting behavioral data. The data collected during visual observations therefore provided limited information about reactions of marine mammals to ION's seismic survey. The relevant data collected from the *Geo Arctic* and *Polar Prince* included estimated distance to the vessel, movement relative to the vessel, and behavior and reaction of animals at the time of the initial or subsequent detections.

Cetaceans

Cetacean Initial Sighting Distance and Distribution

The initial sighting distance of cetaceans was calculated using all sightings that occurred during the 2012 ION survey (Fig. 5.16). The mean initial sightings distance of cetaceans from the *Geo Arctic* during full array activity was 2941 m (1.83 mi), while it was 3539 m (2.20 mi) during non-seismic periods. From the *Polar Prince*, the mean initial sightings distance where RSLs were ≥160 and <120 dB (rms) were 2754 m (1.71 mi) and 2538 m (1.58 mi), respectively. The two cetacean sighting in the Beaufort Sea were from the *Polar Prince* in an area where RSLs were <120 dB (rms) and the mean initial sightings distance to the vessel was 3363 m (2.09 mi). Since almost all cetacean sightings occurred while the airguns were active it is not possible to make a meaningful interpretation of the differences in initial sighting distances between periods when airguns were active and when they were not.

Cetacean Closest Point of Approach

The mean closest points of approach (CPAs) of cetaceans were calculated using only sightings that occurred during periods of effort that met the criteria for being able to reliably detect cetaceans (See Chapter 4, section *Cetacean Sighting Rates*, and Appendix F). Cetacean CPA values will not be presented separately by sea due to the limited number of cetacean sightings (n=1) in the Beaufort Sea that met the data analysis criteria.

The mean closest point of approach (CPA) of cetaceans from the *Geo Arctic* during full array activity was 2980 m (1.85 mi), while it was 3030 m (1.88 mi) during non-seismic periods (Table 5.8). From the *Polar Prince*, the mean CPA where RSLs were ≥160 and <120 dB (rms) were 2754 m (1.71 mi) and 2725 m (1.69 mi), respectively (Table 5.8). The only cetacean sighting in the Beaufort Sea was from the *Polar Prince* in an area where RSLs were <120 dB (rms) and the CPA to the vessel was 2725 m (1.69 mi). Since almost all cetacean sightings occurred while the airguns were active it is not possible to make a meaningful interpretation of the differences in CPA distances between periods when airguns were active and when they were not.

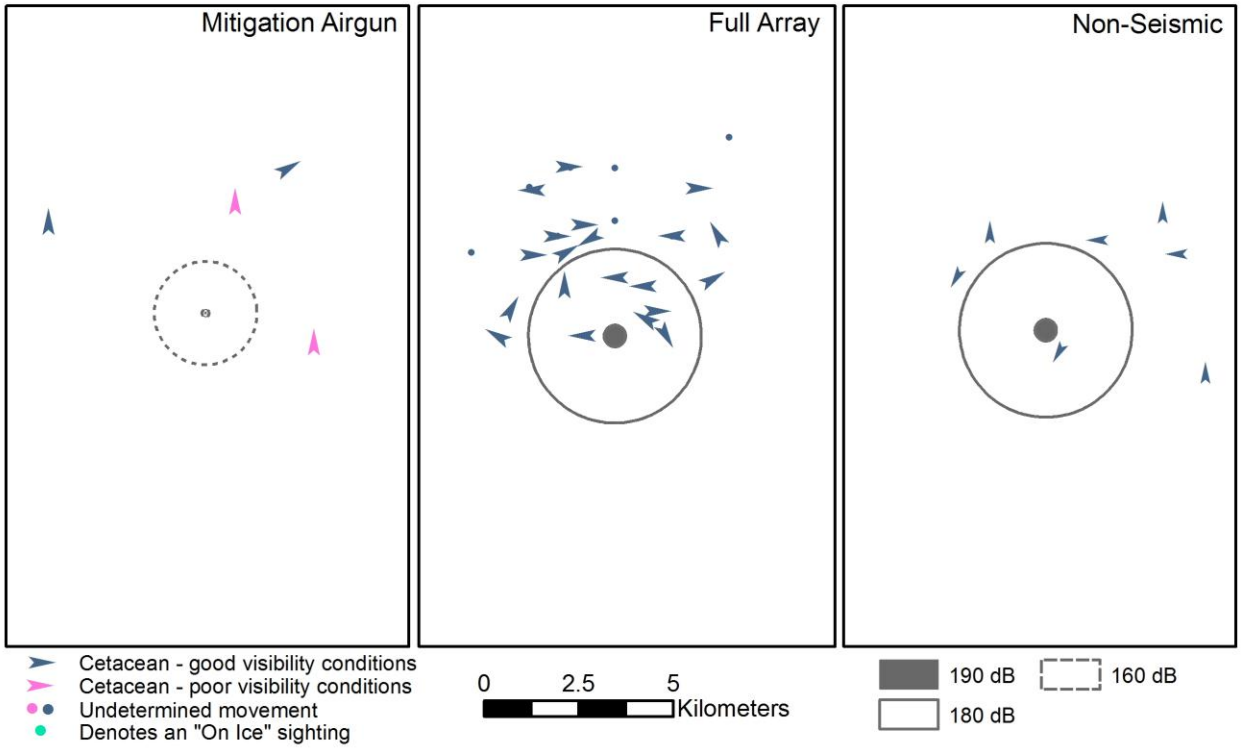

FIGURE 5.16. Initial cetacean sighting distances and distribution relative to the *Geo Arctic* and *Polar Prince* by airgun status during ION's seismic survey, 12 Oct – 16 Nov 2012. Arrows indicate direction of animal movement.

TABLE 5.8. Comparison of mean cetacean CPA distances by seismic status from the *Geo Arctic* and received sound level from the *Polar Prince* during ION's seismic survey, 12 Oct – 16 Nov 2012. The overall mean includes CPA distances from all three seismic activity or RSL bins.

Vessel and Seismic Status or Received Sound Level (dB re 1µPa rms)	**Mean CPA[a] (m)**	**s.d.**	**Range (m)**	***n***
***Geo Arctic* Full Array**	2980	975	913-4424	16
***Geo Arctic* Mitigation Gun**	4417	0	4417	1
***Geo Arctic* Non-seismic**	3030	0	3030	3
***Geo Arctic* Overall**	***3059***	***923***	***913-4424***	***20***
***Polar Prince* ≥160**	2754	1440	614-5463	14
***Polar Prince* 159-120**	–	–	–	0
***Polar Prince* <120**	2725	0	2725	2
***Polar Prince* Overall**	***2751***	***1340***	***614-5463***	***16***

[a] CPA = *Closest Point of Approach*. For the *Geo Arctic* this value is the marine mammal's closest point of approach to the airgun array. For the *Polar Prince*, this value is the marine mammal's closest point of approach to the PSO position on the vessel.

Cetacean Movement

The movement relative to the vessel of most cetaceans (79%) observed from the *Geo Arctic* and *Polar Prince* was either unknown or neutral (Table 5.9). Neutral movement means the animal(s) was swimming neither directly towards nor directly away from the vessel (i.e. parallel to vessel). When the full array was active on the *Geo Arctic*, there was one cetacean sighting observed swimming away and one cetacean sighting observed swimming towards the *Geo Arctic*. All other (*n*=14) cetacean sightings observed from the *Geo Arctic* while the full array was active showed either unknown or neutral movement relative to the vessel. When the mitigation gun was firing on the *Geo Arctic*, two cetacean sightings were observed swimming away and one cetacean sighting showed unknown movement relative to the *Geo Arctic*. During non-seismic periods, all (*n*=5) cetacean sightings from the *Geo Arctic* showed unknown movement relative to the vessel.

In areas where the RSLs were ≥160 dB (rms) from the *Polar Prince*, three cetacean sightings were observed swimming away from the vessel, while the remaining 12 cetacean sightings showed either unknown, neutral or no movement relative to the vessel. In areas where the RSLs were <120dB (rms) from the *Polar Prince*, one cetacean sighting was observed swimming towards the vessel and three cetacean sightings showed neutral movement relative to the vessel. Due to the low number of cetacean sightings during periods without seismic activity, meaningful comparisons of cetacean movements during ION's seismic survey were not possible.

Cetacean Initial Behavior

The number of cetacean sightings was insufficient to make meaningful comparisons of differences in observed behaviors across received sound level bins. Most (58%) initial cetacean behaviors recorded from the *Geo Arctic* and *Polar Prince* were blow (Table 5.10). This is typical because a blow is also a highly visible sighting cue. The other recorded initial behaviors were swim (28%), travel (7%), breaching (2%), fluking (2%) and resting (2%; Table 5.10).

Cetacean Reaction Behavior

No cetacean sightings observed during ION's seismic survey exhibited an overt (or discernible) reaction to the vessel.

TABLE 5.9. Number of cetacean sightings by movement relative to vessels by seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* during ION's seismic survey, 12 Oct – 16 Nov 2012.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)	Movement Relative to Vessel					
	Neutral	Swim Away	Swim Towards	None	Unknown	Totals
***Geo Arctic* Full Array**	7	1	1	0	7	***16***
***Geo Arctic* Mitigation Gun**	0	2	0	0	1	***3***
***Geo Arctic* Non-seismic**	0	0	0	0	5	***5***
***Geo Arctic* Total**	***7***	***3***	***1***	***0***	***13***	***24***
***Polar Prince* ≥160**	8	3	0	1	3	***15***
***Polar Prince* 159-120**	–	–	–	–	–	***0***
***Polar Prince* < 120**	3	0	1	0	0	***4***
***Polar Prince* Total**	***11***	***3***	***1***	***1***	***3***	***19***

TABLE 5.10. Comparison of cetacean behaviors by seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* during ION's seismic survey period, 12 Oct – 16 Nov 2012.

Vessel and Seismic Status or Received Sound Level (dB re 1µPa rms)	Initial Behavior						
	Blow	Breach	Fluking	Swim	Resting	Travel	Totals
***Geo Arctic* Full Array**	12	0	0	4	0	0	***16***
***Geo Arctic* Mitigation Gun**	3	0	0	0	0	0	***3***
***Geo Arctic* Non-seismic**	5	0	0	0	0	0	***5***
***Geo Arctic* Total**	***20***	***0***	***0***	***4***	***0***	***0***	***24***
Polar Prince ≥160	3	1	1	7	1	2	***15***
***Polar Prince* 159-120**	–	–	–	–	–	–	***0***
***Polar Prince* < 120**	2	0	0	1	0	1	***4***
***Polar Prince* Total**	***5***	***1***	***1***	***8***	***1***	***3***	***19***

Seals

Seal Initial Sighting Distance and Distribution

The initial sighting distance of seals in water was calculated using all sightings that occurred during the 2012 ION survey (Fig. 5.16). The mean initial sighting distance for seals in water observed from the *Geo Arctic* was slightly farther than the mean initial sighting distance for seals in water from the *Polar Prince* during non-seismic periods (662 m and 415 m; 724 yd and 454 yd, respectively). The average initial sighting distance of seals in water was 644 m (704 yd) while the average initial sighting distance of seal hauled out on ice was 2491 m (1.5 mi).

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, section *Seal Sighting Rates*, and Appendix F). In addition, seal sightings in water were only used to calculate the mean closest point of approach.

The mean CPA of seals observed in the water during non-seismic periods from both vessels combined in the Beaufort Sea was 615 m (0.38 mi), which was slightly lower than the mean CPA distance during non-seismic periods in the Chukchi Sea from both vessels combined (744 m, 0.46 mi). Since almost all seal sightings occurred while the airguns were off it is not possible to make a meaningful interpretation of the differences in CPA distances between periods when airguns were active and when they were not. In the Beaufort Sea, seals in water were observed as close as 67 m (73 yd) and as far as 3035 m (1.89 mi) from the *Geo Arctic* and from 15 m (16 yd) to 967 m (0.60 mi) from the *Polar Prince* (Table 5.11). In the Chukchi Sea, seals in water were observed as close as 25 m (27 yd) and as far as 2984 m (1.85 mi) from the *Geo Arctic* and from 50 m (55 yd) to 2725 m (1.69 mi) from the *Polar Prince* (Table 5.12).

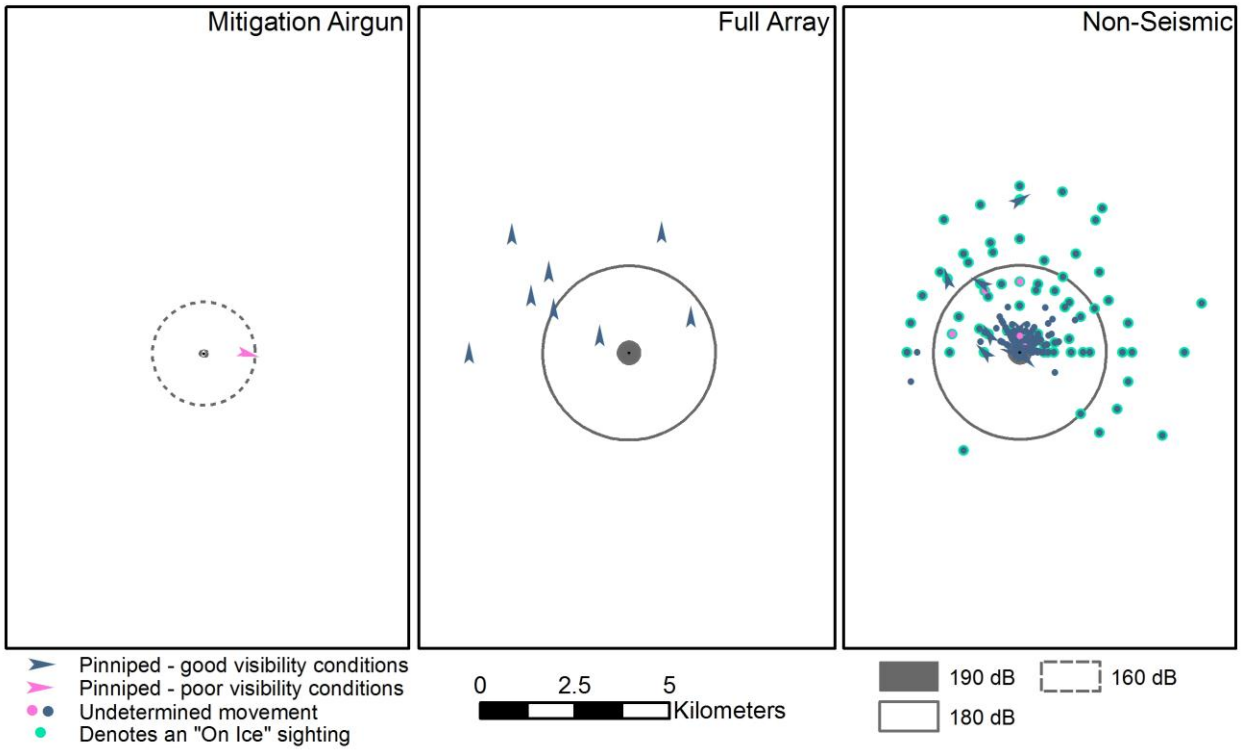

FIGURE 5.17. Initial seal sighting distances and distribution relative to the *Geo Arctic* and *Polar Prince* by airgun status during ION's seismic survey, 12 Oct – 16 Nov 2012. Arrows indicate direction of animal movement.

TABLE 5.11. Comparison of seal CPA distances from PSO sightings in the Beaufort Sea by seismic status from the *Geo Arctic* and received sound levels from the *Polar Prince* during ION's seismic survey, 12 Oct – 16 Nov 2012. The overall mean includes CPA distances for all three seismic activity or RSL bins in the calculation.

Vessel and Seismic Status or Received Sound Level (dB re 1µPa rms)	Mean CPA[a] (m)	s.d.	Range (m)	*n*
***Geo Arctic* Full Array**	–	–	–	0
***Geo Arctic* Mitigation Gun**	–	–	–	0
***Geo Arctic* Non-seismic**	696	554	67-3035	57
***Geo Arctic* Overall**	***696***	***554***	***67-3035***	***57***
***Polar Prince* ≥160**	–	–	–	0
***Polar Prince* 159-120**	15	0	15	1
***Polar Prince* <120**	431	193	100-967	18
***Polar Prince* Overall**	***409***	***211***	***15-967***	***19***

[a] CPA = *Closest Point of Approach*. For the *Geo Arctic* this value is the marine mammal's closest point of approach to the airgun array. For the *Polar Prince*, this value is the marine mammal's closest point of approach to the PSO position on the vessel.

Seal Movement

Most of the seal movements recorded in both the Beaufort and Chukchi seas were either unknown or no movement relative to the vessels (89% and 91%, respectively; Table 5.13). The only other remaining seal movements observed from the *Geo Arctic* were neutral (*n*=1) and swimming towards (*n*=2) the vessel, whereas seals observed from the *Polar Prince* were most often either neutral or swimming away from the vessel (90%). There was no discernible difference between seal movement relative to the *Geo Arctic's* seismic status or the *Polar Prince's* RSLs (Table 5.13).

Seal Initial Behavior

Most of the initial seal behaviors (81%) observed from the *Geo Arctic* and *Polar Prince* were of seals looking or resting (Table 5.14). However, in the Chukchi Sea there were a significantly higher number of seal sightings resting than in the Beaufort Sea (χ^2 = 115.23, *df* = 1 *p* = <0.0001, power [1-β] = 0.26). This difference is likely due to the majority of the survey operations occurring later in the season in the Chukchi Sea when there were higher concentrations of ice. Most of the remaining identifiable initial behaviors of seals sighted from both vessels were swimming (32%), surface-active (21%) and sink dive or diving (21%; Table 5.14).

Seal Reaction Behavior

Seals observed from the *Geo Arctic* and *Polar Prince* were most often recorded as having no reaction (89%), while the second-most observed seal reaction to both vessels was looking at the vessel (7% of the total; Table 5.15). Most of the remaining sightings (3% of the total) were recorded as having a reaction of splash in response to the vessels. The only other observed seal reaction from the *Geo Arctic* and *Polar Prince* was entering the water (*n*=3).

TABLE 5.12. Comparison of seal CPA distances from PSO sightings in the Chukchi Sea by seismic status from the *Geo Arctic* and received sound levels from the *Polar Prince* during ION's seismic survey, 12 Oct – 16 Nov 2012. The overall mean includes CPA distances for all three seismic activity or RSL bins in the calculation.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)	Mean CPA[a] (m)	s.d.	Range (m)	*n*
***Geo Arctic* Full Array**	886	0	886	1
***Geo Arctic* Mitigation Gun**	–	–	–	0
***Geo Arctic* Non-seismic**	766	827	25-2984	16
***Geo Arctic* Overall**	***773***	***801***	***25-2984***	***17***
***Polar Prince* ≥160**	–	–	–	0
***Polar Prince* 159-120**	–	–	–	0
***Polar Prince* <120**	712	716	50-2725	16
***Polar Prince* Overall**	***712***	***716***	***50-2725***	***16***

[a] CPA = *Closest Point of Approach*. For the *Geo Arctic* this value is the marine mammal's closest point of approach to the airgun array. For the *Polar Prince*, this value is the marine mammal's closest point of approach to the PSO position on the vessel.

TABLE 5.13. Comparison of seal movement relative to vessels by seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* during ION's seismic survey, 12 Oct – 16 Nov 2012.

Vessel and Seismic Status or Received Sound Level (dB re 1µPa rms)	Movement Relative to Vessel					
	Neutral	Swim Away	Swim Towards	None	Unknown	Totals
***Geo Arctic* Full Array**	0	0	0	4	1	***5***
***Geo Arctic* Mitigation Gun**	–	–	–	–	–	***0***
***Geo Arctic* Non-seismic**	1	0	2	79	75	***157***
***Geo Arctic* Total**	***1***	***0***	***2***	***83***	***76***	***162***
***Polar Prince* ≥160**	0	0	0	3	1	***4***
***Polar Prince* 159-120**	0	1	0	3	0	***4***
***Polar Prince* < 120**	8	9	2	38	9	***66***
***Polar Prince* Total**	***8***	***10***	***2***	***44***	***10***	***74***

TABLE 5.14. Initial recorded behavior of seals by seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* during ION's seismic survey, 12 Oct – 16 Nov 2012.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)	Initial Behavior										
	Dive	Logging	Looking	Milling	Resting	Surface Active	Sink Dive	Swim	Other	Unknown	Totals
***Geo Arctic* Full Array**	0	0	0	0	4	0	0	1	0	0	***5***
***Geo Arctic* Mitigation Gun**	–	–	–	–	–	–	–	–	–	–	***0***
***Geo Arctic* Non-seismic**	2	0	63	0	68	0	0	2	4	18	***157***
***Geo Arctic* Total**	***2***	***0***	***63***	***0***	***72***	***0***	***0***	***3***	***4***	***18***	***162***
***Polar Prince* ≥160**	0	0	0	0	3	0	1	0	0	0	***4***
***Polar Prince* 159-120**	0	0	0	0	3	0	0	1	0	0	***4***
***Polar Prince* <120**	3	2	17	1	32	6	0	5	0	0	***66***
***Polar Prince* Total**	***3***	***2***	***17***	***1***	***38***	***6***	***1***	***6***	***0***	***0***	***74***

TABLE 5.15. Recorded reactions of seals by seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* during ION's seismic survey, 12 Oct – 16 Nov 2012.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)	Reaction Behavior				
	Splash	Look at Vessel	Rush	None	Totals
***Geo Arctic* Full Array**	0	0	0	5	***5***
***Geo Arctic* Mitigation Gun**	–	–	–	–	***0***
***Geo Arctic* Non-seismic**	6	10	2	139	***157***
***Geo Arctic* Total**	***6***	***10***	***2***	***144***	***162***
***Polar Prince* ≥160**	0	1	0	3	***4***
***Polar Prince* 159-120**	0	0	0	4	***4***
***Polar Prince* <120**	0	5	1	60	***66***
***Polar Prince* Total**	***0***	***6***	***1***	***67***	***74***

Polar Bears

Polar Bear Initial Sighting Distance and Distribution

All polar bears were observed on ice during survey activities in the Chukchi Sea on Nov 14th and 15th. The average initial detection distance was 2784 m (1.7 mi) (Fig 5.18).

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 detect polar bears (See Chapter 4, section *Polar Bear Sighting Rates*, and Appendix F). All polar bear sightings during ION's 2012 seismic survey were observed in the Chukchi Sea, and thus comparisons of CPA values by sea will not be made.

The mean CPA of polar bears observed from the *Geo Arctic* during full airgun array activity was 2760 m (1.72 mi; Table 5.16) and the mean CPA distance from the *Polar Prince* in areas where RSL were ≥160 dB (rms) was similar (3732 m, 2.32 mi). The CPA for the single polar bear sighting in areas where RSLs were <120 dB (rms) from the *Polar Prince* was 967 m (0.60 mi). Polar bears were observed as close as 354 m (387 yd) and as far as 4398 m (2.73 mi) from the *Geo Arctic* and from 967 m (0.60 mi) to 5463 m (3.40 mi) from the *Polar Prince* (Table 5.16).

Polar Bear Movement

Movements neutral relative to the vessels were the most commonly recorded movements from both the *Geo Arctic* and *Polar Prince* during ION's seismic survey (Table 5.17). The only other movement recorded from the *Geo Arctic* was unknown. From the *Polar Prince*, the only other observed polar bear movement was walking away (33%).

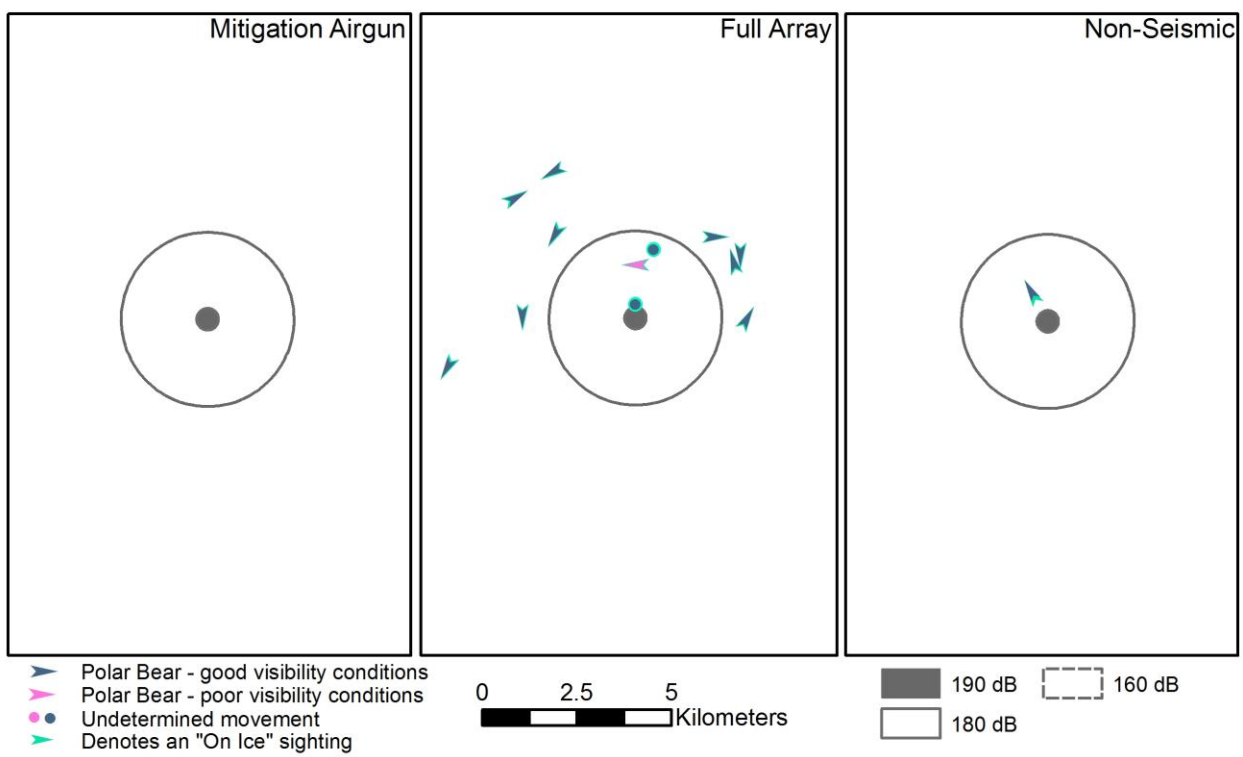

FIGURE 5.18. Initial polar bear sighting distances and distribution relative to the *Geo Arctic* and *Polar Prince* by airgun status during ION's seismic survey, 12 Oct – 16 Nov 2012. Arrows indicate direction of animal movement.

TABLE 5.16. Comparison of Polar Bear CPA distances by seismic status from the *Geo Arctic* and received sound levels from the *Polar Prince* during ION's seismic survey, 12 Oct – 16 Nov 2012. The overall mean includes CPA distances from all three seismic activity or RSL bins.

Vessel and Seismic Status or Received Sound Level (dB re 1µPa rms)	Mean CPA[a] (m)	s.d.	Range (m)	*n*
***Geo Arctic* Full Array**	2760	1472	354-4398	5
***Geo Arctic* Mitigation Gun**	–	–	–	0
***Geo Arctic* Non-seismic**	–	–	–	0
***Geo Arctic* Overall**	***2760***	***1472***	***354-4398***	***5***
***Polar Prince* ≥160**	3732	1304	2725-5463	4
***Polar Prince* 159-120**	–	–	–	0
***Polar Prince* <120**	967	NA	967	1
***Polar Prince* Overall**	***3179***	***1675***	***967-5463***	***5***

[a] CPA = *Closest Point of Approach*. For the *Geo Arctic* this value is the marine mammal's closest point of approach to the airgun array. For the *Polar Prince*, this value is the marine mammal's closest point of approach to the PSO position on the vessel.

TABLE 5.17. Comparison of polar bear movement relative to vessels by seismic activity status from the Geo Arctic or received sound level from the Polar Prince during ION's seismic survey, 12 Oct – 16 Nov 2012.

Vessel and Seismic Status or Received Sound Level (dB re 1µPa rms)	Movement Relative to Vessel				
	Neutral	Walk Away	None	Unknown	Totals
***Geo Arctic* Full Array**	5	0	0	1	***6***
***Geo Arctic* Mitigation Gun**	–	–	–	–	***0***
***Geo Arctic* Non-seismic**	–	–	–	–	***0***
***Geo Arctic* Total**	***5***	***0***	***0***	***1***	***6***
***Polar Prince* ≥160**	4	1	0	0	***5***
***Polar Prince* 159-120**	–	–	–	–	***0***
***Polar Prince* <120**	0	1	0	0	***1***
***Polar Prince* Total**	***4***	***2***	***0***	***0***	***6***

Polar Bear Initial Behavior

The initial behavior of nearly all polar bears (*n*=11) observed from the *Geo Arctic* and *Polar Prince* were of animals walking/traveling on ice (Table 5.18). The only other initial behavior recorded was resting.

Polar Bear Reaction Behavior

Polar bears observed from the *Geo Arctic* and *Polar Prince* were most often recorded as having no reaction (~83%) to the vessels. The only polar bear sightings that exhibited a reaction to the vessel were observed looking at the vessel and increasing speed in response to the *Geo Arctic* (Table 5.19).

TABLE 5.18. Comparison of polar bear initial behaviors by seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* during ION's seismic survey, 12 Oct – 16 Nov 2012.

Vessel and Seismic Status or Received Sound Level (dB re 1µPa rms)	Initial Behavior			
	Resting	Traveling	Walking	Totals
***Geo Arctic* Full Array**	1	0	5	***6***
***Geo Arctic* Mitigation Gun**	–	–	–	***0***
***Geo Arctic* Non-seismic**	–	–	–	***0***
***Geo Arctic* Total**	***1***	***0***	***5***	***6***
***Polar Prince* ≥160**	0	2	3	***5***
***Polar Prince* 159-120**	–	–	–	***0***
***Polar Prince* <120**	0	0	1	***1***
***Polar Prince* Total**	***0***	***2***	***4***	***6***

TABLE 5.19. Comparison of reaction of polar bears by seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* during ION's seismic survey, 12 Oct – 16 Nov 2012.

Vessel and Seismic Status or Received Sound Level (dB re 1µPa rms)	Reaction Behavior			
	Increase Speed	Look at Vessel	None	Totals
***Geo Arctic* Full Array**	1	1	4	***6***
***Geo Arctic* Mitigation Gun**	–	–	–	***0***
***Geo Arctic* Non-seismic**	–	–	–	***0***
***Geo Arctic* Total**	***1***	***1***	***4***	***6***
***Polar Prince* ≥160**	0	0	5	***5***
***Polar Prince* 159-120**	–	–	–	***0***
***Polar Prince* <120**	0	0	1	***1***
***Polar Prince* Total**	***0***	***0***	***6***	***6***

Pacific Walruses

Pacific Walrus Initial Sighting Distance and Distribution

All Pacific walruses were observed during transit through the southern Chukchi Sea on Nov 16th. Only a few sightings of walruses on sea ice were made (*n*=5) and the mean initial detection distance of those sightings was 1469 m (0.9 mi). The mean initial detection distance of walruses in water was only slightly less 1335 m (0.8 mi)(Fig. 5.19).

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, section *Pacific Walrus Sighting Rates*, and Appendix F). All Pacific walrus sightings during ION's 2012 seismic survey were observed in the Chukchi Sea while the *Geo Arctic's* airguns were off. Therefore, mean CPA values will not be compared by seismic status from the *Geo Arctic* or RSL bins from the *Polar Prince*.

The overall mean CPA of Pacific walruses observed in the water from the *Geo Arctic* was 1392 m (0.86 mi; Table 5.20), which was slightly greater than the overall mean CPA distance from the *Polar Prince* (1101 m, 0.68 mi). Pacific walruses observed on ice from the *Polar Prince* were farther away than those observed in the water. Pacific walruses were observed as close as 246 m (269 yd) and as far as 2984 m (1.85 mi) from the *Geo Arctic* and from 250 m (273 yd) to 2725 m (1.69 mi) from the *Polar Prince* (Table 5.20).

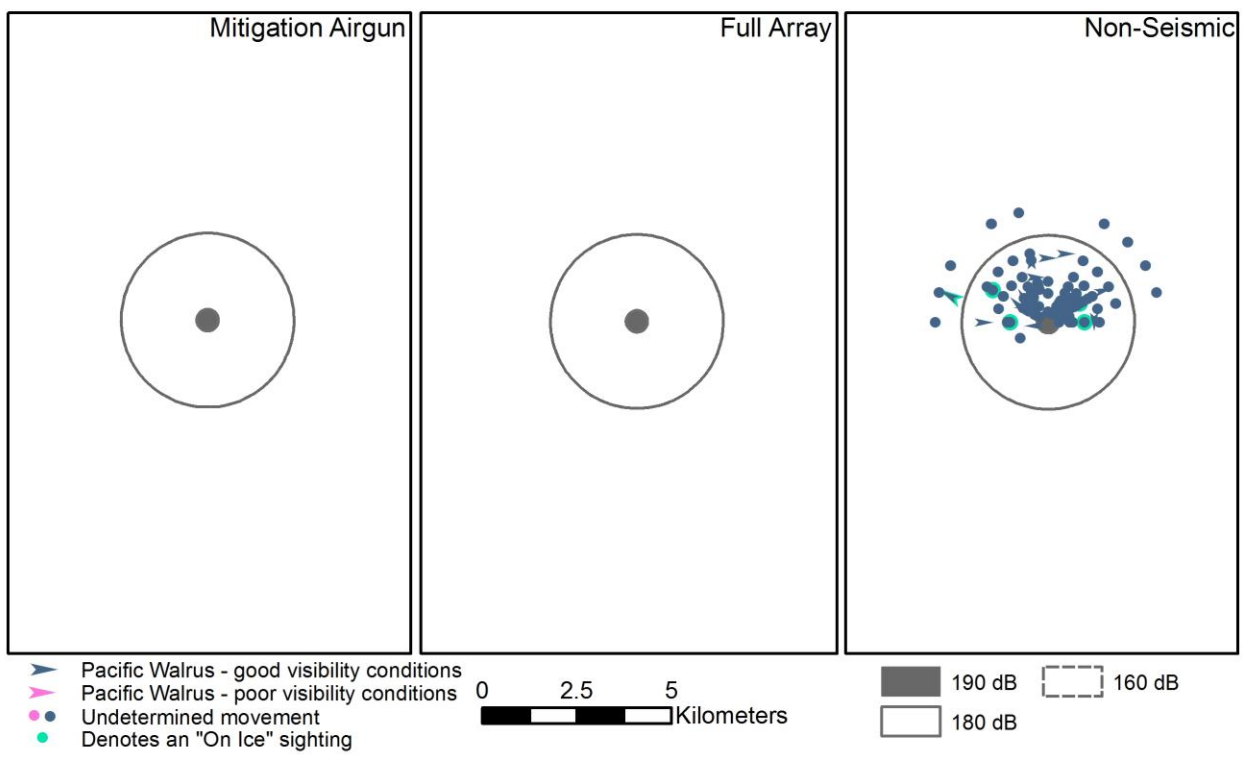

FIGURE 5.19. Initial Pacific walrus sighting distances and distribution relative to the *Geo Arctic* and *Polar Prince* by airgun status during ION's seismic survey, 12 Oct – 16 Nov 2012. Arrows indicate direction of animal movement.

Pacific Walrus Movement

The majority (89%) of the Pacific walruses showed either unknown or no movement relative to the vessels (Table 5.21). The only other observed Pacific walrus movement swim away (8%), neutral movement (3%), and swam towards (1%) the vessels.

Pacific Walrus Initial Behavior

Most of the initial walrus behaviors (87%) observed from the *Geo Arctic* were of animals looking at the boat (Table 5.22). The only other initial behaviors recorded from the *Geo Arctic* were blowing (13%) and swimming (<1%). From the *Polar Prince*, there were several initial behaviors recorded for Pacific walruses in water including blowing (11%), looking (17%), traveling (11%), swimming (28%), surface active (28%), and surface active travel (6%). The only initial behaviors recorded from the *Polar Prince* for Pacific walruses on ice were resting (80%) and moving into the water (20%).

Pacific Walrus Reaction Behavior

Pacific walruses observed from the *Geo Arctic* and *Polar Prince* were most often recorded as having no reaction (84%). The two most common reactions to the vessel were splashing (11% of sightings) and looking at the vessel (4% of sightings; Table 5.23). All of the Pacific walruses observed on ice (*n*=5) showed no reaction to the vessel.

TABLE 5.20. Comparison of Pacific walrus CPA distances from the *Geo Arctic* and *Polar Prince* during ION's seismic survey, 12 Oct – 16 Nov 2012.

Vessel and Species	Mean CPA[a] (m)	s.d.	Range (m)	*n*
Geo Arctic				
Pacific walruses in the water	1392	835	246-2984	137
Pacific walruses on ice	–	–	–	0
***Geo Arctic* Overall**	***1392***	***835***	***246-2984***	***137***
Polar Prince				
Pacific walruses in the water	999	550	250-1687	18
Pacific walruses on ice	1469	766	967-2725	5
***Polar Prince* Overall**	***1101***	***616***	***250-2725***	***23***

[a] CPA = *Closest Point of Approach*. For the *Geo Arctic* and the *Polar Prince* this value is the marine mammal's closest point of approach to the PSO position on the vessel.

TABLE 5.21. Comparison of Pacific walrus movements relative to vessels from the *Geo Arctic* and *Polar Prince* during ION's seismic survey, 12 Oct – 16 Nov 2012.

	Movement Relative to Vessel					
Vessel and Species	**Neutral**	**Swam Away**	**Swim Towards**	**None**	**Unknown**	**Totals**
Geo Arctic						
Pacific walruses in the water	1	7	0	0	148	***156***
Pacific walruses on ice	–	–	–	–	–	***0***
***Geo Arctic* Total**	***1***	***7***	***0***	***0***	***148***	***156***
Polar Prince						
Pacific walruses in the water	4	6	1	5	2	***18***
Pacific walruses on ice	0	1	0	4	0	***5***
***Polar Prince* Total**	***4***	***7***	***1***	***9***	***2***	***23***

TABLE 5.22. Comparison of Pacific walrus initial behavior from the *Geo Arctic* and the *Polar Prince* during ION's seismic survey, 12 Oct – 16 Nov 2012.

	Initial Behavior							
Vessel and Species	**Blow**	**Looking**	**Resting**	**Surface Active**	**Surface Active Travel**	**Swim**	**Traveling**	**Totals**
Geo Arctic								
Pacific walruses in the water	20	135	0	0	0	1	0	***156***
Pacific walruses on ice	–	–	–	–	–	–	–	***0***
***Geo Arctic* Total**	***20***	***135***	***0***	***0***	***0***	***1***	***0***	***156***
Polar Prince								
Pacific walruses in the water	2	3	0	5	1	5	2	***18***
Pacific walruses on ice	0	0	4	1	0	0	0	***5***
***Polar Prince* Total**	***2***	***3***	***4***	***6***	***1***	***5***	***2***	***23***

TABLE 5.23. Comparison of Pacific walrus reaction behavior from the *Geo Arctic* and *Polar Prince* during ION's seismic survey, 12 Oct – 16 Nov 2012.

	Reaction Behavior					
Vessel and Species	**Splash**	**Look at Vessel**	**Increase Speed**	**Change Direction**	**None**	**Totals**
Geo Arctic						
Pacific walruses in the water	19	7	1	0	129	***156***
Pacific walruses on ice	–	–	–	–	–	***0***
***Geo Arctic* Total**	***19***	***7***	***1***	***0***	***129***	***156***
Polar Prince						
Pacific walruses in the water	0	1	0	1	16	***18***
Pacific walruses on ice	0	0	0	0	5	***5***
***Polar Prince* Total**	***0***	***1***	***0***	***1***	***21***	***23***

Mitigation Measures Implemented

ION's seismic survey incorporated both design features and operational procedures for minimizing potential impacts on marine mammals and on subsistence hunts. The location and timing of operations were planned to avoid the highest bowhead whale concentrations and subsistence hunting activities from coastal villages. During survey operations, mitigation procedures such as seismic array ramp ups, delayed ramp ups, power downs, and shut downs were in place and/or implemented as necessary. These measures are standard procedures during seismic surveys and are described in detail in Appendix C. Mitigation also included those measures specifically identified in the IHA and LOA as described in Chapter 4 and Appendix C. PSOs aboard the two ION vessels also routinely contacted the whaling communication centers (while they were operational) in order to ensure that the vessels did not interfere with subsistence activities.

Location and Timing of Survey Operations

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 plan for ION's seismic operations. The operational plan was designed to avoid the majority of the fall bowhead whale migration by not beginning operations until Oct 1st and starting those operations on the eastern end of the Alaskan Beaufort Sea. In order to avoid impacts to bowhead whale subsistence hunting in this region, ION also agreed not to begin seismic survey activities in the eastern half of the survey area until after the subsistence hunts at Kaktovik and Nuiqsut were completed, even if that was after Oct 1st. The start of the ION survey was delayed by a couple weeks due to vessel availability issues, so by the time the vessels were transiting towards the survey area, both Kaktovik and Nuiqsut had successfully completed their subsistence hunts; therefore, additional delays of the survey to mitigate potential impacts to the hunt were not necessary.

In some years, bowhead whale subsistence hunting near Barrow can occur through the end of Oct or into early Nov. To mitigate potential impacts to that subsistence hunt and to avoid higher concentrations of migrating bowhead whales that may be present near Pt. Barrow, ION did not plan to operate in the eastern half of the Alaskan Beaufort Sea until after the Barrow subsistence hunt was completed or late Oct, whichever was later. ION conducted SSV measurements in the eastern Alaskan Beaufort Sea from Oct 20th to 23rd and began seismic data collection on Oct 24th. The AEWC informed ION that the bowhead subsistence hunt in Barrow was completed on Oct 24th. Since the Barrow subsistence hunt was over and it was late Oct, ION continued collecting seismic data along and east-west survey line that took the vessels into the eastern half of the Alaskan Beaufort Sea on Oct 27th.

Safety Radii

Prior to having results from the sound source verification measurements, PSOs on the ION vessels used the modeled safety radii presented in JASCO's acoustic modeling report (Zykov et al. 2011) and outlined in the IHA issued by NMFS (NMFS 2012) for mitigation purposes. Once the results from ION's site specific sound source verification (SSV) measurements were reported on 29 Oct, the distances shown in Table 4.1 were implemented for mitigation purposes throughout the duration of the survey (MacDonnell and Wladichuk 2012). However, the SSV radii were revised after the field season, and these refined estimates were used during processing of the monitoring data presented in this chapter and to estimate the numbers of marine mammals potentially exposed to various sound levels.

The SSV field report ≥190 dB and ≥180 dB safety radii for the full array in intermediate (100-1000 m; 0.06-0.62 mi) and deep water areas (>1000 m; 0.62 mi) all increased compared to the modeled safety radii (Table 4.1). However, the biggest difference between the modeled and SSV field report ≥190 dB

and ≥180 dB safety radii for the full array occurred in shallow water areas (<100 m, 328 ft). The SSV field report ≥190 dB safety radius in shallow water areas was nearly three times less than the modeled ≥190 dB safety radius, and the ≥180 dB SSV field report safety radius was nearly four times less than the modeled ≥180 dB safety radius in shallow water areas (Table 4.1).

After ION's 2012 seismic survey concluded, more extensive analysis of the field measurements were completed for preparation of this report as described in Chapter 3. Those analyses resulted in some refinements of the various radii. The final analysis was not completed until after the field season; therefore the results were not available for use by the PSOs in the field. However, the revised estimates were used during processing of the monitoring data presented in this chapter and to estimate the numbers of marine mammals exposed to various sound levels. The biggest difference between the SSV field report and "final" ≥190 dB and ≥180 dB safety radii for the full array also occurred in shallow water areas. However, this time the ≥190 dB and ≥180 dB safety radii for the full array increased. The "final" ≥190 dB safety radius in shallow water areas was nearly 1.5 times greater than the SSV field report ≥190 dB safety radius, and the ≥180 dB "final" safety radius was nearly three times greater than the SSV field report ≥180 dB safety radius in shallow water areas (Table 4.1). All other "final" safety radii for the full array decreased slightly, except for the ≥180 dB safety radius in deep water areas which increased slightly (Table 4.1).

Mitigation Actions

No power downs or shut downs were requested during ION's seismic survey as a result of marine mammal sightings within or approaching the applicable safety radius. However, when the sound source measurement data were analyzed further during preparation of this report (see Chapter 3), the ≥180 dB safety radius for cetaceans in shallow water areas (<100 m; 328 ft water depth) was increased from 832 m (0.52 mi) to 2290 m (1.42 mi) around the full airgun array. As a result of this increase, seven sightings of 10 bowhead whales on Nov. 14th, for which PSOs did not call a power down of the full airgun array based on the 832 m (0.52 mi) ≥180 dB safety zone in effect at the time, occurred within the revised ≥180 dB (rms) safety radius (2290 m; 1.42 mi). These seven sightings would have triggered power-downs had the revised radii been in effect at that time (Table 5.24). There were no other such occurrences during the project for bowhead whales or any other species. These seven bowhead whale sightings are described in detail below.

The layout of ION's airgun array created stronger sound propagation in narrow windows broadside to the vessel (i.e. to the sides) compared to the "endfire" (forward or stern) directions. This means that whales observed forward or behind the vessel may have experienced seismic sounds that were not as strong as those estimated by the maximum broadside distances used for the ≥180 dB radius distance. Table 5.25 shows the location of each sighting relative to the vessel as well as the estimated received sound level at that distance using both sound propagation equations (endfire and broadside) generated from the sound source measurements. The received levels estimated by the "endfire" equation are likely most applicable to animals that were observed ahead of the vessel and traveling away from it, while the levels estimated from the broadside equation are likely most applicable to those sightings observed in the broadside direction. The received levels estimated by the broadside equation may also apply to animals that were initially observed ahead of the vessel but did not swim away from the vessel and therefore likely occurred broadside to the vessel at a similar distance as recorded by the observers. It should also be noted that movements of the animals after these sightings occurred are not known and some animals may have avoided the vessel while others may have occurred at distances closer than those recorded by the observers.

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—referred to as M-weighting functions—for five functional hearing groups of marine mammals. The M-weighted cumulative SEL metric considers the total SEL received from multiple pulses and also accounts for frequency-dependent hearing sensitivity of different species groups. The original auditory injury cumulative SEL thresholds proposed by Southall et al. (2007) were 198 dB re 1 μPa^2-s (M-weighted) for cetaceans and 186 dB re 1 μPa^2-s (M-weighted) for pinnipeds under water. In order to estimate the cumulative SEL (CSEL) exposure of these bowhead whales in comparison to the recommended threshold, the sound energy received at the recorders during the shallow water SSV measurements were analyzed and the CSEL levels at those distances were calculated (Chapter 3).

For the two SSV recorders closest to the survey line (at 400 m [437 yd] and 1840 m [1.1 mi] off the survey line), the highest SEL contributions occurred from airgun shots at the closest point of approach and the majority of SEL was generated by airgun shots within a few kilometers of the recorders. Consequently, the CSEL received by an animal passing within approximately 2 km of the survey line can be estimated by determining its closest point of approach to the operating airgun array. This assumes that the animal travels more slowly than the survey vessel and that it does not swim parallel to the operating array for significant distance. The estimate can then be obtained from the interpolated CSEL value from the plots of CSEL versus fixed recorder range off the survey line (Table 3.8 and Fig. 3.20 in Chapter 3). These calculations indicate that for low frequency cetaceans like bowhead whales, an individual would have had to remain stationary 114 m (125 yd; Table 3.9 in Chapter 3) off the survey trackline as the airgun array passed by in order to accumulated sound energy above the CSEL injury threshold proposed by Southall et al. (2007).

TABLE 5.24. Bowhead whale sightings during seismic survey activities on Nov 14, 2012 where received sound levels at the animal(s) may have been ≥180 dB (rms).

Sighting ID	Species	No. of Individuals	Date	Time	Initial Behavior	Reaction Behavior	Initial Sightings Distance[a] (m)	CPA[b] to Airguns (m)
POL201267	Bowhead	1	14-Nov	15:41	Swim	None	967	1532
GEO2012105	Bowhead	1	14-Nov	15:45	Swim	None	886	913
POL201268	Bowhead	1	14-Nov	15:47	Swim	None	614	870
GEO2012108	Bowhead	1	14-Nov	15:55	Swim	None	1359	1360
POL201272	Bowhead	3	14-Nov	16:01	Swim	None	1687	1313
POL201276*	Bowhead	1	14-Nov	16:16	Swim	None	967	1362
GEO2012115	Bowhead	2	14-Nov	16:43	Blow	None	1861	1899

[a]Initial sightings distance to the PSO position on the vessel.
[b]CPA = Closest Point of Approach to the airgun array.
*Sighting was observed from the *Geo Arctic* and the *Polar Prince.*

TABLE 5.25. Bowhead whale sightings during seismic survey activities on Nov 14, 2012 where received sound levels at the animal(s) may have been ≥180 dB (rms). Received level estimates in bold indicate the sound levels most like to have been experienced by the animals at the time of the sighting.

Sighting ID	CPA Distance (m)	Clockface Position of Sighting	Clockface Heading of Whale(s)	Direction of Travel	Estimated Received Sound Level - dB (rms)			
					Endfire 90%	Broadside 90%	Endfire 50%	Broadside 50%
POL201267	1532	12:00	9:00	perpendicular	**177.9**	181.8	**176.3**	181.2
GEO2012105	913	2:00	10:00	across bow and away	**181.7**	183.8	**180.1**	183.2
POL201268	870	9:00	9:00	perpendicular	182.1	**184.0**	180.5	**183.4**
GEO2012108	1360	3:00	5:00	parallel and away	178.8	**182.2**	177.2	**181.6**
POL201272	1313	2:00	3:00	perpendicular	179.0	182.4	177.4	181.8
POL201276	1362	1:00	9:00	across bow / perpendicular	**178.8**	182.2	**177.2**	181.6
GEO2012115	1899	10:30	12:00	parallel	**176.3**	180.8	**174.7**	180.2

POL201267

This sighting was of a single bowhead whale observed from the *Polar Prince* while the *Geo Arctic's* full array was active. The *Polar Prince* PSOs alerted the PSOs aboard the *Geo Arctic* of the presence of the whale and continued to observe the whale at a distance of 967 m (0.60 mi) ahead of the vessel as it travelled away in a direction perpendicular to the *Polar Prince's* and the *Geo Arctic's* trackline. This bowhead whale was estimated to have a CPA of 1532 m (0.95 mi) from the airgun array. The bowhead whale exhibited no overt reaction to the vessel. Because this animal was first sighted directly ahead of the airgun array and moved away from it in a perpendicular fashion, the sound levels estimated by the endfire equations (Table 5.21) are the most applicable at the time of the sighting. The 50th percentile and 90th percentile endfire equations estimate the received sound level of a seismic pulse at that distance and direction to be 176.3 to 177.9 dB (rms) respectively.

GEO2012105

This sighting was of a single bowhead whale observed from the *Geo Arctic* while the full array was active. The bowhead whale was initially observed at the 2 o'clock position from the *Geo Arctic* at a distance of 886 m (0.55 mi) from the PSOs. The whale was swimming in a direction away from the vessel so the CPA to the observer was the same as the initial sighting distance. The CPA to the active airgun array was 913 m (0.57 mi). The bowhead whale exhibited no overt reaction to the vessel. At the 2 o'clock position relative to the airgun array, this animal was not likely in the stronger broadside lobe of the airgun array, although it may have been at some point prior to the time it was detected. The median received level using the endfire equation at that distance would have been 180.1 dB (rms) while the 90th percentile estimate of received level would have been 181.7 dB (rms) (Table 5.21). The median received level in the broadside direction at that distance would have been 183.2 dB (rms).

POL201268

This sighting was also of a single bowhead whale observed from the *Polar Prince* while the *Geo Arctic's* full array was active. The bowhead whale was initially observed off the port beam (9 o'clock position) of the *Polar Prince* at a distance of 614 m (0.38) from the PSOs. The *Polar Prince* PSOs alerted the PSOs aboard the *Geo Arctic* of the presence bowhead whale, and continued to observe the

whale to make sure that it did not enter the ≥180 dB (rms) safety radius that was in effect at the time (832 m; 0.52 mi). The bowhead whale was swimming away in a direction perpendicular to the trackline of the vessels. This bowhead whale was estimated to have a CPA of 870 m (0.54 mi) from the airgun array. The bowhead whale exhibited no overt reaction to the vessel. This animal was likely in the stronger broadside lobe of the array when it was sighted. Based on the broadside SSV measurements, the median received level at that location would have been 183.4 dB (rms) and the 90th percentile received level would have been 184.0 dB (rms).

GEO2012108

This sighting was of a single bowhead whale observed from the *Geo Arctic* while the full array was active. The bowhead whale was initially observed off the starboard beam of the *Geo Arctic* (3 o'clock position) at a distance of 1359 m (0.84 mi) from the PSOs. The whale was swimming towards clock face five in a direction almost opposite to the vessels trackline. The CPA to the active airgun array was 1360 m (0.85 mi). The bowhead whale exhibited no overt reaction to the vessel. In the broadside position the median received level at that location would have been 181.6 dB (rms) and the 90th percentile received level would have been 182.2 dB (rms).

POL201272

This sighting was of a group of three bowhead whales observed from the *Polar Prince* while the *Geo Arctic's* full array was active. The bowhead whales were initially observed ahead and off of the starboard side of the *Polar Prince* at a distance of 1687 m (1.05 mi) from the PSOs. The *Polar Prince* PSOs alerted the PSOs aboard the *Geo Arctic* of the presence of the whale, and continued to observe the whales as they travelled away in a direction perpendicular to the trackline. These bowhead whales were estimated to have a CPA of 1313 m (0.82 mi) from the active array. The bowhead whales exhibited no overt reaction to the vessel. At the 2 o'clock position relative to the airgun array, these animals were not likely in the stronger broadside lobe of the airgun array at the time of their sighting, although they likely were at some point after they were detected. The median received level using the endfire equation at that distance would have been 177.4 dB (rms) while the 90th percentile estimate of received level would have been 179.0 dB (rms) (Table 5.21). Assuming the animals were present broadside to the airgun array soon after the sighting was made and at a similar distance the median received level would have been 181.8 dB (rms).

POL201276

This sighting of a single bowhead whale was observed from the *Polar Prince* and the *Geo Arctic* (alternate sighting ID: GEO2012113) while the *Geo Arctic's* full array was active. The bowhead whale was initially observed ahead of and off of the starboard side of the *Polar Prince* (1 o'clock position) at a distance of 967 m (0.60 mi) from the PSOs. The *Polar Prince* PSOs alerted the PSOs aboard the *Geo Arctic* of the presence of the whale, and continued to observe the whale as it crossed the bow of the *Polar Prince* and travelled away in a direction perpendicular to the vessels trackline. PSOs aboard the *Geo Arctic* initially observed this whale 40 s later at a distance of 1359 m (0.84 mi) from the observers. This bowhead whale was estimated to have a CPA of 1362 m (0.85 mi) from the active array. The bowhead whale exhibited no overt reaction to the vessel. Since this animal was observed in the endfire direction from the airgun array, the median received level would have been about 177.2 dB (rms) and the 90th percentile received level would have been 178.8 dB (rms).

GEO2012115

This sighting was of a group of two bowhead whales observed from the *Geo Arctic* while the full array was active. These bowhead whales were initially observed ahead of the *Geo Arctic* at the 10:30

clockface position at a distance of 1861 m (1.16 mi) from the PSOs. The whales were swimming in the same direction as the vessel. These bowhead whales were estimated to have a CPA of 1899 m (1.18 mi) from the active array. The bowhead whales exhibited no overt reaction to the vessel. These animals were not likely within the stronger broadside lobe of the array and thus the median received level at that location would likely have been about 174.7 dB (rms) and the 90th percentile received level would have been 176.3 dB (rms).

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 (RSL) reaches a specific criterion such as 190 dB, 180 dB, or 160 dB re 1 µPa (rms) is variable. The RSL depends on water depth, sound source depth, water-mass and bottom conditions, and - for directional sources - aspect (Chapter 3; see also Greene 1997, Greene et al. 1998; Burgess and Greene 1999; Caldwell and Dragoset 2000; Tolstoy et al. 2004a,b). ***(4)*** the sounds received by marine mammals vary depending on 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 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 marine mammal densities calculated from observational data collected during this survey. The actual number of individuals exposed to, and potentially impacted by, strong seismic survey 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 RSLs at various distances from the *Geo Arctic's* airgun array. The NMFS required that distances to RSLs of 180 dB and 190 dB (rms) be used to implement mitigation measures for cetaceans and seals respectively. The USFWS required that distances to RSLs of 180 dB and 190 dB (rms) be used to implement mitigation measures for Pacific walruses and polar bears, respectively. Both agencies assume that disturbance to marine mammals may occur at RSLs ≥160 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 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. Also, RSLs of ≥160 dB (rms) were estimated to occur out to 18.7 km (11.6 mi) by the revised SSV measurements of the full airgun array. This distance was well beyond that at which PSOs aboard the *Geo Arctic* and the *Polar Prince* could detect even

the more conspicuous animals under favorable sighting conditions. Furthermore, marine mammals could not be seen effectively during periods of darkness, which increased as the survey progressed. Nighttime observations were conducted regularly from the *Polar Prince* (~91 h total, between 2-4 h nightly), however only two sightings of two unidentified seals and one sighting of a polar bear by a crew member were observed during the entire survey during darkness periods.

Animals may also have avoided the area near the *Geo Arctic* while the airguns were firing (see Richardson et al. 1995, 1999; Stone 2003; Gordon et al. 2004; Smultea et al. 2004). 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 *Geo Arctic* and the *Polar Prince* themselves. 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 34 sightings of 75 bowhead whales recorded from the *Geo Arctic* and the *Polar Prince* while the *Geo Arctic's* airguns were operating in the Chukchi Sea, and 64 of these individuals were likely exposed to received sound levels ≥160 dB (rms). None of these sightings occurred within the ≥180 dB (rms) safety radius that was in effect at that time (832 m). However, based on the final analysis of the SSV measurements, it was estimated that seven sightings of 10 bowhead whales would have been within the ≥180 dB (rms) radius (Table 5.26; see previous section *Mitigation Measures Implemented*). There were no other such occurrences during the project for cetaceans or any other species.

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

From the *Geo Arctic*, five seals were observed while airguns were operating. In addition, PSOs aboard the *Polar Prince* observed 13 seals while the vessel was within the ≥160 dB radius of the *Geo Arctic's* active airgun array. All 18 of these seals were observed during survey activities in the Chukchi Sea, but only two were in the water and likely exposed to RSLs ≥160 dB (rms). Based on the final analysis of the SSV measurements (Table 4.1), no seals were within the ≥190 dB (rms) radius. However, one unidentified pinniped (likely a bearded seal) observed from the *Geo Arctic* was likely exposed to RSLs ≥180 dB (rms).

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

Twelve of the thirteen polar bears observed from the *Geo Arctic* and the *Polar Prince* were sighted while the *Geo Arctic's* airguns were operating in the Chukchi Sea. None of these polar bears were observed in the water or entered the water as the vessels approached; however, 11 polar bears could have potentially been exposed to ≥160 dB (rms) if they had entered the water. No polar bears were estimated to be within the ≥190 dB (rms) radius (Table 4.1). One polar bear observed from the *Polar Prince* and the *Geo Arctic* was within the ≥180 dB (rms) radius; however, the polar bear was on ice and therefore not exposed to RSLs ≥180 dB (rms).

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

No Pacific walruses were observed from the *Geo Arctic* or the *Polar Prince* while the airguns were active and thus no Pacific walruses were likely exposed to RSLs ≥160 (rms).

TABLE 5.26. Number of individual marine mammals observed within specific safety radii and potentially exposed to the respective sound levels during ION's seismic survey, 12 Oct – 16 Nov 2012.

Number of Individuals and Exposure Level in dB re 1 μPa (rms)			
Cetaceans ≥180	**Seals ≥190**	**Polar Bears ≥190**	**Pacific Walruses ≥180**
10	0	0	0

Estimates Extrapolated from Density

The number of marine mammals visually detected by PSOs likely underestimated the actual numbers that were present. To correct for animals that may have been present but not detected by observers, the sightings of animals in the water recorded during seismic and non-seismic periods along with detectability corrections $f(0)$ and $g(0)$ were used to calculate separate densities of in-water marine mammals present in the survey area. Since most of the sightings occurred in just a few specific locations, site specific densities were calculated for those areas in order to better estimate the numbers present in those patches. The estimated densities of marine mammals were then multiplied by the area of water ensonified (exposed to seismic sounds) during all seismic activities (not just those during which PSO observations were made) to estimate the number of individual marine mammals exposed to RSLs ≥160 (rms; Table 5.27). The methodology used to estimate the areas exposed to RSLs ≥160, 170, 180 and 190 dB (rms) was described in Chapter 4 and in more detail in Appendix C and it includes the additional area exposed due to the operation of the 4880 in^3 array for ~6.5 hrs in the Beaufort Sea. The ratios of the total area exposed to seismic sound including multiple counts of areas ensonified more than once ("Including Overlap Area", Table 5.27) to the area of water exposed excluding multiple counts of those areas ("Excluding Overlap Area", Table 5.27) were 1.9 in each sea as well as both seas combined. This ratio represents the average number of exposures per individual marine mammal if that individual had remained present in the same location throughout the survey. The 1.9 value is quite low compared to recent 3D seismic surveys or shallow hazards surveys and reflects the widely spaced lines of ION's 2D survey compared to the closely spaced survey lines of more focused 3D seismic and shallow hazards surveys.

Marine mammal densities were based on PSO effort and in-water marine mammal sightings collected during good visibility conditions from the *Geo Arctic* and the *Polar Prince* during ION's seismic operations in the Beaufort and Chukchi seas. When observational data from the entire survey were lumped together, the densities shown in Table 5.28 were the result. By pooling the data from locations and days with few or no sightings with those from days with many sightings, the calculations effectively spread out the sightings from the high sighting days across the entire survey area; therefore, density estimates from the pooled data underestimate the number of animals present in the locations where the sightings were concentrated and overestimate the number of animals present where few or no sightings took place. In order to achieve results that better represent the locations of few and many sightings, densities were calculated for four separate periods including; 1) Nov 11th during transit through the Beaufort Sea, 2) Nov 14th and 15th during seismic and non-seismic periods in the north-central Chukchi Sea, 3) Nov 16th during transit through the southern Chukchi Sea (Table 5.29), and 4) during all other dates and locations of operations (Table 5.30). Periods 1–3 are consistent with those described in detail at the start of the *Marine Mammal Sightings* section of this chapter. Period 4 represents the data collected during seismic and non-seismic periods in the Beaufort Sea excluding the Nov 11th transit day.

TABLE 5.27. Estimated areas (km^2) ensonified to various sound levels during the ION seismic survey in the Beaufort and Chukchi seas, 12 Oct – 16 Nov 2012.

	Level of ensonification in dB re 1 µPa (rms)				
Area (km^2)	**190**	**180**	**170**	**160**	**120**
Beaufort Sea					
Including Overlap Area	1,716	7,775	30,483	84,142	1,787,806
Excluding Overlap Area	1,601	6,421	20,358	45,297	299,120
Chukchi Sea					
Including Overlap Area	67	548	2,580	6,057	97,500
Excluding Overlap Area	49	355	1,570	3,323	51,893
Both Seas Combined					
Including Overlap Area	1,783	8,323	33,062	90,199	1,885,306
Excluding Overlap Area	1,650	6,776	21,928	48,620	351,013

TABLE 5.28 Densities of in-water marine mammals calculated from observation data pooled across all survey days during the ION seismic survey, 12 Oct – 16 Nov 2012. Densities are corrected for *f*(0) and *g*(0) biases (see Appendix C).

	No. individuals / km^2					
	Seismic			Non-seismic		
Species	**Density**	**LCL**	**UPC**	**Density**	**LCL**	**UPC**
Cetaceans						
Bowhead Whale	0.0489	0.0092	0.2590	0.0029	0.0004	0.0209
Unid. Mysticete Whale	0	--	--	0.0007	0.0003	0.0019
Total Cetaceans	***0.0489***	***0.0092***	***0.2590***	***0.0036***	***0.0007***	***0.0200***
Seals						
Ringed Seal	0	--	--	0.2125	0.0487	0.9266
Bearded Seal	0	--	--	0.0295	0.0076	0.1148
Unid. Seal	0	--	--	0.3294	0.0892	1.2156
Unid. Pinniped	0.0054	0.0004	0.0682	0.0089	0.0007	0.1075
Total Seals	***0.0054***	***0.0004***	***0.0682***	***2.8380***	***0.3100***	***25.9824***
Pacific walrus	0	--	--	2.2577	0.1860	27.4015

TABLE 5.29 Densities of in-water marine mammals calculated from observation data collected on specified days (Nov 11, 14-15, and 16) during the ION seismic survey, 12 Oct – 16 Nov 2012. Densities are corrected for *f*(0) and *g*(0) biases (see Appendix C).

	No. individuals / km2					
Date	**Seismic**			**Non-seismic**		
Species	**Density**	**LCL**	**UPC**	**Density**	**LCL**	**UPC**
Nov 11 - Beaufort Sea						
Seals						
Ringed Seal	0	--	--	2.9076	0.5612	15.0644
Bearded Seal	0	--	--	0.1061	0.0321	0.3507
Unid. Seal	0	--	--	5.4390	1.4623	20.2299
Total Seals	***0***	--	--	***8.4527***	***2.8665***	***24.9255***
Nov 14 & 15 - North-Central Chukchi Sea						
Cetaceans						
Bowhead Whale	0.9730	0.4107	2.3046	0.0524	0.0201	0.1365
Total Cetaceans	***0.9730***	***0.4107***	***2.3046***	***0.0524***	***0.0201***	***0.1365***
Seals						
Unid. Seal	0	--	--	0.9801	0.4279	2.2452
Unid. Pinniped	0.3168	0.2418	0.4152	0	--	--
Total Seals	***0.3168***	***0.2418***	***0.4152***	***0.9801***	***0.4279***	***2.2452***
Nov 16 - Southern Chukchi Sea						
Cetaceans						
Bowhead Whale	0	--	--	0.0341	0.0048	0.2444
Total Cetaceans	***0***	--	--	***0.0341***	***0.0048***	***0.2444***
Seals						
Ringed Seal	0	--	--	0.8660	0.2285	3.2814
Bearded Seal	0	--	--	0.2843	0.0623	1.2968
Unid. Seal	0	--	--	0.6271	0.1755	2.2406
Unid. Pinniped	0	--	--	0.1138	0.0094	1.3829
Total Seals	***0***	--	--	***30.9061***	***2.7502***	***347.3216***
Pacific walrus	0	--	--	29.0150	2.3880	352.5433

TABLE 5.30 Densities of in-water marine mammals calculated from observation data on all days ***except*** those specified in Table 5.29 (Nov 11, 14-15, and 16) during the ION seismic survey, 12 Oct – 16 Nov 2012. Densities are corrected for *f*(0) and *g*(0) biases (see Appendix C).

	No. individuals / km^2					
	Seismic			Non-seismic		
Species	**Density**	**LCL**	**UPC**	**Density**	**LCL**	**UPC**
Cetaceans						
Bowhead Whale	0	--	--	0	--	--
Unid. Mysticete Whale	0	--	--	0.0008	0.0003	0.0022
Total Cetaceans	***0***	***--***	***--***	***0.0008***	***0.0003***	***0.0022***
Seals						
Ringed Seal	0	--	--	0.0121	0.0039	0.0372
Bearded Seal	0	--	--	0.0029	0.0002	0.0429
Unid. Seal	0	--	--	0.0095	0.0032	0.0278
Total Seals	***0***	***--***	***--***	***0.0245***	***0.0101***	***0.0594***

The non-seismic densities shown in Table 5.30 were based on 603 km (375 mi) of observation effort during good visibility conditions in the Beaufort Sea while the seismic densities were based on 582 km (362 mi) of effort during good visibility conditions also in the Beaufort Sea. This amount of observation effort is enough to provide reasonable estimates of the number of marine mammals present and suggests that the low densities are not simply a results of a low sample size. However, the much higher seal densities encountered on Nov 11th in the Beaufort Sea (Table 5.29) indicated that seals were distributed in concentrated patches and not entirely absent from the region. Although the seal densities on Nov 11th were based on only 84 km (62 mi) of observation effort during good visibility conditions, they likely provide a reasonable estimate of the number of seals present in the immediate vicinity of the vessels on that day.

Densities shown in Table 5.29 for species observed on Nov 14th and 15th were based on just 50 km (31 mi) of effort during good visibility conditions when airguns were active (seismic densities) and only 31 km (19 mi) of effort during good visibility conditions when airguns were not active (non-seismic densities). Although the calculated densities may be reasonable estimates of the numbers of animals present in the immediate vicinity of the vessel on those days, the low amount of observational effort means they are not representative of marine mammal densities in the region as a whole. Similar to the seal observations in the Beaufort Sea on Nov 11th, the densities reflect a patch of animals encountered at a discrete time and location. Close inspection of the sighting locations and the period of good visibility conditions shows the nature of the patch of bowhead whales quite well (Fig. 5.20). As the vessels transited westward along the survey line with good visibility conditions they began to record bowhead whale sightings every 20-30 minutes (6 sightings in 1.5 hr; Fig. 5.20). Sightings then began to be recorded every 5-10 minutes for a total of 23 sightings in 1.5 hr, with the final sighting occurring 15 minutes after the penultimate sighting. Good visibility conditions persisted for another 1.5 hours after the final sighting with no more bowhead whale detections, which suggests the vessels likely departed from the patch of bowhead whales.

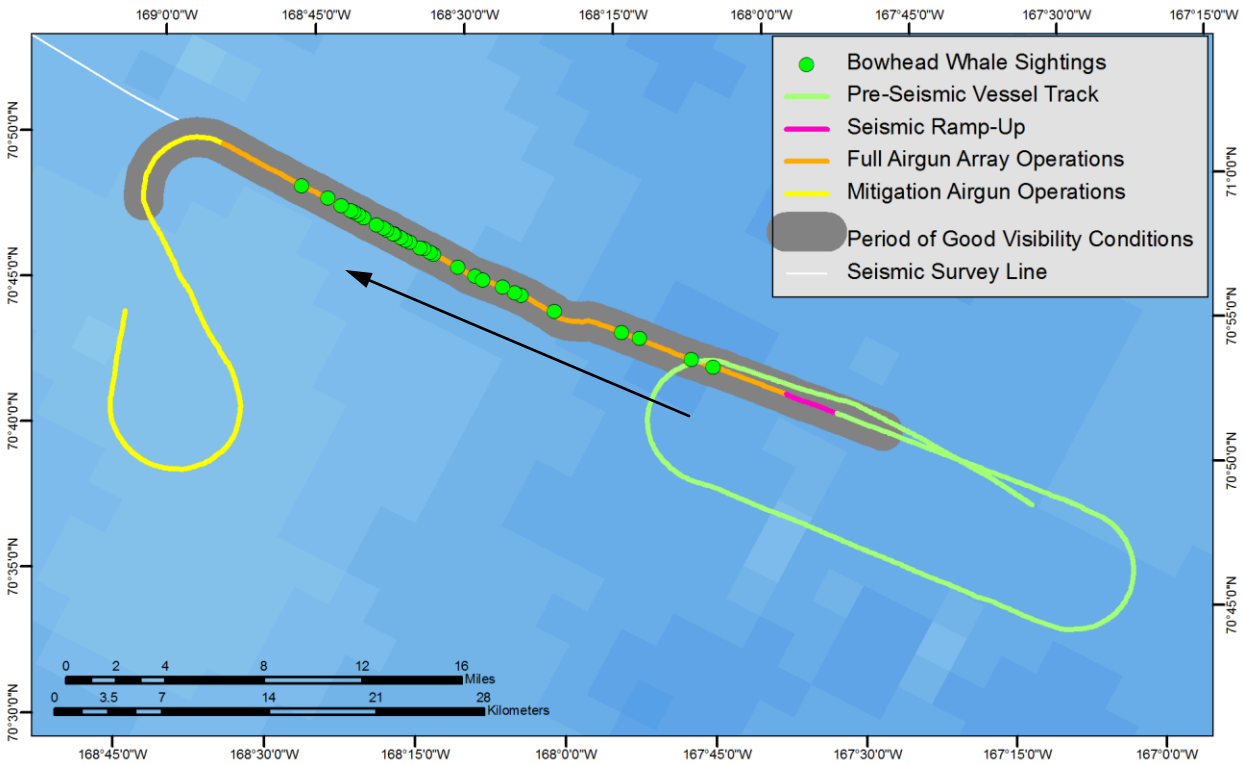

FIGURE 5.20. Seismic survey vessel trackline showing airgun activity status, the period of good visibility conditions, and bowhead whale sightings on Nov 14th in the north-central Chukchi Sea. The black arrow indicates the direction of vessel travel during good visibility conditions.

The following exposure estimates based on density calculations assume that all mammals present were well below the surface where they were exposed to RSLs at various distances as described 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 *Geo Arctic* before it arrived, either because the *Polar Prince* was travelling in front of the *Geo Arctic*, or because of an avoidance response to the approaching source vessel and its airguns.

Table 5.31 shows the number of individuals potentially exposed to received seismic sounds ≥160 dB (rms) based on densities observed and seismic activity that occurred during survey operations in the Beaufort Sea, excluding the non-seismic sightings recorded on Nov 11th. Specifically, these estimates were made by multiplying the Beaufort Sea "Excluding Overlap" ensonified area shown in Table 5.27 by the densities shown in Table 5.30. For reasons described above, this approach is believed to provide the best density based estimate of the number of marine mammals potential exposed by survey activities in the Beaufort Sea. During some previous seismic programs the marine mammal densities observed during seismic periods have been lower than those observed during non-seismic periods indicating some avoidance of the seismic sounds may have occurred. Although this relationship between seismic and non-seismic densities is present in the data from the Beaufort Sea during the ION survey, the lack of sightings, and therefore density estimates, during seismic activities and the relatively low densities during non-seismic periods likely say more about the overall limited number of marine mammals present in the deeper offshore waters where most activities occurred than it does about potential avoidance of seismic sounds.

TABLE 5.31 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 that occurred on all days ***except*** Nov 11, 14–15, and 16, 2012.

	Estimated No. Individuals						Requested Take	
	Seismic Densities			Non-seismic Densities				
Species	**Mean**	**LCL**	**UCL**	**Mean**	**LCL**	**UCL**	**Mean**	**Max**
Cetaceans								
Bowhead Whale	0	--	--	0	--	--	285	1,136
Unid. Mysticete Whale	0	--	--	36	14	100	--	--
Total Cetaceans	0	--	--	36	14	100	***5,404***	***22,435***
Seals								
Ringed Seal	0	--	--	548	177	1,686	60,574	91,244
Bearded Seal	0	--	--	131	9	1,945	93	377
Unid. Seal	0	--	--	430	145	1,261	--	--
Total Seals	0	--	--	1,110	457	2,690	***60,711***	***91,807***

Table 5.32 shows the number of individuals potentially exposed to received seismic sounds ≥160 dB (rms) based on densities observed and seismic activity that occurred on Nov 14th and 15th in the north-central Chukchi Sea. These estimates were made by multiplying the Chukchi Sea "Excluding Overlap" ensonified area shown in Table 5.27 by the Nov 14th & 15th in-water marine mammal densities shown in Table 5.29. We believe this approach provides the best estimate of the number of marine mammals potential exposed by survey activities in the Chukchi Sea. In contrast to the monitoring results from some previous seismic surveys, the density of marine mammals encountered during seismic activity was much greater than during non-seismic periods. This was likely due in large part to the very limited amount of effort in either category in this region, and does not suggest that animals were attracted to the seismic sounds. Instead, the data reflect the fact that a high concentration of marine mammals was encountered during the limited amount of effort and survey activities on Nov 14th as described above and shown in Fig. 5.20. The area exposed to ≥160 dB (rms) in the Chukchi Sea along with the airgun activity and bowhead sightings on Nov 14th and 15th are shown together in Fig. 5.21. This shows that the highest concentration of bowheads, upon which the seismic density and take estimates are based (Tables 5.29 and 5.32), occurred in only a portion of the area surveyed and exposed to >160 dB (rms). Bowhead whales and other marine mammals were clearly present throughout the general area, but extrapolating the density from the highest concentration area to the entire ensonified area, as the calculations shown in Table 5.32 do, may overestimate the number of bowhead whales that were actually present within the area during all of the survey activities.

TABLE 5.32 Estimated numbers of individual marine mammals exposed to pulsed seismic sounds at received levels ≥160 dB (rms) based on densities observed during seismic and non-seismic periods that occurred in the north-central Chukchi Sea (Nov 14 & 15).

	Estimated No. Individuals						Requested Take	
	Seismic Densities			Non-seismic Densities				
Species	**Mean**	**LCL**	**UCL**	**Mean**	**LCL**	**UCL**	**Mean**	**Max**
Cetaceans								
Bowhead Whale	3,233	1,365	7,658	174	67	454	285	1,136
Total Cetaceans	3,233	1,365	7,658	174	67	454	***5,404***	***22,435***
Seals								
Ringed Seal	0	--	--	0	--	--	60,574	91,244
Bearded Seal	0	--	--	0	--	--	93	377
Unid. Seal	0	--	--	3,257	1,422	7,461	--	--
Unid. Pinniped	1,053	804	1,380	0	--	--	--	--
Total Seals	1,053	804	1,380	3,257	1,422	7,461	***60,711***	***91,807***

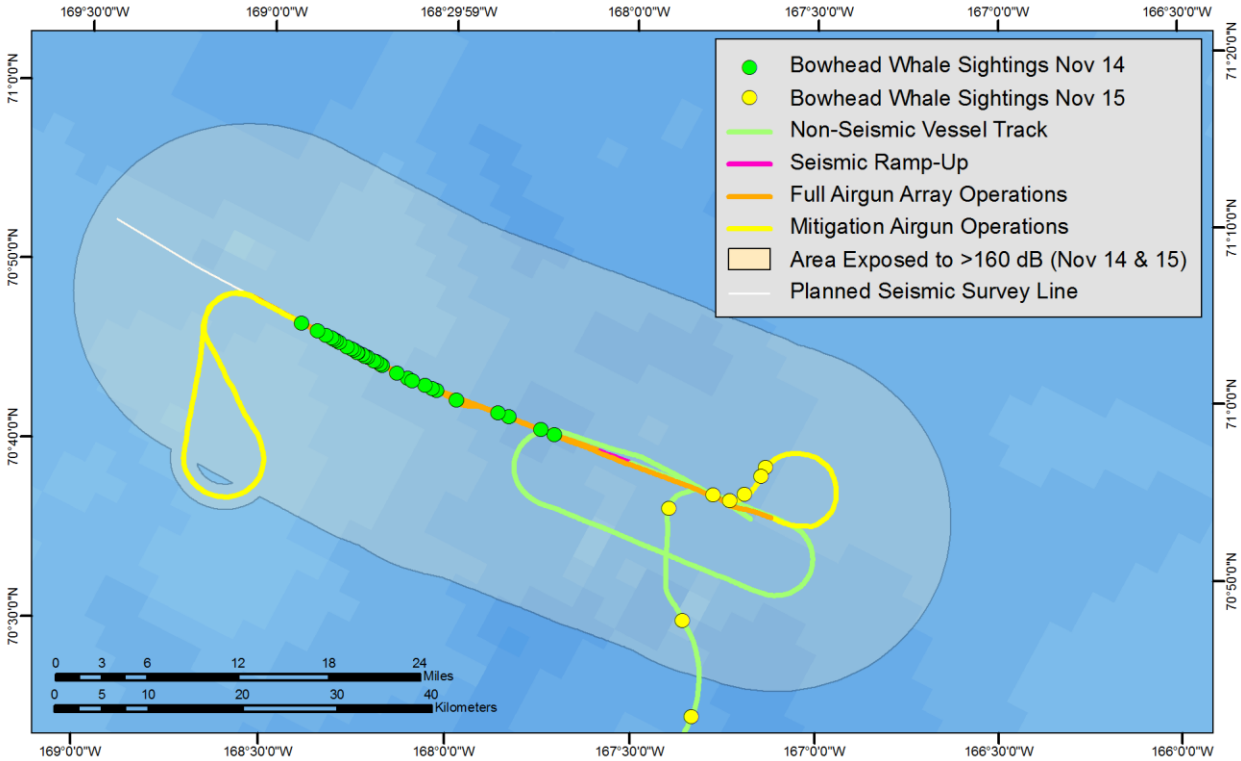

FIGURE 5.21. Seismic survey vessel tracklines showing airgun activity status and the area exposed to ≥160 dB (rms) in the north-central Chukchi Sea on Nov 14 & 15 bowhead whale sightings on Nov 14th in the Chukchi Sea.

Cetaceans

There were 64 individual bowhead whales directly observed within the ≥160 dB (rms) zone during airgun activity. This undoubtedly underestimates the actual number that may have been present. Since very few cetaceans were observed in the Beaufort Sea during either seismic or non-seismic periods, the number of cetaceans exposed during survey activities there was likely quite small and may have been similar to the ~36 individuals estimated in Table 5.31. Density based estimates from the Chukchi Sea suggest that ~3,233 bowhead whales may have been present during survey activities there (Table 5.32); however, this estimate may be biased somewhat high by extrapolating the density from a high concentration area over the entire area exposed to seismic sounds ≥160 dB (rms).

Seals

Only two seals were observed in the water within the ≥160 dB (rms) radius of the operating airguns during the ION survey. However, density based calculations of exposures in both the Beaufort and Chukchi seas estimate that 1000–4500 seals may have been present in the water within the ≥160 dB zone. Given the size of the >160 dB zone in the various water depths (Table 4.1) and the inability to reliably detect seals from a vessel at those distances, the density based calculations provide a much more realistic estimate of the number of seals potentially exposed to seismic sounds at the threshold level.

Polar Bears

No polar bears were observed in the water during either seismic or non-seismic periods of the ION survey; therefore, both estimation methods results in zero polar bears being potentially exposed to seismic sounds ≥160 dB. It is possible that some polar bears were present in the water and with the ≥160 dB zone during survey activities in the Chukchi Sea, but were not detected by PSOs. However, these animals were likely near the surface where sound levels at any given distance would be substantially below those shown in Table 4.1 and used in these analyses.

Pacific Walruses

Pacific walruses were only observed during a single day while the vessels transit south of Pt. Hope where no seismic activity occurred. Thus, it is unlikely that many, if any, walruses were present during the survey activities in the north-central Chukchi Sea during the previous two days. Pacific walruses are very uncommon in the Beaufort Sea, especially at the time of year that survey operations were conducted, so it is likely that no walruses were exposed to seismic sounds ≥160 dB by survey operations there.

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APPENDICES TO
MARINE MAMMAL MONITORING AND MITIGATION DURING A MARINE SEISMIC SURVEY BY ION GEOPHYSICAL IN THE ARCTIC OCEAN, OCTOBER–NOVEMBER 2012: 90-DAY REPORT

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APPENDIX A: DESCRIPTION OF VESSELS AND EQUIPMENT

M/V *Geo Arctic*

Vessel	Owner/Operator	Length m (ft)	Beam m (ft)	Draft m (ft)
M/V *Geo Arctic*	Sevmorneftegeofizika (SMNG)	81.8 (268.4)	14.8 (48.6)	5.4 (17.7)

Figure A-1. The seismic source vessel *M/V Geo Arctic*.

The *M/V Geo Arctic* (Fig. A-1) is a Russian-flagged 2D seismic survey vessel. It is equipped with standard navigation, radar, communication, and depth-sounding it equipment. The *Geo Arctic* is ice strengthened to the KM UL (1) A2 (Russian) Ice Class, equivalent to the Canadian Ice Class CASPPR Type A. This vessel was built in Poland in 1988, and then rebuilt in Norway in 1997. The main engine is a 3090 kW Zgoda-Zulcer 6ZL 40/48. Fuel capacity is 710 t and endurance is 67 days. Cruising speed is 12 knots, however the *Geo Arctic* travelled at a speed of ~4 knots while surveying. The *Geo Arctic* was escorted by the icebreaker support vessel *M/V Polar Prince* during the project.

Airgun Description

The *Geo Arctic* towed an airgun array comprised of 28 Sercel G-gun airguns, of which 26 were active. Total discharge volume was 4380 in^3. The 28 airguns were distributed in two sub-arrays with 14 airguns per sub-array (Fig. A-2). Individual airgun sizes ranged from 70 to 250 in^3, and were operated at 2000 psi. The sub-arrays were deployed 23 m (75.5 ft) astern of the vessel (25.5 m [83.7 ft] from the stern to the centre of the array) at a depth of ~8.5 m (27.9 ft). The distance between the array and the position from which the PSOs conducted observations on the bridge was 83 m (272.3 ft).

The nominal zero-to-peak source pressure level @ 1 m for each pulse was estimated at 250 dB re 1µPa (broadside, 10-2000 Hz). The source pressure averaged over the length of the pulse (*rms*) was estimated to be 220.5 dB re 1µPa @ 1 m (10-2000 Hz), and the sound exposure level (SEL) at 1 m from the source was estimated at 230.5 dB re 1 μPa^2 s (10-2000 Hz) (Matthews and MacGillivray 2012). The *Geo Arctic* travelled along the pre-determined survey lines at ~4 knots. The shot interval was 18-20 s.

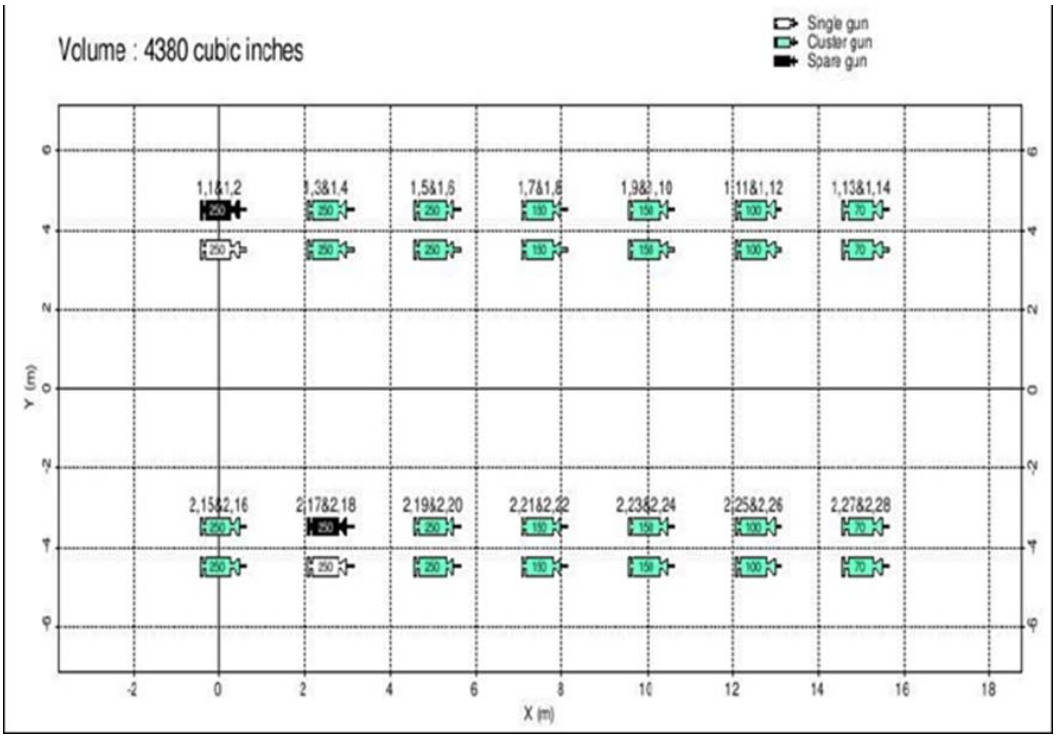

Figure A-2. Geometric layout of the 4380 in3 airgun array. The volume of each airgun is in cubic inches. Tow direction is to the right; tow depth is 8.5 m (27.9 ft).

Recording Equipment

The *Geo Arctic* towed a single 9 km (5.6 mi) long streamer to receive the reflected signals from the bottom, and transfer the data to an on-board processing system. The streamer was an ION Geophysical DigiSTREAMER™ with DigiFIN™ units attached every 300m (0.19 mi), and was towed at ~9.5 m (31.2 ft) below the water surface. The DigiFIN units maintained the streamer at the desired depth, and provided lateral control for avoiding deep ice keels, acoustic positioning, and depth measurements. The DigiSTREAMER contained an environmentally-friendly solid fill to reduce self-noise properties while providing consistent buoyancy. The DigiSTREAMER technology performs well in cold weather, unlike Sentinel® solid streamers, which may become stiff and difficult to handle.

Additional Equipment

The *Geo Arctic* used one navigational echo sounder during the project. The downward facing single-beam Simrad EA 600 hydrographic echosounder operates at frequencies ranging from 38 to 200 kHz with an output power of 100–2000 Watts. Pulse durations are between 0.064 and 4.096 milliseconds and the pulse repetition frequency (PRF or ping rate) depends on the depth range. The highest PRF at shallow depths is about 40 pings per second. It can be used for water depths up to 4000 m and provides up to 1 cm resolution.

M/V *Polar Prince*

Vessel	Owner/Operator	Length m (ft)	Beam m (ft)	Draft m (ft)
M/V *Polar Prince*	GX Technology Canada Ltd.	67.1 (220.1)	15.0 (49.2)	6.0 (19.7)

Figure A-3. The icebreaker support vessel *M/V Polar Prince*.

The *M/V Polar Prince* (Fig. A-3) is a Canadian-flagged Lloyds 100A (Arctic Class 1+) ice-breaker cargo ship. Built in Quebec for the Canadian Coast Guard in 1959, it was totally rebuilt and modernized by the Coast Guard in 1986. It was refit in 2010, and is certified by Transport Canada Marine Safety & DNV 1A1. The *Polar Prince* is propelled by 4x Morse-Fairbanks 38 D 8 1/8 diesels engines (main engines) and 2x fixed blade Superston 70 propellers. Fuel capacity is 701 m^3, maximum speed is 14.5 knots and cruising speed is 11 knots. In addition to scouting for ice and facilitating crew transfers, the *Polar Prince* travelled ~500 m (0.31 mi) in front of the *Geo Arctic* to clear a path when in ice-covered waters.

Additional Equipment

The *Polar Prince* used one echo sounder, an ELAC LAZ-72. The LAZ-72 has an operating frequency of 30 kHz. The ping rate depends on the water depth and the fastest rate, which occurs in shallow depths, is about 5 pings per second.

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APPENDIX B: SOUND SOURCE MEASUREMENT RESULTS

Part 1: Calibration Tables

The calibration approach yields the value Sysgain that represents the relationship between full digital scale of the recorder and the absolute pressure in micropascals. Sysgain is the value presented in the last row of the following tables. For the high-frequency measurements, Sysgain was calculated from the gain of the recording system combined with the hydrophone gain based on the central frequency of the source.

Table B.1. High sensitivity calibration measurement (Location S1, 22 Oct) used in data analysis for OBH S-11.

Pre-deployment		*Post-retrieval*
Atm. Press.	*1027.6 hPa*	*1036.1 hPa*
Press. Corr. Factor	*0.12 dB*	*0.19 dB*
Bandwidth	*50 Hz*	*50 Hz*
Calibrator:	*G.R.A.S. 42AC*	*G.R.A.S. 42AC*
Frequency:	*250.0 Hz*	*250.0 Hz*
Sensor:	*RESON TC4032*	*RESON TC4032*
Cal_lev:	*156.0 dB re 1 µPa*	*156.0 dB re 1 µPa*
Sysgain:	*-190.0 dB re 1 FS/µPa*	*-189.7 dB re 1 FS/µPa*

Table B.2. Low sensitivity calibration measurement (Location S1, 22 Oct) used in data analysis for OBH S-11.

Pre-deployment		*Post-retrieval*
Atm. Press.	*1027.6 hPa*	*1036.1 hPa*
Press. Corr. Factor	*0.12 dB*	*0.19 dB*
Bandwidth	*50 Hz*	*50 Hz*
Calibrator:	*G.R.A.S. 42AC*	*G.R.A.S. 42AC*
Frequency:	*250.0 Hz*	*250.0 Hz*
Sensor:	*RESON TC4043*	*RESON TC4043*
Cal_lev:	*165.5 dB re 1 µPa*	*165.5 dB re 1 µPa*
Sysgain:	*-218.6 dB re 1 FS/µPa*	*-218.8 dB re 1 FS/µPa*

Table B.3. High sensitivity calibration measurement (Location S2, 20 Oct) used in data analysis for OBH S-12.

Pre-deployment		*Post-retrieval*
Atm. Press.	*1013.1 hPa*	*1030.8 hPa*
Press. Corr. Factor	*0.00 dB*	*0.15 dB*
Bandwidth	*50 Hz*	*50 Hz*
Calibrator:	*G.R.A.S. 42AC*	*G.R.A.S. 42AC*
Frequency:	*250.0 Hz*	*250.0 Hz*
Sensor:	*RESON TC4032*	*RESON TC4032*
Cal_lev:	*156.0 dB re 1 µPa*	*156.0 dB re 1 µPa*
Sysgain:	*-186.5 dB re 1 FS/µPa*	*-186.3 dB re 1 FS/µPa*

Table B.4. High sensitivity calibration measurement (Location S3, 20 Oct) used in data analysis for OBH S-06.

Pre-deployment		*Post-retrieval*
Atm. Press.	*1030.0 hPa*	*1037.6 hPa*
Press. Corr. Factor	*0.14 dB*	*0.21 dB*
Bandwidth	*50 Hz*	*50 Hz*
Calibrator:	*G.R.A.S. 42AC*	*G.R.A.S. 42AC*
Frequency:	*250.0 Hz*	*250.0 Hz*
Sensor:	*RESON TC4032*	*RESON TC4032*
Cal_lev:	*156.0 dB re 1 µPa*	*156.0 dB re 1 µPa*
Sysgain:	*-185.6 dB re 1 FS/µPa*	*-186.0 dB re 1 FS/µPa*

Table B.5. High Sensitivity calibration measurement (Location D1, 23 Oct) used in data analysis for OBH S-10B.

Pre-deployment		*Post-retrieval*
Atm. Press.	*1033.0 hPa*	*1031.6 hPa*
Press. Corr. Factor	*0.17 dB*	*0.16 dB*
Bandwidth	*50 Hz*	*50 Hz*
Calibrator:	*G.R.A.S. 42AC*	*G.R.A.S. 42AC*
Frequency:	*250.0 Hz*	*250.0 Hz*
Sensor:	*RESON TC4032*	*RESON TC4032*
Cal_lev:	*156.0 dB re 1 µPa*	*156.0 dB re 1 µPa*
Sysgain:	*-189.0 dB re 1 FS/µPa*	*-189.3 dB re 1 FS/µPa*

Part 2: Third-octave Band Levels

TABLE B.6. 1/3-octave band SEL for the *Geo Artic* 4380 in^3 airgun array.

Frequency (Hz)	Pulse (dB re 1 µPa^{2}s)
10.0	202.4
12.6	212.4
15.8	214.4
20.0	216.1
25.1	220.5
31.6	215.8
39.8	214.7
50.1	218.3
63.1	218.4
79.4	216.8
100	222.0
126	222.8
159	224.8
200	215.0
251	212.6
316	207.3
398	204.5
501	200.5
631	198.6
794	195.5
1000	188.9
1260	185.4
1580	185.3
2000	186.2
2510	187.9
3160	184.3
3980	185.6
5010	186.3
6310	185.6
7940	183.0
10000	186.3
Broadband	230.7

TABLE B.7. 1/3-octave band SEL for the 70 in^3 mitigation airgun.

Frequency (Hz)	Pulse (dB re 1 µPa^{2}s)
10.0	181.9
12.6	196.4
15.8	195.2
20.0	185.7
25.1	200.1
31.6	192.6
39.8	193.2
50.1	195.8
63.1	197.6
79.4	197.1
100	199.1
126	201.3
159	201.3
200	197.4
251	192.7
316	189.8
398	189.2
501	187.6
631	183.3
794	176.6
1000	170.3
1260	168.7
1580	169.4
2000	171.3
2510	170.5
3160	166.5
3980	167.2
5010	166.6
6310	166.4
7940	163.0
10000	162.0
Broadband	209.2

TABLE B.8 *Geo Arctic* and *Polar Prince* source levels. Acoustic source depths for the *Geo Arctic* and *Polar Prince* were approximately 2.6 and 3 m, respectively. Vessel transit speed was 4 kts for *Geo Arctic* and 5 kts for *Polar Prince*.

Frequency (Hz)	*Geo Arctic* SL (dB re 1 µPa @ 1 m)	*Polar Prince* SL (dB re 1 µPa @ 1 m)
10.0	131.4	125.1
12.6	148.1	142.9
15.8	155.5	147.4
20.0	153.7	149.4
25.1	175.5	153.0
31.6	159.2	154.9
39.8	156.6	145.7
50.1	159.3	159.0
63.1	160.9	163.7
79.4	160.9	169.5
100	163.6	168.1
126	165.5	167.9
159	167.6	170.1
200	166.4	163.2
251	166.9	167.3
316	169.6	166.0
398	169.7	160.9
501	169.5	157.1
631	170.1	154.7
794	169.8	149.1
1000	163.7	142.8
1260	160.1	137.8
1580	160.2	140.0
2000	162.2	140.3
2510	164.5	136.3
3160	162.4	134.1
3980	162.2	133.1
5010	162.1	130.6
6310	161.4	128.5
7940	158.4	127.7
10000	157.7	127.4
12600	155.9	126.8
15800	153.8	126.2
20000	152.1	126.0
25100	147.0	126.9
Broadband	181.0	176.9

APPENDIX C: DETAILS OF MONITORING, MITIGATION, AND ANALYSIS METHODS

This appendix provides details on the standard visual monitoring methods and data analysis techniques implemented for this project. Five protected species observers (PSOs) were aboard the seismic source vessel, M/V *Geo Arctic,* throughout the cruise. Two PSOs were biologists experienced in marine mammal identification and observation methods, one PSO was an Inupiat with experience identifying arctic marine mammals during previous Arctic surveys, and the other two PSOs were Inuvialuit with various levels of experience identifying arctic marine mammals during previous Arctic surveys. In addition to the PSOs onboard the *Geo Arctic*, ION placed 4 PSOs on the icebreaker, *Polar Prince.* The PSOs on the *Polar Prince* consisted of two biologists with experience in marine mammal identification and observation methods, one Inupiat with experience identifying arctic marine mammals during previous Arctic surveys, and an Inuvialuit PSO with one Arctic survey experience identifying arctic marine mammals. PSOs generally worked 2–4 hr shifts for up to 12 hrs per day throughout the cruise.

All PSOs participated in an extensive three day observer training course designed to familiarize them with the operational and data recording procedures, reporting protocols, and permit stipulations. The permit stipulations and requirements were also explained to the vessels' Captains and Operations Managers aboard the *Geo Arctic* during a meeting prior to seismic operations. PSO duties included:

- recording environmental and sighting conditions;
- searching for and identifying marine mammals, and recording their numbers, distances from the vessel, and behavior;
- recording possible reactions of marine mammals to the seismic operations; and
- initiating mitigation measures when appropriate.

Visual Monitoring for Marine Mammals

PSOs monitored marine mammals from the *Geo Arctic* during all daytime seismic operations and during most daylight hours while the airguns were not active, as specified in the permits. PSOs onboard the *Polar Prince* conducted watches similar to those of PSOs onboard the source vessel. However, observers on the *Polar Prince* also maintained night-watches, typically between 2-4 h a night, using night-vision goggles (NVD) and a forward looking thermal imaging (FLIR) camera system. Protocols were in place to suspend or amend seismic operations if a marine mammal had been observed within, or about to enter, the designated safety radii described in the permits. In general, observations for marine mammals were conducted using the following guidelines:

- Observations during daylight hours were conducted in good and poor visibility whenever the airgun(s) were operating, and by two observers when possible, unless precluded by safety considerations.
- PSOs observed during transit periods without airgun operations, at the discretion of the lead PSO, to obtain baseline data on marine mammal distribution and (in the case of less experienced observers) to become more familiar with observation protocols.
- Two PSOs observed for 30 min prior to the planned start of seismic operations after an extended shut down and the entirety of the ≥180 re 1 μPa-m dB (rms) radius was required to be visible for those 30 min.
- PSOs also recorded locations and movements of vessels when on watch; information regarding vessels as well as marine mammals was recorded in a database.

Aboard both vessels, PSO(s) systematically scanned the area around the vessel in a sweeping pattern, usually alternating scan sweeps between reticle binoculars (e.g., Fujinon 7 × 50) and the unaided eye during the daytime. Observations were focused forward and to the sides of the vessel in an arc of ~210º, but PSOs also regularly checked for the presence of marine mammals astern of the vessel. Night vision devices were used limitedly aboard both vessels during twilight and darkness hours using a similar sweep search pattern. A forward looking thermal imaging (FLIR) camera system was also available on the *Polar Prince* for observations at night.

The duration of a single visual shift was no longer than 4 hr to minimize observer fatigue. Use of two observers simultaneously was desirable and was scheduled when possible to increase detection of marine mammals near the safety radii. In addition to the dedicated PSOs, bridge personnel were responsible for detecting marine mammals and implementing mitigation requirements when PSOs were not present on the bridge.

While on watch, PSOs kept systematic written records of the vessel's position, activity, and environmental conditions using codes that were entered either onto a datasheet and later transcribed onto database, or entered directly into a database using a notebook-style computer. Vessel and environmental data were recorded onto the datasheet every 30 min or whenever conditions changed significantly. Additional data were recorded when marine mammals were observed. For all records, the date and time, vessel position (longitude and latitude), and environmental conditions were recorded. The database was constructed to prevent entry of out-of-range values and codes. Data entries were checked visually by the lead PSO in the field and in the Anchorage office by a validation program.

The following information was recorded for each marine mammal sighting: date, time, species, total number of individuals, number of juveniles, bearing relative to vessel's heading, direction of movement relative to the vessel, distance from the vessel, behavior when sighted, whether animal was in the water or hauled out on ice or land, behavioral pace, reaction to the vessel, vessel position, water depth, observer initials, species identification reliability, closest point of approach (CPA), time of CPA, and the time that mitigation measures were requested (if necessary). Distance to marine mammals was measured from the PSO's location on the bridge rather than from the nominal center of each vessel. The distance of the animal from the airgun array was calculated during data error checking and processing at the end of the season. However, for sightings near or within the safety radius in effect at the time, the distance from the marine mammal to the nearest airgun was estimated and recorded for the purposes of implementing power downs or shut downs. The bearing from the vessel to individual or groups of marine mammals was estimated using positions on a clock face, with the bow of the vessel considered to be 12 o'clock and the stern 6 o'clock.

Operational activities that were recorded by PSOs included the number of airguns in use, total volume of the airguns, and the type of vessel/seismic activity. Intra-ship communication between seismic technicians and PSOs was conducted via radio or telephone and used to alert PSOs of any changes in operations, and to request power or shut downs by PSOs. The position of the vessel was logged every 60 sec by GPS and these data were integrated with the marine mammal database to check for data recording errors. Details regarding the seismic activities (start and stop times, number of guns firing, etc.) was collected from the airgun operators log and also used to error check PSO data.

Marine Mammal Mitigation During Operations

The following mitigation measures were adopted for marine mammal sightings during the seismic program: ramp ups, power ups, shut downs, power downs, and course alterations.

Ramp Up

A ramp up is a process commonly used by seismic vessels with large airgun arrays that involves a gradual increase in the number of airguns firing from none or one airgun until the full array is active. A ramp up from no airguns cannot be initiated during times when the full safety radii are not visible to PSOs for 30 minutes while a ramp up from one airgun can be initiated during times when the full safety radius is not visible because the mitigation airgun has been firing.

Daylight Procedure

During daylight hours, a ramp up was required when the full airgun array had not been operating for a period of >10 min. A 30 min watch period performed by at least two PSOs was required prior to a ramp up. The entire ≥180 dB (rms) safety radius for the full array must have been visible for the entire 30-min pre-ramp up observation period before the ramp up could commence. However, if the mitigation airgun had been operating during the break in full array activity, then a ramp up could be initiated at any time provided two PSOs were on active watch during the ramp up. If the airguns had been shut down or powered down because of the presence of a marine mammal within or near the applicable safety radius, a ramp up could not begin until that safety radius was clear of marine mammals. Following a marine mammal sighting, the safety radius was considered clear when the marine mammal was observed outside of the safety radius, or if the marine mammal(s) were not seen in the safety radii again for 15 min (for small odontocetes and pinnipeds) or 30 min (for mysticetes, large odontocetes and Pacific walruses). If a marine mammal was observed within the applicable safety radius during the 30-min pre-ramp up observation period, the airgun operator was informed and the ramp up was postponed.

Ramp ups of the airgun array began with firing a single airgun. The number of airguns firing was then increased at a rate no greater than an increase of ~6 dB (rms) per 5-min period. During a ramp up from the mitigation airgun, the same procedure was applied by increasing the number of operating guns from the single mitigation airgun to the full array. During a ramp up, the safety radius for the full airgun array was maintained even though fewer airguns were operating.

PSOs informed the airgun operators when ramp up could proceed. If a marine mammal was observed within its applicable safety radius during the 30-min observation period, or during the ramp up, the bridge and airgun operators were informed, as usual, of any necessary mitigation measures (i.e. power down or shutdown).

Darkness Procedures

During hours of darkness, ramp up could commence only if the entire ≥180 dB (rms) safety radius for the full array was visible to PSOs for 30 min using either the unaided eye or night-vision devices (unlikely with very large safety radii). However, similar to daylight periods with poor visibility conditions, a ramp up from the single mitigation airgun could commence at night even if the full array ≥180 dB (rms) radius was not visible.

Power Down

A power down is a reduction in the number of operating airguns (usually from all airguns firing to a single mitigation airgun firing). If marine mammals were detected outside the applicable safety radius of the full airgun array but were likely to enter the safety radius (i.e., if the mammals were moving towards the vessel or if the vessel was moving in the direction of the mammals), and if the vessel's course or speed could not be changed to avoid having the mammals enter the safety radius, the airgun array was powered down to the single mitigation airgun before the mammals were within the full array safety radius. Likewise, if a mammal was first observed already within the full array safety radius, the airguns

were immediately powered down. The mitigation airgun continued firing at a source level of at least 180 dB (rms) during the interruption of full array seismic operations. A shut down (see below) was implemented only if a marine mammal was detected within or about to enter the smaller safety radius around the mitigation airgun. Full airgun activity did not resume (via a ramp up) until the marine mammal had cleared the safety radius of the full array.

Shut Down

A shut down is the cessation of all airgun activity, including the single mitigation airgun. If a marine mammal was detected within or about to enter the applicable safety radius of the mitigation gun, the airgun was shut down. After a shut down, the animal must have cleared the safety radius before start up procedures could begin. If the mitigation airgun was shut down for >10 min, then at least 30 min of observation by two PSOs was necessary prior to ramp up. PSOs informed the bridge when ramp up of the airgun(s) could proceed.

Course Alteration

If a marine mammal was detected outside the applicable safety radius and, based on its position and direction of travel, was likely to enter the safety radius, one possible mitigation measure was to adjust the ship track and/or speed to avoid close approach to the mammal. However, while the streamer(s) and airgun(s) are being towed behind the vessel, the turning rate of the vessel is very limited, and course alteration is generally not a practical mitigation method for a seismic vessel. Instead, the marine mammal's activities and movements relative to the seismic vessel were closely monitored. If the mammal appeared likely to enter the safety radius, further mitigation actions were taken, i.e., power or shut down of the airgun(s). Vessels reduced speed and altered their course, if practicable, to avoid Pacific walruses and polar bears in water and on ice as per the 2012 LOA.

Analyses

Marine Mammal Monitoring

This section describes the analyses of the marine mammal sightings and survey effort recorded during this project. It also describes the methods used to calculate densities and estimate the number of marine mammals potentially exposed to airgun sounds associated with ION's seismic survey.

The sightings and effort data were grouped into three categories, or bins, to assess potential effects of seismic sounds on marine mammals. These categories were designed to distinguish potential differences in distribution, abundance, and behavior of marine mammals at multiple levels of seismic survey influence. In previous reports, observer data were categorized as "seismic", "non-seismic", or "post-seismic" based on the time and location where data were collected relative to seismic activity. However, the relatively broad criteria used to define these categories did not fully account for difference in the sounds produced by different airgun arrays or the number of guns firing during a given period (i.e. full array activity vs. mitigation airgun activity). Also, the method did not allow data collected from support vessels (icebreaker) to be considered along the gradient of received sound levels that actually exists around a seismic source while it is operating. For those reasons, the results from sound source measurements were used to categorize sightings and observer effort within 10 dB (rms) sound level bins from >190 through <120 dB (rms).

Data collected aboard the source vessel (*Geo Arctic*) were categorized according to the status of airgun activity at the time. Three categories were defined as follows: *(1)* full array activity (all 26 airguns were active, also includes all ramp up and seismic testing periods), *(2)* mitigation airgun activity (only the single 70 in^3 airgun was active), and (3) non-seismic periods (no airguns were firing). In order to keep

sample sizes large enough for comparisons among received sound level bins, data collected on the icebreaker, *Polar Prince*, were also grouped into 3 bins: *(1)* ≥160 dB (rms), *(2)* 159–120 dB (rms), and *(3)* <120 dB (rms). The ≥160 dB (rms) bin was roughly equivalent to the seismic category in previous reports and the full array periods defined for the source vessel data, while the <120 dB (rms) bin was roughly equivalent to the non-seismic category. The <120 dB (rms) bin included data collected while seismic activity was ongoing, but at distances where sounds were estimated to be <120 dB (rms), as well as all data collected when seismic activity was not occurring. The 159–120 dB (rms) bin represented data collected in locations where reactions to seismic (both distributional and behavior) may vary among species.

Data meeting the traditional post-seismic period definition (3 min to 1 h for pinnipeds and polar bears after cessation of seismic activity or 3 min to 2 h for cetaceans) were not included in the <120 dB (rms) bin since the distribution and behavior of animals during this time may still have been altered due to the recent seismic activity. The rate of recovery toward "normal" during the post-seismic period is uncertain. Marine mammal responses to seismic sound likely diminish with time after the cessation of seismic 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).

As summarized in Chapter 4, marine mammal density was one of the variables examined to assess differences in the distribution of marine mammals relative to the seismic vessel between seismic and non-seismic periods. Densities were calculated using line-transect procedures for vessel-based surveys (Buckland et al. 2001). To allow for animals missed during observations, we corrected our visual observations using correction factors calculated with these procedures.

Line Transect Density Estimates

The line transect model described by Buckland et al. (2001) was used to estimate densities by reporting cell. Each cell was defined by species or species group and seismic status, as well as by date range for the site specific densities calculated for Nov 11, 14-15, 16, and all other days combined:

$$D_{ij} = \frac{N_{ij}\bar{S}_{ij} f(0)_i}{2L_{ij} g(0)_i}$$

Where:

D	is the density of a species (numbers of animals / km^2);
$f(0)$	is equal to the sighting probability density function at zero perpendicular distance;
$g(0)$	is equal to the detection function at zero perpendicular distance;
i	denotes categories for sightings in-water or on-ice, or effort in open water or ice (> 5% ice cover);
j	denotes received sound pressure level category (<120 dB, or >160 dB), and;
N	is the total number of sightings for each category, such that:

$$N_{ij} = \sum_{m=1}^{M_{ij}} n(m)_{ij}$$

Where:

m	represents a unique sampling unit, defined as a segment of trackline surveyed on a given day;
M	is the total number of survey days for a given water/ice and sound pressure level combination (here-after 'sighting-effort' category), and;
$n(m)$	is the number of sightings of a certain species in the mth sampling unit for each sighting-effort category.

The average group size $\bar{S}$ for each sighting-effort category was given by:

$$\bar{S}_{ij} = \frac{\sum_{x=1}^{X_{ij}} s(x)_{ij}}{X_{ij}}$$

Where:

x	represents an individual sighting for a given sighting-effort category;
X	is the total number of sightings for a given sighting-effort combination, and;
$s(x)$	is the number of individuals in the xth sighting for a given sighting-effort category.

The total effort for each effort category was given by:

$$L_{ij} = \sum_{m=1}^{M_{ij}} l(m)_{ij}$$

Where: $l(m)$ is the length of useable track-line covered for a given effort category.

The variance of n and $\bar{S}$ was given as:

$$Var\left[N_{ij}\right] = \frac{L_{ij} \sum_{m=1}^{M_{ij}} \left[l(m)_{ij} \left(n(m)_{ij} / l(m)_{ij} - N_{ij} / L_{ij} \right)^2 \right]}{M_{ij} - 1}$$

$$Var\left[\bar{S}_{ij}\right] = \frac{\sum_{x=1}^{X_{ij}} \left(s(x)_{ij} - \bar{S}_{ij} \right)^2}{X_{ij} - 1}$$

There was no uncertainty for *L*, no uncertainty was assumed for *g(*0*)*, and the variance for *f(0)* was output by the program Distance along with the *f(0)* point estimates. When there was only one sighting for a reporting cell, the variance for $\bar{S}$ could not be estimated as $n = 1$. For these situations, we multiplied the maximum coefficient of variation (CV) observed across all species and cells within the species grouping (i.e., cetaceans or pinnipeds) times $\bar{S}$ and squared the product to approximate the variance. Likewise, for those scenarios where densities were only calculated from a single day's data, it was not possible to calculate the sighting rate variance under the assumptions adopted here, and hence the maximum encounter rate variance was used as a proxy when calculating confidence intervals on those densities. Borrowing the highest relative variance likely overestimates the variances in question, but was considered a conservative remedy for dealing with unknown uncertainty.

The variance of *D* was propagated from all input variances as:

$$Var\left[D_{ij}\right] = D_{ij}^2 \left\{ \frac{Var\left[N_{ij}\right]}{N_{ij}^2} + \frac{Var\left[f(0)_{ij}\right]}{f(0)_{ij}^2} + \frac{Var\left[\bar{S}_{ij}\right]}{\bar{S}_{ij}^2} \right\}$$

Because the distribution of *D* was truncated at zero and positively skewed, we assumed *D* was log-normally distributed when estimating the lower (LCL) and upper (UCL) 95% confidence limits (Buckland et al. 2001):

$$LCL_{ij} = D_{ij} \Big/ \exp\left[z_a \sqrt{\ln\left(1 + \frac{Var\left[D_{ij}\right]}{D_{ij}^2}\right)} \right] \qquad UCL_{ij} = D_{ij} \exp\left[z_a \sqrt{\ln\left(1 + \frac{Var\left[D_{ij}\right]}{D_{ij}^2}\right)} \right]$$

Consequently, the confidence interval around *D* was not symmetrical, but had a greater chance of capturing the true density.

The distance surveys in the present study consisted of samples that were likely autocorrelated through time and/or space. We used the naïve estimator of variance for the total number of sightings (*n*) by treating observations as a simple random sample, which pooled both process variation and sampling variation in its estimate. Simulation studies have shown this estimator can overestimate the true sampling variance of count type data when the underlying process exhibits a non-random pattern such as stratification, autocorrelation, or linear trends (Wolter 1985; Skalski et al. 1993). Wolter (1984, 1985) recommended two alternative estimators depending on sample size and the underlying process in the data. These estimators use differences among consecutive observations to remove short-term autocorrelation and local trends. LGL is currently investigating these alternative estimators and offer the reported confidence intervals as first approximations to uncertainty around the density estimates.

Corrections for Sightability

As is standard for line-transect estimation procedures, corrections for the following two parameters were included in the calculation of densities:

- *g*(0), a measure of detection bias. This factor allows for the fact that less than 100% of the animals present along a transect line are detected.
- *f*(0), the reduced probability of detecting an animal with increasing distance from a transect line.

Where species-specific values did not exist, values for similar species were used, and when it was not possible to calculate correction factors using the data collected during this study, values from previous studies were substituted.

The *g*(0) values for cetaceans and pinnipeds were taken from previous studies. The *g*(0) value for cetaceans (0.902) was taken from Forney and Barlow (1998). This g(0) value is based on estimates for humpback, fin, and blue whales that were calculated using data collected off the coast of California. In the absence of better data, these estimates were applied to bowhead, gray and unidentified whales in this study. The estimate for minke whales (0.84) comes from Table 4 in Barlow and Gerrodette (1996). The best available *g*(0) value for pinnipeds (0.6) was taken from Bengtson et al. (2005) based on a study that involved the use of satellite-linked time-depth recorders to study the haulout patterns of ringed seals. In the absence of better data specific to each species, this correction factor was applied to all pinniped species.

The *f*(0) factors used in the analysis were calculated from observations made during this study combined with observations in the Beaufort and Chukchi seas from vessels of similar height in 2006–2011. Only non-seismic period sightings that met the analysis criteria described in Chapter 4 were used for the calculations. These sightings were imported into Distance 6.0 Release 2 where the *f*(0) values were calculated separately for each species or species group and vessel height (Table C.1; Figs. C.1–12). The conventional distance sampling engine in Distance was used to compare half-normal and uniform models with cosine expansions and 0-10% right truncation distances using the AIC model selection criterion.

Table E.1. *f*(0) values used to correct survey data collected during ION's seismic survey. Sightings used in the calculations include sightings from the two ION survey vessels as well as all vessels with observer height <10 m above mean water line in from 2006–2011.

			95% CI	
	n	*f* (0)	Lower	Upper
Bearded seal	212	5.346	4.681	6.106
Bowhead whale	102	0.966	0.825	1.132
Pacific walrus	104	3.307	2.776	3.939
Ringed seal	470	11.274	10.168	12.501
Unidentified mysticete whale	67	0.696	0.607	0.798
Unidentified pinniped	80	4.815	3.976	5.830
Unidentified seal	643	8.844	8.027	9.745

Number of Individuals Exposed

Estimates of the number of individual marine mammals potentially exposed to sound levels ≥160 dB (rms; and other received sound levels) were calculated by multiplying the area of water ensonified to that level by the density of marine mammals estimated by line-transect methods. The area of water ensonified was calculated using MapInfo Geographic Information System (GIS) software to create a buffer that extended around the vessel's trackline to the measured received sound level distances. The area of water covered by the buffer was calculated two different ways: 1) "Including Overlap Area" is the area of water ensonified to the given received sound level where areas exposed on more than one occasion (as a result of crossing tracklines or tracklines that were close enough for the received sound level distances to overlap) were counted repeatedly each time they were exposed; and 2) "Excluding Overlap Area" was the area of water that was exposed to a given received sound level where areas exposed on more than one occasion were counted only once.

Number of Exposures per Individual

The estimated number of potential exposures per individual is the ratio of the two area calculations described above and represents the average number of times a given area of water was exposed to a given received sound level.

Figure C.1. Detection function (red line) plotted on a histogram showing the frequency of counts at the indicated distances of bearded seal sightings from ION vessels and other industry vessels of similar height from 2006–2011. The model selected had a half-normal key function with cosine expansion and right truncation of 5% (500 m) of the sightings, *n* = 212.

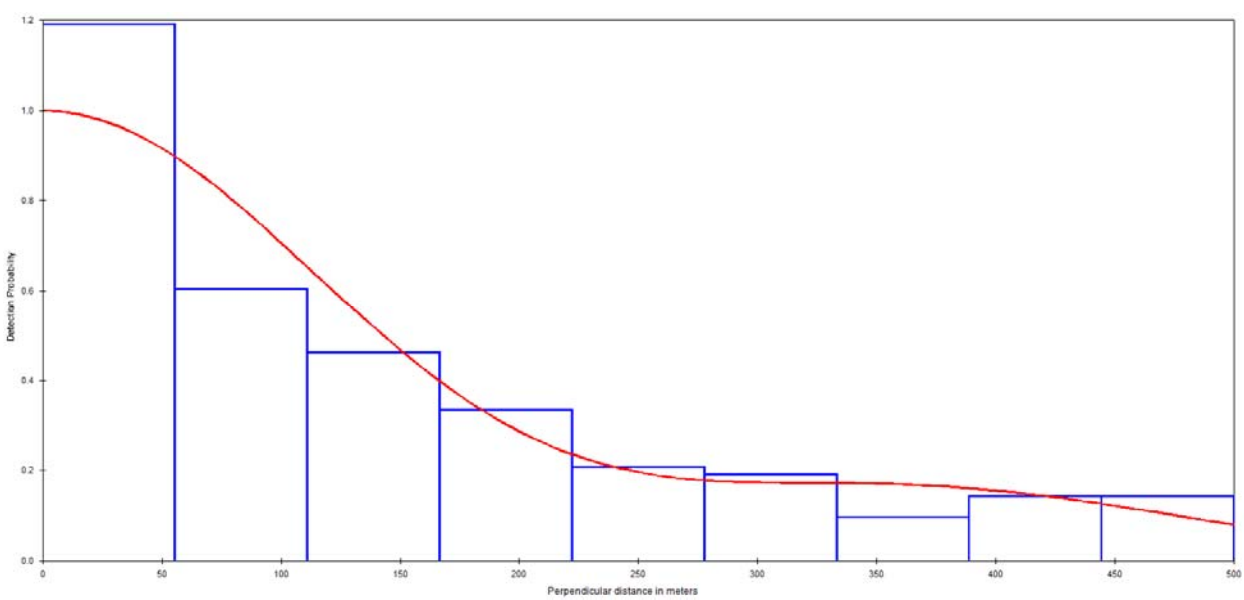


Figure C.2. Detection function (red line) plotted on a histogram showing the frequency of counts at the indicated distances of bowhead whale sightings from ION vessels and other industry vessels of similar height from 2006–2011. The model selected had a half normal key function with cosine expansion with no right truncation, *n* = 102.

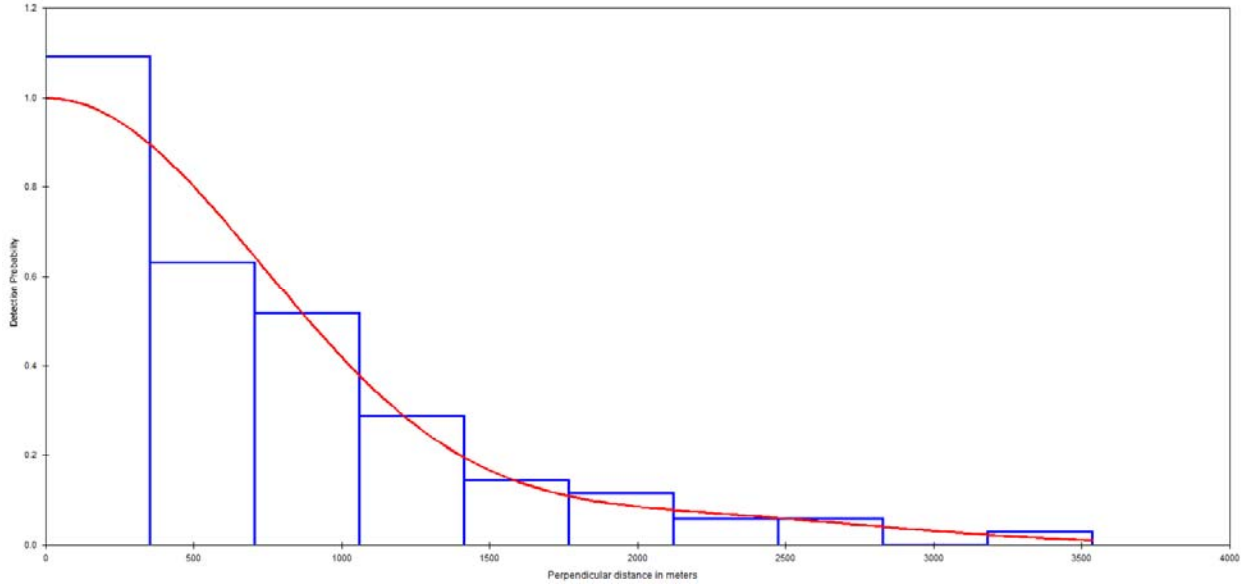


Figure C.3. Detection function (red line) plotted on a histogram showing the frequency of counts at the indicated distances of Pacific walrus sightings from ION vessels and other industry vessels of similar height from 2006–2011. The model selected had a uniform key function with a half normal expansion and a right truncation of 5% (1316 m) of the sightings, *n* = 104.

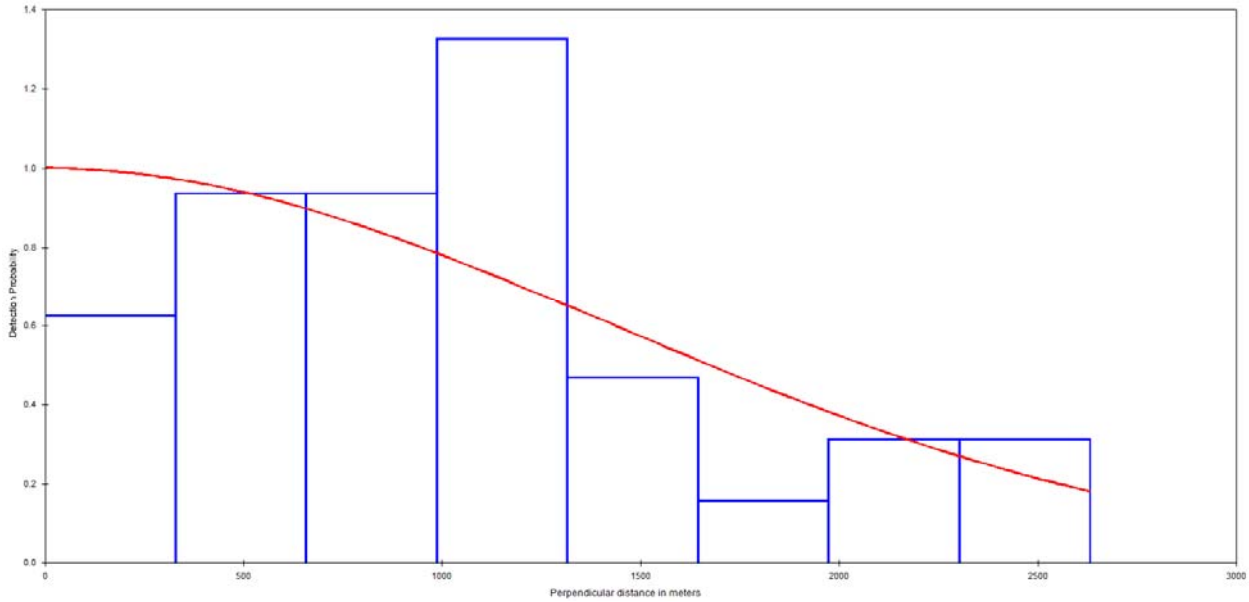


Figure C.4. Detection function (red line) plotted on a histogram showing the frequency of counts at the indicated distances of ringed seal sightings from ION vessels and other industry vessels of similar height from 2006–2011. The model selected had a half normal key function with cosine expansion and a right truncation of 5% (369 m) of the sightings, *n* = 470.

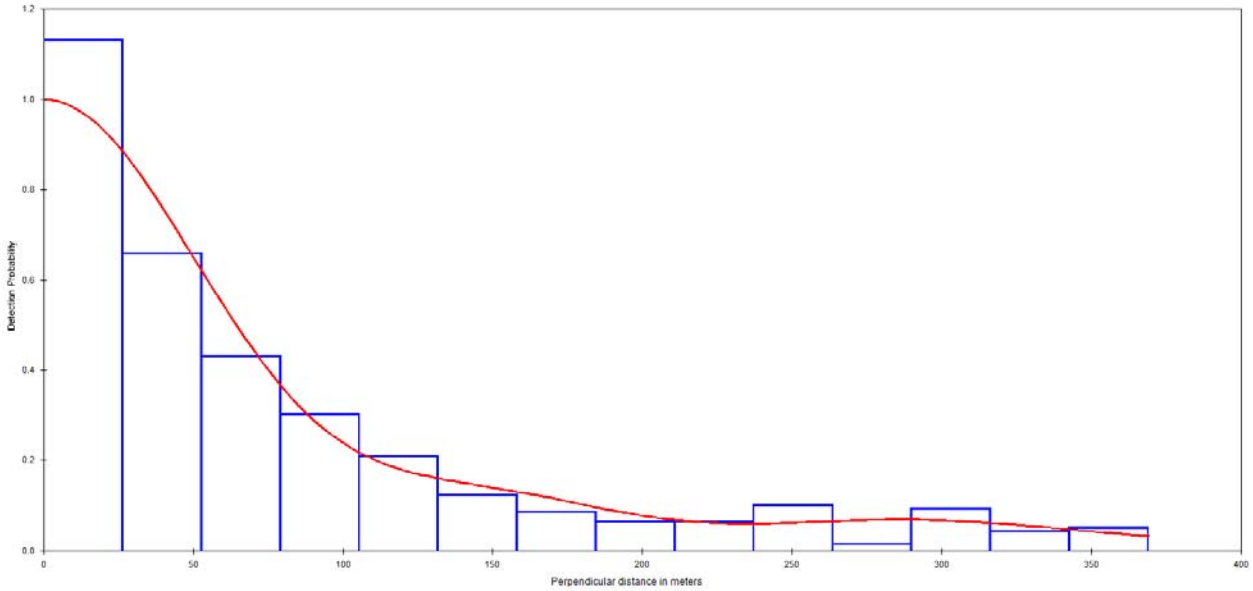


Figure C.5. Detection function (red line) plotted on a histogram showing the frequency of counts at the indicated distances of unidentified mysticete whales from ION vessels and other industry vessels of similar height from 2006–2011. The model selected had a uniform key function with cosine expansion and a right truncation of 5% (2500 m) of the sightings, *n* = 67.

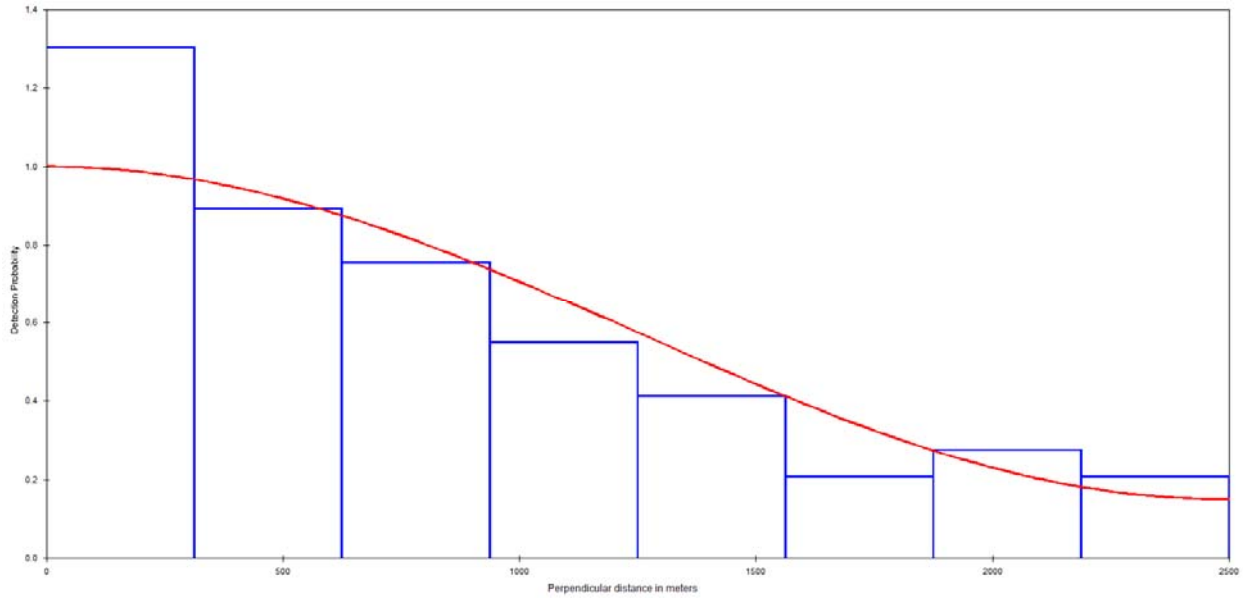


Figure C.6. Detection function (red line) plotted on a histogram showing the frequency of counts at the indicated distances of unidentified pinniped sightings from ION vessels and other industry vessels of similar height from 2006–2011. The model selected had a half normal key function with cosine expansion and a right truncation of 5% (2500 m) of the sightings, *n* = 67.

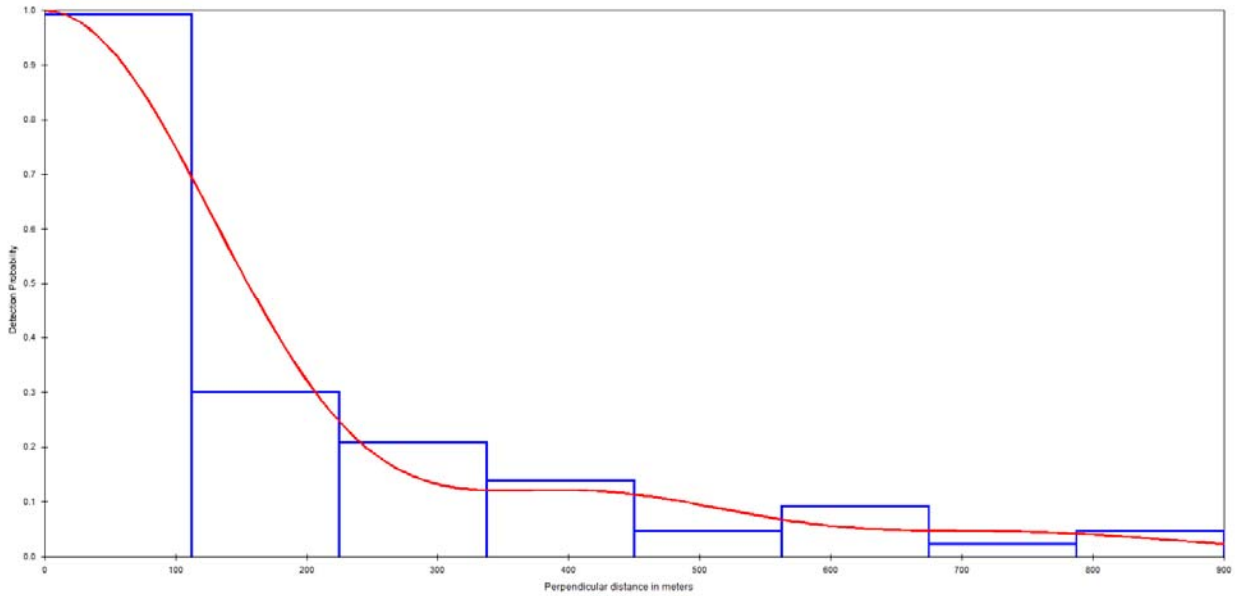
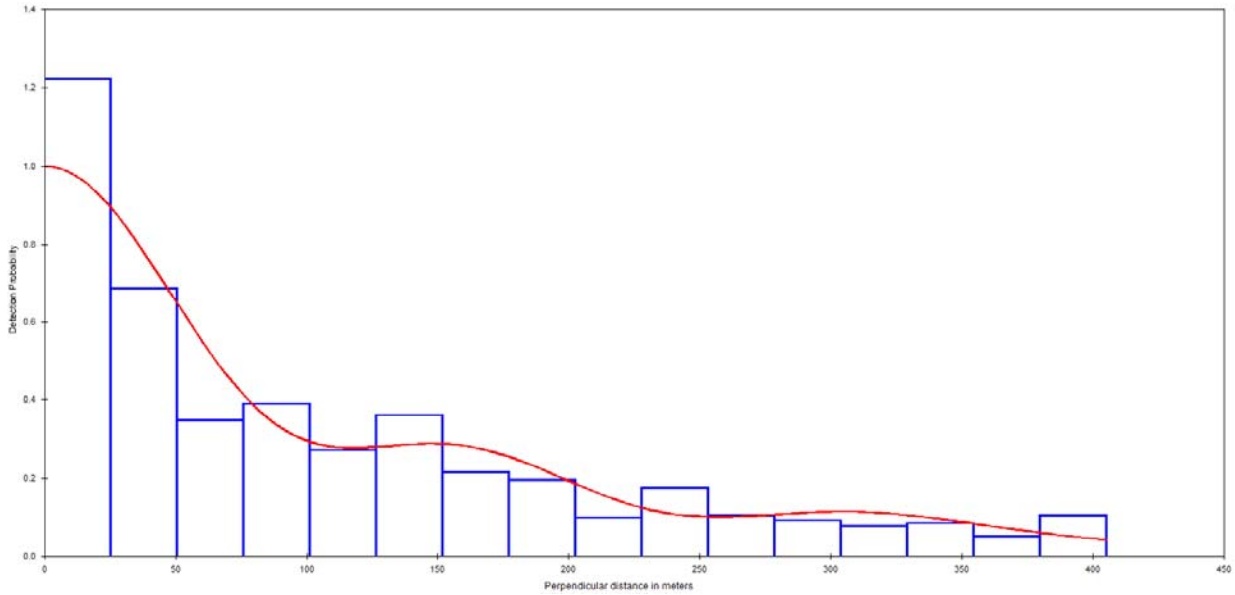


Figure C.7. Detection function (red line) plotted on a histogram showing the frequency of counts at the indicated distances of unidentified seal sightings from “Short” vessels (observer eye height <11 m) in 2006–2011. The model selected had a half normal key function with cosine expansion and a right truncation of 10% (405 m) of the sightings, *n* = 643.



APPENDIX D: BEAUFORT WIND FORCE DEFINITIONS

Wind Speed		Beaufort Wind Force	World Meteorological Organization Terms	Wave Height (m)	Description
Knots	m/s				
<1	<0.5	0	Calm	0	Glassy like a mirror
1-3	0.5-1.5	1	Light air	<0.1	Ripples with the appearance of scales but no whitecaps or foam crests
4-6	2.1-3.1	2	Light breeze	0-0.1	Small wavelets, crests have a glassy appearance but do not break (no whitecaps)
7-10	3.6-5.1	3	Gentle breeze	0.1-0.5	Smooth large wavelets, crests begin to break, occasional/scattered whitecaps
11-16	5.7-8.2	4	Moderate breeze	0.5-1.2	Slight; small fairly frequent whitecaps
17-21	8.7-10.8	5	Fresh breeze	1.2-2.4	Moderate waves becoming longer, some spray, frequent moderate whitecaps
22-27	11.3-13.9	6	Strong breeze	2.4-4	Rough, larger waves, longer-formed waves, many large whitecaps
28-33	14.4-17.0	7	Near gale	4-6	Very rough, large waves forming, white foam crests everywhere, spray is present
34-40	17.5-20.6	8	Gale		
41-47	21.1-24.2	9	Strong gale		
48-55	24.7-28.3	10	Storm	6-9	High
56-63	28.8-32.4	11	Violent storm	11-14	Very high

APPENDIX E: MARINE MAMMAL STATUS AND ABUNDANCE IN THE ARCTIC OCEAN

TABLE E-1. The habitat, abundance (in the Beaufort and Chukchi seas if available), and conservation status of marine mammals inhabiting the survey area.

Species	Habitat	Abundance	ESA[1]	IUCN[2]	CITES[3]
Odontocetes Beluga whale (*Delphinapterus leucas*) (Eastern Chukchi Sea Stock)	Offshore, Coastal, Ice edges	3,710[4]	Not listed	NT	–
Beluga whale (Beaufort Sea Stock)	Offshore, Coastal, Ice edges	39,258[5]	Not listed	NT	–
Harbor Porpoise (*Phocoena phocoena*) (Bering Sea Stock)	Coastal, inland waters, shallow offshore waters	48,215[4] Common (Chukchi)[6] Uncommon (Beaufort)	Not listed	LR-lc	–
Killer whale (*Orcinus orca*)	Widely distributed	Uncommon	Not listed	DD	–
Narwhal (*Monodon monoceros*)	Offshore, Ice edge	Rare[7]	Not listed	NT	–
Mysticetes Bowhead whale (*Balaena mysticetus*)	Pack ice & coastal	10,545[8] 12,631[9]	Endangered	LR-lc	I
Gray whale (*Eschrichtius robustus*) (eastern Pacific population)	Coastal, lagoons, shallow offshore waters	17,500[10] Uncommon (Beaufort)	Not listed	LR-lc	I
Minke whale (*Balaenoptera acutorostrata*)	Shelf, coastal	Rare	Not listed	LR-lc	I
Fin whale (*Balaenoptera physalus*)	Slope, mostly pelagic	Rare	Endangered	EN	I
Humpback whale (*Megaptera novaeangliae*)	Shelf, coastal	Rare	Endangered	LR-lc	I
Pinnipeds Bearded seal (*Erignathus barbatus*)	Pack ice, shallow offshore waters	250,000-300,000[11] 155,000[12]	Threatened	LR-lc	–
Spotted seal (*Phoca largha*)	Pack ice, coastal haulouts, offshore	~141,497[13]	Arctic pop. segments not listed	DD	–
Ringed seal (*Pusa hispida*)	Landfast & pack ice, offshore	(Chukchi) ~208,000-252,000[14] (Beaufort) 18,000 [15] 326,500 [16]	Threatened	LR-lc	–
Ribbon seal (*Histriophoca fasciata*)	pack ice, offshore	90-100,000[17] Uncommon (Beaufort)	Not Listed	DD	–
Pacific Walrus (*Odobenus rosmarus*)	Coastal, Pack ice, ice floes	~200,000 to 246,000[18]	Candidate for listing	–	II
Ursids Polar Bear (*Ursus maritimus*)	Pack ice	4700[19]	Threatened	–	–

[1] U.S. Endangered Species Act.

[2] Red List of Threatened Species (IUCN 2010). Codes for IUCN classifications: CR = Critically Endangered; EN = Endangered; VU = Vulnerable; LR = Lower Risk (nt = Near Threatened; lc = Least Concern); DD = Data Deficient

[3] Convention on International Trade in Endangered Species of Wild Fauna and Flora (UNEP-WCMC 2004)

[4] Allen and Angliss (2012)
[5] Beaufort Sea population (IWC 2000, Allen and Angliss 2012)
[6] Vessel-based observations from Industry activities in 2006–2010 (Hartin et al. 2011)
[7] Population in Baffin Bay and the Canadian arctic archipelago is ~60,000 (DFO 2004); very few enter the Beaufort Sea
[8] 2001 B-C-B Bowhead population estimate (Zeh and Punt 2005)
[9] 2004 B-C-B Bowhead population estimate (Koski et al. 2010)
[10] North Pacific gray whale population (Rugh 2003 *in* Keller and Gerber 2004) ; see also Rugh et al. (2005)
[11] Alaska population (MMS 1996)
[12] Beringia Distinct Population Segment (NMFS 2010a)
[13] Central and Eastern Bering Sea stock based on aerial surveys in 2007 (Allen and Angliss 2012)
[14] Eastern Chukchi Sea population (Bengtson et al. 2005)
[15] Beaufort Sea minimum estimate with no correction factor based on aerial surveys in 1996-1999 (Frost et al. 2002 *in* Allen and Angliss 2010)
[16] Alaskan Beaufort Sea population estimate (Amstrup 1995)
[17] Bering Sea, (Burns 1981a)
[18] Pacific walrus population, 1975-1990 (Allen and Angliss 2011).
[19] Chukchi Sea and northern and southern Beaufort Sea populations combined (Aars et al. 2006; USFWS 2008).

APPENDIX F: MARINE MAMMAL MONITORING RESULTS

Data that met the Analysis Criteria used in Chapter 5

Data presented below met the analysis criteria and was used to calculate sighting rates and closest points of approach (CPAs). The analysis criteria are described in detail in Chapter 4 of this report.

Beaufort Wind Force

TABLE F.1. Cetacean effort (km) in the Beaufort Sea by Beaufort wind force and seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* that met the analysis criteria during ION's seismic survey, 12 October – 16 November 2012.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)	Beaufort Wind Force						
	0	**1**	**2**	**3**	**4**	**5**	***Total***
***Geo Arctic* Full Array**	0	17	67	126	150	131	***490***
***Geo Arctic* Mitigation Gun**	0	4	5	22	23	16	***69***
***Geo Arctic* Non-seismic**	0	10	139	75	143	51	***417***
***Geo Arctic* Overall**	***0***	***31***	***211***	***223***	***315***	***198***	***977***
***Polar Prince* ≥160**	0	18	0	9	65	42	***135***
***Polar Prince* 159-120**	0	42	4	41	60	31	***177***
***Polar Prince* <120**	0	118	119	108	122	300	***765***
***Polar Prince* Overall**	***0***	***178***	***123***	***158***	***247***	***372***	***1078***

TABLE F.2. Pinniped effort (km) in the Beaufort Sea by Beaufort wind force and seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* that met the analysis criteria during ION's seismic survey, 12 October – 16 November 2012.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)	Beaufort Wind Force						
	0	**1**	**2**	**3**	**4**	**5**	***Total***
***Geo Arctic* Full Array**	0	17	67	126	150	131	***490***
***Geo Arctic* Mitigation Gun**	0	4	5	22	23	16	***69***
***Geo Arctic* Non-seismic**	0	16	139	78	153	61	***447***
***Geo Arctic* Overall**	***0***	***37***	***211***	***226***	***325***	***208***	***1007***
***Polar Prince* ≥160**	0	18	0	10	66	42	***136***
***Polar Prince* 159-120**	0	45	4	54	83	34	***220***
***Polar Prince* <120**	0	131	119	108	162	300	***818***
***Polar Prince* Overall**	***0***	***194***	***123***	***171***	***311***	***375***	***1174***

TABLE F.3. Cetacean effort (km) in the Chukchi Sea by Beaufort wind force and seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* that met the analysis criteria during ION's seismic survey, 12 October – 16 November 2012.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)	Beaufort Wind Force						
	0	1	2	3	4	5	*Total*
***Geo Arctic* Full Array**	0	11	29	0	0	0	***40***
***Geo Arctic* Mitigation Gun**	0	0	5	0	2	0	***7***
***Geo Arctic* Non-seismic**	0	77	14	102	17	102	***312***
***Geo Arctic* Overall**	***0***	***88***	***48***	***102***	***18***	***102***	***359***
***Polar Prince* ≥160**	4	15	31	0	0	0	***50***
***Polar Prince* 159-120**	0	0	0	0	0	0	***0***
***Polar Prince* <120**	0	91	60	58	19	185	***413***
***Polar Prince* Overall**	***4***	***106***	***91***	***58***	***19***	***185***	***463***

TABLE F.4. Pinniped effort (km) in the Chukchi Sea by Beaufort wind force and seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* that met the analysis criteria during ION's seismic survey, 12 October – 16 November 2012.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)	Beaufort Wind Force						
	0	1	2	3	4	5	*Total*
***Geo Arctic* Full Array**	0	11	29	0	0	0	***40***
***Geo Arctic* Mitigation Gun**	0		5	0	2	0	***7***
***Geo Arctic* Non-seismic**	0	77	15	102	20	102	***316***
***Geo Arctic* Overall**	***0***	***88***	***49***	***102***	***22***	***102***	***363***
***Polar Prince* ≥160**	4	15	31	0	0	0	***50***
***Polar Prince* 159-120**	0	0	0	0	0	0	***0***
***Polar Prince* <120**	0	96	62	58	19	185	***420***
***Polar Prince* Overall**	***4***	***112***	***92***	***58***	***19***	***185***	***470***

TABLE F.5. Cetacean sightings in the Beaufort Sea by Beaufort wind force and seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* that met the analysis criteria during ION's seismic survey, 12 October – 16 November 2012.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)	**Beaufort Wind Force**						
	0	**1**	**2**	**3**	**4**	**5**	***Total***
***Geo Arctic* Full Array**	0	0	0	0	0	0	***0***
***Geo Arctic* Mitigation Gun**	0	0	0	0	0	0	***0***
***Geo Arctic* Non-seismic**	0	0	0	0	0	0	***0***
***Geo Arctic* Overall**	***0***	***0***	***0***	***0***	***0***	***0***	***0***
***Polar Prince* ≥160**	0	0	0	0	0	0	***0***
***Polar Prince* 159-120**	0	0	0	0	0	0	***0***
***Polar Prince* <120**	0	0	1	0	0	0	***1***
***Polar Prince* Overall**	***0***	***0***	***1***	***0***	***0***	***0***	***1***

TABLE F.6. Seal sightings in the Beaufort Sea by Beaufort wind force and seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* that met the analysis criteria during ION's seismic survey, 12 October – 16 November 2012. Includes both seals in the water and on ice.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)	**Beaufort Wind Force**						
	0	**1**	**2**	**3**	**4**	**5**	***Total***
***Geo Arctic* Full Array**	0	0	0	0	0	0	***0***
***Geo Arctic* Mitigation Gun**	0	0	0	0	0	0	***0***
***Geo Arctic* Non-seismic**	0	0	67	1	2	0	***70***
***Geo Arctic* Overall**	***0***	***0***	***67***	***1***	***2***	***0***	***70***
***Polar Prince* ≥160**	0	0	0	0	0	0	***0***
***Polar Prince* 159-120**	0	3	0	0	0	0	***3***
***Polar Prince* <120**	0	23	3	1	0	0	***27***
***Polar Prince* Overall**	***0***	***26***	***3***	***1***	***0***	***0***	***30***

TABLE F.7. Cetacean sightings in the Chukchi Sea by Beaufort wind force and seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* that met the analysis criteria during ION's seismic survey, 12 October – 16 November 2012.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)	Beaufort Wind Force						
	0	**1**	**2**	**3**	**4**	**5**	***Total***
***Geo Arctic* Full Array**	0	2	14	0	0	0	***16***
***Geo Arctic* Mitigation Gun**	0	0	0	0	1	0	***1***
***Geo Arctic* Non-seismic**	0	0	0	2	0	1	***3***
***Geo Arctic* Overall**	***0***	***2***	***14***	***2***	***1***	***1***	***20***
***Polar Prince* ≥160**	0	1	13	0	0	0	***14***
***Polar Prince* 159-120**	0	0	0	0	0	0	***0***
***Polar Prince* <120**	0	1	0	0	0	0	***1***
***Polar Prince* Overall**	***0***	***2***	***13***	***0***	***0***	***0***	***15***

TABLE F.8. Seal sightings (in water) in the Chukchi Sea by Beaufort wind force and seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* that met the analysis criteria during ION's seismic survey, 12 October – 16 November 2012. Includes both seals in the water and on ice.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)	Beaufort Wind Force						
	0	**1**	**2**	**3**	**4**	**5**	***Total***
***Geo Arctic* Full Array**	0	2	3	0	0	0	***5***
***Geo Arctic* Mitigation Gun**	0	0	0	0	0	0	***0***
***Geo Arctic* Non-seismic**	0	61	0	13	0	0	***74***
***Geo Arctic* Overall**	***0***	***63***	***3***	***13***	***0***	***0***	***79***
***Polar Prince* ≥160**	2	0	1	0	0	0	***3***
***Polar Prince* 159-120**	0	0	0	0	0	0	***0***
***Polar Prince* <120**	0	25	5	5	0	0	***35***
***Polar Prince* Overall**	***2***	***25***	***6***	***5***	***0***	***0***	***38***

TABLE F.9. Pacific walrus sightings in the Chukchi Sea by Beaufort wind force and seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* that met the analysis criteria during ION's seismic survey, 12 October – 16 November 2012. Includes Pacific walruses in the water and on ice.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)	**Beaufort Wind Force**						
	0	**1**	**2**	**3**	**4**	**5**	***Total***
***Geo Arctic* Full Array**	0	0	0	0	0	0	***0***
***Geo Arctic* Mitigation Gun**	0	0	0	0	0	0	***0***
***Geo Arctic* Non-seismic**	0	137	0	0	0	0	***137***
***Geo Arctic* Overall**	***0***	***137***	***0***	***0***	***0***	***0***	***137***
***Polar Prince* ≥160**	0	0	0	0	0	0	***0***
***Polar Prince* 159-120**	0	0	0	0	0	0	***0***
***Polar Prince* <120**	0	23	0	0	0	0	***23***
***Polar Prince* Overall**	***0***	***23***	***0***	***0***	***0***	***0***	***23***

TABLE F.10. Polar bear sightings in the Chukchi Sea by Beaufort wind force and seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* that met the analysis criteria during ION's seismic survey, 12 October – 16 November 2012. Includes polar bears on ice.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)	**Beaufort Wind Force**						
	0	**1**	**2**	**3**	**4**	**5**	***Total***
***Geo Arctic* Full Array**	0	3	2	0	0	0	***5***
***Geo Arctic* Mitigation Gun**	0	0	0	0	0	0	***0***
***Geo Arctic* Non-seismic**	0	0	0	0	0	0	***0***
***Geo Arctic* Overall**	***0***	***3***	***2***	***0***	***0***	***0***	***5***
***Polar Prince* ≥160**	1	2	1	0	0	0	***4***
***Polar Prince* 159-120**	0	0	0	0	0	0	***0***
***Polar Prince* <120**	0	0	0	0	1	0	***1***
***Polar Prince* Overall**	***1***	***2***	***1***	***0***	***1***	***0***	***5***

Number of PSOs

TABLE F.11. Cetacean effort (km) in the Beaufort Sea by the number of PSOs on watch and seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* that met the analysis criteria during ION's seismic survey, 12 October – 16 November 2012.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)	Number of PSOs			
	1	2	3	*Total*
***Geo Arctic* Full Array**	0	101	389	***490***
***Geo Arctic* Mitigation Gun**	0	15	54	***69***
***Geo Arctic* Non-seismic**	5	50	362	***417***
***Geo Arctic* Overall**	***5***	***167***	***806***	***977***
***Polar Prince* ≥160**	0	135	0	***135***
***Polar Prince* 159-120**	0	177	0	***177***
***Polar Prince* <120**	40	716	10	***765***
***Polar Prince* Overall**	***40***	***1028***	***10***	***1078***

TABLE F.12. Pinniped effort (km) in the Beaufort Sea by the number of PSOs on watch and seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* that met the analysis criteria during ION's seismic survey, 12 October – 16 November 2012.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)	Number of PSOs			
	1	2	3	*Total*
***Geo Arctic* Full Array**	0	101	389	***490***
***Geo Arctic* Mitigation Gun**	0	15	54	***69***
***Geo Arctic* Non-seismic**	5	59	384	***447***
***Geo Arctic* Overall**	***5***	***175***	***827***	***1007***
***Polar Prince* ≥160**	0	136	0	***136***
***Polar Prince* 159-120**	0	220	0	***220***
***Polar Prince* <120**	40	769	10	***818***
***Polar Prince* Overall**	***40***	***1125***	***10***	***1174***

TABLE F.13. Cetacean effort (km) in the Chukchi Sea by the number of PSOs on watch and seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* that met the analysis criteria during ION's seismic survey, 12 October – 16 November 2012.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)	Number of PSOs			
	1	2	3	*Total*
***Geo Arctic* Full Array**	0	7	33	***40***
***Geo Arctic* Mitigation Gun**	0	0	6	***7***
***Geo Arctic* Non-seismic**	0	127	185	***312***
***Geo Arctic* Overall**	***0***	***135***	***224***	***359***
***Polar Prince* ≥160**	0	33	17	***50***
***Polar Prince* 159-120**	0	0	0	***0***
***Polar Prince* <120**	9	326	77	***413***
***Polar Prince* Overall**	***9***	***359***	***94***	***463***

TABLE F.14. Pinniped effort (km) in the Chukchi Sea by the number of PSOs on watch and seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* that met the analysis criteria during ION's seismic survey, 12 October – 16 November 2012.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)	Number of PSOs			
	1	2	3	*Total*
***Geo Arctic* Full Array**	0	7	33	***40***
***Geo Arctic* Mitigation Gun**	0	0	6	***7***
***Geo Arctic* Non-seismic**	0	132	185	***316***
***Geo Arctic* Overall**	***0***	***139***	***224***	***363***
***Polar Prince* ≥160**	0	33	17	***50***
***Polar Prince* 159-120**	0	0	0	***0***
***Polar Prince* <120**	9	333	77	***420***
***Polar Prince* Overall**	***9***	***366***	***94***	***470***

TABLE F.15. Cetacean sightings in the Beaufort Sea by the number of PSOs on watch and seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* that met the analysis criteria during ION's seismic survey, 12 October – 16 November 2012.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)	Number of PSOs			
	1	2	3	*Total*
***Geo Arctic* Full Array**	0	0	0	***0***
***Geo Arctic* Mitigation Gun**	0	0	0	***0***
***Geo Arctic* Non-seismic**	0	0	0	***0***
***Geo Arctic* Overall**	***0***	***0***	***0***	***0***
***Polar Prince* ≥160**	0	0	0	***0***
***Polar Prince* 159-120**	0	0	0	***0***
***Polar Prince* <120**	0	1	0	***1***
***Polar Prince* Overall**	***0***	***1***	***0***	***1***

TABLE F.16. Seal sightings in the Beaufort Sea by the number of PSOs on watch and seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* that met the analysis criteria during ION's seismic survey, 12 October – 16 November 2012. Includes seals in the water and on ice.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)	Number of PSOs			
	1	2	3	*Total*
***Geo Arctic* Full Array**	0	0	0	***0***
***Geo Arctic* Mitigation Gun**	0	0	0	***0***
***Geo Arctic* Non-seismic**	0	1	69	***70***
***Geo Arctic* Overall**	***0***	***1***	***69***	***70***
***Polar Prince* ≥160**	0	0	0	***0***
***Polar Prince* 159-120**	0	3	0	***3***
***Polar Prince* <120**	4	23	0	***27***
***Polar Prince* Overall**	***4***	***26***	***0***	***30***

TABLE F.17. Cetacean sightings in the Chukchi Sea by the number of PSOs on watch and seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* that met the analysis criteria during ION's seismic survey, 12 October – 16 November 2012.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)	Number of PSOs			
	1	2	3	*Total*
***Geo Arctic* Full Array**	0	5	11	***16***
***Geo Arctic* Mitigation Gun**	0		1	***1***
***Geo Arctic* Non-seismic**	0	1	2	***3***
***Geo Arctic* Overall**	***0***	***6***	***14***	***20***
***Polar Prince* ≥160**	0	3	11	***14***
***Polar Prince* 159-120**	0	0	0	***0***
***Polar Prince* <120**	0	0	1	***1***
***Polar Prince* Overall**	***0***	***3***	***12***	***15***

TABLE F.18. Seal sightings in the Chukchi Sea by the number of PSOs on watch and seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* that met the analysis criteria during ION's seismic survey, 12 October – 16 November 2012. Includes seals in the water and on ice.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)	Number of PSOs			
	1	2	3	*Total*
***Geo Arctic* Full Array**	0	2	3	***5***
***Geo Arctic* Mitigation Gun**	0	0	0	***0***
***Geo Arctic* Non-seismic**	0	9	65	***74***
***Geo Arctic* Overall**	***0***	***11***	***68***	***79***
***Polar Prince* ≥160**	0	3	0	***3***
***Polar Prince* 159-120**	0	0	0	***0***
***Polar Prince* <120**	3	17	15	***35***
***Polar Prince* Overall**	***3***	***20***	***15***	***38***

TABLE F.19. Pacific walrus sightings in the Chukchi Sea by the number of PSOs on watch and seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* that met the analysis criteria during ION's seismic survey, 12 October – 16 November 2012. Includes Pacific walruses in the water and on ice.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)	Number of PSOs			
	1	2	3	*Total*
***Geo Arctic* Full Array**	0	0	0	***0***
***Geo Arctic* Mitigation Gun**	0	0	0	***0***
***Geo Arctic* Non-seismic**	0	127	10	***137***
***Geo Arctic* Overall**	***0***	***127***	***10***	***137***
***Polar Prince* ≥160**	0	0	0	***0***
***Polar Prince* 159-120**	0	0	0	***0***
***Polar Prince* <120**	0	0	23	***23***
***Polar Prince* Overall**	***0***	***0***	***23***	***23***

TABLE F.20. Polar bear sightings in the Chukchi Sea by the number of PSOs on watch and seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* that met the analysis criteria during ION's seismic survey, 12 October – 16 November 2012. Includes polar bears on ice.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)	Number of PSOs			
	1	2	3	*Total*
***Geo Arctic* Full Array**	0	0	5	***5***
***Geo Arctic* Mitigation Gun**	0	0	0	***0***
***Geo Arctic* Non-seismic**	0	0	0	***0***
***Geo Arctic* Overall**	***0***	***0***	***5***	***5***
***Polar Prince* ≥160**	0	4	0	***4***
***Polar Prince* 159-120**	0	0	0	***0***
***Polar Prince* <120**	0	1	0	***1***
***Polar Prince* Overall**	***0***	***5***	***0***	***5***

Seismic Status or Received Sound Level

TABLE F.21. Cetacean effort (km) in the Beaufort Sea by seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* that met the analysis criteria during ION's seismic survey, 12 October – 16 November 2012.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)		Effort (km)
Geo Arctic	**Full Array**	490
Geo Arctic	**Mitigation Gun**	69
Geo Arctic	**Non-seismic**	417
	***Geo Arctic* Overall**	***977***
Polar Prince	**≥160**	135
Polar Prince	**159-120**	177
Polar Prince	**<120**	765
	***Polar Prince* Overall**	***1078***

TABLE F.22. Pinniped effort (km) in the Beaufort Sea by seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* that met the analysis criteria during ION's seismic survey, 12 October – 16 November 2012.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)		Effort (km)
Geo Arctic	**Full Array**	490
Geo Arctic	**Mitigation Gun**	69
Geo Arctic	**Non-seismic**	447
	***Geo Arctic* Overall**	***1007***
Polar Prince	**≥160**	136
Polar Prince	**159-120**	220
Polar Prince	**<120**	818
	***Polar Prince* Overall**	***1174***

TABLE F.23. Cetacean effort (km) in the Chukchi Sea by seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* that met the analysis criteria during ION's seismic survey, 12 October – 16 November 2012.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)	Effort (km)
***Geo Arctic* Full Array**	40
***Geo Arctic* Mitigation Gun**	7
***Geo Arctic* Non-seismic**	312
***Geo Arctic* Overall**	***359***
***Polar Prince* ≥160**	50
***Polar Prince* 159-120**	0
***Polar Prince* <120**	413
***Polar Prince* Overall**	***463***

TABLE F.24. Pinniped effort (km) in the Chukchi Sea by seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* that met the analysis criteria during ION's seismic survey, 12 October – 16 November 2012

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)	Effort (km)
***Geo Arctic* Full Array**	40
***Geo Arctic* Mitigation Gun**	7
***Geo Arctic* Non-seismic**	316
***Geo Arctic* Overall**	***363***
***Polar Prince* ≥160**	50
***Polar Prince* 159-120**	0
***Polar Prince* <120**	420
***Polar Prince* Overall**	***470***

TABLE F.25. Cetacean sightings in the Beaufort Sea by seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* that met the analysis criteria during ION's seismic survey, 12 October – 16 November 2012.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)	Number of Sightings
***Geo Arctic* Full Array**	0
***Geo Arctic* Mitigation Gun**	0
***Geo Arctic* Non-seismic**	0
***Geo Arctic* Overall**	***0***
***Polar Prince* ≥160**	0
***Polar Prince* 159-120**	0
***Polar Prince* <120**	1
***Polar Prince* Overall**	***1***

TABLE F.26. Seal sightings in the Beaufort Sea by seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* that met the analysis criteria during ION's seismic survey, 12 October – 16 November 2012. Includes seals in the water and on ice.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)	Effort (km)
***Geo Arctic* Full Array**	0
***Geo Arctic* Mitigation Gun**	0
***Geo Arctic* Non-seismic**	70
***Geo Arctic* Overall**	***70***
***Polar Prince* ≥160**	0
***Polar Prince* 159-120**	3
***Polar Prince* <120**	27
***Polar Prince* Overall**	***30***

TABLE F.27. Cetacean sightings in the Chukchi Sea by seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* that met the analysis criteria during ION's seismic survey, 12 October – 16 November 2012.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)	Number of Sightings
***Geo Arctic* Full Array**	16
***Geo Arctic* Mitigation Gun**	1
***Geo Arctic* Non-seismic**	3
***Geo Arctic* Overall**	***20***
***Polar Prince* ≥160**	14
***Polar Prince* 159-120**	0
***Polar Prince* <120**	1
***Polar Prince* Overall**	***15***

TABLE F.28. Seal sightings in the Chukchi Sea by seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* that met the analysis criteria during ION's seismic survey, 12 October – 16 November 2012. Includes seals in the water and on ice.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)	Number of Sightings
***Geo Arctic* Full Array**	5
***Geo Arctic* Mitigation Gun**	0
***Geo Arctic* Non-seismic**	74
***Geo Arctic* Overall**	***79***
***Polar Prince* ≥160**	3
***Polar Prince* 159-120**	0
***Polar Prince* <120**	35
***Polar Prince* Overall**	***38***

TABLE F.29. Pacific walrus sightings in the Chukchi Sea by seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* that met the analysis criteria during ION's seismic survey, 12 October – 16 November 2012. Includes Pacific walrus in the water and on ice.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)	Number of Sightings
***Geo Arctic* Full Array**	0
***Geo Arctic* Mitigation Gun**	0
***Geo Arctic* Non-seismic**	137
***Geo Arctic* Overall**	***137***
***Polar Prince* ≥160**	0
***Polar Prince* 159-120**	0
***Polar Prince* <120**	23
***Polar Prince* Overall**	***23***

TABLE F.30. Polar bear sightings in the Chukchi Sea by seismic activity status from the *Geo Arctic* or received sound level from the *Polar Prince* that met the analysis criteria during ION's seismic survey, 12 October – 16 November 2012. Includes polar bears on ice.

Vessel and Seismic Status or Received Sound Level (dB re 1μPa rms)	Number of Sightings
***Geo Arctic* Full Array**	5
***Geo Arctic* Mitigation Gun**	0
***Geo Arctic* Non-seismic**	0
***Geo Arctic* Overall**	***5***
***Polar Prince* ≥160**	4
***Polar Prince* 159-120**	0
***Polar Prince* <120**	1
***Polar Prince* Overall**	***5***

APPENDIX G: ALL MARINE MAMMAL DETECTIONS

Table G.1. All marine mammal detections during ION's seismic survey in the Arctic Ocean, 12 October – 16 November 2012.

Sea	Sighting ID[a]	Species	No.[b]	Date (AKDT)	Lat (°N)	Long (°W)	Initial Sighting Dist.[c] (m)	CPA[d,e] (m)	Bf[f]	Behav.[g]	Rxn to Vessel[h]	Vessel Activity[i]	Array Vol. (in^3)	Dup. Sight.[j]
Chukchi	POL201210	Unidentified mysticete w hale	2	10/12/2012 17:25:44	66.71	-168.51	700	700	X	BL	NO	OT	X	N
Chukchi	GEO20123	Unidentified mysticete w hale	2	10/14/2012 11:44:30	71.32	-161.15	2984	3030	5	BL	NO	OT	0	N
Beaufort	POL201211	Unidentified mysticete w hale	1	10/15/2012 10:12:45	70.87	-146.52	2725	2725	2	BL	NO	OT	X	N
Beaufort	GEO20124	Unidentified seal	1	10/15/2012 15:52:41	71.03	-146.45	207	254	3	LO	LO	OT	0	N
Beaufort	GEO20125	Ringed seal	1	10/18/2012 09:21:55	69.58	-138.63	15	67	4	LO	LO	JO	0	N
Beaufort	GEO20126	Ringed seal	1	10/18/2012 15:30:15	69.90	-139.33	10	62	4	LO	LO	OT	0	N
Beaufort	POL201212	Beluga w hale	125	10/19/2012 14:47:57	70.16	-140.79	4000	4000	5	TR	NO	OT	X	N
Beaufort	POL201213	Ringed seal	1	10/25/2012 08:54:45	69.41	-138.70	30	30	1	MI	NO	OT	X	N
Beaufort	POL201214	Ringed seal	45	10/25/2012 11:56:09	69.56	-138.94	900	900	2	RE	NO	OT	X	N
Beaufort	GEO20127	Bearded seal	1	10/25/2012 14:37:19	70.45	-144.33	110	144	4	SW	LO	OT	0	N
Beaufort	POL201215	Bearded seal	1	10/28/2012 10:08:12	69.56	-138.94	200	200	7.1	LG	NO	AN	X	N
Beaufort	POL201220	Unidentified seal	1	11/05/2012 11:10:31	72.14	-151.00	1228	1228	2	RE	NO	OT	X	N
Beaufort	POL201221	Unidentified seal	1	11/05/2012 13:32:09	72.00	-150.54	359	359	3	LO	NO	OT	X	N
Beaufort	POL201222	Ringed seal	1	11/09/2012 12:50:55	70.29	-141.49	15	15	1	SW	NO	OT	X	N
Beaufort	POL201223	Ringed seal	10	11/09/2012 13:03:51	70.26	-141.51	2080	2080	1	RE	NO	OT	X	N
Beaufort	POL201224	Bearded seal	1	11/09/2012 13:27:33	70.20	-141.49	1687	1687	1	RE	NO	OT	X	N
Beaufort	POL201225	Unidentified seal	1	11/09/2012 18:32:45	70.00	-141.74	200	200	1	RE	NO	OT	X	N
Beaufort	GEO20129	Unidentified seal	1	11/11/2012 11:24:50	71.10	-148.34	400	374	2	LO	LO	TI	0	N
Beaufort	POL201226	Ringed seal	1	11/11/2012 12:44:52	71.13	-148.89	310	310	1	LO	NO	OT	X	N
Beaufort	POL201227	Ringed seal	1	11/11/2012 12:49:34	71.14	-148.93	679	679	1	RE	NO	OT	X	N
Beaufort	POL201228	Ringed seal	2	11/11/2012 13:12:00	71.15	-149.08	426	426	2	LO	NO	OT	X	N
Beaufort	POL201229	Ringed seal	3	11/11/2012 13:23:37	71.15	-149.16	523	523	2	LO	LO	OT	X	N

Table G.1 (cont). All marine mammal detections during ION's seismic survey in the Arctic Ocean, 12 October – 16 November 2012.

Sea	Sighting ID[a]	Species	No.[b]	Date (AKDT)	Lat (°N)	Long (°W)	Initial Sighting Dist.[c] (m)	CPA[d,e] (m)	Bf[f]	Behav.[g]	Rxn to Vessel[h]	Vessel Activity[i]	Array Vol. (in^3)	Dup. Sight.[j]
Beaufort	GEO201210	Unidentified seal	1	11/11/2012 13:27:45	71.15	-149.17	178	218	2	LO	NO	TI	0	N
Beaufort	GEO201211	Unidentified seal	1	11/11/2012 13:28:58	71.15	-149.18	178	225	2	LO	NO	TI	0	N
Beaufort	GEO201212	Unidentified seal	1	11/11/2012 13:29:14	71.15	-149.18	500	553	2	LO	SP	TI	0	N
Beaufort	GEO201213	Unidentified seal	1	11/11/2012 13:35:03	71.16	-149.22	125	158	2	LO	NO	TI	0	N
Beaufort	POL201230	Ringed seal	2	11/11/2012 13:35:23	71.16	-149.23	967	967	1	DI	NO	OT	X	N
Beaufort	POL201231	Ringed seal	2	11/11/2012 13:40:57	71.16	-149.27	679	679	1	LO	NO	OT	X	N
Beaufort	GEO201214	Unidentified seal	1	11/11/2012 13:45:18	71.16	-149.28	250	280	2	LO	NO	TI	0	N
Beaufort	GEO201215	Unidentified seal	1	11/11/2012 13:47:46	71.16	-149.30	500	528	2	LO	NO	TI	0	N
Beaufort	POL201232	Ringed seal	6	11/11/2012 13:50:50	71.16	-149.34	600	600	1	SA	NO	OT	X	N
Beaufort	GEO201216	Unidentified seal	1	11/11/2012 13:54:36	71.17	-149.35	1072	800	2	LO	NO	TI	0	N
Beaufort	GEO201217	Unidentified seal	1	11/11/2012 13:59:25	71.17	-149.38	1000	1027	2	LO	NO	TI	0	N
Beaufort	POL201233	Ringed seal	1	11/11/2012 14:01:45	71.17	-149.41	100	100	1	SA	NO	OT	X	N
Beaufort	GEO201218	Unidentified seal	1	11/11/2012 14:02:49	71.17	-149.40	582	610	2	LO	NO	TI	0	Y
Beaufort	GEO201219	Unidentified seal	1	11/11/2012 14:07:35	71.17	-149.43	650	678	2	LO	NO	TI	0	N
Beaufort	POL201234	Ringed seal	1	11/11/2012 14:08:01	71.17	-149.45	258	258	1	LO	LO	OT	X	N
Beaufort	GEO201220	Unidentified seal	1	11/11/2012 14:14:33	71.17	-149.48	582	610	2	LO	NO	TI	0	N
Beaufort	GEO201221	Unidentified seal	1	11/11/2012 14:18:29	71.18	-149.51	346	385	2	LO	NO	TI	0	N
Beaufort	POL201235	Bearded seal	1	11/11/2012 14:20:24	71.18	-149.54	679	359	1	SA	NO	OT	X	N
Beaufort	GEO201222	Unidentified seal	2	11/11/2012 14:20:46	71.18	-149.52	2984	3030	2	U	NO	TI	0	N
Beaufort	GEO201223	Unidentified seal	1	11/11/2012 14:24:28	71.18	-149.55	755	757	2	RE	RH	TI	0	N
Beaufort	GEO201224	Unidentified seal	1	11/11/2012 14:27:44	71.18	-149.57	1072	1087	2	LO	NO	TI	0	N
Beaufort	GEO201225	Ringed seal	1	11/11/2012 14:28:52	71.18	-149.58	400	429	2	LO	LO	TI	0	N
Beaufort	GEO201226	Unidentified seal	1	11/11/2012 14:30:05	71.18	-149.59	755	801	2	LO	LO	TI	0	N
Beaufort	POL201236	Bearded seal	1	11/11/2012 14:40:54	71.19	-149.68	359	359	1	DI	NO	OT	X	N

Table G.1 (cont). All marine mammal detections during ION's seismic survey in the Arctic Ocean, 12 October – 17 November 2012.

Sea	Sighting ID[a]	Species	No.[b]	Date (AKDT)	Lat (°N)	Long (°W)	Initial Sighting Dist.[c] (m)	CPA[d,e] (m)	Bf[f]	Behav.[g]	Rxn to Vessel[h]	Vessel Activity[i]	Array Vol. (in^3)	Dup. Sight.[j]
Beaufort	GEO201227	Unidentified seal	2	11/11/2012 14:41:02	71.19	-149.67	582	584	2	LO	NO	TI	0	N
Beaufort	GEO201228	Unidentified seal	2	11/11/2012 14:43:15	71.19	-149.68	582	584	2	DI	SP	TI	0	N
Beaufort	GEO201229	Unidentified seal	3	11/11/2012 14:45:11	71.19	-149.70	755	801	2	LO	NO	TI	0	N
Beaufort	GEO201230	Unidentified seal	1	11/11/2012 14:45:24	71.19	-149.70	1072	1118	2	LO	NO	TI	0	N
Beaufort	POL201237	Ringed seal	1	11/11/2012 14:45:49	71.19	-149.71	523	523	1	LO	NO	OT	X	N
Beaufort	GEO201231	Unidentified seal	2	11/11/2012 14:47:18	71.19	-149.71	755	801	2	LO	NO	TI	0	Y
Beaufort	POL201238	Ringed seal	3	11/11/2012 14:47:49	71.19	-149.73	200	200	1	SA	NO	OT	X	N
Beaufort	GEO201232	Unidentified seal	1	11/11/2012 14:48:36	71.19	-149.72	1072	1110	2	U	NO	TI	0	N
Beaufort	GEO201233	Unidentified seal	1	11/11/2012 14:49:50	71.19	-149.72	657	703	2	LO	NO	TI	0	N
Beaufort	GEO201234	Unidentified seal	1	11/11/2012 14:51:04	71.19	-149.73	474	477	2	LO	NO	TI	0	N
Beaufort	GEO201235	Unidentified seal	1	11/11/2012 14:51:28	71.19	-149.74	400	429	2	LO	NO	TI	0	N
Beaufort	GEO201236	Unidentified seal	1	11/11/2012 14:52:29	71.19	-149.74	225	244	2	DI	SP	TI	0	N
Beaufort	GEO201237	Unidentified seal	1	11/11/2012 14:52:56	71.19	-149.74	755	806	2	LO	NO	TI	0	N
Beaufort	GEO201238	Unidentified seal	1	11/11/2012 14:53:43	71.19	-149.75	582	633	2	LO	NO	TI	0	N
Beaufort	GEO201239	Unidentified seal	1	11/11/2012 14:59:12	71.20	-149.79	1861	1907	2	LO	RH	TI	0	Y
Beaufort	POL201239	Unidentified seal	1	11/11/2012 14:59:29	71.20	-149.81	1228	1228	1	RE	NO	OT	X	N
Beaufort	GEO201240	Unidentified seal	1	11/11/2012 15:02:06	71.20	-149.81	886	913	2	LO	NO	TI	0	N
Beaufort	GEO201241	Unidentified seal	2	11/11/2012 15:02:15	71.20	-149.81	400	429	2	LO	NO	TI	0	N
Beaufort	GEO201242	Ringed seal	1	11/11/2012 15:02:43	71.20	-149.81	305	352	2	LO	NO	TI	0	N
Beaufort	GEO201243	Unidentified seal	1	11/11/2012 15:04:22	71.20	-149.82	1072	1033	2	U	NO	TI	0	N
Beaufort	GEO201244	Unidentified seal	1	11/11/2012 15:04:31	71.20	-149.82	582	584	2	LO	NO	TI	0	N
Beaufort	GEO201245	Unidentified seal	1	11/11/2012 15:04:53	71.20	-149.83	755	757	2	LO	NO	TI	0	N
Beaufort	GEO201246	Unidentified seal	1	11/11/2012 15:06:01	71.20	-149.83	305	310	2	LO	NO	TI	0	N
Beaufort	GEO201247	Unidentified seal	1	11/11/2012 15:07:23	71.20	-149.84	582	610	2	LO	NO	TI	0	Y

Table G.1 (cont). All marine mammal detections during ION's seismic survey in the Arctic Ocean, 12 October – 16 November 2012.

Sea	Sighting ID[a]	Species	No.[b]	Date (AKDT)	Lat (°N)	Long (°W)	Initial Sighting Dist.[c] (m)	CPA[d,e] (m)	Bf[f]	Behav.[g]	Rxn to Vessel[h]	Vessel Activity[i]	Array Vol. (in^3)	Dup. Sight.[j]
Beaufort	POL201240	Unidentified seal	1	11/11/2012 15:07:47	71.20	-149.86	359	359	1	LO	NO	OT	X	N
Beaufort	GEO201248	Unidentified seal	1	11/11/2012 15:08:54	71.20	-149.85	657	703	2	LO	NO	TI	0	N
Beaufort	GEO201249	Unidentified seal	1	11/11/2012 15:09:34	71.20	-149.86	523	561	2	LO	NO	TI	0	N
Beaufort	GEO201250	Unidentified seal	1	11/11/2012 15:09:55	71.20	-149.86	346	375	2	LO	NO	TI	0	N
Beaufort	POL201241	Unidentified seal	1	11/11/2012 15:10:28	71.20	-149.88	426	426	1	LO	NO	OT	X	N
Beaufort	GEO201251	Unidentified seal	1	11/11/2012 15:10:39	71.20	-149.86	582	610	2	LO	NO	TI	0	N
Beaufort	GEO201252	Unidentified seal	1	11/11/2012 15:11:46	71.20	-149.87	755	806	2	LO	NO	TI	0	N
Beaufort	POL201242	Unidentified seal	1	11/11/2012 15:12:47	71.21	-149.89	523	523	1	LO	NO	OT	X	N
Beaufort	GEO201253	Unidentified seal	1	11/11/2012 15:13:46	71.21	-149.88	400	446	2	LO	NO	TI	0	N
Beaufort	GEO201254	Unidentified seal	1	11/11/2012 15:15:28	71.21	-149.90	1359	1405	2	U	NO	TI	0	N
Beaufort	POL201243	Unidentified seal	1	11/11/2012 15:15:28	71.21	-149.91	523	523	1	RE	NO	OT	X	N
Beaufort	GEO201255	Unidentified seal	1	11/11/2012 15:17:13	71.21	-149.91	400	446	2	LO	NO	TI	0	N
Beaufort	GEO201256	Unidentified seal	1	11/11/2012 15:17:36	71.21	-149.91	523	574	2	LO	NO	TI	0	N
Beaufort	GEO201257	Ringed seal	1	11/11/2012 15:18:21	71.21	-149.91	500	333	2	SW	NO	TI	0	N
Beaufort	POL201244	Ringed seal	1	11/11/2012 15:19:17	71.21	-149.94	426	426	1	SW	NO	OT	X	N
Beaufort	GEO201258	Unidentified seal	1	11/11/2012 15:19:55	71.21	-149.92	346	350	2	LO	NO	TI	0	N
Beaufort	GEO201259	Unidentified seal	1	11/11/2012 15:21:24	71.21	-149.93	886	913	2	U	NO	TI	0	N
Beaufort	GEO201260	Unidentified seal	1	11/11/2012 15:22:00	71.21	-149.94	474	520	2	LO	NO	TI	0	N
Beaufort	POL201245	Ringed seal	4	11/11/2012 15:23:30	71.21	-149.97	2725	2725	1	RE	NO	OT	X	N
Beaufort	GEO201261	Unidentified seal	1	11/11/2012 15:25:14	71.21	-149.96	582	628	2	LO	NO	TI	0	N
Beaufort	GEO201262	Unidentified seal	4	11/11/2012 15:25:39	71.21	-149.96	1861	1912	2	DI	NO	TI	0	Y
Beaufort	GEO201263	Unidentified seal	1	11/11/2012 15:26:50	71.21	-149.97	2984	3035	2	U	NO	TI	0	N
Beaufort	GEO201264	Unidentified seal	1	11/11/2012 15:39:05	71.22	-150.05	582	610	2	LO	NO	TI	0	N
Beaufort	POL201246	Bearded seal	2	11/11/2012 15:47:20	71.22	-150.13	4013	4013	1	RE	NO	OT	X	N

Table G.1 (cont). All marine mammal detections during ION's seismic survey in the Arctic Ocean, 12 October – 17 November 2012.

Sea	Sighting ID[a]	Species	No.[b]	Date (AKDT)	Lat (°N)	Long (°W)	Initial Sighting Dist.[c] (m)	CPA[d,e] (m)	Bf[f]	Behav.[g]	Rxn to Vessel[h]	Vessel Activity[i]	Array Vol. (in^3)	Dup. Sight.[j]
Beaufort	GEO201265	Unidentified seal	1	11/11/2012 15:47:29	71.22	-150.11	2984	3021	2	U	NO	TI	0	N
Beaufort	GEO201266	Bearded seal	1	11/11/2012 15:53:24	71.23	-150.15	1861	1875	2	U	NO	TI	0	Y
Beaufort	GEO201267	Bearded seal	1	11/11/2012 15:54:35	71.23	-150.15	1861	1907	2	U	NO	TI	0	N
Beaufort	POL201247	Bearded seal	1	11/11/2012 15:54:43	71.23	-150.17	4013	4013	1	RE	NO	OT	X	N
Beaufort	GEO201268	Unidentified seal	1	11/11/2012 15:55:49	71.23	-150.16	5000	5014	2	U	NO	TI	0	N
Beaufort	GEO201269	Unidentified seal	1	11/11/2012 15:58:03	71.23	-150.18	755	770	2	LO	NO	TI	0	N
Beaufort	POL201248	Unidentified seal	1	11/11/2012 15:59:17	71.23	-150.21	359	359	1	SA	NO	OT	X	N
Beaufort	GEO201270	Unidentified seal	1	11/11/2012 16:00:36	71.23	-150.19	755	757	2	LO	NO	TI	0	N
Beaufort	GEO201271	Unidentified seal	2	11/11/2012 16:01:22	71.23	-150.20	2984	3035	2	U	NO	TI	0	N
Beaufort	GEO201272	Unidentified seal	2	11/11/2012 16:04:07	71.23	-150.22	1861	1899	2	U	NO	TI	0	N
Beaufort	GEO201273	Unidentified seal	1	11/11/2012 16:07:09	71.23	-150.23	1359	1374	2	U	NO	TI	0	N
Beaufort	GEO201274	Unidentified seal	1	11/11/2012 16:07:37	71.23	-150.23	523	576	2	LO	NO	TI	0	N
Beaufort	GEO201275	Unidentified seal	1	11/11/2012 16:07:52	71.23	-150.24	1861	1862	2	U	NO	TI	0	N
Beaufort	POL201249	Ringed seal	3	11/11/2012 16:08:41	71.24	-150.26	2725	2725	1	RE	NO	OT	X	N
Beaufort	GEO201276	Unidentified seal	2	11/11/2012 16:08:47	71.23	-150.24	4371	4417	2	U	NO	TI	0	N
Beaufort	GEO201277	Unidentified seal	3	11/11/2012 16:09:22	71.24	-150.25	2984	3030	2	U	NO	TI	0	Y
Beaufort	GEO201278	Unidentified seal	1	11/11/2012 16:10:44	71.24	-150.25	474	520	2	LO	NO	TI	0	N
Beaufort	POL201250	Unidentified seal	1	11/11/2012 16:25:24	71.24	-150.37	2725	2725	1	RE	NO	OT	X	N
Beaufort	GEO201279	Ringed seal	1	11/11/2012 16:39:55	71.25	-150.44	2984	1907	2	U	NO	TI	0	N
Beaufort	GEO201280	Unidentified seal	1	11/11/2012 16:46:35	71.25	-150.48	1861	1912	2	U	NO	TI	0	N
Beaufort	GEO201281	Unidentified seal	1	11/11/2012 16:48:48	71.25	-150.50	2984	2856	2	U	NO	TI	0	N
Beaufort	GEO201282	Ringed seal	7	11/11/2012 16:54:39	71.25	-150.53	1861	1912	2	U	NO	TI	0	N
Chukchi	POL201251	Ringed seal	1	11/12/2012 16:17:09	71.02	-159.53	159	159	3	SA	LO	OT	X	N
Chukchi	POL201252	Polar bear	1	11/13/2012 17:16:34	71.18	-167.07	967	967	4	WK	NO	OT	X	N

Table G.1 (cont). All marine mammal detections during ION's seismic survey in the Arctic Ocean, 12 October – 16 November 2012.

Sea	Sighting ID[a]	Species	No.[b]	Date (AKDT)	Lat (°N)	Long (°W)	Initial Sighting Dist.[c] (m)	CPA[d,e] (m)	Bf[f]	Behav.[g]	Rxn to Vessel[h]	Vessel Activity[i]	Array Vol. (in^3)	Dup. Sight.[j]
Chukchi	POL201253	Bearded seal	1	11/13/2012 17:40:16	71.21	-167.17	426	426	1	RE	RH	OT	X	N
Chukchi	POL201254	Polar bear	1	11/14/2012 12:38:50	70.81	-167.78	2725	2725	1	WK	NO	OT	X	N
Chukchi	GEO201283	Polar bear	1	11/14/2012 12:41:48	70.80	-167.78	2984	2985	1	WK	IS	RU	4880	N
Chukchi	GEO201284	Bearded seal	1	11/14/2012 13:11:39	70.81	-167.87	2984	3021	1	RE	NO	LS	4380	N
Chukchi	GEO201285	Polar bear	1	11/14/2012 13:17:04	70.81	-167.89	4371	3043	1	WK	NO	LS	4380	N
Chukchi	POL201255	Bearded seal	10	11/14/2012 13:21:55	70.81	-167.92	2047	2047	0	RE	NO	OT	X	N
Chukchi	GEO201286	Bow head w hale	3	11/14/2012 13:26:16	70.81	-167.93	4371	4398	1	BL	NO	LS	4380	N
Chukchi	POL201256	Polar bear	1	11/14/2012 13:27:58	70.81	-167.95	5463	5463	0	WK	NO	OT	X	N
Chukchi	POL201257	Ringed seal	1	11/14/2012 13:28:32	70.81	-167.95	4013	4013	0	RE	NO	OT	X	N
Chukchi	GEO201287	Bearded seal	1	11/14/2012 13:32:16	70.81	-167.95	4371	4408	1	RE	NO	LS	4380	N
Chukchi	POL201258	Polar bear	2	11/14/2012 13:34:19	70.81	-167.97	4013	4013	1	TR	NO	OT	X	N
Chukchi	GEO201288	Polar bear	1	11/14/2012 13:36:54	70.81	-167.96	4371	4398	1	WK	NO	LS	4380	N
Chukchi	GEO201289	Bow head w hale	1	11/14/2012 13:37:08	70.81	-167.97	4371	4417	1	BL	NO	LS	4380	N
Chukchi	POL201259	Bow head w hale	3	11/14/2012 13:58:52	70.81	-168.06	2080	2080	1	TR	NO	OT	X	N
Chukchi	GEO201290	Bow head w hale	3	11/14/2012 14:00:09	70.81	-168.06	2984	3030	1	BL	NO	LS	4380	Y
Chukchi	GEO201291	Polar bear	1	11/14/2012 14:03:02	70.81	-168.07	2984	2984	1	WK	NO	LS	4380	N
Chukchi	GEO201292	Polar bear	1	11/14/2012 14:09:09	70.81	-168.09	2288	354	2	RE	NO	LS	4380	N
Chukchi	GEO201293	Bow head w hale	1	11/14/2012 14:10:00	70.81	-168.10	2984	3030	2	BL	NO	LS	4380	N
Chukchi	POL201260	Bearded seal	1	11/14/2012 14:11:51	70.82	-168.12	2725	2725	2	RE	NO	OT	X	N
Chukchi	POL201261	Polar bear	1	11/14/2012 14:16:22	70.82	-168.13	1228	1228	2	RA	LO	OT	X	Y
Chukchi	POL201262	Bow head w hale	4	11/14/2012 14:37:36	70.82	-168.22	2725	2725	2	TR	NO	OT	X	N
Chukchi	GEO201294	Bow head w hale	2	11/14/2012 14:39:07	70.81	-168.21	2500	2551	2	BL	NO	LS	4380	Y
Chukchi	GEO201295	Bow head w hale	1	11/14/2012 14:57:23	70.82	-168.28	2984	3035	2	BL	NO	LS	4380	N
Chukchi	GEO201296	Bow head w hale	2	11/14/2012 15:00:22	70.82	-168.29	4371	4424	2	BL	NO	LS	4380	N

Table G.1 (cont). All marine mammal detections during ION's seismic survey in the Arctic Ocean, 12 October – 17 November 2012.

Sea	Sighting ID[a]	Species	No.[b]	Date (AKDT)	Lat (°N)	Long (°W)	Initial Sighting Dist.[c] (m)	CPA[d,e] (m)	Bf[f]	Behav.[g]	Rxn to Vessel[h]	Vessel Activity[i]	Array Vol. (in^3)	Dup. Sight.[j]
Chukchi	GEO201297	Polar bear	1	11/14/2012 15:03:16	70.82	-168.30	2984	3021	2	WK	NO	LS	4380	N
Chukchi	GEO201298	Bow head w hale	1	11/14/2012 15:06:10	70.82	-168.32	2984	3011	2	BL	NO	LS	4380	N
Chukchi	POL201263	Polar bear	1	11/14/2012 15:08:15	70.82	-168.34	2725	2725	2	WK	NO	OT	X	N
Chukchi	GEO201299	Bow head w hale	4	11/14/2012 15:10:46	70.82	-168.33	2984	3021	2	BL	NO	LS	4380	Y
Chukchi	POL201264	Bow head w hale	4	11/14/2012 15:15:09	70.82	-168.37	3215	3215	2	SW	NO	OT	X	N
Chukchi	GEO2012100	Bow head w hale	1	11/14/2012 15:15:15	70.82	-168.35	2984	3030	2	BL	NO	LS	4380	N
Chukchi	GEO2012101	Unidentified pinniped	1	11/14/2012 15:21:55	70.82	-168.38	886	913	2	SW	NO	LS	4380	N
Chukchi	GEO2012102	Bow head w hale	1	11/14/2012 15:27:47	70.83	-168.40	2984	3030	2	BL	NO	LS	4380	N
Chukchi	POL201265	Bow head w hale	1	11/14/2012 15:29:28	70.83	-168.42	2695	2695	2	BR	NO	OT	X	Y
Chukchi	GEO2012103	Bow head w hale	3	11/14/2012 15:39:11	70.83	-168.45	2984	3021	2	SW	NO	LS	4380	N
Chukchi	POL201266	Bow head w hale	2	11/14/2012 15:40:30	70.83	-168.46	2695	2695	2	SW	NO	OT	X	Y
Chukchi	GEO2012104	Bow head w hale	1	11/14/2012 15:41:05	70.83	-168.45	2984	3030	2	SW	NO	LS	4380	N
Chukchi	POL201267	Bow head w hale	1	11/14/2012 15:41:15	70.83	-168.47	967	967	2	SW	NO	OT	X	N
Chukchi	GEO2012105	Bow head w hale	1	11/14/2012 15:45:50	70.83	-168.47	886	913	2	SW	NO	LS	4380	N
Chukchi	POL201268	Bow head w hale	1	11/14/2012 15:47:59	70.83	-168.49	614	614	2	SW	NO	OT	X	N
Chukchi	POL201269	Bow head w hale	3	11/14/2012 15:51:08	70.83	-168.51	2725	2725	2	MI	NO	OT	X	Y
Chukchi	GEO2012106	Unidentified seal	1	11/14/2012 15:52:28	70.83	-168.50	1861	1888	2	RE	NO	LS	4380	N
Chukchi	GEO2012107	Bow head w hale	6	11/14/2012 15:52:54	70.83	-168.50	2984	3011	2	BL	NO	LS	4380	N
Chukchi	GEO2012108	Bow head w hale	1	11/14/2012 15:55:20	70.83	-168.51	1359	1360	2	SW	NO	LS	4380	N
Chukchi	POL201270	Bow head w hale	2	11/14/2012 15:55:32	70.83	-168.52	5463	5463	2	FL	NO	OT	X	N
Chukchi	GEO2012109	Bow head w hale	1	11/14/2012 15:58:56	70.83	-168.52	2984	3030	2	BL	NO	LS	4380	N
Chukchi	POL201271	Bow head w hale	1	11/14/2012 15:59:32	70.84	-168.54	2695	2695	2	BL	NO	OT	X	N
Chukchi	GEO2012110	Bow head w hale	1	11/14/2012 15:59:43	70.83	-168.53	2984	3030	2	BL	NO	LS	4380	Y
Chukchi	POL201272	Bow head w hale	3	11/14/2012 16:01:06	70.84	-168.54	1687	1687	2	SW	NO	OT	X	N

Table G.1 (cont). All marine mammal detections during ION's seismic survey in the Arctic Ocean, 12 October – 16 November 2012.

Sea	Sighting ID[a]	Species	No.[b]	Date (AKDT)	Lat (°N)	Long (°W)	Initial Sighting Dist.[c] (m)	CPA[d,e] (m)	Bf[f]	Behav.[g]	Rxn to Vessel[h]	Vessel Activity[i]	Array Vol. (in^3)	Dup. Sight.[j]
Chukchi	GEO2012111	Bearded seal	1	11/14/2012 16:05:24	70.84	-168.55	2984	3011	2	RE	NO	LS	4380	N
Chukchi	GEO2012112	Bow head w hale	4	11/14/2012 16:06:59	70.84	-168.56	2984	3037	2	BL	NO	LS	4380	N
Chukchi	POL201273	Bow head w hale	3	11/14/2012 16:10:45	70.84	-168.58	4021	4021	2	BR	NO	OT	X	N
Chukchi	POL201274	Bow head w hale	2	11/14/2012 16:13:06	70.84	-168.59	4013	4013	2	SW	NO	OT	X	N
Chukchi	POL201275	Bow head w hale	3	11/14/2012 16:15:17	70.84	-168.60	4021	4021	2	BL	NO	OT	X	N
Chukchi	POL201276	Bow head w hale	1	11/14/2012 16:16:50	70.84	-168.61	967	967	2	SW	NO	OT	X	N
Chukchi	GEO2012113	Bow head w hale	1	11/14/2012 16:17:30	70.84	-168.60	1359	1362	2	BL	NO	LS	4380	Y
Chukchi	POL201277	Bow head w hale	2	11/14/2012 16:21:12	70.84	-168.62	4013	4013	2	RE	NO	OT	X	N
Chukchi	GEO2012114	Bow head w hale	3	11/14/2012 16:24:53	70.84	-168.63	2984	3030	2	BL	NO	LS	4380	Y
Chukchi	POL201278	Bow head w hale	4	11/14/2012 16:28:22	70.84	-168.65	2080	2080	2	SW	NO	OT	X	N
Chukchi	GEO2012115	Bow head w hale	2	11/14/2012 16:43:19	70.85	-168.70	1861	1899	2	BL	NO	LS	4380	N
Chukchi	POL201279	Polar bear	1	11/15/2012 00:30:00	70.78	-168.94	1000	1000	1	TR	NO	SH	70	N
Chukchi	POL201280	Unidentified seal	1	11/15/2012 11:54:00	70.84	-167.32	679	679	2	SI	LO	OT	X	N
Chukchi	GEO2012117	Bow head w hale	3	11/15/2012 12:01:17	70.83	-167.32	2984	2964	3	BL	NO	SH	70	N
Chukchi	GEO2012118	Bow head w hale	4	11/15/2012 12:08:40	70.82	-167.33	2984	3035	3	BL	NO	SH	70	N
Chukchi	GEO2012119	Polar bear tracks	1	11/15/2012 12:10:41	70.82	-167.33	X	X	3	X	X	SH	70	N
Chukchi	POL201281	Bow head w hale	3	11/15/2012 12:20:53	70.80	-167.36	4021	4021	1	BL	NO	OT	X	N
Chukchi	GEO2012120	Bow head w hale	1	11/15/2012 12:24:00	70.80	-167.35	4371	4398	3	BL	NO	SH	70	Y
Chukchi	GEO2012121	Bow head w hale	1	11/15/2012 12:39:50	70.79	-167.40	4371	4417	4	BL	NO	SH	70	N
Chukchi	GEO2012122	Bow head w hale	1	11/15/2012 12:52:53	70.79	-167.45	4371	4408	4	BL	NO	OT	X	N
Chukchi	GEO2012123	Polar bear tracks	1	11/15/2012 13:32:20	70.78	-167.55	X	X	4	X	X	OT	X	N
Chukchi	GEO2012124	Polar bear tracks	1	11/15/2012 13:36:11	70.78	-167.56	X	X	4	X	X	TI	0	N
Chukchi	GEO2012125	Bow head w hale	1	11/15/2012 13:41:51	70.77	-167.56	4371	4350	4	BL	NO	TI	0	N
Chukchi	GEO2012126	Bow head w hale	2	11/15/2012 15:22:44	70.67	-167.44	2984	3030	3	BL	NO	RC	0	N

Table G.1 (cont). All marine mammal detections during ION's seismic survey in the Arctic Ocean, 12 October – 17 November 2012.

Sea	Sighting ID[a]	Species	No.[b]	Date (AKDT)	Lat (°N)	Long (°W)	Initial Sighting Dist.[c] (m)	CPA[d,e] (m)	Bf[f]	Behav.[g]	Rxn to Vessel[h]	Vessel Activity[i]	Array Vol. (in^3)	Dup. Sight.[j]
Chukchi	GEO2012127	Unidentified seal	1	11/15/2012 15:40:58	70.65	-167.39	305	352	3	OT	NO	RC	0	N
Chukchi	GEO2012128	Unidentified seal	2	11/15/2012 15:53:20	70.64	-167.37	886	585	3	OT	NO	RC	0	N
Chukchi	GEO2012129	Unidentified seal	1	11/15/2012 15:56:40	70.63	-167.37	582	610	3	OT	NO	RC	0	N
Chukchi	POL201282	Unidentified seal	1	11/15/2012 16:33:14	70.59	-167.34	4021	4021	2	RE	NO	RC	X	N
Chukchi	GEO2012130	Unidentified seal	1	11/15/2012 16:37:05	70.59	-167.34	2984	3030	3	RE	NO	RC	0	N
Chukchi	GEO2012131	Unidentified seal	1	11/15/2012 16:40:06	70.58	-167.34	2984	3035	3	RE	NO	RC	0	N
Chukchi	GEO2012132	Bow head w hale	1	11/15/2012 16:41:30	70.58	-167.34	2984	3030	3	BL	NO	RC	0	N
Chukchi	GEO2012133	Unidentified seal	1	11/15/2012 16:50:20	70.57	-167.35	2984	3030	3	RE	NO	RC	0	N
Chukchi	GEO2012134	Unidentified seal	1	11/15/2012 16:53:36	70.57	-167.35	886	924	3	OT	NO	RC	0	N
Chukchi	GEO2012135	Unidentified seal	1	11/15/2012 17:04:31	70.55	-167.36	1861	1875	3	RE	NO	RC	0	N
Chukchi	GEO2012136	Unknow n	1	11/15/2012 17:16:52	70.54	-167.37	1359	1405	3	BL	NO	RC	0	N
Chukchi	GEO2012137	Unidentified seal	1	11/15/2012 17:51:41	70.50	-167.39	2984	3035	3	RE	NO	RC	0	N
Chukchi	GEO2012138	Unidentified seal	3	11/16/2012 11:43:48	68.45	-168.50	1861	1914	1	RE	NO	TI	0	N
Chukchi	GEO2012139	Unidentified seal	1	11/16/2012 11:44:08	68.45	-168.50	2984	3037	1	RE	NO	TI	0	N
Chukchi	GEO2012140	Bearded seal	2	11/16/2012 11:47:33	68.44	-168.50	1072	503	1	RE	NO	TI	0	N
Chukchi	GEO2012141	Unidentified seal	1	11/16/2012 11:47:50	68.44	-168.50	2984	3037	1	RE	NO	TI	0	N
Chukchi	GEO2012142	Unidentified seal	2	11/16/2012 11:51:40	68.44	-168.50	2984	3011	1	RE	NO	TI	0	N
Chukchi	GEO2012143	Unidentified seal	10	11/16/2012 11:55:57	68.43	-168.51	1861	1888	1	RE	NO	TI	0	N
Chukchi	GEO2012144	Unidentified seal	1	11/16/2012 11:56:19	68.43	-168.51	1861	1907	1	RE	NO	TI	0	N
Chukchi	GEO2012145	Unidentified seal	1	11/16/2012 11:58:52	68.43	-168.52	2984	3011	1	RE	NO	TI	0	N
Chukchi	GEO2012146	Unidentified seal	1	11/16/2012 12:02:18	68.43	-168.53	2984	2943	1	RE	NO	TI	0	N
Chukchi	GEO2012147	Unidentified seal	1	11/16/2012 12:02:35	68.43	-168.53	4371	4330	1	RE	NO	TI	0	N
Chukchi	GEO2012148	Unidentified seal	1	11/16/2012 12:02:47	68.43	-168.53	2984	2926	1	RE	NO	TI	0	N
Chukchi	GEO2012149	Unidentified seal	1	11/16/2012 12:04:50	68.43	-168.54	2288	2230	1	RE	NO	TI	0	N

Table G.1 (cont). All marine mammal detections during ION's seismic survey in the Arctic Ocean, 12 October – 16 November 2012.

Sea	Sighting ID[a]	Species	No.[b]	Date (AKDT)	Lat (°N)	Long (°W)	Initial Sighting Dist.[c] (m)	CPA[d,e] (m)	Bf[f]	Behav.[g]	Rxn to Vessel[h]	Vessel Activity[i]	Array Vol. (in^3)	Dup. Sight.[j]
Chukchi	GEO2012150	Unidentified seal	1	11/16/2012 12:08:14	68.44	-168.55	2984	3030	1	RE	NO	TI	0	N
Chukchi	GEO2012151	Unidentified seal	1	11/16/2012 12:12:41	68.44	-168.55	2984	2998	1	RE	NO	TI	0	N
Chukchi	GEO2012152	Unidentified seal	2	11/16/2012 12:14:11	68.45	-168.55	4371	4417	1	RE	NO	TI	0	N
Chukchi	GEO2012153	Unidentified seal	2	11/16/2012 12:15:40	68.45	-168.55	2984	2912	1	RE	NO	TI	0	N
Chukchi	GEO2012154	Unidentified seal	3	11/16/2012 12:17:45	68.45	-168.54	4371	4371	1	RE	NO	TI	0	N
Chukchi	POL201283	Unidentified seal	1	11/16/2012 12:17:47	68.45	-168.53	591	591	1	LO	NO	OT	X	N
Chukchi	GEO2012155	Unidentified seal	2	11/16/2012 12:18:52	68.45	-168.54	4371	4424	1	RE	NO	TI	0	N
Chukchi	POL201284	Ringed seal	2	11/16/2012 12:20:19	68.45	-168.52	2725	2725	1	RE	NO	OT	X	N
Chukchi	GEO2012156	Bearded seal	1	11/16/2012 12:21:35	68.45	-168.53	2984	3037	1	RE	NO	TI	0	N
Chukchi	GEO2012157	Unidentified seal	1	11/16/2012 12:22:46	68.45	-168.52	4371	4424	1	RE	NO	TI	0	N
Chukchi	POL201285	Unidentified seal	1	11/16/2012 12:24:03	68.45	-168.51	967	967	1	LO	NO	OT	X	N
Chukchi	GEO2012158	Unidentified seal	3	11/16/2012 12:24:06	68.45	-168.52	2984	3021	1	RE	NO	TI	0	N
Chukchi	GEO2012159	Unidentified seal	2	11/16/2012 12:25:10	68.45	-168.52	2288	2315	1	RE	NO	TI	0	N
Chukchi	GEO2012160	Unidentified seal	2	11/16/2012 12:26:52	68.45	-168.51	1861	1907	1	RE	NO	TI	0	N
Chukchi	GEO2012161	Unidentified seal	1	11/16/2012 12:27:47	68.45	-168.51	2288	2334	1	RE	NO	TI	0	N
Chukchi	GEO2012162	Unidentified seal	7	11/16/2012 12:29:02	68.45	-168.50	4371	4422	1	RE	NO	TI	0	N
Chukchi	POL201286	Ringed seal	4	11/16/2012 12:29:17	68.44	-168.50	967	967	1	RE	NO	OT	X	N
Chukchi	GEO2012163	Unidentified seal	1	11/16/2012 12:32:13	68.44	-168.50	2984	3011	1	RE	NO	TI	0	N
Chukchi	POL201287	Bearded seal	2	11/16/2012 12:32:13	68.44	-168.50	1687	1687	1	RE	NO	OT	X	N
Chukchi	GEO2012164	Unidentified seal	2	11/16/2012 12:32:39	68.44	-168.50	2984	3021	1	RE	NO	TI	0	N
Chukchi	GEO2012165	Unidentified seal	1	11/16/2012 12:38:10	68.43	-168.50	2984	3035	1	RE	NO	TI	0	N
Chukchi	GEO2012166	Unidentified seal	1	11/16/2012 12:39:03	68.43	-168.50	2984	2984	1	RE	NO	TI	0	N
Chukchi	GEO2012167	Unidentified seal	1	11/16/2012 12:39:18	68.43	-168.50	1861	1862	1	RE	NO	TI	0	N
Chukchi	POL201288	Bearded seal	1	11/16/2012 12:41:06	68.42	-168.50	1687	1687	1	RE	NO	OT	X	N

Table G.1 (cont). All marine mammal detections during ION's seismic survey in the Arctic Ocean, 12 October – 17 November 2012.

Sea	Sighting ID[a]	Species	No.[b]	Date (AKDT)	Lat (°N)	Long (°W)	Initial Sighting Dist.[c] (m)	CPA[d,e] (m)	Bf[f]	Behav.[g]	Rxn to Vessel[h]	Vessel Activity[i]	Array Vol. (in^3)	Dup. Sight.[j]
Chukchi	POL201289	Unidentified seal	4	11/16/2012 12:42:54	68.41	-168.50	2725	2725	1	RE	NO	OT	X	N
Chukchi	GEO2012168	Unidentified seal	1	11/16/2012 12:43:12	68.42	-168.50	2984	2998	1	RE	NO	TI	0	N
Chukchi	GEO2012169	Bearded seal	22	11/16/2012 12:44:10	68.42	-168.50	2984	3037	1	RE	NO	TI	0	N
Chukchi	POL201290	Unidentified seal	4	11/16/2012 12:44:12	68.41	-168.50	2080	2080	1	RE	NO	OT	X	N
Chukchi	POL201291	Unidentified seal	6	11/16/2012 12:47:20	68.40	-168.50	2725	2725	1	RE	NO	OT	X	N
Chukchi	GEO2012170	Unidentified seal	2	11/16/2012 12:48:08	68.41	-168.50	2984	2998	1	RE	NO	TI	0	N
Chukchi	POL201292	Bearded seal	11	11/16/2012 12:48:17	68.40	-168.50	4021	4021	1	RE	NO	OT	X	N
Chukchi	GEO2012171	Bearded seal	1	11/16/2012 12:48:54	68.41	-168.50	657	659	1	RE	NO	TI	0	N
Chukchi	GEO2012172	Unidentified seal	1	11/16/2012 12:49:18	68.41	-168.50	2984	2984	1	RE	NO	TI	0	N
Chukchi	GEO2012173	Ringed seal	1	11/16/2012 12:50:01	68.41	-168.50	1359	1360	1	RE	NO	TI	0	N
Chukchi	GEO2012174	Unidentified seal	1	11/16/2012 12:51:35	68.40	-168.50	1861	1888	1	RE	NO	TI	0	N
Chukchi	GEO2012175	Unidentified seal	1	11/16/2012 12:51:47	68.40	-168.50	1861	1888	1	RE	NO	TI	0	N
Chukchi	GEO2012176	Unidentified seal	1	11/16/2012 12:54:16	68.40	-168.50	1861	1888	1	RE	NO	TI	0	N
Chukchi	GEO2012177	Unidentified seal	1	11/16/2012 12:54:42	68.40	-168.50	2984	3030	1	RE	NO	TI	0	N
Chukchi	GEO2012178	Bearded seal	2	11/16/2012 12:56:50	68.39	-168.50	4371	1907	1	RE	NO	TI	0	N
Chukchi	GEO2012179	Unidentified seal	4	11/16/2012 12:58:37	68.39	-168.50	2984	3030	1	RE	NO	TI	0	N
Chukchi	GEO2012180	Unidentified seal	1	11/16/2012 12:59:05	68.39	-168.50	4371	4422	1	RE	NO	TI	0	N
Chukchi	GEO2012181	Unidentified seal	1	11/16/2012 12:59:34	68.39	-168.50	2984	2998	1	RE	NO	TI	0	N
Chukchi	GEO2012182	Unidentified seal	3	11/16/2012 12:59:54	68.39	-168.50	2984	3011	1	RE	NO	TI	0	N
Chukchi	GEO2012183	Bearded seal	5	11/16/2012 13:04:48	68.37	-168.50	2984	2984	1	RE	NO	TI	0	N
Chukchi	GEO2012184	Unidentified seal	1	11/16/2012 13:06:20	68.37	-168.50	2984	2998	1	RE	NO	TI	0	N
Chukchi	GEO2012185	Unidentified seal	1	11/16/2012 13:07:11	68.37	-168.50	1072	1087	1	LO	NO	TI	0	N
Chukchi	POL201293	Bearded seal	3	11/16/2012 13:07:32	68.35	-168.50	967	967	1	RE	LO	OT	X	N
Chukchi	POL201294	Ringed seal	1	11/16/2012 13:07:32	68.35	-168.50	359	359	1	SW	NO	OT	X	N

Table G.1 (cont). All marine mammal detections during ION's seismic survey in the Arctic Ocean, 12 October – 16 November 2012.

Sea	Sighting ID[a]	Species	No.[b]	Date (AKDT)	Lat (°N)	Long (°W)	Initial Sighting Dist.[c] (m)	CPA[d,e] (m)	Bf[f]	Behav.[g]	Rxn to Vessel[h]	Vessel Activity[i]	Array Vol. (in^3)	Dup. Sight.[j]
Chukchi	GEO2012186	Unidentified seal	1	11/16/2012 13:08:45	68.36	-168.50	1072	1099	1	RE	NO	TI	0	N
Chukchi	GEO2012187	Unidentified seal	1	11/16/2012 13:10:37	68.36	-168.50	2984	2984	1	RE	NO	TI	0	N
Chukchi	GEO2012188	Unidentified seal	1	11/16/2012 13:13:52	68.35	-168.50	1861	1899	1	RE	NO	TI	0	N
Chukchi	POL201295	Ringed seal	1	11/16/2012 13:16:42	68.33	-168.50	426	426	1	RE	NO	OT	X	N
Chukchi	GEO2012189	Bearded seal	1	11/16/2012 13:18:00	68.34	-168.50	346	350	1	RE	NO	TI	0	N
Chukchi	POL201296	Bearded seal	2	11/16/2012 13:19:12	68.33	-168.50	1687	1687	1	RE	NO	OT	X	N
Chukchi	GEO2012190	Ringed seal	2	11/16/2012 13:20:15	68.33	-168.50	1861	1821	1	RE	NO	TI	0	N
Chukchi	GEO2012191	Unidentified seal	1	11/16/2012 13:21:08	68.33	-168.50	2984	3030	1	RE	NO	TI	0	N
Chukchi	POL201297	Unidentified seal	1	11/16/2012 13:21:13	68.32	-168.50	2725	2725	1	RE	NO	OT	X	N
Chukchi	GEO2012192	Unidentified seal	1	11/16/2012 13:25:10	68.32	-168.50	1359	1360	1	RE	RH	TI	0	N
Chukchi	GEO2012193	Unidentified seal	6	11/16/2012 13:25:36	68.32	-168.50	2984	2998	1	RE	NO	TI	0	N
Chukchi	POL201298	Unidentified seal	1	11/16/2012 13:26:06	68.31	-168.50	2725	2725	1	RE	NO	OT	X	N
Chukchi	POL201299	Bow head w hale	6	11/16/2012 13:28:47	68.30	-168.50	2725	2725	1	SW	NO	OT	X	N
Chukchi	GEO2012194	Unidentified seal	1	11/16/2012 13:30:55	68.30	-168.50	1861	1888	1	RE	NO	TI	0	N
Chukchi	GEO2012195	Unidentified seal	1	11/16/2012 13:31:11	68.30	-168.50	2984	2964	1	RE	NO	TI	0	N
Chukchi	GEO2012196	Unidentified seal	2	11/16/2012 13:31:29	68.30	-168.50	2984	3011	1	RE	NO	TI	0	N
Chukchi	GEO2012197	Bow head w hale	6	11/16/2012 13:33:57	68.29	-168.50	2984	3011	1	BL	NO	TI	0	Y
Chukchi	GEO2012198	Pacific w alrus	30	11/16/2012 13:35:13	68.29	-168.50	2984	2984	1	BL	NO	TI	0	N
Chukchi	POL2012100	Bearded seal	5	11/16/2012 13:38:32	68.27	-168.50	2725	2725	1	RE	NO	OT	X	N
Chukchi	POL2012101	Ringed seal	2	11/16/2012 13:39:54	68.27	-168.50	2725	2725	1	RE	NO	OT	X	N
Chukchi	POL2012102	Pacific w alrus	15	11/16/2012 13:43:00	68.26	-168.50	967	967	1	RE	NO	OT	X	N
Chukchi	POL2012103	Pacific w alrus	13	11/16/2012 13:45:31	68.26	-168.50	967	967	1	TR	NO	OT	X	N
Chukchi	GEO2012199	Pacific w alrus	40	11/16/2012 13:47:34	68.26	-168.50	1861	1888	1	LO	NO	TI	0	N
Chukchi	POL2012104	Pacific w alrus	2	11/16/2012 13:48:38	68.25	-168.50	1000	1000	1	RE	NO	OT	X	N

Table G.1 (cont). All marine mammal detections during ION's seismic survey in the Arctic Ocean, 12 October – 17 November 2012.

Sea	Sighting ID[a]	Species	No.[b]	Date (AKDT)	Lat (°N)	Long (°W)	Initial Sighting Dist.[c] (m)	CPA[d,e] (m)	Bf[f]	Behav.[g]	Rxn to Vessel[h]	Vessel Activity[i]	Array Vol. (in^3)	Dup. Sight.[j]
Chukchi	GEO2012200	Pacific walrus	11	11/16/2012 13:50:18	68.25	-168.50	755	783	1	LO	NO	TI	0	N
Chukchi	POL2012105	Pacific walrus	2	11/16/2012 13:50:24	68.24	-168.50	300	300	1	SA	LO	OT	X	N
Chukchi	GEO2012201	Pacific walrus	7	11/16/2012 13:52:54	68.24	-168.50	1861	1888	1	BL	NO	TI	0	N
Chukchi	GEO2012202	Pacific walrus	2	11/16/2012 13:53:19	68.24	-168.50	1359	1386	1	LO	NO	TI	0	N
Chukchi	GEO2012203	Pacific walrus	3	11/16/2012 13:55:37	68.24	-168.50	2984	3011	1	BL	NO	TI	0	N
Chukchi	GEO2012204	Pacific walrus	3	11/16/2012 13:56:38	68.24	-168.50	1861	1888	1	LO	NO	TI	0	N
Chukchi	POL2012106	Bearded seal	1	11/16/2012 13:59:19	68.23	-168.51	1687	1687	1	RE	NO	OT	X	N
Chukchi	POL2012107	Ringed seal	1	11/16/2012 13:59:19	68.23	-168.51	967	967	1	RE	NO	OT	X	N
Chukchi	GEO2012205	Pacific walrus	2	11/16/2012 13:59:28	68.23	-168.51	850	812	1	LO	NO	TI	0	N
Chukchi	GEO2012206	Unidentified seal	3	11/16/2012 14:00:02	68.23	-168.51	1861	1888	1	LO	NO	TI	0	N
Chukchi	GEO2012207	Pacific walrus	2	11/16/2012 14:00:22	68.23	-168.51	1359	1386	1	BL	LO	TI	0	N
Chukchi	GEO2012208	Pacific walrus	2	11/16/2012 14:01:46	68.23	-168.51	1359	1374	1	BL	NO	TI	0	N
Chukchi	GEO2012209	Pacific walrus	2	11/16/2012 14:06:54	68.22	-168.51	1359	1386	1	LO	NO	TI	0	N
Chukchi	POL2012108	Unidentified seal	1	11/16/2012 14:06:54	68.22	-168.51	679	679	1	RE	NO	OT	X	N
Chukchi	POL2012109	Pacific walrus	6	11/16/2012 14:09:50	68.21	-168.51	1687	1687	1	SA	NO	OT	X	N
Chukchi	GEO2012210	Pacific walrus	1	11/16/2012 14:13:42	68.21	-168.51	1359	1405	1	BL	NO	TI	0	N
Chukchi	GEO2012211	Pacific walrus	3	11/16/2012 14:16:03	68.21	-168.51	1861	1899	1	LO	NO	TI	0	N
Chukchi	POL2012110	Bearded seal	1	11/16/2012 14:16:21	68.19	-168.50	310	310	1	LG	NO	OT	X	N
Chukchi	GEO2012212	Unidentified seal	1	11/16/2012 14:16:46	68.21	-168.51	2984	2943	1	RE	NO	TI	0	N
Chukchi	POL2012111	Pacific walrus	2	11/16/2012 14:19:15	68.18	-168.50	2725	2725	1	RE	NO	OT	X	N
Chukchi	GEO2012213	Pacific walrus	2	11/16/2012 14:19:49	68.20	-168.51	1359	1397	1	LO	NO	TI	0	N
Chukchi	POL2012112	Bearded seal	1	11/16/2012 14:20:30	68.18	-168.50	2725	2725	1	RE	NO	OT	X	N
Chukchi	GEO2012214	Pacific walrus	2	11/16/2012 14:22:32	68.19	-168.51	2984	2998	1	LO	NO	TI	0	N
Chukchi	GEO2012215	Pacific walrus	1	11/16/2012 14:23:00	68.19	-168.51	2984	3011	1	LO	NO	TI	0	N

Table G.1 (cont). All marine mammal detections during ION's seismic survey in the Arctic Ocean, 12 October – 16 November 2012.

Sea	Sighting ID[a]	Species	No.[b]	Date (AKDT)	Lat (°N)	Long (°W)	Initial Sighting Dist.[c] (m)	CPA[d,e] (m)	Bf[f]	Behav.[g]	Rxn to Vessel[h]	Vessel Activity[i]	Array Vol. (in^3)	Dup. Sight.[j]
Chukchi	GEO2012216	Unidentified seal	1	11/16/2012 14:24:20	68.19	-168.51	2984	3030	1	RE	NO	TI	0	N
Chukchi	POL2012113	Unidentified pinniped	4	11/16/2012 14:27:39	68.17	-168.50	1687	1687	1	LO	NO	OT	X	N
Chukchi	GEO2012217	Pacific walrus	1	11/16/2012 14:33:55	68.16	-168.50	886	924	1	LO	NO	TI	0	N
Chukchi	GEO2012218	Pacific walrus	2	11/16/2012 14:34:48	68.16	-168.50	2984	3011	1	LO	NO	TI	0	N
Chukchi	POL2012114	Pacific walrus	1	11/16/2012 14:35:15	68.15	-168.49	390	390	1	LO	NO	OT	X	N
Chukchi	POL2012115	Pacific walrus	3	11/16/2012 14:36:26	68.14	-168.49	1228	1228	1	SW	NO	OT	X	N
Chukchi	GEO2012219	Pacific walrus	15	11/16/2012 14:36:53	68.15	-168.49	1861	1907	1	BL	NO	TI	0	N
Chukchi	POL2012116	Pacific walrus	9	11/16/2012 14:37:03	68.14	-168.49	1228	1228	1	LO	NO	OT	X	N
Chukchi	GEO2012220	Pacific walrus	4	11/16/2012 14:42:03	68.14	-168.49	1072	1110	1	LO	NO	TI	0	N
Chukchi	POL2012117	Pacific walrus	5	11/16/2012 14:42:08	68.14	-168.49	967	967	1	TR	NO	OT	X	N
Chukchi	GEO2012221	Pacific walrus	2	11/16/2012 14:43:06	68.14	-168.49	2984	3011	1	LO	NO	TI	0	N
Chukchi	GEO2012222	Pacific walrus	2	11/16/2012 14:44:03	68.14	-168.49	755	793	1	LO	NO	TI	0	N
Chukchi	GEO2012223	Pacific walrus	2	11/16/2012 14:45:07	68.14	-168.49	1072	1118	1	LO	NO	TI	0	N
Chukchi	GEO2012224	Pacific walrus	2	11/16/2012 14:45:42	68.14	-168.49	2984	3030	1	LO	NO	TI	0	N
Chukchi	POL2012118	Pacific walrus	2	11/16/2012 14:46:16	68.13	-168.49	967	967	1	RE	NO	OT	X	N
Chukchi	POL2012119	Pacific walrus	3	11/16/2012 14:46:32	68.13	-168.49	967	967	1	SA	NO	OT	X	N
Chukchi	GEO2012225	Pacific walrus	4	11/16/2012 14:46:36	68.13	-168.49	1861	1907	1	LO	NO	TI	0	N
Chukchi	GEO2012226	Pacific walrus	2	11/16/2012 14:46:51	68.13	-168.49	1072	1118	1	LO	NO	TI	0	N
Chukchi	GEO2012227	Pacific walrus	2	11/16/2012 14:47:09	68.13	-168.49	886	932	1	LO	NO	TI	0	N
Chukchi	GEO2012228	Pacific walrus	3	11/16/2012 14:47:44	68.13	-168.49	2984	3030	1	LO	NO	TI	0	N
Chukchi	GEO2012229	Pacific walrus	8	11/16/2012 14:48:17	68.13	-168.49	2984	3030	1	LO	NO	TI	0	N
Chukchi	GEO2012230	Pacific walrus	4	11/16/2012 14:50:03	68.13	-168.49	2984	3030	1	LO	NO	TI	0	N
Chukchi	GEO2012231	Pacific walrus	3	11/16/2012 14:50:14	68.13	-168.49	2984	3030	1	LO	NO	TI	0	N
Chukchi	POL2012120	Pacific walrus	50	11/16/2012 14:51:08	68.12	-168.48	797	797	1	SW	NO	OT	X	N

Table G.1 (cont). All marine mammal detections during ION's seismic survey in the Arctic Ocean, 12 October – 17 November 2012.

Sea	Sighting ID[a]	Species	No.[b]	Date (AKDT)	Lat (°N)	Long (°W)	Initial Sighting Dist.[c] (m)	CPA[d,e] (m)	Bf[f]	Behav.[g]	Rxn to Vessel[h]	Vessel Activity[i]	Array Vol. (in^3)	Dup. Sight.[j]
Chukchi	GEO2012232	Pacific walrus	4	11/16/2012 14:51:20	68.13	-168.49	2984	3030	1	LO	NO	TI	0	N
Chukchi	GEO2012233	Pacific walrus	6	11/16/2012 14:52:17	68.13	-168.48	1359	1405	1	SW	SP	TI	0	N
Chukchi	GEO2012234	Pacific walrus	2	11/16/2012 14:54:13	68.12	-168.48	657	659	1	LO	NO	TI	0	N
Chukchi	GEO2012235	Pacific walrus	2	11/16/2012 14:54:50	68.12	-168.48	1861	1875	1	LO	NO	TI	0	N
Chukchi	GEO2012236	Pacific walrus	2	11/16/2012 14:55:06	68.12	-168.48	1359	1360	1	LO	NO	TI	0	N
Chukchi	POL2012121	Pacific walrus	5	11/16/2012 14:55:34	68.12	-168.48	1687	1687	1	SA	NO	OT	X	N
Chukchi	GEO2012237	Pacific walrus	3	11/16/2012 14:55:37	68.12	-168.48	2984	2998	1	LO	NO	TI	0	N
Chukchi	GEO2012238	Pacific walrus	8	11/16/2012 14:57:17	68.12	-168.48	1861	1899	1	BL	NO	TI	0	N
Chukchi	GEO2012239	Pacific walrus	2	11/16/2012 14:58:02	68.12	-168.48	1861	1899	1	BL	NO	TI	0	N
Chukchi	GEO2012240	Pacific walrus	12	11/16/2012 14:58:29	68.12	-168.48	886	924	1	BL	LO	TI	0	N
Chukchi	POL2012122	Pacific walrus	30	11/16/2012 14:59:52	68.11	-168.48	679	679	1	LO	CD	OT	X	N
Chukchi	GEO2012241	Pacific walrus	4	11/16/2012 15:01:07	68.11	-168.48	2984	3021	1	LO	NO	TI	0	N
Chukchi	GEO2012242	Pacific walrus	1	11/16/2012 15:01:26	68.11	-168.48	474	513	1	BL	NO	TI	0	N
Chukchi	GEO2012243	Pacific walrus	1	11/16/2012 15:02:14	68.11	-168.48	582	628	1	LO	NO	TI	0	N
Chukchi	GEO2012244	Pacific walrus	6	11/16/2012 15:02:31	68.11	-168.48	1072	1118	1	LO	NO	TI	0	N
Chukchi	GEO2012245	Pacific walrus	2	11/16/2012 15:02:51	68.11	-168.48	1072	1118	1	LO	NO	TI	0	N
Chukchi	GEO2012246	Pacific walrus	7	11/16/2012 15:03:18	68.11	-168.48	1072	1073	1	LO	NO	TI	0	N
Chukchi	GEO2012247	Pacific walrus	5	11/16/2012 15:03:53	68.11	-168.48	1359	1405	1	LO	NO	TI	0	N
Chukchi	GEO2012248	Pacific walrus	5	11/16/2012 15:04:57	68.11	-168.48	886	924	1	LO	SP	TI	0	N
Chukchi	POL2012123	Pacific walrus	86	11/16/2012 15:05:23	68.10	-168.47	273	273	1	SA	NO	OT	X	N
Chukchi	GEO2012249	Pacific walrus	10	11/16/2012 15:06:05	68.11	-168.48	1861	1912	1	LO	LO	TI	0	N
Chukchi	GEO2012250	Pacific walrus	25	11/16/2012 15:06:53	68.11	-168.48	1072	937	1	LO	NO	TI	0	N
Chukchi	GEO2012251	Pacific walrus	6	11/16/2012 15:07:08	68.11	-168.47	1072	1123	1	LO	SP	TI	0	N
Chukchi	POL2012124	Pacific walrus	20	11/16/2012 15:09:09	68.10	-168.47	1687	1687	1	BL	NO	OT	X	N

Table G.1 (cont). All marine mammal detections during ION's seismic survey in the Arctic Ocean, 12 October – 16 November 2012.

Sea	Sighting ID[a]	Species	No.[b]	Date (AKDT)	Lat (°N)	Long (°W)	Initial Sighting Dist.[c] (m)	CPA[d,e] (m)	Bf[f]	Behav.[g]	Rxn to Vessel[h]	Vessel Activity[i]	Array Vol. (in^3)	Dup. Sight.[j]
Chukchi	GEO2012252	Pacific walrus	6	11/16/2012 15:09:57	68.10	-168.47	755	801	1	LO	NO	TI	0	N
Chukchi	GEO2012253	Pacific walrus	8	11/16/2012 15:10:41	68.10	-168.47	755	793	1	LO	NO	TI	0	N
Chukchi	GEO2012254	Pacific walrus	2	11/16/2012 15:10:56	68.10	-168.47	1861	1899	1	LO	NO	TI	0	N
Chukchi	GEO2012255	Pacific walrus	4	11/16/2012 15:11:08	68.10	-168.47	582	620	1	LO	NO	TI	0	N
Chukchi	GEO2012256	Pacific walrus	6	11/16/2012 15:11:34	68.10	-168.47	1359	1397	1	LO	NO	TI	0	N
Chukchi	GEO2012257	Pacific walrus	5	11/16/2012 15:11:56	68.10	-168.47	346	363	1	LO	NO	TI	0	N
Chukchi	GEO2012258	Pacific walrus	7	11/16/2012 15:12:27	68.10	-168.47	755	783	1	LO	NO	TI	0	N
Chukchi	GEO2012259	Pacific walrus	6	11/16/2012 15:12:44	68.10	-168.47	1359	1386	1	LO	NO	TI	0	N
Chukchi	GEO2012260	Pacific walrus	8	11/16/2012 15:13:05	68.10	-168.47	1359	1386	1	LO	NO	TI	0	N
Chukchi	GEO2012261	Pacific walrus	15	11/16/2012 15:13:23	68.10	-168.47	474	520	1	LO	SP	TI	0	N
Chukchi	GEO2012262	Pacific walrus	25	11/16/2012 15:14:32	68.09	-168.47	755	783	1	LO	SP	TI	0	N
Chukchi	GEO2012263	Pacific walrus	2	11/16/2012 15:15:27	68.09	-168.47	346	375	1	LO	LO	TI	0	N
Chukchi	POL2012125	Pacific walrus	90	11/16/2012 15:16:56	68.09	-168.47	273	273	1	ST	NO	OT	X	N
Chukchi	GEO2012264	Pacific walrus	8	11/16/2012 15:17:38	68.09	-168.47	1072	1099	1	LO	NO	TI	0	N
Chukchi	GEO2012265	Pacific walrus	12	11/16/2012 15:18:11	68.09	-168.47	582	610	1	LO	NO	TI	0	N
Chukchi	GEO2012266	Pacific walrus	2	11/16/2012 15:18:26	68.09	-168.47	400	429	1	LO	NO	TI	0	N
Chukchi	GEO2012267	Pacific walrus	14	11/16/2012 15:18:44	68.09	-168.47	400	429	1	LO	SP	TI	0	N
Chukchi	GEO2012268	Pacific walrus	14	11/16/2012 15:19:17	68.09	-168.47	755	783	1	LO	SP	TI	0	N
Chukchi	GEO2012269	Pacific walrus	6	11/16/2012 15:20:30	68.09	-168.47	1359	1386	1	LO	NO	TI	0	N
Chukchi	GEO2012270	Pacific walrus	4	11/16/2012 15:21:30	68.09	-168.47	657	703	1	LO	NO	TI	0	N
Chukchi	GEO2012271	Pacific walrus	10	11/16/2012 15:23:16	68.08	-168.47	657	659	1	LO	NO	TI	0	N
Chukchi	GEO2012272	Pacific walrus	2	11/16/2012 15:23:57	68.08	-168.47	1861	1875	1	LO	NO	TI	0	N
Chukchi	GEO2012273	Pacific walrus	3	11/16/2012 15:24:10	68.08	-168.47	582	584	1	LO	NO	TI	0	N
Chukchi	GEO2012274	Pacific walrus	6	11/16/2012 15:24:25	68.08	-168.47	582	598	1	LO	NO	TI	0	N

Table G.1 (cont). All marine mammal detections during ION's seismic survey in the Arctic Ocean, 12 October – 17 November 2012.

Sea	Sighting ID[a]	Species	No.[b]	Date (AKDT)	Lat (°N)	Long (°W)	Initial Sighting Dist.[c] (m)	CPA[d,e] (m)	Bf[f]	Behav.[g]	Rxn to Vessel[h]	Vessel Activity[i]	Array Vol. (in^3)	Dup. Sight.[j]
Chukchi	GEO2012275	Pacific walrus	6	11/16/2012 15:24:45	68.08	-168.47	1359	1360	1	LO	NO	TI	0	N
Chukchi	GEO2012276	Pacific walrus	4	11/16/2012 15:24:56	68.08	-168.47	657	659	1	LO	NO	TI	0	N
Chukchi	GEO2012277	Pacific walrus	2	11/16/2012 15:25:18	68.08	-168.47	1072	1099	1	LO	NO	TI	0	N
Chukchi	GEO2012278	Pacific walrus	4	11/16/2012 15:25:33	68.08	-168.47	1861	1875	1	LO	NO	TI	0	N
Chukchi	GEO2012279	Pacific walrus	12	11/16/2012 15:25:43	68.08	-168.47	400	417	1	LO	NO	TI	0	N
Chukchi	GEO2012280	Pacific walrus	2	11/16/2012 15:26:34	68.08	-168.47	2984	3021	1	LO	NO	TI	0	N
Chukchi	GEO2012281	Pacific walrus	4	11/16/2012 15:27:30	68.08	-168.47	1359	1397	1	LO	NO	TI	0	N
Chukchi	POL2012126	Pacific walrus	100	11/16/2012 15:27:32	68.07	-168.47	1687	1687	1	SW	NO	OT	X	N
Chukchi	GEO2012282	Pacific walrus	8	11/16/2012 15:28:19	68.08	-168.47	474	520	1	LO	NO	TI	0	N
Chukchi	GEO2012283	Pacific walrus	20	11/16/2012 15:30:48	68.07	-168.47	474	502	1	LO	SP	TI	0	N
Chukchi	GEO2012284	Pacific walrus	8	11/16/2012 15:31:07	68.07	-168.47	582	610	1	LO	SP	TI	0	N
Chukchi	GEO2012285	Pacific walrus	3	11/16/2012 15:31:34	68.07	-168.47	582	610	1	LO	NO	TI	0	N
Chukchi	GEO2012286	Pacific walrus	4	11/16/2012 15:32:04	68.07	-168.47	1861	1888	1	LO	NO	TI	0	N
Chukchi	GEO2012287	Pacific walrus	4	11/16/2012 15:32:32	68.07	-168.47	1072	1099	1	LO	SP	TI	0	N
Chukchi	GEO2012288	Pacific walrus	5	11/16/2012 15:32:59	68.07	-168.47	400	429	1	LO	LO	TI	0	N
Chukchi	GEO2012289	Pacific walrus	4	11/16/2012 15:33:55	68.07	-168.47	1359	1386	1	LO	NO	TI	0	N
Chukchi	GEO2012290	Pacific walrus	10	11/16/2012 15:34:38	68.07	-168.47	1359	1374	1	LO	SP	TI	0	N
Chukchi	GEO2012291	Pacific walrus	6	11/16/2012 15:34:57	68.07	-168.47	1359	1386	1	BL	NO	TI	0	N
Chukchi	GEO2012292	Pacific walrus	8	11/16/2012 15:35:22	68.07	-168.47	2984	3011	1	LO	NO	TI	0	N
Chukchi	GEO2012293	Pacific walrus	3	11/16/2012 15:35:37	68.07	-168.47	886	913	1	LO	NO	TI	0	N
Chukchi	GEO2012294	Pacific walrus	1	11/16/2012 15:36:05	68.06	-168.47	523	551	1	LO	NO	TI	0	N
Chukchi	GEO2012295	Pacific walrus	12	11/16/2012 15:36:23	68.06	-168.47	1072	252	1	LO	NO	TI	0	N
Chukchi	GEO2012296	Pacific walrus	8	11/16/2012 15:36:52	68.06	-168.47	886	913	1	LO	SP	TI	0	N
Chukchi	GEO2012297	Pacific walrus	8	11/16/2012 15:37:16	68.06	-168.47	657	685	1	LO	SP	TI	0	N

Table G.1 (cont). All marine mammal detections during ION's seismic survey in the Arctic Ocean, 12 October – 16 November 2012.

Sea	Sighting ID[a]	Species	No.[b]	Date (AKDT)	Lat (°N)	Long (°W)	Initial Sighting Dist.[c] (m)	CPA[d,e] (m)	Bf[f]	Behav.[g]	Rxn to Vessel[h]	Vessel Activity[i]	Array Vol. (in^3)	Dup. Sight.[j]
Chukchi	GEO2012298	Pacific walrus	1	11/16/2012 15:37:36	68.06	-168.47	474	513	1	LO	LO	TI	0	N
Chukchi	GEO2012299	Pacific walrus	11	11/16/2012 15:37:54	68.06	-168.47	657	695	1	LO	NO	TI	0	N
Chukchi	GEO2012300	Pacific walrus	25	11/16/2012 15:38:12	68.06	-168.47	1359	1386	1	LO	SP	TI	0	N
Chukchi	GEO2012301	Pacific walrus	1	11/16/2012 15:38:57	68.06	-168.47	346	293	1	LO	LO	TI	0	N
Chukchi	GEO2012302	Pacific walrus	2	11/16/2012 15:39:19	68.06	-168.47	582	610	1	LO	IS	TI	0	N
Chukchi	GEO2012303	Pacific walrus	8	11/16/2012 15:40:37	68.06	-168.47	1072	1099	1	BL	NO	TI	0	N
Chukchi	GEO2012304	Pacific walrus	8	11/16/2012 15:40:56	68.06	-168.47	582	610	1	LO	SP	TI	0	N
Chukchi	GEO2012305	Pacific walrus	12	11/16/2012 15:41:17	68.06	-168.47	1861	1899	1	LO	NO	TI	0	N
Chukchi	GEO2012306	Pacific walrus	5	11/16/2012 15:41:33	68.06	-168.47	400	439	1	LO	SP	TI	0	N
Chukchi	GEO2012307	Pacific walrus	19	11/16/2012 15:42:01	68.06	-168.47	1359	1386	1	LO	NO	TI	0	N
Chukchi	GEO2012308	Pacific walrus	2	11/16/2012 15:42:20	68.06	-168.47	400	439	1	LO	NO	TI	0	N
Chukchi	GEO2012309	Pacific walrus	20	11/16/2012 15:42:54	68.05	-168.47	1359	1386	1	BL	NO	TI	0	N
Chukchi	GEO2012310	Pacific walrus	23	11/16/2012 15:43:38	68.05	-168.47	1861	1899	1	BL	NO	TI	0	N
Chukchi	GEO2012311	Pacific walrus	31	11/16/2012 15:45:38	68.05	-168.47	2984	3021	1	BL	NO	TI	0	N
Chukchi	GEO2012312	Pacific walrus	2	11/16/2012 15:46:36	68.05	-168.47	1861	1899	1	LO	NO	TI	0	N
Chukchi	GEO2012313	Pacific walrus	7	11/16/2012 15:46:48	68.05	-168.47	582	620	1	LO	SP	TI	0	N
Chukchi	GEO2012314	Pacific walrus	8	11/16/2012 15:47:48	68.05	-168.47	1359	1397	1	LO	NO	TI	0	N
Chukchi	GEO2012315	Pacific walrus	10	11/16/2012 15:48:19	68.05	-168.47	657	685	1	LO	SP	TI	0	N
Chukchi	GEO2012316	Pacific walrus	4	11/16/2012 15:49:28	68.04	-168.47	1861	1907	1	LO	NO	TI	0	N
Chukchi	POL2012127	Pacific walrus	154	11/16/2012 15:49:37	68.04	-168.47	1687	1687	1	BL	NO	OT	X	N
Chukchi	GEO2012317	Pacific walrus	4	11/16/2012 15:49:46	68.04	-168.47	1359	1397	1	LO	NO	TI	0	N
Chukchi	GEO2012318	Pacific walrus	2	11/16/2012 15:50:27	68.04	-168.47	523	551	1	LO	NO	TI	0	N
Chukchi	GEO2012319	Pacific walrus	9	11/16/2012 15:51:46	68.04	-168.47	755	793	1	LO	NO	TI	0	N
Chukchi	GEO2012320	Pacific walrus	8	11/16/2012 15:52:30	68.04	-168.47	1359	1405	1	LO	NO	TI	0	N

Table G.1 (cont). All marine mammal detections during ION's seismic survey in the Arctic Ocean, 12 October – 17 November 2012.

Sea	Sighting ID[a]	Species	No.[b]	Date (AKDT)	Lat (°N)	Long (°W)	Initial Sighting Dist.[c] (m)	CPA[d,e] (m)	Bf[f]	Behav.[g]	Rxn to Vessel[h]	Vessel Activity[i]	Array Vol. (in^3)	Dup. Sight.[j]
Chukchi	GEO2012321	Pacific walrus	12	11/16/2012 15:52:46	68.04	-168.47	2984	3021	1	LO	NO	TI	0	N
Chukchi	GEO2012322	Pacific walrus	7	11/16/2012 15:53:12	68.04	-168.47	1359	1405	1	LO	NO	TI	0	N
Chukchi	GEO2012323	Pacific walrus	16	11/16/2012 15:53:52	68.04	-168.47	2984	3030	1	BL	NO	TI	0	N
Chukchi	GEO2012324	Pacific walrus	6	11/16/2012 15:54:34	68.04	-168.47	1861	1907	1	BL	NO	TI	0	N
Chukchi	GEO2012325	Pacific walrus	5	11/16/2012 15:54:48	68.04	-168.47	1861	1907	1	LO	NO	TI	0	N
Chukchi	GEO2012326	Pacific walrus	2	11/16/2012 15:55:26	68.04	-168.47	755	808	1	LO	NO	TI	0	N
Chukchi	GEO2012327	Pacific walrus	8	11/16/2012 15:55:41	68.04	-168.47	1861	1907	1	BL	NO	TI	0	N
Chukchi	GEO2012328	Pacific walrus	1	11/16/2012 15:56:42	68.04	-168.47	474	520	1	LO	NO	TI	0	N
Chukchi	GEO2012329	Pacific walrus	1	11/16/2012 15:57:41	68.03	-168.47	1072	1125	1	LO	NO	TI	0	N
Chukchi	GEO2012330	Pacific walrus	4	11/16/2012 15:59:06	68.03	-168.47	1861	1888	1	LO	NO	TI	0	N
Chukchi	GEO2012331	Pacific walrus	3	11/16/2012 15:59:18	68.03	-168.47	1072	1099	1	LO	NO	TI	0	N
Chukchi	GEO2012332	Pacific walrus	4	11/16/2012 16:00:34	68.03	-168.47	2984	3030	1	LO	NO	TI	0	N
Chukchi	GEO2012333	Pacific walrus	2	11/16/2012 16:01:20	68.03	-168.47	886	913	1	BL	NO	TI	0	N
Chukchi	GEO2012334	Unidentified seal	1	11/16/2012 16:02:28	68.03	-168.47	2984	2551	1	RE	NO	TI	0	N
Chukchi	GEO2012335	Pacific walrus	3	11/16/2012 16:03:49	68.03	-168.47	1861	1912	1	LO	SP	TI	0	N
Chukchi	GEO2012336	Pacific walrus	4	11/16/2012 16:04:17	68.03	-168.47	2984	2998	1	LO	NO	TI	0	N
Chukchi	GEO2012337	Unidentified seal	1	11/16/2012 16:07:19	68.02	-168.47	2984	2984	1	RE	NO	TI	0	N
Chukchi	GEO2012338	Pacific walrus	2	11/16/2012 16:08:38	68.02	-168.47	886	932	1	LO	NO	TI	0	N
Chukchi	POL2012128	Pacific walrus	2	11/16/2012 16:08:38	68.01	-168.46	250	250	1	SW	NO	OT	X	N
Chukchi	POL2012129	Pacific walrus	1	11/16/2012 16:12:28	68.01	-168.46	1687	1687	1	SA	NO	OT	X	N
Chukchi	GEO2012339	Pacific walrus	2	11/16/2012 16:13:06	68.01	-168.46	2984	3035	1	LO	NO	TI	0	N
Chukchi	POL2012130	Pacific walrus	4	11/16/2012 16:14:54	68.00	-168.46	1228	1228	1	SW	NO	OT	X	N
Chukchi	POL2012131	Ringed seal	2	11/16/2012 16:22:32	67.99	-168.46	1228	1228	1	RE	NO	OT	X	N
Chukchi	GEO2012340	Bearded seal	1	11/16/2012 16:34:57	67.98	-168.46	400	446	1	LO	NO	TI	0	N

Table G.1 (cont). All marine mammal detections during ION's seismic survey in the Arctic Ocean, 12 October – 16 November 2012.

Sea	Sighting ID[a]	Species	No.[b]	Date (AKDT)	Lat (°N)	Long (°W)	Initial Sighting Dist.[c] (m)	CPA[d,e] (m)	Bf[f]	Behav.[g]	Rxn to Vessel[h]	Vessel Activity[i]	Array Vol. (in^3)	Dup. Sight.[j]
Chukchi	GEO2012341	Unidentified seal	1	11/16/2012 16:37:05	67.98	-168.47	474	520	1	LO	NO	TI	0	N
Chukchi	GEO2012342	Unidentified seal	1	11/16/2012 16:44:56	67.96	-168.47	400	446	1	LO	LO	TI	0	N
Chukchi	GEO2012343	Ringed seal	1	11/16/2012 16:55:10	67.93	-168.48	50	103	1	LO	SP	TI	0	N
Chukchi	GEO2012344	Bearded seal	3	11/16/2012 16:56:13	67.93	-168.48	2984	2964	1	LO	NO	TI	0	N
Chukchi	POL2012132	Ringed seal	2	11/16/2012 17:21:47	67.83	-168.51	679	679	2	LO	NO	OT	X	N
Chukchi	GEO2012345	Unidentified seal	1	11/16/2012 17:23:59	67.85	-168.51	1861	1899	3	LO	NO	TI	0	N
Chukchi	POL2012133	Bearded seal	1	11/16/2012 17:24:00	67.83	-168.51	50	50	2	SW	NO	OT	X	N
Chukchi	POL2012134	Ringed seal	1	11/16/2012 17:26:53	67.82	-168.51	159	159	2	SW	NO	OT	X	N
Chukchi	POL2012135	Bearded seal	3	11/16/2012 17:26:55	67.82	-168.51	523	523	2	LO	NO	OT	X	N
Chukchi	GEO2012346	Unidentified seal	2	11/16/2012 17:27:24	67.84	-168.51	1861	1899	3	LO	NO	TI	0	N
Chukchi	GEO2012347	Unidentified seal	1	11/16/2012 17:33:05	67.82	-168.51	346	397	3	LO	SP	TI	0	N
Chukchi	GEO2012348	Ringed seal	1	11/16/2012 17:50:45	67.77	-168.51	25	69	3	LO	SP	TI	0	N
Chukchi	POL2012136	Ringed seal	1	11/16/2012 17:56:34	67.74	-168.51	100	100	3	DI	NO	OT	X	N
Chukchi	GEO2012349	Unidentified seal	1	11/16/2012 17:59:16	67.75	-168.52	30	80	3	LO	LO	TI	0	N
Chukchi	GEO2012350	Unidentified seal	1	11/16/2012 18:02:32	67.74	-168.52	100	134	3	LO	LO	TI	0	N
Chukchi	POL2012137	Ringed seal	1	11/16/2012 18:04:29	67.72	-168.51	273	273	3	LO	NO	OT	X	N
Chukchi	POL2012138	Ringed seal	1	11/16/2012 18:11:25	67.70	-168.51	359	359	3	SW	LO	OT	X	N
Chukchi	POL2012139	Unidentified seal	1	11/16/2012 18:18:40	67.68	-168.51	1228	1228	3	LO	NO	OT	X	N
Chukchi	GEO2012351	Pacific w alrus	7	11/16/2012 18:29:15	67.66	-168.52	886	932	X	LO	NO	TI	0	N
Chukchi	GEO2012352	Pacific w alrus	17	11/16/2012 18:30:04	67.66	-168.52	1072	1087	X	LO	NO	TI	0	N
Chukchi	GEO2012353	Pacific w alrus	25	11/16/2012 18:30:36	67.66	-168.52	1072	1118	X	LO	NO	TI	0	N
Chukchi	GEO2012354	Pacific w alrus	4	11/16/2012 18:30:59	67.66	-168.52	2984	3030	X	LO	NO	TI	0	N
Chukchi	GEO2012355	Pacific w alrus	25	11/16/2012 18:31:24	67.66	-168.52	523	539	X	LO	NO	TI	0	N
Chukchi	GEO2012356	Pacific w alrus	2	11/16/2012 18:31:51	67.65	-168.52	1072	1099	X	LO	NO	TI	0	N

Table G.1 (cont). All marine mammal detections during ION's seismic survey in the Arctic Ocean, 12 October – 17 November 2012.

Sea	Sighting ID[a]	Species	No.[b]	Date (AKDT)	Lat (°N)	Long (°W)	Initial Sighting Dist.[c] (m)	CPA[d,e] (m)	Bf[f]	Behav.[g]	Rxn to Vessel[h]	Vessel Activity[i]	Array Vol. (in^3)	Dup. Sight.[j]
Chukchi	GEO2012357	Pacific walrus	12	11/16/2012 18:32:13	67.65	-168.52	523	551	X	LO	NO	TI	0	N
Chukchi	GEO2012358	Pacific walrus	12	11/16/2012 18:32:33	67.65	-168.52	582	628	X	LO	NO	TI	0	N
Chukchi	GEO2012359	Pacific walrus	6	11/16/2012 18:32:54	67.65	-168.52	582	633	X	LO	NO	TI	0	N
Chukchi	GEO2012360	Pacific walrus	7	11/16/2012 18:33:19	67.65	-168.52	582	633	X	LO	NO	TI	0	N
Chukchi	GEO2012361	Pacific walrus	3	11/16/2012 18:33:42	67.65	-168.52	2984	3035	X	LO	NO	TI	0	N
Chukchi	GEO2012362	Pacific walrus	2	11/16/2012 18:34:09	67.65	-168.52	886	888	X	LO	NO	TI	0	N
Chukchi	GEO2012363	Unidentified seal	1	11/16/2012 18:34:28	67.65	-168.52	1072	1118	X	LO	NO	TI	0	N
Chukchi	GEO2012364	Unidentified seal	1	11/16/2012 18:34:51	67.65	-168.52	1072	1123	X	LO	NO	TI	0	N
Chukchi	GEO2012365	Pacific walrus	6	11/16/2012 18:35:43	67.64	-168.52	1072	1110	X	LO	NO	TI	0	N
Chukchi	GEO2012366	Pacific walrus	31	11/16/2012 18:42:33	67.62	-168.52	1861	1888	X	LO	NO	TI	0	N
Chukchi	GEO2012367	Pacific walrus	10	11/16/2012 18:52:06	67.60	-168.52	1861	1907	X	LO	NO	TI	0	N
Chukchi	GEO2012368	Pacific walrus	9	11/16/2012 18:52:35	67.60	-168.52	2984	3021	X	LO	NO	TI	0	N
Chukchi	GEO2012369	Pacific walrus	15	11/16/2012 18:57:13	67.58	-168.52	657	673	X	LO	NO	TI	0	N
Chukchi	GEO2012370	Pacific walrus	7	11/16/2012 18:57:32	67.58	-168.52	346	350	X	LO	NO	TI	0	N
Chukchi	GEO2012371	Pacific walrus	16	11/16/2012 18:57:58	67.58	-168.52	755	801	X	LO	NO	TI	0	N

[a] Sighting ID = Vessel name, year (2012) and sequential number given to sighting by PSOs. GEO = *Geo Arctic* and POR = *Polar Prince*. Sightings which occurred during transit are not included.
[b] No. = Number of individual marine mammals observed during sighting.
[c] Initial Sighting Dist. = Initial sighting distance (m) of marine mammal(s) from the PSOs when initially detected.
[d,e] CPA = For the *Geo Arctic* closest point of approach of the marine mammal(s) is to the airgun array. For the *Polar Prince* closest point of approach is to the PSO.
[f] Bf = Beaufort Wind Force (see Appendix F for definitions).
[g] Behav. = Initial behavior of marine mammal(s) observed by PSOs. Codes: BL = Blow; DI = Dive; LG = Logging; LO = Look; MI = Milling; RE = Resting; SA = Surface Active; SI = Sink; ST = Surface Active-Travel; SW = Swim; TH = Thrash; U = Unknown.
[h] Rxn to Vessel = Reaction of marine mammal(s) to vessel observed by PSOs. Codes: CD = Change in Direction; IS = Increase in Speed; LO = Look at Vessel; NO = No reaction; SG = Interactions with Seismic Gear; SP = Splash; U = Unknown.
[i] Vessel Activity = Vessel activity at the time of the initial detection. Codes: DP = Deploying Seismic Gear; LS = Line Shooting; OT = Other; RC = Recovering Seismic Gear; RU = Ramp up; ST = Seismic Testing; SH = Shooting Offline; TI = Transiting in Ice.
[j].Dup. Sighti.= Sighting observed from both *Geo Arctic* and *Polar Prince*.

APPENDIX H: UNIDENTIFIED MARINE MAMMAL DETECTIONS

Table H.1. Unidentified marine mammal detections during ION's seismic survey in the Arctic Ocean, 12 October – 16 November 2012.

Sea	Sighting ID[a]	Species	No.[b]	Date (AKDT)	Comments	Dup. Sight.[c]
Chukchi	POL201210	Unidentified mysticete whale	2	10/12/2012 17:25:44	MODERTATE PUFFY BLOWS, EVERY 7-9.SECONDS, IMPRESSION IS OF A PAIR OF HUMBACKS, SEPARATED BY ABOUT 100 METERS. TOO MANY BLOWS AT SURFACE FOR BOWHEAD, CAPTAIN SAID HE SAW ONE ANIMAL BREACHING, DORSAL FIN AND LARGE FLIPPERS. WE WERE UNABLE TO SEE ANY BODY	N
Chukchi	GEO20123	Unidentified mysticete whale	2	10/14/2012 11:44:30	SAW 3 BLOWS OFF IN THE DISTANCE. BLOWS WERE TALL ENOUGH TO INDICATE THAT IT WAS A BALEEN WHALE. DID NOT SEE A BODY ONLY BLOWS. SAW 2 OF THE BLOWS IN DIFFERENT LOCATIONS SO ASSUME THERE WERE 2 DIFFERENT ANIMALS.	N
Beaufort	POL201211	Unidentified mysticete whale	1	10/15/2012 10:12:45	TALL COLUMNAR BLOWS. SAW 4 BLOWS THEN ANIMAL WENT BENEATH THE SURFACE AND WAS NOT SEEN AGAIN. NEVER SAW THE BODY.	N
Beaufort	GEO20124	Unidentified seal	1	10/15/2012 15:52:41	SAW FULMARS AND GULLS GLIDING AND FLYING LOW OVER WATER BUT DID NOT SEE THEM DIVE TO FEED. SAW SEAL HEAD AT SURFACE WHILE SCANNING BIRD GROUP WITH BINOCULARS. SEAL LOOKED AT US AND THEN SLIPPED BELOW SURFACE - BUT DID NOT DIVE HEAD FIRST	N
Beaufort	POL201220	Unidentified seal	1	11/05/2012 11:10:31	DELETE THAT FIRST RECORD, NOT SHOOTING, JUST TRANSITING THROUGH AREA.	N
Beaufort	POL201221	Unidentified seal	1	11/05/2012 13:32:09	SAW DARK HEAD	N
Beaufort	POL201225	Unidentified seal	1	11/09/2012 18:32:45	SIGHTED A DARK SPOT ON THE ICE. AFTER WATCHING WITH SPENCER AND TIM WE ARE PRETTY CONFIDENT IT IS A SEAL. WE COULD SEE IT WITH THE FLIR, BUT NOT THE NVDS. COULD SEE IT MOVING ON THE CAMERA.	N
Beaufort	GEO20129	Unidentified seal	1	11/11/2012 11:24:50	IN SMALL BIT OF OPEN WATER SURROUNDED BY ICE. SAW IT'S HEAD. IT WENT BELOW SURFACE BUT THEN IT'S HEAD RE-APPEARED. ALSO BRIEFLY SAW IT'S BACK. DID SEVERAL TIMES. WAS NOT LOOKING AT OUR SHIP - WAS LOOKING AT THE POLAR PRINCE, ROUGHLY 750M AHEAD OF US.	N

Table H.1 (cont). Unidentified marine mammal detections during ION's seismic survey in the Arctic Ocean, 12 October – 16 November 2012.

Sea	Sighting ID[a]	Species	No.[b]	Date (AKDT)	Comments	Dup. Sight.[c]
Beaufort	GEO201210	Unidentified seal	1	11/11/2012 13:27:45	SEEN TWICE	N
Beaufort	GEO201211	Unidentified seal	1	11/11/2012 13:28:58	SEEN ONCE	N
Beaufort	GEO201212	Unidentified seal	1	11/11/2012 13:29:14	SEEN TWICE - IT SPLASHED AS IT DOVE	N
Beaufort	GEO201213	Unidentified seal	1	11/11/2012 13:35:03	SURFACED TWICE - NOT SURE IF THE SEAL WAS LOOKING AT THE VESSEL OR NOT. DID NOT SEE IT LONG ENOUGH	N
Beaufort	GEO201214	Unidentified seal	1	11/11/2012 13:45:18	SEEN ONCE	N
Beaufort	GEO201215	Unidentified seal	1	11/11/2012 13:47:46	SEEN TWICE	N
Beaufort	GEO201216	Unidentified seal	1	11/11/2012 13:54:36	SEEN TWICE	N
Beaufort	GEO201217	Unidentified seal	1	11/11/2012 13:59:25	SEEN ONCE	N
Beaufort	GEO201218	Unidentified seal	1	11/11/2012 14:02:49	SEEN ONCE	Y
Beaufort	GEO201219	Unidentified seal	1	11/11/2012 14:07:35	SEEN THREE TIMES	N
Beaufort	GEO201220	Unidentified seal	1	11/11/2012 14:14:33	SEEN 2 TIMES	N
Beaufort	GEO201221	Unidentified seal	1	11/11/2012 14:18:29	X	N
Beaufort	GEO201222	Unidentified seal	2	11/11/2012 14:20:46	X	N
Beaufort	GEO201223	Unidentified seal	1	11/11/2012 14:24:28	REACTION - MOVED OFF ICE AND WENT INTO WATER. BEHAVIOUR 1 WOULD HAVE BEEN RESTING ON ICE.	N
Beaufort	GEO201224	Unidentified seal	1	11/11/2012 14:27:44	X	N
Beaufort	GEO201226	Unidentified seal	1	11/11/2012 14:30:05	X	N
Beaufort	GEO201227	Unidentified seal	2	11/11/2012 14:41:02	X	N
Beaufort	GEO201228	Unidentified seal	2	11/11/2012 14:43:15	X	N
Beaufort	GEO201229	Unidentified seal	3	11/11/2012 14:45:11	LOOKING AT POLAR PRINCE	N
Beaufort	GEO201230	Unidentified seal	1	11/11/2012 14:45:24	X	N
Beaufort	GEO201231	Unidentified seal	2	11/11/2012 14:47:18	AHEAD OF THE POLAR PRINCE	Y
Beaufort	GEO201232	Unidentified seal	1	11/11/2012 14:48:36	SEEN ONCE	N
Beaufort	GEO201233	Unidentified seal	1	11/11/2012 14:49:50	X	N

Table H.1 (cont). Unidentified marine mammal detections during ION's seismic survey in the Arctic Ocean, 12 October – 17 November 2012.

Sea	Sighting ID[a]	Species	No.[b]	Date (AKDT)	Comments	Dup. Sight.[c]
Beaufort	GEO201234	Unidentified seal	1	11/11/2012 14:51:04	X	N
Beaufort	GEO201235	Unidentified seal	1	11/11/2012 14:51:28	X	N
Beaufort	GEO201236	Unidentified seal	1	11/11/2012 14:52:29	IT DOVE. LIKELY SAME ANIMAL SEEN IN ID 29	N
Beaufort	GEO201237	Unidentified seal	1	11/11/2012 14:52:56	X	N
Beaufort	GEO201238	Unidentified seal	1	11/11/2012 14:53:43	X	N
Beaufort	GEO201239	Unidentified seal	1	11/11/2012 14:59:12	REACTION IS DIVE NOT SPLASH	Y
Beaufort	POL201239	Unidentified seal	1	11/11/2012 14:59:29	ANIMAL WAS RESTING ON ICE THEN DOVE IN THE WATER. WE WERE STILL OVER 1 KM AWAY WHEN IT DOVE IN THE WATER	N
Beaufort	GEO201240	Unidentified seal	1	11/11/2012 15:02:06	X	N
Beaufort	GEO201241	Unidentified seal	2	11/11/2012 15:02:15	X	N
Beaufort	GEO201243	Unidentified seal	1	11/11/2012 15:04:22	X	N
Beaufort	GEO201244	Unidentified seal	1	11/11/2012 15:04:31	X	N
Beaufort	GEO201245	Unidentified seal	1	11/11/2012 15:04:53	X	N
Beaufort	GEO201246	Unidentified seal	1	11/11/2012 15:06:01	X	N
Beaufort	GEO201247	Unidentified seal	1	11/11/2012 15:07:23	X	Y
Beaufort	POL201240	Unidentified seal	1	11/11/2012 15:07:47	X	N
Beaufort	GEO201248	Unidentified seal	1	11/11/2012 15:08:54	X	N
Beaufort	GEO201249	Unidentified seal	1	11/11/2012 15:09:34	X	N
Beaufort	GEO201250	Unidentified seal	1	11/11/2012 15:09:55	X	N
Beaufort	POL201241	Unidentified seal	1	11/11/2012 15:10:28	X	N
Beaufort	GEO201251	Unidentified seal	1	11/11/2012 15:10:39	X	N
Beaufort	GEO201252	Unidentified seal	1	11/11/2012 15:11:46	X	N
Beaufort	POL201242	Unidentified seal	1	11/11/2012 15:12:47	X	N
Beaufort	GEO201253	Unidentified seal	1	11/11/2012 15:13:46	X	N

Table H.1 (cont). Unidentified marine mammal detections during ION's seismic survey in the Arctic Ocean, 12 October – 16 November 2012.

Sea	Sighting ID[a]	Species	No.[b]	Date (AKDT)		Comments	Dup. Sight.[c]
Beaufort	GEO201254	Unidentified seal	1	11/11/2012 15:15:28	X		N
Beaufort	POL201243	Unidentified seal	1	11/11/2012 15:15:28	X		N
Beaufort	GEO201255	Unidentified seal	1	11/11/2012 15:17:13	X		N
Beaufort	GEO201256	Unidentified seal	1	11/11/2012 15:17:36	X		N
Beaufort	GEO201258	Unidentified seal	1	11/11/2012 15:19:55	X		N
Beaufort	GEO201259	Unidentified seal	1	11/11/2012 15:21:24	X		N
Beaufort	GEO201260	Unidentified seal	1	11/11/2012 15:22:00	X		N
Beaufort	GEO201261	Unidentified seal	1	11/11/2012 15:25:14	X		N
Beaufort	GEO201262	Unidentified seal	4	11/11/2012 15:25:39	X		Y
Beaufort	GEO201263	Unidentified seal	1	11/11/2012 15:26:50	X		N
Beaufort	GEO201264	Unidentified seal	1	11/11/2012 15:39:05	X		N
Beaufort	GEO201265	Unidentified seal	1	11/11/2012 15:47:29	X		N
Beaufort	GEO201268	Unidentified seal	1	11/11/2012 15:55:49	X		N
Beaufort	GEO201269	Unidentified seal	1	11/11/2012 15:58:03	X		N
Beaufort	POL201248	Unidentified seal	1	11/11/2012 15:59:17	X		N
Beaufort	GEO201270	Unidentified seal	1	11/11/2012 16:00:36	X		N
Beaufort	GEO201271	Unidentified seal	2	11/11/2012 16:01:22	X		N
Beaufort	GEO201272	Unidentified seal	2	11/11/2012 16:04:07	X		N
Beaufort	GEO201273	Unidentified seal	1	11/11/2012 16:07:09	X		N
Beaufort	GEO201274	Unidentified seal	1	11/11/2012 16:07:37	X		N
Beaufort	GEO201275	Unidentified seal	1	11/11/2012 16:07:52	X		N
Beaufort	GEO201276	Unidentified seal	2	11/11/2012 16:08:47	X		N
Beaufort	GEO201277	Unidentified seal	3	11/11/2012 16:09:22	X		Y

Table H.1 (cont). Unidentified marine mammal detections during ION's seismic survey in the Arctic Ocean, 12 October – 17 November 2012.

Sea	Sighting ID[a]	Species	No.[b]	Date (AKDT)	Comments	Dup. Sight.[c]
Beaufort	GEO201278	Unidentified seal	1	11/11/2012 16:10:44	X	N
Beaufort	POL201250	Unidentified seal	1	11/11/2012 16:25:24	X	N
Beaufort	GEO201280	Unidentified seal	1	11/11/2012 16:46:35	X	N
Beaufort	GEO201281	Unidentified seal	1	11/11/2012 16:48:48	X	N
Chukchi	GEO2012101	Unidentified pinniped	1	11/14/2012 15:21:55	EITHER A WALRUS OR A BEARDED SEAL - IT WAS LARGE, BUT LIKELY A BEARDED SEAL. COULD NOT TELL WHAT IT WAS. IT DOVE BUT IT IS UNCERTAIN IF THAT WAS IN REACTION TO THE VESSEL	N
Chukchi	GEO2012106	Unidentified seal	1	11/14/2012 15:52:28	X	N
Chukchi	POL201280	Unidentified seal	1	11/15/2012 11:54:00	X	N
Chukchi	GEO2012127	Unidentified seal	1	11/15/2012 15:40:58	SAW SEAL HEAD SURFACE BRIEFLY IN PATCH OF FLOATING UNCONSOLIDATED ICE. SEAL DID NOT LOOK AT OUR VESSEL. SEEMED TO BE LOOKING IN DIRECTION BEHIND OUR VESSEL. HE THEN DISAPPEARED BELOW WATER. DID NOT DIVE.	N
Chukchi	GEO2012128	Unidentified seal	2	11/15/2012 15:53:20	JUST SEEM TO BE HANGING OUT IN THE WATER...NOT REALLY MOVING AROUND. THEIR HEAD JUST ABOVE THE WATER. IN UNCONSOLIDATED ICE. BEHAVIOR MAY BE RESTING IN WATER AS THEY ARE NOT REALLY MOVING.	N
Chukchi	GEO2012129	Unidentified seal	1	11/15/2012 15:56:40	IN UNCOLSOLIDATED ICE. BEHAVIOUR 1 MAY BE RESTING IN WATER. NOT REALLY MOVING	N
Chukchi	POL201282	Unidentified seal	1	11/15/2012 16:33:14	DARK BODY. IT IS TOO FAR TO SAY A SPECIES RELIABLY	N
Chukchi	GEO2012130	Unidentified seal	1	11/15/2012 16:37:05	X	N
Chukchi	GEO2012131	Unidentified seal	1	11/15/2012 16:40:06	X	N
Chukchi	GEO2012133	Unidentified seal	1	11/15/2012 16:50:20	X	N
Chukchi	GEO2012134	Unidentified seal	1	11/15/2012 16:53:36	X	N
Chukchi	GEO2012135	Unidentified seal	1	11/15/2012 17:04:31	X	N

Table H.1 (cont). Unidentified marine mammal detections during ION's seismic survey in the Arctic Ocean, 12 October – 16 November 2012.

Sea	Sighting ID[a]	Species	No.[b]	Date (AKDT)	Comments	Dup. Sight.[c]
Chukchi	GEO2012136	Unknow n	1	11/15/2012 17:16:52	FREDDIE SAW A BLOW - INITIALLY THOUGHT IT WAS A WHALE, THEN RECONSIDERED THE SIZE OF THE BLOW AND SUGGETED IT COULD HAVE BEEN SOMETHING SMALLER....	N
Chukchi	GEO2012137	Unidentified seal	1	11/15/2012 17:51:41	THIS SEAL WAS SEEN ON THE ICE EVEN THOUGH THE VISIBILITY WAS CODED AS 0.5 KM - WE CAN SEE FURTHER WHEN SEARCHING FOR ANIMALS ON THE ICE ESPECIALLY WITH BINOCULARS	N
Chukchi	GEO2012138	Unidentified seal	3	11/16/2012 11:43:48	3 SEALS - ACTUALLY NOT IN A GROUP - THIS SHOULD PROBABLY BE 3 SIGHTING RECORDS - BUT ALL INFO WOULD BE THE SAME FOR EACH SIGHTING.	N
Chukchi	GEO2012139	Unidentified seal	1	11/16/2012 11:44:08	SEEMS LARGER AT GREATER DISTANCE - MORE LIKELY A BEARDED SEAL - BUT WITH LOW LIGHT IT'S STILL JUST A BLACK LUMP. BOAT IS CIRCLING.	N
Chukchi	GEO2012141	Unidentified seal	1	11/16/2012 11:47:50	X	N
Chukchi	GEO2012142	Unidentified seal	2	11/16/2012 11:51:40	X	N
Chukchi	GEO2012143	Unidentified seal	10	11/16/2012 11:55:57	X	N
Chukchi	GEO2012144	Unidentified seal	1	11/16/2012 11:56:19	X	N
Chukchi	GEO2012145	Unidentified seal	1	11/16/2012 11:58:52	X	N
Chukchi	GEO2012146	Unidentified seal	1	11/16/2012 12:02:18	X	N
Chukchi	GEO2012147	Unidentified seal	1	11/16/2012 12:02:35	X	N
Chukchi	GEO2012148	Unidentified seal	1	11/16/2012 12:02:47	X	N
Chukchi	GEO2012149	Unidentified seal	1	11/16/2012 12:04:50	SEEN AT RETICLE 0.75	N
Chukchi	GEO2012150	Unidentified seal	1	11/16/2012 12:08:14	X	N
Chukchi	GEO2012151	Unidentified seal	1	11/16/2012 12:12:41	X	N
Chukchi	GEO2012152	Unidentified seal	2	11/16/2012 12:14:11	X	N
Chukchi	GEO2012153	Unidentified seal	2	11/16/2012 12:15:40	X	N
Chukchi	GEO2012154	Unidentified seal	3	11/16/2012 12:17:45	X	N
Chukchi	POL201283	Unidentified seal	1	11/16/2012 12:17:47	BOBBING UP ANDDOWN IN THE WATER	N

Table H.1 (cont). Unidentified marine mammal detections during ION's seismic survey in the Arctic Ocean, 12 October – 17 November 2012.

Sea	Sighting ID[a]	Species	No.[b]	Date (AKDT)	Comments	Dup. Sight.[c]
Chukchi	GEO2012155	Unidentified seal	2	11/16/2012 12:18:52	X	N
Chukchi	GEO2012157	Unidentified seal	1	11/16/2012 12:22:46	X	N
Chukchi	POL201285	Unidentified seal	1	11/16/2012 12:24:03	X	N
Chukchi	GEO2012158	Unidentified seal	3	11/16/2012 12:24:06	X	N
Chukchi	GEO2012159	Unidentified seal	2	11/16/2012 12:25:10	0.75 RETICLES	N
Chukchi	GEO2012160	Unidentified seal	2	11/16/2012 12:26:52	X	N
Chukchi	GEO2012161	Unidentified seal	1	11/16/2012 12:27:47	.75 RETICLE	N
Chukchi	GEO2012162	Unidentified seal	7	11/16/2012 12:29:02	X	N
Chukchi	GEO2012163	Unidentified seal	1	11/16/2012 12:32:13	X	N
Chukchi	GEO2012164	Unidentified seal	2	11/16/2012 12:32:39	X	N
Chukchi	GEO2012165	Unidentified seal	1	11/16/2012 12:38:10	X	N
Chukchi	GEO2012166	Unidentified seal	1	11/16/2012 12:39:03	X	N
Chukchi	GEO2012167	Unidentified seal	1	11/16/2012 12:39:18	X	N
Chukchi	POL201289	Unidentified seal	4	11/16/2012 12:42:54	X	N
Chukchi	GEO2012168	Unidentified seal	1	11/16/2012 12:43:12	X	N
Chukchi	POL201290	Unidentified seal	4	11/16/2012 12:44:12	TOO FAR TO TELL, BUT FROM SIZE WOULD GUESS THEY ARE BEARDED SEALS	N
Chukchi	POL201291	Unidentified seal	6	11/16/2012 12:47:20	GROUPED TOGEHER A NUMBER OF SEALS	N
Chukchi	GEO2012170	Unidentified seal	2	11/16/2012 12:48:08	X	N
Chukchi	GEO2012172	Unidentified seal	1	11/16/2012 12:49:18	X	N
Chukchi	GEO2012174	Unidentified seal	1	11/16/2012 12:51:35	X	N
Chukchi	GEO2012175	Unidentified seal	1	11/16/2012 12:51:47	X	N
Chukchi	GEO2012176	Unidentified seal	1	11/16/2012 12:54:16	X	N
Chukchi	GEO2012177	Unidentified seal	1	11/16/2012 12:54:42	X	N

Table H.1 (cont). Unidentified marine mammal detections during ION's seismic survey in the Arctic Ocean, 12 October – 16 November 2012.

Sea	Sighting ID[a]	Species	No.[b]	Date (AKDT)	Comments	Dup. Sight.[c]
Chukchi	GEO2012179	Unidentified seal	4	11/16/2012 12:58:37	X	N
Chukchi	GEO2012180	Unidentified seal	1	11/16/2012 12:59:05	X	N
Chukchi	GEO2012181	Unidentified seal	1	11/16/2012 12:59:34	X	N
Chukchi	GEO2012182	Unidentified seal	3	11/16/2012 12:59:54	X	N
Chukchi	GEO2012184	Unidentified seal	1	11/16/2012 13:06:20	X	N
Chukchi	GEO2012185	Unidentified seal	1	11/16/2012 13:07:11	X	N
Chukchi	GEO2012186	Unidentified seal	1	11/16/2012 13:08:45	X	N
Chukchi	GEO2012187	Unidentified seal	1	11/16/2012 13:10:37	X	N
Chukchi	GEO2012188	Unidentified seal	1	11/16/2012 13:13:52	X	N
Chukchi	GEO2012191	Unidentified seal	1	11/16/2012 13:21:08	X	N
Chukchi	POL201297	Unidentified seal	1	11/16/2012 13:21:13	X	N
Chukchi	GEO2012192	Unidentified seal	1	11/16/2012 13:25:10	X	N
Chukchi	GEO2012193	Unidentified seal	6	11/16/2012 13:25:36	X	N
Chukchi	POL201298	Unidentified seal	1	11/16/2012 13:26:06	X	N
Chukchi	GEO2012194	Unidentified seal	1	11/16/2012 13:30:55	X	N
Chukchi	GEO2012195	Unidentified seal	1	11/16/2012 13:31:11	X	N
Chukchi	GEO2012196	Unidentified seal	2	11/16/2012 13:31:29	X	N
Chukchi	GEO2012206	Unidentified seal	3	11/16/2012 14:00:02	X	N
Chukchi	POL2012108	Unidentified seal	1	11/16/2012 14:06:54	X	N
Chukchi	GEO2012212	Unidentified seal	1	11/16/2012 14:16:46	X	N
Chukchi	GEO2012216	Unidentified seal	1	11/16/2012 14:24:20	X	N
Chukchi	POL2012113	Unidentified pinniped	4	11/16/2012 14:27:39	WERE BOBBING UP AND DOWN	N
Chukchi	GEO2012334	Unidentified seal	1	11/16/2012 16:02:28	STILL AROUND 0.5 RETICLES AWAY	N

Table H.1 (cont). Unidentified marine mammal detections during ION's seismic survey in the Arctic Ocean, 12 October – 17 November 2012.

Sea	Sighting ID[a]	Species	No.[b]	Date (AKDT)	Comments	Dup. Sight.[c]
Chukchi	GEO2012337	Unidentified seal	1	11/16/2012 16:07:19	X	N
Chukchi	GEO2012341	Unidentified seal	1	11/16/2012 16:37:05	NOT LOOKING AT VESSELS	N
Chukchi	GEO2012342	Unidentified seal	1	11/16/2012 16:44:56	X	N
Chukchi	GEO2012345	Unidentified seal	1	11/16/2012 17:23:59	X	N
Chukchi	GEO2012346	Unidentified seal	2	11/16/2012 17:27:24	X	N
Chukchi	GEO2012347	Unidentified seal	1	11/16/2012 17:33:05	X	N
Chukchi	GEO2012349	Unidentified seal	1	11/16/2012 17:59:16	X	N
Chukchi	GEO2012350	Unidentified seal	1	11/16/2012 18:02:32	X	N
Chukchi	POL2012139	Unidentified seal	1	11/16/2012 18:18:40	X	N
Chukchi	GEO2012363	Unidentified seal	1	11/16/2012 18:34:28	X	N
Chukchi	GEO2012364	Unidentified seal	1	11/16/2012 18:34:51	X	N

[a] Sighting ID = Vessel name, year (2012) and sequential number given to sighting by PSOs. GEO = *Geo Arctic* and POR = *Polar Prince*. Sightings which occurred during transit are not included.
[b] No. = Number of individual marine mammals observed during sighting.
[c] Dup. Sight. = Sighting observed by both the *Geo Arctic* and *Polar Prince*.

APPENDIX I: WEEKLY ACTIVITY AND SIGHTINGS MAPS

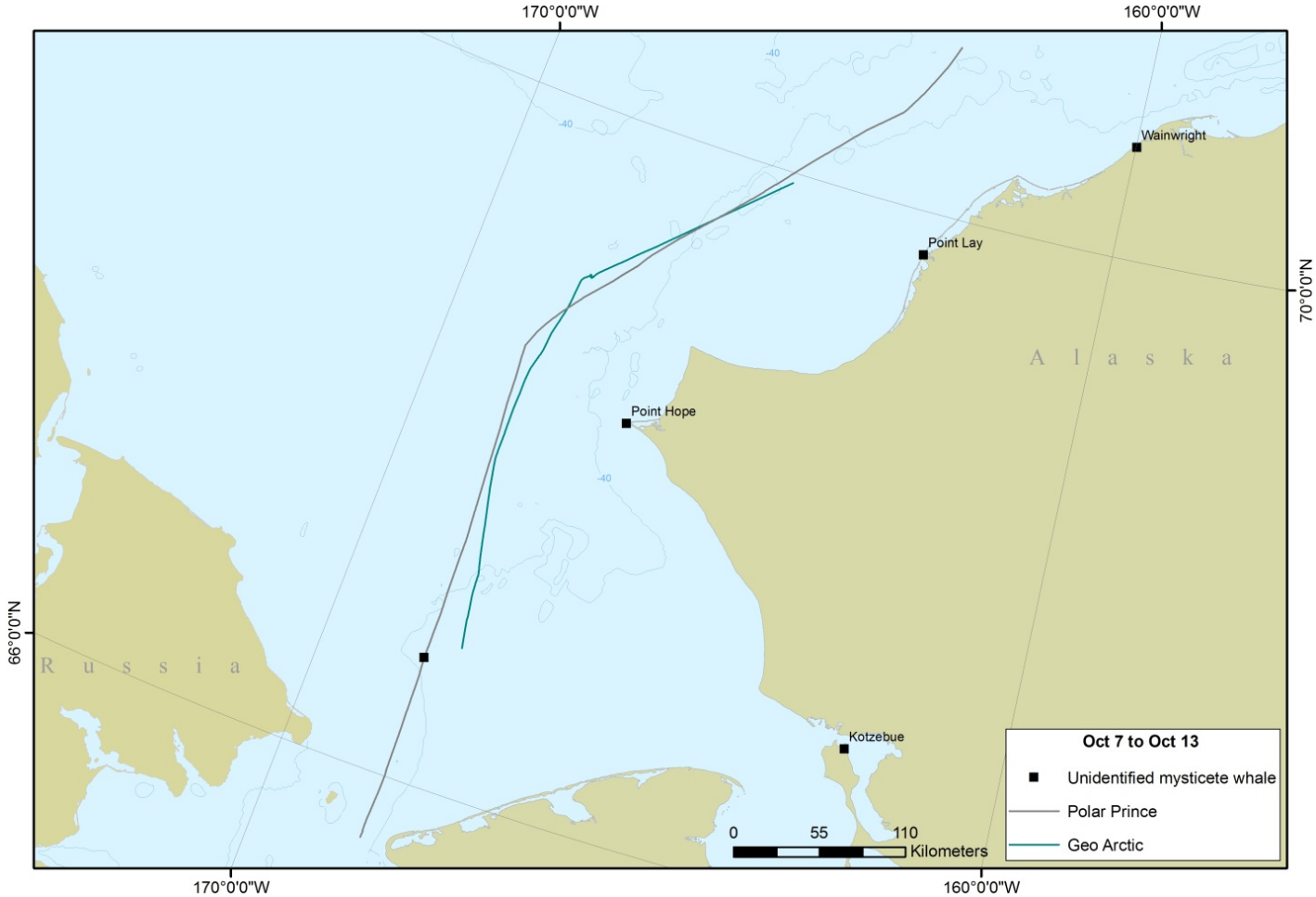


FIGURE I.1. Vessel tracklines and marine mammal sightings that occurred within the survey between 7-13 Oct 2012, during ION's seismic survey. The *Geo Arctic* and *Polar Prince* left Nome on 11 Oct and entered the Chukchi Sea on 12 Oct. The vessels transited through the Chukchi Sea between 12-14 Oct. No seismic survey activities were conducted during this transit.

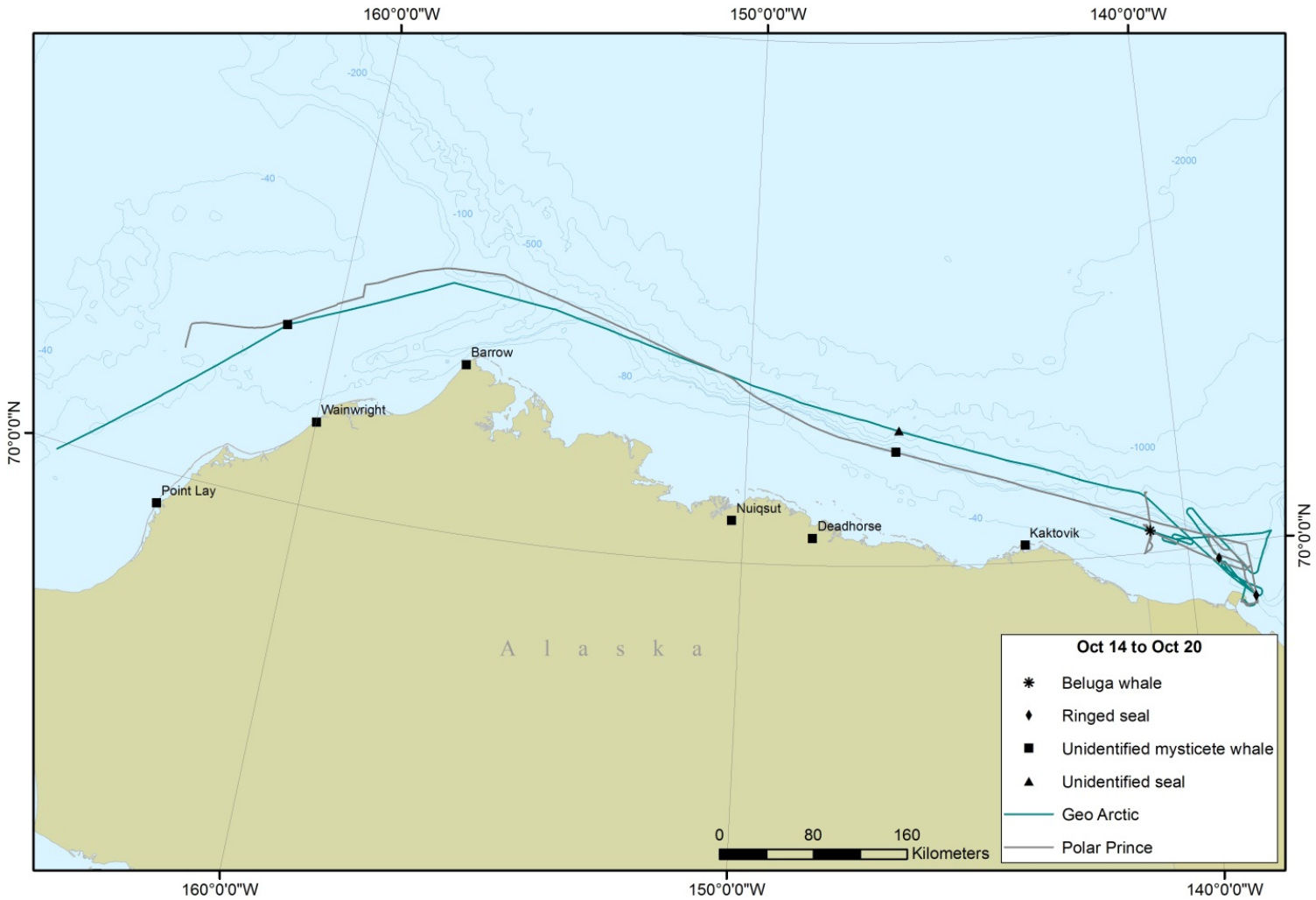


FIGURE I.2. Vessel tracklines and marine mammal sightings that occurred within the survey between 14-20 Oct 2012, during ION's seismic survey. The vessels transited through the Chukchi Sea and rounded Pt. Barrow on 14 Oct, and then crossed the Alaskan Beaufort Sea and entered Canadian waters on 16 Oct. No seismic survey activities were conducted during this transit. The vessels waited out some poor weather and then took fuel from a barge near Herschel Island from 16 Oct to 18 Oct. While transiting to the eastern edge of the survey area on 19 Oct, the *Geo Arctic* began deploying and testing the airgun array while the *Polar Prince* prepared to deploy acoustic recorders as part of the sound source measurement program.

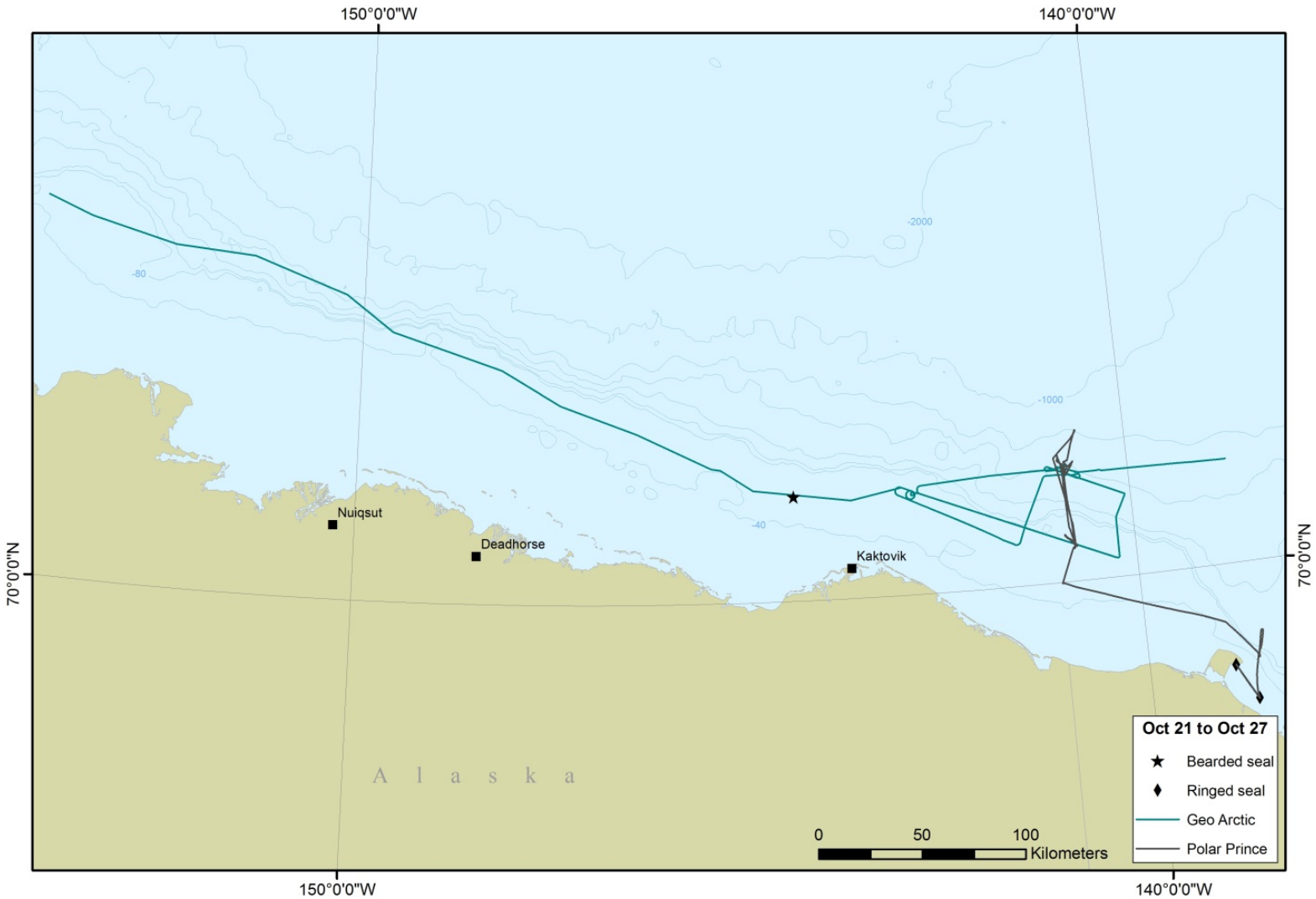


FIGURE I.3. Vessel tracklines and marine mammal sightings that occurred within the survey between 21-27 Oct 2012, during ION's seismic survey. Sound source measurements were conducted from 20 to 23 Oct. The *Geo Arctic* began collecting seismic data in the Beaufort Sea on 24 Oct. The *Polar Prince* retrieved the acoustic recorders on 23 Oct and headed towards Herschel Island to disembark the JASCO personnel.

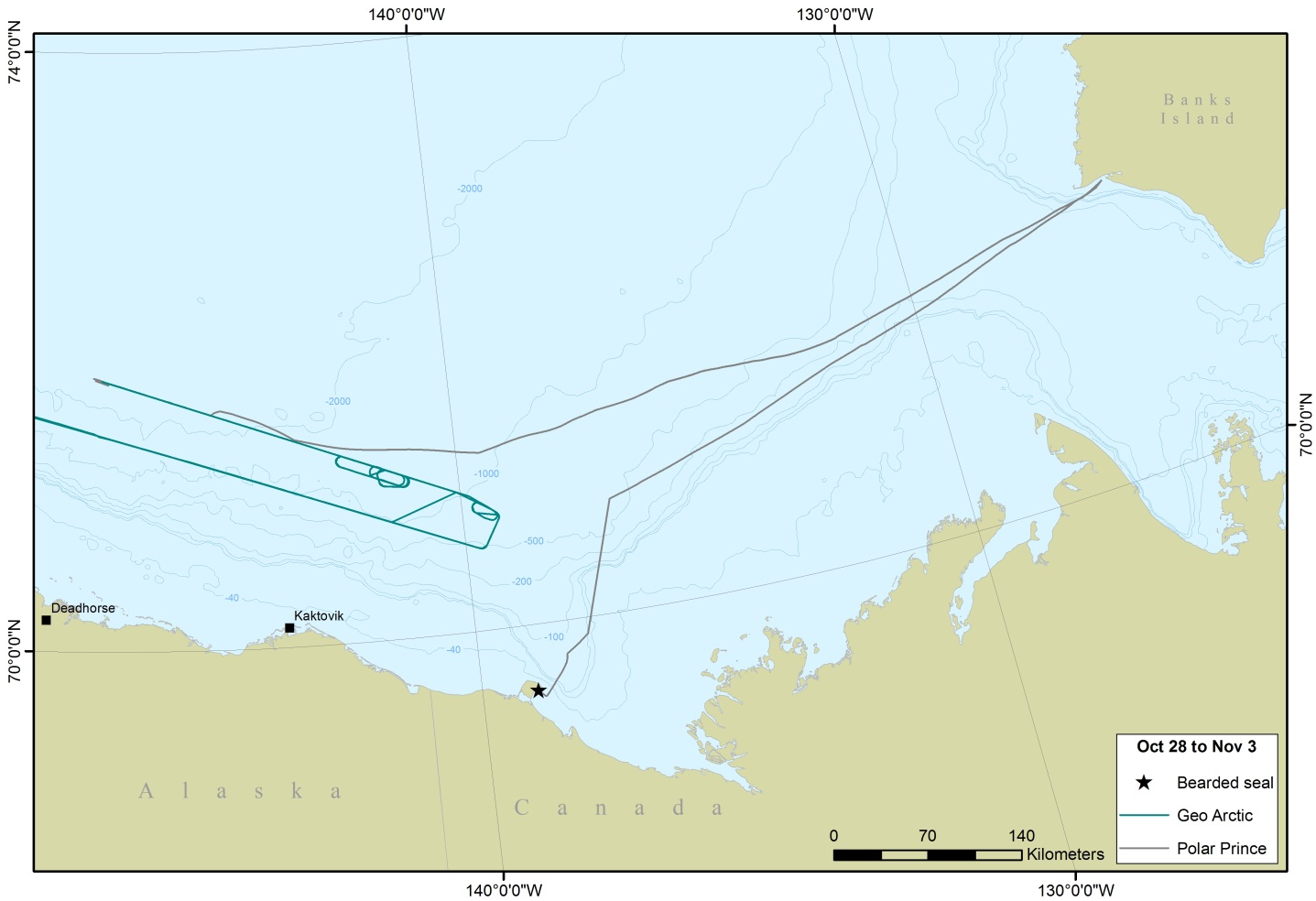


FIGURE I.4. Vessel tracklines and marine mammal sightings that occurred within the survey between 28 Oct -3 Nov 2012, during ION's seismic survey. The *Geo Arctic* continued survey activities in the Beaufort Sea during this period, primarily on east-west lines. The *Polar Prince* had been delayed near Herschel Island attempting to disembark the JASCO personnel after the sound source measurements were completed. After several days of poor weather conditions prevented the personnel transfer at that location, the *Polar Prince* transited to Sachs Harbour, NT where the personnel disembarked on 31 Oct. On the evening of Oct. 31st, the *Polar Prince* departed Sachs Harbour to join the *Geo Arctic*.

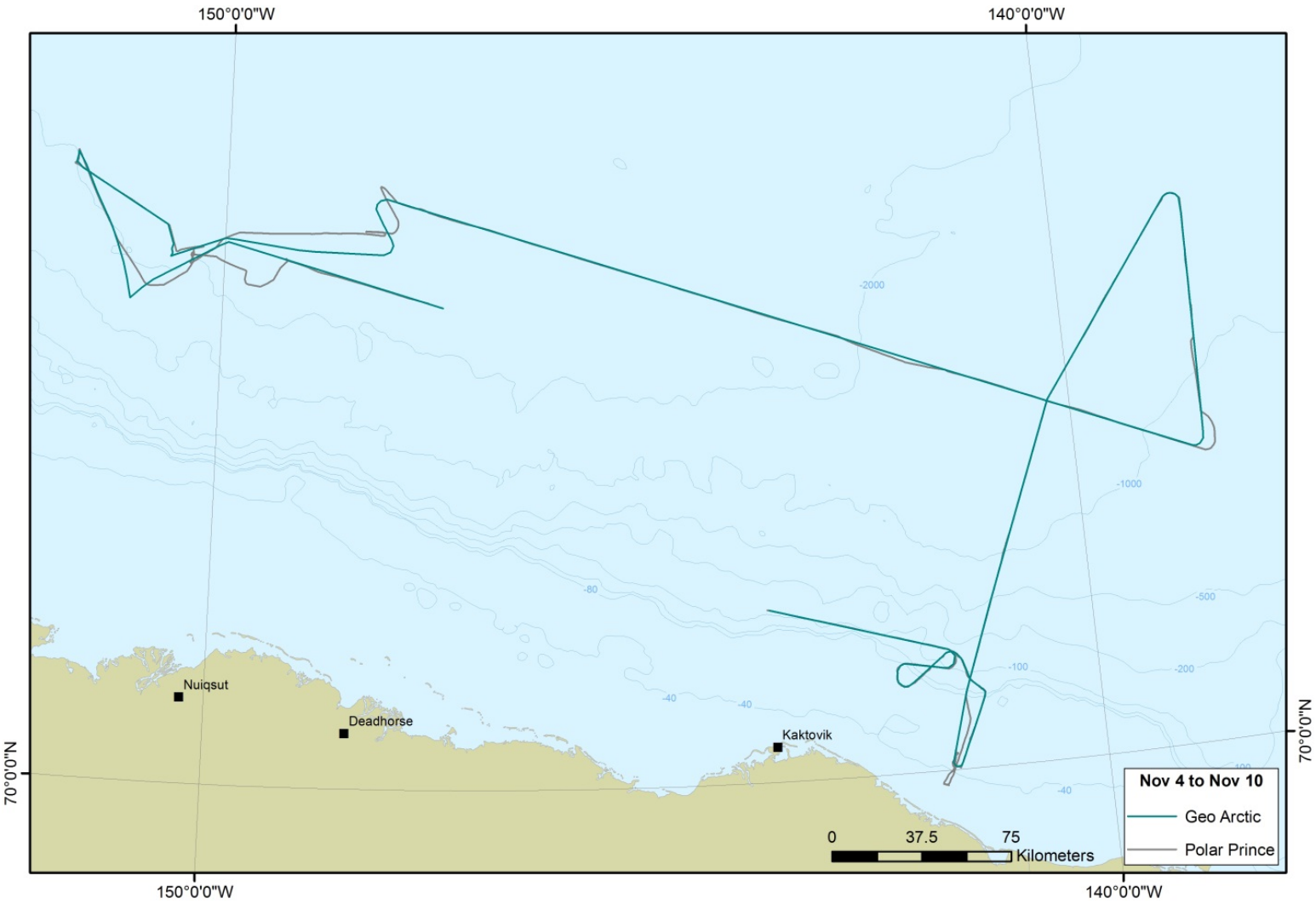


FIGURE I.5. Vessel tracklines and marine mammal sightings that occurred within the survey between 4-10 Nov 2012, during ION's seismic survey. The *Geo Arctic* continued survey activities in the Beaufort Sea, primarily on east-west lines, through 9 Nov. The *Polar Prince* rejoined the *Geo Arctic* on 4 Nov and began scouting ice and assisting with monitoring for marine mammals. After encountering some thicker ice conditions on 9 Nov, and with ice forecasts indicating heavier ice forming near Pt. Barrow, the decision was made to end seismic survey activities in the Beaufort Sea, retrieve the seismic gear, and transit to the Chukchi Sea. The vessels began their transit on 10 Nov.

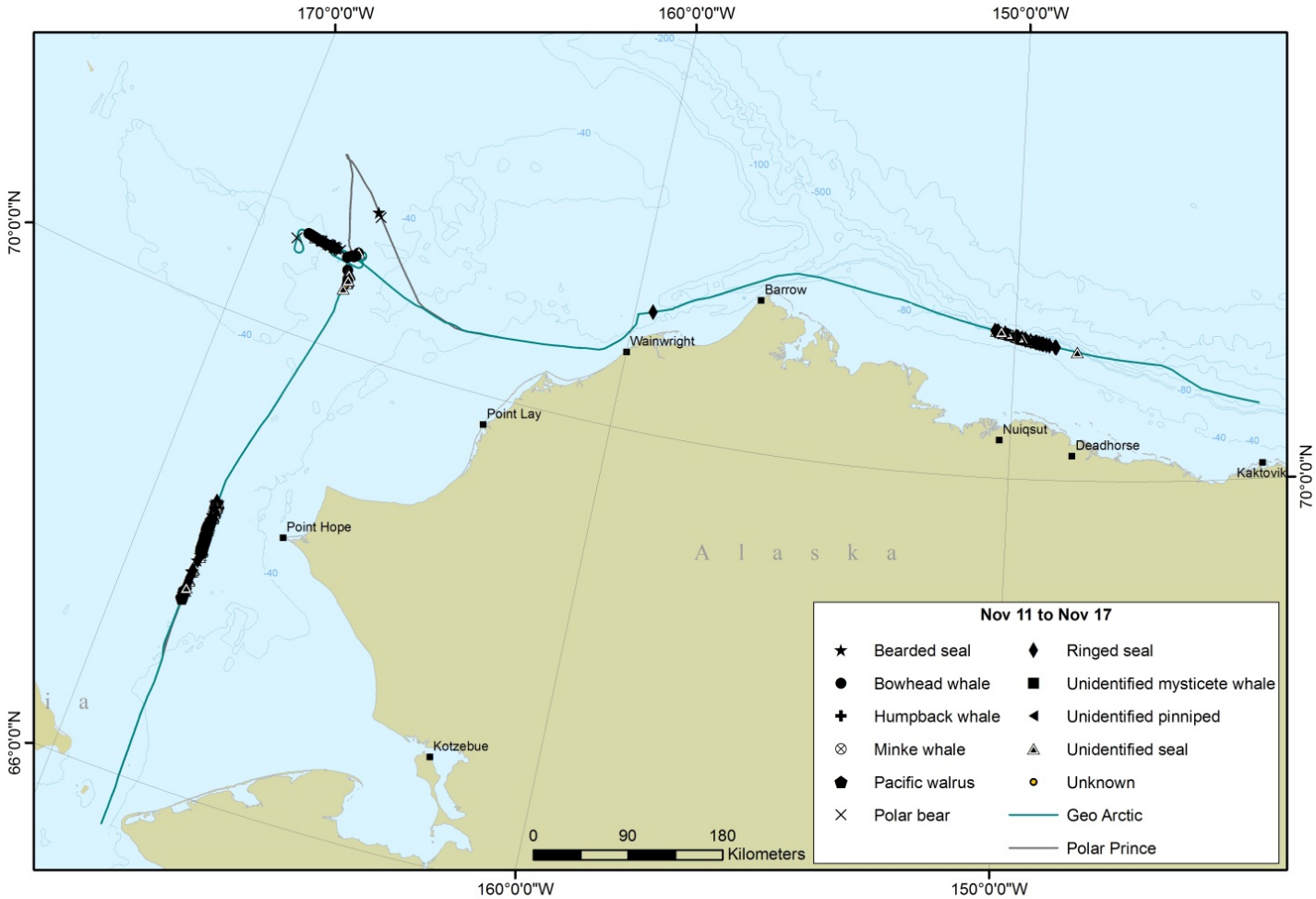


FIGURE I.6. Vessel tracklines and marine mammal sightings that occurred within the survey between 11-17 Nov 2012, during ION's seismic survey. Both vessels transited towards the Chukchi Sea survey area from 10 Nov through 12 Nov, when the vessels passed Pt. Barrow. The *Geo Arctic* traveled towards the southern-most seismic line while on 13 Nov the *Polar Prince* headed to a seismic line further north to assess ice conditions there. It was determined that ice conditions were too heavy at the more northern location, so the *Polar Prince* returned to the southern line to escort the *Geo Arctic* while it collected seismic data. The *Geo Arctic* and *Polar Prince* conducted survey activities in the Chukchi Sea on Nov 14th and the morning of Nov 15th. On Nov 15th the survey was terminated and the vessels began transiting south towards Dutch Harbor while the seismic equipment was recovered. The *Geo Arctic* and *Polar Prince* passed through the Bering Strait on 17 Nov. During their transit of the Bering Sea they remained on the east side of St. Lawrence Island and arrived in Dutch Harbor on 20 Nov.