Marine Mammal and Acoustical Monitoring of The Eni/PGS Open-Water Seismic Program Near Thetis, Spy and Levitt Islands, Alaskan Beaufort Sea, 2008: 90-Day Report

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by

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ACRONYMS AND ABBREVIATIONS

~	approximately
AES	ASRC Energy Services
AKDT	Alaska Daylight Time
Asl	above sea level
Bf	Beaufort Wind Force
BOWFEST	Bowhead Whale Feeding Ecology Study
CAA	Conflict Avoidance Agreement
CFR	(U.S.) Code of Federal Regulations
CITES	Convention on the International Trade in Endangered Species
cm	centimeter
Com-Center	Communication Center
CPA	Closest (Observed) Point of Approach
cu. in.	cubic inches
dB	decibels
DIBs	Demaree Inflatable Boats
EA	Environmental Assessment
Eni	Eni US Operating Co. Inc.
ESA	(U.S.) Endangered Species Act
FFT	Fast Fourier Transforming
ft	feet
GIS	Geographic Information System
GMT	Greenwich Mean Time
GPS	Global Positioning System
h	hours
HFC	high-frequency cetacean
hp	horsepower
Hz	Hertz (cycles per second)
IHA	Incidental Harassment Authorization (under the U.S. MMPA)
in	inches
in^3	cubic inches
ITS	Incidental Take Statement
IUCN	International Union for the Conservation of Nature
kHz	kilohertz
km	kilometer
km^2	square kilometers
km/h	kilometers per hour

kW	kilowatt
kt	knots
LFC	low-frequency cetacean
LOA	Letter of Authorization
µPa	micro Pascal
m	meters
MFC	mid-frequency cetacean
mi	miles
min	minutes
MMO	Marine Mammal Observer
MMPA	(U.S.) Marine Mammal Protection Act
n.mi.	nautical miles
NMFS	(U.S.) National Marine Fisheries Service
No.	number
OBC/TZ	Ocean Bottom Cable/Transition Zone
OBH	Ocean Bottom Hydrophone
OCC	Oliktok Construction Camp
OPP	Oliktok Production Pad
PGS	PGS Onshore, Inc.
PINN	pinniped
pk-pk	peak-to-peak
psi	pounds per square inch
re	in reference to
RL	received (sound) level
rms	root-mean-square
rpm	revolutions per minute
s	seconds
s.d.	standard deviation
SEL	Sound Exposure Level
SID	Spy Island Drillsite
SPL	Sound Pressure Level
TTS	Temporary Threshold Shift
UNEP	United Nations Environmental Programme
U.S.	United States
USFWS	U.S. Fish and Wildlife Service
yd	yards
3-D	three-dimensional

EXECUTIVE SUMMARY

Background and Introduction

Eni US Operating Co. Inc. (Eni) contracted Petroleum Geo-Services Onshore, Inc. (PGS) to conduct ocean bottom cable/transition zone (OBC/TZ) seismic surveys covering Eni's Nikaitchuq Unit. In August and September 2008, the seismic source vessels, M/V *Wiley Gunner, Shirley V,* and *Peregrine*, operated small airgun arrays in the nearshore waters off Oliktok Point near Spy, Leavitt, and Thetis islands in the Alaskan Beaufort Sea.

The purpose of this document is to meet reporting requirements specified in an Incidental Harassment Authorization (IHA) and Letter of Authorization (LOA) issued to PGS by the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS), respectively. The IHA and LOA authorized small levels of incidental "takes" by harassment of certain marine mammal species during the Eni/PGS seismic surveys. Behavioral disturbance and (if they occur) auditory effects could constitute "take" under provisions of the U.S. Marine Mammal Protection Act (MMPA). Requirements described in the IHA and LOA were implemented to minimize exposures to sound levels potentially high enough to cause hearing impairment to marine mammals close to the seismic source and to reduce behavioral disturbance.

Of the marine mammal species that may occur in the central Alaska Beaufort Sea, USFWS manages the polar bear (*Ursus maritimus*) and walrus (*Odobenus rosmarus;* considered rare in the survey area) and NMFS has authority over all other species of pinnipeds and cetaceans. Ringed (*Phoca hispida*), spotted (*Phoca largha*), and bearded seals (*Erignathus barbatus*), and bowhead (*Balaena mysticetus*) and beluga whales (*Delphinapterus leucas*) are relatively common in the central Alaska Beaufort Sea, but there are only rare occurrences of gray whales (*Eschrichtius robustus*) and harbor porpoises (*Phoecena phoecena*). Of the species occurring in the Eni/PGS survey area, the bowhead whale is listed as endangered and the polar bear is listed as threatened under the Endangered Species Act (ESA).

A monitoring and mitigation program was conducted to avoid or minimize potential impacts of the Eni/PGS seismic survey on marine mammals and to ensure that the survey was in compliance with provisions of the IHA and LOA. Marine mammal observers (MMOs) were placed on each of the source vessels to detect marine mammals within or about to enter the prescribed safety radii and initiate immediate power- or shut-downs of the airgun arrays as necessary. An aerial survey program was also conducted to support marine mammal monitoring after 24 August 2008 when bowhead whales were expected to pass north of the survey area during their fall migration. Lastly, sound source verification (SSV) studies were conducted at the initiation of seismic operations for each of the airgun arrays (and acoustic measurements of support vessels), as indicated in the IHA and LOA.

Seismic Survey Described

The Eni/PGS seismic survey utilized small cable-laying boats to deploy cables on the ocean bottom (and to a limited extent across barrier islands), forming a pattern of three parallel receiver lines. Hydrophones and geophones attached to the cables were used to detect seismic pulses reflected from rock strata below the surface. Three shallow-water seismic source vessels (W*iley Gunner, Shirley V,* and *Peregrine*) were used during the Eni/PGS survey, each equipped with airgun arrays with a maximum volume of 880 in^3. Several support vessels were also involved during the project, including barges that contained recording equipment, cable-laying boats, crew transport and supply vessels, a fuel boat, a Project Manager/Client boat, and a mechanical support vessel.

Seismic surveys began with airgun testing on 2 August 2008 using the *Wiley Gunner*. The *Wiley Gunner* experienced many technical and mechanical problems during the survey and was removed from the project on 25 August 2008. By 9 August 2008, the *Shirley V* arrived as a second source vessel and began seismic testing on 18 August 2008; the *Shirley V* was used as a source vessel for the remainder of the survey period. The *Peregrine* was added as a second source vessel on 28 August 2008 until the end of the survey on 28 September 2008. During periods when two vessels were functional, seismic operations alternated between source vessels.

Sound Source Verification

Prior to seismic data acquisition, SSV tests were conducted by JASCO Research Ltd. to measure the sound levels produced by the *Wiley Gunner* and *Shirley V*'s full airgun arrays and single mitigation source. Similar testing was conducted (by Greeneridge Sciences, Inc.) in July 2008 for the *Peregrine* before its arrival in the Eni/PGS survey area. Field measurements and subsequent modeling results were used to determine safety radii for marine mammal monitoring and mitigation. The results are presented in detail in Chapter 3 and summarized in Table 4.1.

Results of Marine Mammal Monitoring

Vessel-based Monitoring Results

<u>Survey Effort</u>

A total of 1268 h (along 4912 km of ship trackline) of marine mammal monitoring occurred during the Eni/PGS seismic survey, including 245, 576, and 447 h (757, 2434, and 1721 km) from the *Wiley Gunner, Shirley V,* and *Peregrine*, respectively. Of those observations, ~67% (853 h; 3278 km) were considered as "daylight effort" useable for analyses, and occurred during daylight conditions with Bf <6, visibility ≥1 km (0.6 mi), and no to moderate glare. Data were categorized as seismic, post-seismic (3 min to 1 h after a seismic period), and non-seismic periods and these periods accounted for 64, 6, and 30% (547, 52, and 253 h) of the effort during "daylight" conditions, respectively.

<u>Cetaceans and Seals</u>

A total of 38 seal sightings (total of 38 individuals) and one cetacean sighting (of three unidentified mysticetes) were made from the source vessels. Of those 39 sightings, ~62% (24 sightings), 28% (11 sightings), and 10% (4 sightings) were made from the *Wiley Gunner*, *Shirley V*, and *Peregrine*, respectively. Over half of the seal sightings (52% of 38 sightings) were of unidentified seals, ~18% were of bearded or spotted seals (7 sightings, each), and ~11% (4 sightings) were of ringed seals. The single cetacean sighting was made from the *Shirley V* during a post-seismic period. Sighting rates for bearded, spotted and unidentified seals were higher during non-seismic vs. seismic periods, and, for most species, post-seismic sighting rates were also greater than those during seismic periods. Considering all species combined, the seal sighting rate for non-seismic periods (67.1 seals/1000 h of "daylight effort") was significantly greater than the seismic rate (~31.1 seals/1000 h of "daylight effort").

The single cetacean sighting involved three blows seen over three km away from the source vessel during a post-seismic period. There was no obvious reaction by these unidentified mysticetes to the Eni/PGS survey operations. For seals, the average closest (observed) point of approach (CPA) was smaller during seismic (222 m) than non-seismic periods (327 m). Irrespective of seismic state, seals tended to move away from the source vessels (70% of 37 sightings with movement recorded). "Looking" was the most frequently recorded behavior for seals (55% of 38 sightings), during both seismic and non-seismic periods. "Looking" and "no reaction" were the most frequently recorded reactions by seals (48 and 29% of 38 sightings, respectively).

A power-down to the single mitigation airgun was requested once during the Eni/PGS seismic survey due to a bearded seal sighted near the ≥190 dB re 1 μPa_{rms} safety radius on the *Shirley V*. Ten shut-downs of the airguns were implemented due to seals observed within or about to enter the ≥190 dB safety radius. Details of each of these shut-downs and power-down are included in *Implementation of Mitigation Measures* in Chapter 5.

Any cetaceans or seals that might have been exposed to received sound levels ≥160 dB re 1 μPa_{rms} were assumed to have been potentially disturbed during the study. The estimated number of seals and cetaceans exposed to seismic sounds ≥160 dB based on direct observations of the number of animals within the sound radii was zero cetaceans and 16 seals. Of those 16 seals, eight were observed within the ≥190 dB safety radius and a shut-down was implemented in each case. Each of these seals may have received sound levels ≥190 dB for some of the seismic pulses prior to shut-down. Indirect estimates of the number of individual seals exposed to sound levels ≥190 and ≥160 dB were also calculated based on the observed density of seals in the area. Based on indirect estimates, a total of 40 and 18 individual seals may have been exposed to received sound levels ≥160 dB and ≥190 dB, respectively, during the Eni/PGS seismic survey.

<u>*Polar Bears*</u>

No walruses were observed during the Eni/PGS seismic survey. A total of 13 sightings of 16 polar bears were made from source vessels during the Eni/PGS seismic survey. Of those 13 sightings, ~15%, 46%, and 38% were made from the *Wiley Gunner*, *Shirley V*, and *Peregrine*, respectively. With the exception of one polar bear swimming in the water, all polar bears were observed on the barrier islands. Therefore, analyses of polar bear sightings by seismic state did not have the same relevance as for other marine mammals. Polar bears on land, if they elicited a response to the Eni/PGS seismic survey, would be influenced by airborne sound, visual cues and perhaps olfactory cues. These potential influences would not necessarily differ between seismic, post-seismic, and non-seismic periods. Of the 13 polar bear sightings, most occurred during non-seismic periods (61%), while 30% and 8% of sightings occurred during seismic and post-seismic periods, respectively.

The single polar bear observed in the water occurred during a seismic period and the bear was observed swimming away from the vessel. All polar bears observed on the barrier islands showed no obvious direction of movement relative to the vessel location, other than one group of bears that walked away. Resting was the most frequently recorded behavior (54% of 13 sightings), followed by walking (39%). "No reaction" was displayed during most polar bear sightings (69% of 13 sightings), including during both seismic or non-seismic periods, and looking was recorded during the remaining polar bear sightings.

No power-downs were implemented due to polar bears seen within or about to enter the ≥190 dB safety radius. However, there was a single shut-down due to the polar bear observed in the water, and details of this shut-down are included in *Implementation of Mitigation Measures* in Chapter 6. There were also seven occasions when a source vessel moved away from the location of a polar bear sighting. There were never any strong behavioral reactions by polar bears to the presence of seismic source vessels. Additionally, no polar bears were observed within the ≥190 dB safety radius, but one polar bear was estimated to have potentially received sound levels ≥160 dB before the above mentioned shut-down was implemented. Indirect estimates of the number of individual polar bears exposed to sound levels ≥190 dB were also estimated. It was estimated that were a total of four individuals that were potentially exposed to received sound levels of ≥190 dB during the Eni/PGS seismic survey. This assumes the polar bears were swimming underwater and showed no avoidance of the sound source.

Aerial Survey Monitoring Results

Aerial surveys were conducted at least three days per week, weather permitting, from 25 August to 27 September with the goal of obtaining data on the occurrence, distribution, and movements of marine mammals in and near the Eni/PGS seismic survey area. During a total of 15 surveys, comprising 4184 km of "useable" data (i.e., suitable environmental conditions), there were 25 bowhead whales (34 individuals), seven beluga whales (15 individuals), one harbor porpoise (five individuals), 25 bearded seal (34 individuals), 60 ringed seal (116 individuals), two spotted seal, and 67 unidentified seal (228 individuals) sightings.

Bowhead whales were observed during 67% of aerial surveys, with an average of two sightings per survey. Sighting rates were highest in late August and early September. Most bowhead whales (20 of 25 "useable" sightings) were seen during seismic operations, but sighting rates did not statistically differ among seismic states. Distance of bowhead whale sightings from the Eni/PGS survey area also did not vary by seismic state. The aerial survey area was divided into three regions: "central" (directly north of the Eni/PGS survey area), "east", and "west". The number of bowhead whale sightings was significantly higher in the east area relative to the central and west areas. Heading was recorded for 15 bowhead sightings. Mean headings were northwesterly during both seismic and non-seismic periods and the overall mean heading was 294ºT. Travel was the most frequently recorded behavior (43.5% of 14 sightings) and these whales were mostly recorded as moving at a moderate speed. Peak bowhead whale sighting rate was observed 25-30 km from shore, and all bowhead whale sightings occurred in water depths of 20 to 31 m. Comparisons among seismic states were limited since the majority of aerial surveys (70% of effort) were conducted during seismic operations. In general, however, there was little indication that bowhead whale migration patterns, behavior, distance from shore, or distance from the seismic survey area were affected by the Eni/PGS seismic activities. The numbers of bowhead whales potentially affected by received sound levels ≥180 and ≥160 dB were estimated as five and eight bowheads, respectively. These estimates are likely conservative because these sound levels were not expected to occur in the typical migration corridor of bowhead whales.

All seven beluga whale sightings occurred during seismic periods, and sighting rates varied between 0 and 9.1 sightings/1000 km per survey. Most sightings occurred in the central area. Half of all beluga whales were observed swimming at a moderate pace, mostly between 90 and 110 km from shore and in water depths of 1900-2100 m. One useable sighting of five harbor porpoises occurred at a water depth of 30 m and 57 km from the center of the seismic survey area. All of the seal sightings occurred during seismic and post-seismic periods. The numbers of beluga whales potentially affected by received sound levels ≥180 and ≥160 dB were each estimated as one beluga whale. As with bowhead whales, these estimates are likely conservative because the beluga migration occurs well seaward of the Eni/PGS survey area.

1. BACKGROUND AND INTRODUCTION

Eni US Operating Co. Inc. (Eni) contracted Petroleum Geo-Services Onshore, Inc. (PGS) to collect marine seismic data in the nearshore waters of the Alaskan Beaufort Sea at Eni's Nikaitchuq Unit in August and September 2008. The unit is located adjacent to the Colville River delta, north of Oliktok Point and includes Thetis, Spy, and Leavitt islands (Fig. 1.1). The seismic survey area extended ~5 km (3.1 mi) offshore of the barrier islands. Water depths in the seismic survey area ranged from 0 to 15 m (0 to 49 ft). The three-dimensional (3-D) marine seismic survey was conducted by PGS using an ocean bottom cable/transition zone (OBC/TZ) method. The OBC/TZ survey involved the use of small boats to deploy cables on the ocean floor and across the barrier islands. Hydrophones and geophones attached to the cables were used to detect seismic pulses released from the airgun arrays deployed from the source vessels. The source vessels M/V *Wiley Gunner* and M/V *Shirley V* were equipped with arrays of 10 operational airguns with a total volume of 880 in^3. The M/V *Peregrine* was used later in the program as a source vessel and was equipped with arrays of four and eight airguns with maximum volumes of 440 in^3 and 880 in^3, respectively. Seismic vessels did not operate their airgun arrays simultaneously during the survey.

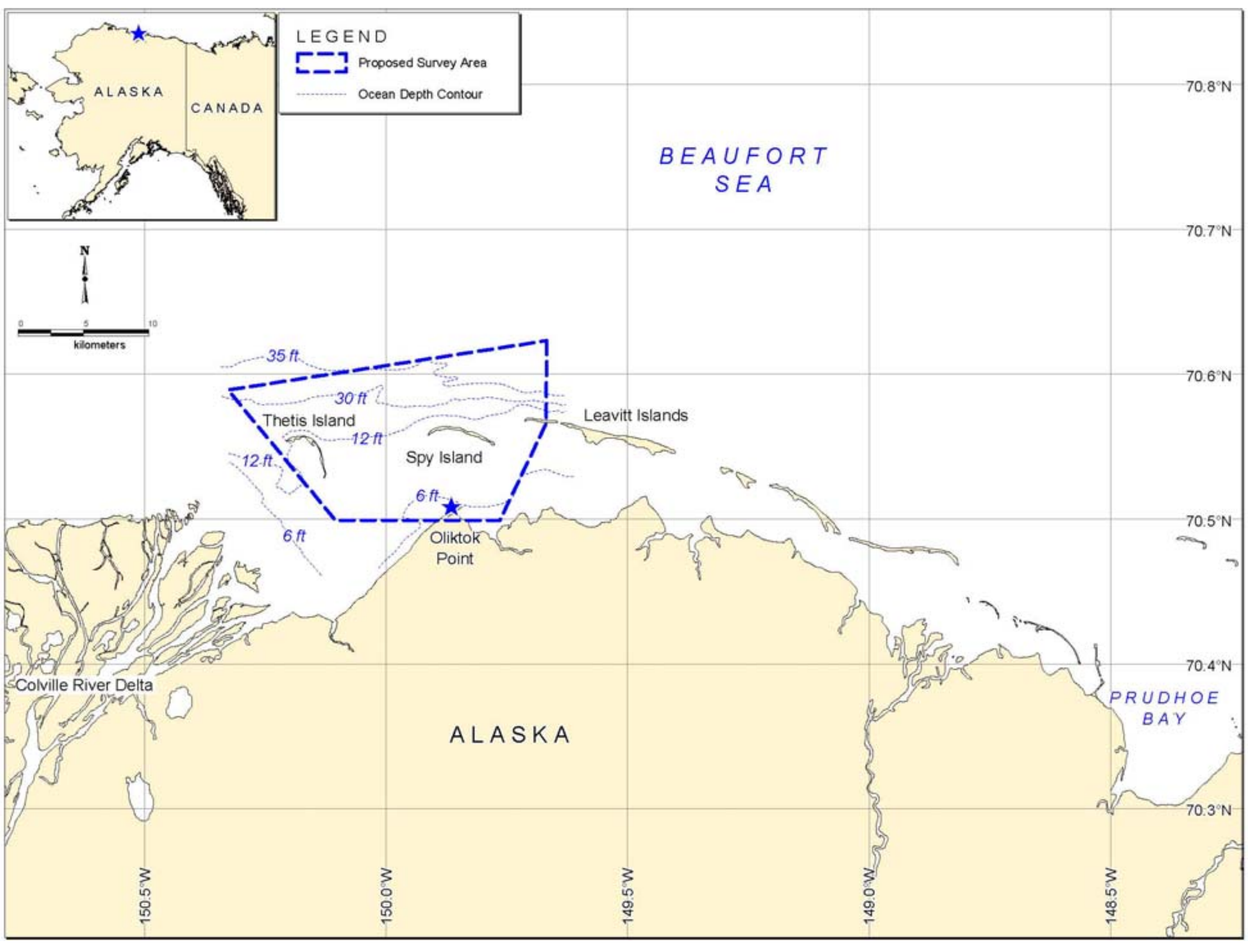

FIGURE 1.1. Locations of Eni's OBC/TZ seismic survey area (proposed) near Thetis, Spy, and Leavitt islands in the central Alaskan Beaufort Sea, August – September 2008. The Oliktok construction camp is denoted with a blue star.

Marine seismic surveys transmit strong noise pulses into the water at regular intervals (Greene and Richardson 1988; Breitzke et al. 2008). Known auditory and behavioral sensitivities of many marine mammals to underwater sounds suggest that marine seismic projects have the potential to affect marine mammals (Richardson et al. 1995; Gordon et al. 2004; Southall et al. 2007). A review of the effects of seismic surveying on marine mammals, including those species which occur in the Eni/PGS survey area, is provided later in this chapter and in ASRC (2008a). Seals and whales in the Beaufort Sea are harvested by subsistence hunters. Thus, disturbance of marine mammals from seismic operations could have indirect effects on the accessibility of whales and seals to hunters. Ringed and bearded seals occur in the nearshore waters of the Alaskan Beaufort Sea. Spotted seals are thought to occur regularly in the seismic survey area because they occupy a haul-out site in the Colville River delta. Bowhead and beluga whales migrate westward through the region in late summer and autumn, although the main migration corridor for belugas is far offshore from the survey area. Polar bears occur in nearshore waters of the central Alaskan Beaufort Sea and on barrier islands during the open-water period. Gray whales, harbor porpoise, and walrus are considered rare in the central Alaskan Beaufort Sea. More information on the distribution, abundance, and conservation status of each species is provided in Chapters 5 and 6.

Behavioral disturbance to marine mammals is considered to be "take by harassment" under the provisions of the U.S. Marine Mammal Protection Act (MMPA). The Endangered Species Act (ESA) and pursuant regulations prohibits the take of endangered (i.e., bowhead whale) and threatened (i.e., polar bear) species without special exemption. It is not known whether seismic exploration sounds are strong enough to cause temporary or permanent hearing impairment in marine mammals that occur close to airguns.

The National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) share regulatory authority over the marine mammal species that occur in the seismic survey area. USFWS manages the polar bear (and walrus), while all other marine mammals in the area fall under NMFS jurisdiction. Under the MMPA, Incidental Harassment Authorizations (IHAs) can be issued by NMFS and Letters of Authorization (LOAs) can be issued by USFWS which allow "taking" of marine mammals if the "taking will have negligible impact on the species or stock(s) of marine mammals and will not have an unmitigable adverse effect on the availability of the species or stock(s) for subsistence uses".

On 9 May 2008, PGS requested that NMFS issue an IHA to authorize non-lethal "takes" (i.e., Level B), through harassment only, of marine mammals in conjunction with the planned seismic survey (ASRC 2008a). The IHA was requested pursuant to Section 101(a)(5)(D) of the MMPA. An IHA was issued by NMFS on 30 July 2008 (Appendix A). Small numbers of "take by harassment" were authorized for bowhead, gray, and beluga whales, and ringed, spotted, and bearded seals during the seismic survey. An Incidental Take Statement (ITS) specified a take of bowhead whales no greater than 28 animals (Appendix A). In March 2008, PGS also requested a LOA from USFWS to authorize potential "taking" of polar bears and walrus in the Beaufort Sea. On 10 July 2008, USFWS issued a LOA allowing PGS to "take small numbers" of polar bears and walrus incidental to the Eni/PGS seismic survey (Appendix B).

This 90-day draft report was prepared to meet reporting requirements specified in the IHA and LOA. Reporting requirements included the provision of: a description of the Eni/PGS seismic program conducted by PGS, the procedures and results of the marine mammal monitoring and mitigation program, the results of the acoustical measurements used to verify the safety radii, estimates of the numbers and species of marine mammals potentially affected by the seismic survey, and any impacts of the seismic survey on the subsistence use of marine mammals in and near the survey area.

A draft comprehensive report will be submitted to NMFS (and USFWS) in cooperation with other companies which received authorization to conduct exploration activities in the region under NMFS. This report will integrate, to the extent possible, the various marine mammal monitoring studies as part of a broad assessment of all industries in the U.S. portion of the Arctic Ocean during 2008. It is understood that this draft comprehensive report will be finalized after incorporation of recommendations by participants at the 2009 Open Water Scientific Meeting to be held in Anchorage.

Incidental Harassment Authorization (NMFS)

Provisions to minimize the possibility of temporary or permanent hearing loss to marine mammals are included in IHAs issued to seismic operators. During this project, impulsive sounds were generated by the operating source vessel's airguns (the *Wiley Gunner*, *Shirley V*, or *Peregrine*) during the seismic activities. No serious injuries or deaths of marine mammals were anticipated nor attributed to the Eni/PGS seismic survey, particularly given the timing and location of the survey and implemented mitigation measures. However, there was still potential to "take" marine mammals by harassment in the form of behavioral disturbance under the provisions of the MMPA.

"Safety radii" for marine mammals around airgun arrays have been specified in current NMFS guidelines (e.g., NMFS 2007) as the distances within which the received sound levels are ≥180 dB re 1 μPa (rms)[1] for cetaceans and ≥190 dB re 1 μPa (rms) for pinnipeds. These safety radii are implemented on the assumption that seismic pulses received at lower levels will not impair or injure hearing of marine mammals. However, it is also assumed that seismic pulses received at higher levels *might* have some such effects. Thus, IHAs require mitigation measures designed to avoid or minimize the numbers of marine mammals that may be exposed to sound levels greater than the prescribed safety radii. Chapter 3 provides additional details on the development and implementation of the safety radii for the Eni/PGS seismic survey in the Beaufort Sea.

Marine mammals could still be disturbed by seismic surveys if exposed to moderately strong pulsed sounds at distances greater than the safety zones (Richardson et al. 1995). Current NMFS guidelines designate that marine mammals are potentially disturbed by received levels ≥160 dB, based primarily on studies of behavioral responses of baleen whales to seismic airguns, as summarized by Richardson et al. (1995) and Gordon et al. (2004). For dolphins and pinnipeds, 170 dB may be a more appropriate safety zone for behavioral disturbance given that these groups generally exhibit less response than baleen whales (e.g., Stone 2003; Gordon et al. 2004). In general, a number of factors will affect the potential of a sound source to disturb an individual marine mammal, including species of marine mammal, the individual's activity at the time of the disturbance, distance from the sound source, the received sound level, and the associated water depth (Southall et al. 2007). Behavioral responses may be elicited by some individuals at received levels somewhat below the designated 160 or 170 dB levels, while other individuals may tolerate somewhat higher levels without appreciable response. For example, beluga and migrating bowhead whales have exhibited avoidance to seismic pulses at received levels below 160 dB in some cases (Miller et al. 1999; Richardson et al. 1999; Miller et al. 2005), but bowhead whales have also been observed on summer feeding grounds where received levels ≥160 dB from an airgun array have been estimated (Miller et al. 2005).

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[1] "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, 2000). Other measures of energy levels, particularly sound exposure levels (SELs) may be more relevant to measuring the effects of pulsed sounds to marine mammals (Southall et al. 2007), but current regulatory requirements are based on rms values. All airgun pulse levels in this report are provided as rms levels, unless otherwise noted.

NMFS published a notice announcing the proposed issuance of an IHA for the Eni/PGS seismic program in the *Federal Register* on 17 June 2008, inviting public comments (NMFS 2008). Subsequently, a revised IHA application was prepared in response to comments (ASRC 2008a), and the IHA was issued to PGS by NMFS on 30 July 2008, to cover the period from 30 July 2008 to 1 August 2009 (Appendix A).

The IHA issued by NMFS to PGS authorized harassment "takes" of one ESA-listed species, bowhead whales, in addition to non-listed gray whales, beluga whales, ringed seals, spotted seals, and bearded seals. Up to 28 bowhead whales were permitted to be "taken" by harassment as well as "small" numbers of the other species, as specified in the ITS and NMFS (2008).

NMFS granted the IHA to PGS based on the following assumptions:

- a "small" number of whales and seals would be potentially harassed (as defined by the NMFS criteria) during the seismic survey,
- there would be a negligible overall effect of such harassment on any marine mammal population,
- no marine mammals would be seriously injured or killed,
- the availability of marine mammals for Alaskan subsistence harvest would not suffer any unmitigated adverse effect, and
- PGS would implement the designated monitoring and mitigation measures.

Letter of Authorization (USFWS)

In 2006, USFWS began requiring operators of arctic seismic projects to operate under a LOA. PGS requested a LOA from USFWS on 20 March 2008 for the incidental take of polar bears and Pacific walruses associated with seismic surveys in the nearshore Beaufort Sea. On 10 July 2008, USFWS issued a LOA to PGS (Appendix B). The LOA required a ≥180 dB safety radius for walruses and a ≥190 dB radius for polar bears. Other monitoring and mitigation requirements were similar to those required in the IHA provided by NMFS for all other marine mammals and are discussed in more detail later in this chapter and Chapter 4.

Conflict Avoidance Agreement

Pursuant to the MMPA (50 CFR 216.104(a)(12)), IHA and LOA applications for activities in arctic waters require a plan of cooperation identifying approaches to minimize impacts of the proposed activity on the availability and accessibility of marine mammals for subsistence purposes. From February to May 2008, Eni and PGS coordinated meetings to discuss appropriate mitigation measures with potentially affected stakeholders, subsistence users, and community groups, including: Alaska Eskimo Whaling Committee, North Slope Borough, Kuukpikmiut Subsistence Oversight Panel, NMFS, town of Barrow, and villages of Nuiqsut, Wainwright, and Kaktovik (ASRC 2008b). On 30 May 2008, a conflict avoidance agreement (CAA) was finalized (CAA 2008). Specific agreements were designated in the CAA (CAA 2008) and included measures to:

- Avoid marine mammal and fish migration routes and areas during migration times,
- Avoid subsistence harvest areas during periods of subsistence activities,
- Perform data acquisition outside the barrier islands before 25 August 2008 or after the completion of the fall bowhead hunt to avoid migrating whales and subsistence activities,
- Perform data acquisition inside the barrier islands after 5 August 2008 to avoid migrating fish,

- Begin data acquisition in the east and move towards the west, and
- Maintain regular communications with user groups through Communication and Call Centers (Com-Center) and a designated individual.

Eni/PGS adhered to these designated agreements.

Mitigation and Monitoring Objectives

The IHA application materials (ASRC 2008a), as well as the IHA and LOA that were issued to PGS by NMFS and USFWS (Appendices A and B, respectively), detail the objectives of the mitigation and monitoring program associated with the Eni/PGS seismic program. NMFS also published explanatory material about the mitigation and monitoring objectives in the *Federal Register* (NMFS 2008).

The overarching goal of the mitigation and monitoring plan was to avoid or minimize potential effects of the seismic program on marine mammals. This was achieved by placing trained observers on source vessels to detect marine mammals within or about to enter the designated safety radii (≥180 dB for cetaceans and walrus, ≥190 dB for other pinnipeds and polar bears) and initiate a power-down or shut-down of airguns in such cases. Power-downs reduced the sound levels of the operating aiguns by reducing the seismic source to the smallest airgun in the airgun array. A shut-down required a temporary termination of all operating airguns. Additional mitigation objectives included procedures associated with detecting marine mammals prior to the initiation of airguns after extended periods of airgun inactivity. Ramp-up of airguns was only permitted after a 30 min period during which no marine mammals were seen within or about to enter the designated safety radii.

After 24 August 2008, airgun arrays were to be shut-down whenever aggregations of 12 or more balaenopterid whales were observed within the ≥160 dB zone or 4 or more bowhead whale cow/calf pairs were detected within the ≥120 dB zone. Also, seismic operations were restricted to areas inside of the barrier islands after this date until the subsistence hunt by Nuiqsut residents for bowheads was complete. Given the location and shallow water depths within the survey area, balaenopterid whales were not expected in most situations to occur in either the ≥160 dB or ≥120 dB zone. Aerial monitoring also began after 24 August 2008; surveys were required three days per week, weather permitting, to detect marine mammals within the designated 160 and 120 dB radii.

The primary objectives of the vessel-based and aerial monitoring program were to:

- Provide real-time sighting data needed to implement the mitigation requirements,
- Estimate the numbers of marine mammals potentially exposed to seismic pulses exceeding 190, 180 or 160 dB sound levels, and
- Determine the reactions (if any) to marine mammals potentially exposed to seismic pulses during the Eni/PGS survey.

Specific mitigation and monitoring objectives were included in the IHA and LOA issued by NMFS and USFWS, found in Appendices A and B, respectively. Chapter 4 provides a detailed description of the mitigation and monitoring procedures implemented during the Eni/PGS seismic survey near Thetis, Spy, and Leavitt islands in the Beaufort Sea.

Report Structure

The main purpose of this report is to meet reporting requirements specified in the IHA and LOA (Appendices A and B) and to describe the mitigation and monitoring objectives and results of the OBC/TZ seismic survey within the Eni/PGS seismic survey area. The report includes seven chapters:

1. Background and introduction (this chapter),

2. Description of the Eni/PGS seismic survey,
3. Description of the sound source verification program conducted in the field at the commencement of the seismic program and subsequent modeling results,
4. Description of the marine mammal mitigation and monitoring program,
5. Results of the vessel-based marine mammal mitigation and monitoring program for seals and cetaceans,
6. Results of the vessel-based marine mammal mitigation and monitoring program for polar bears and walruses, and
7. Results of the aerial marine mammal mitigation and monitoring program.

Those chapters are followed by an Acknowledgements section.

Additionally, there are six appendices, including:

A. Copy of the IHA and the ITS issued by NMFS to PGS (Appendix A),
B. Copy of the LOA issued by USFWS to PGS (Appendix B),
C. Description of vessels and equipment used during the seismic program (Appendix C),
D. Additional information on vessel-based visual effort and sightings (Appendix D),
E. Incidental marine mammal sightings and stationary effort (Appendix E), and
F. Additional information on aerial survey effort and sightings (Appendix F).

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2. SEISMIC SURVEY DESCRIBED

Eni's open-water seismic program in 2008 consisted of an OBC/TZ seismic survey in the nearshore waters of the central Alaskan Beaufort Sea. The seismic work was conducted by PGS from 2 August to 28 September 2008. The sound source for each source vessel consisted of airgun arrays of four to 10 Bolt type airguns of various individual volumes, totaling 440 in^3 to 880 in^3. Cables were deployed on the ocean floor and, in some instances, across barrier islands within a targeted seismic data acquisition area (known as a swath). The cables were equipped with acoustic sensors (hydrophones and geophones) to detect seismic energy which is reflected by the underground rock strata after being emitted from the array of airguns. The source vessel travelled perpendicular to the cable pattern deployed on the seafloor. The seismic data were transmitted through the cables to a recording vessel for data storage.

The Eni/PGS survey involved three seismic source vessels (M/V *Wiley Gunner,* M/V *Shirley V,* and M/V *Peregrine*), seven cable laying vessels, one recorder barge (M/V *Garrett*), one crew transport vessel (M/V *American Discovery*), one fuel vessel (M/V *Spiridon*), and two support vessels. All vessels were required to operate according to IHA, LOA, and CAA requirements. The following sections briefly describe the seismic survey, the source vessels used during the survey, and operational details to satisfy reporting requirements of the IHA and LOA (Appendices A and B). Additional information on each of the vessels and other equipment used during the survey is provided in the following sections and in Appendix C. Results of the sound source verification program by JASCO are provided in Chapter 3.

Operating Areas, Dates, Navigation

The Eni/PGS survey was conducted in the Nikaitchuq Unit north of Oliktok Point and included nearshore waters surrounding Thetis, Spy, and Leavitt islands in Alaska state waters of the Beaufort Sea (Fig. 2.1). Water depths in the survey area range from 0 to 15 m (0 to 49 ft), with ~ one third of the survey area less than 3 m (10 ft) deep. Eni/PGS originally planned to acquire seismic data in a 305 km^2 (118 mi^2) survey area (see blue outlined area in Fig. 2.1). Marine waters comprised ~303 km^2 (117 mi^2) of the total planned survey area and the remaining area included portions of the barrier islands which were overlaid with cables. The proposed survey area was bounded as follows: northwest 70°35' 24"N, 150°19' 48"W, southwest 70°29' 55"N, 150°06' 36"W, northeast 70°36' 53"N, 149°39' 53"W and southeast 70°29' 55"N, 149°39' 58"W (Fig. 2.1).

In addition to the seismic operations being conducted in this area by Eni/PGS, multiple concurrent oilfield related activities such as well drilling, pipe corrosion checking, and oil rig movements took place onshore. Other offshore activities included barge and helicopter transport of equipment and personnel to the Pioneer Ooguruk[2] drillsite and Eni Spy Island[3] drill pad. Vessel activity in the area was monitored acoustically as part of an offshore acoustic monitoring program in cooperation with Pioneer Natural Resources, Inc., (Pioneer), Eni, and Shell Offshore, Inc. This program was an extensive in-water acoustic monitoring program using nine bottom-founded acoustic recorders around the Oooguruk drillsite (ODS), the Spy Island drill pad, and the PGS seismic survey from mid-August through late September 2008. It was conducted as part of the North Slope Borough permitting stipulations for projects in

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[2] The Ooguruk offshore drillsite, completed in April 2008, is a 6-acre, 4 m-high artificial gravel island located ~9 km from the shoreline.

[3] Spy Island is one of the barrier islands that has been developed as a drill pad for Eni. A permit application was submitted in summer 2008 to develop a drillsite on the island (SID or Spy Island drillsite). Survey activities were conducted in summer 2008 in preparation for winter construction.

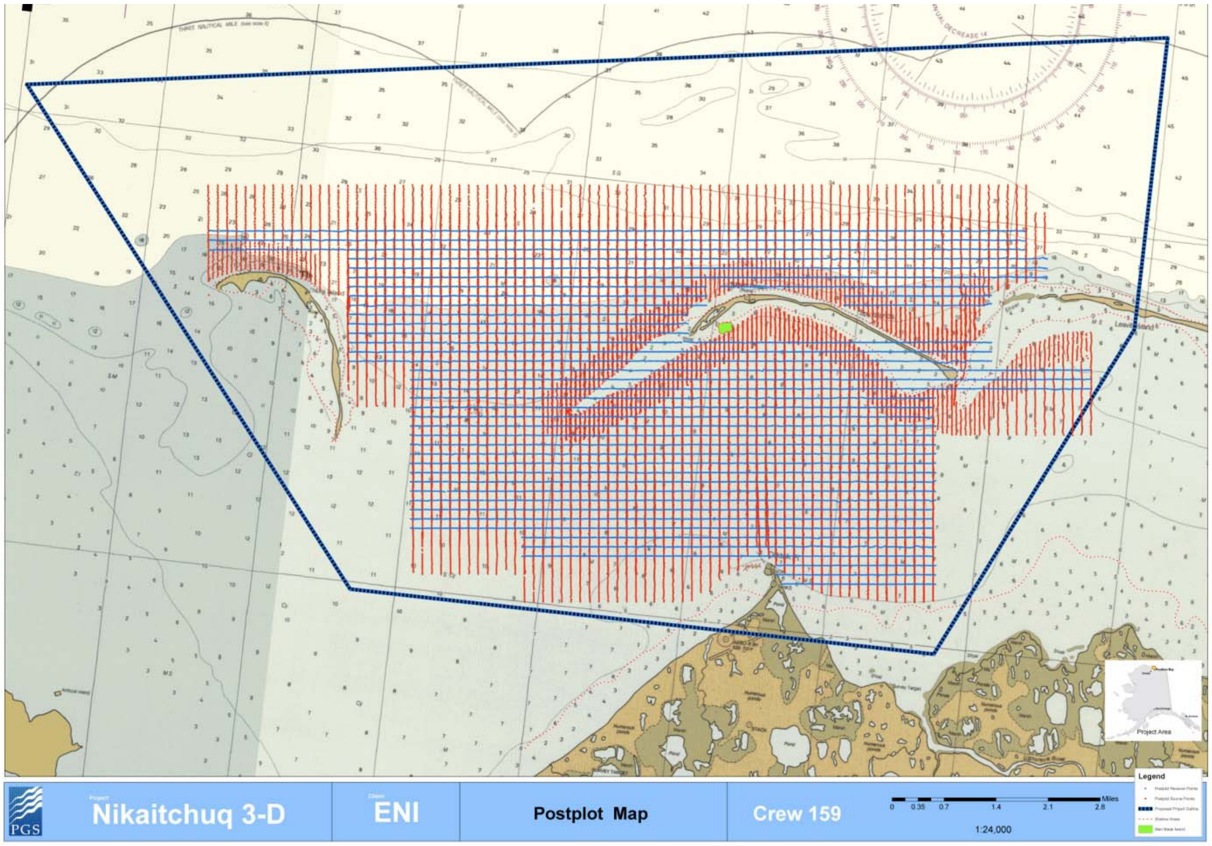

FIGURE 2.1. Locations of the proposed Eni/PGS seismic survey area (blue outline) and the cable receiving lines (blue east-west lines) and source lines (red north-south lines) where seismic data were acquired (provided by PGS).

2008 and the goal was to characterize sounds produced from drilling (ODS), island construction (SID), vessels, and seismic airguns. These data will be used in the preparation of a multi-project comprehensive report encompassing oil and gas activities in the U.S. Arctic Ocean which will be submitted by spring 2009 (see Chapter 1).

The source vessel *Wiley Gunner,* cable boats and other support vessels were trucked to the North Slope (Alaska) in June 2008. The Eni Oliktok construction camp (OCC) which had been established at Oliktok Point for construction of the Nikaitchuq Development was used to mobilize vessels and other equipment. The vessels and other equipment were then transported to a docking system at the Oliktok Production Pad (OPP). The *Shirley V* was trucked to the North Slope and arrived 9 August for use in the Eni/PGS survey. The *Peregrine* was released from another project in the central Alaskan Beaufort Sea and began Eni/PGS seismic survey operations on 28 August.

The seismic survey started on 2 August with airgun testing on the source vessel *Wiley Gunner*; the *Shirley V* began seismic testing on 18 August, and the *Peregrine* began on 28 August. [Seismic vessels did not operate their airgun arrays simultaneously during the survey; airgun activity alternated between source vessels during periods when two source vessels were in the survey area.] Some technical and mechanical problems controlling airgun volume and timing were initially encountered on both the *Wiley Gunner* and *Shirley V*, leading to the need to frequently test seismic equipment during periods of data acquisition. Due to persistent mechanical problems, the *Wiley Gunner* discontinued operations on 25 August.

JASCO conducted SSV measurements of the airgun array for the *Wiley Gunner* on 3-5 August and for the *Shirley V* on 18-19 August (see Chapter 3). SSV for the *Peregrine* was determined during a seismic survey conducted earlier in the summer in the nearshore waters at the Liberty prospect (Aerts et al. 2008). JASCO provided estimates of various sound level and safety radii (summarized in Table 4.1 in Chapter 4) based on SSV measurements which were used by MMOs aboard each source vessel for marine mammal monitoring and mitigation during the Eni/PGS seismic survey. Prior to the application of SSV safety radii, MMOs used safety radii distances designated in the IHA and LOA.

Seismic data acquisition started on 8 August and ended at 0152 h on 28 September. Seismic activity was restricted to areas inside the barrier islands after 24 August during the bowhead subsistence hunt by residents of Nuiqsut, in accordance with the IHA. After data acquisition ended on 28 September, the cable and crew support vessels operated in the survey area for an additional five days, until 3 October, to retrieve cables and demobilize the recording barge. All vessels were demobilized at the OPP and Eni construction camp before being trucked off-site. All operations were completed by 8 October 2008.

Seismic data were acquired over ~78.2 km^2 (48.6 mi^2). A total of 19 swaths were proposed for this survey. Seismic data were acquired for 13 swaths and no data were acquired for six other swaths. About 450 km (279.7 mi) of cable were deployed and retrieved. A total of 54,362 source shot points were acquired. Data acquisition was completed in 60 days and ended on 28 September. It took 75 days for mobilization and 11 days for demobilization. The total duration of the Eni/PGS program, including mobilization, seismic surveys, and project demobilization, was 146 days.

Airgun Array Description and Operations

Three source vessels were used for the Eni/PGS seismic survey: the *Wiley Gunner*, *Shirley V*, and *Peregrine*. It was originally proposed that two source vessels would operate in the survey area, but only one would activate its airguns while the other vessel repositioned for its next line. However, vessel availability, and array deployment depth constraints limited the occasions when two vessels could alternate seismic operations. Table 2.1 summarizes the dates of operation and airgun array capacity for each of the source vessels.

The airgun array for the *Wiley Gunner* and *Shirley V* were identical and consisted of 10 Bolt 600 C airguns with a total volume of 880 in^3; two additional airguns (20 in^3 and 40 in^3) were included as spares in the array (Table 2.1 and Figs. C.4 and C.5 in Appendix C). Airguns were suspended by chains off the port and starboard sides of the vessel with six airguns deployed per side (see Figs. C.2 and C.4 in Appendix C) and were positioned ~1.5 m (~5 ft) from the sides of the vessel at 1–2 m (~3-6.5 ft) depth depending on the swath. A swath generally consisted of three receiver lines and 72 airgun shotpoints. The airguns were operated at 1900 psi and the 20 in^3 airgun was used as a mitigation source for power-downs due to marine mammals seen within or about to enter the relevant safety radius. A single airgun was sometimes activated during turns between survey lines as is commonly done by source vessels towing larger airgun arrays and streamers in this region. However, due to the close proximity of the production lines, source vessels often suspended activation of airguns if the turn would take less than 10 minutes to complete. If the period of airgun shutdown was less than 10 min, the array could be reactivated at full volume (as per the IHA).

The *Peregrine* initially towed two 440 in^3 arrays comprised of four Bolt 600 C airguns each in clusters of 2 x 70 in^3 and 2 x 150 in^3, but the array was changed to 2 x 220 in^3 airgun arrays on 9 September, and then changed back to the 2 x 440 in^3 arrays on 20 September. The 70 in^3 airgun was used as a mitigation source and during turns between survey lines. The 2 x 440 in^3 array was used for surveying in deeper water (>10 ft or 3 m) while the 2 x 220 in^3 array was used for shallower areas (<10 ft or 3 m; Table 2.1). The *Peregrine* airgun arrays were towed at a distance of ~8-10 m (~26-32 ft) behind the source vessel at a depth of 1-2 m (~3-6.5 ft) depending on the airgun array volume and swath.

TABLE 2.1. Seismic source vessel dates of operation, and airgun array maximum volume, mitigation airgun volume, and number of operational airguns used during the Eni/PGS seismic survey.

Source vessel	Dates of operation	Array max. volume (in^3)	Mitigation airgun volume (in^3)	No. of operational airguns
Wiley Gunner	2 – 25 Aug.	880	20	10
Shirley V	18 Aug-28 Sept.	880	20	10
Peregrine	28 Aug-5 Sept.	880	70	8
Peregrine	6 -19 Sept.	440	70	4
Peregrine	20 - 28 Sept.	880	70	8

Each vessel traveled along pre-determined survey lines with an average speed of 3 kt (5.6 km/h); however, survey speed varied from 3 kt (5.6 km/h) to 5 kt (9.3 km/h). The shotpoint interval for all vessels was 33.5 m (110 ft) or ~ every 13-22 s depending on vessel speed.

Vessel Descriptions

Numerous vessels were involved with the Eni/PGS seismic survey—details are provided in Appendix C and the following subsections provide an overview.

Source Vessels

The source vessels *Wiley Gunner* and *Shirley V* are both ~13 m (44 ft) long, 5.8 m (19 ft) wide, and 3.5 m (11.5 ft) high, with a draft of 0.7 m (2.2 ft). The source vessel *Peregrine* is 27.4 m (90 ft) long, 7.3 m (24 ft) wide, with a draft of 0.9 m (3 ft). These vessels were able to maneuver in waters less than 1.2 m (4 ft) deep.

MMOs conducted watches from each source vessel. On the *Wiley Gunner* and *Shirley V* MMOs were positioned either on the bridge or on the bow of the vessel. On the *Wiley Gunner*, the bridge and bow were 0.6 m (2.0 ft) and 1.1 m (3.8 ft) above sea level (asl), respectively. On the *Shirley V*, the bridge and bow were 0.51 (1.7 ft) and 1.2 m (4.0 ft) asl, respectively. The MMOs on the *Peregrine* conducted watches from the bridge that was 3.5 m (11.6 ft) asl.

Recording Vessels

The navigation center or recording vessel, *Garrett*, is a self-propelled barge and has hydraulic gravity spuds that can be lowered in water up to 6 m (20 ft) deep. The spuds were used to secure or anchor the vessel during data acquisition. The navigation center monitored all vessel operations at all times and was the control center for data acquisition.

Cable Laying Vessels

Seven shallow-water cable boats (Demaree Inflatable Boats (DIBs) and Reliance vessels) were used to deploy cable for the survey. The DIBs were 12.5 m (41 ft) long and 4.3 m (14 ft) wide and had a 0.76 m (2.5 ft) draft. The Reliance vessels were newly designed (in 2008) cable boats of similar dimensions to the DIBs, but with an aluminum hull and no inflatable pontoons.

Other Vessels

The *American Discovery* served as the crew transport vessel. This vessel was 12.2 m (40 ft) long and 5.5 m (18 ft) wide and had a cruising speed of 25 kt. The *Spiridon* was used for refueling the seismic vessels and generators on the recording barge. Refueling at sea was undertaken to keep the boats in production and not have to return to dock to fuel. The *Spiridon* was also used to transport small items or small groups of people and could be used as an emergency response vessel if required.

A support vessel was available for use by the Project Manager, the client, or other personnel for transportation. The "Project Manager/Client" boat was 7.3 m (24 ft) long, 2.4 m (8 ft) wide, and had a draft of 0.45 m (1.5 ft). Another support vessel, was used to provide maintenance and mechanical support for marine vessels used during the project. This support vessel was 7.9 m (26 ft) long, 2.4 m (8 ft) wide, and had a 0.45 m (1.5 ft) draft. More details on the vessels and equipment used in the survey are provided in Appendix C.

Ocean Bottom Cable System and Source Lines

To receive the airgun array signal after it had reflected back from subsurface structures, PGS deployed receiving cables in a specified configuration (a "swath") on the ocean floor (Fig. 2.1). A total of 13 swaths were surveyed in the Eni/PGS 2008 seismic program. The cables used for this project were 2400 Sercel FDU Operative Remote Acquisition Units. A standard swath consisted of three parallel receiving cables spaced ~201 m (660 ft) apart and oriented in an east-west direction. Receiving cables varied in length and had a hydrophone/geophone located at 33 m intervals along the cable. The cables were deployed on the ocean bottom by a series of cable laying vessels (see Appendix C). Reliance boats were used for moving and laying out large amounts of cables, typically in front of the swath spread. DIBs were primarily used for troubleshooting and positioning the cables (i.e., "pinging"; see below). Cables were moved from one swath to another in front of shooting operations to expedite data acquisition. Generally, a total of ~15 km (9.3 mi) of cable was deployed in a 24-h period. In areas where the cables crossed barrier islands, cable technician(s) disembarked from the cable laying vessel and two ends of the cable (one from the seaward and one from the landward portions of the barrier island) were connected on the island. In total, ~450 km (~280 mi) of receiving cable were deployed during the Eni/PGS survey.

All cables were acoustically positioned (i.e., the x,y,z location of the sensors (transponders) on the seafloor were determined) with the Sonardyne OBC12 system. Acoustic positioning of the cable required sailing along either side of the cable at a 25-35 m (82-98 ft) offset observing multiple ranges to each transponder located next to a hydrophone. This operation was referred to as "pinging" the line. It was accomplished using either the source vessels or DIB boats which were equipped with a transducer (GeoSpace GS-PV1 sensor) which operated at a frequency of 35-55 kHz and source level of 190 dB (sound metric unavailable). The transducer on the vessel was a combination transmitter and receiver. The transducer sent out signals to transponders on the cable and each transponder responded with a unique "ping". The transducer received this "pinging" information and calculated the position of the vessel or cable.

Pinging one line would take ~0.5-1.5 h at a speed of about 4 kt (7.4 km/h). After the initial receiver positioning, subsequent ping runs were conducted when any changes were made to the cable (i.e., battery changes, replacing cable sections). Ping runs were also conducted periodically to confirm the current receiver station coordinates or when movement of the cable was suspected.

The source vessels operated along a series of source lines oriented perpendicular (i.e., north-south) to the receiving cables. The Eni/PGS seismic survey consisted of 182 seismic source lines.

Bathymetric equipment was located on each of the source vessels and the shallow-water cable boats. A Concept Systems GATOR provided bathymetric data which were recorded simultaneously with the seismic data by employing Interspace Tech DX 150. The Furuno RD30 depth sounder which operated at 235 kHz was part of this system.

Marine Mammal Monitoring and Mitigation

MMOs were stationed aboard each of the seismic source vessels during all periods of seismic operations. Aerial surveys for marine mammals were conducted after 24 August 2008, in accordance with the IHA requirements.

Vessel-Based Monitoring

Vessel-based marine mammal monitoring and mitigation was conducted from the source vessels *Wiley Gunner*, *Shirley V*, and *Peregrine* throughout seismic operations during the Eni/PGS survey in the central Alaskan Beaufort Sea. The survey mitigation procedures were conducted with a crew consisting of two MMOs (one LGL biologist MMO and one Inupiat MMO). Crew changes for each vessel were conducted at sea after a 12 h period unless vessels were brought to the dock for repairs or poor weather conditions. Chapter 4 provides a detailed description of the monitoring and mitigation procedures.

Aerial Monitoring

Aerial surveys were conducted over waters in and adjacent to the seismic survey area in the central Alaskan Beaufort Sea. The aerial monitoring program was initiated on 25 August 2008 and surveys were flown three days per week, weather permitting. Flights occurred along nine north-south transect lines designed to monitor the area near to and offshore of the Eni/PGS seismic program. A Twin Otter aircraft was flown at a nominal altitude of 305 m (1000 ft) asl and at a ground speed of ~110 kt. Flights were completed on 27 September 2008. A total of 15 surveys were conducted, totaling 4184 km (2600 mi) of survey effort. Chapter 7 provides a detailed description of survey procedures and results.

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3. SOUND SOURCE VERIFICATION

Introduction

An underwater acoustic measurement study was performed by JASCO Research Ltd. under contract to LGL Alaska Research Associates Inc. for Eni. The study was carried out from 3-5 August and 18-19 August 2008 at Eni's Nikaitchuq Unit on Alaska's North Slope during commencement of seismic survey activities in that area. The Eni seismic survey site lies on the east side of the Colville River delta, Beaufort Sea, Alaska. The seismic survey was performed by PGS under contract to Eni. The survey used identical 880 cubic inch (in^3) airgun arrays mounted on two seismic source vessels, the M/V *Wiley Gunner* and the M/V *Shirley V*.[4]

The objectives of this SSV acoustic study included the measurement of sound levels as a function of distance and direction from the operating airgun arrays and a single airgun at two nominal water depths within the survey area. The measurements were necessary to satisfy terms of an IHA permit granted by NMFS for this seismic survey program, which mandated the reporting of the distances at which sound levels produced by airgun operations reached root-mean-square (*rms*) sound pressure levels of 190, 180, 160 and 120 dB re 1 μPa. A last requirement was to measure sound levels produced by seismic support vessels and to determine the distances from the vessels at which sound levels reached 120 dB re 1 μPa. These requirements were addressed immediately following each of the field measurement programs and the results were reported in 72-h reports (Mouy et al. 2008; Warner et al. 2008a,b) to NMFS as was stipulated in the IHA.

To meet the above objectives, JASCO deployed four Ocean Bottom Hydrophone (OBH) autonomous acoustic recording systems at two sites within the survey area. A deep site (9-14 m), seaward of the barrier islands, and a shallow site (1.5-2.5 m), shoreward of the barrier islands, were chosen for separate measurement programs. Underwater sound was recorded by the OBHs while the seismic vessels operated the full 880 in^3 airgun array configuration, a single 20 in^3 mitigation airgun, and an increasing progression of airgun array volumes during a ramp-up procedure. These trials were performed along pre-defined test sail tracks as shown in Figure 3.1. Approximately 75 h of airgun sounds were recorded on the OBH recorders at distances between 100 m and 20 km from the test sail tracks. The OBH deployment locations were oriented relative to the vessel sail tracks so as to allow sound measurements to be obtained from both the forward and broadside directions relative to the fore-aft axis of the airgun array. Acoustic data were analyzed to compute the peak and *rms* sound pressure levels and the per-pulse sound exposure level (SEL) for individual airgun pulses. Distances corresponding to the above-mentioned *rms* thresholds were determined by fitting smooth empirical functions to the sound level versus distance data. The analysis also included a recently proposed noise exposure metric referred to as M-weighted cumulative SEL (Southall et al. 2007) that accounts for the additive effect of exposures from multiple airgun pulses.

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[4] A third source vessel, MV *Peregrine* was used from 28 August to 28 September 2008. It operated a 440 in^3 and 880 in^3 array, as well as a 70 in^3 single airgun. The SSV of the *Peregrine*'s airgun(s) were performed as part of BPXA's Liberty OBC program and the results are provided in *Chapter 3, Acoustic Monitoring* of Aerts et al. (2008).

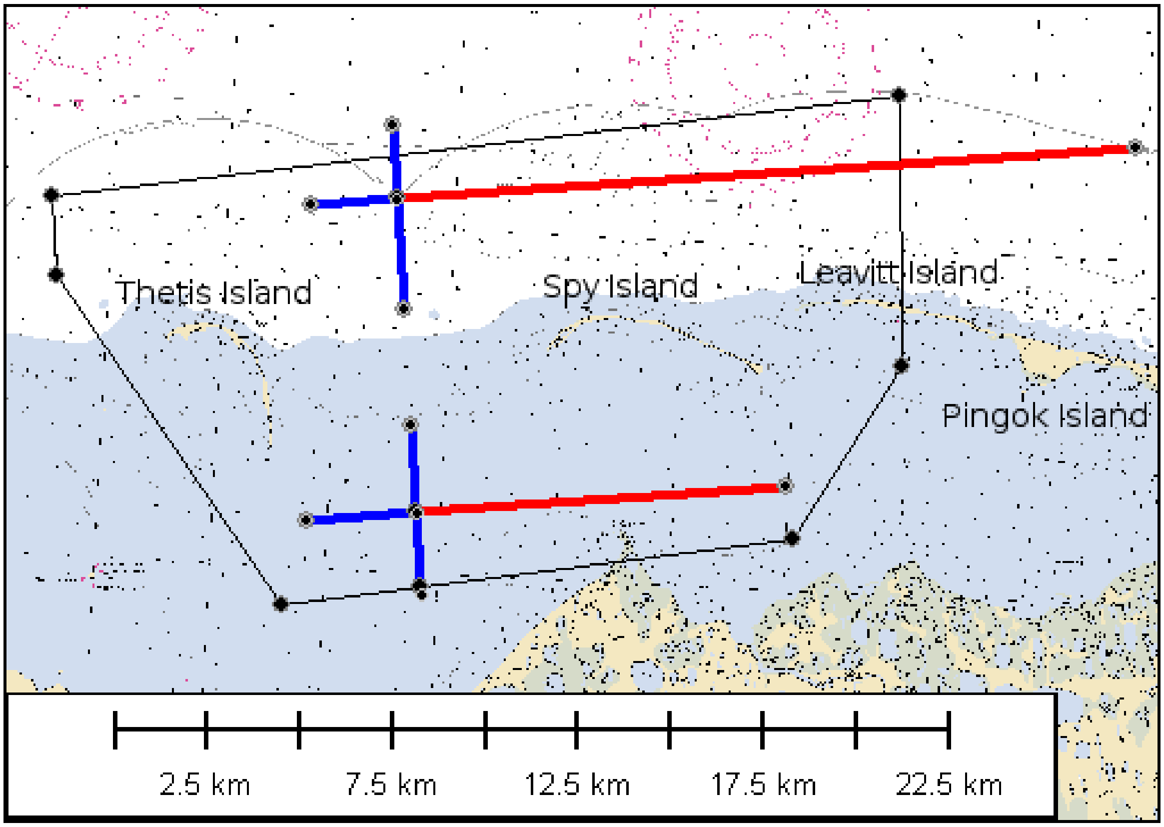

FIGURE 3.1. Eni/PGS survey area with seismic survey test tracks (blue) and OBH deployment lines (red).

Two additional OBHs were deployed to measure sounds produced by the nine seismic survey support vessels. These OBHs were deployed in 9 m water depth ~ 3 km northeast of Thetis Island (see Figure 3.5). Each vessel (separate trials per vessel) sailed a 20 km east-west test track that started 5 km west of the OBH deployment locations, passed directly over the OBHs and ended 15 km east of them. The OBHs recorded the sound signatures of the vessels, and those data were analyzed to compute sound pressure level versus distance. Empirical functions were fit as previously described, and the distances at which vessel sounds reached thresholds between 140 and 100 dB re µPa were determined from these functions.

Purpose

The purpose of this study was to measure the distances at which the sound levels from a seismic airgun array and from various support vessels reached certain thresholds. The shallow water environment within the Eni/PGS survey area strongly affects acoustic propagation, and much uncertainty existed prior to this study about how well seismic sound energy would propagate in the shallow Eni/PGS survey area[5]. The present study was designed to quantify sound levels at two water depths within the survey area and also to investigate the spectral and directional characteristics of the airgun equipment used. The following results were required to meet the purpose and objectives of the study:

- Absolute *rms* pressure as a function of distance (up to 20 km) for airgun pulses from the 880 in^3 airgun arrays and single 20 in^3 mitigation airgun;

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[5] Some shallow water acoustic monitoring programs have been conducted in 1996-1999 in the Alaskan Beaufort Sea (e.g.,Greene and Burgess 2000).

- Directivity difference of sound emissions for the forward-endfire and broadside aspects of the full arrays;
- Spectral characteristics of airgun array pulses up to 10 kHz;
- Propagation dependency on water depth; and
- Noise produced by the propellers and engines from the seismic program support vessels.

Methods

The survey vessels for this program, M/V *Wiley Gunner* and M/V *Shirley V* used identical 880 in^3 airgun arrays towed at 2.5 m depth. The airgun configuration and volumes within the array are indicated in Figure 3.2. The 20 and 40 in^3 airguns at the front end of the two substrings were not included in the normal 880 in^3 firing configuration. The 20 in^3 airgun, however, was nominally operated as a mitigation sound source during turns between seismic lines. The individual airguns were suspended by steel chains off the port and starboard sides of the survey vessels.

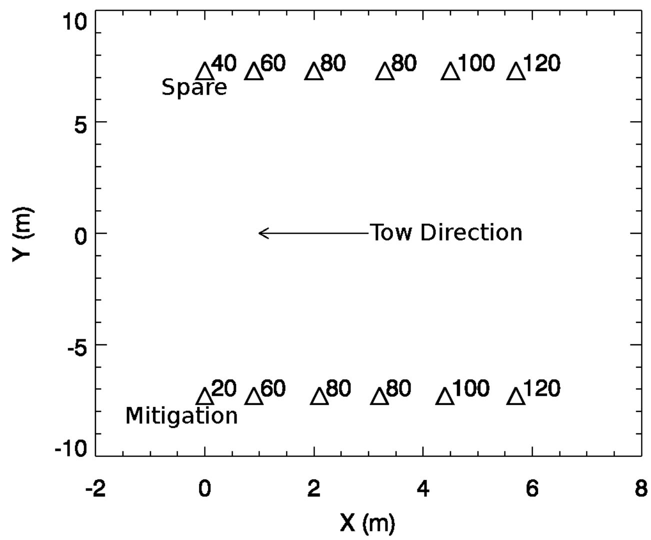

FIGURE 3.2. Plan view layout of the *Wiley Gunner* and *Shirley V* 880 in^3 airgun array. Tow direction is to the left.

A ramp-up procedure was employed to gradually increase sound emission levels at the start of array operations. The ramp-up sequence typically started with a single 60 in^3 airgun and proceeded to sequentially bring more airguns on-line in five min intervals. The specific airguns used in the five steps of the ramp-up procedure are indicated in Tables 3.1 and 3.2.

TABLE 3.1. Airgun volumes within the 880 in^3 airgun array.

Gun#	Volume (in^3)	Gun #	Volume (in^3)
1	20	7	40
2	60	8	60
3	80	9	80
4	80	10	80
5	100	11	100
6	120	12	120

TABLE 3.2. Ramp-up procedure for the 880 in^3 airgun array.

Step	Guns	Volume (in^3)
1	2	60
2	2+8	120
3	2+8+6	240
4	2+8+6+3+4+9	480
5	2+8+6+3+4+9+5+10+11+12	880

Field measurements were acquired during a dedicated test program on 3-5 and 18-19 August 2008 for the *Wiley Gunner* and *Shirley V,* respectively. The airgun arrays operated from both vessels were tested at two depth environments as described in the next section. Four calibrated OBH recording systems were deployed from the support vessel M/V *American Discovery* in advance of the seismic vessels starting operations on the test tracks. The negatively buoyant OBH units were deployed on the seafloor with a 3 m (10 ft) sinking line attached to a Danforth anchor which prevented the OBHs from being dragged by slow currents. The anchor was also attached by a length of line to a small surface float. The separation between anchor and OBH decoupled the recorder from any strumming noise produced by the float and surface line.

Locations

Two locations with differing water depths within the seismic survey area were selected for the SSV tests (Figure 3.1). The nearshore location had a nominal water depth of 2.5 m (8.2 ft) and is referred to as the shallow water site in this report. The offshore location had a nominal depth of 10 m (33 ft) and is referred to as the deep water site. Two locations were included in the study because it was expected that the sound propagation characteristics would be depth-dependent.

The four OBHs (A, B, C and D) were deployed along a line oriented perpendicularly to the nominal north-south survey test track, at distances of 200 m, 500 m, 3000 m, and 20000 m off the test track for the deep water test and 100 m, 400 m, 2500 m, and 10000 m off the test track for the shallow water test. Figure 3.3 shows a diagram of the OBH positions relative to the test tracks. OBH deployments were performed from the vessel *American Discovery* which later departed the area to avoid noise contamination of the recordings. The seismic vessels sailed along the test track at the nominal survey speed of 1.6 kt while operating the airgun arrays. Digital acoustic recordings of 75 h of seismic data were obtained from each OBH. The *American Discovery* returned to the survey area after the test tracks were completed to retrieve the OBHs.

Acoustic Recording Equipment

All four OBH's (Fig. 3.4; for locations see Table 3.4) were equipped with calibrated reference hydrophones from Reson Inc. Two hydrophone models with different sensitivities were deployed on each OBH: a TC4043 (nominal sensitivity of -201 dB re V/µPa), and a TC4032 (nominal sensitivity of -166 dB re V/µPa). The TC4043 hydrophones were calibrated on site using a GRAS Pistonphone Calibrator, with an accuracy of 0.1 dB at 250 Hz[6]. The concurrent use of two hydrophones with different sensitivities allowed optimal capture of the large range of sound pressure levels experienced as the source moved from more than 20 km to less than 200 m from the measurement locations. The hydrophone signals were digitally acquired at 24-bit resolution by calibrated Sound Devices model 722 audio hard-drive recorders set to a sampling rate of 48 kHz.

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[6] An adapter for the 4032 hydrophones was not available for the *Wiley Gunner* measurements so the factory calibration sensitivities of the individual 4032 hydrophones were used for that analysis. A post-field comparison between calibrations using the GRAS Pistonphone Calibrator and the factory calibration sensitivities revealed differences of less than 0.3 dB re µPa.

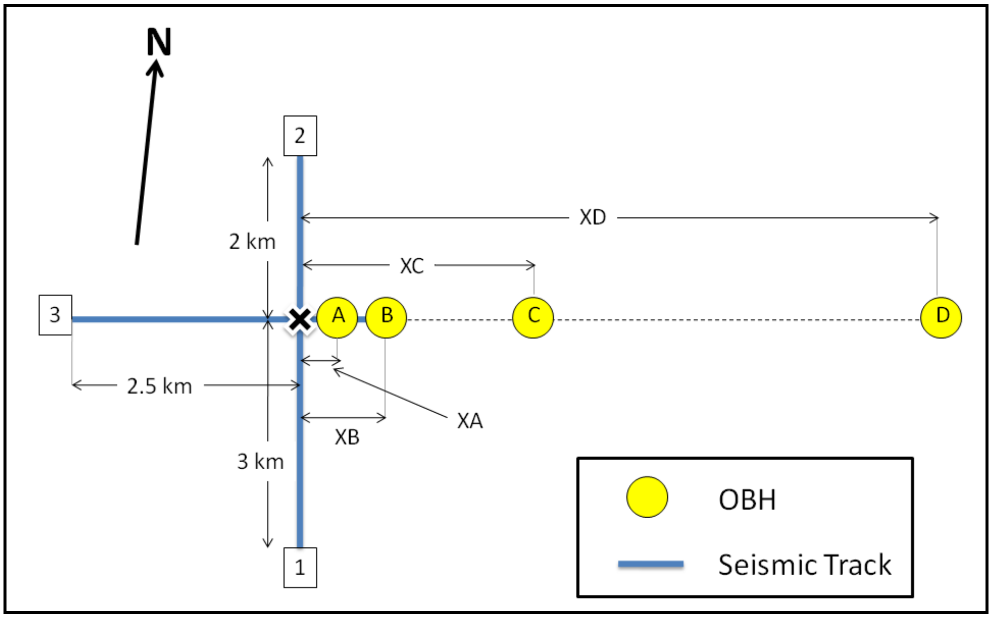

FIGURE 3.3. Source vessel survey test tracks relative to OBH positions for acoustic measurements (diagram not to scale). Note that the distances of OBHs from the survey lines for deep and shallow water test sites are different (see Table 3.3).

TABLE 3.3. Distances from point X to each OBH for the deep and shallow water test sites.

Line Segment	Distance in Deep Water (m)	Distance in Shallow Water (m)
XA	200	100
XB	500	400
XC	3000	2500
XD	20000	10000

FIGURE 3.4. OBH system ready for deployment.

TABLE 3.4. SSV coordinates, Eni/PGS seismic survey area, Alaskan Beaufort Sea.

	Deep Water			Shallow Water		
Waypoint	Latitude °N	Longitude °W	DEPTH (m)	Latitude °N	Longitude °W	DEPTH (m)
OBH A	70.5901	150.0379	8.8 (29 ft)	70.5142	150.0151	2.8 (9.3 ft)
OBH B	70.5905	150.0299	9.1 (30 ft)	70.5150	150.0065	2.3 (7.7 ft)
OBH C	70.5931	149.9631	9.8 (32 ft)	70.5171	149.9508	2.0 (6.7 ft)
OBH D	70.6107	149.5076	14.0 (46 ft)	70.5249	149.7511	1.9 (6.2 ft)
X	70.5899	150.0437	9.0 (30.3 ft)	70.5144	150.0177	3.0 (9.8 ft)
1	70.5632	150.0345	6.2 (20.3 ft)	70.4943	150.0109	2.2 (7.2 ft)
2	70.6077	150.0498	11.5 (37.7 ft)	70.5358	150.0251	3.7 (12.1 ft)
3	70.5874	150.1052		70.5112	150.0977	3.1 (10.2 ft)

Measurement Procedure

Deep Water

Each source vessel performed its 30 min ramp-up procedure at the deep site starting at waypoint 1 and moving to waypoint 2 (see Figure 3.3). At waypoint 2, the vessel turned 180 degrees and operated its full 880 in^3 array while transiting from waypoint 2 back to waypoint 1. It turned again at waypoint 1 and sailed toward waypoint 2 firing only the mitigation gun. The ramp up procedure was again performed as the vessel transited from waypoint 2 to waypoint 3, achieving full array operating power when it reached waypoint 3. The vessel then sailed from waypoint 3 to OBH B while operating its full 880 in^3 airgun array to obtain endfire measurements.

Shallow Water Measurements

At the shallow water site, inshore of the barrier islands (Figure 3.1), each source vessel performed its 30 min ramp-up procedure while anchored at point X (see Figure 3.3). After the array reached the full 880 in^3 operating volume, the vessel sailed northward on the test track from point X to waypoint 2, then south to waypoint 1. From there the vessel transited to waypoint 3 and continued shooting the full array until it reached point X. The full array was then switched off and the mitigation gun was fired as the vessel sailed to the location of OBH C.

Vessel Measurements

Measurements of sound levels versus distance from nine different support vessels were obtained as the vessels transited a pre-determined track line over a recording site at their nominal operating speeds (see Appendix 3.A for vessel specifications and photos). Acoustic data for the vessel SSV tests were collected using two calibrated OBH acoustic recorder systems deployed from the crew vessel *American Discovery* at GPS locations 70° 35' 14.8" N, 150° 06' 10.9" W and 70° 35' 17.5" N, 150° 05' 11.0" W. Figure 3.5 shows a map of the recording locations and the vessel track. The water depth at the OBH deployment sites ranged from 9 m (30 ft) to 13 m (43 ft) from west to east end. The eastern OBH system was deployed primarily as a backup, in case of failure of the primary OBH. Both systems operated properly so all measurements presented in this report were from the primary (western) OBH.

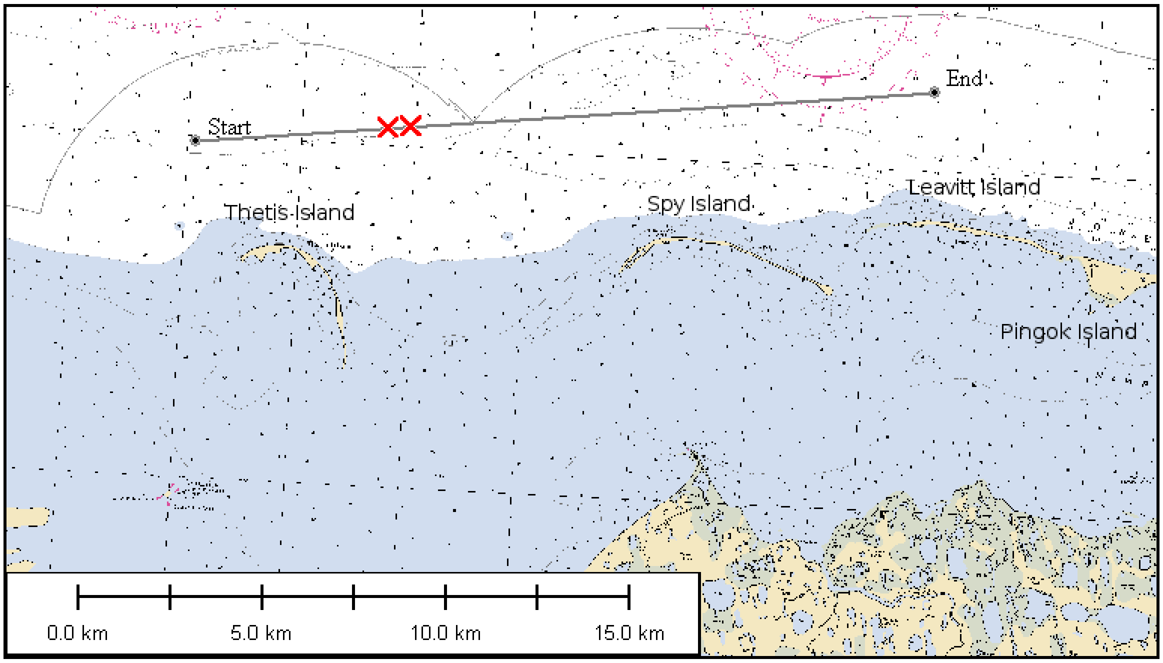

FIGURE 3.5. Map of OBH locations (red X) and support vessel measurement track line.

Analyses of vessel sounds were carried out to determine *rms* sound pressure levels (SPL) versus distance. The logged GPS tracks from each vessel were used to compute the range to the OBH throughout the measurement period.

Data Analysis Approach

Per-shot Seismic Pulse Levels

The recorded acoustic data were analyzed to compute peak pressure, *rms* pressure and SEL acoustic levels versus range from the airgun array sources. The data processing steps were as follows:

1. Apply hydrophone sensitivity and digital conversion gain to digital recording units to convert to micropascals (µPa).
2. Determine start times of seismic pressure signals in digital recordings.
3. Determine the maximum sound pressure level for each pulse in dB/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 90% *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.

Cumulative SEL Levels

Southall et al. (2007) have recently proposed alternative criteria for injury in marine mammals, based on the peak pressure and sound exposure level metrics. These take into account the type of sound (non-pulse, single-pulse, or multiple pulse), as well as the frequency-dependent hearing sensitivity of the species group. For multiple pulse sounds such as those from an airgun array during a typical survey, the more sensitive criterion for auditory injury is given by the SEL metric reaching 198 dB re 1 μPa^2-s (M-weighted) for cetaceans or 186 dB re 1 μPa^2-s (M-weighted) for pinnipeds.

The SEL criterion must take into account the cumulative effect of multiple exposures. Southall et al. (2007) propose summing multiple pulse exposures to produce a single exposure "equivalent" value by assuming that there is no recovery of hearing between exposures, so that the cumulative SEL is defined as follows:

$$\mathrm{SEL} = 10\log_{10}\left\{\frac{\sum_{n=1}^{N}\int_0^T p_n^2(t)dt}{p_{ref}^2}\right\} \qquad \text{Equation (1),}$$

where N is the number of exposures, and $p_{ref} = 1$ µPa in water. In the present study, the cumulative SEL (flat-weighted and M-weighted) for each of the broadside test lines was computed from the measured per-shot SEL values.

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 (see Ireland et al. 2007a). Noises are less likely to disturb animals if they are at frequencies that the animal cannot hear well. An exception is when the sound pressure is so high that it can cause physical injury. For non-injurious sound levels, frequency weighting curves based on audiograms may be applied to weight 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 (LFC),
2. Mid-frequency cetaceans (MFC),
3. High-frequency cetaceans (HFC),
4. Pinnipeds in water (PINN), 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 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. Figure 3.6 shows the decibel frequency response of the four standard underwater M-weighting filters.

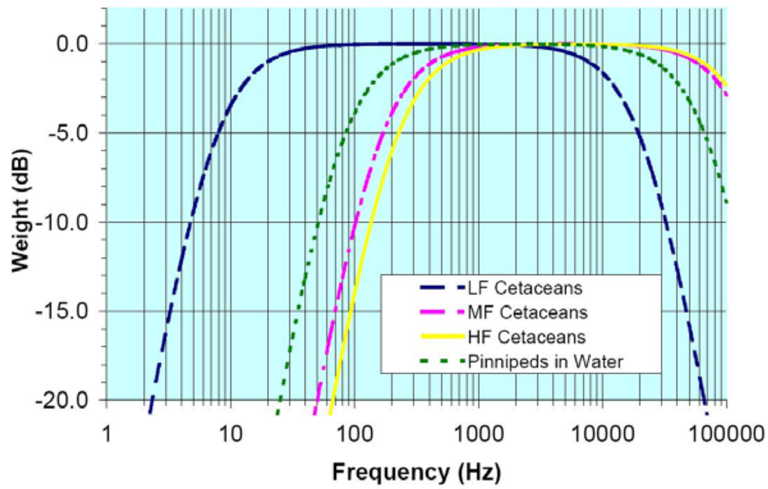

FIGURE 3.6. Plot of standard M-weighting curves for low frequency, mid-frequency, and high frequency cetaceans and for pinnipeds in water.

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 3.5.

TABLE 3.5. 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 (LFC)	7	22000
Mid-frequency cetaceans (MFC)	150	160000
High-frequency cetaceans (HFC)	200	180000
Pinnipeds underwater (PINN)	75	75000

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 Figure 3.6. 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. The M-weighting filters applicable to marine mammal species commonly encountered in the Alaskan Beaufort Sea are as follows:

1. LFC: Bowhead whales and other mysticetes.
2. MFC: Beluga whales and other odontocetes.
3. PINN: Spotted seals, ringed seals, bearded seals, and Pacific walruses.

Vessel Sound Levels

The acoustic data recorded during the track line traversal for each vessel (see Figure 3.5) were analyzed to compute 1-s average SPLs as a function of horizontal range from the OBH system. The sound pressure data were high-pass filtered at 10 Hz to remove low frequency noise mainly due to water flow against the hydrophone transducers.

An empirical transmission loss curve of the form L = A + B Log(r) was fit to the data by least-square regression of the coefficients A and B to obtain estimates of distances at which broadband vessel noise levels reached thresholds between 140 dB re 1 μPa and 100 dB re 1 μPa. The fits to the various datasets were performed only on measurements above ambient noise levels; vessel sounds were not detected over the entire track line.

Results

Level vs. Range Data Plots

Ranges from the airgun array to the OBH recording positions were computed for the times corresponding to each shotpoint using the navigation logs supplied by the source vessels upon completion of the surveys. Peak and 90% *rms* SPLs and SEL for each shotpoint were computed for each OBH system and these three metrics were plotted against the corresponding source-receiver ranges.

The empirical function fit to the measurements had the form: $RL = SL - n \log R + \alpha R$, where RL is the received level in decibels, SL is the source level term, R is the source-receiver range, n is the geometric spreading loss coefficient, and α is the absorptive loss coefficient. It must be pointed out that the source level, spreading coefficient and loss coefficients as given by these relations do not necessarily represent meaningful physical values. This mathematical representation has a valid physical basis and is useful for approximating the data trend, but cannot be considered a realistic model of the sound propagation laws in shallow water environments.

In the sections that follow the computed best-fit (least squares regression) curve is shown in Figures 3.7 to 3.18 as a solid line. For the purpose of obtaining conservative estimates of ranges to various sound level thresholds, an offset was applied to the best-fit functions so they would exceed 90% of the measured data points; the resulting curve is shown in Figures 3.7 to 3.18 as a dashed line.

Deep Water

Wiley Gunner

The endfire and broadside measurement plots shown in Figure 3.7 and Figure 3.8, respectively, were obtained from all four OBHs in deep water. The broadside measurement plot shows data points extracted from the overall datasets at the time corresponding to the passing and close approach by the *Wiley Gunner* past point X (see Figure 3.3).

The endfire data had some pulses that were truncated at close range on the more sensitive hydrophone. These pulses were removed from the data in Figure 3.7. The broadside plot (Figure 3.8) was modified from the earlier 72 h report to include only the five highest SPL airgun array pulses recorded on each OBH. This is a more precautionary approach that best captures the broadside directivity peak.

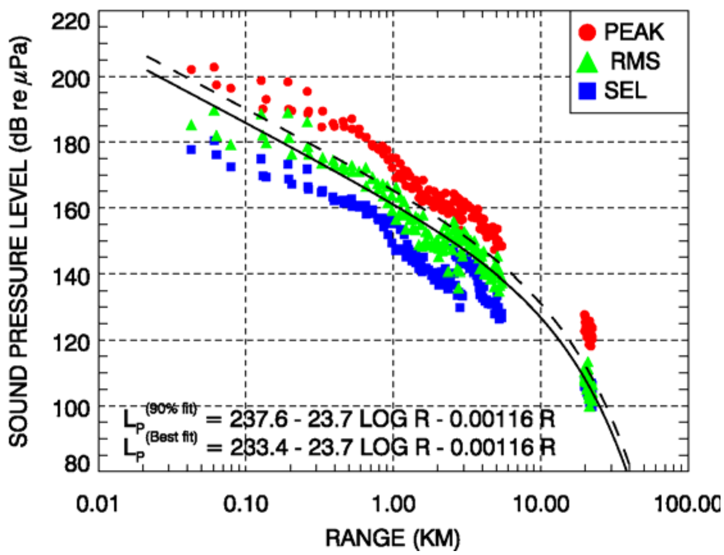

FIGURE 3.7. Peak, *rms*, and SEL levels for airgun pulses received from array forward-endfire in deep water. The solid line is the best fit of the empirical function to *rms* values. The dashed line represents a shift of the best-fit line by +4.2 dB to exceed 90% of the *rms* data values.

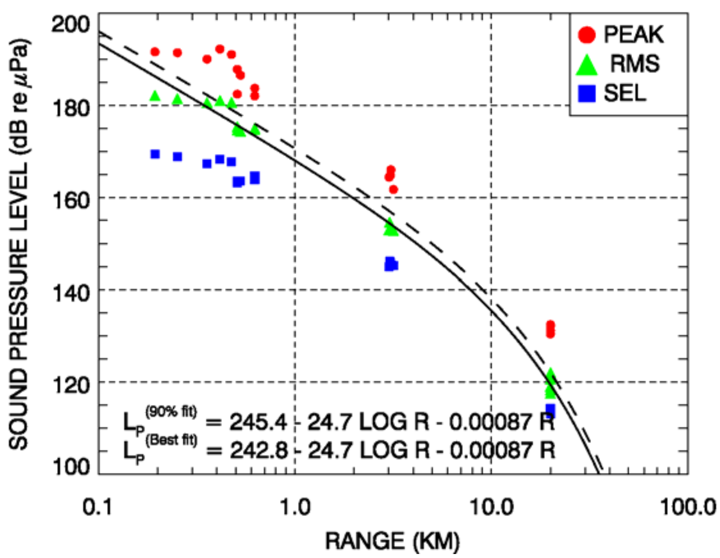

FIGURE 3.8. Peak, *rms*, and SEL levels for airgun pulses received from array broadside in deep water. The solid line is the best fit of the empirical function to *rms* values. The dashed line is the best-fit line shifted by +2.6 dB to exceed 90% of data values.

The peak, *rms*, and SEL were also calculated for the mitigation airgun. SPLs for airgun shotpoints were computed from four OBH systems and were plotted against the corresponding source-receiver ranges in Figure 3.9. The sound levels from the single mitigation airgun are expected to be omnidirectional (no variation with bearing).

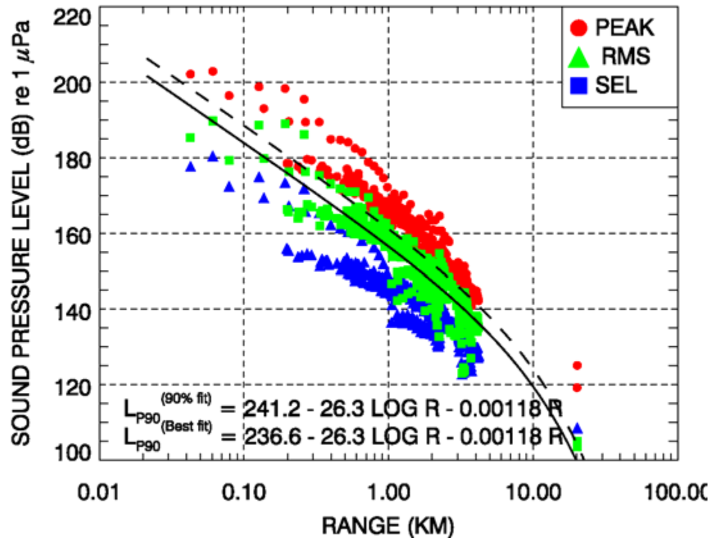

FIGURE 3.9. Peak, *rms*, and SEL levels versus distance from the mitigation airgun in deep water. The solid line is the best fit of the empirical function to *rms* values. The dashed line is the best-fit line shifted by +4.6 dB to exceed 90% of data values.

<u>*Shirley V*</u>

The endfire and broadside measurement plots, shown in Figure 3.10 and Figure 3.11, respectively, were obtained from all four OBHs in deep water. The endfire data presented in the 72 h report contained some pulses that were truncated; in the present report these pulses were removed from the data analysis. Because the data showed a change in trend at the 1 km range, two different empirical functions of the form RL = SL – n logR – αR (where RL is the received level in decibels, SL is the source level, R is the source-receiver range, n is the geometric spreading loss coefficient, and α is the absorptive loss coefficient) were fitted to the data. These two functions were mathematically constrained to have the same RL at the transition range of 1 km.

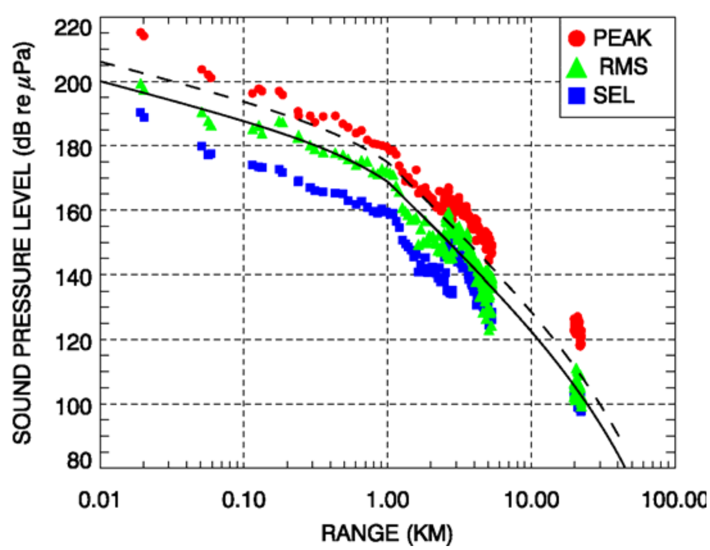

FIGURE 3.10. Peak, *rms*, and SEL levels for airgun pulses received from array forward-endfire in deep water. The solid line is the best fit of the empirical function to *rms* values. The dashed line represents a shift of the best-fit line by +6.1 dB to exceed 90% of the *rms* data values. The transition range for the empirical fit was set to 1 km.

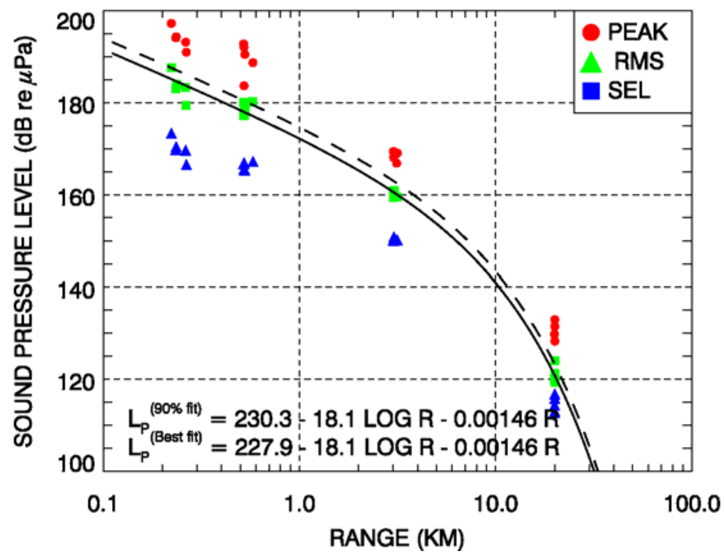

FIGURE 3.11. Peak, *rms*, and SEL levels for airgun pulses received from array broadside in deep water. The solid line is the best fit of the empirical function to *rms* values. The dashed line is the best-fit line shifted by +2.4 dB to exceed 90% of data values.

At ranges less than 1 km, the empirical fit was RL = 211.9 – 11.8 log(R) – 0.0078 R. Beyond 1 km, the empirical fit was RL = 168.8 – 42.7 log (R/1000) – 0.00041 (R-1000).

The broadside measurement plot shows data points extracted from the overall datasets at the time corresponding to the passing and close approach by the *Shirley V* past point X (see Figure 3.3).

The peak, *rms*, and SEL were also calculated for the mitigation airgun. SPLs for shotpoints were computed from four OBH systems and were plotted against the corresponding source-receiver ranges in Figure 3.12. The mitigation airgun sound emission pattern is omnidirectional.

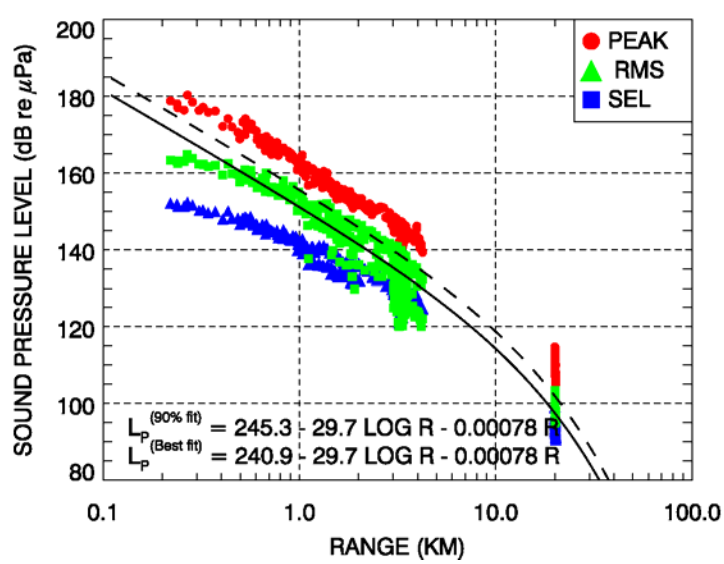

FIGURE 3.12. Peak, *rms*, and SEL levels versus distance from the mitigation airgun in deep water. The solid line is the best fit of the empirical function to *rms* values. The dashed line is the best-fit line shifted by +4.4 dB to exceed 90% of data values.

Shallow Water

Wiley Gunner

The endfire and broadside measurement plots shown in Figure 3.13 and Figure 3.14, respectively, were obtained at the shallow water test site. The endfire measurement plot excludes data from OBH D because recorded broadband levels were less than 110 dB re μPa and therefore, were comparable with high values in the background noise level; not doing so would have incorrectly biased the empirical function fits. The broadside measurement plot shows data points extracted from the overall datasets at the time corresponding to the approach and passing by *Wiley Gunner* past point X (see Figure 3.3). Only the few points very close to broadside were used 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 OBH's enters and exits the array's broadside directivity peak.

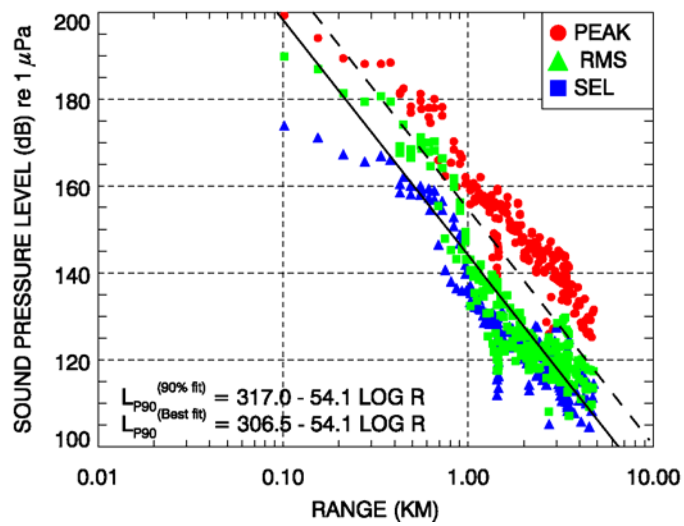

FIGURE 3.13. Peak, *rms*, and SEL levels for airgun pulses received from array forward-endfire in shallow water. The solid line is the best fit of the empirical function to *rms* values. The dashed line represents a shift of the best-fit line by +10.6 dB to exceed 90% of the data values.

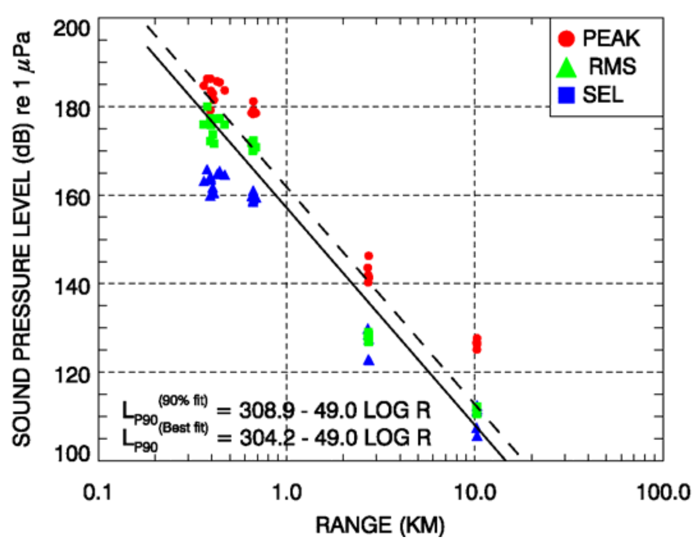

FIGURE 3.14. Peak, *rms*, and SEL levels for airgun pulses received from array broadside in shallow water. The solid line is the best fit of the empirical function to *rms* values. The dashed line is the best-fit line shifted by +4.7 dB to exceed 90% of data values.

The peak, *rms*, and SEL were also calculated for the mitigation airgun. SPLs of shotpoints were computed from OBHs A, B, and C and were plotted against the corresponding source-receiver ranges in Figure 3.15. Broadband levels received at OBH D were near the background noise level and were consequently excluded.

An empirical function of the form RL = SL – n logR – αR (where RL is the received level in decibels, SL is the source level, R is the source-receiver range, n is the geometric spreading loss coefficient, and α is the absorptive loss coefficient) was fitted to the data. Because the data collected at close range did not follow the same trend as the longer range data, we performed separate fits of the same function to the near and longer-range levels. The two fits were mathematically constrained to have the same RL at the transition range of 800 m.

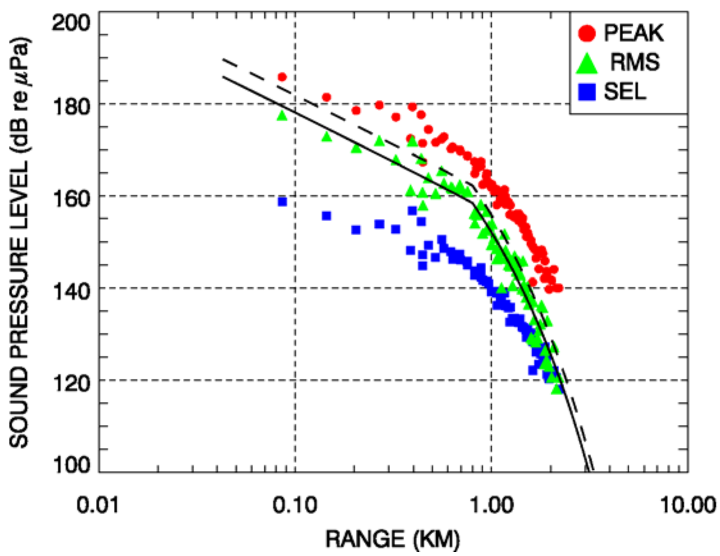

FIGURE 3.15. Peak, *rms*, and SEL levels versus distance from the mitigation airgun in shallow water. The solid line is the best fit of the empirical function to *rms* values. The dashed line is the best-fit line shifted by +3.8 dB to exceed 90% of data values. The transition range for the empirical 5 parameter fit was set to 800 m.

At ranges less than 800 m, the best empirical fit function was RL = 220.2 – 21.0 logR – 0.00088 R. Beyond 800 m, it was RL = 158.4 – 30.5 log (R/800) – 0.017 (R-800).

<u>*Shirley V*</u>

The endfire and broadside measurement plots shown in Figure 3.16 and Figure 3.17, respectively, were obtained at the shallow water test site. The endfire measurement plot excludes data from OBH D as recorded broadband levels were less than 110 dB re μPa and therefore, were comparable with the higher levels of background noise; not doing so would have incorrectly biased the empirical function fits. Measurements showed some variability in levels. To obtain conservative fit estimates we shifted the best fits upward to exceed 90% of the *rms* data values.

The broadside measurement plot shows data points extracted from the overall datasets at the time corresponding to the close approach and passing by the *Shirley V* past point X (see Figure 3.3). Only the few points very close to broadside were used 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 OBH's enters and exits the array's broadside directivity peak.

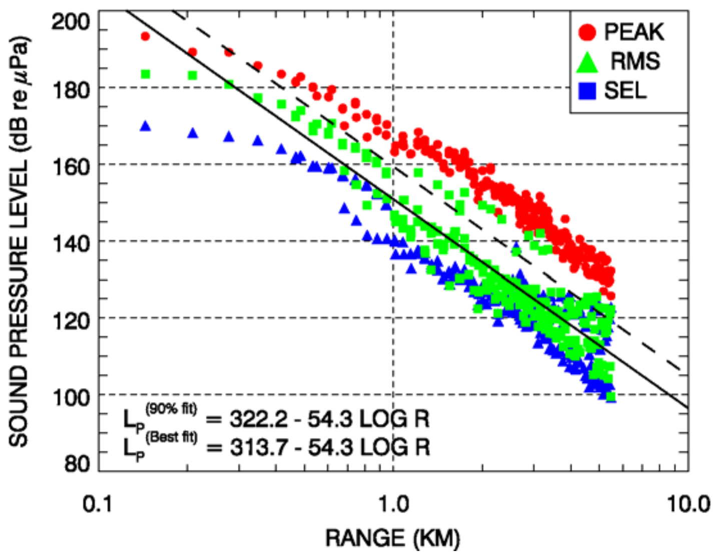

FIGURE 3.16. Peak, *rms*, and SEL levels for airgun pulses received from array forward-endfire in shallow water. The solid line is the best fit of the empirical function to *rms* values. The dashed line represents a shift of the best-fit line by +8.5 dB to exceed 90% of the *rms* data values.

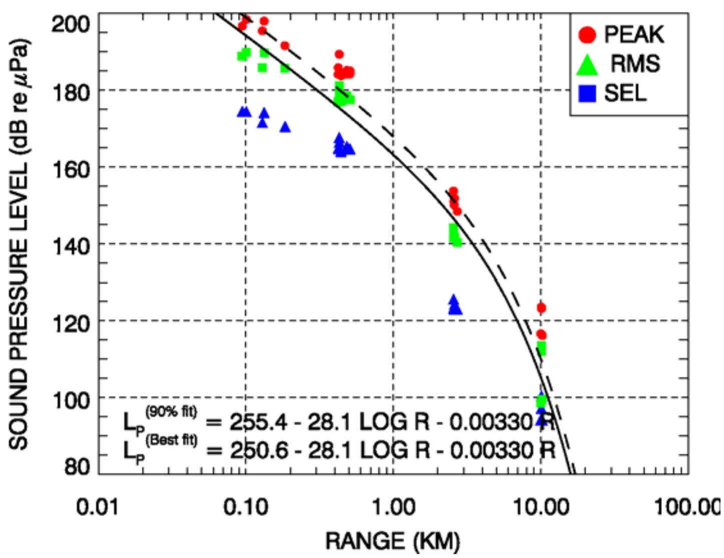

FIGURE 3.17. Peak, *rms*, and SEL levels for airgun pulses received from array broadside in shallow water. The solid line is the best fit of the empirical function to *rms* values. The dashed line is the best-fit line shifted by +4.8 dB to exceed 90% of data values.

The peak, *rms*, and SEL were also calculated for the mitigation airgun. SPLs of shotpoints were computed from OBHs A, B, and C and were plotted against the corresponding source-receiver ranges in Figure 3.18. Broadband levels received at OBH D were near background noise level and were consequently excluded.

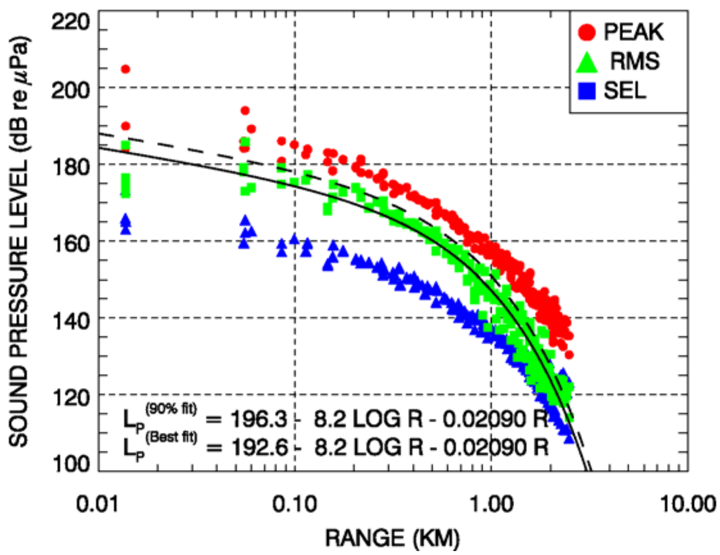

FIGURE 3.18. Peak, *rms*, and SEL levels versus distance from the mitigation airgun in shallow water. The solid line is the best fit of the empirical function to *rms* values. The dashed line is the best-fit line shifted by +3.7 dB to exceed 90% of data values.

Cumulative SEL

The cumulative SEL metric was calculated for each source vessel in deep and shallow water. SEL values were taken from the broadside test tracks (see Figure 3.1) because the higher levels caused by the strong directional lobe of the array at the closest point of approach (CPA) provide the most conservative estimate of cumulative SEL. Various types of M-weighting were also applied to the SEL values before summing to provide M-weighted cumulative SEL. The plots below show the flat and M-weighted cumulative SEL curves as they evolve with the progression of the survey track, as well as flat-weighted per shot SEL values for comparison. Each plot is specific to an OBH; in aggregate they provide an indication of the cumulative SEL at different distances from a seismic survey line.

Deep Water

Wiley Gunner.—Figure 3.19-3.21 show cumulative SEL for receivers 200 m, 500 m, and 3000 m off the deep water seismic survey track, corresponding respectively to OBHs A, B, and C. Note that in all plots the LFCs cumulative SEL is difficult to see because it overlaps with the flat-weighted cumulative SEL. Figure 3.22 is a map showing the relative locations of the receivers to the shot points.

The received per-shot SEL levels change over the length of the test track due to the changing source-receiver range and also because of airgun array directivity. The directivity was maximum at array broadside which was recorded by the line of OBHs as the seismic vessel passed the CPA.

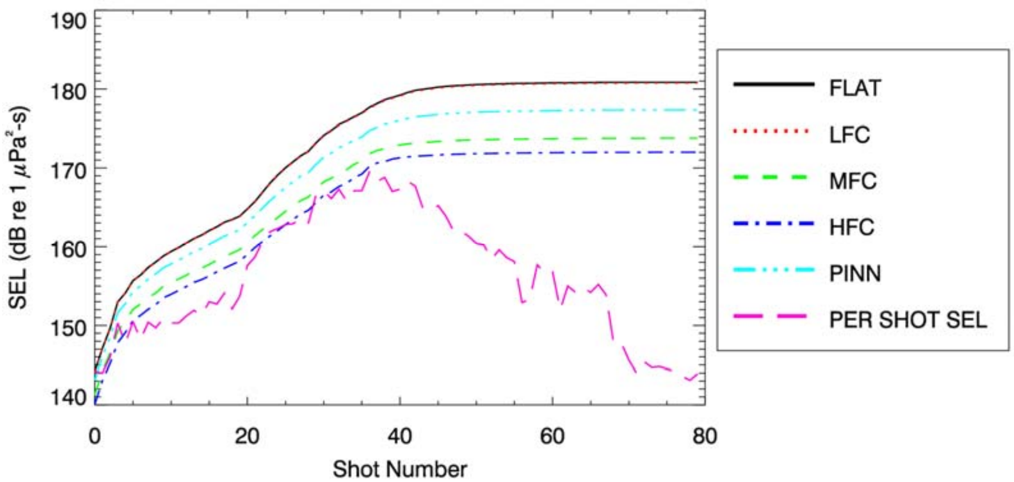

FIGURE 3.19. Flat and M-weighted cumulative SEL with flat-weighted per shot SEL for the *Wiley Gunner* in deep water as measured along the seismic survey test track (see Figure 3.1) from OBH A, 200 m off the track.

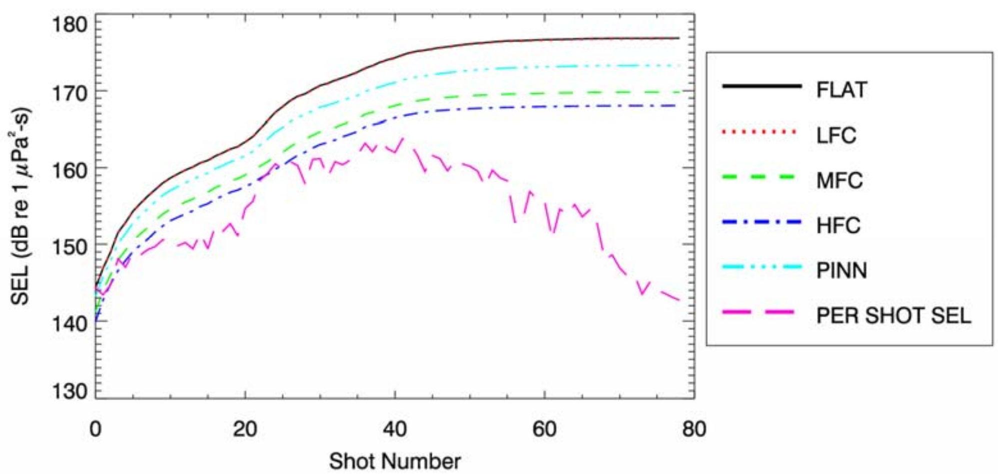

FIGURE 3.20. Flat and M-weighted cumulative SEL with flat-weighted per shot SEL for the *Wiley Gunner* in deep water as measured along the seismic survey test track (see Figure 3.1) from OBH B, 500 m off the track.

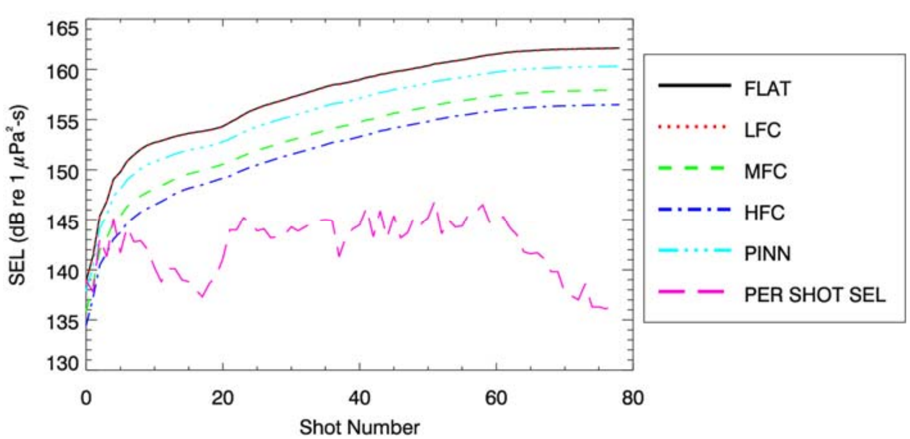

FIGURE 3.21. Flat and M-weighted cumulative SEL with flat-weighted per shot SEL for the *Wiley Gunner* in deep water as measured along the seismic survey test track (see Figure 3.1) from OBH C, 3000 m off the track.

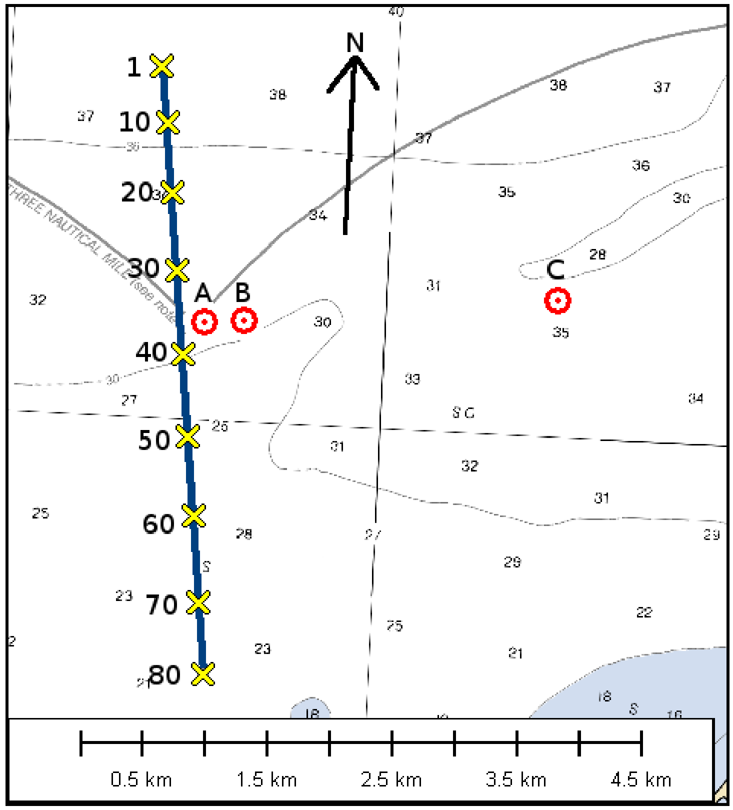

FIGURE 3.22. Map of the broadside seismic survey track for the *Wiley Gunner* in deep water with shot points (labels by yellow Xs indicate shot number) and OBH locations.

Though the seismic survey test track is not as long as a full seismic survey line, shots near the test track ends did not contribute as much as those near the CPA to the cumulative SEL levels. That is less so for the 3000 m distance of OBH C because of the relatively smaller difference in distance from that OBH between the track ends and CPA. ***Shirley V.***—Figure 3.24-3.26 show cumulative SEL for the same receivers and seismic survey test track as described for the *Wiley Gunner* in deep water. Figure 3.27 is a map showing the relative locations of the receivers to the shot points.

TABLE 3.6 Table 3.6 provides the maximum cumulative SEL for each receiver, and Figure 3.23 shows these maxima as a function of distance off the survey track.

Shirley V.—Figure 3.24-3.26 show cumulative SEL for the same receivers and seismic survey test track as described for the *Wiley Gunner* in deep water. Figure 3.27 is a map showing the relative locations of the receivers to the shot points.

TABLE 3.6. Maximum cumulative SEL from the *Wiley Gunner* measurements in deep water.

Distance off seismic survey track (m)	Cumulative SEL (dB re 1 µPa^2-s)				
	Flat-weighted	Low Frequency Cetaceans	Mid-Frequency Cetaceans	High Frequency Cetaceans	Pinnipeds underwater
200	180.8	180.8	173.8	172.0	177.3
500	176.8	176.8	169.8	168.0	173.3
3000	162.1	162.0	158.0	156.5	160.3

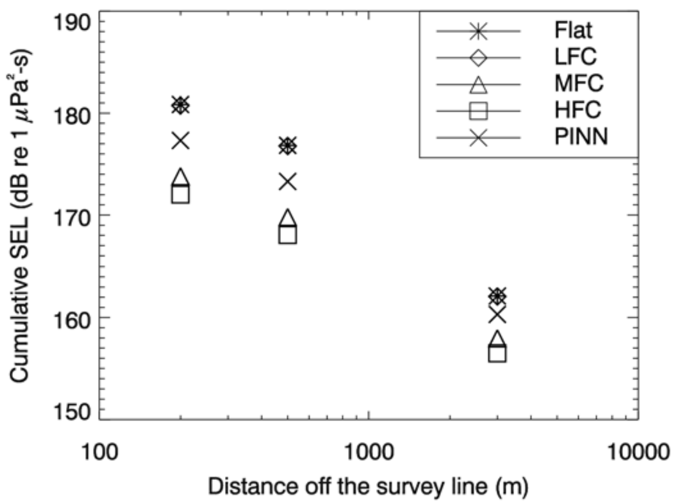

FIGURE 3.23. Cumulative SEL as a function of perpendicular distance off the survey test track for the *Wiley Gunner* in deep water.

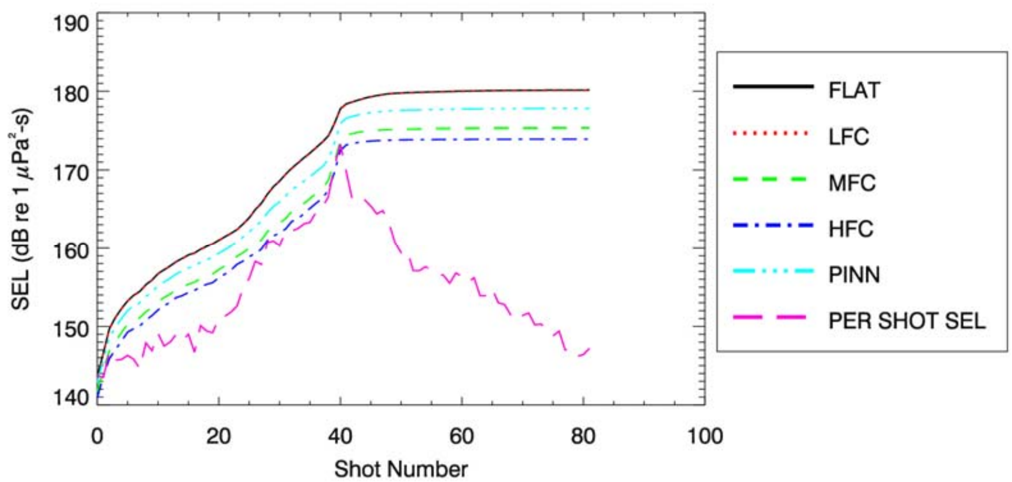

FIGURE 3.24. Flat and M-weighted cumulative SEL with flat-weighted per shot SEL for the *Shirley V* in deep water as measured along the seismic survey test track (see Figure 3.1) from OBH A, 200 m off the track.

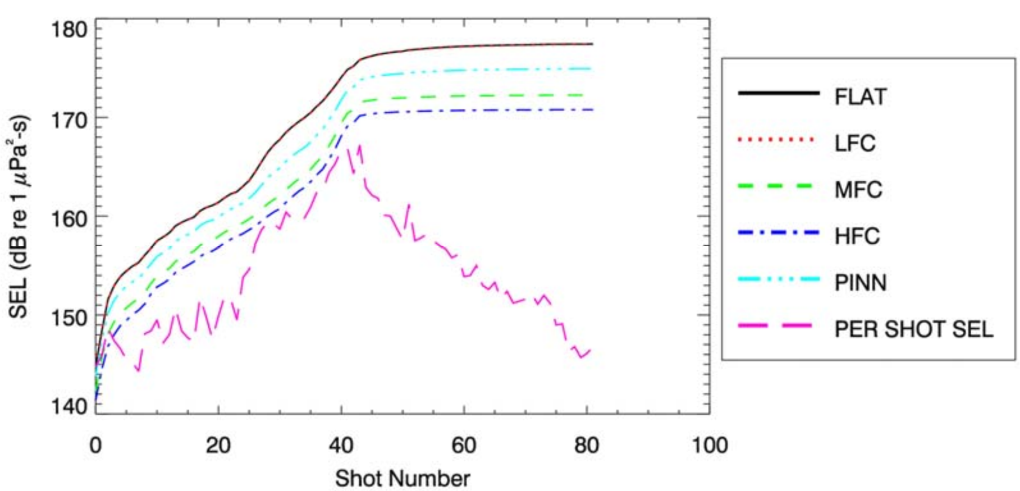

FIGURE 3.25. Flat and M-weighted cumulative SEL with flat-weighted per shot SEL for the *Shirley V* in deep water as measured along the seismic survey test track (see Figure 3.1) from OBH B, 500 m off the track.

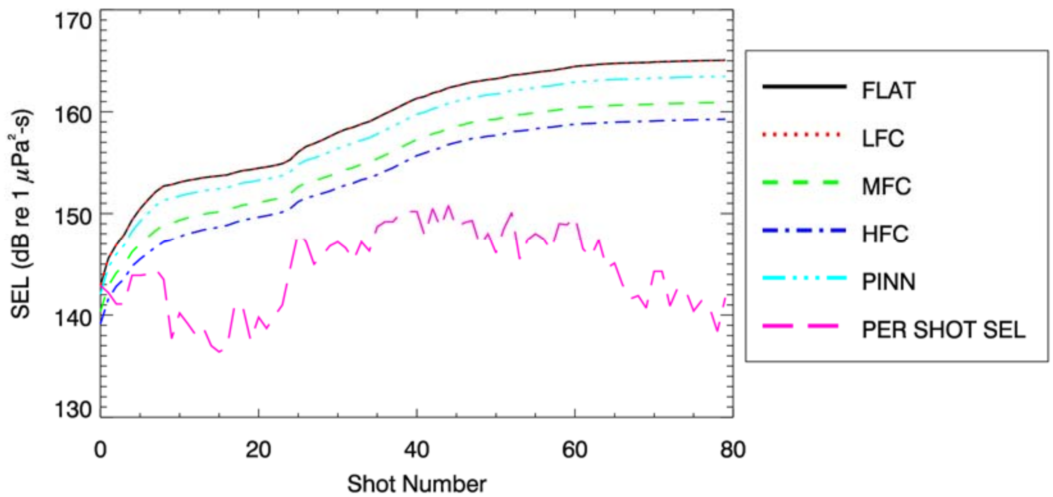

FIGURE 3.26. Flat and M-weighted cumulative SEL with flat-weighted per shot SEL for the *Shirley V* in deep water as measured along the seismic survey test track (see Figure 3.1) from OBH C, 3000 m off the track.

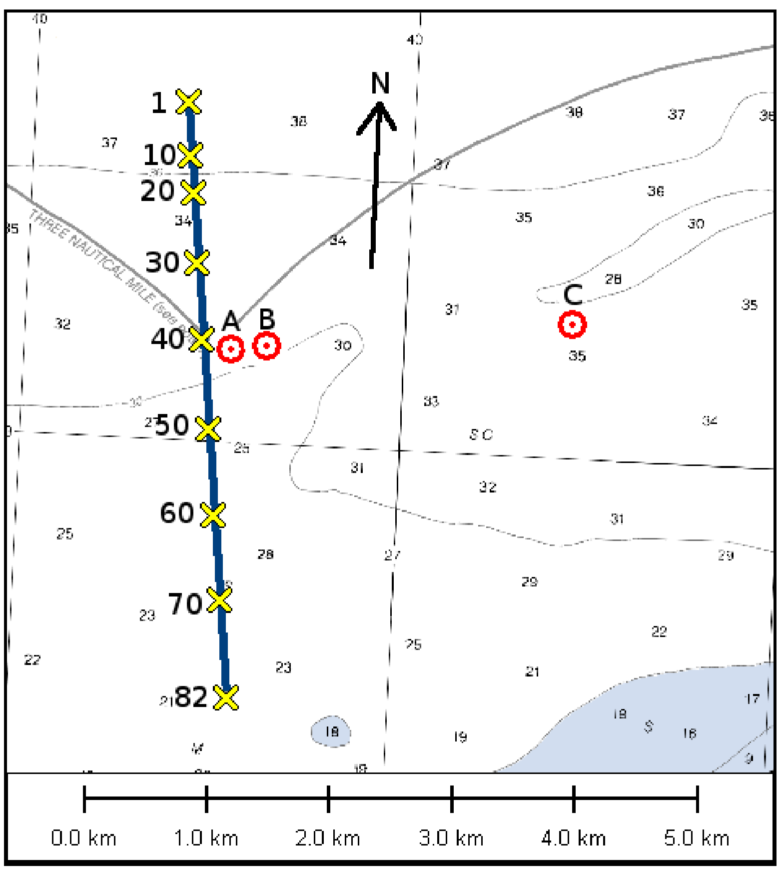

FIGURE 3.27. Map of the broadside seismic survey track for the *Shirley V* in deep water with shot points (labels by yellow Xs indicate shot number) and OBH locations.

The same overall trends of the cumulative SEL for the *Shirley V* measurements are observed, with highest per-shot SEL at the CPA and the cumulative SELs asymptotically approaching a maximum value. Table 3.7 presents these maxima for each receiver, and Figure 3.28 shows these maxima as a function of distance off the survey test track.

TABLE 3.7. Maximum cumulative SEL from the *Shirley V* measurements in deep water.

Distance off seismic survey track (m)	Cumulative SEL (dB re 1 μPa²-s)				
	Flat-weighted	Low Frequency Cetaceans	Mid-Frequency Cetaceans	High Frequency Cetaceans	Pinnipeds underwater
200	180.1	180.1	175.3	174.0	177.8
500	177.4	177.4	172.3	170.8	174.9
3000	165.1	165.0	160.9	159.3	163.5

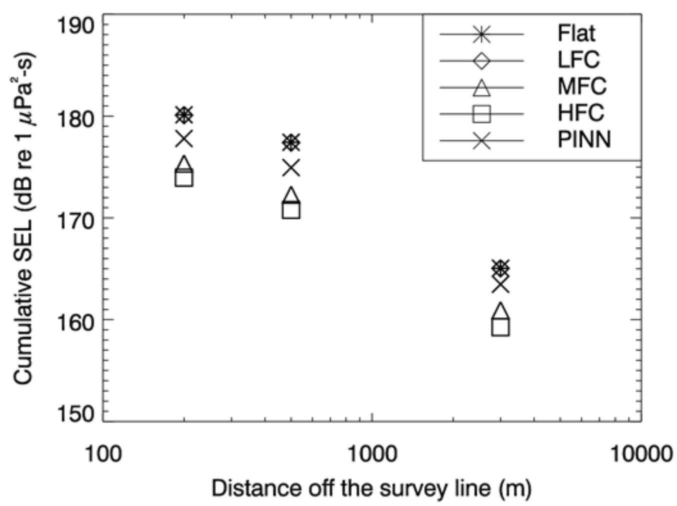

FIGURE 3.28. Cumulative SEL as a function of perpendicular distance off the survey test track for the *Shirley V* in deep water.

Shallow Water

Wiley Gunner.—Figure 3.29-3.31 show cumulative SEL for receivers 100 m, 400 m, and 2500 m off the northern half of the shallow water seismic survey test track corresponding to OBHs A, B, and C, respectively. Figure 3.32 shows a map of the relative locations of the receivers to the shot points.

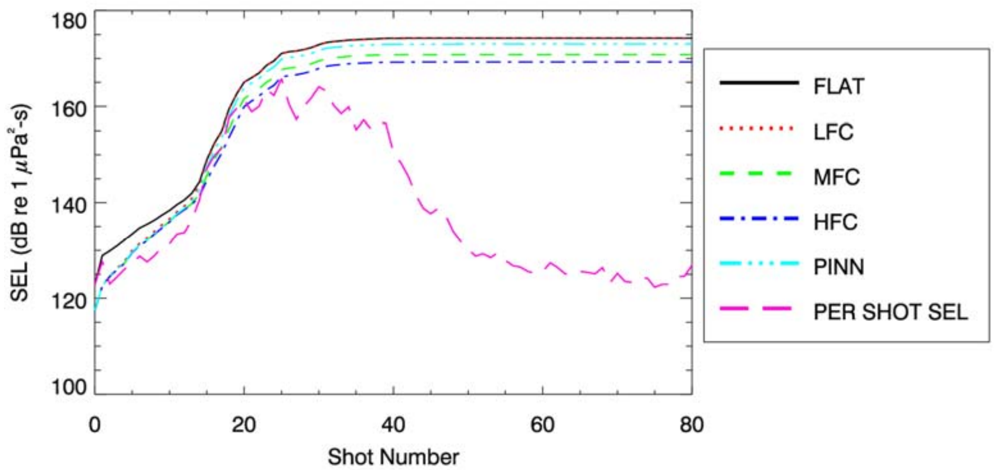

FIGURE 3.29. Flat and M-weighted cumulative SEL with flat-weighted per shot SEL for the *Wiley Gunner* in shallow water as measured along the seismic survey test track (see Figure 3.1) from OBH A, 100 m off the track.

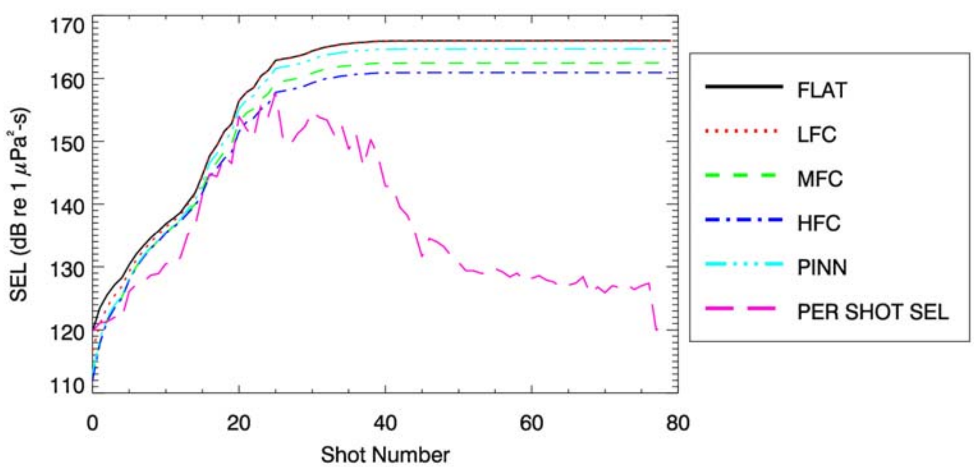

FIGURE 3.30. Flat and M-weighted cumulative SEL with flat-weighted per shot SEL for the *Wiley Gunner* in shallow water as measured along the seismic survey test track (see Figure 3.1) from OBH B, 400 m off the track.

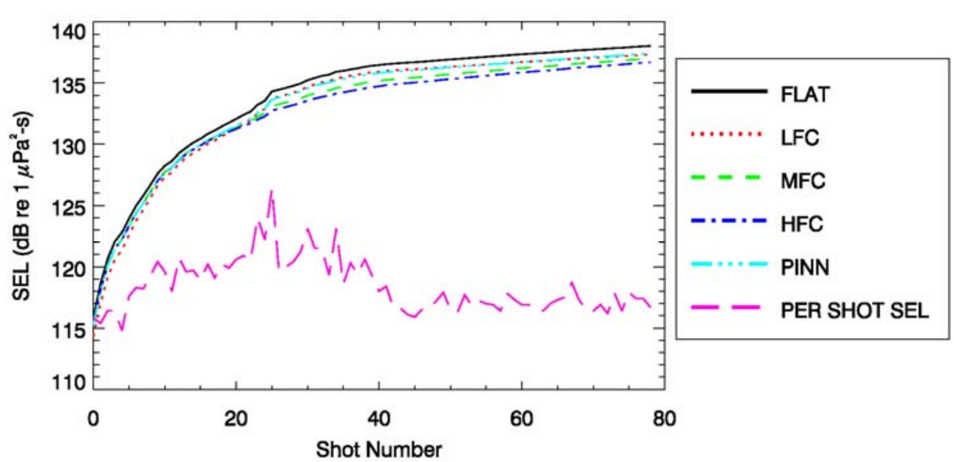

FIGURE 3.31. Flat and M-weighted cumulative SEL with flat-weighted per shot SEL for the *Wiley Gunner* in shallow water as measured along the seismic survey test track (see Figure 3.1) from OBH C, 2500 m off the track.

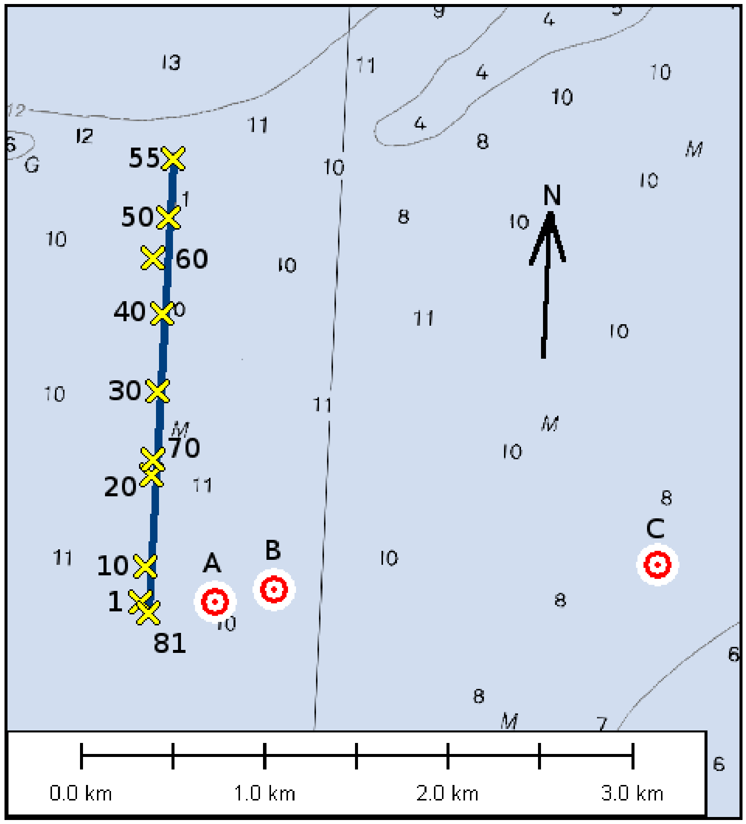

FIGURE 3.32. Map of the broadside seismic survey track for the *Wiley Gunner* in shallow water with shot points (labels by yellow Xs indicate shot number) and OBH locations.

Data for this section were taken from the *Wiley Gunner's* track north of OBH A because a navigation error caused the vessel to deviate off track when it was south of OBH A. SEL measurements were high at the start of the track (near OBH A), then decreased until the *Wiley Gunner* reached the northern waypoint, and increased again until it reached point X again. Plotting cumulative SEL vs. shot number for this type of a data set would produce a misleading increase in cumulative SEL at the end of the survey track. The data were rearranged in time so that SEL started low, peaked around the median shot number, and then decreased again to the last shot point to simulate a typical continuous seismic survey line like the one followed by the *Shirley V* (see Figure 3.37).

Very low frequency flow noise from water current past the OBH hydrophones contributed to flat-weighted SEL values. We applied a high-pass filter with cutoff frequency at 5 Hz to filter out this noise.

Table 3.8 provides maxima of cumulative SEL for each receiver, and Figure 3.33 presents these maxima as a function of distance off the survey test track.

TABLE 3.8. Maximum cumulative SEL from the *Wiley Gunner* measurements in shallow water.

Distance off seismic survey track (m)	Cumulative SEL (dB re 1 µPa^2-s)				
	Flat-weighted	Low Frequency Cetaceans	Mid-Frequency Cetaceans	High Frequency Cetaceans	Pinnipeds underwater
100	174.3	172.2	170.8	169.2	173.0
400	166.0	166.0	162.5	160.9	164.7
2500	138.0	137.3	137.0	136.7	137.4

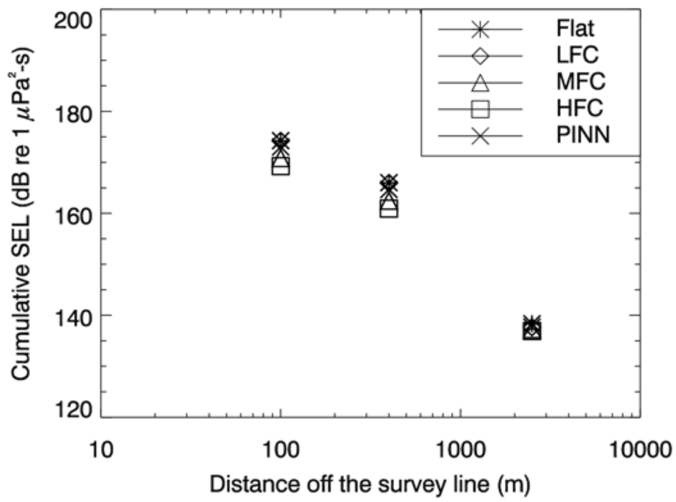

FIGURE 3.33. Cumulative SEL as a function of perpendicular distance off the survey track for the *Wiley Gunner* in shallow water.

Shirley V.—Figure 3.34-3.36 show cumulative SEL for receivers 100 m, 400 m, and 2500 m off the shallow water seismic survey test track corresponding to OBHs A, B, and C, respectively. Figure 3.37 is a map showing the relative locations of the receivers to the shot points.

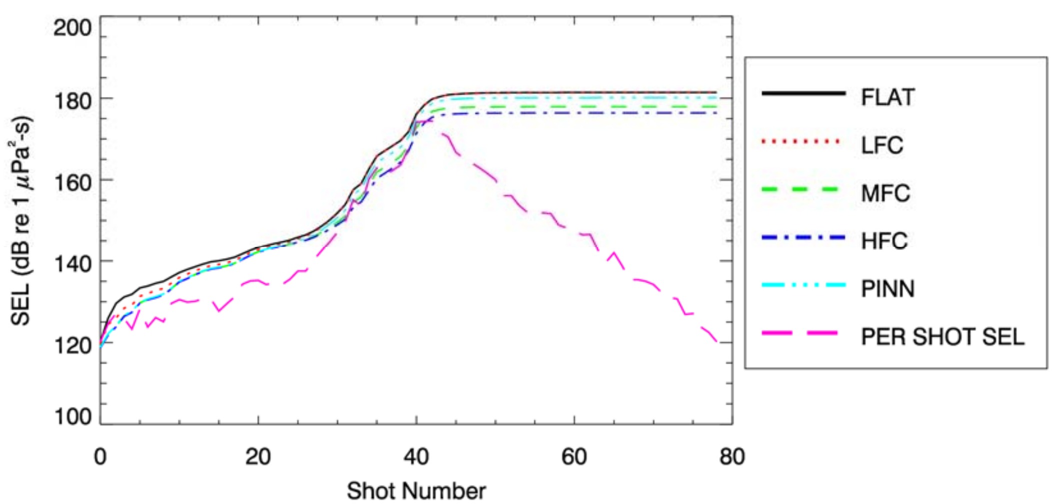

FIGURE 3.34. Flat and M-weighted cumulative SEL with flat-weighted per shot SEL for the *Shirley V* in shallow water as measured along the seismic survey test track (see Figure 3.1) from OBH A, 100 m off the track.

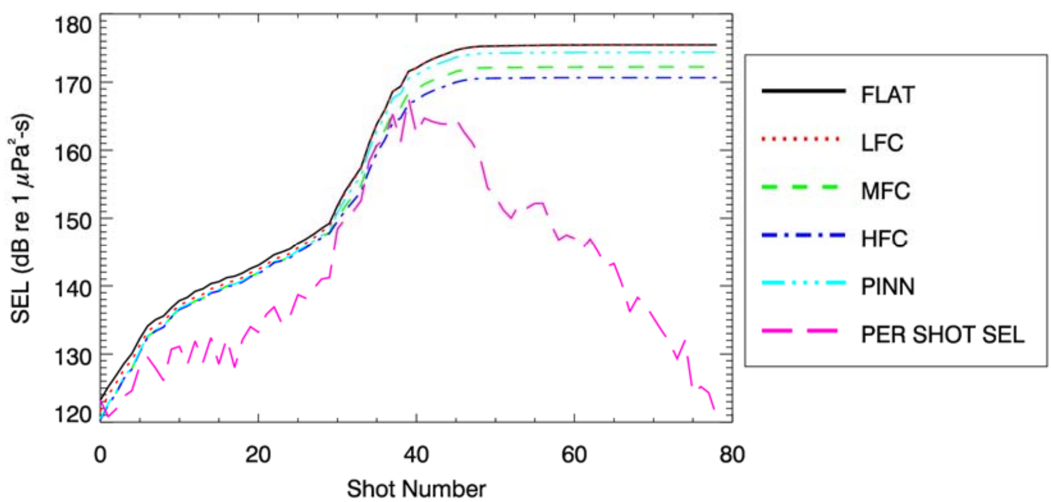

FIGURE 3.35. Flat and M-weighted cumulative SEL with flat-weighted per shot SEL for the *Shirley V* in shallow water as measured along the seismic survey test track (see Figure 3.1) from OBH B, 400 m off the track.

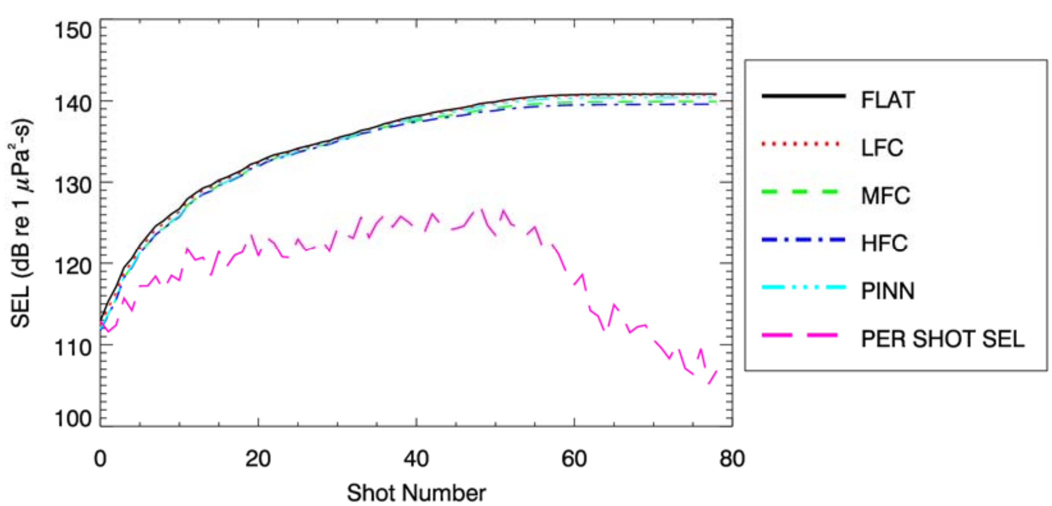

FIGURE 3.36. Flat and M-weighted cumulative SEL with flat-weighted per shot SEL for the *Shirley V* in shallow water as measured along the seismic survey test track (see Figure 3.1) from OBH C, 2500 m off the track.

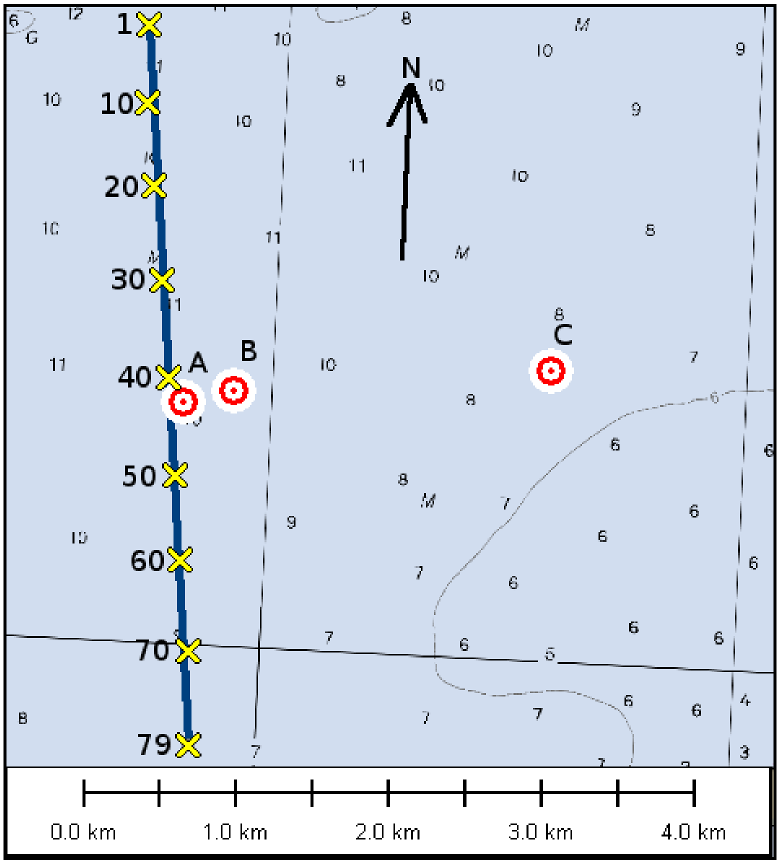

FIGURE 3.37. Map of the broadside seismic survey track for the *Shirley V* in shallow water with shot points (labels by yellow Xs indicate shot number) and OBH locations.

Table 3.9 presents these maxima for each receiver and Figure 3.38 shows these maxima as a function of distance off the survey test track.

TABLE 3.9: Maximum cumulative SEL from the *Shirley V* measurements in shallow water.

Distance off seismic survey track (m)	Cumulative SEL (dB re 1 μPa^2-s)				
	Flat-weighted	Low Frequency Cetaceans	Mid-Frequency Cetaceans	High Frequency Cetaceans	Pinnipeds underwater
100	181.4	181.4	177.9	176.4	180.1
400	175.5	175.4	172.2	170.7	174.4
2500	140.8	140.7	139.9	139.6	140.4

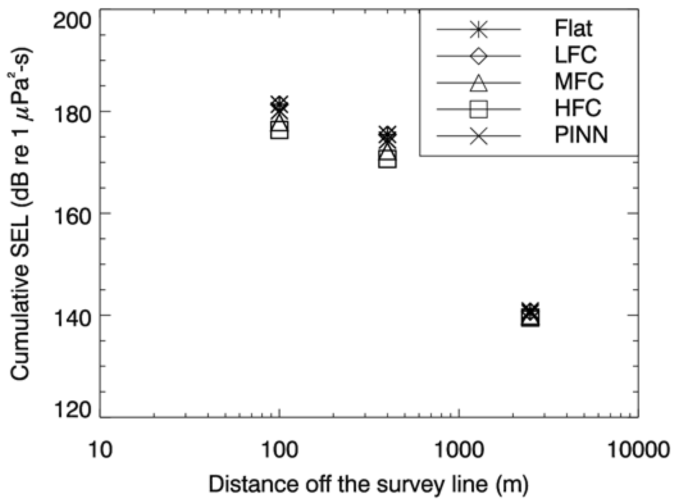

FIGURE 3.38. Cumulative SEL as a function of perpendicular distance off the survey test track for the *Shirley V* in shallow water.

Airgun Spectrograms

Spectrograms provide a useful representation of the spectral content of airgun pulse arrivals and the time evolution of the spectral components. The spectrograms presented in this report show frequency on the vertical axis, time along the horizontal axis, and pressure spectral levels (dB re 1 $\mu Pa^2/Hz$) as different colors.

Figure 3.39 shows spectrograms of measured airgun pulses from the full 880 in^3 array at four different distances from the source at the deep water site. Panels (a), (c), (e), and (g) in that figure show spectrograms of a single pulse from the *Wiley Gunner* recorded on the four OBHs. Panels (b), (d), (f), and (h) correspondingly show spectrograms of a single pulse from the *Shirley V*. These plots illustrate how the dispersive propagation characteristics of the environment at this site (10-14 m depth) influenced the time/ frequency evolution of the airgun pulse power spectrum with range. Panels (a) through (d) in Figure 3.39 show that the energy of the pulse was concentrated in a brief 100 ms window and there was no obvious frequency dispersion (the low frequency components after the main arrival corresponds to the airgun bubble pulses).

In Figure 3.39 (e) and (f), low frequency energy (less than 100 Hz) arrives about 0.4 s before the main pulse. This low-frequency ground wave is predicted by normal mode theory and corresponds to seismic energy that has traveled from the airgun array to the OBH recorder through the seabed. The airgun pulses in these plots show some signs of geometric dispersion (i.e., spreading out in time) at the lower frequencies (see Ireland et al. 2007b).

In Figure 3.39 (g) and (h), the geometric dispersion is very pronounced and the duration of the pulse (90% pulse duration) has increased to about one second. Sound energy below 100 Hz was stripped from the airgun waveform because of the relatively shallow water depth environment. Note that the 100 Hz tone in the background of Figure 3.39 (g) and (h) was self-noise from the OBH recorder hard disk and was not due to the airguns or the survey vessel.

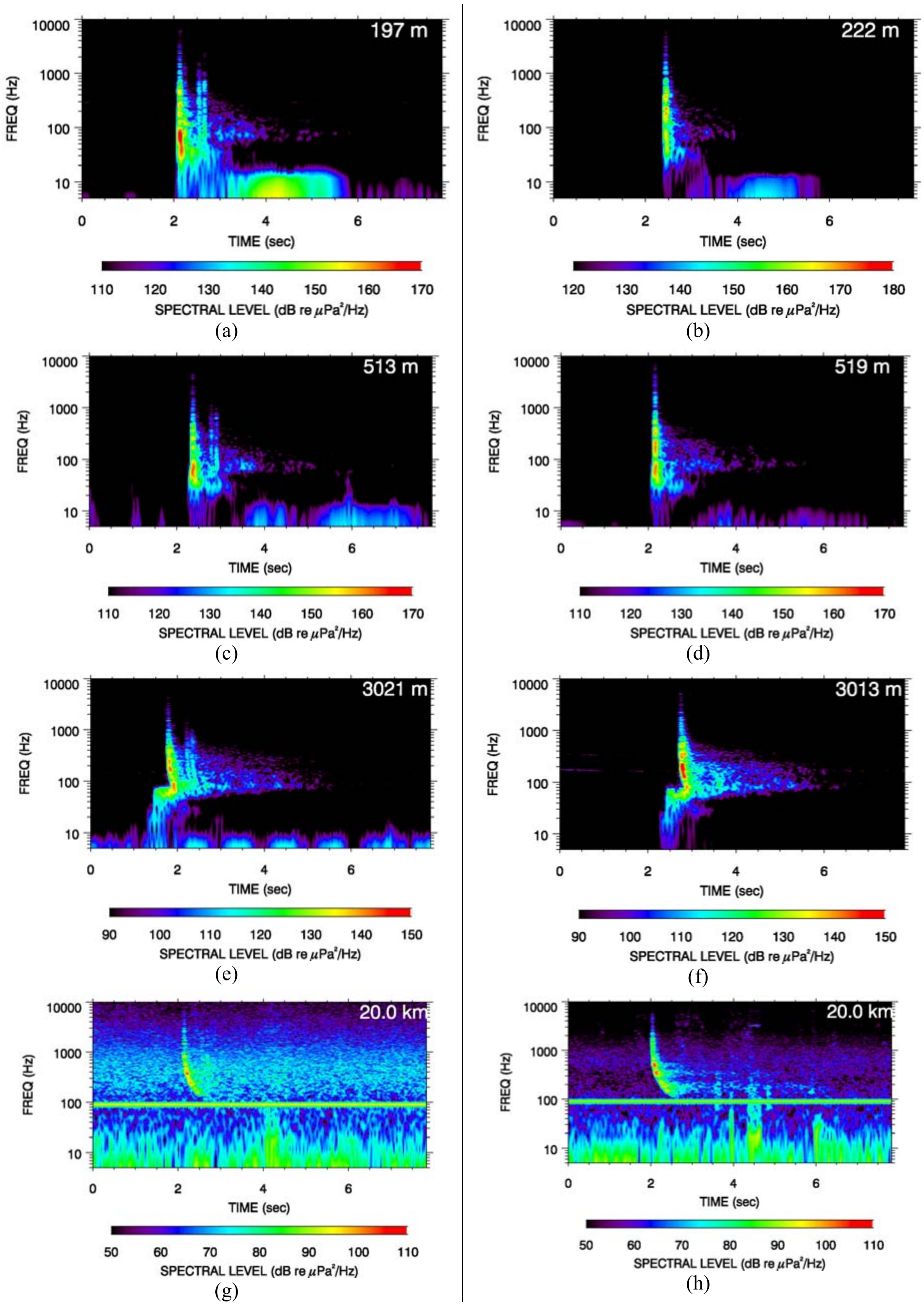

FIGURE 3.39. Spectrograms of airgun pulses at different ranges in deep water from the *Wiley Gunner* (a, c, e, and g) and *Shirley V* (b, d, f, and h).

Figure 3.40 shows spectrograms of measured airgun pulses from the full 880 in^3 array recorded at three different OBHs at the shallow water site. Airgun pulses at 10 km distance (OBH D) were not detectable above background noise. Panels (a), (c), and (e) in that figure show spectrograms of a single pulse from the *Wiley Gunner* recorded on OBHs A, B, and C, respectively. Panels (b), (d), and (f) correspondingly show spectrograms of a single pulse from the *Shirley V*. These plots again illustrate how the dispersive propagation characteristics of the environment at this measurement site (1.5 – 2.5 m depth) influenced the time/frequency evolution of the airgun pulse power spectrum with range (see Ireland et al. 2007b). Panels (a) through (d) in Figure 3.40 show that the energy of the pulse was concentrated in a brief 100 ms window with very little dispersion.

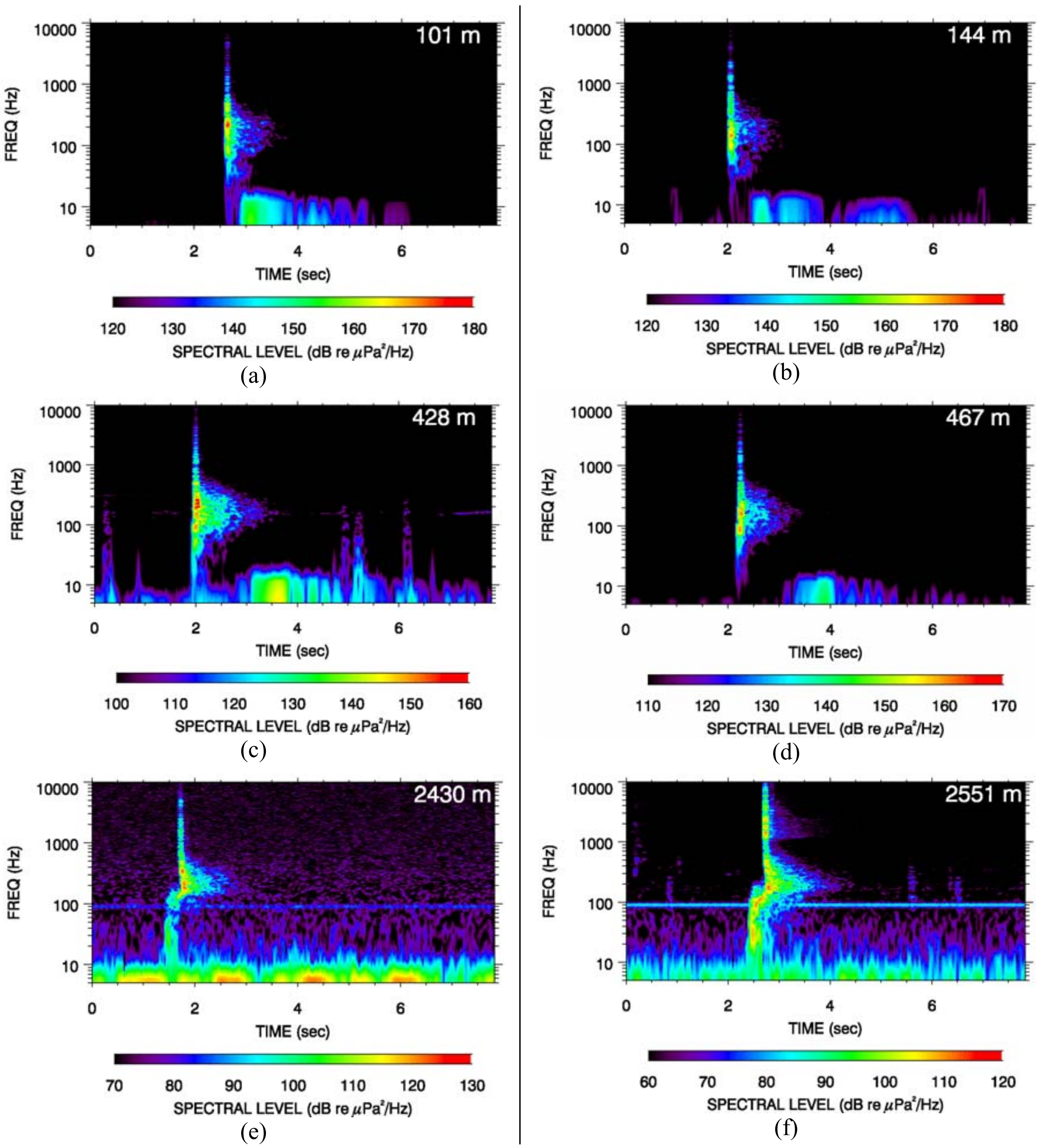

FIGURE 3.40. Spectrograms of airgun pulses at different ranges in shallow water from the *Wiley Gunner* (a, c, and e) and *Shirley V* (b, d, and f).

Similar to the deep water site, panels (e) and (f) in Figure 3.40 show a low frequency energy head wave arriving about 0.5 seconds before the main pulse. Again, this wave has travelled through the seafloor and arrived ahead of the waterborne sound because of the higher speed of sound in the seabed. Note that the 100 Hz tone in the background of these two figures was self-noise from the OBH recorder hard disk.

Based on the discussion above, Figure 3.39 and Figure 3.40 show similar geometric dispersion characteristics as range increases; the shallow water site, however, strips away more of the low frequency energy. The deep water site at the 3 km range (Figure 3.39 (c) and (d)) show the pulses' lower frequency limit around 30 Hz, whereas the shallow water site at the 2.5 km range (Figure 3.40 (c) and (d)) show the pulses' lower frequency limit for the waterborne sound to be above 100 Hz.

Ranges to Threshold Levels

Ranges from the airgun array to specified broadband SPL thresholds between 190 and 120 dB re 1 µPa *rms* were determined from the empirical fits to the sound level versus distance measurements. This was done in both the deep and shallow water environments for the full airgun array and the mitigation gun, and for the forward-endfire and broadside directions for the full airgun array. A greater number of airgun shot measurements were obtained in the forward-endfire direction than in the broadside direction due to the configuration of the deployment geometries (broadside measurements can only be collected in a narrow angular range near the CPA). The mitigation airgun shots were recorded while the *Wiley Gunner* performed broadside and endfire passes in deep and shallow water respectively.

Deep Water: *Wiley Gunner*

The nominal ranges to the decibel thresholds 190, 180, 170, 160 and 120 dB re µPa (*rms*) from measurements in the forward-endfire direction in deep water are listed in Table 3.10.

TABLE 3.10. Forward-endfire sound level threshold radii for the full 880 in^3 airgun array in deep water.

rms SPL (dB re µPa)	Best fit range (m)	90th percentile range (m)
190	67	100
180	170	260
170	450	660
160	1100	1600
120	13000	16000

Broadside direction measurements at the four broadside ranges: 200 m, 500 m, 3 km and 20 km were made simultaneously as the seismic vessel passed point X (see Figure 3.3). The variation at each range represents sampling over the peak of the directivity function lobe. A fit of an empirical level versus range function was used to interpolate between the sampled broadside ranges. The empirical fit was used to estimate the threshold ranges presented in Table 3.11.

TABLE 3.11. Broadside sound level threshold radii for the full 880 in^3 airgun array in deep water.

rms SPL (dB re µPa)	Best fit range (m)	90th percentile range (m)
190	140*	180*
180	340	440
170	840	1100
160	2000	2400
120	20000	21000

*Extrapolated from minimum measurement range of 200 m.

The nominal ranges to relevant sound level thresholds for the mitigation airgun measurements are presented in Table 3.12.

TABLE 3.12. Sound level threshold radii for the 20 in^3 mitigation airgun in deep water.

rms SPL (dB re µPa)	Best fit range (m)	90th percentile range (m)
190	59	87
180	140	210
170	330	480
160	750	1100
120	9800	12000

Deep Water: Shirley V

The nominal ranges to the decibel thresholds 190, 180, 170, 160 and 120 dB re µPa (*rms*) from measurements in the forward-endfire direction in deep water are listed in Table 3.13.

TABLE 3.13. Forward-endfire sound level threshold radii for the full 880 in^3 airgun array in deep water.

rms SPL (dB re µPa)	Best fit range (m)	90th percentile range (m)
190	66	180
180	320	640
170	910	1300
160	1600	2200
120	11000	14000

Broadside direction measurements at the four broadside ranges: 200 m, 500 m, 3 km and 20 km were made simultaneously as the seismic vessel passed point X (see Figure 3.3). The variation at each range represents sampling over the peak of the directivity function lobe. A fit of an empirical level versus range function was used to interpolate between the sampled broadside ranges. The empirical fit was used to estimate the threshold ranges presented in Table 3.14.

TABLE 3.14. Broadside sound level threshold radii for the full 880 in^3 airgun array in deep water.

rms SPL (dB re µPa)	Best fit range (m)	90th percentile range (m)
190	120*	160*
180	410	550
170	1300	1600
160	3200	3800
120	20000	22000

*Extrapolated from minimum measurement range of 200 m.

The nominal ranges to relevant sound level thresholds for the mitigation airgun measurements are presented in Table 3.15. These ranges are suitable for establishing safety ranges near the mitigation airgun source.

TABLE 3.15. Sound level threshold radii for the 20 in^3 mitigation airgun in deep water.

rms SPL (dB re µPa)	Best fit range (m)	90th percentile range (m)
190	52*	73*
180	110*	160*
170	240	340
160	510	720
120	7500	9400

*Extrapolated from minimum measurement range of 200 m.

Shallow Water: Wiley Gunner

The nominal ranges to the decibel thresholds 190, 180, 170, 160 and 120 dB re µPa (*rms*) from measurements in the forward-endfire direction in deep water are listed in Table 3.16.

TABLE 3.16. : Forward-endfire sound level threshold radii for the full 880 in^3 airgun array in shallow water.

rms SPL (dB re µPa)	Best fit range (m)	90th percentile range (m)
190	140	220
180	220	340
170	330	520
160	510	800
120	2800	4400

Broadside direction measurements at the four broadside ranges: 100 m, 400 m, 2.5 km and 10 km were made simultaneously as the seismic vessel passed point X (see Figure 3.3). The levels at these ranges changed rapidly as the airgun array passed the CPA (point X) relative to the OBHs due to strong array directivity. The shallow water environment strongly attenuates the low frequency component of each pulse, so the directivity effect is strong because the remaining high frequency sound is highly directional. The variation at each range represents sampling over the peak of the 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 used to estimate the threshold ranges presented in Table 3.17.

TABLE 3.17. Broadside sound level threshold radii for the full 880 in^3 airgun array in shallow water.

rms SPL (dB re µPa)	Best fit range (m)	90th percentile range (m)
190	210*	270*
180	340*	430
170	550	680
160	870	1100
120	5700	7100

*Extrapolated from minimum measurement range of 375 m.

The nominal ranges to relevant sound level thresholds for the mitigation airgun measurements are presented in Table 3.18.

TABLE 3.18. Sound level threshold radii for the 20 in^3 mitigation airgun in shallow water.

rms SPL (dB re µPa)	Best fit range (m)	90th percentile range (m)
190	27*	41*
180	81*	120
170	240	360
160	680	870
120	2200	2400

*Extrapolated from minimum measurement range of 85 m.

Shallow Water: Shirley V

The nominal ranges to the decibel thresholds 190, 180, 170, 160 and 120 dB re µPa (*rms*) from measurements in the forward-endfire direction in deep water are listed in Table 3.19.

TABLE 3.19. Forward-endfire sound level threshold radii for the full 880 in^3 airgun array in shallow water.

rms SPL (dB re µPa)	Best fit range (m)	90th percentile range (m)
190	190	270
180	290	420
170	440	640
160	680	970
120	3700	5300

Broadside direction measurements at the four broadside ranges: 100 m, 400 m, 2.5 km and 10 km were made simultaneously as the seismic vessel passed point X (see Figure 3.3). The levels at these ranges changed rapidly as the airgun array passed the CPA (point X) relative to the OBHs due to strong array directivity. The shallow water environment strongly attenuates the low frequency component of each pulse, so the directivity effect is strong because the remaining high frequency sound is highly directional. The variation at each range represents sampling over the peak of the 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 used to estimate the threshold ranges presented in Table 3.20.

TABLE 3.20. Broadside sound level threshold radii for the full 880 in^3 airgun array in shallow water.

rms SPL (dB re µPa)	Best fit range (m)	90th percentile range (m)
190	140	200
180	300	430
170	630	870
160	1200	1600
120	6900	7900

The nominal ranges to important sound level thresholds for the mitigation airgun measurements are presented in Table 3.21.

TABLE 3.21. Sound level threshold radii for the 20 in^3 mitigation airgun in shallow water.

rms SPL (dB re µPa)	Best fit range (m)	90th percentile range (m)
190	2*	6*
180	29	67
170	190	290
160	500	640
120	2200	2300

*Extrapolated from minimum measurement range of 14 m.

Vessel Measurements

Demaree Inflatable Boats (DIBs)

PGS used three DIBs for cable laying operations. Specifications for these vessels are provided in Appendix 3.A. The data from these measurements, as well as the best-fit and 90th percentile transmission loss curves, are presented in Figure 3.41-3.43. Measured levels past 2 km were comparable to the background noise, and therefore, were not used for function fits.

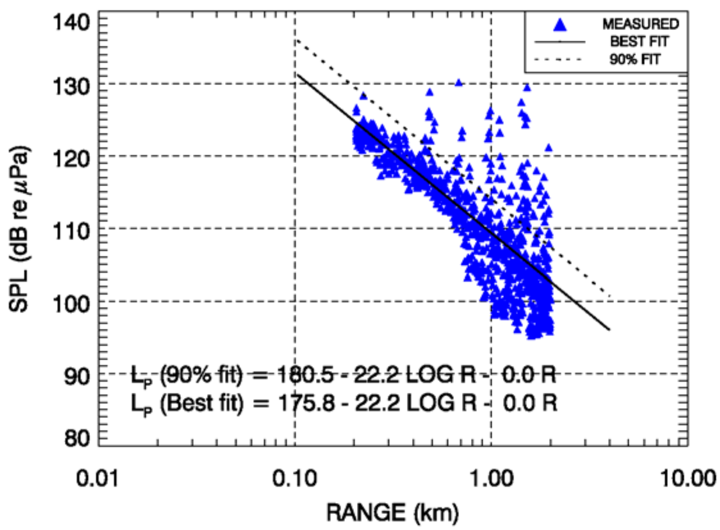

FIGURE 3.41. *DIB 1* – Best-fit equation (solid line) and 90th percentile fit (dashed line) of sound pressure level versus distance measurements.

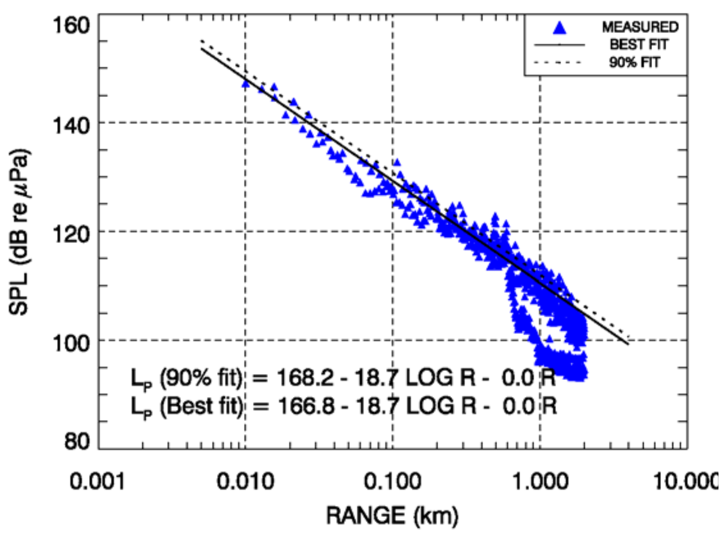

FIGURE 3.42. *DIB 2* – Best-fit equation (solid line) and 90th percentile fit (dashed line) of sound pressure level versus distance measurements.

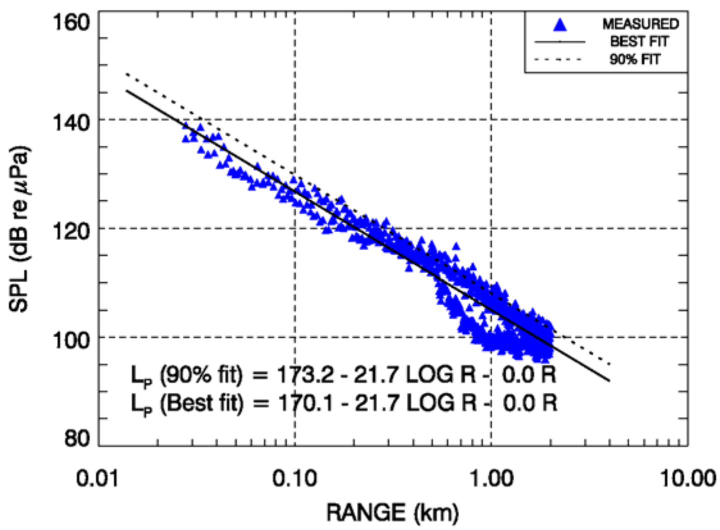

FIGURE 3.43. *DIB 3* – Best-fit equation (solid line) and 90th percentile fit (dashed line) of sound pressure level versus distance measurements.

<u>*Reliance Boats*</u>

PGS used four *Reliance* boats for cable laying operations. Specifications for these vessels are provided in Appendix 3.A. *Reliance 3* had navigational problems, and *Reliance 4* had mechanical problems at the time of the acoustic measurement program so they could not be measured. Data from measurements of *Reliance 1* and *Reliance 2*, as well as the best-fit and 90th percentile function fit curves, are presented in Figure 3.44 and Figure 3.45 below. Measured levels beyond 4 km and 2 km for *Reliance 1* and *Reliance 2*, respectively, were comparable to background noise levels and were removed from analyses.

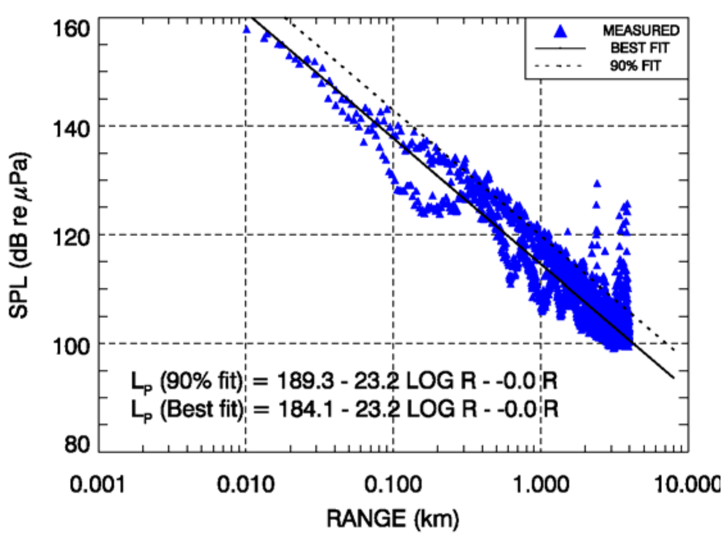

FIGURE 3.44. *Reliance 1* – Best-fit equation (solid line) and 90th percentile fit (dashed line) of sound pressure level versus distance measurements.

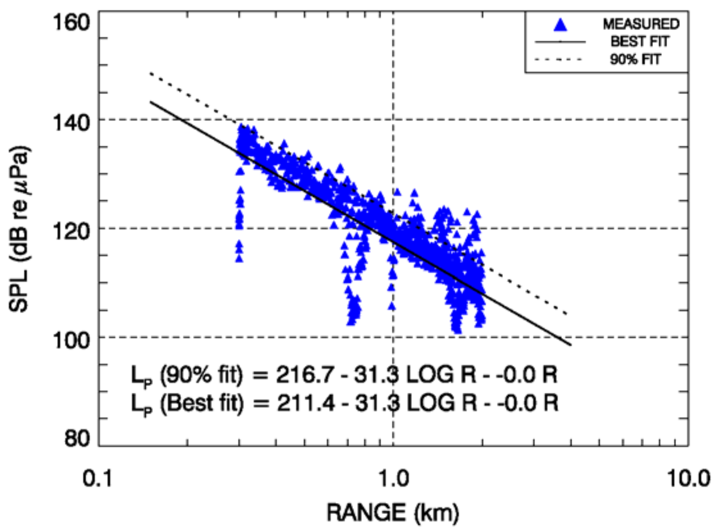

FIGURE 3.45. *Reliance 2* – Best-fit equation (solid line) and 90th percentile fit (dashed line) of sound pressure level versus distance measurements.

Wiley Gunner

The results from the *Wiley Gunner* sound level measurements (with no airguns operating) are shown below in Figure 3.46. Note that the empirical transmission loss curve was fit only to data acquired during the first 2 km approach of the vessel, since the measured sound levels were observed to be higher in front of the vessel.

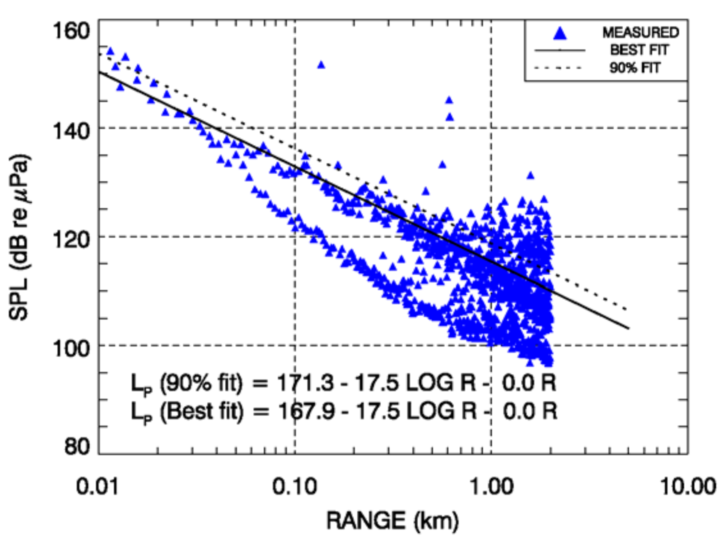

FIGURE 3.46. *Wiley Gunner* – Best-fit equation (solid line) and 90th percentile fit (dashed line) of sound pressure level versus distance measurements.

American Discovery

The *American Discovery* conducted crew changes for PGS. Specifications for this vessel are provided in Appendix 3.A. Data from this vessel, as well as the transmission loss curve fits, are provided in Figure 3.47. Measured levels beyond 5 km were comparable to the background noise, and therefore, were removed from analyses.

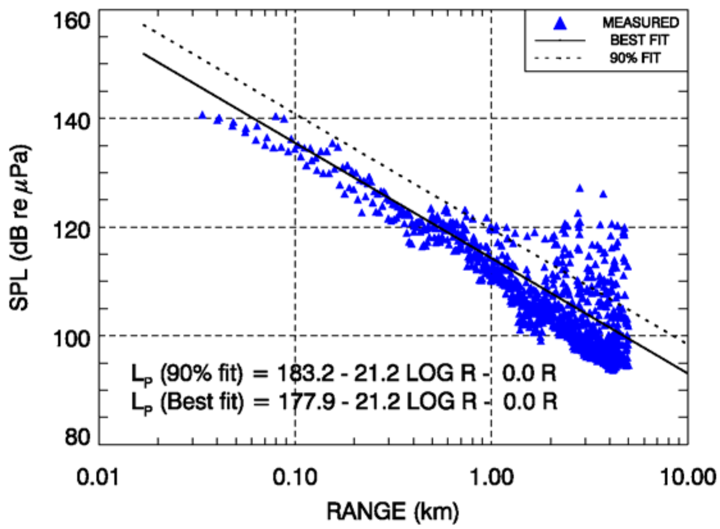

Figure 3.47. *American Discovery* – Best-fit equation (solid line) and 90th percentile fit (dashed line) of sound pressure level versus distance measurements.

Summary

Airgun Array Sound Levels

Underwater acoustic measurements were performed using four JASCO OBH systems to quantify sound levels as a function of distance and direction from two 880 in^3 airgun arrays operated during the 2008 seismic survey at Eni's survey area. These measurements were performed at two depth environments, in shallow water between 1.5 and 2.5 m and in deep water between 9 and 14 m. These water depths span the full depth range present in the survey area. The bottom types at these sites are unknown. The measurements were made at distances from 14 m to 20 km from the airgun sources in both endfire and broadside aspects from the arrays. Empirical functions were fit to the received sound levels versus distance using a least squares approach. The empirical functions were used to determine distances corresponding with sound levels reaching several thresholds. A summary of the results are presented Tables 3.22 and 3.23.

TABLE 3.22. Ranges to sound level thresholds for the 880 in^3 arrays in 9-14 m water depth.

rms SPL (dB re µPa)	90th percentile range (m)			
	Wiley Gunner		*Shirley V*	
	Forward-endfire	Broadside	Forward-endfire	Broadside
190	100	180*	180	160*
180	260	440	640	550
170	660	1100	1300	1600
160	1600	2400	2200	3800
120	16000	21000	14000	22000

* Extrapolated from minimum measurement range of 200 m.

TABLE 3.23. Ranges to sound level thresholds for the 880 in^3 arrays in 1.5 – 2.5 m water depth.

rms SPL (dB re µPa)	90th percentile range (m)			
	Wiley Gunner		*Shirley V*	
	Forward-endfire	Broadside	Forward-endfire	Broadside
190	220	270*	270	200
180	340	430	420	430
170	520	680	640	870
160	800	1100	970	1600
120	4400	7100	5300	7900

* Extrapolated from minimum measurement range of 375 m.

Maximum ranges in the deep environment to the 190 and 180 dB thresholds were 180 and 640 m, respectively. Both of these results were observed from the *Shirley V* in the forward-endfire direction. The maximum range to 120 dB in the deep environment was 22000 m which was extrapolated from the *Shirley V* measurements in the broadside direction. In the shallow water environment, the maximum range to the 190 dB threshold was 270 m which occurred in the forward-endfire direction from the *Shirley V*. The maximum ranges to the 180 and 120 dB thresholds were 430 m and 7900 m, respectively, both of which occurred in the broadside direction from the *Shirley V*. Broadside distances were greater than forward-endfire for all thresholds except for the *Shirley V* 190 and 180 dB levels in the deep environment and the 190 dB level in the shallow environment. These distances are most likely overestimates because the 90% offset fit functions overestimate the close range data (see Figure 3.10 and Figure 3.16).

Spectrograms at 200 m distance (Figure 3.39) showed waterborne energy above 20 Hz arriving 1 – 3 seconds before sub-20 Hz sub-bottom reflections. At 500 m distance, sub-10 Hz energy arrived between 1.5 – 5.5 seconds after the waterborne arrival. At 3 km distance, the waterborne energy occurred mainly above 50 Hz, but shallow sub-bottom propagation was observed in the 20-60 Hz frequency range that arrived ~0.4 seconds before the water arrival. Modal dispersion started to be apparent at 3 km, with low frequency mode components arriving later than the high frequency components. At 20 km distance, all significant received acoustic energy is above 100 Hz. Modal dispersion is strongly apparent at this range.

Sub-bottom sound propagation is important at both the deep and shallow water sites. The shallow site did not support low frequency sound propagation in the water but very low frequency sound was observed to propagate through the bottom. Sound levels at the shallow water site were lower than at the same distance at the deep water site. It is likely that there is bottom-propagated sound at both sites but it is masked at the deeper site by the higher amplitude water-propagated sound (see Figure 3.40 and Figure 3.39).

Airgun pulses from the *Wiley Gunner* in deep water (Figure 3.39 a, c, and e) show two secondary pulses after the first break. These pulses are most likely delayed airgun shots from an improperly operating system. This problem may also be responsible for shorter distances to sound level thresholds than from the array operated from *Shirley V* for all thresholds except for 190 dB re 1 µPa, and 120 dB re 1 µPa in the forward-endfire direction in the deep environment.

A further analysis of the airgun array data was performed to compute M-weighted cumulative SEL for the airgun array test tracks. This metric was recently proposed as an alternative to the *rms* metric that has been applied in the past for marine mammal exposures (Southall et al. 2007). M-weighted cumulative SEL was computed at the OBH positions at 200 m, 500 m, and 3000 m off the survey test track in the deep water, and 100, 400, and 2500 m off the survey test track in the shallow water. The levels at these positions are shown below in Figure 3.48.

M-weighted cumulative SELs were consistent between both vessels at each test site. Cumulative SELs at the deep environment were significantly greater than those at the shallow environment. For example, the flat weighted cumulative SEL from the *Wiley Gunner* 200 m off the test track (see Figure 3.48a) was 181 dB re 1 μPa^2-s whereas it would be ~ 170 dB re 1 μPa^2-s for the same range at the shallow water site. The cumulative SELs at 400 – 500 m were 177 dB re 1 μPa^2-s for the deep environment and 166 dB re 1 μPa^2-s for the shallow environment. At 2500 – 3000 m off the test sail track, the level at the deep environment was 162 dB re 1 μPa^2-s, and the level at the shallow environment was 138 dB re 1 μPa^2-s. The differences between cumulative SELs at the deep and shallow environments therefore increased with distance from the source.

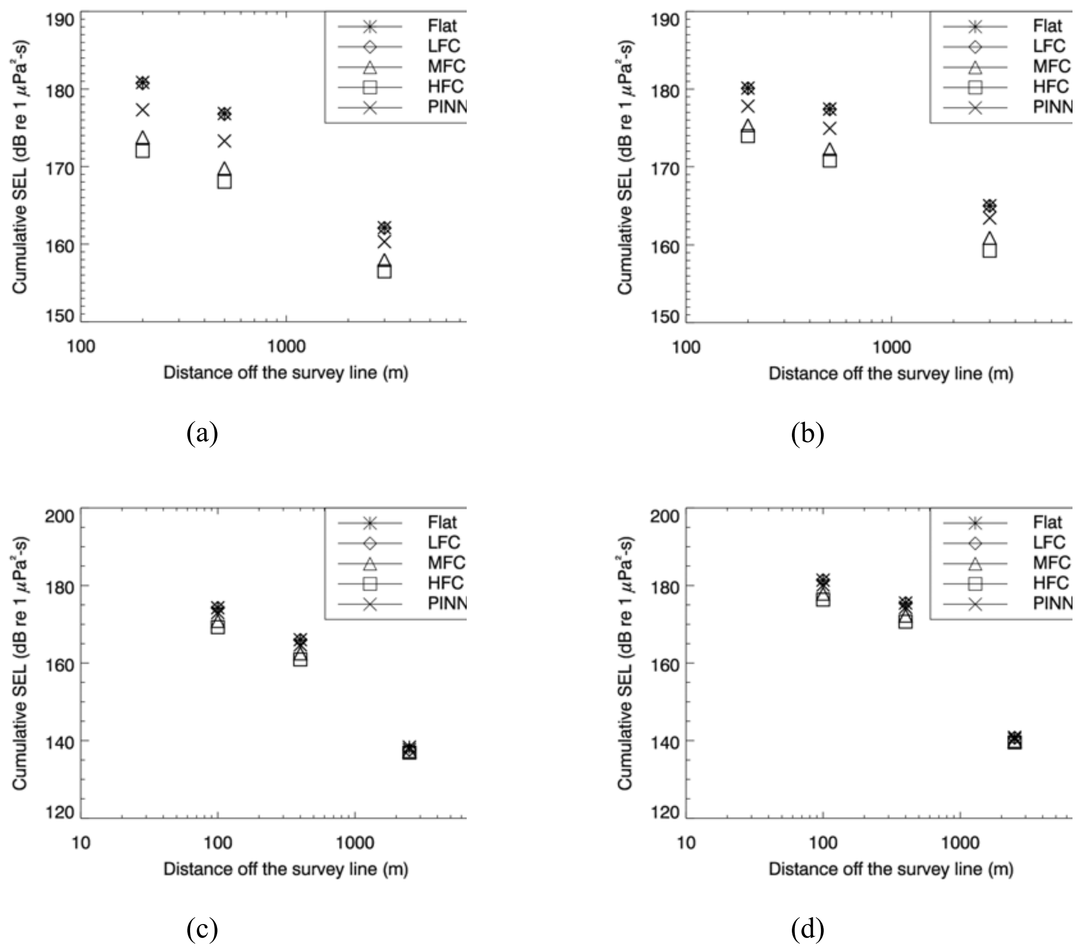

FIGURE 3.48. M-weighted cumulative SEL as a function of distance off the test tracks for the *Wiley Gunner* in deep (a) and shallow (c) water, and the *Shirley V* in deep (b) and shallow (d) water.

The Colville River could expel large amounts of fresh water into the survey area which would change the salinity, and therefore, sound speed profiles. This is not expected to significantly affect sound transmission because the sound frequencies of airgun pulses have wavelengths that are too large to be influenced strongly by in-water refraction.

The barrier islands (see Figure 3.1) would block propagation of most sound at frequencies above 10 Hz. The openings between islands would allow fans of sound radiation to pass through to open water, but the openings are relatively shallow and will only support relatively high frequency sound propagation. Sound frequencies below 10 Hz could pass through the islands without significant additional attenuation because low frequency energy propagates mainly through the bottom in the shallow waters inside the islands. This low frequency energy may be audible at very low levels to bowhead whales, but would not be audible to other animals. These effects were not measured because of the SSV geometries (see Figure 3.1).

Support Vessel Self-Noise

Continuous underwater sound levels were measured as a function of distance from the nine support vessels as they sailed along a 20 km test track in water depths 9 - 14 m. The OBHs for this measurement were deployed in 9 m water depth. Empirical functions of sound level versus distance from the vessel were fit to the data using a least-squares method. The best-fit functions were then increased by a constant decibel offset to exceed 90 % of the data values. These 90th percentile fits were used to determine slightly conservative distances corresponding to sound levels reaching thresholds between 140 and 100 dB re μPa. Those distances are summarized in Table 3.24.

TABLE 3.24. Ranges to SPL thresholds for support vessels.

		Range to SPL (m)				
Vessel Name	Speed during test	140 dB re 1 μPa	130 dB re 1 μPa	120 dB re 1 μPa	110 dB re 1 μPa	100 dB re 1 μPa
DIB 1	7.4 km/h (4 kt)	67	190	520	1400	3300
DIB 2	16.9 km/h (9.2 kt)	31	100	310	810	1700
DIB 3	13.3 km/h (7.2 kt)	34	98	280	810	2300
Reliance 1	14.9 km/h (8.1 kt)	140	370	1000	2900	11000
Reliance 2	11.7 km/h (6.3 kt)	290	610	1300	3100	9500
Wiley Gunner	14.2 km/h (7.7 kt)	61	230	820	2900	8900
American Discovery	29.9 km/h (16.1 kt)	110	300	800	1900	3700

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Appendix 3.A

Vessel Class	Demaree Inflatable Boat
Vessel Names	*DIB 1* *DIB 2* *DIB 3*
Function	Seismic cable lay vessel
Captains	Harry Pinell, Cody Theriot, Bobby Robin, Jeffrey Landry, Sean Hardy, and Mike Haise
# of Engines	2
Power per Engine (HP)	200
Length (ft)	41
Beam (ft)	12
Draft (ft)	2
Propulsion Type	Propeller (3 blades)

Vessel Name	*Wiley Gunner*
Function	Airgun vessel
Captains	Larry Landry and Travis Stelly
# of Engines	3
Power per Engine (HP)	275/250/275
Length (ft)	48
Beam (ft)	12
Draft (ft)	2.2
Propulsion Type	Propeller

Vessel Name	*American Discovery*
Function	Crew change and supply vessel
Captains	Bill Wade and Justin Theriot
# of Engines	2
Power per Engine (HP)	336
Length (ft)	40
Beam (ft)	18
Draft (ft)	1.5
Propulsion Type	Double propeller on each engine

Vessel Class	Reliance
Vessel Names	*Reliance 1* *Reliance 2* *Reliance 3* *Reliance 4*
Function	Seismic cable lay vessel
Captains	Willie Hart, Curtis Borgerson, Steve Ellis, Tim Ewing, Chad Gros, and Mark Landry
# of Engines	2
Power per Engine (HP)	330
Length (ft)	41
Beam (ft)	16
Draft (ft)	2.5
Propulsion Type	Propeller (3 blade, 18 in, 23 degree pitch)

4. MARINE MAMMAL MONITORING AND MITIGATION

This chapter provides details on the monitoring protocols and required mitigation measures for the vessel-based and aerial monitoring program implemented during the Eni/PGS seismic survey. As stated earlier, monitoring and mitigation measures were requirements specified in the IHA and LOA issued by NMFS and USFWS, respectively (see Appendices A and B).

Vessel-based Monitoring and Mitigation

The goal of the vessel-based marine mammal monitoring program was to assist with the implementation of the IHA and LOA requirements and thereby, minimize effects of activities associated with the seismic program on marine mammals. A summary of the monitoring and mitigation tasks are listed below:

- Use dedicated MMOs to visually observe the occurrence and behavior of marine mammals prior to and during seismic operations;
- Request mitigation power-downs and shut-downs as required; and
- Estimate the number of marine mammals potentially exposed to airgun sound levels ≥160, ≥180 and ≥190 dB.

Monitoring

The visual monitoring protocol used during the seismic survey was designed to meet requirements specified in the IHA and LOA. MMOs were hired by either ASRC Energy Services (AES) or LGL Alaska Research Associates, Inc. MMOs hired by ASRC were Inupiat individuals familiar with the marine mammals in the region. All MMOs participated in a training program to provide familiarization with the designated monitoring and mitigation methods, regional marine mammals, and daily operations. All MMOs participated in daily pre-watch safety meetings and post-watch debriefing meetings with an on-site project manager who coordinated data entry, reporting, and interactions with the seismic crew.

Seismic Source Vessels M/V Wiley Gunner, *M/V* Shirley V, *M/V* Peregrine

All MMOs and crew associated with the Eni/PGS survey were housed at the Eni construction camp (the OCC) at Oliktok Point. Each day MMOs were transported from camp to the dock where they boarded a crew vessel (*American Discovery*) for transport to the seismic source vessel or boarded a docked source vessel. Each source vessel had two crews of MMOs that alternated shifts on the boat. A crew typically consisted of at least one Inupiat MMO and one LGL MMO, but there were up to three MMOs during a watch. MMOs were typically on the boat for about 12 h per day, with crew changes occurring around 0630 h and 1830 h AKDT. Each MMO conducted watches 2-4 h in length with equal amounts of rest time in between watches to prevent fatigue. Once a shift was over, the crew met with the on-site manager again for a debriefing period. MMOs were able to contact the on-site manager at any time from the vessel via cellular telephone or VHF radio. LGL MMOs and Inupiat MMOs typically participated in the Eni/PGS project for ~10 weeks and 4-5 weeks, respectively.

MMO watches were conducted from the source vessel's bridge or bow (see Chapter 2 for each source vessel's height asl). The airgun arrays were positioned alongside the *Wiley Gunner* and *Shirley V* and towed behind the *Peregrine*. Depending on the number of MMOs on watch, observers were positioned in the port, center, or starboard sides of the bridge or bow.

MMOs systematically scanned the area around the seismic vessel with the unaided eye and using Fujinon 7 x 50 reticle binoculars during daylight operations. Observations were focused forward of the vessel while it was underway, however, the area behind the stern of the vessel was also regularly checked for the presence of marine mammals. When the vessel was stationary all visible directions were monitored. Operations during periods of darkness did not require the presence of a MMO, other than during the 30 min watch prior to ramp-up (if the full safety zone was visible by vessel lights) after a full shut down for marine mammals or when the airgun(s) were inactive for a period of >10 min. However, MMOs typically continued watches during periods of darkness with the aid of night vision binoculars.

Systematic data were recorded by on-watch MMOs, including date, time, vessel position, speed, activity, number and location of other nearby vessels, water depth, Beaufort wind scale, visibility, glare, and sea ice conditions. Data were recorded every 30 min or whenever conditions changed. Additional data were collected for marine mammal sightings, including: date, time, vessel position, species, total group size, number of distinguishable juveniles, bearing of the sighting relative to the vessel, animal(s) course relative to the vessel, distance to the animal(s), initial and subsequent behaviors, whether the animal(s) was on land, ice, or in the water, pace, reaction to the vessel, sighting cue, the final time, distance, and bearing for the CPA, if a power- or shut-down was requested, the time of the mitigation request, the time of the mitigation implementation, and any additional comments. Communication Centers (Com-Centers) were operated by ASRC Energy Services, and were called every six hours and documented in a log book. MMOs and airgun operators communicated directly (on the bridge of the *Wiley Gunner* and *Shirley V*) or via VHF radio (on the *Peregrine*) for updates on operations status and implementation of power- and shut-downs. Navigators were located on the recording barge, and MMOs communicated with them through the vessel's captain via radio. Data were entered into an Excel database at a later date and cross-checked for accuracy. Additional data processing was conducted prior to analysis and is described in Chapter 5.

Mitigation Measures

Mitigation measures for all vessels associated with the Eni/PGS seismic program, as well as specific measures for the source vessels, were specified in the IHA issued by NMFS (Appendix A). The LOA issued by USFWS (Appendix B) detailed mitigation measures similar to those in the IHA.

Field Source Verification

Field source level verification tests were required for each source vessel to determine the empirical distances from the airgun array to broadband received levels of 190, 180, 160, and 120 dB, as well as the radiated sounds vs. distances from the primary seismic vessels. NMFS also requested that distances to other sound isopleths down to 120 dB in 10 dB increments be included. A report of these measurements and the distances to the various radii was submitted to NMFS and USFWS within 72 h and 120 h, respectively, after acoustic field testing ended. Chapter 3 describes the testing procedures and results in detail. Table 4.1 (later in this chapter) summarizes the SSV results.

General Mitigation Measures (All Vessels)

General mitigation measures employed by all vessels during the Eni/PGS project are summarized below in bullet points, as detailed in the IHA and LOA. These mitigation measures were implemented by the captain and crew of all project vessels during the seismic survey period, as necessary. Specific measures for the seismic source vessels, applied by MMOs, are described in the next section. It is important to note that crew safety took priority, when applicable, over mitigation measures aimed at avoiding disturbance of marine mammals.

- Avoid walrus or polar bear concentrations on land or ice, and conduct activities at the maximum possible distance. Never operate within 800 m (0.5 mi) of walruses or polar bears on land or ice. However, permission was obtained by USFWS to use the barrier islands for shelter during poor weather conditions even if the vessel entered the 800 m exclusion zone.

- Maintain an 800 m (0.5 mi) exclusion zone to avoid harassment of walruses or polar bears in the water. A 457 m (500 yd) zone should be maintained around whales. Also, reduce speed (specifically when within 274 m [300 yd] of whales) and steer around these animals. Do not operate vessels in such a way as to separate members of a group of these animals.
- Multiple changes in direction or speed should be avoided in the presence of walruses, polar bears, or whales (specifically when within 274 m [300 yd] of whales). Check the waters adjacent to the vessel for whales before engaging a vessel's propellers.
- Support vessels should not be operated at a speed that would make collisions with whales likely and should adjust their speed accordingly when weather conditions require.
- The restriction of walrus or polar bear movements in water or on land is prohibited, and exclusion zones should be enforced until the animal(s) has left the area.
- Operate in compliance with the CAA. Establish and operate at least two Com-Centers to be staffed by Inupiat operators. Plan vessel and aircraft routes to minimize potential conflict with bowhead whales or subsistence whaling activities. Confine geophysical activity to specified boundaries and dates for the Kaktovik, Nuiqsut, and Barrow regions (see Appendix A). Assist in at-sea emergencies or towing of a whale taken in a traditional whale hunt as notified by a Com-Center.

Seismic Source Vessel Mitigation Measures

Mitigation measures were requested by trained MMOs on the seismic vessels. Mitigation measures included monitoring of safety zones, monitoring before and during ramp-ups, implementation of power-downs and shut-downs, and course alterations, among others. These actions are typically required during seismic surveys in the Alaskan Beaufort Sea and present in many previous IHAs and LOAs issued for work in this region. Crew members of the source and other vessels associated with the seismic program were also responsible for immediately contacting the MMO on the source vessel whenever a marine mammal was within or approaching the relevant safety radius of the source vessel.

General Requirements.—The volume of the airgun array was reduced or completely shut-down during vessel turns. To the extent possible, course alterations and changes in speed were implemented at times when a marine mammal was seen outside the safety zone; course and speed alterations were based on the position and behavior of the animal(s) relative to the vessel track. At least two MMOs were on watch during ramp-ups, 30 minutes prior to full ramp-ups, and at other times, to the extent possible. At least one MMO was on watch at all times that the seismic array (or single airgun) was operating and during power-down situations due to the presence of marine mammals. MMOs were on watch for no more than four consecutive hours before taking a break and were provided with reticule binoculars. Big-eye binoculars were not used, because it was not possible to effectively mount them on the small source vessels used for the Eni/PGS seismic survey. Whenever marine mammals were observed, monitoring consisted of recording: species, group size, age/size/sex categories (as possible), general initial and subsequent behavioral activity, heading, bearing and distance from the seismic vessel, sighting cue, behavioral pace, and any apparent reactions to the seismic source vessel. Environmental conditions and vessel position, speed, and activity were also recorded for each sighting and throughout each watch. USFWS required weekly reports of all walrus and polar bear sightings from all project vessels, including detailed information on the environmental conditions, animal(s) behavior, and activity of the vessel (Appendix B). Weekly reports were also sent to NMFS with vessel activity and seal and cetacean sighting information. Incident reports of polar bears or walruses within the acoustic safety radii or 800 m distance were also required to be submitted to USFWS within 24 h.

Safety Zones.—Trained observers monitored and implemented appropriate mitigation measures for safety zones for cetaceans and walrus (≥180 dB) and seals and polar bears (≥190 dB), as described in the IHA and LOA (Appendices A and B, respectively). Before SSV results were available, NMFS stipulated that the 180 dB and 190 dB zones should be 492 m (0.3 mi) and 180 m (0.1 mi), respectively. These safety zones applied to both the 880 in^3 array and the single airgun in all water depths. New 180 and 190 dB marine mammal safety zones for both shallow (shoreward of the barrier islands) and deep (seaward of the barrier islands) water areas within the seismic survey area were implemented for the *Wiley Gunner* and *Shirley V* on 8 August and 22 August, respectively, following analysis of the field verification measurements. Safety zone estimates for the *Peregrine* were implemented based on the SSV results conducted during BP's Liberty project. Chapter 3 presents the results of the SSV and Table 4.1 presents all of the nominal safety radii for each source vessel.

Mitigation Source.—The smallest airgun in each vessel's airgun array was used as a mitigation source whenever possible to alert marine mammals to the presence of airgun sounds. On the *Wiley Gunner* and *Shirley V*, the mitigation source had a volume of 20 in^3. During periods when a single airgun with a larger volume than 20 in^3 was used during line changes, the larger 880 in^3 array safety zone was implemented by MMOs. The *Peregrine*'s mitigation source had a volume of 70 in^3. In some cases, the airgun array was completely shut-down during line changes when seismic lines were ~19 m (60 ft) apart and the vessel could start a new line in less than 10 min.

***Ramp-up Procedures*.—**Ramp-up involved the gradual increase in the number of activated airguns over a nominal 30 min period. A gradual increase in sound level is intended to alert marine mammals to the presence of airgun sounds and provide an opportunity for them to move away before the array reaches full volume. Ramp-up was required to proceed at no greater than a 6 dB increase in SPL per five minute period, starting with the smallest airgun in the array and adding additional airguns in sequence until the full array was activated. Ramp-up was required whenever seismic operations were commencing or if the array had been powered or shut-down for greater than 10 min. A 30 min watch of the safety zones by at least one MMO was required prior to the commencement of ramp-up when: *(a)* seismic operations were commencing, and *(b)* at any time airguns were shut-down for 10 min or more and the MMO watch was suspended. Ramp-up was delayed anytime that the complete safety radii were not visible for at least 30 min prior to ramp-up. Ramp-up was not permitted if the full 180 dB safety zone was not visible (e.g., due to darkness or fog), unless the array had been operating with a sound source of at least 180 dB.

Power-down/Shut-down.—Mitigation power- and shut-downs were implemented whenever a marine mammal was observed within or about to enter the relevant safety radius when the airguns were operating. A power-down is a reduction in active airguns down to the mitigation source (described above), whereas a shut-down is a complete termination of all airgun activity. Mitigation power- and shut-downs were implemented as follows:

- A power-down occurred when a marine mammal was observed outside but approaching the appropriate nominal safety radius of the full airgun array but would be outside of the (smaller) mitigation source radius, or if a polar bear or a walrus was sighted within the 800 m (0.5 mi) exclusion zone;

Table 4.1. Summary of SSV results (distances in meters) for the (A) *Wiley Gunner*, (B) *Shirley V*, and (C) *Peregrine* airgun arrays and single airgun in "deep" and "shallow" waters sea- and shoreward, respectively, of the barrier islands.

Sound Level Radius (dB)	Pre-SSV[a]		Post-SSV (72-h Report/Final Report)			
	All Depths		Deep Water		Shallow Water	
(A) *Wiley Gunner*	880 in^3 airgun array	20 in^3 airgun	880 in^3 airgun array	20 in^3 airgun	880 in^3 airgun array	20 in^3 airgun
190	203	203	185/180	87	266/270	236/41
180	492	492	466/440	207/210	425/430	352/120
170	-	-	1122/1100	483/480	680	527/360
160	-	-	2484/2400	1088/1100	1088/1100	787/870
120	-	-	17987/21000	11848/12000	7125/7100	3924/2400

	Deep Water		Shallow Water		Deep Water		Shallow Water	
(B) *Shirley V*	880 in^3 airgun array	20 in^3 airgun	880 in^3 airgun array	20 in^3 airgun	880 in^3 airgun array	20 in^3 airgun	880 in^3 airgun array	20 in^3 airgun
190	185	87	266	236	164/160	73	272/270	6
180	466	207	425	352	546/550	157/160	430	67
170	-	-	-	-	1604/1600	338/340	868/870	294/290
160	-	-	-	-	3805/3800	718/720	1612/1600	640
120	-	-	-	-	21816/22000	9410/9400	7863/7900	2334/2300

		All Depths		
(C) *Peregrine* [b]		880 in^3 airgun array	440 in^3 airgun array	70 in^3 airgun
190	NA	300	250	100
180	NA	800	550	200
170	NA	1650	1200	600
160	NA	1700	1450	1400
120	NA	4100	8600	9000

[a] Safety radii specified in the IHA (see Appendix A) and used prior to the SSV results availability. Post-SSV safety radii were used starting on 8 August and 22 August 2008 for the *Wiley Gunner* and *Shirley V*, respectively.

[b] The SSV for the *Peregrine* was conducted in July 2008 at Foggy Island, just east of the OBC/TZ seismic survey area in the Beaufort Sea. Another SSV was not conducted within the ENI/PGS OBC/TZ survey area. The values reported here were based on the field report values provided in Kim and Greene (2008). The final acoustic report (presented in Aerts et al. 2008) was unavailable during preparation of this report.

- A shut-down could occur via two scenarios:
  - An immediate shut-down occurred whenever a marine mammal was first observed within the nominal safety radius of the mitigation airgun, and
  - After a power-down of the full array to the mitigation source, and the animal was still observed traveling towards or about to enter the reduced (mitigation airgun) safety radius;
- After a power-down or shut-down was implemented, ramp-up was delayed until there was visual confirmation that the marine mammal had cleared the safety zone. Alternatively, ramp-up could proceed if no marine mammal was detected within the appropriate safety zones for a minimum of 15 min (for polar bears, walruses, small odontocetes, and seals) or 30 min (for mysticetes) and the MMO had observed the safety zone for at least 30 min; and

- Emergency shut-downs were required if there were any observations that an injured or dead marine mammal was in the seismic area. For polar bears and walruses, seismic operations could not resume until the incident was reviewed by the Service Incidental Take Coordinator at USFWS. For all other marine mammals, ramp-up could proceed if the lead MMO could certify the animal had been deceased for at least 72 h or that the injury or death resulted from something other than the seismic survey. In both cases, the on-site manager was required to contact NMFS within 24 h. If the animal was not deceased for greater than 72 h or the lead MMO was unable to determine alternative causes of death or injury, the airgun array could not be restarted until NMFS reviewed the circumstances and provided approval.

Cetacean Monitoring and Mitigation After 24 August.—The IHA also specified measures for cetacean monitoring and mitigation from 25 August until the end of the seismic program, which coincided with periods of offshore bowhead whale migrations (and the subsistence hunt for bowheads by Nuiqsut residents). These provisions included:

- Airguns were required to shut-down whenever aggregations of 12 or more balaenopterid whales were observed within a 160 dB radius. Ramp-up could not proceed until two consecutive aerial or vessel surveys confirmed that no such aggregations were within the 160 dB zone;
- Airguns were required to shut-down whenever four or more bowhead whale cow/calf pairs were detected during aerial surveys within a 120 dB zone of the source vessel. Ramp-up would be delayed until two consecutive aerial surveys could confirm that no more than three bowhead whale cow/calf pairs were observed within the area to be surveyed by the airgun array within the next 24 h; and
- Seismic operations had to occur shoreward of the barrier islands from 25 August until the end of the bowhead hunt by Nuiqsut residents.

Aerial Monitoring and Mitigation

The IHA also specified that aerial surveys of the seismic survey area and nearby waters were required for at least three days per week beginning August 25, weather permitting, until the end of seismic operations (Appendix A). The objectives of the aerial program were to:

- Detect aggregations of 12 or more balaenopterid whales or four bowhead cow/calf pairs within the nominal 120 or 160 dB sound radii, respectively, of source vessels. In these cases, the aerial surveyor would immediately contact the MMO aboard the source vessels to request any required mitigation;
- Monitor the presence, distribution, and behavior of marine mammals near the seismic operations, particularly migrating bowhead whales; and
- Document the extent and duration of any potential bowhead whale responses to seismic activities.

Monitoring

Aerial surveys were conducted a minimum of three times per week, weather permitting, from 25 August to 27 September 2008. Nine transects oriented north-south, ranging in length from 68 to 112 km (42 to 70 mi), were surveyed from a Twin Otter aircraft for marine mammals near the Eni/PGS seismic survey area. Surveys were conducted at a nominal altitude of 305 m (1000 ft) and at a ground speed of ~110 kt.

Two primary observers and up to two secondary observers conducted the aerial surveys. During a marine mammal sighting, species, number of individuals, sighting cue, size, sex and age class, activity state, heading, swimming speed, and inclinometer reading were recorded. Time, sighting conditions, Beaufort wind force, sea ice conditions, and sun glare were also recorded every 2 min along the transect. If required, aerial surveyors would have contacted MMOs aboard the source vessels to shut-down airgun activity for the presence of aggregations of balaenopterid whales or cow/calf pairs within the 120 or 160 dB radii, respectively. Additional information on aerial survey methods, data analysis, and results are presented in Chapter 7.

Mitigation

The following mitigation measures applied to the aerial survey program:

- A 1,000 ft altitude (305 m; aircraft) and 500 lateral yard (457 m; hovering helicopters) zone was maintained around whales. Under poor weather conditions, aircrafts could operate below 1,000 ft (305 m) but known whale concentrations and flying directly over or within 500 yd (457 m) of a group of whales were to be avoided. Aircrafts were to be flown at a nominal ground speed of 100 kt.
- At least four trained observers and the pilot surveyed for aggregations of balaenopterid whales and cow/calf pairs. The lead observer would contact the seismic source vessel MMO on watch whenever an aggregation of 12 or more whales or four or more bowhead whale cow/calf pairs were seen within the 160 or 120 dB zones, respectively. An aggregation of 12 whales was judged as 12 whales seen within a circular area with a 15 km diameter.

Literature Cited

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Kim, K.H. and C. Greene. 2008. Field reports for sound source verification of the 880 in3, 440 in^3 airgun arrays and the 70 in^3 airgun on M/V *Peregrine* in Foggy Island Bay.

5. VESSEL-BASED MARINE MAMMAL MONITORING AND MITIGATION: ANALYSIS AND RESULTS FOR SEALS AND CETACEANS

This chapter provides the results of vessel-based marine mammal monitoring and mitigation during the Eni/PGS project as it pertains to seals and cetaceans covered under the IHA issued by NMFS (Appendix A). A description of post-season data processing and analysis techniques is provided. Sightings of seals (ringed, bearded, and spotted seals) and cetaceans (bowhead and beluga whales and harbor porpoise) made during aerial surveys are described in detail in Chapter 7. Additional incidental sightings of seals made while MMOs were off-watch or from a non-source vessel are not included in this chapter, but are described in Appendix E.

Status of Seals and Cetaceans in the Area

The ringed, spotted, and bearded seal, bowhead, beluga, and gray whales and harbor porpoise are all known to occur within the Beaufort Sea, although not all are common in the shallow and nearshore regions where the Eni/PGS survey occurred. Of these, the bowhead whale is listed as endangered under the ESA. The known abundance, habitat, and conservation status of each of these species is summarized below and in Table 5.1.

Ringed Seal

Ringed seals are circumpolar in distribution, with year-round residency in the Beaufort Sea. They are well adapted to using seasonal and permanent ice throughout the year, and appear to prefer large ice floes in areas with greater than 90% sea ice coverage (Simpkins et al. 2003). During the winter, they maintain winter ice lairs built into accumulated snow for resting and pupping (Smith and Stirling 1975). Pupping and breeding occurs in the spring, and surveys in the Chukchi Sea indicate that the highest spring densities occur in nearshore fast and pack ice (Bengston et al. 2005). Ringed seals disperse as singles or in small groups throughout open-waters during the summer and also appear to move into coastal areas of the Beaufort Sea (Moulton and Lawson 2002). They are the most abundant marine mammal in the Alaskan Beaufort Sea.

A single stock of ringed seals is recognized by NMFS, but a reliable abundance estimate is not currently available (Anglis and Outlaw 2008). Anglis and Outlaw (2008) suggest there is a minimum of 249,000 ringed seals in Alaskan waters. Ringed seals were the most commonly encountered seal (94.8% of all identified seals) during open-water seismic marine mammal monitoring programs conducted in the nearshore waters of the central Alaskan Beaufort Sea from 1996-2001 (Moulton and Lawson 2002). Ringed seals in Alaska are not considered a strategic stock by NMFS.

Spotted Seal

Spotted seals are found along the continental shelf in the Beaufort, Chukchi, Bering, and Okhotsk seas. Alaskan spotted seals are primarily centered in the Bering and Chukchi Seas during the winter, but some range into the Beaufort Sea. They appear to prefer coastal areas and small ice floes close to the ice edge during the winter and spring (Simpkins et al. 2003). Pupping, breeding, and molting all occur at the ice edge in the spring before seals move to nearshore haulout locations on islands and spits during the summer and fall open-water season, particularly in the Beaufort and Chukchi seas (Lowry et al. 1998; Lowry et al. 2000; Anglis and Outlaw 2008).

TABLE 5.1. Habitat, abundance, and conservation status of seals and cetaceans that occur in the central Alaska Beaufort Sea.

Species	Habitat during open-water season[a]	Abundance in Survey Area[b]	ESA[c]	IUCN[d]	CITES[e]
Seals					
Ringed seal (*Phoca hispida*)	Coastal	249,000[f]	NL	LC	N.A.
Spotted seal (*Phoca largha*)	Coastal	59,214	NL	DD	N.A.
Bearded seal (*Erignathus barbatus*)	Continental shelf edge < 200 m depth	NR	NL	LC	N.A.
Cetaceans					
Bowhead whale (*Balaena mysticetus*)	Continental shelf	10,545	E	LC	I
Beluga whale (*Delphinapterus leucas*)	Offshore pack ice	39,258[g]	NL	NT	II
Gray whale (*Eschricitius robustus*)	Shallow coastal waters	18,813[h]	NL	LC	I
Harbor porpoise (*Phoecena phoecena*)	Shallow coastal waters	66078[i]	NL	VU	II

[a]Open-water season refers to the summer and fall period when there is no land-fast ice present. The Eni/PGS survey coincided with the open-water season.
[b]Abundance estimates for the 'Alaska stock' taken from Anglis and Outlaw (2008), unless otherwise noted. NR means no reliable estimate is available.
[c]Endangered Species Act. Codes for ESA: E = Endangered; T = Threatened; NL = Not listed.
[d]IUCN Red List of Threatened Species (2008). Codes for IUCN classifications: EX = Extinct; EW = Extinct in the Wild; CR =Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient; NE = Not Evaluated
[e]Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (UNEP-WCMC 2008). Codes for CITES: Appendix I = threatened with extinction, and controlled trade; II = not necessarily threatened with extinction, but trade is controlled; III = protected in at least one country
[f]There are no current estimates specific to the Bering Sea population, but an estimate of 18,000 hauled out seals were surveyed from Barrow to Kaktovik by Frost et al. (2002).
[g]For the Beaufort Sea stock.
[h]For the eastern North Pacific stock.
[i]For northeast Pacific Ocean population.

A single stock of spotted seals is recognized by NMFS, but a reliable abundance estimate is not currently available (Anglis and Outlaw 2008). Aerial surveys were flown in 1992 and 1993 over the Bering Sea pack ice in spring and along the western coast of Alaska during summer; after applying correction factors to the maximum count in 1992, Anglis and Outlaw (2008) provide an estimate of 59,214 Alaskan spotted seals. A few spotted seal haul out sites exist in the central Beaufort Sea, including a site at the delta of the Colville River west of the Eni/PGS survey area. Between 1996 and 2001, a total of 12 spotted seals (0-4 per open-water season or 1.3% of all identified seals) were identified during marine mammal monitoring programs in the nearshore waters of the central Alaskan Beaufort Sea (Moulton and Lawson 2002). Spotted seals in Alaska are not considered a strategic stock by NMFS.

Bearded Seal

The bearded seal is a circumpolar ice-associated seal. Bearded seals are typically found in waters less than 200 m (656 ft) deep, and prefer transitional ice types with small to large ice floes and between 70 and 90% sea ice coverage (Simpkins et al. 2003; Bengston et al. 2005). They have a broad summer distribution, rarely hauling out on land and sometimes summering along the ice edge in the Chukchi Sea

(Anglis and Outlaw 2008). Somewhat less preferable habitat is found in the Beaufort Sea during the open-water season since the pack ice edge occurs seaward of the continental shelf and over waters greater than 200 m (656 ft) deep.

A single stock of bearded seals is recognized by NMFS, but a reliable abundance estimate is not currently available (Anglis and Outlaw 2008). Between 1996 and 2001, a total of 36 bearded seals (0-23 per open-water season or 3.9% of all identified seals) were identified during marine mammal monitoring programs in the nearshore waters of the central Alaskan Beaufort Sea (Moulton and Lawson 2002). Some Alaskan Inupiat hunters from the village of Nuiqsut typically hunt bearded seals near Thetis Island, and note that they sight 50 to 75 bearded seals and harvest ~20 bearded seals per summer (ASRC 2008). Bearded seals in Alaska are not considered a strategic stock by NMFS.

Bowhead Whale

There are five stocks of bowhead whales recognized by NMFS, but the Western Arctic Stock found in the Bering, Chukchi and Beaufort seas is considered the largest (Anglis and Outlaw 2008). This population migrates annually between wintering areas in the northern Bering Sea and summering areas in the Canadian Beaufort Sea (Moore and Reeves 1993). During the summer, this population is typically found in ice-free open waters of the southern Beaufort Sea (Richardson et al. 1987). Their fall migration through the Alaskan Beaufort Sea occurs along the continental shelf (Moore 2000), typically within 55 km (34 mi) of shore during years with light or moderate sea ice conditions (Treacy et al. 2006).

All stocks of bowhead whales were depleted during intense industrial whaling. The Western Arctic Stock is currently estimated to be 10,545 individuals and has been increasing at an annual rate of ~3.5% (Anglis and Outlaw 2008). The bowhead whales is listed as Endangered under the ESA and, therefore, the Western Arctic Stock is also considered a strategic stock by NMFS and “depleted” under the MMPA.

Beluga Whale

Five stocks of beluga whales are recognized by NMFS, but only the distributions of the Beaufort Sea and possibly Eastern Chukchi Sea stocks overlap with the Eni/PGS survey area. The Beaufort Sea stock winters in the offshore pack ice of the Chukchi Sea and migrates to the Canadian Beaufort Sea during the summer (Anglis and Outlaw 2008). During August and September, this population migrates westward along the offshore continental shelf of the Beaufort Sea (Richard et al. 2001). During the westward migration, very small numbers of beluga whales are sometimes seen near the north coast of Alaska. However, late summer and autumn surveys show that most beluga whales migrate far offshore along or beyond the pack-ice front (Frost et al. 1988; Hazard 1988; Clarke et al. 1993; Miller et al. 1998).

Beluga whales were most recently surveyed in July 1992, and an estimate of 19,629 individuals was reported (Harwood et al. 1996). The current estimate of 39,258 individuals was derived after application of a correction factor for availability, but the current population trend is unknown (Anglis and Outlaw 2008). The Beaufort Sea Stock of beluga whales is not classified as a strategic stock by NMFS.

Gray Whale

Gray whales were once found in both the North Atlantic and Pacific Oceans, but now only occur in the North Pacific. The Eastern North Pacific Stock ranges from Baja California in Mexico during the winter for calving, to the west coast of North America during spring and late fall migrations, and in recent years, as far north as the Bering, Chukchi, and Beaufort seas during the summer foraging period (Anglis and Outlaw 2008). Gray whales prefer shallow waters for benthic feeding and are often observed close to shore during the summer. Although they are common summer residents in the nearshore waters of the eastern Chukchi Sea, they are only occasionally seen in the Beaufort Sea east of Point Barrow in late summer (ASRC 2008).

Gray whales were once targeted by industrial whaling, but the Eastern North Pacific Stock has recovered significantly. Gray whales have been systematically counted during their southerly migrations along the California coast since 1967; the current population estimate is 18,813 individuals (Anglis and Outlaw 2008). The population has been increasing for several decades and was removed from the ESA in 1994. The Eastern North Pacific Stock is currently not classified as a strategic stock by NMFS.

Harbor Porpoise

The harbor porpoise is a small odontocete that inhabits shallow, coastal waters—temperate, subarctic, and arctic—in the Northern Hemisphere (Read 1999). The subspecies *Phoecena phoecena vomerina* ranges from the Chukchi Sea, Pribilof Islands, Unimak Island, and the southeastern shore of Bristol Bay south to San Luis Obispo, California. Point Barrow, Alaska, is the approximate northeastern extent of their typical range (Suydam and George 1992), though there are extralimital records east to the mouth of the Mackenzie River in the Northwest Territories, Canada and recent sightings in the Beaufort Sea in the vicinity of Prudhoe Bay during surveys in 2007 and 2008 (Lyons et al. 2008; see Chapter 7). MMOs onboard industry vessels reported one harbor porpoise sighting in the Alaskan Beaufort Sea in 2006 and no sightings were recorded in 2007 (Jankowski et al. 2008). Monnett and Treacy (2005) did not report any harbor porpoise sightings during aerial surveys in the Beaufort Sea from 2002 through 2004.

Aerial surveys in 1999 were conducted in Bristol Bay, and resulted in an uncorrected abundance estimate for the Bering Sea stock of 16,271 (Anglis and Outlaw 2008). Anglis and Outlaw (2008) estimated that the corrected abundance estimate is 66,078, but this estimate is considered conservative since surveys did not encompass large portions of this stock's potential range. The Bering Sea stock is classified as a strategic stock by NMFS because population estimates are based on relatively old abundance estimates and there is a poor understanding of potential incidental mortality from fisheries.

Data Analyses

The observer effort and marine mammal sighting data were categorized by vessel activity and sighting conditions similar to the approach used during other recent seismic studies in the Alaskan Beaufort Sea (e.g., Aerts et al. 2008; Funk et al. 2008). To limit biases that may influence the ability of MMOs to detect marine mammals, analyses were restricted to effort and sightings collected during periods termed "daylight effort." "Daylight effort" was defined as MMO effort occurring during daylight conditions (excluding darkness) with Bf <6, visibility ≥1 km (0.6 mi), and no to moderate glare. Of note, all marine mammal sightings were made during periods of "daylight effort", and thus, none were excluded in the results described in the sections below.

Seismic State Categories

For comparisons of behavior and sighting distance of marine mammals relative to seismic activity, data were categorized as seismic, post-seismic, or non-seismic for each of the three source vessels (*Wiley Gunner*, *Shirley V*, and *Peregrine*). The seismic category included all periods when one or more airguns were operating, including periods of data acquisition (line shooting), ramp-ups, power-downs, seismic testing, and use of the mitigation airgun. If one source vessel (a primary vessel) had active airguns, but there was a secondary source vessel within 5 km (3.1 mi) with no airguns activated, the secondary vessel's seismic state was also considered as "seismic". Post-seismic periods included periods up to one hour after the cessation of all airgun(s). Non-seismic periods included all data when the airguns were silent with the exception of the period three minutes to one hour after the airgun(s) were deactivated.

Post-seismic data were excluded from statistical analyses which compared seismic and non-seismic data because it is assumed that animal responses to seismic pulses diminish with time after airgun cessation. This assumption is based on studies showing that pinnipeds show limited behavioral responses to seismic sound (e.g., Harris et al. 2001; Moulton and Lawson 2002) and return to "normal" behavior relatively quickly (Gordon et al. 2004). However, the rate of return to "normal" behavior following exposure to seismic sounds is not well known. Thus, the post-seismic period was defined to be sufficiently long enough to ensure that there were no behavioral and distributional effects of exposure for sightings made during non-seismic periods.

Other Considerations

Environmental conditions, such as poor visibility, glare, and sea state could also potentially affect the ability of MMOs to identify marine mammals, particularly seals, to species level. Vessel speed and varying heights of MMOs asl among the different source vessels can also contribute to the ability to detect marine mammals. Some pinniped species, particularly ringed and spotted seals, can be difficult to distinguish. Seals were often only at the surface for a short period of time, further complicating species identification. Thus, seals that could not be reliably identified were classified as unidentified seals.

We have not accounted for the potential confounding effects of other industrial activity (e.g., at Pioneer's Oogurak site) within the Eni/PGS seismic survey area on marine mammals. This was considered beyond the scope of this 90-day report.

Estimated Number of Exposures

When NMFS issues an IHA, it is assumed that any cetacean or pinniped potentially exposed to seismic pulses with received levels ≥180 or 190 dB re 1µPA (rms), respectively, may have experienced hearing impairment. Additionally, disturbance to animals could occur at distances greater than the 180 or 190 dB safety radii if marine mammals were exposed to moderately strong seismic pulses. Accordingly, NMFS assumes that marine mammals exposed to sounds with received levels ≥160 dB re 1µPA (rms) may be disturbed appreciably.

The actual number of animals observed within the applicable 190, 180, and 160 dB radii during seismic periods is assumed to be the estimated *minimum* number of marine mammals that could have been exposed to seismic pulses with these received sound levels. However, not all of the marine mammals present within these zones were visible to MMOs in darkness periods, or sometimes during daylight. Thus, the application of the actual number of animals observed within nominal sound level radii does not account for all marine mammals potentially present.

Indirect estimates of the number of marine mammals exposed to seismic pulses can be calculated based on the estimated density of marine mammals in the area. Typically densities of each species are calculated using line transect methodology for seismic surveys and then used to estimate the number of marine mammal exposures to seismic sounds (e.g., Haley et al. 2008). However, line transect calculation of densities is inappropriate for the vessel-based portion of the Eni/PGS survey given the slow vessel speeds, sometimes stationary vessels, and closely spaced seismic lines (see Fig. 5.1). Rather, indirect estimates of exposures can be made based on estimates of animal density for observer effort within a given distance from the vessel, as done for similar OBC types of seismic surveys (e.g., Moulton and Lawson 2000, 2001, 2002). The procedures used to obtain density estimates and the minimum and maximum estimated numbers of marine mammal exposures presented later in this chapter are described in *Estimated Number of Seals and Cetaceans Potentially Affected*.

Monitoring Results

This section summarizes the monitoring effort and seal and cetacean sightings from the *Wiley Gunner, Shirley V,* and *Peregrine* during the Eni/PGS survey conducted from August through late September 2008. General data summaries of effort and sightings are provided in Appendix D. Appendix

E provides information on incidental sightings of marine mammals (not included in the following analyses) that occurred from non-source vessels or while MMOs were considered "off-watch."

Survey Effort

A total of 1268 h (4912 km) of marine mammal monitoring occurred during the Eni/PGS seismic survey, including 245, 576, and 447 h (757, 2434, and 1721 km) from the *Wiley Gunner, Shirley V,* and *Peregrine*, respectively (Fig. 5.1; Table 5.2). Of those observations, ~67% (853 h; 3278 km) were considered as "daylight effort" useable for analyses, and occurred during daylight conditions with Bf <6, visibility ≥1 km (0.6 mi), and no to moderate glare (Fig. 5.2; Table 5.2). Most (~66%) of the 415 h that were excluded from analyses were due to watches that occurred during darkness; a combination of darkness and poor visibility accounted for another 18%, poor visibility accounted for 11%, severe glare accounted for 3%, Bf >5 accounted for 1%, and combinations of these factors accounted for the remaining effort that were excluded from analyses. The *Shirley V* was the only source vessel where seismic effort contributed from a secondary source vessel influenced its total amount of seismic effort. About 4% (12.1 h) of the total *Shirley V* seismic "daylight effort" was attributable to a secondary source vessel operating its airguns within 5 km of the *Shirley V*. Only sightings and effort during "daylight" conditions were considered in the following analyses. Since the seismic survey covered a relatively small marine area (303 km^2 / 117 mi^2) and vessels were often traveling slowly or were anchored during MMO observations, effort for all of the following analyses will be considered based on hours of observation rather than kilometers surveyed.

Seismic, post-seismic, and non-seismic periods made up 64, 6, and 30% (547, 52, and 253 h) of the effort during "daylight" conditions, respectively (Fig. 5.2; Table 5.2). Of the 853 h of "daylight effort", 82% occurred in Beaufort wind force 3 or less (Fig. 5.3). Just over half (58%) of "daylight effort" occurred in the "deep" waters seaward of the barrier islands vs. "shallow" waters shoreward of the barrier islands (Fig. 5.4). There were two and three MMOs on-watch during 59% (475 h) and 37% (293 h), respectively, of "daylight effort" periods; otherwise, a single MMO was on-watch (Fig. 5.5).

Species Composition and Distribution

A total of 38 seal sightings (total of 38 individuals) and one cetacean sighting (of three unidentified mysticetes) were made from source vessels during the Eni/PGS seismic survey (Table 5.3; Fig. 5.1). Of those, ~62% (24 of 39 sightings), 28% (11 sightings), and 10% (4 sightings) were made from the *Wiley Gunner*, *Shirley V*, and *Peregrine*, respectively (Table 5.3). Over half of the seal sightings (52% of 38 sightings) were of unidentified seals, ~18% were of bearded or spotted seals (7 sightings, each), and ~11% (4 sightings) were of ringed seals (Table 5.3; Fig. 5.6). Based primarily on body size and abundance in the area, it is likely that unidentified seals were either spotted or ringed seals but this was not differentiated in the field.

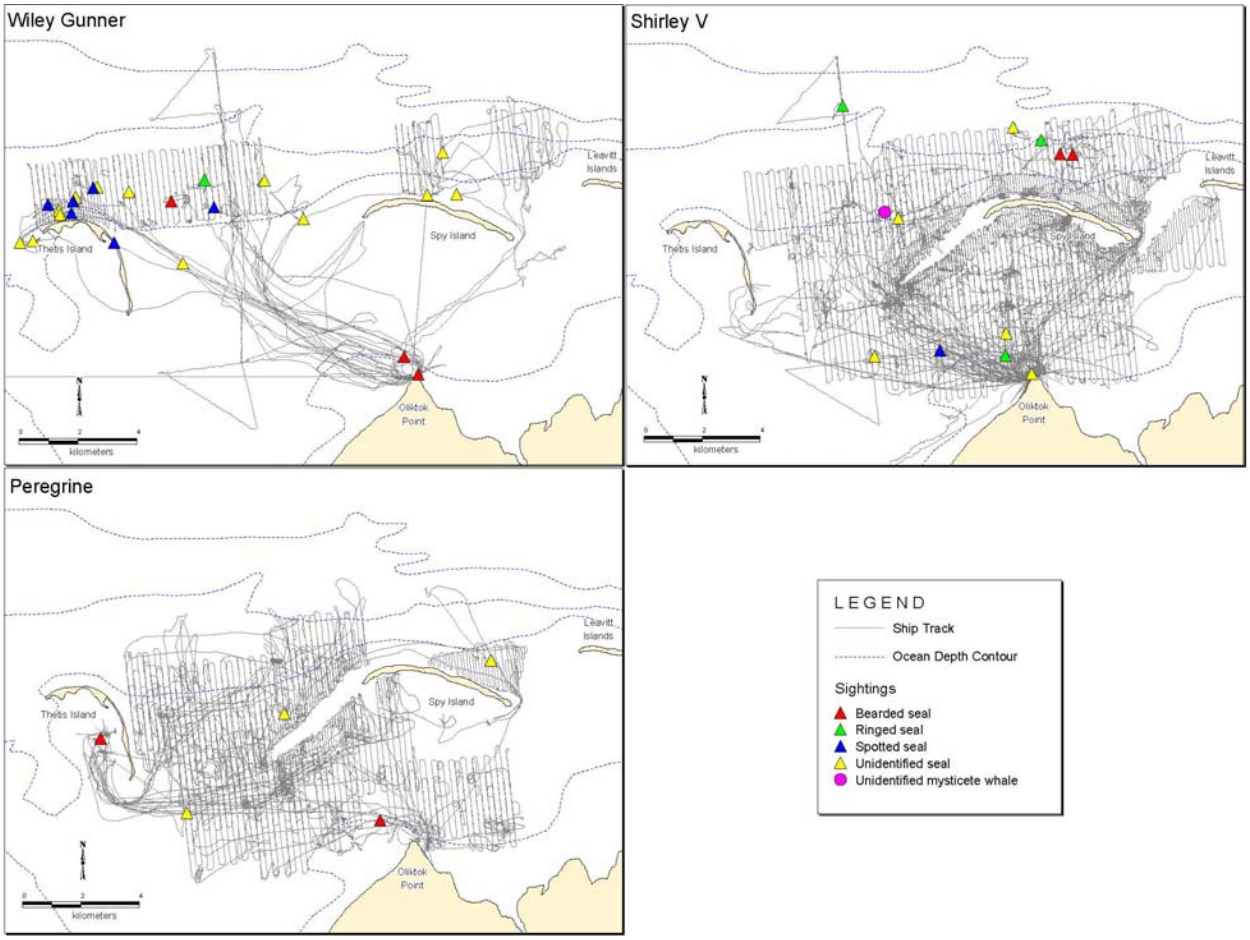

FIGURE 5.1. Seal and cetacean sightings made from the *Wiley Gunner*, *Shirley V*, and *Peregrine* during the Eni/PGS seismic survey, August-September 2008, central Alaska Beaufort Sea. Specific locations shown are those where the source vessels were located at the time of the sighting.

All seal and cetacean sightings were made during watches in “daylight conditions”. As such, the following analyses do not exclude any sightings based on environmental conditions. More seals were sighted in August than September (~82% or 31 of 38 sightings), and seal species composition seemed to vary between August and September (Fig. 5.7) but sample sizes of seals identified to species level were limited. In August, there were more seals identified as bearded (5) and spotted (7) than in September when there were 2 bearded seals and no sightings of spotted seals. Two ringed seals were seen in August as well as September.

TABLE 5.2. Summary of total marine mammal monitoring effort and "daylight effort" used for analyses from each source vessel.

	Seismic	Post-Seismic[a]	Non-Seismic	Grand Total
Operations in h				
MMO Effort				
Wiley Gunner	140.3	24.4	79.8	**244.6**
Shirley V	447.9[b]	33.4	95.0	**576.4**
Peregrine	197.8	19.3	230.2	**447.3**
Total	**786.1**	**77.1**	**405.1**	**1268.3**
Daylight Effort[c]				
Wiley Gunner	129.2	22.0	64.5	**215.7**
Shirley V	323.1[d]	23.5	76.6	**423.2**
Peregrine	95.0	6.8	112.2	**214.0**
Total	**547.3**	**52.4**	**253.3**	**852.9**
Operations in km				
MMO Effort				
Wiley Gunner	359.4	112.7	284.5	**756.7**
Shirley V	1994.9[e]	156.2	282.4	**2433.5**
Peregrine	1312.9	107.9	300.5	**1721.3**
Total	**3667.2**	**376.8**	**867.4**	**4911.5**
Daylight Effort				
Wiley Gunner	322.8	106.6	234.3	**663.6**
Shirley V	1418.7[f]	97.1	234.8	**1750.6**
Peregrine	656.5	31.6	175.2	**863.2**
Total	**2398.0**	**235.2**	**644.2**	**3277.5**

[a]Post-seismic is defined as 3 min to 1 h after seismic periods.

[b]This value includes 26.2 h of effort where another source vessel was within five km of the *Shirley V* with it's airguns activated.

[c]Daylight effort is defined as MMO effort during daylight conditions, Bf <6, visibility ≥1 km (0.6 mi), and with no to moderate glare.

[d]This value includes 12.1 h of effort where another source vessel was within five km of the *Shirley V* with it's airguns activated.

[e]This value includes 122.1 km of effort where another source vessel was within five km of the *Shirley V* with it's airguns activated.

[f]This value includes 61.0 km of effort where another source vessel was within five km of the *Shirley V* with it's airguns activated.

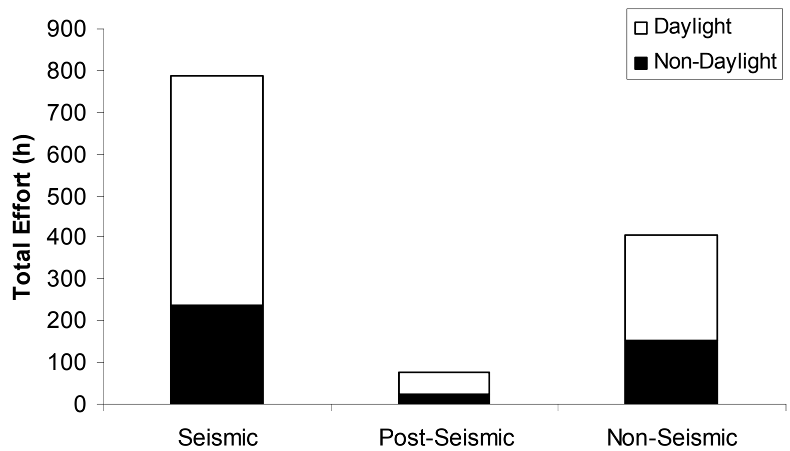

FIGURE 5.2. Total MMO effort categorized as “daylight effort” or “non-daylight” for each seismic state.

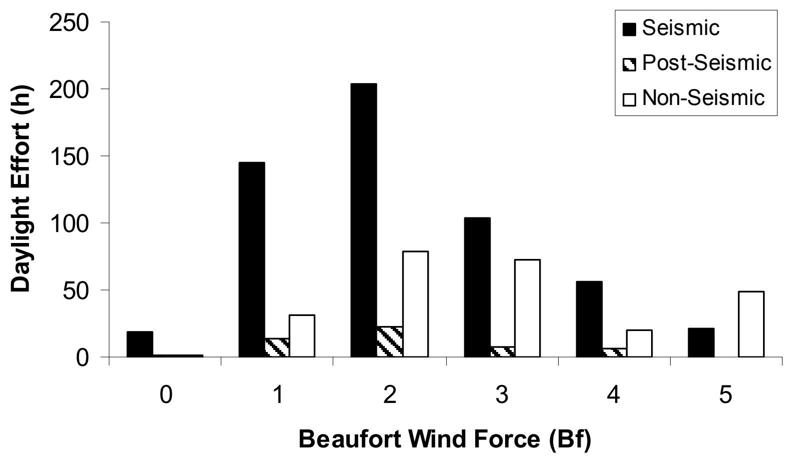

FIGURE 5.3. Total “daylight effort”, categorized by Beaufort wind force and seismic state.

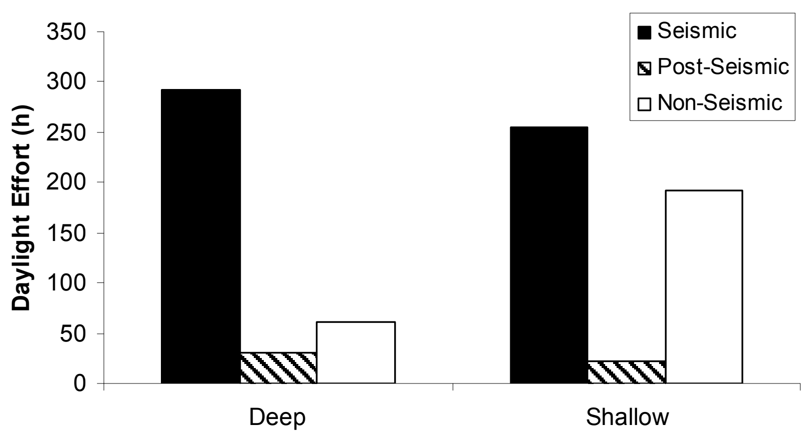

FIGURE 5.4. Total “daylight effort”, categorized by seismic state, for the “deep” areas seaward of the barrier islands and the “shallow” areas shoreward of the barrier islands.

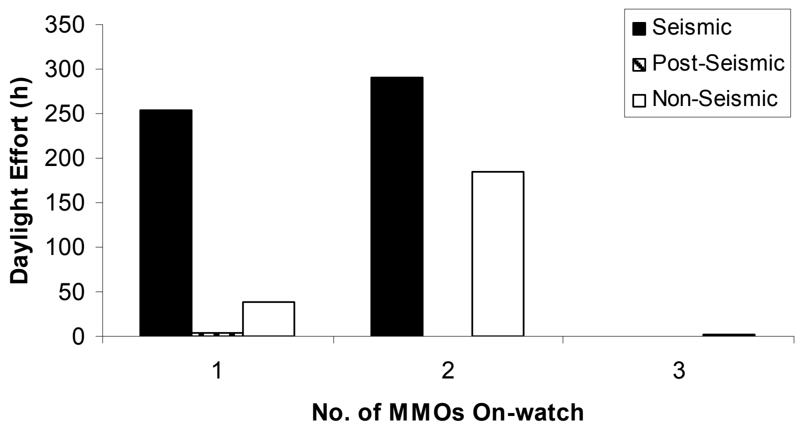

FIGURE 5.5. Total "daylight effort", categorized by seismic period, for the number of MMOs on-watch.

TABLE 5.3. Numbers of seals and cetaceans observed from the *Wiley Gunner*, *Shirley V*, and *Peregrine* by seismic state.

	Seismic		Post-Seismic[a]		Non-Seismic		Total	
Species	**Groups**	**Indiv.**	**Groups**	**Indiv.**	**Groups**	**Indiv.**	**Groups**	**Indiv.**
Wiley Gunner								
Bearded seal	0	0	1	1	2	2	**3**	**3**
Ringed seal	0	0	1	1	0	0	**1**	**1**
Spotted seal	1	1	1	1	4	4	**6**	**6**
Unidentified seal	7	7	1	1	6	6	**14**	**14**
Total	**8**	**8**	**4**	**4**	**12**	**12**	**24**	**24**
Shirley V								
Bearded seal	2	2	0	0	0	0	**2**	**2**
Ringed seal	3	3	0	0	0	0	**3**	**3**
Spotted seal	0	0	0	0	1	1	**1**	**1**
Unidentified seal	2	2	0	0	2	2	**4**	**4**
Unidentified mysticete	0	0	1	3	0	0	**1**	**3**
Total	**7**	**7**	**1**	**3**	**3**	**3**	**11**	**13**
Peregrine								
Bearded seal	0	0	0	0	2	2	**2**	**2**
Unidentified seal	2	2	0	0	0	0	**2**	**2**
Total	**2**	**2**	**0**	**0**	**2**	**2**	**4**	**4**
Total Seals								
Bearded seal	2	2	1	1	4	4	7	7
Ringed seal	3	3	1	1	0	0	4	4
Spotted seal	1	1	1	1	5	5	7	7
Unidentifed seal	11	11	1	1	8	8	20	20
Total Pinnipeds	**17**	**17**	**4**	**4**	**17**	**17**	**38**	**38**
Total Cetaceans	**0**	**0**	**1**	**3**	**0**	**0**	**1**	**3**
Grand Total	***17***	***17***	***5***	***7***	***17***	***17***	***39***	***41***

Note: There was one incidental sighting of a single unidentified seal that occurred while MMOs were not on-watch. Details are included in Appendix E. Three seals (one bearded and two unidentified) were also sighted during crew transport and are reported in Appendix E.
[a]Post-seismic is defined as 3 min to 1 h after seismic periods.

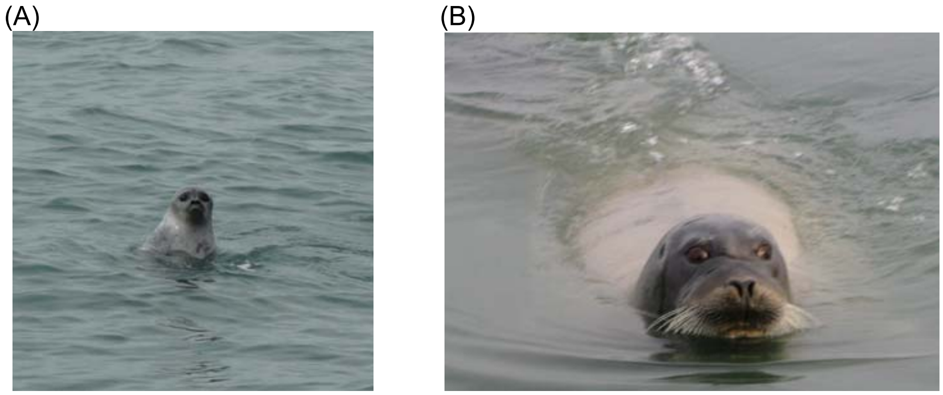

FIGURE 5.6. A ringed seal (A) and bearded seal (B) observed from the cable boats during the Eni/PGS seismic survey.

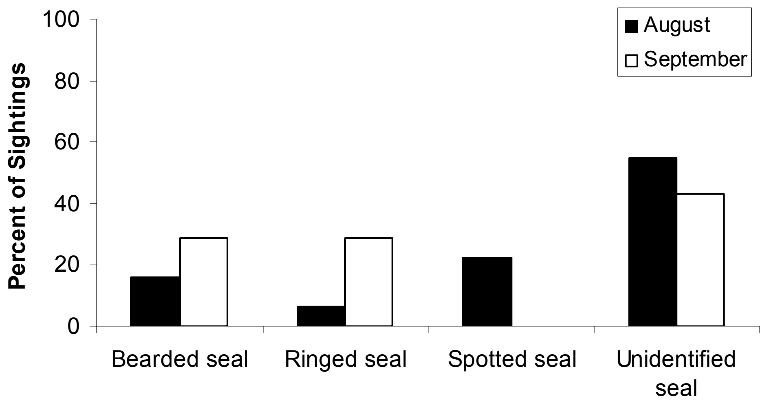

FIGURE 5.7. Percent of seal sightings (total n = 38) by species, during August and September 2008.

Sighting Abundance and Rates, With vs. Without Seismic

Cetaceans were not expected in the Eni/PGS survey and the one sighting of three unidentified mysticetes seen >3 km (1.6 mi) seaward of the barrier islands supported evidence that whales typically avoid the shallow waters of the Alaskan Beaufort Sea. No analyses of cetaceans were conducted.

As mentioned previously, data were standardized to number of seal sightings per (1000) hours of "daylight effort" to allow meaningful comparisons of the numbers of seals encountered during different seismic states.

Sightings by Seismic State

Of the 39 total marine mammal sightings, the only cetacean sighting (of three unidentified mysticetes) was made from the *Shirley V* during a post-seismic period (Table 5.3). There were an equal number of seal sightings during both seismic and non-seismic periods, each comprising ~45% (17 of 38, each) of the seal sightings (Table 5.3). The remaining four seal sightings were made during the post-seismic period (Table 5.3). Most sightings (62% of 17 sightings) made during non-seismic periods occurred from the *Wiley Gunner*, as did the greatest percentage of seal sightings during seismic periods (47% of 17 sightings Fig. 5.8). Most seal sightings were made in the "deep" waters seaward of the barrier islands (~76% of 38 sightings) vs. the "shallow" waters shoreward of the barrier islands, and the greatest percentage of "deep" water sightings occurred during seismic periods (~82% of 17 sightings; Fig. 5.9). All seal sightings during post-seismic periods were made in "deep" water, and more non-seismic seal sightings occurred in "deep" vs. "shallow" water (65% of 17 sightings; Fig. 5.9).

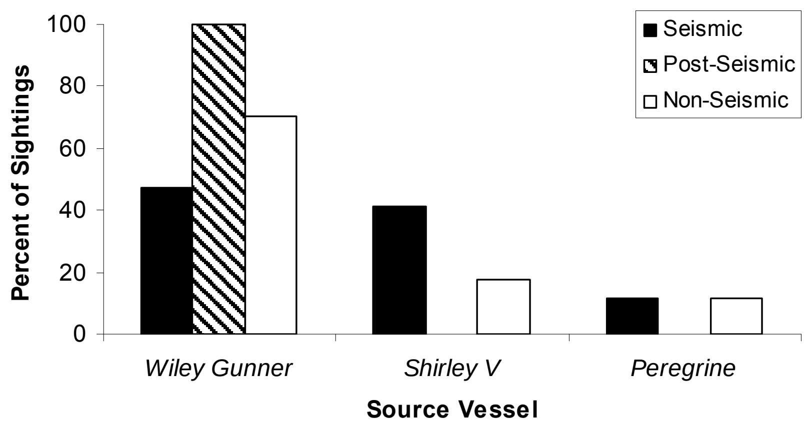

FIGURE 5.8. Percent of seal sightings (total *n* = 38) by source vessel made during seismic, post-seismic, and non-seismic periods.

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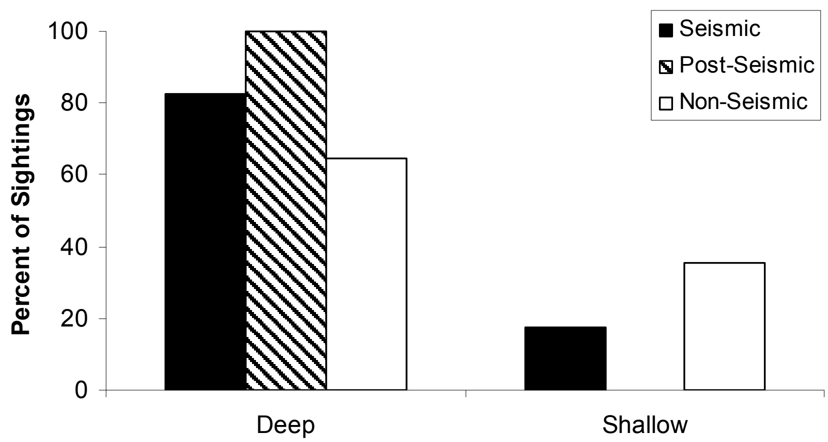

FIGURE 5.9. Percent of seal sightings (total *n* = 38) made during seismic, post-seismic, and non-seismic periods while in "deep" waters seaward of the barrier islands or "shallow" waters shoreward of the barrier islands.

A power-down was requested once during the Eni/PGS seismic survey due to bearded seal sighted near the 190 dB safety radius. Ten shut-downs of the then-operating airguns were implemented due to seals observed within or about to enter the 190 dB safety radius. Details of each of these shut-downs and power-down are included later in this chapter in *Implementation of Mitigation Measures*.

Sighting Rates

Sighting rates (number of sightings per unit of effort) for each seismic state are presented in Table 5.4. Sighting rates for bearded, spotted, and unidentified seals were greater during non-seismic than seismic periods, and, for most species, post-seismic sighting rates were also greater than those during seismic periods (Table 5.4). No ringed seals were sighted during non-seismic periods for comparisons. Considering all species combined, the seal sighting rate for non-seismic periods (67.1 seals/1000 h of "daylight effort") was significantly greater than the seismic rate (~31.1 seals/1000 h of "daylight effort"; χ^2 =13.22, df = 1, p <0.005; Table 5.4). The highest overall seal sighting rate (111.3 seals/1000 h of "daylight effort") was recorded from the *Wiley Gunner* vs. the *Shirley V* and *Peregrine* (23.6 and 18.69 seals/1000 h of "daylight effort", respectively; Fig. 5.10). Potentially, the *Wiley Gunner* had higher sighting rates due to its early August operations while the *Shirley V* and *Peregrine* operated in mid to late August through late September.

TABLE 5.4. Sighting rates (no./1000 h of "daylight effort[a]") of cetaceans and seals, categorized by seismic state.

	Seismic		Post-Seismic[b]		Non-Seismic		Total	
	No.	Sighting Rate (No./ 1000h)	No.	Sighting Rate (No./ 1000h)	No.	Sighting Rate (No./ 1000h)	No.	Sighting Rate (No./ 1000h)
Bearded seal	2	3.65	1	19.10	4	15.79	7	**8.21**
Ringed seal	3	5.48	1	19.10	0	0.00	4	**4.69**
Spotted seal	1	1.83	1	19.10	5	19.74	7	**8.21**
Unidentifed seal	11	20.10	1	19.10	8	31.58	20	**23.45**
All seals	*17*	*31.06*	*4*	*76.41*	*17*	67.11	*38*	**44.55**

[a]Daylight effort is defined as MMO effort during daylight conditions, Bf <6, visibility ≥1 km (0.6 mi), and with no to moderate glare. Daylight effort for calculation of seismic, post-seismic, non-seismic, and overall sighting rates was 547.3, 52.4, 253.3, and 853.0 h, respectively.
[b]Post-seismic is defined as 3 min to 1 h after seismic periods.

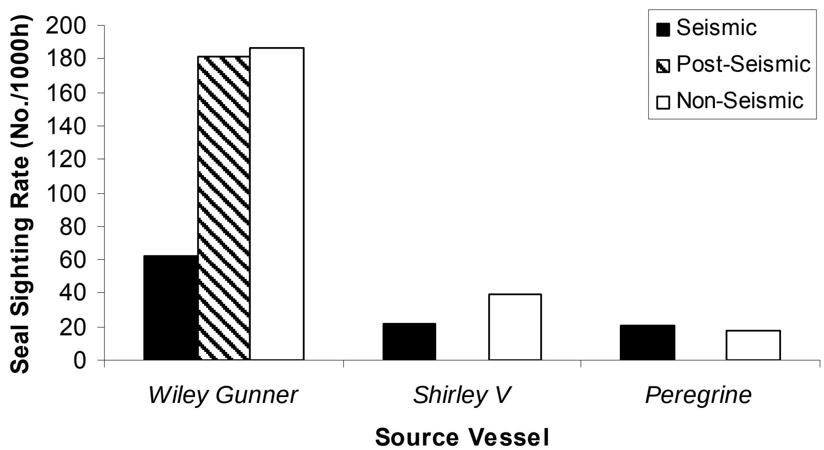

FIGURE 5.10. Sighting rates (no./1000 h of "daylight effort") of seals from source vessels, categorized by seismic state.

Overall seal sighting rates declined as Beaufort wind force increased. Seal sighting rates during seismic periods were similar among Beaufort wind forces, but sighting rates during non-seismic periods declined with increasing Beaufort wind force (Fig. 5.11). A decreasing sighting rate with increasing Beaufort wind force is typical for marine mammal surveys, since rougher sea conditions make it more difficult to detect animals, particularly small seals. Seals were only sighted at times when there was one (34% of 38 sightings) or two observers (66%) on-watch. Sighting rates for one vs. two observers were similar for both seismic (39.4 vs. 24.1 seals/1000 h of "daylight effort") and non-seismic periods (76.8 vs. 75.9 seals/1000 h of "daylight effort", respectively).

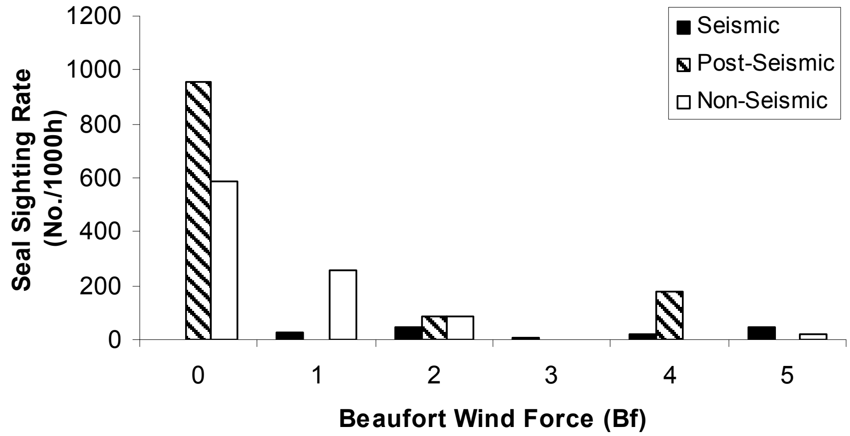

FIGURE 5.11. Sighting rates (no./1000 h of "daylight effort") of seals by Beaufort wind force, categorized by seismic state.

Sighting Distances and Behavior, With vs. Without Seismic

The analyses below provide information about behavioral responses of seals to the Eni/PGS seismic survey. The closest (observed) point of approach (CPA) to the airguns, animal movement, and initial and reaction behavior are relevant measures of behavioral response. Only one cetacean sighting was made of three unidentified mysticetes. Three blows were seen over three km from a source vessel while no airguns were active but within one hour of airgun cessation (post-seismic period). Only blowing behavior was observed, and no movement patterns could be determined. There was no obvious reaction by the unidentified mysticetes to the Eni/PGS survey operations.

Marine mammal behavior can be difficult to observe, particularly from a seismic vessel. Often individuals and/or groups are only seen briefly at the surface, and there may be some form of avoidance behavior. Thus, it can become difficult to identify and re-sight the same animal(s), especially when consecutive sightings are some minutes apart. The position of MMOs on the source vessels and the focus of their observation efforts toward the front of the vessel also generated a distribution of sightings that was skewed towards the front of the vessel.

Closest Observed Point of Approach

For seals, the average CPA was smaller during seismic (222 m) than non-seismic periods (327 m; Table 5.5). However, no significant differences in seal CPAs between seismic and non-seismic periods were found (Mann-Whitney Test; $U = 131$; $n = 17, 17$; $P = 0.642$). On average, seals were sighted closer to the airguns during seismic than non-seismic periods from the *Wiley Gunner* and *Peregrine* (Table 5.5). From the *Shirley V*, seals were sighted closer to the airguns during non-seismic than seismic periods (Table 5.5).

Movement

Movement patterns were determined for 37 of the 38 seal sightings. Most (70% or 26 sightings) were determined to be swimming away, eight (22%) had neutral movement, and three (8%) were swimming toward the vessel. Of the 16 sightings during seismic periods with movement assigned, most (69%) moved away from the vessel's path; 82% of the 17 non-seismic sightings were also of seals moving away from the vessel; and 50% of the four post-seismic sightings moved towards the path of the vessel (Fig. 5.12). These results suggest that, irrespective of seismic state, seals tended to move away from the source vessels

TABLE 5.5. The mean, s.d., minimum, and maximum closest point of (observed) approach (CPA) to the airguns for cetaceans and seals from source vessel, categorized by seismic, post-seismic, non-seismic periods.

	Seismic					Post-Seismic[a]					Non-Seismic				
	n	Mean CPA (m)	s.d.	Min.	Max.	*n*	Mean CPA (m)	s.d.	Min.	Max.	*n*	Mean CPA (m)	s.d.	Min.	Max.
Wiley Gunner															
Bearded seal	0	-	-	-	-	1	20.0	N/A	20	20	2	70.0	42.4	40	100
Ringed seal	0	-	-	-	-	1	20.0	N/A	20	20	0	-	-	-	-
Spotted seal	1	25	N/A	25	25	1	30.0	N/A	30	30	4	343.5	312.0	70	712
Unidentified seal	7	223.6	166.4	30	492	1	20.0	N/A	20	20	6	431.2	280.5	103	858
All seal sightings	**8**	**223.6**	**169.1**	**25**	**492**	**4**	**20.0**	**0.0**	**20**	**30**	**12**	**340.9**	**450.4**	**40**	**858**
Shirley V															
Bearded seal	2	192.5	116.7	110	275	0	-	-	-	-	0	-	-	-	-
Ringed seal	3	78.3	72.5	5	150	0	-	-	-	-	0	-	-	-	-
Spotted seal	0	-	-	-	-	0	-	-	-	-	1	144.0	N/A	144	144
Unidentified seal	2	671.0	298.4	460	882	0	-	-	-	-	2	150.0	141.4	50	250
Unidentified mysticete	0	-	-	-	-	1	3100[b]	N/A	3100	3100	0	-	-	-	-
All seal sightings	**7**	**124**	**187.6**	**5**	**882**	**0**	**-**	**-**	**-**	**-**	**3**	**144.0**	**0.0**	**50**	**250**
Peregrine															
Bearded seal	0	-	-	-	-	0	-	-	-	-	2	503.0	588.3	87	919
Unidentified seal	2	109.0	31.1	87	131	0	-	-	-	-	0	-	-	-	-
All seal sightings	**2**	**192.5**	**116.7**	**110**	**275**	**0**	**-**	**-**	**-**	**-**	**2**	**503.0**	**588.3**	**87**	**919**
All Seals															
Bearded seal	2	192.5	116.7	110	275	1	20	N/A	20	20	4	286.5	422.5	40	919
Ringed seal	3	78.3	72.5	5	150	1	20	N/A	20	20	0	-	-	-	-
Spotted seal	1	25	N/A	25	25	1	30	N/A	30	30	5	303.6	284.5	70	712
Unidentified seal	11	284.1	253.5	30	882	1	20	N/A	20	20	8	360.9	275.7	50	858
All Pinnipeds	***17***	***221.8***	***225.2***	***5***	***882***	***4***	***20.0***	***0.0***	***20***	***30***	***17***	***326.5***	***296.8***	***40***	***919***
All Cetaceans	***0***	***-***	***-***	***-***	***-***	***1***	***3100***	***N/A***	***3100***	***3100***	***0***	***-***	***-***	***-***	***-***

Note: N/A = not applicable; s.d. = standard deviation

[a]Post-seismic is defined as 3 min to 1 h after seismic periods.

[b]Distance was recorded as >3 km for this sighting and is estimated to be 3100 m.

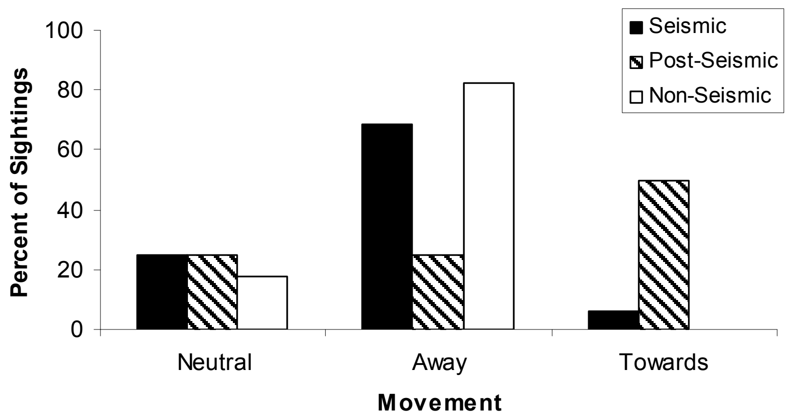

FIGURE 5.12. Percent of seal sightings (n = 37) showing various movement categories by seismic state.

<u>*Initial Behavior*</u>

Of the 38 seal sightings, behavior was most frequently recorded as looking (55%); looking was also the most common behavior during non-seismic periods (76% of 17 sightings; Fig. 5.13). Of the 17 seal sightings made during seismic periods, looking was the most frequently recorded behavior (47%), but swimming, front diving, sinking, logging, and unknown behaviors were also recorded, in decreasing order of frequency. During post-seismic periods, two of four seals were recorded as swimming (Fig. 5.13). The relative frequency of behaviors during seismic and non-seismic periods is not noticeably different between seismic and non-seismic periods; however, small sample sizes preclude conclusions about behavioral response.

<u>*Reaction Behavior*</u>

Looking or no reaction were the most frequently recorded "reactions" by seals (48 and 29% of 38 sightings, respectively; Fig. 5.14). Looking and no reaction occurred during 41% and 35% of 17 sightings during seismic periods; looking made up 47% of the 17 non-seismic sightings (Fig. 5.14). A change in direction, increase in speed, splash, and unknown reactions were also recorded during seismic periods, in decreasing order of frequency. These reactions were also observed during non-seismic periods. There were no statistically significant differences in reactionary behavior categories between seismic and non-seismic periods (chi-square test; χ^2 = 2.93; df = 5; P = 0.71).

Other Vessels

Several vessels were in use during most times of the Eni/PGS seismic survey. At times, two source vessels were operational in the survey area, although airguns were not fired simultaneously. The number of other vessels that were within a five kilometer radius was recorded continuously by the MMOs. On average, there were ~three vessels nearby one of the source vessels during seismic, post-seismic, and non-seismic periods, but the number of vessels nearby a source vessel ranged from 0 to 11 vessels (Table 5.6). Other vessels in the survey area were typically associated in some way with the Eni/PGS seismic survey.

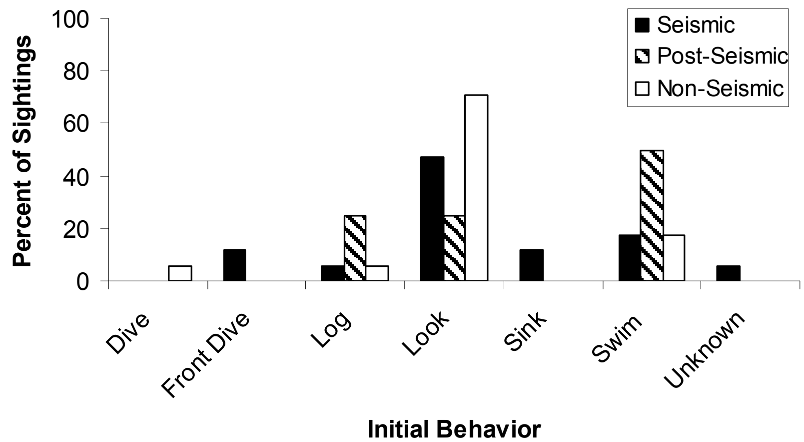

FIGURE 5.13. Percent of seal sightings (n = 38) showing various initial behavior types by seismic state.

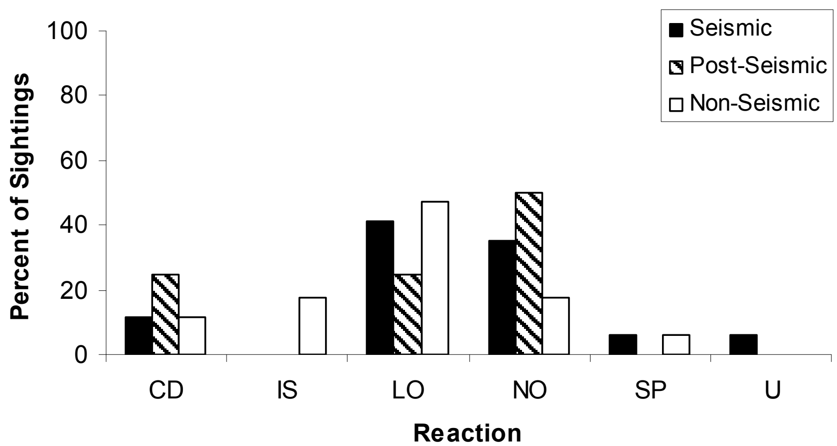

FIGURE 5.14. Percent of seal sightings (n = 38) showing various reaction behavior types by seismic state. CD = change direction; IS = increase speed; LO = look; NO = no reaction; SP = splash; U = unknown.

TABLE 5.6. The number of MMO records (n), mean, s.d., minimum, and maximum number of other vessels within five kilometers of a source vessel during seismic, post-seismic, non-seismic periods.

No. Vessels	Seismic	Post-Seismic[a]	Non-Seismic	Total
n	4496	170	868	5534
Mean	3.1	3.3	3.0	3.1
s.d.	1.6	2.1	1.9	1.7
Max.	10	10	11	11
Min.	0	1	0	0

Note: s.d. = standard deviation.

[a]Post-seismic is defined as 3 min to 1 h after seismic periods.

Implementation of Mitigation Measures

Mitigation measures for marine mammals during the Eni/PGS survey included ramp-ups, power-downs, shut-downs, and course changes. Ramp-ups were conducted during daylight operations whenever the airguns were activated after a prolonged period of inactivity (>10 min); however, see *Problems with Implementation of Mitigation Measures* below for detailed description for occasions when mitigation measures were not properly implemented. Course or route changes occurred whenever possible, and were often initiated to avoid potential power- or shut-downs due to an animal about to enter the relevant safety radius. Power- or shut-downs occurred when a marine mammal was seen about to enter or within the relevant safety radius or when course changes were not possible.

Power-downs and Shut-downs

There were no power- or shut-downs due to cetaceans during the Eni/PGS seismic survey. However, a total of one power-down and 10 shut-downs were implemented for seals observed in the water and within or about to enter the nominal 190 dB safety radius (Table 5.7). There were no delays in ramp ups for either seals or cetaceans.

From the Wiley Gunner

- On 9 August at 14:29:25 AKDT, a single unidentified seal was observed at a distance of 139 m (456 ft) from the airgun array. The seal was observed looking at the vessel, and showed no detectable response to the operations. The water depth was 5.7 m (19 ft). A shut-down was immediately requested and initiated at 14:29:42 AKDT. The seal dove and was not re-sighted. Ramp-up commenced at 14:49:30 AKDT. The animal was inside the nominal 190 dB safety radius of the full airgun array when first observed, and it was possible that this animal was exposed to received sound levels ≥190 dB.
- On 9 August at 14:29:42 AKDT, a single unidentified seal (distinct from the previous sighting) was observed at a distance of 30 m (98 ft) from the airgun array. The seal looked at the vessel before sinking in place below the water surface, with no other obvious reaction to the operations. A shut-down was initiated at the exact time this seal was observed, due to the previously described sighting that occurred on this day. The seal was not re-sighted, and ramp-up commenced at 14:49:30 AKDT. The seal was observed within the nominal 190 dB safety radius of the full airgun array at the time of the shut-down, so the seal was potentially exposed to received sound levels ≥190 dB.
- On 9 August, an unidentified seal was observed at 16:24:00 AKDT at a distance of 183 m (600 ft) from the airgun array in water ~4.4 m (14.4 ft) deep. The seal looked at the vessel and then sank in place, exhibiting no other obvious reaction. A shut-down was requested and initiated at 16:24:21 AKDT. The seal was not re-sighted, and ramp-up commenced at 16:53:39 AKDT. The seal was observed within the nominal 190 dB safety radius of the full airgun array, and may have been exposed to levels ≥190 dB.
- A spotted seal was observed looking at the vessel on 16 August at 14:51:22 AKDT at a distance of 45 m (148 ft) from the airgun array in water ~6.5 m (21.3 ft) deep. The animal swam at a moderate pace away from the vessel. A shut-down was called for and initiated at 14:51:30 AKDT. The seal was re-sighted swimming at distances of 25, 35, and 50 m (82, 115, and 164 ft) at 14:52, 14:53, and 14:53:30 AKDT, respectively. At 15:15:20 AKDT, ramp-up commenced. The seal was initially observed within of the nominal 190 dB safety radius of the full airgun array, so it may have been exposed to received sound levels ≥190 dB.

TABLE 5.7. List of airgun power- and shut-downs for seals within or about to enter the 190 dB safety radius from each source vessel during the Eni/PGS seismic survey.

Source Vessel	Species	Group size	Date	Water depth (m)	Initial Behavior[a]	Movement[b]	Reaction[c]	CPA (m)[d]	Mitigation (PZ or SZ)[e]	Estimated Received Sound Level (dB re 1 μPa$_{rms}$)
Wiley Gunner	Unidentified Seal	1	Aug-09	5.7	LO	MO	NO	139	SZ	190
	Unidentified Seal	1	Aug-09	5.7	LO	MO	LO	30	SZ	190
	Unidentified Seal	1	Aug-09	4.4	LO	MO	LO	183	SZ	190
	Unidentified Seal	1	Aug-17	6.8	LO	U	LO	25	SZ	190
	Spotted Seal	1	Aug-16	6.5	SW	MO	LO	100	SZ	190
Shirley V	Ringed Seal	1	Aug-19	9.4	LO	MO	LO	5	SZ	190
	Ringed Seal	1	Sep-26	9.3	FD	MO	CD	80	SZ	190
	Bearded Seal	1	Aug-23	8.6	SI	SE	NO	275	PZ	170
	Bearded Seal	1	Aug-23	8	FD	U	U	110	SZ	180
Peregrine	Unidentified Seal	1	Sep-15	3.9	LO	U	LO	87	SZ	190
	Unidentified Seal	1	Sep-23	4.7	SW	MO	NO	131	SZ	180

[a] First observed behavior: LO = look; SW = swim; FD = front dive; SI = sink in position.
[b] Initial movement of animal relative to the vessel: SE = sedate; MO = moderate; U = unknown.
[c] Reaction of animal to the vessel: NO = no reaction; LO = look; CD = change direction; U = unknown.
[d] The closest (observed) point of approach (CPA) to the airguns before mitigation.
[e] PZ = power-down, SZ = shut down.

- At 13:33:00 AKDT on 17 August, an unidentified seal was observed looking at the vessel from a distance of 100 m (328 ft) from the airgun array where water depth was ~6.8 m (22.3 ft). The seal was observed twice, but showed no other obvious reaction to the vessel operations. A shut-down was requested and initiated at 13:34:00 AKDT. The animal was not re-sighted again, and ramp-up commenced at 13:52:00 AKDT. The seal was first observed within the 190 dB safety radius of the full airgun array and may have been exposed to sound levels ≥190 dB.

From the Shirley V

- On 19 August at 11:03:00 AKDT, a ringed seal was observed looking at the vessel from a distance of 50 m (164 ft) from the airgun array. At the time, the vessel was in water ~9.4 m (31 ft) deep. A shut-down was called for and initiated at 11:03:15 AKDT. The seal re-surfaced several more times near the vessel and eventually moved progressively farther away. The seal's CPA was 5 m (16 ft) at 11:13:00 AKDT. The airguns were ramped-up at 11:52:00. The seal was initially observed within the nominal 190 dB safety radius of the full airgun array while the airguns were activated and may have been exposed to sound levels ≥190 dB.
- On 26 September at 15:05:30 AKDT, a ringed seal was observed at a distance of 80 m (262 ft) from the airgun array. The vessel was in ~9.4 m (31 ft) deep water at the time. A shut-down was requested and occurred at 15:05:35 AKDT. The seal dove and changed its direction upon the second surfacing at 15:06:55 AKDT at 100 m (328 ft) distance. It was not seen again, and ramp-up commenced at 15:23:00 AKDT. The seal was observed within the nominal 190 dB safety radius of the full airgun array prior to shut-down, and may have been exposed to sound levels ≥190 dB.
- On 23 August, at 6:36:00 AKDT, a bearded seal was observed at a distance of 275 m (902 ft) from the airgun array. The water depth was 8.6 m (28 ft). The seal sank in place and showed no obvious reaction to the vessel operations. A power-down to the mitigation gun was requested and implemented at 6:38:00 AKDT. The animal did not reappear within 10 min, and line shooting of a 720 in^3 array was re-initiated at 6:52:28 AKDT. Since the airguns were powered-down for >10 min, a ramp-up should have been implemented but was not (see Table 5.9). The error was discussed during de-briefing at the end of this particular watch to prevent future errors. The seal was observed outside the nominal 190 dB safety radius of the full airgun array, and it was estimated to have been exposed to received sound levels ≥170 dB (but <190 dB) prior to mitigation implementation.

- On 23 August at 12:17:00 AKDT, a bearded seal was observed diving and changing direction at a distance of 110 m (361 ft) from the airgun array where water depth was ~8 m (26 ft). A shut-down was implemented at 12:17:30 AKDT. The seal was not seen again, and the vessel repositioned for another seismic line. Ramp-up did not commence until 14:34:00 AKDT. The seal was observed near the 190 dB safety radius of the full airgun array, and may have been exposed to sound levels ≥180 dB.

From the Peregrine

- An unidentified seal was seen on 15 September at 8:55:00 AKDT at a distance of 70 m (230 ft) from the MMOs and 87 m (285 ft) from the airgun array. The vessel was in 3.9 m (13 ft) of water at the time. The seal looked around and dove, but displayed no other obvious reactions to the seismic operations. A shut-down was implemented at 8:56:00 AKDT and the vessel changed course to the opposite direction from where the seal was sighted. The vessel moved away, the MMOs did not re-sight the seal and began a 30 min watch prior to ramp-up. The seal was observed within the 190 dB safety radius of the full airgun array prior to shut-down and may have been exposed to sound levels ≥190 dB.
- On 23 September at 18:51:05 AKDT, an unidentified seal was observed swimming away from the vessel at a distance of 350 m (0.2 mi) from the MMOs and 367 m (1204 ft) from the airgun array (880 in^3). The seal was then seen looking at the vessel at 18:52:20 AKDT from a distance of 120 m (394 ft) from the MMOs and 131 m (430 ft) from the airgun array. According to the MMO database, a shut-down occurred at 18:51:12 AKDT while the vessel was in 4.7 m (15 ft) of water. The seal was not seen again, and the airguns were re-initiated at full volume at 18:52:13. To comply with mitigation measures outlined in the IHA, the airguns should have remained silent until the animal was seen to leave the area or not observed again within 15 min (see Table 5.9). After 15 min, the airguns should have been ramped-up. In this case, the MMOs recorded a shut-down and did not record a re-initiation of airguns until 19:05:49, but shot point records indicate that only a brief shut-down occurred (described in the preceding sentences). It is likely that there was a mis-communication between airgun technicians (located on the recording vessel) and MMOs (located on the *Peregrine* and communicating through the vessel's captain). The seal was observed near the nominal 190 dB safety radius of the full airgun array prior to the mitigation request, but it was never sighted within the radius and it is estimated that the seal was potentially exposed to sound levels ≥180 dB. However, given the error in re-initiating the airguns in a short period of time, it is possible that the seal actually was exposed to higher sound levels.

In summary, eight seals were initially detected within the nominal 190 dB safety radius and may have been exposed to underwater sound levels ≥190 dB during the Eni/PGS seismic survey; two seals were about to enter the 190 dB safety radius and may have been exposed to sound levels ≥180 dB prior to power-down (Table 5.8). A power-down was implemented for one bearded seal, and it was potentially exposed to sound levels ≥170 dB prior to power-down. This assumes that the seals, while inside or about to enter the safety radius, were well below the water surface when one or more seismic pulses were received.

Problems with Implementation of Mitigation Measures

Occasionally, mechanical, MMO, airgun technician and recorder to source vessel communication errors affected the appropriate implementation of mitigation measures specified in the IHA. Table 5.8 provides details on each type of problem including the vessel, date, time, water depth, and location when the error occurred, the associated change in array volume, and whether any marine mammals were sighted within 30 min of the problem. There were a total of 26 occasions when an error in the implementation of mitigation measures occurred, and eight general types of problems which are discussed below.

TABLE 5.8. List of errors in implementation of mitigation measures that occurred during the Eni/PGS seismic survey, August-September 2008 in the central Alaskan Beaufort Sea.

Vessel	Error Type[a]	Date	Time (AKDT)	Latitude (ºN)	Longitude (ºW)	Vol. Change (in^3)[b]	Elapsed Time from Previous Entry	Water Depth (m)	Light (L) or Dark (D)	Marine Mammal Sightings w/in 30 min?
Wiley Gunner	PI	02-Aug	11:00:15	70 33.79	150 02.07	U to 880	0:30:39	6.8	L	N
	No RU: potential mechanical error	03-Aug	13:09:20	70 33.78	150 02.05	0 to 880	0:38:20	6.7	L	N
	PI	03-Aug	17:00:00	70 36.48	150 03.04	U to 880	0:29:24	11.8	L	N
	RU not recorded	04-Aug	23:00:00	70 33.37	150 02.05	80 to 880	0:27:50	5.7	L	N
	No RU: large volume change for elapsed time	05-Aug	2:30:54	70 30.91	150 01.52	0 to 880	0:28:03	3.2	L	N
	Vol. increase	06-Aug	13:26:00	70 31.14	149 50.50	20 to 60	0:01:52	2.0	L	N
	Vol. increase	08-Aug	16:29:23	~70 33.72	150 07.95	120 to 360	0:06:45	7.1	L	N
	PI	10-Aug	18:00:00	70 33.91	150 10.65	U to 820	0:22:00	7.9	L	N
	RU >1	10-Aug	22:32:20	70 33.79	~150 10.74	0 to 100	0:40:00	7.8	L	Y (spotted seal at 22:32)
	Me error	11-Aug	14:03:16	70 33.34	150 06.84	0 to 720	0:31:46	6.2	L	N
	SD >10 min	18-Aug	19:02:20	70 33.56	149 59.64	0 to 680	0:11:50	5.2	L	N
Shirley V	Vol. increase	19-Aug	14:05:00	70 36.48	150 03.10	20 to 60	0:05:00	11.5	L	N
	RU vol. increase	21-Aug	13:53:00	70 33.86	149 53.50	20 to 880	0:23:00	3.2	L	N
	RU vol. increase	21-Aug	19:20:28	70 34.96	149 52.23	20 to 880	0:20:28	9.4	L	Y (unid. seal at 19:45)
	No RU: PZ[c] >10 min	23-Aug	6:52:28	70 34.84	149 50.46	20 to 720	0:15:47	8.8	L	Y (bearded seal PZ)
	No RU: large volume change for elapsed time	24-Aug	7:41:06	70 34.55	149 52.28	20 to 880	0:05:20	7.7	L	N
	No RU: large volume change for elapsed time	04-Sep	4:22:07	70 31.93	149 53.67	20 to 380	0:09:37	2.2	D	N
	RU vol. increase	24-Sep	17:21:00	70 33.76	150 01.78	40 to 680	0:21:00	6.1	L	N
Peregrine	SD >10 min	29-Aug	2:22:05	70 33.22	149 00.23	0 to 880	0:14:01	4.6	D	N
	SD >10 min	29-Aug	4:47:31	~70 33.14	~149 02.48	0 to 880	0:15:04	~4.6	L	N
	SD >10 min	01-Sep	3:11:01	70 32.91	150 00.12	0 to 880	0:18:15	4.9	D	N
	SD >10 min	08-Sep	4:13:35	~70 31.76	~150 30.33	0 to 440	0:14:15	~3.7	D	N
	SD >10 min	22-Sep	4:25:10	70 33.13	149 55.60	0 to 880	0:10:27	2.3	D	N
	No RU: SZ[d] <15 min and re-initiation of array	23-Sep	18:52:13	70.5475	149.986	0 to 880	0:01:01	4.7	L	Y (unid. seal SZ)
	SD >10 min	23-Sep	20:23:29	~70 33.85	~149 59.80	0 to 730	0:23:29	~6.3	L	N
	SD >10 min	24-Sep	2:40:05	70 32.67	150 07.55	0 to 880	0:15:05	4.7	D	N

[a]Change in array volume error type: PI = potential increase >6 dB/5 min; No RU = No ramp-up occurred when it should have, reason given; RU not recorded = Ramp-up not recorded, but may have occurred appropriately and cannot be verified; RU >1 = Ramp-up was initiated with more than one airgun; Me error = Mechanical error that caused last shot from previous line shooting be emitted at RU initiation; SD >10 min = No ramp-up occurred when it should have because airguns were shut-down >10 min; Vol. increase = Volume increase >6dB/5 min; RU vol. increase = Ramp-up occurred with at least one volume increase >6dB/5min.

[b]Airgun array volume; U = unknown number of guns; gun no. >0 and ≤880.

[c]PZ = power-down mitigation

[d]SZ = shut-down mitigation

For four of these 26 occasions, seals were sighted within 30 min. A spotted seal was seen from the *Wiley Gunner* on 10 August at 22:32 AKDT at the time ramp-up was initiated. On 21 August at 19:20 AKDT an unidentified seal was seen from the *Shirley V* 20 min after a problem with ramp-up volume. As described in *Power- and Shut-downs* above, on 23 August at 6:52 AKDT, no ramp-up was initiated following a power-down due to a bearded seal about to enter the 190 dB safety radius. During a shut-down implemented from the *Peregrine* for an unidentified seal on 23 September, airguns were re-initiated at full volume at 18:52 AKDT. The airguns were shut-down less than the required 15 min and also should have been started with a ramp-up at the time of initiation. Other than the last case, it is very unlikely that these seals would have been affected, beyond perhaps a slight disturbance response to the airgun sounds.

MMOs recorded occasions when there may have been potential erroneous changes in array volume in their logbooks. In several cases, mechanical problems with the airguns likely led to the observed errors. These errors and the problems which may have led to them are summarized below.

- Potential increase >6 dB/5 min (occurred three times)
    - The computer that displayed airgun volume on the *Wiley Gunner* failed several time so that the MMOs were unable to assess the change in airgun volume. However, the MMOs observed the airgun technicians initiating the proper firing procedures. There was no way to verify the array volume at these times.
- Ramp-up did not occur at the required time (occurred six times)
    - This problem occurred when the *Wiley Gunner* initially began operations. There were mechanical (compressor) and technical (computer) problems controlling airgun volumes.
- Ramp-up was not recorded but may have occurred appropriately and cannot be verified (occurred once)
    - At times, an individual MMO may have forgotten to record ramp-ups when they occurred. During debriefing meetings, the MMO verified that it was done correctly.
- Ramp up was initiated with more than one airgun (occurred once)
    - This problem occurred when the *Wiley Gunner* initially began operations. There were mechanical problems controlling airgun volumes and the number of airguns firing when airguns were started.
- Mechanical error that caused the last shot from previous seismic line to occur at ramp-up initiation (occurred once)
    - The *Wiley Gunner* initially had problems controlling airgun volumes when the airguns were started.
- No ramp-up occurred when if should have when airguns were shut-down >10 min (occurred eight times)
    - These errors occurred almost exclusively on the *Peregrine* and appeared frequently during a period when this vessel was first deployed for operation. On the *Peregrine*, MMOs had to contact the airgun technicians through the captain's radio. Thus, MMOs were not in direct contact with the airgun technicians as on the *Shirley V* and *Wiley Gunner*. These errors appear to have occurred during turns when the vessel's seismic crew decided to cease firing the airguns during a turn rather than power-down. Thus,

these errors could have been attributed to communication and timing problems between the *Peregrine* bridge and airgun technician.

- Array volume increase>6 dB/5 min (occurred three times)
  - When this problem occurred on the *Wiley Gunner* and *Shirley V*, the error resulted from mechanical problems with airgun volume control. Frequent mechanical problems with the *Wiley Gunner* led PGS to eventually remove the vessel from seismic operations.
- Ramp-up occurred with at least one volume increase potentially >6 dB/5min (occurred three times)
  - On 21-22 August, the *Shirley V* was having technical problems during ramp-up. These problems were attributed to computer problems.

Estimated Number of Seals and Cetaceans Potentially Affected

It is challenging to estimate "take by harassment" for marine mammals for several reasons: (*a)* it is difficult to ascertain the relationship between the numbers of marine mammals that are observed and the number that are actually present; (*b*) the appropriate criteria for "take by harassment" are difficult to determine and are presumably variable among species and circumstances of the encounter; (*c*) the distance for various sound radii (i.e., 190, 180, or 160 dB re 1 μPa_{rms}) is variable depending on factors like water depth, airgun depth, and aspect for directional sources (e.g. Greene 1997; Greene et al. 1998; Burgess and Greene 1999; Caldwell and Dragoset 2000; Chapter 3); and (*d*) the received sound level for individual marine mammals depends on their depth in the water, and the received sound level will be considerably reduced for animals at or near the water surface (Greene and Richardson 1988).

Sound Level Criteria

Table 4.1 (in Chapter 4) presents the estimated distances for various received sound levels from the airgun array of each source vessel used during the Eni/PGS seismic survey. The NMFS have indicated that both cetaceans and seals exposed to seismic pulses with received levels ≥160 dB should be considered disturbed. Such effects were authorized for a small number of seals and cetaceans in the IHA and ITS issued to PGS (see Appendix A).

Two methods were used to estimate the number of marine mammals disturbed by exposure to sound levels high enough that they may have caused a disturbance or other potential impacts. The minimum estimate was based on the direct observations of seals and cetaceans by MMOs during the survey, and the maximum estimate was derived by multiplying the estimated density of marine mammals in the survey area by the area estimated to have been exposed to seismic sounds at a given received level (see *Indirect Estimates of the Number of Exposures and Individuals Exposed* below). The actual number of individual seals and cetaceans exposed to, and potentially disturbed by, seismic pulses was likely between the minimum and maximum estimates. The estimates of marine mammals potentially exposed to seismic sounds are presented in Tables 5.9 and 5.10.

TABLE 5.9. Number of seals seen within a 50 m (164 ft) lateral distance during non-seismic periods, “daylight” trackline effort, estimated seal densities, and estimated number of seal exposures and individual seals exposed to sound levels ≥160 or 190 dB from each source vessel in “deep” waters seaward of the barrier islands (A and B, respectively) or in “shallow” waters seaward of the barrier islands (C and D, respectively).

	No. Seal Sightings[a]	**Trackline Effort (km)[b]**	**Effort in 100 m Strip (km^2)[c]**	**Seal Density (No./km^2)**	**Ensonified Area Assuming Overlap (km^2)[d]**	***No. Seal Exposures***	**Ensonified Area Assuming No Overlap (km^2)[e]**	***No. Indiv. Seals Exposed***
(A) Deep: Estimated exposures and individuals exposed to ≥160 dB								
Wiley Gunner	2	157.7	15.8	0.13	1907.7	*242*	144.1	*19*
Shirley V	1	160.6	16.1	0.06	176.4	*11*	176.4	*11*
Peregrine	2	140.5	14.0	0.14	2007.2	*12*	82.0	*12*
All Vessels	**5**	**458.7**	**45.9**	**0.11**	9565.8	***1043***	**186.9**	***21***
(B) Deep: Estimated exposures and individuals exposed to ≥190 dB								
Wiley Gunner	2	157.7	15.8	0.13	115.1	*15*	26.8	*4*
Shirley V	1	160.6	16.1	0.06	59.8	*4*	59.8	*4*
Peregrine	2	140.5	14.0	0.14	368.4	*53*	47.0	*7*
All Vessels	**5**	**458.7**	**45.9**	**0.11**	711.8	***78***	**74.7**	***9***
(C) Shallow: Estimated exposures and individuals exposed to ≥160 dB								
Wiley Gunner	2	157.7	15.8	0.13	464.1	*59*	106.1	*14*
Shirley V	1	160.6	16.1	0.06	6396.5	*399*	131.0	*0*
Peregrine	2	140.5	14.0	0.14	2264.1	*323*	96.9	*14*
All Vessels	**5**	**458.7**	**45.9**	**0.11**	9124.7	***995***	**172.8**	***19***
(D) Shallow: Estimated exposures and individuals exposed to ≥190 dB								
Wiley Gunner	2	157.7	15.8	0.13	16.6	*255*	9.6	*2*
Shirley V	1	160.6	16.1	0.06	566.5	*36*	71.6	*5*
Peregrine	2	140.5	14.0	0.14	327.1	*47*	54.9	*8*
All Vessels	**5**	**458.7**	**45.9**	**0.11**	910.2	***100***	**75.7**	***9***

[a]Number of seal sightings within 0-50 m (0-164 ft) lateral distance of the vessel trackline.

[b]Vessel "daylight effort" (km) during non-seismic periods with two observers.

[c]Vessel "daylight effort" (km) during non-seismic periods with two observers within a 100 m (328 ft) strip centered on the vessel trackline.

[d]Area estimated to be ensonified to the 160 or 190 dB radius, including multiple exposures to an area.

[e]Area estimated to be ensonified to the 160 or 190 dB radius, excluding multiple exposures to an area.

TABLE 5.10. Number of each seal species seen within a 50 m (164 ft) lateral distance during non-seismic periods, estimated seal densities, and estimated number of seal exposures, individual seals exposed, and direct estimates of the number of individuals exposed to sound levels ≥160 or 190 dB in "deep" waters seaward of the barrier islands (A and B, respectively) or "shallow" waters inshore of the barrier islands (C and D, respectively).

	No. Seal Sightings[a]	Seal Density (No./km^2)	No. Seal Exposures[b]	No. Indiv. Seals Exposed[c]	Direct Estimate of No. Exposed[d]
(A) Deep: Estimated exposures and individuals exposed to ≥160 dB					
Bearded Seal	2	0.04	418	9	2
Spotted Seal	2	0.04	418	9	2
Ringed Seal	0	0.00	0	0	1
Unidentified Seal	1	0.02	209	5	11
All Seals	**5**	**0.11**	**1043**	**21**	**16**
(B) Deep: Estimated exposures and individuals exposed to ≥190 dB					
Bearded Seal	2	0.04	31	4	0
Spotted Seal	2	0.04	31	4	2
Ringed Seal	0	0.00	0	0	1
Unidentified Seal	1	0.02	16	2	5
All Seals	**5**	**0.11**	**78**	**9**	**8**
(C) Shallow: Estimated exposures and individuals exposed to ≥160 dB					
Bearded Seal	2	0.04	398	8	2
Spotted Seal	2	0.04	398	8	2
Ringed Seal	0	0.00	0	0	1
Unidentified Seal	1	0.02	199	4	11
All Seals	**5**	**0.11**	**995**	**19**	**16**
(D) Shallow: Estimated exposures and individuals exposed to ≥190 dB					
Bearded Seal	2	0.04	40	4	0
Spotted Seal	2	0.04	40	4	2
Ringed Seal	0	0.00	0	0	1
Unidentified Seal	1	0.02	20	2	5
All Seals	**5**	**0.11**	**100**	**9**	**8**

Note: N/A means not applicable.

[a]Number of seal sightings within 0-50 m (0-164 ft) lateral distance of the vessel trackline.

[b]Number of seal exposures estimated by multiplying seal density by the 160 or 190 dB ensonified area for "deep" or "shallow" areas (including repeated exposures to an area).

[c]Number of seal exposures estimated by multiplying seal density by the 160 or 190 dB ensonified area for "deep" or "shallow" areas (excluding repeated coverages to an area).

[d]The number of seals estimated to be exposed to 160 or 190 dB, based on the actual number observed within the nominal safety radii by MMOs.

Estimates from Direct Observations

Observations of seals and cetaceans close to the source vessels during seismic operations provide a minimum estimate of the number potentially affected by seismic sounds. This approach most likely underestimated the actual number of individuals potentially exposed to various received levels. Some animals may have moved beyond the visual range of MMOs and would not have been detected. It was also unlikely that MMOs could detect all animals near the vessel trackline. During daylight periods, animals below the surface may have been missed by MMOs or not observed due to limited visibility (e.g., fog, sea conditions, glare, or other factors limiting visibility). Furthermore, it was not possible to observe animals effectively during periods of darkness. Only a limited amount (~20%) of MMO effort occurred during periods of darkness during the Eni/PGS seismic survey, and this effort was not included in "daylight effort" calculations.

Additionally, it was possible that some animals avoided the area around a seismic vessel while the airguns were activated (see Richardson et al. 1995, 1999; Gordon et al. 2004; Stone and Tasker 2006; Weir 2008). Marine mammals may respond at received sound levels lower than 160 dB or to the presence of the source or support vessels themselves. The extent to which the distribution and behavior of seals and cetaceans might be affected by the Eni/PGS survey beyond the detection distance for MMOs was unknown. Most of the cetaceans that occur in the Alaskan Beaufort Sea, however, are uncommon in the shallow, nearshore waters of the survey area and tend to prefer deeper waters farther offshore.

It should be noted that the 190 and 180 dB safety radii are the *maximum* distances from the airgun array where sound levels could be expected to reach ≥190 or 180 dB, respectively. These distances are applicable at the water depth and in the direction from the array where sounds are the strongest. Thus, it is complicated to assess the maximum level to which any given individual marine mammal might be exposed, because:

- Received sound levels are appreciably reduced near the water surface due to pressure-release effects. It is often unknown whether animals that are observed at the surface were earlier (or later) exposed to the maximum sound levels that they would receive should they dive. Pinnipeds observed on land or ice would potentially receive very little, if any, of the sound propagated underwater.
- Some marine mammals could have been within the predicted sound radii and/or within the safety radii but remained underwater and not visible to observers; subsequently they could be observed outside the safety radii. The direction of movement and reaction behaviors recorded by MMOs can provide some indication of behavioral differences during seismic and non-seismic periods.
- MMOs were positioned on the bridge or bow of each vessel. Although these were small vessels, the nominal safety zones were not centered on the observer's station, but rather on the airgun array. The observers accounted for this minor difference when deciding whether a power- or shut-down was necessary.
- The airguns were sometimes activated during periods of darkness when MMOs were not on duty or when they had a much reduced ability to detect marine mammals. A total of ~21% of the seismic operations occurred during periods of darkness for the Eni/PGS seismic survey (all vessels). If marine mammals were encountered at similar rates during darkness as during light, then the total numbers of animals exposed to various sound levels would be greater than those estimated from daylight periods. Thus, it is expected that the frequency of exposure to high sound levels could be somewhat higher during darkness without sighting data for darkness periods that is necessary for implementing power- and shut-downs at night, on a per-encounter basis. Similarly,

MMOs are less effective at detecting marine mammals within or about to enter the nominal safety radii during poor environmental conditions (e.g., fog, glare, Bf >5). A total of approximately ~8% of MMO effort during seismic periods occurred during periods with <500 m visibility (all vessels).

Pinnipeds Potentially Exposed to Sounds ≥160 dB

During the Eni/PGS survey, a total of 17 seals were observed during seismic periods. Of these, 16 seals were seen within the 160 dB radius (Table 5.10). Most (n = 11) were of unidentified seals, but two bearded, two spotted, and one ringed seal were seen within the 160 dB radius (Table 5.10). The sound levels received by these individuals may have been ≥160 dB if the seals went below the water surface while one or more airgun pulses were received within the 160 dB radius.

Pinnipeds Potentially Exposed to Sounds ≥190 dB

During the Eni/PGS survey, 11 seals were sighted within or about to enter the nominal 190 dB safety radius around the airguns; a power- or shut-down was implemented in each case (see Table 5.7). Eight of these seals may have received sound levels ≥190 dB prior to shut-down, based on the distance of the closest approach to the airgun arrays (Table 5.10). Exposure to sound levels ≥190 dB was based on the assumption that the seals were underwater within the safety radius during airgun activity.

Cetaceans Potentially Exposed to Sounds ≥160 or 180 dB

A single sighting of three unidentified mysticetes was observed >3 km from the *Shirley V* during the Eni/PGS seismic survey on 29 August. The *Shirley V* had no airguns activated at the time but the *Peregrine*'s 880 in^3 array had been active in the previous hour. No cetaceans were observed within the 160 (or 180) dB sound radii of any of the source vessels while airguns were activated, and it was unlikely that any cetaceans were exposed to sound levels ≥180 dB (Table 5.10). Therefore, the direct estimate of cetaceans exposed to sound levels ≥160 or 180 dB is zero.

Indirect Estimates of the Number of Exposures and Individuals Exposed

Estimating Density

Ship-based density was estimated for seals but not cetaceans encountered during the Eni/PGS survey. Cetaceans were not expected to occur in the Eni/PGS survey area, particularly for operations shoreward of the barrier islands. The single cetacean sighting precluded the estimation of densities based on observations from the source vessels. Chapter 7 provides density and indirect estimates of cetaceans potentially affected by seismic operations based on aerial monitoring.

Moulton and Lawson (2002) showed that the ability to detect seals decreases dramatically beyond lateral distances of 50 m (164 ft). Thus, density calculations were restricted to the number of individual seals seen within 100 m (328 ft) centered on the vessel's trackline (i.e., within lateral distances of 50 m of the observers, in all directions). Only sightings made during MMO watches conducted during non-seismic periods in "daylight" conditions with two observers were considered for density estimation. A total of five seals were seen during 184.4 h of observations under these conditions. These seals were seen along 458.7 km (285.0 mi) of vessel trackline periods, for a complete area of ~ 45.9 km^2 (17.7 mi^2).

Thus, the observed seal density within a 100 m (328 ft) strip during non-seismic "daylight effort" was ~0.11 seals/km^2. This estimate, however, did not allow for any seals that may not have been visible at the surface or that may have been at the surface but were not otherwise detected. Table 5.10 summarizes the calculation of seal density for each vessel, based on the area surveyed during non-seismic periods with "daylight" conditions and two observers on watch. The density of each seal species was also calculated, based on a ship trackline strip of 45.9 km^2 (17.7 mi^2), and densities are provided in Table 5.9.

Estimating Number of Exposures

Estimates of the number of potential *exposures* of seals to sound levels ≥160 dB were calculated by multiplying the observed seal density (0.11 seals/km^2) by the trackline area assumed to be ensonified by sounds ≥160 dB (based on water depth (shoreward or seaward of the barrier islands) and the estimated 160 dB sound radii for each vessel in Table 4.1). For "deep" waters seaward of the barrier islands, a total of ~9566 km^2 was estimated to be ensonified during seismic periods of the survey, and a total of ~9125 km^2 was estimated to be ensonified in "shallow" waters shoreward of the barrier islands (Table 5.9). The calculation of seal exposures likely (greatly) overestimated the number of different individual seals exposed to airgun sounds at received levels ≥160 dB, because some incidents of exposure may involve the same individuals previously exposed, given that some seismic lines crossed and many were spaced closely together (see Fig. 5.1).

Estimating Number of Individuals

Estimates of the number of *individual* seals exposed to sound levels ≥160 dB was obtained similarly to the method described for "exposures" above, except that the observed seal density was, in this case, multiplied by the area that was estimated to be ensonified ≥160 dB at least one time. MapInfo Geographic Information System (GIS) software was used to calculate the ≥160 dB ensonified area which had been exposed one or more times. A "buffer" was created that extended to the predicted 160 dB radius (from Table 4.1) to both sides of the vessel's trackline, based on the vessel water depth ("deep" areas seaward of the barrier islands vs. "shallow" areas shoreward of the barrier islands). The buffer would then include areas that were exposed multiple times to seismic pulses ≥160 dB for crossing tracklines or tracklines that were close enough for their 160 dB zones to overlap. The overlapping buffers were then removed so that a given area of water exposed to 160 dB more than once was only counted one time. As a result, the estimate of the number of individual seals exposed to ≥160 dB is considered a minimum indirect estimate since animal movement during the course of the survey is not accounted for in this estimate. Including multiple exposures by one or more vessels, a total of ~187 km^2 was estimated to be ensonified by sound levels ≥160 dB in "deep" waters (seaward of the barrier islands) and ~173 km^2 in "shallow" waters (shoreward of the barrier islands; Table 5.9).

The above calculations were repeated to find the number of seal exposures and individuals that may have received sounds levels *≥190 dB*, assuming they had not altered their course or behavior to avoid those sound levels. Estimates of the number of exposures and individuals exposed were rounded to the nearest individual.

Estimated Number of Seal Exposures and Individuals Exposed to ≥160 dB

In "deep" waters seaward of the barrier islands, the estimated number of individual seals exposed to sound levels ≥160 dB was 21. It was estimated that ~1043 exposures of seals to sound levels ≥160 dB may have occurred (Tables 5.9 and 5.10). In "shallow" waters shoreward of the barrier islands, the estimated number of individual seals exposed to sound levels ≥160 dB was 19 and there were an estimated ~995 exposures (Tables 5.9 and 5.10). Thus, an overall total of ~40 seals may have been exposed to sound levels ≥160 dB and there may have been a maximum of ~2038 exposures during the seismic survey. Estimates for each vessel and seal species are shown in Tables 5.9 and 5.10, respectively. The "individuals" estimate would be reasonable if seals did not react to the approaching source vessel. The "exposures" estimate would be reasonable if seals did not react to the approaching vessel and remained largely stationary throughout the survey. Since both of these assumptions are unlikely, the actual number of seals that were exposed to sound levels ≥160 dB, or that moved away in reaction to the approaching vessel before experiencing sound levels ≥160 dB, are expected to be somewhere between the "exposures" and "individuals" estimates shown in Tables 5.9 and 5.10.

Estimated Number of Seal Exposures and Individuals Exposed to ≥190 dB

In total, considering both shallow and deep areas, the estimated number of individual seals exposed to sound levels ≥190 dB was 18 and there were an estimated ~178 exposures (Tables 5.9 and 5.10). Estimates for each vessel and seal species are shown in Tables 5.9 and 5.10, respectively.

Effect on Accessibility to Hunters

There was no evidence that seals were displaced far enough from the seismic operation to affect accessibility to hunters. The Eni/PGS seismic program did not noticeably affect bowhead whales or the bowhead hunt, particularly considering seismic operations occurred shoreward of the barrier islands during the hunt from Cross Island. There were no reports of the Eni/PGS seismic survey interfering with subsistence hunt reported via the communication centers located at Barrow and Deadhorse (W.V. Hickey, Senior Project Manager, AES, pers. comm.). The communication center in Deadhorse did record that Nuiqsut whalers were leaving for Cross Island on 29 August 2008. The Nuiqsut bowhead hunt had concluded by 9 September 2008.

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6. VESSEL-BASED MARINE MAMMAL MONITORING AND MITIGATION: ANALYSIS AND RESULTS FOR POLAR BEARS AND WALRUSES

This chapter provides the results of vessel-based marine mammal monitoring and mitigation during the Eni/PGS seismic survey as it pertains to polar bears and walruses covered under the LOA issued to PGS by USFWS (Appendix B). However, no walruses were expected, nor observed during the survey, and only results of polar bear sightings are presented in the following sections. In addition to vessel-based sightings, a single sighting of a polar bear was reported during aerial surveys for marine mammals and this sighting is described in Chapter 7. Incidental sightings of polar bears during periods when MMOs were off-watch or when the source vessel was inactive and stationary are described in Appendix E.

Status of Polar Bears and Walrus in the Area

The polar bear is common throughout the central Alaskan Beaufort Sea, but Pacific walruses are rare in the same area. The polar bear is listed as threatened under the ESA. The known abundance, habitat, and conservation status of both of these species is summarized below and in Table 6.1.

TABLE 6.1. Habitat, abundance, and conservation status of polar bears and walruses that occur in the Beaufort Sea.

	Polar bear (*Ursus maritimus*)	**Walrus (*Odobenus rosmarus*)**
Habitat during open-water season[d]	Nearshore[a]	Shallow continental shelf
Abundance in Survey Area	1,500[b]	N.A.[c]
ESA[e]	T	NL
IUCN[f]	VU	DD
CITES[g]	II	III

[a]Nearshore distribution during the summer and fall open-water season is common within the Beaufort Sea region (Schliebe at al. 2006).

[b]Estimate for the SBS stock (Schliebe et al. 2006).

[c]Pacific walrus are common in the Bering and Chukchi Seas, and are only occasionally seen in the Beaufort Sea. There is currently no reliable population estimate for the Alaska Stock of Pacific walrus (FWS 2002).

[d]Open-water season refers to the summer and fall period when there is no land-fast ice present. The Eni/PGS survey coincided with the open-water season.

[e]Endangered Species Act. Codes for ESA: E = Endangered; T = Threatened; NL = Not listed.

[f]IUCN Red List of Threatened Species (2008). Codes for IUCN classifications: EX = Extinct; EW = Extinct in the Wild; CR =Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient; NE = Not Evaluated.

[g]Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (UNEP-WCMC 2008). Codes for CITES: Appendix I = threatened with extinction, and controlled trade; II = not necessarily threatened with extinction, but trade is controlled; III = protected in at least one country.

Polar Bear

The polar bear is an ice-associated ursid distributed throughout sea ice covered waters and adjacent coastal lands in the Arctic. Radio telemetry data suggest that a single population, the Southern Beaufort Sea (SBS) stock, occupies the region between Icy Cape, Alaska, and Pearce Point, Canada (Amstrup and DeMaster 1988; Stirling et al. 1988). For the SBS stock, polar bears extend their range to the southernmost proximity of sea ice into the Chukchi Sea during the winter and follow retreating pack ice as it melts in the summer (Garner 1994). During open-water and fall seasons, polar bear distribution has been changing in recent years. Greater numbers of polar bears were observed on shore (including the central Alaskan Beaufort Sea) from 2000 to 2005 than any previous time period, apparently in response to the pack ice shifting farther from shore (Schliebe et al. 2006). Polar bears regularly occur on Cross Island to forage on the remains of bowhead whales which have been harvested by Alaskan Inupiats.

Early population estimates suggested that there were ~1,800 polar bears in the SBS stock, but there was limited confidence in this estimate due to uneven sampling techniques (Amstrup and DeMaster 1988). Recent capture-recapture studies suggest that the current population estimate is now ~1,500 individuals (Schliebe et al. 2006). New management boundaries for this stock relative to the Chukchi Sea and Northern Beaufort Sea stock are currently under consideration and subject to change by USFWS, based on recent telemetry results (Amstrup et al. 2004, 2005). In Alaska, there are currently an estimated 3,500 polar bears (Schliebe et al. 2006). Based primarily on threats posed by changing sea ice conditions, polar bears were listed as threatened under the ESA in May 2008.

Walrus

The walrus can be separated into two geographically distinct sub-species in the Atlantic and the Pacific. The Pacific walrus (*O. r. divergens*) occurs in the Bering and Chukchi seas, with only occasional movements into the East Siberian and Beaufort seas. During winter, walruses concentrate in the Bering Sea around thin ice, polynas, or open water leads (FWS 2002). Most of the population migrates into the Chukchi Sea during the summer, although several thousand animals (primarily adult males) congregate at a few haulout sites in Bristol Bay before fall migration (Jay and Hills 2005).

The population size of the Alaskan walrus is not well known. It has been speculated that the population size of Pacific walruses have fluctuated dramatically since the 19th century in response to varying levels of human harvest (Fay et al. 1989). Aerial surveys of the Chukchi Sea, conducted every five years from 1975 to 1990, resulted in a Pacific walrus population estimate of 234,020 (Gilbert 1989a, b), with the most recent estimate being 201,039 (FWS 2002). However, there are still unresolved problems with the aerial survey methods and unacceptably large confidence intervals (FWS 2002), so a reliable estimate of the population size is unavailable. The Alaska Stock of the Pacific walrus is not considered a strategic stock by USFWS.

Data Analyses

Data processing and analysis relative to polar bear sightings followed the procedures described in Chapter 5 (see *Data Analyses*) for other marine mammal sightings. A brief description is provided here. MMO effort that occurred during daylight conditions (excluding darkness) with visibility ≥1 km (0.6 mi), Bf <6, and no to moderate glare are referred to as "daylight effort," and the following results were restricted to effort and sightings that occurred in these conditions. Vessel activity was categorized as seismic, post-seismic, and non-seismic. Seismic periods included times when airguns were operating, including ramp-ups, power-downs, seismic testing, data acquisition (line shooting), and activation of the mitigation airgun. If one source vessel (a primary vessel) had active airguns, but there was a secondary source vessel within 5 km (3.1 mi) with no airguns activated, the secondary vessel's seismic state was also considered as "seismic". Post-seismic periods included periods up to one hour after cessation of all airgun(s). Non-seismic periods included all data when the airguns were silent with the exception of the period three minutes to one hour after the airgun(s) were deactivated. The procedures for estimating "take" are provided in *Estimated Number of Polar Bears Potentially Affected* later in this chapter.

Monitoring Effort and Encounter Results

This section summarizes the monitoring effort and polar bear encounters from the *Wiley Gunner, Shirley V,* and *Peregrine* during the Eni/PGS survey off Oliktok Point near Spy, Leavitt, and Thetis islands during August to September 2008. Data summaries of effort and sightings are provided in Appendix D. Sightings of polar bears that occurred while MMOs were off-watch (one polar bear) or from a source vessel engaged in stationary monitoring (two polar bears) are described in Appendix E.

Survey Effort

Survey effort is described in detail in *Survey Effort* of Chapter 5. A brief description is provided here. A total of 1268 h (4912 km) of marine mammal monitoring occurred during the Eni/PGS seismic survey, including 245, 576, and 447 h (757, 2434, and 1721 km) from the *Wiley Gunner, Shirley V,* and *Peregrine*, respectively (see Table 5.2 in Chapter 5). Of those observations, ~67% (853 h; 3278 km) were considered as "daylight effort" useable for analyses (see Table 5.2). Most (~66%) of the 415 h that were excluded from analyses were due to watches that occurred during darkness; a combination of darkness and poor visibility accounted for another 18%, poor visibility accounted for 11%, severe glare accounted for 3%, Bf <6 accounted for 1%, and combinations of these factors accounted for the remaining effort that were excluded from analyses. It was assumed that detectability of polar bears was greatly diminished during these excluded periods unless a polar bear occurred very close to the vessel. Seismic, post-seismic, and non-seismic periods made up 64, 6, and 30% (547, 52, and 253 h) of the effort during "daylight" conditions (see Fig. 5.2 and Table 5.2 in Chapter 5). The following analyses were restricted to observations during "daylight" conditions only.

Sightings of Polar Bears

Total Numbers of Polar Bears Sighted

A total of 13 sightings of 16 individual polar bears were made from source vessels during the Eni/PGS seismic survey (Table 6.2). Of those, ~15% (2 of 13 sightings) were made from the *Wiley Gunner*, 46% (6 sightings) from the *Shirley V*, and 38% (5 sightings) from the *Peregrine* (Table 6.2). All sightings were of polar bears on the barrier islands, other than one sighting made from the *Peregrine* of an animal swimming in the water (Fig. 6.1). It is uncertain how many of these polar bears were repeat sightings of the same individual. For the purposes of this report, we have assumed that they were all unique sightings.

All sightings were made during "daylight effort". As such, the following analyses do not exclude any sightings based on environmental conditions. More polar bears were sighted in August than September (~69% of 13 sightings).

Sightings by Seismic State

With the exception of one polar bear observed in the water, all other polar bears were seen on the barrier islands. Therefore, analyses of sightings by seismic state based on water-borne sound from the airgun(s) do not have the same relevance as for other marine mammals. Polar bears on land, if they elicited a response to the Eni/PGS seismic program, would be influenced by airborne sound, visual cues and perhaps olfactory cues. These potential influences would not necessarily differ between seismic, post-seismic, and non-seismic periods. The results provided below should be interpreted with this in mind.

TABLE 6.2. Numbers of polar bear sightings made during seismic, post-seismic, and non-seismic periods from source vessels.

	Seismic		Post-Seismic[a]		Non-Seismic		Total	
	Groups	Indiv.	Groups	Indiv.	Groups	Indiv.	Groups	Indiv.
Wiley Gunner	0	0	1	1	1	1	**2**	**2**
Shirley V	3	5	0	0	3	4	**6**	**9**
Peregrine	1	1[b]	0	0	4	4	**5**	**4**
Total	***4***	***6***	***1***	***1***	***8***	***9***	***13***	***16***

Note: There were 3 incidental sightings of individual polar bears that occurred while MMOs were not on-watch. Details are included in Appendix E. Two polar bears were also sighted during stationary MMO watches from the *Peregrine* and are included in Appendix E.
[a]Post-seismic is defined as 90s to 1 h after seismic periods.
[b]This was the only polar bear observed in the water. All other sightings were of animals on land.

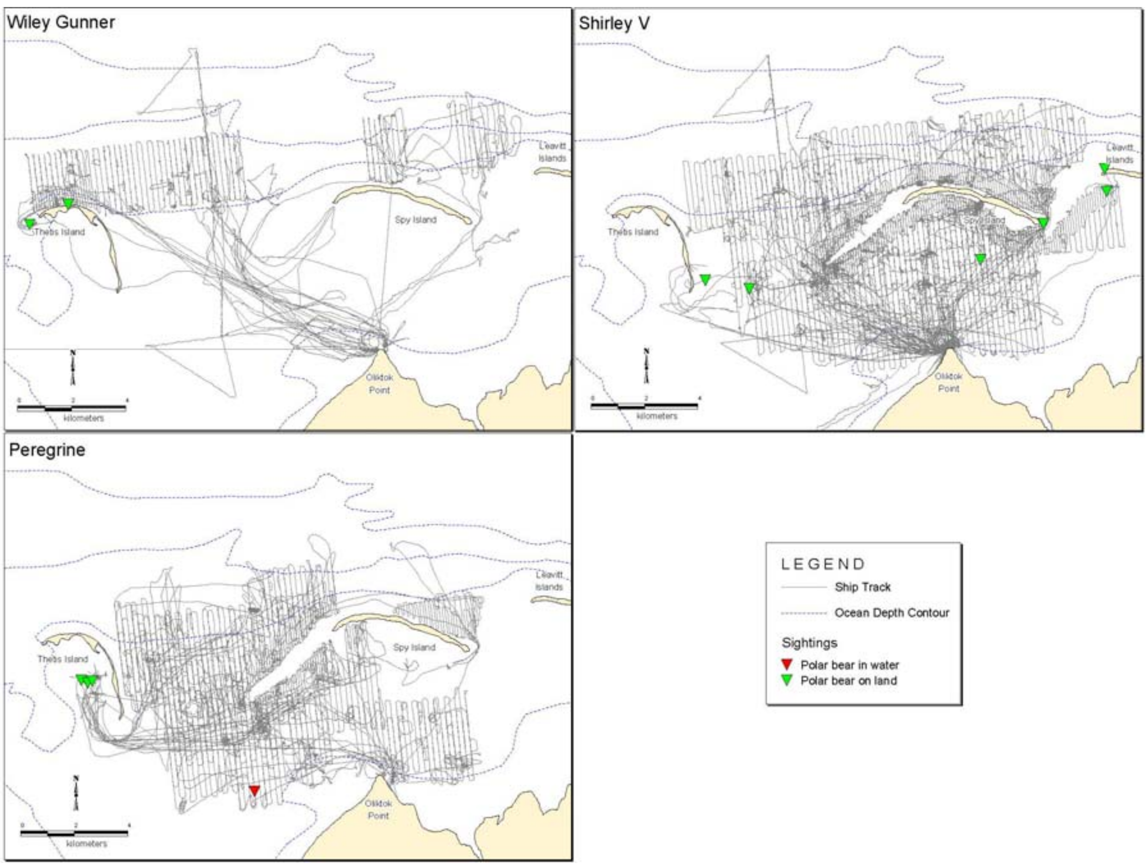

FIGURE 6.1. Locations of polar bear sightings made during the Eni/PGS seismic survey, August-September 2008, central Alaska Beaufort Sea. Specific locations shown are those where the source vessels were located at the time of the sighting.

Of the 13 polar bear sightings, most occurred during non-seismic periods (61%), while 30% and 8% of sightings occurred during seismic and post-seismic periods, respectively (Table 6.2). Half of the eight non-seismic sightings were made from the *Peregrine.* During seismic periods, 75% (or 4 sightings) were made from the *Shirley V.* The only sighting made during post-seismic periods was from the *Wiley Gunner* (Table 6.2). Most polar bear sightings were made when the source vessel was in the “shallow” waters shoreward of the barrier islands during seismic, post-seismic, and non-seismic periods (~85% of 13 sightings), other than two sightings made when the source vessel was in "deep" waters seaward of the barrier islands during non-seismic periods. All sightings of polar bears during seismic periods (n = 4) were made while one MMO was on watch, and polar bear sightings during post- and non-seismic periods (n = 1 and n = 8, respectively) were made while two MMOs were on watch. No power-downs were implemented due to polar bears within or about to enter the 190 dB safety radius. However, there was a single shut-down due to the polar bear observed in the water, and details of this shut-down are included later in this chapter in *Power-downs and Shut-downs*. On seven occasions, a source vessel also moved away from the position of a polar bear sighting; these occasions are described in *Other Mitigation for Polar Bears Observed on Islands.*

Sighting Rates

Sighting rates (number of sightings per unit of effort) for each seismic state are presented in Table 6.3. The swimming polar bear sighting was combined with sightings of polar bears on land for sighting rate calculations. Polar bear sighting rates were highest during non-seismic periods (~31 bears/1000 h of "daylight effort") relative to post-seismic (~19 bears/1000 h) and seismic periods (~7 bears/1000 h; Table 6.3). Polar bear sighting rates were highest for the *Peregrine* (~23 bears/1000 h of "daylight effort") followed by the *Shirley V* (~14 bears/1000 h) and *Wiley Gunner* (~9 bears/1000 h; Table 6.3).

Polar bear sighting rates were higher during non-seismic than seismic periods for Beaufort wind forces of 2 and 4 (no sightings occurred in other Bf during seismic periods; Fig. 6.2). This was not surprising considering that 12 of 13 sightings were of bears seen on the barrier islands. The polar bear sighting rate was similar for periods with one vs. two MMOs on-watch (~14 vs. 17 bears/1000 h of "daylight effort").

TABLE 6.3. Polar bear sighting rates (no./1000 h of "daylight effort") from each source vessel and during seismic, post-seismic, and non-seismic periods. It should be noted that the single sighting of a polar bear in the water (from the *Peregrine* during a seismic period) is included in sighting rate calculations.

Vessel/Seismic State	No. Sightings	Daylight effort (h)[b]	Sighting Rate (No./1000h)
Wiley Gunner	2	215.7	9.3
Shirley V	6	423.3	14.2
Peregrine	5	214	23.4
All vessels			
Seismic	4	547.3	7.3
Post-Seismic[a]	1	52.4	19.1
Non-Seismic	8	253.3	31.6
Total	*13*	*853.0*	*15.2*

[a]Post-seismic is defined as 3 min to 1 h after seismic periods.

[b]Daylight effort is defined as MMO effort during daylight conditions, Bf <6, visibility ≥1 km (0.6 mi), and with no to moderate glare.

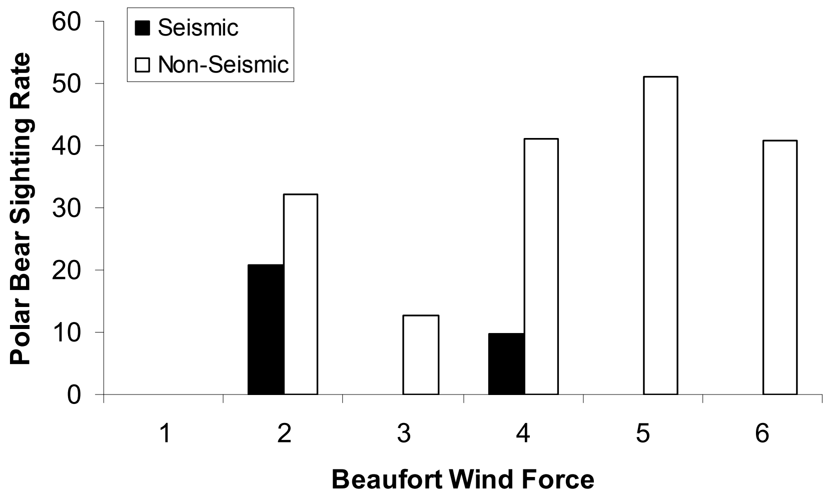

FIGURE 6.2. Polar bear sighting rates (no./1000 h of "daylight effort") for each Beaufort wind force categorized by seismic activity during the Eni/PGS seismic survey. One sighting of a polar bear in the water during Bf 2 seismic periods is included.

Distribution and Behavior

The analyses below provide information about behavioral responses of polar bears to the Eni/PGS seismic survey. Sightings of polar bears on land are combined with the single sighting of a swimming polar bear, but observations specific to the swimming bear are also noted. The closest (observed) points of approach (CPA) to the airguns, animal movement, initial and reactionary behavior were analyzed.

Closest Observed Point of Approach

The average CPA to airguns was smaller during non-seismic (858 m) than seismic periods (1403 m; Table 6.4). However, sample sizes among seismic states were too small to conduct statistical testing. As discussed earlier, all but one of the polar bears were seen on land, and bears out of the water would not likely experience any direct effects of the sound from the airgun(s). The single polar bear observed in the water had a CPA of 631 m (0.4 mi).

Movement

Movement patterns were also determined for all 13 polar bear sightings. The single polar bear observed in the water during seismic periods was observed swimming away from the vessel. All polar bears observed on the barrier islands showed no obvious direction of movement relative to the vessel location, other than one group of polar bears observed on land that walked in a direction oriented away from the vessel's location.

Initial Behavior

Of the 13 polar bear sightings, resting was the most frequently recorded behavior (54%), followed by walking and swimming (39% and 8%, respectively; Fig. 6.3). Swimming was recorded for the polar bear seen in the water. Of the remaining sightings during seismic periods, two were of resting bears and one was of walking bears (Fig. 6.3). Of the eight polar bear sightings seen during non-seismic periods, half were of resting and half were of walking bears. The polar bear seen during a post-seismic period was recorded as resting (Fig. 6.3).

TABLE 6.4. Summary of polar bear CPA to the airguns of each source vessel by seismic state.

	Seismic					Post-Seismic[a]					Non-Seismic				
	n	Mean CPA (m)	s.d.	Min.	Max.	*n*	Mean CPA (m)	s.d.	Min.	Max.	*n*	Mean CPA (m)	s.d.	Min.	Max.
Wiley Gunner	0	-	-	-	-	1	400	N/A	400	400	1	858	N/A	858	858
Shirley V	3	1660.7	810.7	882	2500	0	-	-	-	-	0	-	-	-	-
Peregrine	1	631	N/A	631	631	0	-	-	-	-	0	-	-	-	-
All sightings	**4**	**1403.3**	**1824.5**	**631**	**2500**	**1**	**400**	**N/A**	**400**	**400**	**1**	**858**	**N/A**	**858**	**858**

Note: N/A = not applicable; s.d. = standard deviation; the single swimming polar bear (observed during seismic periods) had a CPA of 631 m.

[a]Post-seismic is defined as 3 min to 1 h after seismic periods.

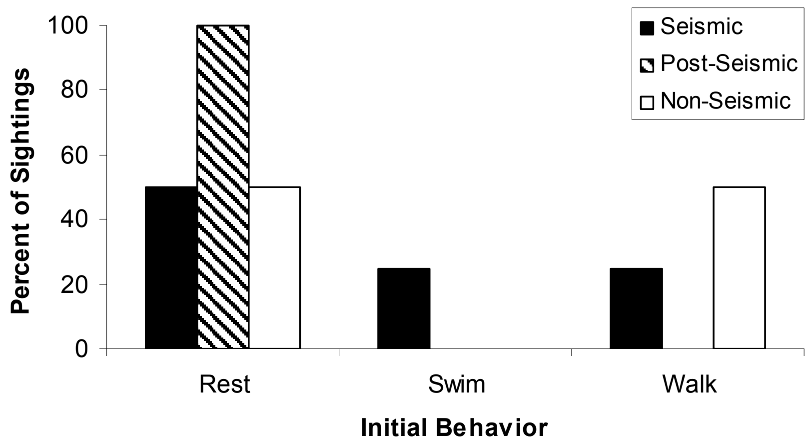

Figure 6.3. Percent of polar bear sightings categorized as exhibiting resting, swimming, or walking behavior by seismic state. Only one polar bear was observed in the water and it was recorded as swimming.

<u>*Reaction Behavior*</u>

"No reaction" was recorded during most polar bear sightings (69% of 13 sightings), and "looking" was recorded during the remaining polar bear sightings (Fig. 6.4). During both seismic and non-seismic periods, 25% of polar bears were observed looking. No reaction was recorded for the remaining 75% of sightings during both seismic and non-seismic periods; looking was recorded as the reaction behavior during the only post-seismic sighting (Fig. 6.4). For the swimming polar bear, reaction was recorded as looking.

FIGURE 6.4. Percent of polar bear sightings categorized as "looking" or showing "no reaction" behavior by seismic state. "No reaction" was recorded for the only polar bear observed in the water (during seismic periods).

Implementation of Mitigation Measures

Mitigation measures for the presence of marine mammals during the Eni/PGS survey included ramp-ups, power-downs, shut-downs, and course changes. Ramp-ups were conducted whenever the airguns were activated after a prolonged period of inactivity (>10 min); however, see *Problems with the Implementation of Mitigation Measures* in Chapter 5 for instances when this was not observed, most often due to mechanical problems.[7] Course or route changes occurred whenever possible, and were often initiated to avoid potential power- or shut-downs due to an animal about to enter the relevant safety radius. When course changes were not possible, power- or shut-downs occurred when a marine mammal was seen about to enter or within the relevant safety radius.

Power-downs and Shut-downs

No power-downs (or delay of ramp-ups) due to polar bears were required during the Eni/PGS seismic survey. A single shut-down occurred due to the only swimming polar bear sighting, on 13 September 2008. The polar bear was observed 614 m (2014 ft) from the MMOs located on the bridge of the *Peregrine* and 631 m (2070 ft) from the airguns at 1050 h AKDT. The bear was initially observed swimming away from the vessel at a moderate pace in water 1.7 m (5.6 ft) deep while the *Peregrine* was shooting a 440 in^3 array. A complete shut-down was requested and implemented at 1055 h AKDT. The *Peregrine* also moved away from the polar bear to increase the distance from the vessel to the bear to >800 m (0.5 mi) as required under the LOA. The vessel resumed operating the 440 in^3 array within 10 min, with no ramp-up, since the animal was outside the 800 m (0.5 mi) exclusion zone and swimming away. The polar bear was last seen at 1120 h at a distance of 1500 m (0.9 mi), still swimming away from the vessel. The 190 dB nominal safety radius for the 440 in^3 array is 250 m (820 ft; see Chapter 4), and it is estimated that the animal may have been exposed to sound levels ≥170 dB (but <190 dB) prior to the shut-down (if the animal put it's head below the water surface).

Other Mitigation for Polar Bears Observed on Islands

On seven occasions, polar bears were observed on islands from source vessels, and the vessel altered its position, activities, or course to avoid behavioral disturbance of the bears, including:

- One polar bear was observed resting on an island during a 30 min watch prior to starting ramp-up from the *Wiley Gunner* on 10 August 2008. The bear was observed sleeping initially and then sometimes looking at the vessel. Rather than ramp-up, the vessel left the area without activating its airguns and prepared to shoot another line. The polar bear was not seen again after leaving the area.
- The *Shirley V* was inactive on 25 August 2008 when two polar bears were observed 882 m (0.5 mi) away laying down on Leavitt Island. The polar bears showed no movement, and the vessel moved farther away upon sighting them.
- A polar bear was observed walking on an island on 26 August 2008 at a distance of 250 m (0.15 mi) from the *Shirley V* while no airguns were activated. The vessel moved away once the bear was sighted. The bear was later observed swimming to another island and continued walking down the beach of that island.
- From the *Shirley V* on 29 August 2008, a polar bear was observed resting on the shore of Thetis Island 2500 m (1.6 mi) away. The vessel's airguns were operating at the time of the sighting, and the bear was observed sitting up and looking at the vessel before laying back down. The vessel moved away from the polar bear at the time of the sighting.
- On 5 September 2008, a resting polar bear was sighted on Spy Island from the *Shirley V* at a distance of 2319 m (1.4 mi). The vessel's airguns were operating at the time, and the MMO

[7] Polar bears were not observed within 30 min of any of the mitigation measure problems described in this section.

requested that the vessel move away. The vessel did move away, and the polar bear never showed any reaction to the vessel.

- A polar bear was sighted from the *Peregrine* on 2 September 2008 750 m (0.5 mi) away resting on the beach at Spy Island. The polar bear showed no obvious reaction to the vessel. The vessel had no airguns firing at the time and moved away upon sighting the bear.
- On 2 September, the *Peregrine* was anchored (with no airguns activated) in the lee of Thetis Island when a polar bear was sighted walking 450 m (0.3 mi) away. The polar bear showed no obvious reaction to the vessel, and the vessel moved away from the area after sighting the polar bear.

Estimated Number of Polar Bears Potentially Affected

It is challenging to estimate "take by harassment" for marine mammals for several reasons—see *Estimated Number of Seals and Cetacean Potentially Affected* in Chapter 5. Polar bears observed on the barrier islands (or ice) would not be exposed to waterborne sound from the airguns. Also, polar bears observed in the water do not frequently dive, and are even less likely to do so in the shallow waters of the Eni/PGS seismic survey area. For the majority of time, polar bears in water would not lower their ears below the water surface and would not directly receive underwater sound from the airguns.

Sound Level Criteria

Any polar bear that may have been exposed to activated airguns with received sound levels ≥190 dB was assumed to have been potentially affected. Table 4.1 (in Chapter 4) presents the estimated received sound levels at various distances from the airgun array of each source vessel during the Eni/PGS seismic survey.

Two methods were used to estimate the number of polar bears potentially affected by exposure to sound levels strong enough that they may have caused a disturbance or other potential impacts. The minimum estimate was based on the direct observations of polar bears by MMOs during the survey, and the maximum estimate was derived by methods similar to those used for seals.

Estimates from Direct Observations

Observations of polar bears close to the source vessels during seismic operations provide a minimum estimate of the number potentially affected by seismic sounds. This approach may have underestimated the actual number of individuals potentially impacted. During daylight periods, it was possible that animals would be missed because of limited visibility. Furthermore, it was not possible to observe animals effectively during darkness periods.

Additionally, it was possible that polar bears would avoid the area around a seismic vessel even when the airguns were not active. The largest 190 dB sound radius of all the source vessels was 300 m (0.2 mi) for the 880 in^3 array operated from the *Peregrine*, but polar bears may respond at lower received sound levels or to the presence of the source or support vessels themselves. The extent to which the distribution and behavior of polar bears might be affected by the Eni/PGS survey beyond the detection distance for MMOs is unknown.

It should be noted that the 190 dB safety radius is the *maximum* distance from the airgun array where sound levels would be expected to reach ≥190 dB. This distance was applicable at the water depth and in the direction from the array where sounds were strongest. Thus, it was complicated to assess the maximum level to which any given individual marine mammal might be exposed. Also, polar bears observed on land or ice would have potentially received very little, if any, of the sound propagated underwater. Polar bears also swim with their ears above the water surface and seldom dive, so they would also be assumed to receive relatively little of the underwater sound in these cases.

Polar Bears Potentially Exposed to Sounds ≥190 dB

No polar bears were observed within the 190 dB safety radius during the Eni/PGS seismic operations. However, the airguns on the *Peregrine* were shut-down once for a swimming polar bear seen at a distance of 631 m (2070 ft) from the airgun array when they were operating at 440 in^3. Given the distance of the initial (and closest) sighting of this animal, it is likely that the sound levels received by the polar bear was ≥170 dB (but less than 190 dB), assuming that the animal lowered its ears below the water surface before the airguns were shut-down.

Strong Behavioral Responses of Polar Bears

There were 12 sightings of polar bears (15 individuals) on the barrier islands from source vessels during the Eni/PGS seismic survey. The vessel changed position, course, and/or activities on seven of these occasions. In no cases did MMOs observe strong behavioral reactions to the seismic operations. All polar bear reactions were recorded as “no reaction” or “looking” at the vessel. One polar bear was observed swimming away from the *Peregrine* while its airguns were activated, but it showed no obvious fleeing behavior or changes in direction or increase in speed. None of the two polar bears observed incidentally (see Appendix E) exhibited strong behavioral responses to the seismic vessels.

Indirect Estimates of the Number of Exposures and Individuals Exposed

The number of polar bear exposures and individuals exposed to seismic sound levels ≥190 dB was estimated using methods similar to those used for seals in Chapter 5. First, the density of polar bears was derived from the number of polar bears observed in the water within a 2000 m strip centered on the vessel’s trackline. This value was multiplied by the estimated 190 dB ensonified area to provide the number of polar bear *exposures* to sound levels ≥190 dB. To estimate the number of *individual* polar bears exposed to sound levels ≥190 dB, polar bear density was multiplied by the 190 dB ensonified area, but corrected for multiple exposures in a given area (for crossing tracklines or overlapping 190 dB areas). The methods to calculate each of these estimates are provided below.

Estimating Density

As for most marine mammals, it was assumed that the detectability of polar bears in the water decreases with distance. Additionally, it was assumed that only polar bears sighted in the water would be available to receive seismic sounds produced by the Eni/PGS survey. Therefore, a detection distance of 1000 m (0.6 mi) lateral distance was applied to sightings of polar bears in the water. To account for the potential bias of environmental conditions and the number of observers on the ability to detect polar bears, effort for density estimation was restricted to “daylight effort” during seismic periods. A total of one polar bear sighting was made during 547.3 h of observations under these conditions. It was seen along 2398.0 km (1490.0 mi) of vessel trackline during seismic periods, for a complete area (including 1000 m distance on both sides of the vessel, or 2000 m total) of ~48.0 km^2 (18.5 mi^2). Thus, the observed polar bear density within a 2000 m (1.2 mi) strip during seismic “daylight effort” was 0.02 polar bears/ km^2. Table 6.5 summarizes the calculation of polar bear density (for all vessels combined).

Estimating Number of Exposures

Estimates of the number of potential *exposures* of polar bears to sound levels ≥190 dB were calculated by multiplying the observed polar bear density (0.02 polar bears/km^2) by the trackline area assumed to be ensonified by ≥190 dB (based on all vessels and areas). This ensonified area included repeated counts of areas exposed multiple times due to the close proximity of seismic survey lines. A total area of ~1622 km^2 was found to be ensonified to sound levels ≥190 dB during seismic periods of the survey. The calculation of polar bear exposures likely overestimates the number of individual polar bears exposed to airgun sounds at received levels ≥190 dB, because some incidents of exposure may involve the same individuals previously exposed, given that some seismic lines crossed other lines or were spaced closely together (see Fig. 6.1).

Estimating Number of Individuals

Estimates of the number of *individual* polar bears exposed to sound levels ≥190 dB was obtained similarly to the method described for "exposures" above, except that the observed polar bear density was, in this case, multiplied by the area that was estimated to be ensonified ≥190 dB at least one time. MapInfo GIS software was used to calculate the ensonified area for the number of individual polar bears potentially exposed to ≥190 dB. A "buffer" was created that extended to the predicted 190 dB radius (from Table 4.1) to both sides of the vessel's trackline, based on the vessel water depth ("deep" areas seaward of the barrier islands vs. "shallow" areas shoreward of the barrier islands). The buffer would then include areas that were exposed multiple times to seismic pulses ≥190 dB for crossing tracklines or tracklines that were close enough for their 190 dB zones to overlap. The overlapping buffers were then removed so that a given area of water exposed to 190 dB more than once was only counted one time. As a result, the estimate of the number of individual polar bears exposed to ≥190 dB is considered a minimum indirect estimate since animal movement during the course of the survey is not accounted for in this estimate. After accounting for repeated coverage, a total of 150.4 km^2 was estimated to be ensonified to sound levels ≥190 dB.

Estimated Number of Polar Bears Exposed to ≥190 dB

During the Eni/PGS survey, it was estimated that there would have been ~four individual polar bears potentially exposed to sound levels ≥190 dB if no polar bears moved out of 190 dB safety zone in response to the approaching airguns and vessel (Table 6.5). There were an estimated 34 exposures of polar bears. The estimates of the number of individual bears exposed and exposures per individual would be reasonable if polar bears did not react to the approaching vessel. However, most bears probably avoided the seismic survey activities and the number of animals actually exposed to sound levels ≥190 dB is likely lower than the estimated numbers.

TABLE 6.5. Number of polar bears seen within a 1000 m (0.6 mi) lateral distance during seismic periods, "daylight" trackline effort, estimated polar bear densities, and estimated number of polar bear exposures and individual polar bears exposed to sound levels ≥190 dB.

No. Polar Bear Sightings[a]	1
Trackline Effort (km)[b]	2398.0
Trackline Effort in 2000 m Strip (km^2)[c]	47.96
Polar Bear Density (No./km^2)	0.02
Ensonified Area Assuming Overlap (km^2)[d]	1622.05
No. Polar Bear Exposures	***34***
Ensonsified Area Assuming No Overlap (km^2)[e]	150.42
No. Indiv. Polar Bears Exposed	***4***

[a]Number of sightings of polar bears in the water within 0-1000 m (0-0.6 mi) lateral distance of the vessel trackline.

[b]Vessel "daylight effort" (km) during seismic periods.

[c]Vessel "daylight effort" (km) during seismic within a 2000 m (1.2 mi) strip centered on the vessel trackline.

[d]Area estimated to be ensonified to the 190 dB radius, including multiple exposures to an area by one or more vessels.

[e]Area estimated to be ensonified to the 190 dB radius, excluding multiple exposures to an area by one or more vessels.

Subsistence Hunt

No walrus are hunted in the Eni/PGS seismic survey area. Polar bears are occasionally hunted but as discussed in Chapter 5, the com-centers did not receive any reports of Eni/PGS seismic operations affecting any subsistence hunt in the area.

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7. AERIAL MARINE MAMMAL MONITORING AND MITIGATION: ANALYSIS AND RESULTS

Introduction

An aerial monitoring program for marine mammals was conducted in the central Alaskan Beaufort Sea during August and September 2008 to monitor potential cumulative impacts in support of seismic exploration activities by PGS and drilling and production operations by Pioneer Natural Resources, Inc. Surveys were flown a minimum of three times per week, weather permitting, from 25 August through 27 September, to obtain data on the occurrence, distribution, and movements of marine mammals, particularly bowhead whales, in waters surrounding the seismic survey area. Bowhead whales were not expected to occur inside the barrier islands and, as such, aerial surveys were designed to cover the area north of the barrier islands, through which migrating bowhead whales pass (Ljungblad et al. 1986) and into which sound from the seismic surveys propagated. NMFS required a shutdown of airgun operations if aerial surveyors detected an aggregation of ≥12 bowhead whales or ≥4 bowhead whale cow/calf pairs within the 160 or 120 dB zones, respectively.

Previous studies have shown that migrating bowhead whales in the Alaskan Beaufort Sea have avoided seismic operations at received levels of 116–135 dB re 1 µPa (Miller et al. 1999; Richardson et al. 1999). If the Eni/PGS seismic operations were affecting bowhead whales, we would expect lower sighting rates during seismic vs. non-seismic periods, particularly in the immediate vicinity of seismic activities (e.g. “central areas”; see Fig. 7.1 later). Furthermore, we might expect migrating whales to alter their headings and increase distance from shore to avoid areas of seismic activity, in areas near (central area) and west (west area) of the seismic prospect.

Beluga whales also have the potential to be negatively affected by seismic activity (Richardson et al. 1995; Richardson and Würsig 1997). However, little is known about specific reactions of this species to seismic activities during their migration, and it has been suggested that because belugas migrate at great distances offshore during the fall, they are unlikely to be strongly affected by seismic exploration (Richardson 1999). Beluga whales in the Canadian Beaufort Sea have been shown to avoid an area 10-20 km (6.2-12.4 mi) from an operating seismic ship where received sound levels from airgun pulses were estimated to be ~150 to 130 dB re 1 µPa; Miller et al. 2005). To help elucidate beluga whale responses to seismic activity, sighting rates, distribution and headings in relation to seismic activities were examined.

Objectives

The objectives of the aerial survey program were to:

- advise operating vessels as to the presence of marine mammals in the general area of operation to meet requirements of the IHA issued by NMFS;
- collect and report information on the distribution, abundance, direction of travel, and activities of marine mammals near the seismic operations with special emphasis on migratory bowhead whales;
- support regulatory reporting related to the estimation of impacts of seismic operations on marine mammals;
- document the extent, duration, and location of any bowhead whale deflections in response to seismic activities, to the degree possible.

Methods

Study Area

<u>*Transects flown*</u>

Nine transects, ranging in length from 68 km (42 mi) to 112 km (70 mi), covering an area of ~6620 km^2 (2556 mi^2) were surveyed to monitor the ≥120 dB radius around PGS seismic operations and surrounding waters. The 160 dB zone was limited to a small area, mostly shoreward of the barrier islands, where cetaceans were not expected to occur. The survey area included transects designed specifically to monitor PGS seismic activities (transects 39–47) and pre–existing transects designed for Shell Offshore Inc's seismic monitoring program (transects 64–66, Fig. 7.1). The total length of transects in the aerial survey area was 757 km (470.4 mi). Although the IHA stated that the aircraft was to break transect and circle any large whales sighted, permission was granted by NMFS to continue along transect lines without circling. Circling whales would have impeded calculation of accurate density estimates in the study area, precluded comparisons to data from previous years, and would have resulted in fewer total km of transects surveyed. Permission was also granted to fly at an altitude of 1000 ft rather than the suggested 1500 ft in order to maintain consistency among years and to maximize accuracy in mammal identification.

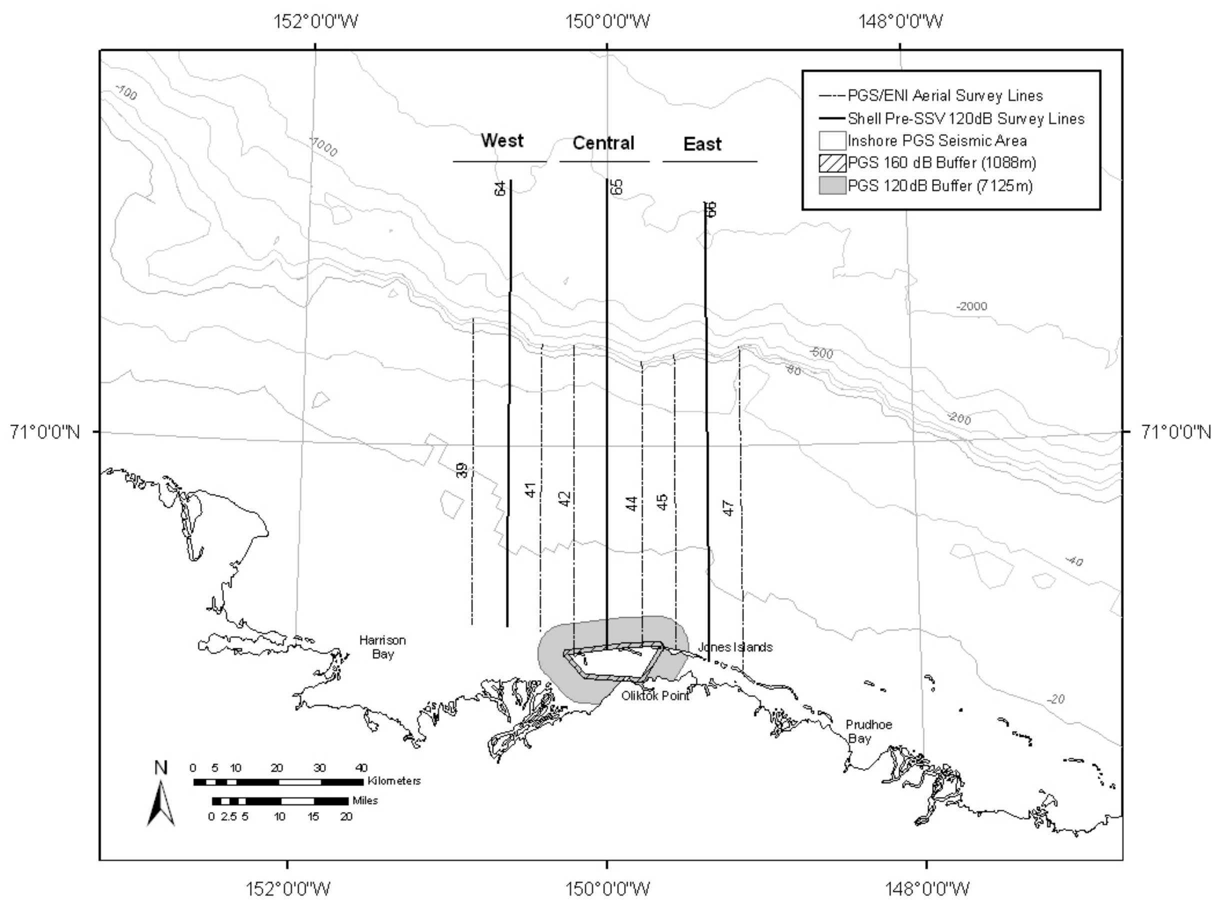

FIGURE 7.1. Aerial survey transect lines flown for Eni/PGS in the central Alaskan Beaufort Sea from 25 August through 27 September 2008. The Eni/PGS seismic survey area, with ≥160 dB and ≥120 dB zones, is also shown.

Survey Procedures

Surveys were performed in a DHC-300 Twin Otter aircraft, operated by Bald Mountain Air. The aircraft was specially modified for survey work including upgraded engines, a STOL kit to allow safer flight at low speeds, wing–tip fuel tanks, multiple GPS navigation systems, bubble windows for primary observers, and 110 V AC power for survey equipment. Surveys were conducted at an altitude of 305 m (1000 ft) above sea level and at a ground speed of approximately 222 km/hr (110 kt). Fuel capacity and weather conditions determined flight length.

Two primary observers were positioned at bubble windows on opposite sides of the aircraft and scanned the water within ~ 2 km (1.2 mi) of the aircraft for marine mammals. Up to two secondary observers, present usually for training purposes, were positioned at flat windows in the back of the aircraft. When a marine mammal was sighted, observers dictated into a digital voice recorder the species, number of individuals, sighting cue, age class when determinable, heading, swimming speed category (if traveling), and inclinometer reading. If possible, behavior (movements or processes in which animal is engaged) and activity (a collection of behaviors that indicate the animal is working toward an overall goal such as migrating) were recorded for each sighting. Behaviors included swimming, diving, surface active (flipper or fluke slaps, splashing, etc.), and hauled out, whereas activities included feeding, traveling, socializing, resting, and milling. Due to the limited time period for which an animal was observed, it was not always possible to record the behavior, activity, speed, and heading for every sighting; as a result, a subset of this information was often collected. The inclinometer reading was recorded when the animal's location was perpendicular to the path of the aircraft, allowing calculation of lateral distance from the aircraft trackline.

In addition to marine mammal sightings, each observer recorded the time, sightability (subjectively classified as excellent, good, moderately impaired, seriously impaired or impossible), sea conditions (Beaufort wind force), ice cover (percentage), ice type, slush cover (percentage), and sun glare (none, little, moderate, or severe) at 2–min intervals along transects, and at the end of each transect. The collection of these data provided information suitable for statistical summaries and analyses of effects of these variables on the probability of detecting animals (see Davis et al. 1982; Miller et al. 1999; Thomas et al. 2002).

Data Recording

An additional observer (the data recorder) onboard the aircraft entered sightings and effort data from primary observers into a laptop computer and searched for marine mammals during periods when data entry was not necessary. This observer entered GPS waypoints for transect starts and stops, 2–min intervals at which environmental data were collected, and sightings into the GPS–linked laptop. At the start of each transect, the data recorder also recorded the transect start time, ceiling height (ft), cloud cover (%), wind speed (kt), and outside air temperature (°C). NRoute® position logging software was used to automatically record time and aircraft position at pre–selected intervals (typically at two seconds for straight–line transect surveys) for later calculation and analysis of survey effort.

Analyses of Aerial Survey Data

Sightings and Effort

Environmental factors such as sea conditions and glare can affect an observer's ability to detect marine mammals during aerial surveys and can bias results. To minimize bias, environmental data were used to classify sightings and effort as "useable" or "other" for quantitative analyses. Cetacean sightings and effort were considered "useable" when the following criteria were met: the animal was sighted by a primary observer while the aircraft was flying a pre–established north–south oriented transect, Beaufort wind force was 4 (winds 20–30 km/h or 11–16 kt) or less, glare covered 30% or less of the field of view of the observer, and overall sightability was described as excellent to moderately impaired. Furthermore, sightings detected at distances greater than 2 km (determined using an inclinometer) or immediately below the aircraft were excluded. Only sightings considered "useable" were mapped, analyzed and discussed, with the exception of polar bears and harbor porpoises. Pinniped sightings were considered useable if Beaufort wind force was no greater than 2 (winds ~7–11 km/hr or 11–15 kt). Because the observer's ability to see and correctly identify pinnipeds from 305 m (1000 ft) was highly weather dependent, we did not conduct in–depth analyses of pinniped data. Differences in sighting rates were compared by using a Chi–square goodness–of–fit test.

Seismic State

Effort and sightings data were divided into categories based on seismic state (seismic, post-seismic, and non-seismic), as determined by data compiled by MMOs on the seismic source vessels. Survey effort (and associated sightings) was categorized as seismic at times when airguns were active (including periods of ramp–up and mitigation gun firing) and up to three minutes after airgun activity ceased. Survey effort occurring from three min to 24 h after airgun activity ceased was considered post–seismic. All other effort was considered non–seismic. The post–seismic category represented the refractory period during which mammals impacted by seismic activities were assumed to return to normal behavior and hence was analyzed separately. This decision was based on research by Miller et al. (1999) indicating that migrating bowhead whales resumed their "normal" (pre–seismic) migratory course 12 to 24 hrs after the cessation of seismic activities.

Mapping

All on–transect sightings made during aerial surveys were mapped using ArcMap 9.3 (ESRI, 1999–2008) and coded with different symbols to indicate seismic state and species at the time of sighting. Each symbol represented one sighting, regardless of the number of individuals recorded within that sighting. We emphasized sightings rather than individuals for analyses because sightings were statistically independent, whereas a tally of individuals would include groups of individuals that were not independent of one another. In addition, bowheads often traveled alone or in pairs and average group sizes during offshore aerial surveys of the Beaufort Sea were not higher than 1.5 individuals from 2006–2008 (Thomas et al. 2007; Lyons et al. 2008).

Abundance and Density

We calculated bowhead whale abundance and density using DISTANCE software (Thomas et al. 2006) for each survey. Estimated density and abundance were calculated for surveys when effort was greater than 250 km (155 mi). $f(0)$ values were calculated by DISTANCE using data from sightings in the Chukchi and Beaufort seas collected over the past three years (2006–2008; Thomas et al. 2007; Lyons et al. 2008). $g(0)$ values were based on previous research (Thomas et al. 2002; bowhead whales $g(0) = 0.144$, beluga whales $g(0) = 0.580$). In addition, right truncation distances were calculated by graphing sightings and excluding sightings past the 90% confidence interval. Left truncation distances were set at 30.5 m (100 ft), because animals directly below the aircraft were difficult to see. Several models were created and compared in DISTANCE and the best fitting model, with the lowest Akaike's Information Criterion (Burnham and Anderson 1998), was chosen. Bootstrapped average abundance and density over the entire survey period were calculated using the Resampling Tool add–on in Excel.

Spatial Differences

Differences in distance from shore and longitudinal distribution of bowhead whales relative to seismic activity were also of interest. To assess these differences, we divided the survey area into three sub–areas: east, central, and west. The areas were designed so that central area included the seismic survey area (see Fig. 7.1). We expected that if bowhead whales responded to seismic survey activity, sighting rates in the central area would peak farther from shore than in the eastern area, and that this deflection might continue into the western area.

Effort and sightings data were also divided into 5–km (3-mi) distance from shore bins, with a "0 km from shore" line delineating the shoreline or the outer edge of the barrier islands. To assess any offshore deflections, sighting rates were computed within each of these bins and statistically compared between seismic and non–seismic states with a bootstrapped Kolmogorov–Smirnov test (K–S test) in the R statistical software package. This test compares two distributions and calculates a maximum distance between them (D–max). As such, a K–S test can assess two types of differences: shifting of curves to either the right or the left and differences in means. The statistical power of a standard K–S test decreases when the data are grouped, with a further decrease in power as the categories are broadened. Grouping was necessary, however, to relate sightings to survey effort by distance from shore. The loss of power can be minimized by using a larger number of narrow categories and for this reason, we used 5–km (3–mi) categories, even through 10–km (6–mi) categories resulted in a smoother distribution of sightings–per–unit–effort vs. distance from shore. In addition, the bootstrapped K–S test was more robust than the standard K–S test when datasets include ties and was used to further increase the validity of tests. This analysis was conducted for each area (east, central, west), when sample sizes permitted, to determine whether the effect of seismic activity on whale distributions varied among areas.

Distribution Relative to Center of the Seismic Survey Area

The distribution of mammal sightings relative to the center of the seismic survey area was calculated by plotting the seismic survey area in ArcMap 9.3 and estimating the geographical center with the measure tool. Sightings were then plotted and the GIS add–on "Hawth's Tools" (Beyer 2004) used to determine distances between sightings and the center point of the prospect. Data were then compared with the non–parametric Kruskall–Wallis test to determine whether average distance from the seismic center differed among seismic states.

Activities, Headings, and Speed

Seismic activity has the potential to alter patterns in spatial use of an area by whales and could potentially interfere with migration. We examined activities, headings, and speeds in relation to seismic activities in the study areas to address these concerns. Headings were grouped by seismic state and area (west, central, east) and mean vectors determined with Oriana statistical software. We were interested in behavioral changes of migrating whales, hence speeds and headings were only assessed for whales observed to be either swimming or traveling, and whales that were socializing, resting, surface-active, or feeding were excluded.

Estimated Exposures

Aerial survey densities used to estimate exposures of bowhead and beluga whales were calculated using DISTANCE software. Densities were calculated for each survey individually, and then a weighted average was calculated for the total survey area. The weighted average density was then multiplied by the area of water exposed to received sound levels ≥160 dB and ≥ 180 dB to calculate the estimated number of individual whales potentially exposed at those levels. Estimated number of exposures per individual was calculated by determining the ratio of the total area of water ensonified (including areas that were ensonified multiple times) to the area of water ensonified with overlapping areas excluded. We did not calculate exposures for species other than bowhead and beluga whales because our aerial surveys were designed to document the occurrence of large cetaceans expected to be migrating through the area.

Results

Survey Effort

A total of 15 aerial surveys were flown over the central Alaskan Beaufort Sea from 25 August through 27 September 2008. Each survey took one day to complete and a total of 4883.3 km (3034.3 mi) of survey effort was obtained, of which 4184 km (2600 mi) were considered "useable" based on data analysis criteria. Throughout the rest of this report, only useable survey effort will be discussed. Three flights per week were achieved for all five weeks of survey activity, though one of the three flights on the first week (28 August) had no useable effort. Low ceiling heights or high winds frequently truncated or prohibited surveys (Appendix F: Figs. F.1 and F.2). Effort ranged from 6.6 km to 646.3 km per survey (1% to 85% of the survey area) and was too low to estimate densities (less than 500 km or 311 mi) on all but two days (Table 7.1). Most aerial survey effort occurred during seismic operations (2939 km of effort; 1826 mi), compared with post–seismic effort (858 km, 533 mi) and non–seismic effort (387 km, 240 mi; Fig. 7.2). Dates of aerial surveys were compared with hours of vessel–based seismic data acquisition in Fig. F.3 in Appendix F. Survey effort was similar among the three survey areas, with slightly more effort in the central area than other areas (Fig. 7.3). Effort was greatest within 35 km (22 mi) of shore and declined gradually at greater distances offshore (Fig. 7.4).

TABLE 7.1. Summary of aerial survey effort and sighting rates. Values in parentheses are to be interpreted with caution, as they were calculated using less than 500 km (311 mi) of effort. Sighting rates were not calculated ("NC") when effort was less than 250 km (155 mi).

Date	Survey No.	Effort (km)	Percent of Survey Area	Bowhead Whale			
				Sightings	Individuals	Sightings/ 1000 km	Individuals/ 1000 km
25 Aug	1	646.3	85	1	1	1.5	1.5
29 Aug	2	580.8	77	11	17	18.9	29.3
31 Aug	3	75.4	10	(0)	(0)	NC	NC
05 Sep	4	258.9	34	(2)	(3)	(8)	(12)
06 Sep	5	307.2	41	(0)	(0)	(0.0)	(0.0)
09 Sep	6	250.5	33	(0)	(0)	(0.0)	(0.0)
10 Sep	7	264.2	35	(0)	(0)	(0.0)	(0.0)
12 Sep	8	386.2	51	(3)	(3)	(8)	(8)
14 Sep	9	6.6	1	(0)	(0)	NC	NC
18 Sep	10	228.2	30	(1)	(1)	NC	NC
19 Sep	11	218.6	29	(1)	(1)	NC	NC
23 Sep	12	67.5	9	(1)	(2)	NC	NC
24 Sep	13	113.3	15	(2)	(3)	NC	NC
25 Sep	14	230.3	30	(2)	(2)	NC	NC
27 Sep	15	549.6	73	1	1	1.8	1.8
Total	**15**	**4184**	**37**	**25**	**34**	**7.56***	**10.4***

* average sighting rates

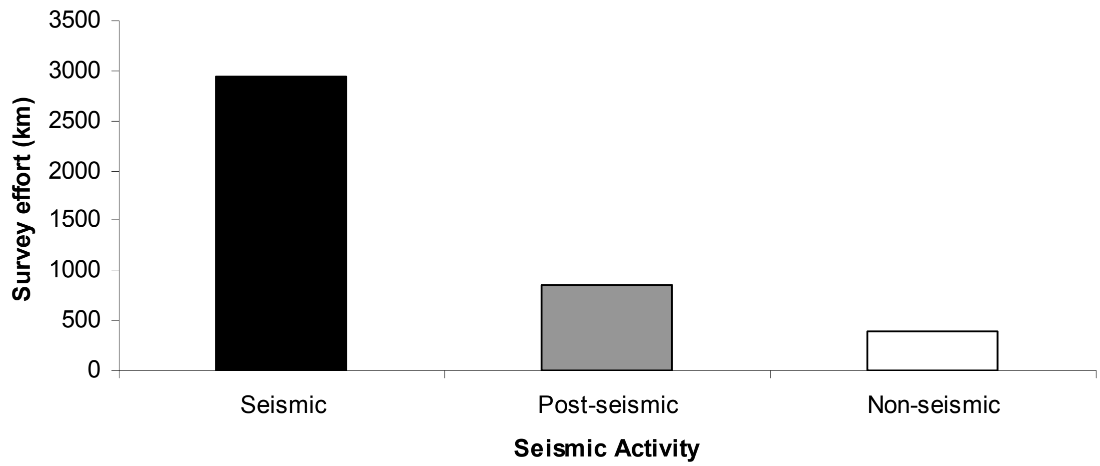

FIGURE 7.2 Aerial survey effort (km) by seismic state.

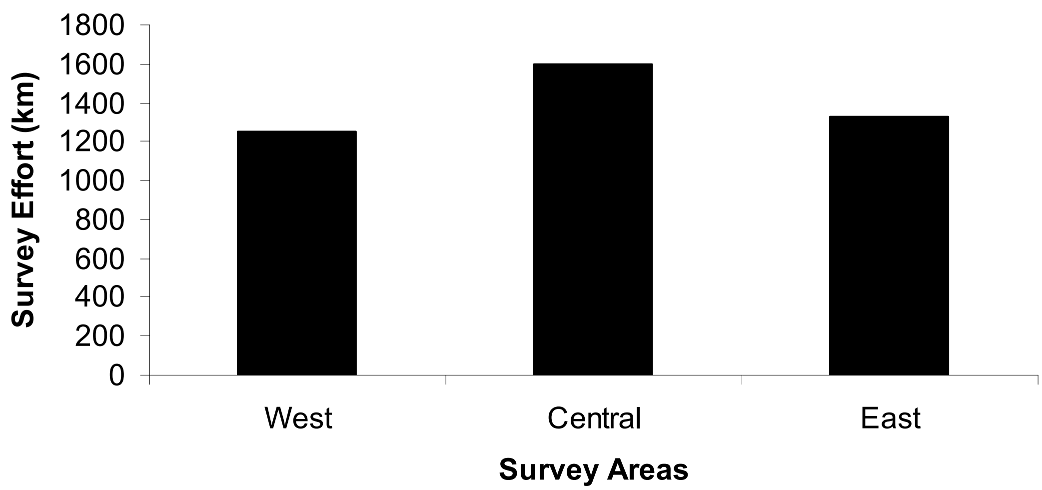

FIGURE 7.3. Aerial survey effort (km) within the west, central and east areas of the survey area.

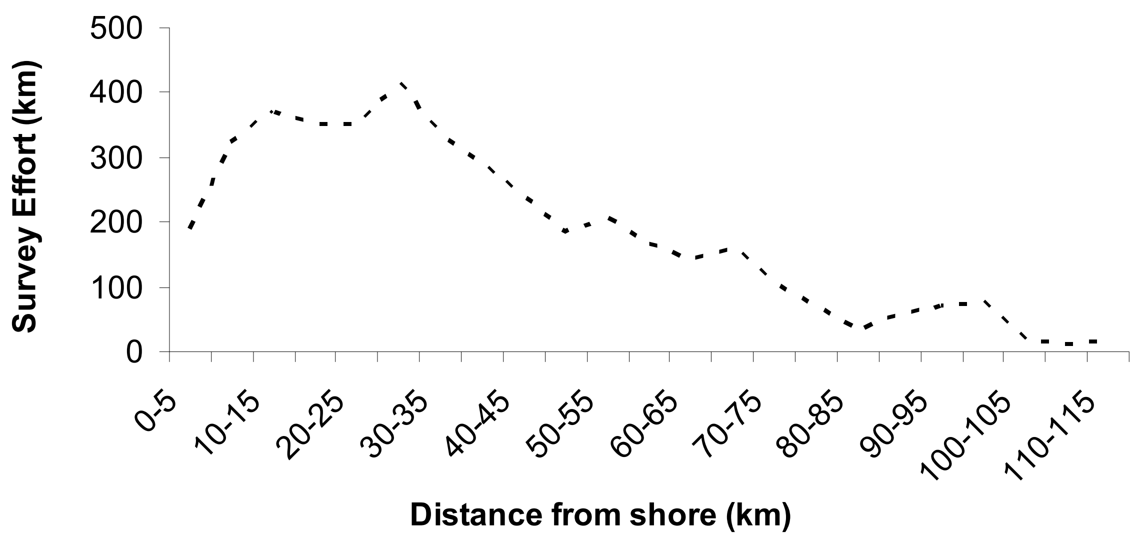

FIGURE 7.4. Aerial survey effort (km), by 5-km distance from shore bins.

Bowhead Whales

Sightings and Sighting Rates

A total of 40 bowhead whale sightings (55 individual whales) was observed during 2008 aerial surveys of the Eni/PGS aerial survey area (25 August through 27 September). Twenty-five sightings (34 individuals) were recorded in "useable" conditions (Table 7.1 and Fig. 7.5). The following analyses and discussion only consider the 25 "useable" sightings. Bowhead whales were observed on 67% of surveys, with an average of two sightings (two individuals) per survey. Sightings varied in frequency from 0–11 per survey (0–17 individuals), with corresponding sighting rates from 0–19 sightings/1000 km (0-31 sightings/1000 mi) and 0–29 individuals/1000 km (0-47 individuals/1000 mi). Bowhead whale sighting rates observed during this study were highest in late August and early September, with a peak rate of 19 sightings/1000 km (12 sightings/1000 mi) on 29 August. One unidentified mysticete whale and one whale track (rings visible in the water indicating a recent dive by a whale) were also recorded during aerial surveys (Fig. 7.5).

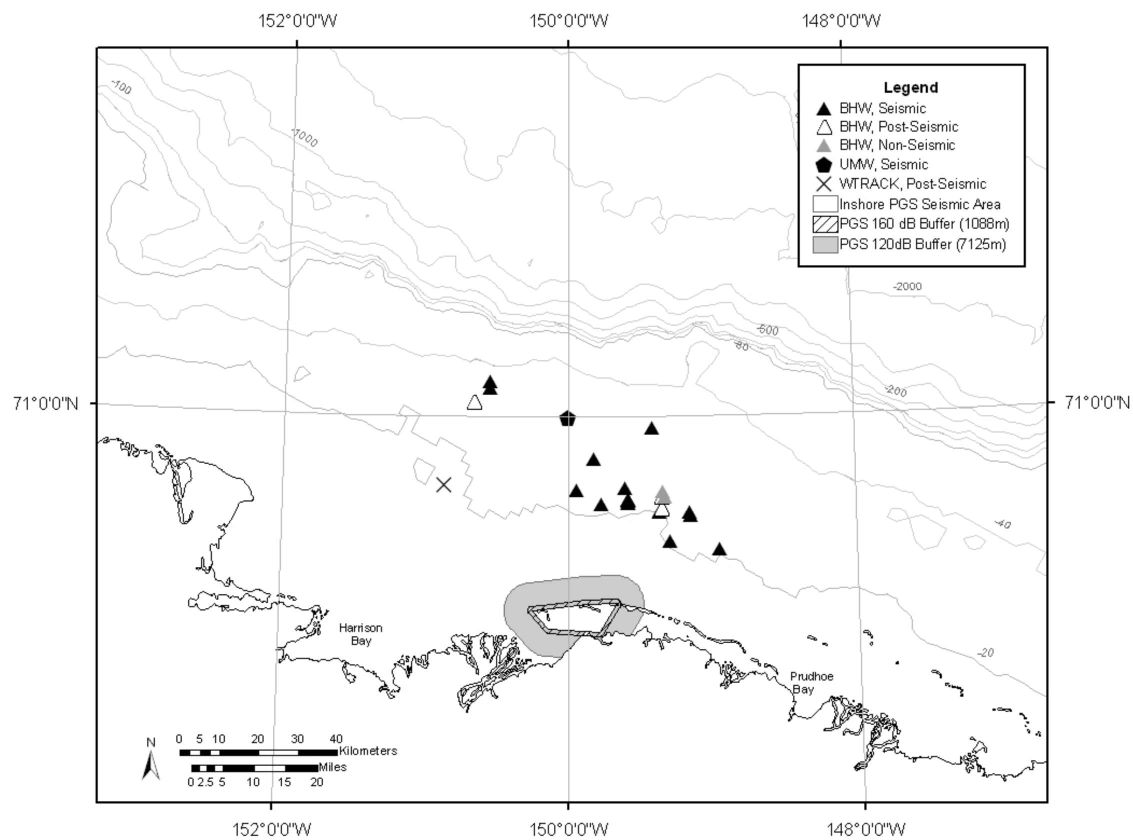

FIGURE 7.5. Bowhead whale (BHW), unknown mysticete whale (UMW), and whale track (WTRACK) sightings during aerial surveys in the central Alaskan Beaufort Sea from 25 August to 27 September 2008. The Eni/PGS seismic survey area, along with corresponding 160 dB and 120 dB buffers are shown.

Sighting Rates by Seismic State.— Bowhead sighting rates were calculated for aerial surveys conducted during seismic, post–seismic, and non–seismic states (Table 7.2, Fig. 7.6). Most bowhead whale observations (20 of 25 sightings) were made during seismic survey activities. When corrected for effort, however, sighting rates did not differ significantly among seismic states (Chi–square test, $P > 0.05$; Table 7.3).

TABLE 7.2. Bowhead whale sightings and sighting rates by seismic state.

		Seismic	Post-seismic	Non-seismic	Total
West	Sightings	2	1	--	3
	Individuals	2	1	--	3
	Sightings/1000 km	2.2	3.3	--	5.5
	Individuals/1000 km	2.2	3.3	--	5.5
Central	Sightings	3	--	--	3
	Individuals	3	--	--	3
	Sightings/1000 km	2.6	--	--	2.6
	Individuals/1000 km	2.6	--	--	2.6
East	Sightings	15	2	2	19
	Individuals	23	3	2	28
	Sightings/1000 km	17.4	6.4	13.0	36.8
	Individuals/1000 km	26.6	9.7	13.0	49.2
All areas	Sightings	20	3	2	25
	Individuals	28	4	2	34
	Sightings/1000 km	6.8	3.5	5.2	15.5
	Individuals/1000 km	9.5	4.7	5.2	19.4

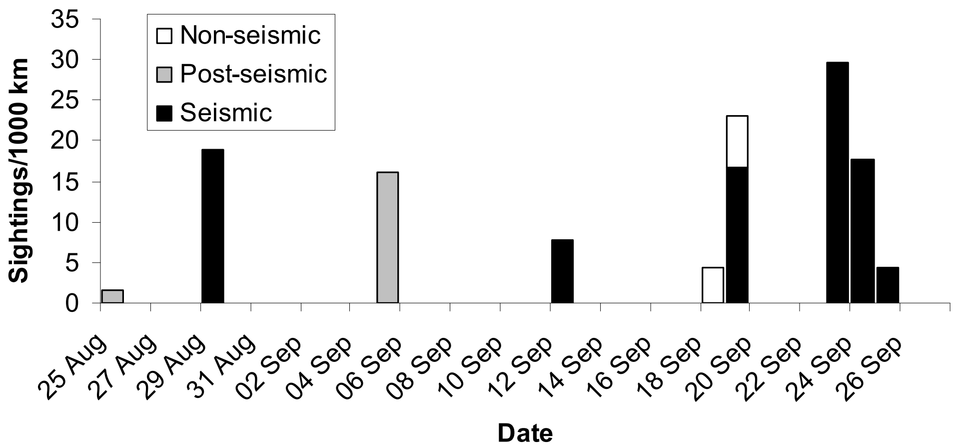

FIGURE 7.6. Daily sighting rates of bowhead whales observed during aerial surveys.

TABLE 7.3. Chi–square test comparing differences in number of bowhead whale sightings by seismic state.

	Seismic	Post-seismic	Nonseismic	χ^2	*P*-value (One-tailed)
Sightings (obs.)	20	3	2	1.262	0.532
Sightings (exp.)	18	5	2		
Effort (km)	2939	858	387		

Sighting Rates by Area.— Most bowhead whales were observed in the east, and sighting rates were highest in the eastern area (Table 7.2). Sighting rates differed significantly among areas, with 49 sightings/1000 km (30.4 sightings/1000 mi) observed in the east, 6 sightings/1000 km (3.7 sightings/1000 mi) in the west, and 3 sightings/1000 km (1.9 sightings/1000 mi) in the central area (Chi–square test: *P* <0.001; Table 7.4).

TABLE 7.4. Chi–square test comparing bowhead whale sighting rates by area.

	West	Central	East	χ^2	*P*-value (One-tailed)
Sightings (obs.)	3	3	19	22.600	<0.001
Sightings (exp.)	8	10	8		
Effort (km)	1254	1601	1329		

<u>*Distance from Shore and Water Depth*</u>

Overall, peak bowhead sighting rates were observed at 25–30 km (16–19 mi) from shore (Fig. 7.7D). This trend was also observed in the east and central areas (Fig. 7.7B–C). In the west, however, peak sighting rates occurred farther from shore (55–60 km, 34–37 mi; Fig. 7.7A). Sighting rates for all distance–from–shore bins are presented in Table F.1 in Appendix F. There was no obvious effect of seismic survey activities on bowhead whale distributions, although effort was low for non-seismic periods (Table 7.5).

Distance from shore was strongly correlated to water depth and patterns in sighting rates by depth should mirror those observed in the distance from shore analysis. Raw data are therefore presented. Bowhead whales were observed in water depths ranging from 20 to 31 m (66–102 ft). The majority of observations were made during periods of seismic activity, and no patterns were observed with respect to seismic state (Fig. 7.8).

<u>*Distance from Seismic Operations*</u>

Differences in distance of sightings from the center of the seismic survey area were examined by seismic state. A total of 25 bowhead sightings were made over the study period, 20 of which were recorded during seismic activity (Table 7.6). In general, differences in sighting distance from the center of the seismic area did not vary by seismic state, although the small number of sightings and survey effort, particularly during non-seismic and post-seismic periods, preclude statistical analysis.

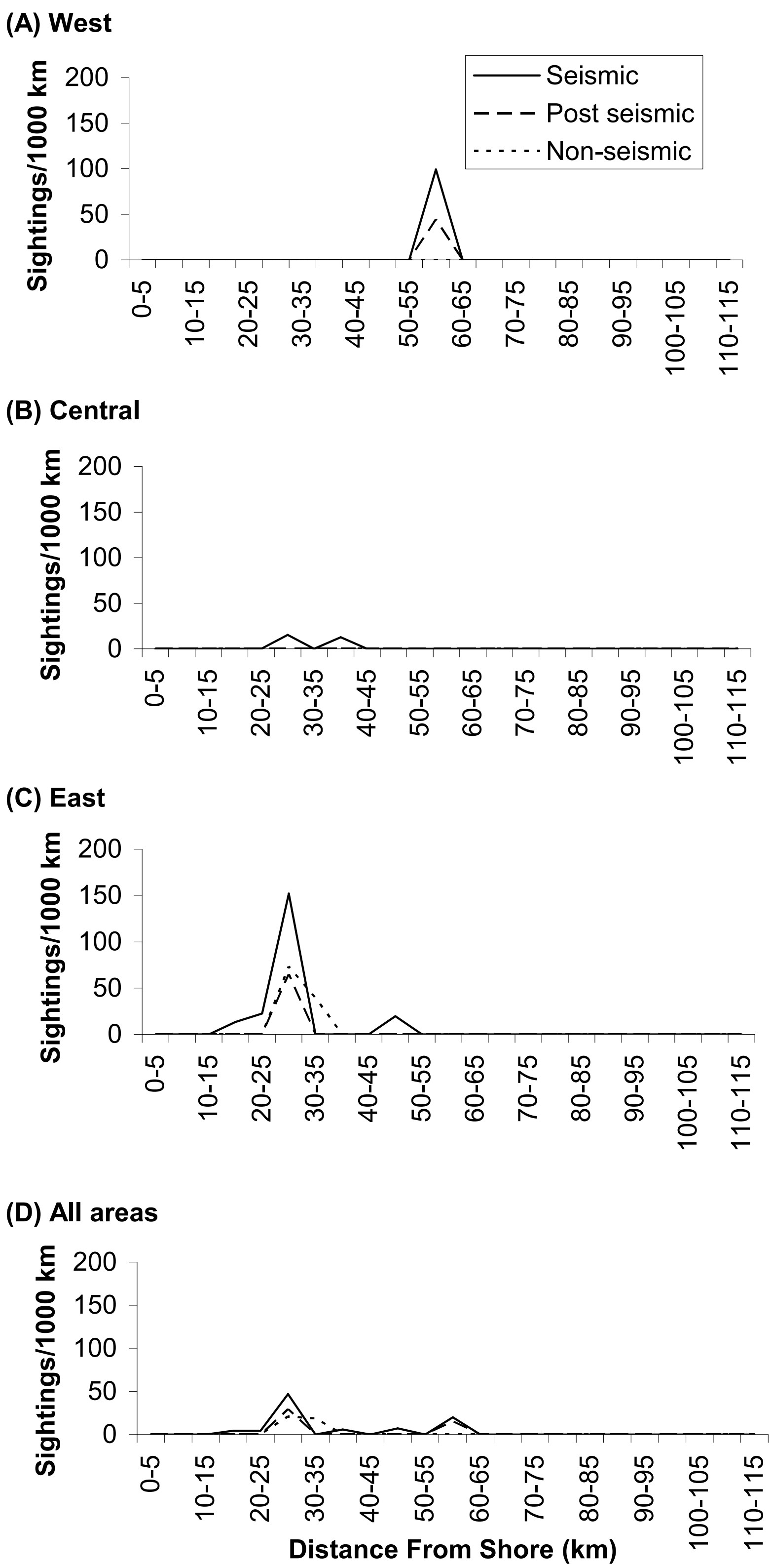

FIGURE 7.7. Bowhead sighting rates within 5–km distance from shore bins during aerial surveys in (A) west, (B) central, (C) east, and (D) all areas.

TABLE 7.5. Results of statistical analysis (Kolmogorov–Smirnov test) comparing offshore distributions of bowhead sighting rates (5– km distance from shore bins) by seismic state. The number of distance from shore bins surveyed ("Effort") and the number in which sightings took place ("Sightings") are also shown.

Test of	Seismic		Non-seismic		Dmax	Bootstrapped P
	Effort	Sightings	Effort	Sightings		
Sightings/1000 km by distance from shore	23	6	9	2	0.135	0.684

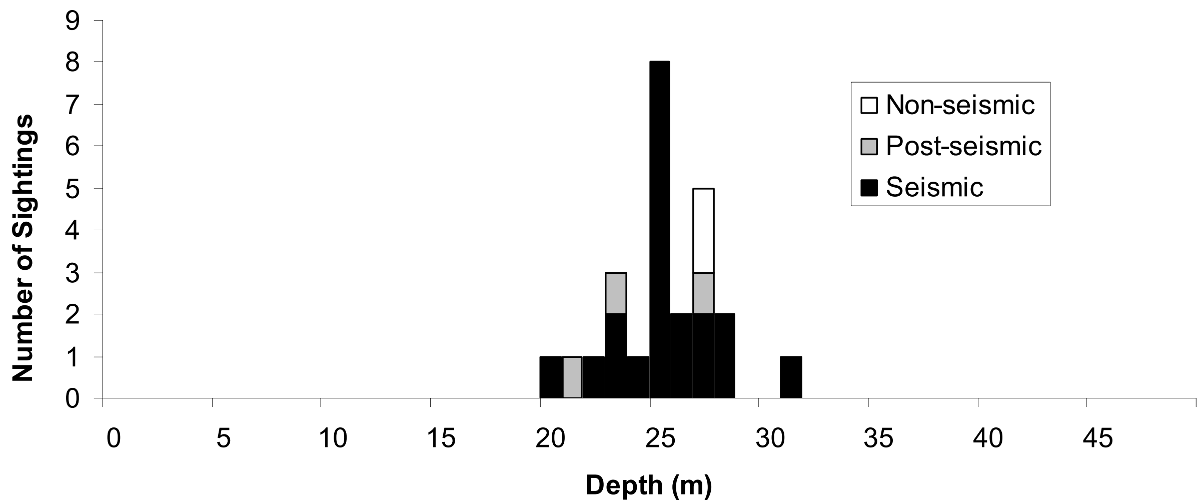

FIGURE 7.8. Number of bowhead sightings made during aerial surveys by water depth (m) and seismic state.

TABLE 7.6. Minimum, maximum and mean distance (km) of bowhead whale sightings from the center of the Eni/PGS seismic survey area by seismic state.

Seismic State	Distance from seismic (km)			
	n	Min.	Max.	Mean
Seismic	20	30.1	64.2	38.7
Post-seismic	3	38.2	61.1	45.0
Non-seismic	2	38.7	39.6	39.1

Density and Abundance

Density and abundance of bowheads within the entire area covered by aerial surveys were estimated using DISTANCE software (Table 7.7). On average, approximately 306 (weighted average based on data in Table 7.5, s.d.=140.6, 95% C.I.=85.4–611.9) bowhead whales were estimated to have been present in the study area each day during the survey period. Estimates by survey ranged from 71 (on 25 August) to 1183 (on 29 August). Survey effort during seven surveys was too low to calculate an estimate of bowhead whale abundance by individual survey, although the effort and sightings from these surveys were included in the calculation of weighted average abundance.

TABLE 7.7. Estimated numbers of bowhead whales in the entire aerial survey area, 25 August- 27 September 2008.

Survey No.	Date	Effort (km)	Sightings	Density (No./1000 km^2)	Est. No. Whales	95% C.I.	
1	25 Aug	646.3	1	10.7	71	10	484
2	29 Aug	580.8	11	178.8	1183	262	5343
3	31 Aug	75.4	0	(0.0)	NC	NC	NC
4	05 Sep	258.9	2	(80.2)	(531)	(26)	(11023)
5	06 Sep	307.2	0	(0.0)	--	--	--
6	09 Sep	250.5	0	(0.0)	--	--	--
7	10 Sep	264.2	0	(0.0)	--	--	--
8	12 Sep	386.2	3	(17.9)	(119)	(16)	(893)
9	14 Sep	6.6	0	(0.0)	NC	NC	NC
10	18 Sep	228.2	1	(30.3)	NC	NC	NC
11	19 Sep	218.6	1	(0.0)	NC	NC	NC
12	23 Sep	67.5	1	(205.0)	NC	NC	NC
13	24 Sep	113.3	2	(183.3)	NC	NC	NC
14	25 Sep	230.3	2	(60.1)	NC	NC	NC
15	27 Sep	549.6	1	0.0	--	--	--

Notes: Estimates were obtained using DISTANCE software for each individual survey. Numbers in parentheses should be interpreted with caution due to low effort (<500 km or 311 mi). Estimates include allowance for f(0) (as calculated by DISTANCE) and g(0) (value of 0.144 from Thomas et al. 2002). Dashes represent values that could not be calculated. Densities of 19 and 27 September are 0.0 because all sightings on those days were outside truncation boundaries.

Activities

Specific activities were recorded for 14 bowhead whale sightings. Travel was the most frequently observed activity (43.5%), followed by resting (21.5%; Fig. 7.9). Socializing was observed slightly more frequently (14%) than feeding, milling or surface active (7% each). Most observations of behavioral activity were made during periods of seismic activity. Only one observation of activity was made during non-seismic periods; it was of a resting whale. Travel was the only observed activity for whales sighted during post-seismic periods.

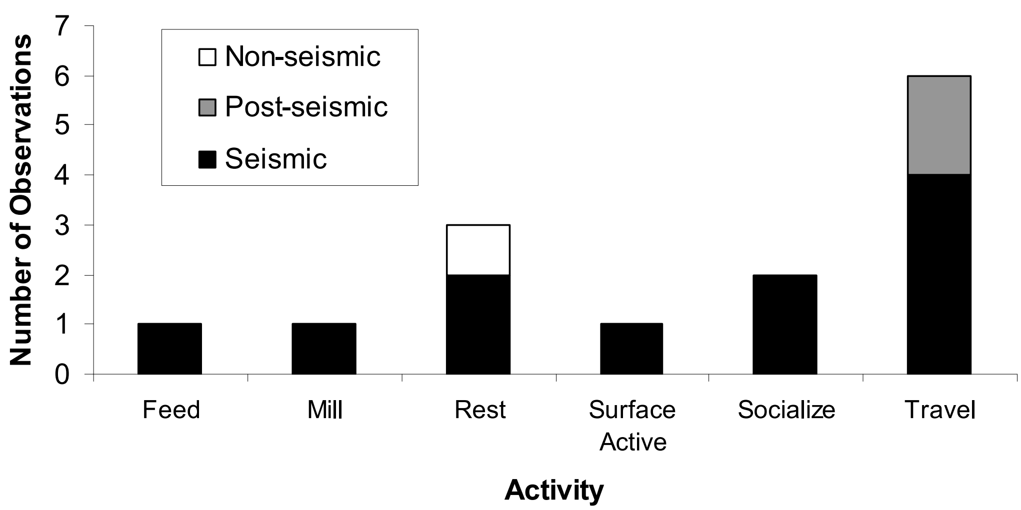

FIGURE 7.9. Observed behavioral activities of bowhead whales by seismic state observed during aerial surveys.

<u>*Speed*</u>

Observations of speed were recorded for 12 bowhead sightings in which whales were considered to be swimming or traveling. The majority of observations were of whales moving at moderate speeds (67%; Fig. 7.10). The remainder of observations consisted of whales traveling at slow speeds (33%). Most observations of speed were made during seismic periods. All sightings during post-seismic periods were of whales moving at a moderate pace. Speed was not recorded for any whales during non-seismic periods.

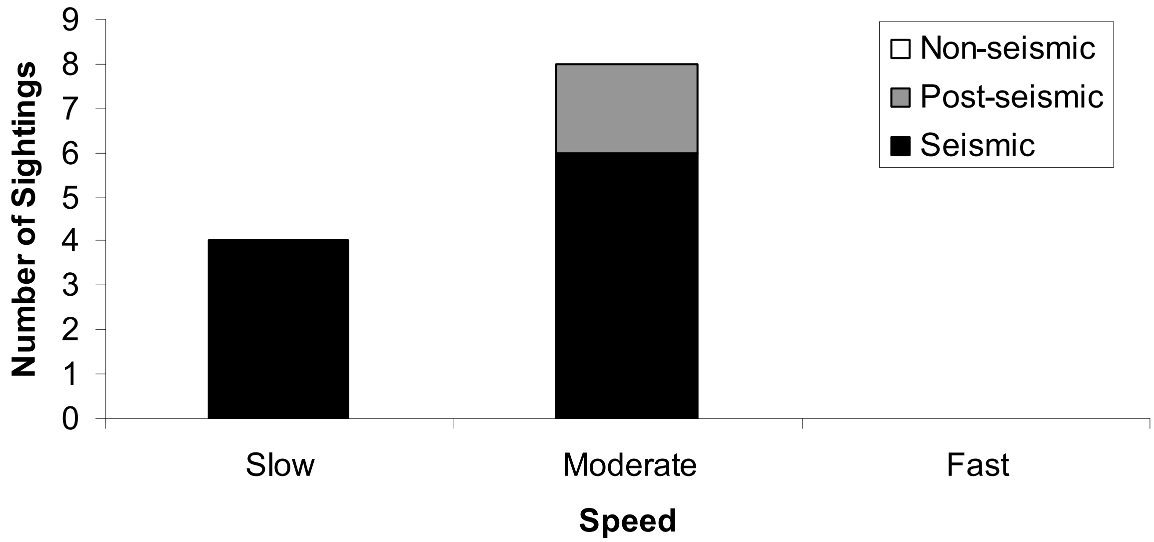

FIGURE 7.10. Observed speeds of bowhead whales by seismic state observed during aerial surveys.

<u>*Headings*</u>

The headings of bowhead whales that appeared to be traveling or swimming (15 sightings) were analyzed. The overall vector mean heading for these sightings was northwest (294°T ± 47°T). When assessed by seismic state, vector mean headings were northwesterly during seismic and post-seismic periods (Fig. 7.11). Only one bowhead heading (westerly) was recorded during a non-seismic period. When assessed by area, vector mean headings were northwesterly in the east portion of the survey area and southwesterly in the west and central portions of the survey area (Fig. 7.12) though sample sizes were low, precluding meaningful conclusions.

<u>*Mitigation Measures Implemented*</u>

According to the 2008 IHA issued by the NMFS, mitigation was necessary if an aggregation of 12 or more bowhead whales was observed within the ≥160 dB (rms) zone, or if four or more cow/calf pairs were detected within the ≥120 dB zone. The 160 dB zone was not monitored during aerial surveys (this area occurred in shallow water depths where bowheads were not expected). No bowhead whales were detected within the ≥120 dB zone of Eni/PGS seismic survey, hence, no mitigation was required due to the presence of bowhead cow/calf pairs[8]. On the two occasions cow/calf pairs were observed (6 and 23 September), they were over 40 km (25 miles) from the center of the Eni/PGS seismic survey area.

[8] Of note, the 120 dB distance estimate (7125 m) used in the field by aerial surveyors was based on SSV results for areas shoreward of the barrier islands. Some seismic operations were conducted seaward of the barrier islands after 24 August and the maximum 120 dB zone was estimated at 22 km (see Chapter 3 and Table 4.1).

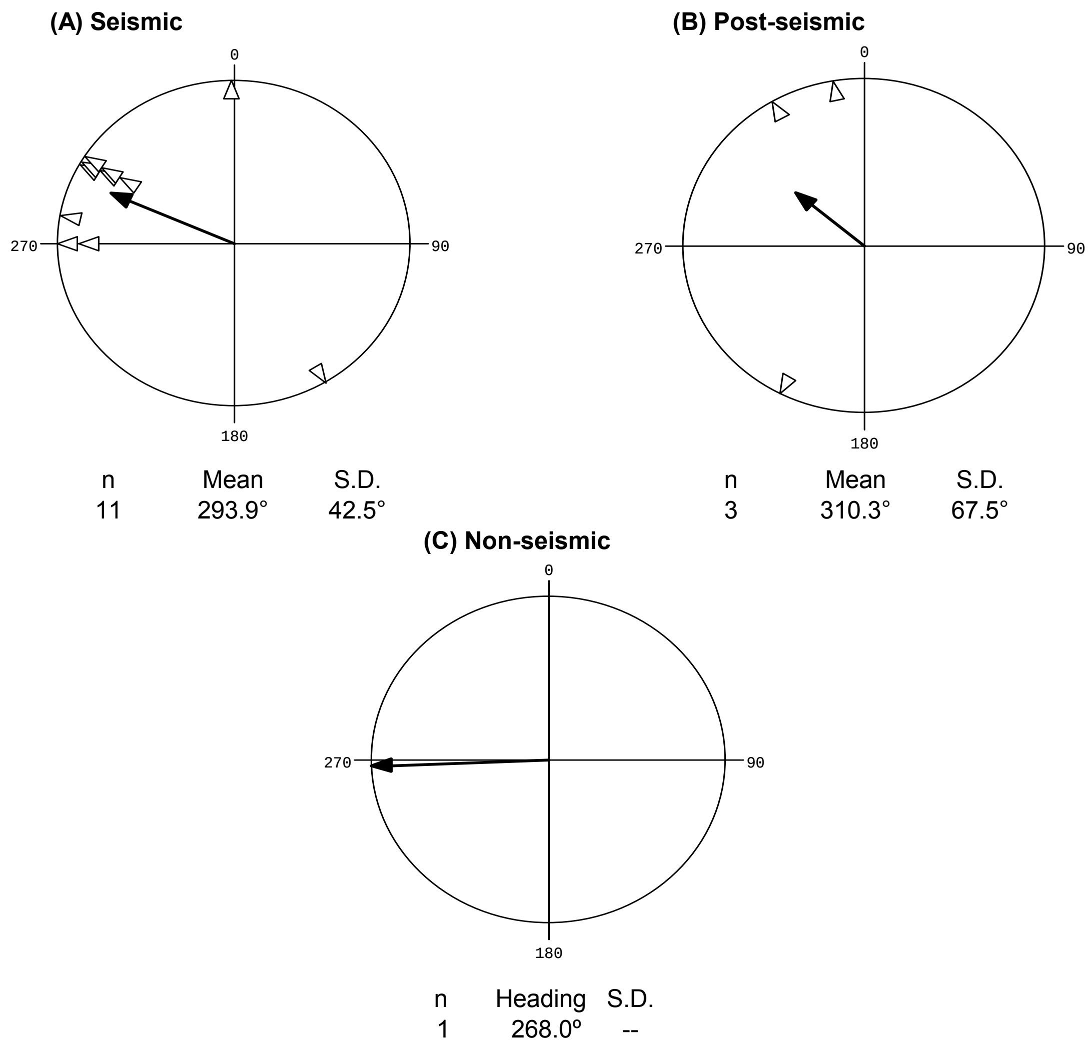

FIGURE 7.11. Headings of traveling bowheads during (A) seismic, (B) post-seismic, and (C) non-seismic periods as observed during aerial surveys.

Estimated Number of Bowheads Present and Potentially Affected

Two received level criteria have been specified by NMFS as relevant in estimating cetaceans potentially affected by seismic sound:

- 180 dB, above which there is concern about possible temporary effects on hearing;
- 160 dB, above which avoidance and other behavioral reactions may occur.

Using a weighted average of density estimates from the aerial surveys calculated with DISTANCE software and the total area of water ensonified by survey activities calculated with ArcMap 9.3, the numbers of potential exposures to received sound levels were estimated for each of the received sound level criteria assuming no avoidance of the survey area by bowheads (Table 7.8).

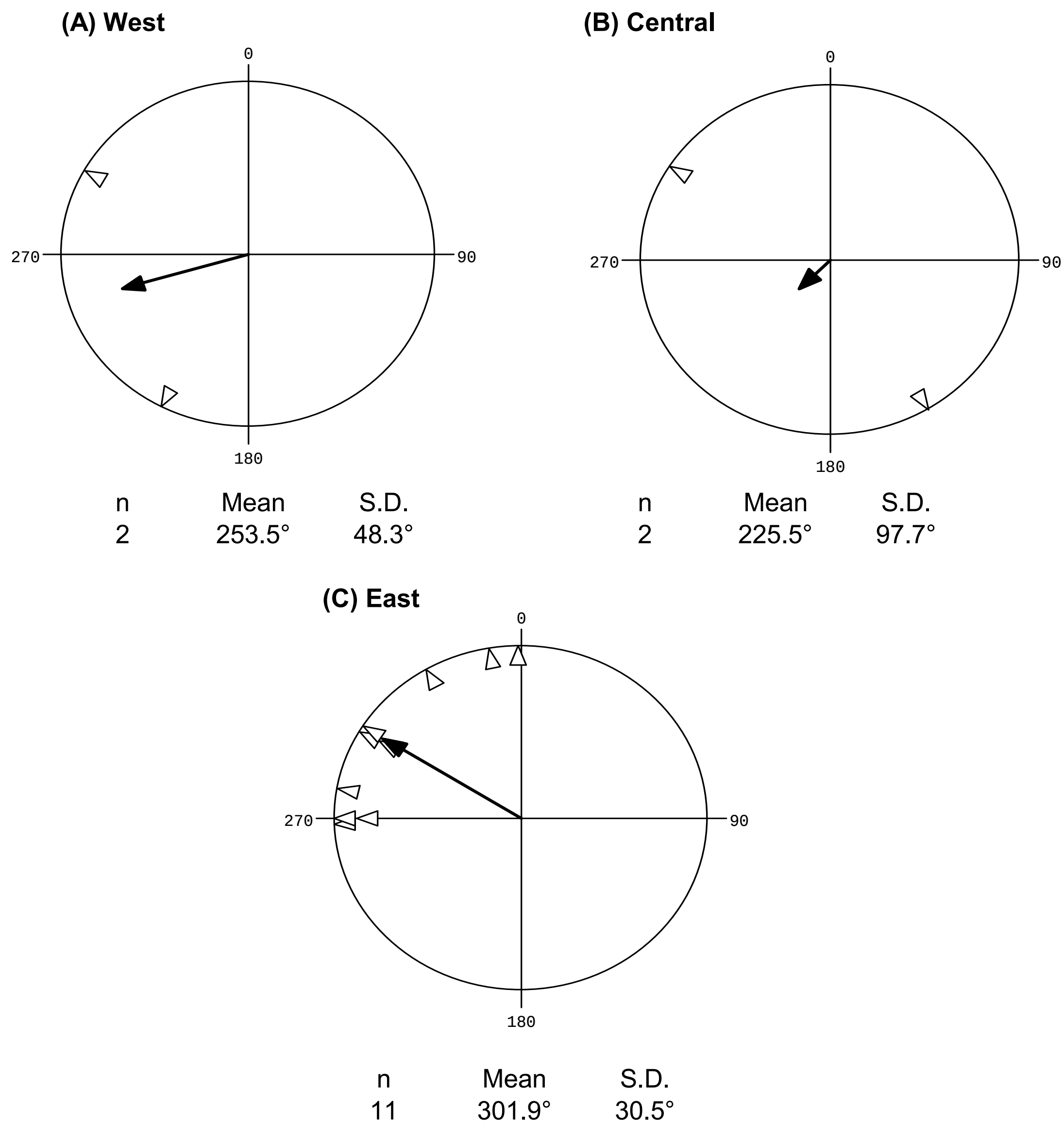

FIGURE 7.12. Headings of traveling bowheads sighted within the (A) west, (B) central, and (C) east areas during aerial surveys.

TABLE 7.8. Estimated number of individual bowhead whales exposed to received levels ≥180 and ≥160 dB (rms) during seismic survey activities by Eni/PGS from 25 August through 27 September 2008 using aerial survey data.

Exposure level in dB re 1 uPa (rms)	Individuals Exposed	Exposures per individual
≥180dB	4.2	17.5
≥160dB	8.0	52.8

The exposure estimates in Table 7.8 are based on estimated densities of whales in offshore waters. The 180 and 160 dB radii, however, did not extend into offshore waters where bowheads typically occur and it was unlikely that whales migrating beyond the seismic survey area were exposed to these sound levels. These estimates represent the maximum number of bowheads may have been exposed to sound levels ≥160 and ≥180 dB and the true number of individuals exposed was probably lower.

Beluga Whales

Sighting rates

Sighting Rates by Seismic State and Area.— A total of 12 beluga sightings (73 individuals) were observed, of which seven (15 individuals) were considered useable and analyzed in further detail. Beluga sightings were recorded on three days: 12, 24, and 27 September 2008 (Table 7.9; Fig. 7.13). All sightings were observed during seismic periods, and the highest number of belugas (13 individuals) was detected on 27 September (Fig. 7.14). Sighting rates varied between 0 and 9.1 sightings/1000 km (0 and 14.7 sightings/1000 mi), with a maximum of 24 individuals sighted per 1000 km (38.6 individuals/1000 mi). Most beluga sightings were in the central area (five sightings, 13 individuals), and a small number (two sightings, two individuals) were sighted in the east survey area.

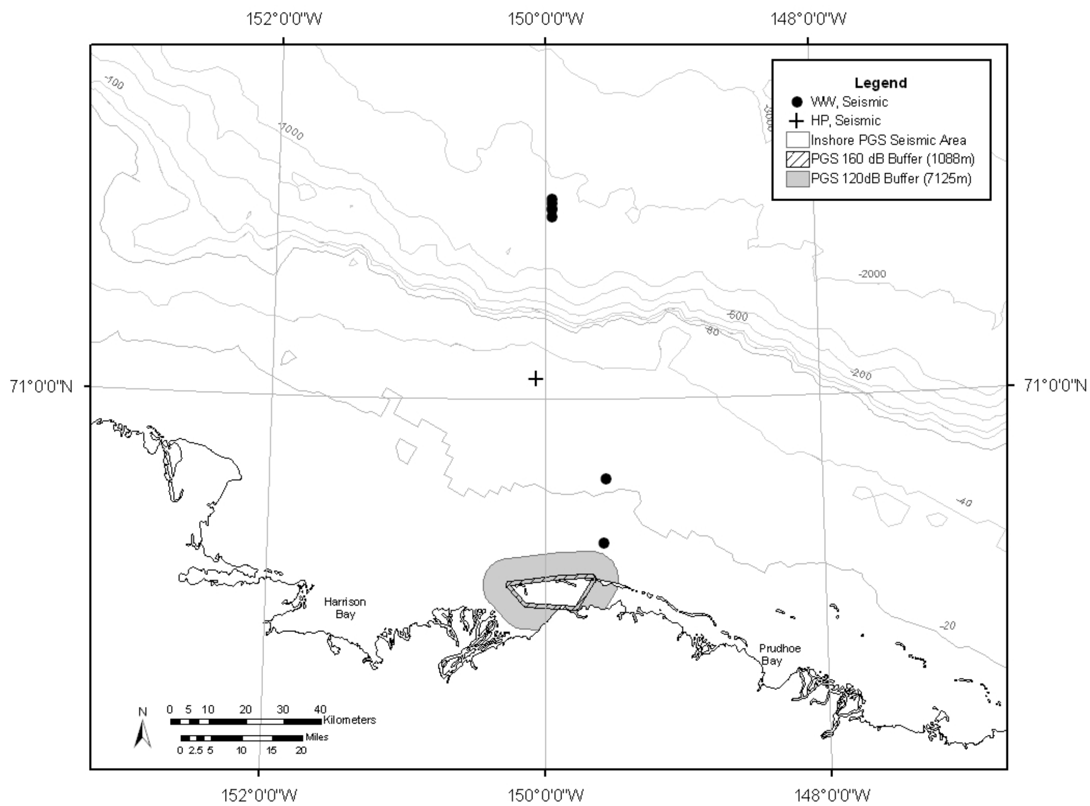

FIGURE 7.13. Beluga whale (WW) and harbor porpoise (HP) sightings during aerial surveys.

TABLE 7.9. Summary of aerial survey effort and beluga whale sighting rates. Values in parentheses are to be interpreted with caution, as they were calculated using less than 500 km (311 mi) of effort. Sighting rates were not calculated ("NC") when effort was less than 250 km (155 mi).

Date	Survey No.	Effort (km)	Percent of Survey Area	Beluga Whale			
				Sightings	Individuals	Sightings/ 1000 km	Individuals/ 1000 km
25 Aug	1	646.3	85	0	0	0.0	0.0
28 Aug	2	0.0	0	(0)	(0)	NC	NC
29 Aug	2	580.8	77	0	0	0.0	0.0
31 Aug	3	75.4	10	(0)	(0)	NC	NC
05 Sep	4	258.9	34	(0)	(0)	(0.0)	(0.0)
06 Sep	5	307.2	41	(0)	(0)	(0.0)	(0.0)
09 Sep	6	250.5	33	(0)	(0)	(0.0)	(0.0)
10 Sep	7	264.2	35	(0)	(0)	(0.0)	(0.0)
12 Sep	8	386.2	51	(1)	(1)	(3)	(3)
14 Sep	9	6.6	1	(0)	(0)	NC	NC
18 Sep	10	228.2	30	(0)	(0)	NC	NC
19 Sep	11	218.6	29	(0)	(0)	NC	NC
23 Sep	12	67.5	9	(0)	(0)	NC	NC
24 Sep	13	113.3	15	(1)	(1)	NC	NC
25 Sep	14	230.3	30	(0)	(0)	NC	NC
27 Sep	15	549.6	73	5	13	9.1	23.7
Total	**15**	**4184**	**35**	**7**	**15**	**2.92***	**6.56***

* average sighting rates

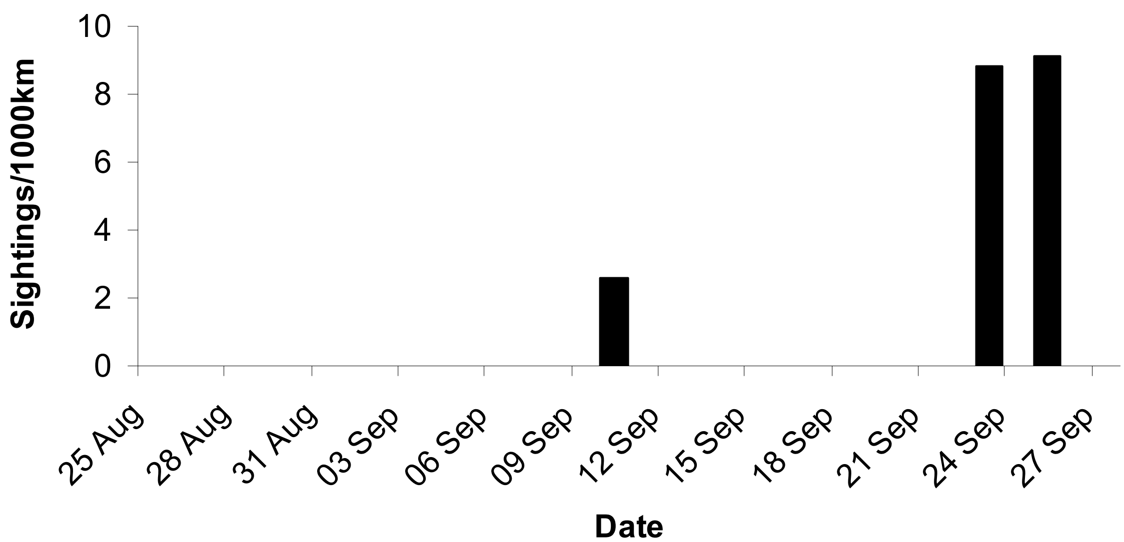

FIGURE 7.14. Beluga whale sighting rates by date during aerial surveys. All sightings were made during periods of seismic operations.

Distance from Shore and Water Depth

Beluga whales were primarily observed between 90–110 km (56–68 mi) from shore (five sightings), with two sightings close to shore, at 5–10 km (3–6 mi) and 25–30 km (16–19 mi). The belugas sighted far from shore were in water 1900–2100 m (6200–6900 ft) deep, whereas sightings close to shore occurred in waters less than 30 m (100 ft) deep.

Activities, Speed, and Headings

Only one observation of beluga activity was made. This individual was resting. Headings were recorded for three swimming belugas. Two of these headings were to the west (239 ºT and 275ºT), while the third heading was to the east (88ºT).

Estimated Number of Belugas Present and Potentially Affected

Received level criteria for beluga whales are identical to those specified for bowhead whales and methods used to estimate the numbers of beluga whales exposed to sound level ≥160 dB and ≥180 dB were the same as those used for bowhead whales (Table 7.10). The estimated numbers of beluga exposures were based on estimated densities of whales in offshore waters. The 180 dB and 160 dB radii did not extend into these waters where beluga whales were most abundant, and it was unlikely that beluga whales migrating past the seismic survey area were affected by seismic activity. It was estimated that at most one beluga whale (rounding up) was exposed to sound levels ≥160 dB and ≥180 dB.

TABLE 7.10. Estimated number of beluga whales exposed to received levels ≥180 and ≥160 dB during seismic survey activities by Eni/PGS from 25 August - 27 September 2008 using aerial survey data.

Exposure level in dB re 1 uPa (rms)	Individuals Exposed	Exposures per individual
≥180dB	0.4	17.5
≥160dB	0.8	52.8

Harbor Porpoise

Two harbor porpoise sightings were recorded during aerial surveys. The first was sighted off transect on 25 August at a depth of 380 m (1247 ft) and 78 km (48 mi) from the center of the seismic survey area. The second harbor porpoise sighting occurred on 10 September; a group of five harbor porpoises was seen in water 30 m (100 ft) deep and 57 km (35 mi) from the center of the seismic survey area (Fig. 7.13). While harbor porpoise sightings from aerial surveys in the Beaufort Sea are rare, we are confident in these identifications, as the observer (B. Koski of LGL) was experienced and sighting conditions were optimal. The number of harbor porpoise exposures to received levels ≥160 dB and ≥ 180 dB was not estimated because harbor porpoises were considered extralimital in the survey area, and the sightings were recorded well outside of the 160 dB and 180 dB zones.

Polar Bears

One adult polar bear was seen off–transect on Thetis Island on 19 September (Fig. 7.15). The polar bear was resting and did not appear to react to the aircraft.

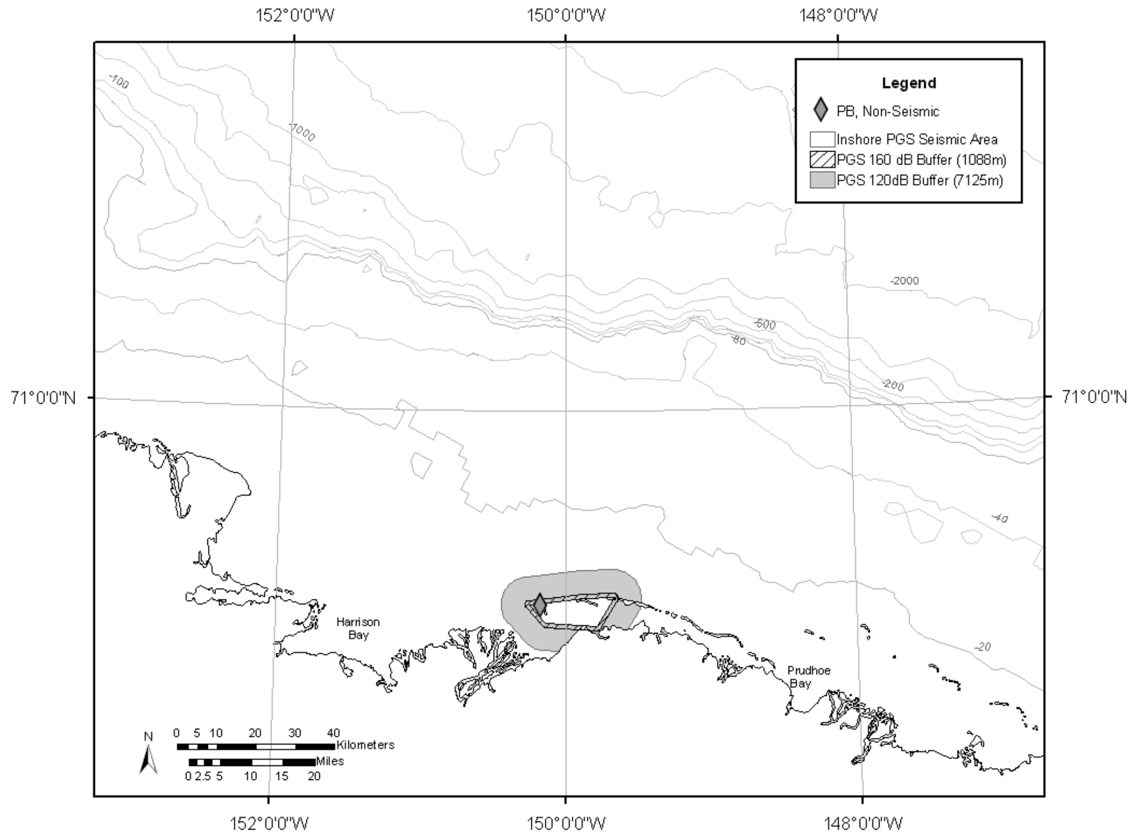

FIGURE 7.15. The single polar bear (PB) sighting made during aerial surveys in the central Alaskan Beaufort Sea from 25 August - 27 September 2008.

Seals

A total of 25 bearded seal sightings (34 individuals), 60 ringed seal sightings (116 individuals), two spotted seal sightings (two individuals) and 67 sightings (228 individuals) of small, unidentified seals were recorded as "useable" during aerial surveys (Figs. 7.16 and 7.17). Seals often cannot be reliably identified to species during surveys conducted at 305 m (1000 ft) above sea level. An observer's ability to sight seals is highly dependent on sea conditions and most seals were recorded when Beaufort wind force was between 0 and 2. Aerial surveys were designed to monitor cetaceans rather than to estimate seal densities, so seal densities and potential exposures to received sound levels were not calculated.

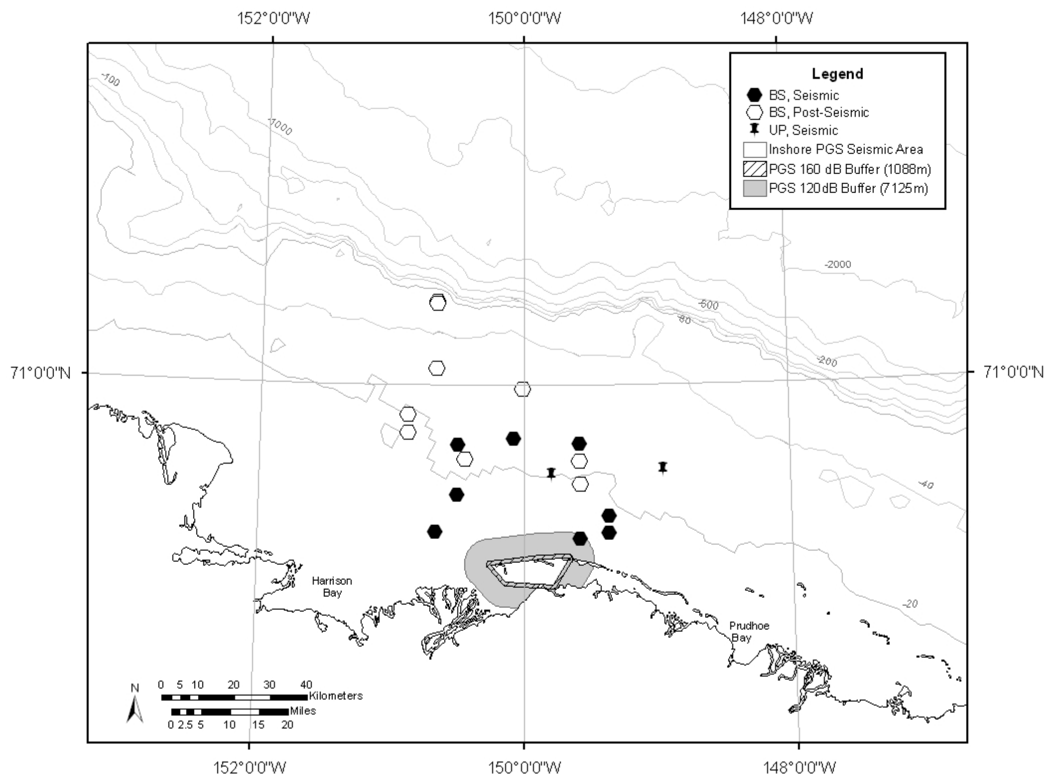

FIGURE 7.16. Bearded seal (BS) sightings made during aerial surveys in the central Alaskan Beaufort Sea. Unknown pinniped (UP) sightings are also shown.

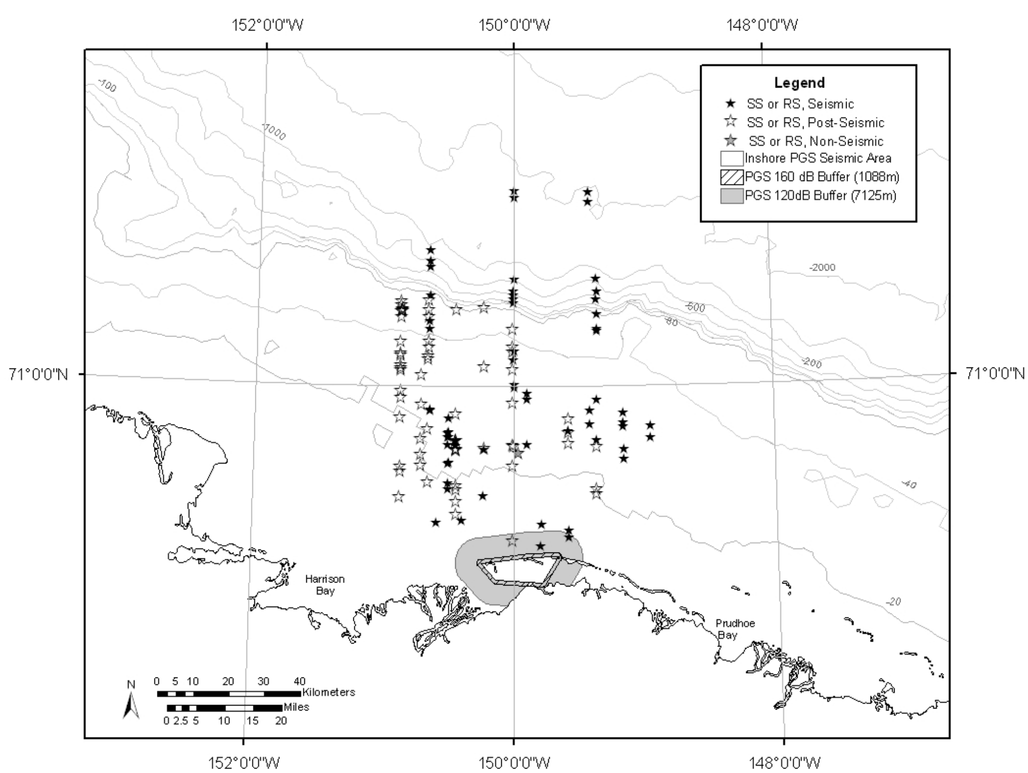

FIGURE 7.17. Ringed seal (RS) and spotted seal (SS) sightings made during aerial surveys in the central Alaskan Beaufort Sea.

Discussion and Conclusions

The majority of aerial survey effort in support of the Eni/PGS seismic program in 2008 occurred during seismic periods, with minimal aerial survey effort during non–seismic and post–seismic periods. The low amount of effort during non-seismic and post-seismic periods reduced our ability to statistically test differences in marine mammal sighting rates and activities among seismic states. In general, deflection of marine mammals, and bowhead whales in particular, around seismic operations was not apparent. Sighting rates did not differ among seismic states, nor did mean distance of bowhead sightings from the center of the seismic survey area. Sample size was not sufficient to accurately determine whether the headings of migrating bowheads varied with seismic state. Furthermore, reliable comparisons of bowhead offshore distributions by seismic state could not be made within east, west, and central areas due to low non– and post–seismic effort in the western and central areas. Peak sightings in the west area were 30 km (19 mi) farther offshore than in the central and eastern areas which may have been due to the geography of the Alaskan coastline, which dips southward into Harrison Bay in the west area. Distinct patterns in bowhead whale depth and distance–from–shore distribution were observed, with peak bowhead whale sighting rates observed 25-30 km from shore, and all bowhead whale sightings occurred in water depths of 20 to 31 m. This range is characteristic of bowhead whales during fall migration in light–ice years (Treacy et al. 2006).

Typically, bowhead whales of the Bering–Chukchi–Beaufort stock feed in Canadian waters during summer and travel through the Alaskan Beaufort Sea during fall migration toward wintering areas in the Bering Sea. During the fall 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 (Landino et al. 1994; Thomas et al. 2002). In summer and fall 2008, patterns in bowhead whale abundance, headings, and migration timing supported the findings of previous studies (i.e., Miller et al. 1999, 2002; Würsig et al. 2002); the majority of sightings consisted of north and westward traveling whales, moving at moderate speeds through the study area in pulses, followed by periods of low abundance.

Previous research (Treacy et al. 2006) has linked trends in bowhead distribution relative to distance from shore with ice cover. In heavy ice years, a zone of ridging forms as landfast ice advances and pack ice moves shoreward in nearshore areas. In light ice years, however, travel is unrestricted and whale distributions are influenced by factors such as bathymetry and food availability. While feeding in Alaskan waters is more likely during light ice years, it is considered to be more common in the eastern Alaskan Beaufort Sea (Würsig et al. 2002) than in this study area (Thomas et al. 2002). Observations of activity and speed in our 2008 surveys supported those findings, with moderately paced travel the predominantly observed activity. In addition, preliminary findings by Goetz et al. (2008) from the BOWFEST (Bowhead Whale Feeding Ecology Study) aerial surveys of the Beaufort Sea in fall 2008 lend support to the conclusion that the principal activity of bowheads in the Alaskan Beaufort Sea from late August to late September 2008 was traveling rather than feeding.

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8. ACKNOWLEDGEMENTS

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We thank the captains and crews of the *Wiley Gunner, Shirley V, Peregrine, American Discovery,* and the other vessels for their support during the Eni/PGS survey. We thank the pilots and crew from Bald Mountain Air for their assistance with the aerial survey program. Additionally, we appreciate the comments and advice from representatives of the NMFS, USFWS, North Slope Borough, Alaska Eskimo Whaling Commission, the villages, whaling captains and teams of Barrow and Nuiqsut, and Minerals Management Service during discussions prior to and during the field season.

Darren Ireland, Michael Link, and Craig Reiser were instrumental in MMO training, pre-season planning, management and ensuring data quality. Susan Inglis acted as the on-site manager of MMOs for the Eni/PGS survey, entered all of the MMO data, conducted all field reporting with agencies, and was the chief liaison with PGS during the survey and post-season processing. Mark Fitzgerald and Ted Elliot of LGL assisted with the processing and analysis of MMO data and produced the maps for this report. We are grateful to several vessel-based and aerial observers —biologists and Inupiat— who assisted with this project, including: Alicia Ferreras, Ann Johnson, Ben Neibalski, Brian O'Donnell, Callie Wilder, Clara Oktollik, Cliff Passmore, Daryl Kyra Lee, Dennis Pangeo, Dolly Patterson, Elias Elias, Felton Serran, Frank Akpik, Greg Sagmeister, Jenell Schwab, Jeremy Aamodt, Joe Beland, Kim Fuchs, Laura Evans, Leanna Russell, Leon Matumeck, Molly Hopson, Nathan Fishel, Patuk Glenn, Robert Long, Suzie Hanlan, Susan Inglis, and Tannis Thomas. Bill Koski provided guidance and oversight of the project.

This work was conducted under an IHA issued by NMFS and a LOA issued by USFWS. We thank Brad Smith and James Wilder, Candace Nachman and others of NMFS and Craig Perham and others of USFWS for processing the application, addressing various agency and public comments, and working with PGS to determine the monitoring and mitigation requirements for this project. We also thank Darren Ireland and Bob Rodrigues for reviewing a draft of this report.

APPENDIX A[9]: NATIONAL MARINE FISHERIES SERVICE INCIDENTAL HARASSMENT AUTHORIZATION AND INCIDENTAL TAKE STATEMENT

1

DEPARTMENT OF COMMERCE

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

NATIONAL MARINE FISHERIES SERVICE

Incidental Harassment Authorization

PGS Onshore, Inc. (PGS), 3201 C Street, Suite 403, Anchorage, Alaska, is hereby authorized under section 101(a)(5)(D) of the Marine Mammal Protection Act (16 U.S.C. 1371(a)(5)(D)) and 50 CFR 216.107 to take, by Level B harassment only, small numbers of marine mammals incidental to conducting a 3D ocean-bottom cable/transition zone (OBC/TZ) seismic survey program in the Beaufort Sea in Arctic Ocean waters under the jurisdiction of the United States, contingent upon the following conditions:

1. This Authorization is valid from July 30 2008, through July 29, 2009.

2. This Authorization is valid only for activities (including support vessels and aircraft) associated with the *M/V Wiley Gunner* and *M/V Little Joe* OBC/TZ seismic surveys in the U.S. Beaufort Sea in the area off Oliktok Point near Thetis, Spy, and Leavitt Islands, as specified in PGS' May, 2008, application and addendum.

3. (a). The species authorized for incidental harassment takings are: bowhead whales (*Balaena mysticetus*), gray whales (*Eschrichtius robustus*), beluga whales (*Delphinapterus leucas*), ringed seals (*Phoca hispida*), spotted seals (*P. largha*), and bearded seals (*Erignathus barbatus*).

(b). The authorization for taking by harassment is limited to the following acoustic sources without an amendment to this Authorization:

(i) A seismic airgun array with a total discharge volume of 880 in^3 on both source vessels;

(ii) Bathymetric equipment, including: Interspace Tech DX 150 (or equivalent) instruments, a Gator INM system, and a Gator INS system; and

(iii) Sonardyne Acoustic transponders.

(c). The taking of any marine mammal in a manner prohibited under this Authorization must be reported within 24 hours of the taking to the Alaska Regional Administrator (907-586-7221) or his designee in Anchorage (907-271-5006), National Marine Fisheries Service (NMFS) and the Chief of the Permits, Conservation and Education Division, Office of Protected Resources, NMFS, at (301) 713-2289, ext 110, or his designee (301-713-2289 ext 156).

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[9] Complete (scanned) copies of the IHA and ITS are included here.

4. The holder of this Authorization is required to cooperate with NMFS and any other Federal, state or local agency with authority to monitor the impacts of the activity on marine animals. The holder must notify the Chief of the Permits, Conservation and Education Division, Office of Protected Resources at least 48 hours prior to the start of collecting seismic data (unless constrained by the date of issuance of this Authorization in which case notification shall be made as soon as possible) and whenever not conducting seismic for more than 48 hours.

5. <u>Prohibitions</u>

(a). The taking, by incidental harassment only, is limited to the species listed under condition 3(a) above. The taking by Level A harassment, serious injury (i.e., injury that is likely to lead to mortality), or death of these species or the taking of any kind of any other species of marine mammal is prohibited and may result in the modification, suspension, or revocation of this Authorization.

(b). The taking of any marine mammal is prohibited whenever the required seismic vessel marine mammal observer (MMO), required by condition 7(a)(i), is not onboard in conformance with condition 7(a)(i) or the dedicated vessel monitoring program has not been fully implemented as required by this Authorization; the Holder shall be found to be in non-compliance with this Authorization, which may result in the modification, suspension, or revocation of this Authorization.

(c). The taking of any marine mammals by seismic sounds when the seismic vessel is within 15 miles of another operating seismic vessel, which is being used for a separate operation, is prohibited.

6. <u>Mitigation</u>.

(a). <u>General Mitigation</u>: The holder of this Authorization is required to:

(i). (<u>A</u>). Avoid concentrations or groups of whales by all vessels and aircraft under the direction of PGS. Operators of support vessels and aircraft should, at all times, conduct their activities at the maximum distance possible from such concentrations of whales. Under no circumstances, other than an emergency, should aircraft operate at an altitude lower than 1,000 feet when within 500 lateral yards of groups of whales. Helicopters may not hover or circle above such areas or within 500 lateral yards of such areas; and (<u>B</u>). When weather conditions do not allow a 1,000-ft flying altitude, such as during severe storms or when cloud cover is low, aircraft may be operated below the 1,000-ft altitude stipulated above. However, when aircraft are operated at altitudes below 1,000 feet because of weather conditions, the operator must avoid known whale concentration areas and should take precautions to avoid flying directly over or within 500 yards of groups of whales.

(ii). Take every precaution to avoid harassment of whale concentrations when a vessel is operated near these animals. Vessels should reduce speed when within 300 yards of whales and those vessels capable of steering around such groups should do so. Vessels may not be operated in such a way as to separate members of a group of whales from other members of the group.

(iii). Avoid multiple changes in direction and speed when within 300 yards of whales. In addition, operators should check the waters immediately adjacent to a vessel to ensure that no whales will be injured when the vessel's propellers (or screws) are engaged.

(iv). Not operate support vessels (including small boats) at a speed that would make collisions with whales likely.

(v). When weather conditions require, such as when visibility drops, adjust vessel speed accordingly to avoid the likelihood of injury to whales.

(vi). (A). Operate in full compliance with the Conflict Avoidance Agreement signed on June 23, 2008; or (B). If the signed Conflict Avoidance Agreement has expired or been nullified by the holder of this Authorization, the following mitigation measures must be fully implemented:

(I) For purposes of reducing or eliminating conflicts between subsistence whaling activities and PGS' seismic program, the holder of this Authorization will establish and operate at least two Communication Centers (Com-Centers) to be staffed by Inupiat operators. The Com-Centers will be operated 24 hours/day during the 2008 fall subsistence bowhead whale hunt.

(II) Plan all vessel and aircraft routes to minimize any potential conflict with bowhead whales or subsistence whaling activities. All vessels shall avoid areas of active or anticipated whaling activity.

(III) During the bowhead whaling season, aircraft shall not operate below 1500 ft unless approaching, landing or taking off, or unless engaged in providing assistance to a whaler or in poor weather (low ceilings) or other emergency situations.

(IV) All geophysical activity in the Beaufort Sea shall be confined as set forth below:

(*1*) *Kaktovik*: No geophysical activity from the Canadian border to the Canning River (~146 deg. 4 min. W) from 10 August to the end of the fall bowhead whale hunt in Kaktovik and Nuiqsut;

(*2*) *Nuiqsut*: (*a*) Point Storkersen (~148 deg. 42 min. W) to Thetis Island (~150 deg. 10.2 min. W): (*i*) Inside the barrier islands, no geophysical activity prior to August 5; geophysical activity allowed from August 5 until completion of operations. Geophysical activity allowed in this area after August 25 shall include a source array of no more than 12 airguns, a source layout no greater than 8 m x 6 m, and a single source volume of no greater than 880 in^3. (*ii*) Outside the barrier islands, no geophysical activity from August 25 to the close of fall bowhead whale hunting in Nuiqsut; geophysical activity allowed at all other times; (*b*) Canning River (~146 deg. 4 min. W) to Point Storkersen (~148 deg. 42 min. W): No geophysical activity from August 25 to the close of the bowhead whale subsistence hunting in Nuiqsut.

(3) *Barrow*: No geophysical activity from Pitt Point on the east side of Smith Bay (~ 152 deg. 15 min. W) to a location about half way between Barrow and Peard Bay (~157 deg. 20 min. W) from September 15 to the close of fall bowhead whale hunting in Barrow.

(V) Upon notification by a Com-Center operator of an at-sea emergency, the holder of this Authorization shall provide such assistance as necessary to prevent the loss of life.

(VI) Upon request for emergency assistance made by a subsistence whale hunting organization, or by a member of such an organization in order to prevent the loss of a whale, the holder of this Authorization shall assist towing of a whale taken in a traditional subsistence whale hunt.

(VII) Post-Season Review: Following the end of the fall 2008 bowhead whale subsistence hunt and prior to the 2009 Pre-season Introduction Meetings, PGS and other Industry Participants will host a joint meeting with all whaling captains of the Villages of Nuiqsut, Kaktovik, and Barrow, the Inupiat Communicator(s), and with the Chairman and Executive Director of the AEWC at a mutually agreed upon time and place on the North Slope to review the results of the 2008 fall season (unless it is agreed by all designated individuals or their representatives that such a meeting is not necessary).

(b). Seismic Vessel Mitigation: The holder of this Authorization is required to:

(i). Reduce the volume of the airgun array during vessel turns while running seismic lines to one airgun or a reduced number of airguns.

(ii). Whenever a marine mammal is detected outside the exclusion zone radius, and based on its position and motion relative to the ship track is likely to enter the safety radius, calculate and implement an alternative ship speed or track.

(iii). Exclusion and Monitoring-Safety Zones:

(A) Establish and monitor with trained observers a preliminary exclusion zone for cetaceans surrounding the seismic airgun array on the *M/V Wiley Gunner* and *M/V Little Joe* where the received level would be 180 dB re 1 μPa rms. For purposes of the field verification test, described in condition 7(c), this radius is estimated to be 0.31 mi (492 m) from the seismic source.

(B) Establish and monitor with trained observers a preliminary exclusion zone for pinnipeds surrounding the seismic airgun array on the *M/V Wiley Gunner* and *M/V Little Joe* where the received level would be 190 dB re 1 μPa rms. For purposes of the field verification test described in condition 7(c), this radius is estimated to be 0.13 mi (203 m) from the seismic source.

(C) Immediately upon completion of data analysis of the field verification measurements required under condition 7(c) below, establish and monitor the new 180-dB and 190-dB marine mammal exclusion zones.

(D) Cetacean Monitor (Safety) Zones after August 25:

(I) Whenever an aggregation of 12 or more balaenopterid whales are detected within an acoustically verified 160-dB rms zone ahead of, or perpendicular to, the seismic vessel track: (*1*) Immediately upon notification from the observer shutdown the airgun array; and (*2*) Not commence with ramp-up of the seismic airgun array until two consecutive surveys (aerial or vessel) confirm that no balaenopterid aggregations have been detected within the 160-dB safety zone of seismic surveying operations. For purposes of the field verification test described in condition 7(c), this radius is estimated to be 1.8 mi (2,894 m) from the seismic source. An aggregation of 12 whales is defined as 12 whales seen, either on transect or while circling (in the aircraft), within a circular area with a diameter of 15 km (7.5 km radius); and

(II) Whenever 4 or more bowhead whale cow/calf pairs are detected through aerial monitoring within an acoustically-verified 120-dB monitoring zone: (*1*) Immediately upon notification from the observer shutdown the airgun array; and (*2*) Not commence with ramp-up of the seismic airgun array until two consecutive aerial surveys confirm that there are no more than 3 bowhead whale cow/calf pairs within the area to be seismically surveyed within the next 24 hours. For purposes of the field verification test described in condition 7(b), this radius is estimated to be 6.2-9.3 mi (10-15 km) from the seismic source.

(iv). Power-down/Shut-down:

(A) Immediately power-down the seismic airgun array and/or other acoustic sources, whenever any cetaceans are sighted approaching close to or within the area delineated by the 180 dB (re 1 μPa_{rms}), or pinnipeds are sighted approaching close to or within the area delineated by the 190 dB re 1 μPa rms isopleth as established under condition 6(b)(iii) for the authorized seismic airgun array. If the power-down operation cannot reduce the received sound pressure level at the cetacean or pinniped to 180 dB or 190 dB, whichever is appropriate, the Holder of this Authorization must immediately shut-down the seismic airgun array and/or other acoustic sources.

(B) Not proceed with powering up the seismic airgun array unless the marine mammal exclusion zones described in condition 6(b)(iii)(A) and (B) are visible and no marine mammals are detected within the appropriate safety zones; or until 15 minutes (for small odontocetes, pinnipeds) or a minimum of 30 minutes (for mysticetes) after there has been no further visual detection of the animal(s) within the safety zone and the trained MMO on duty is confident that no marine mammals remain within the appropriate safety zone.

(C) In the unanticipated event that an injured or dead marine mammal is sighted within an area where the holder of this Authorization deployed and utilized seismic airguns within the past 24 hours, immediately shutdown the seismic airgun array.

(I) In the event that the marine mammal has been determined to have been deceased for at least 72 hours, as certified by the lead MMO onboard the seismic vessel, and no other marine mammals have been reported injured or dead during that same 72 hour period, the airgun array may be restarted (by conducting the necessary ramp-up procedures described in condition 6(b)(v) below) upon completion of a written certification, including supporting documents (e.g., photographs or other evidence to support the certification) by the MMO. Within 24 hours after the event specified herein, the holder of this Authorization must notify the designated staff person (see III below) by telephone or email of the event and ensure that the written certification and supporting documents are provided to the NMFS staff person.

(II) In the event that the marine mammal injury resulted from something other than seismic airgun operations (e.g., gunshot wound, polar bear attack), as certified by the lead MMO onboard the seismic vessel, the airgun array may be restarted (by conducting the necessary ramp-up procedures described in condition 6(b)(v) below) upon completion of a written certification, including supporting documents (e.g., photographs or other evidence to support the certification) by the MMO. Within 24 hours after the event specified herein, the holder of this Authorization must notify the designated staff person (see III below) by telephone or email of the event and ensure that the written certification and supporting documents are provided to the NMFS staff person.

(III) In the event the animal has not been dead for a period greater than 72 hours or the cause of the injury or death cannot be immediately determined by the lead MMO, the holder shall immediately report the incident to either the NMFS staff person designated by the Director, Office of Protected Resources (Candace Nachman, Office of Protected Resources, NMFS, 301-713-2289 ext 156 or Candace.Nachman@noaa.gov) or to the staff person(s) designated by the Alaska Regional Administrator (Brad Smith or James Wilder, Alaska Regional Office, NMFS, 907-271-5006 or Brad.Smith@noaa.gov or James.Wilder@noaa.gov).

(*1*) The seismic airgun array shall not be restarted until NMFS is able to review the circumstances of the take, make determinations as to whether modifications to the activities are appropriate and necessary, and has notified the holder that activities may be resumed.

(*2*) NMFS approval to resume operations may be given by the Director, Office of Protected Resources, NMFS, or his designee or by the Alaska Regional Administrator, NMFS, or his designee. NMFS approval may be provided in writing via a letter or an email or via the telephone.

(v). Ramp-up:

(A) Conduct a 30-minute period of marine mammal observations by at least one trained MMO prior to commencing ramp-up described in condition 6(b)(v)(C): (*1*) at the commencement of seismic operations and (*2*) at any time electrical power to the airgun array has been discontinued for a period of 10 minutes or more and the MMO watch has been suspended;

(B) Not commence ramp-up if the complete safety radii are not visible for at least 30 minutes prior to ramp-up in either daylight or nighttime and not commence ramp-up at night unless the seismic source has maintained a sound source pressure level at the source of at least 180 dB re 1 µPa rms during the interruption of seismic survey operations. If a sound source of at least 180 dB re 1 µPa rms has been maintained during the interruption of seismic operations, then the 30 minute pre-ramp-up visual survey is waived; and

(C) Ramp-up the airgun arrays at no greater than 6 dB per 5-minute period starting with the smallest airgun in the array and then adding additional guns in sequence until the full array is firing, if no marine mammals are observed while undertaking conditions 6(v)(A) and (B): (*2*) at the commencement of seismic operations and (*2*) anytime after the airgun array has been powered down for more than 10 minutes.

7. Monitoring.

(a). Vessel Monitoring:

(i). The holder of this Authorization must designate biologically-trained, on-site individuals to be onboard the *M/V Wiley Gunner* and *M/V Little Joe* approved in advance by NMFS (one may be an Inupiat), to conduct the visual monitoring programs required under this Authorization and to record the effects of seismic surveys and the resulting noise on marine mammals.

(ii). To the extent possible, MMOs should be on duty for 4 consecutive hours or less, although more than one 4-hour shift per day is acceptable.

(iii). Monitoring is to be conducted by the MMOs described in condition 7(a)(i) above, onboard each active seismic vessel, to (A) ensure that no marine mammals enter the appropriate safety zone whenever the seismic array is on, and (B) to record marine mammal activity as described in condition 7(a)(vi) below, at least two observers must be on watch during ramp ups and the 30 minutes prior to full ramp ups, and for as large a fraction of the other operating hours as possible. At all other times, at least one observer must be on active watch whenever the seismic airgun array is operating during all daytime airgun operations, during any nighttime power-ups of the airguns and at night, whenever daytime monitoring resulted in one or more power-down situations due to marine mammal presence.

(iv). The crew must be instructed to keep watch for marine mammals at all times. If any are sighted, the bridge watch-stander must immediately notify the biological observer on-watch. If a marine mammal is within, or closely approaching, its designated safety zone, the airgun array must be immediately powered down or shutdown (in accordance with condition 6(b)(iv)(A) above).

(v). Observations by the MMOs described in condition 7(a)(i) above on marine mammal presence and activity will begin a minimum of 30 minutes prior to the estimated time that the seismic source is to be turned on and/or ramped-up.

(vi). Monitoring will consist of recording: (a) the species, group size, age/size/sex categories (if determinable), the general behavioral activity, heading (if consistent), bearing and distance from seismic vessel, sighting cue, behavioral pace, and apparent reaction of all marine mammals seen near the seismic vessel and/or its airgun array (e.g., none, avoidance, approach, paralleling, etc); (b) the time, location, heading, speed, and activity of the vessel (shooting or not), along with sea state, visibility, cloud cover and sun glare at (1) any time a marine mammal is sighted, (2) at the start and end of each watch, and (3) during a watch (whenever there is a change in one or more variable); and (c) the identification of all vessels that are visible within 3.1 mi (5 km) of the seismic vessel whenever a marine mammal is sighted, and the time observed, bearing, distance, heading, speed and activity of the other vessel(s).

(vii). All MMOs must be provided with and use appropriate night-vision devices, Big Eyes, and reticulated and/or laser range finding binoculars.

(b). Aerial Monitoring:

(i). In accordance with the survey design described in PGS' Offshore Monitoring Plan in addition to the aerial monitoring protocol described herein, the holder of this Authorization must conduct aerial surveys of the seismic area and nearby waters at least 3 days each week beginning August 25, weather permitting, until the end of seismic operations.

(ii). Monitoring is to be conducted by 4 trained biological observer(s) seated in the rear of the plane. The pilots will also survey the area ahead of the aircraft.

(iii). Aerial monitoring will consist of noting the marine mammal species, number, age/size/sex class (if determinable), general activity, heading (if consistent), swimming speed category (if traveling), sighting cue, ice conditions (type and percentage), and inclinometer reading.

(iv). After August 25, 2008, the aerial survey will look for aggregations of balaenopterid whales and cow/calf pairs during normal survey activity. If the biological observers onboard the aircraft see an aggregation of 12 or more whales or 4 or more migratory bowhead whale cow/calf pairs within the surveyed portion of the 160-dB or 120-dB isopleths, respectively, from the seismic survey vessel, the lead observer or his/her designee will contact the MMO on watch onboard the seismic vessel of the observation. The location, bearing and approximate speed of the whales will be recorded. Shutdown measures will be taken, as necessary, in accordance with condition 6(b)(iii)(D)(I) and (II).

(v). Aircraft must be flown at 100 knots ground speed at an altitude of 1,500 ft.

(vi). When a large whale is sighted, the pilot shall break transect and circle the sighting at least twice to confirm species, group size, and composition. If additional sightings are made in the vicinity, these shall also be circled to confirm species, group size, composition, and activity if it can be determined (such as feeding or migrating). An aggregation of 12 whales is defined as 12 whales seen, either on transect or while circling, within a circular area with a diameter of 15 km. Therefore, after a sighting is made, it should be circled sufficiently to check a 7.5 km radius around the area, and any subsequent sightings should be circled to see if they are within 15 km of the original sighting.

(c). Field Source Verification. The holder of this Authorization is required to measure and report within 72 hours of completing the test the empirical distances from the airgun array to broadband received levels of 190, 180, 170, 160, and 120 dB (rms) re 1 μPa, and the radiated sounds vs. distance from the primary seismic vessels supporting the survey.

8. Research: The holder of the Authorization, in cooperation with other oil company participants must conduct all research described in the "Oooguruk and Nikaitchuq Development Projects Offshore Monitoring Plan, 2008." The components of the Plan include: (i) monitoring in-water sound near and distant from ODS, SID, and vessel operations using 4 autonomous seafloor acoustic recorders (ASARs); (ii) characterizing in-water sound source levels and spectral content of sound from vessels associated with the projects; (iii) monitoring and characterizing sounds produced from the seismic survey in the areas inshore and offshore of Thetis and Spy islands using ASARs and directional autonomous seafloor recorders (DASARs); (iv) detecting and localizing marine mammal vocalizations using an array of DASARs positioned north and northwest of the Pioneer and ENI projects; and (v) visually surveying the coastal Beaufort Sea from an aircraft to search for bowhead whales and characterizing the behavior of the observed animals.

9. Reporting.

(a). Field Source Verification and the distances to the various radii are to be reported to NMFS within 72 hours of completing the measurements. In addition to reporting the radii of specific regulatory concern, distances to other sound isopleths down to 120 dB rms (if measurable) will be reported in increments of 10 dB.

(b). Seismic Vessel Monitoring Program: A draft report will be submitted to NMFS within 90 days after the end of PGS' seismic survey program in the Beaufort Sea. The report will describe in detail: (i) the operations that were conducted; (ii) the results of the acoustical measurements to verify the safety radii; (iii) the methods, results, and interpretation pertaining to all monitoring tasks; (iv) the results of the 2008 shipboard marine mammal monitoring; (v) a summary of the dates and locations of seismic operations, including summaries of power downs, shut downs, and ramp up delays; (vi) marine mammal sightings (species, numbers, dates, times and locations, age/size/gender, environmental correlates, activities, associated seismic survey activities); (vii) estimates of the amount and nature of potential take (exposure) of marine mammals (by species) by harassment or in other ways to industry sounds; (viii) an analysis of the effects of seismic operations (e.g., on sighting rates, sighting distances, behaviors, movement patterns of marine mammals); (ix) provide an analysis of factors influencing detectability of marine mammals; and (x) provide summaries on communications with hunters and potential effects on subsistence uses.

(c). The 90-day draft report will be subject to review and comment by NMFS. Any recommendations made by NMFS must be addressed in the final report prior to acceptance by NMFS. The draft report will be considered the final report for this activity under this Authorization if NMFS has not provided comments and recommendations within 90 days of receipt of the draft report.

(d). A draft comprehensive report describing the acoustic, vessel-based, and aerial monitoring programs will be prepared and submitted within 240 days of the date of this Authorization (in cooperation with other authorized companies for 2008). The comprehensive report will describe the methods, results, conclusions and limitations of each of the individual data sets in detail. The report will also integrate (to the extent possible) the studies into a broad based assessment of all industry activities and their impacts on marine mammals in the Arctic Ocean during 2008.

(e). The draft comprehensive report will be reviewed by participants at the 2009 Open Water Scientific Meeting to be held in Anchorage, AK, in the spring of 2009. The draft comprehensive report will be accepted by NMFS as the final comprehensive report upon incorporation of recommendations by the workshop participants.

10. Activities related to the monitoring described in this Authorization do not require a separate scientific research permit issued under section 104 of the Marine Mammal Protection Act.

11. The Plan of Cooperation and the Conflict Avoidance Agreement outlining the steps that will be taken to cooperate and communicate with the native communities to ensure the availability of marine mammals for subsistence uses, must be implemented to the extent one exists.

12. This Authorization may be modified, suspended or withdrawn if the holder fails to abide by the conditions prescribed herein or if the authorized taking is having more than a negligible impact on the species or stock of affected marine mammals, or if there is an unmitigable adverse impact on the availability of such species or stocks for subsistence uses.

13. A copy of this Authorization must be in the possession of each seismic vessel operator taking marine mammals under the authority of this Incidental Harassment Authorization.

14. PGS is required to comply with the Terms and Conditions of the Incidental Take Statement corresponding to NMFS' Biological Opinion.

James H. Lecky
Director, Office of Protected Resources
National Marine Fisheries Service

JUL 3 0 2008
Date

Incidental Take Statement - PGS Onshore, Inc. (PGS) for its 2008 seismic geophysical program in the U.S. Beaufort Sea.

August 2008

Proposed Action
This Incidental Take Statement addresses a seismic geophysical research program by PGS Onshore, Inc. (PGS) in the U.S. Beaufort Sea during 2008. Details of this program and its effects on the endangered bowhead whale may be found in the NMFS July 17, 2008 Biological Opinion and in the notice for an incidental take authorization for this work (FR73, No.117, 34254). The ESA allows takings of threatened or endangered marine mammals only if such taking is authorized by section 101(a)(5)of the MMPA. NMFS's July 17, 2008 biological opinion did not authorize the taking of listed marine mammals since the proposed taking had not been authorized under the MMPA at the time the opinion was issued.

Section 9 of the Endangered Species Act (Act) and federal regulations pursuant to section 4(d) of the Act prohibit the take of endangered and threatened species, respectively, without special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct. NMFS further defines harm as an act which actually kills or injures fish or wildlife. Such an act may include significant habitat modification or degradation that actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns including breeding, spawning, rearing, migrating, feeding or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and 7(o)(2), taking that is incidental to and not intended as part of the proposed action is not considered to be prohibited taking under the Act, provided that such taking is in compliance with this Incidental Take Statement. Section 7(b)(4) of the ESA states that, for actions which have received consultation and that involve the taking of listed species, NMFS will issue a statement that specifies the impact of any incidental taking. It also states that reasonable and prudent measures, and terms and conditions to implement the measures, be provided that are necessary to minimize such impacts. Only incidental take resulting from the agency action and any specified reasonable and prudent measures and terms and conditions identified in the incidental take statement are exempt from the taking prohibition of section 9(a), pursuant to section 7(o) of the ESA.

The terms and conditions described below are nondiscretionary, and must be undertaken by NMFS so that they become binding conditions of any grant or permit issued to PGS, as appropriate, for the exemption in section 7(o)(2) to apply. NMFS has a continuing duty to regulate the activity covered by this incidental take statement. If NMFS (1) fails to assume and implement the terms and conditions, or (2) fails to require PGS to adhere to the terms and conditions of the incidental take statement through enforceable terms that are added to the permit or grant document, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impact of incidental take, NMFS must monitor the progress of the action and its impact on the species as specified in the incidental take statement (50 CFR 402.14(I)(3)).

Amount or Extent of Take

Available information indicates that incidental acoustic harassment of small numbers of bowhead whales may occur during PGS's seismic exploration activities within the Beaufort Sea. NMFS does not expect any bowhead whales to be injured or killed by the PGS seismic survey. It is not possible that the hearing systems of marine mammals very close to an airgun would be at risk of temporary or permanent hearing impairment, and temporary threshold shift in hearing is a possibility for animals within a few hundred meters of the source. However, planned monitoring and mitigation measures are designed to avoid sudden onsets of seismic pulses at full power, to detect marine mammals occurring near the array, and to avoid exposing them to sound pulses that may cause hearing impairment. Moreover, bowhead whales are known generally to avoid an area many kilometers in radius around ongoing seismic operations, reducing any risk of hearing damage.

In its application, PGS provides estimates of the number of bowhead whales which may be taken based on the potential "exposures" to sound levels from the seismic array. These figures must be considered speculative. Specific estimates for take are confounded by several factors, including:

1. The sound levels from the seismic source may vary with water depths and bottom type.

2. The majority of bowhead whales from the Western Arctic stock is thought to summer in Canadian waters off the Mackenzie delta, and would not overlap in time or space with much of this work.

3. Beginning in early August, PGS will move their operations inside the barrier islands, and remain there throughout the bowhead whale migration. Consequently, the closest 120 dB level sounds could reach migrating whales is a point 3 km (1.9 mi) north of a line between Spy and Thetis islands. At this point the water depth is approximately 6 m (20 ft), less than suitable habitat for migrating bowhead whales. Further, much of the sound emanating from inside the barrier islands would be blocked by Spy, Thetis, and Leavitt Islands, leaving on a fraction of the survey area inside the barrier islands from which the 120-dB radius could even reach a point 3 km (1.9 mi) north of barrier islands. During most of the survey inside the barrier islands it is expected that the 120-dB radii would not extend at all outside the barrier islands.

The PGS' application provides both average and maximum density data for bowhead whales that are likely to be adversely affected. These density numbers were based on survey and monitoring data of bowhead whales in recent years in the vicinity of the proposed action area. In addition, PGS also provided maximum density estimates for those marine mammal populations. However, PGS did not provide a rationale regarding the maximum estimate or a description as to how these maximum density estimates were calculated. NMFS decides that the average density data of bowhead whales will be used to calculate estimated take numbers because these numbers are based on surveys and monitoring in the vicinity of the proposed project area.

Estimates were derived by calculating the distances to the 160-dB isopleths, using 250 dB as the source output. Based on this, the total area of ensonification using the 160-dB criteria is 7,398.4 km^2 (2,856.5 mi^2; including 4,450.6 km^2, or 1,718.4 mi^2 outside the barrier islands; and 2,947.8 km^2, or 1,138.1 mi^2 inside the barrier islands). However, given that none of the area occurs in waters greater than 15 m (49 ft) deep (and half the area is in waters less than 4 m, 13 ft, deep), which is not suitable habitat for migrating bowhead whales, which has been defined as waters 15-200 m (49-660 ft) deep (Richardson and Thomson, 2002), this calculation provides a very conservative estimate of potential take. Therefore, only the area outside the barrier islands was used in the calculations for bowhead whales.

The "take" estimates were determined by multiplying the density estimates by the ensonification area using the 160-dB criteria. Based on the calculation of using the average density estimates presented in PGS' application for an incidental harassment authorization and the area of ensonification outlined above, it is estimated that up to approximately 28 bowhead whales would be affected by harassment as a result of the proposed seismic survey.

The amount of take will have been exceeded if the number of whales "taken" exceeds twenty eight.

Effect of the Take
NMFS 2008 biological opinion: Oil and Gas Leasing and Exploration Activities in the U.S. Beaufort and Chukchi Seas, Alaska; and Authorization of Small Takes Under the Marine Mammal Protection Act describes the effects of seismic noise on bowhead whales, and concludes that the subject activities, including seismic geophysical research programs such as this, are not likely to jeopardize the continued existence of the bowhead whale or result in the destruction or adverse modification of critical habitat. Exposure to seismic noise and other sound sources associated with this work have the potential to harass bowhead whales, although such takes are expected to be temporary and not to affect the reproduction, survival, or recovery of this species. The estimated level of take represents 0.27 percent of the western Arctic stock of bowhead whales, all of which would be by harassment by noise. NMFS does not consider this level of non-injurious take to be significant in terms of the survival and recovery of the stock.

Reasonable and Prudent Measures
NMFS believes the following reasonable and prudent measures are necessary and appropriate to minimize impacts of incidental take of bowhead whales.

(1). This ITS is valid only during the open water season from the date of the Authorization until December 31, 2008.

(2). This ITS is valid only for activities associated with conducting seismic geophysical survey in the Alaskan Beaufort Sea.

(3). The taking of bowhead whales shall be by incidental harassment only. The taking by serious injury or death of bowhead whales, or the taking by harassment of bowhead whales greater than authorized in this ITS is prohibited and may result in the modification, suspension or revocation of the ITS.

(4). All activities must comply with the Incidental Harassment Authorization (attached) issued under section 101(a)(5)(D) and 50 CFR 216.107

Terms and Conditions
In order to be exempt from the prohibitions of section 9 of the Act, the MMS must comply with the following terms and conditions, which implement the reasonable and prudent measures, described above, and outline required reporting/monitoring requirements. These terms and conditions are non-discretionary.

(1) NMFS must ensure the holder of this Authorization must consult weekly by telephone with Brad Smith, or his designee, at the Western Alaska Field Office, Alaska Region, NMFS (907-271-5006), providing a status report on the appropriate reporting items, unless other arrangements for monitoring are agreed in writing.

(2) Except in emergency situations or when conducting marine mammal surveys, aircraft (including helicopters) supplying the seismic vessels should maintain an altitude of at least 1,000 ft (305 m) until within 0.5 nm (926 m) of the seismic vessel.

(3) NMFS must ensure the holder of this Authorization shall configure the airgun array to maximize the proportion of the energy that is directed downward and to minimize horizontal sound propagation. In particular, closely spaced airguns whose overall radiation pattern is nearly omni-directional must be avoided. The size of the airgun arrays, as measured by the source level, must not be any larger than required to meet the technical objectives for the seismic survey.

(4) NMFS must ensure the holder of this Authorization shall employ the following additional mitigative measures to reduce potential impact to bowhead whales:

(A) take every precaution to avoid harassment of whale concentrations when a vessel is operated near these animals. Vessels must reduce speed when within 300 yards of whales and those vessels capable of steering around such groups must do so. Vessels must not be operated in such a way as to separate members of a group of whales from other members of the group.

(B) avoid multiple changes in direction and speed when within 300 yards of whales. In addition, operators must check the waters immediately adjacent to a vessel to ensure that no whales will be injured when the vessel's propellers (or screws) are engaged.

(C) not operate small boats at a speed that would make collisions with whales likely.

(D) when weather conditions require, such as when visibility drops, vessels must adjust speed accordingly to avoid the likelihood of injury to whales.

(E) reduce the volume of the airgun array during vessel turns while running seismic lines.

(F) whenever a bowhead whale is detected outside the exclusion zone radius, and based on its position and motion relative to the ship track is likely to enter the safety radius, an alternative ship speed or track must be calculated and implemented.

(G) use the lowest sound levels feasible to accomplish acoustic data-collection needs.

These reasonable and prudent measures, with their implementing terms and conditions, are designed to minimize the impact of incidental take that might otherwise occur from the proposed action. If, during the course of these activities, this level of incidental take is exceeded, NMFS must re-initiate consultation, which will include a review of the reasonable and prudent measures provided. NMFS must immediately provide an explanation, in writing, of the causes of such exceedence and discuss possible modifications to the reasonable and prudent measures with NMFS' Alaska Regional Office. Reinitiation of consultation is required if: (1) new information reveals effects of the action that may affect listed species in a manner or, to an extent, not previously considered; (2) the identified action is subsequently modified in a manner that causes an effect to the listed species that was not considered in the biological opinion; or (3) it is estimated that the annual harassment levels are met or exceeded for any of these species of whales; or (4) if a new species is listed or critical habitat designated that may be affected by the identified action.

APPENDIX B[10]: U.S. FISH AND WILDLIFE SERVICE LETTER OF AUTHORIZATION

United States Department of the Interior

FISH AND WILDLIFE SERVICE
1011 E. Tudor Road
Anchorage, Alaska 99503-6199

IN REPLY REFER TO:
AFES/MMM

ISSUED: July 3, 2008
EXPIRES: October 31, 2008

LETTER OF AUTHORIZATION
(08-12)

Petroleum Geo-Services Onshore Inc. (PGS) has been contracted by Eni to conduct an exploratory three-dimensional (3D) marine seismic survey in State of Alaska waters of the Beaufort Sea utilizing an ocean bottom cable/transition zone (OBC/TZ) technique during the 2008 open-water season. The proposed start date for the first portion of this project is mid July, 2008. The 2008 PGS Beaufort Sea 3D Seismic Survey Area has 2 components:

1. a 3D, ocean bottom Cable (OBC) seismic survey in state waters north of the Oliktok Point area during the open-water season (July through September 2008); where timing will be divided into two parts. The area outside the barrier islands will be surveyed by August 5, 2008, and areas inside the barrier islands will be surveyed between August 5 to September 15, 2008.

2. use of a field camp on the mainland coast, either a field camp run by PGS to be located on an existing gravel pad at Oliktok Point or use of existing Eni facilities near Oliktok Point.

Petroleum Geo-Services Onshore Inc. (PGS) is hereby authorized to take small numbers of polar bears and Pacific walrus incidental to activities occurring during the 2008 open-water season. On behalf of Eni, PGS will conduct a 3-D marine seismic survey in State of Alaska waters of the Beaufort Sea utilizing an ocean bottom cable/transition zone (OBC/TZ) technique. This project is scheduled for the period of mid July 2008 through September 2008. These activities are discussed in detail in the, "Beaufort Sea Seismic Survey Fact Sheet North Slope, Alaska, Summer 2008, February 2008."

This authorization and the required conditions below include contractors of PGS performing PGS-approved work under the scope of operations to be conducted. Authorization is subject to the following conditions:

1. PGS Operations Managers, or their designates, must be fully aware, understand, and capable of implementing the conditions of this authorization.

[10] This is an entire (scanned) copy of the Letter of Authorization (LOA) issued by USFWS.

2. This Authorization is valid only for activities (including support vessels) associated with PGS's 2008 3D OBC Seismic Survey Activities, as specified in PGS's March 20, 2008 application.

3. Intentional take is prohibited under this authorization.

4. PGS must cooperate with the U.S. Fish and Wildlife Service (Service), and other designated Federal, State, or local agencies to monitor the impacts of oil and gas exploration activities on Pacific walrus and polar bears.

5. If any changes develop in your project during the 2008 open-water season, such as activities or location, notify the Marine Mammals Management Office prior to the planned operation.

6. The PGS polar bear interaction plan (Bear and Pacific Walrus Awareness and Interaction Plan, Proposed Seismic Survey Beaufort Sea, Alaska, Summer 2008) is approved and all provisions must be complied with unless specifically noted otherwise in this Letter of Authorization. A copy of this polar bear interaction plan must be available on site for all personnel.

7. The species authorized for takings, by Level B Harassment only, are: Pacific walrus (*Odobenus rosmarus divergens*), and polar bear (*Ursus maritimus*). The taking of any walrus or polar bear in a manner prohibited under this authorization must be reported within 24 hours of the taking to the Service Incidental Take Coordinator in Anchorage Alaska (907-786-3800), or their designee, as specified in condition 10(d).

8. The holder of this Authorization is required to cooperate with the Service and any other Federal, state or local agency monitoring the impacts of the activity on walruses and polar bears. The holder must notify the Service Incidental Take Coordinator at least 24 hours prior to the start of collecting seismic data.

9. At the discretion of the Service, the operator will allow the Service to place an observer on site (vessels and aircraft) to monitor the impacts of the activity on Pacific walruses and polar bears.

10. Prohibitions:

(a) The taking, by incidental Level B harassment only, is limited to the species listed under condition 4 above. The taking by Level A harassment, serious injury, or death of these species is prohibited and may result in the modification, suspension or revocation of this Authorization.

(b) The taking of any walrus or polar bear whenever the required marine mammal mitigation and monitoring measures (conditions 11 and 12) have not been fully implemented as required by this Authorization, is prohibited.

11. Mitigation:

(a) *General Mitigation*:

The holder of this Authorization is required to:

(i) (A) Avoid concentrations or groups of walruses and polar bears hauled out onto land or ice by all vessels under the direction of PGS. Operators of support vessels should, at all time, conduct their activities at the maximum distance possible from known or observed concentrations of animals. Under no circumstances, other than an emergency, should vessels operate within 800 meters (½ mile) of walruses or polar bears observed on land or ice.

(ii) Take every precaution to avoid harassment of walruses or polar bears in water when a vessel is operated near these animals. Maintain an 800 meter (½ mile) exclusion zone, when practicable. Vessels must reduce speed when walruses or polar bears are observed in water and vessels capable of steering around these animals must do so. Vessels may not be operated in such a way as to separate members of a group of walruses or polar bears from other members of the group. Vessels should avoid multiple changes in direction and speed when walruses or polar bears are present.

(iii) Operate in full compliance with the terms identified in the approved document identified in Condition 6.

(iv) Restriction of walrus or polar bear movements, by any means, in sea or on land, is prohibited. Exclusion zones will be enforced until animals have left the area.

(b) *Seismic Vessel Mitigation:*

The holder of this Authorization is required to:

(i) Reduce the volume of the airgun array during vessel turns while running seismic lines.

(ii) To the extent practical, whenever a marine mammal is detected outside the exclusion zone radius, and based on its position and motion relative to the ship track is likely to enter the safety radius, an alternative ship speed or track will be calculated and implemented.

(iii) Exclusion and Monitoring-Safety Zones:

(A) Establish and monitor with trained observers an exclusion zone (safety radius) for walruses surrounding the seismic airgun array where the received level would be 180 dB.

(B) Establish and monitor with trained observers an exclusion zone (safety radius) for polar bear surrounding the seismic airgun array where the received level would be 190 dB.

(iv) Power-down/Shut-down Procedures:

(A) During seismic operations, if a bear or a walrus is sighted in the PGS-established exclusion zone of 800m (PGS polar bear/walrus interaction plan, Page 7), operations will power down/shut-down until the animal moves out of the exclusion zone or established safety radii, whichever is greater.

(B) Immediately shut-down the seismic airgun array and/or other acoustic sources, whenever any walruses are sighted approaching close to or within the area delineated by the established safety radii for pinnipeds of 180 dB isopleth, or polar bear are sighted approaching close to or within the area delineated by the 190 dB isopleth established under condition 11(b)(iii).

(C) Do not proceed with ramping up the seismic airgun array unless the safety zones described in condition 11(b)(iii) are visible and no walruses and polar bears are detected within the appropriate safety zones; or until 15 minutes after there has been no further visual detection of the animal(s) within the safety zone and the trained marine mammal observer on duty is confident that no walruses and polar bears remain within the appropriate safety zone, provided the entire safety zone was visible for at least 30 minutes.

(D) Emergency shut-down. If observations are made or credible reports are received that one or more walruses and polar bears are within the area of the seismic survey are in an injured or mortal state, or are indicating acute distress due to seismic noise, the seismic airgun array will be immediately shut down and the Service Incidental Take Coordinator contacted. The airgun array will not be restarted until review and approval has been given by either the Service Incidental Take Coordinator or their designee.

(v) Ramp-up Procedures:

(A) Prior to commencing ramp-up described in condition 11 (b)(v)(C) the safety radius for polar bears and walruses has to be visible and observed by a marine mammal observer if: a complete shut-down has occurred; or at any time electrical power to the airgun array is discontinued for a period of 10 minutes or more; and the marine mammal observer watch has been suspended;

(B) If the safety radii are not completely visible for at least 30 minutes prior to ramp-up in either daylight or nighttime, ramp up can commence following established procedures.

(C) If the complete 180 dB safety range is visible and no walruses and polar bears are observed while undertaking pre-ramp-up monitoring under conditions 11(b)(v)(A) and (B), ramp-up airgun arrays slowly over a period of at least 15 minutes starting with the smallest airgun in the array and then adding additional guns in sequence, until the full array is firing: (1) At the commencement of seismic operations, and (2), anytime after the airgun array has been powered down for more than 10 minutes.

(vi) Poor Visibility Conditions

(A) During any nighttime operations, if the entire 180–dB safety radius is visible using vessel lights and/or night vision devices, then start of a ramp-up procedure after a complete shutdown of the airgun array may occur following a 30–min period of observation without sighting marine mammals in the safety zone.

(B) If during foggy conditions or darkness, the full 180–dB safety zone is not visible, the airguns cannot commence a ramp-up procedure from a full shutdown.

(C) If one or more airguns have been operational before nightfall or before the onset of foggy conditions, they can remain operational throughout the night or foggy conditions. In this case, ramp-up procedures can be initiated, even though the entire safety radius may not be visible, on the assumption that marine mammals will be alerted by the sounds from the single airgun and have moved away.

12. Monitoring.

(a) *Seismic Vessel Monitoring:*

(i) The holder of this Authorization must have biologically-trained, marine mammal observers (MMOs) to be onboard the seismic source vessels.

(ii) MMOs will monitor to:

(A) Ensure that no walruses and polar bears enter the appropriate safety zones established under condition 11(b)(iii), whenever the seismic array is on.

(B) Record marine mammal activity as described in condition 12(a)(v) below. A observer must be on watch during ramp ups and the 30 minutes prior to full ramp ups, and for as large a fraction of the other operating hours as possible. At all other times, one observer must be on active watch whenever the seismic airgun array is operating during all daytime airgun operations, during any nighttime power-ups of the airguns and at night, whenever that day's monitoring resulted in one or more power-downs due to marine mammal presence.

(iii) The vessel crews also must be instructed to keep watch for walruses and polar bears at all times. If any are sighted, the bridge watch-stander must immediately notify the MMO on-watch.

(iv) Observations by the MMOs on marine mammal presence and activity will begin a minimum of 30 minutes prior to the estimated time that the seismic source is to be turned on and/or ramped-up.

(v) For each walrus or polar bear sighting, MMOs will record the following:

(A) Species, group size, age/size/sex categories (if determinable), behavioral activity, heading (if consistent), bearing and distance from seismic vessel, sighting cue, and apparent reaction of animals seen near the seismic vessel and/or its airgun array.

(B) Time, location, heading, speed, and activity of the vessel, along with sea state, ice cover, visibility, cloud cover and sun glare at: (1) any time a marine mammal is sighted, (2) at the start and end of each watch, and (3) during a watch (whenever there is a change in one or more variable)

(C) The identification of all vessels that are visible within 5 km of the seismic vessel whenever a marine mammal is sighted, and the time observed, bearing, distance, heading, speed and activity of the other vessel(s).

(vi) All MMOs must be provided with and use appropriate night-vision devices, Big Eyes, and reticulated and/or laser range finding binoculars.

(vii) The operator of the seismic vessel must maintain a log of seismic activity noting the date and time of all changes in seismic activity (e.g. ramp up, power down, shut down, changes in the number of active airguns or the volume of airgun arrays) and any corresponding changes in monitoring radii.

(b) *Non-seismic Vessel Monitoring:*

(i) A designated crew member on a non-seismic vessel will immediately contact the seismic survey ship if walruses and polar bears are sighted within the 800m exclusion zone of the source vessels.

(ii) For each walrus or polar bear sighting, a designated crew member will either record or communicate to the source vessel MMO the following:

(A) Species, group size, age/size/sex categories (if determinable), behavioral activity, heading (if consistent), bearing and distance from vessel, sighting cue, and apparent reaction of animals seen near the vessel.

(B) Time, location, heading, speed, and activity of the vessel, along with sea state, visibility, cloud cover and sun glare at any time a walrus or polar bear is sighted.

(C) The identification of all vessels that are visible within 5 km of the vessel whenever a marine mammal is sighted, and the time observed, bearing, distance, heading, speed and activity of the other vessel(s).

13. Reporting:

(a) *Marine mammal observer training manual and data collection protocols.* Prior to the initiation of seismic operations, the operator must provide the Service with:
(i) A description and documentation of the MMO training program;
(ii) a copy of the MMO field manual and/or operating procedures; and,
(iii) a key to MMO data codes, including definitions and descriptions of all data fields.

(b) *Sound source verification report.* The results of field source verification and the distances to the various sound radii are to be reported to the Service within 120 hours of completing the measurements.

(c) *Weekly summary of walrus and polar bear sightings.* The operator must tabulate and report all walrus and polar bear sightings recorded by the MMOs from all project vessels to the Service on a weekly basis. For each walrus or polar bear sighting include:
(i) a unique sighting identification number;
(ii) species, group size, age/size/sex categories, and substrate (on ice, in water, both);
(iii) date, time and location (for pre-lease seismic surveys, specific location information may be withheld until the results of the next lease sale are announced);
(iv) environmental conditions including: water depth (meters), sea state (Beaufort scale), visibility 1 (#km), visibility 2 (light/dark), visibility 3 (glare: none, little, moderate, severe), ice condition 1 (estimated % ice cover in vicinity of sighting), ice condition 2 (estimated distance (km) to pack ice);
(v) estimated range (meters) at first sighting, estimated range (meters) at closest approach;
(vi) the behavior of animals sighted (if determinable);
(vii) Whether animals appeared to react to the presence of the ship (yes, no), if yes, describe the reaction of the animal(s);
(viii) vessel activity at time of sighting including: vessel name; vessel speed (knots); seismic activity code; action taken by operator in response to sighting? (yes, no) If yes, specify (e.g. powerdown, shutdown); and,
(ix) any MMO comments or notes

(d) *Notification of incident report.* The operator must report:

(A) any incidental lethal take or injury of a polar bear or walrus; and,

(B) observations of walruses or polar bears within the prescribed safety zones (180/190 dB radii around seismic arrays, or 0.5 mile marine buffer areas) to the Service within 24 hours. Reports should include all information specified under 10(c) as well as a full written description of the encounter and any actions taken by the operator.

(e) *Post season seismic monitoring report*: A draft report will be submitted to the Service within 90 days after the end of the seismic survey program in the Chukchi Sea. The report will describe in detail:

(i) the operations that were conducted;
(ii) the results of the acoustical measurements to verify the safety radii;
(iii) the methods, results, and interpretation pertaining to all monitoring tasks;
(iv) the results of the 2008 shipboard marine mammal monitoring;
(v) a summary of the dates and locations of seismic operations, including summaries of power downs, shut downs, and ramp up delays;
(vi) marine mammal sightings (species, numbers, dates, times and locations; age/size/gender, environmental correlates, activities, associated seismic survey activities);
(vii) estimates of the amount and nature of potential take (exposure) of walruses and polar bears (by species) by harassment or in other ways to industry sounds;
(viii) an analysis of the effects of seismic operations (e.g., on sighting rates, sighting distances, behaviors, movement patterns of walruses and polar bears);
(ix) provide an analysis of factors influencing detectability of walruses and polar bears; and,
(x) provide summaries on communications with hunters and potential effects on subsistence uses

The draft report will be subject to review and comment by the Service. Any recommendations made by the Service must be addressed in the final report prior to acceptance by the Service. The draft report will be considered the final report for this activity under this Authorization if the Service has not provided comments and recommendations within 90 days of receipt of the draft report.

(f) *Seismic monitoring data*: An electronic copy of all seismic monitoring data described in condition 12(a)(v) and (vii) will be submitted to the Service within 90 days after the end of the seismic survey program.

14. Activities related to the monitoring described in this Authorization do not require a separate scientific research permit issued under section 104 of the Marine Mammal Protection Act.

15. A copy of this Authorization and the Service-approved Polar Bear Interaction Plan must be in the possession of the operator of all vessels and aircraft engaging in the activity operating under the authority of this Letter of Authorization.

16. Per the "Programmatic Biological Opinion for the Beaufort Sea Incidental Take Regulations for Polar Bear (June 2008)", your request also triggers the second of the two-tiered programmatic process. In order for incidental take of the polar bear to be exempted from the prohibitions of the ESA, the LOA also serves as an "Incidental Take Statement" (ITS), required under section 7 of the Endangered Species Act of 1973 (ESA). Issuance of the LOA/ITS fulfills the requirements for Tier 2 Consultation of the Programmatic Biological Opinion for the activities described in this letter.

Acting Regional Director

10 July 08
Date

APPENDIX C: DESCRIPTION OF SURVEY VESSELS AND EQUIPMENT

Source Vessels

M/V Wiley Gunner

The seismic source vessel the *Wiley Gunner* (Fig. C.1) is owned by Mayze Consulting. It is a steel-constructed airgun source vessels designed for shallow water surveys. The *Wiley Gunner* is 13 m (44 ft) long, 3.6 m (11.6 ft) wide with a 0.5 m (21 in) draft. It was powered by three 150 hp OMC offshore engines with a maximum speed of 18 kt (33.3 km/hr).

FIGURE C.1. The *Wiley Gunner* source vessel used during the Eni/PGS seismic survey 2-25 August 2008 in the central Alaska Beaufort Sea.

M/V Shirley V

The *Shirley V*, another seismic source vessel used during the Eni/PGS seismic survey, is owned by Mayze Consulting (see Fig. C.2). It is also a steel-constructed airgun source vessel designed for shallow water surveys. The Shirley *V* is 13 m (44 ft) long, 5.8 m (19 ft) wide, and 3.5 m (11.5 ft) high with a draft of 0.69 m (2.2 ft). It is powered by three 150 hp OMC offshore engines with a maximum speed of 18 kt (33.3 km/hr).

FIGURE C.2. The *Shirley V* source vessel used during the Eni/PGS seismic survey, 18 August-28 September 2008 in the central Alaska Beaufort Sea.

M/V Peregrine

The *Peregrine* is an aluminum landing craft with a 0.76 m (30 in) draft that is 28.7 m (94 ft) in length and 7.3 m (24 ft) abeam (see Fig. C.3). It is powered by jet- and prop-driven engines. The engines are three 300 hp Cummins diesels, driving two Kodiak model 403 water jets, and a single four-bladed propeller mounted within a 0.76 m (30 in) recess at the stern. Onboard accommodations were available for crew, but MMOs did not live on the vessel during the survey and returned to the camp after each shift.

FIGURE C.3. The *Peregrine* source vessel used during the Eni/PGS seismic survey, 28 August - 5 September 2008 in the central Alaska Beaufort Sea.

Airgun Array Specifications

Wiley Gunner *and* Shirley V

The airgun array for the *Wiley Gunner* and *Shirley V* were identical and consisted of a main section of ten Bolt 600 C airguns with a total volume of 880 in^3 (see the airgun configuration in Fig. C.4). Two additional airguns (20 in^3 and 40 in^3) airguns were included as spares in the array with the 20 in^3 airgun designated for mitigation power-downs. The airguns on the *Wiley Gunner* and *Shirley V* were positioned ~1.5 m (~5 ft) from the port and starboard sides of the vessel and towed at 1-2 m (~3-6.5 ft) depth, depending on line swath (Fig. C.5). The array was towed at speeds of 5.6-9.3 km/hr (3-5 kt). The source layout was 8 m (26 ft) wide by 6 m (20 ft) long. Energy for the airguns was supplied by a compressor powered by two 6.5 kilowatt generators operating at 1900 psi.

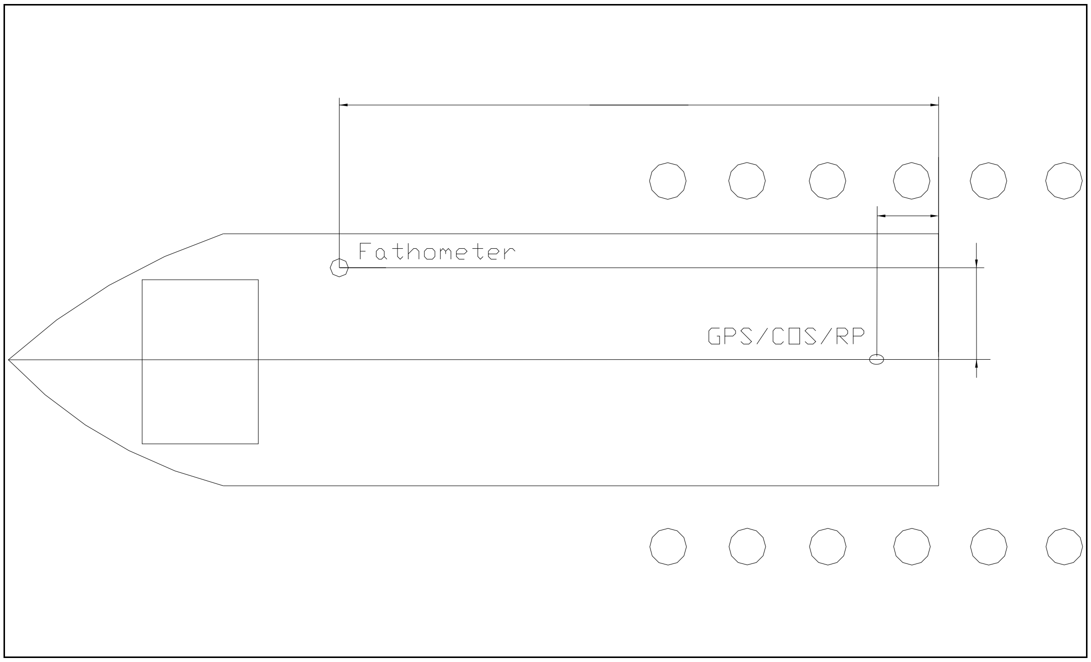

FIGURE C.4. The airgun tow configuration for the *Wiley Gunner* and *Shirley V.*

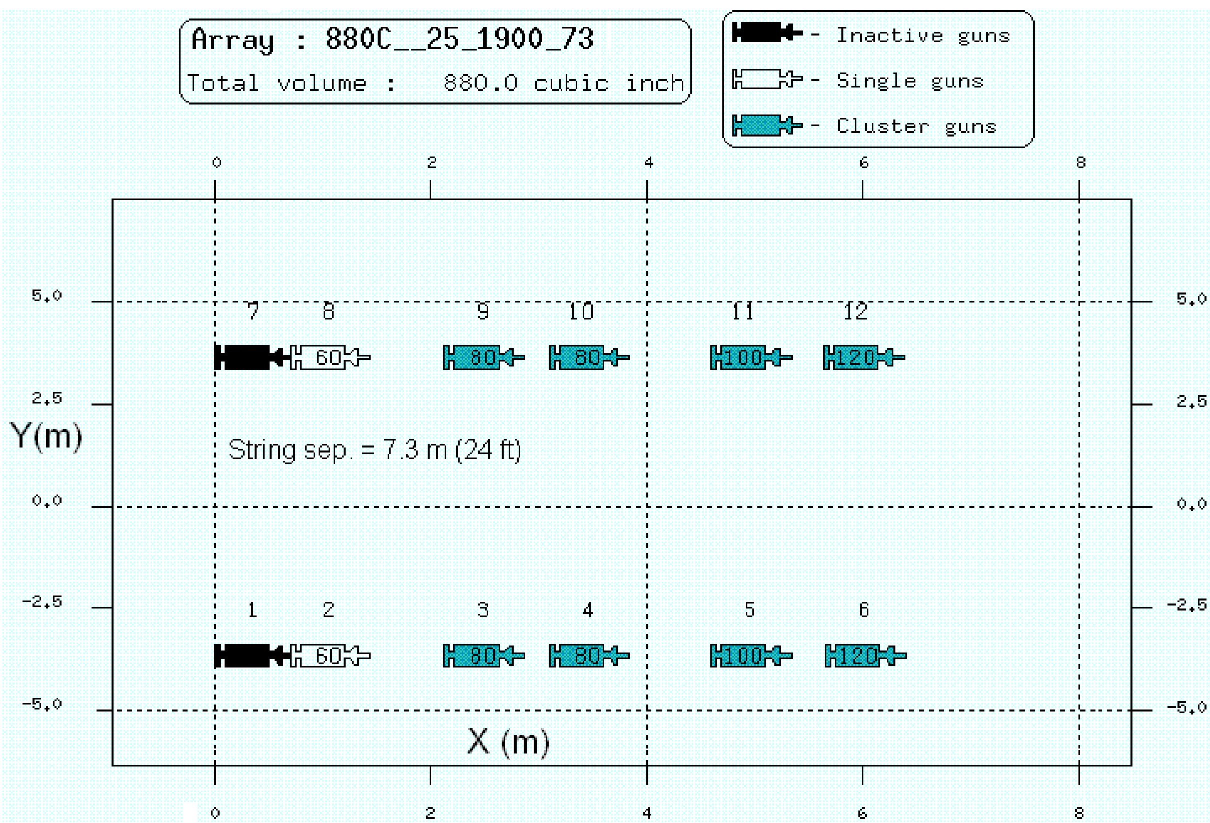

FIGURE C.5. Top-view of the airgun array configuration for the *Wiley Gunner* and *Shirley V* used during the Eni/PGS seismic survey (provided by PGS). The vessel's bow is towards the Y-axis and the vessel's port side is denoted by the X-axis. Airgun number is labeled above each airgun schematic, and airgun volume (in^3) is labeled inside each airgun schematic. Inactive spare airguns are colored black, single airguns have no coloration, and active airguns are shown in blue.

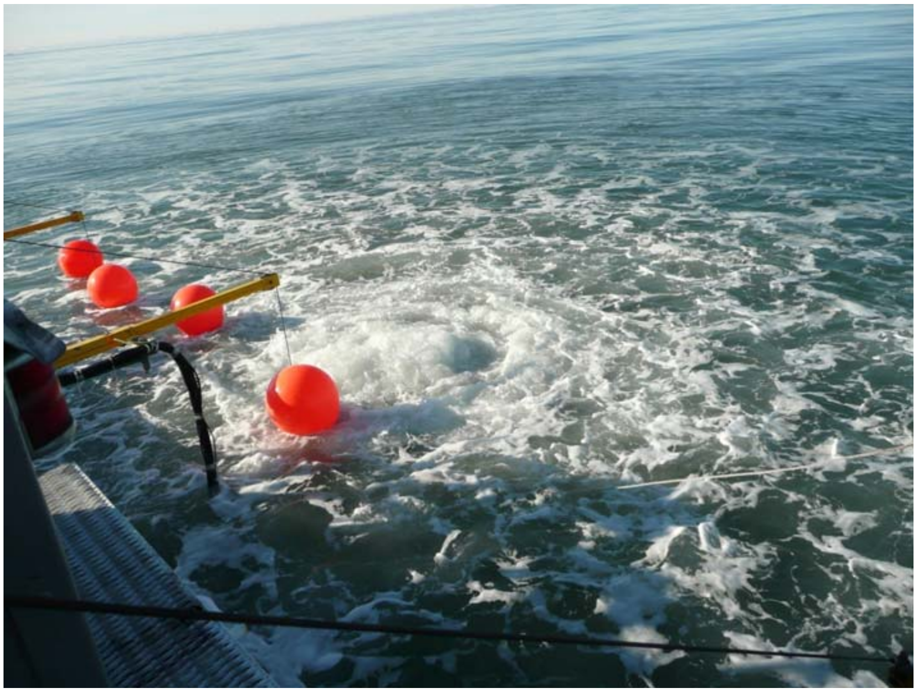

FIGURE C.6. Placement location of (half) of the airgun array from the *Wiley Gunner* or *Shirley V* used during the Eni/PGS seismic survey.

Peregrine

The *Peregrine* initially towed two 440 in^3 arrays comprised of four Bolt 600 C airguns each in clusters of 2 x 70 in^3 and 2 x 150 in^3, but the gear array was changed to two 220 in^3 airgun arrays on 9 September, and then changed gear back to the two 440 in^3 arrays on 20 September 2008 (see array configuration in Fig. C.8). The 70 in^3 airgun was used as a mitigation airgun source during turns between survey lines and mitigation power-downs. The two 440 in^3 arrays were used for surveying in deeper water (>3 m or 10 ft) while the two 220 in^3 arrays were used for shallower areas (<3 m or 10 ft). The airgun arrays were towed at a speed of 5.6-9.3 km/hr (3-5 kt) at a distance of ~8-10 m (26-32 ft) from behind the source vessel and a depth of 1-2 m (~3-6.5 ft) depending on the airgun array volume and swath line (see Table 2.2 and Fig. C.7 and Fig. C.10). Fig. C.9 shows the airguns firing from the *Peregrine*.

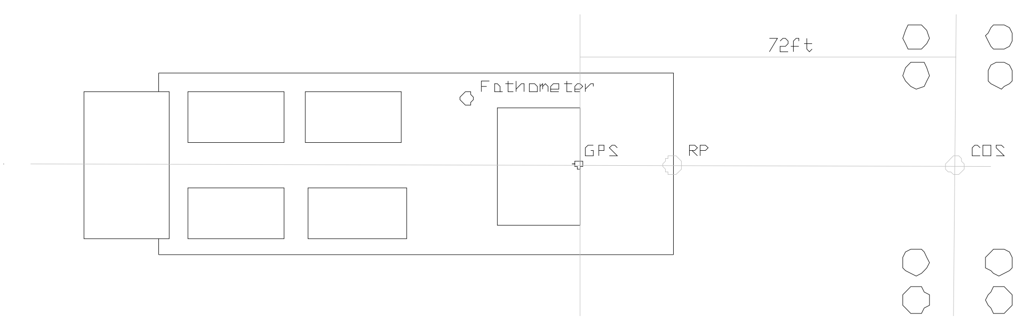

FIGURE C.7. The airgun tow configuration for the *Peregrine.*

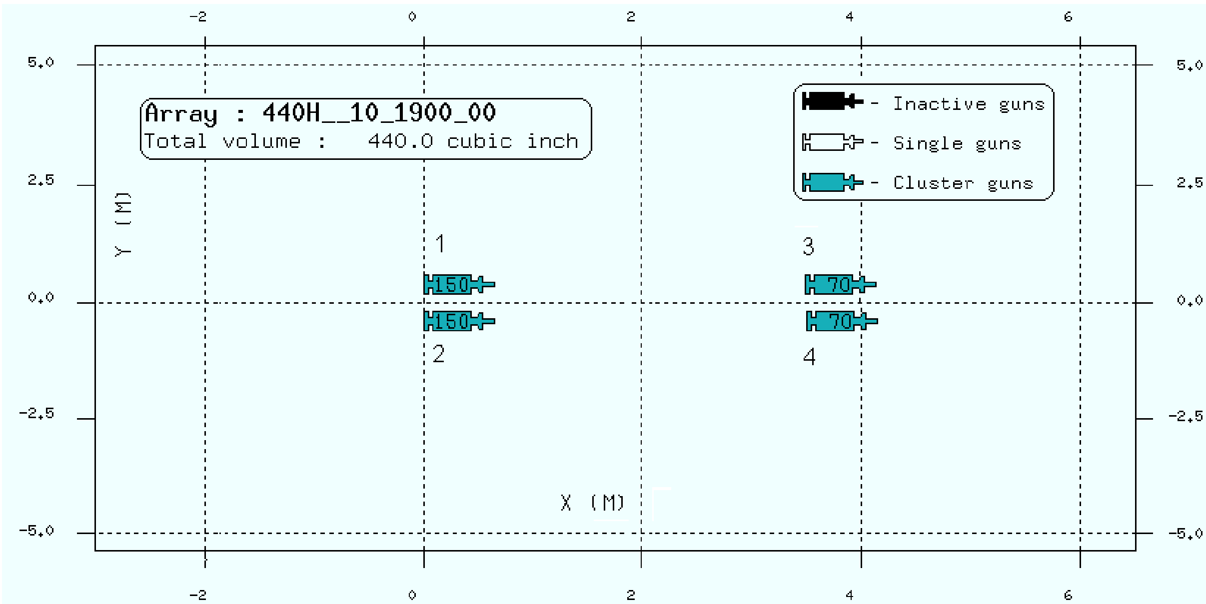

FIGURE C.8. Top-view of the airgun array configuration for the *Peregrine* used during the Eni/PGS seismic survey (provided by PGS). The vessel's bow is towards the Y-axis and the vessel's port side is denoted by the X-axis. Airgun number is labeled above each airgun schematic, and airgun volume (in^3) is labeled inside each airgun schematic. The 880 in^3 airgun array was made up of 2 x 440 in^3 arrays.

Figure C.9. Airguns firing from *Peregrine* source vessel.

FIGURE C.10. Photo from the *Shirley V* showing starboard side placement of the airgun array (in the foreground) versus the stern towed placement of the airgun array on the *Peregrine* (in the background) used during the Eni/PGS seismic survey.

Cable Vessels

DIB or Demaree Inflatable Boats

The DIB shallow water cable boats were built in 2002 in Houston, Texas and are owned by PGS (Fig. C.11). They have an overall length of 12.5 m (41 ft) with a beam of 4.2 m (14 ft) and draft of 0.8 m (2.6 ft). They have a cruising speed of 33.3 km/h (18 kt). The main engines are two Volvo Penta AD41-P with 2 x 3 blade propellers for a total horsepower of 2 x 200 hp. The generators run off the main engines. The seismic capabilities include cable handling equipment such as a bow puller, deck handler, stern squirter and line checker. The DIB vessels were used primarily for trouble shooting and positioning cables. PGS used three of these cable vessels during the Eni/PGS seismic survey.

FIGURE C.11. An example of a cable DIB vessel used during the Eni/PGS seismic survey.

Reliance Vessels

The Reliance cable vessels are similar in dimension and seismic capabilities as the DIB cable vessels described above, except that Reliance cable vessels have an aluminum hull without soft pontoons (Fig. C.12). They carry the same navigational system as the DIB cable vessels, other than the acoustic equipment for positioning cables. Reliance boats were used for moving and laying out large amounts of cables into the front of the swath spread. PGS used four of these cable boats during the OBC/TZ seismic survey.

FIGURE C.12. An example of a cable Reliance vessel used during the Eni/PGS seismic survey.

Cable Equipment and Acoustic Transponders

The data acquisition units consisted of two major components, line acquisition units (LAUL) and links including field digitizer units (FDUs). LAULs collect, buffer, decimate, filter and compress data received from the FDUs. The cables were configured with four ground stations per link. For this survey, a pair of Sercel FDUs were designed into a station to record both geophone and hydrophone elements of a Geospace PV1 phone. Thus, a geophone and hydrophone were placed at each station (see Fig. C.13). Alternate stations also included a Sonardyne acoustic transponder. The 7911 Sonardyne OBC12 acoustic positioning system was used to determine the final settled location of each receiver location on the seabed. The Sonardyne operated at a frequency of 35 to 55 kHz and an SPL of 190 dB (unknown sound metric). Pings from transducers on the source vessel varied in frequency, and generally occurred every 1-5 s, and were received by the transponders. The stations were placed every 33.5 m (110 ft). When cables were laid over land (the barrier islands), there were 33.5 m (110 ft) between stations with each phone 0.61 m (2 ft) apart in a triangle configuration. Cables (Fig. C.14) varied in length between 67 m (220 ft) and 1200 mini-cables of 1 m (3.3 ft) length.

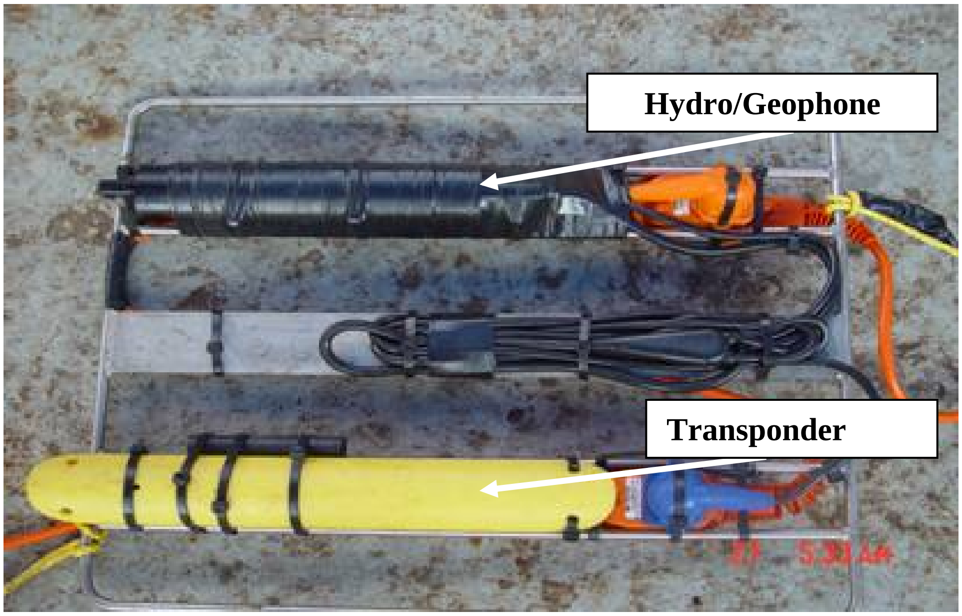

FIGURE C.13. An example of a cable station that included a dual hydro- and geophone as well as an acoustic Sonardyne transponder.

FIGURE C.14. An example of ocean-bottom cables being prepared for deployment. Hydro- and geophone stations are attached to the cables (laying on the vessel deck).

Recording Vessel

M/V Garrett

The *Garrett* is owned by Agvik Marine and was the navigation center or recording vessel for the Eni/PGS survey (Fig. C.15). It is a self-propelled barge and has hydraulic gravity spuds that can be lowered in water up to 6 m (20 ft) deep. The spuds were used to secure or anchor the vessel during data acquisition. The navigation center monitored all vessel operations at all times and was the center for data acquisition.

FIGURE C.15. The *Garret* recording vessel used during the Eni/PGS seismic survey.

Bathymetric Equipment for Source Vessels and Cable Boats

Bathymetric equipment was located on each of the source vessels and the shallow-water cable boats. A Concept Systems GATOR provided bathymetric data which were recorded simultaneously with the seismic data, by employing Interspace Tech DX 150. The Furuno RD30 depth sounder which operated at 235 kHz was part of this system.

Support Vessels

M/V American Discovery

The *American Discover*y is an aluminum catamaran build in 1994 and is owned by American Marine Corporation with its home port in Anchorage, Alaska (Fig. C.16). It has a length of 12.2 m (40 ft) and beam of 4.5 m (18 ft) with a 0.61 m (2 ft) draft. The main engines are twin Volvo D6, 330 HP Diesel Engines with Volvo DPH outdrives. It has a speed of 46.3 km/h (25 kt). The *American Discovery* was used to transfer personnel from shore to other vessels involved in the Eni/PGS seismic survey activities.

FIGURE C.16. The *American Discovery* support vessel used during the Eni/PGS seismic survey.

Mechanic and Party Manager's Vessels

The "Project Manager/Client" boat is 7.3 m (24 ft) long, 2.4 m (8 ft) wide, and has a draft of 0.45 m (1.5 ft; Fig. C.17). It was powered with a 90 hp engine. This vessel was used for fast transportation to and from the seismic area. Another support vessel, the "Mechanic's" boat was used to provide maintenance and mechanical support for marine vessels used during the project. This support boat is 7.9 m (26 ft) long, 2.4 m (8 ft) wide, and has a 0.45 m (1.5 ft) draft. This vessel was powered by twin 90 hp engines (Fig. C.17).

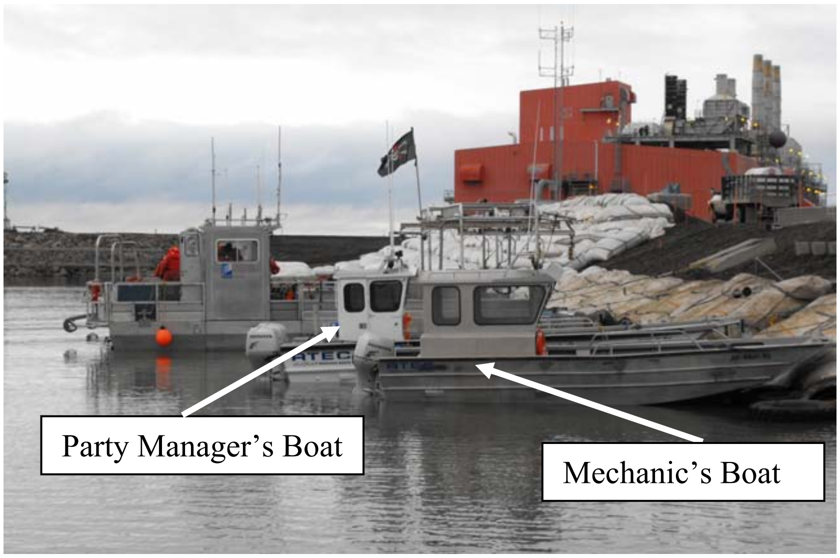

FIGURE C.17. The Mechanic's boat (foreground) and Project Manager/Client boat (second vessel) used during the Eni/PGS seismic survey.

Fueling Vessel: M/V Spiridon

The *Spiridon* was supplied to the project by Silverado Charters and was used for refueling the seismic vessels and generators on the recording barge (Fig. C.18). The *Spiridon* was also used to quickly transport small items or small groups of people and could be used as an emergency response vessel, if required.

FIGURE C.18. The *Spiridon* used as a refueling vessel during the Eni/PGS seismic survey.

APPENDIX D: VESSEL-BASED VISUAL EFFORT AND SIGHTINGS

TABLE D.1. MMO effort in hours (h), categorized as all and "daylight effort" (DE[a]) and by Beaufort wind force, from each seismic source vessel during the Eni/PGS seismic survey, August-September 2008 in the central Alaska Beaufort Sea.

	Beaufort Wind Force															
	0		1		2		3		4		5		6*		Total	
Array Volume	Total	DE[a]	Total	DE	Total	DE	Total	DE	Total	DE	Total	DE	Total	DE	Total	DE
(A) *Wiley Gunner*																
Total Airguns On (Seismic)	**4.6**	**4.6**	**26.0**	**24.2**	**65.1**	**60.7**	**31.1**	**29.0**	**12.2**	**9.4**	**1.3**	**1.3**	**0.0**	**0.0**	**140.3**	**129.2**
Mitigation Source (20 in^3)	1.6	1.6	0.8	0.8	2.9	2.8	0.0	0.0	0.2	0	0.0	0.0	0.0	0.0	**5.4**	**5.1**
Array Activated (40-880 in^3)	3.0	3.0	25.3	23.4	62.2	58.0	31.1	29.0	12.0	9.4	1.3	1.3	0.0	0.0	**134.9**	**124.1**
Total Airguns Off	**4.0**	**2.4**	**22.5**	**19.2**	**47.1**	**39.4**	**16.4**	**13.4**	**13.3**	**11.2**	**0.9**	**0.9**	**0.0**	**0.0**	**104.3**	**86.5**
Non-Seismic	3.2	1.6	16.9	14.2	35.8	29.0	12.7	10.6	10.6	8.5	0.7	0.7	0.0	0.0	**79.8**	**64.5**
Post-Seismic[b]	0.8	0.8	5.6	5.0	11.3	10.4	3.8	2.8	2.7	2.7	0.3	0.3	0.0	0.0	**24.4**	**22.0**
Total Effort (Airguns On&Off)	***8.6***	***7.0***	***48.6***	***43.4***	***112.2***	***100.1***	***47.5***	***42.4***	***25.4***	***20.6***	***2.2***	***2.2***	***0.0***	***0.0***	***244.6***	***215.7***
(B) *Shirley V*																
Total Airguns On (Seismic)	**19.0**	**9.7**	**113.7**	**85.3**	**161.8**	**123.5**	**99.0**	**60.6**	**45.9**	**35.9**	**8.6**	**8.5**	**0.0**	**0.0**	**447.9**	**323.5**
Mitigation Source (20 in^3)	0.0	0.0	0.5	0.5	5.6	3.5	1.2	1.0	1.0	1.0	0.0	0.0	0.0	0.0	**8.2**	**6.0**
Array Activated (40-880 in^3)	19.0	9.7	113.2	84.8	156.3	120.0	97.8	59.6	44.9	34.9	8.6	8.5	0.0	0.0	**439.7**	**317.5**
Total Airguns Off	**0.8**	**0.3**	**17.9**	**15.2**	**46.6**	**37.3**	**54.4**	**39.4**	**7.8**	**7.8**	**0.9**	**0.2**	**0.0**	**0.0**	**128.5**	**100.2**
Non-Seismic	0.6	0.1	11.9	9.8	30.2	25.5	46.2	35.1	5.9	5.9	0.2	0.2	0.0	0.0	**95.0**	**76.6**
Post-Seismic	0.2	0.2	6.0	5.4	16.4	11.7	8.2	4.3	1.9	1.9	0.7	0.0	0.0	0.0	**33.4**	**23.5**
Total Effort (Airguns On&Off)	**19.8**	**10.1**	**131.6**	**100.5**	**208.4**	**160.7**	**153.4**	**99.9**	**53.7**	**43.7**	**9.5**	**8.7**	**0.0**	**0.0**	**576.4**	**423.6**
(C) *Peregrine*																
Total Airguns On (Seismic)	**4.2**	**4.0**	**67.6**	**35.3**	**41.5**	**19.3**	**36.7**	**14.5**	**19.2**	**10.6**	**25.6**	**11.3**	**3.0**	**0.0**	**197.8**	**95.0**
Mitigation Source (70 in^3)	0.5	0.5	9.5	2.7	2.0	1.0	2.1	1.4	4.6	2.3	3.6	0.3	0.0	0.0	**22.3**	**8.3**
Array Activated (70-880 in^3)	3.7	3.5	58.1	32.7	39.5	18.2	34.6	13.0	14.6	8.3	22.0	11.0	3.0	0.0	**175.6**	**86.7**
Total Airguns Off	**1.0**	**0.0**	**28.5**	**10.9**	**51.4**	**25.4**	**57.9**	**28.2**	**20.5**	**6.3**	**85.5**	**48.4**	**4.7**	**0.0**	**249.5**	**119.1**
Non-Seismic	1.0		21.2	7.1	49.8	24.5	54.7	27.3	18.1	5.2	81.0	48.1	4.5	0.0	**230.2**	**112.2**
Post-Seismic	0	0	7.4	3.8	1.6	0.9	3.2	0.9	2.4	1.1	4.5	0.3	0.2	0.0	**19.3**	**6.8**
Total Effort (Airguns On&Off)	***5.2***	***4.0***	***96.1***	***46.2***	***92.9***	***44.7***	***94.6***	***42.6***	***39.7***	***16.9***	***111.1***	***59.7***	***7.7***	***0.0***	***447.3***	***214.1***

*Effort in Bf >5 excluded for "daylight effort."

[a]DE = "daylight effort" and is defined as MMO effort during daylight conditions, Bf <6, visibility ≥1 km (0.6 mi), and with no to moderate glare.

[b]Post-seismic is defined as 3 min to 1 h after seismic periods.

TABLE D.2. MMO effort in kilometers (km), categorized as all and "daylight effort" (DE[a]) and by Beaufort wind force, from each seismic source vessel.

	Beaufort Wind Force															
	0		1		2		3		4		5		6*		Total	
Array Volume	Total	DE[a]	Total	DE	Total	DE	Total	DE	Total	DE	Total	DE	Total	DE	Total	DE
(A) *Wiley Gunner*																
Total Airguns On (Seismic)	**1.1**	**1.1**	**73.4**	**68.2**	**157.4**	**141.5**	**87.0**	**80.1**	**36.6**	**27.9**	**3.9**	**3.9**	**0.0**	**0.0**	**359.4**	**322.8**
Mitigation Source (20 in^3)	0.3	0.3	0.1	0.1	9.9	9.7	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	**10.6**	**10.1**
Array Activated (40-880 in^3)	0.8	0.8	73.3	68.1	147.6	131.8	87.0	80.1	36.2	27.9	3.9	3.9	0	0.0	**348.8**	**312.7**
Total Airguns Off	**1.3**	**0.7**	**108.6**	**85.3**	**204.7**	**189.2**	**40.0**	**33.4**	**37.3**	**27.0**	**5.3**	**5.3**	**0.0**	**0.0**	**397.3**	**340.9**
Non-Seismic	1.2	0.6	82.3	61.1	143.8	131.0	25.5	20.2	26.7	16.5	4.9	4.9	0.0	0.0	**284.5**	**234.3**
Post-Seismic[b]	0.1	0.1	26.3	24.1	60.9	58.2	14.5	13.2	10.5	10.5	0.4	0.4	0	0.0	**112.7**	**106.6**
Total Effort (Airguns On&Off)	***2.4***	***1.7***	***182.0***	***153.5***	***362.2***	***330.7***	***127.0***	***113.6***	***73.8***	***55.0***	***9.2***	***9.2***	***0.0***	0.0	***756.7***	***663.6***
(B) *Shirley V*																
Total Airguns On (Seismic)	**93.7**	**39.1**	**567.1**	**427.5**	**725.7**	**548.4**	**393.8**	**250.1**	**185.7**	**125.4**	**28.9**	**28.8**	**0.0**	**0.0**	**1994.9**	**1419.4**
Mitigation Source (20 in^3)	0.0	0.0	0.9	0.9	13.8	8.6	5.2	5.0	1.8	1.8	0.0	0.0	0.0	0.0	**21.7**	**16.3**
Array Activated (40-880 in^3)	93.7	39.1	566.2	426.6	711.9	539.8	388.6	245.2	184.0	123.6	28.9	28.8	0	0.0	**1973.2**	**1403.1**
Total Airguns Off	**6.6**	**2.0**	**73.5**	**62.6**	**179.4**	**143.7**	**122.3**	**72.7**	**50.5**	**50.5**	**6.3**	**0.3**	**0**	**0.0**	**438.6**	**331.8**
Non-Seismic	6.5	1.8	44.9	35.2	108.8	103.8	87.5	59.2	34.5	34.5	0.3	0.3	0.0	0.0	**282.4**	**234.8**
Post-Seismic	0.1	0.1	28.6	27.5	70.7	40.0	34.8	13.5	16.1	16.1	6.0	0.0	0.0	0.0	**156.2**	**97.1**
Total Effort (Airguns On&Off)	***100.3***	***41.1***	***640.6***	***490.1***	***905.1***	***692.1***	***516.1***	***322.8***	***236.2***	***175.9***	***35.2***	***29.1***	***0.0***	***0.0***	***2433.5***	***1751.2***
(C) *Peregrine*																
Total Airguns On (Seismic)	**29.3**	**27.7**	**444.5**	**241.7**	**285.3**	**130.5**	**247.1**	**104.3**	**125.2**	**68.2**	**162.8**	**84.0**	**18.8**	**0.0**	**1312.9**	**656.5**
Mitigation Source (70 in^3)	1.9	1.9	30.8	8.0	9.8	6.7	10.0	8.5	19.2	9.0	8.4	1.7	0.0	0.0	**80.0**	**35.9**
Array Activated (70-880 in^3)	27.4	25.8	413.7	233.7	275.4	123.8	237.1	95.8	106.0	59.1	154.4	82.3	18.8	0.0	**1232.9**	**620.6**
Total Airguns Off	**0.3**	**0.0**	**74.7**	**24.6**	**72.5**	**37.1**	**106.7**	**55.0**	**36.3**	**27.0**	**111.1**	**63.0**	**6.9**	**0.0**	**408.4**	**206.8**
Non-Seismic	0.3	0.0	45.6	11.9	66.2	35.5	88.0	50.2	18.8	15.9	76.1	61.7	5.6	0.0	**300.5**	**175.2**
Post-Seismic	0.0	0	29.1	12.7	6.3	1.6	18.6	4.8	17.5	11.1	35.0	1.3	1.3	0.0	**107.9**	**31.6**
Total Effort (Airguns On&Off)	***29.5***	***27.7***	***519.2***	***266.4***	***357.7***	***167.6***	***353.8***	***159.3***	***161.5***	***95.1***	***273.9***	***147.1***	***25.7***	***0.0***	***1721.3***	***863.2***

*Effort in Bf >5 excluded for "daylight effort."

[a]DE = "daylight effort" and is defined as MMO effort during daylight conditions, Bf <6, visibility >1 km (0.6 mi), and with no to moderate glare.

[b]Post-seismic is defined as 3 min to 1 h after seismic periods.

TABLE D.3. Sightings of cetaceans and seals made from source vessels during all effort (including when MMOs were off-watch).

Species	MMO Effort?[a]	Group size	Date & Time (AKDT)	Latitude (ºN)	Longitude (ºW)	CPA (m)[b]	Movement[c]	Initial Behavior[d]	Bf[e]	Water Depth (m)[f]	Vessel Activity[g]	Array Volume (in^3)	Mitigation[h]	Inside/ Outside Barrier Islands[i]	No. Vessels within 4 km	Light/ Dark
Cetaceans																
Shirley V																
Unidentified mysticete whale	Y	3	29/08/2008 05:42:00	70.56	-150.006	>3000	UN	BL	0	5.8	OT	0	None	outside	5	L
Seals																
Wiley Gunner																
Bearded seal	Y	1	02/08/2008 06:24:15	70.5103	-149.864	100	SA	LO	1	1	IA	0	None	inside	3	L
Bearded seal	Y	1	02/08/2008 08:08:06	70.5157	-149.876	40	NE	SW	1	7.9	OT	0	None	inside	4	L
Unidentified seal	Y	1	08/08/2008 20:39:15	70.551	-150.216	404	SA	LO	2	1.6	LS	880	None	inside	3	L
Spotted seal	Y	1	09/08/2008 05:42:19	70.5619	-150.202	100	SA	LO	2	7.1	OT	0	None	outside	3	L
Unidentified seal	Y	1	09/08/2008 14:29:25	70.5603	-150.192	139	SA	LO	2	5.7	LS	800	SZ	outside	6	L
Unidentified seal	Y	1	09/08/2008 14:29:42	70.5602	-150.192	30	SA	LO	2	5.7	LS	800	SZ	outside	6	L
Unidentified seal	Y	1	09/08/2008 16:24:00	70.5589	-150.191	183	SA	LO	2	4.4	LS	800	SZ	outside	4	L
Spotted seal	Y	1	09/08/2008 17:51:30	70.5505	-150.142	30	NE	SW	2	5.2	OT	0	None	outside	0	L
Unidentified seal	Y	1	09/08/2008 22:49:45	70.5442	-150.079	600	SA	LO	2	4.3	OT	0	None	outside	3	L
Spotted seal	Y	1	09/08/2008 23:05:02	70.5595	-150.181	70	NE	DI	2	6.5	OT	0	None	outside	3	L
Unidentified seal	Y	1	10/08/2008 04:08:15	70.5505	-150.228	20	SA	LG	4	4.7	OT	0	None	outside	5	L
Unidentified seal	Y	1	10/08/2008 16:15:42	70.5643	-150.177	492	SA	U	2	7.9	PD	80	None	outside	1	L
Unidentified seal	Y	1	10/08/2008 20:35:02	70.5673	-150.157	346	SA	LG	1	8	IA	0	None	outside	4	L
Spotted seal	Y	1	10/08/2008 21:47:50	70.5671	-150.161	492	SA	LO	1	8	IA	0	None	outside	7	L
Unidentified seal	Y	1	10/08/2008 22:18:51	70.5631	-150.179	858	SA	LO	1	8	IA	0	None	outside	7	L
Spotted seal	Y	1	10/08/2008 22:32:20	70.5631	-150.179	712	SA	SW	1	7.8	IA	0	None	outside	7	L
Unidentified seal	Y	1	11/08/2008 11:43:00	70.566	-150.128	217	NE	SW	1	7.8	LS	720	None	outside	5	L
Bearded seal	Y	1	12/08/2008 07:03:30	70.5631	-150.089	20	ST	LO	2	6.3	OT	0	None	outside	1	L
Ringed seal	Y	1	16/08/2008 09:28:20	70.5695	-150.059	20	ST	SW	0	6.9	OT	0	None	outside	3	L
Spotted seal	Y	1	16/08/2008 14:51:22	70.5612	-150.05	25	ST	SW	2	6.5	LS	880	SZ	outside	2	L
Unidentified seal	Y	1	17/08/2008 13:33:00	70.5694	-150.004	100	SA	LO	4	6.8	LS	740	SZ	outside	2	L
Unidentified seal	N	1	18/08/2008 02:11:27	70.565	-149.856	100	SA	LO	X	4.5	OT	0	None	outside	2	L
Unidentified seal	Y	1	19/08/2008 03:34:14	70.5577	-149.969	103	SA	LO	2	4.6	IA	0	None	outside	3	L
Unidentified seal	Y	1	23/08/2008 06:42:12	70.5779	-149.841	500	SA	LO	1	7.8	OT	0	None	outside	0	L
Unidentified seal	Y	1	23/08/2008 14:59:00	70.5653	-149.828	180	SA	LO	0	4.9	IA	0	None	outside	5	L
Shirley V																
Spotted seal	Y	1	18/08/2008 11:07:00	70.5173	-149.954	144	SA	LO	2	2.1	OT	0	None	inside	2	L
Unidentified seal	Y	1	18/08/2008 22:19:54	70.5155	-150.015	460	SA	LG	2	2.8	ST	160	None	inside	6	L
Ringed seal	Y	1	19/08/2008 11:03:00	70.5927	-150.045	5	SA	LO	2	9.4	OT	0	SZ	outside	1	L
Unidentified seal	Y	1	20/08/2008 15:17:19	70.558	-149.993	50	SA	SW	2	5.2	OT	0	None	outside	3	L
Unidentified seal	Y	1	21/08/2008 19:45:42	70.5861	-149.887	882	SA	SI	2	10.2	SH	880	None	outside	4	L
Bearded seal	Y	1	23/08/2008 06:36:41	70.5779	-149.843	275	SA	SI	2	8.6	PZ	20	PZ	outside	3	L
Bearded seal	Y	1	23/08/2008 12:17:00	70.5776	-149.832	110	SA	FD	1	8	OT	0	SZ	outside	0	L
Unidentified seal	N	1	23/08/2008 23:55:00	70.5101	-149.87	X	ST	SW	X	0.8	IA	0	None	inside	0	L
Ringed seal	Y	1	10/09/2008 07:44:13	70.5158	-149.894	150	NE	LO	1	1.7	OT	0	None	inside	1	L
Unidentified seal	Y	1	19/09/2008 16:58:21	70.5226	-149.893	250	SA	LO	1	2.3	OT	0	None	inside	4	L
Ringed seal	Y	1	26/09/2008 15:05:30	70.5822	-149.861	80	NE	FD	3	9.3	LS	680	SZ	outside	5	L

TABLE D.3. Concluded.

Peregrine																
Bearded seal	Y	1	02/09/2008 20:30:00	70.5413	-150.157	919	SA	LO	5	0.671	IA	0	None	inside	0	L
Unidentified seal	Y	1	15/09/2008 08:55:00	70.5654	-149.795	87	X	LO	5	3.933	LS	440	SZ	outside	1	L
Unidentified seal	N	1	19/09/2008 09:40:30	70.5183	-150.077	X	X	LO	X	1.921	IA	0	None	inside	0	L
Unidentified seal	Y	1	23/09/2008 18:51:12	70.549	-149.986	131	NE	SW	1	4.665	OT	0	SZ	outside	3	L
Bearded seal	Y	1	24/09/2008 19:40:01	70.516	-149.898	87	NE	LO	2	0.671	IA	0	None	inside	1	L

[a] MMOs on-watch = Y; MMOs off-watch =N.
[b] CPA is the distance at the closest observed point of approach to the nearest airgun. This is not necessarily the distance at which the individual or group was initially seen nor the closest it was observed to the vessel.
[c] The initial movement of the individual or group relative to the vessel. NE = neutral movement; ST = swimming toward the vessel; SA = swimming away from vessel; UN = movement unknown; X = movement not recorded.
[d] The initial behavior observed. LO = looking; SW = swimming; BL = blowing; DI = diving; FD = front dive; SI = sink; LG = logging; U = unknown behavior.
[e] Beaufort Wind Force Scale.
[f] Water depth was recorded for the vessel's location at the time of the sighting.
[g] Activity of the vessel at the time of the sighting. PD = power-down (not for marine mammal mitigation); PZ = power-down (for marine mammal mitigation); IA = inactive; LS = line shooting with airgun(s); SH = shooting between or off lines; OT = other or no seismic activity.
[h] Mitigation measures. PZ = power down to a single airgun; SZ = safety zone shut down.
[I] Vessel located shoreward (inside) or seaward (outside) the barrier islands. Inside = inside Thetis, Spy, or Leavitt islands; Outside = outside Thetis, Spy, or Leavitt islands.

TABLE D.4. Sightings of polar bears made from source vessels during all effort (including when MMOs were off-watch).

Vessel	MMO Effort?[a]	Group size	No. Juveniles	Date & Time (AKDT)	Latitude (ºN)	Longitude (ºW)	CPA (m)[b]	Movement[c]	Initial Behavior[d]	Bf[e]	Water Depth (m)[f]	Vessel Activity[g]	Array Volume (in^3)	Mitigation[h]	Inside/ Outside Barrier Islands[i]	No. Vessels within 4 km	Light/ Dark
Polar Bears in Water																	
Peregrine	Y	1	0	13/09/2008 10:50:00	70.5042	-149.993	631	Away	LO	2	1.7	LS	440	SZ, move away	Inside	3	L
Polar Bears on Land																	
Wiley Gunner	Y	1	0	10/08/2008 04:18:32	70.551	-150.216	400	NE	RE	4	0.3	OT	0	None[j]	Inside	5	L
	Y	1	0	10/08/2008 11:45:00	70.5577	-150.178	858	NE	RE	3	3.3	OT	0	Move away	Outside	0	L
Shirley V	Y	2	0	25/08/2008 19:40:00	70.5699	-149.71	882	NO	RE	2	0.3	IA	0	Move away	Inside	5	L
	Y	3	0	25/08/2008 22:18:00	70.5623	-149.708	1600	NE	WK	1	2.1	SH	880	None	Inside	2	L
	Y	1	0	26/08/2008 20:24:43	70.5514	-149.772	250	Away	WK	1	2.9	IA	0	Move away	Inside	1	L
	Y	1	0	29/08/2008 15:17:00	70.5296	-150.069	2500	NE	RE	1	4.5	LS	760	None	Inside	4	L
	Y	1	0	29/08/2008 21:00:00	70.5325	-150.113	275	NE	RE	3	0.8	OT	0	Move away	Outside	4	L
	Y	1	1	05/09/2008 09:19:00	70.5393	-149.836	882	NE	RE	3	1.6	LS	740	Move away	Inside	1	L
Peregrine	Y	1	0	30/08/2008 06:08:33	70.5415	-150.168	1991	NE	WK	4	0.9	IA	0	None	Inside	1	L
	Y	1	0	31/08/2008 09:55:02	70.5407	-150.161	818	NE	WK	3	2.3	IA	0	None	Inside	2	L
	Y	1	1	02/09/2008 06:41:46	70.5413	-150.157	767	NE	RE	5	1.0	OT	0	Move away	Inside	0	L
	Y	1	1	02/09/2008 07:15:00	70.5413	-150.157	450	NE	WK	5	0.4	OT	0	Move away	Inside	0	L
	N	1	1	03/09/2008 19:12:40	70.5413	-150.157	900	Away	WK	5	1.5	IA	0	None	Inside	0	L

[a] MMOs on-watch = Y; MMOs off-watch =N.

[b] CPA is the distance at the closest observed point of approach to the nearest airgun. This is not necessarily the distance at which the individual or group was initially seen nor the closest it was observed to the vessel.

[c] The initial movement of the individual or group relative to the vessel. NE = neutral movement; Away = walking away from vessel; NO = no ovious directin of movement.

[d] The initial behavior observed. LO = looking; RE = resting; WK = walking.

[e] Beaufort Wind Force Scale.

[f] Water depth was recorded for the vessel's location at the time of the sighting.

[g] Activity of the vessel at the time of the sighting. IA = inactive; LS = line shooting with airgun(s); SH = shooting between or off lines; OT = other or no seismic activity.

[h] Mitigation measures. PZ = power down to a single airgun; SZ = safety zone shut down; Move away = vessel moved away from location of sighting.

[i] Vessel located shoreward (inside) or seaward (outside) the barrier islands. Inside = inside Thetis, Spy, or Leavitt islands; Outside = outside Thetis, Spy, or Leavitt islands.

[j] Sighting made while vessel sheltering from poor weather conditions in lee of Thetis Island, and permitted by USFWS.

APPENDIX E: INCIDENTAL MARINE MAMMAL SIGHTINGS, STATIONARY EFFORT AND SIGHTINGS, AND OFF-WATCH MARINE MAMMAL SIGHTINGS

Incidental Marine Mammal Sightings

Sightings by MMOs from support vessels or vessel crew members were recorded as incidental to the mitigation and monitoring efforts. Three individual seals (one bearded and two unidentified seals) were observed by MMOs off-watch during transport following an MMO crew change on 23 September 2008 (Table E.1). All sightings were made from the crew transfer vessel, *American Discovery*. The *Peregrine* was operating at full volume during each of these three sighting. However, it is not known how close the seals or the *American Discovery* was to the *Peregrine* at the time of the sightings, although they were likely within one kilometer of the *Peregrine* based on the timing of sightings after crew change, speed of the transport vessel, and distance traveled during crew transports. There were no sightings on the *Peregrine* at the same time as those made from the *American Discovery*, although there was a shut-down due to an unidentified seal at 18:52 AKDT on 23 September (see *Implementation of Mitigation Measures* in Chapter 5). However, in the case of the three incidental sightings, it is unlikely that any of these individuals were exposed to sound levels ≥190 dB at the times of these sightings since they were outside of the 190 dB safety radius of the *Peregrine* (300 m; see Chapter 3 and Table 4.1).

TABLE E.1. Incidental sightings of individual seals made by MMOs during crew transport on the *American Discovery* on 23 September 2008.

Species	Time[1]	Initial Behavior	Pace	Reaction	CPA (m)[2]	Substrate
Bearded Seal	18:01:20	Front dive	Moderate	None	150	Water
Unidentified Seal	18:03:27	Look	Sedate	Look	200	Water
Unidentified Seal	18:05:00	Look	Sedate	Look	250	Water

[1]Time listed in Alaska Daylight Time (AKDT).

[2]CPA means closest (observed) point of approach (to the MMOs).

Stationary Effort and Marine Mammal Sightings from the Peregrine

During prolonged periods of airgun inactivity for stationary vessels at anchor, alternative data collection methods were employed. Prolonged stationary periods were defined as such by the lead MMO, but typically were periods greater than six hours at anchor. Marine mammal watches were maintained as if the vessel was still moving, but there were slight changes to data collection. Environmental conditions were recorded once per hour unless conditions changed significantly within the hour. Sightings were recorded as within the associated hourly sighting period. At the end of a shift, stationary effort and sightings were entered into separate databases from data when the vessel was moving and then error checked.

All stationary effort was conducted from the *Peregrine.* There was a total of just over 61 h of stationary watch conducted from 11 to 27 September 2008 (Table E.2). Typically there was one observer on watch during daylight conditions, although a limited amount of stationary effort included darkness conditions and two observers (Table E.2). Polar bears were the only species observed during stationary watches, and individual bears were observed on 11 and 27 September 2008 (Table E.2). The *Peregrine* was inactive and never had airguns activated during stationary watches, but the *Shirley V* acted as the source vessel during these periods. During stationary periods on the *Peregrine*, the *Shirley V* was typically operating more than one airgun (28% or 17 h) or no airguns (25% or 15 h; Table E.3). However, there were also occasions where they operated a single airgun (~1.5 h), a variable number of airguns during ramp-up procedures (~2.5 h), or had shut-down for marine mammal mitigation (~1 h; Table E.3).

TABLE E.2. Stationary effort dates, times, number of observers, daylight conditions, and number of polar bear sightings from the *Peregrine*.

Date	Time Start[1]	Last Time[2]	Total Effort (h)	Number of Observers	Light or Dark	Number of Polar Bear Sightings
11/09/2008	6:55	12:11	5:16	1	Light	1
14/09/2008	6:53	18:00	11:07	1	Light	0
20/09/2008	8:00	23:30	15:30	1: 8:00-19:30; 2: 19:30-23:30	Light; Dark after 21:30	0
21/09/2008	0:30	4:30	4:00	2	Dark	0
21/09/2008	19:45	23:45	5:00	2	Light; Dark after 21:45	0
22/09/2008	0:00	0:45	0:45	1	Dark	0
25/09/2008	8:01	17:55	9:54	1	Light	0
26/09/2008	8:45	16:00	4:00	1	Light	0
27/09/2008	7:30	17:00	5:30	1	Light	1
Total			***61:02***			***2***

[1]Time that stationary watch started (AKDT).
[2]Time of last stationary entry (AKDT).

TABLE E.3. MMO effort and number of polar bear sightings at different airgun activity levels on the source vessel, the *Shirley V*, during stationary watches from the *Peregrine*, 11 to 27 September 2008.

Shirley V activity[1]	Total Effort (h)	Number of Polar Bear Sightings
0	15:03:00	0
1	1:22:06	0
RU - Variable	2:30:22	0
>1	17:06:32	2
SZ - 0	1:00:00	0
Total	***61:02:00***	***2***

[1]Airgun activity (number of activated airguns) on the source vessel, the *Shirley V* , during stationary watches on the *Peregrine* . RU = ramp-up; SZ = safety zone shut-down mitigation.

One polar bear (on 11 September 2008) was observed swimming in the water away from the vessel at a sedate pace and reacted by looking at the observers (Table E.4). The behavior, pace, and reaction of the second bear, seen on land on 27 September 2008, could not be determined due to the distance and environmental conditions at the time of the sighting (Table E.4).

TABLE E.4. Sightings of individual polar bears made by MMOs during stationary watches on the *Peregrine*, September 2008.

Date	Time[1]	*Peregrine* position	Initial Behavior	Pace	Reaction	Substrate	Comments
11-Sep	8:23	70º30.72N 149º51.19W	Swim	Sedate	Look	Water	Animal spotted swimming away from vessel.
27-Sep	13:45	70º33.04N 149º46.17W	Unknown	Unknown	Unknown	Land	Animal too far away to determine behavior, and then fog moved in to obscure subsequent observation.

[1]Time listed in Alaska Daylight Time (AKDT).

Distance of animals to the *Shirley V* and *Peregrine* was not recorded, and there were no coincidental marine mammal sightings on the *Shirley V*. However, MMO notes confirm that the polar bears sighted during *Peregrine* stationary watches were not likely exposed to sound levels ≥190 dB. On 11 September 2008, the *Peregrine* was anchored near Oliktok Point and MMOs noticed the bear swimming towards Spy Island while the *Shirley V* was operating its full array shoreward and west of Spy Island. The distance between vessels at this time was at least three km, the bear was swimming at a sedate pace towards Spy Island but not necessarily towards the *Shirley V*'s position; swimming polar bears typically do not have their ears below the water's surface while swimming. No polar bears were sighted on the *Shirley V* on 11 September, and the 190 dB sound radius of the *Shirley V* was 164 m (538 ft; see Chapter 3 and Table 4.1). Thus, it is unlikely that this bear was affected by the seismic activities of the *Shirley V*. On 27 September 2008, the *Peregrine* was anchored off the southeast tip of Spy Island while the *Shirley V* was operating its full array on the northern (seaward) side of Spy Island. The polar bear was sighted over 2.5 km (1.6 mi) away on Leavitt Island. Since this bear was observed on land several kilometers away from the operating *Shirley V*, it is unlikely that it was appreciably affected by the Eni/PGS survey operations.

Off-Watch Marine Mammal Sightings by MMOs

Four marine mammals (three unidentified seals and one polar bear) were sighted by MMOs while they were considered "off-watch." Details of each sighting are provided in Table E.5.

TABLE E.5. Incidental sightings of marine mammals made by MMOs while off-watch during the Eni/PGS seismic survey, August to September 2008 in the central Alaska Beaufort Sea.

Source Vessel	Species	Group Size	Date & Time (AKDT)	Latitude (ºN)	Longitude (ºW)	CPA (m)[a]	Movement[b]	Initial Behavior[c]	Land or Water	In/Out the barrier islands	Water Depth (m)	Vessel Activity[d]	No. Airguns Activated
Wiley Gunner	Unidentified seal	1	18/08/2008 02:11:27	70.565	-149.856	100	SA	LO	Water	Outside	4.5	OT	0
Shirley V	Unidentified seal	1	23/08/2008 23:55:00	70.5101	-149.87	100	ST	SW	Water	Inside	0.8	IA	0
Peregrine	Polar bear	1	03/09/2008 19:12:40	70.5413	-150.157	900	SA	WK	Land	Inside	1.5	IA	0
Peregrine	Unidentified seal	1	19/09/2008 09:40:30	70.5183	-150.077	30	X	LO	Water	Inside	1.9	IA	0

[a]Closest (observed) point of approach to the airguns.

[b]Animal movment: SA = swim away; ST = swim towards; X = not determined.

[c]First observed behavior: LO = look; SW = swim; WK = walk.

[d]Vessel activity: OT = other non-seismic activities (e.g., transit, fueling); IA = inactive.

APPENDIX F: ADDITIONAL INFORMATION ON AERIAL SURVEY EFFORT AND SIGHTINGS

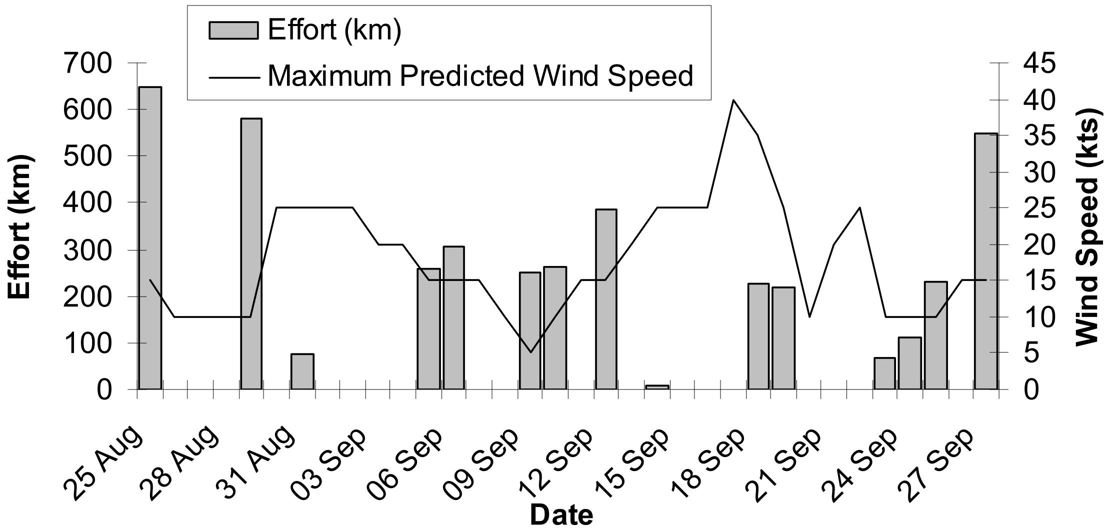

FIGURE F.1. Relationship between aerial survey effort and maximum predicted wind speed from 25 August - 27 September in the Alaskan Beaufort Sea.

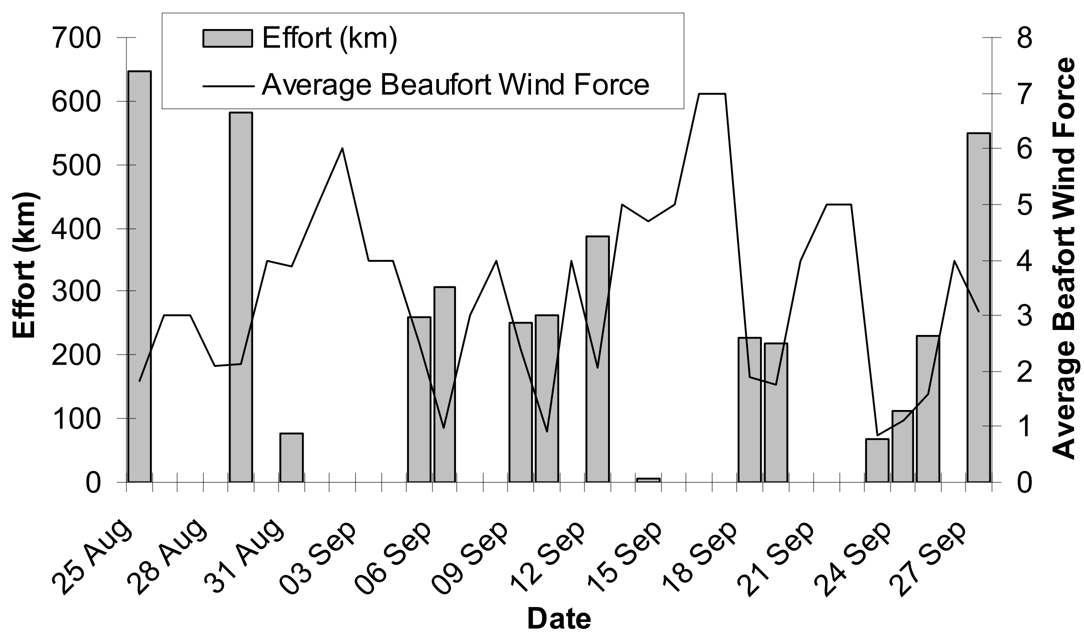

FIGURE F.2. Relationship between aerial survey effort and average Beaufort Wind Force from 25 August - 27 September in the Alaskan Beaufort Sea.

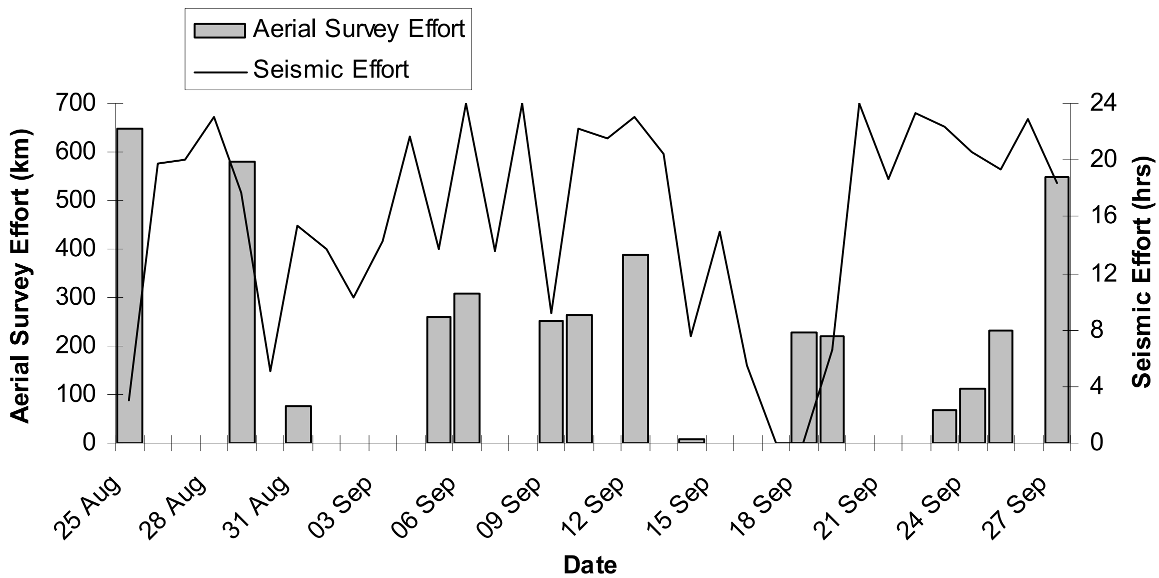

FIGURE F.3. Comparison of aerial survey effort to seismic survey effort in the Alaskan Beaufort Sea from 25 August - 27 September 2008.

TABLE F.1. Sighting rates of bowhead whales (sightings/1000 km) in 5-km distance from shore bins by survey area and seismic state. Numbers in bold indicate maximum values. Dashes represent bins in which no effort was collected.

	West			Central			East			All		
Distance bin	**Seismic**	**Post**	**Non**	**Seismic**	**Post**	**Non**	**Seismic**	**Post**	**Non**	**Seismic**	**Post**	**Non**
0-5	--	--	--	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5-10	0.0	--	--	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10-15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15-20	0.0	0.0	--	0.0	0.0	0.0	13.4	0.0	0.0	4.3	0.0	0.0
20-25	0.0	0.0	**0.0**	0.0	0.0	0.0	22.5	0.0	0.0	4.3	0.0	0.0
25-30	0.0	0.0	0.0	**15.5**	0.0	0.0	**152.1**	**64.7**	**73.3**	**47.0**	**29.4**	**20.8**
30-35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	39.3	0.0	0.0	18.8
35-40	0.0	0.0	0.0	12.9	0.0	0.0	0.0	0.0	0.0	5.8	0.0	0.0
40-45	0.0	0.0	0.0	0.0	0.0	--	0.0	0.0	--	0.0	0.0	0.0
45-50	0.0	0.0	--	0.0	0.0	--	19.8	0.0	--	7.0	0.0	--
50-55	0.0	0.0	--	0.0	0.0	--	0.0	0.0	--	0.0	0.0	--
55-60	**99.3**	**44.2**	--	0.0	0.0	--	0.0	0.0	--	19.9	15.1	--
60-65	0.0	0.0	--	0.0	0.0	--	0.0	0.0	--	0.0	0.0	--
65-70	0.0	0.0	--	0.0	0.0	--	0.0	0.0	--	0.0	0.0	--
70-75	0.0	0.0	--	0.0	0.0	--	0.0	0.0	--	0.0	0.0	--
75-80	0.0	0.0	--	0.0	--	--	0.0	0.0	--	0.0	0.0	--
80-85	0.0	0.0	--	0.0	--	--	--	--	--	0.0	0.0	--
85-90	0.0	--	--	0.0	--	--	0.0	--	--	0.0	--	--
90-95	0.0	--	--	0.0	--	--	0.0	0.0	--	0.0	0.0	--
95-100	0.0	--	--	0.0	--	--	0.0	0.0	--	0.0	0.0	--
100-105	--	--	--	0.0	--	--	--	--	--	0.0	--	--
105-110	--	--	--	0.0	--	--	0.0	--	--	0.0	--	--
110-115	--	--	--	0.0	--	--	--	--	--	0.0	--	--
Average	**5.2**	**2.9**	**0.0**	**1.2**	**0.0**	**0.0**	**10.4**	**3.6**	**14.1**	**3.8**	**2.3**	**4.4**

TABLE F.2. All bowhead whale sightings observed during seismic activities from 29 August - 27 September 2008. Dashes indicate sightings for which headings (°T) were not recorded.

Date	Time (AKDT)	Number of Individuals	On/Off Transect	Distance (km) from center of seismic patch	Heading	Start of seismic		Time elapsed since start of seismic
29 Aug	12:55:02	1	On	39.6	300	29-Aug	02:22:05	10:32:57
29 Aug	12:55:18	2	On	40.2	300	29-Aug	02:22:05	10:33:13
29 Aug	13:26:09	1	On	35.4	277	29-Aug	02:22:05	11:04:04
29 Aug	13:26:17	2	On	35.0	280	29-Aug	02:22:05	11:04:12
29 Aug	13:46:36	1	On	32.7	270	29-Aug	02:22:05	11:24:31
29 Aug	13:46:36	4	On	32.7	270	29-Aug	02:22:05	11:24:31
29 Aug	13:46:47	1	On	33.1	270	29-Aug	02:22:05	11:24:42
29 Aug	13:46:49	1	On	33.2	270	29-Aug	02:22:05	11:24:44
29 Aug	13:46:49	1	On	33.2	270	29-Aug	02:22:05	11:24:44
29 Aug	13:46:51	2	On	33.4	302	29-Aug	02:22:05	11:24:46
29 Aug	13:46:51	1	On	33.4	302	29-Aug	02:22:05	11:24:46
29 Aug	15:03:56	1	Off	38.9	280	29-Aug	02:22:05	12:41:51
29 Aug	15:08:12	1	Off	24.9	--	29-Aug	02:22:05	12:46:07
29 Aug	15:53:31	2	Off	51.1	--	29-Aug	02:22:05	13:31:26
29 Aug	15:53:41	1	Off	50.6	--	29-Aug	02:22:05	13:31:36
31 Aug	17:03:30	3	Off	53.2	--	31-Aug	08:35:00	8:28:30
06 Sep	14:32:41	1	Off	55.9	10	05-Sep	21:47:00	16:45:41
06 Sep	15:09:07	2	Off	54.2	280	05-Sep	21:47:00	17:22:07
06 Sep	15:09:59	2	Off	57.2	280	05-Sep	21:47:00	17:22:59
12 Sep	11:43:34	1	Off	51.3	302	11-Sep	08:04:45	3:38:49
12 Sep	11:43:59	1	On	52.5	280	11-Sep	08:04:45	3:39:14
12 Sep	17:05:13	1	On	62.6	290	12-Sep	13:05:00	4:00:13
12 Sep	17:05:41	1	On	64.2	299	12-Sep	13:05:00	4:00:41
23 Sep	14:42:35	2	On	41.2	--	23-Sep	10:13:14	4:29:21
23 Sep	14:44:29	1	Off	38.9	280	23-Sep	10:13:14	4:31:15
23 Sep	14:44:58	1	Off	38.4	--	23-Sep	10:13:14	4:31:44
24 Sep	16:32:33	1	On	31.6	--	24-Sep	07:58:48	8:33:45
24 Sep	17:01:05	1	On	30.1	149	24-Sep	07:58:48	9:02:17
25 Sep	12:30:52	1	Off	32.9	7	25-Sep	07:45:33	4:45:19
25 Sep	12:41:51	1	On	35.7	6	25-Sep	07:45:33	4:56:18
25 Sep	13:04:33	1	On	41.2	10	25-Sep	07:45:33	5:19:00
27 Sep	14:55:26	1	On	32.7	--	27-Sep	05:38:36	9:16:50