# Marine Mammal Monitoring and Mitigation During Open Water Seismic Exploration by Shell Offshore Inc. in the Chukchi and Beaufort Seas, July–November 2007: 90-day Report

Prepared by

Alaska Research Associates, Inc.
1101 E. 76th Ave.  Suite B, Anchorage, AK  99518

**LGL Ltd., environmental research associates**
P.O. Box 280, 22 Fisher Street, King City, Ont. L7B 1A6, Canada

and

**JASCO Research Ltd**
Suite 2101, 4464 Markham St., Victoria, BC V8Z 7X8, Canada

for

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

and

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

and

**U.S. fish and Wildlife Service, Marine Mammal Management**
1101 E. Tudor Road, M.S. 341, Anchorage, AK  99503

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Edited by

Dale Funk[a], David Hannay[c], Darren Ireland[a],
Robert. Rodrigues[a], and William R. Koski[b]

[a] **LGL Alaska Research Associates, Inc.**
1101 East 76th Ave., Suite B, Anchorage, AK 99518, U.S.A.

[b] **LGL Limited, environmental research associates**
P.O. Box 280, 22 Fisher Street, King City, Ont. L7B 1A6, Canada

[c] **JASCO Research Ltd**
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# TABLE OF CONTENTS

# LIST OF ACRONYMS AND ABBREVIATIONS

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

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

# EXECUTIVE SUMMARY

## *Background and Introduction*

Shell Offshore, Inc. (SOI) collected marine seismic data in the Chukchi and Beaufort seas during the summer of 2007 in support of potential future oil and gas leasing and development. Deep seismic acquisition for SOI was conducted by WesternGeco using the M/V *Gilavar*, a source vessel that towed an airgun array as well as hydrophone streamers to record reflected seismic data. SOI also conducted site clearance, shallow hazard surveys and geotechnical surveys from the M/V *Henry Christoffersen* (*Henry C.*) in the Beaufort Sea in 2007.

Marine seismic surveys 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. SOI’s seismic surveys and other exploration activities in the Chukchi and Beaufort seas were conducted under the jurisdiction of Incidental Harassment Authorizations (IHAs) issued by NMFS and USFWS. The IHAs included provisions to minimize the possibility that marine mammals close to the seismic source might be exposed to levels of sound high enough to cause hearing damage or other injuries, and to reduce behavioral disturbances that might be considered as “take by harassment” under the MMPA.

A mitigation program was conducted to avoid or minimize potential effects of SOI’s seismic survey on marine mammals, and to ensure that SOI was in compliance with the provisions of the IHAs. This required that marine mammal observes (MMOs) onboard the seismic vessels detect marine mammals within or about to enter the designated safety radii, and in such cases initiate an immediate power down (or shut down if necessary) of the airguns. Mitigation was also required for larger disturbance radii which were monitored by MMOs onboard chase/monitoring vessels. SOI also conducted an aerial survey program in the Beaufort Sea in support of its seismic exploration and shallow hazards surveys.

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; and
3. determine the reactions (if any) of marine mammals potentially exposed to seismic sound impulses.

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

## *Seismic Surveys Described*

The *Gilavar* collected seismic data in the Chukchi Sea from 28 Aug through 10 Sep and entered the Beaufort Sea on 12 Sep to collect seismic data on specific SOI lease holdings. Seismic activities were conducted in the Beaufort Sea from 18 Sep through 3 Oct and the *Gilavar* returned to the Chukchi Sea on 8 Oct to conduct further seismic exploration. The *Gilavar* continued seismic acquisition in the Chukchi Sea from 20 Oct through 4 Nov at which time weather conditions precluded further exploration activities.

Five different vessels were used as chase/monitoring boats for the *Gilavar* at alternating periods during the 2007 open-water period. At times the *Gilavar* used two chase/monitoring vessels simultaneously.

SOI used WesternGeco's 3147 $in^3$ 3-string array of Bolt airguns for its 3–D seismic survey operations in the Chukchi and Beaufort seas. This energy source was towed approximately 245 m (268 yd) behind the *Gilavar*. The system also included 6 hydrophone streamers 4200 m (2.6 mi) in length and spaced 100 m (109 yd) apart, which recorded reflected sound energy. Measurements of the sound produced by the *Gilavar's* airgun array and its mitigation gun were conducted in both the Chukchi and Beaufort seas at the start of seismic acquisition. These measurements were used to determine safety and disturbance radii.

The *Henry C*. entered the Beaufort Sea on 16 Aug from Canada to conduct shallow hazards and site clearance surveys. Site clearance operations were conducted on 23 days in specific nearshore areas ranging from Thetis Island near the Colville River Delta east to Camden Bay from 30 Aug to 2 Oct. An airgun cluster consisting of two 10-$in^3$ airguns was used once during site clearance operations. Measurements of the sound produced by the small airgun array on the *Henry C.* were conducted in Harrison Bay on 30 Aug and in Camden Bay on 14 Sept. Other acoustic sources onboard the *Henry C.* included a bubble pulser, a chirp sonar, a multibeam bathymetric sonar, and a side-scan sonar.

The aerial survey program in the Beaufort Sea began on 22 Aug and was completed on 8 Oct. Completion of some surveys required effort on two consecutive days. A total of 13 surveys were conducted during the survey period. Surveys from 22 Aug through 3 Sep were in support of shallow hazards surveys by the *Henry C.* and were flown in offshore areas from the Sagavanirktok River delta west to Harrison Bay. Aerial surveys beginning on 10 Sep were flown in support of deep seismic exploration from the *Gilavar* and were flown over offshore waters from the Sagavanirktok River delta east to Kaktovik.

### *Sound Source Measurements*

JASCO Research Ltd, under contract to LGL Alaska Research Associates Inc., conducted a Sound Source Verification (SSV) program for Shell Offshore Incorporated (SOI) during the 2007 open water season in the Alaskan Chukchi and Beaufort seas. The SSV program involved field measurements of underwater sound produced by SOI's seismic survey and shallow hazards survey programs. Six separate field studies were carried out using autonomous sound recorders deployed on the seabed near the SOI work activities, which included seismic surveying with airgun arrays, shallow hazards surveying with airgun and sonar sources, and support vessel operations. Initial results of SSV measurement programs were provided within 72 hours of measurement completions to Fish and Wildlife Service, and within 5 days to National Marine Fisheries Service. Those results were also used to establish marine mammal exclusion zones around the survey sources. Further analyses of these data were carried out following the open water season. The field study descriptions, data collection methods, and results of all analyses are presented in this chapter.

### *Results of Marine Mammal Monitoring*

***Chukchi Sea Seismic, Gilavar.—****Gilavar* MMOs completed a total of ~7434 km (4619 mi) of observation effort during the two seismic surveys conducted in the Chukchi Sea in 2007 (~5704 km or ~3544 mi in summer; ~1729 km or 1074 mi in fall). Multiple chase/monitoring vessels accompanied the *Gilavar* to assist with marine mammal monitoring and the implementation of mitigation measures. Conditions were marked by frequent periods of poor visibility (<3.5 km or <2.2 mi) and high winds (>

Beaufort wind force 5). Therefore, traditional criteria for ‘useable’ sightings data were replaced by the inclusion of all daylight observation data to increase sample sizes used in analyses.

A grand total of 3247 individual marine mammals in 656 groups was observed by *Gilavar* and chase/monitoring vessel MMOs during daylight watch periods. The majority of these, 601 sightings of 3192 individuals, was recorded during the summer survey. Pacific walruses comprised the majority of these 601 summer sightings (402). Walrus distribution was patchy and most observations were recorded on a few isolated days. The most notable of these ‘patches’ was recorded by MMOs on the *Gilavar* on 24 Aug when 148 walrus sightings were documented. Additionally there were 48 cetacean sightings, 150 seal sightings, and a single sighting of a Steller sea lion during daylight watches in summer. By comparison, only 55 marine mammal sightings were recorded during the fall survey (2 of cetaceans, 52 of seals, and one Pacific walrus).

Marine mammal sighting rates were highest when winds were light and when more than one MMO was on watch. In general, marine mammals were observed closer to the *Gilavar* during non-seismic periods (when airguns were not firing), but Pacific walruses were an exception and were on average observed closer to the *Gilavar* during seismic periods (while airguns were firing).

Mitigation measures were implemented 27 times during the 2007 Chukchi Sea surveys, and all but one of these events occurred during the summer survey. *Gilavar* MMOs requested 26 airgun power downs from full array volume (3147 $in^3$) to the single mitigation gun volume (30 $in^3$) during the summer survey. Each of these power downs was initiated after Pacific walruses were sighted inside the ≥180 dB safety radius. USFWS previously required a ≥190 dB sound level radius be employed as the safety radius for Pacific walruses. JASCO calculated the 2007 ≥180 dB safety radius to be 2470 m (2701 yd). This distance was greater than that at which MMOs could readily spot large pinnipeds in most sea conditions. To assist with this challenge, Shell voluntarily used multiple chase/monitoring vessels to monitor the ≥180 dB safety radius. Nine of the 26 summer survey walrus power downs were the result of chase/monitoring vessel MMO sightings. The single fall survey power down was for a bearded seal sighted inside the ≥190 dB safety radius. There were no complete airgun array shut downs in the Chukchi Sea in 2007 as a result of marine mammals.

Sound level exposure estimates from direct MMO observations estimated that no cetaceans were exposed to ≥180 dB, no seals were exposed to ≥190 dB, and 50 Pacific walruses were potentially exposed to ≥180 dB. Exposure estimates calculated using marine mammal densities estimated from daylight MMO observations during non-seismic periods resulted in the potential exposure of five cetaceans to ≥180 dB, 97 seals to ≥190 dB, and 253 Pacific walruses to ≥180 dB. (The estimated number of walruses exposed to ≥180 dB was 154 using a density value which excluded the anomalous 24 Aug sightings event). The actual number of individuals exposed was likely between the estimates from direct observation and those calculated using densities due to possible avoidance behavior of marine mammals near vessels and/or airguns during seismic operations.

***Beaufort Sea Seismic, Gilavar.—***In 2007, a total of ~6142 km (~3817 mi; ~602 h) of daylight visual observations were conducted from the *Gilavar* and its chase/monitoring vessels in the Beaufort Sea, ~3210 km (1994 mi) of which were during seismic periods. Conditions in the Beaufort Sea in 2007 were dominated by poor visibility (< 3.5 km or 2.2 mi) and high sea states (Beaufort wind force > 5). The vessels also tended to operate near one another (within 5 km or 3 mi). Therefore, the majority of daylight observation data collected in 2007 was not considered “useable” in the traditional sense (only 11% of the *Gilavar’s* and 25% of the chase/monitoring vessels’ data). Instead, all daylight observation effort was used in most analyses to increase sample sizes. The majority of daylight observation effort from both the

*Gilavar* and its chase/monitoring vessels was carried out by one observer at a time (~4453 km/2767 mi versus ~1689 km/1050 mi with two or more observers on watch).

During seismic operations in the Beaufort Sea, a total of 87 marine mammal groups was recorded including an estimated 126 individual marine mammals. All sightings occurred during daylight hours. Seven marine mammal species were identified in total, including bowhead whale, minke whale, ringed seal, spotted seal, bearded seal, Pacific walrus, and polar bear. The bowhead whale was the most commonly identified cetacean, while ringed and spotted seals were the most commonly identified seal. The Pacific walrus and polar bear were rarely encountered in the Beaufort Sea study area. One possible ringed seal carcass was recorded in the Beaufort Sea away from seismic operations, but no deaths or injuries of animals were observed during the seismic program. In addition to the three chase/monitoring vessels associated with the *Gilavar*, the only other vessel that was present in the study area was the *Henry C.*, which came within 17 km (11 mi) of the *Gilavar.*

Detection rates increased when more MMOs were on watch and decreased with higher winds and sea conditions. Detection rates for cetaceans were almost twice as high from the *Gilavar* compared to the chase/monitoring vessels, possibly because the *Gilavar* had a higher observation platform. For seals, detection rates were higher from the chase/monitoring vessels, especially during seismic periods (almost four times higher than the *Gilavar*), suggesting that seals may be showing a localized avoidance of the operating seismic ship. No comparison of CPA (closest point of approach) for cetaceans was possible due to insufficient sightings. The CPA of seals during seismic periods was, on average, larger than that during non-seismic periods, however small sample sizes again precluded statistical analysis of CPA data.

Power downs were initiated for two sightings of single seals and for four sightings totaling seven individual cetaceans. Using direct observations to estimate the number of marine mammals exposed to particular sound levels, two seals were likely exposed to sound levels ≥190 dB rms and five cetaceans were likely exposed to sound levels ≥180 dB rms. There was one sighting of an unidentified pinniped during a ramp up sequence for which no mitigation measures were taken. It is unlikely that this animal was exposed to sound levels ≥190 dB rms, however if the unidentified pinniped was a Pacific walrus, it is possible that it was exposed to sound levels ≥180 dB rms. Using marine mammal densities to estimate the numbers of marine mammals exposed to various sound levels, we estimated that 20 cetaceans, 165 seals, three Pacific walruses, and two polar bears would have been exposed to sounds ≥160 dB rms.

***Beaufort Sea Shallow Hazards Survey, Henry Christofferson.*—**SOI conducted site clearance and shallow hazards surveys in the Beaufort Sea from the vessel *Henry Christoffersen (Henry C.)* to identify hazardous or sensitive conditions and sites at or below sea level that could affect potential future drilling operations. During the 2823 km (1754 mi; 368h) of daylight visual observations conducted from the *Henry C.*, airguns were operated for only 98 km (~61 mi) over ~15 h. Seismic survey effort with the *Henry C.'s* small airgun array (2 x 10 $\text{in}^3$ airguns) was limited due to high wind and sea conditions.

A total of 280 individual marine mammals were seen in 232 groups within the US Beaufort Sea in 2007 from the *Henry C.* This included 11 sightings of cetaceans, 203 sightings of seals and 18 sightings of polar bears. No Pacific walruses were observed from the *Henry C.* Five marine mammal species were identified in total, including bowhead whale, ringed seal, spotted seal, bearded seal, and polar bear. The bowhead whale was the only identified whale species, while ringed and spotted seals were the most commonly identified seal.

During this project, two seal sightings were noted during seismic operations. Neither was sighted within the ≥190 dB safety radius around the operating airguns. As no marine mammals were seen within the safety radius around the airguns during seismic operations from the *Henry C.*, the direct estimate of the numbers of marine mammals exposed to ≥180 or ≥190 dB was zero. Using marine mammal densities to estimate the numbers of marine mammals exposed to various sound levels, we estimated that one cetacean, 63 seals, no Pacific walruses, and no polar bears would have been exposed to sounds ≥160 dB rms.

***Beaufort Sea Aerial Surveys.—*** Typically, bowheads of the Bering-Chukchi-Beaufort stock feed in Canadian waters during the late spring and summer, traveling through the Alaskan Beaufort Sea during their fall migration toward wintering areas in the Bering Sea. The most common feeding areas in the Alaskan Beaufort Sea are located near and east of Kaktovik and near Point Barrow (Thomson et al. 2002). In comparison, the areas where seismic surveys were conducted in 2007 have not been heavily used by feeding whales during previous years and long-term studies have noted relatively low sighting rates of bowheads in these waters. In 2007, however, observed trends were much different and it is possible that these differences are linked to changes in productivity due to the record low ice cover extent in 2007.

In contrast to most years, bowhead sighting rates in the central Alaskan Beaufort Sea remained high through mid-September. The whales showed no evidence of migratory travel, and a high proportion of sighted whales appeared to be feeding or traveling slowly with trends similar across seismic states. Also, bowheads observed in the eastern part of the survey area (Camden Bay) traveled in a more westward direction than those observed in the central and western areas, suggesting that less feeding was occurring in the Camden Bay area than near and west of Sivulliq. Additionally, offshore displacement was not apparent; sighting rates in the central seismic area peaked at approximately the same distance offshore as the location of the seismic prospect.

Previous studies (LGL and Greenridge 1987; Richardson et al. 1999; Schick and Urban 2000) have indicated that certain types of seismic and drilling noise can cause migrating bowheads to deflect from their typical migration route. However, studies from the summer feeding area suggest that bowheads are much more tolerant of seismic operations when an attractant such as food is present (Miller et al. 2005). The observed pattern of offshore bowhead distribution in 2007 supports the idea that feeding bowheads are more tolerant of seismic activities than migrating whales. It also suggests that whales may not be deflected as far from seismic operations as previous studies have suggested (i.e., Miller et al. 1999), because had they deflected at those distances, whales would not have encountered the food resources west of Sivulliq.

More research is needed to determine influences of potential food resources or other biological factors on bowhead whale distribution and movements when potential sources of disturbance are present. Also, in the case of feeding whales, using SELs instead of assuming behavioral takes, at certain received levels of sounds, may be a more appropriate method of calculating bowhead take estimates.

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# 1. BACKGROUND AND INTRODUCTION[1]

Shell Offshore, Inc. (SOI) collected marine seismic data in the Chukchi and Beaufort seas during the open-water period of 2007 in support of potential future oil and gas leasing and development. Deep seismic acquisition for SOI was conducted by WesternGeco using the M/V *Gilavar*, a seismic vessel that towed an airgun array as well as hydrophone streamers to record reflected seismic data. In addition to seismic activities in the Chukchi and Beaufort seas, SOI also conducted site clearance, shallow hazard surveys and geotechnical activities in the Beaufort Sea from the M/V *Henry Christoffersen* (*Henry C.*), an NTCL vessel.

Marine seismic surveys emit sound energy into the water (Greene and Richardson 1988; Tolstoy et al. 2004a,b) 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 close to the sound source) temporary or permanent reduction in hearing sensitivity. Either behavioral/distributional effects or (if they occur) auditory effects 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.”

Numerous species of cetaceans and pinnipeds inhabit parts of the Chukchi and Beaufort seas. Three species listed as “Endangered” under the ESA do or may occur in portions of the survey area, including bowhead whale (*Balaena mysticetus*), humpback whale (*Megaptera novaeangliae*), and perhaps fin whale (*Balaenoptera physalus*). 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. USFWS manages two species occurring in the Chukchi and Beaufort seas, the walrus (*Odobenus rosmarus*) and the polar bear (*Ursus maritimus*); NMFS manages all the other marine mammals occurring in those areas.

Other species of concern (birds) that might occur in the survey area are the spectacled (*Somateria fischeri*) and Steller’s (*Polysticta stelleri*) eiders that are listed as “Threatened” under the ESA. Of the two species, spectacled eider is more abundant, has been documented farther offshore (40 km) in the Beaufort Sea, and uses some lagoon systems in the Beaufort and Chukchi seas during their molt migration. Within the project area the USFWS has designated nearly 14,000 km$^2$ as critical habitat for spectacled eiders in Ledyard Bay. No critical habitat has been designated for Steller’s eiders within the project area.

In Nov 2006, SOI requested that NMFS issue an Incidental Harassment Authorization (IHA) to authorize non-lethal “takes” of marine mammals incidental to SOI’s planned 3D seismic operations in the Chukchi and Beaufort seas, and for site clearance and shallow hazards surveys in the Beaufort Sea (SOI 2006). The IHA was requested pursuant to Section 101(a)(5)(D) of the MMPA. An IHA to cover 3D seismic activities in the Chukchi and Beaufort seas and site clearance and shallow hazards surveys in the Beaufort Sea was issued to SOI by NMFS on 20 Aug 2007 (Appendix A). The IHA authorized “potential take by harassment” of various cetaceans and seals during the marine geophysical cruises described in this report. In Apr 2007, SOI also requested an IHA from USFWS to authorize potential “taking” of walruses and polar bears in the Chukchi Sea. The USFWS published a notice of the proposed rule to

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[1] Chapter 1 by R. Rodrigues, B. Haley, and D. Ireland (LGL).

authorize incidental "takes" of walruses and polar bears (USFWS 2007) and issued an IHA to SOI for activities in the Chukchi Sea on 20 Jul 2007 (Appendix B).

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

## *Incidental Harassment Authorization*

IHAs issued to seismic operators include provisions to minimize the possibility that marine mammals close to the seismic source might be exposed to levels of sound high enough to cause short or long-term hearing loss. During this project, sounds were generated by the *Gilavar*'s airguns during the seismic activities, and by a small airgun array on the *Henry C.* The *Henry C.* also operated several types of lower-energy sound sources including bottom mapping and seafloor imaging sonar, a chirp sonar, and a bubble pulser. Given the nature of the operations and mitigation measures, no serious injuries or deaths of marine mammals were anticipated from the seismic and shallow hazards surveys. No such injuries or deaths were attributed to these activities. Nonetheless, the seismic survey operations described in Chapter 2 had the potential to "take" marine mammals by harassment. Behavioral disturbance to marine mammals is considered to be "take by harassment" under the provisions of the MMPA. Appendix C provides further background on the issuance of IHAs relative to seismic operations and "take".

Under current NMFS guidelines (e.g., NMFS 2007), "safety radii" for marine mammals around airgun arrays are customarily defined as the distances within which the received pulse levels are ≥180 dB re 1 μPa (rms)[2] for cetaceans and ≥190 dB re 1 μPa (rms) for pinnipeds. Those safety radii are based on an assumption that seismic pulses 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. The development and implementation of the safety radii for the current project are discussed in detail in Appendix C.

Disturbance to marine mammals could occur at distances beyond the safety (shut down) radii if the mammals were exposed to moderately strong pulsed sounds generated by the airguns or perhaps by sonar (Richardson et al. 1995). NMFS assumes that marine mammals exposed to airgun sounds with received levels ≥160 dB re 1 μPa (rms) are likely to be disturbed. That assumption is based mainly on data

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[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. 1998, 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" basis, for which the units are dB re $(1\ \mu\text{Pa})^2 \cdot \text{s}$. 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. 1998, 2000a,b), with considerable variability (Madsen et al. 2006; see also Chapter 4 of this report). SEL (energy) measures may be more relevant to marine mammals than are rms values, but the current regulatory requirements are based on rms values.

concerning behavioral responses of baleen whales, as summarized by Richardson et al. (1995) and Gordon et al. (2004). Dolphins and pinnipeds are generally less responsive than baleen whales (e.g., Stone 2003; Gordon et al. 2004), and 170 dB (rms) may be a more appropriate criterion of potential behavioral disturbance for those groups (LGL Ltd. 2005a,b). In general, disturbance effects are expected to depend on the species of marine mammal, the activity of the animal at the time of disturbance, 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 or 170 dB (rms) criteria, but others may tolerate levels somewhat above 160 or 170 dB without reacting in any substantial manner. For example, migrating bowhead whales in the Alaskan Beaufort Sea show avoidance at received levels substantially lower than 160 dB re 1 $\mu Pa_{rms}$ (Miller et al. 1999; Richardson et al. 1999). Beluga whales may also show avoidance at levels below 160 dB (G. Miller et al. 2005). In contrast, bowhead whales on the summer feeding grounds tolerate received levels of 160 dB or sometimes more without showing significant avoidance behavior (Richardson et al. 1986; G. Miller et al. 2005).

A notice regarding the proposed issuance of an IHA for the survey in the Chukchi and Beaufort seas was published by NMFS in the *Federal Register* on 7 Jun 2007 and public comments were invited (NMFS 2007). The IHA was issued to SOI by NMFS to cover the period from 20 Aug 2007 through 1 Aug 2008 (Appendix A).

The IHA issued by NMFS to SOI authorized harassment “takes” of one ESA-listed species bowhead whale (*Balaena mysticetus*) as well as several non-listed species including gray whale (*Eschrichtius robustus*), killer whale (*Orcincus orca*), beluga whale (*Delphinapterus leucas*), harbor porpoise (*Phocoena phocoena*), ringed seal (*Phoca hispida*), spotted seal (*Phoca largha*), and bearded seal (*Erignathus barbatus*).

NMFS granted the IHA to SOI on the assumptions 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.

USFWS determined in 2006 that proponents of arctic seismic projects should operate under IHAs issued by USFWS. On 4 Apr 2007, SOI requested an IHA from USFWS for the incidental taking of walruses and polar bears in conjunction with seismic activities in the Chukchi Sea. A notice regarding the proposed issuance by USFWS of an IHA for the survey in the Chukchi Sea was published in the *Federal Register* on 1 Jun 2007 and public comments were invited (USFWS 2007). An IHA was issued to SOI by USFWS on 20 Jul 2007 (Appendix B). The IHA required SOI to observe a ≥190 dB safety radius for polar bears and a ≥180 dB safety radius for walruses. The ≥180 dB safety zone for walruses in 2007 was more conservative than the 190 dB zone required in 2006.

## *Mitigation and Monitoring Objectives*

The objectives of the mitigation and monitoring program were described in detail in SOI’s IHA application (SOI 2007) and in the IHA issued by NMFS to SOI (Appendix A). Explanatory material about the monitoring and mitigation requirements was published by NMFS and USFWS in the *Federal Register* (NMFS 2007).

The main purpose of the mitigation program was to avoid or minimize potential effects of SOI's seismic survey on marine mammals. This required that shipboard personnel detect marine mammals within or about to enter the designated safety radii (190 dB for pinnipeds and 180 dB for cetaceans), 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 air volume. A shut down involves temporarily terminating the operation of all airguns. An additional mitigation objective was to detect marine mammals within or near the safety radii prior to starting the airguns, or during ramp up toward full power. In these cases, the start of airguns was to be delayed or ramp up discontinued until the safety radius was free of marine mammals, insofar as this can be determined visually, for a period of 30 minutes (see Appendix A and Chapter 5).

In 2007 mitigation was also required, as specified by the IHA issued by NMFS, at the 160 dB isopleth. This area was monitored by chase/monitoring vessels that accompanied the seismic vessel. Power down of the seismic airgun array was required if an aggregation of 12 or more non-migratory balaenopterid whales was detected ahead of, or perpendicular to, the seismic vessel track and within the 160 dB isopleth. Monitoring of the 120 dB isopleth around the seismic vessel(s) was also required after 1 Sep in the Beaufort Sea. Power down would be required if 4 migratory bowhead cow/calf pairs were detected within the surveyed 120 dB isopleth.

The primary objectives of the monitoring program were

- provide real-time sighting data needed to implement the mitigation requirements;
- estimate the numbers of marine mammals potentially exposed to strong seismic pulses; and
- determine the reactions (if any) of marine mammals potentially exposed to seismic sound impulses.

Specific mitigation and monitoring objectives identified in the IHAs are described in Appendices A and B. Mitigation and monitoring measures that were implemented during the activities in the Chukchi and Beaufort seas are described in detail in Chapter 5.

This 90-day report describes the methods and results for the monitoring work specifically required to meet the above primary objectives. Various other marine mammal and acoustic monitoring and research programs not specifically tied to the above objectives were also implemented by SOI in the Chukchi and Beaufort seas during 2007. Results of those additional efforts are, for the most part, not mentioned in this 90-day report. Those additional results will be reported at a later date.

## *Report Organization*

The primary purpose of this report is to describe the 2007 seismic survey activities in the Chukchi and Beaufort seas including the associated monitoring and mitigation programs, and to present results as required by the IHAs (Appendices A and B). This report includes six chapters:

1. background and introduction (this chapter);
2. description of SOI's seismic and site clearance studies;
3. sound source and propagation modeling prior to the field season;
4. sound source measurements during the field season;

5. description of the marine mammal monitoring and mitigation requirements and methods, including safety radii; and
6. results of the marine mammal monitoring program, including estimated numbers of marine mammals potentially "taken by harassment".

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

A. a copy of the IHA issued by NMFS to SOI for this study;

B. a copy of the IHA issued by USFWS to SOI for this study;

C. additional tables and figures detailing monitoring effort marine mammals observed

D. English unit tables and figures from monitoring results in Chapter 5

E. details on visual and acoustic monitoring, mitigation, and data analysis methods;

F. conservation status and densities of marine mammals in the project region;

G. characteristics of the *Gilavar* and *Henry Christoffersen*;

H. a copy of the Conflict Avoidance Agreement between SOI, the Alaska Eskimo Whaling Commission, and the Whaling Captains Associations;

I. English unit tables and figures from sound source measurement results in Chapter 4; and

J. Beaufort Wind Force Scale.

# 2. SEISMIC SURVEYS DESCRIBED[3]

## *Chukchi and Beaufort Sea Seismic Surveys*

The *Gilavar* was used as the source vessel during SOI's 3D seismic exploration activities in the Chukchi and Beaufort seas in 2007. Several other vessels including the *Gulf Provider*, *Norseman II*, *Jim Kilabuk*, *Nanuq*, and *American Islander* were used as chase/monitoring vessels that accompanied the *Gilavar* at various times during the open-water season. SOI used the *Henry Christofferson* for shallow hazards surveys in the Beaufort Sea (Table 1). In addition, the *Peregrine* and *Maxime*, vessels with minimal draft, were used for transfer of personnel and equipment from shore to the larger vessels. Appendix D contains a description of the vessels used during the seismic activities.

All vessels operated in accordance with the provisions of both IHA's and a Conflict Avoidance Agreement (CAA) between the seismic industry, the Alaska Eskimo Whaling Commission (AEWC), and the Whaling Captains Associations from Barrow, Nuiqsut, Kaktovik, and Wainwright. The CAA provided mitigation guidelines, including avoidance, to be followed by SOI while working in or transiting through the vicinity of active subsistence hunts. In particular, it addressed bowhead and beluga whale hunts and interactions with whaling crews, but was not limited to whaling activities. Under the terms of the CAA, communication centers were established at Barrow and Deadhorse, and Call Centers at Pt. Hope, Pt. Lay, Wainwright, and Kaktovik. The CAA outlined a communication program and specified locations and times when surveys could be conducted to avoid any possible conflict with the subsistence hunts.

### *Operating Areas, Dates, and Navigation*

The geographic region where the deep seismic survey occurred was located in the Chukchi Sea MMS OCS Planning Area designated as Chukchi Sea Sale 193 (see Fig. 2.1) and at specific SOI lease holdings in the Beaufort Sea (Fig. 2.2). Since the Chukchi Sea deep seismic program was conducted as a pre-lease activity, the exact locations of operations remain confidential for business reasons. That is, the seismic data acquired in 2007 will be used by SOI to identify leases on which it may bid in a forthcoming competitive lease sale. However, in general, seismic acquisition occurred in the Chukchi Sea well offshore (>80 km or 50 mi) from the Alaska coast in OCS waters averaging greater than 40 meters (m) or 131 ft deep and outside the polynya zone.

The *Gilavar* left Dutch Harbor on 18 Jul to travel to the project area, and entered the Chukchi Sea on 21 Jul. Operations were then delayed while SOI waited for final approval of the IHA which was issued on 20 Aug. SOI's seismic contractor deployed the seismic acquisition equipment and sound source verification of the airgun array was conducted by JASCO on 28 and 29 Aug during 9 hr of seismic shooting (see Chapter 4 below). JASCO calculated preliminary disturbance and safety radii within 72 hr of completion of the measurements and SOI began collecting seismic data.

The *Gilavar* collected seismic data in the Chukchi Sea from 28 Aug to 10 Sep and entered the Beaufort Sea on 12 Sep to collect seismic data on specific SOI lease holdings. Prior to collecting seismic data in the Beaufort Sea, JASCO conducted sound source verification measurements of the airgun array on 17 and 18 Sep near Camden Bay in the area of SOI's proposed 2007 seismic activities. JASCO calculated disturbance and safety radii which were used by MMOs for mitigation during the seismic activities in the Beaufort Sea.

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[3] Chapter 2 by R. Rodrigues, B. Haley, and D. Ireland (LGL).

Table 2.1. Vessels operated by SOI in the Chukchi and Beaufort seas in support of seismic exploration activities during 2007.

| Vessel | Activity | Chukchi | Beaufort |
|---|---|---|---|
| *Gilavar* | Seismic source vessel | X | X |
| *Henry Christoffersen* | Shallow hazards vessel | | X |
| *Gulf Provider* | Chase boat | X | X |
| *Norseman II* | Chase boat, deploy acoustic equipment | X | X |
| *Jim Kilabuk* | Chase boat | | X |
| *American Islander* | Chase boat, bathymetric survey | X | |
| *Nanuq* | Chase boat, deployment and recovery of acoustic equipment | X | |

The *Gilavar* conducted seismic activities in the Beaufort Sea from 18 Sep through 3 Oct and returned to the Chukchi Sea on 8 Oct to conduct further seismic exploration. The Gilavar was not able to conduct seismic acquisition at this time due to possible conflict with whalers at Wainwright and Point Hope and transited the Chukchi Sea to Nome. The *Gilavar* reentered the Chukchi Sea on 15 Oct and collected seismic data from 20 Oct through 5 Nov at which time weather conditions precluded further exploration activities. The *Gilavar* left the Chukchi Sea on 8 Nov and arrived at Dutch Harbor on 11 Nov. SOI completed ~2916.1 km (1812.0 mi) of deep-seismic data acquisition in the Chukchi Sea and ~791.7 km (491.9 mi) in the Beaufort Sea in 2007.

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 seismic line start point. 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. The analyses of marine mammal data collected during "seismic" periods included these ramp up, lead in, and lead out periods, and totaled ~3931 km (~2443 mi) of trackline in the Chukchi Sea and ~1561 km (~968 mi) in the Beaufort Sea in 2007.

Throughout the survey the *Gilavar's* position, speed, and water depth were logged digitally every ~60 s. In addition, the position of the *Gilavar*, water depth, and information on the airgun array were logged for every airgun shot while the *Gilavar* was on a seismic line and collecting geophysical data. The geophysics crew kept an electronic log of events, as did the marine mammal observers (MMOs) while on duty. The MMOs also recorded the number and volume of airguns that were firing when the *Gilavar* was offline (e.g., prior to shooting at full volume) or was online but not recording data (e.g., during airgun or computer problems).

### *Airgun Description*

SOI used a WesternGeco 3147 in$^3$ three-string array of Bolt airguns towed approximately 276 m behind the *Gilavar* for its 3–D seismic survey operations in the Chukchi Sea. This was the same array used during the 2006 seismic surveys. The array was composed of three identically-tuned Bolt airgun sub-arrays, each with eight airguns and a total volume of 1049 in$^3$, operated at an air pressure of 2000 psi. Each string was 15 m (16 yd) in length, and was 8 m (8 yd) from the adjacent string(s). The individual airguns ranged in volume from 30 to 235 in$^3$, and each string included two 235 in$^3$ and two 125 in$^3$ airguns in two-gun clusters. A 30 in$^3$ airgun was used as a mitigation source during power downs when marine mammals were observed within or about to enter the applicable full array safety radius and during turns. The airgun arrays were towed at a depth of 6 m. The system also included four to six hydrophone streamers with hydrophones distributed over a length of 4200 m (4593 yd) and spaced 100 m apart, which recorded reflected sound energy. Air compressors aboard the *Gilavar* were the source of high pressure air used to operate the airgun arrays. Seismic pulses were emitted at intervals of 25 m (27 yd; ~10 sec) while the *Gilavar* traveled at a speed of 4 to 5 knots (7.4–9.3 km/h, 4.6–5.8 mi/h). In general, the *Gilavar* towed this system along a predetermined survey track, although adjustments were occasionally made during the field season to avoid obstacles or during repairs to the equipment. Characteristics of the airgun arrays are detailed in Appendix D.

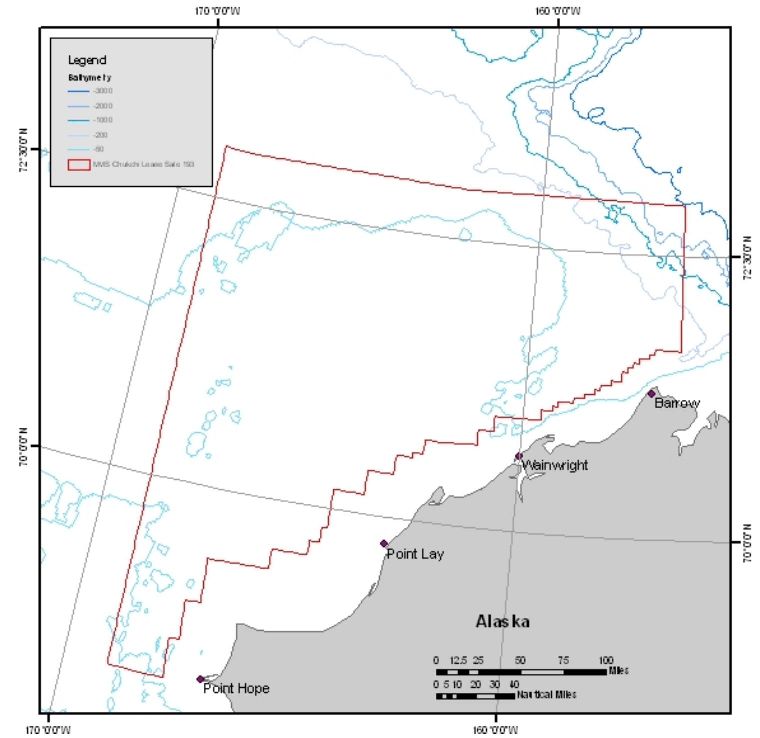

FIGURE 2.1. Location of the proposed MMS Chukchi Sea Lease Sale 193 within which SOI's 2007 deep seismic activities were conducted.

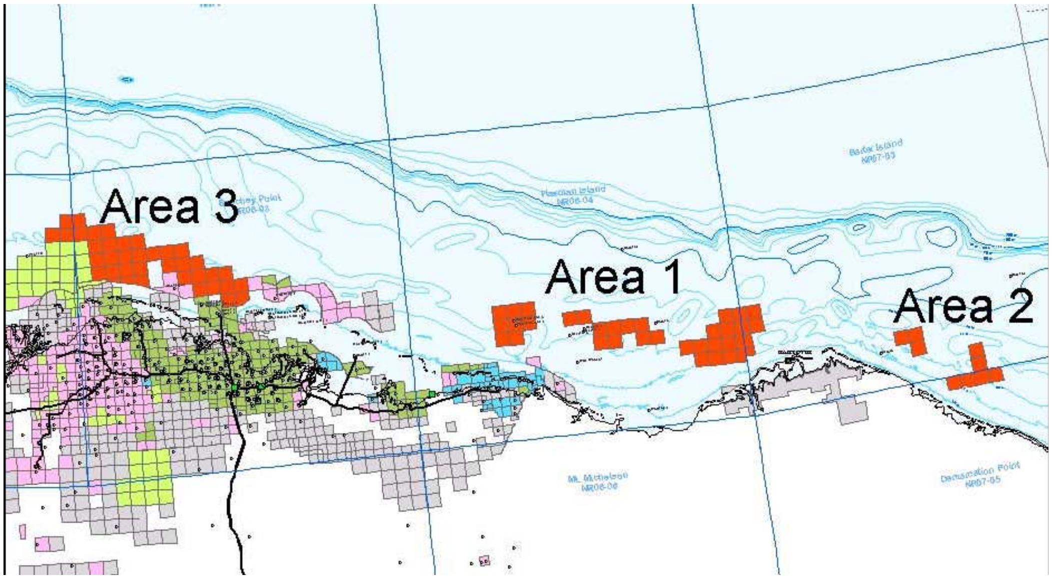

FIGURE 2.2. Location of SOI lease holdings in the Alaskan Beaufort Sea.

## *Beaufort Sea Shallow Hazards and Site Clearance Surveys*

In addition to deep seismic surveys in the Chukchi and Beaufort seas, SOI also conducted site clearance and shallow hazards surveys of potential exploratory drilling locations within SOI's lease areas in the Beaufort Sea as required by MMS regulations. Before drilling can begin, a site clearance survey and analysis is necessary to identify and/or evaluate potentially hazardous or otherwise sensitive conditions and sites at or below the seafloor that could affect the safety or appropriateness of operations. Examples of such conditions include subsurface faults, fault scarps, shallow gas, steep-walled canyons and slopes, buried channels, current scour, migrating sedimentary bedforms, ice gouging, permafrost, gas hydrates, unstable sediment conditions, pipelines, anchors, ordnance, shipwrecks, or other geophysical or man-made features.

Offshore site clearance surveys use various geophysical methods and tools to acquire graphic records of seafloor and sub-seafloor geologic conditions. The data acquired and the types of investigations outlined below are performed routinely for most exploratory drilling and production facilities in marine areas, and for submarine pipelines, port facilities, and other offshore projects. High-resolution geophysical data such as two-dimensional, high-resolution multi-channel seismic, medium penetration seismic, subbottom profiler, side scan sonar, multibeam bathymetry, magnetometer, and possibly piston core sediment sampling are typical types of data acquired. These data are interpreted to define geologic, geotechnical and archeological conditions at the site and to assess the potential engineering significance of these conditions. The following section provides a brief description of the operations and instrumentation used during SOI's 2007 Beaufort Sea site clearance program insofar as they may impact marine mammals.

### *Operating Areas, Dates, and Navigation*

The site clearance surveys were confined to very small, specific areas within defined OCS blocks (Fig. 2.2). The surveys were conducted from the *Henry Christofferson* (*Henry C.*; Table 2.1). Small geophysical survey sources with limited energy output were employed to measure bathymetry, topography, geohazards, and other seabed characteristics. The strongest sound source was a cluster of two 10 $in^3$ airguns, which was used for work in the Beaufort Sea. Sound levels of the two airgun array were modeled prior to the field season (Chapter 3).

The *Henry C.* entered the Beaufort Sea on 16 Aug from Canada and sailed to the east side of Harrison Bay. The *Henry C.* remained anchored near Thetis Island until 30 Aug when sound source measurements of the airgun array were conducted by JASCO in the Beaufort Sea west of Prudhoe Bay to determine safety and disturbance radii to be used for mitigaton during the shallow hazards surveys (Chapter 4).

After completion of the sound source verification, the *Henry C.* conducted shallow hazards surveys in the Beaufort Sea west of Prudhoe Bay until 10 Sep at which time it sailed east to the Camden Bay area where it conducted shallow hazards surveys from 11 Sep to 2 Oct. JASCO conducted a second sound source verification of the airgun array in the Camden Bay area on 14 Sep (Chapter 4).

Between 30 Aug and 2 Oct, site clearance operations were conducted in specific nearshore areas ranging from Thetis Island near the Colville River Delta east to Camden Bay (Fig. 2.2). Site clearance survey activities occurred on ~23 days during this period. Other than during sound source verification on 30 Aug and 14 Sep, the airgun array was operated only on 17-18 Sep near Camden Bay for ~12 hr. At all other times during surveys, the acoustical sources in use were lower-energy medium- and high-frequency sources as described below. On days when surveys did not occur, the *Henry C.* was usually transiting to a new site or anchored while waiting for bad weather to subside.

Throughout the survey the *Henry Christoffersen*'s position, speed, and water depth were logged digitally every ~60 s. In addition, the position of the *Henry C.*, water depth, and information on the output of the airgun array or other geophysical tools were logged during all site clearance activities. The geophysics crew kept an electronic log of events, as did the marine mammal observers (MMOs) while they were on duty.

### *Geophysical Tools for Site Clearance*

An airgun cluster consisting of two 10-in$^3$ airguns was used during site clearance operations to locate potential hazards, such as gas deposits, at relatively shallow locations. Several other lower-energy acoustic sources were operated for shallow-penetration subbottom surveys and to map the bottom. A bubble pulser operating at frequencies near 400 Hz was used for medium penetration and a Chirp II sonar operating at 2–7 kHz was used for shallow penetration. Other acoustic sources included a multibeam bathymetric sonar operating at 240 kHz and a side-scan sonar operating at 190–210 kHz. Characteristics of this equipment are described in more detail in Appendix D.

## *Marine Mammal Monitoring and Mitigation*

### *Vessel based monitoring*

Vessel-based marine mammal monitoring and mitigation was conducted from the *Gilavar* and its associated chase/monitoring vessels and from the *Henry C.* throughout the seismic operations in the Chukchi and Beaufort seas. Chapter 5 provides a detailed description of the methods and equipment used for monitoring and mitigation during the seismic surveys.

### *Aerial Monitoring*

SOI conducted aerial surveys in support of the *Gilavar's* 3D seismic activities and shallow hazards surveys from the *Henry C.* in the Beaufort Sea. A series of north–south transect lines was established to monitor the areas where SOI planned to conduct seismic exploration and shallow hazard and site clearance surveys. The aerial surveys were conducted using a Twin Otter fixed-wing aircraft flown at 1000 ft above ground level at an airspeed of approximately 120 knots. The aerial survey methods and equipment are described in detail in Chapter 5.

The aerial survey program in the Beaufort Sea began on 22 Aug and was completed on 8 Oct. Each survey required two days to complete and 13 surveys were conducted during the survey period. In some cases the entire survey could not be completed due to weather conditions on one of the survey days. Surveys from 22 Aug through 3 Sep were in support of shallow hazards surveys by the *Henry C.* and were flown in offshore areas from the Sagavanirktok River delta west to Harrison Bay. Aerial surveys beginning on 10 Sep were flown in support of deep seismic exploration from the Gilavar and were flown in offshore waters from the Sagavanirktok River delta east to Kaktovik.

# 3. SOUND SOURCE VERIFICATION MEASUREMENTS

## *Introduction*

This chapter presents the results of SSV measurements, for SOI's 2007 seismic survey and shallow hazards survey programs. These studies were conducted in the Alaskan Beaufort and Chukchi seas in the summer/fall of 2007 to quantify sound levels in the vicinity of noise-generating vessels and equipment used in SOI's seismic and shallow hazards survey programs. The underwater sound measurement programs were performed by JASCO Research Ltd. (JASCO) under subcontract to LGL Alaska Research Associates. Inc.

## *SSV Program Tasks*

- Measure site-specific sound levels as a function of distance from all vessels working for SOI in the Alaskan Chukchi and Beaufort seas in 2007.
- Measure site-specific sound levels in the vicinity of marine seismic survey operations to determine the distance at which the levels reach various thresholds between 190 and 120 dB re 1 μPa (*rms*).
- Quantify the directivity (sound emission characteristics in different directions) of the seismic airgun systems.
- Measure sound levels as a function of distance from SOI's shallow hazards survey acoustic sources.
- Report distances to 190, 180 and 160 dB re 1 μPa (rms) to marine mammal observers on the seismic survey and shallow hazards survey vessels to be used for establishing safety zones around those operations.

JASCO personnel deployed autonomous Ocean Bottom Hydrophone (OBH) recorders to record *in situ* the sound levels produced by the seismic survey airgun array, the shallow hazards survey acoustic sources, and the vessels supporting both surveys. The vessels monitored in these programs included the seismic survey vessel *Gilavar*, the research vessel *Norseman II*; survey vessel *Henry Christofferson*; and the support vessels *American Islander*, *Gulf Provider*, *Maxime*, *Mikkelsen Bay*, and *Jim Kilabuk*.

The acoustic data recorded for each SSV program were analyzed in the field immediately following each of the measurements and the results were reported in 72-hour reports to the U.S. Fish and Wildlife Service (USFWS) and in 5-day reports to NOAA National Marine Fisheries Service (NMFS) as was stipulated in the respective Incidental Harassment Authorizations (IHA's) from these agencies. The initial reports gave nominal distances (radii) from the various sources indicating the distances from the source that sound levels reached thresholds between 190 and 120 dB re μPa (*rms*). Those radii were also relayed to marine mammal observers on the seismic vessel and support vessels who used them to define the safety zones for marine mammals during the operations. The results of six independent SSV studies are presented in this chapter. Additional analysis of the seismic survey airgun recordings has been performed that considers frequency-dependent hearing sensitivities of different marine mammal species groups. This analysis, referred to as M-weighting (Gentry et al. 2004), produced weighted sound levels from which species-dependent radii were computed. Those radii are also presented in this chapter.

## *Overview of SSV Programs*

The results of six separate SSV programs are presented in this chapter. Brief overviews of each of the six programs are given below.

### *Measurements of Airgun Array sounds during SOI's 2007 Alaskan Chukchi Sea Seismic Survey Program*

SOI contracted WesternGeco and seismic survey vessel MV *Gilavar* to perform seismic surveys in the Alaskan Chukchi and Beaufort seas using an airgun array seismic source (Mouy et al. 2007). The Chukchi Sea survey program started on 28 Aug 2007. The first 9 hours of seismic shooting sounds were recorded on six autonomous OBH recorders deployed at various distances, up to 100 km (62 mi), and in two directions from the initial seismic survey line; the OBH systems were deployed in a geometry that provided measurements from both the forward-endfire and broadside directions from the full 3147 $in^3$ operating array. Additional measurements were made during operation of the 30 $in^3$ mitigation airgun up to a maximum range of 45 km (28 mi). The 3147 $in^3$ airgun array layout is shown later in this chapter in Fig. 3.2.

### *Measurements of Airgun Array Sounds and Support Vessel noise during SOI's 2007 Seismic Survey at Sivulliq Prospect, Alaska*

A second seismic survey was performed by WesternGeco at SOI's Sivulliq prospect in the Alaskan Beaufort Sea (Laurinolli et al. 2007a). The acoustic monitoring program was carried out 17-18 Sep 2007 at a location off of Camden Bay, Alaska. Approximately 6 hours of seismic shooting at the start of the Sivulliq survey was recorded on six OBH recorders deployed at various distances up to 50 km (31 mi) from the first seismic survey line of this seismic survey program. Measurements of both the full 3147 $in^3$ airgun array and a single 30 $in^3$ marine mammal mitigation airgun were made in the forward-endfire and broadside directions from the array. Additional vessel-only measurements were obtained of the *Gilavar* itself and the support vessels MV *American Islander* and *Gulf Provider*.

### *Measurements of Small Airgun Array Sounds during SOI's 2007 Shallow Hazards Survey, Beechey Point Site, Alaska*

SOI contracted GEO LLC to perform shallow hazards surveys over various prospects in the Alaskan Beaufort Sea (Laurinolli et al. 2007b). The primary acoustic source for this survey was a small airgun array of two 10 $in^3$ guns at a separation of 50 cm (ref. Fig. 3.6). A second configuration used only one of the two airguns. The airguns were towed at a depth of 2.25 meters by the Northern Transportation Company Ltd (NTCL) survey vessel *Henry Christofferson*. Two other sound sources were used during the shallow hazards surveys: a dual frequency *sub-bottom* profiler - the Datasonics CAP6000 Chirp II (2-7 kHz or 8-23 kHz) and the medium penetration *sub-bottom* profiler - a Datasonics SPR-1200 Bubble Pulser (400Hz). See Fig. 3.7 for a photograph of the profilers. JASCO carried out acoustic measurements on the vessel and survey sources off Beechey Point Alaska on 30 Aug 2007.

The underwater sound level measurements were made using two of JASCO's OBH systems, deployed in 22 m (73 ft) of water at 200 m (0.12 mi) and 1 km (0.62 mi) perpendicular to the survey sail line at a distance of 5 km (3.1 mi) north of the start of the line. Two additional measurements of vessel-only noise were performed while the *Henry Christofferson* sailed the survey line at 7.4 km/h (4 kt) and 20 km/h (11 kt) with none of its survey instruments operating. These measurements were performed 30 Aug 2007 before any survey operations were initiated in the Beaufort Sea.

### *Measurements of Small Airgun Array Sounds during SOI's 2007 Shallow Hazards Survey, Camden Bay Site, Alaska.*

A second shallow hazards survey was performed near the Sivulliq prospect in Camden Bay starting 14 Sep 2007 (Laurinolli et al. 2007c). Underwater acoustic measurements of sound levels from the small airgun array were made at this site using two OBH recorders. Measurements of sound levels as a function of distance to 20 km (12.4 mi) maximum range from the array were performed on 14 Sep 2007. Additional measurements of vessel-only noise were collected to distances of 2 km (1.2 mi) from the survey vessel *MV Henry Christofferson* when the survey sound sources were turned off.

### *Measurements of Nearshore Support Vessels at Prudhoe Bay, Alaska.*

SOI contracted the vessels *Maxime* and *Mikkelsen Bay* in support of offshore operations in the Beaufort Sea in the summer/fall of 2007 (Laurinolli and Whitt 2007d). These vessels performed primarily crew and equipment transfers at Prudhoe Bay between West Dock and the larger seismic and research vessels. An acoustic monitoring program was carried out by JASCO to quantify sound emissions and sound levels as a function of distance from these vessels on 21 Sep 2007 off of West Dock in Prudhoe Bay, Alaska. Approximately 2 hours of data were recorded on an autonomous OBH recorder deployed in approximately 7.6 m (25 ft) of water in an area representative of the typical operating conditions of these vessels.

### *Measurements of Seismic Support Vessels*

The vessels MV *Jim Kilabuk* and *Norseman II* served as support vessels for SOI's 2007 seismic survey programs in the Chukchi and Beaufort seas (MacGillivray and Austin 2007). Their primary tasks involved performing marine mammal observation surveys near the seismic survey operations.

JASCO Research personnel carried out underwater sound measurements to quantify the sound levels produced by the seismic support vessels. The acoustic measurements were carried out 2-3 Oct 2007, 37 km (23 mi) offshore of West Dock near Prudhoe Bay, Alaska. Data were recorded on an autonomous OBH recorder deployed in approximately 30 m (100 ft) water depth, representative of the typical operating environment for the seismic survey program. The vessel sounds were measured separately on two consecutive days. The duration of each test was approximately 2 hours. The OBH recorders were deployed on 2 Oct and remained on the seafloor through 3 Oct.

## *Acoustic Recording Equipment*

JASCO's OBH recorder systems (ref. Fig. 3.1) were used for all measurements reported in the SSV studies of this chapter. These systems each use two calibrated Reson preamplified reference hydrophones:

Reson TC4043, with nominal sensitivity -201 dB re V/μPa.

Reson TC4032, with nominal sensitivity -170 dB re V/μPa.

The use of hydrophones with different sensitivities allowed accurate capture of the wide range of sound pressure variation: ranging from high amplitude seismic pulses to near-ambient vessel sounds. The hydrophone signals were recorded on Sound Devices model 722 digital hard-disk recorders. The hydrophone signals were digitized at a sampling rate of 48 kHz with 24-bit samples directly onto hard-disk.

The OBH systems were deployed on the seabed and so were effectively decoupled from surface motion that often introduces non-acoustic signal contamination in surface-deployed hydrophone configurations. The systems were recovered by pinging from the surface with an acoustic command unit. An integral acoustic release in the OBH disengaged its anchor, thereby allowing the system to float back to the surface for retrieval[4].

Figure 3.1: OBH system being deployed from the *Norseman II*.

The OBH hydrophones were factory-calibrated to NIST traceable standards. The voltage and frequency responses of the OBH recorders were calibrated in the lab prior to carrying out the measurement programs. The OBH recorders were calibrated by inserting a reference signal, with

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[4] For the sound level measurements of the *Maxime* and *Mikkelsen Bay* in Prudhoe Bay, the OBH systems were deployed with a surface buoy instead of an acoustic release system.

known amplitude and frequency, into the calibration lines of the Reson hydrophones while they were connected to the recorders. The electrical system calibration of the systems was obtained from the recorded digital level relative to the input signal voltage. This voltage insertion test, combined with the pressure calibration of the hydrophones, gave an end-to-end calibration of the combined acoustic and electrical system; the test signal was fed to the hydrophone preamplifier inputs so any impedance matching effects between the hydrophone preamplifier outputs and the recorder inputs were accounted for.

## *Field Recording Operations*

### *Seismic Surveys*

## Sound Source Verification of Chukchi Seismic Program

Six OBH recording systems were deployed 28 Aug 2007 from the 32.9 m (108 ft) research vessel *Norseman II* in advance of arrival of the *Gilavar* on its first survey line. After deployment of the OBH systems, the *Norseman II* departed the deployment area to avoid noise contamination of the recordings while the *Gilavar* performed airgun array shooting along the survey line with its 3147 in$^3$ airgun array. The airgun layout within this array is shown in Fig. 3.2.

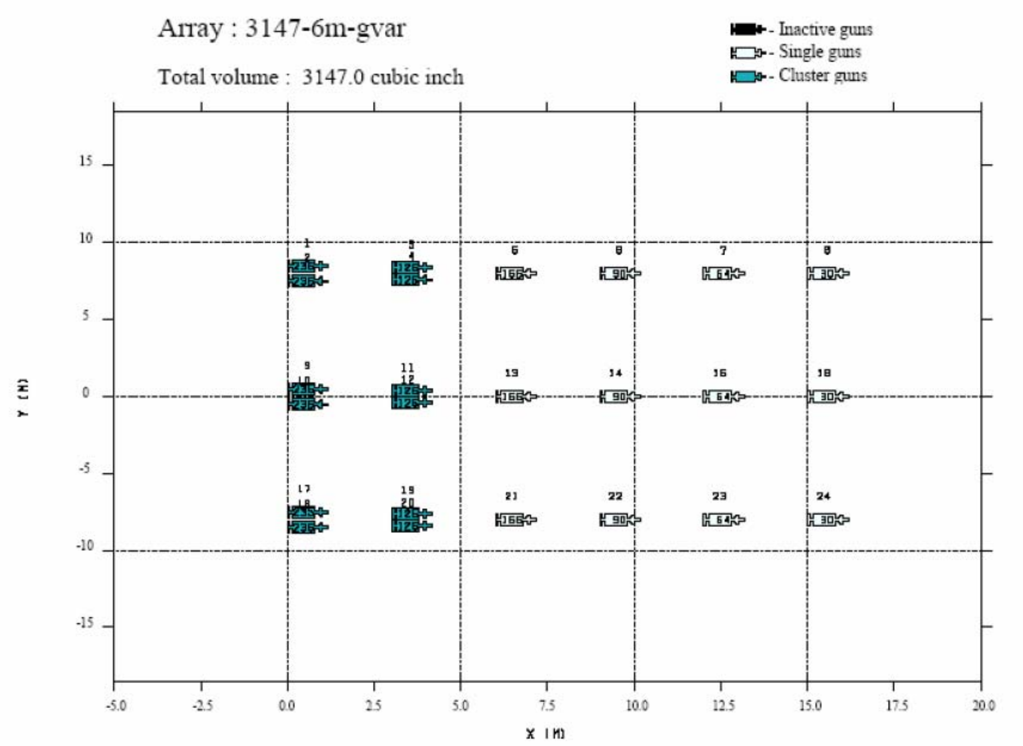

Figure 3.2: Plan view layout of the Western GeoCo 3147 in$^3$ airgun array.

Digital acoustic recordings of approximately 9 hours of shooting data were obtained from each OBH as the *Gilavar* followed the survey line with airgun array in operation. The *Norseman*

*II* then returned to the survey area and recovered the OBHs. Fig. 3.3 is a diagram of the OBH deployment geometry relative to the survey vessel track for this measurement.

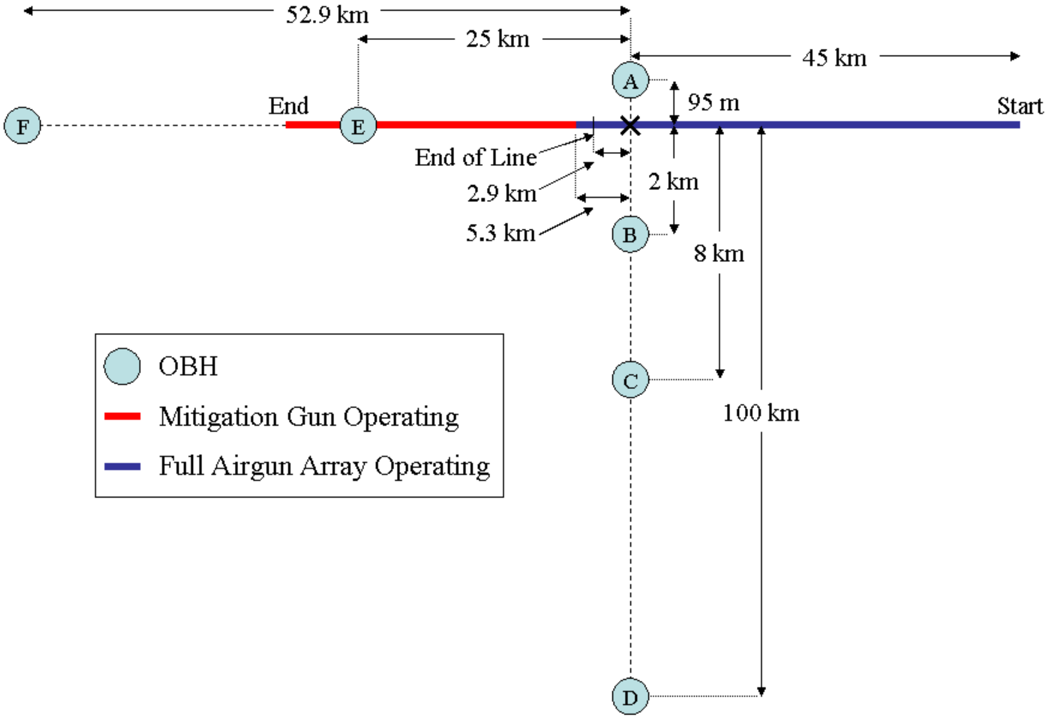

Figure 3.3. Survey vessel track lines relative to OBH positions for acoustic measurements. Distance conversion to miles and feet: multiply km by 0.62 (e.g. 10 km equals 6.2 miles) and multiply meters by 3.3 to get distance in feet (e.g. 10 m equals 33 ft).

The *Gilavar* surveyed the full line while operating its airgun array at full capacity. The survey line extended to 2.9 km (1.8 mi) beyond point *X* in Fig. 3.3, but full array shooting continued 5.3 km (3.3 mi) past point *X*. Shooting then switched from the full array to a mitigation gun alone for the next 25 km (15.5 mi), placing the last mitigation airgun shot approximately 5 km (3.1 mi) past OBH-E as shown in the diagram. This provided mitigation gun measurements for ranges 0 to 45 km (28 mi).

## Sound Source Verification of Sivulliq Prospect Seismic Program (Camden Bay)

Six calibrated OBH recording systems were deployed from the 80-foot research vessel *American Islander* on 18 September, 2007 in advance of arrival of the *Gilavar* on its first survey line at SOI’s Sivulliq Prospect in Camden Bay. One OBH (E) was deployed at the end of the 58 km line (36 mi). Three of the OBHs (A, B and C) were deployed in a perpendicular line, 5 km (3.1 mi) before the end of the survey line, at respectively 500 m (0.31 mi), 2500 m (1.55 mi) and 10 km (6.2 mi) inshore of the survey line. The remaining two OBHs (D and E) were placed on the same line but respectively 10 km (6.2 mi) and 50 km (31 mi) in the offshore direction. We had planned to deploy OBH-E at approximately 100 km (62 mi) north of the survey line, as was done for the Chukchi measurements, but the proximity of the shelf edge precluded deployment further north because water depth increased rapidly. The actual OBH deployment positions and first survey line are shown on the map in Fig. 3.4 with geographic coordinates given in Table 3.1. After completing OBH deployments, the *American Islander* departed the deployment area to avoid noise-contamination of the recordings while the *Gilavar* performed airgun array shooting along the survey line at a nominal speed of 8.5 km/h (4.6 kt). The same 3147 in$^3$ airgun array that was used for the Chukchi Sea survey was used for the Camden Bay survey. Digital acoustic recordings of 6 hours of shooting data were obtained from all six OBHs as the *Gilavar* followed the survey line with the airgun array operating. The *American Islander* then returned to the survey area after the seismic line was completed and recovered the OBHs.

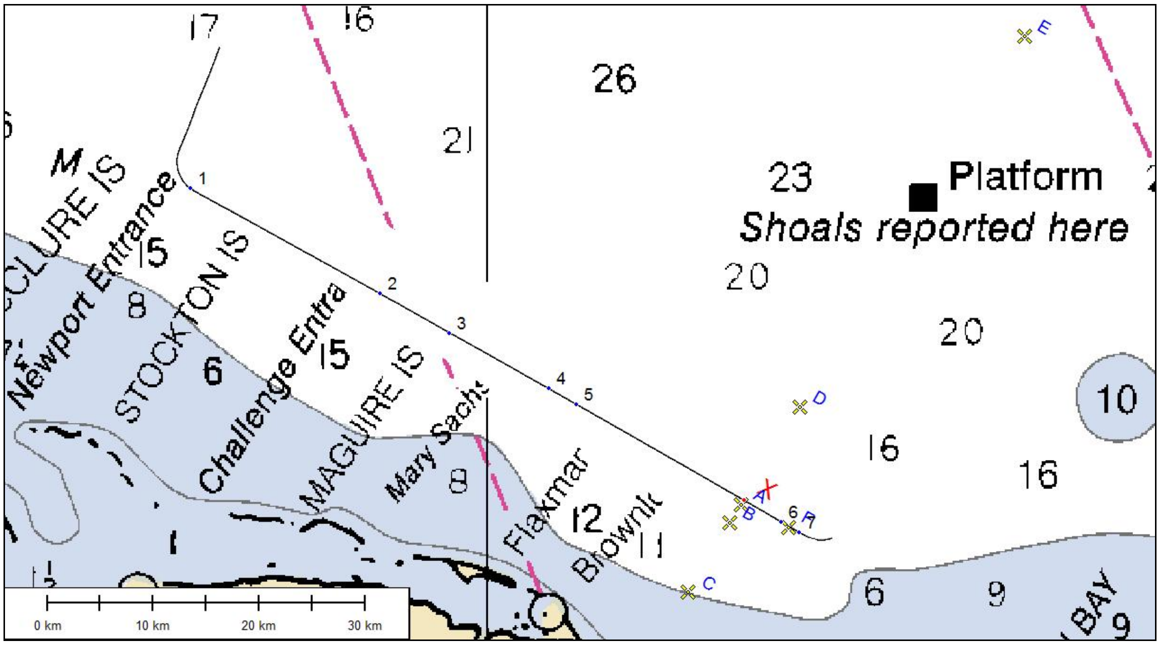

Figure 3.4: Survey vessel track lines relative to OBH positions for acoustic measurements. Distance conversion to miles: multiply km by 0.62 (e.g. 10 km equals 6.2 miles).

The *Gilavar* fired its airgun array at full power starting at point 1 (ref. Fig. 3.4). At point 3 it switched to the mitigation airgun due to mammal sightings. Full array power was resumed at point 4 and continued until point 6. Between point 6 and 7 only the mitigation airgun was used. Forward direction measurements were obtained from 58 km (36 mi) to approximately 500 m (0.31 mi), with a gap between 20 and 30 km (12.4 and 18.6 mi) due to the power down. The mitigation airgun was measured as the *Gilavar* passed over OBH-F between points 6 and 7.

Table 3.1. *Gilavar* SSV coordinates, Sivulliq Prospect, Alaska.

| | Latitude | Longitude | UTM (N) | UTM (E) | DEPTH (m) |
|---|---|---|---|---|---|
| OBH A | 70.2477 N | 145.3650 W | 7794323 | 561664 | 24 (79 ft) |
| OBH B | 70.2327 N | 145.3940 W | 7792627 | 560613 | 24 (79 ft) |
| OBH C | 70.1744 N | 145.4959 W | 7786027 | 566929 | 18 (59 ft) |
| OBH D | 70.3290 N | 145.2216 W | 7803534 | 566806 | 35 (115 ft) |
| OBH E | 70.6351 N | 144.6666 W | 7838354 | 586333 | 75 (246 ft) |
| OBH F | 70.2282 N | 145.2501 W | 7792275 | 566056 | 24 (79 ft) |
| Point X | 70.2517 N | 145.3592 W | 7794773 | 561869 | 24 (79 ft) |
| Start | 70.5074 N | 146.7115 W | 7822480 | 510743 | 35 (115 ft) |
| Stop | 70.2291 N | 145.2438 W | 7792375 | 566294 | 24 (79 ft) |

### *Shallow Hazards Surveys*

## Beechey Point Site

JASCO deployed OBH systems from the *Henry Christofferson* at two fixed recording sites inside the Beechey Point block 6311 survey area. Table 3.2 lists the planned OBH deployment locations, the closest point of approach (CPA), and the survey line start and end points. The OBH systems were deployed at 200 m (0.12 mi) and 1 km (0.62 mi) perpendicular to the airgun survey line of the *Henry Christofferson.* OBH-A was 200 m (0.12 mi) west of a point on the survey line that was 5 km (3.1 mi) north of the start of the south-north line. OBH-B was 800 m (0.5 mi) west of OBH-A. See Figs. 3.5 and 3.9 below for a diagram and map of the deployment geometry. These distances were defined to slightly exceed the ranges that sound levels were expected to reach 180 dB and 160 dB respectively. The survey line started at 5 km (3.1 mi) south of the OBH deployment locations and continued 20 km (12.4 mi) past the OBHs offshore.

Table 3.2. Airgun Test Sail Line Coordinates

| | Latitude | Longitude | UTM (N) | UTM (E) |
|---|---|---|---|---|
| OBH-A | 70.7122 N | 148.7934 W | 7846275.6 | 433893.5 |
| OBH-B | 70.7120 N | 148.8151 W | 7846277.1 | 433093.1 |
| CPA | 70.7123 N | 148.7880 W | 7846280.9 | 434092.8 |
| Start | 70.6675 N | 148.7840 W | 7841282.1 | 434093.4 |
| Stop | 70.8915 N | 148.8041 W | 7866276.4 | 434093.8 |

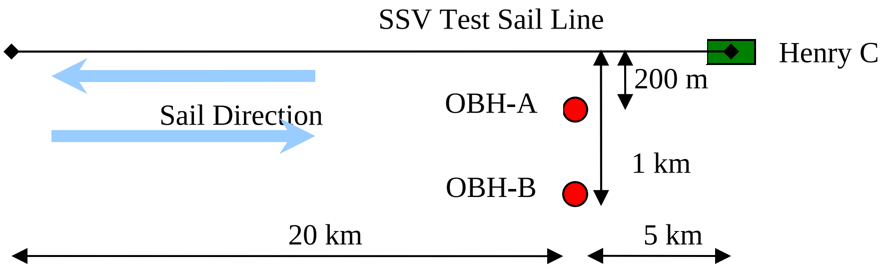

Figure 3.5. Shallow Hazards survey airgun measurements at Beechey Point site; diagram of OBH deployment geometry relative to test survey line. Actual survey line was oriented south-to-north. Distance conversion to miles: multiply km by 0.62 (e.g. 10 km equals 6.2 miles) and multiply meters by 3.3 to get distance in feet (e.g. 10 m equals 33 ft).

The coordinates and water depths at the actual OBH deployment sites, designated "A" and "B" respectively, are provided in Table 3.3. A total of 7 hours of airgun sound recordings were obtained as the *Henry Christofferson* sailed along the survey track lines. See Fig. 3.6 below for a picture of the 20 $in^3$ airgun array.

Figure 3.6. GEO LLC two gun array.

Table 3.3. Deployment locations of the OBH recorders for the airgun sound level measurements.

| OBH | Latitude | Longitude | Water depth |
|---|---|---|---|
| A | 70.7112 N | 148.7942 W | 22.3 m (74.3 ft) |
| B | 70.7115 N | 148.8139 W | 22.5 m (74.9 ft) |

Monitoring of the two sub-bottom profilers was performed by surveying a 6 km (3.7 mi) line that passed directly over OBH-A parallel to the airgun survey line. The two profilers monitored were the Datasonics CAP6000 Chirp II and the Datasonics SPR-1200 Bubble Pulser (Fig. 3.7).

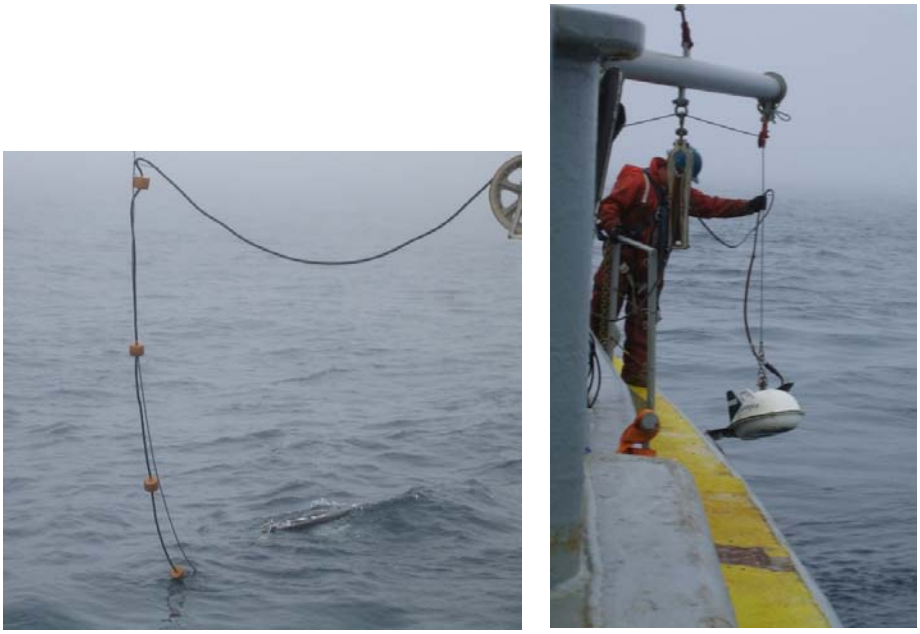

Figure 3.7. Dual Frequency Bubble Pulser (left) and Datasonics Chirp II (right).

The planned survey geometries for the profilers are shown below in Table 3.4, and Figs. 3.8 and 3.9.

Table 3.4. Sub-bottom Profiler Test Sail Line Coordinates

| | Latitude | Longitude | UTM (N) | UTM (E) |
|---|---|---|---|---|
| OBH-A | 70.7122 N | 148.7934 W | 7846275.6 | 433893.5 |
| OBH-B | 70.7120 N | 148.8151 W | 7846277.1 | 433093.1 |
| CPA | 70.7122 N | 148.7934 W | 7846275.6 | 433893.5 |
| Start | 70.7032 N | 148.7926 W | 7845275.6 | 433893.5 |
| Stop | 70.7570 N | 148.7974 W | 7851275.6 | 433893.5 |

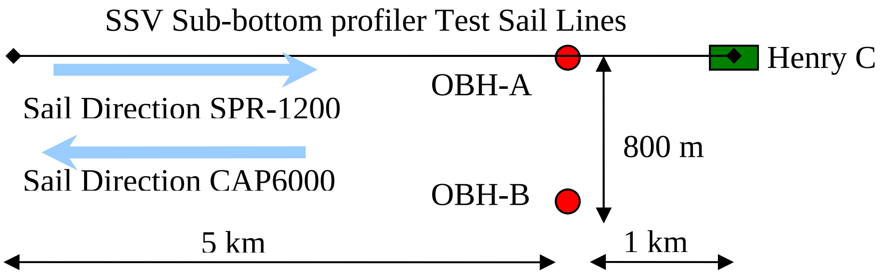

Figure 3.8. Shallow Hazards survey sub-bottom profiler test geometry at Beechey Point site: diagram of OBH deployment locations relative to the test sail line. Distance conversion to miles: multiply km by 0.62 (e.g. 10 km equals 6.2 miles) and multiply meters by 3.3 to get distance in feet (e.g. 10 m equals 33 ft).

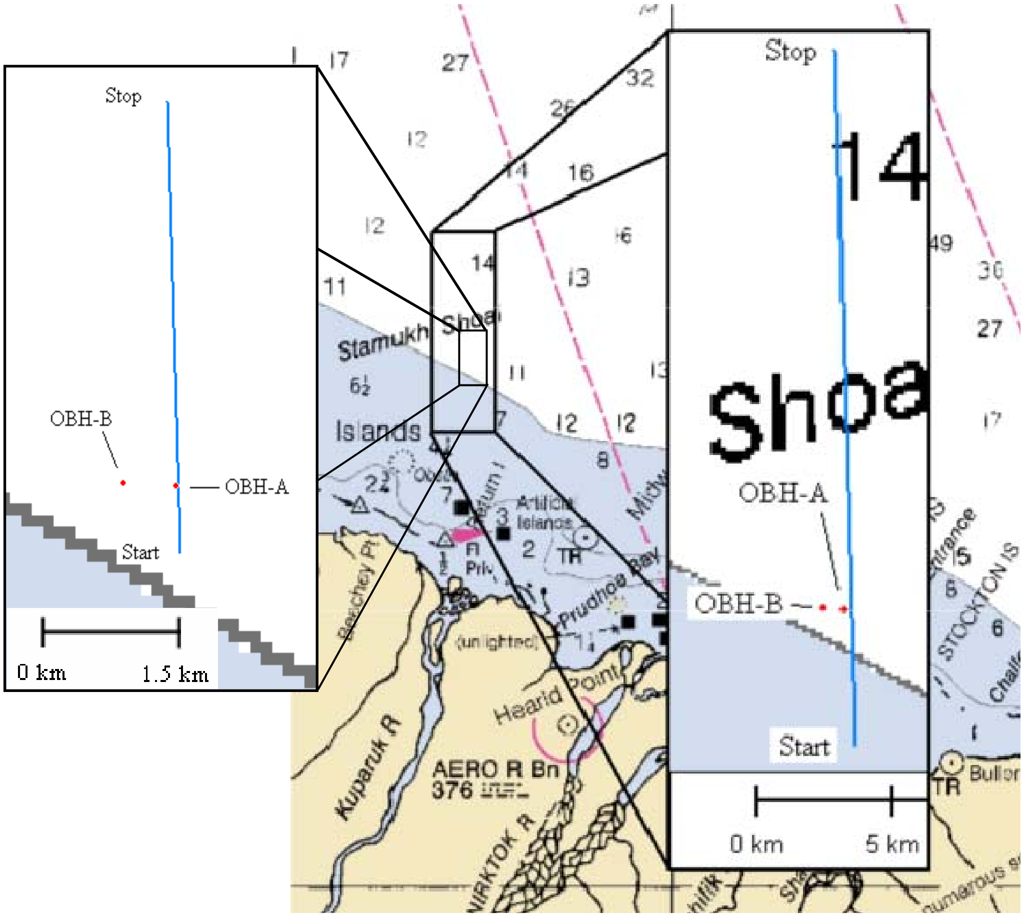

Figure 3.9. Map of OBH locations for seismic vessel *Henry Christofferson* during sub-bottom profiler measurements (left insert) and airgun array operations (right insert) near Beechey Point. Distance conversion to miles: multiply km by 0.62 (e.g. 10 km equals 6.2 miles).

The nominal speed of the survey vessel during the sound measurements was 7.4 km/h (4 kt) and the time interval between shots from the airgun array was approximately 3 seconds. The track lines of the survey vessel were planned in order to fully characterize acoustic emissions from the airgun array in both deep water and shallow water environments and also to measure the directionality pattern of each array to be used during the survey. After completion of the sound measurements, the OBH systems were retrieved aboard the *Henry Christofferson* and the acoustic waveform data were downloaded for analysis.

## Camden Bay Site

OBH systems were deployed from the *Henry Christofferson* at two fixed recording sites inside the Camden Bay survey area. Table 3.5 lists the OBH deployment locations, the closest point of approach (CPA) to the survey line, and the survey line start and end points. The OBH systems were deployed nominally at 200 m (0.12 mi) and 1 km (0.62 mi) perpendicular to the airgun survey line (Fig. 3.10). The survey line was oriented north-east, so the *Henry Christofferson* started at 5 km (3.1 mi) southwest of the OBH deployment locations and continued to 20 km (12.4 mi) northeast. The depth of the water increased from 30 m (100 ft) to 40 m (132 ft) over this track.

Table 3.5. Airgun test survey line coordinates.

| | Latitude | Longitude | UTM (N) | UTM (E) |
|---|---|---|---|---|
| OBH-A | 70.4042 N | 146.5872 W | 7810831.8 | 515453.3 |
| OBH-B | 70.3976 N | 146.5747 W | 7810089.7 | 515925.2 |
| CPA | 70.3962 N | 146.5721 W | 7810107.7 | 516008.9 |
| Start | 70.3758 N | 146.6910 W | 7807795.4 | 511571.7 |
| Stop | 70.4705 N | 146.0850 W | 7818593.7 | 534123.5 |

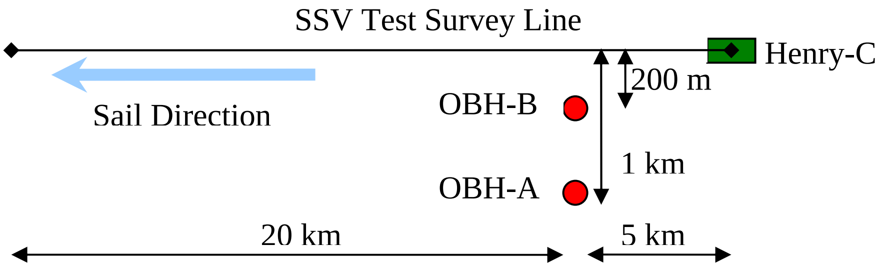

Figure 3.10. Shallow Hazards survey airgun measurements at Camden Bay site; diagram of OBH deployment geometry relative to test survey line. Actual survey line was oriented from south-west to north-east. Distance conversion to miles: multiply km by 0.62 (e.g. 10 km equals 6.2 miles) and multiply meters by 3.3 to get distance in feet (e.g. 10 m equals 33 ft)..

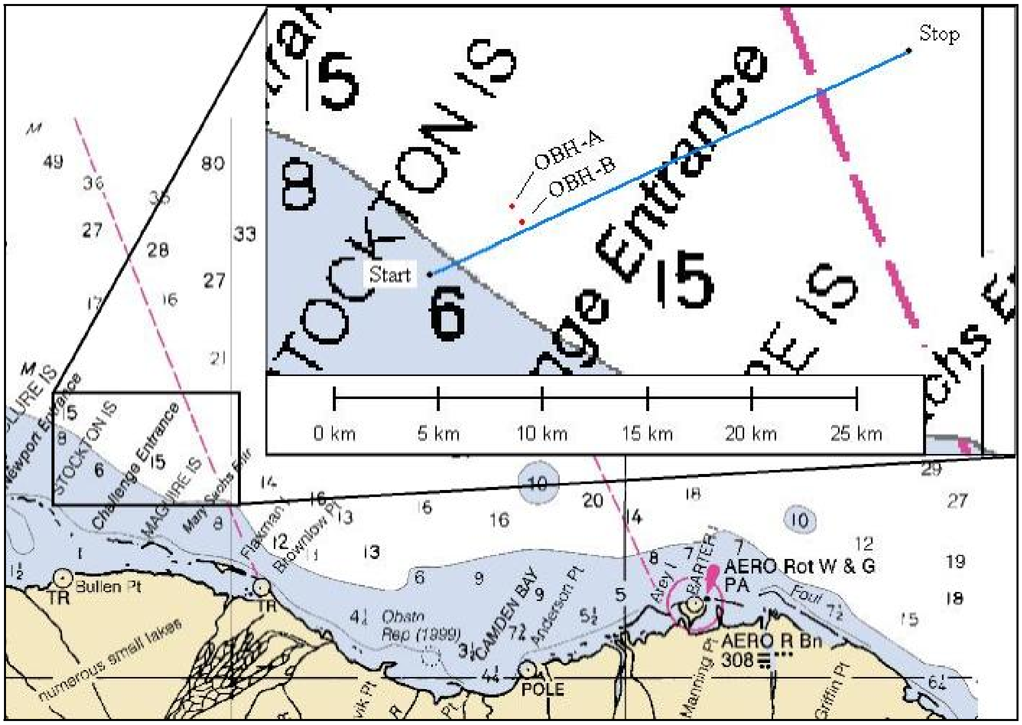

Figure 3.11. Map of OBH locations for seismic vessel *Henry Christofferson* during airgun array operations in Camden Bay. Distance conversion to miles: multiply km by 0.62 (e.g. 10 km equals 6.2 miles).

A total of 4 hours of airgun sound recordings were obtained as the *Henry Christofferson* sailed along the survey track line with airguns operating. The average speed of the survey vessel during the sound measurements was 6.5 km/h (3.5 kt) and the time interval between shots from the airgun array was approximately 2 seconds. After completion of the sound measurements, the OBH systems were retrieved onto the *Henry Christofferson* and the acoustic data were downloaded for analysis.

### *Vessel Measurements*

## *Maxime and Mikkelsen Bay* (Prudhoe Bay)

Underwater sounds produce by the support vessels *Mikkelsen Bay* and *Maxime* were measured using a single OBH deployed at location 70.4613 N, 148.6192 W at a depth of approximately 8 m. This location was chosen to approximate the normal operating conditions of both vessels that operated from West Dock performing crew and equipment transfer duties. These vessels operated primarily in coastal waters at depths usually less than 7 m (23 ft).

The OBH system was deployed with a surface buoy for recovery because of the shallow water depth, and to facilitate efficient deployment and retrieval. For the acoustic measurements, the vessels sailed along approximately straight test tracks on approach and departure from the OBH position. The vessels recorded continuous GPS position tracks that were subsequently used for computing distance as a function of time for the analysis of the recordings. The position of the OBH and the sail tracks of the vessels during the measurement program are shown in Fig. 3.12.

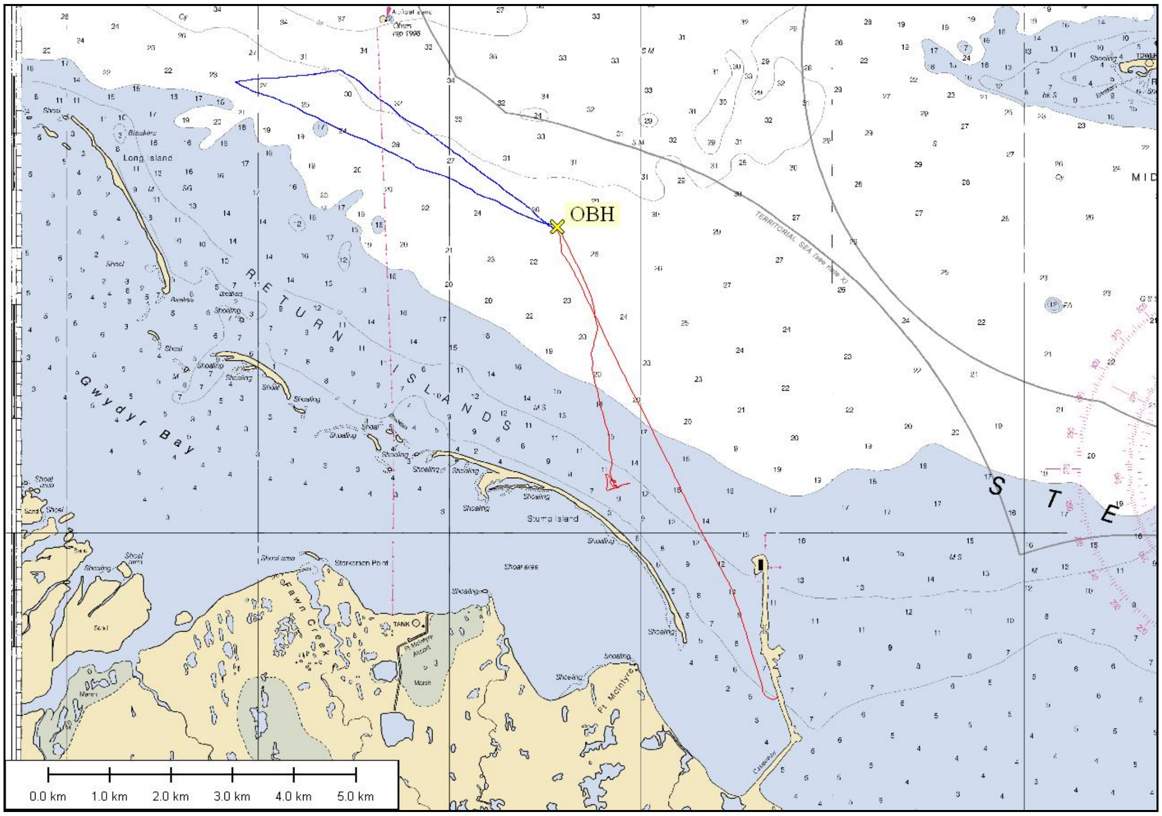

Figure 3.12. Map of OBH location and tracks of the *Maxime* (red) and *Mikkelsen Bay* (blue) during the measurement operations. Distance conversion to miles: multiply km by 0.62 (e.g. 10 km equals 6.2 miles).

## *Jim Kilabuk and Norseman II* (Prudhoe Bay)

A single OBH recording system was deployed from the *Jim Kilabuk* at GPS position 70º 40.110’ N, 147 º 59.904’ W at a depth of approximately 30 m (100 ft). This location was chosen to be representative of the normal operating conditions of both vessels in the prospect area. The OBH was deployed on 2 Oct 2007 immediately preceding the SSV measurement of the *Jim Kilabuk*. The OBH was left on the seafloor overnight and the SSV measurement of the *Norseman II* was performed on 3 Oct 2007 at the same location. The OBH was then retrieved by the *Norseman II* upon completion of the SSV measurement.

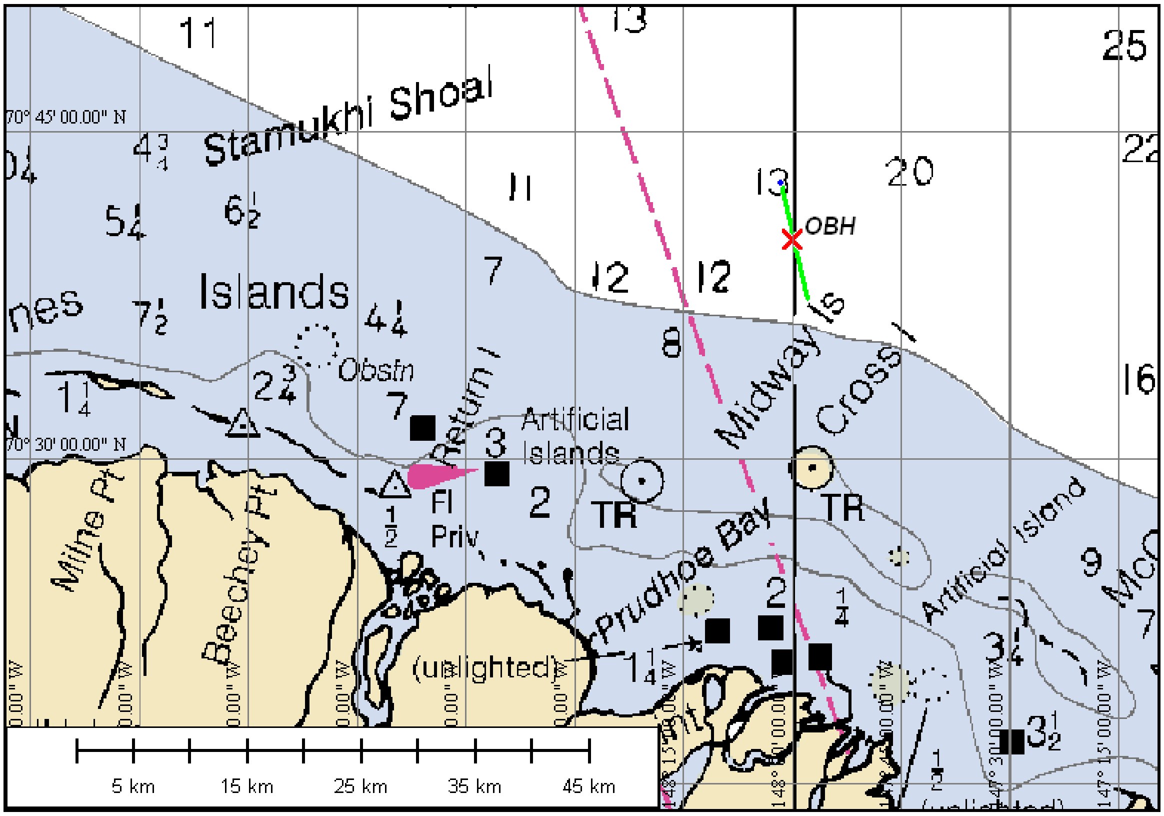

Figure 3.13. Map of OBH location (red X) and vessel track (green line) during the SSV measurements. Distance conversion to miles: multiply km by 0.62 (e.g. 10 km equals 6.2 miles).

During the SSV testing, the vessel under measurement started a track at a distance of 5 km (3.1 mi) from the OBH location heading toward the OBH, passing over top of it and continuing to a range of 5 km (3.1 mi) past the OBH position. Each vessel recorded a continuous, time stamped GPS position track for this analysis. Both the position of the OBH and the track of the vessels are shown in Fig. 3.13.

## *DATA ANALYSIS METHODS*

### *Seismic Survey Data*

Analyses of sound recording data were carried out to determine peak, *rms* and sound exposure level (SEL) sound pressure levels versus range from the airgun array sources. The data processing steps carried out were as follows:

1. Determine start times of seismic pressure signals in digital recordings.
2. Apply hydrophone sensitivity and digital conversion gain to digital recording units to convert to microPascals (µPa).
3. Determine the maximum sound pressure level for each pulse in dB re µPa.
4. Compute cumulative square pressure functions through the duration of each pulse.
5. Determine the interval over which the cumulative square pressure for each received pulse increases from 5% to 95% of the total.

6. For each pulse, compute the standard *rms* level by dividing the cumulative square pressure over the 5% to 95% interval by the number of samples in this period, and taking the square root.

### *Shallow Hazards Survey*

Airgun pressure waveform data from the OBH systems were analyzed using signal processing software which implemented the following analysis steps:

1. Airgun pulses in the OBH recordings were identified using a combination of manual picks and automated detection.
2. Waveform data were converted to units of μPa using the calibrated acoustic response of each OBH system.
3. For each pulse, the distance to the airgun array was computed from the GPS deployment positions of the OBH systems and the time referenced DGPS navigation logs of the *Henry Christofferson*.
4. The waveform data were processed to determine peak sound pressure level (PSPL), rms SPL and SEL.

The measurements are presented in plots showing the three metrics: peak pressure, *rms* pressure and SEL versus range for each of the sound types measured. For the seismic results, the term: "90% *rms* pressure" has been used because the root-mean-square levels were computed from a time window containing 90 percent of the airgun pulse energy.

An empirical sound level propagation equation was fit to the 90% *rms* sound pressure measurements. The equation has the form:

$$RL = SL - n\log_{10} R - \alpha R \qquad \text{Equation} \quad (1)$$

where $R$ is the range from the source in meters, $RL$ is the received sound level, $SL$ is the estimated source level, $n$ is a geometric spreading loss coefficient and $\alpha$ is an absorptive loss coefficient. This equation fit to measurements was performed by finding the coefficients $n$ and $\alpha$ that gave the least squares difference between the trend line and the *rms* sound level data. The best-fit parameters are shown in the plot annotations. The best-fit equation trend lines were then shifted higher by a constant decibel value so they exceeded 90 percent of the *rms* data values. These shifted trend lines are referred to as 90th percentile trend lines. The best-fit and 90th percentile trend lines presented in the figures were then used to derive distances for the ranges corresponding to the various sound level thresholds.

### *Vessel Measurements*

Analyses of vessel sound recordings were performed to determine *rms* SPL versus range from each vessel. GPS tracks from each vessel were used to determine the range from the vessel to the OBH throughout the measurement period. The acoustic data recorded during the period of approach for each vessel were analyzed to compute *rms* SPL, computed from 1 second time windows, versus distance.

Due to variability in data, smooth line fits of an empirical SPL curve of the form of equation (1) were made to determine a representative loss versus range curve. The best-fit curves were then shifted upward in sound level so they exceeded 90 percent of the data points upon which the original fit was based. This step was performed to obtain a precautionary empirical estimate. Finally, the crossings of this shifted curve with specific sound level thresholds between 180 and 120 dB re 1 μPa were used to find the corresponding sound level radii that are presented for each vessel measurement. In some cases a single curve of the form given in equation (1) could not accurately simultaneously fit near- and far-field data. In those cases separate fits were performed to short range and long-range data and the appropriate fit was used for determining the sound level threshold radii (i.e. the shorter range fits were used to determine the threshold crossings at higher levels and the longer range fits were used to determine threshold crossings at lower levels).

### *M-weighting*

The potential for seismic survey noise to impact marine species is highly dependent on how well the species can hear the sounds produced (Ireland et al. 2007). Noises are less likely to disturb animals if they are at frequencies the animal cannot hear well. An exception is when the noise pressure is so high as to cause physical injury (whether temporary or permanent). For non-injurious sound levels, frequency weighting curves based on audiograms may be applied to vary the importance of sound levels at particular frequencies in a manner reflective of the receiver's sensitivity to those frequencies (Nedwell et al. 1998).

A NMFS-sponsored Noise Criteria Committee has proposed standard frequency weighting curves — referred to as M-weighting filters — for use with marine mammal species (Gentry et al. 2004). M-weighting filters are band-pass filter networks that are designed to reduce the importance of inaudible or less-audible frequencies for five broad classes of marine mammals:

1. Low frequency cetaceans,
2. Mid-frequency cetaceans,
3. High-frequency cetaceans,
4. Pinnipeds in water, and
5. Pinnipeds in air.

The amount of discount applied by M-weighting filters for less-audible frequencies is not as great as would be indicated by the corresponding audiograms for these groups of species. The rationale for applying a smaller discount than would be suggested by the audiogram is in part due to a characteristic of human 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 the reason that C-weighting curves for humans, used for assessing very 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 (either temporary or permanent) if pressure levels are very high. The M-weighting filters therefore are designed for use for primarily high sound level impacts such as temporary or permanent hearing threshold shifts. The use of M-weighting could be considered precautionary (in the sense of overestimating the potential for impact) when applied to lower level impacts such as onset of behavioral change impacts. Fig. 3.14 shows the decibel frequency response of the four standard underwater M-weighting filters.

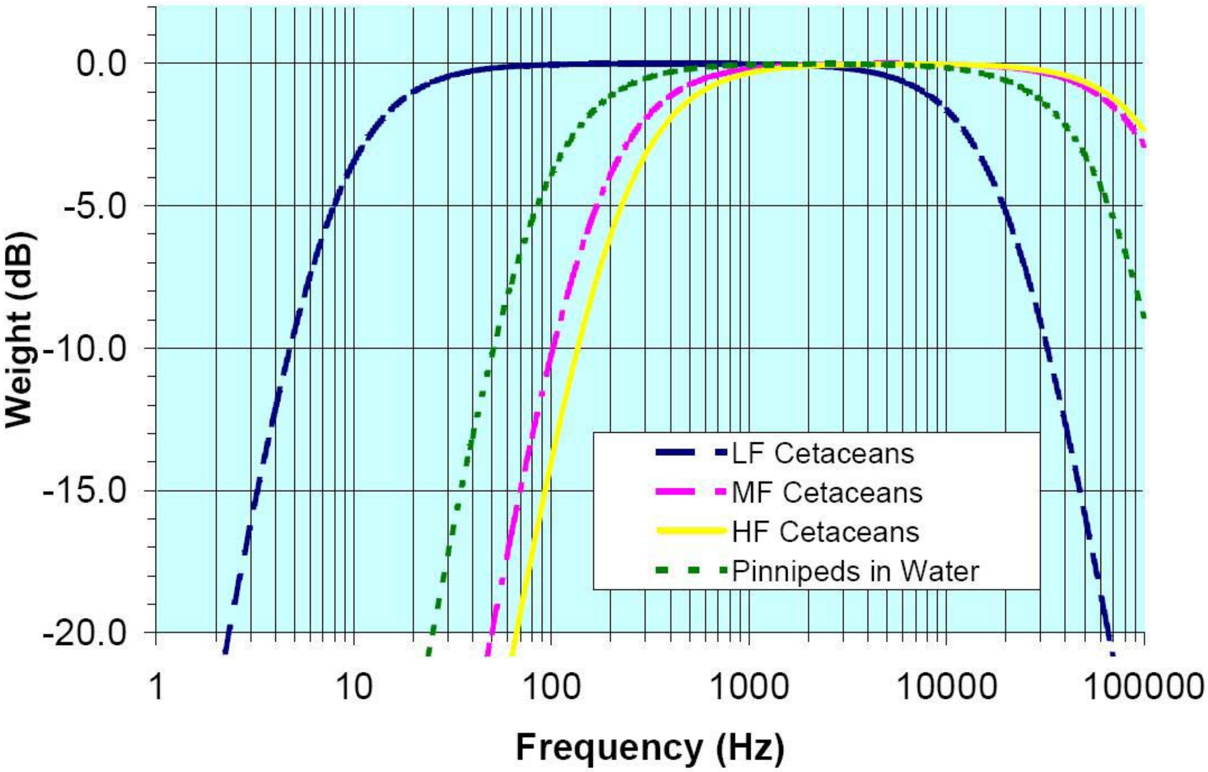

Figure 3.14. Plot of standard M-weighting curves for low frequency, mid-frequency and high frequency cetaceans, and for pinnipeds in water.

These filters have unity gain (0 dB) through the pass band and their high and low frequency roll off is approximately –12 dB per octave. The amplitude response of the M-weighting filters is defined in the frequency domain by the following function:

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

The roll off and pass band of these filters are controlled by the two parameters $f_{lo}$ and $f_{hi}$; the parameter values that are used for the four different standard M-weighing curves are given in Table 3.6.

Table 3.6. Low frequency and high frequency cutoff parameters for standard marine mammal M-weighting curves.

| M-weighting filter | $f_{lo}$ (Hz) | $f_{hi}$ (Hz) |
|---|---|---|
| Low frequency cetaceans | 7 | 22,000 |
| Mid-frequency cetaceans | 150 | 160,000 |
| High-frequency cetaceans | 200 | 180,000 |
| Pinnipeds underwater | 75 | 75,000 |

M-weighting filters were applied to the seismic survey airgun data by Fast Fourier Transforming (FFT) the data and multiplying the spectra by the filter coefficients shown in Fig. 3.14. The filtered data were transformed back to the time domain and then processed to calculate sound level metrics using the same methods used for non-filtered data. This method is the same as was used for analysing sound measurement data from GX Technology's 2006 Chukchi seismic program (Ireland et al. 2006). The M-weighting filters applicable to marine mammal species commonly encountered in the Alaskan Chukchi Sea are as follows:

1. Bowhead whales (*Balaena mysticetus*) and gray whales (*Eschrichtius robustus*): low frequency cetacean M-weighting.
2. Beluga whales (*Delphinapterus leucas*): mid-frequency cetacean M-weighting.
3. Spotted seals (*Phoca largha*), ringed seals (*Phoca hispida*), ribbon seals (*Phoca fasciata*), bearded seals (*Erignathus barbatus*), Pacific walruses (*Odobenus rosmarus*): pinniped underwater M-weighting.

## *MEASUREMENT PROGRAMS*

### *Seismic Survey*

## Broadband Levels for Seismic Survey Program in the Chukchi Sea

### Level vs. Range Data Plots

Ranges from the airgun array to the OBH recording positions were computed for the times corresponding to each shot using the *Gilavar's* navigation log. The data presented in this section are from all OBH systems. At ranges of 8 km (5 mi) and greater from the full airgun array, measurements from only the more sensitive TC4032 hydrophones are shown. At shorter ranges, measurements are from the less-sensitive TC4043 hydrophones. All mitigation airgun results were obtained from TC4032 channels.

**Full Airgun Array.**—The peak and 90% *rms* unweighted SPL and sound exposure level (SEL) for each full airgun array shot were computed for each OBH system and these three metrics were plotted against the corresponding source-receiver ranges. The endfire measurement plots shown in Fig. 3.15 were obtained on OBHs A and E. The broadside measurements shown in the plot of Fig. 3.16 were obtained on OBHs A, B, C and D. The broadside measurement plot shows data points extracted from the overall datasets at the time corresponding to the approach and passing by *Gilavar* past point *X* (ref. Fig. 3.3). The variation of decibel levels apparent at each broadside range is due to strong directivity of the airgun array near broadside; the sound levels increase and then decrease rapidly as the line of OBHs enters and exits the array's broadside directivity peak.

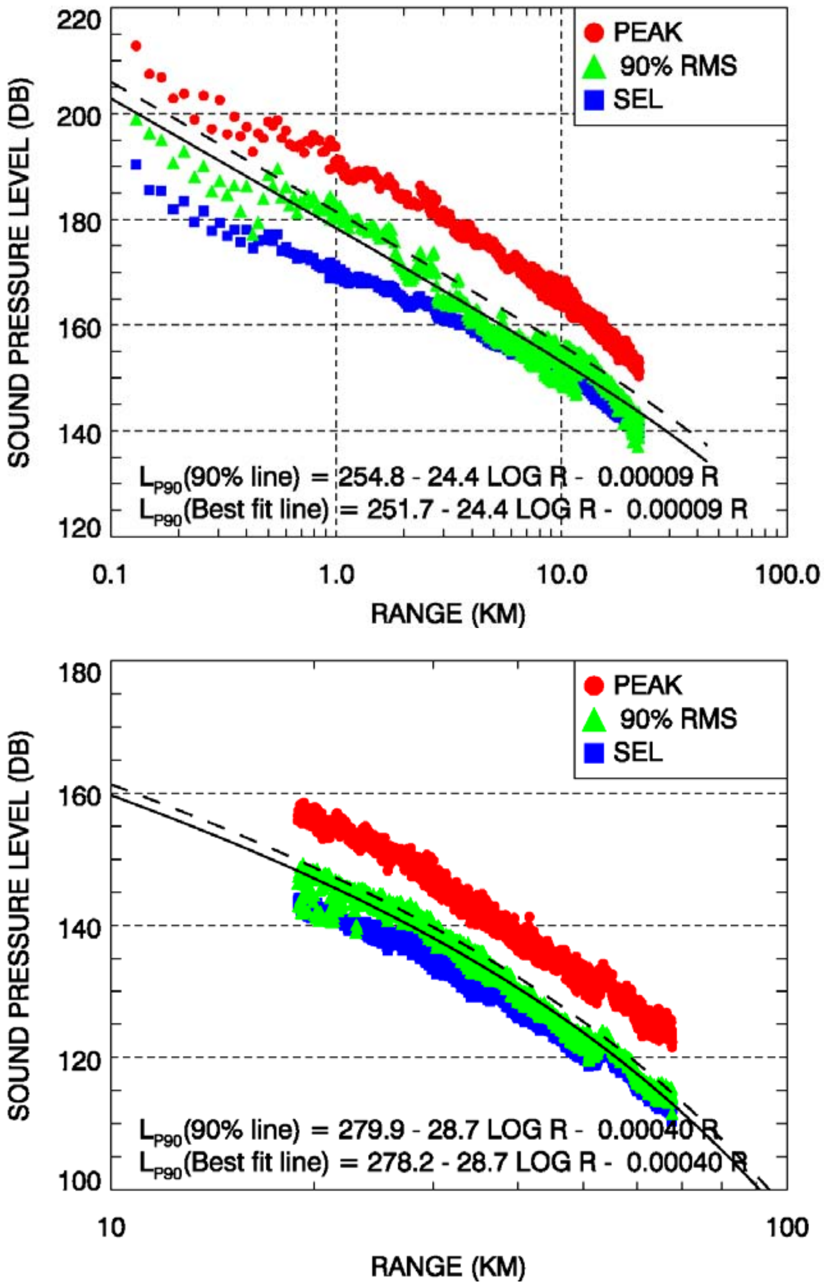

Figure 3.15. Peak, rms, and SEL levels for airgun pulses received from array forward-endfire on OBHs A (upper) and E (lower). Solid lines are best fits of the empirical function to RMS values. Dashed lines are shifted versions of the best-fit lines to exceed 90% of data values. Distance conversion to miles: multiply km by 0.62 (e.g. 10 km equals 6.2 miles).

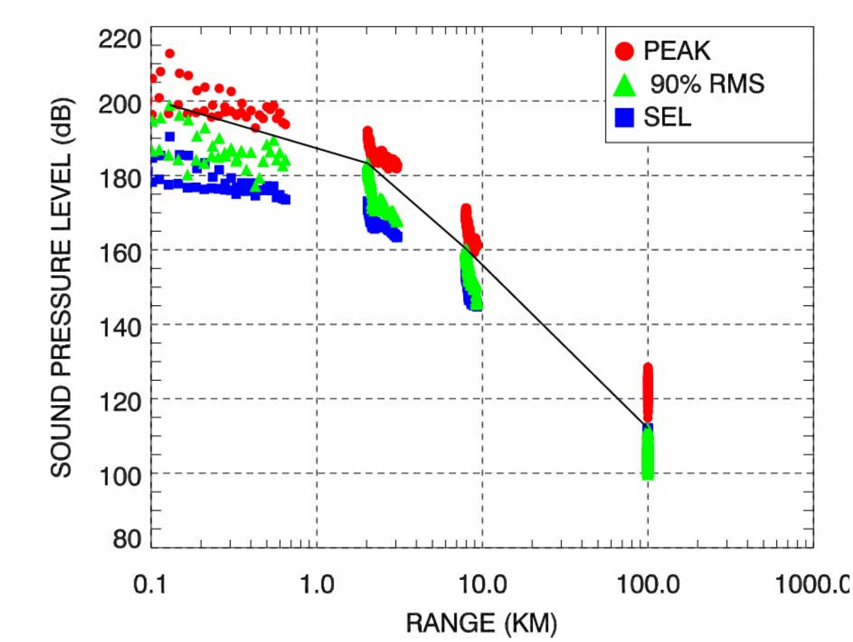

Figure 3.16. Peak, rms, and SEL levels for airgun pulses received from array broadside. Solid lines are drawn between maximum RMS values at the four nominal ranges monitored, and are representative of maximum RMS directivity levels. Distance conversion to miles: multiply km by 0.62 (e.g. 10 km equals 6.2 miles).

**Mitigation Gun.** —Similar processing methods were used to compute peak, *rms*, and SEL levels for the mitigation airgun. Shot sound levels were computed from the recordings on OBH systems E and F. These results are presented as a function of source-receiver range in Figs. 3.17 and 3.18 (both figures show levels at ranges less than 1 km (0.62 mi). Separate fits to long-range and short-range data were performed because the rate of sound level decrease with range (transmission loss) appeared to increase beyond 1 km (0.62 mi).

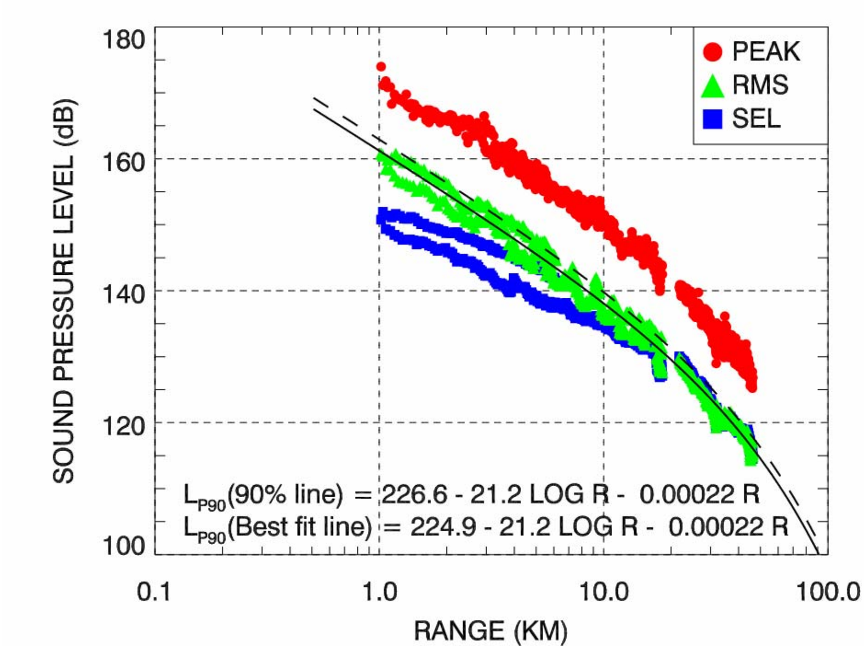

Figure 3.17. Peak, rms, and SEL levels versus distance greater than 1 km (0.62 mi) from the mitigation airgun. Solid line is best fit of the empirical function to rms values. Dashed line is the best-fit line shifted by 1.72 dB to exceed 90% of data values. Distance conversion to miles: multiply km by 0.62 (e.g. 10 km equals 6.2 miles).

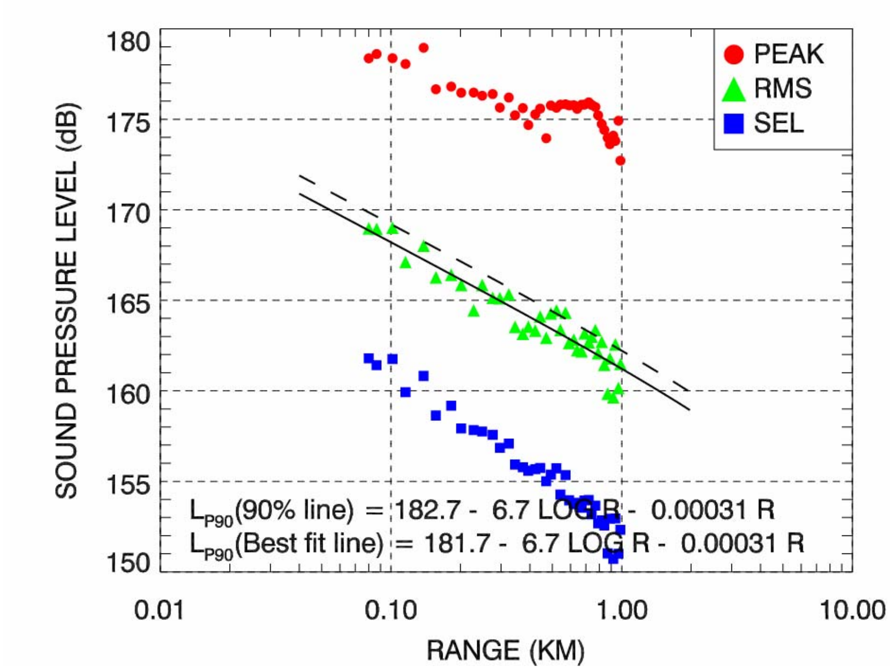

Figure 3.18. Peak, rms, and SEL levels versus distance less than 1 km (0.62 mi) from the mitigation airgun. Solid line is best fit of the empirical function to rms values. Dashed line is the best-fit line shifted by 1.0 dB to exceed 90% of data values. Distance conversion to miles: multiply km by 0.62 (e.g. 10 km equals 6.2 miles).

### Ranges to Threshold Levels

Ranges from the airgun array and mitigation airgun to specified unweighted SPL thresholds between 190 and 120 dB re 1 μPa *rms* were determined from the acoustic data recorded on OBH systems. Ranges from the full airgun array were determined separately in the broadside and endfire directions. Mitigation gun levels are expected to be omnidirectional (same in all directions) so no direction-dependent analysis was undertaken. Substantially more measurements were obtained in the forward-endfire direction from the full airgun array than in the broadside direction due to the fixed OBH deployment geometry. The large number of endfire data values allowed fitting of empirical transmission loss functions to obtain more statistically-reliable estimates of the ranges corresponding to the crossing of the important sound level thresholds. This approach was not used to determine broadside ranges because the number of broadside measurement data points was insufficient for this type of fitting.

The empirical function fit to forward-endfire measurements of the full array had the form of equation (1). Separate fits of this function were made to data for source-receiver ranges 0-18 km (11 mi) and 18-68 km (11-42 mi). The best-fit functions are plotted as the solid lines in Fig. 3.15. For the purpose of obtaining conservative estimates of ranges to various sound level thresholds, offsets were applied to the best-fit functions so they would exceed 90% of the measured data points. The respective shifts for the far- and near-field data were 3.1 dB and 1.7 dB, and these shifted fits are shown as the dashed lines in the figures. The endfire ranges to threshold levels were determined from the threshold crossings of the shifted fits. M-weighting filters were also applied to endfire measurements and the ranges to threshold levels were calculated in the same way as flat-weighted results. Radii applicable to low frequency cetaceans (baleen whales) have been calculated from unweighted (flat-weighted) sound levels. The LF Cetacean M-weighting filter was not applied to seismic data because seismic signals are comprised of sound energy at frequencies entirely inside the flat portion of the LF Cetacean M-weight filter. Consequently flat-weighting can be considered to give the same result as LF Cetacean M-weighting. These ranges are given in Table 3.7.

Table 3.7. Forward-endfire sound level threshold radii in meters for the full 3147 in$^3$ airgun array during the Chukchi Sea seismic survey program.

| | Endfire Range (m) | | | |
|---|---|---|---|---|
| *rms* SPL (dB re μPa) | Flat Weighted (for LF Ceteceans) | Mid Frequency Cetaceans | High Frequency Cetaceans | Underwater Pinnipeds |
| 190 | 450 | 171 | 146 | 224 |
| 180 | 1140 | 478 | 403 | 668 |
| 170 | 2900 | 1304 | 1091 | 1893 |
| 160 | 7150 | 3351 | 2815 | 4834 |
| 120 | 58400 | 40002 | 35390 | 50144 |

Broadside direction measurements at the four broadside ranges of deployed OBHs: 100 m (330 ft), 2 km (1.2 mi), 8 km (5 mi) and 100 km (62 mi) were made simultaneously as the seismic vessel passed point *X* (ref. Fig. 3.3). The levels at these ranges changed rapidly as the airgun array passed the closest point of approach (point *X*) to the OBHs due to strong array directivity that has been discussed previously. The variation at each range represents sampling over the peak of the directivity function lobe. Only the maximum value at each of the four ranges was considered for the purpose of determining broadside sound level threshold ranges. Linear interpolation in range between these maxima provided the broadside threshold ranges in Table 3.8.

The nominal ranges to important sound level thresholds for the mitigation airgun measurements are presented in Table 3.9. These ranges are suitable for establishing safety ranges near the mitigation airgun source. The ranges for thresholds between 190 and 170 dB re 1 μPa *rms* levels were determined by the 90% fit presented in Fig. 3.18. The ranges for lower threshold levels were determined from the fit to longer range data shown in Fig. 3.17.

Table 3.8. Broadside sound level threshold radii in meters for the full 3147 in$^3$ airgun array. The corresponding distances in miles are presented in table I.8 in Appendix I.

| | Broadside Range (m) | | | |
|---|---|---|---|---|
| *rms* SPL (dB re μPa) | Flat Weighted (for LF Cetaceans) | Mid Frequency Cetaceans | High Frequency Cetaceans | Underwater Pinnipeds |
| 190 | 545 | 230 | 183 | 346 |
| 180 | 2470 | 675 | 532 | 1027 |
| 170 | 4500 | 1933 | 1519 | 2923 |
| 160 | 8100 | 5204 | 4134 | 7591 |
| 120 | 66000 | 65236 | 60063 | 73022 |

Table 3.9. Sound level threshold radii in meters for the mitigation airgun. See Table I.9 in Appendix I for distances in feet and miles.

| *rms* SPL (dB re μPa) | Endfire Range (m) |
|---|---|
| 190 | <10* |
| 180 | <10* |
| 170 | 76* |
| 160 | 1360 |
| 120 | 41100 |

* Extrapolated from minimum measurement range 80 m.

## Broadband Levels for Seismic Vessel Gilavar (Camden Bay)

### Level vs. Range Data Plots

Ranges from the airgun array to the OBH recording positions were computed for the times corresponding to each shot using the navigation logs supplied by the *Gilavar*. The data presented in this section are from all six OBH systems. For endfire plots at ranges 25 km (15.5 mi) and greater, measurements from the more sensitive TC4032 hydrophones are shown. At shorter ranges measurements are from the less-sensitive TC4043 hydrophones. For broadside measurements, the more sensitive TC4043 hydrophones are used at ranges of 10 km (6.2 mi) and beyond.

Peak and *rms* SPLs and SELs for each shot were computed for each OBH system, and these three metrics were plotted against the corresponding source-receiver ranges. The endfire measurements shown in Fig. 3.19 were obtained on OBHs A and F. The broadside measurements shown in Fig. 3.20 were obtained on OBHs A, B, C, D and E. The broadside measurement plot shows data points extracted from the overall datasets at the time corresponding to the approach and passing by *Gilavar* past point *X* (ref. Fig. 3.4). Only a few points were plotted from each OBH to capture the directivity maximum at broadside of the airgun; the sound levels increase and then decrease rapidly as the line of OBHs enters and exits the array's broadside directivity peak.

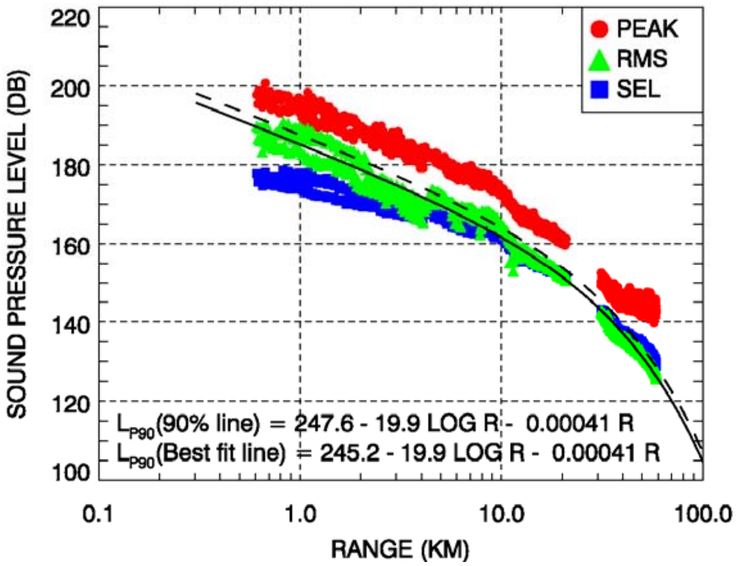

Figure 3.19. Peak, *rms*, and SEL levels for airgun pulses received from array forward-endfire on OBHs A and F. Solid line is best fit of the empirical function to *rms* values. Dashed line represents a shift of the best-fit line by +2.4 dB to exceed 90% of the *rms* data values. Distance conversion to miles: multiply km by 0.62 (e.g. 10 km equals 6.2 miles).

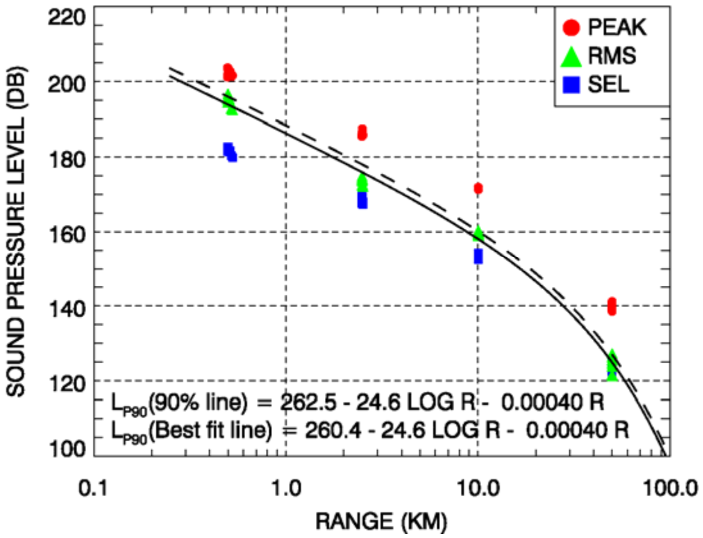

Figure 3.20. Peak, *rms*, and SEL levels for airgun pulses received from array broadside. Solid line is best fit of the empirical function to *rms* values. Dashed

line is the best-fit line shifted by 2.1 dB to exceed 90% of data values. Distance conversion to miles: multiply km by 0.62 (e.g. 10 km equals 6.2 miles).

The peak, *rms*, and SEL were also calculated for the mitigation airgun used at the end of the seismic line. Shot SPLs were computed from four OBH systems and were plotted against the corresponding source-receiver ranges in Fig. 3.21. The mitigation airgun sound levels are omnidirectional (the same in all directions).

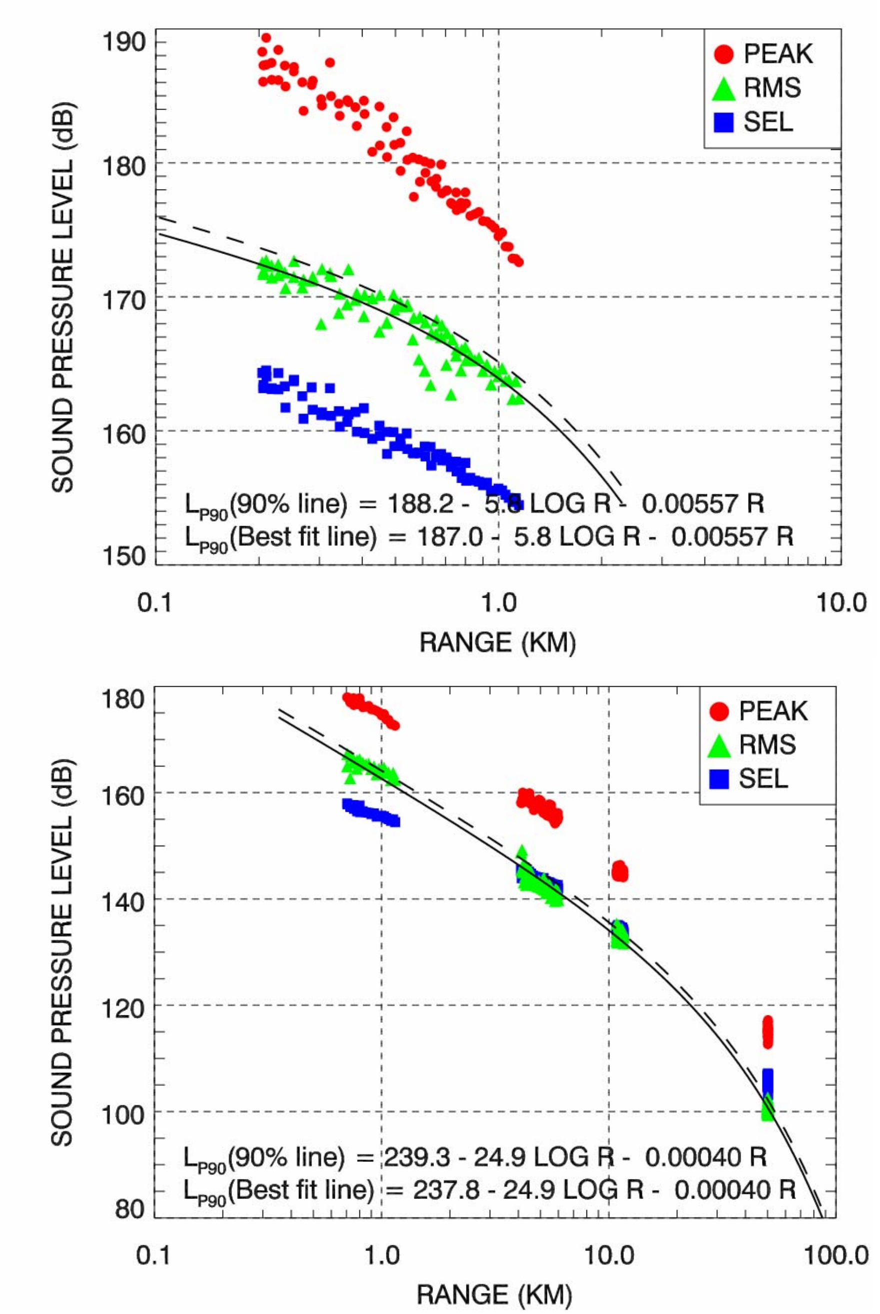

Figure 3.21. Peak, *rms*, and SEL levels versus distance from the mitigation airgun at close range (top) and at long range (bottom). Solid line is best fit of the empirical function to *rms* values. Dashed line is the best-fit

line shifted by 2.5 dB to exceed 90% of data values. Distance conversion to miles: multiply km by 0.62 (e.g. 10 km equals 6.2 miles).

## Ranges to Threshold Levels

Ranges from the airgun array to specified SPL thresholds between 190 and 120 dB re 1 μPa *rms* were determined from the acoustic data recorded on OBH systems in the broadside and endfire directions and also for the mitigation airgun. More airgun shot measurements were obtained in the forward-endfire direction than in the broadside direction due to the configuration of the deployment geometry. The mitigation airgun shots were recorded for the last 20 minutes the *Gilavar* remained on survey line.

The empirical function fit to the measurements had the form of equation (1). The computed best-fit (least squares regression) functions are shown in the figures. The best-fit function is plotted as the solid line. The best-fit line was shifted by a constant offset so it exceeded 90% of the measured data points. This shifted line was used to compute the nominal ranges to the decibel thresholds 190, 180, 170, 160 and 120 dB re μPa (*rms*) from measurements in the forward-endfire direction and these are listed in Table 3.10.

Table 3.10. Forward-endfire sound level threshold radii for the full 3147 in$^3$ airgun array at Sivilluq Prospect in Camden Bay. Distances in feet and miles are given in Appendix I Table I.10.

| *rms* SPL (dB re μPa) | Endfire Range (m)<br>Flat Weighted | <br>Mid Frequency Cetaceans | <br>High Frequency Cetaceans | <br>Underwater Pinnipeds |
|---|---|---|---|---|
| 190 | 757 | 60 | 37 | 176 |
| 180 | 2245 | 285 | 181 | 768 |
| 170 | 5986 | 1291 | 846 | 2989 |
| 160 | 13405 | 4871 | 3435 | 8980 |
| 120 | 74813* | 58886* | 52238 | 67567* |

* Extrapolated from maximum measurement range of 58.7 km (36.5 mi).

Broadside direction measurements at the four broadside ranges: 250 m (0.15 mi), 2.5 km ( (1.6 mi), 10 km (6.2 mi) and 50 km (31 mi) were made simultaneously as the seismic vessel passed point *X* (ref. Fig. 3.4). The levels at these ranges changed rapidly as the airgun array passed the closest point of approach (point *X*) to the OBHs due to strong array directivity that has been discussed previously. The rapid variation in levels at each broadside range is due to the sampling over the peak of the broadside directivity function lobe. Only a few data points near the maximum value at each of the four ranges were considered for the purpose of determining broadside sound level threshold ranges. A fit of an empirical level versus range function was used to interpolate between the sampled broadside ranges. The empirical fit was again shifted to exceed 90% of the data points and the shifted function was used to estimate the threshold ranges presented in Table 3.11.

Table 3.11. Broadside sound level threshold radii for the full 3147 in$^3$ airgun array at Sivulliq Prospect in Camden Bay. See Appendix I Table I.11 for distances in miles.

| | Broadside Range (m) | | | |
|---|---|---|---|---|
| *rms* SPL (dB re µPa) | Flat Weighted | Mid Frequency Cetaceans | High Frequency Cetaceans | Underwater Pinnipeds |
| 190 | 857 | 519 | 414 | 711 |
| 180 | 2088 | 1413 | 1157 | 1857 |
| 170 | 4812 | 3599 | 3041 | 4517 |
| 160 | 10084 | 8128 | 7107 | 9736 |
| 120 | 61887 | 53147 | 50119 | 57952 |

The same approach was used to determine the nominal ranges to sound level thresholds for the mitigation airgun measurements and these are presented in Table 3.12.

Table 3.12. Sound level threshold radii for the 30 in$^3$ mitigation airgun at Sivulliq Prospect in Camden Bay. See Appendix I Table I.12 for distances in miles.

| *rms* SPL (dB re µPa) | Best fit range (m) | 90th percentile range(m) |
|---|---|---|
| 190 | <10* | <10* |
| 180 | 15* | 24* |
| 170 | 365 | 465 |
| 160 | 1261 | 1439 |
| 120 | 22911 | 24600 |

* Extrapolated from minimum measurement range of 200 m.

### *Shallow Hazards Survey*

## Small Airgun Array and Sub-bottom Profiler Measurements at Beechey Point

The OBH data collected during the Beechey Point shallow hazards survey were analyzed to compute peak pressure, 90% *rms* pressure and SEL versus range for each of the sound types measured. The empirical transmission loss function, of equation (1), was fit to the 90% *rms* sound pressure measurements for each source type. The fit coefficients $n$ and $\alpha$ that gave the least squares difference with the *rms* sound level data are shown in the plot annotations. These best-fit equation trend lines were then shifted higher by a constant decibel value so they exceeded 90 percent of the *rms* data values. The shifted trend lines were then used to derive distances to several *rms* sound level thresholds for the two gun array, the single airgun, and the *sub-bottom* profilers.

### Small Airgun Array Measurements

Figs. 3.22 and 3.23 present the measurements for the 2 x 10 in$^3$ airgun array and single 10 in$^3$ airgun, respectively. The 10 in$^3$ airgun array is not strongly directive; it has similar sound emission levels in the endfire and the broadside directions. Airgun operation at shallower depths produced lower levels than in deeper water for similar ranges. For this analysis, data measured in all directions and depths were combined.

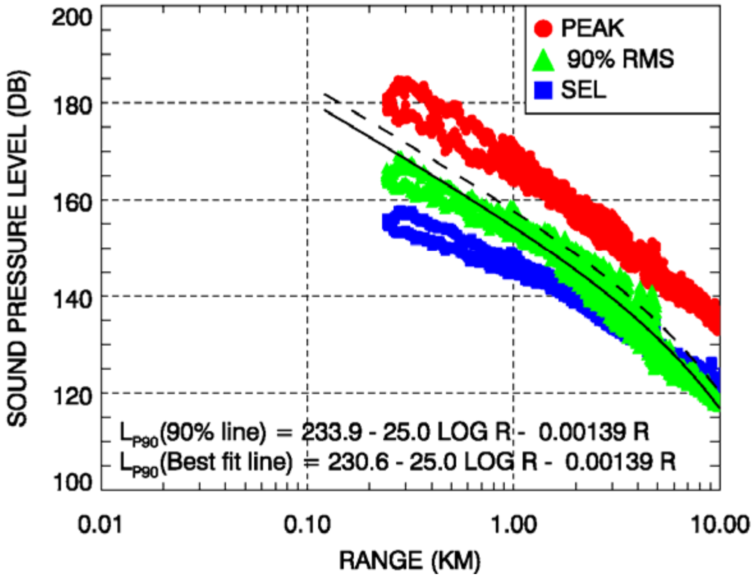

Figure 3.22. Peak, *rms* and SEL levels versus range from the 2 x 10 in$^3$ airgun array. Solid line is least squares best fit of equation (1) to *rms* values. Dashed line represents best fit line increased by 3.3 dB to exceed 90% of all *rms* values (90$^{th}$-percentile fit). Distance conversion to miles: multiply km by 0.62 (e.g. 10 km equals 6.2 miles).

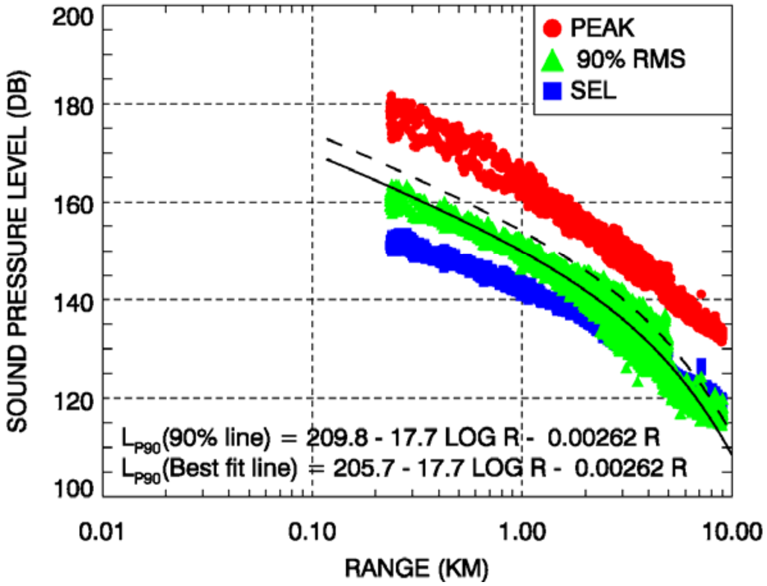

Figure 3.23. Peak, *rms* and SEL levels versus range from the 1 x 10 in$^3$ airgun array. Solid line is least squares best fit of equation (1) to *rms* values. Dashed line represents best fit line increased by 4.1 dB to exceed 90% of all *rms* values. Distance conversion to miles: multiply km by 0.62 (e.g. 10 km equals 6.2 miles).

The nominal ranges to the decibel thresholds 190, 180, 160 and 120 dB re μPa (*rms*) were computed using the shifted empirical fits presented in Fig. 3.23 for the 2 by 10 in$^3$ two-gun array and in Fig. 3.24 for the single 10 in$^3$ airgun. These ranges are listed in Tables 3.13 and 3.14, respectively.

Table 3.13. Sound threshold level radii for 190, 180, 160 and 120 dB re μPa (*rms*) from 2 x 10 in$^3$ airgun array. See Appendix I Table I.13 for distances in feet and miles.

| *rms* SPL | 90$^{th}$ percentile fit (m) |
|---|---|
| 120 dB | 10700 |
| 160 dB | 597 |
| 180 dB | 51 |
| 190 dB | 12 |

Table 3.14. Sound threshold level radii for 190, 180, 160 and 120 dB re μPa (*rms*) from single 10 in$^3$ airgun. See Appendix I Table I.14 for distances in feet and miles.

| *rms* SPL | 90$^{th}$ percentile fit (m) |
|---|---|
| 120 dB | 8130 |
| 160 dB | 333 |
| 180 dB | 20 |
| 190 dB | 5 |

### Sub-bottom Profiler Measurements

Fig. 3.24 presents the measurements for the Datasonics SPR-1200 bubble pulser *sub-bottom* profiler. Fig. 3.25 presents the results from the Datasonics CAP6000 Chirp II *sub-bottom* profiler. The Chirp profiler operating frequency was 2-7 kHz, so frequencies below 1 kHz and above 10 kHz were filtered out prior to the sound level calculations.

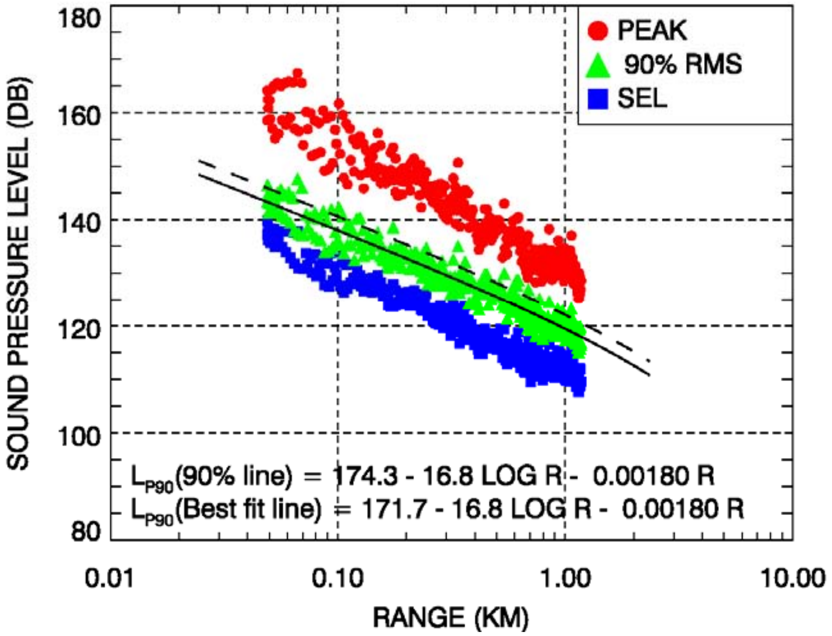

Figure 3.24. Peak, *rms* and SEL levels versus range from the bubble pulser *sub-bottom* profiler. Solid line is least squares best fit of equation (1) to *rms* values. Dashed line represents best fit line increased by 2.6 dB to exceed 90% of all *rms* values.

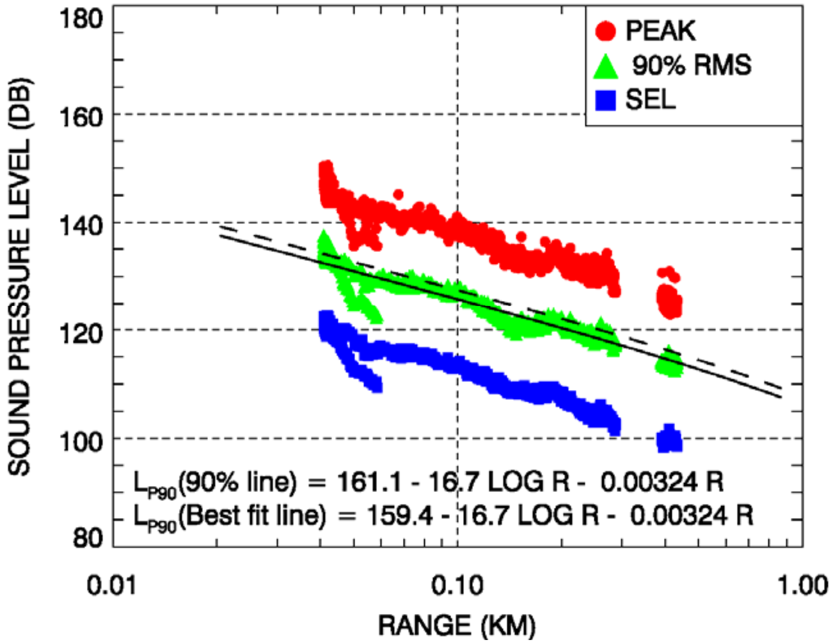

Figure 3.25. Peak, *rms* and SEL levels versus range from the Chirp II *sub-bottom* profiler. Solid line is least squares best fit of equation (1) to *rms* values. Dashed line represents best fit line increased by 1.7 dB to exceed 90% of all *rms* values. Distance conversion to miles: multiply km by 0.62 (e.g. 1 km equals 0.62 miles).

The nominal ranges to the decibel thresholds 160, 150, 140, 130 and 120 dB re μPa (*rms*) were computed from the shifted empirical fits to the data presented in Figs. 3.24 and 3.25 for the Datasonics *sub-bottom* profilers. These ranges are listed in Tables 3.15 and 3.16. The *rms* SPLs of these profilers are unlikely to reach 180 or 190 dB μPa (*rms*) at any range. The source levels for the bubble pulser and chirp profilers are estimated to be 172 and 159 dB μPa (*rms*) respectively, however these estimates are based on measurements to the side of the systems. Levels directly beneath the profilers are likely higher than to the side, where surface reflected sound destructively interferes with the directly arriving signals.

Table 3.15. Sound threshold level radii for 160, 150, 140, 130 and 120 dB re μPa (*rms*) from Datasonics SPR-1200 bubble pulser *sub-bottom* profiler.

| *rms* SPL | Best fit range (m) | 90th percentile fit |
|---|---|---|
| 120 dB | 946 | 1252 |
| 130 dB | 283 | 394 |
| 140 dB | 76 | 107 |
| 150 dB | 20 | 28 |
| 160 dB | 5 | 7 |

Table 3.16. Sound threshold level radii for 160, 150, 140, 130 and 120 dB re μPa (*rms*) from the Datasonics CAP6000 Chirp II *sub-bottom* profiler.

| *rms* SPL | Best fit range (m) | 90th percentile fit |
|---|---|---|
| 120 dB | 210 | 260 |
| 130 dB | 57 | 71 |
| 140 dB | 15 | 18 |
| 150 dB | 4 | 5 |
| 160 dB | 1 | 1 |

## Small Airgun Array Measurements at Camden Bay

### 20 in$^3$ airgun array results

Fig. 3.26 presents the measurements for the 2 × 10 in$^3$ airgun array surveying a southwest to northeast line in Camden Bay against large swells at 6.5 km/h (3.5 kt) over ground. This airgun array is not characterized by a strong directional component; the array has similar sound emission levels in the forward-endfire and the broadside directions at the same range. However, levels at 5 km (3.1 mi) southwest of the recording locations were approximately 7 dB less than at 5 km (3.1 mi) northeast. This difference is attributed to shallower water south of the recorder positions than to the north. For this preliminary analysis, all data were included in the fits that were used to estimate ranges to sound level thresholds.

The nominal ranges to the decibel thresholds 190, 180, 160 and 120 dB re μPa (*rms*) were computed using the shifted (dashed line) fit presented in Fig. 3.26 for the 2 x 10 in$^3$ two gun array. These ranges are listed in Table 3.17.

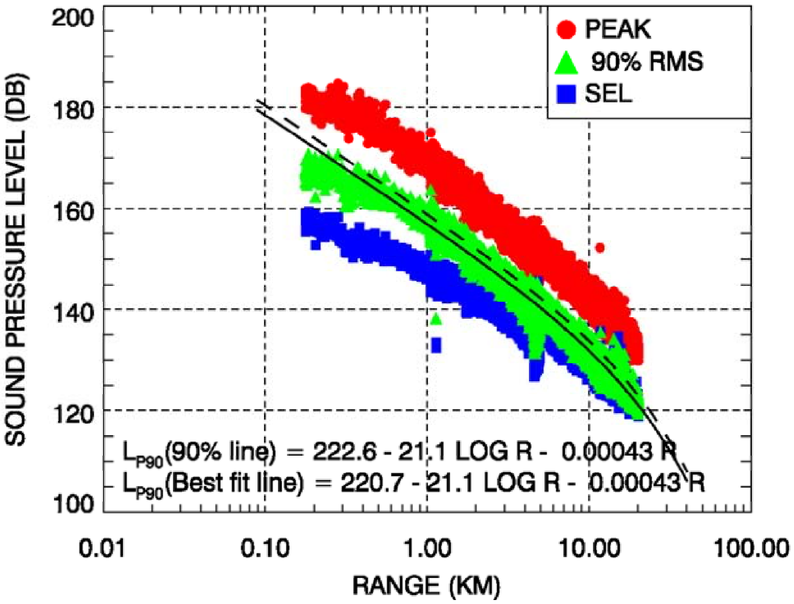

Figure 3.26. Peak, *rms* and SEL levels versus range from the 2 x 10 in$^3$ airgun array. Solid line is least squares best fit of equation (1) to *rms* values. Dashed line represents best fit line increased by 1.9 dB to exceed 90% of all *rms* values (90$^{th}$-percentile fit). Distance conversion to miles: multiply km by 0.62 (e.g. 10 km equals 6.2 miles).

Table 3.17. Sound threshold level distances for 190, 180, 160 and 120 dB re µPa (*rms*) from 2 x 10 in$^3$ airgun array. See Appendix I Table I.17 for distances in feet and miles.

| *rms* SPL | 90$^{th}$ percentile fit (m) |
|---|---|
| 190 dB | 1* |
| 180 dB | 7* |
| 160 dB | 1000 |
| 120 dB | 25200 |

* Extrapolated from minimum measurement range of 200 m.

### *Shallow Hazards Survey Vessel Noise Measurements*

## Sound Levels from Vessel Henry Christofferson at Beechey Point

Figs. 3.26 and3.27 present sound measurements for the *Henry Christofferson* sailing at 7.4 km/h (4 kt) and 26 km/h (14 kt) respectively. During the 7.4 km/h (4 kt) pass, the Chirp II profiler was also operating.

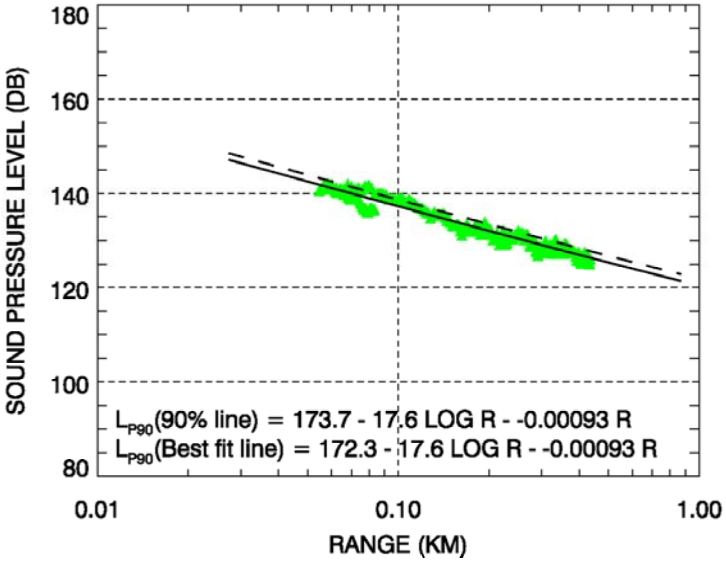

Figure 3.26. Sound pressure level (*rms*) versus range from the *Henry Christofferson* cruising at 7.4 km/h (4 kt) during Chirp II operation. Solid line is least squares best fit of equation (1). Dashed line represents best fit line increased by 1.4 dB to exceed 90% of all values. Distance conversion to miles: multiply km by 0.62 (e.g. 1 km equals 0.62 miles).

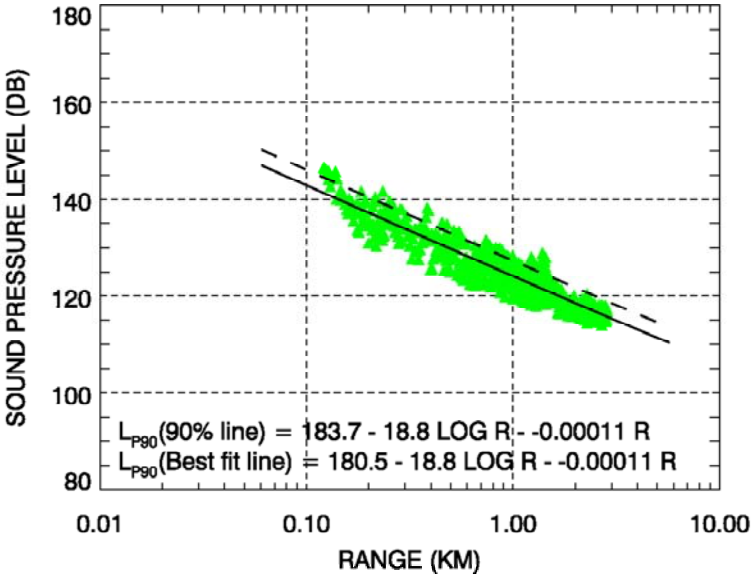

Figure 3.27. Sound pressure level (rms) versus range from the *Henry Christofferson* cruising at full speed (26 km/h or 14 kt). Solid line is least squares best fit of equation (1). Dashed line represents best fit line increased by 3.2 dB to exceed 90% of all values. Distance conversion to miles: multiply km by 0.62 (e.g. 1 km equals 0.62 miles).

The nominal ranges to the decibel thresholds 170, 160, 150, 140, 130 and 120 dB re μPa (*rms*) for the *Henry Christofferson* were computed from the shifted percentile equation fits presented in Figs. 3.26 and 3.27. These ranges are listed inTables 3.18 and 3.19.

Table 3.18. Sound threshold level radii for 120-170 dB re μPa (*rms*) for the *Henry Christofferson* cruising at 7.4 km/h (4 kt) during operation of the Chirp profiler. See Appendix I Table I.18 for distances in feet and miles.

| *rms* SPL | Best fit range (m) | 90th percentile fit |
|---|---|---|
| 120 dB | 1079 | 1338 |
| 130 dB | 264 | 319 |
| 140 dB | 69 | 84 |
| 150 dB | 19 | 22 |
| 160 dB | 5 | 6 |
| 170 dB | 1 | 2 |

Table 3.19. Sound threshold level radii for 120-180 dB re μPa (*rms*) for the *Henry Christofferson* cruising at full speed (22 km/h or 12 kt). See Appendix I Table I.19 for distances in feet and miles.

| *rms* SPL | Best fit range (m) | 90th percentile fit |
|---|---|---|
| 120 dB | 1670 | 2499 |
| 130 dB | 484 | 718 |
| 140 dB | 142 | 210 |
| 150 dB | 42 | 62 |
| 160 dB | 12 | 18 |
| 170 dB | 4 | 5 |
| 180 dB | 1 | 2 |

## Sound Levels from Vessel *Henry Christofferson* at Camden Bay

Additional measurements of vessel-only sound levels were obtained as the *Henry Christofferson* sailed back along the survey line to recover the OBHs after completing airgun shooting tests on the Sivulliq Prospect in Camden Bay. Nominal vessel speed during the sail-back was 6.7 km/h (3.6 kt) and the vessel was sailing in the same direction as a moderate swell. Vessel noise levels were computed in 60-second time windows stepped in 30-second increments. Fig. 3.28 presents these vessel sound levels as a function of distance from the recorder positions.

The nominal ranges to the decibel thresholds 140, 130 and 120 dB re μPa (*rms*) for the *Henry Christofferson* were computed using the shifted fit equation presented in Fig. 3.28. These ranges are listed in Table 3.20.

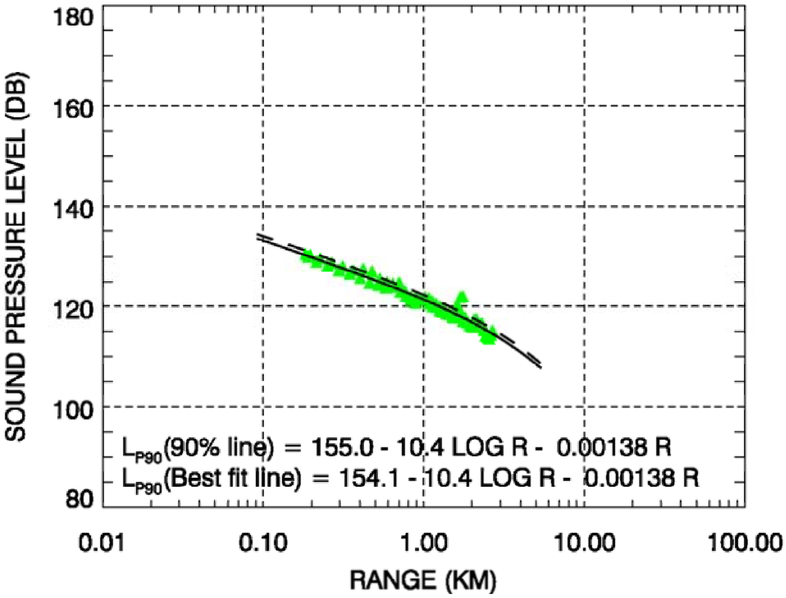

Figure 3.28. Sound pressure level (*rms*) versus range from the *Henry Christofferson* sailing at 6.7 km/h (3.6 kt) with swells. Solid line is least squares best fit of equation (1). Dashed line represents best fit line increased by 0.9 dB to exceed 90% of all values. Distance conversion to miles: multiply km by 0.62 (e.g. 1 km equals 0.62 miles).

Table 3.20. Sound threshold level distances for 140, 130 and 120 dB re μPa (*rms*) for the *Henry Christofferson* sailing at 6.7 km/h (3.6 kt) with swells. See Appendix I Table I.20 for distances in feet and miles.

| *rms* SPL | Best fit range (m) | 90th percentile fit |
|---|---|---|
| 140 dB | 22* | 27* |
| 130 dB | 191 | 230 |
| 120 dB | 1250 | 1440 |

* Extrapolated from minimum measurement range of 200 m.

## Sound Levels from Seismic Vessel *Gilavar*, and Seismic Support Vessels *American Islander* and *Gulf Provider* at Camden Bay

### *Gilavar*

Additional analysis of vessel-only sound levels were made of the 85 m seismic survey vessel *Gilavar* (Fig. 3.29) cruising at a nominal speed of 8.5 km/h (4.6 kt). These sound levels were taken between mitigation airgun shots on OBH A and OBH F. Fig. 3.30 presents these vessel sound levels as a function of distance from the recorder positions.

Figure 3.29. *Gilavar* seismic research vessel.

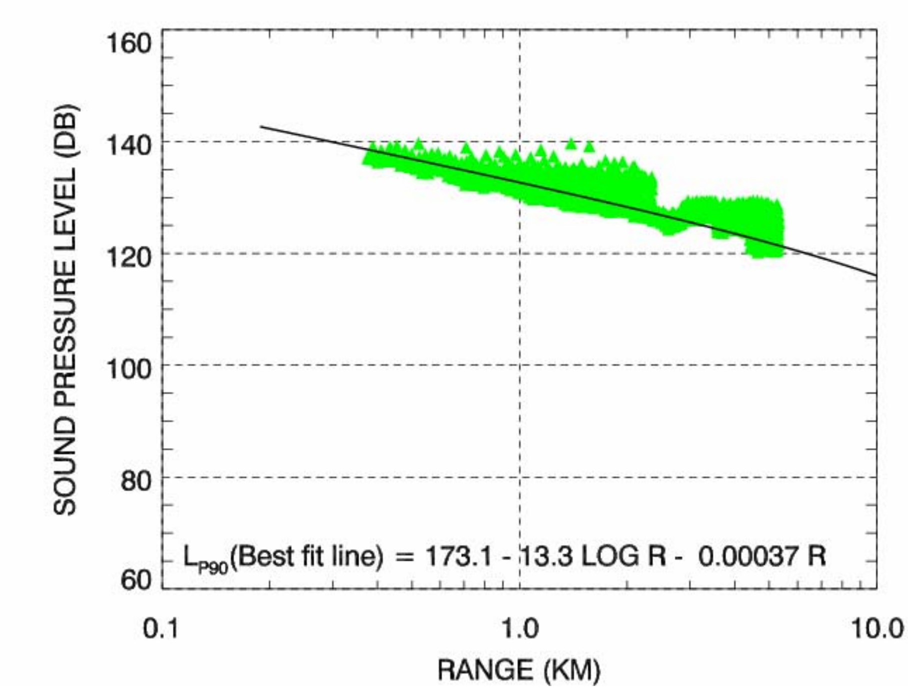

Figure 3.30. Vessel sound pressure levels (rms) for the *Gilavar* at 8.5 km/h (4.6 kt). Line is fit to the lower range of rms values, because mitigation gun reverberation increased the values of some of these data points. Distance conversion to miles: multiply km by 0.62 (e.g. 1 km equals 062 miles).

The nominal ranges to the decibel thresholds 150, 140, 130 and 120 dB re µPa (*rms*) for the *Gilavar* itself were computed from the line fit to data shown in Fig. 3.30. These ranges are listed in Table 3.21.

Table 3.21. Sound level threshold radii for the *Gilavar* at 8.5 km/h (4.6 kt). See Appendix I Table I.21 for distances in feet and miles.

| *rms* SPL (dB re µPa) | Best fit range (m) |
|---|---|
| 150 | 53* |
| 140 | 300* |
| 130 | 1500** |
| 120 | 6300** |

* Extrapolated from minimum measurement range of 350 m.

** These ranges may be overestimated due to inclusion of reverberation noise from simultaneous and nearby mitigation airgun shooting.

### *American Islander*

Measurements of vessel sound levels versus range from the support vessel *American Islander* (Fig. 3.31) were obtained as it sailed back along the survey line to recover OBH-E after the SSV test airgun array shooting was completed in Camden Bay. *American Islander*, owned by American Marine, is a 30 m (100 foot) tug type support vessel for the *Gilavar*. Nominal vessel speed during the sail-back was 14 km/h (7.8 kt). Vessel noise levels were computed in 1-second time windows stepped in 1-second increments. Fig. 3.32 presents these vessel sound levels as a function of distance from the recorder positions.

The nominal ranges to the decibel thresholds 140, 130 and 120 dB re µPa (*rms*) for the *American Islander* were computed from the fit line shown in Fig. 3.32. These ranges are listed in Table 3.22.

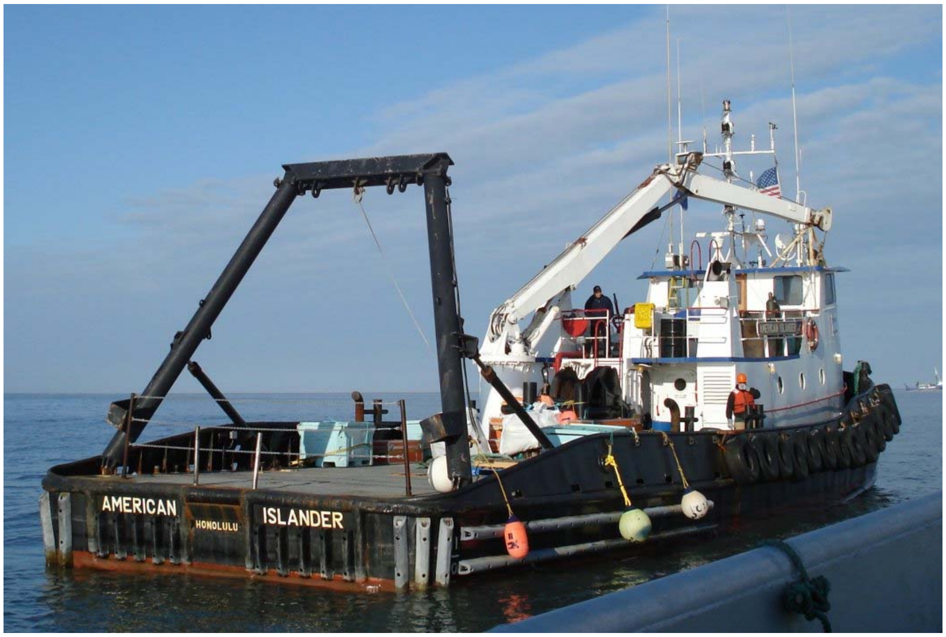

Figure 3.31. *American Islander* tug support vessel.

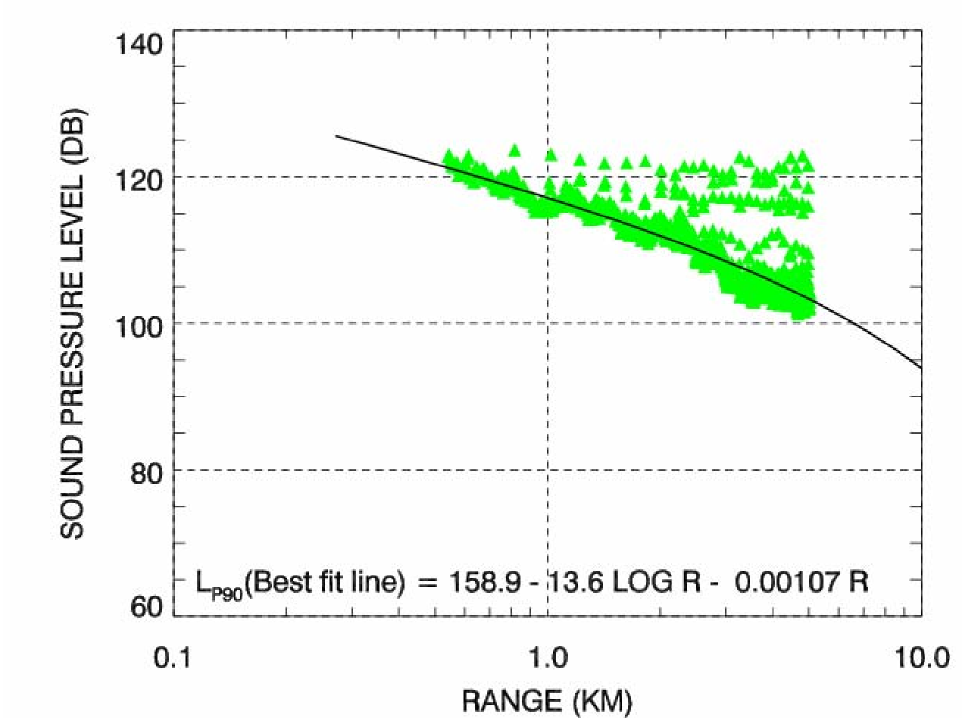

Figure 3.32. Sound pressure levels (*rms*) for support vessel *American Islander* at 14 km/h (7.8 kt). Solid line is fit to the lower range of *rms* values. Higher-level points above the fit are due to mitigation airgun shots and unknown seismic pulses. Distance conversion to miles: multiply km by 0.62 (e.g. 1 km equals 0.62 miles).

Table 3.22. Sound level threshold radii for the support vessel *American Islander* cruising at 14 km/h (7.8 kt). See Appendix I Table I.22 for distances in feet and miles.

| *rms* SPL (dB re µPa) | Range (m) |
|---|---|
| 140 | 25* |
| 130 | 130* |
| 120 | 650 |

* Extrapolated from minimum measurement range of 500 m (0.31 mi).

### *Gulf Provider*

Vessel-only sound levels were made of the seismic survey support vessel *Gulf Provider*. These sound levels were taken between mitigation airgun shots on OBH-C (ref. Fig. 3.4). Fig. 3.33 presents these vessel sound levels as a function of distance from the recorder positions.

The nominal ranges to the decibel thresholds 140, 130 and 120 dB re µPa (*rms*) for the *Gulf Provider* were computed from the line fit to data shown in Fig. 3.33. These ranges are listed in Table 3.23.

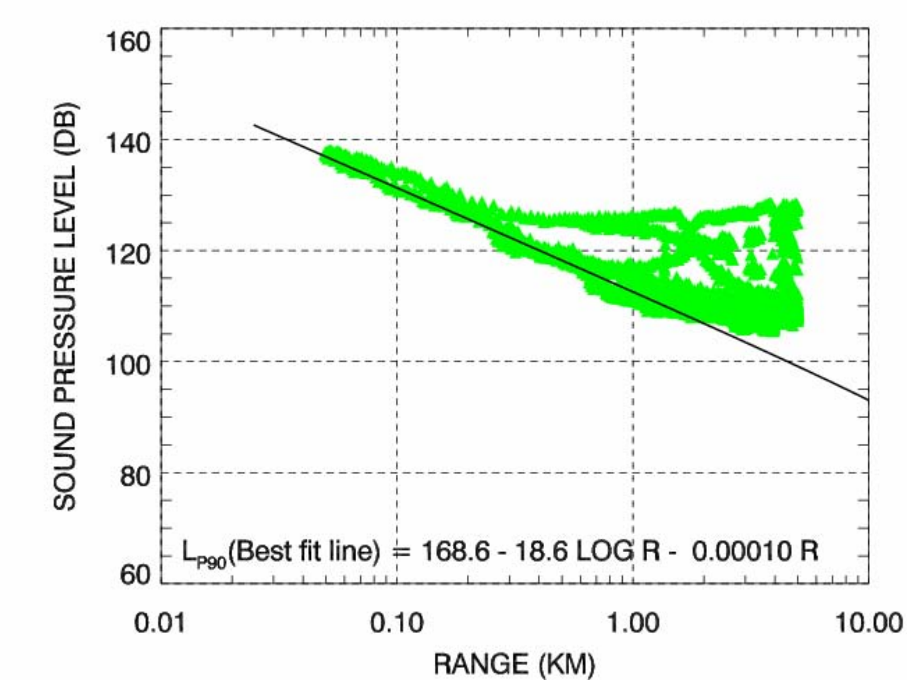

Figure 3.33. Vessel sound pressure levels (*rms*) for the *Gulf Provider*. Line is fit to the lower range of *rms* values, because mitigation gun shots signals and reverberation increased the values of some of these data points. Distance conversion to miles: multiply km by 0.62 (e.g. 1 km equals 0.62 miles).

Table 3.23. Sound level threshold radii for the G*ulf Provider* in Camden Bay. See Appendix I Table I.23 for distances in feet and miles.

| *rms* SPL (dB re µPa) | Best fit range (m) |
|---|---|
| 140 | 34* |
| 130 | 120 |
| 120 | 400 |

* Extrapolated from minimum measurement range of 500 m (0.31 mi).

## Sound Levels from Support Vessel *Maxime* and *Mikkelsen Bay* (Prudhoe Bay)

### *Maxime*

The *Maxime* is an aluminum, water-jet propelled landing craft approximately 40’ in length. For this measurement, the *Maxime* sailed a straight line approach and departure from the OBH for approximately 5 km (3.1 mi) in both directions. Nominal vessel speed during the measurement was 12 km/h (6.5 kt). Vessel noise levels were computed in 1-second time windows stepped in 1-second increments. Fig. 3.35 presents these vessel sound levels as a function of distance from the recorder positions. The overall vessel noise during the measurement was for the most part very low, so only data recorded when the vessel was within 1 km (0.62 mi) of the OBH are presented.

Figure 3.34. *Maxime* support vessel.

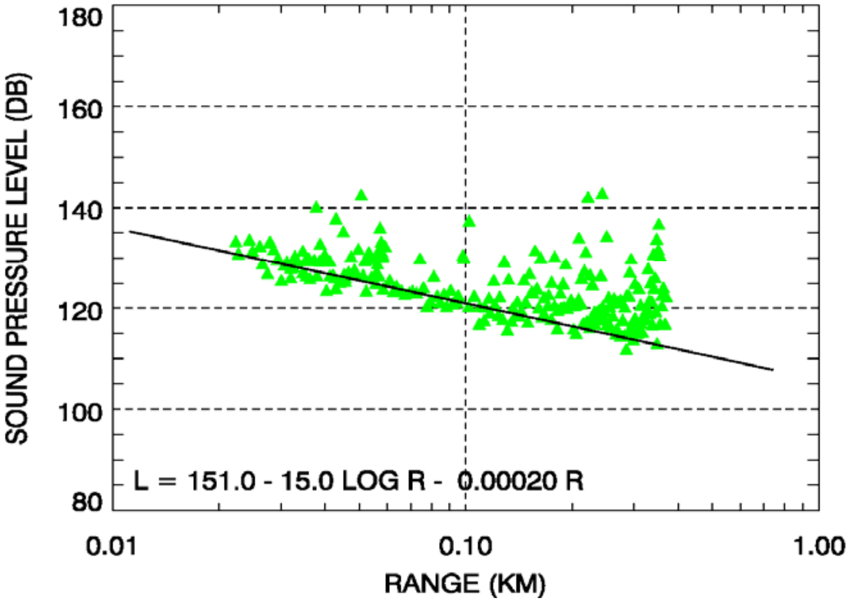

Figure 3.35. Sound pressure levels (*rms*) for support vessel *Maxime* at 12 km/h (6.5 kt). Distance conversion to miles: multiply km by 0.62 (e.g. 1 km equals 0.62 miles).

The nominal range to the decibel threshold of 120 dB re 1 µPa (*rms*) for the *Maxime* was only 116 m (383 ft) based on the empirical function fit line shown in Fig. 3.35. This fit was made through the lower range of the spread in the data due to the presence of noise from a tether and surface float that were used for the OBH deployment. Wave action caused varying tension in the tether rope that was transmitted partially into the recordings. The vessel noise varied relatively slowly with time and is expected to be represented best by the lower range of variability of these measurements.

### *Mikkelsen Bay*

The *Mikkelsen Bay* is a 12.8 m (42 ft) oil spill response vessel, designed for moving and deploying booms and skimmers, moving containment barges and transporting personnel and equipment. It will also be used by SOI for a shallow water survey of strudlescour. It was measured transiting approximately 5 km (3.1 mi) to and from the OBH location at a nominal speed of 10 km/h (5.5 kt). This speed is representative of its typical operating speed during survey work. Again, due to the low source level, only data recorded within 800 m (0.5 mi) of the OBH were used in the analysis. Fig. 3.37 presents these vessel sound levels as a function of distance from the recorder position.

Figure 3.36. *Mikkelsen Bay* spill response vessel.

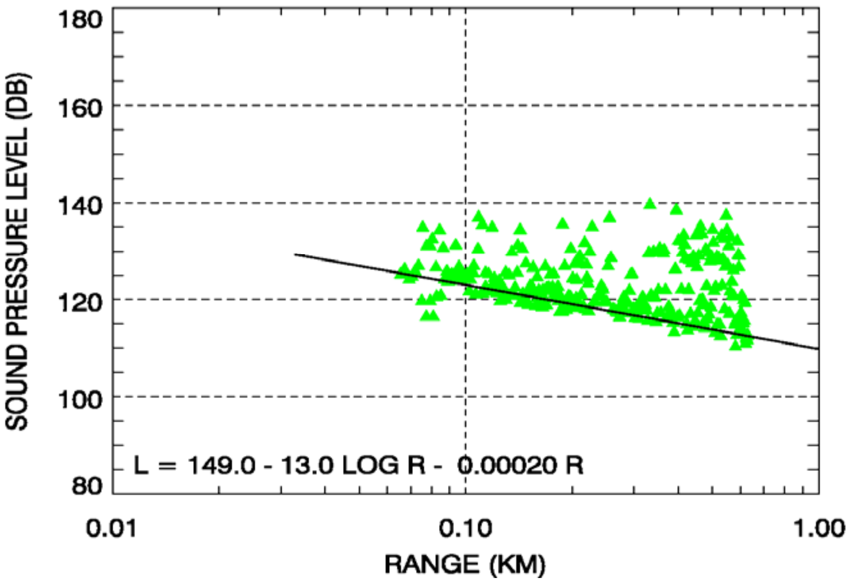

Figure 3.37. Vessel sound pressure levels (*rms*) for the *Mikkelsen Bay* at 10 km/h (5.5 kt). Distance conversion to miles: multiply km by 0.62 (e.g. 1 km equals 0.62 miles).

The nominal range at which sound levels reached 120 dB re µPa (*rms*) from the *Mikkelsen Bay* was 169 m based on the empirical fit shown in Fig. 3.37. This line is fit through the lower range of data variability to exclude noise produced by the surface tether.

## Sound Levels from Support Vessel *Jim Kilabuk* and *Norseman II* at Prudhoe Bay

The acoustic data recorded during the approach and departure of each vessel were analyzed to compute *rms* SPL in 1-second windows with 50% overlap during the periods the vessels were monitored. A 10-second wide median filter was applied to the data to smooth noise generated by the movement of the surface float attached to the OBH during these measurements. An empirical propagation loss curve of the form of equation (1) was fit to the range versus SPL data, using the method of least-squares. To ensure a precautionary estimate of the 120 dB re 1 µPa threshold range, the best-fit line was translated higher in level to encompass 90% of the SPL versus range data.

### *Jim Kilabuk*

Measurements of the *Jim Kilabuk* were performed on 2 Oct 2007 during the period 14:30 to 15:40 AKDT. The *Jim Kilabuk* (ref. Fig. 3.38) is an anchor handling support tug which is operated by Northern Transportation Company Ltd. (NTCL). A summary of the dimensions and propulsion system of this vessel are given Taable 3.24. The *Kilabuk's* nominal speed during the SSV measurement was 8.3 km/h (4.5 kt).

Figure 3.38. *Jim Kilabuk* operated by Northern Transportation Company Limited.

Fig. 3.39 presents the vessel sound levels for the *Kilabuk* as a function of distance from the OBH position, as well as the least-squares and 90% best-fit trend lines. This plot presents the levels received during both the approach and the departure of the vessel from the OBH position. The levels received during the departure were higher than the levels received during the approach. The nominal range to the threshold of 120 dB re 1 µPa (*rms*) for the *Jim Kilabuk* was estimated to be 1.48 km (0.92 mi), as computed from the 90% best-fit trend line shown in Fig. 3.39.

Table 3.24. Dimensions and propulsion specifications for the vessel *Jim Kilabuk.*

| Length | Beam | Draft | Engine | Propeller |
|---|---|---|---|---|
| 62.5 m (205 ft) | 14 m (45 ft) | 4.33 m (14.2 ft loaded) | 7200 HP | Twin props |

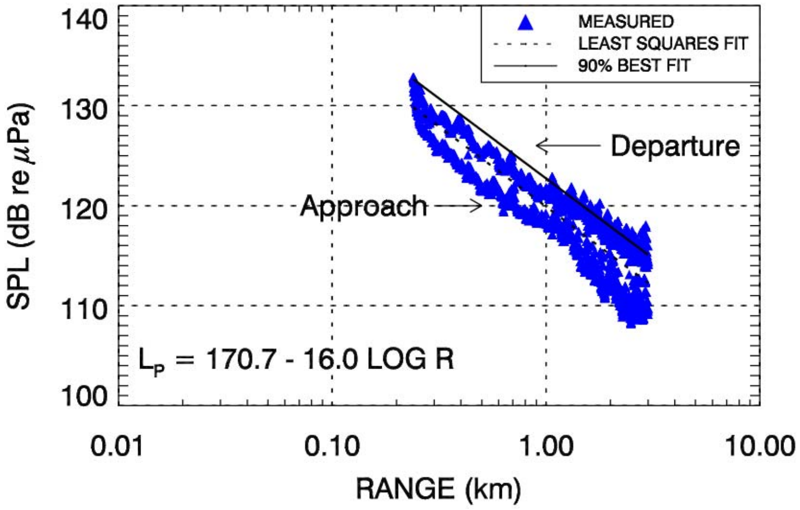

Figure 3.39. Sound pressure level (*rms*) versus range for support vessel *Jim Kilabuk* at 8.3 km/h (4.5 kt). The dashed line is the least-squares fit to trend of the SPL data and the solid line is the least-squares line shifted upwards to encompass 90% of the data. Distance conversion to miles: multiply km by 0.62 (e.g. 10 km equals 6.2 miles).

***Norseman II***

Masurements of *Norseman II* were obtained on 3 Oct 2007 between 17:45 and 18:55 AKDT near Prudhoe Bay. *Norseman II* (ref. Fig. 3.40) is a 35 m (115 ft) support vessel that is utilised in this survey for performing marine mammal observations. A summary of the dimensions and propulsion system of this vessel are given Table 3.25. The vessel was measured while transiting approximately 5 km (3.1 mi) to and from the OBH location at a nominal speed of 19 km/h (10 kt). This speed is representative of the speed at which it operates during survey work.

Figure 3.40. *Norseman II*

Fig. 3.24 presents sound levels from the *Norseman II* as a function of distance from the recorder position for both the approach and departure of the vessel from the OBH. This figure also shows the least-squares and 90% best-fit trend lines to the SPL versus range data beyond 200 m. In this case the levels received during the approach exceeded those received during the departure. The nominal range at which sound levels reached 120 dB re µPa (*rms*) for the *Norseman II* was estimated to be 0.60 km (0.37 mi), based on the shifted fit line to the data shown in Fig. 3.41.

Table 3.25. Dimensions and propulsion specifications for the vessel *Norseman II*.

| Length | Beam | Draft | Engine | Propeller |
|---|---|---|---|---|
| 35 m (115 ft) | 8.2 m (27 ft) | 4.0 m (13 ft) | 850 hp | single screw, 4 flukes |

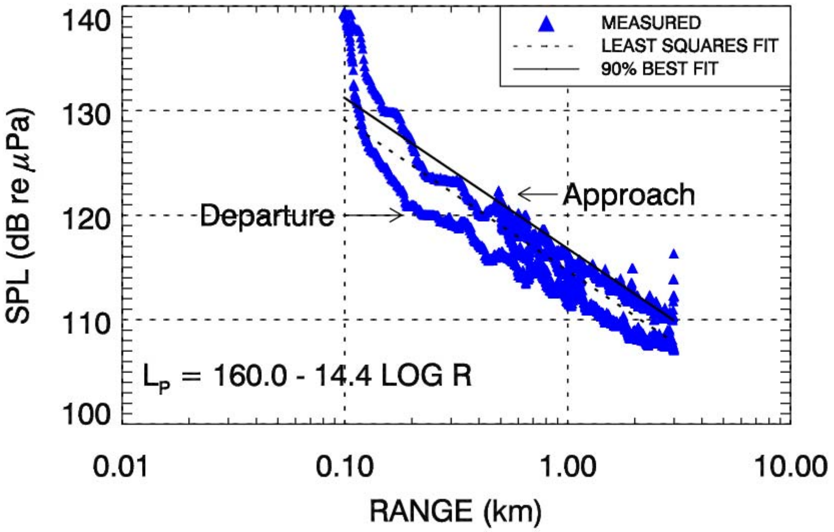

Figure 3.41. Vessel sound pressure levels (*rms*) for the *Norseman II* at 19 km/h (10 kt). The dashed line is the least-squares fit to trend of the SPL data and the solid line is the least-squares line shifted upwards to encompass 90% of the data. Distance conversion to miles: multiply km by 0.62 (e.g. 10 km equals 6.2 miles).

## *SUMMARY*

The sound source verification program for SOI's 2007 Seismic and Shallow Hazards Surveys provided high quality recordings of acoustic pressure waveforms from airgun arrays, mitigation guns, *sub-bottom* profilers, and vessels. Pressure data were analyzed to determine the distances to sound level thresholds that are required for the setting of exclusion or monitoring zones for marine mammals.

### *Broadband Levels for Seismic Survey Airgun Array in the Chukchi Sea*

The sound source verification study for the Chukchi Sea seismic survey program provided high quality recordings of acoustic pressure waveforms from seismic pulses generated by the main 3147 in$^3$ array source and a mitigation airgun. The pressure data were analyzed to determine the distances in the forward-endfire and broadside directions from the full array to sound level thresholds: 190, 180, 170, 160 and 120 dB re 1μPa (*rms*). Omnidirectional distances to the same thresholds from the mitigation airgun were also determined. The distances are given for both directions from the full array and from the mitigation gun inTable 3.26.

Table 3.26. Sound level threshold radii in meters for the airgun array and mitigation gun from seismic vessel *Gilavar* in the Chukchi Sea. See Appendix I Table I.26 for distances in feet and miles.

| *rms* SPL (dB re µPa) | | 190 | 180 | 170 | 160 | 120 |
|---|---|---|---|---|---|---|
| Airgun Endfire Range (m) | Flat Weighted (LF Cetaceans) | 450 | 1140 | 2900 | 7150 | 58400 |
| | Mid Frequency Cetaceans | 171 | 478 | 1304 | 3351 | 40002 |
| | High Frequency Cetaceans | 146 | 403 | 1091 | 2815 | 35390 |
| | Underwater Pinnipeds | 224 | 668 | 1893 | 1893 | 4834 |
| Airgun Broadside Range (m) | Flat Weighted (LF Cetaceans) | 545 | 2470 | 4500 | 8100 | 66000 |
| | Mid Frequency Cetaceans | 230 | 675 | 1933 | 5204 | 65236 |
| | High Frequency Cetaceans | 183 | 532 | 1519 | 4134 | 60063 |
| | Underwater Pinnipeds | 346 | 1027 | 2923 | 7591 | 73022 |
| Mitigation Gun Range (m) | Best Fit | <10* | <10* | 55* | 1121 | 36817 |
| | 90th Percentile | <10* | <10* | 76* | 1360 | 41100 |

* Extrapolated from minimum measurement range 80 m (260 ft).

Sound levels directly broadside the array were found to be 5-15 dB greater than just a few degrees off broadside the airgun array. The higher sound output directly at broadside produces larger broadside distances to all sound level thresholds than found at endfire but the effect is strongest in the near-field. The distances to 180 dB re 1µPa (*rms*) at broadside and forward-endfire were 2470 m (1.53 mi) and 1140 m (0.706 mi) respectively, whereas the distances to 120 dB re 1µPa (*rms*) were 66 km (41 mi) broadside and 58.4 km (36.3 mi) forward-endfire. The higher broadside sound levels were present only in a small angular zone perpendicular to the array tow direction as evidenced by the rapid increase then decrease observed at each monitored broadside range (ref. Fig. 3.16) as the array passed the intersection point of the survey track with the perpendicular line of OBH receivers. The mitigation airgun distances were smaller as expected; the maximum level measured was 169 dB at the minimum measurement range of 80 m (264 ft). A fit to *rms* level versus range data at ranges less than 1 km (0.62 mi) was used to extrapolate the 180 dB re 1µPa (*rms*) threshold range at less than 10 m (33 ft). The 160 dB re 1µPa (*rms*) range from the mitigation gun was 1360 m (0.843 mi) and the 120 dB re 1µPa (*rms*) was 41.1 km (25.5 mi).

### *Broadband Levels for Seismic Survey Airgun Array at Camden Bay*

The sound source verification study during the seismic survey program at SOI's Sivulliq prospect in Camden Bay provided high quality recordings of acoustic pressure signals from seismic sounds generated by the main 3147 in$^3$ array source to 58 km (36 mi) maximum range, and from the single 30 in$^3$ mitigation airgun to 50 km (31 mi) range. The full array pressure data were analyzed to determine the distances in the forward-endfire and broadside directions to sound level thresholds: 190, 180, 170, 160 and 120 dB re 1µPa (*rms*). These distances are given in Table 3.27.

Table 3.27. Sound level threshold radii in meters for the airgun array and mitigation gun from seismic vessel *Gilavar* in Camden Bay. See Appendix I Table I.27 for distances in feet and miles.

| *rms* SPL (dB re µPa) | | 190 | 180 | 170 | 160 | 120 |
|---|---|---|---|---|---|---|
| Airgun Endfire Range (m) | Flat Weighted (LF Cetaceans) | 757 | 2245 | 5986 | 13405 | 74813* |
| | Mid Frequency Cetaceans | 60 | 285 | 1291 | 4871 | 58886* |
| | High Frequency Cetaceans | 37 | 181 | 846 | 3435 | 52238 |
| | Underwater Pinnipeds | 176 | 768 | 2989 | 8980 | 67567* |
| Airgun Broadside Range (m) | Flat Weighted (LF Cetaceans) | 857 | 2088 | 4812 | 10084 | 61887 |
| | Mid Frequency Cetaceans | 519 | 1413 | 3599 | 8128 | 53147 |
| | High Frequency Cetaceans | 414 | 1157 | 3041 | 7107 | 50119 |
| | Underwater Pinnipeds | 711 | 1857 | 4517 | 9736 | 57952 |
| Mitigation Gun Range (m) | Best Fit | <10** | 15** | 365 | 1261 | 22911 |
| | 90th Percentile | <10** | 24** | 465 | 1439 | 24600 |

* Extrapolated from maximum measurement range of 58.7 km (36.5 mi).

** Extrapolated from minimum measurement range of 200 m (660 ft).

Marine mammal observers (MMOs) on board the *Gilavar* and its support vessels implemented exclusion zones during times of airgun array operation. This report has presented distances in the forward-endfire and broadside directions separately to several sound level thresholds. To be precautionary, the MMOs implemented the maximum distance for each sound level threshold of both directions. The following Table 3.28 summarizes these maxima:

Table 3.28. Maxima of broadside and forward-endfire direction flat-weighted sound level radii for the full 3147 in$^3$ airgun array in Camden Bay. See Appendix I Table I.28 for distances in feet and miles.

| *rms* SPL (dB re µPa) | Maximum distance (m) |
|---|---|
| 190 | 857 |
| 180 | 2245 |
| 170 | 5986 |
| 160 | 13405 |
| 120 | 74813* |

***Extrapolated from maximum measurement range of 58.7 km (36.5 mi).**

## *Airgun and Sub-bottom Profiler Measurements at Beechey Point*

The sound source verification for the SOI Shallow Hazards 2007 survey program provided high quality recordings of acoustic pressure waveforms from the various sources at different ranges, thus enabling the measurements of sound levels as a function of distance from the various sources. Data for the two airgun sources and the two profilers involved in the Shallow Hazards work have been analyzed to provide ranges to various levels specified by regulatory agencies, in particular the radii to 190, 180 and 160 dB *rms* were required for the setting of exclusion or disturbance zones for marine mammals. Table 3.29 shows the ranges for the small airgun array configurations and sub-bottom profilers.

Table 3.29. Sound level threshold radii in meters for airgun(s) and *sub-bottom* profilers from seismic vessel *Henry Chistofferson* at Beechey Point. See Appendix I Table I.29 for distances in feet and miles.

| *rms* SPL (dB re μPa) | | 190 | 180 | 170 | 160 | 120 |
|---|---|---|---|---|---|---|
| 2 × 10 in³ Airgun Array Range (m) | 90th Percentile | 12 | 51 | | 597 | 10700 |
| Single 10 in³ Airgun Range (m) | 90th Percentile | 5 | 20 | | 333 | 8130 |
| Bubble Pulser Range (m) | Best Fit | 5 | 20 | 76 | 283 | 946 |
| | 90th Percentile | 7 | 28 | 107 | 394 | 1252 |
| Chirp II Range (m) | Best Fit | 1 | 4 | 15 | 57 | 210 |
| | 90th Percentile | 1 | 5 | 18 | 71 | 260 |

### *Airgun Measurements from Seismic Vessel Henry Christofferson (Camden Bay)*

The sound source verification measurements for SOI’s Shallow Hazards 2007 survey at Sivulliq prospect off Camden Bay provided high quality recordings of underwater sounds from the 20 in$^3$ airgun array. The data were analyzed to compute ranges corresponding with sound levels reaching thresholds between 190 and 120 dB re 1 μPa (*rms*). Table 3.30 presents sound measurements as a function of distance from the small airgun array operating at this site.

Table 3.30. Sound level threshold radii in meters for airgun array from seismic vessel *Henry Christofferson* in Camden Bay. See Appendix I Table I.30 for distances in feet and miles.

| *rms* SPL (dB re μPa) | | 190 | 180 | 160 | 120 |
|---|---|---|---|---|---|
| 2 × 10 in³ Airgun Array Range (m) | 90th Percentile | 1* | 7* | 1000 | 25200 |

* Extrapolated from minimum measurement range of 200 m.

### *Vessel Measurements*

The vessels used in SOI’s 2007 Seismic Survey and Shallow Hazards programs were measured to determine the ranges to the 120 dB re 1 μPa (*rms*) sound level threshold when operating at typical working speeds. The measurements were performed using an anchored OBH recorder system.[5] Plots of sound level measurements versus distance were presented in the previous section. Empirical sound propagation loss curve fits to these data were used to estimate the ranges corresponding to sound levels reaching 120 dB re 1 μPa (*rms*). These ranges are given in below (Table 3.31).

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[5] The OBH systems used to measure sound level measurements of the *Maxime* and *Mikkelsen Bay* were deployed with a surface buoy instead of an acoustic release system for easy recovery in shallow waters.

Table 3.31. Sound threshold level radii in meters for 180-120 dB re µPa (*rms*) for the vessels used in SOI's 2007 Seismic Survey and Shallow Hazards programs. See Appendix I Table I.31 for distances in feet and miles.

| *rms* SPL (dB re µPa) | | 180 | 170 | 160 | 150 | 140 | 130 | 120 |
|---|---|---|---|---|---|---|---|---|
| *Henry C* in Beechey Point at 7.4 km/h (4 kt) Range (m)* | Best Fit | | 1 | 5 | 19 | 69 | 264 | 1079 |
| | 90th Percentile | | 2 | 6 | 22 | 84 | 319 | 1338 |
| *Henry C* in Beechey Point at 22 km/h (12 kt) Range (m) | Best Fit | 1 | 4 | 12 | 42 | 142 | 484 | 1670 |
| | 90th Percentile | 2 | 5 | 18 | 62 | 210 | 718 | 2499 |
| *Henry C* in Camden Bay at 6.7 km/h (3.6 kt) Range (m) | Best Fit | | | | | 22** | 191 | 1250 |
| | 90th Percentile | | | | | 27** | 230 | 1440 |
| *Gilavar* at 8.5 km/h (4.6 kt) in Camden Bay Range (m) | Best Fit | | | | 53† | 300† | 1500†† | 6300†† |
| *American Islander* at 14 km/h (7.8 kt) in Camden Bay Range (m) | Best Fit | | | | | 25††† | 130††† | 650 |
| *Gulf Provider* at 18 km/h (9.7 kt) in Camden Bay Range (m) | Best Fit | | | | | 34††† | 120 | 400 |
| *Maxime* at 12 km/h (6.5 kt) in Prudhoe Bay Range (m) | Best Fit | | | | | | 25 | 116 |
| *Mikkelsen Bay* at 10 km/h (5.5 kt) in Prudhoe Bay Range (m) | Best Fit | | | | | | | 169 |
| *Jim Kilabuk* at 8.3 km/h (4.5 kt) in Prudhoe Bay Range (m) | Best Fit | | | | | | 350 | 1475 |
| *Norseman II* at 19 km/h (10 kt) in Prudhoe Bay Range (m) | Best Fit | | | | | | 121 | 600 |

* The Chirp II profiler was operating during this pass due to miscommunication with the ship crew.

** Extrapolated from minimum measurement range of 200 m (660 ft).

† Extrapolated from minimum measurement range of 350 m (1155 ft).

†† These ranges may be overestimated due to inclusion of reverberation noise from simultaneous and nearby mitigation airgun shooting.

††† Extrapolated from minimum measurement range of 500 m (0.31 mi).

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Nedwell J. R., Turnpenny A. W. H. 1998. The use of a generic frequency weighting scale in estimating environmental effect. Proceedings of the Workshop on Seismics and Marine Mammals. 23-25th June 1998, London, UK.

# 4. MONITORING AND MITIGATION METHODS [6]

This chapter describes the marine mammal monitoring and mitigation measures implemented for SOI's seismic studies in the Chukchi and Beaufort seas and shallow hazards survey work in the Beaufort Sea, addressing the requirements specified in the IHAs (Appendices A and B). The section begins with a brief summary of the monitoring tasks relevant to mitigation for marine mammals. A summary of the mitigation measures required by NMFS and USFWS is then presented. The section ends with a description of the vessel-based and aerial survey monitoring and mitigation methods implemented for these surveys and a description of data analysis methods.

## *Monitoring Tasks*

The main purposes of the vessel-based monitoring program were to ensure that the provisions of the IHAs issued to SOI by NMFS and USFWS were satisfied, effects on marine mammals were minimized, and residual effects on animals were documented. Tasks specific to monitoring are listed below (also see Appendix A):

- Using dedicated Marine Mammal Observers (MMOs), to visually monitor the occurrence and behavior of marine mammals near the airguns when the airguns are operating and during a sample of the times when they are not.
- Visually monitor the occurrence and behavior of marine mammals near support vessels when underway.
- Use support vessels to conduct visual surveys of areas where airgun sounds could reach received levels of ≥160 dB re 1 μPa $_{\text{rms}}$.
- Record (insofar as possible) the effects of the airgun operations and the resulting sounds on marine mammals.
- Use the visual monitoring data as a basis for implementing the required mitigation measures.
- 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 are customarily defined as the distances within which received pulse levels are ≥180 dB re 1 μPa (rms) for cetaceans and ≥190 dB re 1 μPa (rms) for pinnipeds. The ≥180 dB and ≥190 dB guidelines were also employed by the USFWS for the species under its jurisdiction (walrus and polar bear, respectively) in its IHA issued to SOI. These safety criteria are based on an assumption that seismic pulses at lower received levels will not injure these animals or impair their hearing abilities, but that higher received levels *might* have some such effects. Marine mammals exposed to ≥160 dB (rms) are assumed by NMFS to be potentially subject to behavioral disturbance. However, for certain groups (dolphins, pinnipeds), available data indicate that disturbance is unlikely to occur unless received levels are higher, perhaps ≥170 dB rms for an average animal.

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[6] By D. Ireland, R. Rodrigues, and C. Lyons (LGL).

For the current seismic project there has also been concern that received pulse levels as low as 120 dB (rms) may have the potential to elicit a behavioral response from bowhead whales during the fall migration in the Beaufort Sea. In 2007, there was a requirement to implement special mitigation measures if specified numbers of bowhead cow/calf pairs (4) might be exposed to ≥120 dB rms during the fall in the Beaufort Sea or if large groups (≥12 individuals) of bowhead or gray whales might be exposed to ≥160 dB rms (NFMS IHA). Monitoring of the 160 and 120 dB zones at specified times and locations, which was required in the IHA issued by NMFS, is discussed below in the section on *Special Mitigation Measures*.

### Chukchi Sea—Gilavar

SOI's IHA applications described the anticipated underwater sound field around the planned 3147 $in^3$ airgun array with guns at a depth of 6 m (20 ft) based on 2006 sound source measurements by Greenridge Sciences, Inc. in the Chukchi Sea (Patterson et al. 2007). Field measurements of the received airgun sounds as a function of distance and aspect were acquired again in 2007 prior to the beginning of seismic data acquisition (Mouy et al. 2007). During the 2007 field measurements the measured 2006 safety radii distances were used for mitigation purposes. The 2007 measured radii were similar to, but in most cases slightly greater than the 2006 measured radii (Table 4.1). The empirical measurements of the 180 and 190 dB rms radii, as presented by Mouy et al. (2007), were adopted as safety radii for the Chukchi Sea survey (Table 4.1).

More extensive analysis of the field measurements was completed after the field season, as described in Chapter 3. Those analyses resulted in some refinements of the various radii (Tables 4.1-3). The refined values were not available for use by the MMOs in the field. However, the refined estimates have been used in Chapter 5 to estimate the numbers of marine mammals exposed to various sound levels.

Airguns operating underwater do not produce strong sounds in air. Accordingly, no shut downs or power downs were implemented for marine mammals hauled out on ice. (In any case, none of the sightings of marine mammals on the ice occurred during periods of airgun operation.)

### Beaufort Sea—Gilavar

Seismic surveys in the Beaufort Sea were not performed by the *Gilavar* in 2006 and therefore no measurements of the 3147 $in^3$ seismic array within the Beaufort Sea were made. However, 2006 modeling results by JASCO Research Ltd. (JASCO) of the same airgun array in the Beaufort Sea were available. The radii predicted by JASCO (Table 4.2) were based on the worst case model predictions. However, results of the 2007 Chukchi Sea sound source measurements were larger than the Beaufort Sea model results from the previous year, so the 2007 Chukchi Sea results were used by MMOs in the Beaufort Sea until results of the 2007 Beaufort Sea sound source measurements were released.

The results of the 2007 sound source measurements are presented in Laurinolli et al. (2007a) and summarized in Table 4.2. The distances reported were larger than the model predicted and larger than the 2007 Chukchi Sea results (Table 4.1).

TABLE 4.1. Comparison of various predictions and measurements of the ≥190, 180, 170, 160 and 120 dB rms distances (in km) for sound pulses from the 24-gun, 3147 in$^3$ airgun array deployed from M/V *Gilavar* in the Chukchi Sea, Alaska, 2007.

| | Full Airgun Array (3147 in$^3$) | | | Mitigation Gun (30 in$^3$) | |
|---|---|---|---|---|---|
| Received Level (dB rms ) | Radii based on 2006 measurement results | Preliminary Measured Radii (Mouy 2007) | Final Measured Radii (Chapter 3) | Preliminary Radii used by MMOs | Final Measured Radii (Chapter 3) |
| ≥190 | 0.500[a] | 0.545 | 0.550 | 0.05 | 0.010 |
| ≥180 | 1.200[a] | 2.470 | 2.470 | 0.01 | 0.024 |
| ≥170 | 4.720 | 4.500 | 4.500 | - | 0.076 |
| ≥160 | 7.990 | 8.100 | 8.100 | - | 1.360 |
| ≥120 | 82.890 | 66.000 | 66.000 | - | 41.100 |

[a] Specified in the NMFS IHA but not consistent with refined estimates presented in Patterson et al. (2007)

TABLE 4.2. Comparison of various predictions and measurements of the ≥190, 180, 170, 160 and 120 dB rms distances (in km) for sound pulses from the 24-gun, 3147 in$^3$ airgun array deployed from M/V *Gilavar* in the Beaufort Sea, Alaska, 2007.

| | Full Airgun Array (3147 in$^3$) | | | Mitigation Gun (30 in$^3$) | |
|---|---|---|---|---|---|
| Received Level (dB rms ) | Radii based on 2006 Modelling | Preliminary Measured Radii (Laurinolli et al. 2007a) | Final Measured Radii (Chapter 3) | Preliminary Measured Radii (Laurinolli et al. 2007a) | Final Measured Radii (Chapter 3) |
| ≥190 | 0.36 | 0.857 | 0.860 | 0.062 | 0.010 |
| ≥180 | 1.03 | 2.245 | 2.250 | 0.177 | 0.024 |
| ≥170 | 2.64 | 5.986 | 5.990 | 0.499 | 0.465 |
| ≥160 | 5.55 | 13.405 | 13.410 | 1.370 | 1.430 |
| ≥120 | 67.95 | 74.813 | 75.000 | 26.657 | 24.600 |

### *Beaufort Sea—Henry Christoffersen*

Sound levels produced by the 2 x 10 in$^3$ airguns deployed from the *Henry Christoffersen* (*Henry C.*) were modeled by JASCO prior to the 2007 season as this equipment differed from that used in 2006 (Table 4.3). The modeled radii were multiplied by a safety margin of 1.5× to obtain initial protective marine mammal safety radii (based on the 190 and 180 dB rms criteria) for use by MMOs until results of the sound source measurements were released.

Measurements of sounds levels as a function of distance from the source were made at two different locations in the Beaufort Sea in 2007. The first measurements were made offshore of Beechey Point near the east end of Harrison Bay on 30 Aug 2007 (Laurinolli et al. 2007b). The second set of measurements was made in Camden Bay on 14 Sep 2007 (Laurinolli et al. 2007c). Tables 4.3 and 4.4 show the preliminary and final results of analyses of those data (from Laurinolli et al. 2007b,c and Chapter 3, respectively). Measured ≥190, 180, 170 and 160 dB (rms) distances were greater than corresponding predicted distances. The results of the ≥190 and ≥180 dB (rms) radii reported in Laurinolli et al. (2007b,c) were applied as the safety radii during seismic operations; the final values were used for the analyses in Chapter 5.

TABLE 4.3. Comparison of various predictions and measurements of the ≥190, 180, 170, 160 and 120 dB rms distances (in km) for sound pulses from the 2-airgun (20 $in^3$) cluster deployed from M/V *Henry Christoffersen* at the Phoenix prospect near Beechey Point, Alaskan Beaufort Sea, 2007.

| | | West Beaufort (Beechey Point) | | East Beaufort (Camden Bay) | |
|---|---|---|---|---|---|
| Received Level (dB rms ) | Radii based on 2007 modelling | Preliminary Measured Radii (Laurinolli et al. 2007b) | Final Measured Radii (Chapter 3) | Preliminary Measured Radii (Laurinolli et al. 2007c) | Final Measured Radii (Chapter 3) |
| ≥190 | 0.036 | 0.057 | 0.012 | 0.035 | 0.012 |
| ≥180 | 0.124 | 0.142 | 0.051 | 0.103 | 0.051 |
| ≥170 | 0.313 | 0.347 | - | 0.303 | - |
| ≥160 | 0.776 | 0.821 | 0.597 | 0.878 | 1.000 |
| ≥120 | 13.808 | 10.048 | 10.700 | 23.700 | 25.200 |

TABLE 4.4. Comparison of various predictions and measurements of the ≥190, 180, 170, 160 and 120 dB rms distances (in km) for sound pulses from the 2-airgun (20 $in^3$) cluster deployed from M/V *Henry Christoffersen* at the Sivulliq prospect in Camden Bay, Alaskan Beaufort Sea, 2007. The single airgun was not measured at this location.

| | | East Beaufort (Camden Bay) | | | |
|---|---|---|---|---|---|
| | | 2-airgun array (20 $in^3$) | | 1-airgun (10 $in^3$) | |
| Received Level (dB rms ) | Radii based on 2007 modelling | Preliminary Measured Radii (Laurinolli et al. 2007c) | Final Measured Radii (Chapter 3) | Preliminary Measured Radii (Laurinolli et al. 2007c) | Final Measured Radii (Chapter 3) |
| ≥190 | 0.036 | 0.035 | 0.012 | - | - |
| ≥180 | 0.124 | 0.103 | 0.051 | - | - |
| ≥170 | 0.313 | 0.303 | - | - | - |
| ≥160 | 0.776 | 0.878 | 1.000 | - | - |
| ≥120 | 13.808 | 23.700 | 25.200 | - | - |

## *Mitigation Measures as Implemented*

The primary mitigation measures that were implemented during the seismic activities in the Chukchi and Beaufort seas included ramp up, power down, and shut down of the airguns. These measures are standard procedures during seismic cruises and are described in detail in Appendix E. Mitigation also included those measures specifically identified in the IHAs (Appendices A and B) as indicated below.

### *Standard Mitigation Measures*

Standard mitigation measures implemented during the study included the following:

1. Safety radii implemented for the seismic activities were determined based on the preliminary results of the empirical sound measurement studies reported by JASCO (Muoy 2007, Laurinolli et al. 2007a,b,c; Tables 4.1-3).
2. 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.
3. A change in vessel course and/or speed alteration was identified as a potential mitigation measure 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 practice,

this measure was not implemented because the *Gilavar* is unable to maneuver quickly while towing the airguns and streamers. The *Henry C.* did not encounter a marine mammal in such a way as to make a maneuver necessary.

4. A ramp up procedure was implemented whenever operation of the airguns was initiated if >10 min had elapsed since shut down of the full array airguns.
5. In order for seismic operations to start up, the full applicable safety radius must have been visible for at least 30 min.

The specific procedures applied during power downs, shut downs, and ramp ups are described in Appendix E. Briefly, a ***power down*** as implemented aboard the *Gilavar* involved reducing the number of operating airguns from the full array of 24 airguns to a single airgun, “mitigation gun”, when a marine mammal was observed approaching or was seen within the full array safety radius. Power down also occurred when the *Gilavar* was between seismic survey lines to reduce the area of ensonification. Identical procedures were used aboard the *Henry C.* with the 2 airgun cluster dropping to a single active airgun. A ***shut down*** involved suspending operation of all airguns. A shut down was implemented if a marine mammal was sighted within or approaching the mitigation gun safety radius either after the full array had been powered down or upon initial observation. A ***ramp up*** involved a gradual increase in the number of airguns operating (from no airguns firing) usually accomplished by an additional airgun being added to the operating array once each minute. In this report, when a ramp up was initiated while the mitigation airgun had been firing it is referred to as a ***power up***. A ramp up, also called a “cold-start” can not be initiated during times when the full safety radii are not visible to MMOs for 30 minutes because the mitigation gun was not firing. A power up can be initiated during times when the full safety radius is not visible because the mitigation gun has been firing.

### *Special Mitigation Measures as Required by NMFS*

In addition to the standard safety radii based on the ≥190 and ≥180 dB (rms) distances for pinnipeds and cetaceans, respectively, NMFS (in the IHA) required SOI to monitor the 160 dB radius for aggregations of 12 or more non-migratory bowhead or gray whales during all seismic activities. Also, SOI was required to monitor the 120 dB radius in the Beaufort Sea with aerial surveys biweekly through 31 Aug. and daily after 1 Sept. during periods when seismic surveys were occurring, weather permitting.

Depending on the results of the monitoring of the ≥160 dB or ≥120 dB zones, special mitigation measures were to be implemented:

1. Power down or shut down procedures were to be implemented if groups of 12 or more bowhead or gray whales were within the ≥160 dB (rms) radius while the airguns were in operation.
2. Power down or shut down procedures were to be implemented if 4 or more bowhead cow/calf pairs were within the ≥120 dB (rms) radius in the Beaufort Sea.

During monitoring of the ≥160 dB zone the chase/monitoring boat followed a zig-zag pattern ahead and to the sides of the planned seismic survey lines. MMOs onboard the chase/monitoring boat searched the area ahead of the *Gilavar* within the ≥160 dB zone for marine mammals. Mitigation (i.e., power down or shut down of the airgun array) was to be implemented if a group of 12 or more bowhead or gray whales entered the ≥160 dB zone. However, no large groups of baleen whales were observed within the ≥160 dB zone and no power downs or shut downs were necessary to meet this IHA requirement.

The ≥120 dB radius was estimated to extend as much as ~75 km from the *Gilavar*. Monitoring of the ≥120 dB zone was required at specified times in late summer and autumn in the Beaufort Sea due to concerns that seismic noise might disturb bowhead whales, particularly migrating cow/calf pairs, within the ≥120 dB radius. The IHA required that seismic operations be shut down if 4 or more bowhead cow/calf pairs were seen within the 120 dB radius during the aerial monitoring. In the Beaufort Sea, aerial surveys began on 22 Aug, and continued daily, weather permitting, until seismic surveys in the Beaufort Sea ended on 3 Oct.

## *Visual Monitoring Methods*

### *Vessel-Based Monitoring—Chukchi and Beaufort Seas*

Visual monitoring methods were designed to meet the requirements identified in the IHAs (see above and Appendices A and B). The primary purposes of MMOs aboard the seismic, shallow hazards, and support vessels 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 re μPa (rms), or of other pinnipeds and polar bears to ≥190 dB. ***(2)*** Conduct monitoring and implement mitigation measures to avoid or minimize exposure of groups of 12 or more bowhead or gray whales to airgun sounds with received levels ≥160 dB. ***(3)*** 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 the monitoring effort are presented in Chapter 5.

The visual monitoring methods that were implemented during SOI's seismic exploration were very 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 E.

In summary, during the seismic and shallow-hazards surveys in the Chukchi and Beaufort Seas, at least one MMO onboard the source vessel (*Gilavar* or *Henry C.*) maintained a visual watch for marine mammals during all daylight hours while seismic or shallow-hazards surveys were underway. Observers focused their search effort forward and to the sides of the vessel but also searched aft of the vessel occasionally while it was underway. Watches were conducted with the naked eye, Fujinon 7 × 50 reticle binoculars, and Zeiss 20 × 60 image stabilized binoculars. MMOs instructed seismic operators to power down or shut down the airguns if marine mammals were sighted near or about to enter the appropriate safety radii.

MMOs onboard the chase/monitoring boats conducted watches similar to those of MMOs onboard the *Gilavar* and *Henry C*. Various vessels were used as chase/monitoring boats for the *Gilavar* and the days on which they were acting as a chase/monitoring boat are shown in Figure 4.1. MMOs onboard the chase/monitoring boats were prepared to notify MMOs onboard the *Gilavar* if groups of bowheads or gray whales (or bowhead cow/calf pairs) were sighted within the 160 dB radius, allowing the *Gilavar* to implement the appropriate mitigation. Because the size of the ≥180 dB safety radius around the *Gilavar* (2.47 km (1.5 mi) in the Chukchi Sea and 2.25 km (1.4 mi) in the Beaufort Sea) is near the limit within which MMOs can reliably detect marine mammals, SOI voluntarily implemented a protocol that used two chase/monitoring vessels to help monitor the ≥180 dB safety zone. Thus, during most seismic operations from the *Gilavar* at least one chase/monitoring boat (or two if the ≥160 dB zone clearance was not currently underway) traveled approximately 1 km (0.6 mi) ahead of and 1 km to either side of the *Gilavar's* trackline. MMOs aboard the chase/monitoring boats conducting this monitoring called the *Gilavar* MMOs if they observed marine mammals within the *Gilavar's* applicable safety radii. MMOs aboard the *Gilavar* then initiated any necessary mitigation measures.

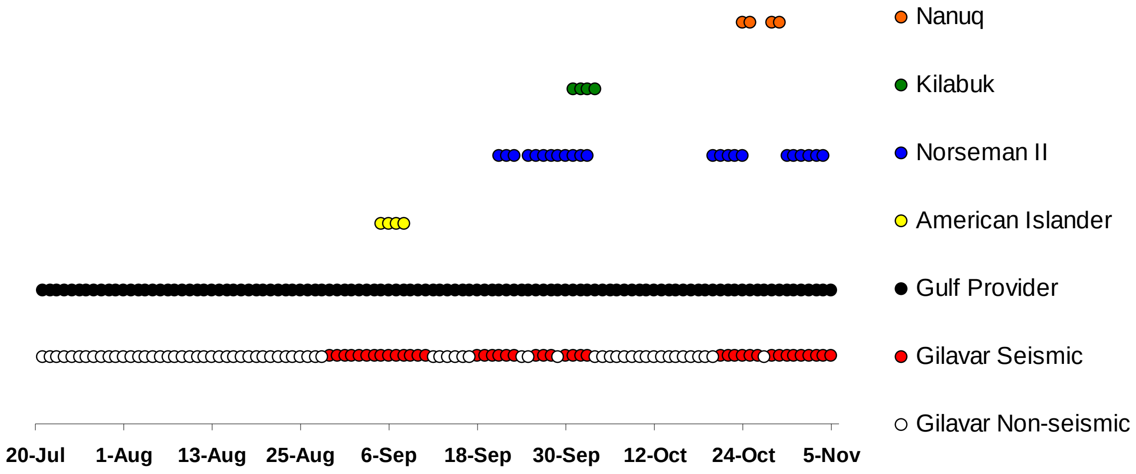

FIGURE 4.1. Dates during which various vessels acted as a chase/monitoring boat for the *Gilavar* during the 2007 season.

## *Aerial Surveys—Beaufort Sea*

An aerial survey program was conducted in support of the seismic program in the Beaufort Sea during 2007. The objectives of the aerial survey were

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

Fall surveys (late Aug to Oct) were planned to obtain detailed data (weather permitting) on the occurrence, distribution, and movements of marine mammals, particularly bowhead whales, within about 50 km (30 mi) to the east and 70 km (45 mi) to the west of the primary seismic vessel, and to monitor the 120 dB radius for bowhead whales prior to seismic activities.

SOI's seismic source vessel, the *Gilavar*, conducted seismic operations in the Chukchi Sea until 10 Sep. On 12 Sep it transited to the Beaufort Sea to continue seismic acquisition within specific lease holdings. The *Henry C.* entered the Beaufort Sea in mid-Aug and was planning to conduct Shallow Hazards surveys near Oliktock Point in late Aug.

Aerial surveys began on 22 Aug covering the area around the *Henry C.'s* planned operations. The *Henry C.* completed sound measurements of the shallow hazards airgun array on 30 Aug but was unable to complete any additional work in that area due to poor weather conditions. After 4 Sep aerial surveys were moved to cover the Camden Bay area where the *Henry C.* completed a small amount of shallow hazards surveys before the *Gilavar* began full array seismic acquisition later in Sept. The final aerial survey was completed on 8 Oct when the *Gilavar* departed the Beaufort Sea. Poor weather did not allow any surveys in the period following the departure of the *Gilavar*.

During the aerial surveys two primary observers were seated at bubble windows on opposite sides of the aircraft. The two primary observers searched the water visible through the bubble windows with the unaided eye concentrating on the area within 1 km (0.6 mi) of the aircraft. When a marine mammal was sighted, the observers dictated into a digital recorder the species, number of individuals, size/sex/and age class when determinable, activity, heading, swimming speed category (if traveling), sighting cue, ice conditions (type and percentage), and inclinometer reading. The inclinometer reading was recorded when the animal's location was 90° to the side of the aircraft track, allowing calculation of lateral distance from the aircraft trackline. In addition, each observer recorded the time, sightability (subjectively classified as excellent, good, moderately impaired, seriously impaired or impossible), sea state (Beaufort wind force), ice cover (in 10ths) and sun glare (none, little, moderate, or severe) at 2-min intervals along the transect, and at the end of each transect. This provided data in units suitable for statistical summaries and analyses of effects of these variables (and position relative to seismic vessel) on the probability of detecting animals (see Davis et al. 1982; Miller et al. 1999; Thomas et al. 2002).

A third observer's primary duty was to enter data into a laptop computer although this observer also searched for marine mammals during periods when data entry was not necessary. Transect information, sighting locations, and environmental data were entered into a GPS-linked laptop computer by the third observer, and simultaneously recorded on digital recorders for backup and validation. At the start of each transect, a designated primary observer recorded the transect start time and position, ceiling height (ft), cloud cover (in 10ths), wind speed (knots), wind direction (°T) and outside air temperature (°C). The laptop computer used Garmin Mapsource (ver 6.9) position logging software. Mapsource automatically stored the time and aircraft position at pre-selected intervals (typically at 2 sec for straight-line transect surveys) to a file as they were obtained. The observer operating the computer recorded a waypoint at the start and end of each transect, at 2-min intervals along the transect line coinciding with the environmental data collected by the primary observers, and when a marine mammal was sighted by any of the observers.

## *Analyses*

### *Vessel-Based Surveys*

***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 (e.g., Holst et al. 2005a,b; Ireland et al. 2005; Ireland et al. 2007a,b; Patterson et al. 2007). These categories are defined briefly below, with a more detailed description provided in Appendix E.

Data were categorized by the geographic region and time period in which they were collected (Figure 4.2). Only sightings and effort from vessel activities north of Point Hope (68.34 °N) were included in the Chukchi Sea section with the "summer" period from 21 Jul to 12 Sep and the "fall" period from 8 Oct. to 5 Nov. The Beaufort Sea section included data from vessels operating east of Pt. Barrow (156.45 °W) to the Canadian border (141 °W) from 26 Aug to 8 Oct.

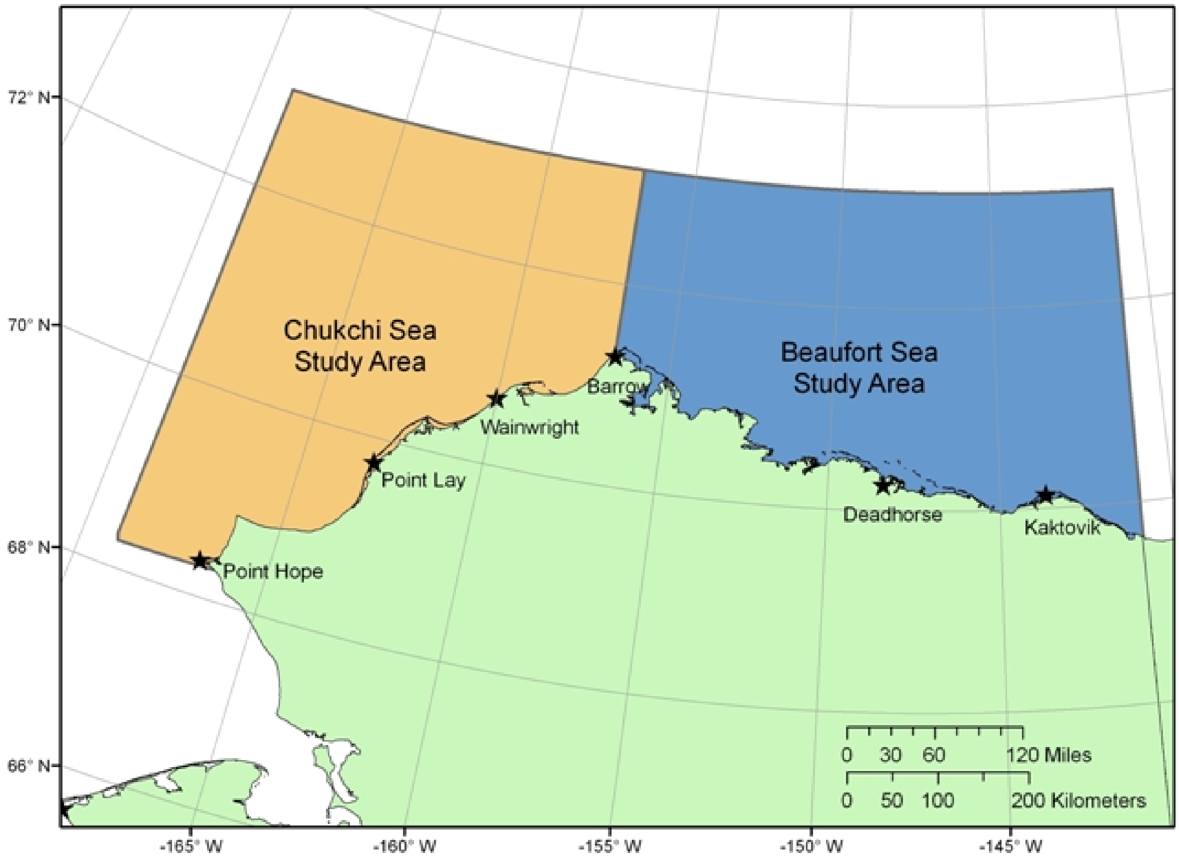

Figure 4.2. The Chukchi Sea and Beaufort Sea study area boundaries used to categorize data for analysis and presentation in Chapter 5 are shown.

Data were categorized as "useable" or "non-useable" for purposes of comparison and for the calculation of densities. Effort and sightings were defined as "useable" when made under the following conditions: daylight periods excluding

- periods 3 min to 1 h for pinnipeds and polar bears, or 2 h for cetaceans, after the airguns were turned off (post-seismic), or
- when ship speed was <3.7 km/h (2 kt), or
- periods with seriously impaired sightability. (This included all nighttime observations, and daytime periods with one or more of the following: visibility <3.5 km or 2.2 mi, Beaufort wind force (Bf) >5 (Bf >2 for minke whales, belugas, and porpoises), or >60º of severe glare between 90º left and 90º right of the bow.)

The amount of useable data available from the 2007 season using this standard definition was limited. For example, the effort deemed useable according to the above criteria would be only 22% of the total daylight observation effort (km) for the *Gilavar* and 43% of the total daylight observation effort (km) for the chase/monitoring vessels for the summer Chukchi Sea survey (Fig 4.3). In order to have larger sample sizes for comparison in this report we chose to summarize data from all daylight observations, regardless of the environmental conditions. Comparisons among data collected under the same conditions are reasonable, but results presented in the following chapter should be interpreted with the understanding that some effort and sightings occurred during sub-optimal conditions.

In general, data were categorized as "seismic", "non-seismic", or "post-seismic". Seismic included all data collected from the source vessel (*Gilavar* or *Henry C.*) while the airguns were operating. Non-seismic included all data obtained before the airguns were activated (pre-seismic) or >1 or >2 h (for pinnipeds/polar bears and cetaceans, respectively) after all airguns were deactivated. Post-seismic periods were from 3 min to 1 h (for pinnipeds and polar bears) or 2 h (for cetaceans) after cessation of seismic activity and were excluded from most analyses. Thus, the post-seismic data (3 min to 1 or 2 h after cessation of seismic activity) were not included in either the seismic or non-seismic categories. The 3 min cutpoint was considered appropriate because of the relatively slow vessel speed during seismic operations (~4 kt or 7.4 km/h, average). The 1 and 2 h cutoff periods correspond to the time required to transit to an area in which the received sound level would not be likely to have much (if any) effect on the distributions of pinnipeds/polar bears and cetaceans, respectively. The chosen sound levels were comparable to those used in other recent seismic cruises (Holst et al. 2005a,b; Ireland et al. 2005; Ireland et al. 2007a,b; Patterson et al. 2007). Observation effort from chase/monitoring vessels was considered seismic if the vessel was within 15 km (for cetaceans) or 5 km (for pinnipeds and polar bears) of the *Gilavar* while the guns were firing. The post seismic period for chase/monitoring vessel data was defined as 3 min to 1 h (for pinnipeds and polar bears) or 2 h (for cetaceans) after all seismic activity concluded or the vessel moved beyond 5 km (for pinnipeds and polar bears) or 15 km (for cetaceans) from the activity seismic array.

This categorization system was designed primarily to distinguish potential differences in behavior and distribution of marine mammals with and without seismic surveys. 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) and is discussed in Appendix E.

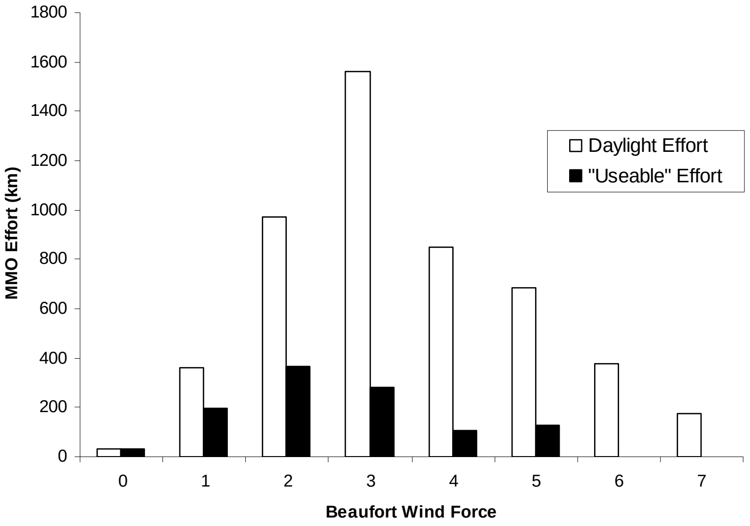

FIGURE 4.3. Daylight marine mammal observer effort from the *Gilavar* vs. "useable" observer effort (by 2006 standards for cetaceans) in the Chukchi Sea study area by Beaufort wind force, summer 2007.

The "post-seismic" category of sightings was excluded when seismic vs. non-seismic sightings were compared. The different definitions of the post-seismic period for cetaceans (3 min to 2 h) and pinnipeds/polar bears (3 min to 1 h) results in different amount of observer effort being categorized as post-seismic. For simplicity, in the results presented in Chapter 5 the longer period for cetaceans was used to define the post-seismic period of all effort analyses

Various factors including high sea conditions, poor visibility, and MMO experience can make marine mammal identification difficult, and both cetaceans and pinnipeds could not always be identified to species. Differentiating ringed from spotted seals was especially difficult and these two species were lumped into one category for analysis purposes. Most of the seals in this category were likely ringed seals given the known densities of these two species in the Chukchi and Beaufort seas.

***Line Transect Estimation of Densities.***—Marine mammal sightings during the "seismic" and "non-seismic" periods were used to calculate sighting rates (#/km). Sighting rates were then used to calculate the corresponding densities (#/km$^2$) of marine mammals near the survey and chase/monitoring vessels during seismic and non-seismic periods. Density calculations were based on line-transect principles (Buckland et al. 2001). Because of assumptions associated with line-transect surveys [sightability, $f(0)$, $g(0)$, etc.], it is most appropriate to use only "useable" effort and sightings for density calculations. However, because the amount of useable data available from the 2007 season was limited and often insufficient to support calculation of densities, densities were calculated from all daylight effort and sightings as well as the available useable data. Use of effort during sub-optimal sighting conditions included in the all daylight effort data to calculate densities would be expected to bias density estimates downward. The relatively small difference in cetacean densities calculated from useable and daylight effort reported in Chapter 5 is consistent with this assumption. However, seal densities estimated from daylight effort were actually greater than those estimated from useable effort suggesting that the useability criteria described above may be more appropriate for cetaceans than for seals.

When calculating sighting rates and densities in non-seismic periods (for comparison with those in seismic periods), only the observations in the Chukchi and Beaufort seas were considered, i.e., observations during transit through the Bering Sea were excluded. Pinnipeds hauled out on the ice were encountered in both the Beaufort and Chukchi seas; these sightings were considered "useable" for analyses.

Correction factors for missed animals, i.e., $f(0)$, were calculated from data collected during this study where possible. Other correction factors were taken from other related studies, as summarized by Koski et al. (1998) and Barlow (1999). This was necessary because of the low number of sightings of some species, making estimation of $f(0)$ from project specific data problematic, and because of the inability to assess trackline sighting probability, $g(0)$, during a study of this type.

Densities estimated from non-seismic observations were used to estimate the numbers of animals that presumably would have been present in the absence of seismic activities. Densities during non-seismic periods were used to estimate the numbers of animals present near the seismic operation and exposed to various sound levels. 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. However, in the case of the *Henry C.*, because of the very limited duration of airgun operations during this study, the reported densities during seismic periods are not reliable indicators of actual densities during seismic operations. Thus, a comparison of densities observed from the *Henry C.* during seismic and non-seismic periods is not a valid method for estimating changes in distribution or behavior during this study. Further details on the line transect methodology used during the survey are provided in Appendix E.

***Estimating Numbers Potentially Affected***.—For purposes of the IHA, NMFS assumes that any marine mammal that might have been exposed to airgun pulses with received sound levels ≥160 dB re 1 µPa (rms) may have been disturbed. When calculating the number of mammals potentially affected, we used the measured 160 dB radii (Tables 4.1-4).

Two calculations were made to estimate the numbers of marine mammals that may have been potentially exposed to sound levels ≥160 dB re 1 µPa (rms):

1. Estimates of the number of *individual* mammals exposed (one or more times), and
2. Estimates of the average numbers of potential *exposures per individual*.

The first calculation involved multiplying the area assumed to be ensonified to ≥160 dB by the densities of marine mammals estimated from this study. The second calculated the average number of times a given area of water within the seismic survey patch was ensonified to ≥160 dB. Thus, animals that remained in areas of water ensonified on more than one occasion, due to overlapping or adjacent tracklines, may have been exposed on multiple occasions.

During the *Gilavar* surveys, many of the tracklines were in close proximity to one another in comparison to the ≥160 dB distance, leading to much overlap of the areas ensonified to ≥160 dB during transits along the various tracklines. This leads to a relatively high estimate of the number of exposures per individual. The *Henry C.* surveys had very little overlap of ensonified areas causing the estimated exposures per individual to be quite low.

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., Holst et al. 2005a,b; Ireland et al. 2005; Ireland et al. 2007a,b; Patterson et al. 2007).

### Aerial Surveys

***Useable data.—***Environmental conditions such as sea state and glare can impact an observer's ability to see marine mammals during aerial surveys and hence bias results. To minimize bias, environmental data were used to classify sightings data as useable or nonuseable. Sightings were considered useable when the following criteria were met: Beaufort wind force of 4 (winds 11-16kts) or less, glare covering 30% or less of the viewing field and overall sightability described as excellent to moderately impaired.

***Seismic State.—***Seismic activities when each aerial survey was flown were determined from data compiled by the marine mammal observers on the seismic source vessels. In order to assess the impact of seismic activity on sighting rates, data were grouped into bins corresponding to the seismic state at time of sighting. Sightings made while guns were active (including periods of ramp-up and mitigation gun firing) and up to three minutes after shut down were considered "seismic". Sightings made from three minutes to 24 hours after shut down were considered "post-seismic". All other times were considered "nonseismic". The post-seismic category represents the refractory period during which mammals impacted by seismic activities return to normal behavior and hence is analyzed separately. The slow speeds at which bowheads usually travel make 24 hours an appropriate span of time to allot for return to normalcy.

***Mapping.—***All useable sightings made during aerial surveys were mapped and color coded to indicate seismic state at the time of sighting. Green symbols indicate non-seismic sightings, yellow symbols indicate seismic sightings and black symbols indicate post-seismic sightings. Each symbol represents one sighting, regardless of the number of individuals recorded during that sighting.

***Spatial differences.—***Differences in both offshore and west-to-east distribution of marine mammals relative to seismic activity were of interest. In order to assess offshore movement of bowheads, sightings were binned into 5-km distance bands, with the "0-km from shore" line consisting of a rough arc along the barrier islands. Sighting rates were then compared amongst bands to determine if any shifts could be seen relative to seismic activity. To assess changes in west-to-east distribution, the survey area was divided into three sub-areas: west, central and east. The central area contained the active seismic patch and extended from approximately 150°26'W to 149°19'W for the Phoenix prospect and 146°24'W to 144° 27'W for the Sivulliq prospect. The west and east areas were considered anything within the survey area to the west and east, respectively, of the central area.

***Distribution Relative to Center of Seismic Patch.—***Both the Phoenix and Sivulliq prospects were plotted using ArcView software and the geographical center of each was estimated utilizing the measure tool. Sightings were then plotted as well and distances from the center point of each seismic patch determined for each using the measure tool. Data were next sorted by date and time and the distance for the then-current seismic patch selected and the other distance value discarded.

***Determination of Estimated Take by Harassment.—***Aerial survey densities used to estimate takes by harassment were calculated using DISTANCE software (Thomas et al., 2006). Densities were calculated for each survey individually and then a weighted average taken for surveys flown during a contiguous stretch of seismic activity was used to calculate takes during that contiguous period.

### *Determination of Estimated Take by Harassment*

***160 dB Criteria***.—NMFS practice in situations with intermittent impulsive sounds like seismic has been to assume that "take by harassment" (Level B) may occur if baleen whales are exposed to received levels of sounds exceeding 160 dB re 1 μPa rms (NMFS 2005b, 2006b). The reaction threshold for most toothed whales is unknown but presumably higher because of their poorer hearing sensitivity at low frequencies (NMFS 2005b; NMFS 2006b; Richardson et al. 1995; Richardson and Würsig 1997). However, the limited empirical data for beluga whales indicate that they may be relatively responsive to airgun sounds as compared with other toothed whales (Miller et al. 2005).

When calculating the number of cetaceans potentially affected, we used the nominal 160 dB (or 180 dB) distances for the situation in which the survey took place (Tables 4.1-3). As described above, two approaches were applied to estimate the number of exposures of marine mammals to sound levels ≥160 dB re 1 µPa (rms), and the number of different individual marine mammals exposed to such levels. These two approaches can be interpreted as providing maximum and minimum (respectively) estimates of the number of marine mammals that would have been exposed to sound levels ≥160 dB re 1 µPa (rms) if they did not show avoidance reactions.

# 5. RESULTS OF SHELL'S MARINE MAMMAL MONITORING PROGRAM[7]

## INTRODUCTION

This chapter describes the results of Shell's 2007 marine mammal monitoring program, including an estimation of the numbers of marine mammals potentially affected during project operations within two study areas. All tables and figures within this chapter that include distance measurements in metric units are repeated in English units in Appendix D with the same table number used in this chapter. The study areas, for the purposes of marine mammal data analyses, were the actual seismic survey areas and transit areas within the Chukchi and Beaufort seas (Fig. 2.1 and 2.2). The Chukchi Sea study area was located in the MMS OCS Program Area designated as Chukchi Sea Sale 193 (1989) and in the proposed 2002-2007 Chukchi Sea Program Area (Fig. 2.1). The Beaufort Sea study area included Shell lease-holdings in the mid- and eastern parts of the Alaskan Beaufort Sea.

The marine mammals known to occur within the Beaufort and Chukchi seas include nine cetacean species, five pinnipeds species, and polar bears. Of these 15 species, three (all cetaceans) are listed under the U.S. Endangered Species Act (ESA) as endangered: the bowhead, humpback, and fin whale. Appendix F summarizes the abundance, habitat, and conservation status of the marine mammal species likely to occur in the cruise area.

## CHUKCHI SEA MONITORING

### *Monitoring Effort and Marine Mammal Encounter Results*

This section summarizes the visual monitoring effort and sightings from the *Gilavar* and its chase/monitoring vessels during both the Chukchi summer and fall seismic surveys. The summer project period began when the *Gilavar* and its chase/monitoring vessels first entered the Chukchi study area on 21 Jul and ended when the *Gilavar* left for the Beaufort Sea on 12 Sep 2007 after conclusion of seismic operations on 10 Sep. The fall Chukchi survey period began when the *Gilavar* and its chase/monitoring vessels returned to the Chukchi study area on 8 Oct and continued until ice conditions forced an end to the project on 5 Nov. The project provided data on the summer and fall occurrence, distribution, and abundance of marine mammals in the Chukchi Sea, an area where few systematic survey data had been previously collected.

Summaries of results of visual monitoring are presented here, with more detailed data presented in Appendix C. A summary of observer effort from both the *Gilavar* and its chase/monitoring vessels by seismic period is illustrated in Figs. 5.1 and 5.2. Chase/monitoring-vessel seismic observation effort differed between cetacean and pinniped groups. This is due to the fact that MMO effort from chase/monitoring vessels was considered seismic if the vessel was within 15 km (9.3 mi; for cetaceans) or 5 km (3.1 mi; for pinnipeds) of the *Gilavar* while the guns were firing (Chapter 4, *Analysis*). Seismic-period information presented within this section is with regard to observer effort for cetaceans. Both *Gilavar* and chase/monitoring vessel observer effort for pinnipeds is presented in Appendix Tables C.2 and C.4. Marine mammals observed during transits outside the study areas are not included in this report, but are summarized in Appendix Table C.5.

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[7] By Beth Haley, Craig Reiser, Meaghan Jankowski, Heather Patterson, Joseph Beland, Courtney Lyons

Summer and fall seismic survey activities were conducted in the Chukchi Sea by the *Gilavar* along 2751 km (1709 mi) and 1514 km (941 mi; summer and fall, respectively) for a total of ~4265 km (2650 mi) of trackline. This total includes periods while the mitigation gun was firing but no seismic data were acquired, e.g. during turns. During the 2007 Chukchi Sea surveys, visual observations were conducted in daylight from the *Gilavar* for ~5009 km (~3112 mi; 564 h) in the summer and 1423 km (884 mi; 150 h) in the fall, for a total of 6432 km (~3997 mi) of visual survey effort (~714 h). Marine mammal observers conducted watch from the chase/monitoring vessels within the Chukchi Sea for 6593 km (4097 mi; 524 h) in the summer and 3682 km (~2288 mi; 322 h) in the fall, for a total of 10,275 km (6385 mi) of survey effort (826 h) during the 2007 Chukchi Sea seismic surveys.

## *Applied Survey Effort Data*

If we were to apply previous standards for "useable" to the marine mammal monitoring data collected in 2007, the number of observer effort data available for consideration would be extremely low, largely due to poor visibility (~75% of the total "unuseable" effort during the summer survey; Chapter 4 *Analyses*). The decision was made to consider all data from effort and sightings that took place during daylight MMO watches for the 2007 general analysis. However, the "post-seismic" category of sightings has been excluded when seismic vs non-seismic sightings were considered (Chapter 4, *Analyses*).

## *Visual Survey Effort*

***Gilavar***.—During a total of ~7434 km (~4619 mi) of *Gilavar* observation effort in the Chukchi Sea (~5704 km [3544 mi] summer and 1729 km [1074 mi] fall), 6432 km (3997 mi) of visual monitoring occurred during daylight (~5009 km [3112 mi] summer and ~1423 km [884 mi] fall; Fig. 5.1; Tables C.1 and C.3). MMOs observed almost exclusively from the bridge (>99.5% of watch time, eye-height 12.4 m [11.7 yd] above water line); monitoring was conducted from the stern for 0.5 h (<0.5% of the total watch time). Of the 7434 km (4619 mi) of visual observation effort, 155 km (96 mi; ~55 km [34 mi] summer and ~100 km [62 mi] fall) occurred during nighttime power ups. The airgun array was never fully ramped up from no airguns firing during darkness. In compliance with the IHA requirement that monitoring take place through the night if one or more power downs were initated during the daytime, a total of 611 km (380 mi; 582 km [362 mi] summer and 29 km [18 mi] fall) were monitored during periods of darkness in the Chukchi Sea due to daytime power downs. No marine mammals were observed during these periods. Marine mammal observers stood watch over an additional ~232 km (144 mi; 56 km [~35 mi] summer and 176 km [109 mi] fall) in darkness associated with time prior to and post power ups. One observer was on watch aboard the *Gilavar* in daylight during a total of ~3271 km (2033 mi; 365 h) and at least two observers were on watch during the remaining ~3162 km (1965 mi; 350 h).

***Chase/monitoring Vessels***.—Within the Chukchi Sea, the MMOs aboard the chase/monitoring vessels observed over a total distance of 10,275 km (6385 mi; ~6593 km [4096 mi] summer; 3682 km [2288 mi] fall; Fig. 5.2; Tables C.1 and C.3). About 180 km (112 mi; 19 h) were monitored from the chase/monitoring vessels during darkness. All visual monitoring on the chase/monitoring vessels occured on the bridge. One observer was on watch aboard the chase/monitoring vessels during 8117 km (5044 mi; ~5730 km [~3561 mi] summer; 2387 km [1483 mi] fall), and at least two observers were on watch during the remaining 2336 km (~1452 mi; 900 km [559 mi] summer; 1436 km [892 mi] fall).

Beaufort wind force (Bf; Appendix J) during observations aboard the *Gilavar* and chase/monitoring vessels in the Chukchi Sea ranged from 0 to 7 (Fig. 5.3). During the summer survey in the Chukchi Sea, the majority of observer effort took place during conditions of Bf = 2 and 3 (wind speed 4–10 kt or 7–19 km/h; Fig. 5.3). Greater than 50% of *Gilavar* effort and ~65% of chase/monitoring vessel effort occurred during Bf

2 and 3 in the summer. The least amount of observer effort in the summer took place when Bf = 0 (<1% of both *Gilavar* and chase/monitoring vessel effort). During the fall survey in the Chukchi Sea, most monitoring occurred during Bf ≥3 (wind speed 10 kt or 19 km/h); ~30% of *Gilavar* effort occurred when Bf=5 and >27% of chase/monitoring vessels effort occurred when Bf = 3 (Fig. 5.3). No fall monitoring was conducted in the Chukchi Sea during conditions of Bf = 0. Higher Beaufort wind force is typical for the fall in the study region (Pilot Chart, date unkn.).

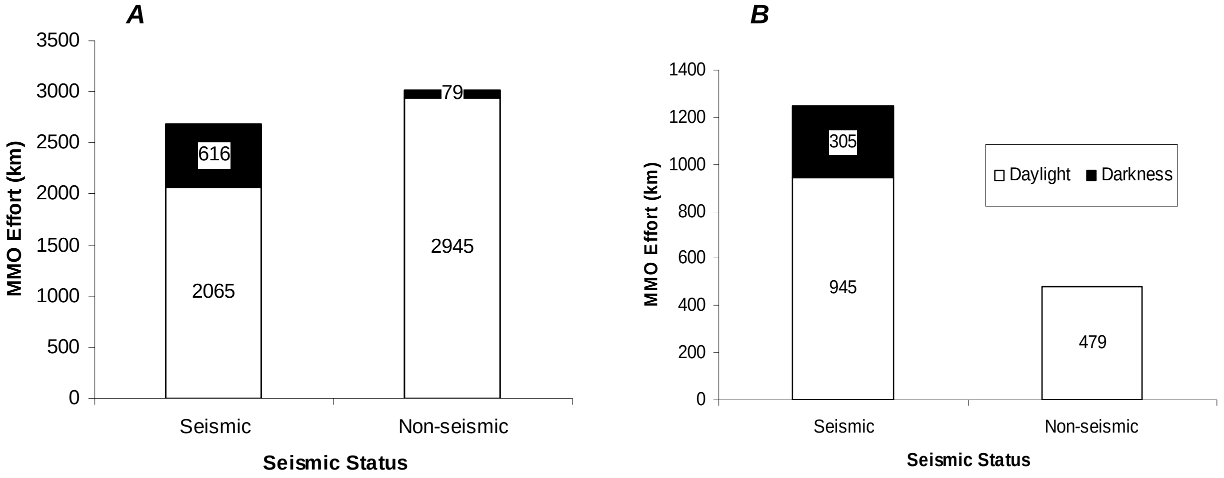

FIGURE 5.1. Total marine mammal observer effort (km) during Chukchi (***A***) summer and (***B***) fall seismic surveys from the *Gilavar* in the Chukchi Sea study area by seismic period in daylight and darkness, 2007. No post seismic effort occurred during the the summer or fall Chukchi Sea surveys from the *Gilavar*.

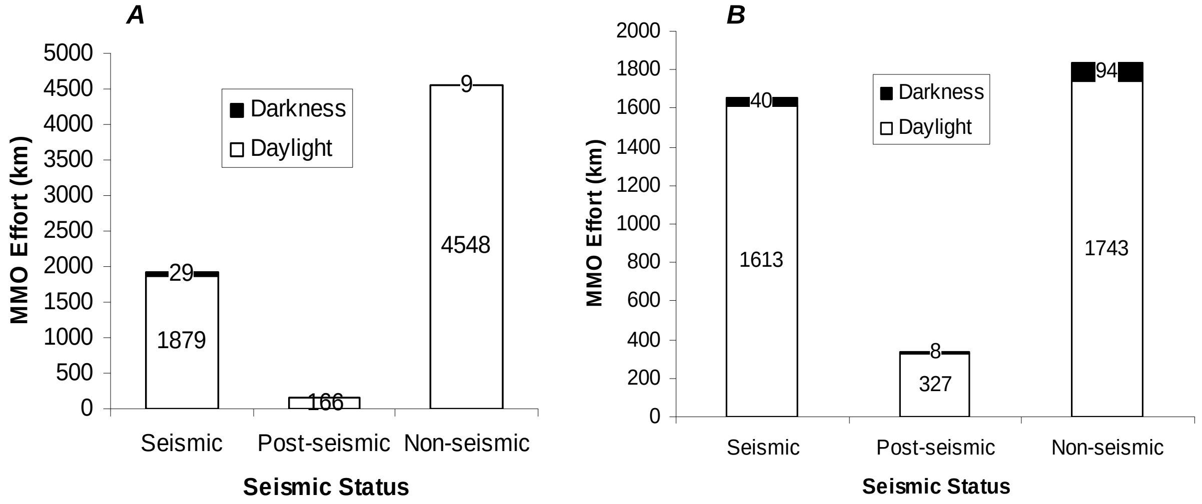

FIGURE 5.2. Total marine mammal observer effort (km) during Chukchi (***A***) summer and (***B***) fall seismic surveys from the chase/monitoring vessels in the Chukchi Sea study area by seismic period in daylight and darkness, summer 2007.

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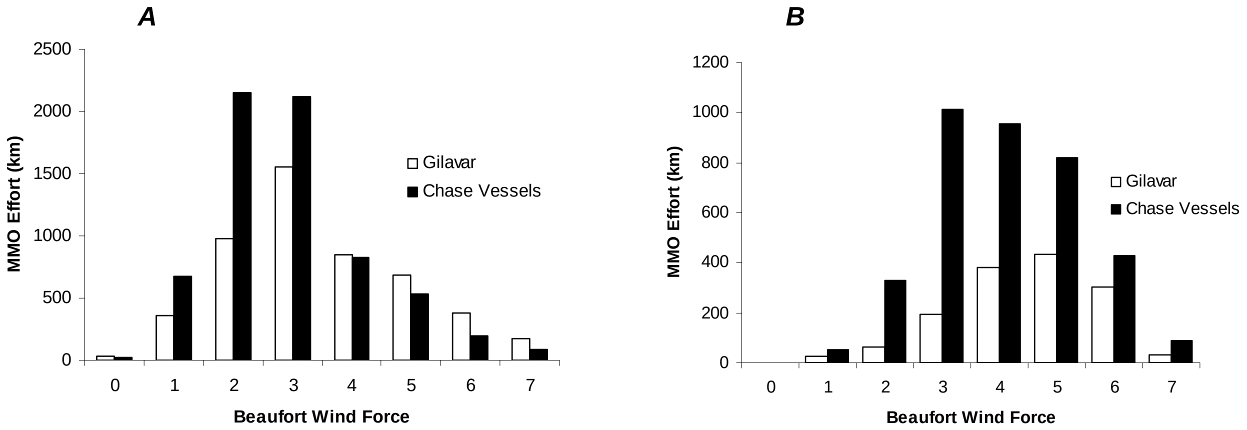


FIGURE 5.3. Total daylight marine mammal observer effort (km) in the Chukchi Sea study area from the *Gilavar* and chase/monitoring vessels by Beaufort wind force in (***A***) summer and (***B***) fall 2007.

## *Visual Sightings of Marine Mammals and Other Vessels*

***Total Numbers of Marine Mammals Seen***.—An estimated 3247 individual marine mammals were seen in 656 groups within the Chukchi Sea study area during the summer and fall study periods in 2007 from the *Gilavar* and its chase/monitoring vessels during daylight MMO watches. MMOs documented an additional 27 sightings totaling 69 individuals either during periods of darkness or opportunistically while not officially on watch. The grand total of all marine mammal sightings in the Chukchi Sea in 2007 was 683 sightings of 3316 individuals (Appendix Table C.5).

The majority of daylight MMO watch observations, 601 sightings comprised of 3192 individuals, were recorded during the summer survey between 21 Jul and 12 Sep (Table 5.1; Fig. 5.4). Only 55 sightings of 55 individuals were detected during the fall survey between 8 Oct and 5 Nov (Table 5.2; Fig. 5.4). Ten different species of marine mammals were identified in the Chukchi Sea during 2007 and each is addressed below within the species group sections.

A large number of Pacific walrus sightings were recorded in the study area by *Gilavar* MMOs within a 24-hour period on 24 Aug. The chase/monitoring vessel was transiting to Barrow to assist with a crew change on this date. This 24 Aug Pacific walrus sightings event, which accounted for 50% of the *Gilavar's* total summer survey marine mammal sighting records (*n* = 148 of 294 total summer sightings), is discussed below in *Pacific walruses*.

***Sightings with Airguns On***.—Fig. 5.5 summarizes sightings by vessel and seismic state. Of the 601 total daylight sightings recorded during the summer Chukchi Sea survey by the *Gilavar* and its chase/monitoring vessels, 134 were made while the airguns were operating, nine were noted during post-seismic periods, and 458 were made during non-seismic periods (148 of these non-seismic sightings were Pacific walruses recorded by the *Gilavar* on 24 Aug; Appendix Table C.6). The two sightings recorded by MMOs in the dark both took place during the summer survey while the airguns were not operating. A total of 55 daylight MMO watch sightings were recorded during the fall Chukchi Sea survey by the *Gilavar* and its chase/monitoring vessels, including 10 while the airguns were operating, 38 during non-seismic periods, and seven during post-seismic periods (Fig. 5.5; Appendix Table C.7).

TABLE 5.1. Number of sightings (number of individuals) of marine mammals during daylight MMO watches during the summer Chukchi Sea survey (21 Jul – 12 Sep 2007) from the *Gilavar* and its chase/monitoring vessels. There were no polar bear sightings during this survey.

| **Species** | ***Gilavar*** | **Chase Vessels** | ***Total*** |
|---|---|---|---|
| **Cetaceans** | | | |
| Bowhead Whale | 3 (4) | 1 (3) | ***4 (7)*** |
| Gray Whale | 2 (2) | 21 (45) | ***23 (47)*** |
| Harbor Porpoise | 3 (4) | 0 | ***3 (4)*** |
| Humpback Whale | 1 (2) | 1 (2) | ***2 (4)*** |
| Killer Whale | 1 (1) | 0 | ***1 (1)*** |
| Unidentified Mysticete Whale | 1 (1) | 1 (2) | ***2 (3)*** |
| Unidentified Whale | 8 (12) | 5 (11) | ***13 (23)*** |
| ***Total Cetaceans*** | ***19 (26)*** | ***29 (63)*** | ***48 (89)*** |
| **Seals and Sea Lions** | | | |
| Bearded Seal | 0 | 14 (15) | ***14 (15)*** |
| Ringed and Spotted Seals[a] | 14 (14) | 122 (137) | ***136 (151)*** |
| Steller Sea Lion | 0 | 1 (1) | ***1 (1)*** |
| ***Total Seals and Sea Lions*** | ***14 (14)*** | ***137 (153)*** | ***151 (167)*** |
| **Pacific Walruses** | | | |
| In Water | 254 (1249) | 132 (284) | ***386 (1533)*** |
| On Ice | 1 (404) | 5 (988) | ***6 (1392)*** |
| Unidentified Pinniped[b] | 6 (7) | 4 (4) | ***10 (11)*** |
| ***Total Pacific Walruses*** | ***261 (1660)*** | ***141 (1276)*** | ***402 (2936)*** |
| ***Grand Total of All Sightings*** | ***294 (1700)*** | ***307 (1492)*** | ***601 (3192)*** |

[a] Includes all records of ringed, spotted, and unidentified seals.

[b] Ten of 10 total unidentified pinniped sightings were added to "Pacific Walruses In Water" based on the ratio of identified large pinniped sightings in water (14 bearded seal to 386 Pacific walrus). All unidentified pinnipeds were sighted in water.

TABLE 5.2. Number of sightings (number of individuals) of marine mammals during daylight MMO watches during the fall Chukchi Sea survey (8 Oct – 5 Nov 2007) from the Gilavar and its chase/monitoring vessels. There were no polar bear sightings during this survey.

| **Species** | ***Gilavar*** | **Chase Vessels** | ***Total*** |
|---|---|---|---|
| **Cetaceans** | | | |
| Humpback Whale | 1 (1) | 0 | ***1 (1)*** |
| Unidentified Mysticete Whale | 1 (1) | 0 | ***1 (1)*** |
| ***Total Cetaceans*** | ***2 (2)*** | ***0*** | ***2 (2)*** |
| **Seals** | | | |
| Bearded Seal | 2 (2) | 9 (9) | ***11 (11)*** |
| Ringed and Spotted Seals[a] | 1 (1) | 40 (40) | ***41 (41)*** |
| ***Total Seals*** | ***3 (3)*** | ***49 (49)*** | ***52 (52)*** |
| **Pacific Walruses** | | | |
| In Water | 0 | 1 (1) | ***1 (1)*** |
| On Ice | 0 | 0 | ***0*** |
| ***Total Pacific Walruses*** | ***0*** | ***1 (1)*** | ***1 (1)*** |
| ***Grand Total of All Sightings*** | ***5 (5)*** | ***50 (50)*** | ***55 (55)*** |

[a] Includes all records of ringed, spotted, and unidentified seals.

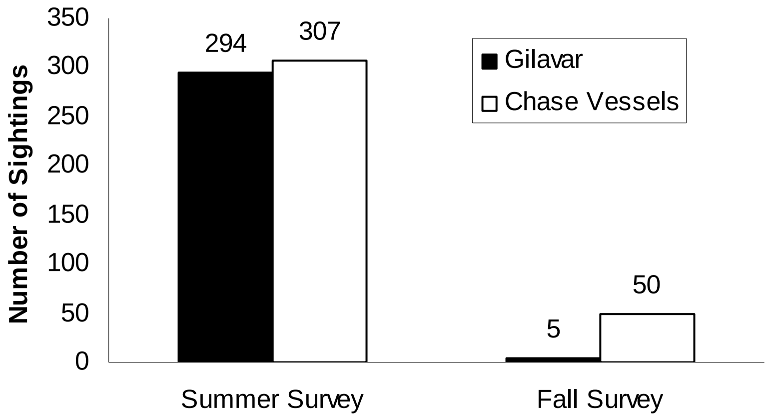


FIGURE 5.4. Total number of marine mammal sightings by vessel and survey period for the *Gilavar* and its chase/monitoring vessels in the Chukchi Sea during summer and fall daylight MMO watches in 2007.

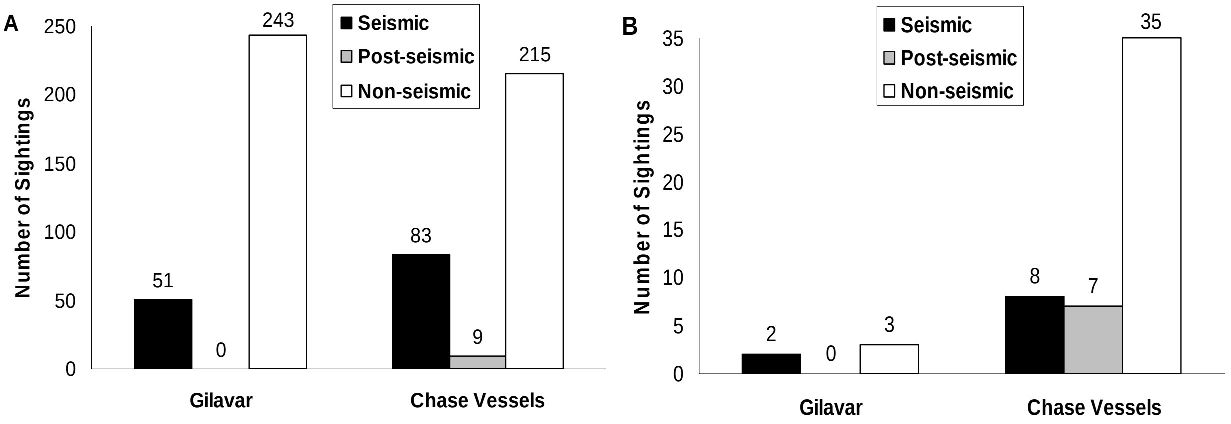


FIGURE 5.5. Marine mammal sightings by seismic state for the *Gilavar* and its chase/monitoring vessels during ***(A)*** summer (21 Jul – 12 Sep 2007) and (***B***) fall (8 Oct – 5 Nov 2007) Chukchi Sea surveys.

Power downs from the full airgun array to the single mitigation gun were requested by *Gilavar* MMOs on 27 occasions during the 2007 summer and fall Chukchi Sea surveys. Most of the power downs (26 of 27) were for Pacific walruses sighted within the 180 dB safety zone around the operating airguns during the summer survey period.

Only one power down was requested by *Gilavar* MMOs during the fall Chukchi Sea survey when a bearded seal was sighted within the 190 dB safety radius. Chukchi Sea power downs are discussed in greater detail later in this chapter within each species' group section and in *Mitigation Measures Implemented*.

***Sighting Rates.***—Sighting rates (number of daylight MMO watch sightings per unit of effort) for the *Gilavar* and its chase/monitoring vessels during the summer and fall Chukchi Sea surveys are presented in Tables 5.3 and 5.4, respectively, and both survey periods are broken down by seismic activity. Sighting rates were much higher during the summer survey than during the fall survey (51.8 and 10.8 sightings per 1000 km of daylight MMO watch effort, respectively; 83.4 and 17.3 sightings per 1000 mi of daylight MMO watch effort, respectively), and this largely was due to the high numbers of Pacific walruses sighted during the summer survey. Sighting rates for various species groups are discussed in detail later in this chapter within each species group section. The total number of sightings was much greater during the summer survey (*n* = 601) when compared with the fall survey (*n* = 55, only five of which came from the *Gilavar*).

*Gilavar* non-seismic sighting rates during the summer Chukchi Sea survey were more than three times greater than seismic sighting rates (Fig. 5.6), though the magnitude of this difference was inflated by the previously mentioned Pacific walrus sightings event on 24 Aug. The non-seismic sighting rate for the *Gilavar* was actually less than the non-seismic sighting rate for chase/monitoring vessels if the *Gilavar's* 24 Aug Pacific walrus sightings are excluded from calculations. Chase/monitoring vessels summer sighting rates were similar during seismic periods compared to non-seismic periods.

Both the *Gilavar* and its chase/monitoring vessels had higher non-seismic than seismic sighting rates during the fall survey, and overall sighting rates were much higher for chase/monitoring vessels than for the *Gilavar* during this survey (Fig. 5.6).

Sighting rates aboard the *Gilavar* and its chase/monitoring vessels were inversely related to Beaufort wind force during both the summer and fall Chukchi Sea surveys (Fig. 5.7). This is typically assumed to be the case for marine mammal surveys because rougher sea conditions make it more difficult for observers to detect animals in the water. Average sea conditions and wind velocities were higher during the fall survey than they were during the summer period, and this may have contributed to the low sighting rates associated with the fall survey.

Sighting rates of marine mammals were directly related to the number of MMOs on watch during both the summer and fall Chukchi Sea surveys (Fig. 5.8). Summer sighting rates for the *Gilavar* and its chase/monitoring vessels while one MMO was on watch were 31.6 and 36.0 sightings per 1000 km of daylight MMO watch effort, respectively (50.9 and 57.9 sightings per 1000 mi of daylight MMO watch effort, respectively), compared to the two MMOs on watch rates of 87.1 and 116.0 sightings per 1000 km of daylight MMO watch effort, respectively (140.2 and 186.7 sightings per 1000 mi of daylight MMO watch effort, respectively). Similarly, sighting rates during the fall survey period also were higher when two MMOs were on watch versus one, but the low number of sightings from the *Gilavar* makes a direct comparison of sighting rates problematic.

TABLE 5.3. Sighting rates for marine mammal sightings during different seismic states from daylight MMO watch effort during the summer Chukchi Sea survey (21 Jul - 12 Sep) from the *Gilavar* and its chase/monitoring vessels. "Ramp-up" and “Power-up” effort is included in the *Seismic* category. Note *Gilavar* non-seismic rate is 34.4 sightings / 1000 km (55.4 sightings / 1000 mi) when 24 Aug Pacific walrus sightings are excluded from calculations (See Fig. 5.6).

| Seismic State | No. of Sightings | Effort (km) | Sighting Rate (No./1000 km) |
|---|---|---|---|
| ***Gilavar*** | | | |
| Seismic | 51 | 2065 | **24.7** |
| Post-Seismic | 0 | 0 | **0.0** |
| Non-Seismic | 243 | 2945 | **82.5** |
| ***Gilavar Total*** | **294** | **5009** | **58.7** |
| **Chase Vessels** | | | |
| Seismic | 83 | 1879 | **44.2** |
| Post-Seismic | 9 | 166 | **54.3** |
| Non-Seismic | 215 | 4548 | **47.3** |
| ***Chase Vessels Total*** | **307** | **6593** | **46.6** |
| ***Grand Total*** | **601** | **11602** | **51.8** |

TABLE 5.4. Sighting rates for marine mammal sightings during different seismic states from daylight MMO watch effort during the fall Chukchi Sea survey (8 Oct - 5 Nov) from the *Gilavar* and its chase/monitoring vessels. "Ramp-up" and "Power-up" effort is included in the *Seismic* category.

| **Seismic State** | **No. of Sightings** | **Effort (km)** | **Sighting Rate (No./1000 km)** |
|---|---|---|---|
| ***Gilavar*** | | | |
| Seismic | 2 | 945 | **2.1** |
| Post-Seismic | 0 | 0 | **0.0** |
| Non-Seismic | 3 | 479 | **6.3** |
| ***Gilavar Total*** | **5** | **1423** | **3.5** |
| **Chase Vessels** | | | |
| Seismic | 8 | 1613 | **5.0** |
| Post-Seismic | 7 | 327 | **21.4** |
| Non-Seismic | 35 | 1743 | **20.1** |
| ***Chase Vessels Total*** | **50** | **3682** | **13.6** |
| ***Grand Total*** | **55** | **5105** | **10.8** |

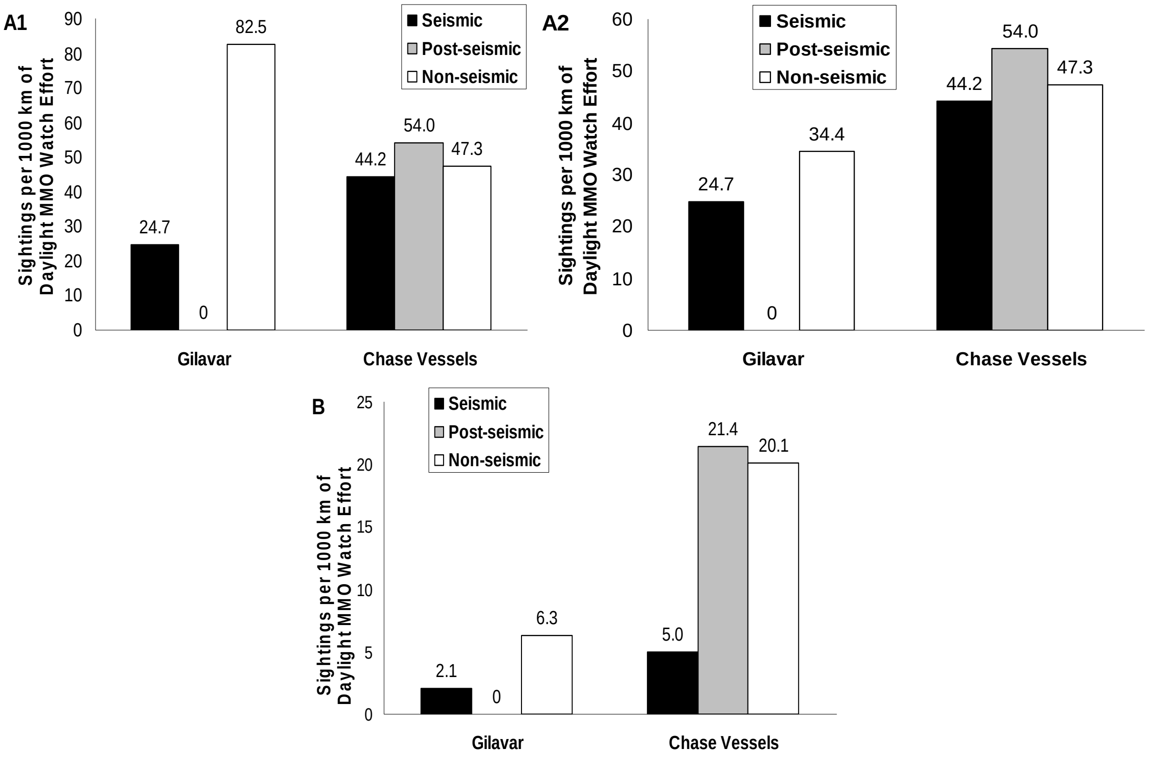


FIGURE 5.6. Marine mammal sighting rates by seismic state for the *Gilavar* and its chase/monitoring vessels during **(*A1*)** summer (21 Jul – 12 Sep 2007), (***A2***) summer excluding *Gilavar* 24 Aug sightings, and (***B***) fall (8 Oct – 5 Nov 2007) Chukchi Sea surveys.

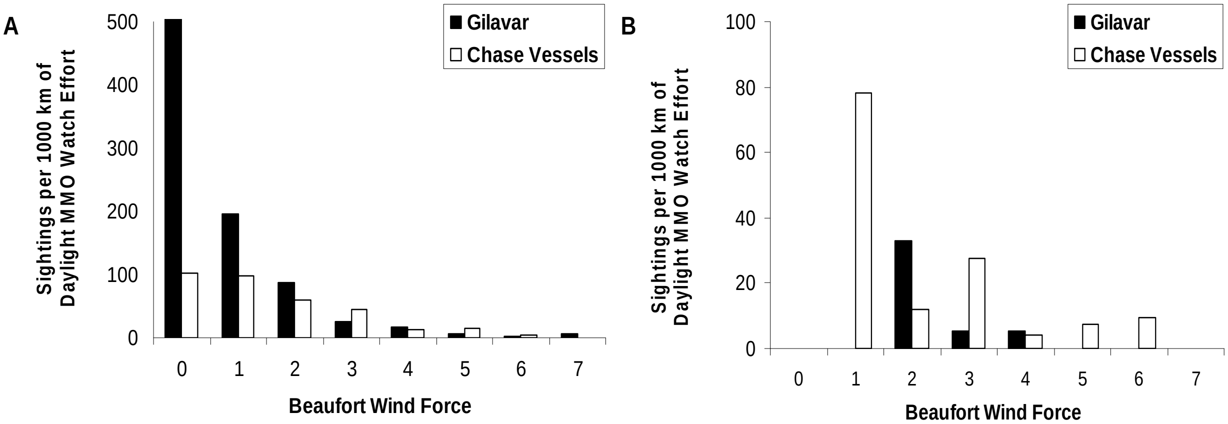


FIGURE 5.7. Marine mammal sighting rates by Beaufort wind force from the *Gilavar* and its chase/monitoring vessels during **(*A*)** summer (21 Jul – 12 Sep 2007) and (***B***) fall (8 Oct – 5 Nov 2007) Chukchi Sea surveys. Note *Gilavar* summer rate at Beaufort wind force of 0 is truncated at 500 – the actual value approaches 2,400 but was inflated as a result of the 24 Aug Pacific walrus sightings event in calm conditions and is not representative of the majority of the season.

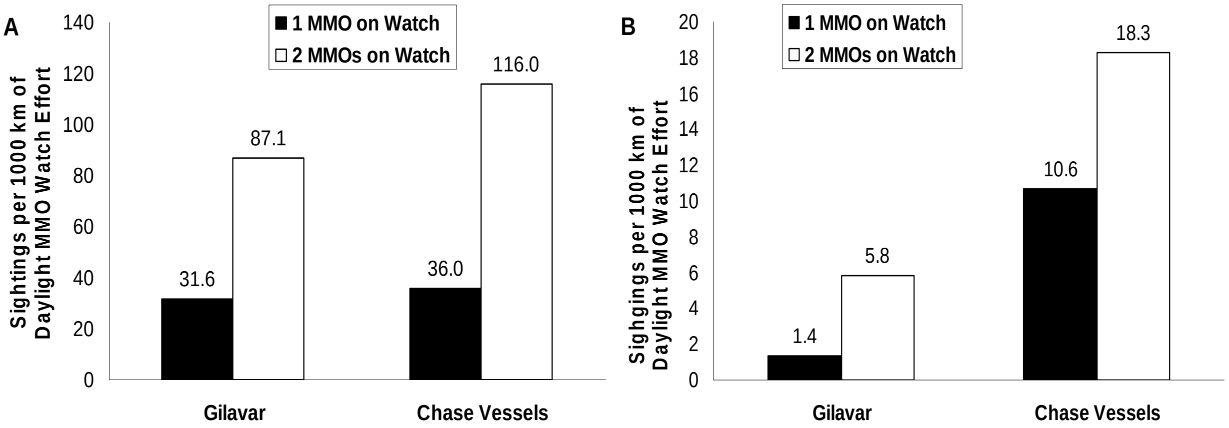


FIGURE 5.8. Marine mammal sighting rates by number of MMOs on watch from the *Gilavar* and its chase/monitoring vessels during (***A***) summer (21 Jul – 12 Sep 2007) and (***B***) fall (8 Oct – 5 Nov 2007) Chukchi Sea surveys.

***Other Vessels***.— The *Gilavar* and its chase/monitoring vessels typically worked within 5 km (3 mi) of each other and often as close as a few hundred meters or yards. Chase/monitoring vessel proximity to the Gilavar was variable over time and this may have influenced the number of marine mammals sighted from different vessels. However, this potential influence was not apparent to the MMOs in real time when they were observing marine mammals.

## *Cetaceans*

***Total Numbers of Cetaceans Observed***.—Fifty cetacean sightings comprised of 91 individuals and five species were observed by *Gilavar* and chase/monitoring vessels MMOs in the Chukchi Sea in 2007. The majority of these sightings were recorded during the summer survey (*n* = 48 sightings of 89 individuals) and the most commonly recorded species in the summer survey was gray whale (*n* = 23 sightings of 47 individuals; Table 5.5).

Only two cetacean sightings were recorded during the fall survey (a single humpback whale and a lone unidentified whale). The low number of fall survey cetacean sightings was believed to be the combination of seasonal timing (many cetaceans may have migrated towards their wintering areas) and rougher sea conditions.

***Cetacean Sightings with Airguns On.***—Sixteen of the 48 total cetacean sightings from the *Gilavar* and its chase/monitoring vessels during the summer Chukchi survey were recorded during seismic periods, 32 during non-seismic periods, and there were no summer cetacean sightings during the post-seismic period (Fig. 5.9; Appendix Table C.8).

The two fall Chukchi Sea survey cetacean sightings were recorded during non-seismic periods (Appendix Table C.9). No cetacean sightings were recorded within the ≥180 dB safety radius during summer or fall Chukchi Sea surveys and no cetacean-related power downs of airgun arrays were requested by MMOs in the Chukchi Sea study area.

***Cetacean Sighting Rates.***—Cetacean sighting rates for the *Gilavar* and its chase/monitoring vessels were relatively uniform during seismic versus non-seismic states and across respective vessels during the summer survey (Fig. 5.10). Overall summer cetacean sighting rates were slightly higher for chase/monitoring vessels than they were for the *Gilavar* (4.4 and 3.8 sightings per 1000 km of daylight MMO watch effort, respectively; 7.1 and 6.1 sightings per 1000 mi of daylight MMO watch effort, respectively; Appendix Table C.10). Fall survey cetacean sighting rates were too low to make comparisons among seismic conditions (Appendix Table C.11).

TABLE 5.5. Number of sightings (number of individuals) of cetaceans during daylight MMO watches during the summer Chukchi Sea survey (21 Jul - 12 Sep 2007) from the *Gilavar* and its chase/monitoring vessels.

| **Species** | ***Gilavar*** | **Chase Vessels** | ***Total*** |
|---|---|---|---|
| **Cetaceans** | | | |
| Bowhead Whale | 3 (4) | 1 (3) | ***4 (7)*** |
| Gray Whale | 2 (2) | 21 (45) | ***23 (47)*** |
| Harbor Porpoise | 3 (4) | 0 | ***3 (4)*** |
| Humpback Whale | 1 (2) | 1 (2) | ***2 (4)*** |
| Killer Whale | 1 (1) | 0 | ***1 (1)*** |
| Unidentified Mysticete Whale | 1 (1) | 1 (2) | ***2 (3)*** |
| Unidentified Whale | 8 (12) | 5 (11) | ***13 (23)*** |
| ***Total Cetaceans*** | ***19 (26)*** | ***29 (63)*** | ***48 (89)*** |

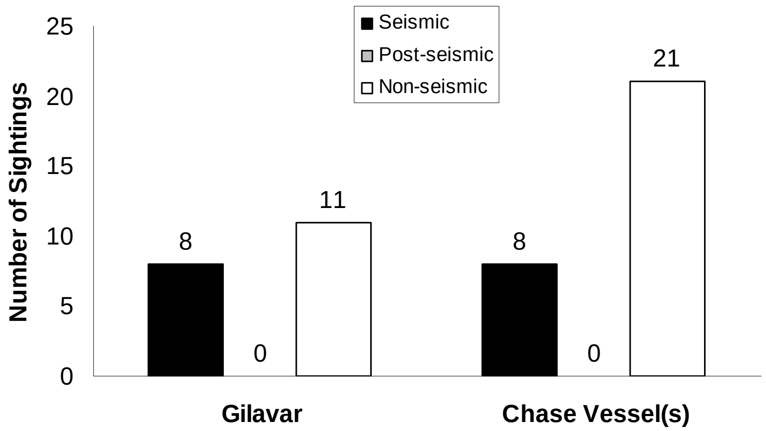


FIGURE 5.9. Number of cetacean sightings by seismic state for the *Gilavar* and its chase/monitoring vessels during the summer Chukchi Sea survey (21 Jul – 12 Sep 2007).

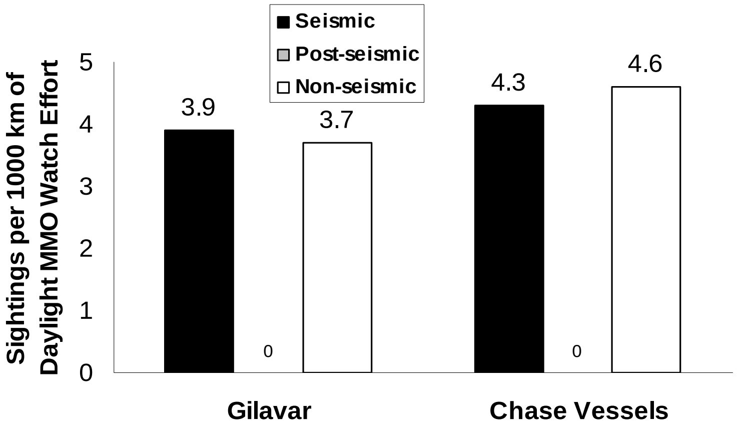


FIGURE 5.10. Cetacean sighting rates by seismic state for the *Gilavar* and its chase/monitoring vessels during the summer Chukchi Sea survey (21 Jul – 12 Sep 2007).

## *Seals and Sea Lions*

***Total Numbers of Seals and Sea Lions Observed***.—There were 167 seals and sea lions sighted in 151 groups by MMOs on the *Gilavar* and its chase/monitoring vessels during the summer Chukchi Sea survey (Table 5.6). Most of the seals observed were recorded as ringed or spotted seals. A small number of bearded seals were recorded from the chase/monitoring vessels and no bearded seals were recorded from the *Gilavar*. The single sighting of an individual Steller sea lion was unusual for the Chukchi Sea. Most of the 151 summer seal and sea lion sightings (137) were recorded by chase/monitoring vessels.

Fewer seals were recorded during the fall survey than were observed during the summer survey (Tables 5.6 and 5.7). Only 52 seals in 52 groups were sighted by *Gilavar* and chase/monitoring vessel MMOs during the fall survey (there were no sea lion sightings during the fall survey; Table 5.7). Most fall seal sightings were recorded by chase/monitoring vessel MMOs. The majority of the 52 total fall seal sightings were either ringed or spotted seals (*n* = 41 sightings of 41 individuals) followed by bearded seal (*n* = 11 sightings of 11 individuals). All seal and sea lion sightings from the 2007 Chukchi Sea surveys were in the water as opposed to on ice or land, and there was little to no ice within the study area during most of the 2007 study period.

***Seal and Sea Lion Sightings with Airguns On.***—Of the 151 total seal and sea lion sightings recorded by the *Gilavar* and its chase/monitoring vessels during the summer Chukchi Sea survey, 126 were recorded during non-seismic periods compared with only 24 sightings during seismic periods and a single sighting during a post-seismic period (Fig. 5.11; Appendix Table C.12). None of the summer seal and sea lion sightings observed during seismic operations were within the *Gilavar's* ≥190 dB safety radius, and therefore, no seal or sea lion-related power downs were requested by *Gilavar* MMOs.

Of the 52 total seal sightings noted by *Gilavar* and chase/monitoring vessels MMOs during the fall survey, 36 were recorded during non-seismic periods, nine sightings during seismic periods, and the remaining seven fall seal sightings were noted by chase/monitoring vessels during post-seismic periods (Fig. 5.11; Appendix Table C.13). There was a single bearded seal sighted within the *Gilavar's* 190 dB safety radius and this led to a power down of the *Gilavar's* airguns from full array volume to the single mitigation gun. This power down is addressed below in *Mitigation Measures Implemented.*

***Seal and Sea Lion Sighting Rates.***—Seal and sea lion sighting rates for both the *Gilavar* and its chase/monitoring vessels were higher during non-seismic periods when compared with seismic periods, but the non-seismic sighting rate was much higher for chase/monitoring vessels than it was for the *Gilavar* during the summer Chukchi Sea survey (Fig. 5.12). Seismic seal and sea lion sighting rates were also much higher for chase/monitoring vessels than they were for the *Gilavar* during the summer survey period (18.6 and 1.5 sightings per 1000 km of daylight MMO watch effort, respectively; Fig. 5.12) (29.9 and 2.4 sightings per 1000 mi of daylight MMO watch effort, respectively).

Similar seal sighting rate trends were noted during the fall Chukchi Sea survey. However, the low number of sightings from the *Gilavar* makes meaningful comparisons difficult. Seal sighting rates for all seismic activity states were higher for the chase/monitoring vessels than for the *Gilavar* (Fig. 5.12).

TABLE 5.6. Number of sightings (number of individuals) of seals and sea lions during daylight MMO watches during the summer Chukchi Sea survey (21 Jul - 12 Sep 2007) from the *Gilavar* and its chase/monitoring vessels.

| Species | *Gilavar* | Chase Vessels | *Total* |
|---|---|---|---|
| **Seals and Sea Lions** | | | |
| Bearded Seal | 0 | 14 (15) | ***14 (15)*** |
| Ringed and Spotted Seals[a] | 14 (14) | 122 (137) | ***136 (151)*** |
| Steller Sea Lion | 0 | 1 (1) | ***1 (1)*** |
| ***Total Seals and Sea Lions*** | ***14 (14)*** | ***137 (153)*** | ***151 (167)*** |

[a] Includes "Unidentified Seal" numbers

TABLE 5.7. Number of sightings (number of individuals) of seals during daylight MMO watches during the fall Chukchi Sea survey (8 Oct - 5 Nov 2007) from the *Gilavar* and its chase/monitoring vessels.

| Species | *Gilavar* | Chase Vessels | *Total* |
|---|---|---|---|
| **Seals** | | | |
| Bearded Seal | 2 (2) | 9 (9) | ***11 (11)*** |
| Ringed and Spotted Seals[a] | 1 (1) | 40 (40) | ***41 (41)*** |
| ***Total Seals*** | ***3 (3)*** | ***49 (49)*** | ***52 (52)*** |

[a] Includes "Unidentified Seal" numbers.

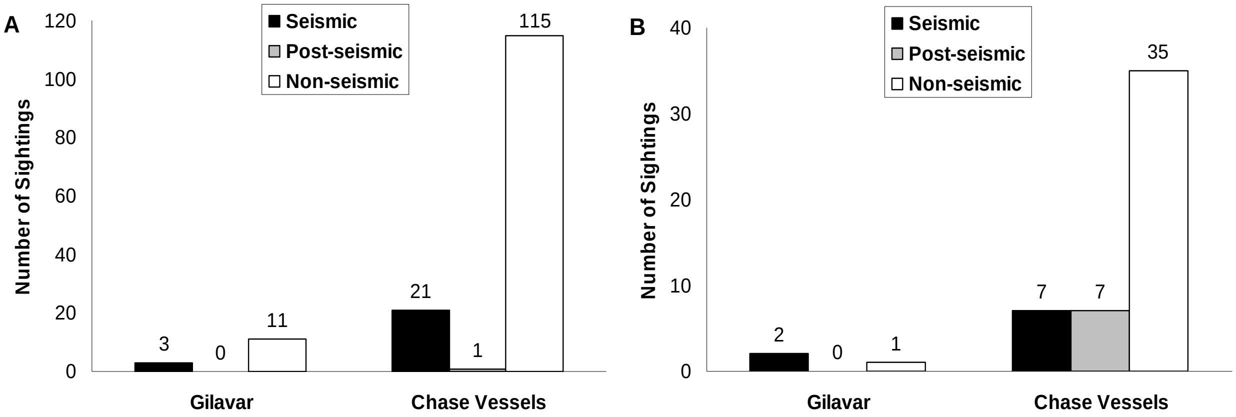


FIGURE 5.11. Number of seal and sea lion sightings by seismic state for the *Gilavar* and its chase/monitoring vessels during **(A)** summer (21 Jul – 12 Sep 2007) and (**B**) fall (8 Oct – 5 Nov 2007) Chukchi Sea surveys.

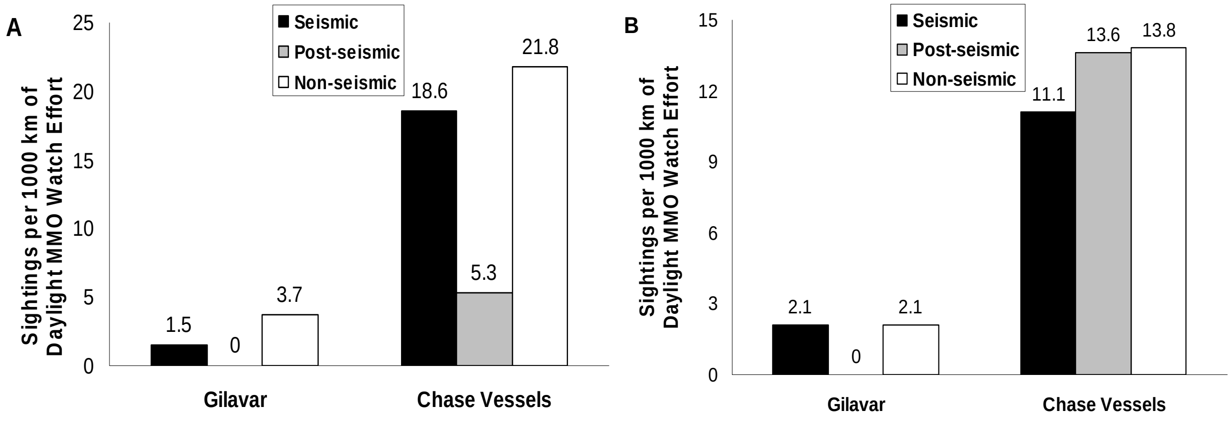


FIGURE 5.12. Sighting rates for seal and sea lion sightings by seismic state for the *Gilavar* and its chase/monitoring vessels during (***A***) summer (21 Jul – 12 Sep 2007) and (***B***) fall (8 Oct – 5 Nov 2007) Chukchi Sea surveys.

## *Pacific Walruses and Polar Bears*

***Total Numbers of Pacific Walruses and Polar Bears***—There were no polar bears recorded in the Chukchi Sea by the *Gilavar* or its chase/monitoring vessels in 2007.

The summer Chukchi survey period was characterized by large numbers of Pacific walrus sightings. A total of 402 Pacific walrus groups comprised of 2936 individuals was sighted by *Gilavar* and chase/monitoring vessel MMOs during the summer survey (Table 5.8). The majority of these sightings was recorded on a few days as opposed to being consistently recorded throughout the survey period. Many of these sightings, 148 or 37%, were recorded by *Gilavar* MMOs on 24 Aug (UTC) while the chase/monitoring vessel was transiting to and from Barrow (Fig. 5.13). Of the total 402 summer Pacific walrus sightings, 396 or nearly 99%, were observed in the water and only six sightings of Pacific walruses were noted as being on ice. However, while these six on-ice sightings represent only one percent of the total number of sightings, the 1392 individuals from these six sightings account for nearly half (47%) of the 2936 total number of individual Pacific walruses recorded during the summer survey period. The summer survey Pacific walrus numbers include an additional 10 sightings of 11 *unidentified pinnipeds* based on the proportion of identified bearded seals to Pacific walrus sightings (14 and 386, respectively). Finally, there was a single sighting of a dead Pacific walrus from the *Gilavar* on 29 Aug. MMOs were not able to photograph the animal or determine what may have caused its death.

The fall Chukchi survey period concluded with only a single Pacific walrus sighting in the water by a chase/monitoring vessel (Table 5.9). Also, there were no large unidentified pinnipeds recorded during the fall survey. It is likely that the large numbers of Pacific walruses observed during the summer Chukchi Sea survey had moved through the study area by the time the fall survey began.

TABLE 5.8. Number of sightings (number of individuals) of Pacific walruses during daylight MMO watches during the summer Chukchi Sea survey (21 Jul - 12 Sep 2007) from the *Gilavar* and its chase/monitoring vessels. All "unidentified pinnipeds" were observed in water.

| **Species** | ***Gilavar*** | **Chase Vessels** | ***Total*** |
|---|---|---|---|
| **Pacific Walruses** | | | |
| In Water | 254 (1249) | 132 (284) | ***386 (1533)*** |
| On Ice | 1 (404) | 5 (988) | ***6 (1392)*** |
| Unidentified Pinniped[a] | 6 (7) | 4 (4) | ***10 (11)*** |
| ***Total Pacific Walruses*** | **261 (1660)** | **141 (1276)** | **402 (2936)** |

[a] Ten of 10 total "unidentified pinniped" sightings were included in the "Pacific Walruses" table based on the ratio of identified large pinniped sightings in water (14 bearded seal to 386 Pacific walrus).

TABLE 5.9. Number of sightings (number of individuals) of Pacific walruses during daylight MMO watches during the fall Chukchi Sea survey (8 Oct - 5 Nov 2007) from the *Gilavar* and its chase/monitoring vessels. There were no "unidentified pinnipeds" reported by the *Gilavar* and its chase/monitoring vessels during this survey.

| Species | *Gilavar* | Chase Vessels | *Total* |
|---|---|---|---|
| **Pacific Walruses** | | | |
| In Water | 0 | 1 (1) | ***1 (1)*** |
| On Ice | 0 | 0 | ***0*** |
| ***Total Pacific Walruses*** | **0** | **1 (1)** | **1 (1)** |

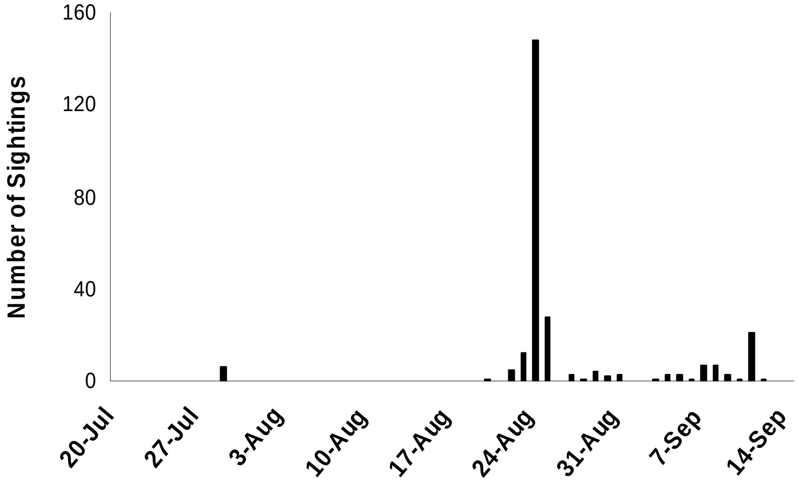


FIGURE 5.13. Number of Pacific walrus sightings by day as recorded by *Gilavar* MMOs during the summer Chukchi Sea survey (21 Jul – 12 Sep 2007). 24 Aug value = 148 sightings.

***Pacific Walrus Sightings with Airguns On.***—Of the 402 total Pacific walrus sightings recorded during daylight MMO watches during the summer Chukchi Sea survey, 300 were noted during non-seismic periods (as were the two sightings of Pacific walruses noted by *Gilavar* MMOs during periods of darkness), 94 sightings took place while the airguns were firing, and the remaining eight sightings were noted during post-seismic periods (Fig. 5.14; Appendix Table C.16). Of the 300 total non-seismic sightings, 148 or 49%, were recorded by *Gilavar* MMOs on 24 Aug (Figs. 5.13 and 5.14).

Pacific walruses were sighted within the *Gilavar's* 180 dB safety radius on 26 occasions during the summer Chukchi Sea survey and MMOs requested a power down to the mitigation gun for all of these sightings. Of these 26 summer power downs for Pacific walruses, nine resulted from notification by MMOs on the chase/monitoring vessels after which mitigation was implemented by MMOs on the *Gilavar*. These multiple-vessel scenarios are discussed in detail later in this chapter in *Mitigation Measures Implemented*.

The single Pacific walrus sighting recorded during the fall Chukchi survey was observed from a chase/monitoring vessel when the *Gilavar's* airguns were firing (Appendix Table C.17). No power downs were requested by MMOs due to Pacific walruses during the fall Chukchi Sea survey.

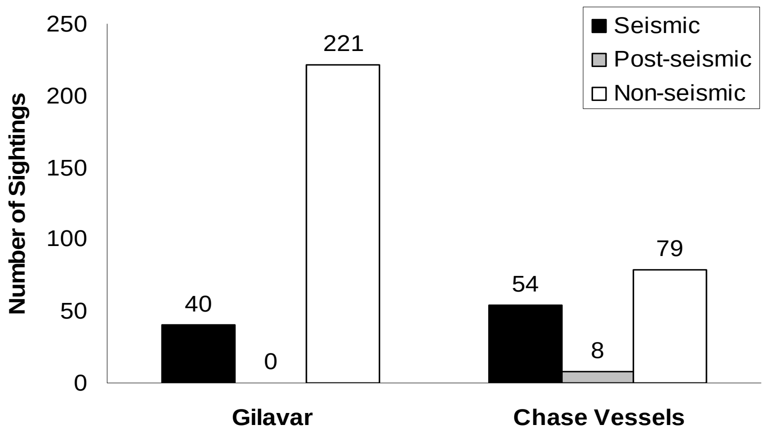


FIGURE 5.14. Number of Pacific walrus sightings by seismic state for the *Gilavar* and its chase/monitoring vessels during the summer Chukchi Sea survey (21 Jul – 12 Sep 2007).

***Pacific Walrus Sighting Rates.***—Pacific walrus sighting rates (number of sightings per unit of daylight MMO watch effort) during the summer Chukchi survey were heavily influenced by the aforementioned 24 Aug sighting event of 148 Pacific walruses by *Gilavar* MMOs while the chase/monitoring vessel was transiting to and from Barrow. As a result, the overall summer sighting rate of Pacific walruses aboard the *Gilavar* was more than twice the value recorded aboard the chase/monitoring vessels (52.1 and 21.4 sightings per 1000 km of daylight MMO watch effort, respectively; 83.8 and 34.4 sightings per 1000 mi of daylight MMO watch effort; Appendix Table C.18). The *Gilavar* non-seismic Pacific walrus sighting rate was much higher than the chase/monitoring vessels non-seismic rate (74.7 and 14.0 sightings per 1000 km of daylight MMO watch effort, respectively; Fig. 5.15; 120.2 and 21.6 sightings per 1000 mi of daylight MMO watch effort). The *Gilavar* non-seismic sighting rate drops to 26.1 sightings per 1000 km if daylight MMO watch effort (42.0 sightings per 1000 mi of daylight MMO watch effort) if the 24 Aug sightings are excluded from rate calculations. The chase/monitoring vessels Pacific walrus sighting rate during seismic periods was twice the value for the *Gilavar* (Fig. 5.15).

The single Pacific walrus sighting by a chase/monitoring vessel during the fall Chukchi Sea survey while airguns were firing resulted in a seismic sighting rate of 1.6 sightings per 1000 km of daylight MMO watch effort (2.5 sightings per 1000 mi of daylight MMO watch effort; Appendix Table C.19). There were no other Pacific walrus sightings during the fall survey.

## *Distribution and Behavior of Marine Mammals*

Bearing and distance from the observer station to the “closest point of approach” (CPA) of marine mammals were calculated and plotted for daylight sightings. The source vessel sighting data were further refined to calculate the CPA of animals to the airgun array located ~300 m or yards aft of the observer station. Most observations were of animals forward of the vessels or lateral to the ships’ tracklines with some sightings of animals aft of the observer. There were more sightings of Pacific walruses during the summer Chukchi Sea survey periods than other species (Table 5.1). This was due in great part to a short period during optimum sighting conditions when >1000 Pacific walruses (148 sightings) were recorded (24 Aug UTC). A smaller number of Pacific walruses was sighted from the chase/monitoring vessels because the chase/monitoring vessels were changing crew in Barrow during the unusually high Pacific walrus count at the prospect area on 24 Aug.

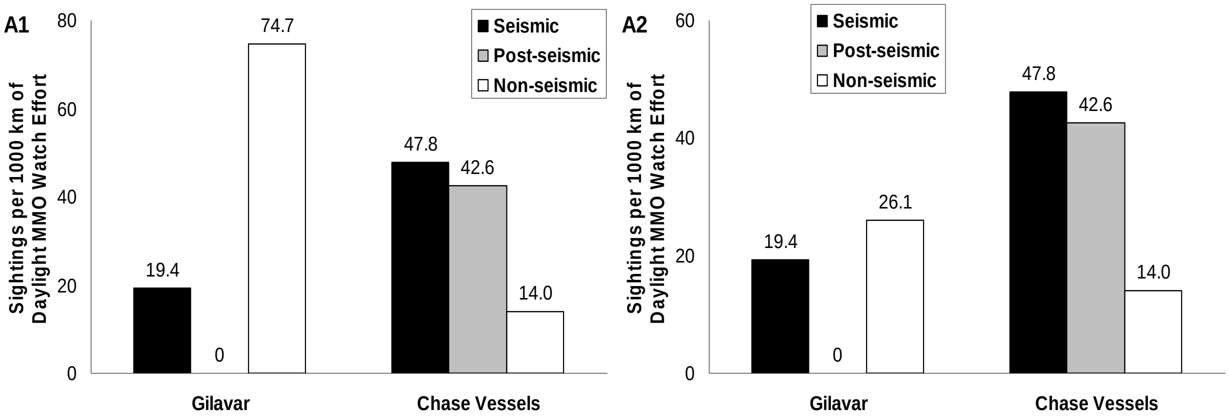


FIGURE 5.15. Pacific walrus sighting rates by seismic state for the *Gilavar* and its chase/monitoring vessels during (***A1***) the summer Chukchi Sea survey (21 Jul – 12 Sep 2007) and (***A2***) the summer Chukchi Sea survey excluding the *Gilavar's* 24 August walrus sightings (*n* = 148 non-seismic sightings).

Information on the direction and movement of observed animals is presented on scatter plots with headings displayed in other figures. In addition to the movement data, observers recorded marine mammal behavior and reaction. Marine mammal behavior and reaction are difficult to observe, especially from a seismic vessel, because individuals and/or groups typically spend most of their time below the water surface. Distribution, movement, behavior and reaction information were collected to analyze the effects of seismic operations on marine mammals. We present both seismic and non-seismic data for the *Gilavar* and chase/monitoring vessels. The chase/monitoring vessels were typically positioned forward of the source vessel; therefore, the chase/monitoring vessels' sightings were forward of the source vessel during both seismic and non-seismic periods.

## *Cetaceans*

***Distribution and Closest Observed Point of Approach—Summer Chukchi Sea survey:*** Nineteen and 29 cetaceans were observed from the *Gilavar* and chase/monitoring vessels respectively, in the Chukchi Sea during the summer survey period. Fewer cetaceans were sighted during seismic operations from both the *Gilavar* and the chase/monitoring vessels than during non-seismic periods (16 animals as opposed to 32; Figs. 5.16 and 5.17). Cetaceans were sighted at greater mean CPAs during seismic operations than during non-seismic periods from both vessels (Table 5.10). The difference in values for mean CPA for seismic versus non-seismic periods was much more pronounced for the *Gilavar* compared to the chase/monitoring vessels (Table 5.10). The mean CPA reported during seismic periods had the potential to be underestimated if some animals avoided the airguns at distances beyond those where they could be detected by MMOs. A total of four cetaceans were observed within the 180 dB sound level radius of the full airgun array from the *Gilavar* during seismic operations, but on each of these occasions, the mitigation gun was operating rather than the full array. It is expected that none of these four animals received sound levels of ≥180 dB and a shut down was not requested (the ≥180 dB sound level radius for the mitigation gun is 10 m or 11 yd).

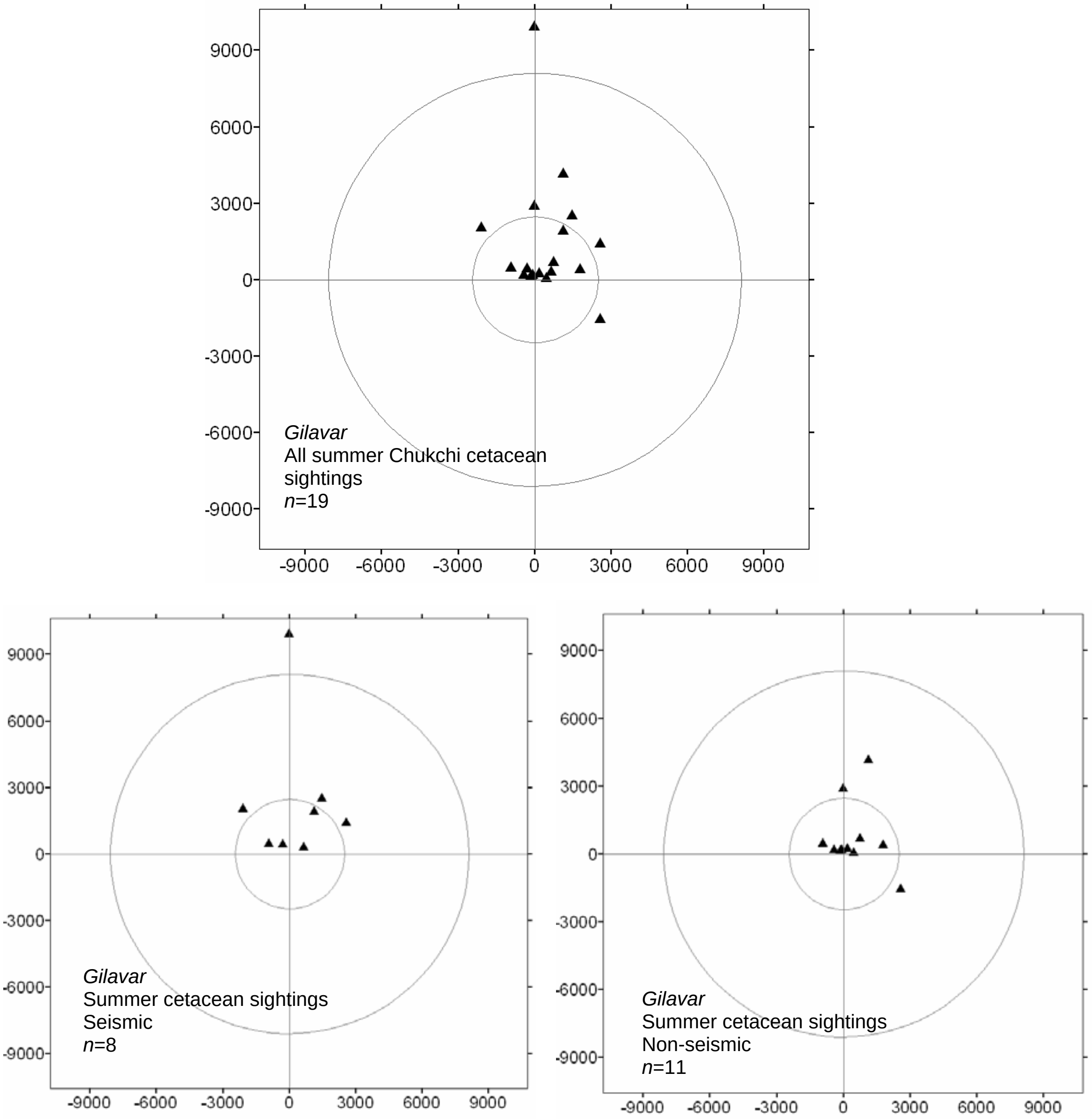


FIGURE 5.16. Relative bearing and distance (m) of cetacean sightings during the summer 2007 seismic survey from the *Gilavar* in the Chukchi Sea. The full seismic array's ≥180 and ≥160 dB sound level radii are shown (2.47 and 8.1 km or 1.53 and 5.03 mi, respectively). The cetacean locations indicate distance from the airgun array, 300 m (328 yd) aft of the observer. Distances between tick marks on both the X and Y axes = 1.86 mi.

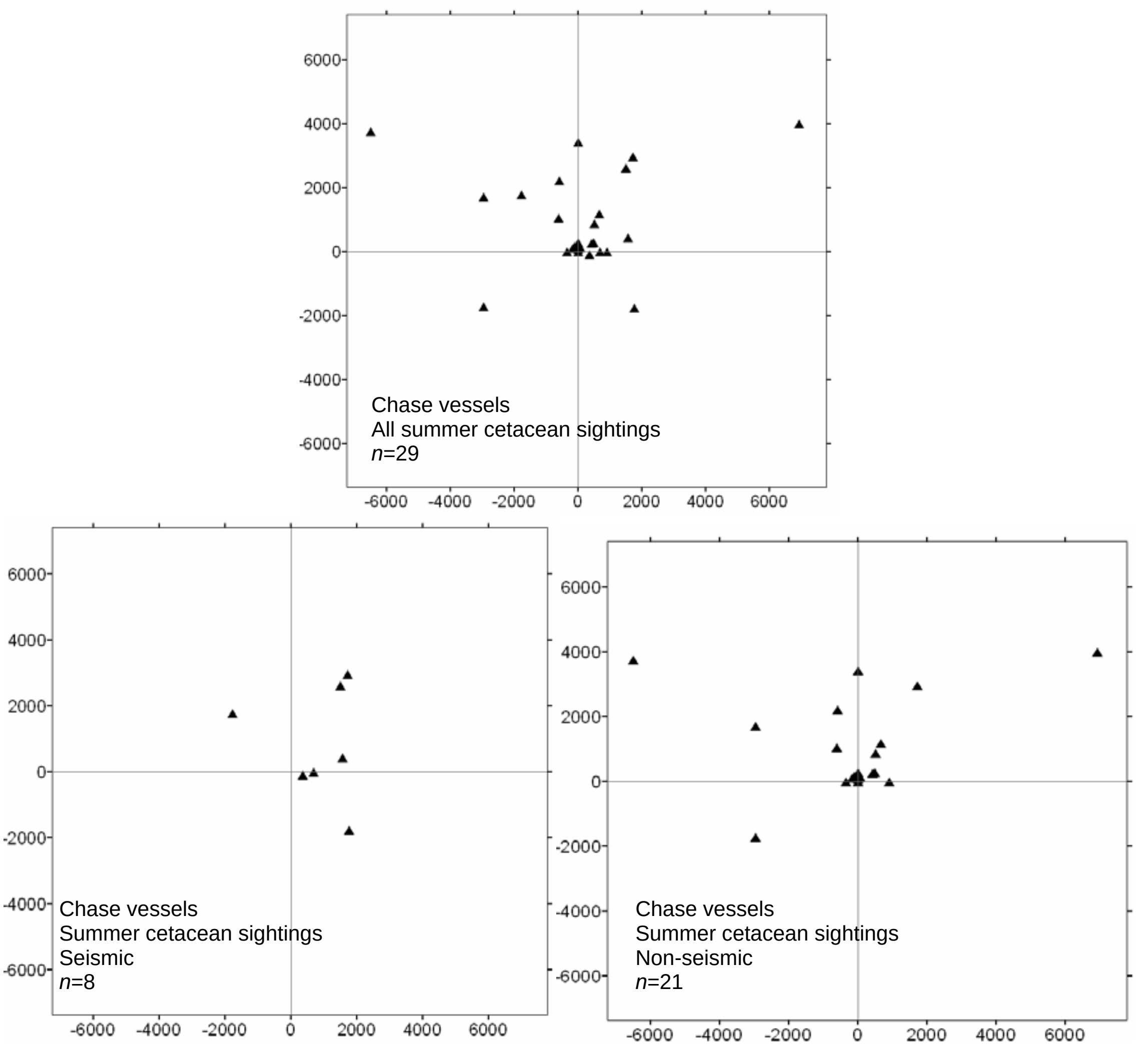


FIGURE 5.17. Relative bearing and distance (m) of cetacean sightings during the summer 2007 seismic survey from the marine mammal observer on the chase/monitoring vessels in the Chukchi Sea. Distances between tick marks on both the X and Y axes = 1.24 mi.

TABLE 5.10. Comparison of cetacean CPA distances by seismic period from daylight MMO watches aboard the *Gilavar* and its chase/monitoring vessels during the summer Chukchi Sea survey (21 Jul - 12 Sep 2007).

| Vessel and Seismic Status | Mean CPA[a] (m) | s.d. | Range (m) | *n* |
|---|---|---|---|---|
| ***Gilavar* Seismic** | 2747 | 3113 | 637-10067 | 8 |
| ***Gilavar* Non-seismic** | 1372 | 1139 | 309-3004 | 11 |
| ***Gilavar* Overall Mean** | ***1951*** | ***2231*** | ***309-10067*** | ***19*** |
| **Chase Vessels Seismic** | 1981 | 1157 | 376-3423 | 8 |
| **Chase Vessels Non-seismic** | 1892 | 2292 | 70-8000 | 21 |
| **Chase Vessels Overall Mean** | ***1917*** | ***2022*** | ***70-8000*** | ***29*** |

[a] CPA = *Closest Point of Approach*. For *Gilavar* this value is the marine mammal's closest point of approach to the airgun array, for chase vessels this value is the marine mammal's closest point of approach to the MMO/vessel.

***Distribution and Closest Observed Point of Approach—Fall Chukchi Sea survey:*** Only two cetaceans were observed during the fall seismic survey in the Chukchi Sea from the *Gilavar* (Fig. 5.18). Both of those sightings were of animals ahead of the vessel and occurred during non-seismic periods. The closer animal was 531 m (581 yd) away from the airgun array location and the other was 1558 m (0.97 mi) away from the airgun array. No cetaceans were observed from the chase/monitoring vessels during the fall survey.

***Movement—Summer Chukchi Sea Survey:*** Movement data and mean values of cetacean headings during non-seismic periods indicate that, in general, cetaceans were moving in a direction toward the stern of both the *Gilavar* and chase/monitoring vessels (Figs. 5.19-22). This suggests that the cetaceans were not vigorously avoiding either of the vessels during non-seismic periods. The MMOs could not determine the movement of the majority of cetaceans that were sighted during seismic periods (four out of seven), making a comparison of cetacean movements during seismic vs. non-seismic periods inappropriate.

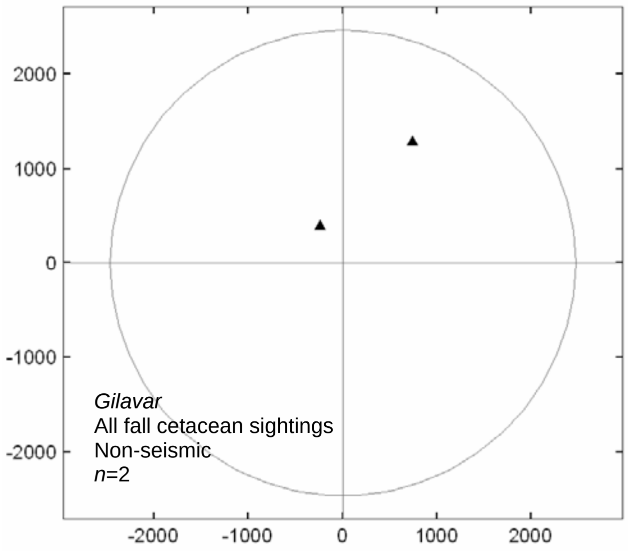


FIGURE 5.18. Relative bearing and distance (m) of cetacean sightings during the fall 2007 seismic survey from the *Gilavar* in the Chukchi Sea. The full seismic array's ≥180 dB sound level radius is displayed (2.47 km or 1.53 mi). Both of the sightings took place during "non-seismic" periods – at least two h after seismic operations had stopped. Distances between tick marks on both the X and Y axes = 0.62 mi.

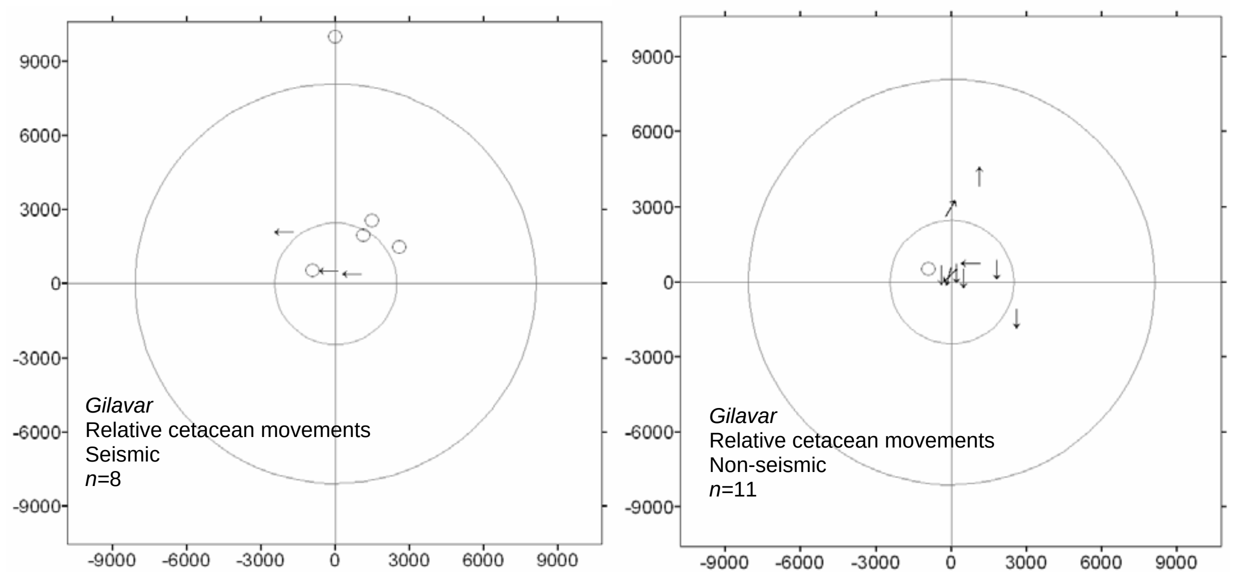
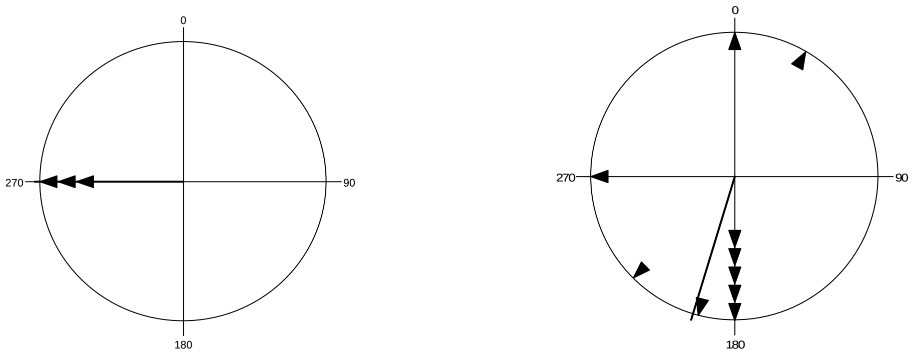


FIGURE 5.19. Movements of cetaceans during both “seismic” and “non-seismic” periods from the *Gilavar* during the summer 2007 seismic survey. The full seismic array’s ≥180 and ≥160 dB sound level radii are shown (2.47 and 8.1 km or 1.53 and 5.03 mi, respectively). The locations indicate distance (m) from the airgun array, 300 m (328 yd) aft of the observer. Circles indicate that the relative movement of the animal was unknown, “X”s indicate that the animal was not moving relative to the vessel. Distances between tick marks on both the X and Y axes = 1.62 mi.



Seismic

Non-seismic

FIGURE 5.20. Headings of cetaceans relative to the *Gilavar’s* trackline during seismic and non-seismic periods in the 2007 summer Chukchi Sea seismic survey. Mean heading is indicated by the line in the “compass”.

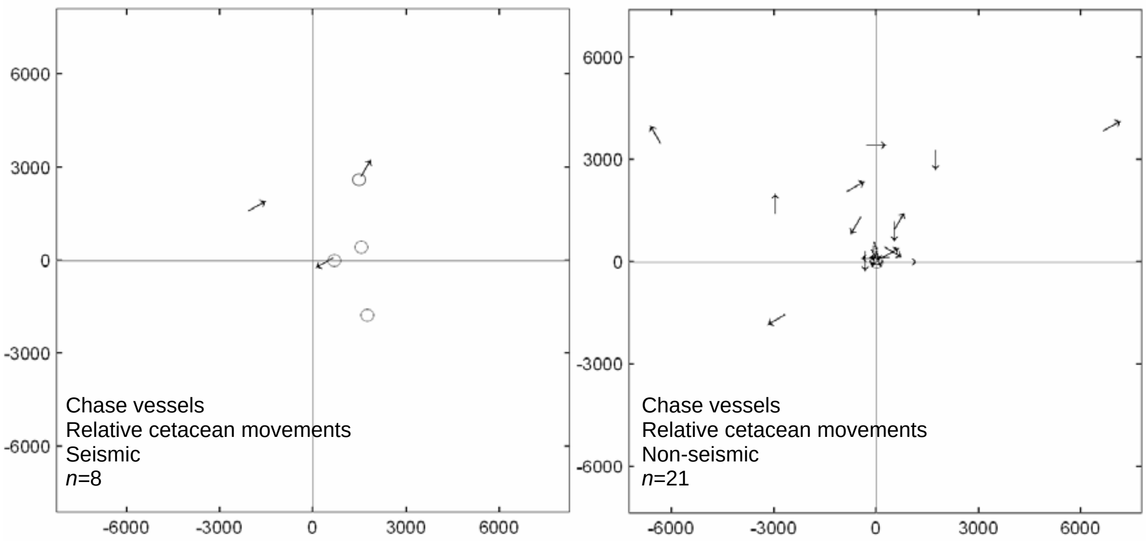


FIGURE 5.21. Movements of cetaceans during both "seismic" and "non-seismic" periods from the chase/monitoring vessels during the summer 2007 Chukchi Sea seismic survey. The locations indicate distance (m) from the observer. Circles indicate that the relative movement of the animal was unknown, "X"s indicate that the animal was not moving relative to the vessel. Distances between tick marks on both the X and Y axes = 1.86 mi.

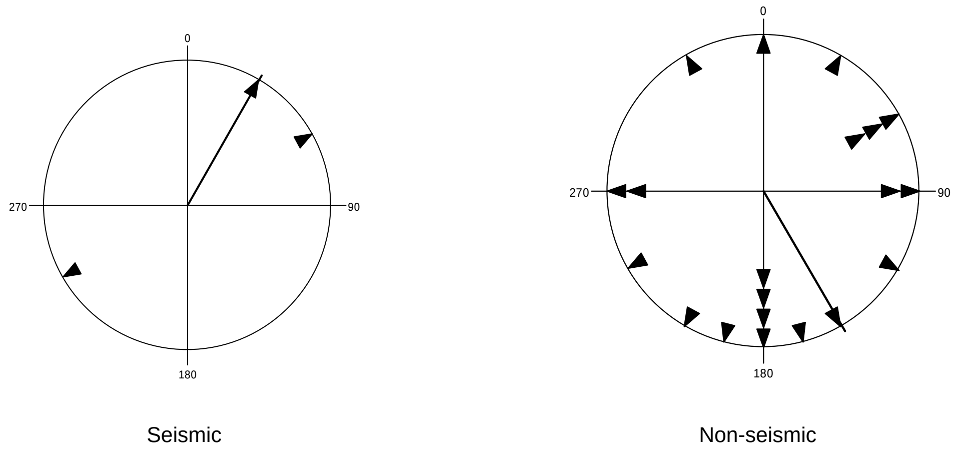


FIGURE 5.22. Headings of cetaceans relative to the chase/monitoring vessels' tracklines during seismic and non-seismic periods in the summer 2007 seismic survey. Mean heading is indicated by the line in the "compass".

***Initial Behavior—Summer Chukchi Sea Survey:*** Cetaceans did not demonstrate detectable differences in observed behaviors when comparing seismic and non-seismic sightings during the Chukchi summer survey period (Table 5.11). Most of the observed cetacean behaviors from both seismic and non-seismic periods were limited to the *surface active* category, and these behaviors include routine surface breathing and fluking behavior between dives.

TABLE 5.11. Comparison of cetacean behaviors by seismic period from daylight MMO watches aboard the *Gilavar* and its chase/monitoring vessels during the Chukchi Sea summer survey period (21 Jul - 12 Sep 2007).

| | **Initial Behavior** | | | | | | |
|---|---|---|---|---|---|---|---|
| **Vessel and Seismic Status** | **Dive** | **Feed** | **Rest** | **Surface Active** | **Swim** | **Other** | **Totals** |
| ***Gilavar*** **Seismic** | 0 | 0 | 0 | 7 | 1 | 0 | ***8*** |
| ***Gilavar*** **Non-seismic** | 1 | 0 | 0 | 10 | 0 | 0 | ***11*** |
| ***Gilavar Total*** | ***1*** | ***0*** | ***0*** | ***17*** | ***1*** | ***0*** | ***19*** |
| **Chase Vessels Seismic** | 0 | 0 | 0 | 2 | 4 | 2 | ***8*** |
| **Chase Vessels Non-seismic** | 0 | 2 | 0 | 18 | 1 | 0 | ***21*** |
| **Chase Vessels *Total*** | ***0*** | ***2*** | ***0*** | ***20*** | ***5*** | ***2*** | ***29*** |

***Reaction Behavior—Summer Chukchi Sea Survey***: Only one of the 48 observed cetaceans during the summer Chukchi Sea survey displayed activity that may have been a reaction to the vessel. An MMO stationed on the *Gilavar* observed an unidentified whale splashing (breaching) during a non-seismic period. The remaining 47 cetaceans sighted during the summer survey (16 during seismic and 31 during non-seismic) from both the *Gilavar* and the chase/monitoring vessels exhibited no overt (or discernable) reaction to the vessel (Table 5.12).

***Movement—Fall Chukchi Sea Survey:*** Both cetaceans observed from the *Gilavar* during the fall Chukchi Sea survey were sighted during non-seismic periods. The movements of both animals were away from the vessel's trackline. Both animals were observed ahead of the vessel (by at least 400 m or 437 yd); one was moving toward 90°of the *Gilavar's* track and the other toward 330° of the vessel's track.

***Initial Behavior—Fall Chukchi Sea Survey:*** One of the *Gilavar's* two Chukchi Sea fall cetacean sightings was coded as *swimming* and the other was noted as being *surface active*.

***Reaction Behavior—Fall Chukchi Sea Survey:*** Neither of the two cetaceans observed during the Chukchi Sea fall survey displayed any reaction. Both were observed during non-seismic periods. There were no observations indicative of distress or injury for any of the Chukchi Sea survey cetacean sightings during 2007.

## *Seals and Sea Lions*

***Distribution and Closest Observed Point of Approach—Summer Chukchi Sea Survey:*** Fourteen and 137 seals were observed from the *Gilavar* and chase/monitoring vessels, respectively, in the Chukchi Sea during the summer seismic and non-seismic periods. No sea lions were seen from the *Gilavar*, but one sea lion was observed from the chase/monitoring vessels during a non-seismic period. Many more seals were observed during non-seismic periods compared to seismic periods (24 and 126 sightings, respectively; Figs. 5.23 and 5.24). CPA values for seals were greater during seismic than during non-seismic periods from both vessels, and on average, animals were observed much closer to the chase/monitoring vessels than to the *Gilavar* during the summer Chukchi Sea survey (Table 5.13).

.TABLE 5.12. Reaction of cetaceans by seismic period from daylight MMO watches aboard the *Gilavar* and its chase/monitoring vessels during the Chukchi Sea summer survey period (21 Jul - 12 Sep 2007).

| | Reaction | | |
|---|---|---|---|
| Vessel and Seismic Status | Splash | None | Totals |
| *Gilavar* Seismic | 0 | 8 | ***8*** |
| *Gilavar* Non-seismic | 1 | 10 | ***11*** |
| ***Gilavar Total*** | ***1*** | ***18*** | ***19*** |
| *Chase Vessel(s)* Seismic | 0 | 8 | ***8*** |
| *Chase Vessel(s)* Non-seismic | 0 | 21 | ***21*** |
| ***Chase Vessel(s) Total*** | ***0*** | ***29*** | ***29*** |

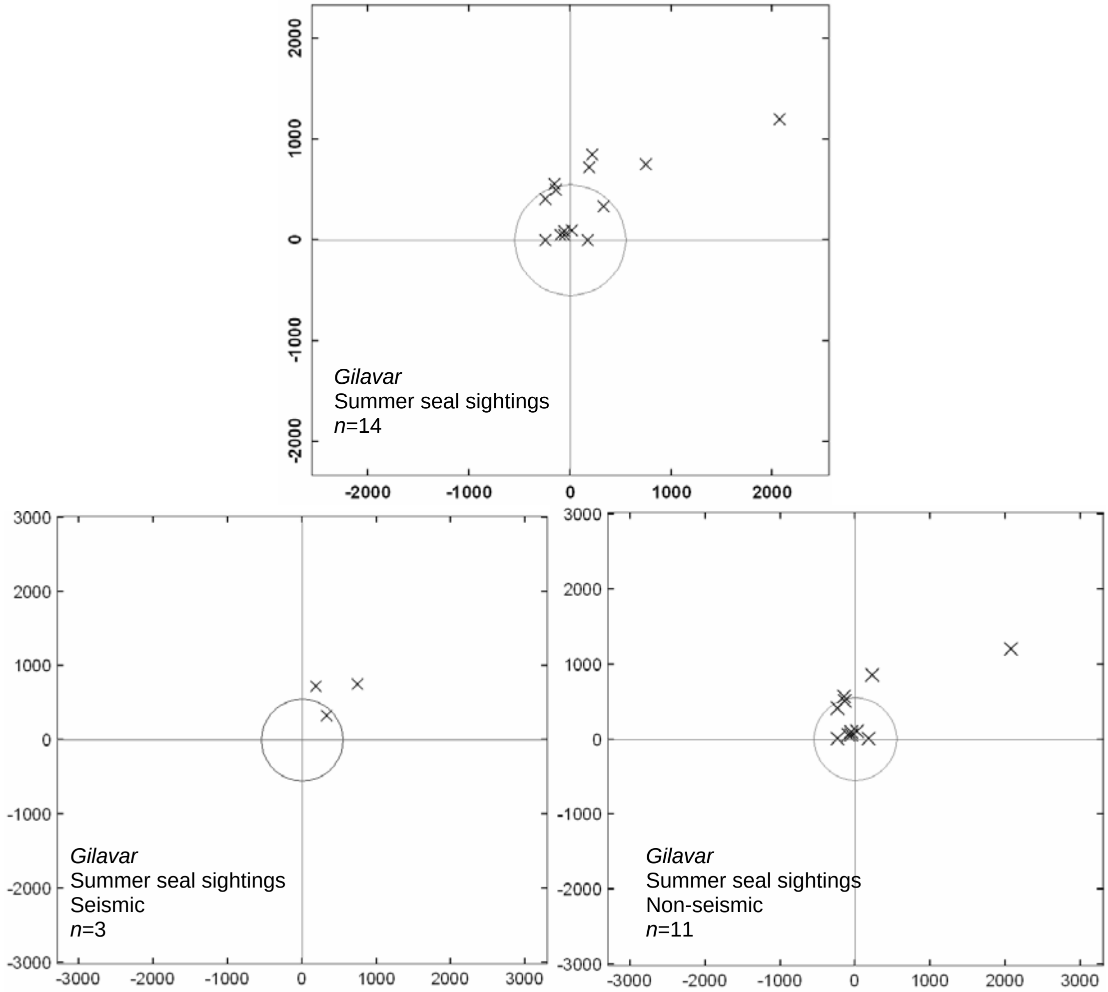


FIGURE 5.23. Relative bearings and distance (m) of seal sightings during the summer 2007 seismic survey from the *Gilavar* in the Chukchi Sea (no sea lions were observed from the *Gilavar*). The full seismic array's ≥190 dB sound level radius is displayed (0.55 km or 0.34 mi). The locations indicate distance from the airgun array, 300 m (328 yd) aft of the observer. Distances between tick marks on both the X and Y axes = 0.62 mi.

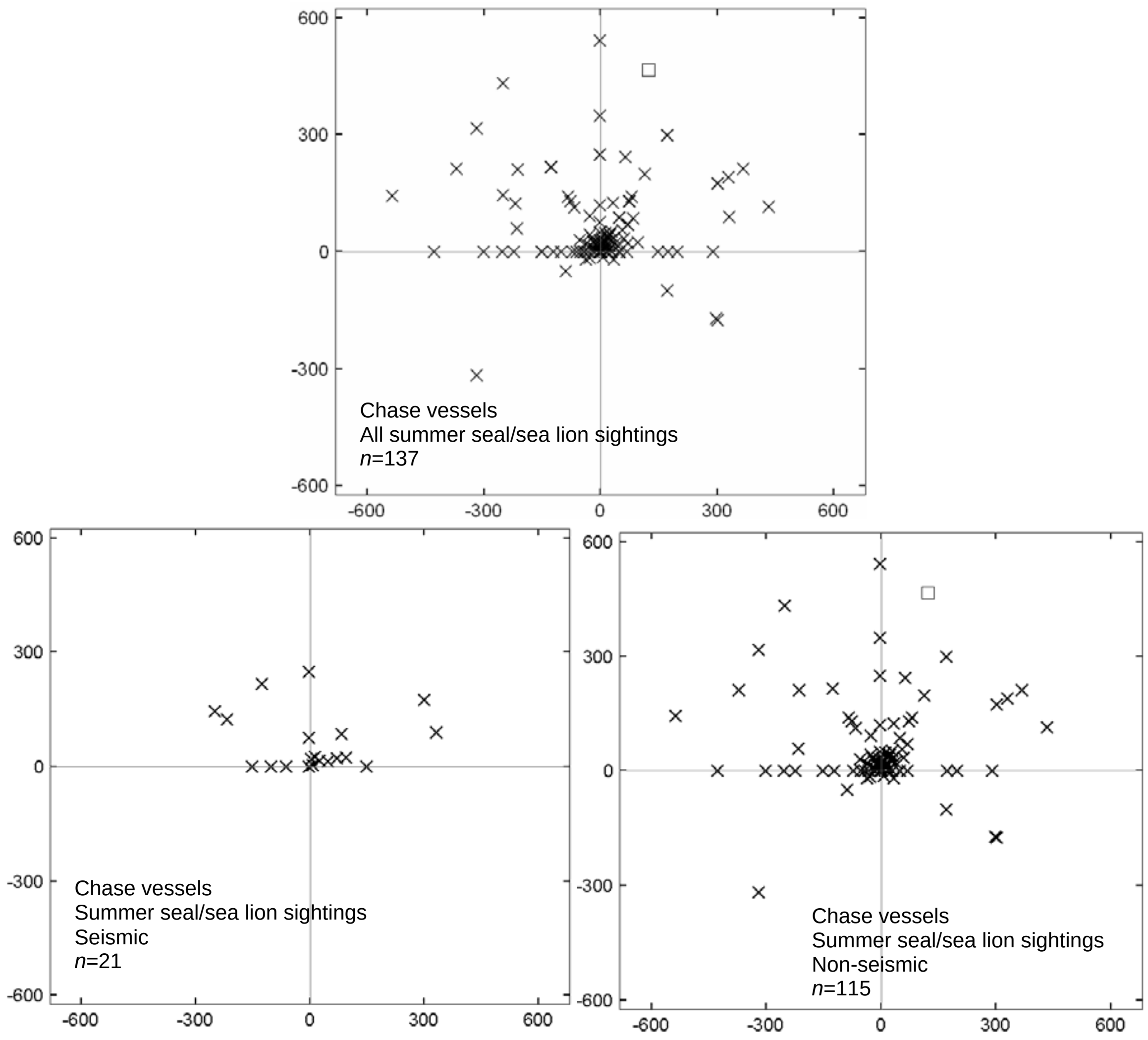


FIGURE 5.24. Relative bearings and distance (m) of seal and sea lion sightings during the summer 2007 seismic survey from the marine mammal observer on the chase/monitoring vessels in the Chukchi Sea. The square depicts theonesea lion sighting. Distances between tick marks on both the X and Y axes = 328 yd.

***Distribution and Closest Observed Point of Approach.—Fall Chukchi Sea Survey:*** Three and 46 seals were observed in water from the *Gilavar* and chase/monitoring vessels, respectively, in the Chukchi Sea during the fall seismic and non-seismic periods (an additional three seals were observed during the post-seismic period; there were no sea lion sightings during the fall Chukchi survey). More seal sightings were noted during non-seismic periods (35) compared to seismic periods (7) from the chase/monitoring vessels (Figs. 5.25 and 5.26). Mean seal CPA to the *Gilavar* was greater during seismic periods than non-seismic periods. However, unlike during the summer Chukchi Sea survey, the mean CPA of seals to the chase/monitoring vessels in the fall was greater during non-seismic than seismic periods (Table 5.14).

TABLE 5.13. Comparison of seal and sea lion CPA distances by seismic period from daylight MMO watches aboard the *Gilavar* and its chase/monitoring vessels during the summer Chukchi Sea survey (21 Jul - 12 Sep 2007).

| Vessel and Seismic Status | Mean CPA[a] (m) | s.d. | Range (m) | *n* |
|---|---|---|---|---|
| ***Gilavar*** **Seismic** | 696 | 155 | 521-815 | 3 |
| ***Gilavar*** **Non-seismic** | 522 | 664 | 131-2434 | 11 |
| ***Gilavar*** **Overall Mean** | ***559*** | ***591*** | ***131-2434*** | ***14*** |
| **Chase Vessels Seismic** | 132 | 112 | 10-350 | 21 |
| **Chase Vessels Non-seismic** | 132 | 138 | 1-554 | 115 |
| **Chase Vessels Overall Mean** | ***132*** | ***134*** | ***1-554*** | ***136*** |

[a] CPA = *Closest Point of Approach* . For *Gilavar* this value is the marine mammal's closest point of approach to the airgun array, for chase vessels this value is the marine mammal's closest point of approach to the MMO/vessel.

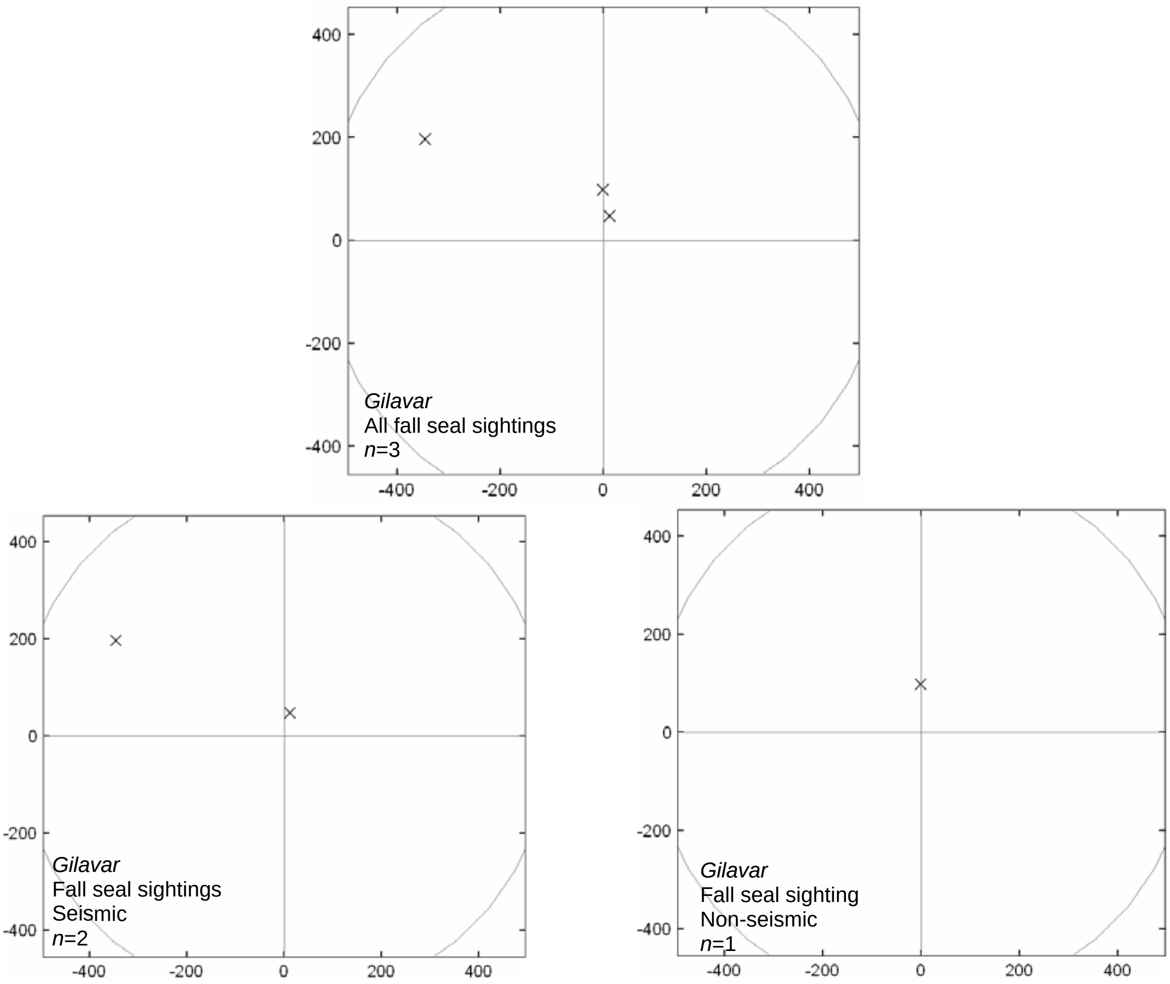


FIGURE 5.25. Relative bearing and distance (m) of seal sightings during the fall 2007 seismic survey from the *Gilavar* in the Chukchi Sea. The animals were observed well within the full seismic array's ≥190 dB sound level radius (0.55 km or 0.34 mi). The locations indicate distance from the airgun array located 300 m (328 yd) aft of the observer. Distances between tick marks on both the X and Y axes = 219 yd.

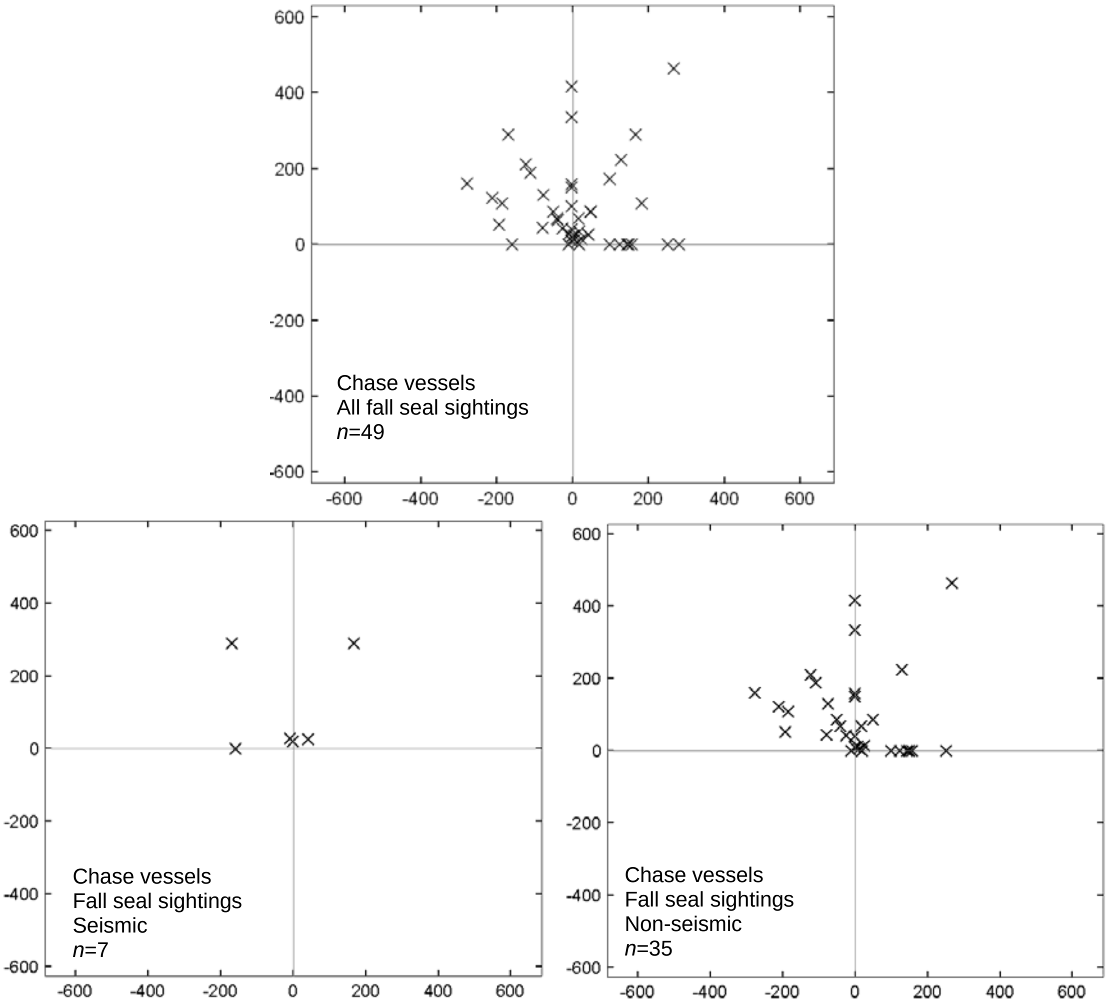


FIGURE 5.26. Relative bearings and distances of seal sightings during the fall 2007 seismic survey from the marine mammal observer on the chase/monitoring vessels in the Chukchi Sea. Distances between tick marks on both the X and Y axes = 219 yd.

TABLE 5.14. Comparison of seal CPA distances by seismic period from daylight MMO watches aboard the *Gilavar* and its chase/monitoring vessels during the fall Chukchi Sea survey (8 Oct - 5 Nov 2007).

| Vessel and Seismic Status | Mean CPA[a] (m) | s.d. | Range (m) | *n* |
|---|---|---|---|---|
| ***Gilavar*** **Seismic** | 274 | 228 | 113-436 | 2 |
| ***Gilavar*** **Non-seismic** | 167 | NA | 167 | 1 |
| ***Gilavar*** **Overall Mean** | ***238*** | ***172*** | ***113-435*** | ***3*** |
| **Chase Vessels Seismic** | 140 | 141 | 20-335 | 7 |
| **Chase Vessels Non-seismic** | 149 | 123 | 10-536 | 35 |
| **Chase Vessels Overall Mean** | ***147*** | ***124*** | ***10-536*** | ***42*** |

[a] CPA = *Closest Point of Approach*. For *Gilavar* this value is the marine mammal's closest point of approach to the airgun array, for chase vessels this value is the marine mammal's closest point of approach to the MMO/vessel.

***Movement—Summer Chukchi Sea Survey:*** Data describing seal movement relative to the *Gilavar* during the summer Chukchi survey were limited (Figs. 5.27 and 5.28). Data regarding seal movement relative to the chase/monitoring vessels during the summer Chukchi Sea survey suggests scattered movement. The mean headings for seals during both seismic and non-seismic periods were similar (both close to 145º; Figs. 5.29 and 5.30).

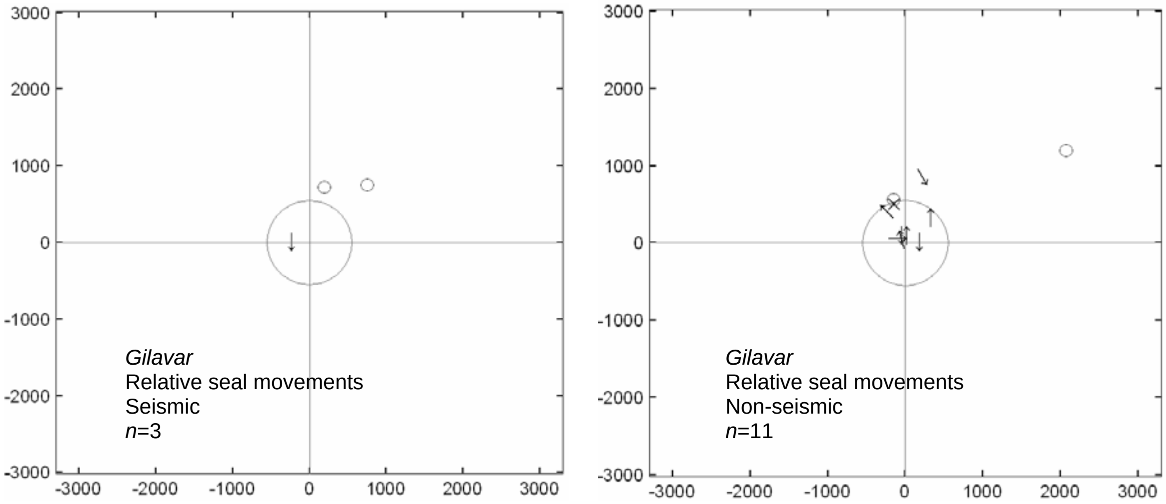


FIGURE 5.27. Movements of seals during both "seismic" and "non-seismic" periods recorded from the *Gilavar* during the summer 2007 seismic survey. The full seismic array's ≥190 dB sound level radius is displayed (0.55 km or 0.34 mi). The locations indicate distance from the airgun array, 300 m (328 yd) aft of the observer. Circles indicate that the relative movement of the animal was unknown, "X"s indicate that the animal was not moving relative to the vessel. Distances between tick marks on both the X and Y axes = 0.62 mi.

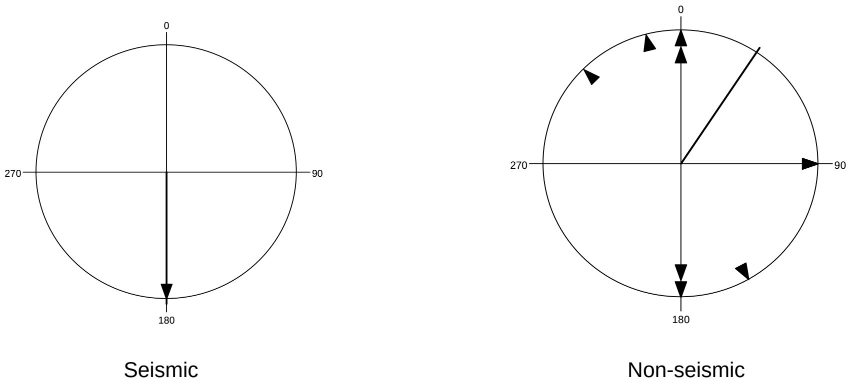


FIGURE 5.28. Headings of seals relative to the *Gilavar's* trackline during seismic and non-seismic periods in the summer 2007 seismic survey. Mean heading is indicated by the line in the "compass".

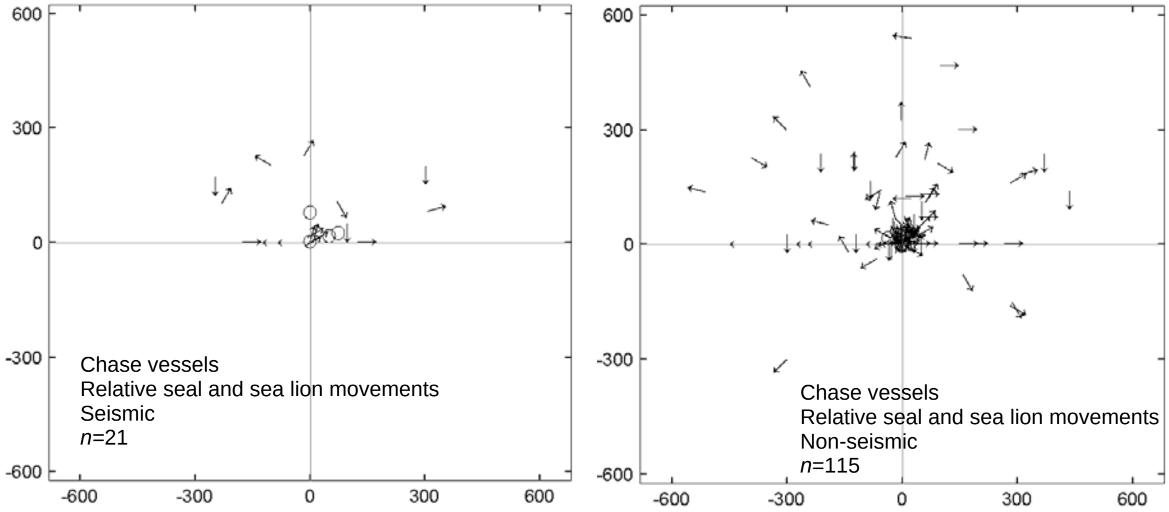
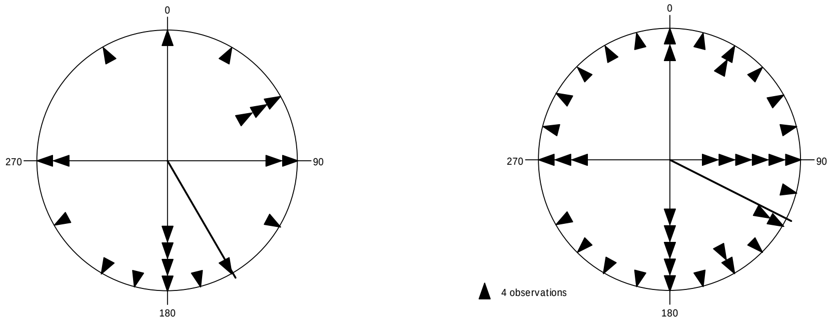


FIGURE 5.29. Movements of seals and sea lions during both "seismic" and "non-seismic" periods from the chase/monitoring vessels during the summer 2007 Chukchi Sea seismic survey. The locations indicate distance from the observer. Circles indicate that the animal's relative movement was unknown, "X"s indicate that the animal was not moving relative to the vessel. Distances between tick marks on both the X and Y axes = 328 yd.



Seismic

Non-seismic

FIGURE 5.30. Headings of seal and sea lions relative to the chase vessels' trackline during seismic and non-seismic periods in the summer 2007 seismic survey. Mean heading is indicated by the line in the "compass".

***Initial Behavior—Summer Chukchi Sea Survey:*** Seals and the single sea lion behaviors when initially detected did not show many notable differences between seismic and non-seismic periods during the summer Chukchi Sea survey period. Over half of the sightings (72 of 136 total) looked at the vessel, and animals appeared to spend more time active at the surface during non-seismic periods (Table 5.15).

TABLE 5.15. Comparison of seal and sea lion initial behavior by seismic period from daylight MMO watches aboard the *Gilavar* and its chase/monitoring vessels during the summer Chukchi Sea survey (21 Jul - 12 Sep 2007).

| | **Initial Behavior** | | | | | |
|---|---|---|---|---|---|---|
| **Vessel and Seismic Status** | **Dive** | **Look at Vessel** | **Rest** | **Surface Active** | **Swim** | **Totals** |
| ***Gilavar*** **Seismic** | 2 | 0 | 0 | 0 | 1 | ***3*** |
| ***Gilavar*** **Non-seismic** | 0 | 2 | 0 | 4 | 5 | ***11*** |
| ***Gilavar Total*** | ***2*** | ***2*** | ***0*** | ***4*** | ***6*** | ***14*** |
| **Chase Vessels Seismic** | 1 | 14 | 0 | 0 | 6 | ***21*** |
| **Chase Vessels Non-seismic** | 3 | 58 | 0 | 33 | 21 | ***115*** |
| **Chase Vessels *Total*** | ***4*** | ***72*** | ***0*** | ***33*** | ***27*** | ***136*** |

***Reaction Behavior—Summer Chukchi Sea Survey:*** The most common reaction recorded for seals and sea lions during the summer Chukchi survey was “none” for both seismic and non-seismic periods (Table 5.16). The *Gilavar* MMOs reported that 64% of the observed seals showed no reaction; chase/monitoring vessels MMOs reported that 78% of the seals and sea lions observed exhibited no reaction. The greatest percentage of recorded seal reaction observed from the *Gilavar* was “looking at vessel” which comprised 29% of total animal sightings (Table 5.16). A “splash” reaction accounted for the highest percentage (70%) of the total seals and sea lion reactions sighted from the chase/monitoring vessels (Table 5.16).

***Movement—Fall Chukchi Sea Survey:*** Two seals were sighted from the *Gilavar* during the fall Chukchi Sea survey while seismic operations were being conducted. One of the seals was moving away from the vessel’s trackline (to 15°) and the other’s movement relative to the vessel was undetermined. The seal observed from the *Gilavar* during a non-seismic period was moving toward 90°, away from the ship’s trackline. Movement and heading plots of the seals observed from the chase/monitoring vessels during the fall survey suggested that during both seismic and non-seismic periods, the animals were moving away from and ahead of the ship (Figs. 5.31 and 5.32).

TABLE 5.16. Reaction of seals and sea lions by seismic period from daylight MMO watches aboard the *Gilavar* and its chase/monitoring vessels during the Chukchi Sea summer survey period (21 Jul - 12 Sep 2007).

| | **Reaction** | | | | | | |
|---|---|---|---|---|---|---|---|
| Vessel and Seismic Status | Splash | Increase in speed | Decrease in speed | Change in direction | Looked at vessel | None | Totals |
| *Gilavar* Seismic | 0 | 0 | 0 | 0 | 1 | 2 | ***3*** |
| *Gilavar* Non-seismic | 0 | 1 | 0 | 0 | 3 | 7 | ***11*** |
| ***Gilavar Total*** | ***0*** | ***1*** | ***0*** | ***0*** | ***4*** | ***9*** | ***14*** |
| Chase vessels Seismic | 3 | 0 | 0 | 2 | 0 | 16 | ***21*** |
| Chase vessels Non-seismic | 18 | 2 | 1 | 4 | 0 | 90 | ***115*** |
| ***Chase vessels Total*** | ***21*** | ***2*** | ***1*** | ***6*** | ***0*** | ***106*** | ***136*** |

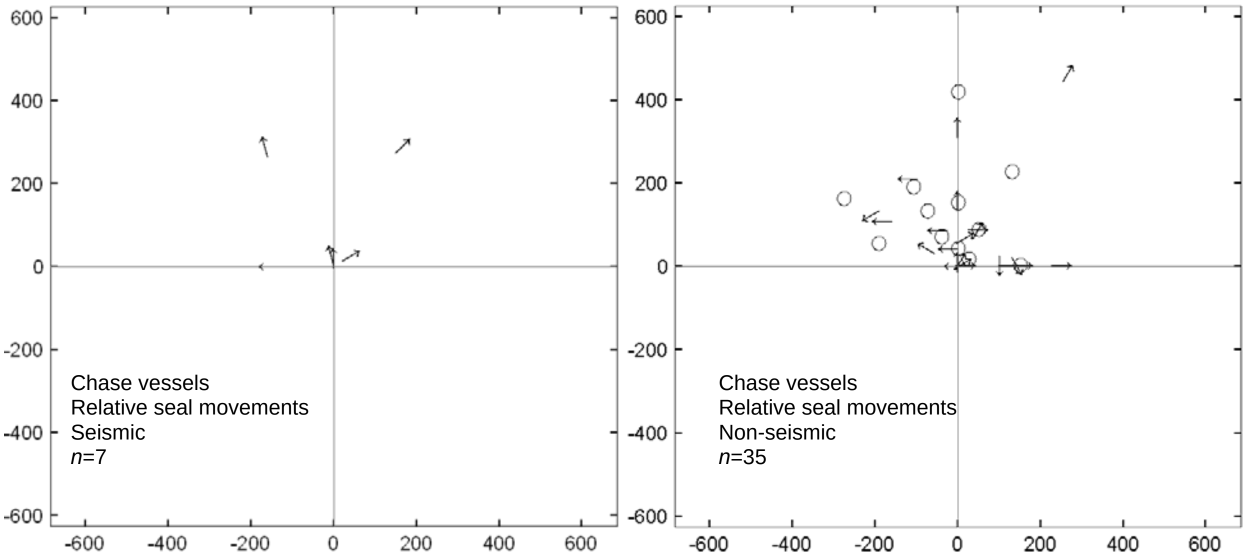


FIGURE 5.31. Movements of both "seismic" and "non-seismic" seal sightings from the chase/monitoring vessels during the fall 2007 Chukchi Sea seismic survey. The locations indicate distance from the observer. Circles indicate that the relative movement of the animal was unknown. Distances between tick marks on both the X and Y axes = 219 yd.

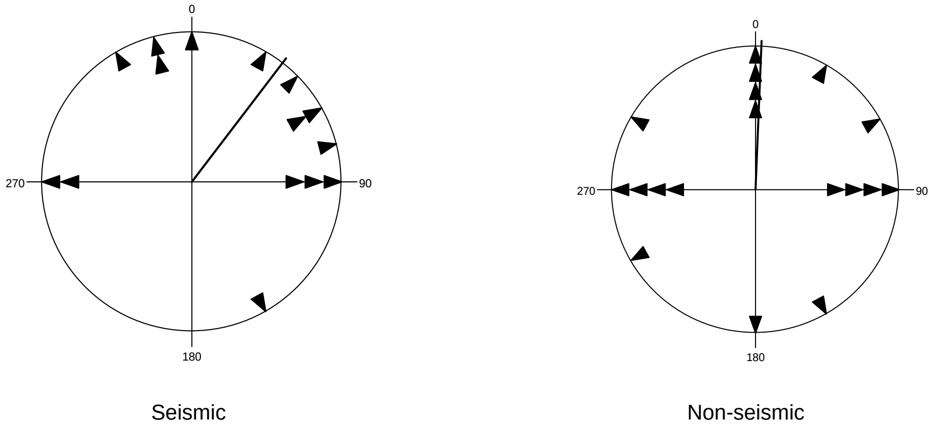


FIGURE 5.32. Headings of seal and sea lion sightings relative to the chase/monitoring vessels' trackline during seismic and non-seismic periods in the fall 2007 seismic survey. Mean heading is indicated by the line in the "compass".

***Initial Behavior—Fall Chukchi Sea Survey:*** Seals showed similar behavioral tendencies during the fall Chukchi Sea survey compared to the summer survey period and most individuals were noted to be active at the surface and/or looking at the vessel. There were no detectable differences in seal behavior between seismic and non-seismic periods during the fall survey (Table 5.17).

TABLE 5.17. Comparison of seal initial behavior by seismic period from daylight MMO watches aboard the *Gilavar* and its chase/monitoring vessels during the fall Chukchi Sea survey (8 Oct - 5 Nov 2007).

| | Initial Behavior | | | | | |
|---|---|---|---|---|---|---|
| **Vessel and Seismic Status** | **Dive** | **Look at Vessel** | **Rest** | **Surface Active** | **Swim** | **Totals** |
| ***Gilavar* Seismic** | 0 | 1 | 0 | 1 | 0 | ***2*** |
| ***Gilavar* Non-seismic** | 0 | 0 | 0 | 1 | 0 | ***1*** |
| ***Gilavar Total*** | ***0*** | ***1*** | ***0*** | ***2*** | ***0*** | ***3*** |
| **Chase Vessels Seismic** | 0 | 6 | 0 | 1 | 0 | ***7*** |
| **Chase Vessels Non-seismic** | 1 | 22 | 0 | 11 | 1 | ***35*** |
| **Chase Vessels *Total*** | ***1*** | ***28*** | ***0*** | ***12*** | ***1*** | ***42*** |

***Reaction Behavior—Fall Chukchi Sea Survey:*** During the fall Chukchi Sea survey, seals were more frequently reported to react to both the *Gilavar* and the chase/monitoring vessels than during the summer survey. "No reaction" comprised 33% of recorded seal reactions from the *Gilavar* and 24% of recorded seal reactions from the chase/monitoring vessels as opposed to 65% and 78% in the summer (Table 5.18). Sighting numbers from the *Gilavar* were too low to make comparisons of seal reactions between seismic and non-seismic periods. The majority (78%) of the total seal reactions recorded from the chase/monitoring vessels were during non-seismic periods. Of those 25 sightings, the most frequent reaction was looking at the vessel (64%), followed by splashing (32%) and change in direction (4%; Table 5.17). Of the 7 reactions of seals recorded from the chase/monitoring vessels during seismic periods, the most frequent reaction was looking at the vessel (86%) and the least frequent noted reaction was splashing (14%; Table 5.18).

## *Pacific Walruses*

***Distribution and Closest Observed Point of Approach—Summer Chukchi Sea Survey:*** There were 261 and 141 Pacific walrus sightings recorded aboard the *Gilavar* and its chase/monitoring vessels, respectively, during the summer Chukchi Sea survey. On average, Pacific walruses approached the chase/monitoring vessels closer than they did the *Gilavar* (mean CPA of 326 and 858 m [356 and 938 yd] respectively), and they were observed closer to the *Gilavar* during seismic compared to non-seismic periods (mean CPA of 663 compared to 894 m [725 compared to 998 yd], respectively) during the summer Chukchi survey (Figs. 5.33 and 5.34; Table 5.19).

TABLE 5.18. Reaction of seals and sea lions by seismic period from daylight MMO watches aboard the *Gilavar* and its chase/monitoring vessels during the Chukchi Sea fall survey (21 Jul - 12 Sep 2007).

| | Reaction | | | | |
|---|---|---|---|---|---|
| Vessel and Seismic Status | Splash | Change in direction | Looked at vessel | None | Totals |
| *Gilavar* Seismic | 1 | 0 | 1 | 0 | ***2*** |
| *Gilavar* Non-seismic | 0 | 0 | 0 | 1 | ***1*** |
| ***Gilavar Total*** | ***1*** | ***0*** | ***1*** | ***1*** | ***3*** |
| Chase vessels Seismic | 1 | 0 | 6 | 0 | ***7*** |
| Chase vessels Non-seismic | 8 | 1 | 16 | 10 | ***35*** |
| ***Chase vessels Total*** | ***9*** | ***1*** | ***22*** | ***10*** | ***42*** |

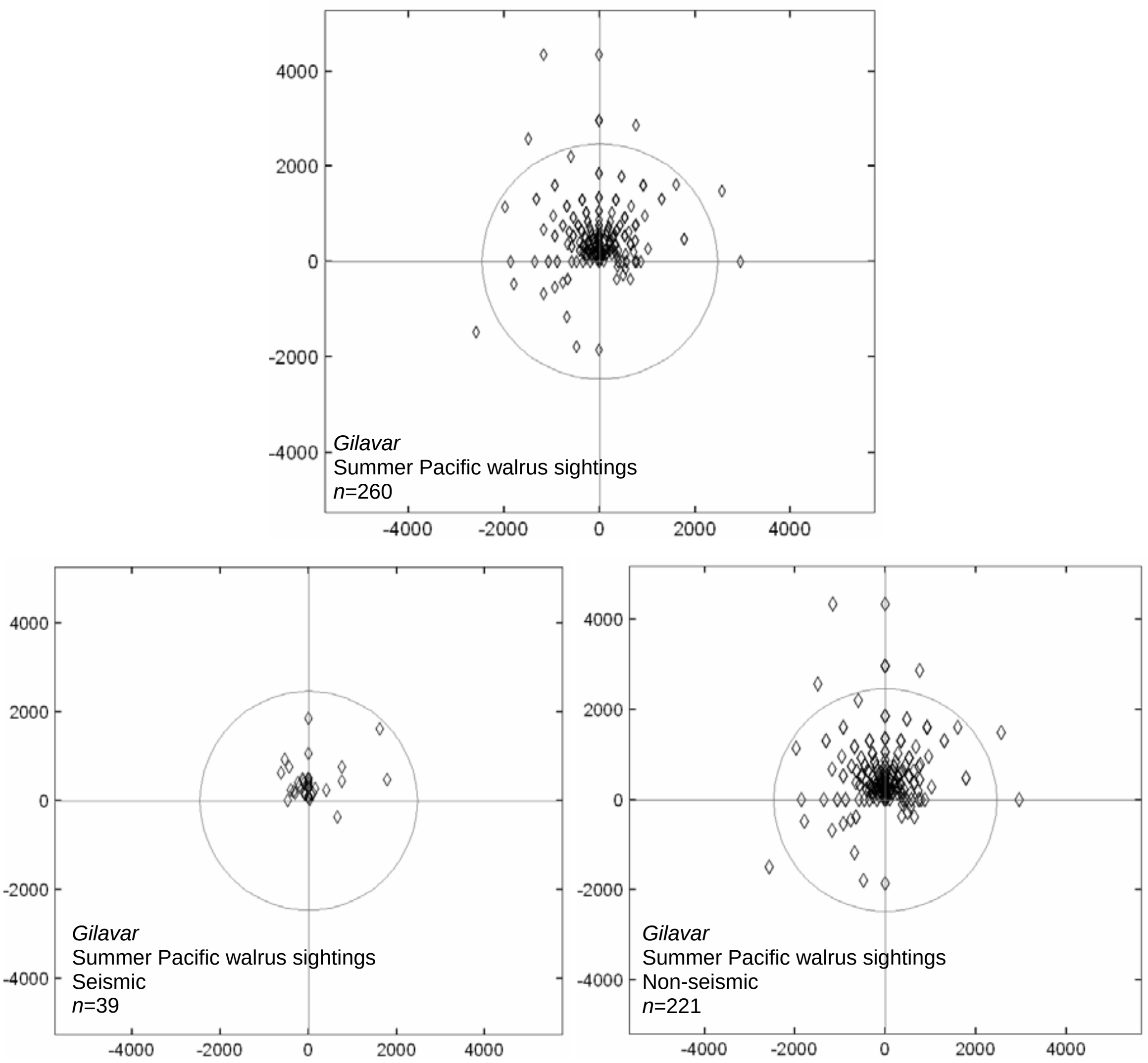


FIGURE 5.33. Relative bearings and distance (m) of Pacific walrus sightings during the summer 2007 seismic survey *Gilavar* in the Chukchi Sea. The full seismic array's ≥180 dB sound level radius is shown (2.47 km or 1.53 mi). The figures include six unidentified pinnipeds that were likely Pacific walruses. Distances between tick marks on both the X and Y axes = 1.24 mi.

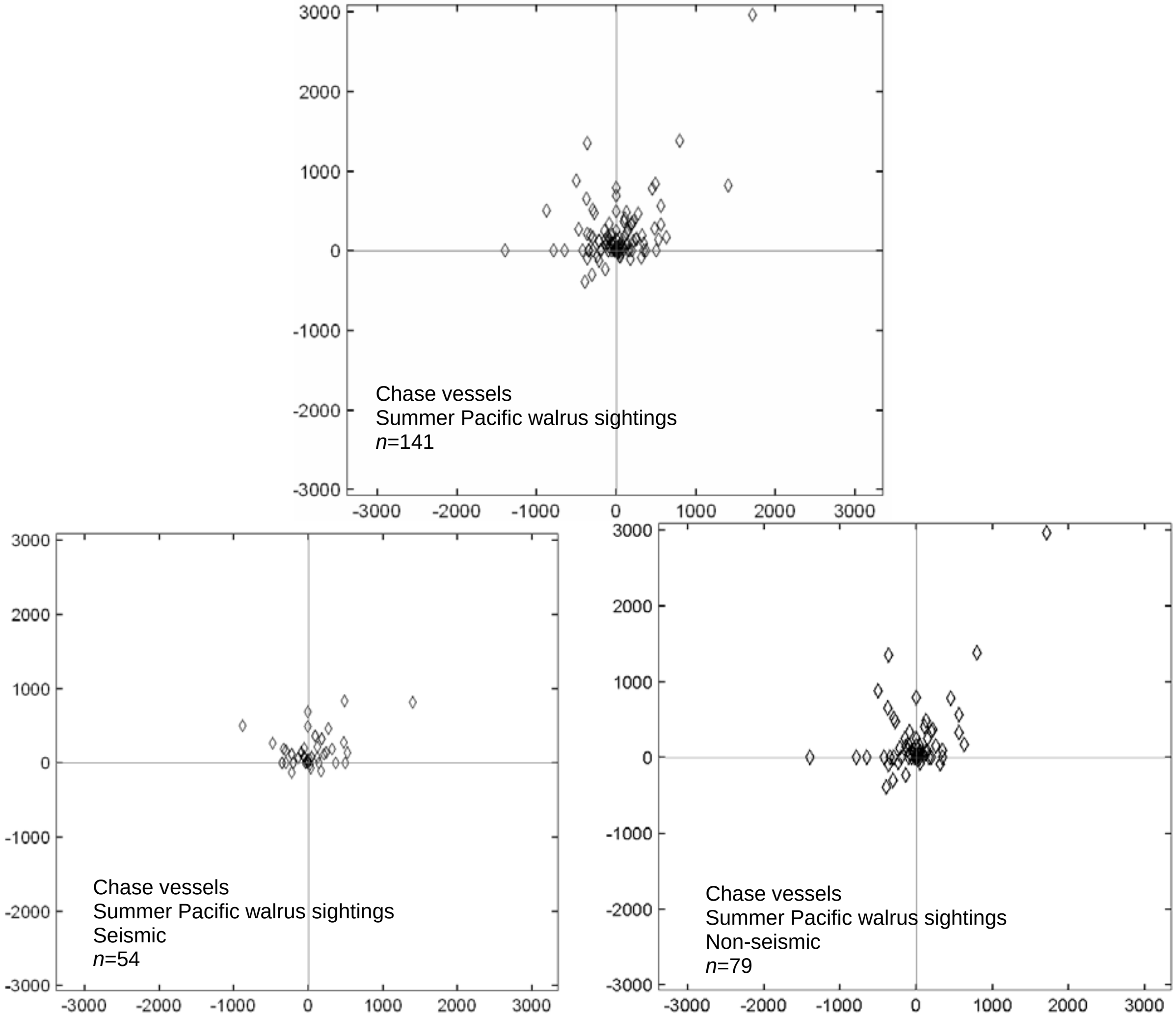


FIGURE 5.34. Relative bearings and distance (m) of Pacific walrus sightings during the summer 2007 seismic survey from the chase/monitoring vessels in the Chukchi Sea. Plots include five sightings of Pacific walruses on ice. Distances between tick marks on both the X and Y axes = 0.62 mi.

TABLE 5.19. Comparison of Pacific walrus CPA distances by seismic period from daylight MMO watches aboard the *Gilavar* and its chase/monitoring vessels during the summer Chukchi Sea survey (21 Jul - 12 Sep 2007).

| **Vessel and Seismic Status** | **Mean CPA[a] (m)** | **s.d.** | **Range (m)** | ***n*** |
|---|---|---|---|---|
| ***Gilavar* Seismic** | 663 | 522 | 82-2324 | 39 |
| ***Gilavar* Non-seismic** | 894 | 688 | 71-4564 | 221 |
| ***Gilavar* Overall Mean** | ***858*** | ***670*** | ***71-4564*** | ***260*** |
| **Chase Vessels Seismic** | 270 | 292 | 1-1631 | 54 |
| **Chase Vessels Non-seismic** | 364 | 490 | 1-3423 | 79 |
| **Chase Vessels Overall Mean** | ***326*** | ***422*** | ***1-3423*** | ***133*** |

[a] CPA = *Closest Point of Approach*. For *Gilavar* this value is the marine mammal's closest point of approach to the airgun array, for chase vessels this value is the marine mammal's closest point of approach to the MMO/vessel.

***Distribution and Closest Observed Point of Approach—Fall Chukchi Sea Survey:*** The single Pacific walrus observed by chase/monitoring vessels during the fall Chukchi survey approached the vessel to a distance of approximately 60 m (66 yd) while the *Gilavar* was firing its airguns ~2.5 km (1.55 mi) away. *Gilavar* MMOs did not observe any Pacific walruses during the fall Chukchi survey period.

***Movement—Summer Chukchi Sea Survey:*** The movement data of several Pacific walrus sightings from the *Gilavar* during seismic operations suggested that walruses were moving ahead of the vessel and away from the active airgun source (Figs. 5.34 and 5.35). Conversely, the movement data of Pacific walruses observed from the chase/monitoring vessels during seismic operations suggested that walruses were heading aft of the chase/monitoring vessels and therefore toward the active airgun array behind the *Gilavar* (Figs. 5.36 and 5.37). Pacific walrus movement information relative to the vessels during non-seismic periods was different from the seismic period data. The mean heading of Pacific walrus observed from the *Gilavar* during non-seismic periods was to the aft of the vessel; the mean heading of Pacific walruses sighted from the chase/monitoring vessels was forward and away from both ships.

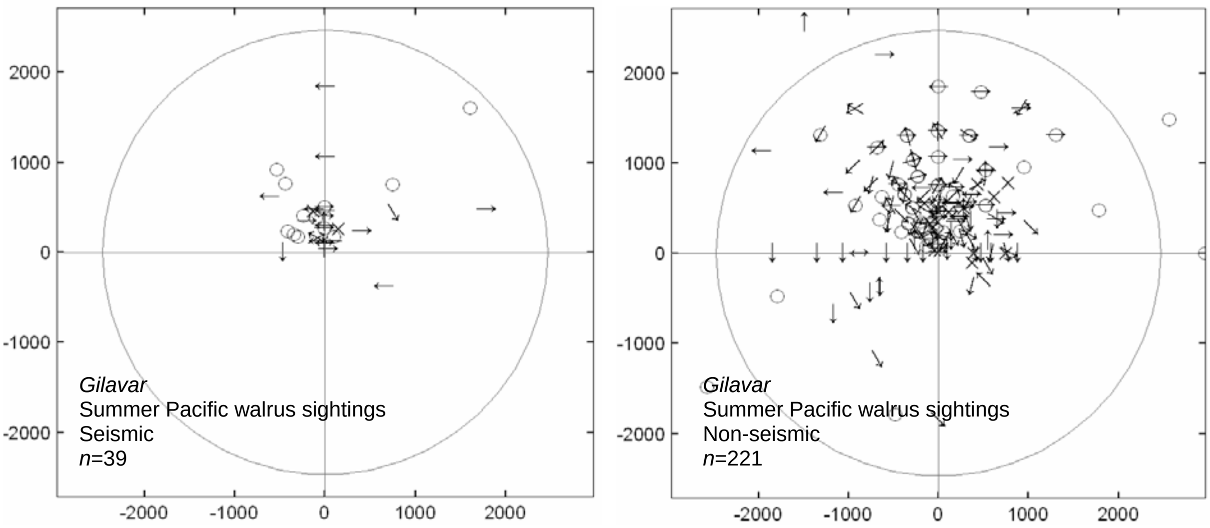


FIGURE 5.35. Movements of both “seismic” and “non-seismic” Pacific walrus sightings from the *Gilavar* during the summer 2007 seismic survey. The full seismic array’s ≥180 dB sound level radius is displayed (2.47 km or 1.53 mi). The scale of the movement plots has been increased from that of the scatter plots for better visibility of the movement. The locations indicate distance (m) from the airgun array, 300 m (328 yd) aft of the observer. Circles indicate that the relative movement of the animal was unknown, “X”s indicate that the animal was not moving relative to the vessel. Distances between tick marks on both the X and Y axes = 0.62 mi.

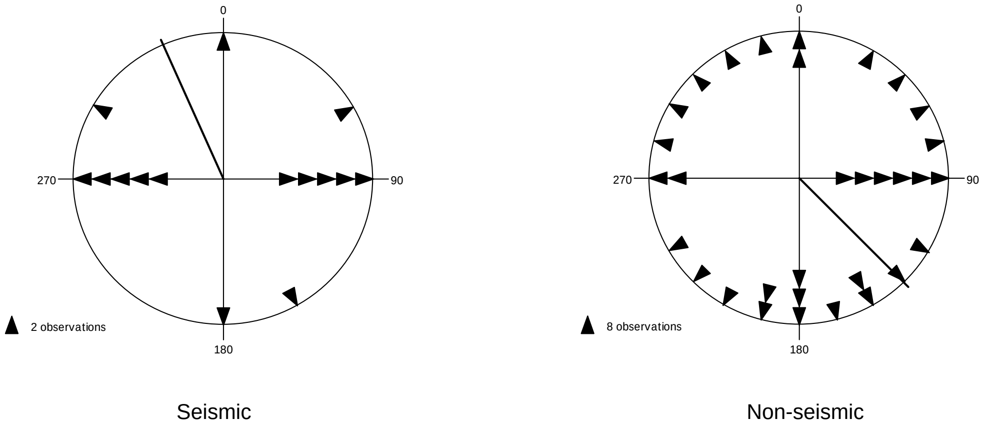


FIGURE 5.36. Headings of Pacific walruses relative to the *Gilavar's* trackline during seismic and non-seismic periods in the fall 2007 seismic survey. Mean heading is indicated by the line in the "compass".

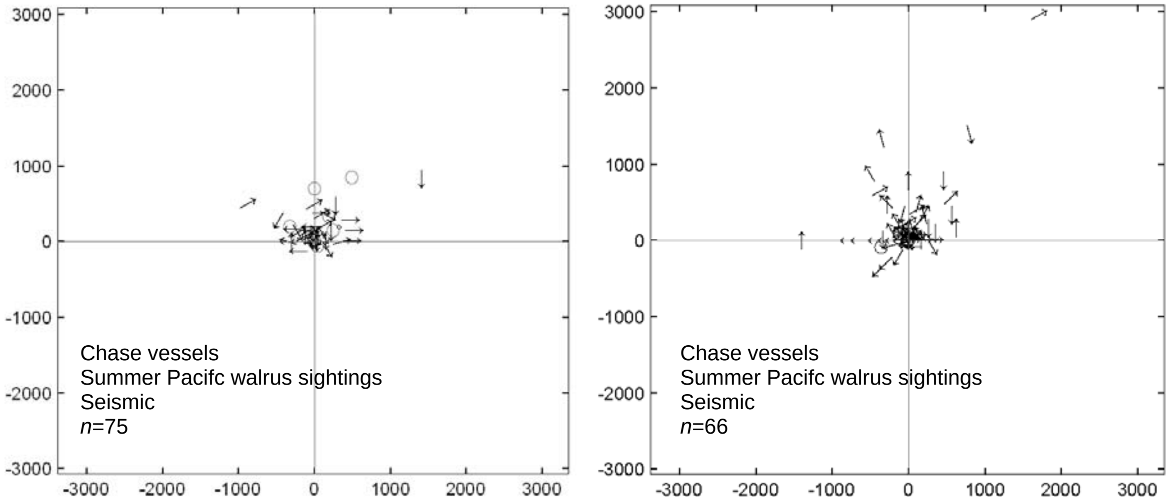
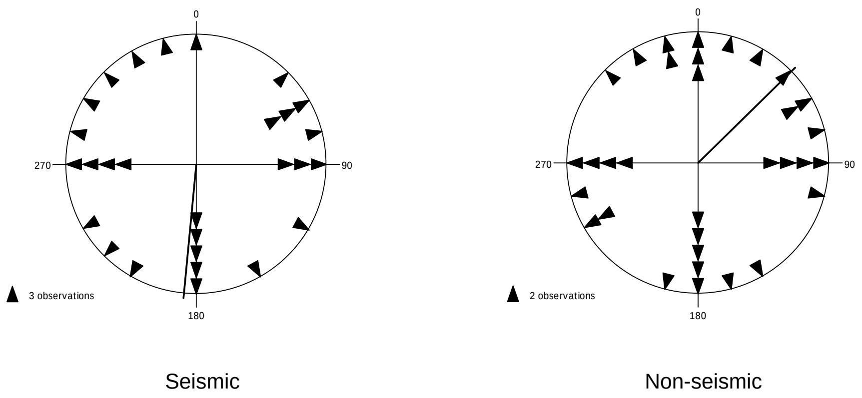


FIGURE 5.37. Recorded movements of both "seismic" and "non-seismic" Pacific walrus sightings from the chase/monitoring vessels during the summer 2007 Chukchi Sea seismic survey. The locations indicate distance (m) from the observer. The scale of the movement plots has been increased from that of the distribution plots (Fig. 5.33) for better visibility of the movement. Circles indicate that the relative movement of the animal was unknown, "X"s indicate that the animal was not moving relative to the vessel. Distances between tick marks on both the X and Y axes = 0.62 mi.



Seismic

Non-seismic

FIGURE 5.38. Headings of Pacific walruses relative to the chase/monitoring vessels' trackline during seismic and non-seismic periods in the fall 2007 seismic survey. Mean heading is indicated by the line in the "compass".

***Initial Behavior—Summer Chukchi Sea Survey:*** Behavioral observations of Pacific walruses during the summer Chukchi survey suggest that animals spent more time active at the surface during non-seismic than seismic periods (33 and two sightings, respectively, for the *Gilavar*; 30 and no sightings, respectively, for the chase/monitoring vessels; Table 5.20). Swimming was the most commonly recorded behavior during both seismic and non-seismic periods.

***Reaction Behavior—Summer Chukchi Sea Survey:*** Overall, Pacific walruses were most frequently recorded as showing no reaction during the summer Chukchi survey by MMOs on both the *Gilavar* and chase/monitoring vessels (85% of total *Gilavar* observations and 79% of total chase/monitoring vessels' observations; Table 5.20). Of the 66 animals that were recorded as exhibiting a reaction, the reactions occurred fairly evenly between seismic and non-seismic periods (32 and 34, respectively; Table 5.20). Looking at the vessel was the most frequently reported reaction during seismic operations (47% of the total), and splash was the least frequently reported reaction (12%; Table 5.21). The most frequent reaction of Pacific walruses observed from the *Gilavar* during non-seismic periods was looking and comprised 77% of the total reactions recorded during non-seismic periods. The majority of Pacific walrus reactions noted by chase/monitoring vessel MMOs was changing direction for both seismic and non-seismic (57% and 43% of the totals, respectively).

***Movement and Initial Behavior—Fall Chukchi Sea Survey:*** The single fall Chukchi Sea survey sighting of a Pacific walrus was noted to be 'playing' in the wake of the chase/monitoring vessels while the *Gilavar* was firing its airguns ~2.5 km (127 mi) away. The animal's heading was 180°, aft of the chase/monitoring vessels and therefore toward the general direction of the *Gilavar*.

***Reaction to Vessel—Fall Chukchi Sea Survey:*** The one Pacific walrus observed during the fall Chukchi Sea survey from the chase/monitoring vessels displayed no reaction to the vessel.

TABLE 5.20. Comparison of Pacific walrus initial behavior by seismic period from daylight MMO watches aboard the *Gilavar* and its chase/monitoring vessels during the summer Chukchi Sea survey (21 Jul - 12 Sep 2007). Five Pacific walruses on ice observed from the *Gilavar* are included in this table.

| | **Initial Behavior** | | | | | |
|---|---|---|---|---|---|---|
| **Vessel and Seismic Status** | **Dive** | **Look at Vessel** | **Rest** | **Surface Active** | **Swim** | **Totals** |
| ***Gilavar*** **Seismic** | 3 | 5 | 0 | 2 | 29 | ***39*** |
| ***Gilavar*** **Non-seismic** | 5 | 15 | 2 | 33 | 166 | ***221*** |
| ***Gilavar Total*** | ***8*** | ***20*** | ***2*** | ***35*** | ***195*** | ***260*** |
| **Chase Vessels Seismic** | 0 | 10 | 0 | 0 | 44 | ***54*** |
| **Chase Vessels Non-seismic** | 2 | 12 | 5 | 30 | 30 | ***79*** |
| **Chase Vessels *Total*** | ***2*** | ***22*** | ***5*** | ***30*** | ***74*** | ***133*** |

## *Mitigation Measures Implemented*

A total of 26 power downs of the airguns was requested by *Gilavar* MMOs due to sightings of Pacific walruses within or approaching the ≥180 dB (rms) safety radius of the full airgun array during the summer Chukchi Sea survey period (Table 5.21A). There were no power downs of the airguns for cetaceans, seals, or sea lions during the summer survey. No shutdowns of the airguns were required or occurred as a result of marine mammal presence within or near safety radii during the summer survey.

The 180dB (rms) safety radius used by SOI during 2006 (1200 m; 1312 yd) was also used for mitigation during the initial seismic acquisition from 29 Aug through 2 Sep 2007 as specified in the IHA. SSV measurements by JASCO determined that the actual 180 dB safety radius was 2470 m (2701 yd) and this distance was used to define the safety radius for walruses and cetaceans beginning on 3 Sep. Four power downs occurred prior to 3 Sep and resulted from the presence of Pacific walruses within the 1200 m (2701 yd) safety radius. The remaining 22 power downs during the 2007 summer Chukchi Sea survey occurred from 3 through 11 Sep during use of the revised 180 dB safety radius. All of the Pacific walruses involved in the 26 power downs were outside the 180 dB (rms) safety radius of the mitigation gun. Thus a complete shutdown of the airguns was not requested.

Of the 26 total summer Chukchi Sea survey power downs for Pacific walruses, one occurred as airguns were being tested (prior to SSV, airgun volume between 30 and 3147 in$^3$), six were during ramp ups of the airgun array (airgun volume between 30 and 3147 in$^3$), and the remaining 19 occurred while the airguns were firing at full array volume (3147 in$^3$). Chase/monitoring vessels assisted with monitoring the larger 2007 Chukchi Sea safety radii (with respect to 2006 Chukchi Sea safety radii) by radioing all of their marine mammal sightings to MMOs aboard the *Gilavar*. *Gilavar* MMOs then used navigation equipment to plot the location of these sightings with respect to the airgun array. Nine of the 26 power downs during the summer Chuikchi Sea survey resulted from information supplied by MMOs on the chase/monitoring vessels.

Pairs of Pacific walruses were the most common group size involved in summer Chukchi survey power downs. Of the 26 total power downs, 16 were for a pair of walruses, six of which were cow/calf pairs. The remaining 10 Pacific walrus power downs from the summer survey period were for single animals (six) and groups of three (four).

The revised safety radii as determined during SSV were also used during the fall Chukchi Sea survey. There was a single power down during the fall survey after a bearded seal was detected inside the ≥190 dB safety radius (Table 5.21B). There were no other power downs or shut downs of airguns during the fall Chukchi Sea survey.

## *Estimated Number of Marine Mammals Present and Potentially Affected*

It is 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 and situations. ***(3)*** The distance to which a received sound level exceeds a specific criterion such as 190 dB, 180 dB, 170 dB, or 160 dB re 1 µPa (rms) is variable. The received sound level depends on water depth, sound-source depth, water-mass and bottom conditions, and—for directional sources—aspect (Chapters 3 and 4; 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 further reduced for animals that are on ice.

### *Disturbance and Safety Criteria*

Table 4.1 shows estimated received sound levels at various distances from the *Gilavar's* 3-string airgun array. USFWS employed the received sound levels of ≥180 dB and ≥190 dB re 1 µPa (rms) as mitigation criteria for Pacific walruses and polar bears, respectively, in 2007. The application of the ≥180 dB (rms) criterion for Pacific walruses was a more conservative approach to walrus mitigation than the use of the ≥190 dB (rms) exclusion area that was required in 2006. The safety and disturbance radii, which are summarized in Tables 4.1, were used after the field season to estimate numbers of marine mammals exposed to various received sound levels.

Two methods were applied 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 include ***(A)*** minimum estimates based on the direct observations of marine mammals by MMOs, and ***(B)*** estimates based on pinniped and cetacean densities obtained during this study. 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.

TABLE 5.21A. List of power downs for marine mammals sighted in the *Gilavar*'s ≥180 dB safety radius (2470 m; 2701 yd)) during the summer Chukchi Sea seismic survey (21 Jul - 12 Sep 2007).

| Sighting ID | Species | Group Size | Day in 2007 UTC | Water Depth (m) | Reaction to Vessel[a] | Distance (m) to airguns at first detection | CPA[b] (m) to airguns |
|---|---|---|---|---|---|---|---|
| 286 | Pacific walrus | 1 | 29-Aug | 41.4 | IS | 237 | 237 |
| 291 | Pacific walrus | 2 | 30-Aug | 14.1 | LO | 883 | 883 |
| 294 | Pacific walrus | 2 | 31-Aug | 41.7 | IS | 167 | 167 |
| 295 | Pacific walrus | 2 | 31-Aug | 41.7 | NO | 338 | 331 |
| 297 | Pacific walrus | 2 | 3-Sep | 40.3 | LO | 476 | 476 |
| 300 | Pacific walrus | 3 | 4-Sep | 41.8 | IS | 210 | 210 |
| 302 | Pacific walrus | 2 | 5-Sep | 41.1 | LO | 567 | 567 |
| 304 | Pacific walrus | 3 | 5-Sep | 39.8 | NO | 411 | 134 |
| *305 | Pacific walrus | 2 | 6-Sep | 42.0 | *NA* | 1454 | 1456 |
| 306 | Pacific walrus | 1 | 6-Sep | 41.8 | LO | 536 | 82 |
| *307 | Pacific walrus | 2 | 6-Sep | 42.5 | *NA* | 2110 | 2082 |
| *308 | Pacific walrus | 1 | 6-Sep | 40.1 | *NA* | 2281 | 2038 |
| 309 | Pacific walrus | 3 | 7-Sep | 40.0 | LO | 108 | 108 |
| *311 | Pacific walrus | 1 | 7-Sep | 39.3 | *NA* | 1866 | 1616 |
| *312 | Pacific walrus | 2 | 7-Sep | 40.5 | *NA* | 2197 | 1930 |
| *313 | Pacific walrus | 2 | 7-Sep | 41.1 | *NA* | 2255 | 1679 |
| *318 | Pacific walrus | 2 | 7-Sep | 40.7 | *NA* | 2436 | 2326 |
| 319 | Pacific walrus | 1 | 7-Sep | 41.0 | LO | 1124 | 1124 |
| 329 | Pacific walrus | 1 | 7-Sep | 40.5 | LO | 381 | 381 |
| 331 | Pacific walrus | 2 | 8-Sep | 40.4 | NO | 1133 | 1085 |
| 340 | Pacific walrus | 2 | 8-Sep | 41.9 | LO | 362 | 312 |
| *343 | Pacific walrus | 2 | 9-Sep | 41.9 | *NA* | 2363 | 2214 |
| *346 | Pacific walrus | 2 | 9-Sep | 42.2 | *NA* | 2420 | 2471 |
| 347 | Pacific walrus | 2 | 10-Sep | 40.5 | LO | 370 | 370 |
| 348 | Pacific walrus | 2 | 11-Sep | 39.7 | LO | 465 | 465 |
| 349 | Pacific walrus | 3 | 11-Sep | 41.7 | NO | 916 | 403 |

TABLE 5.21B. The single power down in the *Gilavar*'s ≥190 dB safety radius (550 m; 601 yd) during the fall Chukchi Sea seismic survey (8 Oct - 5 Nov 2007).

| Sighting ID | Species | Group Size | Day in 2007 UTC | Water Depth (m) | Reaction to Vessel[a] | Distance (m) to airguns at first detection | CPA (m) to airguns |
|---|---|---|---|---|---|---|---|
| 419 | Bearded Seal | 1 | 2-Nov | 39.0 | LO | 435 | 435 |

* Indicates animal(s) sighted by chase vessel and determined to be within the 180 dB safety radius

[a] Observed reaction of animal to vessel: IS=Increase Speed, LO=Look at Vessel, NO=None, *NA* =Not Applicable as sighting was reported by *Chase Vessel*

[b] CPA=Closest Point of Approach

## *Estimates from Direct Observations*

The number of marine mammals observed close to the *Gilavar* during Chukchi Sea monitoring provides a minimum estimate of the number potentially affected by seismic sounds. This is likely an underestimate of the actual number potentially affected. Some animals probably moved away before coming within visual range of MMOs, and it is unlikely that MMOs 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. Some other mammals, even if they surface near the vessel, are missed because of limited visibility (e.g. fog), glare, or other factors limiting sightability. Visibility and high sea conditions were significant limiting factors during both the summer and fall Chukchi Sea surveys. Also, sound levels were estimated to be ≥160 dB re 1 μPa (rms) out to 8 km (5 mi). This distance is well beyond those at which MMOs can detect even the more conspicuous animals under favorable sighting conditions during daytime (this is why SOI implemented the use of multiple chase/monitoring vessels). Furthermore, marine mammals could not be seen effectively during periods of darkness, which occurred for increasing numbers of hours per day after 14 Aug Nighttime observations were generally not required or attempted except prior to and during nighttime power ups.

Animals may also 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). Within the assumed ≥160–170 dB radii around the source (i.e., ~4.5–8.1 km; ~2.8-5.0 mi), 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. This could occur as a result of reactions to the airguns, or as a result of reactions to the *Gilavar* or the chase/monitoring vessels 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 beyond the distance at which they are detectable by MMOs exhibited avoidance behavior.

***Cetaceans Potentially Exposed to Sounds ≥180 dB re 1 µPa (rms)***.—There were eight sightings (13 individuals) of cetaceans observed by *Gilavar* MMOs while the airguns were firing during the summer Chukchi Sea survey. However, none of these were recorded within the ≥180 dB safety radius and it is unlikely that any cetaceans were exposed to ≥180 dB sound level (Table 5.22). Three of these eight cetacean sightings were made while the airguns were firing at full array volume and the remaining five were noted while the single mitigation gun was firing. There were no cetacean sightings aboard the *Gilavar* during seismic operations conducted in the fall Chukchi Sea survey.

***Seals and Sea Lions Potentially Exposed to Sounds ≥190 dB re 1 µPa (rms)***.—There were only three seal sightings (three individuals) observed by *Gilavar* MMOs while airguns were firing during the summer Chukchi Sea survey. None of these summer survey seismic-period seal sightings were within the ≥190 dB safety radius (Table 5.22).

There were two bearded seals observed from the *Gilavar* while airguns were firing during the fall Chukchi Sea survey. One of these was within the ≥190 dB safety radius during the fall Chukchi Sea survey. This individual was determined to be at a distance of ~435 m from the full airgun array and the ≥190 dB safety radius for the full airgun array is 550 m (601 yd). A power down of the airguns was implemented immediately. This individual seal may have been exposed to ≥190 dB sound levels (Table 5.22).

TABLE 5.22. Number of individuals observed within applied sound level safety radii and potentially exposed to the respective sound levels during 2007 seismic operations in the Chukchi Sea.

| | **Number of Individuals and Exposure Level in dB re 1µPa (rms)** | | |
|---|---|---|---|
| **Chukchi Sea Survey Period** | **Cetaceans ≥180** | **Seals and Sea Lions ≥190** | **Pacific Walruses ≥180** |
| **Summer** | 0 | 0 | 50 |
| **Fall** | 0 | 1 | 0 |
| ***Totals*** | ***0*** | ***1*** | ***50*** |

***Pacific Walruses Potentially Exposed to Sounds ≥180 dB re 1 µPa (rms)***.—There were 39 sightings (66 individuals) of Pacific walruses and one of a large, single unidentified pinniped (presumed to be a walrus) recorded from the *Gilavar* while airguns were firing during the summer Chukchi Sea survey. As discussed above, 17 of these *Gilavar* sightings (34 individuals) were within the ≥180 dB safety radius and resulted in power downs of the airgun array. An additional nine Pacific walrus sightings (16 individuals) within the ≥180 dB safety radius were reported by chase/monitoring vessels and these also resulted in power downs of the airgun array. It is likely that many of these 50 individual walruses were exposed to sound levels ≥180 dB due to their location inside the ≥180 dB safety radius (Table 5.22).

*Gilavar* MMOs reported no sightings of Pacific walruses while airguns were operating during the fall Chukchi Sea survey. The chase/monitoring vessels reported a single Pacific walrus during seismic operations, but it was determined to be outside of the ≥180 dB safety radius. It is unlikely that this walrus was exposed to ≥180 dB sound levels (Table 5.22).

## *Estimates Extrapolated from Density*

The methodology used to estimate the areas exposed to received levels ≥160, 170, 180 and 190 dB (rms) was described in Chapter 4 *Monitoring and Mitigation Methods*. Densities were based on data collected from the *Gilavar* and its chase/monitoring vessels (*Gulf Provider, Norseman II, American Islander, Nanuq*) during SOI's seismic operations in the Chukchi Sea. The density data for summer and fall Chukchi Sea surveys are summarized in Tables 5.23 and 5.24, and the ensonified areas are presented in Table 5.25.

The aforementioned densities were used to estimate the number of total *individual* marine mammals exposed to sound levels ≥160, 170, 180, and 190 dB (rms) and the average number of *exposures* per individual marine mammal. These numbers provide estimates of the number of animals potentially affected by seismic operations, as described in Chapter 4.

Estimates for both the summer and fall Chukchi Sea surveys were calculated independently by treating data from each survey separately. The estimates provided here for each Chukchi Sea survey are based on the actual amount of seismic survey completed during each respective survey. In contrast, the estimates provided in the IHA applications for this project were based on the then-anticipated amount of survey, with an allowance for the possibility that some lines would be surveyed more than once. The estimates in the IHA applications assumed that there would be more seismic surveying than actually occurred. In addition, the following estimates assume that all mammals present were well below the surface where they would be exposed to the sound levels predicted in Table 4.1 at a given distance. 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). Finally, some pinnipeds and cetaceans may have moved away from the path of the *Gilavar* before it arrived, either because the chase/monitoring vessels frequently traveled in front of *Gilavar*, or because of an avoidance response to the approaching *Gilavar* and its airguns. Thus, the following estimates, though lower than those in the IHA Application, are nonetheless likely to overstate actual numbers exposed to various received sound levels.

***Cetaceans***.—Table 5.26 summarizes the estimated numbers of cetaceans that might have been exposed to received sounds at various levels relative to the number of "takes" requested in SOI's IHA application for the Chukchi Sea in 2007. These density-based estimates were calculated using sightings recorded by MMOs during daylight watch periods and these density data are shown in Tables 5.23 and 5.24, and the ensonified areas are presented in Table 5.25. The following discussion regarding the estimated numbers of cetaceans exposed to given sound levels is based on densities from non-seismic periods. Note that the estimated number of takes based on non-seismic periods in Table 5.26 represents the number of animals that would have been exposed had they not shown localized avoidance behavior of the airguns or the ship itself. Some of the animals calculated to be within a given safety or disturbance radius would in fact have moved away before being exposed to sounds that strong.

*(A) ≥160 dB (rms)*: We estimated that nine individual cetaceans would each have been exposed ~26 times to airgun pulses with received levels ≥160 dB re 1 μPa (rms) during the survey if all cetaceans showed no avoidance, and all but one of these individual exposures would have occurred during the summer Chukchi Sea survey (Table 5.26). Based on the available densities, approximately half of the individuals (four to five) would have been gray whales. Minimum estimates of the numbers of different individuals exposed to ≥160 dB were far lower than the estimates of the number of exposures to that level. This reflects the overlap in the ensonified areas around different seismic lines, and the fact that an animal remaining in the area would have been exposed repeatedly to ≥160 dB.

(*B) ≥170 dB (rms*): On average, some odontocete species may be disturbed only if exposed to received levels of airgun sounds ≥170 dB re 1 μPa (rms). If so, then the estimated number of exposures would be ~43% of the corresponding estimates for ≥160 dB, based on the proportionally smaller areas exposed to ≥170 dB. Overall, there would have been ~six individual cetaceans each exposed ~18 times to seismic sounds ≥170 dB and all but one of these individual exposures would have occurred during the summer Chukchi Sea survey (Table 5.26).

*(C) ≥180 dB (rms):* If there was no avoidance of airgun noise by cetaceans, it is estimated that there would have been ~12 exposures to each of five individual cetaceans to seismic sounds ≥180 dB (Table 5.26). However, most of these cetaceans probably moved away before being exposed to received levels ≥180 dB. As noted earlier, there were only eight cetacean sightings (13 individuals) from the *Gilavar* when airguns were operating. It is possible that some additional cetaceans were present within the ≥180 dB radius and not seen by the MMOs.

TABLE 5.23. Densities of marine mammals in offshore areas of the Alaskan Chukchi Sea by useable and daylight sightings criteria (see Chapter 4 for more details) for the summer Chukchi Sea survey (21 Jul - 12 Sep 2007). Densities are corrected for *f*(0) and *g*(0) biases.

| | **Non-seismic Densities** | | **Seismic Densities** | |
|---|---|---|---|---|
| | (No. individuals / 1000 km$^2$) | | (No. individuals / 1000 km$^2$) | |
| **Species** | **Useable** | **Daylight** | **Useable** | **Daylight** |
| **Cetaceans** | | | | |
| Unidentified Whale | 0.054 | 0.096 | 0 | 1.922 |
| Harbor Porpoise | 1.277 | 0.565 | 0 | 0 |
| Killer Whale | 0.117 | 0.104 | 0 | 0 |
| Bowhead Whale | 0.341 | 0.302 | 0 | 0.431 |
| Gray Whale | 2.109 | 2.204 | 0 | 0.091 |
| Humpback Whale | 0.119 | 0.105 | 0 | 0.200 |
| Unidentified Mysticete Whale | 0 | 0.040 | 0 | 0.231 |
| ***Cetacean Total*** | ***4.017*** | ***3.418*** | ***0*** | ***2.874*** |
| **Seals and Sea Lions** | | | | |
| Unidentified Seal | 14.541 | 22.253 | 9.757 | 5.204 |
| Bearded Seal | 6.129 | 7.759 | 0 | 3.071 |
| Ringed Seal | 52.769 | 70.075 | 0 | 33.650 |
| Spotted Seal | 3.663 | 4.586 | 0 | 5.244 |
| Steller Sea Lion | 0.097 | 0.095 | 0 | 0.000 |
| ***Seal and Sea Lion Total*** | ***77.199*** | ***104.768*** | ***9.757*** | ***47.168*** |
| **Pacific Walruses*** | | | | |
| Pacific Walrus | 118.277 | 205.658 | 11.799 | 51.915 |
| Unidentified Pinniped | 2.489 | 3.462 | 0 | 0.891 |
| ***Pacific Walrus Total*** | ***120.766*** | ***209.120*** | ***11.799*** | ***52.805*** |

* Daylight Non-seismic density for Pacific Walrus decreases from 209.120 animals per 1000 km$^2$ to 127.306 animals per 1000 km$^2$ when *Gilavar* 24 Aug sightings are excluded from calculations.

***Seals and Sea Lions***.—Table 5.27 summarizes the estimated numbers of seals and sea lions that might have been exposed to received sounds with various levels relative to the number of exposures requested in SOI's IHA application for the Chukchi Sea in 2007. These density-based estimates were calculated using sightings recorded by MMOs during daylight watch periods (Tables 5.23 and 5.24; the ensonified areas are presented in Table 5.25). The following discussion regarding the estimated numbers of seals and sea lions exposed to given sound levels is based on densities from non-seismic periods. Note that the estimated number of takes based on non-seismic periods in Table 5.27 represents the number of animals that would have been exposed had they not shown localized avoidance behavior of the airguns or the ship itself. Some of the animals calculated to be within a given safety or disturbance radius would in fact move away before being exposed to sounds that strong.

TABLE 5.24. Densities of marine mammals in offshore areas of the Alaskan Chukchi Sea by useable and daylight sightings criteria (see Chapter 4 for more details) for the fall Chukchi Sea survey (8 Oct - 5 Nov 2007). Densities are corrected for *f*(0) and *g*(0) biases.

| | **Non-seismic Densities** (No. individuals / 1000 km$^2$) | | **Seismic Densities** (No. individuals / 1000 km$^2$) | |
|---|---|---|---|---|
| **Species** | **Useable** | **Daylight** | **Useable** | **Daylight** |
| **Cetaceans** | | | | |
| Humpback Whale | 0 | 0.178 | 0 | 0 |
| Unidentified Mysticete Whale | 0 | 0.136 | 0 | 0 |
| ***Cetacean Total*** | ***0*** | ***0.314*** | ***0*** | ***0*** |
| **Seals** | | | | |
| Unidentified Seal | 13.485 | 24.832 | 0 | 2.636 |
| Bearded Seal | 1.989 | 6.512 | 0 | 9.331 |
| Ringed Seal | 24.913 | 25.487 | 0 | 19.478 |
| Spotted Seal | 0 | 5.560337764 | 0 | 2.656 |
| ***Seal Total*** | ***40.387*** | ***62.392*** | ***0*** | ***34.102*** |
| **Pacific Walruses** | | | | |
| Pacific Walrus | 0 | 0 | 0 | 0.637 |
| ***Pacific Walrus Total*** | ***0*** | ***0*** | ***0*** | ***0.637*** |

TABLE 5.25. Estimated areas (km$^2$) ensonified with various sound levels during the summer (21 Jul – 12 Sep) and fall (8 Oct – 5 Nov) Chukchi Sea seismic surveys in 2007.

| | **Level of ensonification (dB re1µPa (rms))** | | | | |
|---|---|---|---|---|---|
| **Area (km$^2$)** | **120** | **160** | **170** | **180** | **190** |
| **Summer** | | | | | |
| Including Overlap Area | 879,828 | 46,376 | 21,566 | 10,799 | 2,200 |
| Excluding Overlap Area | 24,674 | 2,511 | 1,615 | 1,209 | 569 |
| **Fall** | | | | | |
| Including Overlap Area | 633,565 | 38,503 | 18,874 | 9,672 | 2,019 |
| Excluding Overlap Area | 25,982 | 2,816 | 1,945 | 1,377 | 592 |

*(A) ≥ 160 dB (rms):* We estimated that ~439 individual seals and sea lions were exposed to airgun pulses ~26 times with received levels ≥160 dB re 1 µPa (rms) during the survey if all animals exhibited no avoidance of the ≥160 dB zone (Table 5.27). Based on the available non-seismic densities from daylight MMO watches, ~250, 27, and one of these individuals would have been ringed/spotted seals, bearded seals, or sea lions, respectively, during the summer Chukchi Sea survey. During the fall Chukchi Sea survey, 175 and 18 would have been ringed/spotted seals and bearded seals, respectively.

TABLE 5.26. Estimated numbers of individual cetaceans exposed to received sound levels ≥160, 170, 180, and 190 dB (rms) and average number of exposures per individual within the Chukchi Sea during both the summer and fall survey periods. Requested number of takes for the Chukchi Sea is also shown. Estimates are based on "corrected" densities of cetaceans calculated from daylight MMO watch effort, and both seismic and non-seismic densities are shown.

| | Non-seismic Densities | | Seismic Densities | | |
|---|---|---|---|---|---|
| **Exposure level in dB re 1µPa (rms)** | **Individuals** | **Exposures per Individual** | **Individuals** | **Exposures per Individual** | **Requested Take** |
| **Summer** | | | | | |
| **≥160** | 9 | 18.5 | 7 | 18.5 | |
| **≥170** | 6 | 13.4 | 5 | 13.4 | |
| **≥180** | 4 | 8.9 | 3 | 8.9 | |
| **≥190** | 2 | 3.9 | 2 | 3.9 | |
| **Fall** | | | | | |
| **≥160** | 1 | 13.7 | 0 | 13.7 | |
| **≥170** | 1 | 9.7 | 0 | 9.7 | |
| **≥180** | 0 | 7.0 | 0 | 7.0 | |
| **≥190** | 0 | 3.4 | 0 | 3.4 | |
| **Total*** | | | | | |
| **≥160** | 9 | 26.0 | 7 | 26.0 | 2987 |
| **≥170** | 6 | 17.7 | 5 | 17.7 | |
| **≥180** | 5 | 11.5 | 3 | 11.5 | |
| **≥190** | 2 | 3.6 | 2 | 3.6 | |

* Totals may not add up to sum of summer and fall values due to rounding

The numbers of different exposures of seals and sea lions to levels ≥160 dB rms, calculated from sighting rates during non-seismic periods, suggested that each animal was exposed an average of ~26 times. The repeated exposure of individuals was a result of the fact that many areas were ensonified repeatedly to ≥160 dB as the seismic vessel moved back and forth along different seismic lines. Most animals that lingered in the area would have been exposed to levels ≥160 dB numerous times over an extended period if they did not move away from the source, but the number of different individuals exposed in this manner would be far less than the estimated number of exposures.

(*B) ≥ 170 dB (rms*): Some seals and sea lions may be disturbed if exposed to received levels of airgun sounds ≥170 dB re 1 µPa (rms). If so, then the estimated number of exposures would be ~43% of the corresponding estimates for ≥160 dB, based on the proportionally smaller area exposed to ≥170 dB. Overall, ~291 individual seals and sea lions would have been exposed to received levels ≥170 dB (rms) ~17.5 times (Table 5.27).

*(C) ≥ 180 dB (rms):* Some pinnipeds were likely within the ≥180 dB radius around the operating airguns but were missed by the observers even during airgun operations conducted in good visibility conditions. It is estimated that there were 11.47 exposures to each of 213 individual seals and sea lions to sounds ≥180 dB (Table 5.27). These figures assume that there was no avoidance by these animals of the ≥180 dB radius around the approaching airguns.

TABLE 5.27. Estimated numbers of individual seals and sea lions exposed to received sound levels ≥160, 170, 180, and 190 dB (rms) and average number of exposures per individual within the Chukchi Sea during both the summer and fall survey periods. Requested number of takes for the Chukchi Sea is also shown. Estimates are based on "corrected" densities of seals and sea lions calculated from daylight MMO watch effort, and both seismic and non-seismic densities are shown.

| | Non-seismic Densities | | Seismic Densities | | |
|---|---|---|---|---|---|
| **Exposure level in dB re 1µPa (rms)** | **Individuals** | **Exposures per Individual** | **Individuals** | **Exposures per Individual** | **Requested Take** |
| **Summer Seals and Sea Lions** | | | | | |
| **≥160** | 263 | 18.5 | 118 | 18.5 | |
| **≥170** | 169 | 13.4 | 76 | 13.4 | |
| **≥180** | 127 | 8.9 | 57 | 8.9 | |
| **≥190** | 60 | 3.9 | 27 | 3.9 | |
| **Fall Seals*** | | | | | |
| **≥160** | 176 | 13.7 | 96 | 13.7 | |
| **≥170** | 121 | 9.7 | 66 | 9.7 | |
| **≥180** | 86 | 7.0 | 47 | 7.0 | |
| **≥190** | 37 | 3.4 | 20 | 3.4 | |
| **Total Seals and Sea Lions**** | | | | | |
| **≥160** | 439 | 26.0 | 214 | 26.0 | |
| **≥170** | 291 | 17.7 | 143 | 17.7 | 5585 |
| **≥180** | 213 | 11.5 | 104 | 11.5 | |
| **≥190** | 97 | 3.6 | 47 | 3.6 | |

* There were no sea lion sightings during the fall survey period

** Totals may not add up to sum of summer and fall values due to rounding

*(D) ≥ 190 dB (rms):* Based on densities calculated from sighting rates during non-seismic periods, we estimated that there would have been 3.57 exposures to each of 97 different seals and sea lions to airgun sounds at ≥190 dB (rms) if there were no avoidance of the airguns or vessels (Table 5.27).

***Pacific Walruses***.—Table 5.28 summarizes the estimated numbers of Pacific walruses that might have been exposed to received sounds with various levels relative to the number of “takes” requested in SOI’s IHA application for the Chukchi Sea in 2007. These density-based estimates were calculated using sightings recorded by MMOs during daylight watch periods (Tables 5.23 and 5.24; the ensonified areas are presented in Table 5.25). The following discussion regarding the estimated numbers of Pacific walruses exposed to given sound levels is based on densities from non-seismic periods. Note that the estimated number of takes based on non-seismic periods in Table 5.28 represents the number of animals that would have been exposed had they not shown localized avoidance behavior of the airguns or the ship itself. Some of the animals calculated to be within a given safety or disturbance radius would in fact move away before being exposed to sounds that strong. The density value for Pacific walrus exposure calculations includes walrus counts for 24 Aug when observation conditions were premium and sightings were exceptionally high. Inclusion of the Pacific walrus sightings during this unusual 24-h period likely inflates the overall density during non-seismic periods for the season (no seismic operations were conducted 24 Aug). Actual exposures of Pacific walruses are expected to be lower. Exposures are approximately 40% lower than the estimates presented in Table 5.28 when using a Pacific walrus density value excluding the anomalous 24 Aug sighting event.

*(A) ≥ 160 dB (rms):* We estimated that ~525 different individual Pacific walruses were exposed to airgun pulses ~26 times with received levels ≥160 dB re 1 μPa (rms) during the survey if all animals showed no avoidance of the ≥160 dB zone (Table 5.28). However, the estimated number of individuals decreases to ~320 if the *Gilavar's* 24 Aug walrus sightings (*n* = 148) are excluded from density calculations. The repeated exposure of individuals was a result of the fact that many areas were ensonified repeatedly to ≥160 dB as the seismic vessel moved back and forth along different seismic lines. Most animals that lingered in the area would have been exposed to levels ≥160 dB numerous times over an extended period if they did not move away from the source as it approached them, but the number of different individuals exposed in this manner would be far less than the estimated number of exposure incidents.

(*B) ≥ 170 dB (rms*): Pacific walruses may be disturbed by exposure to received sound levels of ≥170 dB re 1 μPa (rms). If so, then the estimated number of exposures would be ~43% of the corresponding estimates for ≥160 dB, based on the proportionally smaller areas exposed to ≥170 dB. Overall, there would have been ~338 individual walruses each exposed ~11.47 times to seismic sounds ≥170 dB (Table 5.28). However, the estimated number of individuals decreases to ~206 if the *Gilavar's* 24 Aug walrus sightings (*n* = 148) are excluded from density calculations.

*(C) ≥ 180 dB (rms):* Some Pacific walruses were likely within the ≥180 dB radius (estimated as being up to 2.47 km (1.5 mi), Table 4.1) around the operating airguns but were missed by the observers even during airgun operations conducted in good visibility conditions. It is estimated that there were 11.47 exposures to each of 253 individual walruses to sounds ≥180 dB (Table 5.28). However, the estimated number of individuals decreases to ~154 if the *Gilavar's* 24 Aug walrus sightings (*n* = 148) are excluded from density calculations. These figures assume that there was no effective avoidance by these animals of the ≥180 dB radius around the approaching airguns.

(*D) ≥ 190 dB (rms):* Based on densities calculated from sighting rates during non-seismic periods we estimated that there would have been 3.57 exposures to each of 127 different Pacific walruses to airgun sounds at ≥190 dB (rms) if there were no avoidance of the airguns or vessesl (Table 5.28). However, the estimated number of individuals decreases to ~72 if the *Gilavar's* 24 Aug walrus sightings (*n* = 148) are excluded from density calculations. MMOs did not observe any Pacific walruses within the ≥190 dB safety radius.

Table 5.28. Estimated numbers of individual Pacific walruses exposed to received sound levels ≥160, 170, 180, and 190 dB (rms) and average number of exposures per individual within the Chukchi Sea during both the summer and fall survey periods. Estimates are based on "corrected" densities of Pacific walruses calculated from daylight MMO watch effort, and both seismic and non-seismic densities are shown.

| | **Non-seismic Densities** | | **Seismic Densities** | |
|---|---|---|---|---|
| **Exposure level in dB re 1μPa (rms)** | **Individuals** | **Exposures per Individual** | **Individuals** | **Exposures per Individual** |
| **Summer*** | | | | |
| **≥160** | 525 | 18.5 | 133 | 18.5 |
| **≥170** | 338 | 13.4 | 85 | 13.4 |
| **≥180** | 253 | 8.9 | 64 | 8.9 |
| **≥190** | 119 | 3.9 | 30 | 3.9 |
| **Fall** | | | | |
| **≥160** | 0 | 13.7 | 2 | 13.7 |
| **≥170** | 0 | 9.7 | 1 | 9.7 |
| **≥180** | 0 | 7.0 | 1 | 7.0 |
| **≥190** | 0 | 3.4 | 0 | 3.4 |
| **Total**** | | | | |
| **≥160** | 525 | 26.0 | 134 | 26.0 |
| **≥170** | 338 | 17.7 | 87 | 17.7 |
| **≥180** | 253 | 11.5 | 65 | 11.5 |
| **≥190** | 119 | 3.6 | 30 | 3.6 |

* Estimated number of Pacific walruses exposed to 160, 170, 180, and 190 dB using daylight non-seismic densities decrease from 525, 338, 253, and 119, respectively, to 320, 206, 154, and 72, respectively, when *Gilavar* 24 Aug sightings (*n* = 148) are excluded from density calculations.

** Totals may not add up to sum of summer and fall values due to rounding

# BEAUFORT SEA MONITORING

## *Monitoring Effort and Marine Mammal Encounter Results*

This section summarizes the visual monitoring effort and sightings from the *Gilavar* and its chase/monitoring vessels during the 2007 Beaufort Sea seismic survey. The survey period began on 12 Sep when the *Gilavar* and its chase/monitoring vessels entered the Beaufort Sea study area from the Chukchi Sea and ended on 8 Oct 2007 when the *Gilavar* returned to the Chukchi Sea. Additional information describing survey activities is presented in Chapter 2.

Poor visibility (< 3.5 km or < 2.2 mi), high sea states (Beaufort wind force > 5; Appendix J), and the proximity of other vessels (within 5 km or 3 mi), were common in the Beaufort Sea during the 2007 survey. These factors influence marine mammal sightings and were used to define "useable" data (see *Methods* in Chapter 4). In the Beaufort Sea in 2007, only 11% of the *Gilavar*'s total daylight observation effort (km) and 25% of the chase/monitoring vessels total daylight observation effort (km) were considered useable. Due to the low amounts of "useable" data all daylight observation effort was used in the following analyses.

### *Visual Survey Effort*

SOI's 2007 Beaufort Sea seismic survey activities were conducted by the *Gilavar* along a total of 5328 km (3311 mi, 630 h) of trackline. Associated with these survey activities, a total of ~6142 km (~3817 mi, ~602 h) of daylight visual observations were conducted from the *Gilavar* and its chase /monitoring vessels. Daylight observer effort (km) by Beaufort wind force is shown in Figure 5.38. Beaufort wind force (Bf) during observations aboard the *Gilavar* and chase/monitoring vessels in the Beaufort Sea ranged from 0 to 8 (Fig. 5.39). Most observer effort from the *Gilavar* took place during conditions of Bf = 4 and 5 (~60% of daylight effort; Fig. 5.39). Greater than 60% of the chase/monitoring vessels effort occurred during Bf 3 and 4 (Fig. 5.39). The difference in effort distribution for the *Gilavar* versus the chase/monitoring vessels likely arises from the difference in methods used to assign Beaufort wind force. Aboard the Gilavar, an anemometer (used to measure wind speed) was used to help assign Beaufort wind force, whereas on board the chase/monitoring vessels the sea state was used as an indicator of the current Beaufort wind force conditions. Wind speeds can increase relatively quickly, but sea states change more slowly. Overall, the least amount of observer effort took place when Bf = 0 (<1% for the *Gilavar* and 0% for the chase/monitoring vessels). Daylight observation effort from the *Gilavar* and chase/monitoring vessels, in km and h or mi and h, subdivided by seismic activity and Beaufort wind force, are presented in Appendix Table C.20.

***Gilavar***.—During a total of 2216 km (1377 mi, ~251 h) of *Gilavar* observation effort in the Beaufort Sea, 1908 km (1186 mi, 215 h) of visual monitoring occurred during daylight (Fig. 5.40). MMOs on the *Gilavar* observed exclusively from the bridge (eye-height 10.7 m or 11.7 yds) while in the Beaufort Sea. Of the 2216 km (1377 mi) of visual observation effort, ~308 km (~191 mi, 36 h) occurred during darkness, with ~68 km (~42 mi) of effort associated with nighttime power ups from one airgun. The airgun array was never started from no airguns during darkness. In compliance with the IHA requirement that monitoring take place through the night if one or more power downs were implemented during the daytime, a total of ~214 km (~133 mi) of effort in darkness was carried out in the Beaufort Sea due to daytime power downs. No marine mammals were observed during darkness periods. The remainder of the MMO effort during periods of darkness occurred prior to and after power ups and prior to dawn and after dusk. One observer was on watch aboard the *Gilavar* in daylight during a total of ~1067 km (~663 mi, 126 h) and at least two observers were on watch during the remaining ~841 km (~523 mi, 89 h).

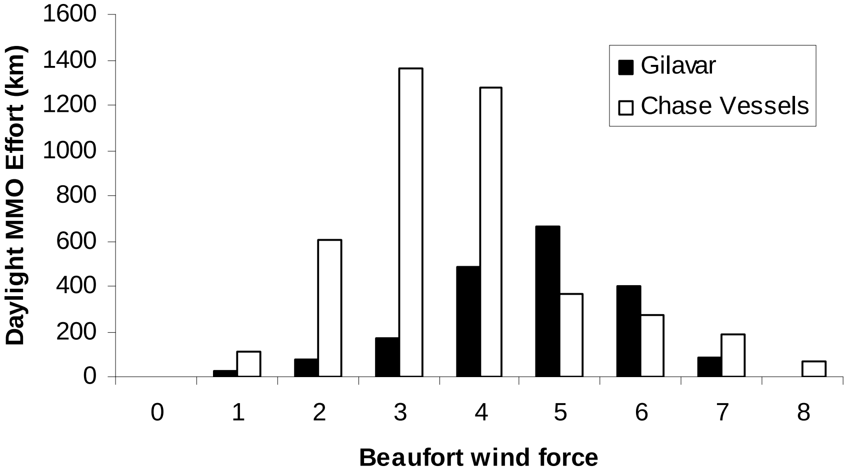


FIGURE 5.39. Total daylight marine mammal observer effort (km) in the Beaufort Sea study area from the *Gilavar* and its chase/monitoring vessels by Beaufort wind force, 12 Sep – 8 Oct 2007.

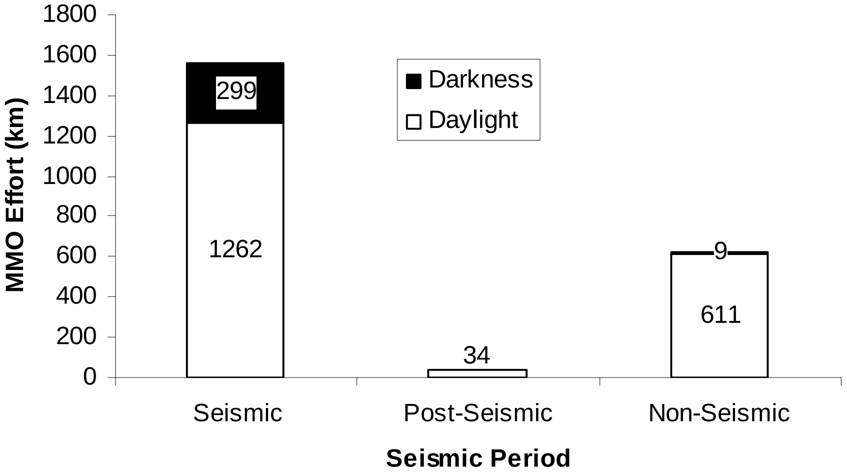


FIGURE 5.40. Total marine mammal observer effort (km) from the *Gilavar* in the Beaufort Sea study area by seismic period, in daylight and darkness, 12 Sep – 8 Oct 2007.

***Chase/Monitoring Vessels*.**—Within the Beaufort Sea, MMOs aboard chase/monitoring vessels observed over a total distance of ~4332 km (~2692 mi, ~397 h), ~4234 km (~2631 mi, ~387 h) of which was during daylight hours (Fig. 5.41). Only ~98 km (~61 mi, ~10 h) were monitored from chase/monitoring vessels during darkness. Observation effort from chase/monitoring vessels was considered "seismic" if the vessel was within 15 km / 9 mi (for cetaceans) or 5 km / 3 mi (for pinnipeds and ursids) of the *Gilavar* while the guns were firing (Chapter 4 *Analysis*). All visual monitoring on the chase/monitoring vessels occurred from the bridge. One observer was on watch in daylight aboard the chase/monitoring vessels during 3386 km (2104 mi, 301 h), and at least two observers were on watch during the remaining 848 km (527 mi, 86 h).

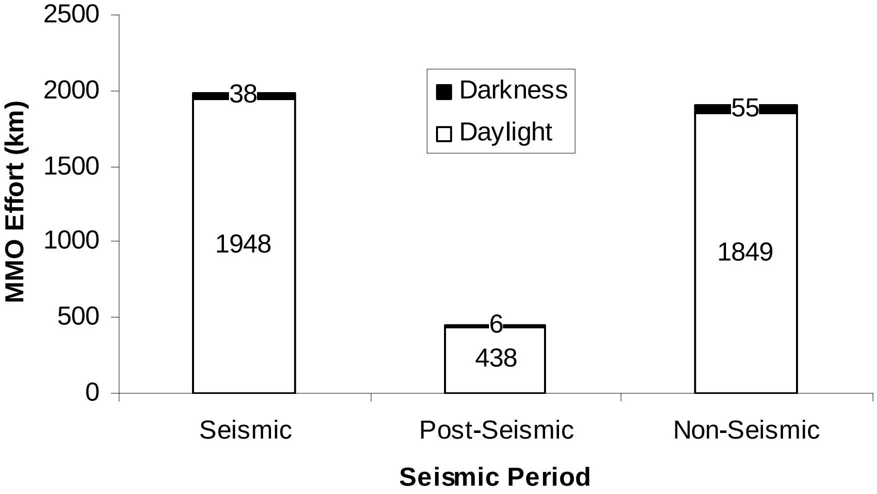


FIGURE 5.41. Total marine mammal observer effort (km) from chase/monitoring vessels in the Beaufort Sea study area by seismic period, in daylight and darkness, 12 Sep – 8 Oct 2007. Numbers in figure are rounded up and may not equal the total of the more precise numbers reported in the text.

## *Visual Sightings of Marine Mammals and Other Vessels*

***Total Numbers of Marine Mammals Observed*.**—During seismic operations in the Beaufort Sea, an estimated 126 individual marine mammals were seen in 87 groups by MMOs on the *Gilavar* and its chase/monitoring vessels during daylight hours. There were no marine mammal sightings during periods of darkness. Seven marine mammal species were identified, including two cetacean species, three seal species, Pacific walrus, and polar bear. Three times the number of total marine mammal sightings were recorded from the chase/monitoring vessels compared to the *Gilavar* (66 vs. 21; Fig. 5.42), but the chase/monitoring vessel data is a combination of the sometimes simultaneous effort of the three different chase/monitoring vessels that operated in the Beaufort Sea (the *Gulf Provider*, the *Norseman II*, and the *Kilabuk*). Overall, MMOs on the *Gilavar* observed cetaceans more than any other species groups while more seals were observed from the chase/monitoring vessels. Pacific walruses and polar bears were rarely observed in the Beaufort Sea by MMOs on either the *Gilavar* or its chase/monitoring vessels (Fig. 5.42). A summary of all sightings within the Beaufort Sea, including sightings made when the chase/monitoring vessels were not conducting chase vessel duties, or “opportunistic” sightings when MMOs were not officially on-watch are presented in Appendix Table C.21.

***Marine Mammal Sightings by Seismic State.*—**There was a total of 87 marine mammal sightings associated with seismic operations; 46 were made during seismic periods when the *Gilavar*’s airguns were on, 33 were made during non-seismic periods, and the remaining eight sightings were noted during “post-seismic” periods (Fig. 5.43). Break-downs by species are shown in Appendix Tables C.22, C.23 and C.24. Power downs were requested on six occasions when pinnipeds or cetaceans were sighted in the water within or approaching the ≥190 dB or ≥180 dB (rms) safety radii (respectively) around the *Gilavar*’s operating airguns. Further details on these encounters are provided later in this chapter (see *Mitigation Measures Implemented*). No deaths or injury of animals were observed during the seismic program. Only one marine mammal carcass was recorded in the Beaufort Sea; a possibly[8] dead ringed seal was observed by MMOs on one of the chase/monitoring vessels while it was away from seismic operations.

***Marine Mammal Detection Rates***.—Detection rates (# groups sighted per 1000 km or 1000 mi of daylight MMO effort) are one measure of the concentration of animals encountered by vessels in a given area. Various factors can affect detection rates, including the number of observers on watch and survey conditions as measured by Beaufort wind force. As expected, increasing the number of marine mammal observers from one to two increased the detection rate on both the *Gilavar* and chase/monitoring vessels (Fig. 5.44). Detection rates doubled on the *Gilavar* when a second MMO was on watch (7.5 to 15.5 per 1000 km or 12. 1 to 23.8 per 1000 mi) while the increase was more modest on the chase/monitoring vessels (Fig. 5.44). Detection rates by MMOs decreased as Beaufort wind force increased for both the *Gilavar* and its chase/monitoring vessels (Fig. 5.45). This result was also expected since animals are more difficult to detect as sea conditions deteriorate. Additional detail regarding these calculations is presented in Appendix Tables C.25 and C.26.

## Cetaceans

***Total Numbers of Cetaceans Observed***.—There was a total of 39 cetacean sightings of 75 individuals by MMOs on the *Gilavar* and chase/monitoring vessels. Bowhead whale was the most commonly identified whale (*n* = 43 individuals in 22 groups). Of the 43 bowhead whales identified, two were recorded as juveniles. One minke whale was also identified (Table 5.29).

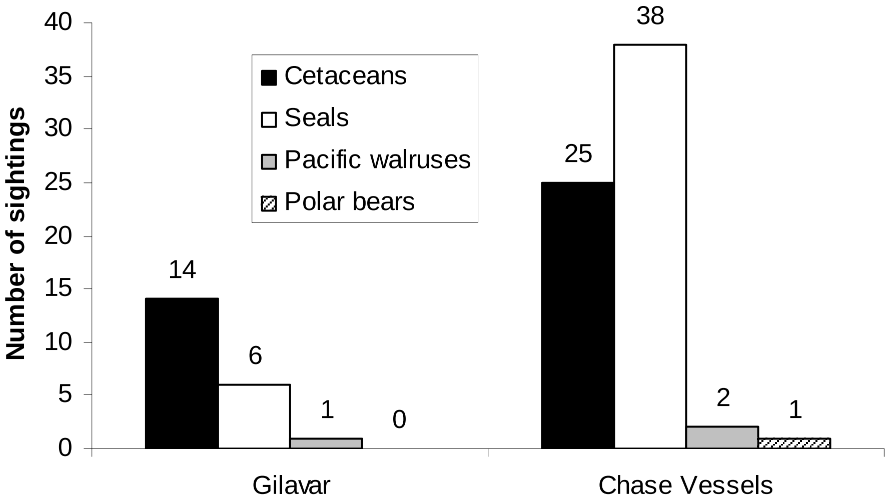


FIGURE 5.42. Number of sightings for each species group from the *Gilavar* and its chase/monitoring vessels during the Beaufort Sea seismic program (12 Sep – 8 Oct 2007).

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[8] A freshly dead ringed seal carcass was reported on 24 Aug 2007 by the *Norseman II*, while it was not acting as a *Gilavar* chase vessel. In the comments section of the carcass report: “Carcass sighted by observers floating below surface belly down. Carcass in very fresh condition and we were unsure that it was dead”.

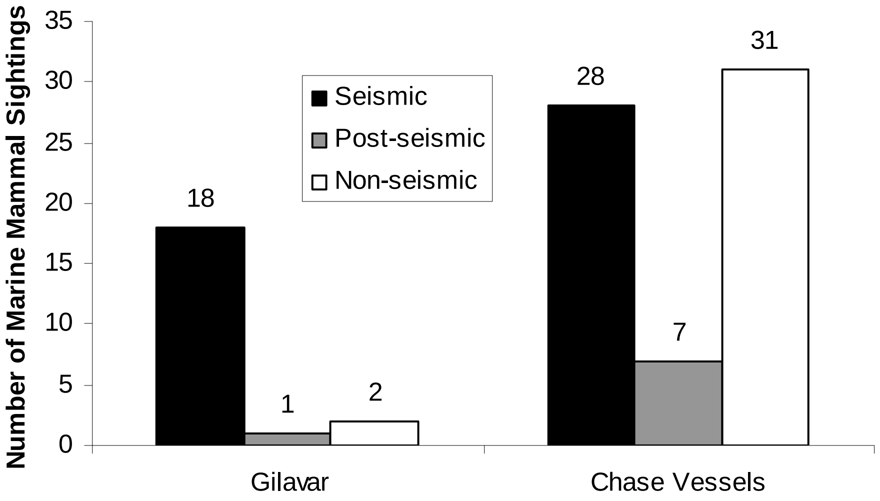


FIGURE 5.43. Number of marine mammal sightings in the Beaufort Sea from the *Gilavar* and its chase/monitoring vessels during each seismic state (12 Sep – 8 Oct 2007).

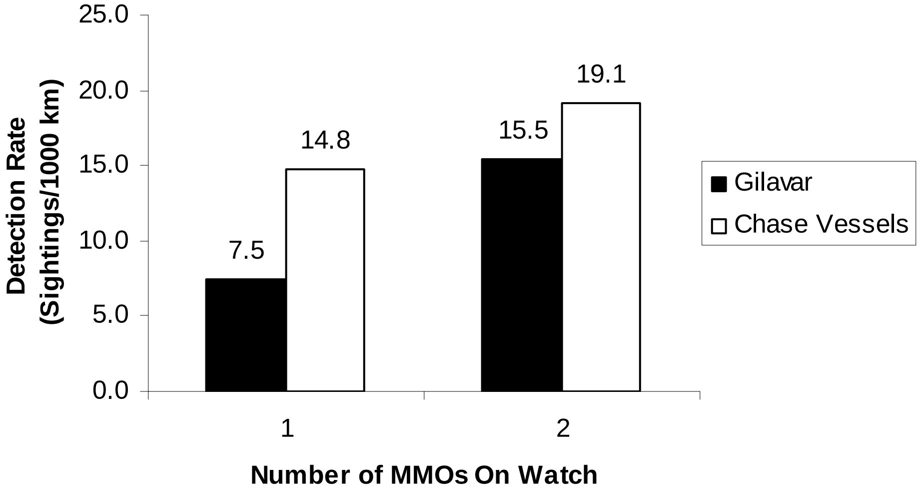


FIGURE 5.44. Marine mammal detection rates (sightings per 1000 km of daylight MMO effort) for the *Gilavar* and its chase/monitoring vessels during watches with one or two observers in the Beaufort Sea (12 Sep – 8 Oct 2007).

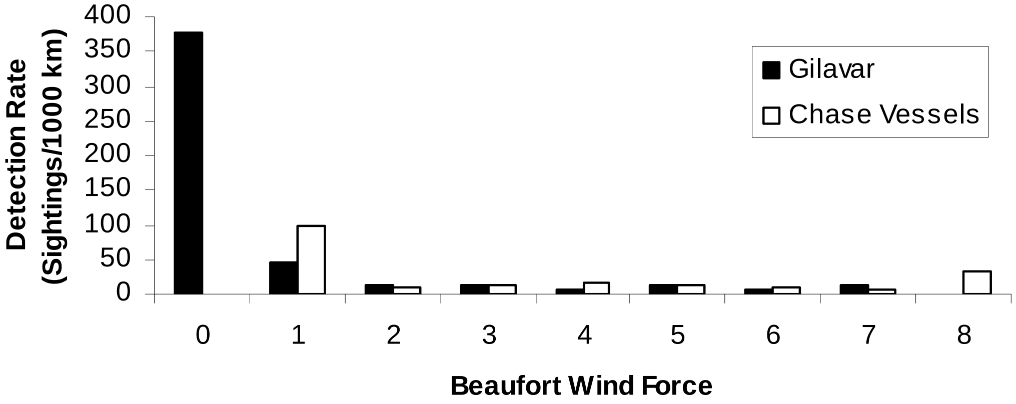


FIGURE 5.45. Marine mammal detection rates (sightings per 1000 km of daylight MMO effort) from the *Gilavar* and its chase/monitoring vessels during different Beaufort wind force conditions during the Beaufort Sea survey (12 Sep – 8 Oct 2007).

TABLE 5.29. Number of cetacean sightings (number of individuals) in daylight during the Beaufort Sea survey (12 Sep – 8 Oct 2007) from the *Gilavar* and its chase/monitoring vessels.

| **Species** | ***Gilavar*** | ***Chase Vessels*** | ***Total*** |
|---|---|---|---|
| **Cetaceans** | | | |
| Unidentified Whale | 5 (8) | 1 (1) | ***6 (9)*** |
| Bowhead Whale | 6 (11) | 16 (32) | ***22 (43)*** |
| Minke Whale | 0 | 1 (1) | ***1 (1)*** |
| Unidentified Mysticete Whale | 3 (5) | 7 (17) | ***10 (22)*** |
| ***Total Cetaceans*** | ***14 (24)*** | ***25 (51)*** | **39 (75)** |

***Cetacean Sightings by Seismic State***.—Twenty-four of the 39 total cetacean sightings occurred during seismic periods. An additional six sightings occurred during post-seismic periods and the remaining nine cetacean sightings were noted during non-seismic periods. For a similar break-down by species, see Appendix Table C.22.

***Cetacean Detection Rates***.—Detection rates for cetaceans were almost twice as high from the *Gilavar* compared to the chase/monitoring vessels (Fig. 5.46). This may be due to the observation area on the *Gilavar* having a greater height above the water than the chase/monitoring vessels. Sighting rates were higher during seismic periods on the *Gilavar* but were similar on the chase/monitoring vessels during seismic and non-seismic periods (Fig. 5.46). The *Gilavar* only had a moderate amount of non-seismic effort (~612 km or 380 mi of daylight MMO effort; Appendix Table C.27), so the low number of cetacean sightings during non-seismic periods may be due to the lower amount of effort.

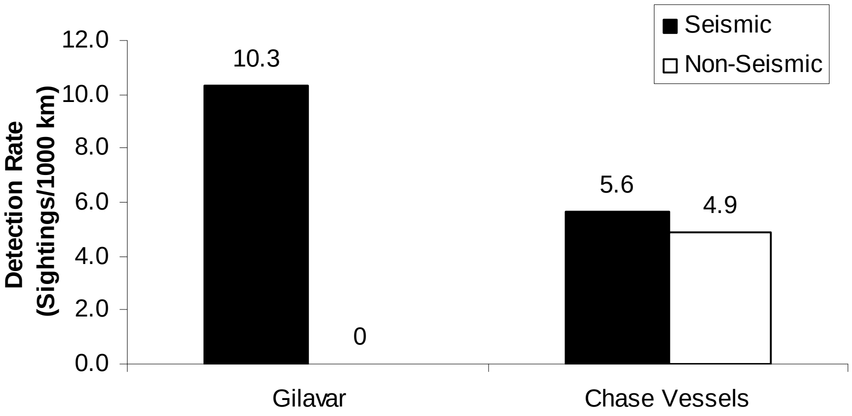


FIGURE 5.46. Detection rates (sighings per 1000 km daylight MMO effort) for cetaceans during seismic versus non-seismic periods during the Beaufort Sea survey (12 Sep – 8 Oct 2007) from the *Gilavar* and its chase/monitoring vessels. Ramp up and power up effort is included in the *Seismic* category.

## *Seals*

***Total Numbers of Seals Observed***.—A total of 44 sightings of 44 individual seals were recorded from the *Gilavar* and the chase/monitoring vessels during the Beaufort Sea survey in 2007 (Table 5.30). More seal sightings were made from the chase/monitoring vessels than from the *Gilavar* and ringed/spotted seals were more abundant than bearded seals. Ringed and spotted seals are considered together along with unidentified seals so that more accurate small seal numbers can be discussed. Most small seals were likely ringed seals given the known distribution of this species in the study area.

***Seal Sightings by Seismic State***.—Twenty seal sightings were recorded during seismic periods. An additional two sightings occurred during post-seismic periods. The remaining 22 sightings were during non-seismic periods. For a similar break-down by species, see Appendix Table C.23.

***Seal Detection Rates***.—During seismic periods, seal detection rates from the chase/monitoring vessels were much higher than from the *Gilavar* (Fig. 5.47), suggesting that seals may be showing a localized avoidance of the operating seismic ship. This is further supported by the decrease in the chase/monitoring vessel detection rates from seismic to non-seismic periods (Fig. 5.47). Again, the *Gilavar* had limited effort during non-seismic periods (See Appendix Table C.28) and therefore the comparison of detection rates during seismic and non-seismic periods from the *Gilavar* may not be meaningful.

## *Walruses and Polar bears*

***Total Numbers of Walruses and Polar bears Observed***.—Pacific walruses were not prevalent in the Beaufort Sea study area, with only three sightings of four animals (Table 5.31), including one sighting of an adult with a juvenile. A single unidentified pinniped sighting was assigned to the Pacific walrus category based on the relative numbers of identified large pinnipeds within the Beaufort Sea. The areas associated with seismic operations did not generally occur near ice or land, so few polar bears were sighted ($n$ = 3 individuals in one group; Table 5.31).

TABLE 5.30. Number of seal sightings (number of individuals) in daylight during the Beaufort Sea survey (12 Sep – 8 Oct 2007) from the Gilavar and its chase/monitoring vessels.

| Species | *Gilavar* | *Chase Vessels* | *Total* |
|---|---|---|---|
| **Seals in Water** | | | |
| Bearded Seal | 0 | 2 (2) | ***2 (2)*** |
| Ringed and Spotted Seals[a] | 6 (6) | 36 (36) | ***42 (42)*** |
| ***Total Seals*** | ***6 (6)*** | ***38 (38)*** | **44 (44)** |

[a] Includes Unidentified Seal numbers.

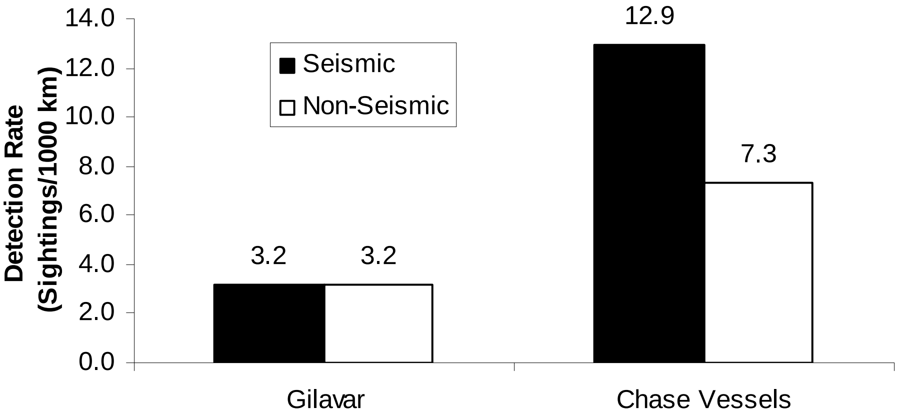


FIGURE 5.47. Detection rates (sighings per 1000 km daylight MMO effort) for seals during seismic versus non-seismic periods during the Beaufort Sea survey (12 Sep – 8 Oct 2007) from the *Gilavar* and its chase/monitoring vessels. Ramp up and power up effort is included in the *Seismic* category.

***Walrus and Polar bear Sightings by Seismic State***.—Two of the Pacific walrus sightings occurred during seismic periods, and the remaining sighting was during a non-seismic period. The single polar bear sighting was recorded during a non-seismic period. For more details, see Appendix Table C.24.

***Walrus and Polar bear Detection Rates***.—The small number of Pacific walrus and polar bear sightings is insufficient to make comparisons of sighting rates between seismic and non-seismic periods (see Appendix Tables C.29 and C.30).

TABLE 5.31. Number of Pacific walrus and polar bear sightings (number of individuals) in daylight during the Beaufort Sea survey (12 Sep – 8 Oct 2007) from the *Gilavar* and its chase/monitoring vessels.

| **Species** | ***Gilavar*** | ***Chase Vessels*** | ***Total*** |
|---|---|---|---|
| **Pacific Walruses in Water** | | | |
| Pacific Walrus | 0 | 2 (3) | ***2 (3)*** |
| Unidentified Pinniped[a] | 1 (1) | 0 | ***1 (1)*** |
| ***Total Pacific Walruses*** | ***1 (1)*** | ***2 (3)*** | **3 (4)** |
| **Polar Bears on Ice or Land** | | | |
| Polar Bear | ***0*** | ***1 (3)*** | **1 (3)** |

[a] The single "unidentified pinniped" sighting was included as a Pacific walrus, based on the ratio of identified large pinnipeds within the Beaufort Sea.

## Other Vessels

There were three different chase/monitoring vessels that worked as chase/monitoring boats for the *Gilavar* in the Beaufort Sea, including the *Gulf Provider*, the *Norseman II*, and the *Kilabuk*. The periods during which each vessel worked with the *Gilavar* is shown in Figure 4.2. Over the 28 day period of operations in the Beaufort Sea (12 Sep – 8 Oct 2007), the *Gulf Provider* was a *Gilavar* chase/monitoring vessel throughout. Seismic shooting occurred on 14 different days in the Beaufort Sea, with two or more chase/monitoring vessels accompanying the *Gilavar* on 10 of those days. Only the *Gulf Provider* was the chase/monitoring vessel on the remaining four seismic days. The accompanying chase/monitoring vessels were within 5 km (3 mi) of the *Gilavar* the majority of the time (59% of the time the *Gilavar* was in the Beaufort Sea). It is difficult to determine whether the presence of the chase/monitoring vessels had any effect on the behavior of marine mammals, but no obvious reactions to the chase/monitoring vessels were recorded by observers on board the *Gilavar*.

The *Henry C.* was also in the Beaufort Sea and was recorded on one occasion within 17 km (~11 mi) of the *Gilavar*. The *Henry C.* was shooting seismic within 25–112 km (16–70 mi) of the *Gilavar* over a period of 20.4 h. No other vessels came within visual range of the *Gilavar*.

## *Marine Mammal Distribution and Behavior*

The data collected during visual observations provide information about behavioral responses of marine mammals to the seismic survey. The relevant data include estimated closest observed points of approach (CPA) to the vessel, movement relative to the vessel during seismic and non-seismic periods, and observed behavior of animals at the time of the initial sightings.

The mean CPA during seismic periods was underestimated if some animals avoided the airguns at distances beyond those where they could be detected by MMOs. In other studies, marine mammals were usually observed at greater distances from the vessel and lower sighting rates when the airguns were operating than when the airguns were silent (e.g., Smultea et al. 2004; Haley and Koski 2004; MacLean and Koski 2005;

Holst et al. 2005a,b). This was also true for similar studies conducted in nearby Arctic regions (Harris et al. 2001; Haley and Ireland 2005).

Marine mammal behavior is difficult to observe, especially from a seismic vessel, because individuals and/or groups are often at the surface only briefly, and there may be avoidance behavior. This causes difficulties in resighting those animals, and in determining whether two sightings some minutes apart are repeat sightings of the same individual(s). Only limited behavioral data were collected during this project because marine mammals were often seen at a distance from the vessel, and it was not possible to track them for long distances or durations while the vessel was underway. The two variables that were examined quantitatively to assess potential seismic effects on behavior were the categories of movement and behavior when the animal(s) were first observed.

The position of MMOs on the vessels, and where they focused their observation efforts, yielded a distribution of animal sightings relative to both the chase/monitoring vessels and the *Gilavar* that was skewed heavily towards the fore of the vessel. Nearly all sightings were of animals located in the forward 180° surrounding the vessel. Exceptions are noted.

## *Cetaceans*

***Closest Observed Point of Approach.—***As no cetaceans were sighted from the *Gilavar* during non-seismic periods (Table 5.32), it is not possible to compare CPA during seismic and non-seismic periods for cetaceans sighted from the source vessel. The mean CPA for cetaceans sighted from the chase/monitoring vessels was slightly greater during seismic than non-seismic periods (Table 5.32), however the sample sizes were too small to allow valid statistical comparison.

***Distribution and Movement.—***A total of 10 cetacean sightings from the chase/monitoring vessels during seismic periods had movement records (Fig. 5.48). Of these, nine animals were sighted alongside or ahead of the vessel, and one was sighted behind the vessel's midship line. The direction of travel was always away from or parallel with the vessel direction of travel. For cetaceans sighted during non-seismic periods, the location of the animal relative to the vessel was ahead of the midship line. The movement of animals during non-seismic periods, when discernable, was towards the vessel for six of seven sightings (Fig. 5.48).

TABLE 5.32. Comparison of cetacean CPA distances by seismic period from daylight MMO watches aboard the *Gilavar* and its chase/monitoring vessels during the Beaufort Sea survey (12 Sep - 8 Oct 2007).

| Vessel and Seismic Status | Mean CPA[a] (m) | s.d. | Range (m) | *n* |
|---|---|---|---|---|
| ***Gilavar*** **Seismic** | 2404 | 900 | 1124-4411 | 13 |
| ***Gilavar*** **Non-seismic** | N/A | N/A | N/A | 0 |
| ***Gilavar*** **Overall Mean** | 2404 | 900 | 1124-4411 | 13 |
| ***Chase Vessels*** **Seismic** | 831 | 418 | 252-1397 | 11 |
| ***Chase Vessels*** **Non-seismic** | 796 | 896 | 80-3000 | 9 |
| ***Chase Vessels*** **Overall Mean** | 955 | 884 | 80-3000 | 20 |

[a] CPA = Closest Point of Approach. For the *Gilavar* this value is the marine mammal's closest point of approach to the airgun array, for chase/monitoring vessels this value is the marine mammal's closest point of approach to the MMO/vessel.

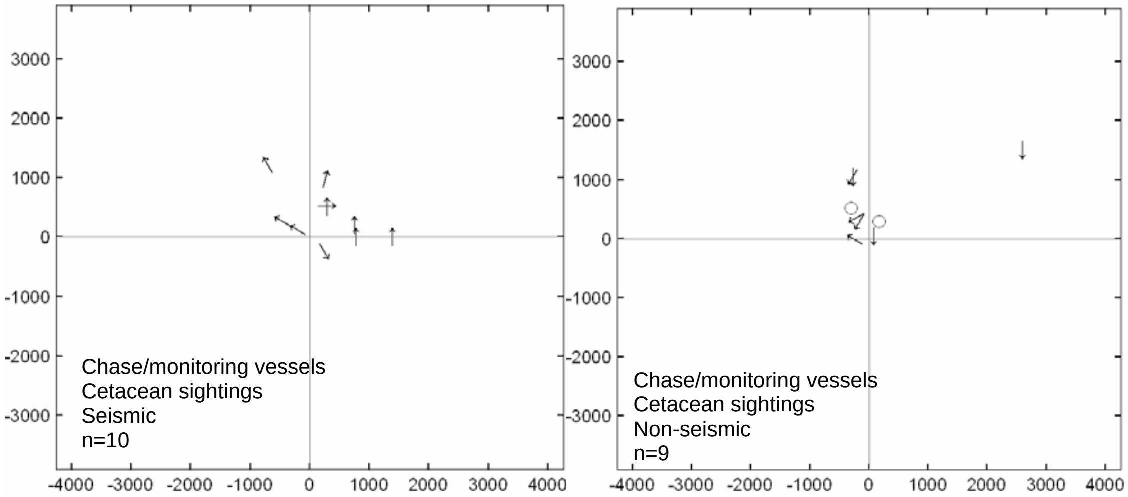


FIGURE 5.48. Location, range, and direction of travel relative to the vessel trackline of cetaceans sighted from chase/monitoring vessels during seismic the Beaufort Sea survey (12 Sep – 8 Oct). Distance between tick marks on the x and y axis is 914 yd.

Movement was recorded for 14 cetacean sightings from the *Gilavar* during seismic periods for which movement was recorded, six animals showed no movement (Fig. 5.49). All but one animal was sighted within 3 km (2 miles) of the ship. Of the eight animals that showed movement, six were traveling away from the vessel perpendicular to the vessel trackline, one was traveling away from the vessel on a diagonal, and one was traveling toward the vessel's trackline. There were no sightings of cetaceans during non-seismic periods.

***First Observed Behavior***.—Behavior was recorded for 14 cetaceans sighted from the *Gilavar*. One of these cetacean sightings occurred during post-seismic periods and was not included in behavioral analyses (see Chapter 4). The most common "first observed behavior" of cetaceans for the remainder of sightings, which were all during seismic periods, was swimming (seven of 13 sightings for which behavior was recorded, or 54%; Fig. 5.50). The first observed behavior of the remaining six cetacean sightings was "surface active".

Behavior was recorded for 26 cetaceans observed from the chase/monitoring vessels. Of these, 13 cetacean sightings occurred during post-seismic periods and were not included in behavioral analyses. The most commonly observed first behaviors for cetaceans were swimming and "surface active" (Fig. 5.51). Swimming was observed for seven of 13 (54%) sightings; six occurred during seismic periods and one during non-seismic periods. There were five cetacean sightings for which "surface active" was the first observed behavior and all five sightings occurred during seismic periods. There was also one animal observed looking during non-seismic periods.

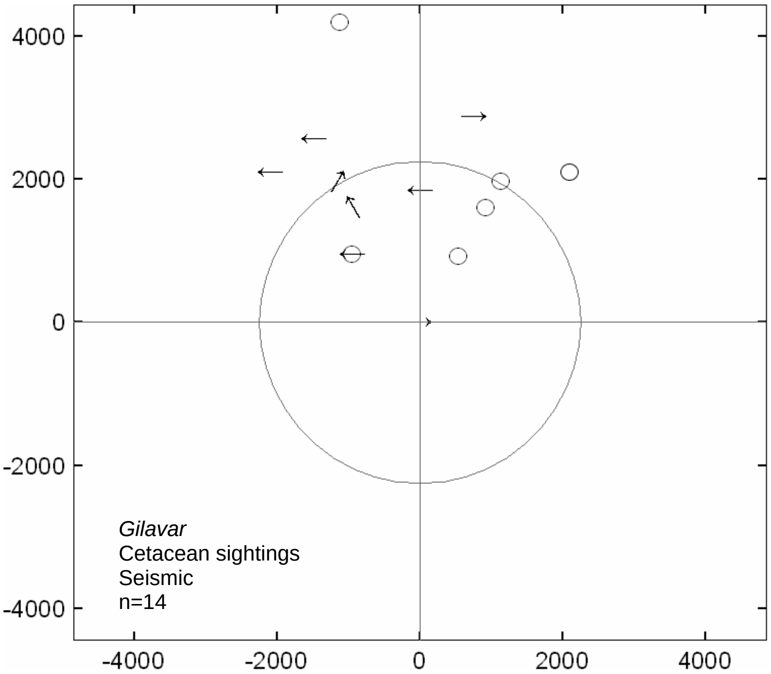


FIGURE 5.49. Location, range, and direction of travel relative to the vessel trackline of cetaceans sighted from the *Gilavar* during seismic periods during the Beaufort Sea survey (12 Sep – 8 Oct 2007). The 180dB radius is 2250m (2057yd). Distance between tick marks on the x and y axis is 1829 yd.

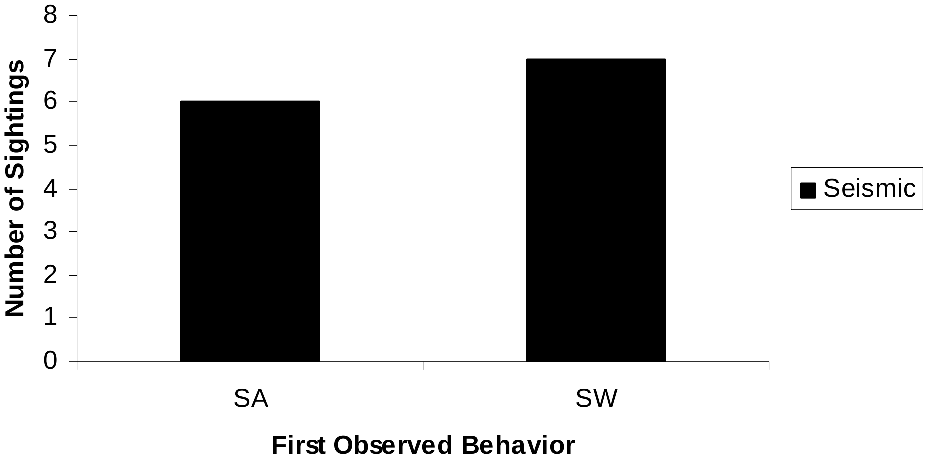


FIGURE 5.50. First observed behavior of cetaceans sighted from the *Gilavar* during the 2007 Beaufort Sea survey (12 Sep – 8 Oct).

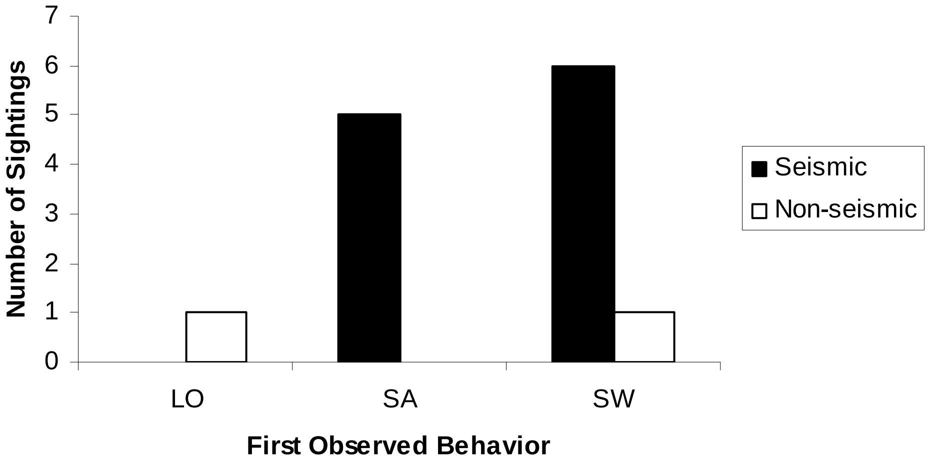


FIGURE 5.51. First observed behavior of cetaceans sighted from chase/monitoring vessels during the 2007 Beaufort Sea survey (12 Sep – 8 Oct).

## *Seals*

***Closest Observed Point of Approach.***—As with cetaceans, the mean CPA for seals sighted from the Gilavar and the chase/monitoring vessels was slightly higher during seismic periods than during non-seismic periods (Table 5.33). Again, small sample sizes precluded statistical analysis of these data.

***Distribution and Movement.***—During seismic periods, a total of 15 seals observed from the chase/monitoring vessels had movement records (Fig. 5.52). Of the 15 sightings, seven animals were within 100m (91 yd) of the vessel. Three of these animals were swimming towards the vessel, four were swimming away. Of the remaining eight sightings, all animals were observed swimming away from the vessel. During non-seismic periods, seven of 20 seals sighted showed no movement. Six of these animals were within approximately 100 m (91 yd) of the vessel. Of the remaining thirteen seals, twelve were headed away from the vessel. There was no clear difference in initial movement of seals between seismic and non-seismic periods.

All of the five seals sighted from the *Gilavar* during seismic activity, for which there was movement data, were within 500 m (546 yd) of the vessel (Fig. 5.53). Two of these animals showed no movement, two were swimming away from the vessel in a direction perpendicular to the vessel trackline, and one animal swam directly towards the vessel. During non-seismic periods there were only two seal sightings with movement data, both animals were very close to the vessel (Fig. 5.53). One animal showed no movement while the other swam away from the vessel.

***First Observed Behavior.***—The first observed behaviors recorded for the six seal sightings from the *Gilavar* were equally divided between swimming and looking (Fig. 5.54). All of the swimming seals were observed during seismic periods and only one of the looking seals was observed during non-seismic periods.

Table 5.33. Comparison of seal CPA distances by seismic period from daylight MMO watches aboard the *Gilavar* and its chase/monitoring vessels during the Beaufort Sea survey (12 Sep - 8 Oct 2007).

| Vessel and Seismic Status | Mean CPA[a] (m) | s.d. | Range (m) | *n* |
|---|---|---|---|---|
| ***Gilavar*** **Seismic** | 236 | 152 | 117-457 | 4 |
| ***Gilavar*** **Non-seismic** | 109 | 32 | 86-131 | 2 |
| ***Gilavar*** **Overall Mean** | 194 | 136 | 86-457 | 6 |
| ***Chase Vessels*** **Seismic** | 165 | 152 | 5-426 | 16 |
| ***Chase Vessels*** **Non-seismic** | 104 | 89 | 10-346 | 20 |
| ***Chase Vessels*** **Overall Mean** | 131 | 123 | 5-426 | 36 |

[a] CPA = Closest Point of Approach. For the *Gilavar* this value is the marine mammal's closest point of approach to the airgun array, for chase/monitoring vessels this value is the marine mammal's closest point of approach to the MMO/vessel.

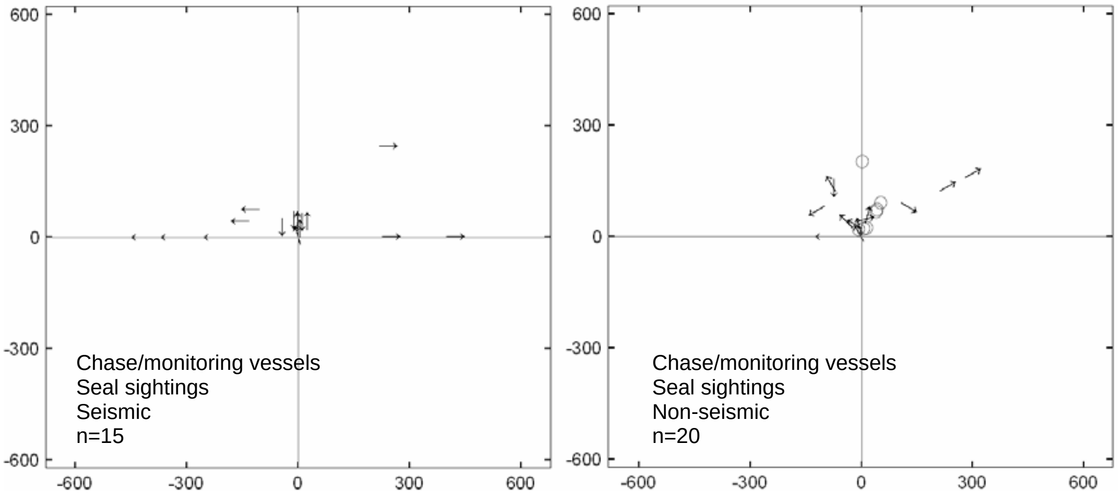


FIGURE 5.52. Location, range, and direction of travel relative to the vessel trackline of seals sighted from chase/monitoring vessels during seismic (left) and non-seismic (right) periods during the Beaufort Sea survey (12 Sep – 8 Oct 2007). Distance between tick marks on the x and y axes is 274 yd.

Of the 36 seals observed from the chase/monitoring vessels for which behavior was analysed, 22 animals (67%) were observed looking at the vessel; nine of these sightings occurred during seismic periods and 13 occurred during non-seismic periods (Fig. 5.55). Other behaviors observed were “surface active”, with seven sightings during non-seismic periods and three during seismic periods, and swimming, with four sightings during seismic periods. Two sightings occurred during post-seismic periods and were not included in analyses.

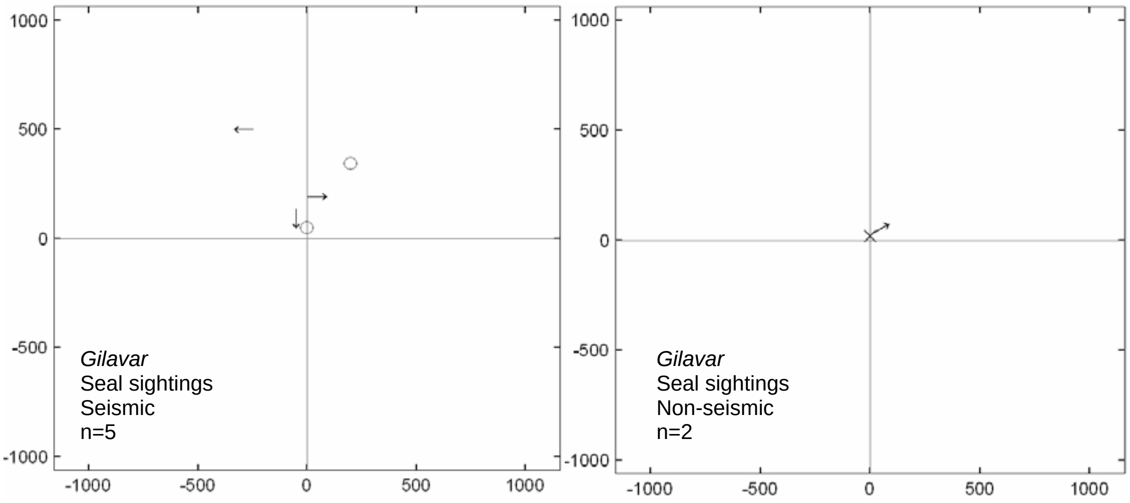


FIGURE 5.53. Location, range, and direction of travel relative to the vessel trackline of seals sighted from the *Gilavar* during seismic (left) and non-seismic (right) periods during the Beaufort Sea survey (12 Sep – 8 Oct 2007). Distance between tick marks on the x and y axes is 274 yd.

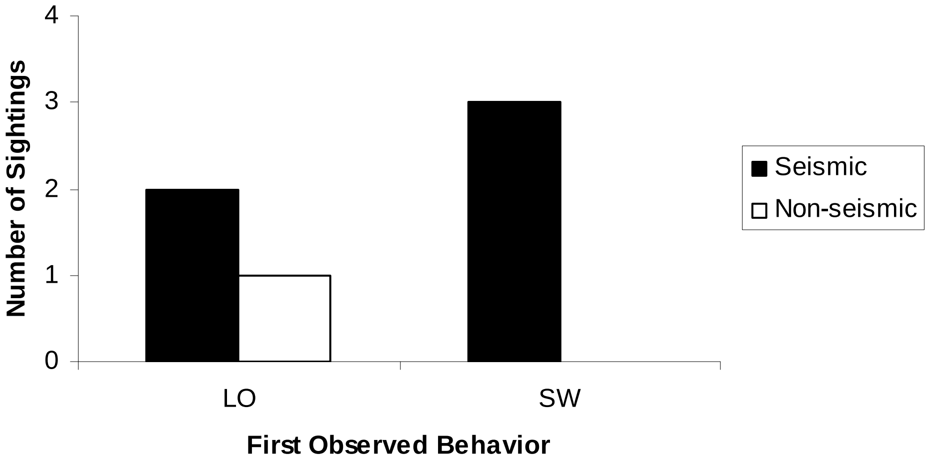


FIGURE 5.54. First observed behavior of seals sighted from the *Gilavar* during the 2007 Beaufort Sea survey (12 Sep – 8 Oct 2007).

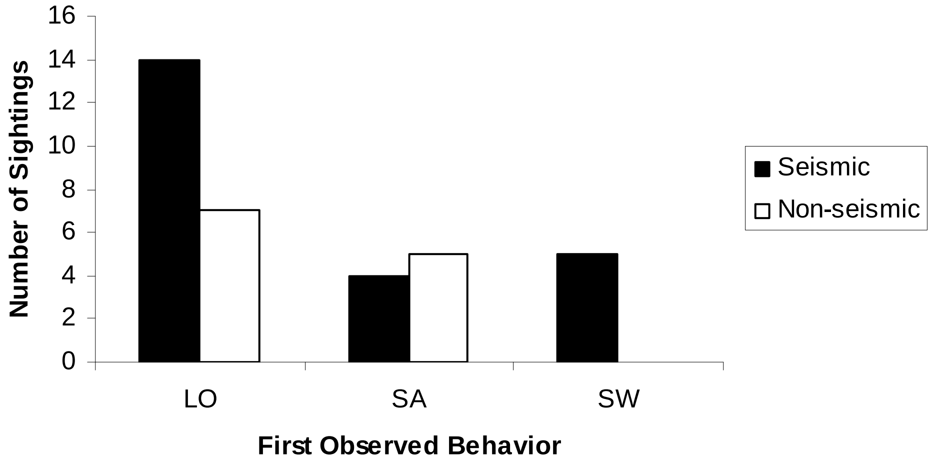


FIGURE 5.55. First observed behavior of seals sighted from chase/monitoring vessels during the 2007 Beaufort Sea survey (12 Sep – 8 Oct 2007).

## *Pacific Walrus and Polar Bears*

***Closest Observed Point of Approach.—***Pacific walrus CPA from chase/monitoring vessels was greater during seismic (637 m, 582 yd) than non-seismic (347 m, 317 yd) periods. However this included only two total walrus sightings so no conclusions can be drawn from this data. No Pacific walrus were sighted from the *Gilavar* during non-seismic periods. One unidentified pinniped was sighted at 579 m (529 yd) from the *Gilavar* during seismic periods.

Only one polar bear sighting occurred from the chase/monitoring vessels, at a distance of 417 m (381 yd), and none were sighted from the *Gilavar*, therefore no comparisons of CPA can be made for seismic vs. non-seismic periods or for source vs. chase/monitoring vessels.

***Distribution and Movement.—***Two sightings of Pacific walruses were recorded from the chase/monitoring vessels, one each during seismic and non-seismic periods. The animal sighted during seismic activity was close to and swimming towards the vessel (within 50m, 46 yd). The animal sighted during a non-seismic period was approximately 200m (183 yd) from the vessel and was swimming away. The one polar bear sighting from a chase/monitoring vessel was recorded as walking on ice during a non-seismic period.

An unidentified pinniped, which was later assigned to the Pacific walrus category, was recorded swimming away from the *Gilavar*. There were no sightings of polar bears from the *Gilavar*.

***First Observed Behavior.—***The one walrus sighting (the unidentified pinniped mentioned above) from the Gilavar was a swimming animal observed during seismic activity. The one polar bear sighitng from a chase/monitoring vessel, during non-seismic periods, was walking on the ice.

The behavior of both Pacific walruses observed from the chase/monitoring vessels was recorded as looking. One of these sightings occurred during seismic periods, one during non-seismic periods. There was only one polar bear sighting from the chase/monitoring vessels and the animals were observed walking on ice.

## *Mitigation Measures Implemented*

A total of six power downs were implemented during the Beaufort Sea survey, no shut downs were implemented. The power down safety radius applied for cetaceans in the Beaufort Sea was 2250m (2057 yd). Four power downs were implemented for cetaceans (Table 5.34). Two of the power downs were for sightings of bowhead whales, totaling three individuals, and two power downs were for unidentified whales, totaling four individuals. All power downs resulted from sightings of cetaceans within the *Gilavar*'s 180 dB radius while the full airgun array was firing.

Two power downs were implemented for pinnipeds (Table 5.35). Each sighting involved a single animal, one a ringed seal and one an unidentified seal that was likely a ringed or spotted seal. Both power downs resulted from sightings of pinnipeds within the *Gilavar*'s 190 dB radius (860m, 786 yd) while the full airgun array was firing.

No power downs or shut downs were implemented for Pacific walruses or polar bears during the Beaufort Sea survey.

TABLE 5.34. List of power downs for cetaceans sighted in the *Gilavar*'s ≥180 dB safety radius (2250 m, 2057 yd) during the Beaufort Sea seismic survey (12 Sep – 8 Oct 2007).

| Sighting ID | Species | Group Size | Day in 2007 UTC | Water Depth (m) | Reaction to Vessel[a] | Distance (m) to Airguns at First Detection | CPA[b] (m) to Airguns |
|---|---|---|---|---|---|---|---|
| 382 | unidentified whale | 1 | 19-Sep | 29.8 | NO | 1400 | 1400 |
| 383 | bowhead whale | 2 | 19-Sep | 28.1 | SP | 1919 | 1919 |
| 386 | bowhead whale | 1 | 19-Sep | 26.1 | NO | 1400 | 1400 |
| 391 | unidentified whale | 3 | 26-Sep | 33.5 | NO | 1124 | 1124 |

[a] Observed reaction of animal to vessel:SP=splash, NO=none

[b] CPA=Closest Point of Approach

TABLE 5.35. List of power downs for pinnipeds sighted in the *Gilavar*'s ≥180 dB safety radius (860 m) during the Beaufort Sea seismic survey (12 Sep – 8 Oct 2007).

| Sighting ID | Species | Group Size | Day in 2007 UTC | Water Depth (m) | Reaction to Vessel[a] | Distance (m) to Airguns at First Detection | CPA[b] (m) to Airguns |
|---|---|---|---|---|---|---|---|
| 377 | ringed seal | 1 | 18-Sep | 27.8 | LO | 161 | 161 |
| 378 | unidentified seal | 1 | 18-Sep | 27.7 | LO | 117 | 117 |

[a] Observed reaction of animal to vessel:LO=Look at Vessel

[b] CPA=Closest Point of Approach

## *Estimated Number of Marine Mammals Present and Potentially Affected*

It is difficult to obtain meaningful estimates of "take by harassment". Reasons contributing to these difficulties are discussed in the previous section on mitigation measures for the Chukchi Sea.

### *Disturbance and Safety Criteria*

Two methods were used to estimate the numbers of marine mammals exposed to the various sound pressure levels. These methods included estimates from direct observations and estimates based on calculated densities which are discussed in the previous section for the Chukchi Sea.

### *Estimates from Direct Observations*

The number of marine mammals observed close to the *Gilavar* during the Beaufort Sea survey provides a minimum estimate of the number potentially affected by seismic sounds. This is likely an underestimate of the actual number potentially affected. Some animals probably moved away before coming within visual range, and not all of those that remained would have been seen by observers. A more detailed discussion of factors affecting the accuracy of these estimates is located in the introduction to Estimates from Direct Observations for the Chukchi Sea survey.

***Cetaceans Potentially Exposed to Sounds ≥180 dB re 1 μPa (rms)***.—There were 14 cetacean sightings, involving 11 individual animals, from the *Gilavar* while the airguns were operating. Of these, six sightings occurred while the mitigation gun was firing and eight sightings occurred while the full array was in operation. For the six sightings occurring during times when the mitigation gun was firing, the animals were well outside the ≥180 dB radius of the mitigation gun so it is very unlikely that these cetaceans were exposed to sounds ≥180 dB rms. Of the eight sightings occurring during full array operation, the animals were well outside the ≥180 dB radius on four occasions and were not likely exposed to sounds ≥180 dB rms. The four remaining sightings resulted in power downs. For three of the four sightings that resulted in power downs, the animals dove below the surface of the water within the ≥180 dB radius before the airgun array was powered down and it is likely that these animals were briefly exposed to sounds ≥180db rms. The animals involved in the fourth sighting also dove before the airgun array was powered down, however the animals were ahead of the vessel at considerable distance (sighting 383, Table 5.34). As sound levels measured during the SSV were considerably greater to the side and stern of the vessel than those measured off the bow of the vessel, it is possible, but not certain, that the actual sound levels received at the location of the animals were <180 dB rms.

***Pinnipeds Potentially Exposed to Sounds ≥190 dB re 1 μPa (rms)***.—There were six sightings of individual pinnipeds from the *Gilavar* while the airguns were operating. Of these, three occurred while the mitigation gun was firing, two occurred while the airgun was operating at full array, and one occurred shortly after the beginning of a ramp up sequence. The three animals sighted while the mitigation gun was firing were well outside the ≥190 dB radius for the mitigation source and it is very unlikely that these animals were exposed to sound levels ≥190 dB rms. Both sightings during full array operation resulted in power downs. In each case the animal dove below the surface within the 190 dB radius before the airgun array was powered down, therefore it is likely that these animals were briefly exposed to sound levels ≥190 dB rms. For the sighting occurring during ramp up, the ramp up sequence had just started and the animal was sighted 647m (592 yd) from the vessel and was swimming away, therefore it is unlikely that this animal was exposed to to sound levels ≥190 dB rms.

***Pacific walruses Potentially Exposed to Sounds ≥180 dB re 1 μPa (rms)***.—It is possible that the sighting of a pinniped during ramp up sequence (above) involved a Pacific walrus. No Pacific walruses were sighted by MMOs aboard the *Gilavar* during the Beaufort Sea survey, however post-season analyses of the sighting data from all vessels operating in the Beaufort Sea indicate that this animal, originally documented as an unidentified pinniped, may have been a Pacific walrus. If so, it is likely that one Pacific walrus was exposed to sounds ≥180 dB rms.

***Polar Bears Potentially Exposed to Sounds ≥180 dB re 1 μPa (rms)***.—No polar bears were sighted from or near the *Gilavar*, thus there were no directly observed takes of polar bears.

### *Estimates Extrapolated from Density*

The methodology used to estimate the areas exposed to received levels ≥120 dB, ≥160 dB, ≥170 dB, ≥180 dB and ≥190 dB was described in Chapter 4 *Methods* and in more detail in Appendix E. Densities were based on data collected from all vessels (*Gilavar*, *Kilabuk*, *Norseman II*, and *Gulf Provider*) during SOI's seismic operations in the Beaufort Sea.

The aforementioned densities were used to estimate both the number of *individual* marine mammals exposed to ≥160, 170, 180, and 190 dB, and the number of *exposures* of different individual marine mammals. These numbers provide estimates of the number of animals potentially affected by seismic operations, as described in Chapter 4 and Appendix E. A discussion of the difficulties and limitations of density calculations and associated estimates is given in the introduction of the *Estimates Extrapolated from Density* section for the Chukchi Sea survey.

Estimates of the densities of marine mammals are given in Table 5.36, including approximate corrections for sightability biases. These corrected densities were used to estimate the number of marine mammals that were exposed to various received levels of airgun sound, and thus potentially affected by seismic operations (Tables 5.38, 5.37, 5.39). The ensonified areas used to estimate the numbers of marine mammals exposed to various sound levels are shown in Table 5.37.

***Cetaceans***.—The estimated numbers of cetaceans that might have been exposed to various levels of received sounds, relative to the number of "takes" requested in the IHA application, are summarized in Table 5.38. The density data used to calculate these numbers, for non-seismic as well as seismic periods, are presented in Table 5.36. Note that the estimated numbers in Table 5.38A represent the cetaceans that would have been exposed had the animals not shown localized avoidance of the airguns or the ship itself. Many of the animals calculated to be within the ≥180 or ≥190 dB zones would in fact move away before being exposed to sounds that strong. This may partially explain why the estimated numbers based on sightings during seismic periods were lower than those during non-seismic periods (Table 5.38A vs B).

*(A) ≥160 dB (rms):* We estimated that there would have been ~16 different individual cetaceans exposed to airgun pulses with received levels ≥160 dB re 1 μPa (rms) approximately 19 times each during the survey if all cetaceans showed no avoidance of airguns or vessels (Table 5.38). The product of individuals and number of exposed individuals, 304, is considerably less than 2729- the number of bowhead and gray whale takes requested by SOI in their IHA application to NMFS (SOI 2006). Based on the available densities, all of these animals would have been bowhead whales. The estimated number of exposures per individual reflects the overlap in the ensonified areas around different seismic lines, and the fact that an animal remaining in the area would have been exposed repeatedly to ≥160 dB.

TABLE 5.36. Expected densities of marine mammals in offshore areas of the Alaskan Beaufort Sea (see Chapter 5 for more details). Densities are corrected for *f*(0) and *g*(0) biases. A lack of "useable" effort required that 1) all daylight observations and effort were used in calculating densities, and 2) that data from all vessels operating in the Beaufort Sea was used instead of data from only the *Gilavar* and its chase/monitoring vessels.

| **Species** | **Seismic**<br>(No. individuals /1000 km$^2$) | **Non-seismic**<br>(No. individuals /1000 km$^2$) |
|---|---|---|
| **Cetaceans** | | |
| Unidentified Whale | 0.7872 | 0.1467 |
| Unidentified Mysticete | 1.3219 | 0.9857 |
| Bowhead Whale | 3.3523 | 3.2232 |
| Minke Whale | | 0.0893 |
| **Pinnipeds** | | |
| Unidentified Pinniped | 1.1392 | |
| **Odobenids** | | |
| Pacific Walrus | 0.8049 | 0.3001 |
| **Phocids** | | |
| Unidentified Seal | 9.9840 | 9.9264 |
| Bearded Seal | 1.9637 | 1.4643 |
| Ringed Seal | 24.5935 | 29.8004 |
| Spotted Seal | 8.3834 | |
| **Ursids** | | |
| Polar Bear | | 0.4478 |

TABLE 5.37. The areas (km$^2$) potentially ensonified to various levels by the *Gilavar's* airgun array volumes, operating within the study area during seismic periods of the Beaufort Sea cruise, 12 Sep − 8 Oct 2007. Maximum area ensonified is shown with overlapping areas counted multiple times (“Including Overlap Area”), total area ensonified shown with overlapping areas counted only once (“Excluding Overlap Area”).

| | **Level of ensonification (dB re1µPa (rms))** | | | | |
|---|---|---|---|---|---|
| **Area (km$^2$)** | **120** | **160** | **170** | **180** | **190** |
| Including Overlap Area | 1,137,150 | 68,265 | 22,562 | 6819 | 2411 |
| Excluding Overlap Area | 29,620 | 3616 | 1955 | 1021 | 645 |

*(B) ≥170 dB (rms):* On average, some odontocete species may be disturbed only if exposed to received levels of airgun sounds ≥170 dB re 1 µPa (rms). If so, then the estimated number of exposures would be ~33% of the corresponding estimates for ≥160 dB, based on the proportionally smaller areas exposed to ≥170 dB. Overall, there would have been ~nine individuals exposed to seismic sounds ≥170 dB (Table 5.38) with ~11 exposures per individual.

TABLE 5.38 Estimated numbers of individual cetaceans exposed to received sound levels ≥160, 170, 180, and 190 dB (rms) and average number of exposures per individual within the Beaufort Sea, ***(A)*** based on non-seismic density, and ***(B)*** based on seismic density. Requested number of takes for the Beaufort Sea is also shown.

| | **A. Based on Non-seismic density**[a] | | **B. Based on Seismic density**[a] | | |
|---|---|---|---|---|---|
| **Exposure level in dB re 1µPa (rms)** | **Individuals** | **Exposures per Individual** | **Individuals** | **Exposures per Individual** | **Requested Take** |
| **≥160** | 16 | 19 | 20 | 19 | 2729 |
| **≥170** | 9 | 11 | 11 | 11 | |
| **≥180** | 5 | 6 | 6 | 6 | |
| **≥190** | 3 | 4 | 4 | 3 | |

[a] These density estimates are presented in Table 5.35.

*(C) ≥180 dB (rms):* If there were no avoidance of airgun noise by cetaceans, it is estimated that there would have been ~five individual cetaceans exposed ~six times each to seismic sounds ≥180 dB (Table 5.38). As noted earlier, there were only two cetacean sightings from *Gilavar* when airguns were operating. It is possible that some additional cetaceans were present within the ≥180dB radius and not seen by the MMOs during good visibility conditions. However, under those conditions, most cetaceans present were likely seen.

*Estimates Based on Densities during Seismic Periods:* Only one species, the bowhead whale, had useable sightings sufficient for the calculation of a density applicable to periods of seismic activity (Table 5.36). The density of bowheads during non-seismic periods slightly lower. This indicated bowhead whales may not have avoided the seismic operation. Based on the corrected densities recorded during seismic periods, the minimum numbers of individuals exposed and exposures per individual are summarized in Table 5.38B.

***Seals***.—Table 5.39 summarizes the estimated numbers of pinnipeds that might have been exposed to received sounds with various levels relative to the number of “takes” requested in SOI’s IHA application for the Beaufort Sea. These estimates are based on the ensonified area figures from Table 5.37 and the density data from Table 5.36. The latter table gives the density estimates derived from vessel-based surveys during both non-seismic and seismic periods. Note that the estimated numbers in Table 5.39, based on density data from non-seismic periods, represent the pinnipeds that would have been exposed had the animals not shown localized avoidance of the airguns or the ship itself, and assume that all pinnipeds present were in the water. Some of the animals calculated (based on density) to be within the ≥190-dB zone would in fact move away before being exposed to sounds that strong. Also, some of those calculated to be in the ≥160- or ≥170 dB zones would be on the ice and not exposed to the underwater sounds.

TABLE 5.39 Estimated numbers of individual seals exposed to received sound levels ≥160, 170, 180, and 190 dB (rms) and average number of exposures per individual within the Beaufort Sea, ***(A)*** based on non-seismic density, and ***(B)*** based on seismic density. Requested number of takes for the Beaufort Sea is also shown.

| | **A. Based on Non-seismic density**[a] | | **B. Based on Seismic density**[a] | | |
|---|---|---|---|---|---|
| **Exposure level in dB re 1µPa (rms)** | **Individuals** | **Exposures per Individual** | **Individuals** | **Exposures per Individual** | **Requested Take** |
| **≥160** | 149 | 19 | 165 | 19 | 32,314 |
| **≥170** | 81 | 11 | 89 | 12 | |
| **≥180** | 42 | 7 | 47 | 7 | |
| **≥190** | 27 | 4 | 30 | 4 | |

[a] These density estimates are presented in Table 5.35.

*(A) ≥160 dB (rms):* We estimated that there would have been ~19 exposures to each of ~149 different individual seals to airgun pulses with received levels ≥160 dB re 1 µPa (rms) during the survey if all seals were in the water and showed no avoidance of the ≥160 dB zone (Table 5.39).. The product of individuals and number of exposed individuals, 2831, is considerably less than 32,314- the number of takes requested by SOI in their IHA application to NMFS (SOI 2006). Based on the available densities and prorating of unknown individuals, 144 of the animals would have been ringed seals and 4 would have been bearded seals. Prorating of unidentified individuals may have artificially inflated or underestimated the takes of individual species.

*(B) ≥170 dB (rms):* Some seals may be disturbed only if exposed to received levels of airgun sounds ≥170 dB re 1 µPa (rms). If so, then the estimated number of exposures would be ~33% of the corresponding estimates for ≥160 dB, based on the proportionally smaller areas exposed to ≥170 dB (Table 5.37). Overall, there would have been ~11 exposures to each of ~81 individual seals to seismic sounds ≥170 dB (Table 5.39).

*(C) ≥180 dB (rms):* Some seals were likely within the ≥180 dB radius (estimated as being up to 2.4 km or 1.5 mi, Table 4.4) around the operating airguns but were missed by the observers even during airgun operations conducted in good visibility conditions. It is estimated that there were ~seven exposures to each of ~42 individual seals to sounds ≥180 dB (Table 5.39). These figures assume that there was no effective avoidance by pinnipeds of the 180 dB radius around the approaching airguns.

*(D) ≥190 dB (rms):* Based on densities calculated from sighting rates during non-seismic periods, we estimated that there would have been 27 individual seals exposed four times each to airgun sounds at ≥190 dB (rms) if there were no avoidance (Table 5.39). Even the smaller of these estimates is far higher than the number of pinnipeds (*n* = 2) that direct observations indicated were possibly exposed to ≥190 dB (Table bftpz). Some pinnipeds within the ≥190 dB radius presumably were missed during times when MMOs were on watch as well as at night when MMOs generally were not on watch. Even during times when MMOs are on watch, some seals at the surface can be missed due to brief surface times, poor visibility, rough seas, and other factors. Because of this, density-based estimates of exposures and exposed individuals are higher than those based on direct observation. However, estimates based on densities during non-seismic periods may be overestimates. The chase/monitoring vessels might be expected to

displace some pinnipeds from the trackline before the *Gilavar* arrived, and some additional pinnipeds likely swam away in response to the approaching *Gilavar* to avoid exposure to seismic sound. Therefore, the actual number exposed to ≥190 dB rms was probably lower than the above estimates.

*Estimates Based on Densities during Seismic Periods:* The estimates quoted in the above paragraphs are all based on densities recorded during non-seismic periods. Densities of seals recorded during seismic periods were generally similar to those during non-seismic periods (Table 5.36). However, some densities were higher during seismic periods, which was unexpected. Lower densities might be expected during seismic periods, either because of displacement (to the extent it occurs) or the tendency of seismic activity to take place further away from pack ice. (Arctic pinnipeds tend to concentrate near ice in summer.) Alternatively, locally abundant food resources near seismic track lines may be responsible for occasional high densities during seismic surveys. On several occasions the *Gilavar* passed through very strong tide rips and fronts. These areas frequently contain prey biomass higher than surrounding areas and thus attract seals (Suryan and Harvey 1998). The minimum numbers of individuals exposed and exposures per individual, based on the corrected densities recorded during seismic periods, are summarized in Table 5.39.

Overall, these minimum figures are somewhat higher than those based on densities during non-seismic periods. The estimated number of exposures per individual reflects the degree of overlap in the ensonified areas around different seismic lines.

***Pacific Walrus and Polar Bear****—(A) ≥160 dB (rms):* We estimated that there would have been ~10 exposures to one individual Pacific walrus and ~16 exposures to each of ~two individual polar bears to airgun pulses with received levels ≥160 dB re 1 μPa (rms) during the survey all animals showed no avoidance of the ≥160 dB zone (Table 5.40). The walrus number included prorating of exposures and individuals from the "unidentified pinniped" category, which potentially included bearded seals and Pacific walruses.

*(B) ≥170 dB (rms):* Some walruses may be disturbed only if exposed to received levels of airgun sounds ≥170 dB re 1 μPa (rms). Overall, there would have been no exposures of Pacific walruses and ~10 exposures to one individual polar bear to seismic sounds ≥170 dB (Table 5.40).

*(C) ≥180 dB (rms):* The large size of the ≥180 dB radius means that some Pacific walruses and polar bears may have been present around the operating airguns but were missed by the observers even during airgun operations conducted in good visibility conditions. Based on available densities, it is estimated that there were no exposures of either Pacific walruses or polar bears to sounds ≥180 dB re 1 μPa (rms).

*Estimates Based on Densities during Seismic Periods:* Lack of usable and daylight effort precluded the calculation of a density of polar bears during seismic periods (Table 5.36). Densities of Pacific walrus recorded during seismic periods were, unexpectedly, higher than those observed during non-seismic periods (Table 5.36).

TABLE 5.40 Estimated numbers of individual Pacific walruses and polar bears exposed to received sound levels ≥160, 170, 180, and 190 dB (rms) and average number of exposures per individual within the Beaufort Sea, ***(A)*** based on non-seismic density, and ***(B)*** based on seismic density. Requested number of takes for the Beaufort Sea is also shown.

| | **A. Based on Non-seismic density**[a] | | **B. Based on Seismic density**[a] | | |
|---|---|---|---|---|---|
| **Exposure level in dB re 1µPa (rms)** | **Individuals** | **Exposures per Individual** | **Individuals** | **Exposures per Individual** | **Requested Take** |
| **1. Pacific Walrus** | | | | | |
| **≥160** | 1 | 10 | 3 | 18 | |
| **≥170** | 0 | 0 | 2 | 9 | |
| **≥180** | 0 | 0 | 1 | 5 | |
| **≥190** | 0 | 0 | 1 | 2 | |
| **2. Polar Bears** | | | | | |
| **≥160** | 2 | 16 | N/A | N/A | |
| **≥170** | 1 | 10 | N/A | N/A | |
| **≥180** | 0 | 0 | N/A | N/A | |
| **≥190** | 0 | 0 | N/A | N/A | |

[a] These density estimates are presented in Table 5.35.

# SHALLOW HAZARDS SURVEY MONITORING

## *Monitoring Effort and Marine Mammal Encounter Results*

This section summarizes the visual monitoring effort and marine mammal sightings from the *Henry Christoffersen (Henry C.)* during the Beaufort Sea shallow hazards seismic and bathymetric survey. The project began when the *Henry C.* entered the Alaskan Beaufort Sea on 16 Aug, and ended when the *Henry C.* returned to Canadian waters on 2 Oct. Additional information regarding the activities of the *Henry C.* can be found in Chapter 2.

Poor visibility (<3.5 km (2.2 mi) from the boat, often due to fog) resulted in categorization of 50% of the data collected from the *Henry C.* as unuseable (see Methods). Therefore, all daylight observation effort was considered in the following analyses to increase the sample size.

### *Visual Survey Effort*

The 2007 shallow-hazards seismic survey activities were conducted in the Beaufort Sea by the *Henry C.* along a total of 4240 km (2635 mi; 1125h) of trackline. During a total of 2916 km (1812 mi; ~391 h) of *Henry C.* observation effort within the Beaufort Sea, 2823 km (1754 mi; 368 h) of visual monitoring occurred during daylight (Fig. 5.56; Appendix Table C.31). MMOs observed primarily from the conning tower of the *Henry C.* (eye-height ~14.5 m (15.8 yd) above water; 98.9% of watch time), with the remaining observations conducted from the bridge (eye-height ~8.4 m (9.2 yd)). Seismic survey effort with the *Henry C.'s* small airgun array (2 x 10 in$^3$ airguns) was very limited due to high winds and sea states. Airguns were operated for only 147 km (91 mi) over 23 h, with 98 km (61 mi) over ~15 h occurring during daylight. There were no power downs or shut downs implemented during the daytime, so no nighttime visual observation during seismic activity was conducted. One observer was on watch aboard the *Henry C.* in daylight during a total of ~1939 km (1205 mi) (248 h) and at least two observers were on watch during the remaining ~884 km (549 mi) (119 h).

Survey effort from the *Henry C.*, subdivided by seismic activity and Beaufort wind force, is summarized in Appendix Table C.31. Observer effort by seismic period and Beaufort wind force is displayed in Figs. 5.56 and 5.57.

Beaufort wind force (sea state; Bf) during observations aboard the *Henry C.* ranged from one to eight within the study area, with 37.0% of the total effort (in h) occurring during conditions of Beaufort one (Fig. 5.57). Most observations were conducted during conditions with Bf ≤ 2 (70.6% in h). The *Henry C.* was anchored during periods of high sea states resulting in a higher percentage of effort occurring at low sea states compared to the *Gilavar* and chase/monitoring vessels.

### *Visual Sightings of Marine Mammals and Other Vessels*

***Total Numbers of Marine Mammals Observed***— A grand total of 304 individual marine mammals in 240 groups were recorded aboard the Henry C. in 2007 (Appendix Table C.32). An estimated 280 individuals in 232 groups were observed during daylight MMO watch periods within the Beaufort Sea study area in 2007 from the *Henry C* (Table 5.41). These daylight MMO watch sightings included 11 sightings of cetaceans, 203 sightings of seals and 18 sightings of polar bears (Table 5.41). No Pacific walruses were observed from the *Henry C.*

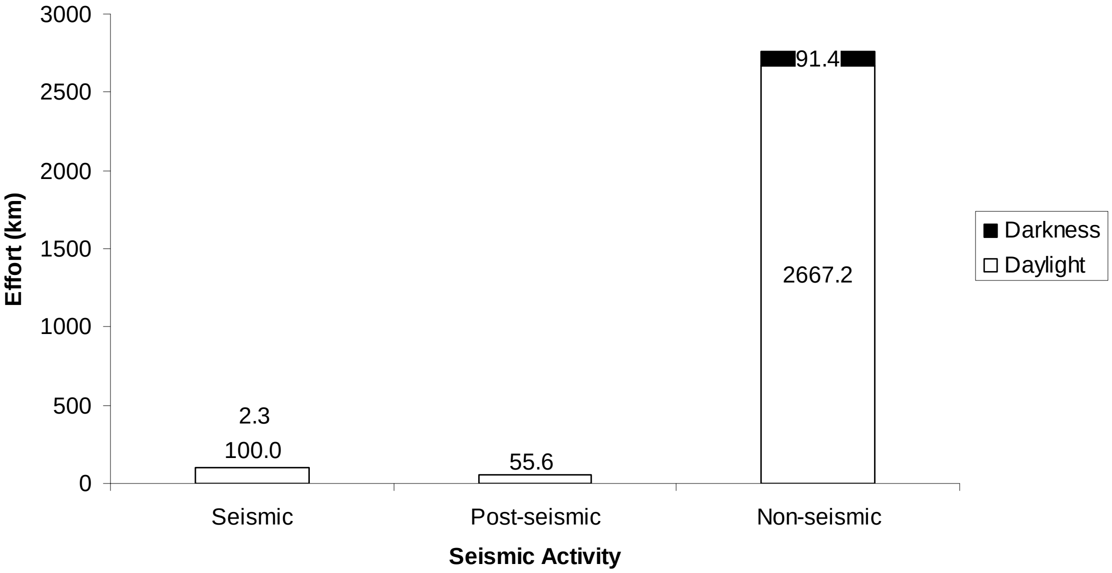


FIGURE 5.56. Total marine mammal observer effort (km) from the *Henry C.* in the Beaufort Sea study area by seismic activity in daylight and darkness.

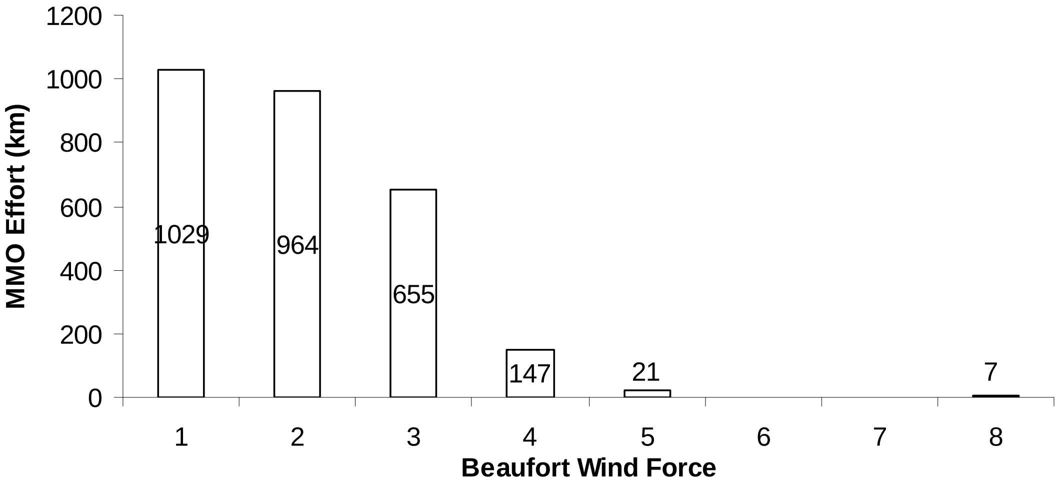


FIGURE 5.57. Total daylight marine mammal observer effort (km) in the Beaufort Sea study area from the *Henry C.* by Beaufort wind force.

TABLE 5.41. Number of sightings (number of individuals) of marine mammals observed from the *Henry C.* during daylight in the Beaufort Sea (16 Aug – 2 Oct 2007), during different seismic states.

| Species | Seismic | Post-Seismic | Non-Seismic | *Total* |
|---|---|---|---|---|
| **Cetaceans** | | | | |
| Bowhead Whale | 0 (0) | 1 (1) | 7 (19) | *8 (20)* |
| Unidentified Mysticete Whale | 0 (0) | 0 (0) | 2 (2) | *2 (2)* |
| Unidentified Whale | 0 (0) | 0 (0) | 1 (1) | *1 (1)* |
| ***Total Cetaceans*** | ***0 0*** | ***1 1*** | ***10 22*** | ***11 23*** |
| **Seals** | | | | |
| Bearded Seal | 0 (0) | 0 (0) | *32* (34) | *32 (34)* |
| Ringed and Spotted Seals[a] | 2 (2) | 0 (0) | *169* (190) | *171 (192)* |
| ***Total Seals*** | ***2 (2)*** | ***0 (0)*** | ***201 (224)*** | ***203 (226)*** |
| **Polar bears** | | | | |
| In Water | 0 (0) | 0 (0) | *2* (4) | *2* (4) |
| On Land | 0 (0) | 0 (0) | *16* (27) | *16 (27)* |
| ***Total Polar Bears*** | ***0 (0)*** | ***0 (0)*** | ***18 (31)*** | ***18 (31)*** |
| ***Total*** | ***2 (2)*** | ***1 (1)*** | ***229 (277)*** | ***232 (280)*** |

[a] Includes all records of ringed, spotted, and unidentified seals

Bowhead whale was the only cetacean identified to species ($n$ = 20 in 8 groups), however, there were observations of unidentified mysticete whales ($n$ = two sightings of two individuals) and an unidentified whale ($n$ = one sightings of one individuals).

There were 226 seals sighted in 203 groups by MMOs on the *Henry C.* during the Beaufort Sea survey. All of these individuals were in the water as opposed to on ice or land. Ringed, spotted and unidentified seals were combined into a single category to accurately represent the number of small seals observed from the *Henry C.* MMOs were more concerned with documenting seal position with respect to the vessel, and considering the potential need to implement mitigation measures than they were with precisely identifying small seals to species. Of the 203 seal sightings recorded by the *Henry C.*, 171 or 84.2%, were either ringed or spotted seals. The remaining 32 sightings were of bearded seals.

Polar bears were sighted frequently during the cruise in areas close to land. A total of 18 polar bear groups were sighted totaling 31 individuals. The majority of these sightings were recorded while the *Henry C.* was anchored near barrier islands.

The majority of the sightings (96.3% or 232 groups) within the study area were made during daylight hours, while MMOs were on active watch. These sightings, along with corresponding effort data, are the basis for the ensuing analyses comparing detection rates and behaviors of marine mammals seen during the cruise. There were no dead animals observed during monitoring from the *Henry C.*

***Sightings with Airguns On***— Most marine mammal sightings were recorded during non-seismic periods, which constituted the overwhelming majority of the observation time (Fig. 5.58). Only two seal sightings and no cetaceans sightings were noted during the 23 h while the airguns were operating. A total of 229 sightings were made during non-seismic periods and one cetacean sighting was made during the 7 h of post-seismic observation effort (Table 5.41). No power downs or shut downs were required during seismic activity, as no marine mammals were sighted in the water within the applicable safety radii around the operating airguns.

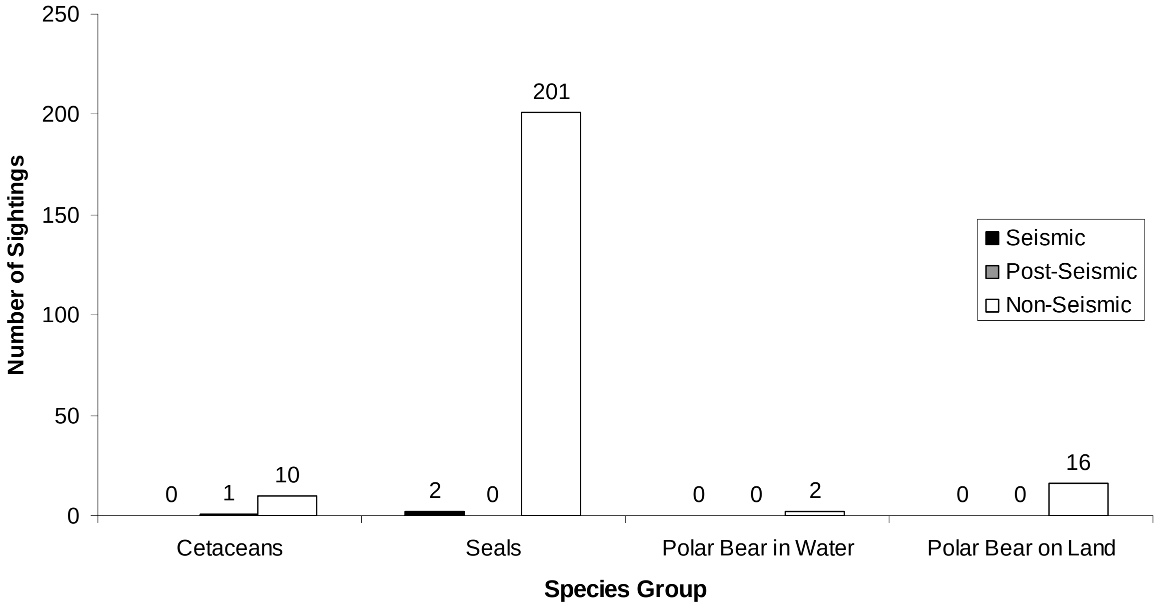


FIGURE 5.58. Marine Mammal Sightings by seismic state from the *Henry C.* during the Beaufort Sea shallow hazards survey (16 Aug – 2 Oct 2007).

***Detection Rates***— Detection rates (# groups sighted per unit of daylight MMO effort) by seismic activity from the *Henry C.* during the 2007 Beaufort Sea survey are presented in Fig. 5.59 (see Appendix Table C.33 for raw data). The lack of sightings while the airguns were on (two sightings in 23 h, of which 15 h were during daylight) could simply reflect the brief duration and location of seismic operations. However, it may also reflect avoidance of the seismic survey by marine mammals. During seismic operations, the detection rate was about one-fourth of the rate during non-seismic conditions (20.0 vs. 85.9 groups/1000 km, 32.2 vs. 138.2 groups/1000 mi; Fig/ 5.59).

Detection rates were inversely related to sea state and wind velocity (Fig. 5.60). This is typical for marine mammal surveys because rougher sea conditions make it more difficult for observers to detect animals in the water.

Detection rates of marine mammals were directly related to the number of MMOs on watch (Fig. 5.61). Detection rates for the Henry C. were twice as high when two MMOs were on watch compared to a single observer.

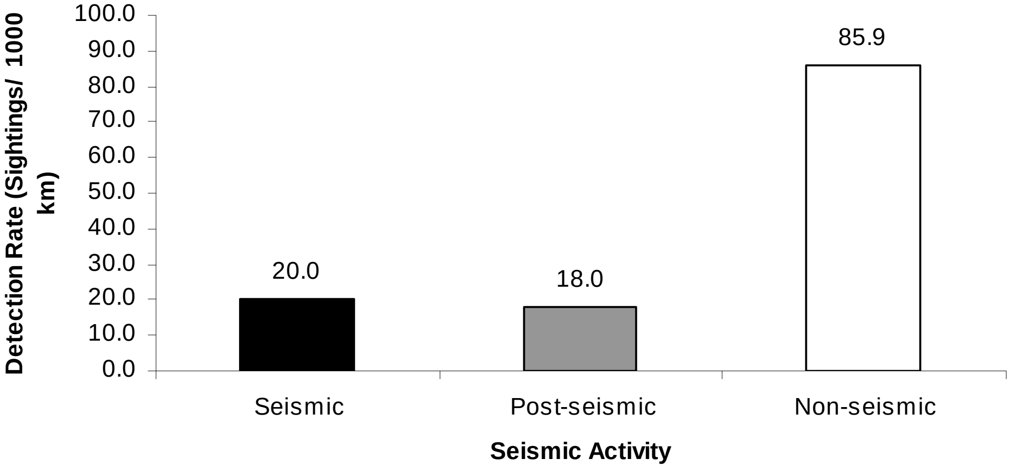


FIGURE 5.59. Detection rates from the *Henry C.* in different seismic periods during the shallow hazards survey (16 Aug – 2 Oct 2007).

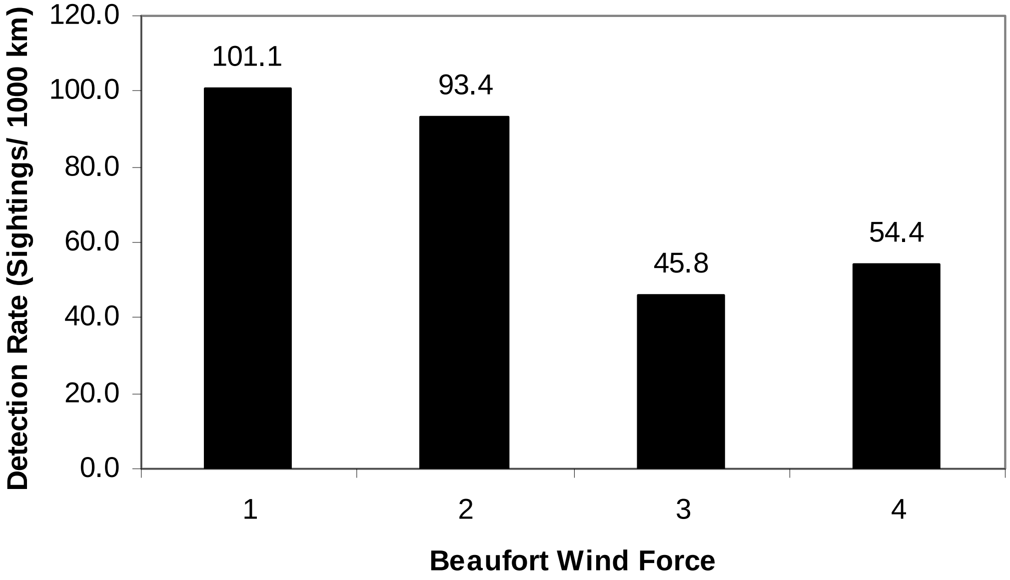


FIGURE 5.60. Detection rates from the *Henry C.* in different Beaufort wind force categories during the shallow hazards survey (16 Aug–2 Oct 2007).

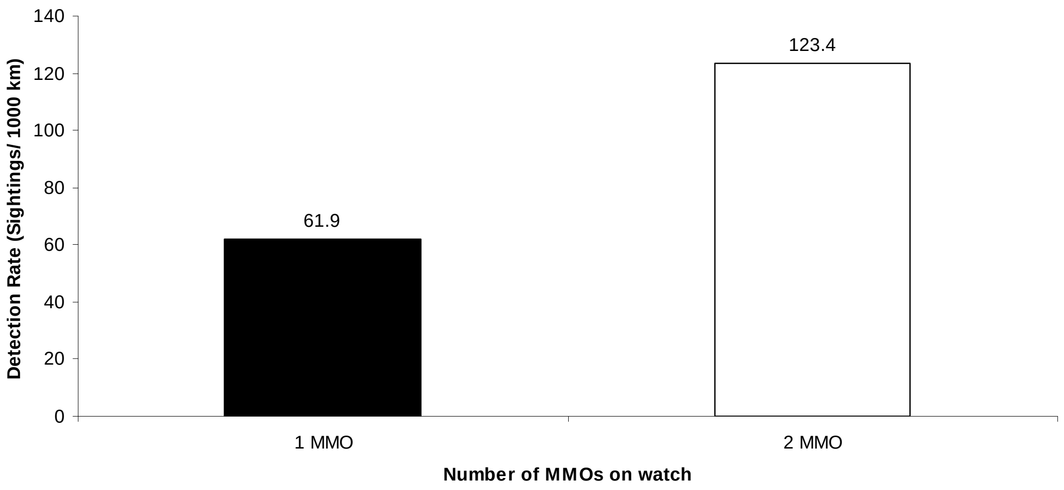


FIGURE 5.61. Detection rates for one vs. two MMOs on watch aboard the *Henry C.* during the shallow hazards survey (16 Aug – 2 Oct 2007).

***Other Vessels***—The IHA required that MMOs record the number and characteristics of vessels within 5 km (3107 mi) of the *Henry C.* There were few vessels near the *Henry C.* during the 2007 monitoring period. Vessels present were generally barges or supply vessels affiliated with this project. The majority of vessels observed by the *Henry C.* were seen while seeking shelter (anchored) from rough weather or during transits to and from West Dock. Most of these vessels were at distances >5 km (3107 mi). However ten vessels were sighted within 5 km (3107 mi) of the *Henry C.* There were eight marine mammals sighted while another vessel was known to be within 5 km (3107 mi) of the *Henry C.* but, there were no obvious reactions by marine mammals to the other vessels noted.

## *Cetaceans*

***Total Numbers of Cetaceans Observed***—11 cetacean sightings comprised of 23 individuals were recorded in the Beaufort Sea from the Henry C. We saw 20 bowheads in 8 groups, while the remaining cetaceans were unidentified.

***Cetacean Sightings with Airguns On***—Of the 11 total cetacean sightings recorded by the *Henry C.*, none were made while the airguns were operating. However, there was one cetacean sighting made during the 7 h of post-seismic observation effort (Table 5.42).

***Cetacean Detection Rates***—Cetacean detection rates (# groups sighted per unit of daylight MMO effort) by seismic activity from the *Henry C.* are presented in Fig. 5.62 (see Appendix Table C.34 for raw data). The absence of sightings while the airguns were on (0 sightings in 23 h, of which 15 h were during daylight) may simply reflect the brief duration and location of seismic operations. However, it may also be consistent with avoidance of the operating airguns by cetaceans that has been observed during previous seismic surveys. The cetacean sightings rate for the post-seismic period is skewed by the single cetacean sighting in a very limited amount of effort (one sighting in 55.6 km (34.5 mi) of effort).

Table 5.42. Number of sightings (number of individuals) of cetaceans observed from the Henry C during daylight in the Beaufort Sea. (16 Aug – 2 Oct 2007) during the different seismic states.

| Species | Seismic Sightings (Indiv.) | Post-Seismic Sightings (Indiv.) | Non-Seismic Sightings (Indiv.) | *Total* Sightings (Indiv.) |
|---|---|---|---|---|
| ***A. Henry C.*** | | | | |
| **Cetaceans** | | | | |
| Bowhead Whale | 0 (0) | 1 (1) | 7 (19) | *8 (20)* |
| Unidentified Mysticete Whale | 0 (0) | 0 (0) | 2 (2) | *2 (2)* |
| Unidentified Whale | 0 (0) | 0 (0) | 1 (1) | *1 (1)* |
| ***Total Cetaceans*** | ***0 (0)*** | ***1 (1)*** | ***10 (22)*** | ***11 (23)*** |

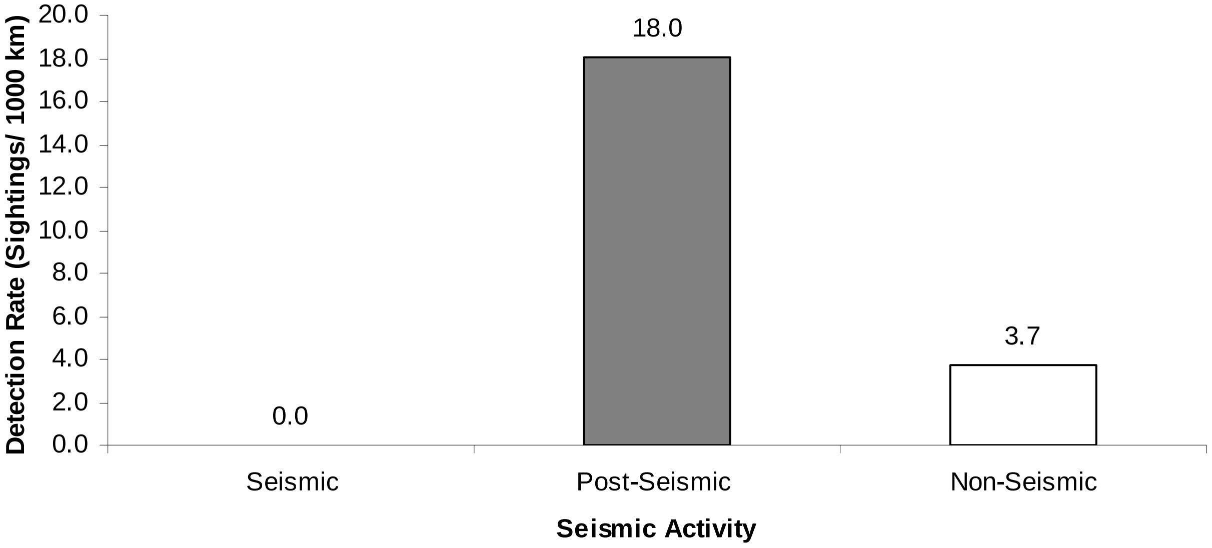


FIGURE 5.62. Detection rates for cetaceans during different seismic states from daylight effort aboard the *Henry C.* during the shallow hazards survey (16 Aug – 2 Oct 2007).

## *Seals*

***Total Numbers of Seals Observed***—There were 226 seals sighted in 203 groups by the *Henry C.* during the shallow hazards survey (Table 5.43). Three different seal species were identified, with ringed seals being the most frequently identified species (*n* = 106 individuals in 90 groups), followed by bearded seals (*n* = 34 in 32 groups). In addition, 10 groups (13 individuals) of spotted seals were observed. Of the 153 seals in the study area that were identified by MMOs, 106 (or 69.3%) were ringed seals. Most of the unidentified seals (*n* = 73 individuals in 71 groups) were likely ringed seals given the visual monitoring results and the known occurrence of this species throughout the study area. However, the unidentified seals moved too rapidly or were too far away for the observer to make a positive identification. All of these individuals were in the water as opposed to on ice or land.

***Seal Sightings with Airguns On***—Of the 203 total seal sightings recorded by the *Henry C.* only two seal sightings were noted during the 23 h while the airguns were operating. Neither was sighted within the 190 dB safety radius around the operating airguns.

***Seal Detection Rates***—Seal detection rates (# groups sighted per unit of daylight MMO effort) from the *Henry C.* by seismic activity are presented in Fig. 5.63 (see Appendix Table C.35 for raw data). The lack of sightings while the airguns were on (two sightings in 23 h, of which 15 h were during daylight) may simply reflect the brief duration and location of seismic operations.

TABLE 5.43. Number of sightings (number of individuals) of seals observed from the *Henry C.* in daylight (16 Aug - 2 Oct 2007) during different seismic states.

| **Species** | **Seismic Sightings (Indiv.)** | **Post-Seismic Sightings (Indiv.)** | **Non-Seismic Sightings (Indiv.)** | ***Total* Sightings (Indiv.)** |
|---|---|---|---|---|
| ***A. Henry C.*** | | | | |
| **Seals** | | | | |
| Bearded Seal | 0 (0) | 0 (0) | 32 (34) | *32 (34)* |
| Ringed and Spotted Seals[a] | 2 (2) | 0 (0) | 169 (190) | *171 (192)* |
| ***Total Seals*** | ***2 (2)*** | ***0 (0)*** | ***201 (224)*** | ***203 (226)*** |

[a] Includes "Unidentified Seal" numbers

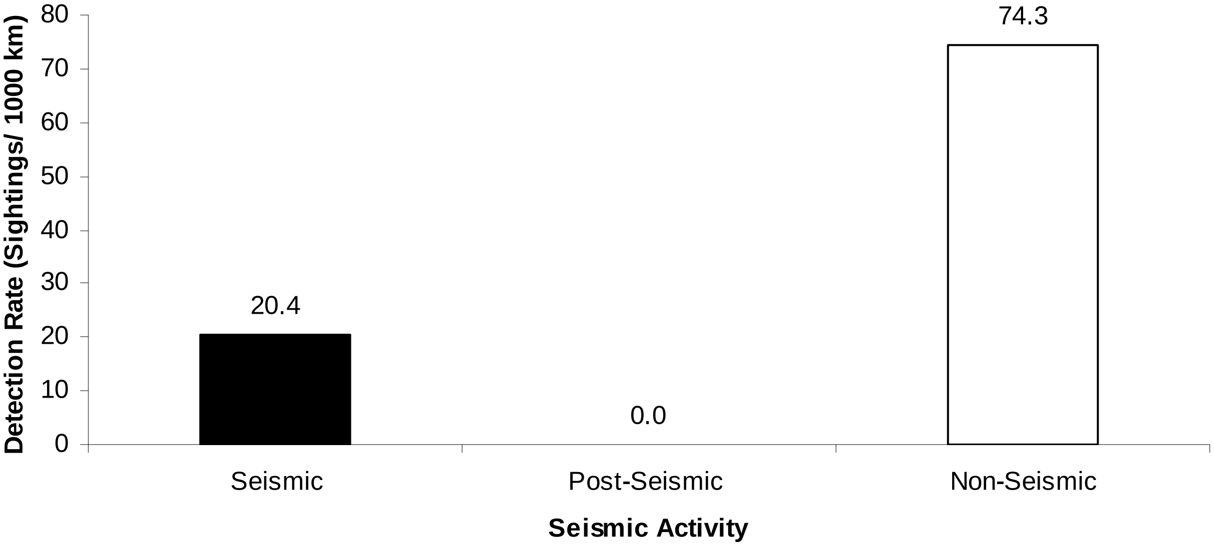


FIGURE 5.63. Detection rates of seals during different seismic states from daylight effort aboard the *Henry C.* during the shallow hazards survey (16 Aug – 2 Oct 2007).

## *Pacific Walrus and Polar Bears*

***Total Numbers of Pacific Walrus and Polar Bears***—There were no Pacific walruses recorded in the Beaufort Sea from the *Henry C.* in 2007.

Eighteen polar bear sightings comprised of 31 individuals were recorded in the Beaufort Sea from the *Henry C.*

***Polar Bear Sightings with Airguns On***—Of the 18 polar bear sightings recorded by the *Henry C.*, none of them were made while the airguns were operating (Table 5.44).

***Polar Bear Detection Rates***—Polar bear detection rates (# groups sighted per unit of daylight MMO effort) during non-seismic periods were 0.7 in water and 5.9 on land. The absence of sightings while the airguns were on (0 sightings in 23 h, of which 15 h were during daylight) may simply reflect the brief duration and location of seismic operations. However, much of the seismic activity occurred quite a distance from the barrier islands or pack ice, greatly reducing the likelihood of encountering a polar bear while the guns were active. Therefore, the amount of seismic activity would probably not have influenced the detection rates of polar bears greatly. However, the rough seas and high winds encountered this season had a significant effect on the number of polar bear sightings, as most of the polar bears were seen while the *Henry C.* was anchored near barrier islands seeking shelter from the rough weather.

TABLE 5.44. Number of sightings (number of individuals) of polar bears observed from the *Henry C.* during daylight (16 Aug – 2 Oct 2007) during different seismic states.

| **Species** | **Seismic Sightings (Indiv.)** | **Post-Seismic Sightings (Indiv.)** | **Non-Seismic Sightings (Indiv.)** | ***Total* Sightings (Indiv.)** |
|---|---|---|---|---|
| ***A. Henry C.*** | | | | |
| **Polar Bears in Water** | | | | |
| Polar Bear | 0 (0) | 0 (0) | *2* (4) | *2* (4) |
| **Polar Bears on Land** | | | | |
| Polar Bear | 0 (0) | 0 (0) | *16* (27) | 16 (27) |
| ***Total Polar Bears*** | ***0 (0)*** | ***0 (0)*** | ***18 (31)*** | ***18 (31)*** |

## *Distribution and Behavior of Marine Mammals*

The data collected during visual observations provide information about behavioral responses of marine mammals to the seismic survey. The relevant data collected from the *Henry C.* include estimated closest observed points of approach (CPA) to the vessel, movement relative to the vessel, and behavior of animals at the time of the initial sightings. CPA of marine mammals to the vessel was calculated from the location the airguns would have been positioned if deployed. Bearing and distances from the observer station to the CPA of marine mammals were calculated and plotted for daylight cetacean and seal sightings.

Marine mammal behavior is difficult to observe, especially from a seismic vessel, because individuals and/or groups are often at the surface only briefly, and there may be avoidance behavior. This causes difficulties in resighting those animals, and in determining whether two sightings some minutes apart are repeat sightings of the same individual(s). Only limited behavioral data were collected during this project because marine mammals were often seen at a distance from the vessel, and it was not possible to track them for long distances or durations while the vessel was underway along a predetermined course.

Sample sizes for this cruise were small and there were only two sightings during the brief duration of seismic operations. However, previous studies in the Alaskan Beaufort Sea have provided comparable data on seal behavior in the presence and absence of airgun operations (e.g., Moulton and Lawson 2002). The 2007 data from non-seismic periods could be useful as a basis of comparison with any future related results.

### Cetaceans

### Distribution and Closest Observed Point of Approach

No cetaceans were observed from the *Henry C.*, while the airguns were operating. There was one cetacean observed at a distance of 464 m during the post-seismic period. The mean CPA for cetaceans during non-seismic periods was more then double (829.9 m; *n*=10) that of the one sighting during the post-seismic period (Appendix Table C.36), however, due to the limited number of sightings during the post-seismic period, no valid statistical comparison of CPA values is possible.

***Movement and Initial Behavior***—The behavior recorded for most of the observed cetaceans was *surface active* (eight). The other two behaviors recorded for cetaceans were swimming and feeding. Surface active behavior included routine surfaces for breathing and fluking between dives. Of the 10 animals that showed movement, most (six) were traveling away from the vessel in a direction perpendicular to the vessel trackline (Fig. 5.64; Appendix Table C.37).

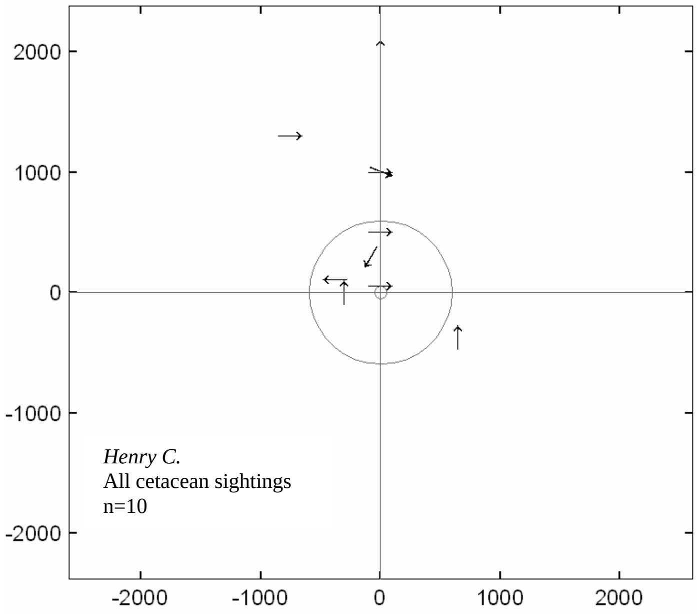


FIGURE 5.64. Location, range, and direction of travel of cetaceans observed from the *Henry C.* during non-seismic periods (16 Aug. –2 Oct). The circle indicates the 180 db safety radius if airguns had been firing. Distances between tick marks on both the X and Y axes = 0.62 mi.

## *Seals*

### *Distribution and Closest Observed Point of Approach*

The two seals observed while the airguns were operating were at distances of 118 m and 143 m (Table 5.45). The mean CPA for seals during non-seismic periods was 168.4 m (*n*=201) which is greater than the distances recorded during seismic activity, but once again, due to the limited number of sightings during the seismic period, no valid statistical comparison of CPA values is possible.

***Movement and Initial Behavior***—The two seals observed during seismic activity did not demonstrate detectable differences in observed movement or behavior from those observed during non-seismic periods. One of the seals during seismic activity was observed swimming and looking toward the vessel, whereas the other seal was seen swimming and diving away from the vessel. Seals showed similar movement and behavioral tendencies during non-seismic periods with 96% of sightings noted to be active at the surface and/or looking at the vessel (Fig. 5.65; Fig. 5.66; Appendix Table C.37).

TABLE 5.45. Closest observed points of approach (CPA) of seals to the airguns of the *Henry C.* during seismic and non-seismic periods of the shallow hazards survey (16 Aug – 2 Oct 2007).

| **Species and Seismic Status** | ***n* Sightings** | **Mean CPA (m)[a]** | **s.d.** | **Range (m)** |
|---|---|---|---|---|
| ***Henry C.*** | | | | |
| **Seals in Water** | | | | |
| Seismic | 2 | 130.5 | 17.7 | 118-143 |
| Non-Seismic | 201 | 168.4 | 118.3 | 54-1056 |

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

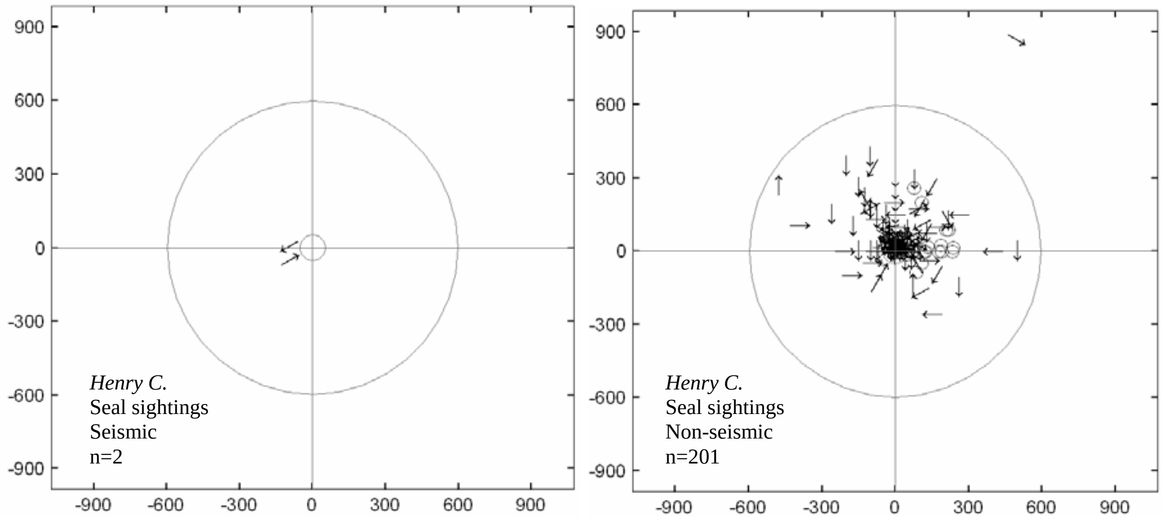


FIGURE 5.65. Location, range, and direction of travel of seals sighted from the *Henry C.* during seismic and non-seismic periods during the shallow hazards survey (16 Aug –2 Oct). Distances between tick marks on both the X and Y axes = 328 yd.

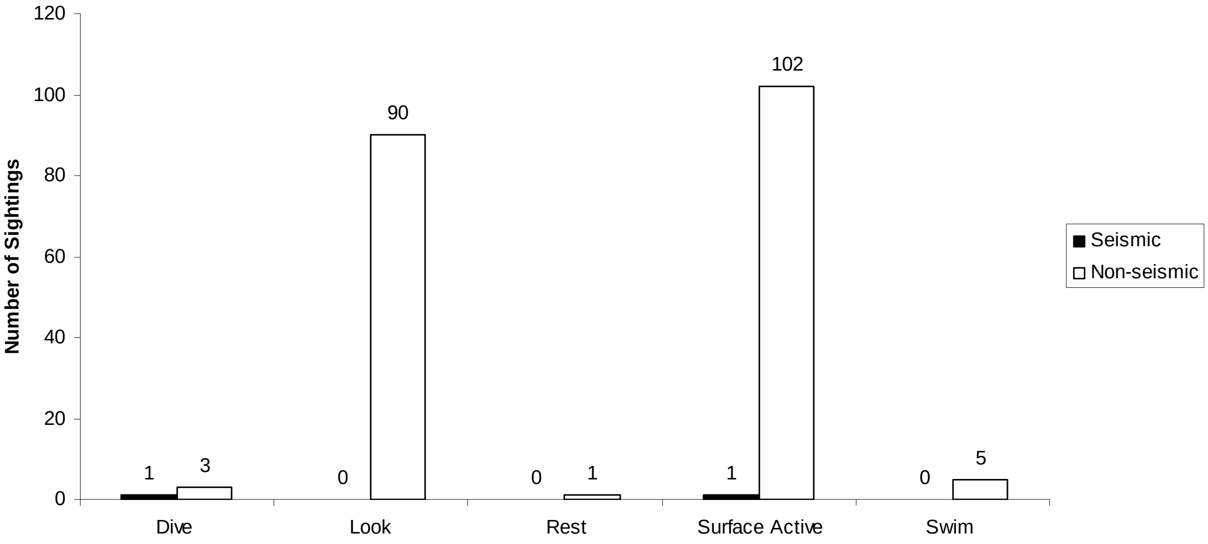


FIGURE 5.66. Initial behavior of seals observed from the *Henry C.* during seismic and non-seismic periods during the Beaufort Sea shallow hazards surveys (Aug 16 - Oct 2, 2007).

## *Polar Bears*

### *Distribution and Closest Observed Point of Approach*

All 18 polar bear sightings recorded by the *Henry C.* occurred during non-seismic periods. The mean CPA for polar bears in the water was 1072.5 m (*n* = 2; s.d.= 589.02; range 656-1489 m), and the mean CPA distance for polar bears on land was 1615.3 m (*n* = 16; s.d.= 765.29; range 870-3396 m)

***Movement and Initial Behavior***—The majority of the polar bear sightings were recorded while the *Henry C.* was anchored near barrier islands. All but one of the polar bears were seen on land or swimming <100 meters from land. The single observation of a polar bear >100 meters from land consisted of a lone adult swimming perpendicular to the bow of the vessel. The behavior of the animal did not appear to be altered by the presence of the vessel. The remaining polar bears movements and activities were variable, as they were often observed actively feeding, swimming, and walking on the islands (Appendix Table C.37).

## *Mitigation Measures Implemented*

No power downs or shut-downs of the airguns were necessary or requested due to the detection of a marine mammal within the ≥180 and ≥190 dB safety radii. The two seal sightings during seismic activity were outside the ≥190 db safety radius. All other sightings occurred during either post-seismic or non-seismic periods.

## *Estimated Number of Marine Mammals Present and Potentially Affected*

It is difficult to obtain meaningful estimates of “take by harassment” for several reasons as described in the previous *Gilavar* sections. In addition to those reasons, the limited amount of seismic activity (and sightings in seismic periods) during the 2007 shallow hazards surveys make it difficult to obtain meaningful estimates of “take” by harassment.

### *Disturbance and Safety Criteria*

Table 4.3 shows measured received sound levels at various distances from the airgun(s) deployed from the *Henry C*. The ≥160 dB rms radius is an assumed behavioral disturbance criterion. The ≥180 and ≥190 dB radii are safety radii, used in determining when mitigation measures were required. During this and many other recent projects, NMFS has required that mitigation measures be applied to avoid, or minimize, the exposure of cetaceans and seals to impulse sounds with received levels ≥180 dB and ≥190 dB re 1 μPa (rms), respectively. No power downs or shut downs of the airguns were required during the brief duration of airgun operations from the *Henry C.* in 2007. However, the safety and disturbance radii were used after the field season to estimate numbers of marine mammals potentially exposed to various received sound levels based on observed densities.

This section applies two methods to estimate the number of seals and cetaceans exposed to seismic sound levels strong enough that they might have caused disturbance or other effects. The first procedure is based on direct observations of seals and cetaceans exposed to airgun sounds. The second is based on an indirect estimation process that involves calculating the total areas ensonified by various levels of sound (Appendix Table C.38), and multiplying those areas by the estimated density of seals and cetaceans within the study area (Table 5.46).

### *Estimates from Direct Observations*

The number of marine mammals observed close to the *Henry C.* during Beaufort Sea monitoring provided a minimum estimate of the number potentially affected by seismic sounds. This is likely an underestimate of the actual number potentially affected. Some animals probably moved away before coming within visual range, and not all of those that remained would have been seen by observers.

***Cetaceans Potentially Exposed to Sounds ≥180 dB re 1 μPa (rms)***.—There were no cetaceans sighted during the shallow hazards survey when the airguns were operating.

***Seals Potentially Exposed to Sounds ≥190 dB re 1 μPa (rms)***.—During this project, no marine mammals were sighted within the relatively small safety radii around the airguns while seismic operations were conducted. The estimated ≥180 dB and ≥190 dB radii shown in Table 4.3 are the *maximum* distances from the airguns where sound levels were expected to be ≥180 or ≥190 dB re 1 μPa (rms). These distances were applied as mitigation radii during all airgun operations. There were two seal sightings while the airguns were operating, but neither seal came within the 190 dB rms sound level distance, so they were unlikely to have been exposed to ≥190 dB rms. However, one of these seals, a ringed seal, was observed within the >160 dB radius of the then operating 1-airgun (333 m).

***Polar bears Potentially Exposed to Sounds ≥190 dB re 1 μPa (rms)***.— There were no polar bears sighted during the shallow hazards survey when the airguns were operating.

### *Estimates Extrapolated from Density*

The number of marine mammals visually detected by MMOs likely underestimates the actual number that are present, as described in previous sections. Indirect estimates based on the marine mammal densities (Table 5.46) multiplied by the area ensonified (exposed to seismic sounds) (Table 5.47) provide an alternative method for determining exposures.

The methodology used for the indirect estimates was described briefly in Chapter 4 *Monitoring and Mitigation Methods*. Methods used to estimate the areas exposed to received levels ≥160, ≥180 and ≥190 dB were also described there. Densities of marine mammals in the study area were estimated based on direct observations during seismic and non-seismic periods, analyzed using standard line-transect estimation procedures, and adjusted to allow for missed animals.

The aforementioned densities were used to estimate both the number of different *individual* marine mammals potentially exposed to ≥160, ≥180, and ≥190 dB (rms), and the number of *exposures* per individual. These numbers provide estimates of the number of animals potentially affected by seismic operations, as described in Chapter 4.

The estimates provided here are based on the actual airgun operations from the *Henry C.* during this project. In contrast, the estimates provided in the IHA application for this project were based on the then-anticipated amount of survey. The estimates in the IHA application assumed that SOI would conduct far more shallow hazards surveying in the Beaufort Sea than actually occurred. Additionally, the requested "takes" by SOI in the Beaufort Sea included those from the planned 3-D seismic work conducted from the *Gilavar*.

The following estimates assume that all mammals present were well below the surface, and that mammals did not move away from the path of the approaching vessel. Those assumptions probably did not apply to all animals, so (as described earlier for the *Gilavar*), indirect estimates based on densities in seismic and non-seismic periods are probably overestimates.

Estimates of the densities of seals and cetaceans in the Beaufort Sea study area are given in Table 5.46. These densities are based on daylight sighting and daylight observation effort from the *Henry C.* during seismic and non-seismic periods, including corrections for sightability biases ($f(0)$ and $g(0)$). These corrected densities were used to estimate the number of marine mammals that were exposed to various received levels of airgun sounds, and thus potentially affected by seismic operations.

***Cetaceans***— The estimated numbers of cetaceans that might have been exposed to various levels of received sounds, relative to the number of "takes" requested in the IHA application, are summarized in Table 5.48. The density data used to calculate these numbers, for non-seismic periods, are presented in Table 5.46. Note that the estimated numbers in Table 5.48 represent the cetaceans that would have been exposed had the animals not shown localized avoidance of the airguns or the ship itself. Many of the animals calculated (based on density) to be within the 180 dB or 190 dB zones would in fact move away before being exposed to sounds that strong.

*(A) ≥160 dB (rms):* Based on densities from non-seismic periods we estimated there may have been one individual cetacean exposed to airgun pulses with received levels ≥160 dB re 1 µPa (rms) during the shallow-hazards survey if all cetaceans were below the surface of the water and showed no avoidance of the approaching vessel (Table 5.48).

*(B) ≥180 dB (rms):* Based on non-seismic densities we estimated that no cetaceans were exposed to seismic sounds ≥180 dB even if there was no avoidance of the seismic sounds or vessel (Table 5.48).

***Seals***.—Table 5.49 summarizes the estimated numbers of seals that might have been exposed to received sounds at various levels relative to the number of "takes" requested in SOI's IHA application for the Beaufort Sea (SOI 2006). Table 5.46 gives the density estimates derived from vessel-based surveys during both seismic and non-seismic periods. Note that the estimated numbers in Table 5.49, based on daylight density data from non-seismic periods, represent the seals that would have been exposed had the animals not shown localized avoidance of the airguns or the ship itself.

*(A) ≥160 dB (rms):* We estimate that there would have been ~63 different individual seals (ringed, bearded, and spotted) exposed to airgun pulses with received levels ≥160 dB re 1 µPa (rms) during the shallow-hazards survey if all seals were below the surface of the water and showed no avoidance of the approaching vessel (Table 5.49). Given the predominance of ringed seals in the Beaufort Sea, most of the individuals exposed would have been of ringed seals, with lesser numbers of bearded and spotted seals.

*(B) ≥180 dB (rms):* Some seals may have been within the ≥180 dB radius around the operating airguns but were not seen by the observers even though the majority of airgun operations were during daylight. The ≥180 dB radius for the one airgun and the two airgun cluster were measured in the Beaufort Sea by JASCO as 2 m and 51 m, respectively. Based on the densities of seals estimated from sightings data under non-seismic conditions four individuals may have been exposed to sounds ≥180 dB, assuming no avoidance reaction (Table 5.49). The latter estimate far exceeds the zero seals directly observed in areas within to the ≥180 dB radius.

*(C) ≥190 dB (rms):* Likewise, based on the densities of seals calculated from our daylight sighting data, we estimate that there would have been one seal exposed to airgun sounds with received levels ≥190 dB (rms) assuming all seals were below the surface and showed no avoidance of the approaching vessel (Table 5.49).

TABLE 5.46. Estimated densities of marine mammals in offshore areas of the Alaskan Beaufort Sea based on all daylight effort and sightings from the *Henry C.* (see Chapter 4 for more details). Densities are corrected for *f*(0) and *g*(0) biases.

| **Species** | **Density - Seismic**[a] (No. individuals /1000 km$^2$) | **Density - Non-seismic**[a] (No. individuals /1000 km$^2$) |
|---|---|---|
| **Cetaceans** | | |
| Bowhead Whale | -- | 4.03 |
| Unidentified Mysticete Whale | -- | 0.23 |
| Unidentified Whale | -- | 0.14 |
| **Seals** | | |
| Ringed Seal | 76.79 | 299.31 |
| Spotted Seal | -- | 20.21 |
| Bearded Seal | -- | 61.91 |
| Unidentified Seal | 41.57 | 111.09 |
| **Polar Bears** | | |
| Polar Bear | -- | 5.75 |

[a] These density estimates are based on daylight sighting and daylight observation effort.

TABLE 5.47. The areas (km$^2$) potentially ensonified to various levels by the *Henry C.* airgun(s) during the shallow hazards survey, (16 Aug.- 2 Oct. 2007). (A) Maximum area ensonified, with overlapping areas counted multiple times. (B) Total area ensonified, with overlapping areas counted only once.

| | **Level of ensonification dB re 1 µPa (rms)** | | | |
|---|---|---|---|---|
| **Area (km$^2$)** | **120** | **160** | **180** | **190** |
| **A. Including Overlap Area** | 13714.23 | 240.21 | 12.87 | 3.04 |
| **B. Excluding Overlap Area** | 5089.78 | 161.51 | 11.38 | 2.93 |

TABLE 5.48. Estimated numbers of individual cetaceans exposed to received sound levels ≥160,180, and 190 dB (rms) and average number of exposures per individual within the Beaufort Sea survey period. Estimates are based on "corrected" densities of cetaceans calculated from daylight sighting effort during non-seismic periods. No cetaceans were sighted during seismic periods

| | **Based on Non-seismic Density**[a] | | |
|---|---|---|---|
| ***Exposure level in dB re 1µPa (rms)*** | **Individuals** | **Exposures per Individual** | ***Requested Take*** |
| **Cetaceans** | | | |
| **≥160** | 1 | 1.5 | 353 |
| **≥180** | 0 | 0.0 | |
| **≥190** | 0 | 0.0 | |

[a] These density estimates are based on daylight sighting and daylight observation effort.

*Estimates Based on Densities during Seismic Periods:* The estimates in the above paragraphs are all based on densities recorded during non-seismic periods. Densities of seals recorded during seismic periods were markedly lower than those recorded during non-seismic. Lower densities might be expected during seismic periods for the *Henry C.*, either because of displacement (to the extent it occurs) or the brief duration and location of seismic operations by the *Henry C.* The minimum number of individuals and exposures per individual, based on the corrected daylight densities recorded during seismic periods, are summarized in Table 5.49.

***Polar bears***.—Based on non-seismic densities we estimated that no polar bears were exposed to seismic sounds ≥160 dB, 180 dB, or 190 dB (rms), even if there was no avoidance of the seismic sounds or vessel.

TABLE 5.49. Estimated numbers of individual seals exposed to received sound levels ≥160, 180, and 190 dB (rms) and average number of exposures per individual within the Beaufort Sea survey period. Estimates are based on "corrected" densities of seals calculated from daylight sighting effort.

| | **Based on Non-seismic Density[a]** | | **Based on Seismic Density[a]** | | |
|---|---|---|---|---|---|
| ***Exposure level in dB re 1µPa (rms)*** | **Individuals** | **Exposures per Individual** | **Individuals** | **Exposures per Individual** | ***Requested Take*** |
| **Seals** | | | | | |
| **≥160** | 63 | 1.5 | 19 | 1.5 | 771* |
| **≥180** | 4 | 1.1 | 1 | 1.1 | |
| **≥190** | 1 | 1.0 | 0 | 0.0 | |

[a] These density estimates are based on daylight sighting and daylight observation effort.

* The requested take of 771 seals is for ≥ to 170 dB, however, SSV results did not report a 170 dB distance radius for this sound level.

# BEAUFORT SEA AERIAL SURVEY MONITORING

## *Monitoring effort*

### *Ice cover*

No pack ice was encountered during surveys in 2007, as it was an especially low-ice year (Fig. 5.67, NSIDC 2007). However, thin layers of new ice started to form in nearshore areas on 7-8 Oct.

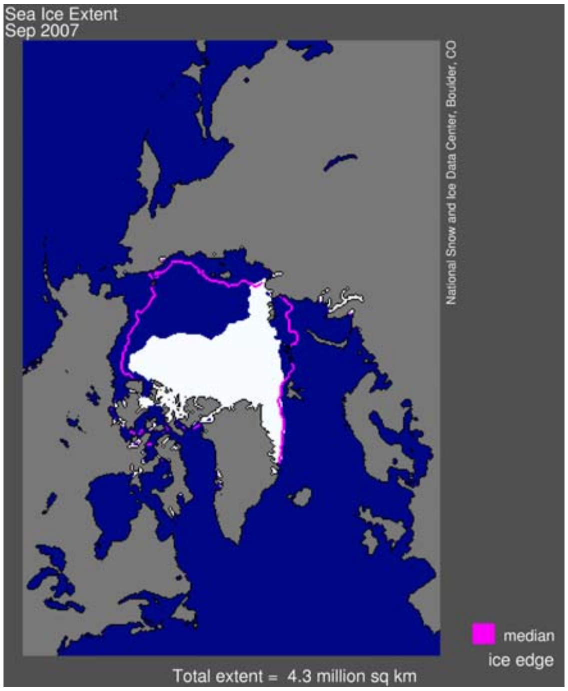


FIGURE 5.67. Average sea ice extent in Sep 2007, pink line represents the median ice edge from 1979 to 2000. Image from NSIDC Sea Ice Index.

### *Survey effort*

Aerial surveys were flown over the central Beaufort Sea from 22 Aug through 8 Oct 2007 and a total of 7380 km (4586 mi) of useable effort was obtained during approximately 75 flight hours. Survey effort and bowhead and beluga whale sighting information are summarized in Table 5.50.

Three survey grids were flown; one grid was designed to monitor marine mammal distribution near seismic operations of the *Henry C.* in Harrison Bay at the Phoenix prospect (Fig. 5.68). The other two grids were designed to monitor distributions during operations at the Sivulliq prospect in Camden Bay. The first grid (Fig. 5.69) was designed based on the 120 dB re 1 ųPa (rms) radius as estimated before the field season and the second grid was designed when measurements of the 120 dB radius were obtained during sound source verification, prior to the start of seismic activity at Sivulliq (Fig. 5.70).

TABLE 5.50. Summary of aerial survey effort and sighting rates in the central Alaskan Beaufort Sea, 22 Aug through 8 Oct 2007. Sighting rates are based on useable sightings and effort. Values in parentheses are based on less than 500 km (311 mi) of effort. Estimates were not calculated when effort was less than 250 km (155 mi).

| | | | | **Bowhead Whale** | | | | **Beluga Whale** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Date in 2007** | **Survey No.** | **Effort km** | **Percent of Survey Area** | **Sightings** | **Individuals** | **Sightings/ 1000km** | **Individuals/ 1000km** | **Sightings** | **Individuals** | **Sightings/ 1000km** | **Individuals/ 1000km** |
| 22 Aug | 1 | 869 | 69 | 4 | 5 | 4.6 | 5.8 | 1 | 13 | 1.2 | 15.0 |
| 24 Aug | 2 | 290 | 23 | (4) | (4) | (13.8) | (13.8) | (0) | (0) | (0.0) | (0.0) |
| 03 Sep | 3 | 339 | 27 | (5) | (5) | (14.7) | (14.7) | (0) | (0) | (0.0) | (0.0) |
| 10 Sep | 4 | 882 | 49 | 16 | 19 | 18.1 | 21.5 | 0 | 0 | 0.0 | 0.0 |
| 11 Sep | 4,5 | 1074 | 59 | 20 | 26 | 18.6 | 24.2 | 30 | 48 | 27.9 | 44.7 |
| 14 Sep | 5 | 458 | 25 | (8) | (15) | (17.5) | (32.8) | (0) | (0) | (0.0) | (0.0) |
| 18 Sep | 6 | 708 | 39 | 14 | 17 | 19.8 | 24.0 | 0 | 0 | 0.0 | 0.0 |
| 19 Sep | 6 | 7 | 0 | (0) | (0) | NC | NC | (0) | (0) | NC | NC |
| 20 Sep | 7 | 488 | 27 | (4) | (4) | (8.2) | (8.2) | (0) | (0) | (0.0) | (0.0) |
| 21 Sep | 8 | 1178 | 65 | 6 | 18 | 5.1 | 15.3 | 0 | 0 | 0.0 | 0.0 |
| 26 Sep | 9 | 51 | 3 | (0) | (0) | NC | NC | (0) | (0) | NC | NC |
| 30 Sep | 10 | 241 | 13 | (3) | (5) | NC | NC | (0) | (0) | NC | NC |
| 02 Oct | 11 | 92 | 8 | (0) | (0) | NC | NC | (0) | (0) | NC | NC |
| 03 Oct | 11,12 | 552 | 48 | 1 | 1 | 1.8 | 1.8 | 0 | 0 | 0.0 | 0.0 |
| 07 Oct | 13 | 134 | 12 | (0) | (0) | NC | NC | (0) | (0) | NC | NC |
| 08 Oct | 13 | 18 | 2 | (0) | (0) | NC | NC | (0) | (0) | NC | NC |
| ***Total*** | | **7380** | **27** | **85** | **119** | **12.226** | **16.211** | **31** | **61** | **4.847** | **9.942** |

Three surveys (1498 km (931 mi) of useable effort) were completed at the Phoenix prospect in support of seismic operations conducted by the *Henry C*. and an additional 10 surveys (5882 km (3655 mi) of useable effort) were conducted in association with seismic work conducted by the *Gilavar* at the Sivulliq prospect (Fig. 5.71). Approximately half of the aerial survey effort at Phoenix was conducted during nonseismic periods (3897 km; 2421 mi) and approximately 1737 km (1079 mi) and 1747 km (1086 mi) of survey effort were conducted during seismic and post-seismic periods, respectively (Fig. 5.72). Poor weather (i.e., low cloud ceilings and high winds) (Figs. 5.73 and 5.74) and dense smoke from wildfires prevented surveying on numerous days.

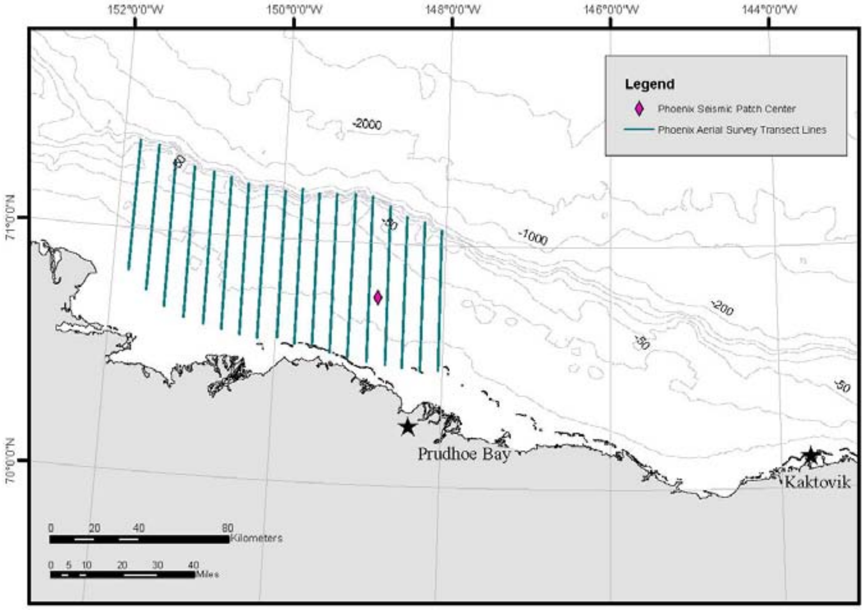


Figure 5.68. Transect lines surveyed near the Phoenix prospect in Harrison Bay from 22 Aug through 4 Sep 2007 in support of seismic operations conducted by the *Henry C* from 30 Aug to 31.

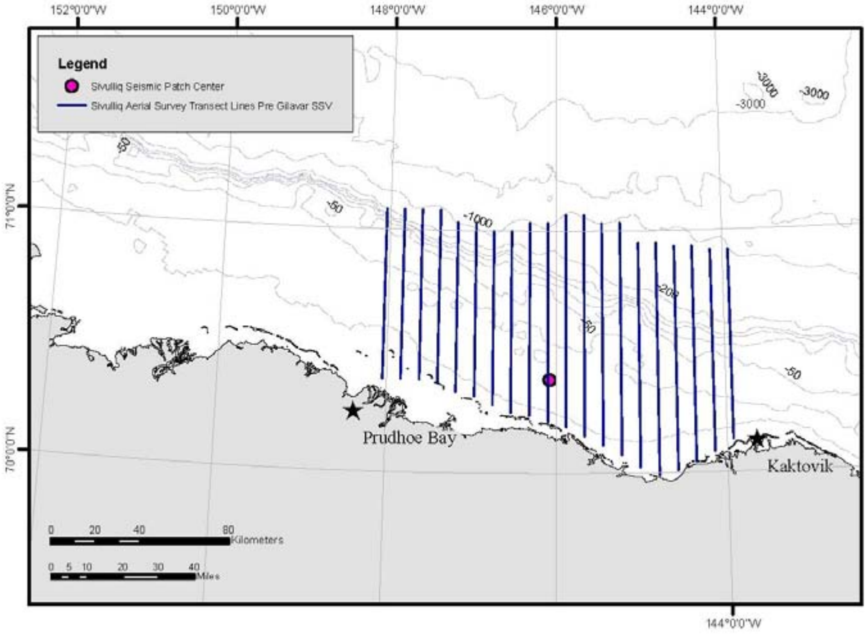


Figure 5.69. Transect lines surveyed near the Sivulliq prospect from 10 through 26 Sep 2007 and designed using pre-season estimates of the 120 dB radius of the Gilavar operating at Sivulliq. Surveys were flown in support of the Gilavar, which conducted seismic activities at Sivulliq from 18 Sep through 8 Oct 2007 and the Henry C., which conducted seismic there from 10 Sep through 2 Oct.

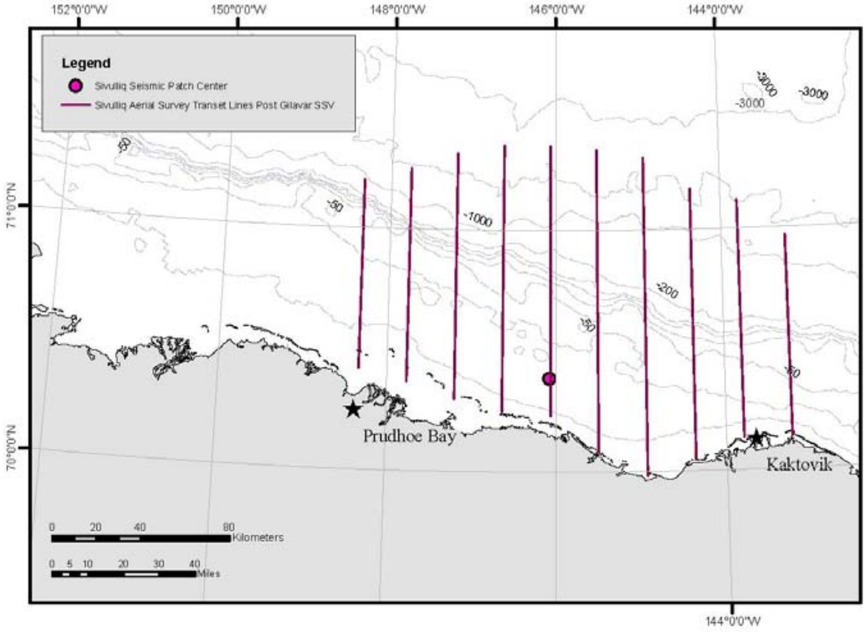


Figure 5.70. Transect lines surveyed near the Sivulliq prospect from 30 Sep through 8 Oct 2007 and designed when the 120 dB radius estimates were revised following sound source verification. Surveys were flown in support of the *Gilavar*, which conducted seismic activities at Sivulliq from 18 Sep through 8 Oct 2007 and the *Henry C*. which conducted seismic there from 10 Sep through 2 Oct.

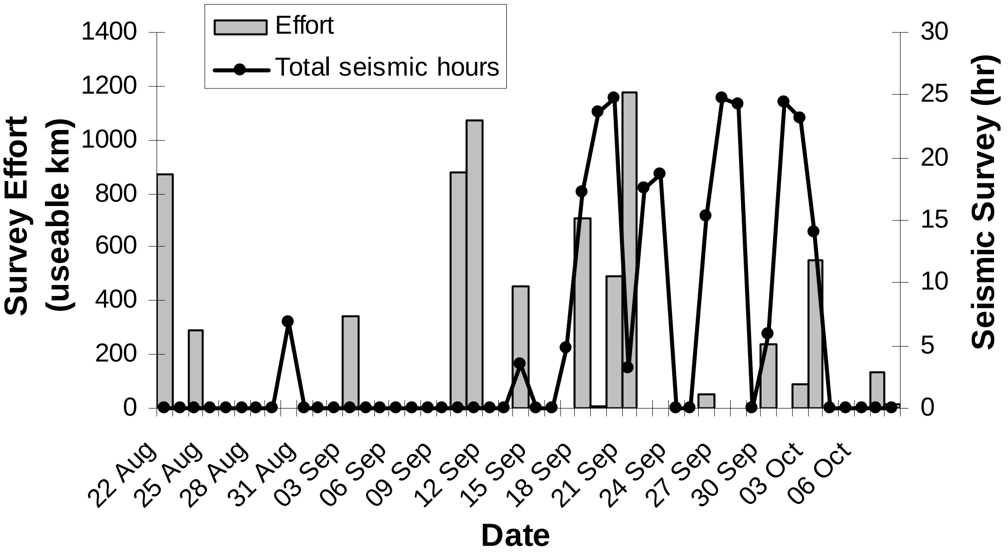


Figure 5.71. Useable aerial survey effort (km) and seismic survey effort (hr) in the Alaskan Beaufort Sea from 22 Aug through 8 Oct 2007.

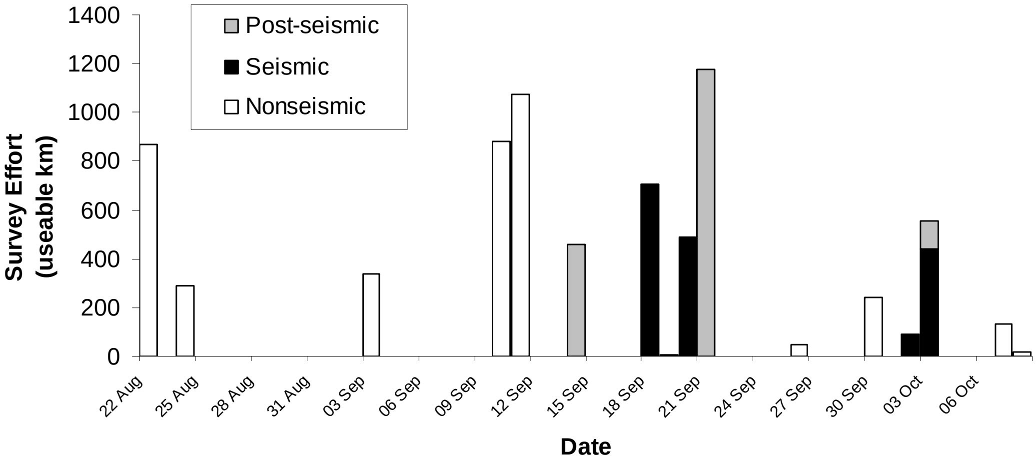


Figure 5.72. Useable aerial survey effort (km) by seismic state in the Alaskan Beaufort Sea from 22 Aug through 8 Oct 2007.

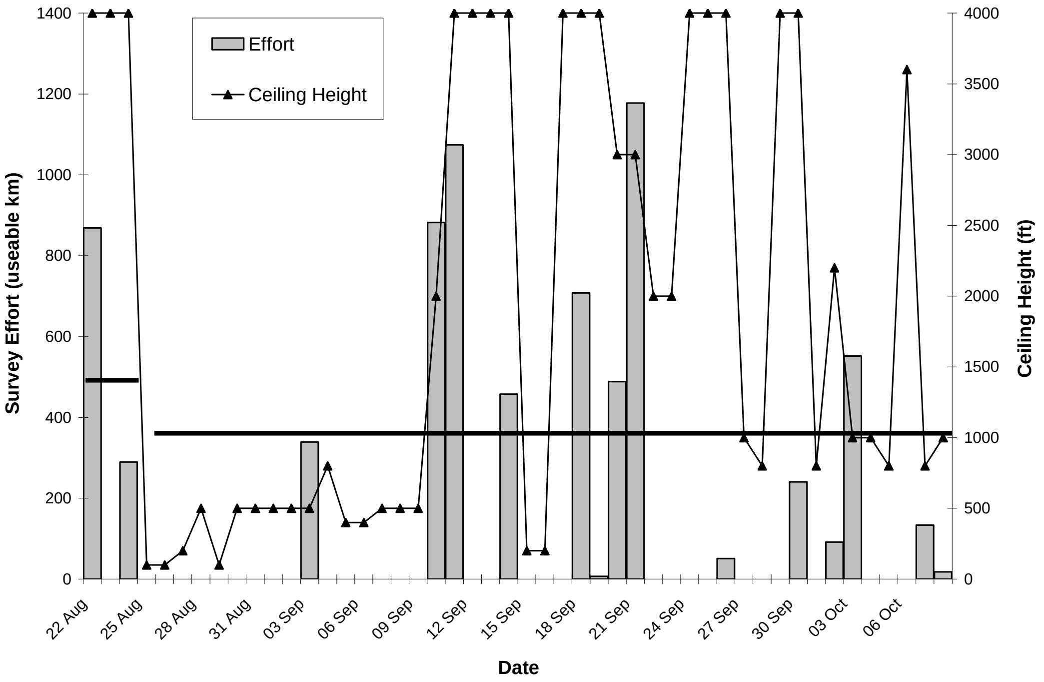


Figure 5.73. Useable aerial survey effort (km) and average daily cloud ceiling height (ft) (NWS 2007) from 22 Aug through 8 Oct 2007 in the central Beaufort Sea. Cloud ceiling height is a proxy for useable sighting conditions. Horizontal black bar indicates minimum survey altitude (1500 ft prior to issuance of IHA on 24 Aug and 1000 ft after 24 Aug).

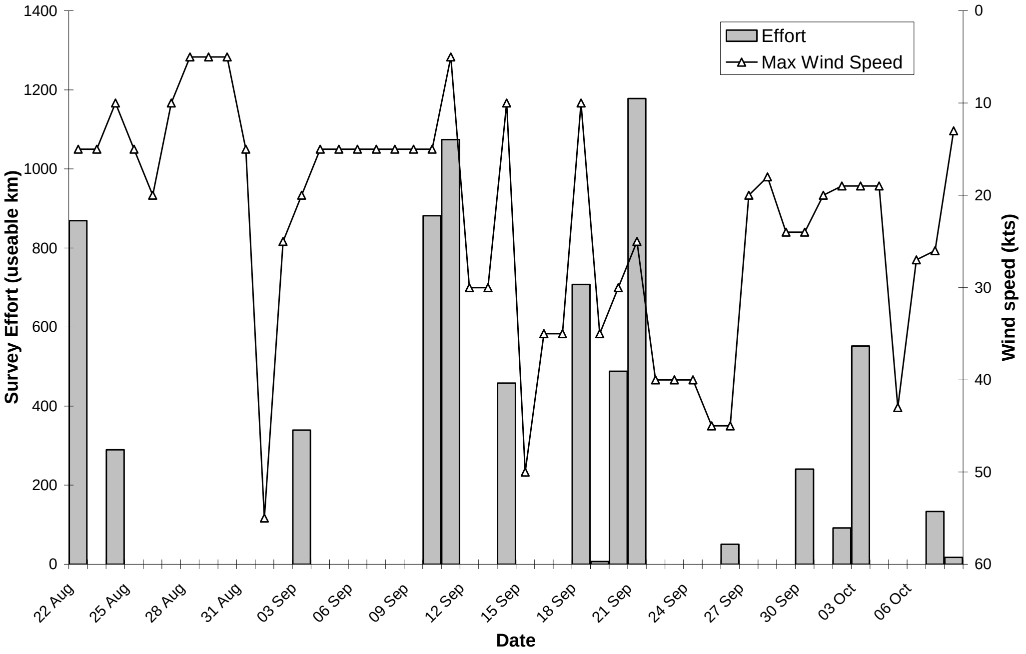


Figure 5.74. Useable aerial survey effort (km) and average daily wind speed (the inverse of wind speed is a proxy for useable sighting conditions) from 22 Aug through 8 Oct 2007 in the central Beaufort Sea.

## *Summary of Sightings*

Six species of marine mammals were seen during the study and 458 useable sightings of 1414 individuals were made. The vast majority of useable sightings (414 sightings) were made during nonseismic periods, with the remainder split evenly (22 each) between seismic and post-seismic periods.

## *Bowhead Whales*

***Sighting rates.***—Bowheads were seen on 65% of survey days. Group size ranged from one to 12, with an average of 1.5 individuals (Fig. 5.75, Table 5.51). In general, bowhead sighting rates were similar during all three seismic states, though rates were slightly higher during nonseismic periods than seismic or post-seismic periods. Of the three spatial sub-areas into which surveys were divided, average daily sighting rates were highest in the western area (16.2 sightings/1000km; 26.1 sightings/mi). Sighting rates were highest in September (14.0 sightings/1000km; 22.5 sightings/1000mi), peaking in mid-September and declining through October. These results are described in more detail below.

***Abundance.***—The number of bowheads present in the Alaskan Beaufort Sea prospect areas was estimated using DISTANCE software (Table 5.52 and Table 5.53). Separate estimates were made for the Phoenix and Sivulliq prospects, due to differences in altitude of flights and in the area surveyed.

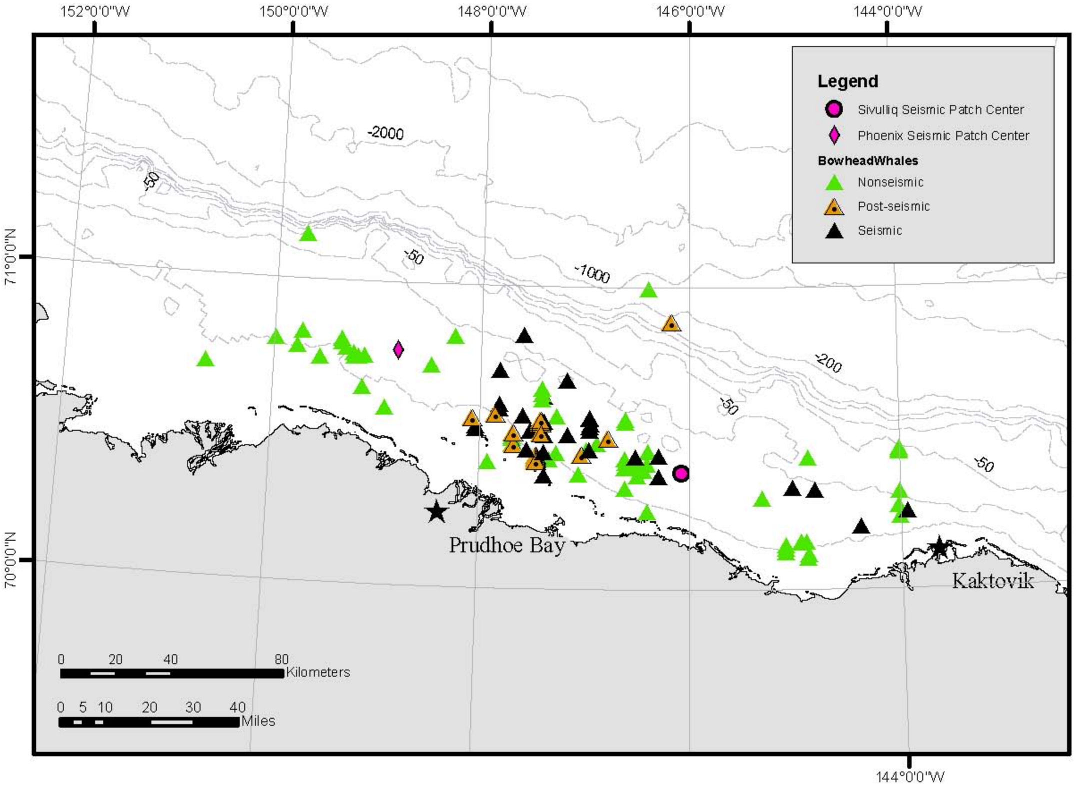


Figure 5.75. Bowhead sightings relative to the two seismic prospects explored in the Alaskan Beaufort Sea from 22 Aug through 8 Oct 2007. Colors indicate seismic state at time of sighting.

TABLE 5.51. Bowhead sightings and sighting rates in the Beaufort Sea by seismic state, 22 Aug- 8 Oct 2007.

| | | | Seismic | Post-seismic | Non-seismic | Total |
|---|---|---|---|---|---|---|
| **All sightings** | | | | | | |
| | ***All areas*** | Sightings | 31 | 18 | 73 | 122 |
| | | Individuals | 35 | 37 | 90 | 162 |
| | | Sightings/1000km | 17.9 | 10.3 | 18.7 | 16.5 |
| | | Individuals/1000km | 20.2 | 21.2 | 23.1 | 22.0 |
| **Useable sightings** | | | | | | |
| | ***All areas*** | Sightings | 19 | 14 | 52 | 85 |
| | | Individuals | 22 | 33 | 64 | 119 |
| | | Sightings/1000km | 10.9 | 8.0 | 13.3 | 11.5 |
| | | Individuals/1000km | 12.7 | 18.9 | 16.4 | 16.1 |
| | ***West*** | Sightings | 11 | 12 | 15 | 38 |
| | | Individuals | 12 | 31 | 21 | 64 |
| | | Sightings/1000km | 17.9 | 18.1 | 9.6 | 13.4 |
| | | Individuals/1000km | 19.5 | 46.8 | 13.4 | 22.5 |
| | ***Central*** | Sightings | 5 | 2 | 21 | 28 |
| | | Individuals | 7 | 2 | 23 | 32 |
| | | Sightings/1000km | 6.8 | 1.8 | 13.2 | 8.2 |
| | | Individuals/1000km | 9.5 | 1.8 | 14.4 | 9.4 |
| | ***East*** | Sightings | 3 | -- | 16 | 19 |
| | | Individuals | 3 | -- | 20 | 23 |
| | | Sightings/1000km | 7.8 | -- | 21.8 | 16.9 |
| | | Individuals/1000km | 7.8 | -- | 27.2 | 20.5 |

Table 5.52. Estimated numbers of bowhead whales in the Phoenix prospect area. Estimates calculated using DISTANCE software for each individual survey. Numbers in parentheses represent estimates that should be interpreted with caution due to low effort (<500 km). No estimates were calculated when effort was less than 250 km (155 mi). Estimates include allowance for f(0) (as calculated by DISTANCE) and g(0) (value of 0.144 from Thomas et al 2002.).

| Survey No. | Date in 2007 | Effort (km) | Sightings | Density (No./1000km$^2$) | Est. No. Whales | 95% C.I. | |
|---|---|---|---|---|---|---|---|
| 1 | 22 Aug | 869 | 4 | 11.5 | 109 | 32 | 365 |
| 2 | 24 Aug | 290 | 4 | (68.9) | (653) | 163 | 2617 |
| 3 | 03 Sep | 339 | 5 | (58.8) | (916) | 325 | 2582 |

A total of 13 sightings, with an average group size of 1.1, were seen in the vicinity of Phoenix prospect from 22 Aug through 3 Sep. Estimates based on effort and sighting rate as calculated by DISTANCE indicated that approximately 452 (bootstrapped mean; s.d.=237, 95%C.I.=109-916) bowhead whales were present in the study area during that period. Estimates from individual surveys ranged from 109 during Survey 1 to 916 during Survey 3, but marginal effort during surveys 2 and 3 indicate that estimates should be treated cautiously.

TABLE 5.53. Estimated numbers of bowhead whales in the Sivulliq prospect area. Estimates calculated using DISTANCE software for each individual survey. Numbers in parentheses represent estimates that should be interpreted with caution due to low effort (<500 km). No estimates were calculated when effort was less than 250 km (155 mi). Estimates include allowance for *f*(0) (as calculated by DISTANCE) and *g*(0) (value of 0.144 from Thomas et al 2002.).

| Survey No. | Date in 2007 | Effort (km) | Sightings | Density (No./1000km$^2$) | Est. No. Whales | 95% C.I. | |
|---|---|---|---|---|---|---|---|
| 4 | 10 Sep<br>11 Sep | 1809 | 33 | 127.2 | 3047 | 1465 | 6338 |
| 5 | 11 Sep<br>14 Sep | 605 | 11 | 179.0 | 4826 | 1513 | 15397 |
| 6 | 18 Sep<br>19 Sep | 715 | 14 | 132.5 | 3176 | 1651 | 6109 |
| 7 | 20 Sep | 488 | 4 | (13.9) | (332) | (63) | (1755) |
| 8 | 21 Sep | 1178 | 6 | 86.2 | 2065 | 323 | 13214 |
| 9 | 26 Sep | 51 | | NC | NC | -- | -- |
| 10 | 30 Sep | 241 | 3 | NC | NC | -- | -- |
| 11 | 02 Oct<br>03 Oct | 571 | 1 | 11.8 | 284 | 59 | 1364 |
| 12 | 03 Oct | 73 | | NC | NC | -- | -- |
| 13 | 07 Oct<br>08 Oct | 151 | | NC | NC | -- | -- |

A total of 72 bowhead sightings, with an average group size of 1.5 individuals, were made on surveys conducted at the Sivulliq prospect from 10 Sep through 8 Oct. Estimates calculated using DISTANCE varied from 0 individuals (Surveys 9, 12 and 13) to 4789 (Survey 5). A single weighted average for this period is not considered appropriate because migration, as interpreted by observed activities of whales sighted, described below, did not appear to commence until late September. Due to the different densities that can be expected during migratory periods, separate weighted averages were calculated for migratory and non-migratory periods. From 10 Sep through 30 Sep the bootstrapped average of estimated bowhead abundance was 2723 individuals (s.d.=497, 95%C.I.=1689-3617); from 2 Oct through 8 Oct, after migration was thought to have commenced, the bootstrapped average abundance estimate was 306 individuals (s.d.=130, 95%C.I.=0-557).

***Distances from shore.***—The majority of bowhead sightings were made from 5–50 km (3–31 mi) offshore (Figs. 5.76 and 5.77), in waters less than 50 m (55 yds) deep (Fig. 5.78). More sightings were made in the 15–20 km (9–12 mi) band than in other bands (16 sightings, 17 individuals), though the greatest number of individuals (24 in 11 sightings) was slightly farther offshore in the 20–25 km (12–16 mi) from shore band. Due to uneven effort in the various distance from shore bands the number of sightings per km was considered a more appropriate presentation of the offshore distribution (Table 5.54, Fig. 5.79). Data presented in the tables, text and statistical summaries below are based on sighting rates within 5 km (3 mi) distance bands from shore, while data presented in graphical form are based on sighting rates within 20 km (12 mi) distance bins. The 20 km (12 mi) distance bins were chosen for graphical representation due to highly variable sighting rates in areas less than 20 km (12 mi) from shore; lumping these data facilitate the observation of trends.

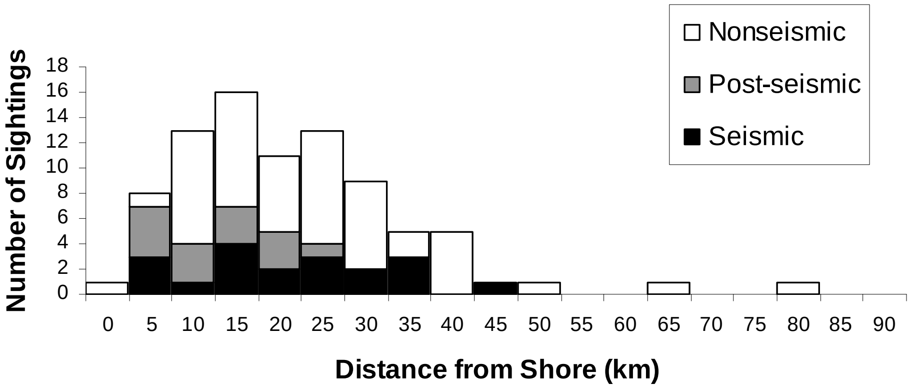


Figure 5.76. Number of bowhead sightings from 22 Aug through 8 Oct 2007 in the central Beaufort Sea by 5 km (3 mi) distance from shore intervals. Seismic state at the time of sighting is indicated by color.

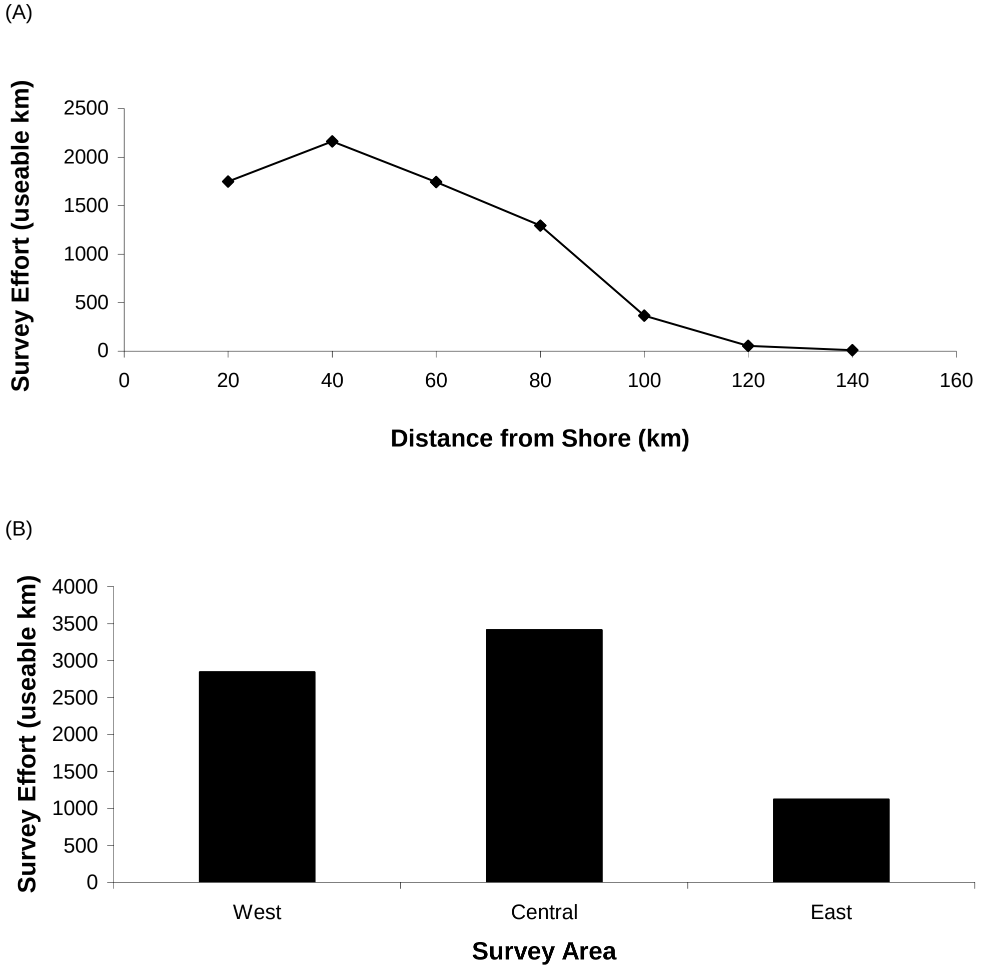


Figure 5.77. Survey effort within the Beaufort Sea. (A) Total survey effort (km) in the central Beaufort Sea over the period of 22 Aug through 8 Oct 2007, by 20 km (12.5 mi) distance from shore intervals. (B) Total survey effort (km) within survey areas over the period 22 Aug through 8 Oct 2007.

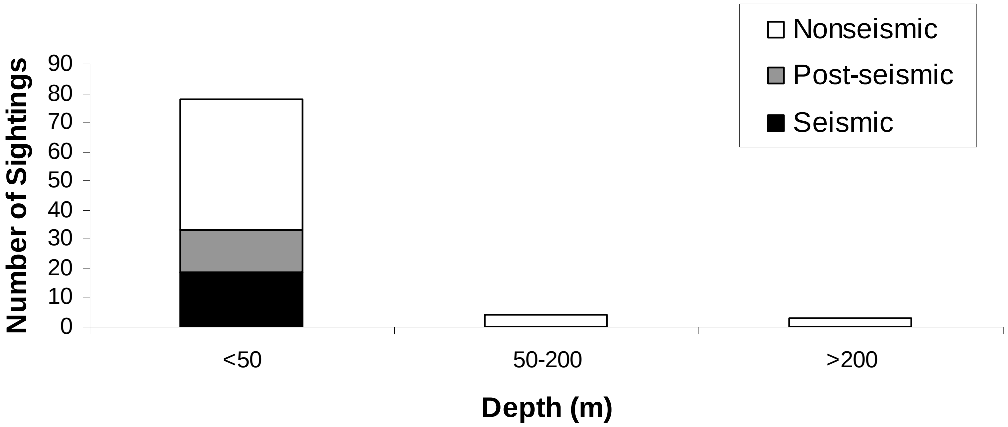


Figure 5.78. Number of bowhead sightings in the central Beaufort Sea by depth categories with seismic state indicated by color. Data collected from 22 Aug through 8 Oct 2007.

TABLE 5.54. Sighting rates (number of sightings/1000km) of bowhead whales from 22 Aug through 8 Oct 2007 in the central Beaufort Sea by 5-km (3-mi) distance from shore intervals. Data are presented by area and seismic state. Numbers in bold indicate maximum values. Effort is <500 km for all bins, so rates should be interpreted with caution.

| | West | | | Central | | | East | | | All | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Distance bin** | **Seismic** | **Post** | **Non** | **Seismic** | **Post** | **Non** | **Seismic** | **Post** | **Non** | **Seismic** | **Post** | **Non** |
| 5 | 51.0 | 52.7 | 0.0 | 0.0 | 0.0 | 6.2 | 0.0 | -- | 0.0 | 26.2 | **34.3** | 3.0 |
| 10 | 17.0 | 38.8 | **52.9** | 0.0 | 0.0 | 26.0 | 0.0 | -- | 14.7 | 6.0 | 20.0 | 33.7 |
| 15 | **68.9** | 25.7 | 0.0 | 0.0 | 13.2 | 16.1 | 22.9 | -- | 157.3 | **26.3** | 19.5 | **34.4** |
| 20 | 22.3 | **58.2** | 0.0 | 0.0 | 0.0 | 38.0 | **30.7** | -- | 19.9 | 17.3 | 26.2 | 17.4 |
| 25 | 0.0 | 0.0 | 21.8 | **56.3** | **14.6** | **44.6** | 0.0 | -- | 14.7 | 22.4 | 8.9 | 28.3 |
| 30 | 34.1 | 0.0 | 46.1 | 14.9 | 0.0 | 23.3 | 0.0 | -- | 0.0 | 14.7 | 0.0 | 29.2 |
| 35 | 21.1 | 0.0 | 0.0 | 25.1 | 0.0 | 20.7 | 24.2 | -- | 0.0 | 23.3 | 0.0 | 7.2 |
| 40 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -- | **182.2** | 0.0 | 0.0 | 23.4 |
| 45 | 33.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -- | 0.0 | 12.4 | 0.0 | 0.0 |
| 50 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -- | 22.4 | 0.0 | 0.0 | 4.4 |
| 55 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -- | 0.0 | 0.0 | 0.0 | 0.0 |
| 60 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -- | 0.0 | 0.0 | 0.0 | 0.0 |
| 65 | 0.0 | 0.0 | 9.8 | 0.0 | 0.0 | 0.0 | | -- | 0.0 | 0.0 | 0.0 | 4.6 |
| 70 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -- | 0.0 | 0.0 | 0.0 | 0.0 |
| 75 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | | -- | 0.0 | 0.0 | 0.0 | 0.0 |
| 80 | 0.0 | | 0.0 | 0.0 | 0.0 | 17.9 | 0.0 | -- | 0.0 | 0.0 | 0.0 | 12.7 |
| 85 | 0.0 | | | 0.0 | 0.0 | 0.0 | | -- | 0.0 | 0.0 | 0.0 | 0.0 |
| 90 | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -- | 0.0 | 0.0 | 0.0 | 0.0 |
| ***Average*** | **14.6** | **12.5** | **7.7** | **5.4** | **1.5** | **10.7** | **5.2** | | **22.8** | **8.3** | **6.1** | **11.0** |

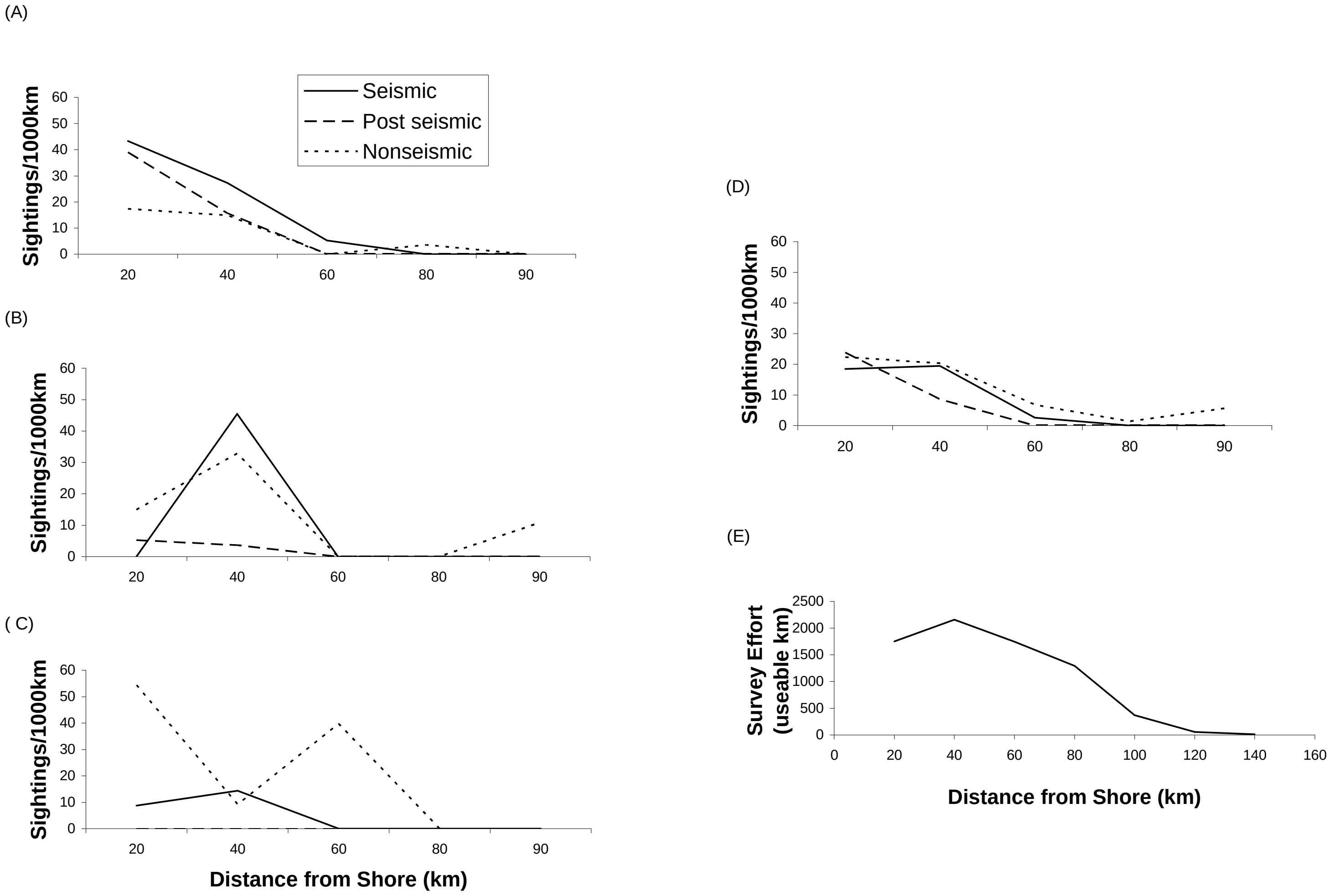


Figure 5.79. Bowhead sighting rates from 22 Aug through 8 Oct 2007 in the central Beaufort Sea by 20-km (12-mi) distance from shore intervals. (A) western area, (B) central area, (C) eastern area, (D) all areas (E) survey effort within 20-km (12-mi) distance from shore bins.

In general, sighting rates were highest (28.2 sightings/1000km in the 15-20 km from shore band; 45.4 sightings/mi in the 9-12 mi from shore band) in areas less than 25 km (16 mi) from shore (Table 5.55) but moderate rates were observed out to 40 km (25 mi) from shore.

Overall, no significant differences were observed in sighting rates between areas or by seismic states (Table 5.55). However, several non-significant trends, which should be interpreted with caution due to varying amounts of effort, do appear. Analysis by seismic state indicated no difference in offshore distribution between seismic and nonseismic periods. Sighting rates peaked at 15-20km (9-12 mi) offshore for seismic and nonseismic periods (42.4 sightings/1000km and 55.4 sightings/1000km, respectively; 68.3 sightings/1000mi and 89.2 sightings/1000mi, respectively), while post-seismic sighting rates were highest from 5-10km (3-6 mi) from shore (55.2 sightings/1000km; 88.9 sightings/1000mi).

Slight non-significant trends were also observed when assessing distances from shore by areas. Sighting rates peaked closer to shore, 10-25km (6-16 mi), in the western area than in the eastern and central areas. Peak sighting rates were slightly farther offshore for the central area, at 25-30km (16-19 mi) from shore. Seismic sighting rates peaked at similar distances from shore in the eastern area (49.4 sightings/1000km at 20-25km from shore; 79.6 sightings/mi at 12-16 mi from shore). However, peak sighting rates were much farther offshore during nonseismic periods within the eastern area (293.3 sightings/1000km at 40-45km; 472.3 sightings/1000mi at 25-28mi from shore).

***Distribution around area of seismic operations.*—**Information was also gathered regarding the distance of sightings from the center of seismic activity. In total, 31 bowhead sightings (35 individuals) were made during seismic activity; 19 of these sightings (22 individuals) were under useable conditions (Table 5.56). In general, bowhead sightings tended to be slightly farther from the center of the seismic prospect during periods of active seismic work (56 km; 35mi) than during post-seismic or nonseismic periods (53 and 45 kms, respectively; 33 and 28 mi, respectively), though this trend was not significant (Table 5.57, Fig. 5.80).

TABLE 5.55. Results of statistical analysis (Kolmogorov-Shmirnov test) comparing bowhead sighting rates among areas and by seismic state in the central Beaufort Sea from 22 Aug through 8 Oct 2007.

| | | | **Number of sightings** | | | **Two-tailed** | |
|---|---|---|---|---|---|---|---|
| **Area** | **Test-type** | **Test of** | **Nonseismic** | **Seismic** | **Post-seismic** | **$D_{max}$** | **P** |
| ***West*** | K-S | Sightings/km | 15 | 11 | 12 | 0.235 | 0.734 |
| ***Central*** | K-S | Sightings/km | 21 | 5 | 2 | 0.278 | 0.491 |
| ***East*** | K-S | Sightings/km | 16 | 3 | 0 | 0.111 | 1.00 |
| ***Combined*** | K-S | Sightings/km | 52 | 19 | 14 | 0.222 | 0.766 |

Table 5.56. Minimum, maximum and mean distance (km) of bowheads in the central Beaufort Sea from center of then-current seismic patch over the period of 22 Aug through 8 Oct 2007.

| Patch locations | Type of sighting | *n* | Minimum Distance | Maximum distance | Mean Distance |
|---|---|---|---|---|---|
| **A. *All*** | Seismic | 19 | 10.5 | 81.2 | 56.0 |
| | Post-seismic | 14 | 29.6 | 77.3 | 53.1 |
| | Nonseismic | 52 | 12.2 | 79.2 | 45.0 |
| **B. *Phoenix*** | Seismic | 0 | -- | -- | -- |
| | Post-seismic | 0 | -- | -- | -- |
| | Nonseismic | 13 | 68.6 | 12.2 | 28.3 |
| **C. *Sivulliq*** | Seismic | 19 | 10.5 | 81.2 | 56.0 |
| | Post-seismic | 14 | 29.6 | 77.3 | 53.1 |
| | Nonseismic | 39 | 12.6 | 79.2 | 50.6 |

Table 5.57. All seismic bowhead sightings in the central Beaufort Sea from 22 Aug through 8 Oct. Sightings in bold are sightings <20 km (12 mi) from the then current seismic patch.

| Date in 2007 | Time | Number | Array Type | On/Off Transect | Distance (km) from center of seismic patch | Heading | Start of seismic | Time elapsed since start of seismic |
|---|---|---|---|---|---|---|---|---|
| 18 Sep | 16:31:21 | 1 | Ramp-up | On | 75 | 60 | 9/18/2007 7:10 | 9:21:21 |
| 18 Sep | 16:31:33 | 1 | Ramp-up | On | 75 | -- | 9/18/2007 7:10 | 9:21:32 |
| 18 Sep | 17:02:20 | 1 | Ramp-up | On | 75 | -- | 9/18/2007 7:10 | 9:52:19 |
| 18 Sep | 17:05:47 | 1 | Ramp-up | On | 69 | 90 | 9/18/2007 7:10 | 9:55:46 |
| 18 Sep | 17:06:09 | 1 | Ramp-up | On | 69 | 100 | 9/18/2007 7:10 | 9:56:08 |
| 18 Sep | 17:21:54 | 2 | Ramp-up | On | 60 | -- | 9/18/2007 7:10 | 10:11:53 |
| 18 Sep | 17:29:57 | 1 | Ramp-up | On | 76 | -- | 9/18/2007 7:10 | 10:19:56 |
| 18 Sep | 17:53:38 | 1 | Ramp-up | Off | 56 | -- | 9/18/2007 7:10 | 10:43:38 |
| 18 Sep | 17:56:05 | 1 | Ramp-up | Off | 52 | -- | 9/18/2007 7:10 | 10:46:05 |
| 18 Sep | 17:57:25 | 1 | Ramp-up | On | 51 | 40 | 9/18/2007 7:10 | 10:47:25 |
| 18 Sep | 17:59:09 | 1 | Ramp-up | Off | 49 | -- | 9/18/2007 7:10 | 10:49:09 |
| 18 Sep | 18:01:24 | 1 | Ramp-up | On | 49 | 20 | 9/18/2007 7:10 | 10:51:24 |
| 18 Sep | 18:10:30 | 1 | Ramp-up | Off | 43 | -- | 9/18/2007 7:10 | 11:00:30 |
| 18 Sep | 18:16:05 | 1 | Ramp-up | On | 53 | -- | 9/18/2007 7:10 | 11:06:05 |
| 18 Sep | 18:43:40 | 1 | Ramp-up | Off | 39 | -- | 9/18/2007 7:10 | 11:33:40 |
| 18 Sep | 18:43:48 | 1 | Ramp-up | Off | 38 | -- | 9/18/2007 7:10 | 11:33:48 |
| 18 Sep | 18:43:50 | 1 | Ramp-up | Off | 38 | -- | 9/18/2007 7:10 | 11:33:50 |
| 18 Sep | 18:44:15 | 1 | Ramp-up | On | 37 | -- | 9/18/2007 7:10 | 11:34:15 |
| 18 Sep | 18:44:37 | 1 | Ramp-up | On | 37 | -- | 9/18/2007 7:10 | 11:34:37 |
| 18 Sep | 18:44:57 | 2 | Ramp-up | On | 36 | 20 | 9/18/2007 7:10 | 11:34:57 |
| 18 Sep | 18:47:03 | 1 | Ramp-up | Off | 34 | -- | 9/18/2007 7:10 | 11:37:03 |
| **18 Sep** | **19:36:43** | **1** | **Full array** | **Off** | **17** | **90** | **9/18/2007 7:10** | **12:26:43** |
| **18 Sep** | **19:49:45** | **2** | **Full array** | **Off** | **8** | **--** | **9/18/2007 7:10** | **12:39:45** |
| **18 Sep** | **19:51:48** | **2** | **Full array** | **On** | **11** | **260** | **9/18/2007 7:10** | **12:41:48** |
| 18 Sep | 20:17:41 | 1 | Full array | Off | 54 | 230 | 9/18/2007 7:10 | 13:07:41 |
| 18 Sep | 20:18:18 | 1 | Full array | Off | 56 | 170 | 9/18/2007 7:10 | 13:08:18 |
| 20 Sep | 10:56:44 | 1 | Ramp-up | On | 81 | 180 | 9/18/2007 7:10 | 51:06:44 |
| 20 Sep | 11:53:03 | 1 | Full array | On | 67 | 68 | 9/18/2007 7:10 | 52:03:03 |
| 20 Sep | 12:59:17 | 1 | Full array | On | 48 | 68 | 9/18/2007 7:10 | 53:09:17 |
| 20 Sep | 13:39:45 | 1 | Full array | On | 40 | 360 | 9/18/2007 7:10 | 53:49:45 |
| 03 Oct | 12:13:51 | 1 | Ramp-up | On | 56 | 315 | 9/30/2007 18:45 | 65:28:51 |

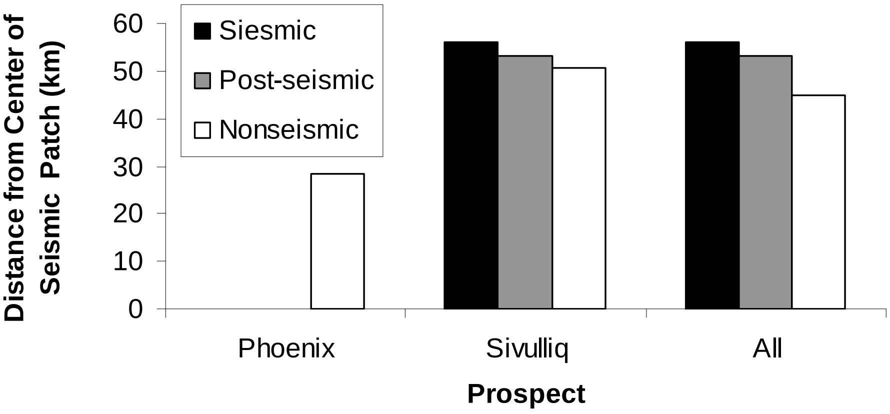
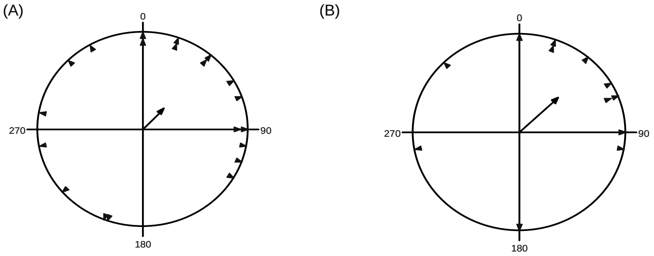


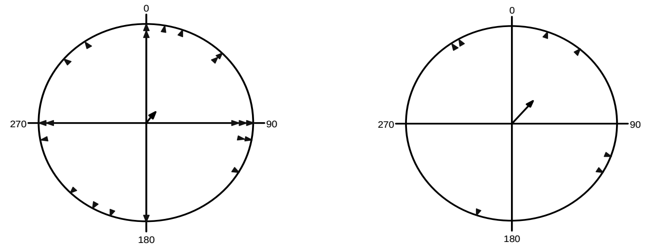
Figure 5.80. Average distance (km) from the center of the then-current seismic patch of bowhead whales in the central Beaufort Sea from 22 Aug through 8 Oct 2007.

***Headings.***—Headings were recorded for 51 useable bowhead sightings. When plotted, these headings showed a uniform distribution, with no strong patterns evident (Fig. 5.81). Vector mean for overall sightings was calculated to be 53°T, with a fairly large circular standard deviation of 121°T (*P*=0.56; Table 5.58).



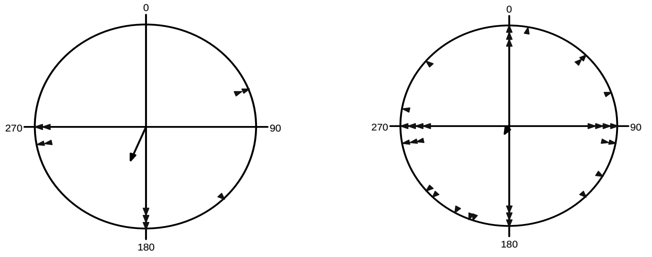
West, all periods (n=20)

All seismic (n=12)



Central, all periods (n=21)

All post-seismic (n=7)



East, all periods (n=10)

All non-seismic (n=32)

Figure 5.81. Bowhead headings by area (A) and seismic state (B) within the central Beaufort Sea from 22 Aug through 8 Oct 2007.

TABLE 5.58. Percentage of observed bowhead headings (°T) that appear to be migratory from data collected in the central Beaufort Sea from 22 Aug through 8 Oct 2007.

| **Area** | **Test of** | **W, NW, N** | | **"Other" Directions** | | **Total** | **Vector mean** | **Circular s.d.** |
|---|---|---|---|---|---|---|---|---|
| | | ***n*** | ***%*** | ***n*** | ***%*** | | | |
| ***East*** | | | | | | | | |
| | Seismic | 0 | 0 | 3 | 100 | 3 | 98° | 56° |
| | Post-seismic | 0 | 0 | 0 | 0 | 0 | -- | -- |
| | Nonseismic | 2 | 29 | 5 | 71 | 7 | 227° | 54° |
| | Total | *2* | *20* | *8* | *80* | *10* | 203° | 82° |
| ***Central*** | | | | | | | | |
| | Seismic | 1 | 33 | 2 | 67 | 3 | 340° | 55° |
| | Post-seismic | 1 | 50 | 1 | 50 | 2 | 263° | 71° |
| | Nonseismic | 4 | 25 | 12 | 75 | 16 | 80° | 100° |
| | Total | *6* | *29* | *15* | *71* | *21* | 40° | 113° |
| ***West*** | | | | | | | | |
| | Seismic | 1 | 17 | 5 | 83 | 6 | 49° | 49° |
| | Post-seismic | 1 | 20 | 4 | 80 | 5 | 53° | 60° |
| | Nonseismic | 3 | 33 | 6 | 67 | 9 | 264° | 108° |
| | Total | *5* | *25* | *15* | *75* | *20* | 42° | 90° |
| ***Combined*** | | | | | | | | |
| | Seismic | 2 | 20 | 10 | 83 | 12 | 46° | 67° |
| | Post-seismic | 2 | 40 | 5 | 71 | 7 | 41° | 89° |
| | Nonseismic | 9 | 39 | 23 | 72 | 32 | 207° | 125° |
| | Total | **13** | **34** | **38** | **75** | **51** | **53°** | **121°** |

There were too few sightings to obtain reliable data on whale headings relative to seismic state and geographic subdivision of the study area. When all areas were combined during seismic and post-seismic periods, bowheads had vector mean headings that were significantly different from random. Unexpectedly, they were to the northeast (46°T, *P*=0.04 and 41°T, *P*=0.05; Table 5.58) rather than west to northwest as expected for migrating whales. In contrast, bowheads sighted during nonseismic periods had random headings, with a non-significant vector mean heading to the south-southwest (207°T, circular s.d. = 125°T, *P*=0.77).

When assessed by area, the number of sightings is too small to make any conclusions about headings relative to seismic state, but during all seismic states combined, bowheads in western and central areas had random headings with a non-significant vector mean heading to the northeast (42°T, *P*=0.19 and 39°T, *P*=0.67) and bowheads sighted in the eastern area had random headings with a non-significant vector mean heading to the south-southwest (203°T, *P*=0.28).

***Migration timing (i.e., sighting rates over time).*****—**Daily sighting rates increased slightly from late Aug, through mid-Sep, peaking on 18 Sep (2 sightings/1000km; 3.2 sightings/mi; Fig. 5.82). This pattern is similar to those observed during previous studies where autumn migration into Alaskan waters has been documented to occur primarily during late Aug to Oct (Wartzok et al. 1989; Moore and Reeves 1993; Miller et al. 1999, 2002; Mate et al. 2000; Treacy 2000.).

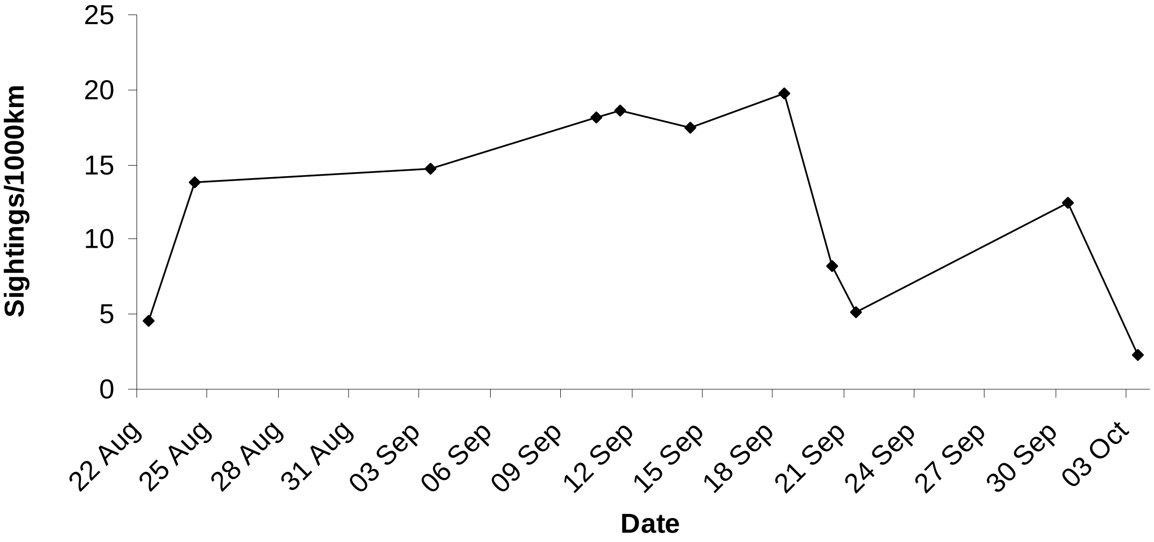


Figure 5.82. Daily sighting rates of bowheads in the central Beaufort Sea from 22 Aug through 8 Oct 2007.

***Activity.*****—**Data on bowhead activities were recorded for 45 sightings. Feeding was the most commonly recorded activity (51%; Fig. 5.83) with traveling (27%) and resting (13%) also frequently observed.

Activities during nonseismic periods were similar to overall trends, with feeding accounting for 47% of recorded activities and traveling accounting for 30%. During post-seismic periods, feeding and traveling were recorded with equal frequency, accounting for 38% of sightings. No bowheads sighted during seismic periods were recorded as traveling; the majority (86%) of recorded activity during this period was feeding.

When assessed by area, activities were similar, with feeding being the predominant activity in all three areas, regardless of seismic state (Fig. 5.84).

***Speed.*****—**The vast majority of recorded speeds (76%) were considered slow (Fig. 5.85). Moderate was the next most commonly recorded speed, comprising 21% of sightings. These patterns were similar for all seismic states and in all areas (Fig. 5.86). Only one bowhead was considered to be moving fast; it was sighted in the eastern area.

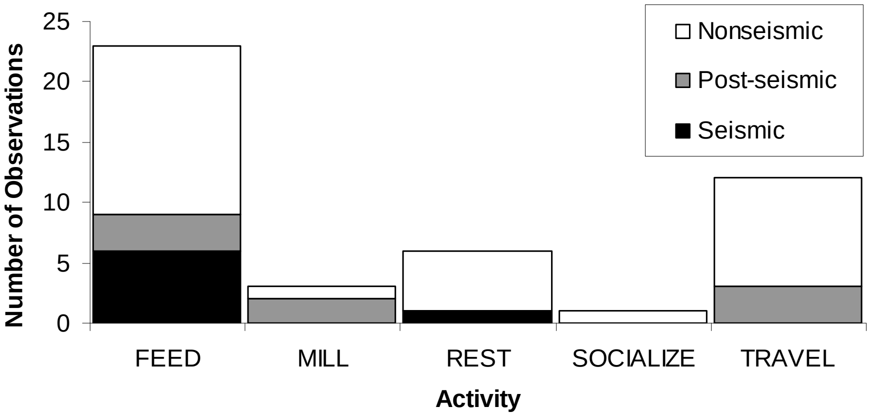


Figure 5.83. Observed activities of bowhead whales from 22 Aug through 8 Oct 2007 in the central Beaufort Sea. Seismic state at time of sighting indicated by color.

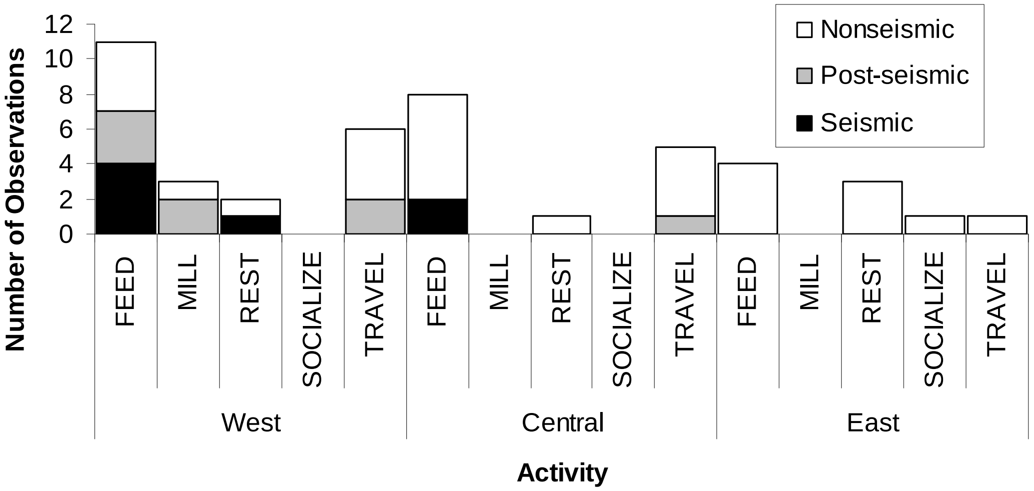


Figure 5.84. Observed activities of bowhead whales from 22 Aug through 8 Oct 2007 in the three subdivisions of our study area in the central Beaufort Sea. Seismic state at time of sighting indicated by color.

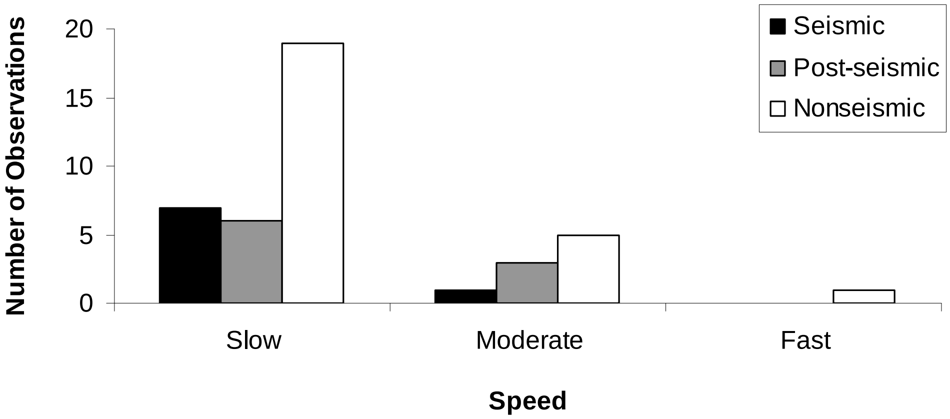


Figure 5.85. Observed speeds of bowhead whales in the central Beaufort Sea from 22 Aug through 8 Oct 2007. Seismic state at time of sighting indicated by color.

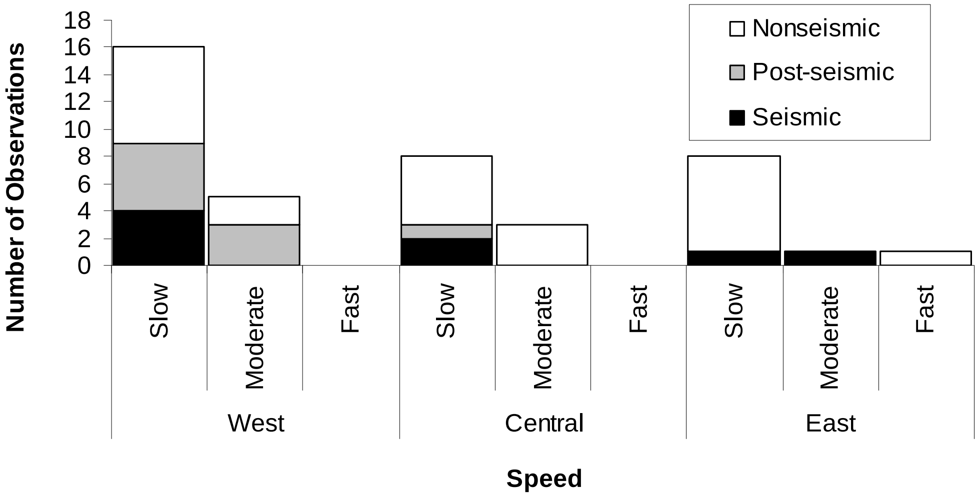


Figure 5.86. Observed speeds of bowhead whales in the three subdivisions of our study area in the central Beaufort Sea from 22 Aug through 8 Oct 2007. Seismic state at time of sighting indicated by color.

## *Discussion*

Typically, bowheads of the B-C-B stock feed in Canadian waters during the late spring and summer and travel through the Alaskan Beaufort Sea during their fall migration toward wintering areas in the Bering Sea. During this migration they occasionally stop to feed, and the most common feeding areas in the Alaskan Beaufort Sea have been found near and east of Kaktovik and near Point Barrow (Thomson et al. 2002). The areas where seismic surveys were conducted in 2007 have not been heavily used by feeding whales during earlier years and long-term studies have noted relatively low sighting rates of bowheads in that area. Although considerable variability has been seen in the areas used and extent of use among years, data collected in the central Alaskan Beaufort Sea during the fall of 2007 showed a different pattern of use of that area than most years, and it is possible that this difference is linked to changes in productivity due to the record low ice cover extent in 2007. Bowhead sighting rates in the central Alaskan Beaufort Sea remained high through mid-September, there was no significant evidence of migratory headings, and a high proportion of the whales sighted appeared to be feeding. In addition, the majority of sightings consisted of individuals categorized as moving slowly. Migrating whales tend to travel at moderate speeds (Würsig et al. 2002) and whales that have been disturbed often travel at fast speed. Thus data on speed of movements suggest that many of the whales sighted during our surveys were lingering in the area or feeding.

This interpretation is supported by the high frequency of observations of apparently feeding whales. Feeding activity (intepreted from behaviors such as as moving slowly and without migratory headings, turning at the surface followed by diving, mouth open or presence of mud splotches on body) and travel activity are considered common summer and fall behaviors in the eastern Alaskan Beaufort (Wursig et al 2002), but in general, feeding is believed to be more common there than in our 2007 study area (Thomson et al. 2002). Also of interest is the trend for bowheads observed in the eastern part of our survey area to have a more westward direction of travel than those observed in the central and western areas, suggesting that less feeding was occurring in Camden Bay area than near and west of Sivulliq.

Previous studies (LGL and Greenridge 1987; Richardson et al. 1999; Schick and Urban 2000) have indicated that certain types of seismic and drilling noise can cause migrating bowheads to deflect from their typical migration route; however, studies from the summer feeding area suggest that bowheads are much more tolerant of seismic operations when an attractant such as food is present (Miller et al. 2005). These observations are supported by our data. High-sighting rates were observed near seismic operations and these sightings consisted primarily of whales engaged in feeding as opposed to migratory activities.

Especially interesting is the trend of sighting rates by distance from shore between seismic areas. While there were no significant differences between groups, peak sighting rates occurred farther offshore in the central area, at a distance roughly corresponding to that of the seismic prospect. Rather than being displaced by seismic operations, bowheads appeared to aggregate in the vicinity of operations. This lends support to the idea that feeding bowheads are more tolerant of seismic activities than are migrating whales. It also suggests that whales may not be deflected as far from seismic operations as previous studies have suggested (i.e., Miller et al. 1999), because had they deflected at those distances, whales would not have known that food resources were present west of Sivulliq.

More research is needed to determine influences of potential food resources or other biological factors on bowhead whale distribution and movements when potential sources of disturbance are present. Also, in the case of feeding whales, using SELs instead of assuming behavioral takes, at certain received levels of sounds, may be a more appropriate method of calculating bowhead take estimates.

## *Mitigation Measures Implemented*

Only one mother-calf pair was seen during aerial surveys associated with seismic monitoring near the Phoenix and Sivulliq prospects during 2007. Mitigation measures (shut-down of operations) were required if four or more mother-calf pairs were sighted within the established 120 dB re 1 ųPa (rms) radius during a survey and thus no mitigation measures were implemented due to observations of mother-calf pairs within the 120 dB radius in 2007.

The IHA required surveys to be flown biweekly through 31Aug and daily (weather permitting) from 1 Sep until three days following the end of seismic work. To the extent possible within safety constraints, this was done.

### *Estimated Number of Cetaceans Present and Potentially Affected*

Three received level criteria have been specified by NMFS as relevant in estimating cetacean "take by harassment":

- 180 dB re 1µPa(rms), above which there is concern about possible temporary effects on hearing;
- 160 dB re 1µPa(rms), above which avoidance and other behavioral reactions are likely; and
- 120 dB re 1µPa(rms), above which displacement of migrating bowhead whales might occur (bowhead mother/calf pairs must be monitored and not exceed three) (NMFS 2007).

Using density estimates during seismic periods calculated with DISTANCE software and total ensonified area calculated with ArcView exposures were estimated for each of the received level criteria (Table 5.59).

These numbers are likely overestimates of the number of individuals exposed to the 160 and 180 dB re 1ųPa (rms) levels because bowhead whales sometimes avoid seismic operations when received levels are much lower than these.

### *Beluga Whales*

A total of 31 useable beluga sightings (61 individuals) were recorded over the course of the study (Fig. 5.87). Sightings were made on two days, 22 Aug and 11 Sept during nonseismic periods. Observed behaviors included milling (1 sighting, 13 individuals), swimming (2 sightings, 2 individuals) and traveling (1 sighting, 2 individuals; Fig. 5.88). Speed was considered slow for all sightings for which it was recorded (Fig. 5.89).

TABLE 5.59. Estimated number of individual bowhead whales exposed to seismic activities by SOI in the central Beaufort Sea and average number of exposures per individual from 22 Aug through 8 Oct 2007.

| Exposure level in dB re 1 uPa (rms) | Individuals Exposed | Exposures per individual | Requested take |
|---|---|---|---|
| **≥190dB** | 21 | 3.74 | |
| **≥180dB** | 40 | 6.68 | |
| **≥170dB** | 75 | 11.54 | |
| **≥160dB** | 192 | 18.88 | |

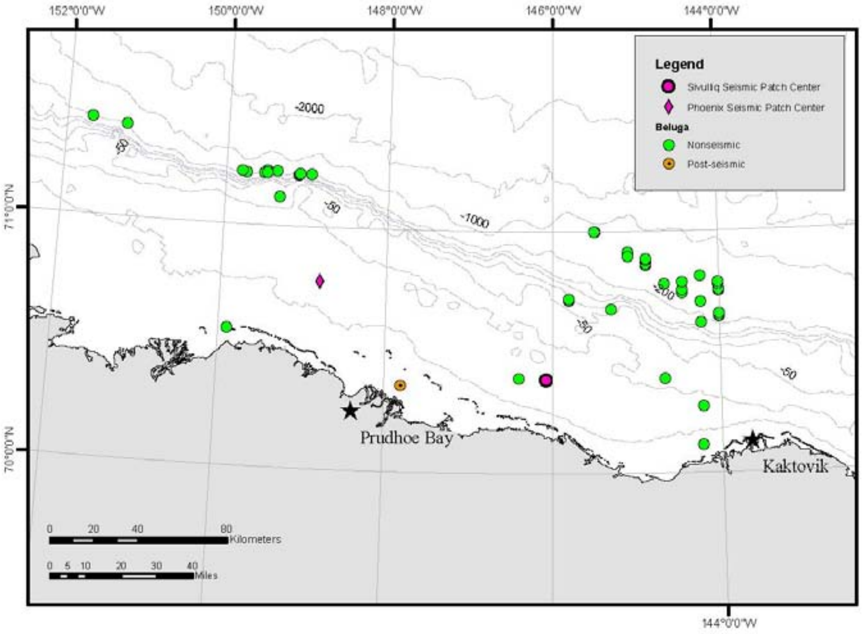


Figure 5.87. Beluga sightings relative to the two seismic prospects explored in the Beaufort Sea from 22 Aug- through 8 Oct 2007. Seismic state at the time of sighting is indicated by color.

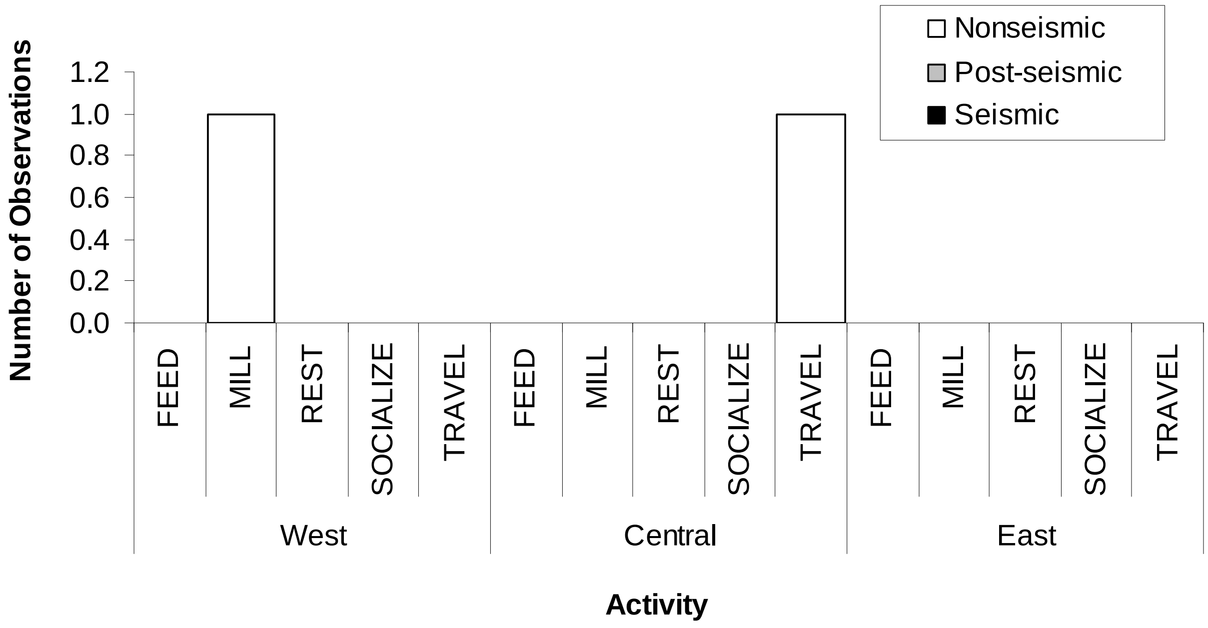


Figure 5.88. Observed activities of beluga whales in the three subdivisions of our study area in the central Beaufort Sea from 22 Aug through 8 Oct 2007. Seismic state at time of sighting is indicated by color.

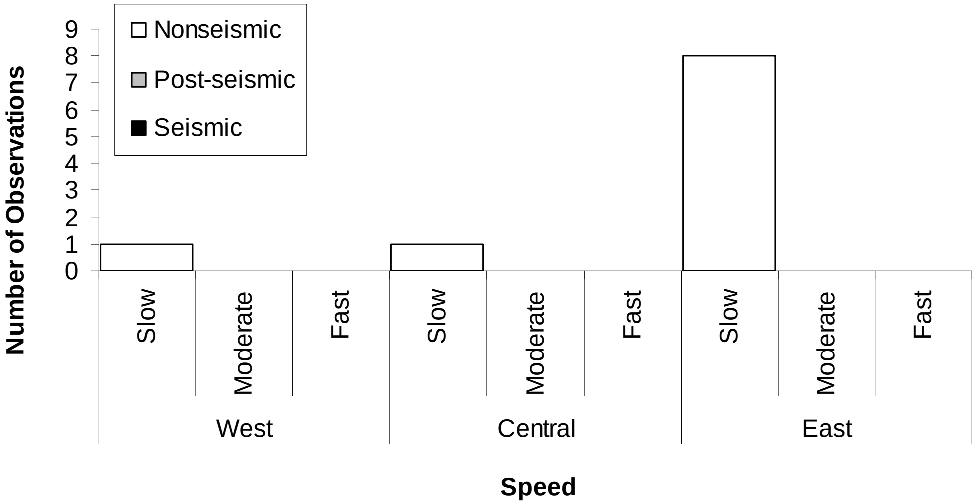


Figure 5.89. Observed speeds of beluga whales in the three subdivisions of our study area in the central Beaufort Sea from 22 Aug through 8 Oct 2007. Seismic state at time of sighting is indicated by color.

## *Seals*

A total of 55 useable bearded seal sightings (69 individuals), 145 ringed seal sightings (559 individuals) and an additional 131 sightings (593 individuals) of small, unidentified seals which were likely ringed or spotted seals, were made during the aerial surveys conducted near the Phoenix and Sivulliq prospects in 2007 (Figs. 5.90 and 5.91). Seals cannot be reliably seen and many of those seen cannot be identified to species during surveys conducted at 1000 and 1500 ft above sea level. Most seals were recorded when Beaufort wind force was 0 to 2 and very few of those present were detected when Beaufort wind force was >2.

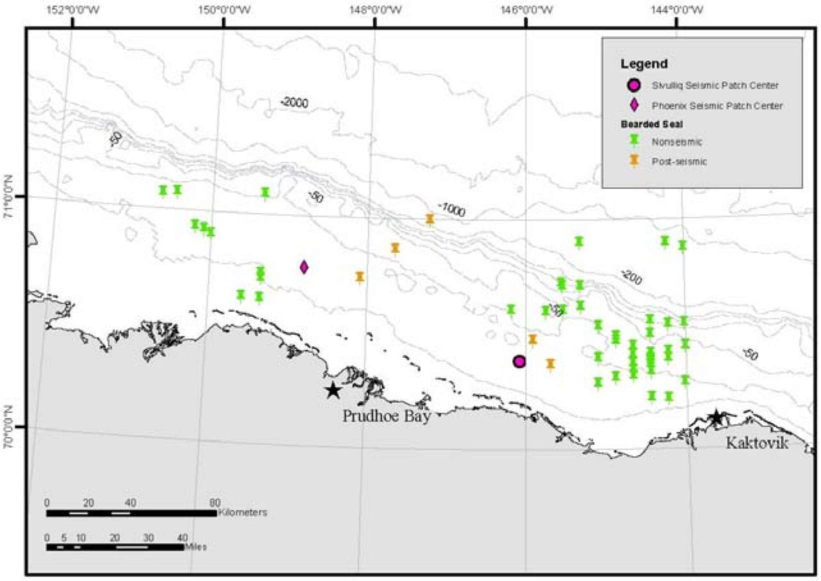


Figure 5.90. Bearded seal sightings relative to the two seismic prospects explored in the Beaufort Sea from 22 Aug through 8 Oct 2007. Seismic state at time of sighting is indicated by color.

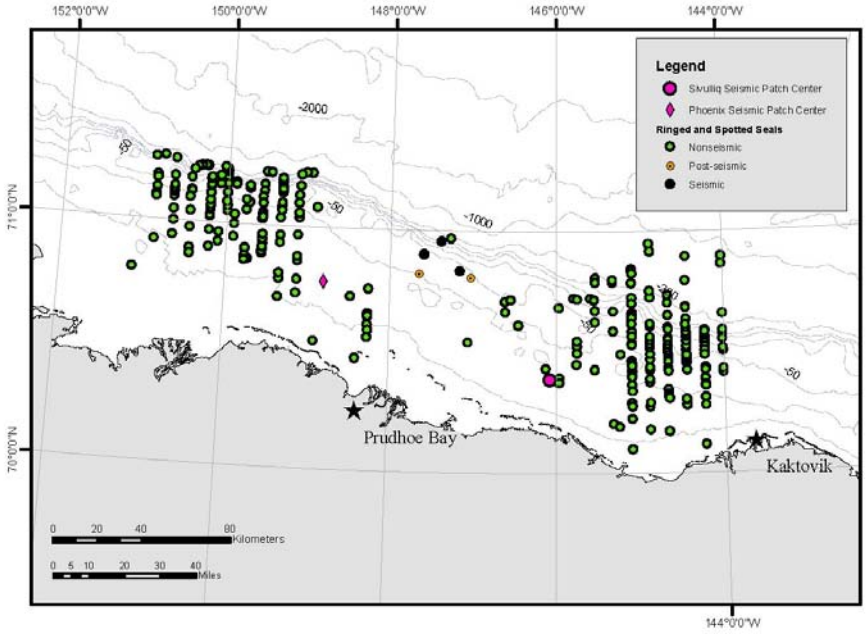


Figure 5.91. Ringed and spotted seal sightings relative to the two seismic prospects explored in the Beaufort Sea from 22 Aug through 8 Oct 2007. Seismic state at time of sighting is indicated by color.

## *Polar Bears and Walruses*

Twenty-seven polar bear sightings (47 individuals) were made during our 2007 aerial surveys. None of these sightings were considered useable because all occurred during transit between transects or to and from the study area (Fig. 5.92). The majority of these sightings were of lone adults (12 sightings) with one sub-adult, nine mother and cub pairs and an additional five bears of indeterminate age also observed. Of the nine mother and cub sightings, three consisted of a mother and her yearling cub, three were of a mother and two young-of-the-year cubs and three were of a mother with two cubs of indeterminate age. Resting (71%) and walking (21%) were the primary activities observed.

In addition, one useable walrus sighting, a mother and calf pair, was made (Figure 5.92).

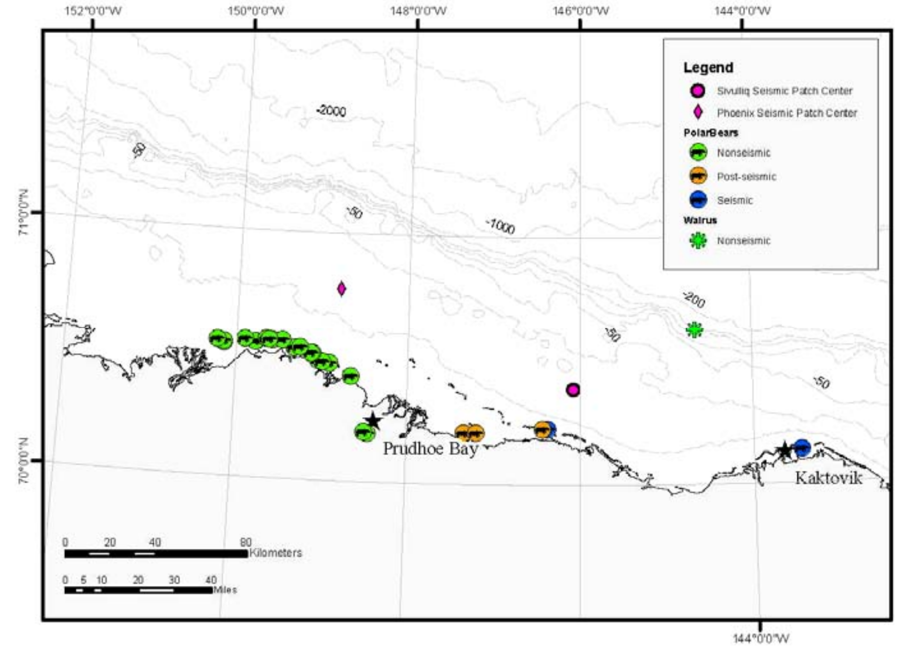


Figure 5.92. Walrus and polar bear sightings relative to the two seismic prospects explored in the Beaufort Sea from 22 Aug through 8 Oct 2007. Seismic state at time of sighting is indicated by color.

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