MONITORING OF INDUSTRIAL SOUNDS, SEALS, AND BOWHEAD WHALES NEAR BP'S NORTHSTAR OIL DEVELOPMENT, ALASKAN BEAUFORT SEA, 2009: ANNUAL SUMMARY REPORT

by

Alaska Research Associates, Inc.

Greeneridge Sciences Inc. & Applied Sociocultural Research

for

BP Exploration (Alaska) Inc.
Dept. of Health, Safety & Environment
900 East Benson Blvd.
Anchorage, AK 99519-6612

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15 March 2010

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Edited by

Lisanne A.M. Aerts[1] and **W. John Richardson**[2]

[1] **LGL Alaska Research Associates Inc.**
1101 East 76th Avenue, Suite B, Anchorage, AK 99518
Phone: 907-562-3339; e-mail: alaska@lgl.com

[2] **LGL Ltd., environmental research associates**
22 Fisher St., POB 280, King City, Ont. L7B 1A6, Canada
Phone: 905-833-1244; e-mail: wjr@lgl.com

for

BP Exploration (Alaska) Inc.
Dept. of Health, Safety & Environment
900 East Benson Blvd, P.O. Box 196612
Anchorage, AK 99519-6612

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*Cover Photograph***:** Deployment of Northstar DASARs (model C) on 25 August 2009 with the ACS boat *Mikkelsen Bay* (photo by Lisanne Aerts).

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INTRODUCTION, DESCRIPTION OF BP'S ACTIVITIES, AND RECORD OF SEAL SIGHTINGS, 2009[1]

by

Lisanne A.M. Aerts

LGL Alaska Research Associates, Inc.
1101 E. 76th Ave., Suite B, Anchorage, AK 99518
Phone: (907) 562-3339; e-mail: alaska@lgl.com

for

BP Exploration (Alaska) Inc.
Dept. of Health, Safety & Environment
900 East Benson Blvd., P.O. Box 196612
Anchorage, AK 99519-6612

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INTRODUCTION

BP Exploration (Alaska) Inc. began constructing offshore oil-production facilities in the Prudhoe Bay area, Alaskan Beaufort Sea, during early 2000, and began producing crude oil from Northstar Island during late 2001. Northstar is the first offshore oil production island in the Beaufort Sea. The Northstar Development includes a gravel island for the main facilities and two pipelines connecting the island to the existing infrastructure in Prudhoe Bay. One pipeline transports crude oil to shore, and the other transports natural gas to the island for power generation and field injection. In winter and early spring, the island is connected to the shore by an ice road from West Dock. The facilities on the island include prefabricated modules for living quarters, utilities, and warehouse/shop. Also present are a drilling rig (now used infrequently) and facilities for waste grind and injection and for oil production and gas injection. The production facilities include gas turbine engines to operate power generators and gas compressors. Northstar Island is approximately 9.5 km (6 mi) offshore from Point Storkersen, northwest of the Prudhoe Bay industrial complex, and 5 km (3 mi) seaward of the closest barrier island. Northstar is 87 km (54 mi) northeast of Nuiqsut, the closest Native Alaskan (Inupiat) community, and approximately 27 km (16.5 mi) west of Cross Island where Nuiqsut residents hunt for bowhead whales during autumn (Fig. 1.1). Northstar Island is, to date, the only offshore oil production facility in the Beaufort Sea north of the barrier islands.

Since August 1998 BP has submitted various requests to the National Marine Fisheries Service (NMFS) to authorize incidental "taking" of small numbers of marine mammals that may result from BP's activities at Northstar. An overview of these requests is provided in Table 1.1. The current Northstar LoA is valid from 7 July 2009 through 6 July 2010. The LoAs issued under the previous (NMFS 2000) and current Northstar regulations (NMFS 2006) have required marine mammal and acoustic monitoring

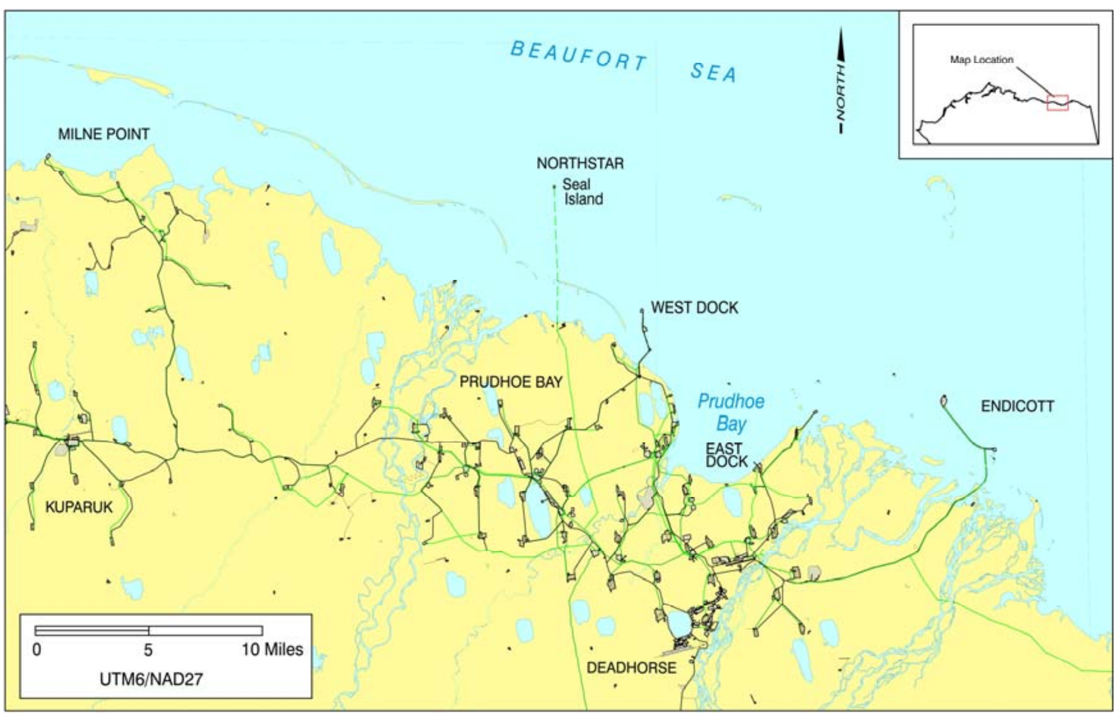

FIGURE 1.1. Location of the Northstar Development at Seal Island in the central Alaskan Beaufort Sea. Seal Island was an artificial gravel island constructed for exploration drilling in the 1980s. Northstar facilities were built on the eroded remnants of Seal Island in 2000.

TABLE 1.1. Overview of BP requests to NMFS seeking IHAs, Regulations and LoAs to allow "taking" of small numbers of marine mammals incidental to BP's activities at Northstar, and summary of the authorizations issued by NMFS.

Date	**BP Request or Regulatory Activity**
Aug 1998	BP applied for an IHA from NMFS
Nov 1998	BP requested NMFS to promulgate regulations allowing for issuance of LoAs
15 Mar 1999	NMFS issued interim IHA for construction phase
25 May 2000	NMFS issued Regulations, effective from 25 May 2000 to 2005
18 Sep 2000	First LoA issued to BP for Northstar construction, effective until expired 30 Nov 2001
14 Dec 2001	Second LoA issued to BP, effective until 30 Nov 2002
9 Dec 2002	Third LoA issued to BP, effective until 30 Nov 2003
4 Dec 2003	Fourth LoA issued to BP, effective until 3 Dec 2004
30 Aug 2004	BP requested renewal of the Regulations and LoA
6 Dec 2004	Fifth LoA issued to BP, effective until 25 May 2005
7 Mar 2006	NMFS renewed the Regulations, effective from 6 Apr 2006 to 2011
7 Jul 2006	NMFS issued initial LoA under the new Regulations, effective until 6 Jul 2007
7 Jul 2007	Second LoA issued to BP, effective until 6 Jul 2008
1 Jul 2008	Third LoA issued to BP, effective from 7 Jul 2008 until 6 Jul 2009
18 Jun 2008	Fourth LoA issued to BP, effective from 7 Jul 2009 until 6 Jul 2010
28 Oct 2009	BP requested renewal of the Regulations and LoA

studies. These studies started in 1997, prior to any construction or formal monitoring requirement, and are ongoing (Richardson and Williams [eds.] 2005; Richardson [ed.] 2006, 2007, 2008; Aerts and Richardson [eds.] 2008, 2009).

The marine mammal and acoustic monitoring results from 1999 to 2004 were reviewed in March 2005 by the Science Advisory Committee (SAC) of the North Slope Borough and by various stakeholders during the annual open-water meetings convened by NMFS. The reviews concluded that the bowhead whale monitoring program could be scaled back starting in 2005, with the possibility of conducting additional whale monitoring during one or more subsequent years. This additional monitoring effort was conducted in 2008. The 2008 acoustic data records, however, were dominated by presence of airgun pulses from nearby and distant seismic surveys. These airgun sounds constituted a strong confounding factor in achieving the objective of assessing the effects of Northstar sounds on bowhead whale call distribution and behavior. Bowhead whales have been shown to react to airgun sounds by deflecting or by changing their calling behavior, or both. Due to the low sound levels generated by Northstar, it was believed that effects on bowhead behavior from airgun sounds would overshadow any effects from Northstar. It was therefore decided to repeat the acoustic monitoring effort of 2008 in 2009, when no or only distant seismic survey activities were planned to take place. Consistent with the earlier recommendations of the SAC and the open-water meeting participants, during 2009

- personnel at Northstar counted seals near the island in a standardized way,
- underwater sounds near Northstar were monitored during the September whale migration season, and
- calling bowhead whales were monitored offshore of Northstar, based on an array of 10 bottom-mounted recorders designed to detect and localize calling bowhead whales offshore of Northstar.

The acoustic and bowhead call data for 2009 were collected and, where possible, analyzed in ways generally consistent with prior years to allow comparison of the 2009 results with those from 2001 to 2008.

This report describes BP's activities during the period 1 November 2008 through 31 October 2009, and it describes the results of the marine mammal and acoustic monitoring studies conducted during 2009. The structure of the current report is similar to that of the annual report for 2008 (Aerts and Richardson [eds.] 2009). Descriptions of BP's activities and the seal counts are included in this chapter. Chapter 2 provides information on the methodology for the acoustic measurements and localization of bowhead whale calls. Chapter 3 summarizes the results from measurements of the underwater sounds from Northstar and other industrial activities, and Chapter 4 describes the results from the localization of bowhead whale calls. Since 2005, observations by subsistence whale hunters at Cross Island have been integrated into the Northstar monitoring study, following a recommendation from the NSB's SAC. They noted that "Such observations might include general offshore distribution of whales, feeding behavior, 'skittish' behavior, number of vessels and reaction to them." Chapter 5 of this report summarizes the results of the 2009 whaling season at Cross Island, consistent with the descriptions provided in the annual reports of 2005, 2006, 2007 and 2008 (Galginaitis 2006, 2007, 2008, 2009).

This report satisfies annual reporting provisions of the current Letter of Authorization issued by NMFS for incidental "taking" of whales and seals by Northstar activities. This report also addresses BP's company goal of implementing studies intended to understand and minimize the environmental effects of BP operations. BP and its contractors are conducting more detailed analyses with the 2009 data to identify and characterize any change in bowhead whale call distribution that is related to Northstar sounds. The results of these analyses will be incorporated into the 2010 comprehensive report, to be submitted to NMFS in August 2010.

The latest revision of the comprehensive report containing the monitoring results from 1999 to 2004 was submitted in February 2008 (Richardson [ed.] 2008), re-issued in March 2009 as a final report, and distributed prior to the open water meeting in April 2009. In addition to the annual reports issued since 2006, the current Federal rules and regulations at 50 CFR §216.206 require BP to develop a similar comprehensive report on the monitoring results from 2006 to mid-2010, to be submitted no later than August 2010.

Based on the Northstar monitoring studies conducted to date, a total of 13 peer-reviewed papers have been published in scientific journals since 2001, with some papers currently in preparation (Table 1.2). Copies of most of the published papers are, with the permission of the relevant journals, included as Appendices in Richardson ([ed.] 2008). In addition, information on various aspects of the Northstar monitoring studies has been disseminated through numerous public presentations, e.g., to BP managers, representatives from other energy companies, scientific conferences, universities in Alaska and elsewhere, and, to some degree, in Barrow and Nuiqsut.

TABLE 1.2. Authors and titles of publications and manuscripts resulting from the Northstar marine mammal and acoustic studies program, 1999–2009.

Authors	Title	Status
Harris, R.E., G.W. Miller and W.J. Richardson. 2001.	Seal responses to airgun sounds during summer seismic surveys in the Alaskan Beaufort Sea.	***Mar. Mamm. Sci.*** 17(4):795-812.
Moulton, V.D., W.J. Richardson, T.L. McDonald, R.E. Elliott and M.T. Williams. 2002.	Factors influencing local abundance and haulout behaviour of ringed seals (*Phoca hispida*) on landfast ice of the Alaskan Beaufort Sea.	***Can. J. Zool.*** 80(11):1900-1917.
Moulton, V.D., W.J. Richardson, M.T. Williams and S.B. Blackwell. 2003.	Ringed seal densities and noise near an icebound artificial island with construction and drilling.	***Acoust. Res. Let. Online*** 4(4):112-117, plus sound files. Available at http://scitation.aip.org/arlo/
Blackwell, S.B., C.R. Greene Jr. and W.J. Richardson. 2004.	Drilling and operational sounds from an oil production island in the ice-covered Beaufort Sea.	***J. Acoust. Soc. Am.*** 116(5):3199-3211.
Blackwell, S.B., J.W. Lawson and M.T. Williams. 2004.	Tolerance by ringed seals (*Phoca hispida*) to impact pipe-driving and construction sounds at an oil production island.	***J. Acoust. Soc. Am.*** 115(5):2346-2357.
Greene, C.R., Jr., M.W. McLennan, R.G. Norman, T.L. McDonald, R.S. Jakubczak and W.J. Richardson. 2004.	Directional Frequency and Recording (DIFAR) sensors in seafloor recorders to locate calling bowhead whales during their fall migration.	***J. Acoust. Soc. Am.*** 116(2):799-813.
Blackwell, S.B. and C.R. Greene Jr. 2005.	Underwater and in-air sounds from a small hovercraft.	***J. Acoust. Soc. Am.*** 118(6):3646-3652.
Moulton, V.D., W.J. Richardson, R.E. Elliott, T.L. McDonald, C. Nations and M.T. Williams. 2005.	Effects of an offshore oil development on local abundance and distribution of ringed seals (*Phoca hispida*) of the Alaskan Beaufort Sea.	***Mar. Mamm. Sci.*** 21(2):217-242.
Blackwell, S.B. and C.R. Greene Jr. 2006.	Sounds from an oil production island in the Beaufort Sea in summer: characteristics and contribution of vessels.	***J. Acoust. Soc. Am.*** 119(1):182-196.
Williams, M.T., C.S. Nations, T.G. Smith, V.D. Moulton and C.J. Perham. 2006.	Ringed seal (*Phoca hispida*) use of subnivean structures in the Alaskan Beaufort Sea during development of an oil production facility.	***Aquatic Mamm.*** 32(3):311-324.
Blackwell, S.B., W.J. Richardson, C.R. Greene Jr. and B. Streever. 2007	Bowhead whale (*Balaena mysticetus*) migration and calling behaviour in the Alaskan Beaufort Sea, autumn 2001-04: an acoustic localization study.	***Arctic*** 60(3): 255-270.
Greene, C.R. Jr., S.B. Blackwell and M.W. McLennan. 2008.	Sounds and vibrations in the frozen Beaufort Sea during gravel island construction.	***J. Acoust. Soc. Am.*** 123(2): 687-695.

TABLE 1.2. Continued.

Authors	Title	Status
Streever, B., R.A. Angliss, R. Suydam and others. 2008.	Progress through collaboration: a case study examining effects of industrial sounds on bowhead whales.	***Bioacoustics*** 17 (1-3): 345-347.
	In Preparation (titles and author lists are tentative)	
Moulton, V.D., M.T. Williams, S.B. Blackwell, W.J. Richardson, R.E. Elliott and B. Streever.	Zone of displacement for ringed seals (*Pusa hispida*) wintering around offshore oil-industry operations in the Alaskan Beaufort Sea.	***In prep.***
McDonald, T.L., W.J. Richardson, C.R. Greene Jr., S.B. Blackwell, C.S. Nations, R.M. Nielsen, and B. Streever	Detecting changes in the distribution of calling bowhead whales exposed to fluctuating anthropogenic sounds.	***In prep.***
Richardson, W.J. T.L. McDonald, C.R. Greene Jr, S.B. Blackwell, and B. Streever.	Distribution of calling bowhead whales near an oil production island at low and higher-noise times.	***In prep.***
Blackwell, S.B. T.L. McDonald, R.M. Nielson, C.S. Nations, C.R. Greene Jr., W.J. Richardson, and B. Streever	Effects of an oil production island in the Beaufort Sea on calling behaviour of bowhead whales.	***In prep.***
Blackwell, S.B., T.L. McDonald, K.H. Kim, L.A.M. Aerts, W.J. Richardson, C.R. Greene Jr., and B. Streever	Directionality in the calls of bowhead whales	***In prep.***

OVERVIEW OF BP ACTIVITIES, NOVEMBER 2008 – OCTOBER 2009

This section discusses BP's activities during the period from 1 November 2008 through 31 October 2009 as required by the 2009/10 LoA issued by NMFS. The ice-covered season is defined as the period 1 November 2008 until 15 June 2009, followed by the open-water season from 16 June through 31 October 2009.

Transportation To and From Northstar Island

Transportation of personnel and equipment to and from Northstar Island during both the ice-covered and the open-water season occurred by Bell 212 helicopters and the Griffon 2000TD hovercraft. In addition to these two forms of transport, transportation during the ice-covered season was provided by Tucker tracked vehicles and by standard vehicles traveling over an ice road between West Dock and Northstar. During the open-water season additional transportation was provided by tugs, barges and ACS (Alaska Clean Seas) *Bay*-class boats. More details about transportation are provided below.

Bell 212 Helicopters

Bell 212 helicopters are medium-sized helicopters each with two turboshaft engines, a 2-bladed main rotor, and a 2-bladed tail rotor (Fig. 1.2). Helicopters were used to transport crew and materials to and from Northstar during the entire year. As in previous years, they were mainly used during transition periods (freeze-up and break-up), and intermittently at other times when ice and water conditions did not permit use of land-based vehicles or boat traffic. During the present reporting period, a total of ~182

FIGURE 1.2. Bell 212 helicopter used for transportation to and from Northstar.

helicopter round trips were made to Northstar. This included ~62 during the 2008/09 ice-covered season, of which the majority occurred in November and December. During the 2009 open-water season helicopters made ~120 round trips to Northstar, most frequently in September and October (Table 1.3).

During the various ice-covered seasons since 2002/03, helicopter traffic to and from Northstar was most frequent during the early production period (2002/03). The number of roundtrips during the ice-covered season of 2008/09 was the lowest of all years since 2002/03. During the open-water season, the number of helicopter round trips in 2009 was within the range of the numbers recorded in previous years (Table 1.4).

The helicopter routes were negotiated among the U.S. Fish and Wildlife Service (USFWS), NMFS, and BP at an early stage in the planning of the Northstar operations, to minimize impacts to waterfowl and marine mammals. During regular helicopter operations in 2009, recommended flight corridors and altitude restrictions were maintained, as in previous seasons. For visual flight rule (VFR) conditions, standard flight altitude was 460 m (1500 ft), weather permitting. One-way flight time to Northstar was ~15 min from West Dock Base of Operations (WDBO) and 30 min from the Deadhorse airport.

Griffon 2000 TD Hovercraft

A hovercraft was also used to transport personnel during both the ice-covered and the open-water period (Fig. 1.3). The hovercraft was powered by a 355 hp air-cooled Deutz diesel engine and was 11.9 m (39 ft) in length (Blackwell 2004; Blackwell and Greene 2005). The hovercraft was capable of carrying a payload of 2268 kg (5000 lbs). During the ice-covered season, most hovercraft activity occurred in December and January. No or very limited hovercraft activity occurred in the period February through April, when mainly pick-up trucks, SUVs, and buses were used to transport personnel. Of a total of 912 roundtrips in 2008/09, the hovercraft made ~539 round trips from West Dock to Northstar during the ice-covered season and ~373 round trips during the open-water season (Table 1.3). The hovercraft made its first test trips in spring 2003, and has been used for transport of personnel and supplies since then. Hovercraft traffic during the ice-covered season increased after that time and has become more or less stable since 2006. During the open-water season, hovercraft use has been more variable over the years, varying from 188 to 560 round trips per year (Table 1.4).

TABLE 1.3. Number of helicopter and hovercraft round trips to Northstar Island for each month during the ice-covered and open-water season of 2008/09. A ½ round trip occurs when the hovercraft leaves shore prior to midnight, and returns from the island after midnight or, occasionally, if the hovercraft leaves the shore but doesn't complete the trip due to weather or other reasons.

Ice-covered season			Open-water season		
Month	**Helicopter**	**Hovercraft**	**Month**	**Helicopter**	**Hovercraft**
November 2008	40	72.5	June 16-30, 2009	120	55.5
December 2008	13	104	July 2009	24	90.5
January 2009	1	159	August 2009	13	79.5
February 2009	0	3	September 2009	46	83
March 2009	0	0	October 2009	35	64.5
April 2009	0	0			
May 2009	8	94.5			
June 1-15, 2009	62	106			

TABLE 1.4. Total number of helicopter and hovercraft round trips to Northstar Island for each year since 2003 during the ice-covered and open-water seasons. A ½ round trip occurs when the hovercraft leaves shore prior to midnight, and returns from the island after midnight or, occasionally, if the hovercraft leaves the shore but doesn't complete the trip due to weather or other reasons. The hovercraft was first tested and used in spring 2003. na = not applicable.

	Ice-covered season		Open-water season	
Year	**Helicopter**	**Hovercraft**	**Helicopter**	**Hovercraft**
2002/03	1122	na	277	202
2003/04	253	141	189	302
2004/05	118	180	103	188
2005/06	465	249	271	560
2006/07	335	574	190	347
2007/08	222	426	119	445.5
2008/09	62	539	120	373

Ice Road Transportation

As in previous years, an offshore ice road of ~12 km (~7.4 mi) length was built between West Dock and Northstar during the 2008/09 ice-covered season to transport personnel, equipment, materials, and supplies between the Prudhoe Bay facilities and Northstar Island. Ice-road construction started on 8 December 2008 and was completed on 20 March 2009. The ice road was officially declared open to light duty traffic on 1 February, but was used for some round trips starting 28 January. The ice road was officially closed for all traffic on 21 May 2009.

FIGURE 1.3. Hovercraft (Griffon 2000 TD) transporting personnel during the break-up period.

Tucker tracked vehicles (model 1600 Tucker-Terra; Fig. 1.4) were mainly used in 2009 to transport personnel and materials between West Dock and Northstar Island during ice-covered periods when the ice road did not permit standard vehicle and van traffic. These situations occurred mainly in the months just prior to completion of the ice road and during break-up when meltwater accumulating on the ice road prevented standard vehicles from safely transiting to and from the island. Passenger capacity is up to 15 persons. Tucker tracked vehicles made a total of 127.5 round trips between West Dock and Northstar Island during the 2008/09 ice-covered season, of which 114.5 occurred in January and the remaining 13 from February through May 2009. The use of tracked vehicles in 2008/09 was slightly higher than in 2007/08 (111.5 round trips), and much higher than in 2006/07 (37 round trips), 2005/06 (70 round trips) and 2004/05 (25 round trips). No detailed records of round trips are available for the construction and early production years (2000–2003), other than that tracked vehicles (Hägglunds) were used on average 14 times a day, mainly prior to the completion of the ice-road.

Standard vehicles, including vans, pick-up trucks, and buses, were the main method of transportation for Northstar personnel from 1 February to 21 May 2009. A total of 2185 round trips were made in this period, with an additional 15 round trips during the four days prior to the official opening date of the ice road.

Tugs and Barges

During the open-water season from 13 July to 13 October 2009, supply runs from West Dock to Northstar occurred mainly by tug and barges. The lengths of the barges used to transport fuel and cargo to the Island are typically ~46–61 m (160–200 ft) and the tug sizes are ~20 m (65 ft). On days with average levels of background sounds, the sounds from tugs maneuvering at Northstar could be detected to a distance of at least 21.5 km (13.4 mi) from Northstar (Blackwell et al. 2009) and possibly further (Blackwell and Greene 2006). A total of ~45 tug and barge trips were made to Northstar during the open-water period. Most barge activity occurred in August (Table 1.5A). The total number of barge trips in 2009 was very similar to the total numbers in 2008 and 2007, lower than in 2003 and 2006, and higher than in 2004 and 2005 (Table 1.5B).

FIGURE 1.4. Tucker tracked vehicle. Power is from a Cummins 6-Qsb 173 hp diesel engine; weight of the Tucker ranges between ~4536 and 7257 kg (10,000 – 16,000 lbs).

TABLE 1.5. Number of round trips to Northstar Island by tugs and barges and by ACS boats during the open-water season ***(A)*** for each month in 2009 and ***(B)*** for each year since 2003. The open-water season includes the break-up period. In 2003, a dedicated crew boat was used instead of an ACS boat until the hovercraft became available. The trip records of the ACS vessels in 2004 and 2005 are incomplete; they cover only an ~32-day period from late August to early October.

(A)

Month	Tugs/Barges	ACS boats
June 16-30	0	0
July	8	15
August	15.5	17
September	16	32
October	5	1
Total	44.5	65

(B)

Year	Tugs/Barges	ACS boats
2003	82	--
2004	24	(22)
2005	21	(14)
2006	64	106
2007	40	137
2008	45	55
2009	44.5	65

ACS Boats

Alaska Clean Seas (ACS) *Bay*-class boats (Fig. 1.5) were used to transport personnel to and from Northstar when weather conditions prevented the use of the hovercraft. These boats are ~13 m (~42 ft) in length and normally used as oil spill response vessels. A total of ~65 round trips to and from Northstar were recorded during the 2009 open-water season from 20 July to 5 October. The highest number of trips occurred during September (Table 1.5A). There were some additional trips by *Bay*-class boats in association with acoustic and visual monitoring of the bowhead whale migration (see “Acoustic and Bowhead Whale Migration Monitoring” below).

FIGURE 1.5. ACS *Bay*-class boat.

Prior to 2004 a dedicated crew boat provided transport of personnel to and from Northstar, with only occasional trips by ACS boats. After the hovercraft became available late 2003, the dedicated crew boat was no longer in operation and ACS boats provided alternative transport in case the hovercraft could not be used. Table 1.5B shows the trip records of the ACS boats for the period 2004–2009. In 2004 and 2005 no round trip records were obtained for July and most of August; the numbers mentioned in Table 1.5B cover a ~32-day period from late August to early October for these two years. The number of round trips of the ACS boats in 2009 is similar as in 2008, and lower than in 2007 and 2006 (Table 1.5B).

Activities At and Near Northstar Island

Production Facilities

Oil production at Northstar began on 31 October 2001 and has occurred almost continuously from that date through the present reporting period. Power generation and compressor equipment on the island was unchanged from previous reporting periods. Three Solar® gas turbine generators provided the main power to the island. Emergency diesel generators were also used intermittently during the reporting period, as back-up to the gas-turbine generators. Two gas-turbine high-pressure compressors (model GE LM-2500) and one electric-powered compressor were also on the island. These three compressors were in use for gas injection into the formations.

Drilling and Pile-Driving

Drilling activities on Northstar Island were conducted over well NS-33 during the entire drilling period from January through May 2009. There was no vibratory or impact pile driving during the reporting period.

Training Activities

A total of three articulated ARKTOS evacuation craft have been available as the island emergency escape vehicles since 2007 (Fig. 1.6). Extra ARKTOS vehicles were added in October 2007 to increase emergency escape capacity and therefore allow for additional personnel to be present on the island.

FIGURE 1.6. Articulated ARKTOS evacuation craft used as island emergency escape vehicles.

These vehicles can operate both on ice and in water. No testing and training activities were conducted with the ARKTOS in the reporting period.

During the 2008/09 ice-covered season, equipment deployment exercises were conducted on 30 March and 6 April. During the open-water season, there were nearshore training operations on 27 July, shoreline containment operations from the island on 10 August, and offshore oil spill response training on 17 August and 28 September. Spill response vessels with lengths of 6.7 to 12.8 m (22 to 42 ft), containment booms, and 2” and 3” trash pumps were used for these exercises.

Training sessions for the Spill Response Team were given every Monday evening. The Fire Brigade underwent weekly training on Saturday evenings. This training included classroom instruction and field activities. The field activities involved simulation of a fire scenario by activation of fire fighting equipment including deployment and charging of hoses.

Oil Spill Inspections

Aerial overflights were conducted weekly with a twin-engine fixed-wing aircraft (Twin Otter DHC-6) to inspect the pipeline for leaks or spills. Forward-looking infrared (FLIR) devices are used on an as needed basis. LEOS technology (Leck Erkennung und Ortangs System, also known as Leak and Location System) and Ed Farmer Mass-Pack leak detection system are used continuously to detect oil spills. No reportable conditions were recorded during those surveys.

Reportable Spills

One small diesel spill reached the water and was captured with an absorbent boom sweeping back and forth within a containment boom. None of the other 28 reportable spills during the ice-covered and open-water seasons reached Beaufort Sea water or ice (Table 1.6). Contaminated snow, ice or gravel was removed with various types of equipment and sorbents and recovered completely. No clean-up activity was necessary after Northstar flare events during the reporting period.

TABLE 1.6. Record of material spilled at Northstar Island during the period 1 November 2008 – 31 October 2009. All spills were cleaned up using standard practices.

Date	Material Released	Did Release reach Beaufort Sea or Sea Ice
11 Jan	Oil leak on high pressure compressor	No
17 Feb	Hydraulic spill from snowblower	No
3 Apr	Tri-ethylene glycol leak	No
22 Apr	5-Gal container leaked inside hazchem storage building	No
3 May	Corrosion inhibitor release	No
6 May	Wastewater spill from utility floor drain sump	No
17 May	Arktos 3A vehicle hydraulic leak	No
19 May	Glycol leak from ruptured radiator hose	No
23 May	Small leak of produced water and condensate	No
23 May	Motor oil leak from oil line to cab heater	No
24 May	Fitting failure on pipe lift	No
26 May	Fuel release from water jetting pump for divers	Yes
5 Jun	Leak from triplex bleed hose	No
20 Jun	Lube oil release from low pressure compressor	No
16 Jul	Hydraulic leak at NS-13 well control panel	No
5 Sep	Hydraulic leak	No
7 Sep	Hydraulic leak	No
9 Sep	Wash water from tank cleaning leaked from hose into secondary containment	No
28 Sep	Leak from NS-27 wellhead hydraulic control panel	No
2 Oct	Gas release from needle valve	No
2 Oct	Hydraulic leak at NS-18 well control panel	No
3 Oct	Hydraulic leak at NS-19 well control panel	No
27 Oct	Hydraulic leak on man lift	No
28 Oct	Gray water leaking from soffit area under PLQ	No
29 Oct	Hydraulic fluid leak from Volvo loader	No
12 Nov	Leak on corrosion inhibitor level indicator valve union	No
7 Dec	Sewage discharge line failure	No
13 Dec	Hydraulic tubing valve failure at NS-30 panel	No

Construction and Maintenance Activities

As in previous years, maintenance activities to repair the block system and fabric barrier around Northstar Island were necessary. The repair techniques were similar to those applied during previous years, and consisted primarily of removing the blocks from the swale, placing new fabric on the slope, installing geotextile bags to buttress the damaged area, covering the bags with fabric and geogrid, and replacing the blocks. Equipment used included a Manitowoc 888 crane, Volvo 150D loader, John Deere 650H excavator, Ingersoll-Rand zoom-boom, air compressors, Chinook 800 and Tioga heaters, and generators (Fig 1.7). The 2009 activities also included bench block repair work on the NNW, NW and WNW sides of the island with divers and a bench repair crew. This work started in the last week of April with the cutting of ice to prepare a moat for the divers to access the water (Fig. 1.7). The project was completed on 18 June prior to break-up of the sea ice.

FIGURE 1.7. Block system and fabric repair (above left and right) and diver repair work (bottom left and right) at Northstar Island in 2009.

Following inspection of the slope protection, minor below-water repairs were conducted by a dive crew. This work, consisting primarily of replacing small sections of damaged or missing blocks and re-linking missing shackles, was performed during the period 27 July to 5 August (including downtime).

To increase knowledge about the wave and ice forces to which the Northstar protection barrier is subjected, three wave, current and ice thickness sensors (Nortek AWAC AST) and two wave and ice thickness sensors (ASL IP-5) were deployed on bottom platforms at three locations ~1 mile offshore from Northstar Island (70^{o}29.973 N 148^{o}44.960 W; 70^{o}29.993 N 148^{o}41.981 W; 70^{o}29.986 N 148^{o}38.997 W) on 9 August 2008. Water depth at these locations was ~41 ft (12.5 m). Data were recorded for a 1-year period on an internal solid-state memory in these sensors.

- The transmit frequency of the ultrasound-based AWAC sensors is 1 MHz, with 8.5-min ping series every 15 min at a ping rate (duty cycle) of 2 per second, sometimes expressed as 2 Hz. At these frequencies, attenuation is very rapid and maximum propagation distance is ~30 to 50 m (~98 to 164 ft).
- The ASL IP-5 ice profilers provide data complementing the ice thickness data from the AWAC sensors. The ASL sensors transmit high frequency energy (420 kHz) with a range up to ~225 m (~738 ft). The ice profilers transmit 17-min ping series every 40 min at a ping rate of 2 per second.

The operating frequencies of these sensors are far above the upper end of the functional hearing range of all marine mammal species (i.e., 180 kHz; Southall et al. 2007). Two of the three bottom platforms containing these sensors were retrieved on 26 August 2009. The bottom platform and instruments (AWAC only) at the third location could not be retrieved and therefore remain on site. In addition to the AWAC and ASL sensors, each bottom platform contained an acoustic release unit (Benthos Model 867-A) which transmits at 12 kHz upon receipt of interrogation signals from a surface vessel. These interrogation signals were transmitted at 11 kHz. The interrogator and acoustic release unit transmitted only during very brief periods during deployment and recovery, when the surface vessel was on site. The sound pressure level for the acoustic releases is ~192 dB re 1 μPa @ 1 m.

Acoustic and Bowhead Whale Migration Monitoring

This section provides a summary of the acoustic and bowhead whale monitoring activities associated with the Northstar project that require use of an ACS *Bay*-class boat in waters offshore of Northstar. Chapters 2 to 4 describe in detail the methods and results of these monitoring activities.

Boat-based work in support of this monitoring was conducted on five days from late August to late September 2009. On 25 August the ACS boat *Mikkelsen Bay* was used to deploy a total of fourteen Directional Autonomous Seafloor Acoustic Recorders (DASARs) offshore of Northstar. Three recorders, including two new DASAR-C units and one “old” DASAR-A, were deployed ~450 m (~1476 ft) north of Northstar's northern shore. The remaining eleven DASARs were deployed farther offshore, ~8 to 38 km (~4.3 to 23.5 mi) north-northeast of Northstar. On 28 September all DASARs were retrieved. The time base and orientation of each DASAR were calibrated three times, on 26 August, 12 September, and 26 September. Health checks were performed on 26 August and during mid-season on 12 September.

In conjunction with the boat-based DASAR work on 25 August and 12 and 26 September, an *Acousonde*™ was deployed close to Northstar for ~8 hours to obtain near real time information on the presence of pop-sounds. These pop sounds were first recorded in 2008. The *Acousonde* is a small self-contained, autonomous underwater acoustic recorder with omnidirectional hydrophones, described at www.acousonde.com. Another attempt to detect the presence of pop sounds was done earlier in the season, on 16 July, with a hydrophone listening system deployed from ACS boat *Gwydyr Bay*. Results of these pop sound measurements are reported in Chapter 3 of this report.

Boat-based visual monitoring seeking to detect bowheads migrating through the middle of the DASAR array was attempted on 19 September from the ACS boat *Mikkelsen Bay*. Two additional attempts to observe visually were made that week (20 and 24 September), but both times the weather offshore of Northstar was too rough to conduct reliable visual observations. Results from these visual observations are included in Annex 4.1 of Chapter 4.

Non-Northstar Related Activities

The MMS and its precursor the Bureau of Land Management have funded and/or conducted aerial surveys of the fall migration of bowhead whales through the western Beaufort Sea each year since 1979. Starting in 2007, the Bowhead Whale Aerial Survey Program (BWASP) was coordinated through NMML, and in 2008 and 2009 these surveys were extended across the northeast Chukchi Sea to document marine mammal distribution there during the open-water (ice-free) months. The surveys in the Chukchi Sea are referred to as COMIDA (Chukchi Offshore Monitoring In Development Area).

In 2009, USGS conducted a seismic survey in deep waters of the Alaskan Beaufort Sea north of Northstar and BP conducted a seismic survey in the Canadian Beaufort Sea. No seismic surveys or other exploration related activities were conducted by oil and gas companies in the Alaskan Beaufort Sea. Hence, no industry-sponsored aerial or vessel based marine mammal monitoring took place in the

Alaskan Beaufort Sea in 2009. As in other recent years, 5 DASAR arrays were deployed by Greeneridge Sciences Inc. for Shell Offshore Inc. in the Beaufort Sea offshore of Alaska's North Slope (Shell 2008, Attachment A). These five arrays were spread over an east-west distance of ~280 km (174 mi) between Harrison Bay and Kaktovik.

OBSERVED SEALS

This section summarizes Northstar seal sightings during the last part of the ice-covered season and the start of the open-water season for 2005 through 2009. These observations were conducted from the 33 m (109 ft) high process module by Northstar Environmental Specialists on behalf of BP. The protocol of the systematic seal count that has been used since 2005 includes the following:

- Count the number of basking seals from 15 May to 15 July on a near-daily basis. Counts are done once each day between 11:00 and 19:00 local time for at least five days per week, when practicable. No counts are made if the cloud ceiling is less than 91 m (300 ft).
- Make seal counts from the roof of the Northstar process module along a strip of width ~950 m (3116 ft) around the entire perimeter of the island. Scan a 360° field of view, thus covering an area of ~281 ha (695 acres).
- Scan with the naked eye, using binoculars to confirm suspected seal sightings. Use an inclinometer to estimate the distance to the seal. If the inclinometer shows that the line of sight to the seal is 2 degrees or more below the horizon, then keep it in the count. (From the height of the observation platform, a 2º depression angle corresponds to a distance of ~950 m or 3116 ft.) If the depression angle is <2º as measured with the inclinometer, then the seal is too far away (outside the monitoring area) and is not counted.

Seal observations in 2009 were conducted during all days but one (=61 days total) from 15 May to 15 July. A total of 811 seals were observed (including presumed repeat sightings of the same animal on different days), which is more than in the previous years over the same period. As was also apparent in previous years, there was much day-to-day variation in number of seals sighted, as shown by the standard deviation values in Table 1.7.

TABLE 1.7. Summary of seal data collected in the period 15 May to 15 July from 2005 to 2009.

Year	Total # of seals*	Total obs. days	Mean # seals/day	Max. # observed	Standard deviation
2005	229	42	5.5	124	19.4
2006	54	49	1.1	4	1.2
2007	3	57	0.1	1	0.2
2008	415	54	7.7	63	15.1
2009	811	61	13.3	87	25.7

*includes repeat sightings from day to day.

These data provide no evidence of a clear year-to-year trend in seal abundance near Northstar. The total number of seals sighted has varied greatly, with a minimum of 3 sightings in 2007 and a maximum of 811 sightings in 2009 (Table 1.7). Generally, most of the seals are observed in June when they bask on the ice (Fig. 1.8). Each year the number of observations increased in June and decreased again toward early July. In 2005, the high number in July was the result of an observation of 124 seals on an ice floe on 11 July (Fig. 1.9). Reports from Northstar do not provide evidence, or reason to suspect, that any seals were killed or injured by Northstar-related activities.

FIGURE 1.8. Ringed seal near breathing hole, observed from the Northstar Process module on 11 June 2009.

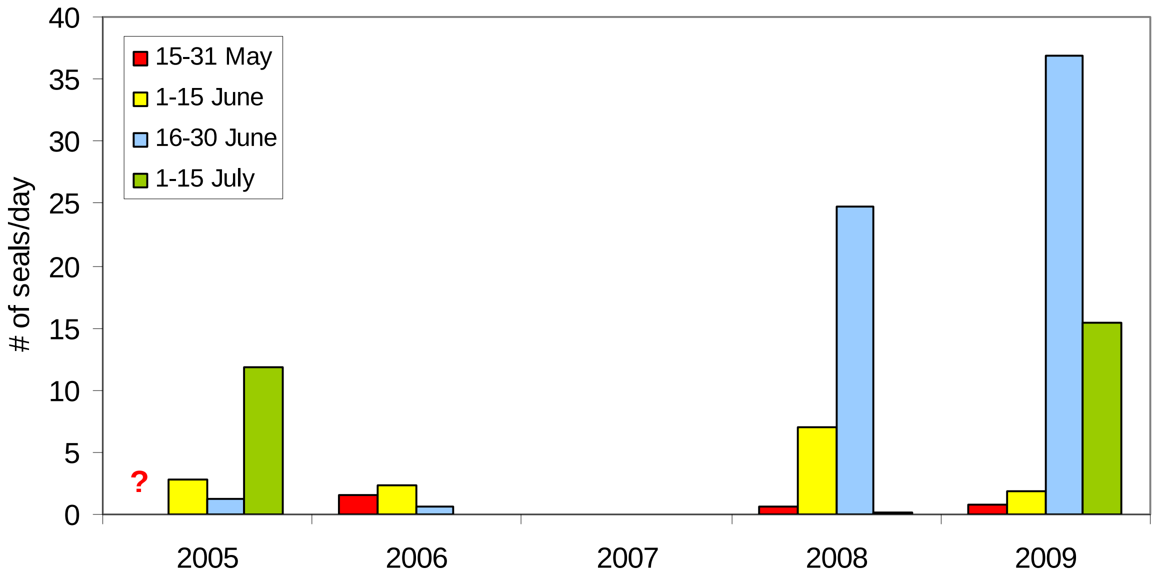

FIGURE 1.9. Average number of ringed seals observed per day from Northstar Island, by half-month, from 15 May to 15 July during 2005 through 2008. In 2005 observations started 1 June, so the number of seals in the period 15-31 May is unknown. Other “missing” bars (1-15 July 2006 and 2008, and all periods in 2007) indicate zero or near zero average numbers.

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CHAPTER 2:

METHODS USED DURING THE ACOUSTIC MONITORING OF BOWHEAD WHALE MIGRATION, AUTUMN 2009[1]

by

Susanna B. Blackwell[a], Katherine H. Kim[a], William C. Burgess[a], Charles R. Greene, Jr.[a], Robert G. Norman[a] , and Lisanne A.M. Aerts[b]

[a]Greeneridge Sciences, Inc.
6160-C Wallace Becknell Road, Santa Barbara, CA 93117
Phone: (805) 967-7720; e-mail: susanna@greeneridge.com

[b]LGL Alaska Research Associates, Inc.
1101 East 76th Avenue, Suite B, Anchorage, AK 99518
Phone: (907) 562-3339; e-mail: alaska@lgl.com

for

BP Exploration (Alaska) Inc.
Dept. of Health, Safety & Environment
900 East Benson Blvd, P.O. Box 196612
Anchorage, AK 99519-6612

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ABSTRACT

During the bowhead whale migration in September 2009, Greeneridge Sciences, on behalf of BP, implemented an acoustic monitoring program north-northeast of BP's Northstar oil development. The primary objective was to assess the effects of Northstar production activities, especially underwater sounds, on the southern edge of the distribution of calling bowhead whales during their autumn migration. This was to be done by comparing the offshore distances of calling bowheads at times with varying levels of industrial sound. If the closest calling bowhead whales tend to be farther offshore at times when Northstar sounds are stronger than average, this would be an indication that some whales are affected by Northstar activities. The acoustic method cannot distinguish whether this effect is a deflection of the whales, a change in their calling behavior, or a combination of both, but the geographic scale of any such effect would provide evidence of the magnitude of the effect, if it occurs.

In 2009, an array of 10 directional autonomous seafloor acoustic recorders (DASARs) was deployed offshore of Northstar for ~33 days (26 Aug–28 Sep). These instruments recorded continuously and provided bearings to calling whales. When two or more DASARs detected a call, its location was triangulated. Concurrently, sounds produced by Northstar and its attending vessels were recorded continuously by DASARs located ~450 m north of the island over the same period. In 2009, the scope of the study was augmented relative to that in 2005–2007 and was generally similar to that in 2001–2004 and 2008, although the study design was somewhat modified from that in 2001–2004. The geometry of the DASAR array was different in 2008–2009, and additional emphasis was placed on understanding how far Northstar sounds propagate offshore, i.e., what type and quantity of Northstar sounds reach the locations of migrating whales.

The present chapter describes the methods used in the study during the 2009 field season. It describes DASARs, the acoustic recorders that were used to make all the sound measurements. It describes the 2009 field operations, including deployment and retrieval of DASARs, and the health check and calibration procedures. It also describes the analyses performed on the acoustic data collected by the DASARs. These include the computation of broadband, narrowband, and one-third octave band levels based on the data collected by DASARs close to Northstar (~450 m away) and farther offshore (8.5–38.5 km or 5.3–24 mi from the island). It also includes the computation of industrial sound indices (ISIs) for a range of DASARs, to allow comparisons between years and between DASARs within 2009. Finally, the procedures for localizing and summarizing the whale calls are described.

Most of the results from the analyses of Northstar and ambient sounds are described in Chapter 3, *Sounds Recorded at Northstar and in the Offshore DASAR Array, Autumn 2009*. Results from the analyses of whale calls are described in Chapter 4, *Acoustic Localization of Migrating Bowhead Whales near Northstar, Autumn 2009.*

INTRODUCTION

This chapter is one of three chapters (2, 3, and 4) on the acoustic monitoring of bowhead whale migration near the Northstar development during the early autumn of 2009. It includes most of the introductory material, the background to the study, and the objectives, followed by the methods used in the field and during data analyses. Chapter 3 reports on the sounds recorded near Northstar—including vessel sounds—and farther offshore. It also reports on other sounds, such as "pops" of unknown origin that were detected on the near-island recorders throughout the 2008 field season and again in 2009. Chapter 4 reports on the whale call analyses, i.e., the number of bowhead calls detected, bearings to the calls, call locations, and call types.

The project in 2009 was a repeat of the effort in 2008, and had the same objective of assessing the effects of Northstar sounds on bowhead whale behavior. However, in 2008 tens of thousands of airgun pulses from non-BP operators were detected on all array (offshore) DASARs (Blackwell et al. 2009b); those pulses originated from many different directions. This constituted a strong confounding factor. Because of concerns that the effects of airgun pulses on bowhead distribution and/or behavior would overshadow any effects by Northstar, a decision was made not to analyze the 2008 data beyond what is presented in Aerts and Richardson (2009), and to repeat the study in 2009 when less seismic survey activity was expected.

In several respects the project paralleled the efforts of 2001–2004, with similar objectives and a similar study design (e.g., Greene et al. 2002, 2003), and to a lesser degree it paralleled the efforts of 2005–2007 (Blackwell et al. 2006c, 2007a, 2008). However, there were a number of differences from what was done in both of those periods. Therefore, this chapter is written as a stand-alone document, with little need to find information in the numerous reports that have been produced on the Northstar bowhead study since 2000 (Greene et al. 2002; Greene et al. 2003; Blackwell et al. 2006a,b,c, 2007a, 2008, 2009a, 2009b).

BP's business rationale for the overall monitoring project, and for the specific bowhead monitoring task, was driven both by corporate policies and by regulatory requirements. BP corporate policies support studies that objectively assess environmental effects that may result from BP operations. In addition, monitoring the autumn migration of bowhead whales past Northstar was required, during the open-water season of 2009, to satisfy (a) provisions of the North Slope Borough zoning ordinance for Northstar, and (b) the monitoring requirements of a Letter of Authorization (LoA) issued by NMFS to BP on 18 June 2009, under regulations that are effective from 6 April 2006 through 6 April 2011 (NMFS 2006).

Background

Since development plans for Northstar Island were announced in the late '90s, concern was expressed that the autumn migration corridor of bowhead whales might be deflected offshore in response to underwater sounds from Northstar construction, operations, and associated vessel and aircraft traffic. Whales, including bowhead whales, are known to avoid various industrial activities when the received sounds are sufficiently strong (see Richardson et al. 1995 for a review). During the planning phase of the acoustic monitoring project, it was assumed that construction (and operational) sounds from Northstar would be detectable underwater for only a relatively short distance, typically on the order of a few kilometers. For that reason, the effort to monitor Northstar effects on the bowhead migration near Northstar concentrated on the southern part of the migration corridor, and was designed to detect small-scale effects.

The main goal of the acoustic monitoring program was to understand the relationship between sounds generated by Northstar activities and the distribution of the southern (proximal) edge of calling bowhead whales during their autumn migration. Every year from 2001 to 2009, between late August and late

September, near-island cabled hydrophones or seafloor recorders were deployed ~450 m north of the island to obtain a continuous record of Northstar sounds. In addition, directional autonomous seafloor acoustic recorders (DASARs) were deployed in arrays of 10 locations (2001–2004, and 2008–2009), or 3–4 locations (2005–2007), in the southern part of the migration corridor, ~6.5–38.5 km (~4–24 mi) northeast of Northstar. The array DASARs were used to record and, where possible, locate bowhead whale calls and obtain information on calling behavior. All acoustic recorders were deployed for ~30 days during late summer/early autumn when bowhead whales were known to migrate past Northstar, i.e. from late August to late September/early October. (The migration is known to continue later in October, but the recorders were recovered in late September or early October each year before boat-based operations were curtailed by ice formation.)

Analyses of the DASAR sound records showed that vessels were the main contributors to the underwater sound field, as documented in Blackwell and Greene (2006). Vessel activities around Northstar include tug-and-barge operations, crew boats (until 2003), a hovercraft (since 2003), and other vessel operations (e.g. oil spill response training) in the general area. Although many of these vessel movements were in support of Northstar, others had no direct connection with the island. Vessel traffic associated with Northstar construction and operations rarely extended >1 km (0.6 mi) north of the island, but the sounds produced by these vessels were often detectable as much as ~30 km (19 mi) offshore. Without vessels, median broadband island sounds reached background values 2–4 km (1.2–2.5 mi) from Northstar. This is consistent with results from other studies in which most underwater sounds propagating from a gravel island like Northstar were found to be quite weak and usually not detectable beyond a few kilometers (Greene 1983; Davis et al. 1985). Statistical analyses of the 2001–2004 data, conducted to detect the effect of Northstar sound on migrating bowhead whales, showed that with increased levels of certain types of Northstar sounds, there was an offshore shift in the locations of whale calls (McDonald et al. 2008). This shift could be the result of whales deflecting away from the island, of the nearest whales reducing their calling rates in response to increased sounds, or both.

The primary objective of the 2009 monitoring program is to assess the effects of Northstar production activities, especially their underwater sounds, on the southern part of the distribution of calling bowhead whales during their “autumn” migration. This primary objective is similar to that in previous years, but specific objectives were developed in 2008 and still used in 2009 that resulted in a new DASAR array layout: the spacing between DASAR locations was increased from 5 km to 7 km (3.1 to 4.3 mi or 2.7 to 3.8 nmi), the recorders were deployed in a double row instead of two overlapping hexagons, and the most northerly DASAR was now 38.5 km (24 mi) seaward of Northstar (vs. 21.5 km or 13.4 mi in 2001–2004). The changes in the array configuration relative to 2001–2004 were designed to obtain acoustic coverage of a larger portion of the bowhead migration corridor.

Specific Objectives

The 2009 objectives were those identified for 2008 but not fully addressed in 2008 because of the presence of numerous airgun pulses on the acoustic records. These objectives were developed based on results from previous years, discussion with stakeholders, and monitoring requirements outlined in the LoAs issued by NMFS on 1 July 2008 and 18 June 2009. The specific objectives for the 2009 bowhead migration study were as follows:

1. Increase the understanding of levels of sound from Northstar as received further offshore by processing the near-island and offshore DASAR sounds and, where possible, relating those to observed changes in industrial and vessel activities at and near Northstar;

2. Identify and characterize any change in bowhead whale call distribution that is related to Northstar sounds, based on both near-island levels and estimated received levels at whale call locations (or as close as possible to these locations);
3. Determine the effect of vessel noise on bowhead calling behavior, assuming that vessel noise is the most relevant type of anthropogenic sound in 2009.

This chapter and Chapter 3 address Objective 1. Compared to previous years, there is an increased focus on understanding to what extent specific Northstar sounds propagate offshore to distances where they could be received by migrating bowhead whales. Chapter 4 summarizes the number of whale calls detected, whale call locations and other call characteristics specific to the 2009 monitoring, and compares those with similar data from previous years. In addition, the whale call data, together with information on Northstar sounds, will form the basis for more detailed statistical analyses required to address Objective 2. Analyses addressing Objective 3 have been deferred to a later date, awaiting the feedback from peer reviewers on manuscripts suggesting that, based on the 2001–2004 data, vessel sounds and tones are an important cause of changes in whale call distribution and behavior.

The analyses to address Objective 2 based on the sound recordings collected in 2009 will be reported in the draft 2010 comprehensive report covering the years 2005–2009, to be submitted to NMFS on 9 August 2010.

INSTRUMENTATION: DASARs

In this study, sounds were recorded using **D**irectional **A**utonomous **S**eafloor **A**coustic **R**ecorders (DASARs, see Greene et al. 2004). Each DASAR contains an omnidirectional pressure sensor and a pair of orthogonal sensors from which bearings to sounds can be determined. A first generation of DASARs (model A) was built in 2000 and these instruments were used successfully in 2001–2007 to monitor whale calls during the bowhead whale migration. From 2003 onwards, these DASARs were also used to record Northstar sounds ~450 m from the island. In 2008 a new generation of DASARs was designed and built, the DASAR model C08 (DASAR-C). This new model differs from the DASAR-A by the following: (1) smaller size, lower profile, and lower weight, making handling easier and improving stability on the sea-floor; (2) larger disk space, allowing longer continuous deployments; (3) longer battery life, which also allows for longer deployments; (4) different computer, with corresponding upgrades in performance; (5) decreased sensitivity, which leads to greater dynamic range in response to high-intensity sounds; (6) an analog anti-alias filter, which has the advantage of being quieter (less self-noise) than the switched-capacitor filter of the DASAR-A; (7) ability to program the instrument from the outside (without opening the housing), which allows convenient reprogramming of the recorders in the field, if necessary; (8) gain matching of the directional sensors, which leads to greater bearing calibration accuracy. In addition, the DASAR-C's omnidirectional channel was calibrated (see below). Unless specified otherwise, "DASAR" in this report will refer to the DASAR-C.

A DASAR consists of a pressure housing containing the recording electronics and alkaline batteries, plus a sensor suspended elastically about 5 in above the pressure housing. After the 2008 field season the suspended sensor of each DASAR was sent back to the manufacturer to be treated with a black anti-corrosion coating. The pressure housing is ~17.8 cm (7 in) high and 32.4 cm (12.75 in) in diameter. The sensor includes two particle motion sensors mounted orthogonally in the horizontal plane for sensing direction. It also includes a flexural pressure transducer for the omni-directional sensor. The pressure housing is bolted to a square frame with 66 cm (26 in) sides. A schematic representation of a DASAR is shown in Figure 2.1A. Before deployment, a spandex "sock" is stretched over the tubular "cage"

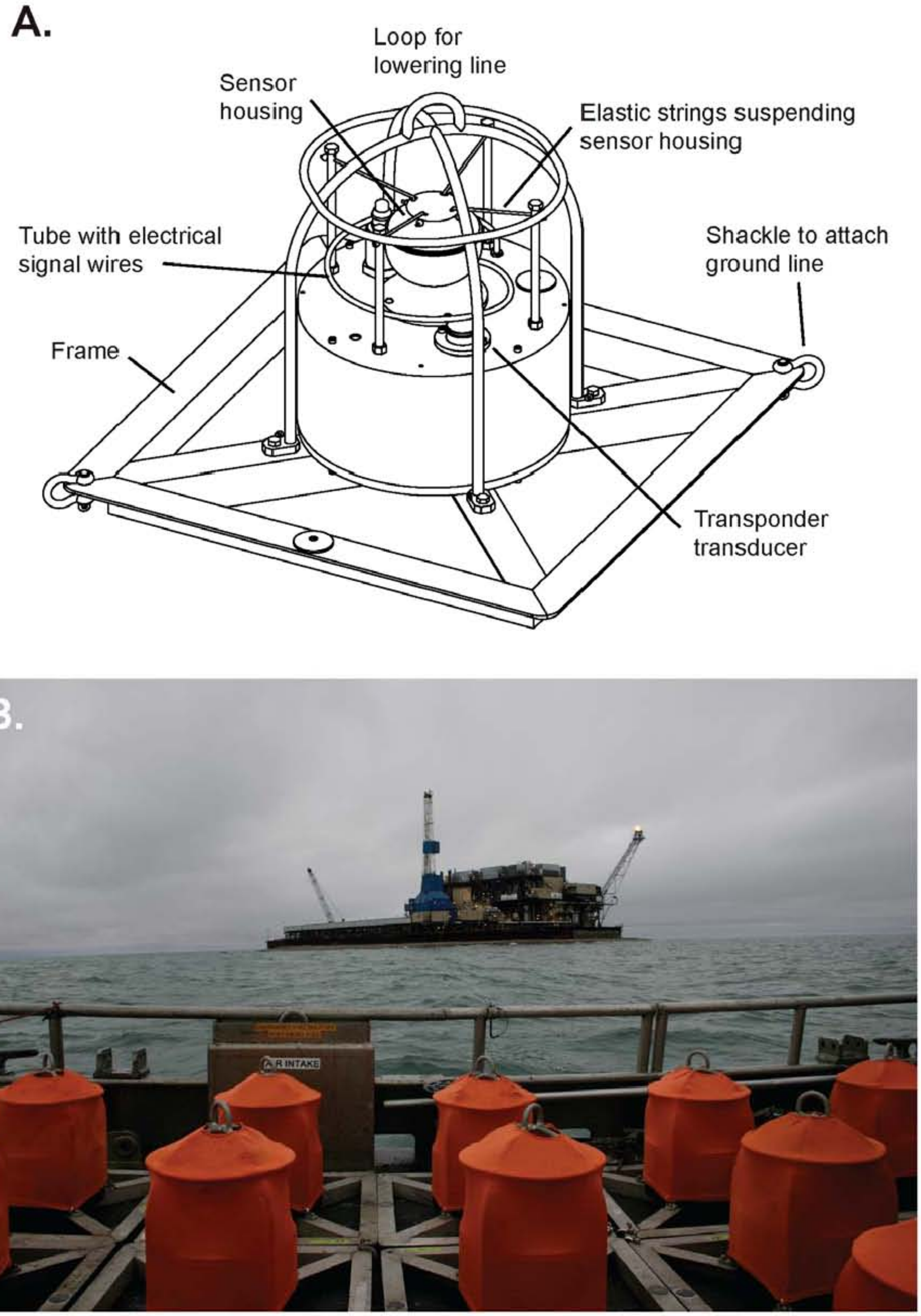

FIGURE 2.1. DASAR recorders. ***(A)*** Schematic diagram of the components of the DASAR-C recorder. ***(B)*** DASARs lined up on the back deck of the ACS vessel *Mikkelsen Bay* on 25 Aug 09, with Northstar in the background.

surrounding the pressure housing to protect the sensors from motion in water currents (see Fig. 2.1B). The total in-air weight is ~32.2 kg (71 lb) and the in-water weight is ~15 kg (33 lb).

DASARs record sound at a 1 kHz sampling rate (1000 samples/s) on each of three data channels: (1) an omnidirectional channel, (2) a "cosine channel" on the primary horizontal axis, and (3) a "sine channel" on the axis perpendicular to the cosine channel. Each directional channel has maximum sensitivity in its primary direction, and the sensitivity falls off with the cosine of the angle away from the axis. The recorder includes a signal digitizer with 16-bit quantization. The samples are buffered for about 45 minutes, and then written to an internal 60 GB hard drive, which takes about 20 s. Allowing for anti-aliasing[2], the 1 kHz sampling rate allows for 116 days of continuous recording and a data bandwidth of 450 Hz.

The DASAR hydrophone sensitivity is -149 dB re 1 V/μPa at 100 Hz and varies with frequency: sensitivity increases with frequency at a 6 dB/octave rate until it flattens at about 800 Hz, then decreases rapidly above 2000 Hz. (This is the same frequency response shape specified for the AN/SSQ-53F DIFAR sonobuoy. Figure 7.6 in Blackwell et al. (2006a) shows the frequency response for the AN/SSQ-53D, which is very similar to the 53F.) The DASAR-C self-noise at 100 Hz is about 20 dB below the extended Knudsen spectral density for sea state zero (Knudsen et al. 1948), close to the minimum sea noise spectrum presented by Wenz (1962). The hydrophone recorder electronics in the DASAR-Cs overloaded (saturated) when the instantaneous sound pressure exceeded 151 dB re 1 μPa at 100 Hz. All DASAR hydrophones were calibrated in spring 2008 according to a method described in Blackwell et al. (2009a).

2009 Field Operations

DASAR Deployments and Retrievals

DASARs were deployed as follows: the DASAR was connected to a Danforth anchor by a 110 m (360 ft) ground line. When the ACS *Bay* vessel was at the target DASAR deployment location, the DASAR was lowered to the seafloor off the stern of the vessel, and a GPS waypoint of the location was obtained. The vessel then moved in a straight line until the end of the ground line was reached, at which point the anchor was deployed and a GPS waypoint was obtained. DASARs were retrieved by dragging a set of weighted grappling hooks on the seafloor, perpendicular to and over the location of the ground line, as defined by the GPS locations of the anchor and DASAR.

DASAR installations took place on 25 Aug 2009 from the ACS vessel *Mikkelsen Bay*. DASARs were deployed in an array located 8.5–38.5 km (5.3–24 mi or 4.6–20.8 nmi) NNE of Northstar Island (Fig. 2.2). The array was organized as a stack of eight equilateral triangles, the long axis of which was tilted to the east by 30° from true north. Adjacent DASARs were spaced 7 km (4.3 mi or 3.8 nmi) apart. The 10 array-DASAR locations were referred to as locations A, B, C, D, E, F, G, H, I, and J, from south to north and west to east (see Fig. 2.2). One DASAR was deployed at each location. In addition, a DASAR-A was deployed as a backup at location C, which is the one offshore location where a functional DASAR has been deployed every autumn since 2001 (in previous reports, described as location "EB"). Table 2.1 lists the deployment locations and recording start and end times for all DASARs.

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[2] Aliasing occurs when sounds at frequencies higher than half the sample rate are allowed to be sampled—the energy at those higher frequencies appears to be at lower frequencies in the sampled data, corrupting the results. Anti-aliasing is low-pass filtering at a frequency slightly less than half the sample rate to reject energy at higher frequencies.

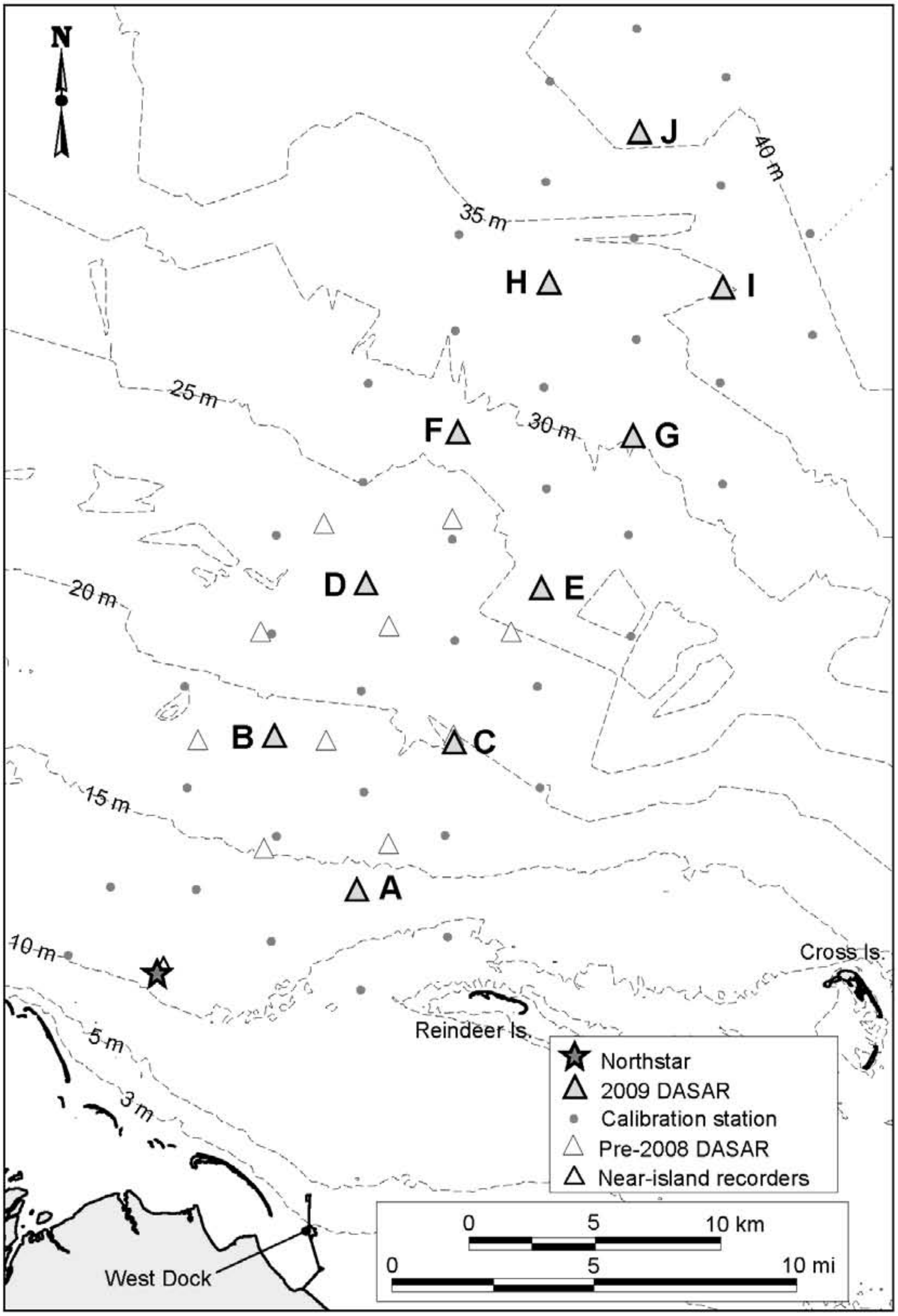

FIGURE 2.2. Locations of 11 array DASARs (2 DASARs were deployed at location C) and 37 calibration stations with respect to Northstar Island, September 2009. The three near-island DASARs are shown just north of Northstar (see Fig. 2.3). For comparison, DASAR locations used in 2001–2004 are also shown (a subset of these locations were used in 2005–2007).

TABLE 2.1. DASAR locations in 2009, with installation date and time, start and end of data collection, position, water depth, and distance from Northstar. All times are local Alaska Daylight Saving times. The "Data End" time is the recovery time. DASAR units A1, 65, and 59 were installed close to Northstar and are redundant of each other. All the other units were deployed in the offshore array. Location C in the array is the same as location EB in 2001–2007. DASARs 36 and 49 were both at the C location. * these distances are in feet.

Location	Unit #	Installed (Date & time)	Data Start	Data End	Latitude (deg N)	Longitude (deg W)	Depth (m)	Distance from Northstar (km)	(mi)
A	37	25 Aug 11:36	26 Aug 00:00	28 Sep 10:21	70.523	148.486	14.9	8.63	5.36
B	52	25 Aug 16:54	26 Aug 00:00	28 Sep 15:43	70.577	148.580	17.7	10.44	6.49
C (=EB)	36	25 Aug 12:02	26 Aug 00:00	28 Sep 11:15	70.577	148.391	22.9	14.82	9.21
C dupl.	49	25 Aug 12:11	26 Aug 00:00	28 Sep 10:55	70.577	148.395	22.9	14.72	9.15
D	58	25 Aug 16:27	26 Aug 00:00	28 Sep 15:01	70.632	148.486	23.5	17.45	10.84
E	51	25 Aug 12:35	26 Aug 00:00	28 Sep 11:43	70.632	148.297	24.7	21.52	13.37
F	50	25 Aug 15:57	26 Aug 00:00	28 Sep 14:31	70.687	148.391	28.0	24.51	15.23
G	47	25 Aug 13:01	26 Aug 00:00	28 Sep 12:15	70.687	148.202	30.5	28.39	17.64
H	45	25 Aug 14:30	26 Aug 00:00	28 Sep 13:50	70.741	148.297	34.4	31.41	19.52
I	48	25 Aug 13:31	26 Aug 00:00	28 Sep 12:41	70.741	148.108	34.7	35.24	21.90
J	57	25 Aug 14:01	26 Aug 00:00	28 Sep 13:18	70.796	148.203	38.4	38.43	23.88
NSa	A1	25 Aug 10:50	26 Aug 00:00	28 Sep 09:06	70.495	148.695	12.8	0.38	1234 *
NSb	65	25 Aug 10:59	26 Aug 00:00	28 Sep 09:26	70.494	148.691	12.8	0.41	1358 *
NSc	59	25 Aug 11:05	26 Aug 00:00	28 Sep 09:48	70.494	148.688	12.8	0.45	1480 *

On 25 Aug, three DASARs—two model C and one model A—were also deployed ~450 m north of Northstar (Fig. 2.3). The primary function of these DASARs was to provide a continuous acoustic record of sounds produced by Northstar and its attending vessels. The three instruments, referred to as DASARs NSa, NSb, and NSc, were located 376 m, 414 m, and 451 m (1234 ft, 1358 ft, and 1480 ft), respectively, from the center of the north shore of Northstar. NSa and NSb were separated by 154 m (505 ft), and NSb and NSc by 157 m (515 ft). One DASAR-C was deployed as a backup to the other, and the DASAR-A was deployed to ensure that the recordings of the new DASAR-C model were comparable to those of the older model.

All 14 DASARs were successfully retrieved on 28 Sep 2009.

Health Checks and Calibrations

Health Checks

On 26 Aug, health checks were performed on all DASARs. Health checks provide an indication whether the deployed recorders and their software are functioning as expected. A surface-deployed transducer (a line- or pole-mounted Benthos DRI-267A Dive Ranger Interrogator) was placed in the water at the recorded GPS location of each DASAR. The transducer interrogated an acoustic transponder (Benthos UAT-376, operational range 25–32 kHz) in each recorder, which responded on one channel if it was recording and on another channel if it was not. None of the DASARs reported any health problems on 26 Aug, 1 day after deployment. Health checks were repeated in mid-season (12 Sep) on all DASARs except the one at location D, again with no health problems reported. The health check of the DASAR at location

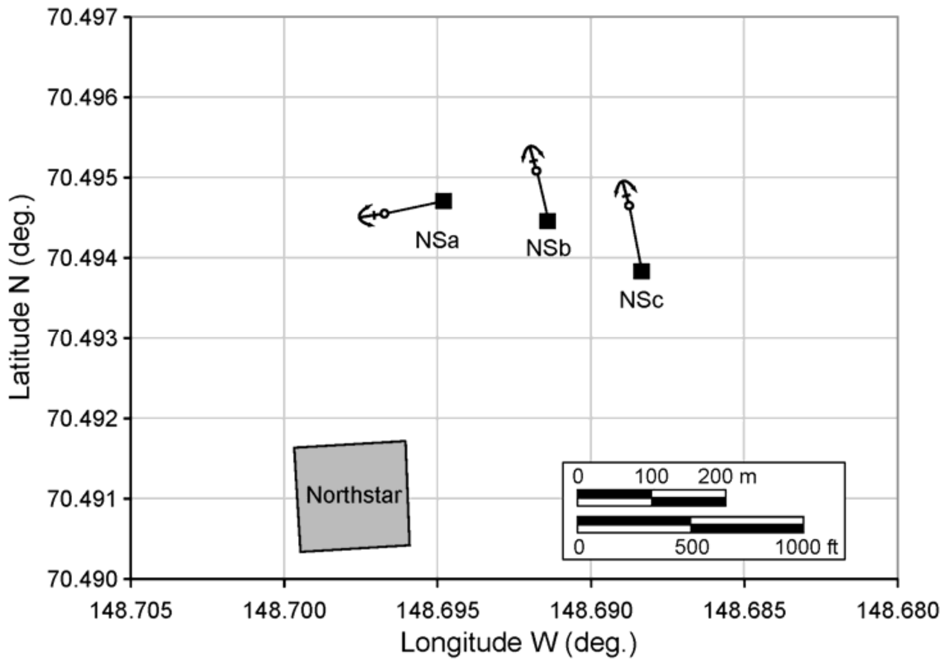

FIGURE 2.3. Locations of the three near-island DASARs (■) and their associated ground lines and anchors in relation to Northstar, September 2009. The primary function of these DASARs was to provide a continuous acoustic record of sounds produced by Northstar and its attending vessels.

D was skipped because on 12 Sep subsistence whalers were scouting for bowhead whales in the area of the DASAR array, so health checks were aborted before completion (see Chapter 5).

Time and Bearing Calibrations

On 26 Aug, the day following DASAR deployment, the clock and reference bearing of each DASAR were calibrated. Partial (see below) time and bearing calibrations were also performed in mid-season (12 Sep) and on 26 Sep, before DASAR retrievals. • Clock calibrations are conducted because each DASAR's clock has a small but significant drift. The rate of drift needs to be quantified in order to maintain an accurate time base over the course of the deployment (Greene et al. 2004). • Bearing calibrations are conducted because, during initial deployment, a DASAR's orientation on the seafloor is random with respect to true north. In addition, during inclement weather DASARs sometimes move on the seafloor. Directional calibration is therefore necessary in order to interpret bearings to whale calls as determined by the DASARs.

Field calibrations (both bearing and clock) involve projecting test sounds underwater at known times and known locations, and recording these sounds on the DASARs. After processing, the collected data allow us to determine each DASAR's orientation on the seafloor, so the absolute directions of whale calls from the DASARs can be obtained. The calibration transmissions also allow us to synchronize the clocks from various DASARs, so that the bearings to a call heard by more than one DASAR can be matched, allowing an estimate of the caller's position by triangulation. Clock synchronization is also important in other situations, for example when matching a particular industrial sound on several DASARs.

On 26 Aug, calibration transmissions were projected at six locations around each array DASAR and three locations around the near-island DASARs, resulting in a total of 37 calibration locations (Fig. 2.2).

With the good weather conditions that prevailed on that day (2–4 knot winds, 2 ft swell), it took about 11 hours to check the health and calibrate all 14 DASARs.

On 12 Sep, calibrations were performed at 23 of 37 stations (62%), mostly the western and northern ones. Because subsistence whalers were at sea scouting for whales on that day, calibrations and health checks were stopped at the request of the whalers before all calibrations had been completed. However, during analysis of the calibration data, the low sea state and resultant low ambient noise on 12 Sep allowed calibration signals transmitted from the westernmost stations to be audible at DASARs across the east-west extent of the array.

On 26 Sep, calibrations were performed as usual at 16 calibration stations encompassing the entire western side of the array. At that point, the J9 sound projector (see below) was accidentally damaged and could no longer be used. Calibrations at the remaining 21 sites were completed using a unique boat-noise signature generated at known times, combined with a 1-s resolution GPS ship track log. As happened for 12 Sep, calibration signals were detectable across the east-west extent of the array, so the boat-noise signatures were not used in the calibration analysis.

Equipment used for calibrations included a J-9 sound projector, an amplifier, a laptop computer to generate the projected waveform, and a GPS to control the timing of the sound source. A spectrogram of the waveform used in 2009 is shown in Figure 2.4. The signal consisted of a 2-s tone at 400 Hz, a 2-s linear sweep from 400 to 200 Hz, a 2-s linear sweep from 200 to 400 Hz, a 2-s linear sweep from 400 to 200 Hz, and 4 s of pseudo-random noise (m-sequence with 255 chips, repeated once every second on a 255 Hz carrier frequency). The first 8 s of this signal are identical to the waveform that has been used for calibrations since 2001; the final 4 s was new in 2009. The source level of the projected sound was ~150 dB re 1 μPa @ 1 m. During calibration a waveform transmission was initiated every 15 s, for a total duration of about 2 min (i.e., 8–9 transmissions). The rationale for the choice of waveform was that the tones provided a well-defined start time, which was used for the DASAR clock calibrations, and the bandwidth of the sweeps provided more accurate bearing measurements than would a tone. In addition, the four seconds of pseudo-random noise were expected to produce the best bearing measurements, because energy was then spread over the entire frequency range for the entire duration of the 4-s signal.

Investigation of Pop Sounds at Northstar

In Sep 2008 an unidentified popping sound was detected on the near-island recorders. The pops were short in duration, on average 1/20th of a second, with measured average received sound pressure levels (SPLs) roughly 131 dB re 1 µPa (see Blackwell et al. 2009b). Most of the energy in the pops resided in the 150–450 Hz band, with some variation among pops. Bearings extracted from the records of each of the three near-island DASARs (NSa, NSb, and NSc) pointed to the northeastern side of Northstar as the most likely source location of the pops. Based on the available information, it is possible that the source level of some pops would reach 180 dB re 1µPa or higher. According to the current LoA, BP is required to implement additional marine mammal monitoring for SPLs that exceed 180 dB re 1 µPa in waters beyond the Northstar facility[3]. BP therefore informed the agencies about the pops and their potential sound levels at Northstar, and agreed to undertake additional efforts at the start of the 2009 open-water season. These efforts were to (1) determine if the pops were still present in 2009 and, if so, (2) attempt to localize their source.

[3] Note that since the source of the pops is not known, it is unclear whether they qualify as “industrial sounds”.

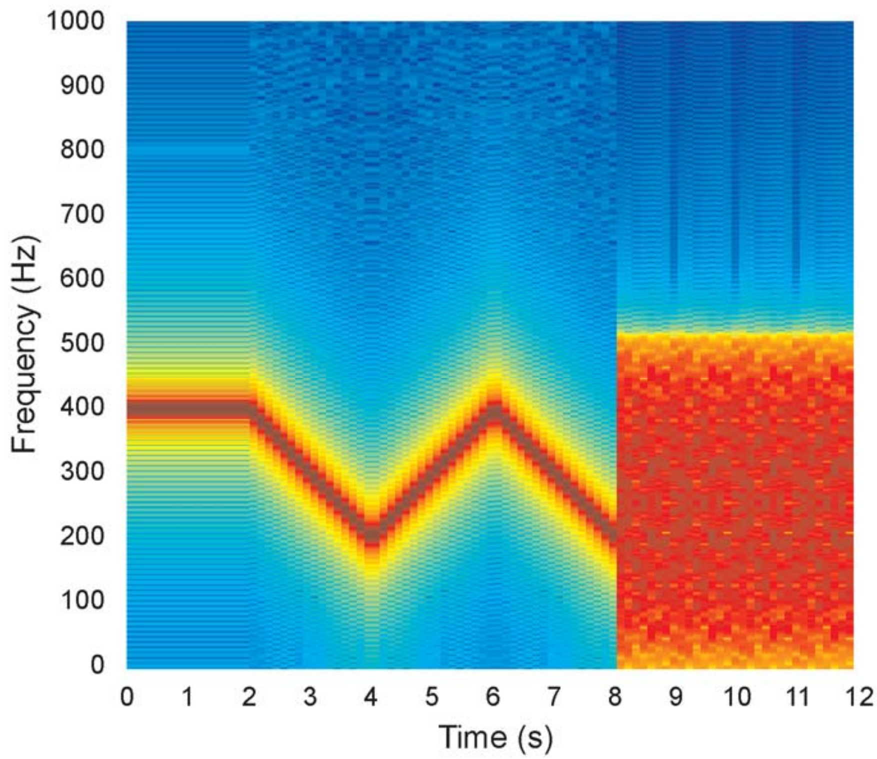

FIGURE 2.4. Spectrogram of the calibration waveform used in 2009.

The first attempt to detect the possible presence of pops was on 11 June 2009. The majority of the sea was still frozen, so a listening system was used from Northstar's shore. The listening system consisted of an ITC 8212 hydrophone, a post-amplifier box, and headphones, with the hydrophone deployed at depth ~0.5 m in a water-filled moat along the western shore of the island (Fig. 2.5). Three different persons[4] independently listened for pops at 09:30, 13:00, and 16:00, each time for a duration of 5–10 min.On 16 July, after break-up, a second attempt was made by deploying the same listening system as used on 11 June, from the ACS vessel *Gwydyr Bay*. The hydrophone was deployed at a depth of ~0.5 m at four different locations within 400 m (0.25 mi) west, north and northeast of the island. Dr. Aerts and the ACS deckhand B. Faulkner listened for a total of ~20 min over a 45 min period (11:15–12:00), i.e., about 5 min per location.

On 25 Aug, 12 Sep, and 26 Sep, in conjunction with DASAR deployments or calibrations, an *Acousonde*^{TM} autonomous recorder ("tag") was deployed near the island. This recording system is described at www.acousonde.com. The tag was attached to a small weighted frame and placed on the seafloor (Fig. 2.6). On the three dates the tag was deployed for ~7 hours, ~8 hours, and ~10 hours, respectively, in locations about 135 m, 35 m, and 45 m northeast of the island's northeastern corner, respectively. The tagrecorded continuously at a sampling rate of 27.33 kHz (27,330 samples/s), and provided acoustic data with bandwidth 20 Hz–9.3 kHz.

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[4] These three persons were (1) Dr. L.A.M. Aerts, Senior Marine Biologist at LGL Alaska; (2) T. Winkel, Environmental Advisor at BP; and (3) Dr. B. Streever, Environmental Studies Program Director at BP.

FIGURE 2.5. Listening for pops with the cabled hydrophone deployed in the moat along the western shore of Northstar, 11 June 2009.

FIGURE 2.6. Deployment of the *Acousonde* (the black cylinder within the metal stand) on 25 Aug 2009. On that date, the *Acousonde* was deployed ~135 m northeast of the northeastern corner of Northstar and retrieved after ~7 hours.

ANALYSIS OF ACOUSTIC DATA FROM DASARS

After retrieval on 28 Sep, the DASARs were opened and dismantled. The sampling program was shut down, and the 60 GB hard drives were removed and hand-carried back to the main Greeneridge office, where they were backed up. Data were transferred to computers running MATLAB and custom analysis software, and were equalized. Equalization is a calibration process that compensates for the fact that the sensitivity curve of a DASAR sensor is not flat across all frequencies (see Blackwell et al. 2006a). Equalization permits computing calibrated sound pressure levels, both on a spectral density basis and in various frequency bands (e.g., 10–450 Hz, or by one-third octave).

Various analyses were performed to address the 2009 study objectives. Many of the analyses were the same as in 2008 (Blackwell et al. 2009a,b), and some sound analyses used the same techniques as in 2001–2007, to allow comparisons with previous years. Details on each of these analyses are presented in the following sections:

- Calibration of DASAR time and bearing.

- Broadband, narrowband, and one-third octave band levels of sound.
- Industrial Sound Indices (ISIs), used to characterize industrial components of the sounds emanating from Northstar and its attending vessels.
- Analyses of “Northstar pops”, a new type of impulsive sound first identified during the 2008 field season and only present on the near-island recorders. These pops seemed to originate at or close to Northstar.
- Whale call analyses.

The results from most of these analyses are presented in Chapter 3, but the results of the whale call analyses are presented in Chapter 4.

Time and Bearing Calibrations

The sample clock utilized in the DASAR hardware design is quite accurate. However, as with all crystal oscillators, there is an inherent tradeoff between precision and power. Low power consumption is desirable for long-term deployments and fortunately, in the Arctic, clock imprecision is readily correctable because the relatively stable water temperature near the seafloor results in a near-constant rate of clock drift. Under such conditions, the DASAR clocks will incur a linear drift that, over 30 to 40 days of deployment, can reach ± one minute.

Figure 2.7A shows a spectrogram of a group of eight calibration signals received by an offshore DASAR. In this example, there are few interfering background sounds and the calibration signals of interest are readily detected in the spectrogram, and further clarified using a matched filter (Fig. 2.7B). The matched filter is especially useful when calibration signals are obscured by background noise. The software accounts for the travel time of the sound propagating between the calibration source and the DASAR and determines what the true time of arrival at the DASAR should be. The time error (the difference between true time and DASAR clock time) was then characterized as a linear function, shown in Figure 2.7C, and used to correct the time measured by the DASAR clock to true time. For the DASAR in Figure 2.7C, the estimated initial time offset is 3.18 sec, and the estimated clock drift is -2.02 sec/day.

The acoustic data from a DASAR consist of three channels (omnidirectional, cosine directional, and sine directional) whose respective time series are combined to determine the direction of an incoming signal. The procedure used for bearing calibration is explained in more detail in Annex 2.1. Basically, when calibration signals are identified in the acoustic records—as described in the paragraph above—the relative bearing of the DASAR to the known position of the calibration vessel is obtained. This is done for all six calibration stations around each DASAR, and the resulting reference bearing is then used to compute the actual bearing to a whale call, relative to True North.

Broadband, Narrowband, and One-third Octave Band Levels

Broadband, narrowband, and one-third octave band levels of the sounds received by all DASARs were determined using the same method as applied in previous years, to allow between-year comparisons. For each DASAR, narrowband spectral densities (1 Hz intervals, 1.7 Hz bandwidth, 23.5% overlap) were determined for a one-min period every 4.37 min (262 s). This provided ~330 spectral measurements per 24-hour day for frequencies in the 10–450 Hz range. To derive each of these one-min spectra, a series of 119 one-second-long data segments, overlapped by 50% and thus spanning one min, were analyzed. The 119 resulting 1-Hz spectra were averaged to derive a single averaged spectrum documenting narrowband levels for the one-min period.

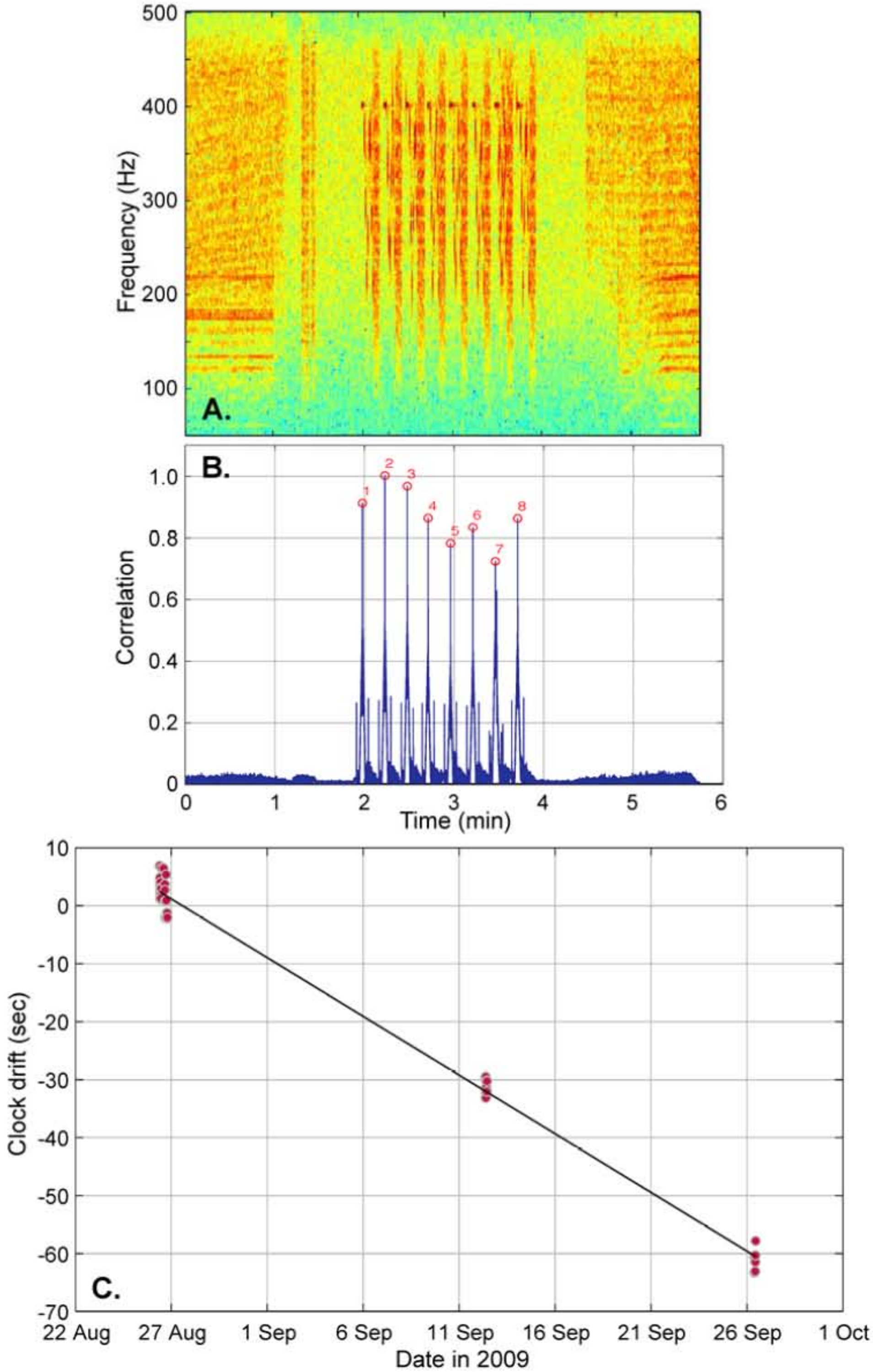

FIGURE 2.7. Calibration of DASAR clocks. ***(A)*** Spectrogram of eight calibration signals in conditions of relatively low background noise. Vessel noise is visible before and after the calibration period. ***(B)*** Matched filter output, coincident with above spectrogram, showing detections of the calibration signals. ***(C)*** Clock drift for array DASAR C determined by plotting time error as a function of date and time. Calibration transmissions were performed on 26 Aug, 12 Sep, and 26 Sep 2009 (red dots).

One-third octave band and broadband levels were derived from the narrowband spectral densities. The bandwidth of a one-third octave band is 23% of its center frequency. Standard center frequencies foradjacent one-third octave bands used here include 10 Hz, 12.5, 16, 20, 25, 31.5, 40, 50, 63, 80, 100, 125, 160, 200, 250, 315 and 400 Hz. One-third octave data are commonly used when considering the audibility of sounds to animals (or humans) because the effective filter bandwidth of mammalian hearing is roughly one-third octave (Richardson et al. 1995). One-third octave band levels were calculated by summing the mean square pressures at all frequencies within the bandwidth of the one-third octave band in question. This provided a measurement of the sound level in each bandwidth, averaged over a one-min period, for each 4.37-min interval. Broadband levels were also derived from the narrowband data by summing the mean square pressures of all frequencies within the 10–450 Hz frequency range. These narrowband, one-third octave, and broadband data provided a continuous record, with 1 min resolution, of the levels of low-frequency underwater sounds ~450 m from Northstar during the period 26 Aug–28 Sep 2009.

The narrowband and one-third octave data were also summarized over the entire deployment period to derive "statistical spectra" showing, for each frequency or one-third octave band, the levels exceeded during various percentages of the 1-min samples. For each of the 1-Hz frequency cells in the spectra, the values were sorted from smallest to largest, and the minimum, 5th-percentile, 50th-percentile, 95th-percentile, and maximum values for that frequency cell were determined. The same procedure was applied to one-third octave band data. This provided a summary of the range of spectral density values or one-third octave band levels over the entire season. It therefore allowed general comparisons between years by identifying, for example, prominent tones or the dominant frequency ranges of industrial sounds.

During the 2008 field season there were two types of sounds that were fairly prominent on the DASAR records and were therefore expected to influence the results of the sound analyses. These two types of sounds—either not known from previous years or not very prominent—were "popping sounds", mainly on the records of the near-island DASARs, and airgun pulses recorded on the array DASARs. To provide a measure of broadband sound exclusive (as much as possible) of both pops and airgun pulses, we calculated broadband (10–450 Hz) levels over 2-s periods. This was done for every second throughout a DASAR's sound record, so each 2-s period had 50% overlap with the period preceding it. For each 10-min period throughout the DASAR record only the lowest value was stored. This essentially provided a record of minimum broadband levels, by 10-min period, throughout the season for a particular site. To allow comparison between years these computations were repeated with the 2009 data.

Industrial Sound Indices (ISIs)

For purposes of this study, where the main interest lies in understanding the relationship between sounds generated by Northstar and migrating bowhead whale distribution and behavior, it is important to understand the contribution of industrial components to the overall underwater sound. For that reason, industrial sound indices (ISIs) were developed in earlier years (Blackwell et al. 2006a) to represent the most important components of the sounds emanating from Northstar or its attending vessels. These components are the ***low frequency sounds***, which are typical of industrial sounds and are represented by *ISI_5band*; ***presence of tones***, which are typical of engines and other machinery and are represented by *ISI_tone;* and ***presence of transient sounds***, such as those produced by passing vessels, as represented by *ISI_transient*.

During the first years of the Northstar study, *ISI_5band* (formerly called simply "*ISI*") was the only index of island sound that was used. In 2005, in response to comments by the North Slope Borough's Science Advisory Committee (SAC; see Chapter 1), the other indices were developed and used in follow-up analyses of 2001–2004 data (e.g., Blackwell et al. 2006a, 2006b). However, the other indices were not used in 2005–2007. Comparison of the 2008 data with those from previous years (2001–2007) was only done for *ISI_5band*.

ISI_5band

This ISI was constructed by summing the mean square sound pressure levels (SPL) in the one-third octave bands centered at 31.5, 40, 50, 63, and 80 Hz. Collectively, those bands span the frequency range 28 to 90 Hz. These one-third octave bands are known to be dominated by industrial components. One-third octave bands that appeared to be substantially influenced by natural sound components (at least in 2001–2002, the years being considered when *ISI_5band* was first defined) were not included when calculating *ISI_5band* (Blackwell 2003; Richardson et al. 2003). Total mean-square sound pressure in the five one-third octave bands considered was computed as

$$ISI\_5band = 10 \cdot \log_{10} \cdot \left(10^{\frac{dB_{31.5}}{10}} + 10^{\frac{dB_{40}}{10}} + 10^{\frac{dB_{50}}{10}} + 10^{\frac{dB_{63}}{10}} + 10^{\frac{dB_{80}}{10}} \right),$$

where $dB_{31.5}$, dB_{40}, dB_{50}, dB_{63}, and dB_{80} are mean square SPLs in the five relevant one-third octaves (Richardson et al. 1995, p. 30). The result is equivalent to the sound pressure in the (approx.) 28 to 90 Hz band.

ISI_tone

This index was designed to quantify tones in the sound spectrum. Tones are produced by machinery and are therefore a characteristic of industrial or vessel sound. The 1-min spectra (10–450 Hz) computed every 4.37 min from the near-island and offshore recorders were examined for the presence of tones. A tone was defined as present when the spectral density value for a set frequency was at least 5 dB above the average level of the two spectral components below and the two spectral components above the component being examined. The average of those 4 "nearby" frequency bins constituted the "background"[5]. The amount by which each tone exceeded its corresponding background was recorded. The *ISI_tone* measure for a given 1-min sample was the sum of the powers (micropascals-squared) of these differences, for all the tones identified by the ≥5 dB criterion, converted back to dB re 1 μPa.

ISI_transient

This index was designed to quantify transient sounds, such as those from a passing vessel. The *ISI_transient* level is calculated by computing a running average of *ISI_5band* levels (one sample every 4.37 min) with a time constant of 4 hr, centered on the time of interest. This running average is mainly determined by background levels prevailing over the 4-hr period. If an individual 1-min level (i.e., in the 28–90 Hz band) is at least 5 dB above the corresponding 4-hr background value, then the amount by which it exceeds the background level is recorded and reported as the value of *ISI_transient* for the corresponding time.

Pop Sounds

Analyses of the data collected in 2008 showed that pops only occurred on the three near-island recorders (and not on any array DASARs), and that bearings to the pops were directed predominantly south and southwestward from those recorders. Therefore, these sounds appeared to originate at or close to Northstar Island, possibly on the eastern side of the island. The main goals of the 2009 pop analyses were to

[5] For example, if the frequency of interest is 20 Hz then the "background" will be calculated from the values of the bins centered at 18 Hz, 19 Hz, 21 Hz, and 22 Hz.

(1) narrow down the source of the pops, and (2) ensure that received sound pressure levels did not exceed 180 dB re 1 μPa at any location in the water around the island.

After retrieving the *Acousonde* tag, the records were downloaded to a computer. The data were high-pass filtered with a 50 Hz cutoff frequency (outside the pops' frequency band) to remove 30 Hz mechanical noise, which was suspected to originate from the *Acousonde* deployment frame (see Fig. 2.6). A peak detector with an instantaneous pressure threshold of 7 Pa (136.9 dB re 1 μPa) was applied to the time series data from each deployment, to identify the locations in the records where pops occurred. Although a lower detection threshold would detect more putative pops, the aforementioned threshold was chosen because it addressed the main goals of this investigation, i.e., to establish the presence of pops and identify source levels of the strongest ones.

Pop sounds are impulsive and were therefore analyzed using routines developed for transient pulses <1 s in duration (Greene 1997; McCauley et al. 1998, 2000; Blackwell et al. 2004), using custom-written software. For each analyzed pulse the following parameters were determined: (1) *peak pressure*, i.e., the instantaneous maximum of the received sound pressure (in dB re 1 μPa); (2) *pulse duration*, defined as the time interval between the arrival of 5% and 95% of the total pulse energy (in s); (3) pulse *sound pressure level* (SPL), averaged over the pulse duration (dB re 1 μPa); and (4) pulse *sound exposure level* (SEL), a measure of the energy in the pulse, defined as the squared instantaneous sound pressure integrated over the pulse duration (dB re 1 $\mu Pa^2 \cdot s$). All pulses with a peak pressure exceeding the aforementioned 7 μPa threshold were analyzed from each *Acousonde* record.

In addition, the same peak detector, utilizing various threshold levels including 7 μPa as with the *Acousonde*, was applied to the entire 2008 and 2009 recordings of near-island DASAR NSb. The purpose was to associate pops received on the *Acousonde* with those received on the near-island DASAR (DASAR NSb was closest to the *Acousonde* deployment locations). This would allow us to determine a simple transmission loss model, in order to further isolate the location of the pop source and estimate its sound level. Running the peak detector on both years also allowed us to compare presence and variability of the pops across years and to confirm hypotheses concerning the mechanism behind the pop source.

Airgun Pulses

During the 2009 field season, airgun pulses from two main seismic surveys at long distances from Northstar, one by the Geological Survey of Canada (GSC) and the other by BP, were detected on the acoustic records of array DASARs. There were many fewer pulses than in 2008, and their average received levels were lower than in 2008. However, because airgun pulses have energy distributed over our entire analysis band of 10–450 Hz, they are a source of interference in the sound records and should therefore be quantified. In addition, bowhead whales have been shown to react to sounds from airguns (Richardson et al. 1986, 1999; Ljungblad et al. 1988). To obtain a quantitative assessment of the number of airgun pulses during the 2009 field season we analyzed pulses in the record of DASAR J (farthest offshore) using software developed by Dr. Aaron Thode (Scripps Institution of Oceanography). For comparison, airgun pulses detected in the record of DASAR J in 2008 were also analyzed this way. The many improvements made to the software since last year required that the record from DASAR J in 2008 be reanalyzed with the same version of the software used to analyze the 2009 data.

The process of automatically detecting and measuring acoustic properties of airgun signals took place in three stages: pulse detection, interval estimation, and finally level measurement. The first two stages (pulse detection and interval estimation) are described in detail in Annex 2.2. Once pulses were identified, the software calculated the following five parameters for each detected pulse: (1) *peak pressure* (in dB re 1 μPa); (2) pulse *duration* (in s); (3) pulse *sound pressure level* (SPL, in dB re 1 μPa); (4) pulse *sound exposure level* (SEL, in dB re 1 $\mu Pa^2 \cdot s$); (5) *background level*, as determined over ~0.5–1 s immediately preceding the pulse. These parameters were defined and measured in the same manner as described above for the new unknown impulsive sounds. Pulses that overloaded the DASAR sensor (i.e., pulses for which the instantaneous sound pressure exceeded 151 dB re 1 μPa) were not included in analyses incorporating sound levels. Data were then summarized by 10-min periods.

Whale Call Analyses

Analysis of whale calls was done manually by trained staff as in previous years. Identification and classification of each whale call was done by examining spectrograms of the acoustic data, one minute at a time, and listening to recordings of each call or suspected call (see Fig. 2.8). The sounds recorded during a given 1-min interval by all DASARs comprising one site were analyzed by a single analyst before that analyst moved on to the next 1-min period. Using a computer mouse, analysts delimited the time-span and frequency-range of each call by positioning a rectangle on the spectrogram, thereby "tagging" it in the records. The computer then calculated several parameters such as the bearing to the call, or the duration of the call. The lead analysts performed regular checks for consistency among analysts. Most calls were detected by more than one DASAR, but each call was classified and tallied only once. Reception of the call at more than one DASAR allowed for triangulation of the call's estimated position, according to a method described in Greene et al. (2004).

FIGURE 2.8. Eight of the 30 workstations at Greeneridge Sciences where analysts identify and localize whale calls. In the top picture, note 10 spectrograms on the screen of the closest analyst, representing the 10 DASAR locations of the Northstar offshore array.

Calls were classified into two major categories, simple calls and complex calls, on the basis of call descriptions by Clark and Johnson (1984), Würsig and Clark (1993), and Blackwell et al. (2007b). Simple calls were frequency modulated tonal calls or "moans" in the 50–300 Hz range. We distinguished (1) ascending-frequency or "up" calls ("/"), (2) descending-frequency or "down" calls ("\"), (3) constant-frequency calls ("—"), (4) inflected calls with u-shaped ("∪") and (5) n-shaped ("∩") frequency patterns, and (6) variations thereof ("~"). Complex calls were infinitely varied and included pulsed sounds, squeals, growl-type sounds with abundant harmonic content, and combinations of two or more simple and complex segments. Subcategories of complex calls could not be consistently discerned, so all subcategories were pooled. In addition to sounds from bowhead whales, acoustic records included sounds produced by other marine mammals such as bearded seals (*Erignathus barbatus*), Pacific walruses (*Odobenus rosmarus divergens*), and gray whales (*Eschrichtius robustus*). These were not classified using the analysis software but were noted in separate logs.

During the whale call classification process, the bearing from each DASAR to each detected call was determined automatically, using information from the bearing calibrations (see section *Time and Bearing Calibrations* above). If a call was detected by at least two DASARs, the bearings to that call were combined to estimate a position by triangulation. After all the calls were processed, two parameters were calculated for DASAR C (called "EB" in 2001–2007) based on the bearings from that DASAR to all whale calls detected by that DASAR: the vector mean bearing and the mean vector length (Batschelet 1981). Figure 2.9 shows how to calculate these two parameters using example bearings to nine different calls. The vector

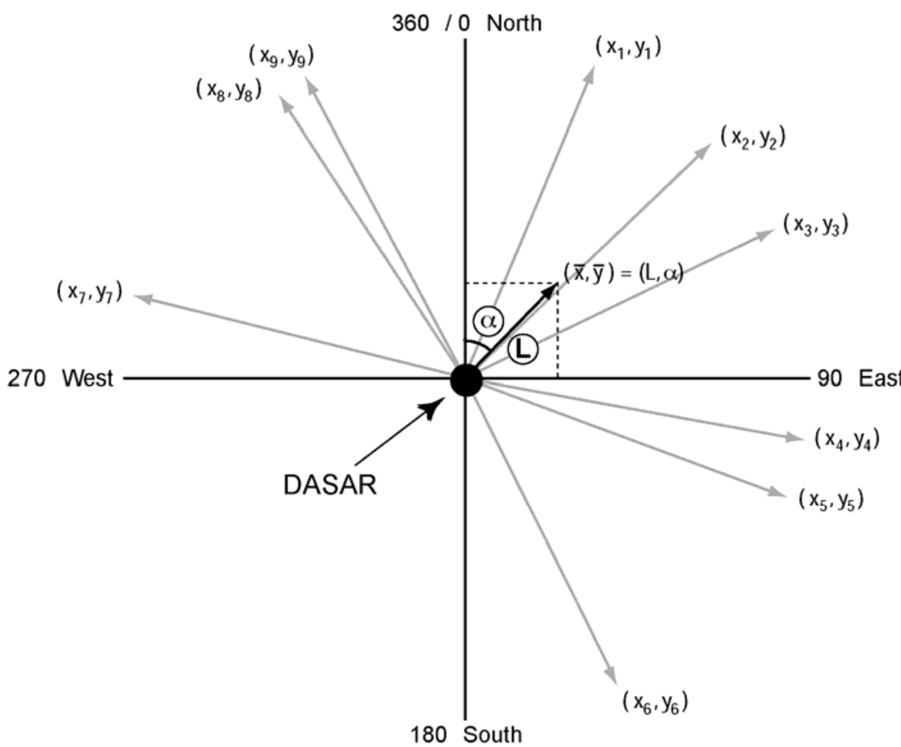

FIGURE 2.9. Average bearing calculation. The gray arrows are example bearings from a DASAR. Mean bearing angle $\alpha = \arctan(\bar{x}, \bar{y})$, where $\bar{x}$ and $\bar{y}$ are the average cos and sin, respectively, of all bearings obtained at one DASAR during a season. Mean vector length, $L = \sqrt{\bar{x}^2 + \bar{y}^2}$, is a measure of the variation of individual bearings around the vector mean direction.

mean bearing indicates the average direction from a given DASAR to the calls it received that year, while the mean vector length (L) is a measure of the variation of the individual bearings around the vector mean direction. For example, if all the bearings to calls were the same (say 45°), then the vector mean would be 45° and the mean vector length would be 1. If the bearings were spread evenly in all directions (say 4 bearings at 0°, 90°, 180°, and 270°), then the vector mean would be indeterminate and the mean vector length would be 0.

The proportion of calls "offshore" versus "inshore" (O/I ratio) was also calculated for DASAR C and compared with values from previous years at that location. "Offshore" and "inshore" were defined in relation to a ***baseline***, which is a line parallel to the general trend of the shoreline (108° to 288° True). Offshore calls were defined as those whose bearings from a specific DASAR were between 288° and 107.9° True (including 360°/0°, true north), and inshore calls were defined as those with bearings between 108° and 287.9° (including 180°, south; Figure 2.10).

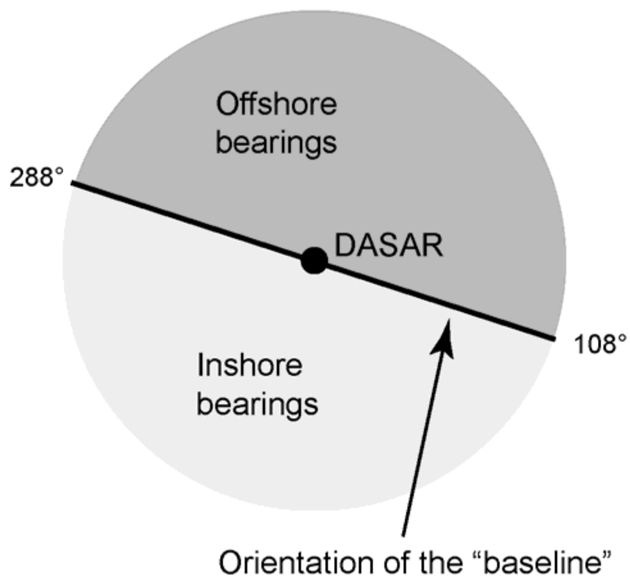

FIGURE 2.10. Definition of the "offshore" and "inshore" sectors in relation to the orientation of the baseline and DASAR location (filled circle in center). See text for details.

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ANNEX 2.1: BEARING CALIBRATION METHODOLOGY

The acoustic data from a DASAR consist of three channels (omnidirectional, cosine directional, and sine directional) whose respective time series are combined to determine cosine and sine components of the incoming signal:

$$I_{NS}(n) = cosch(n) \cdot omni(n) \quad \text{Eq. (1)}$$

$$I_{EW}(n) = sinch(n) \cdot omni(n) \quad \text{Eq. (2)}$$

Here *cosch(n)* is the cosine directional channel time series, *sinch(n)* is the sine directional channel time series, and *omni(n)* is the omnidirectional channel time series. The two directional channels are oriented relative to the DASAR's orientation on the bottom (which is determined via the bearing calibration procedure, described earlier). The *cosch(n)* and *sinch(n)* time series are proportional to particle velocity, and the *omni(n)* time series is proportional to acoustic pressure, so their products are proportional to acoustic intensity, *I(n),* a vector quantity with magnitude and direction. The direction, or bearing, is the measure of interest for calibration signals and other sound sources, for example, a whale call.

Figure 2.11 presents an example of a scatterplot in which the values of I_{NS} and I_{EW} for a specific sample define the location of a dot. The signed amplitude of $I_{NS}(n)$ is the y-coordinate and the signed amplitude of $I_{EW}(n)$ is the x-coordinate. The effect is to show a scattering of sample values that, collectively, show the direction from which the sound is arriving with respect to the reference axis direction of the DASAR on the ocean bottom. Were there no noise (no sound coming from anywhere other than the direction to the calibration sound transmitter), all the points would lie on a line indicating the direction to the source. The presence of background noise along with the calibration signal results in the variation in bearings.

The bearing of a sound relative to the DASAR orientation is estimated by averaging the $I_{NS}(n)$ and the $I_{EW}(n)$ values determined for all the samples in the received calibration sound and taking the arctangent of their ratio:

$$B_{rel} = \arctan\,[\text{avg}\{I_{EW}(n)\} \,/\, \text{avg}\{I_{NS}(n)\}] \quad \text{Eq. (3)}$$

where avg denotes the average or mean intensity, arctan is the inverse tangent operation yielding results in the range of 0° to 360°, and B_{rel} is the estimated bearing of the sound source relative to the DASAR's cosine axis. In Figure 2.11, the measured B_{rel} is 33.2°.

The true bearing from the DASAR to the calibration source, Bgrd, is calculated directly from the known deployment locations of the DASARs and the known GPS positions of the calibration vessel. Examples of true bearings (B_{grd}) for a grid coordinate system, for 63 groups of calibration signals detected by one of the offshore DASARs, are depicted in Figure 2.12A. Figure 2.12B shows the same groups of calibration signals and their measured bearings, B_{rel}, relative to the DASAR's cosine axis, obtained from the scatterplots and methodology described in the previous paragraph. Note that the true bearings to the calibration source and their measured bearings relative to the DASAR share the same pattern and are simply offset by a constant bearing, an indication that there was no direction-dependent bias in the DASAR's bearing measurements, as expected for directional sensors with matched sensitivities (Greene et al. 2004). By subtracting B_{rel} from B_{grd}, one obtains B_{ref}, the reference bearing subsequently used to translate a

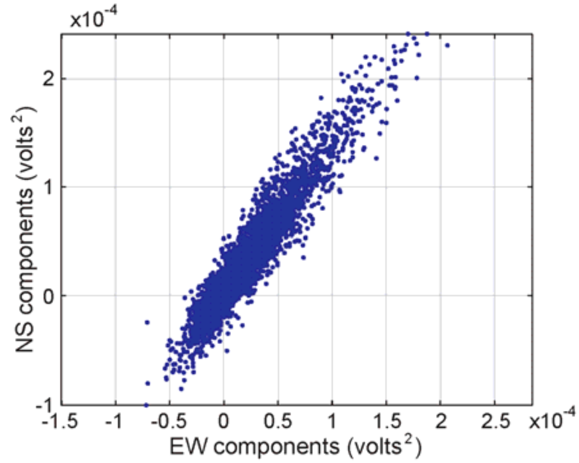

FIGURE 2.11. Example of a scatterplot illustrating the estimated bearing, B_{rel}, to a calibration signal relative to the DASAR's cosine axis. NS = north–south, and EW = east–west.

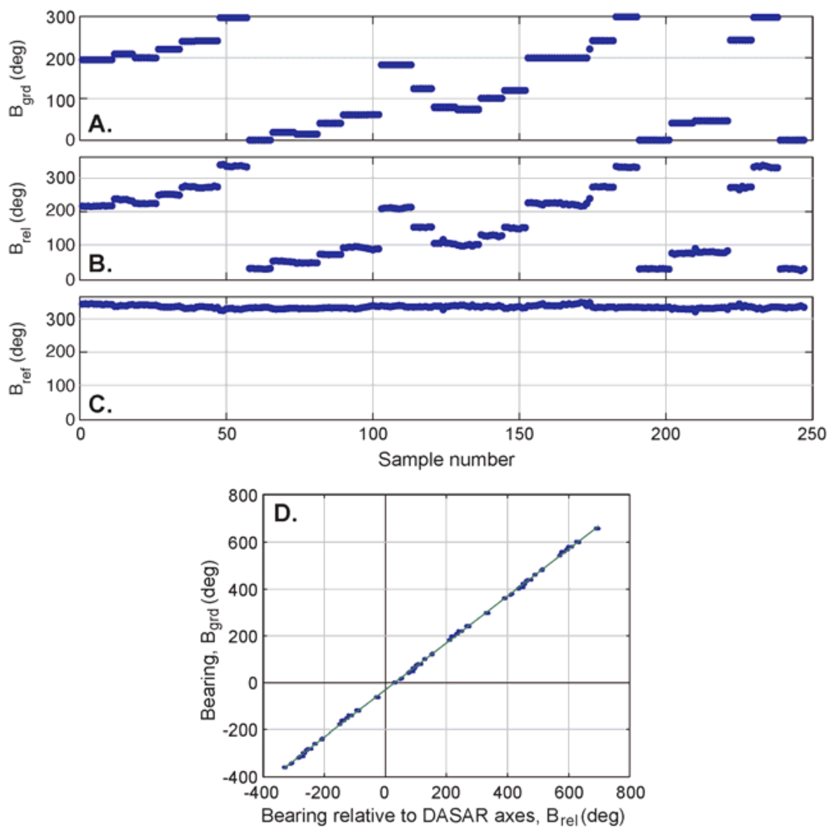

FIGURE 2.12. DASAR bearing calibration. ***(A)*** True bearings (or grid bearings), B_{grd}, from array DASAR D to the calibration source for 27 groups of calibration transmissions. ***(B)*** Measured relative bearings, B_{rel}, from the DASAR to the same calibration transmissions. ***(C)*** Resultant reference bearing, B_{ref}, used to translate estimated bearings received on and relative to the DASAR to bearings relative to True North (μ=329.9°, S.D.=4.5°, n=247). ***(D)*** A secondary method of estimating the reference bearing, B_{ref}, using a straight-line fit between B_{grd} and B_{ref}. Note that the slope of the line is unity, indicating directionally-unbiased sensors, and the y-intercept of the line yields an estimate of B_{ref} (-30.3° or, equivalently, 329.7°).

measured bearing of a sound relative to the DASAR to a bearing relative to True North (Fig. 2.12C). For this example DASAR, B_{ref} is estimated to have a mean value of 329.9° with a standard deviation of 4.45°.

The fact that B_{ref} is a constant, with the same value regardless of the source's bearing, is also verified by the fact that a straight line with slope 1 fits a plot of B_{grd} vs. B_{ref}. A close fit and slope of 1.0 are indicative of directionally-unbiased sensors. The line's y-intercept yields the estimate of B_{ref}. An example of this for one DASAR is shown in Figure 2.12D. Using this alternative approach, B_{ref} was estimated to be 329.7°. In practice, the former method was used to estimate B_{ref} since it provides additional quantitative statistics describing the quality of the estimate, such as its variability (standard deviation) and the number of samples used in the estimate.

ANNEX 2.2: AUTOMATIC PULSE DETECTION SOFTWARE

Aaron Thode (Scripps Institution of Oceanography)

The process of automatically detecting and measuring acoustic properties of airgun signals took place in three stages: pulse detection, interval estimation, and finally level measurement. The first two stages are described below. The components of the third stage are listed in the *Airgun Pulses* section of Chapter 2.

The first stage of the program seeks to identify any transient pulse that occurs in the acoustic data. To accomplish this, the program first creates a succession of spectrograms of FFT (Fast Fourier Transform) length 256 samples (0.256 s), overlap 50%. It then creates a set of "detection functions" by integrating the FFT output over a set of overlapping 37 Hz frequency bands between 10 and 450 Hz. The units of the detection function are in terms of sound exposure level (SEL), or $\mu Pa^2 \cdot s$. The time integration is simply over the FFT window length of 0.256 s. When a new FFT sample arrives, the detection functions are updated. For a given detection function, if the new value of the function does not exceed a threshold value, then it is assigned to a "background" or "equalization" function with weight alpha:

Equalization function (new) = (1– alpha) · Equalization function (old) + alpha · (new FFT sample)

The value of alpha is set so that the contribution of a new sample will decay away in 25 seconds. Thus the equalization function becomes a long-term average of the "smoothed" background noise level.

As a new FFT sample enters the system, the new value of each detection function, divided by the current value of the corresponding equalization function, is compared to a threshold of 8 dB (6.3 ratio on a linear scale). If the new value exceeds the threshold, then the presence of a possible detection is flagged, and the equalization function is not updated. As new detection function samples are computed, one will eventually fall below the threshold and the end of the detection is flagged for that detection function. Once all detection functions fall below threshold, the elapsed time of the transient is computed. If the duration is greater than 100 ms, the event is logged for further analysis, along with values of the minimum and maximum frequencies of the event, and the azimuth from which the pulse is arriving. If the detection lasts longer than 5 s, the program forces the detection to end and resets the equalization function. To prevent momentary dips in the detection function from triggering a new detection, a new detection cannot begin until 20 ms have elapsed since the last detection.

The next stage seeks to assign an "interval" or "repetition rate" to each detected transient. To that end the program marches through each detected pulse. For each pulse, the program looks 40 s into the future and past for the presence of any other pulses that arrived within 15 degrees of the azimuth logged for the current pulse. These "candidate" detections, if they exist, provide a set of possible intervals to test. Each candidate interval is tested by searching ten time intervals into the future, and ten time intervals into the past, relative to the current pulse under consideration. If a pulse is present within 1.0*sqrt(K) s of where an interval would be expected, where K is the number of pulse intervals being projected both forward and backward in time, that candidate interval is awarded a “hit”. If eight or more out of the 20 interval times are “hits”, then the current pulse is assigned that candidate interval. Thus if the pulse is part of a regular series of pulses it will be assigned a number that is equal to the timing between pulses, or some integer multiple thereof.

If a pulse has been associated with an interval, then it is labeled an airgun pulse and various metrics are computed. First the number of times the time series attains the maximum value permitted by the A/D converter is checked. If this count exceeds five the signal is flagged as “clipped” and no further metrics are computed. Next, a high-resolution estimate of the pulse duration is obtained by running the time series through a calibration filter, which removes the frequency-dependent response of the hydrophone, flattening the response. Next the rms value of 0.75 s of signal just before the start of the detection is collected. This rms “noise” value is subtracted from the cumulative sum of the square of the signal across the entire detection window, creating an “equalized cumulative sum”. The points where the equalized cumulative sum reaches 5% and 95% of its maximum value are defined as the high-resolution start and end of the transient detection. From this duration the sound pressure level (SPL) and SEL of the pulse can be computed. The SPL is averaged over the pulse duration and is in units of dB re 1 μPa. The SEL is defined as the squared instantaneous sound pressure integrated over the pulse duration and is in units of dB re 1 $\mu Pa^2 \cdot s$. The frequency window used to compute the metrics lies roughly between 10 Hz and 450 Hz. The instantaneous maximum (or the algebraic minimum) of the pulse pressure within the duration is saved as the instantaneous peak pressure. All “signal” and “noise” metrics are written to a file for further analysis, as well as the arrival bearing and interval for each pulse.

CHAPTER 3:

SOUNDS RECORDED AT NORTHSTAR AND IN THE OFFSHORE DASAR ARRAY, AUTUMN 2009[1]

by

Susanna B. Blackwell[a], Katherine H. Kim[a], William C. Burgess[a],
Robert G. Norman[a], Charles R. Greene, Jr.[a],
and Lisanne A.M. Aerts[b]

[a]Greeneridge Sciences, Inc.
6160-C Wallace Becknell Road, Santa Barbara, CA 93117
Phone: (805) 967-7720; e-mail: susanna@greeneridge.com

[b]LGL Alaska Research Associates Inc.
1101 East 76th Ave., Suite B, Anchorage, AK 99518
Phone: (907) 562-3339; e-mail: alaska@lgl.com

for

BP Exploration (Alaska) Inc.
Dept. of Health, Safety & Environment
900 East Benson Blvd, P.O. Box 196612
Anchorage, AK 99519-6612

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[1] Chapter 3 *In:* Aerts, L.A.M. and W.J. Richardson (eds.). 2010. *Monitoring of industrial sounds, seals, and bowhead whales near BP's Northstar oil development, Alaskan Beaufort Sea, 2009: Annual Summary Report.* LGL Rep. P1132. Rep. from LGL Alaska Res. Assoc. (Anchorage, AK), Greeneridge Sciences Inc. (Santa Barbara, CA), and Applied Sociocultural Research (Anchorage, AK) for BP Exploration (Alaska) Inc., Anchorage, AK.

ABSTRACT

During the bowhead whale migration in September 2009, Greeneridge Sciences (on behalf of BP) implemented an acoustic monitoring program north-northeast of BP's Northstar oil development. The overall study objective was similar to previous years, i.e., to assess the effects of Northstar production activities, as manifested in underwater sounds, on the behavior of migrating bowhead whales. Understanding what sounds are produced by Northstar and its attending vessels, and the degree to which those sounds are received by migrating bowhead whales, is an important component of the study. The current chapter presents results from the analyses of sounds recorded near Northstar and in the offshore DASAR array during the early autumn of 2009.

An array of 10 directional autonomous seafloor acoustic recorders (DASARs) was deployed offshore of Northstar for ~33 days (26 Aug–28 Sep) and recorded sounds continuously at a 1 kHz sampling rate. Concurrently, sounds produced by Northstar and its attending vessels were recorded by DASARs located ~450 m north of the island over the same period. Broadband levels of Northstar sound, as recorded near the island, were generally similar to previous years. The frequency of occurrence of periods with distinct vessel sounds ("vessel spikes") was somewhat higher in 2009 than in 2008, but still below 2006 and 2007 levels. Short-term variability in sound levels was higher than in previous years. This was attributed to the presence in 2009—as in 2008—of impulsive sounds on the records of the near-island DASARs; these sounds are referred to as "pops", and their source (though at or near Northstar) is not known. Pops are broadband in nature and of short duration (~ 0.05 s). Analyses of near-island DASAR records showed that (1) the number of pops detected in 2009 was about 2.5 times that detected in 2008, and (2) pops are wind-dependent, i.e. their number and received levels increase with increasing wind speeds.

One of the specific objectives in 2009 was to better understand which island sounds propagate offshore and the distances offshore at which these sounds can be detected. Mean broadband levels for array DASARs did not change with distance from Northstar and were somewhat higher for the northernmost recorder (J). Large spikes from tugs maneuvering at Northstar could be detected at least to DASAR A, 8.6 km or 5.4 mi from Northstar. The 30 Hz and 60 Hz power frequency tones, on the other hand, despite their omnipresence near Northstar and being the strongest tones in the island spectrum, could not be detected at the southernmost array DASAR (A), even in the quietest conditions.

Nearly 64,700 airgun pulses were detected on the record of DASAR J, the farthest from shore (versus ~147,000 in the 29-day 2008 study period). Besides being less frequent in 2009 than in 2008, average received levels of airgun pulses at DASAR J were 7 dB lower in 2009. Airgun pulses are a confounding factor in achieving our objective of assessing the effects of Northstar sounds on bowhead whale behavior. However, the pulses received in 2009 (unlike 2008) came from two well-defined sources that were located hundreds of km away in two well-defined directions. We believe that, for 2009, they can be included as covariates in the planned analysis of Northstar effects on bowhead call distribution.

INTRODUCTION

The overall study objective is to assess the effects of Northstar production activities, as manifested in underwater sounds, on the distribution and behavior of calling bowhead whales. An important component of this assessment is to understand what sounds are produced by the Northstar operation (island and attending vessels) and received by migrating whales, as they represent the "dose" of sound to which we expect some bowhead whales to react. The current chapter presents results from the analyses of sounds recorded near Northstar and in the offshore DASAR array during the late summer and early autumn of 2009. Measurements of underwater sounds generated by Northstar, as recorded by near-island DASARs, were compared with similar data from previous years. In addition, to determine the extent to which Northstar sounds propagate offshore, sound records obtained close to the island were compared to those obtained in the DASAR array, 8.5–38.5 km (5.3–23.9 mi) northeast of Northstar. When possible, changes in industrial and vessel activities at and near Northstar were related to observed changes in the sound records.

During the 2008 field season, numerous airgun pulses (produced by non-BP operations) were recorded by the array DASARs on most days and were briefly described in the corresponding annual report (Blackwell et al. 2009). Airgun pulses were also present on the acoustic records during the 2009 field season, but the number of pulses detected was smaller and their typical received levels were lower, consistent with the fact that their sources were generally more distant. Also, in 2009 the airgun pulses arrived from two narrow ranges of directions whereas in 2008 they had arrived from a greater variety of directions.

As part of the overall study objective, the current chapter describes the characteristics and propagation of sounds generated by Northstar in the late summer/early autumn 2009 and, where relevant and possible, compares the results with those from previous years. Specifically, the results are presented in the following five sections:

(1) Broadband sound levels near Northstar and offshore;

(2) Percentile one-third octave band and spectral density levels near Northstar and offshore, i.e., frequency composition of the sounds described in (1);

(3) Industrial sound indices (ISIs) of sounds recorded near Northstar and offshore, including *ISI_5band*, *ISI_tone*, and *ISI_transient* (defined in Chapter 2);

(4) Sounds from specific island-related sources, including vessels and "pop sounds". The latter were first identified in 2008 and occurred again in 2009;

(5) Airgun pulses, i.e., the incidence and received levels of airgun pulses at DASAR J, the array DASAR located farthest from shore, and comparison of these results with those from 2008.

BROADBAND SOUNDS NEAR NORTHSTAR AND OFFSHORE

Broadband Sounds Near Northstar

Three DASARs were deployed ~450 m north of Northstar, with two of the instruments considered backups to the third. DASAR NSa was a DASAR-A (see Greene et al. 2004) whereas NSb and NSc were of the newer DASAR-C type (Chapter 2). Data from these three recorders were in close agreement, with differences that were well within the variation one might expect based on reception at slightly different locations (see Fig. 2.3 in Chapter 2). As seen in previous years, mean received levels and variability in received levels decreased from east to west, being highest at DASARs NSc (105.5 ± S.D. 11.2 dB re 1 μPa), intermediate at DASAR NSb (104.4 ± 10.4 dB), and lowest at DASAR NSa (103.9 ± 8.5 dB). As in 2008 and some other previous years, DASAR NSc (southeasternmost) was chosen to be most representative of Northstar sounds because its location was closest to the path taken by tugs and barges and other vessels arriving at Northstar, and vessels are one of the most important sources of sound associated with the Northstar operation (Blackwell and Greene 2006).

The signals from DASAR NSc were analyzed to determine the broadband (10–450 Hz) level of underwater sound based on a one-minute sample every 4.37 minutes. This is the same descriptive technique used since 2001 (see Chapter 2). Figure 3.1B shows the received levels of broadband (10–450 Hz) sound as recorded in 2009 by DASAR NSc, located ~450 m northeast of Northstar (see Chapter 2, Fig. 2.3). The range of broadband levels shown for 2009 is 84–138 dB re 1 μPa. This variation in received levels was correlated with wind speed, which is related to sea state. Figure 3.1A shows mean hourly wind speed as recorded by the Prudhoe Bay weather station (70.4° lat N, 148.517° long W, elevation 15 m=50 ft), during the period 25 Aug–28 Sep 2009. The lowest sound levels in the time series (Fig. 3.1B) are indicative of the quietest times in the water near the island, and generally correspond to times with low wind speeds (Fig. 3.1A). Conversely, times of high wind speed (e.g., 9 or 21–22 Sep) usually correspond to increased broadband levels in the DASAR record. Mean hourly wind speed in 2009 (calculated over the period 31 Aug–30 Sep) was 7.9 m/s (17.7 mph). This is ~10% higher than in 2008 (7.2 m/s or 16.2 mph) and 21% lower than in 2007 (10.0 m/s or 22.3 mph), over the same period and at the same weather station. Figure 3.2

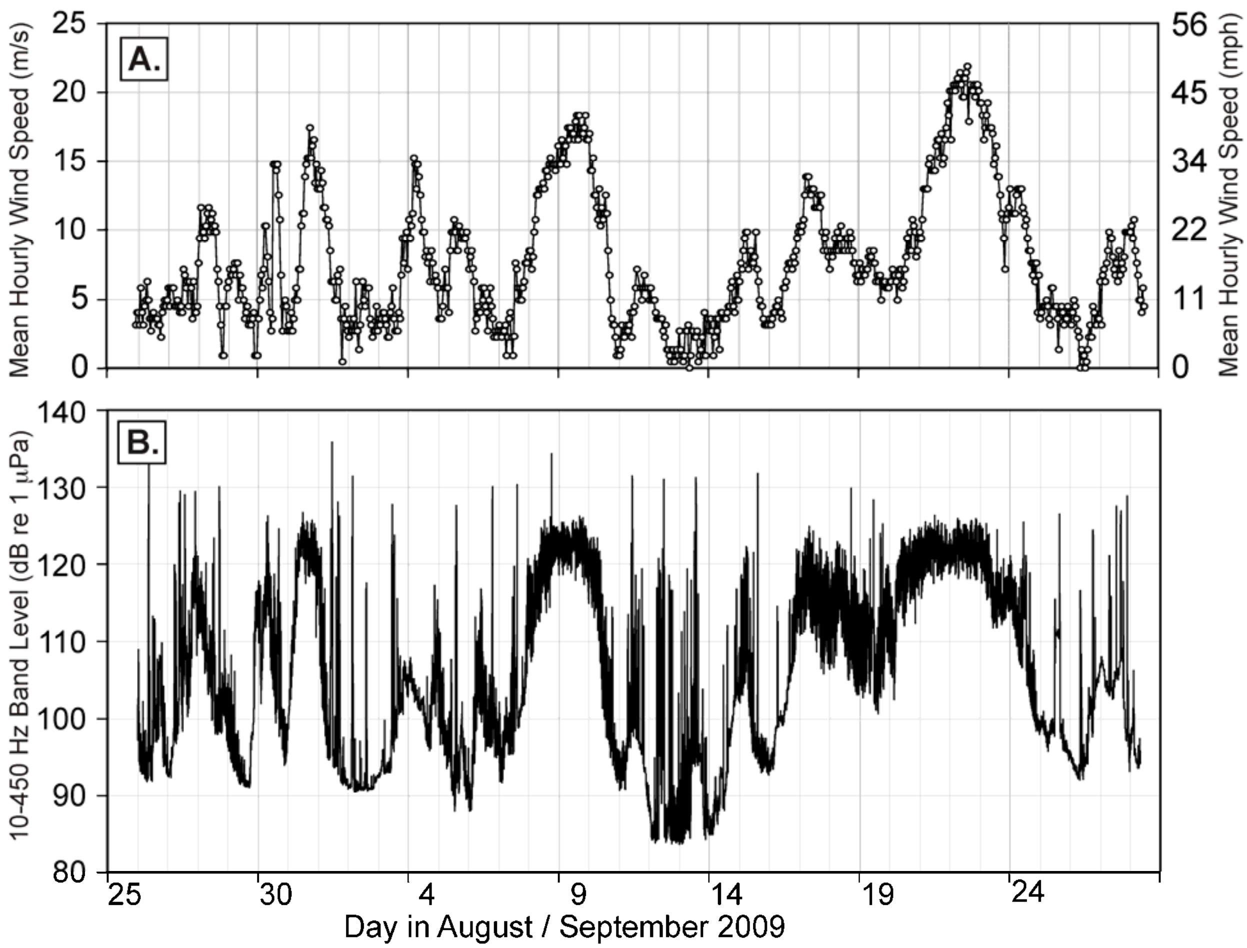

FIGURE 3.1. Variation in levels of underwater sound near Northstar in relation to date and wind speed, 25 Aug–28 Sep 2009. ***(A)*** Mean hourly wind speed as recorded by the Prudhoe Bay weather station (see text for more information). ***(B)*** Broadband (10–450 Hz) levels of underwater sound (1-min averages) near Northstar vs. time, as recorded by DASAR NSc, located ~450 m north of the island. Vertical spikes in the sound pressure time series are generally produced by vessels arriving at or departing the island.

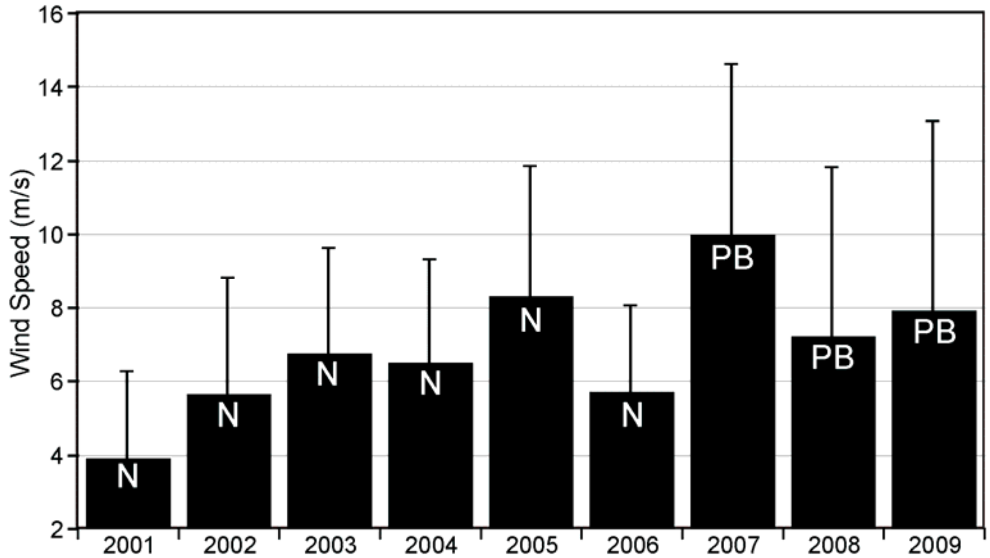

FIGURE 3.2. Mean wind speed for the period 31 Aug–30 Sep in 2001–2009, plus one standard deviation. Data for 2001–2006 were collected by the Northstar (N) weather station, and data for 2007–2009 were collected by the Prudhoe Bay (PB) weather station.

summarizes mean wind speed (31 Aug–30 Sep) in each year of the Northstar study, as recorded by the Northstar[2] (2001–2006) or Prudhoe Bay (2007–2009) weather stations.

Figure 3.3 compares broadband levels, as recorded ~450 m northeast of the island, over nine seasons of monitoring (2001–2009). The number of "vessel spikes"[3] in 2009 is within the range of numbers detected during other production years (see Table 1.5 and section *Sounds from Specific Island-related Sources*, below). For each year, percentile levels of broadband sound (maximum, 95th, 50th, and 5th percentile, and minimum) were computed over the entire field season and are summarized in Table 3.1. Figure 3.4 illustrates how the percentiles of broadband sound in 2009 compare to previous years (2001–2008). Percentile levels of broadband sound near Northstar in 2009 were well within the range for 2001–2008 except for the 75th percentile, which was 6.1 dB higher than the maximum for 2001–2007, and 4.6 dB higher than in 2008. The maximum levels in Table 3.1 and Figure 3.4 are mainly determined by the presence of vessels. Therefore these maximum values could be underestimated, since a vessel such as a tug traveling or maneuvering close to a near-island DASAR could overload the sensor.

During the 2008 field season a new popping sound appeared on the near-island DASARs. Bearings obtained from the three near-island DASARs suggested that "pops" originated at or close to Northstar (Blackwell et al. 2009). "Pops" were also detected during the 2009 field season, and are described in more detail in the section *Sounds from Specific Island-related Sources* below. To get a better estimate of the levels of sound at Northstar in the absence of pops, a "minimum broadband level" was obtained for near-island DASAR NSc by calculating broadband levels (10–450 Hz) every second over a 2-s interval (i.e., 50% overlap between samples, see section *Broadband, Narrowband, and One-third Octave Band Levels* in

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[2] The Northstar weather station was dismantled after the 2006 open-water season. The Northstar and Prudhoe Bay weather stations are located about 12 km apart.

[3] A "vessel spike" is defined as a rapid increase and then a rapid decrease in received levels, causing a vertical line on a long-duration sound pressure time series such as Figure 3.3, with the event usually lasting less than 30 min. A vessel approaching and docking at Northstar causes a vessel spike on the records from the near-island DASARs.

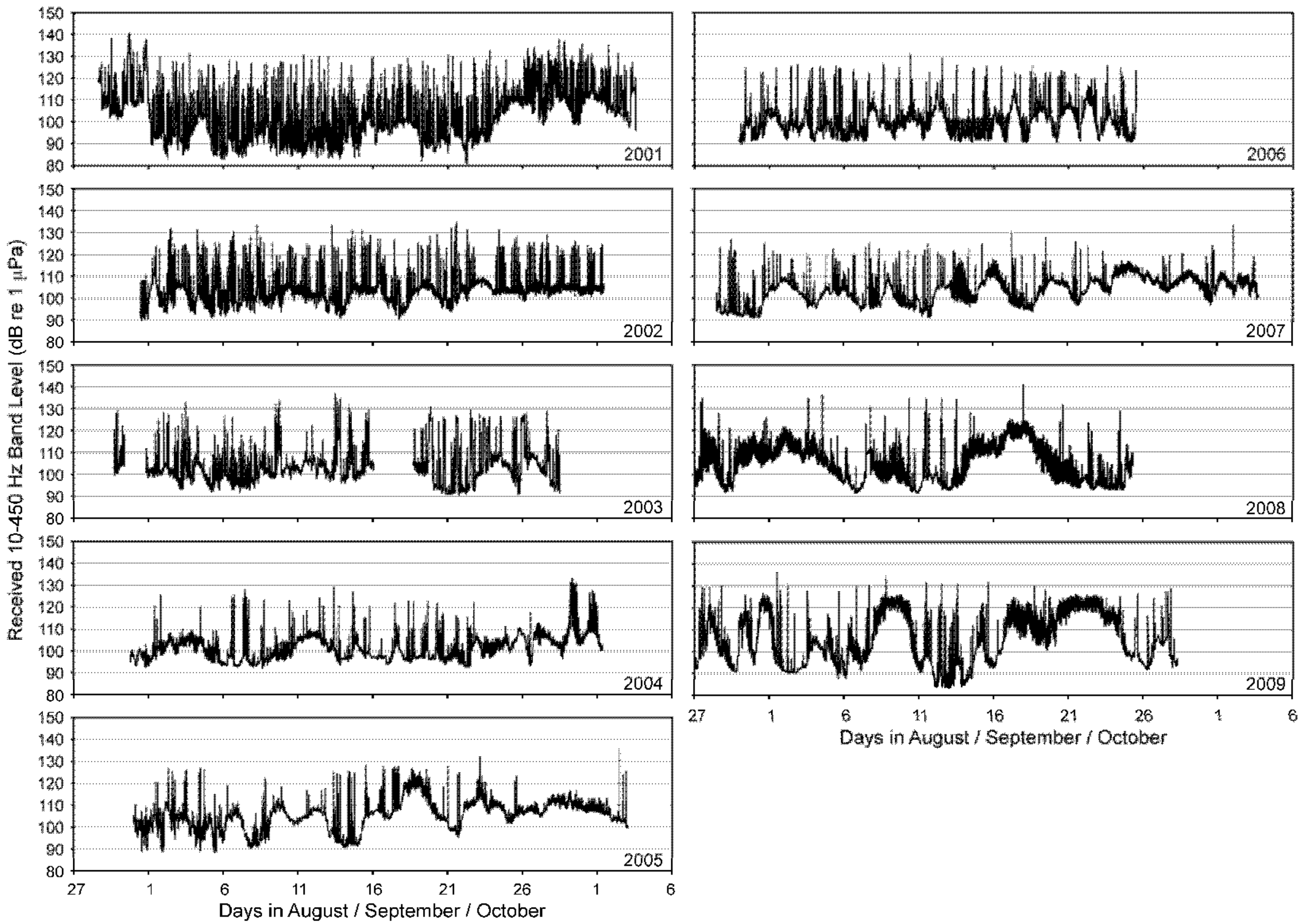

FIGURE 3.3. Sound pressure time series (10–450 Hz band; 1-min averages) for the entire 2001–2009 late summer / early autumn field seasons, as recorded ~450 m north to northeast of Northstar. The recorders were a cabled hydrophone in 2001, 2002, and the first part of 2003, and a DASAR for the second part of 2003 and 2004–2009.

TABLE 3.1. Percentile levels, in dB re 1 μPa, of broadband (10–450 Hz; 1-min averages) underwater sound recorded near Northstar Island during late summer / early autumn, 2001–2009. In 2001 (1–21 Sep) and 2002 (31 Aug–23 Sep), data were collected by cabled hydrophone (CH) #2. In 2003, data were recorded both by CH #2 (29 Aug–16 Sep) and DASAR NS (18–28 Sep). In 2004, 2005, 2006, 2007, and 2008 data were recorded, respectively, by DASAR NSa (30 Aug–1 Oct), DASAR NSb (1 Sep–2 Oct), DASAR NSc (30 Aug–25 Sep), DASAR NSb (28 Aug–3 Oct), and DASAR NSc (27 Aug–25 Sep). In 2009, data were recorded by DASAR NSc (26 Aug–28 Sep). "Range" is the difference between maximum and minimum. All hydrophones were at similar distances (410–550 m or 1345–1804 ft) north of Northstar.

	2001	2002	2003		2004	2005	2006	2007	2008	2009
	CH #2	CH #2	CH #2	NS	NSa	NSb	NSc	NSb	NSc	NSc
Max	140.5	135.0	136.8	131.1	133.1	135.8	131.4	133.3	141.1	137.9
95th %ile	122.7	117.3	116.7	125.1	110.1	118.2	111.4	112.5	119.4	123.0
50th %ile	101.8	103.5	101.8	103.4	100.5	105.5	98.7	104.0	103.6	103.9
5th %ile	87.3	94.8	95.2	91.7	93.7	92.4	91.7	93.4	93.2	89.9
Min	80.8	89.7	91.8	90.4	92.0	88.0	89.8	90.9	91.0	83.6
Range	59.7	45.3	45.0	40.7	41.1	47.8	41.6	42.8	50.0	54.3

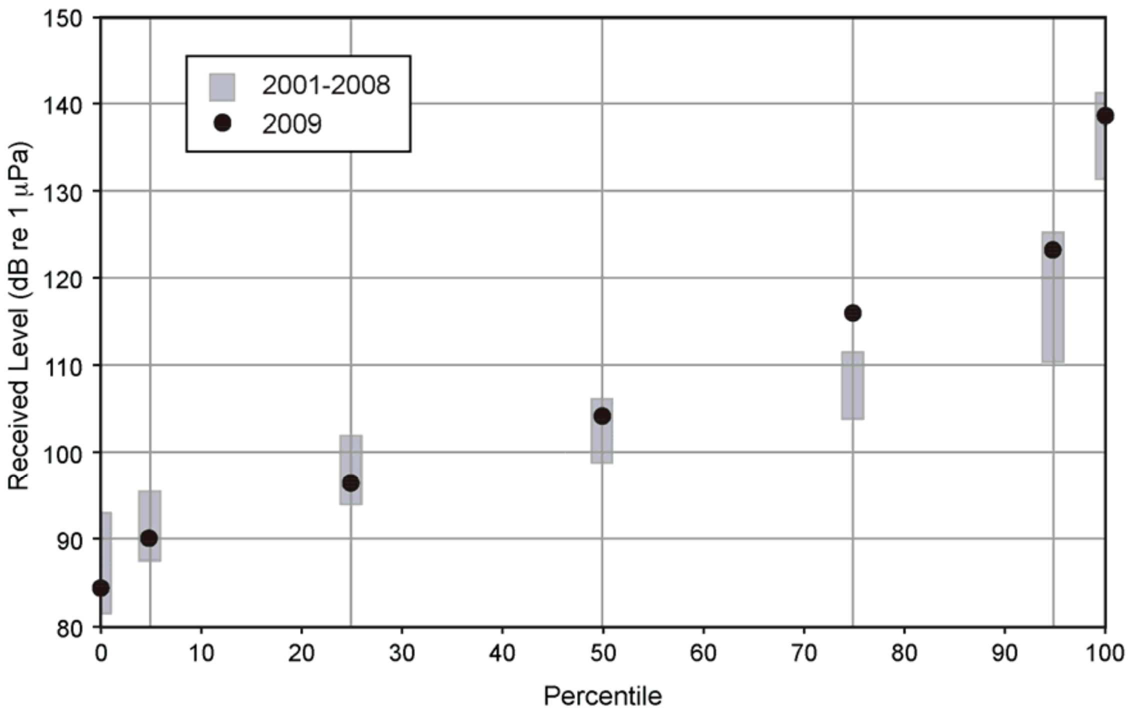

FIGURE 3.4. Percentile levels of broadband (10–450 Hz) sound at DASAR NSc in 2009 (black dots) compared to the range of values for the period 2001–2008 (gray bars). For each year the minimum, 5th, 25th, 50th, 75th, and maximum percentiles were calculated using data collected over the entire field season (7551–11,906 sampled minutes per year).

Chapter 2) and keeping the lowest value per 10-min period. The results of this analysis are shown in Figure 3.5, together with the standard analysis of Northstar sounds (1 min average every 4.37 min) that was shown in Figure 3.1. Mean received levels were 7.4 dB lower for the 2-s minimum analysis compared to the standard analysis (98.1 dB vs. 105.5 dB re 1 μPa, respectively). For comparison, in 2008 the difference between the minimum and standard broadband levels was 5.9 dB. In 2007, a year without pops, mean received levels were 3.4 dB lower for the minimum analysis as compared to the standard analysis. This supports what can be seen by eye in Figure 3.3, i.e., that short-term variability in sound levels at DASAR NSc—as shown by the width ("thickness") of the sound pressure time series line in Figure 3.3—was generally higher in 2008 and 2009 than in several earlier years.

Broadband Sounds Offshore

Sounds recorded by a selection of offshore DASARs (also referred to as "array DASARs") were analyzed in the same two ways as the near-island sounds shown in Figure 3.5, i.e., • average levels over one min every 4.37 min (our "standard" analysis), and • minimum level for each 10-min period, based on 2-s averages computed every second (see Chapter 2 for more details). These two types of broadband (10–450 Hz) levels are shown in Figure 3.6 for five DASARs spanning the entire southwest-to-northeast extent of the array: DASARs A, C, E, G, and J (see Fig. 2.2). These five DASARs were 8.6 km, 14.8 km, 21.5 km, 28.4 km, and 38.4 km from Northstar, respectively (or 5.4 mi, 9.2 mi, 13.4 mi, 17.6 mi, and 23.9 mi). Sea state, and therefore wind speed, determines "baseline" levels of sound. For the standard analysis, baseline refers to the lower edge of the envelope around the plotted SPL (sound pressure level) time series. The minimum level plot also represents a different (and lower) baseline. The five array DASARs shown in Figure 3.6 recorded similar baseline levels, which parallel seasonal variations in wind speed (Fig. 3.6, top), and also parallel the overall shape of the sound pressure time series near the island (Fig. 3.5). Mean broadband

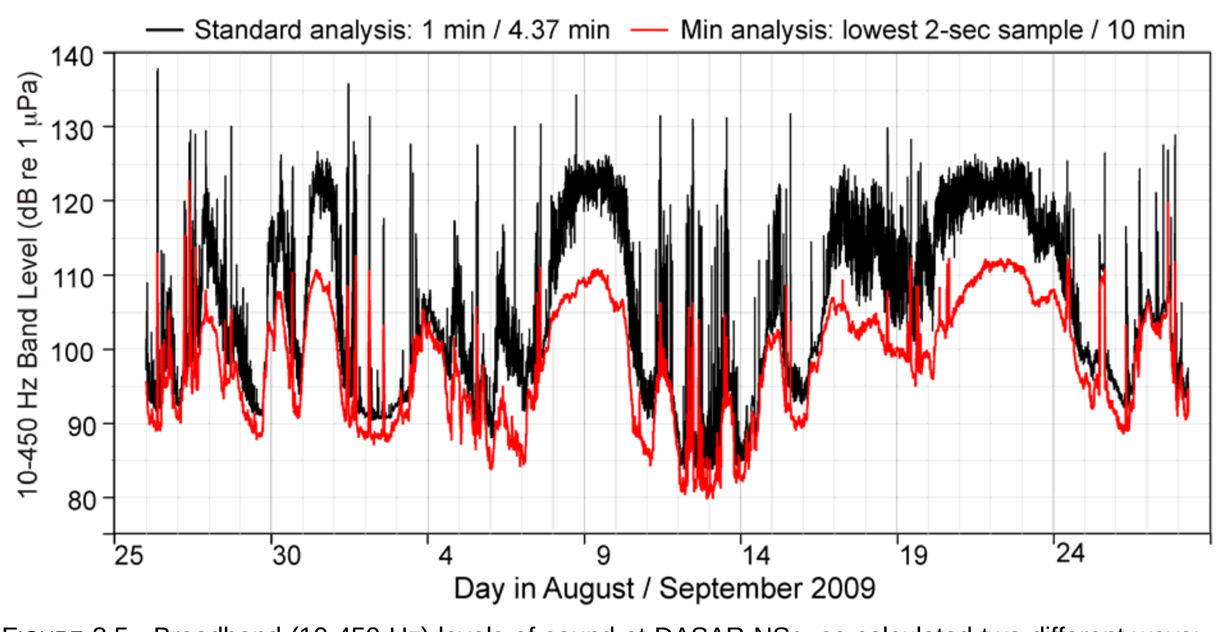

FIGURE 3.5. Broadband (10-450 Hz) levels of sound at DASAR NSc, as calculated two different ways: ***(1)*** "Standard method" (black line): average over one min every 4.37 min (see Fig. 3.1); ***(2)*** "Minimum method" (red line): lowest 2-s sample for every 10 min period. See text for more information.

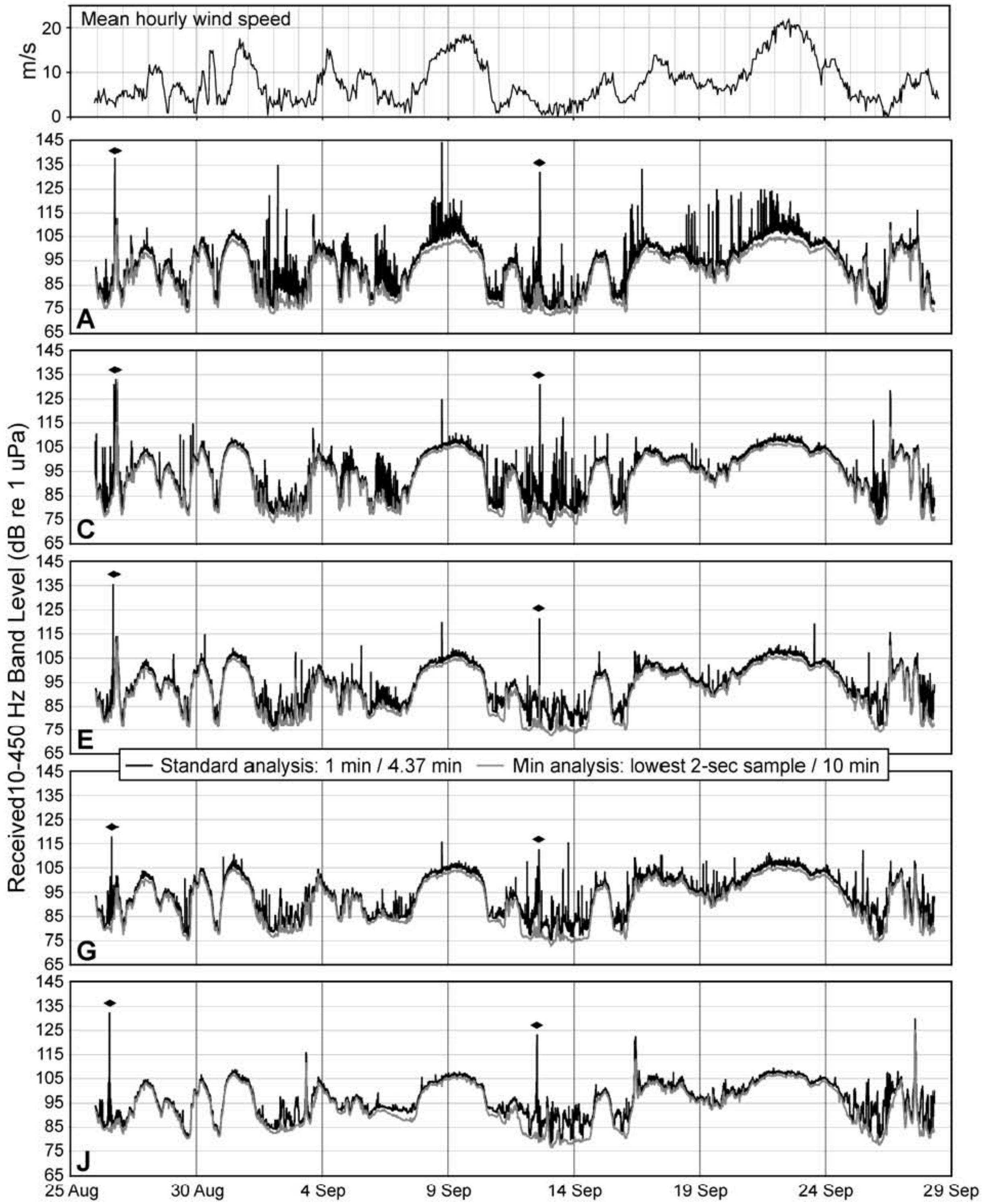

FIGURE 3.6. Broadband (10–450 Hz) levels of sound at five array DASARs (from top to bottom: A, C, E, G, and J), 26 Aug–28 Sep 2009, as calculated using either the "standard method" (black line, average over one min every 4.37 min) or the "minimum method" (red line, lowest 2-s sample for every 10-min period). Diamonds indicate sound spikes created by the acoustic crew's vessel during DASAR health checks on 26 Aug and 12 Sep. Mean hourly wind speed at the Prudhoe Bay weather station is also shown in the top plot.

level[4] (26 Aug–28 Sep) for DASARs A, C, E, G, and J was 93.3 dB, 94.4 dB, 94.0 dB, 93.6 dB, and 96.4 dB, i.e., mean received levels at various offshore DASARs did not vary much with distance from Northstar, except for a slightly higher average at the northernmost DASAR (J), the one farthest from Northstar. These results do not support the notion that Northstar was a large contributor to sound levels offshore given that the mean received levels did not decrease with distance from the island.

During DASAR health checks, the acoustic crew's vessel was stationed above each DASAR in turn, creating sound "spikes" with received levels (at the nearby DASAR) in the range 113–140 dB re 1 μPa. These sound spikes are shown with diamond symbols in Figure 3.6.

For most of the array DASARs in Figure 3.6 (i.e., C, E, G, and J), the mean and minimum lines are close to each other, separated (on average) by less than 3 dB (range 2.6–3.0 dB, see Annex 3.1). The difference between mean and minimum levels was slightly greater at array DASAR A (3.6 dB), and greatest at the near-Northstar DASAR NSc (7.4 dB). The more frequent presence near Northstar of transient sound sources, such as vessels, other industrial activities, or "pops", created short-term fluctuations in received levels and these are the most likely explanation for the larger average difference between mean and minimum levels close to Northstar. Sounds of man-made origin that are recorded at DASAR A could in part originate at Northstar and but could also in part be due to non-Northstar-related vessel traffic, whereas most man-made sound recorded at near-island DASAR NSc is believed to be from Northstar-related sources.

The layout of the DASAR array in 2009 was the same as in 2008 but different from previous years, with greater spacing between DASARs in 2008–2009 than before (7 km vs. 5 km or 4.3 mi vs. 3.1 mi) and a northeasterly double row of recorders instead of the two overlapping hexagons used in 2001–04 (see Fig. 2.1). However, one geographic location has included a functional DASAR each field season since 2001: referred to as location EB up to 2007 and location C since 2008. Comparison of the acoustic records from this location gives us the opportunity to look at the variability in broadband sound levels 14.8 km (9.2 mi) offshore of Northstar since 2001. This comparison is shown in Figure 3.7. Baseline levels of sound at location C / EB in 2009 were somewhat higher than in 2008, but similar to 2005. Mean wind speed in 2009 was about 10% higher than in 2008 and could have contributed to this increase. Figure 3.8 shows percentile levels of broadband sound at C / EB in 2009 compared to the range of values in previous years. The minimum and 25th percentile broadband values were lower in 2009 than in any previous year, and other percentiles were well within the range of previous years (Fig. 3.8).

Figure 3.9 compares broadband sounds near Northstar with those recorded in the array by placing the data for DASARs NSc (near-island) and DASAR C / EB on the same plot. Because wind is the most important determinant of baseline sound levels, average hourly wind speed as recorded at the Prudhoe Bay weather station is also shown. Baseline levels at these DASARs tended to parallel the wind speed plot and one another. However, the baseline levels near Northstar tended to be higher, and upward excursions of the sound level above the baseline were more frequent and stronger near Northstar, indicative of the greater prominence of fluctuating man-made sounds (e.g., vessels) near Northstar than offshore.

STATISTICAL SPECTRA OF NEAR-ISLAND AND OFFSHORE SOUNDS

To characterize the frequency composition of sounds near Northstar and offshore during the study period in 2009, percentile distributions of one-third octave band levels and spectral density levels were calculated for three DASARs: NSc (near-island), A (offshore, farthest south of array DASARs), and J

[4] Because of the large number of sound levels presented in this Chapter for six different DASARs, they are all summarized in Annex 3.1.

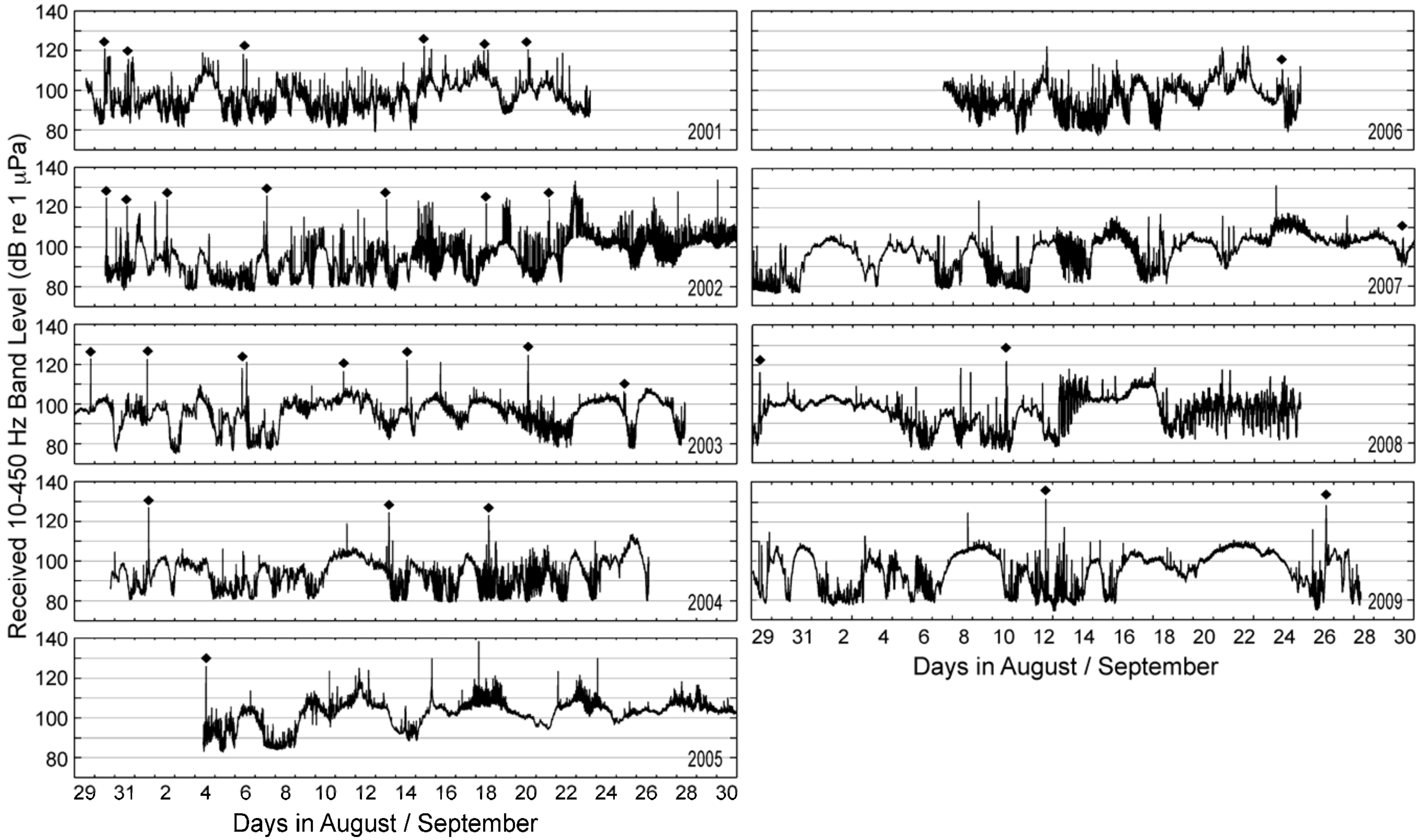

FIGURE 3.7. Broadband sound pressure time series (10–450 Hz band; 1-min averages) at a DASAR location 14.8 km (9.2 mi) from Northstar during nine consecutive years, 2001–2009. This DASAR location was called EB in 2001–2007 and C in 2008–2009. Diamonds indicate sound spikes created by the acoustic crew's vessel during servicing of the array of DASARs.

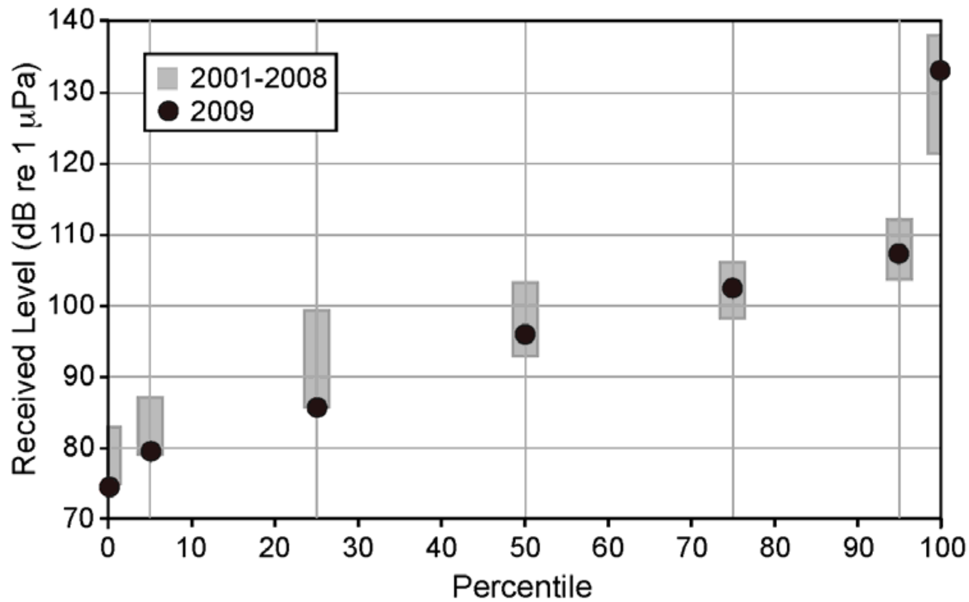

FIGURE 3.8. Percentile levels of broadband (10–450 Hz) sound at DASAR C (=EB in 2001–2007) in 2009 (black dots) compared to the range of values at the same site for the period 2001–2008 (gray bars). For each year the minimum, 5th, 25th, 50th, 75th, and maximum percentiles were calculated using 1-min average values collected over the entire field season (5862–11,906 sampled minutes per year).

(offshore, farthest north of array DASARs, see Fig. 2.2). In all cases, the measurements were averages over 1 min. These plots are two different ways of looking at the same data: one-third octave bands are mainly shown because they are believed to be most relevant to marine mammal hearing (for a review see Richardson et al. 1995), whereas spectral density levels reveal more details on the frequency composition of the sounds emanating from the island. Figure 3.10 shows one-third octave bands and Figure 3.11 shows spectral density levels. Overall, the spectra for Northstar (top plots in both figures) are similar to those from previous years[5]. For example, as in previous years, peaks were present at 30 Hz and 60 Hz—these peaks have been present every year of monitoring and are associated with generation of 60 Hz power. However, the 87 Hz peak, which has been present in the near-island recordings since 2003, only appeared weakly in the 50th percentile data for 2009 (Figure 3.11).

Figure 3.10 shows percentile one-third octave band levels. The main difference between the top plot (near Northstar) and the two bottom plots (in the array) is the presence of a “hump” at the one-third octave bands centered at 31.5 Hz, 40 Hz, 50 Hz, and 63 Hz. This hump is only visible in the minimum and 5th percentile lines. The sound contained in these frequencies is largely of anthropogenic origin, at least when ambient levels are low. It is this observation that led to the definition of the industrial sound index *ISI_5band* in 2001 (Blackwell 2003).[6] Note however that compared to array DASAR A (Fig. 3.10, middle plot), the minimum, 5th, 50th, and 95th percentile one-third octave band levels are elevated at Northstar (Fig. 3.10, top) across the entire frequency range. Also, offshore at DASAR J (Fig. 3.10, bottom plot), the

[5] 2007: Fig. 2.9 in Blackwell et al. (2008); 2006: Fig. 2.7 in Blackwell et al. (2007a); 2005: Fig. 2.8 in Blackwell et al. (2006c); 2004: Fig. 8.9 in Blackwell et al. (2006b); 2003: Fig. 7.16 in Blackwell et al. (2006a); 2002: Fig. 6.19 in Blackwell (2003); 2001: Fig. 7.19 in Blackwell and Greene (2002).

[6] As defined, *ISI_5band* covers a slightly wider range of one-third octave bands, i.e., those centered at 31.5, 40, 50, 63, and 80 Hz.

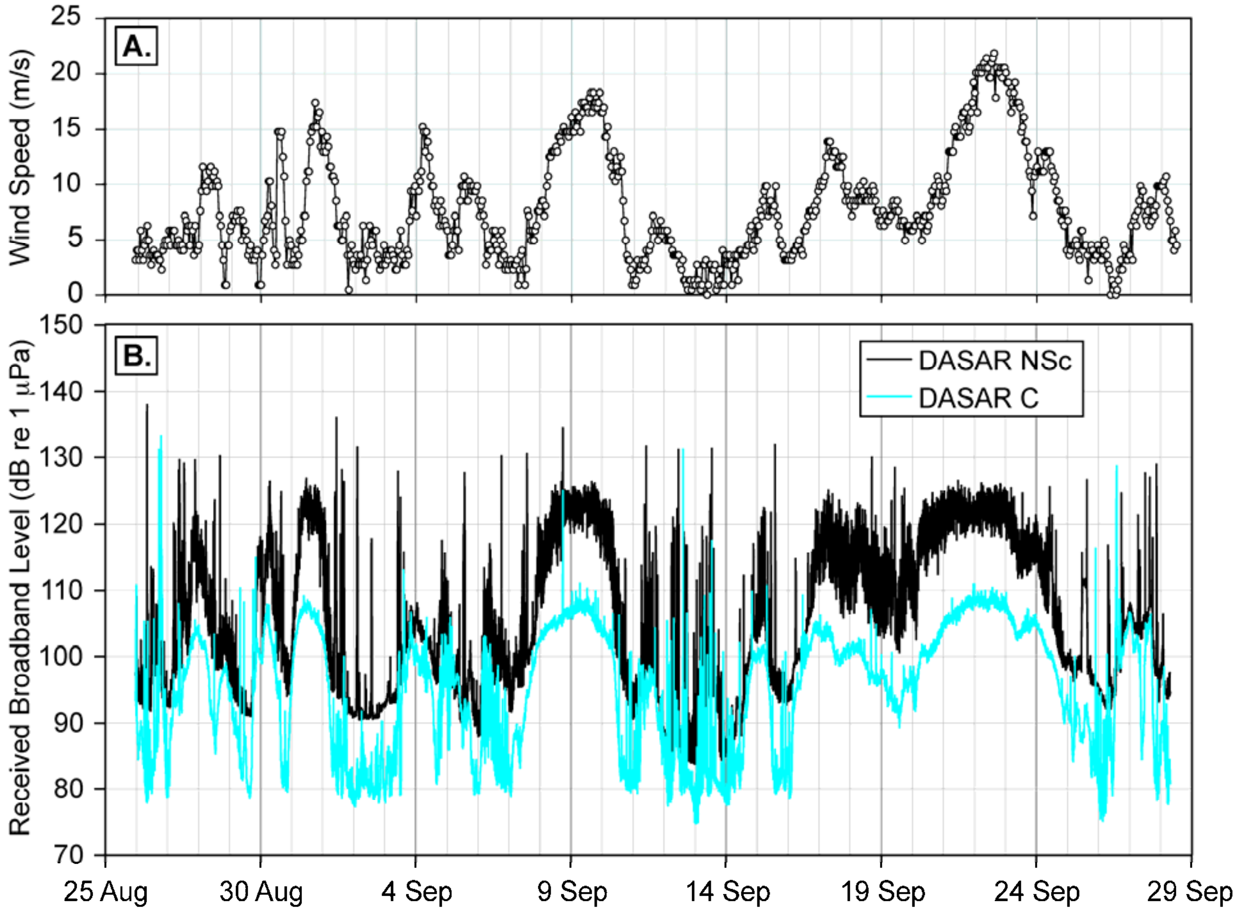

FIGURE 3.9. Sounds close to Northstar and in the DASAR array in relation to wind speed at Prudhoe Bay. ***(A)*** Mean hourly wind speed during the period 25 Aug–28 Sep 2009, as recorded by the Prudhoe Bay weather station. ***(B)*** Broadband sound pressure time series (10–450 Hz band; 1-min averages) at DASAR NSc (~450 m north of Northstar) and DASAR C / EB (~15 km or 9.2 mi northeast of Northstar) over the same time as in *(A)*.

minimum and 5th percentile levels near 80–250 Hz are higher than at Northstar. We have no information on the source(s) of sound at these frequencies offshore in the array.

The same comparison can be made for the percentile spectral density levels shown in Figure 3.11. The maximum levels can be caused by a single vessel pass, so they are generally not used for comparisons. If we ignore the maximum lines, two aspects distinguish the data from NSc and from the array DASARs: (1) The elevated percentile values (minimum, 5th, 50th and 95th) near Northstar at low frequencies, in the range 10–80 Hz. (2) The presence of tones, which in NSc's case can be identified in the minimum, 5th percentile, and 50th percentile lines.

The percentile spectral density plots (Fig. 3.11) allow us to estimate how far from the island tones characteristic of Northstar can be detected. Near Northstar, the 60 Hz power frequency tone is present in the underwater sound all the time, unless the island shuts down completely, which did not happen during our study period. The top plot in Figure 3.11 shows that at least half the time (50th percentile) the received levels for the 30 and 60 Hz tones are above the levels at other nearby frequencies, i.e., these tones are easily detected. In contrast, the percentile spectral density plot for the array DASAR closest to Northstar (A,

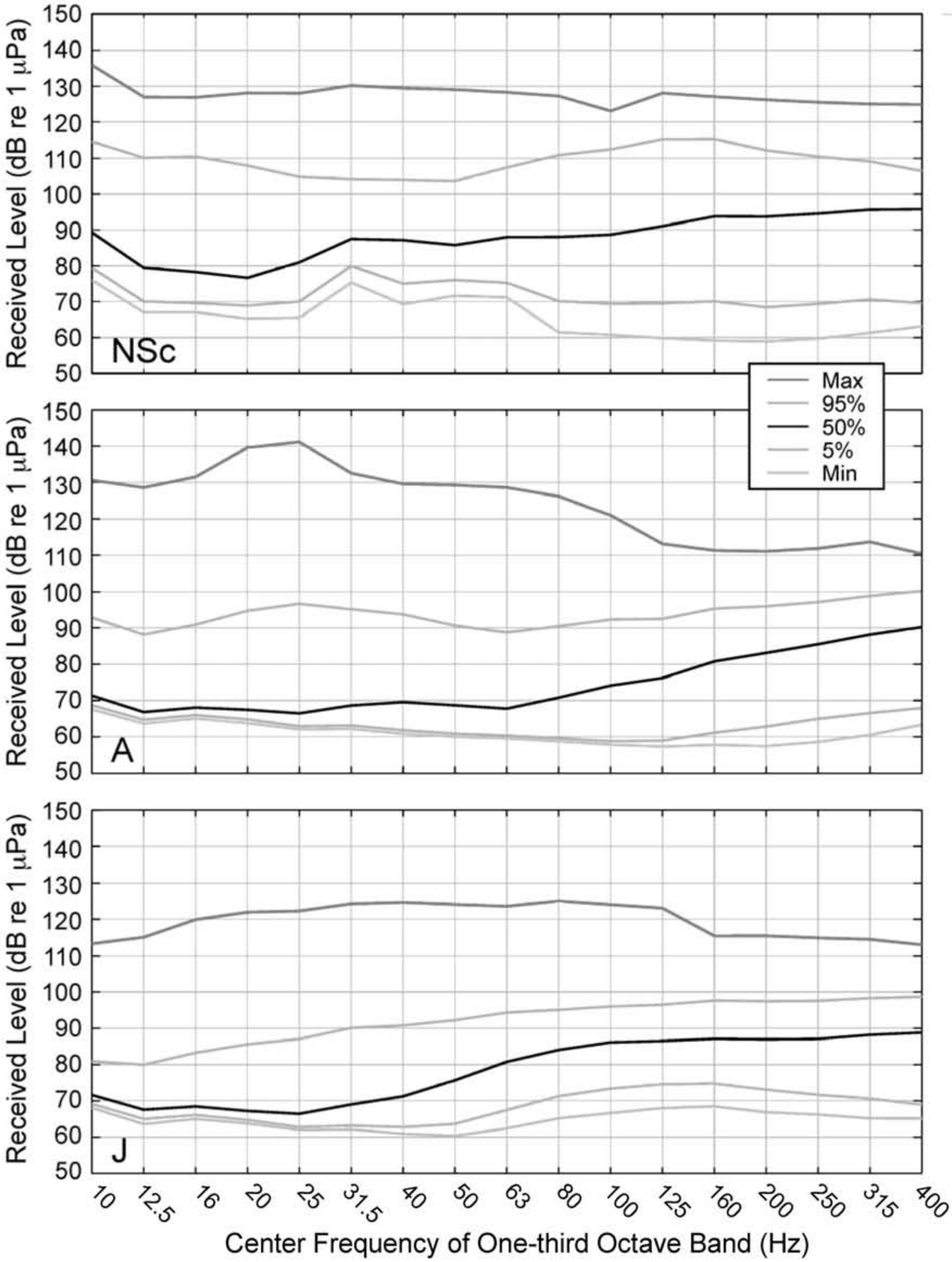

FIGURE 3.10. Percentile one-third octave band levels for sounds recorded by DASARs NSc (near-island, top), A (southernmost DASAR in offshore array, center), and J (northernmost DASAR in offshore array, bottom) during the period 26 Aug–28 Sep 2009. In these plots the five curves show, for each frequency, the minimum, the 5th, 50th, 95th percentiles, and the maximum of the 1-min averages. For all plots the number of 1-min measurements used was 10,986.

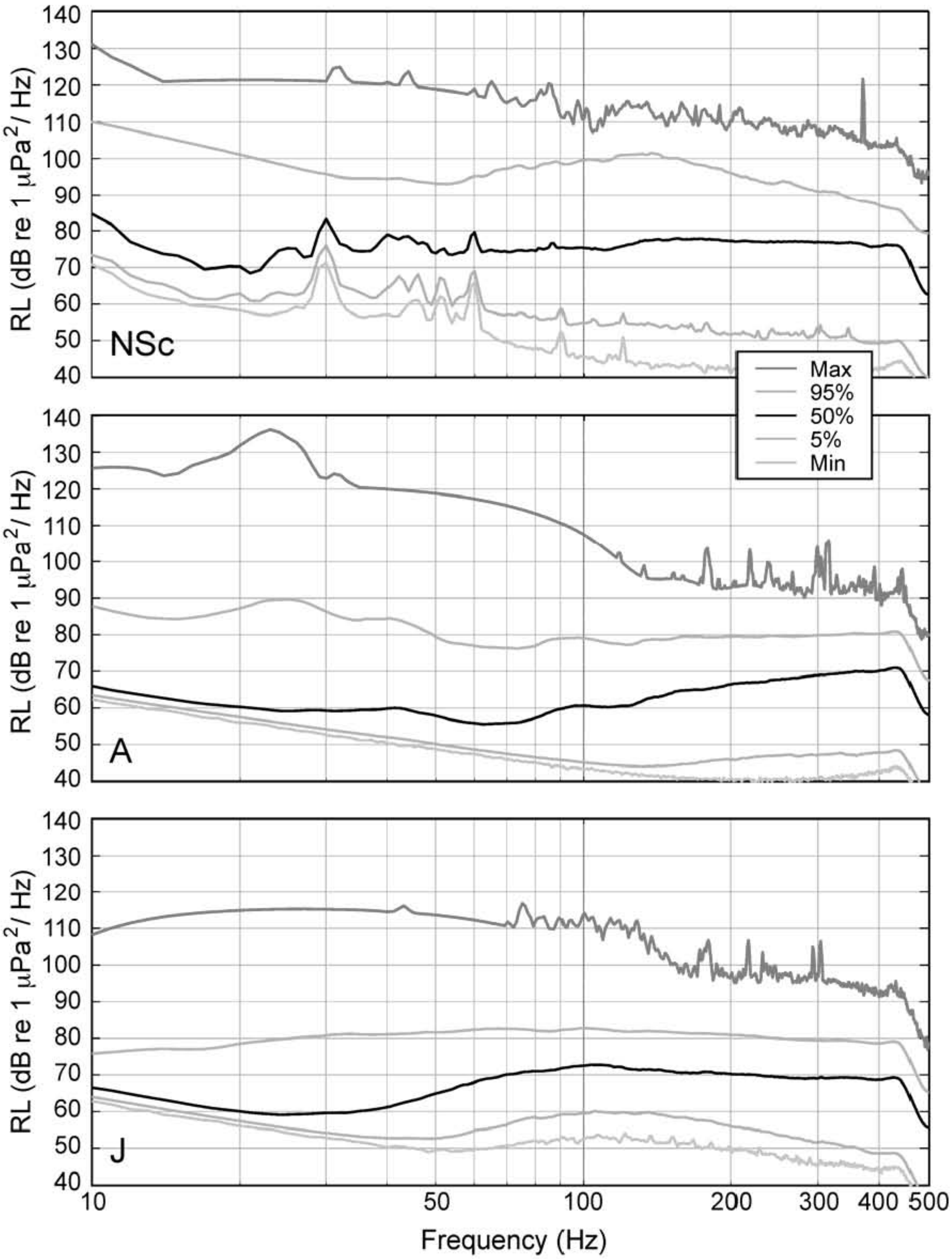

FIGURE 3.11. Percentile spectral density levels for sounds recorded by DASARs NSc (near-island, top), A (southernmost DASAR in offshore array, center), and J (northernmost DASAR in offshore array, bottom) during the period 26 Aug–28 Sep 2009. In these plots the five curves show, for each frequency, the minimum, the 5th, 50th, 95th percentiles, and the maximum of the 1-min averages. For all plots the number of 1-min measurements used was 10,986.

8.6 km or 5.4 mi from the island), shown in the middle plot in Figure 3.11, shows no sign of a 30 or 60 Hz tone (or any other tone) even in the minimum line, which represents the time of lowest background sound during the entire recording period. Similarly, no Northstar-related tones were evident at DASAR J.

INDUSTRIAL SOUND INDICES (ISIS) OF NEAR-ISLAND AND OFFSHORE SOUNDS

ISI_5band

ISI_5band is an Industrial Sound Index (ISI) that was designed to represent the occurrence of low frequencies—typical of industrial activities—in the sounds emanating from Northstar. *ISI_5band* was calculated by adding together the mean square sound pressures in the one-third octave bands centered at 31.5, 40, 50, 63 and 80 Hz (i.e., the 28 to 90 Hz frequency range). Each measurement was for a 1-min interval. Figure 3.12 shows *ISI_5band* values for DASARs NSc, A, C, E, G, and J. Not surprisingly, *ISI_5band* levels were higher near Northstar than in the offshore array, by 11–19 dB on average. Generally, *ISI_5band* was closely related to the overall 10–450 Hz level (compare Fig. 3.12 with Figs. 3.1B and 3.6), but *ISI_5band* tended to be a few decibels lower. This is an expected consequence of the fact that *ISI_5band* excludes sound components at frequencies 10–28 Hz and 90–450 Hz, which are included in the corresponding broadband data. Direct comparison of the two values showed that, in 2009, the mean 1-min *ISI_5band* value at NSc was 7.8 dB below the mean 10–450 Hz broadband value (Annex 3.1). The corresponding difference was 5.7 dB in 2003, 5.0 dB in 2004, 5.7 dB in 2005, 4.2 dB in 2006, 6.9 dB in 2007, and 8.7 dB in 2008.

The somewhat larger differences between 10–450 Hz levels and *ISI_5band* in 2008 and 2009 relative to earlier years could be due to the presence of "pops" of unknown origin recorded on the near-island recorders in 2008–2009. These pops are a new sound type, detected for the first time in 2008 and identified again in 2009 (see section *Pop Sounds* below). Pops are broadband impulsive sounds with most of their energy outside the 28–90 Hz frequency range (see Fig. 3.19 in Blackwell et al. 2009), so the presence of pops should lead to a greater difference between broadband and *ISI_5band* values of a sample. This hypothesis was tested using 2008 data (Blackwell et al. 2009). The difference between broadband values and *ISI_5band* values was computed for a day with many pops (28 Aug 2008, 00:00–12:00 local time) and another day with few pops (13 Sep 2008, 00:00–12:00). The two days had similar wind speeds. The results lent support to the hypothesis: on 28 Aug 08 the mean difference (± one S.D.) was 13.3 ± 2.4 dB, compared to 4.9 ± 2.1 dB on 13 Sep 08.

The difference between mean broadband level and mean *ISI_5band* level in 2009 was 13.3 dB at DASAR A, 15.0 dB at C, 13.8 dB at E, 15.0 dB at G, and 9.2 dB at J (versus 7.8 dB near Northstar). The difference between these two measures of broadband sound was therefore greater at the array DASARs than near Northstar. This is likely due to two reasons: (1) the fact that near Northstar the 28–90 Hz band level is always somewhat elevated by Northstar itself, thereby *reducing* the difference between broadband levels and *ISI_5band* levels; (2) the presence of airgun pulses on array DASAR records. Airgun pulses contain energy outside of the 28–90 Hz frequency range and would therefore tend to *increase* the difference between mean broadband level and mean *ISI_5band* level. The number of airgun pulses was not assessed for all array DASARs in 2009, but several tens of thousands of airgun pulses were detected at DASAR J (see section *Airgun Pulses* below).

When comparing levels of sound between DASARs NSc and each of the array DASARs, there was a greater difference in the *ISI_5band* levels (10.6–19.2 dB) than in the broadband levels (9.1–11.9 dB, see Annex 3.1). This supports the notion that, as a measure of industrial sounds, *ISI_5band* is better than the broadband level.

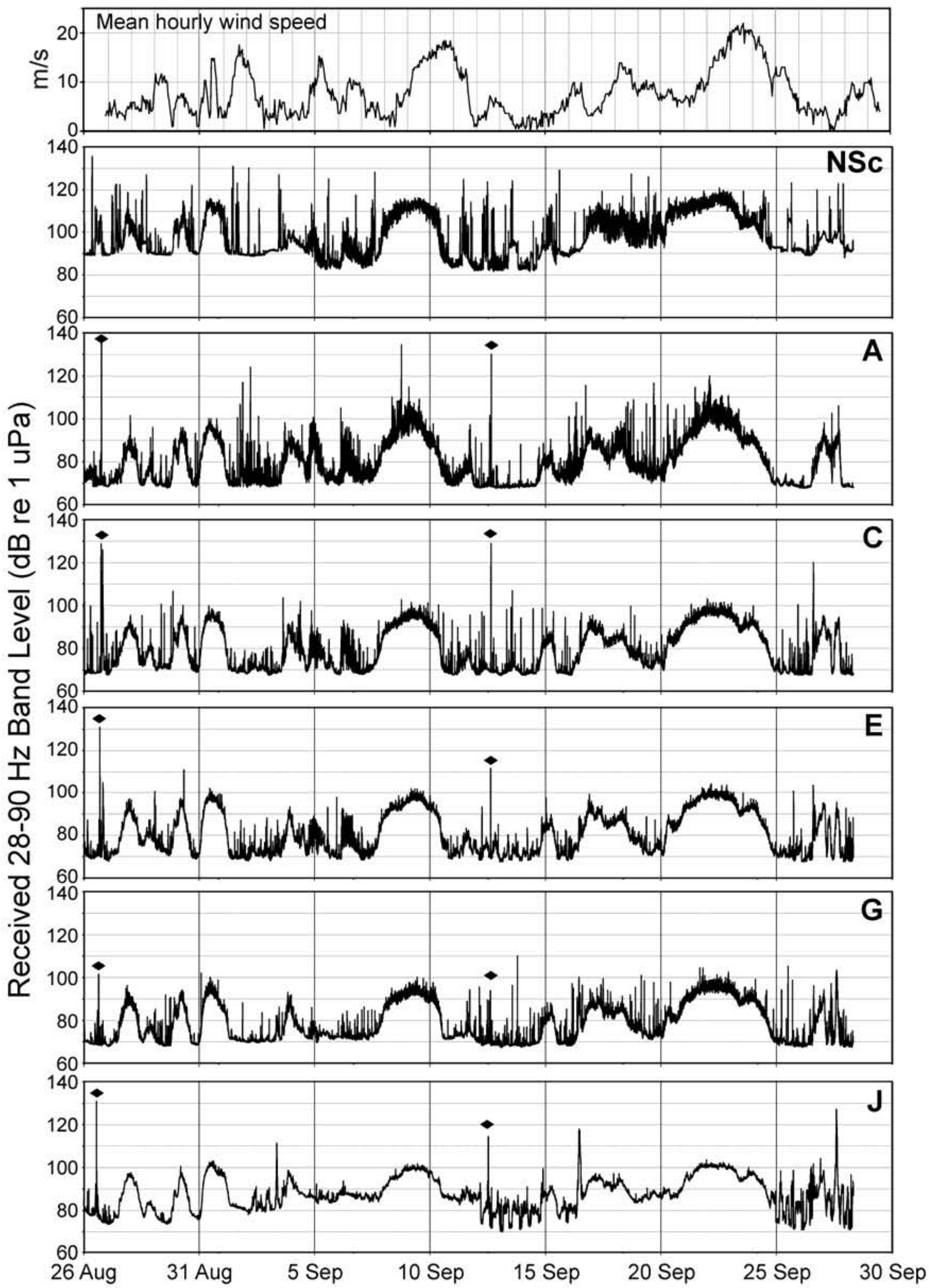

FIGURE 3.12. *ISI_5band* levels (1-min average) as a function of time for near-island DASAR NSc and array DASARs A, C, E, G, and J. Mean hourly wind speed (Prudhoe Bay weather station) is also shown in the top panel. Diamonds indicate sound spikes created by the acoustic crew's vessel during DASAR health checks on 26 Aug and 12 Sep.

There is a condition in which the ISI does not perform well as a measure of low-frequency industrial sound: stormy weather, when background sound levels at all frequencies are high because of wind and wave action. The period 21–23 Sep had the worst weather during the 2009 field season, with mean hourly wind speeds reaching 22 m/s (49 mph, see Fig. 3.1). Sound from wave action is broadband in nature and includes *ISI_5band* frequencies. High winds therefore result in both high broadband levels (Fig. 3.6) and high *ISI_5band* levels (Fig. 3.12). In this case, high *ISI_5band* levels did not indicate high amounts of industrial sounds.

ISI_tone

ISI_tone evaluates the presence and amplitude of tones, which are typical of rotating or vibrating machinery. Most types of large equipment used at Northstar, such as generators, engines of various sorts, vibratory pile-drivers, compactors, etc., are likely to produce tones (Spence 2006). Tones are also produced by vessels such as the tugs used to transport equipment to Northstar (Blackwell and Greene 2006). Figure 3.13 is a graphical representation of the presence of tones near Northstar (DASAR NSc) and in the DASAR array (DASARs A, C, E, G, and J). The entire season's sound record is shown in a spectrogram for each recorder. Black dots denote the times (x-axis) and frequencies (y-axis) at which a tone was detected according to the *ISI_tone* definition (see Chapter 2). Tones are more numerous on NSc's record than on any of the array DASARs. Tones at certain frequencies, like 30 Hz, 60 Hz, and 90 Hz, are present continually for extended periods of time at NSc, creating black horizontal lines on the spectrogram (Fig. 3.13, top left). These tone frequencies can also be seen on the percentile spectral density plot in Figure 3.11.

Times with high levels of sound across the entire DASAR bandwidth appear as reddish vertical bands in Figure 3.13 and closely match days with high wind speeds. For example, compare 31 Aug, 8–9 Sep, and 21–22 Sep in Figures 3.1A and 3.13 (for reference, wind speed is also shown in Fig. 3.6, 3.9, and 3.12). Note that during these times of high wind speeds, sound levels are considerably higher at Northstar (NSc in Fig. 3.13), where the waves pound against the island, than in the array. The detection of tones (shown as black dots in Fig. 3.13) on the array DASAR records coincided with times when background sound levels were lower, i.e., a bluish or greenish background color in the spectrograms. Tones recorded by array DASARs were likely produced by vessels. It is possible that background sounds at higher sea states masked vessel tones that were present, but it also likely that more vessel operations were taking place when sea state was lower. Generally speaking, the presence of tones in the array usually coincided with the presence of tones at Northstar, but the opposite was not true. For example, on 12 and 13 Sep wind speed was low (Fig. 3.1A) and a number of tones were present at Northstar. In contrast, on the array DASAR records, tones were fairly numerous on 12 Sep but scarce on 13 Sep.

The presence of tones was examined in one-min long samples every 4.37 min (see Chapter 2). If no tones were found according to the *ISI_tone* criterion, then *ISI_tone* = 0. Figure 3.14 shows two ways of comparing *ISI_tone* values close to Northstar and in the DASAR array, for 2008 (gray bars and symbols) and 2009 (black bars and symbols). Figure 3.14A shows the percentage of *ISI_tone* samples with a value of 0 (i.e., no tones detected) over the entire deployment period. Figure 3.14B shows the mean *ISI_tone* value for one-min samples that contained tones (i.e., excluding samples for which *ISI_tone* = 0). These two plots demonstrate two main results: (1) tone-producing equipment was operating more frequently at Northstar in 2009 than in 2008, and (2) in general terms, the presence and quantity of tones in the DASAR array were similar in 2008 and 2009, but there were some local tone-producing events that resulted in DASAR-specific differences.

In support of the first point (tone-producing equipment running more often at Northstar in 2009), Figure 3.14A shows that in 2009 56.5% of one-min samples at DASAR NSc had an *ISI_tone* value of 0,

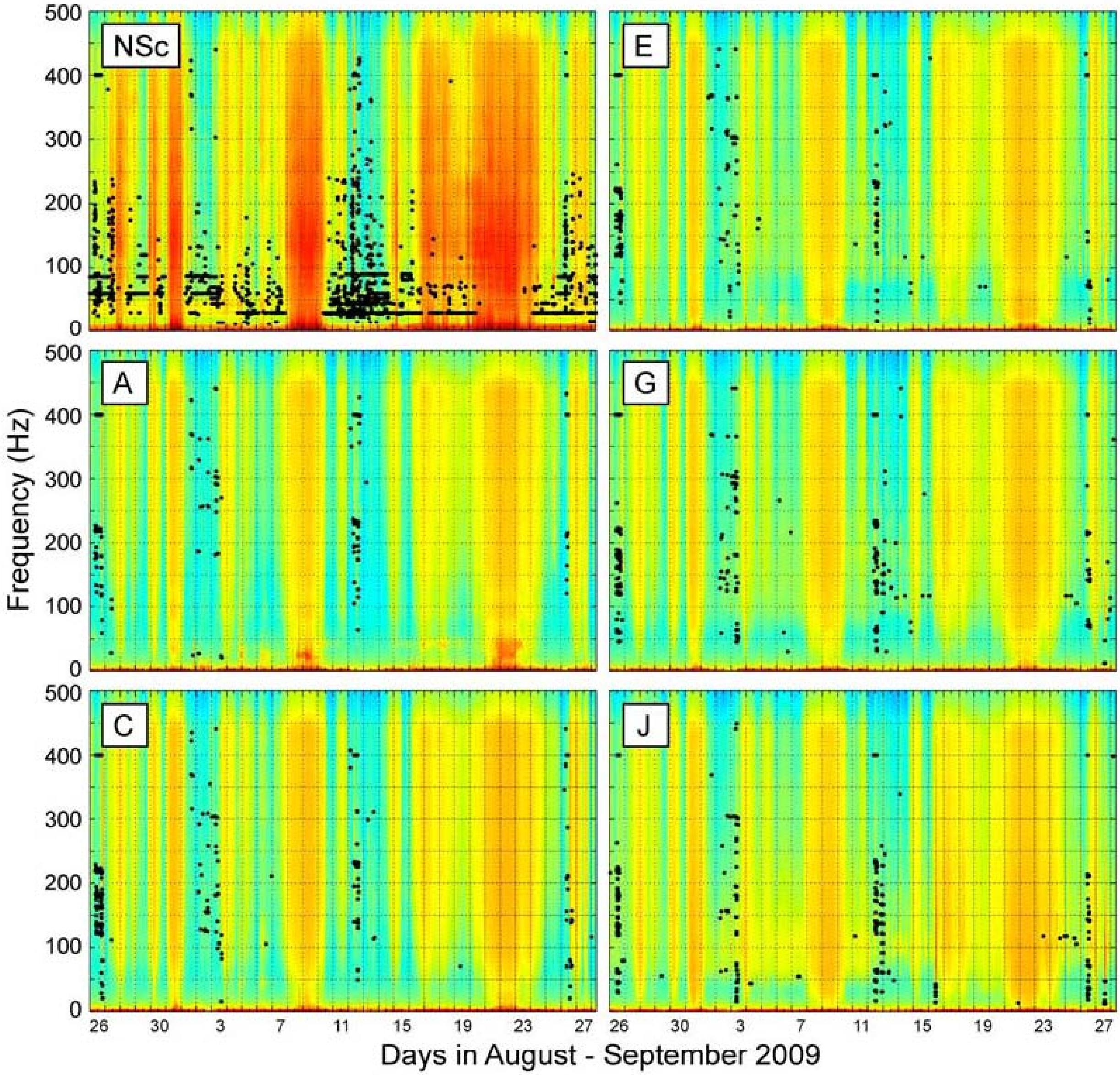

FIGURE 3.13. Spectrograms of the entire 2009 season for DASARs NSc (near-island), A (array DASAR closest to shore), C, E, G, and J (most offshore, see Fig. 2.2). Black dots denote times and frequencies at which tones were identified by the *ISI_tone* algorithm, using a ≥5 dB criterion as described in Chapter 2. Color on the spectrograms varies with received spectrum levels of sound in 1-Hz bins, from low (blue) to high (red).

which is ~9% less than in 2008. Figure 3.14B shows that when excluding tone-free samples, values for NSc in 2008 and 2009 were similar, which indicates that when tone-producing activities were taking place at Northstar, the total amount of "tone energy" was similar.

In support of the second point (similar presence of tones in the DASAR array in 2008 and 2009), Figure 3.14A shows that tones were absent in the array DASARs (A, C, E, G, and J) in 96–98.5% of samples in both years. Greater differences between the two years can however be seen in Figure 3.14B. This figure excludes samples of *ISI_tone* with a value of 0, so it provides a measure of the "sound energy from tones" *when* tone-producing activities—most likely vessels—were present. Figure 3.14B shows that

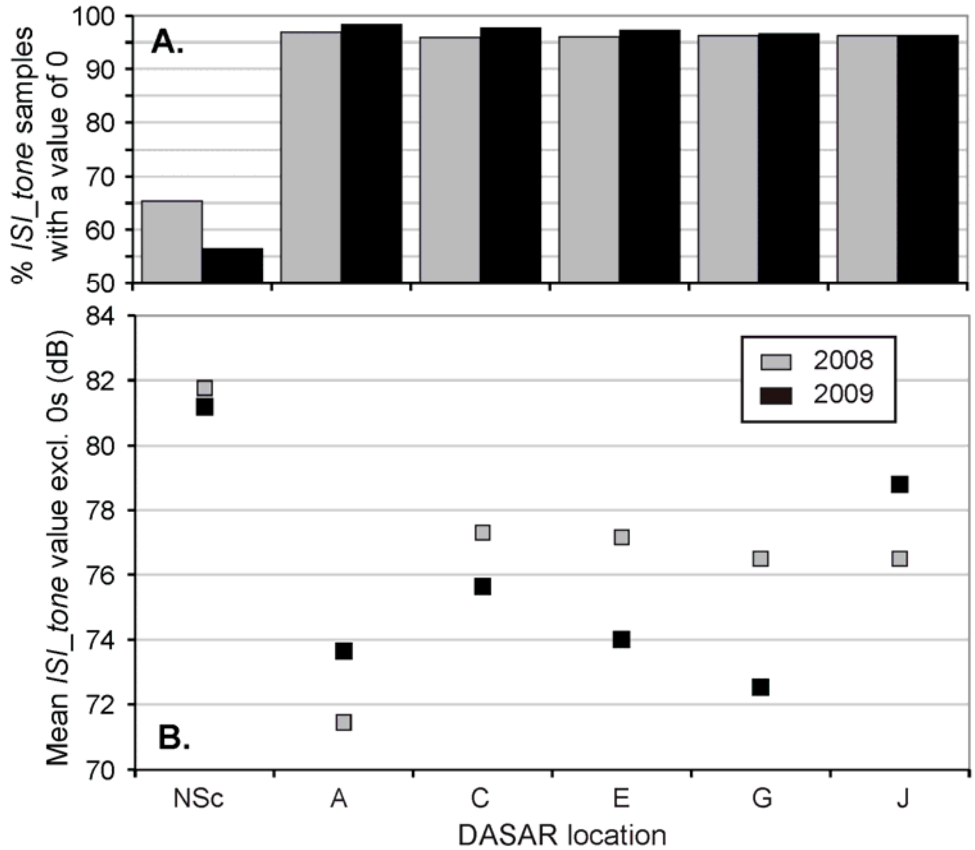

FIGURE 3.14. Comparison of *ISI_tone* values in 2008 (gray symbols and bars) and 2009 (black symbols and bars) for a near-island DASAR (NSc) and five array DASARs (A, C, E, G, and J). ***(A)*** Percentage of *ISI_tone* samples with a value of 0 (no above-threshold tones detected). To be counted as "above threshold", a tone had to have a received level ≥5 dB higher than the level at nearby frequencies (Chapter 2). ***(B)*** Mean *ISI_tone* value (calculated while excluding samples when *ISI_tone*=0) over the entire sea–son for the same six DASARs as shown in *(A)*.

when vessels were present in the DASAR array, the northernmost and southernmost DASARs (A and J) recorded higher *ISI_tone* values in 2009 compared to 2008, whereas the opposite was true at the middle DASARs (C, E, and G). Of all the array recorders DASAR J recorded the highest mean *ISI_tone* value when excluding samples with *ISI_tone*=0. A possible—but unexplored—explanation for this result is that DASAR J may be closer than other array DASARs to where certain types of vessels transit through the area.

ISI_transient

ISI_transient evaluates the presence of broadband transient sounds in the sound record. The most likely source of a transient spike in the sound record is a passing vessel, but it could also be a piece of equipment that is turned on for a period of minutes to hours (if the sound source is on for many hours then the *ISI_transient* algorithm would detect the start of the activity). Figure 3.15 shows *ISI_transient* values (to be read on the right y-axis) for an example day, 11 Sep 2009. Figure 3.15 shows that *ISI_transient*≥5 dB whenever a "spike" occurred in the sound pressure time series. According to vessel records, the sound spikes occurring at about 07:00, 18:30, and 19:30 can be attributed to ACS *Bay* boats making three round-trips to the island, and the spikes occurring between 9:30 and 11:00 (including the highest sound spike of the day) can be attributed to a barge.

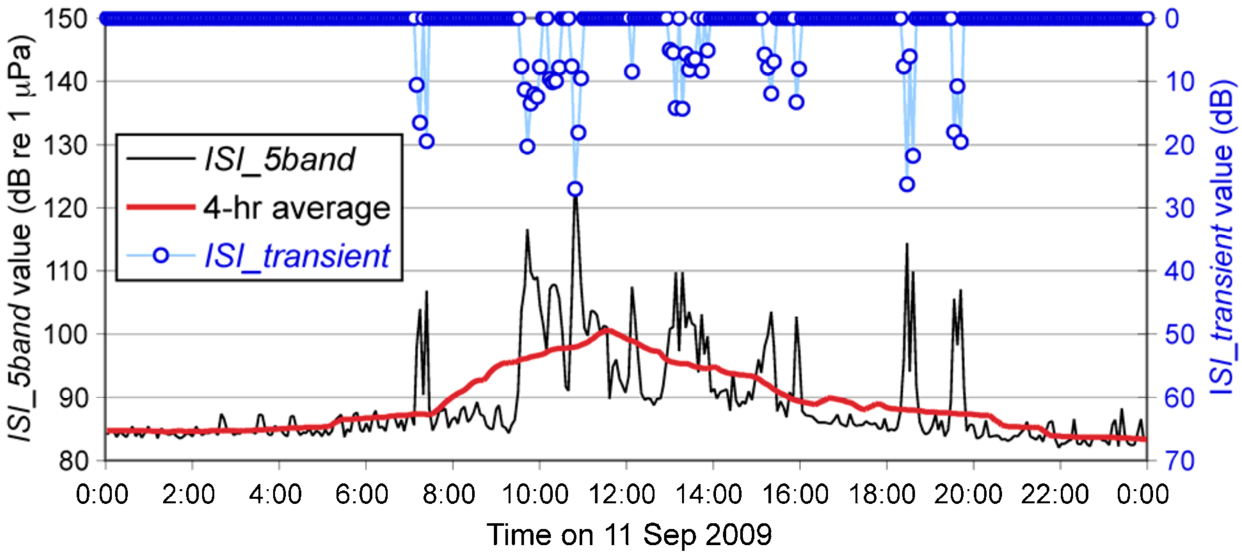

FIGURE 3.15. Computation of *ISI_transient* for sounds recorded at near-island DASAR NSc on 11 Sep 2009. The black line shows the value of *ISI_5band* as a function of time (1-min sample every 4.37 min). The red line shows the 4-hour moving average of the *ISI_5band* levels. A transient sound source is defined as occurring (with the value of *ISI_transient* to be read on the right y-axis) if the value of *ISI_5band* at time *t* is ≥5 dB above the moving average centered on *t*.

For over 90% of the time ISI_transient=0 (no detected transient sound source), but this percentage changed as a function of DASAR location. Figure 3.16 shows the percentage of samples (one sample every 4.37 min) for DASARs NSc, A, C, E, G, and J for which a transient sound was detected, i.e., ISI_transient≥5 dB. The highest percentage was at the near-island DASAR (NSc, 6.6%), and the lowest at the most offshore DASAR (J, 2.4%). In this case there seems to be a progression of decreasing numbers of transient detections with increasing distance from Northstar, at least out to DASAR E, 21.5 km or 13.4 mi from Northstar.

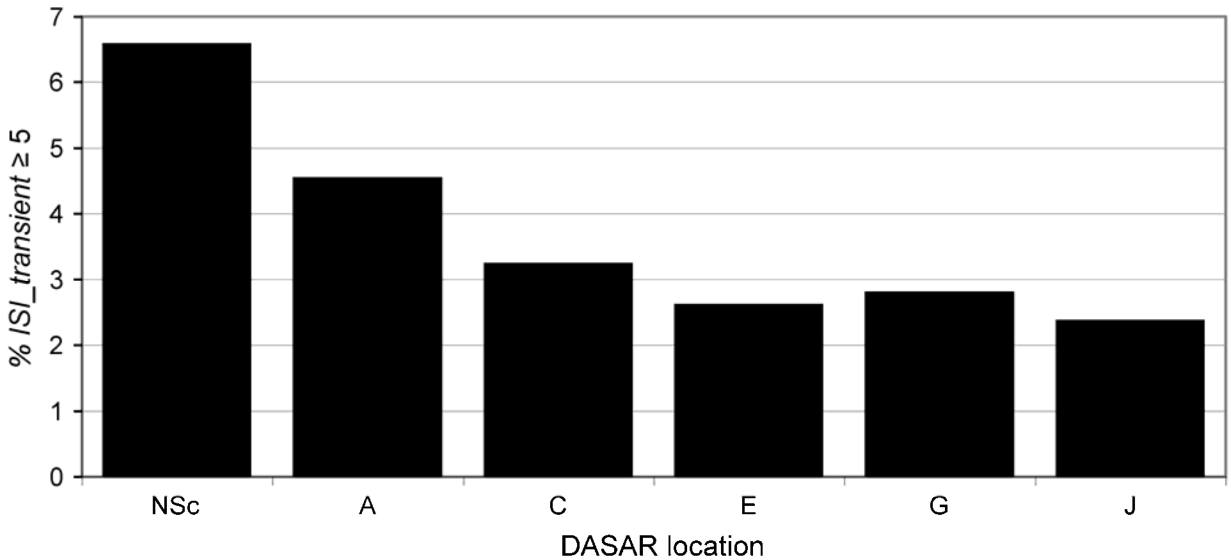

FIGURE 3.16. Percentage of samples with an identified transient sound, i.e., *ISI_transient*≥5. NSc is a near-island DASAR, and DASARs A, C, E, G, and J are in the offshore array.

Figure 3.17 shows *ISI_transient* values over the entire 2009 deployment period (26 Aug–28 Sep) for DASARs NSc, A, C, E, G, and J. Figure 3.17 shows that the near-island DASAR NSc had the highest number of samples with *ISI_transient* ≥ 5, but the highest values of *ISI_transient* were found in the DASAR array (e.g., DASARs A, C, and E). A likely partial explanation for this is simply that baseline levels are higher at Northstar, so the increase in broadband levels upon passage of a vessel is smaller than when that same vessel travels in the quieter area where the DASAR array was deployed. Some of the strongest transients at most offshore DASARs were on 26 Aug, 12 Sep, and 26 Sep, and were therefore likely produced by the ACS *Bay* vessel during health checks or calibrations. Figure 3.17 also shows that vessels operating at Northstar may be the source of only a minority of transient detections in the DASAR array. For example, during the periods 8–9 and 20–23 Sep there were many transient detections at array DASAR A, but few at Northstar. Also, during the period 25–27 Sep there were 14.7 transient detections per day at Northstar, about half that at DASAR A (7.3 / day), and increasing numbers of detections in the array (24, 17, 28, and 38 detections / day at DASARs C, E, G, and J, respectively). The only known sources of transient sounds in the array are vessels, or vessel-related activities. Therefore, these results indicate that even when we consider only transient sounds, which include the highest sound levels generated by the island operation, Northstar's "sound footprint" is often masked by vessel operations located 15 km or more seaward of Northstar.

SOUNDS FROM SPECIFIC ISLAND-RELATED SOURCES

Vessel Sounds

Vessels transport goods and personnel to Northstar. Most personnel transfers during the open-water season are done with a hovercraft, although occasionally an ACS "Bay" boat or Bell 212 helicopter is used when sea state precludes the use of the hovercraft (see Chapter 1). Barges bring goods and equipment to the island. During the period 26 Aug–28 Sep 2008 (~33.5 days) the hovercraft, barges, and ACS vessels made a total of 82, 18, and 41 round trips to Northstar, respectively[7]. These numbers average out to 2.4, 0.5, and 1.2 round trips / day, respectively. The values for ACS vessels do not include the three trips (26 Aug, 12 and 26 Sep) the acoustics crew made to Northstar and the DASAR array using an ACS "*Bay*" boat. The numbers of daily round trips to Northstar by the hovercraft, barges, and ACS vessels are shown in Figure 3.18 for the 2009 field season. The mean daily number of round trips to Northstar for each type of vessel is summarized in Figure 3.19 for the period 2003–2009. For comparison, round trips by the dedicated crew boat are also shown, even though that vessel was not used after the 2003 season when the hovercraft became available.

Vessels such as tugs (which accompany barges) and ACS "*Bay*" boats produce a sound "spike" on the near-island recordings when they are close to or at Northstar (see Fig. 3.1B). Over 80% of the arrivals and departures at Northstar by tugs and ACS vessels could be matched to a spike on the sound pressure time series of DASAR NSc. In 2009 the mean number of round trips per day by the hovercraft was lower than in 2008, with a concomitant increase in the use of ACS vessels. This may be due in part to slightly higher average wind speeds in 2009 compared to 2008 (Fig. 3.2), as ACS *Bay* boats can travel in higher sea states than can the hovercraft. Compared to 2008 the number of trips by tugs and barges remained about the same. To get an estimate of the number of round-trips to Northstar by "spike-causing vessels", we added together values for the crew boat, barges, and ACS vessels in Figure 3.19, and obtained the following: on average 6.0 round-trips / day in 2003, 1.1 in 2004, 0.8 in 2005, 2.0 in 2006, 2.5 in 2007, 0.8 in 2008, and 1.7 in 2009.

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[7] Records obtained from the Northstar Scheduler.

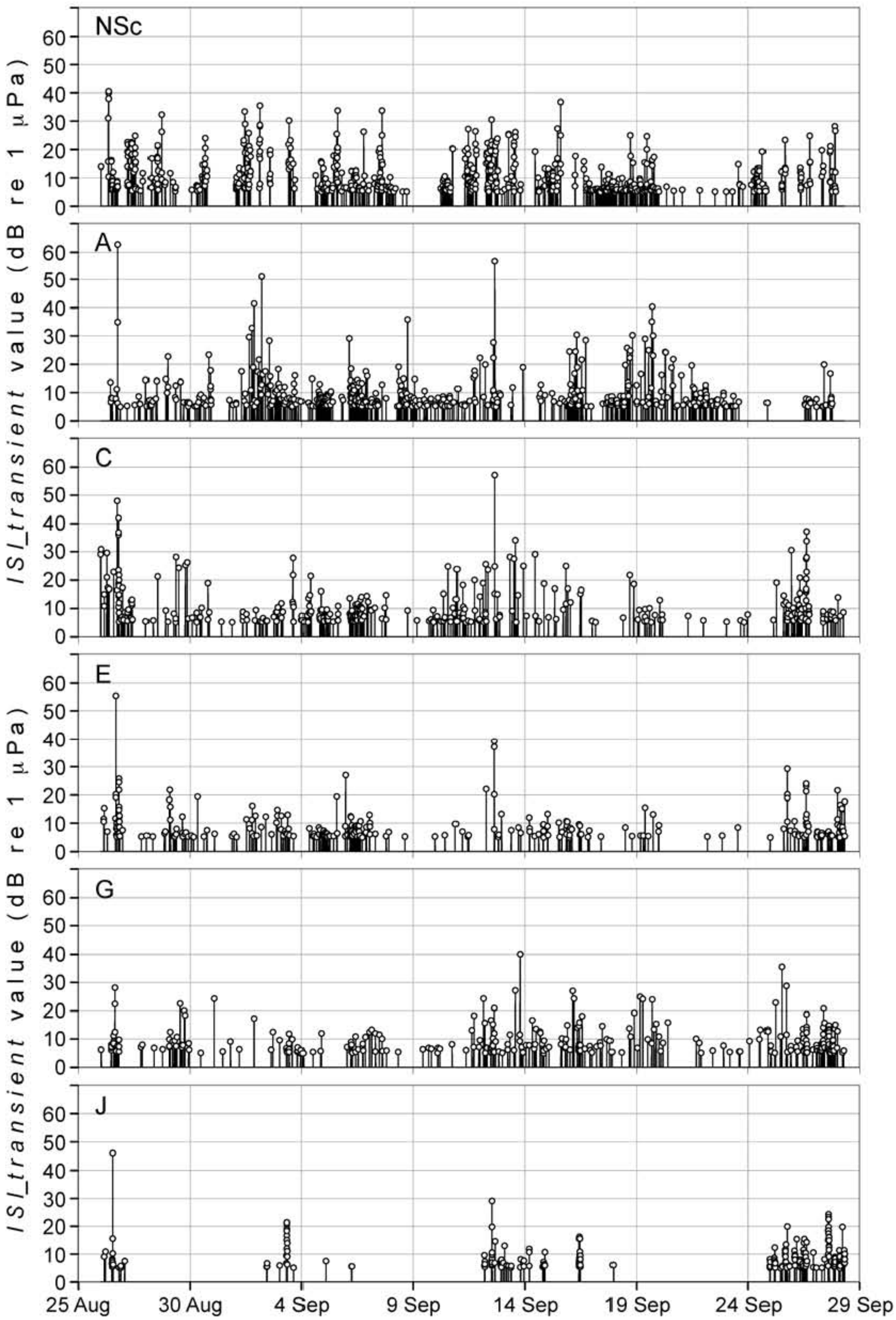

FIGURE 3.17. Values for *ISI_transient* at DASARs NSc, A, C, E, G, and J during the period 26 Aug–28 Sep 2009. For clarity, samples in which *ISI_transient*=0 are not shown.

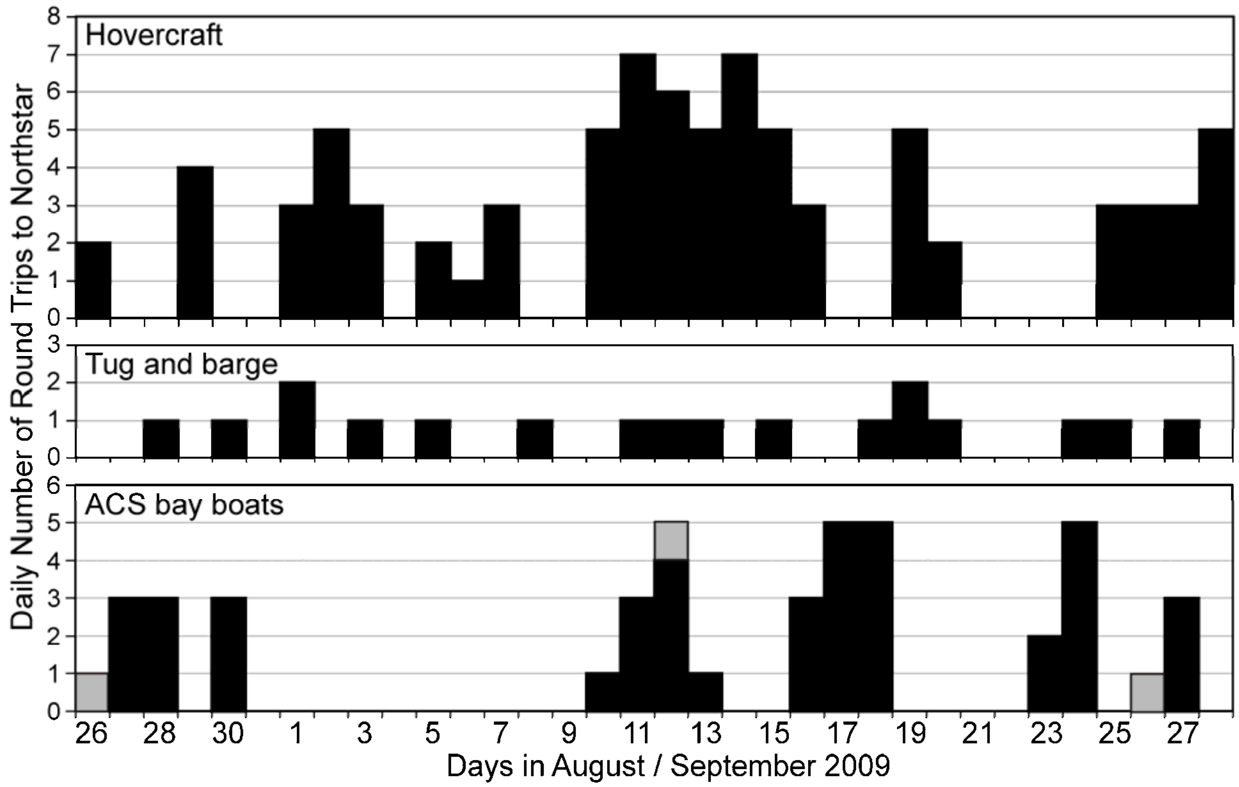

FIGURE 3.18. Daily number of round trips to Northstar by the hovercraft, tugs and barges, and ACS vessels (black shading = Northstar related; gray shading = acoustics crew) during the 2009 field season.

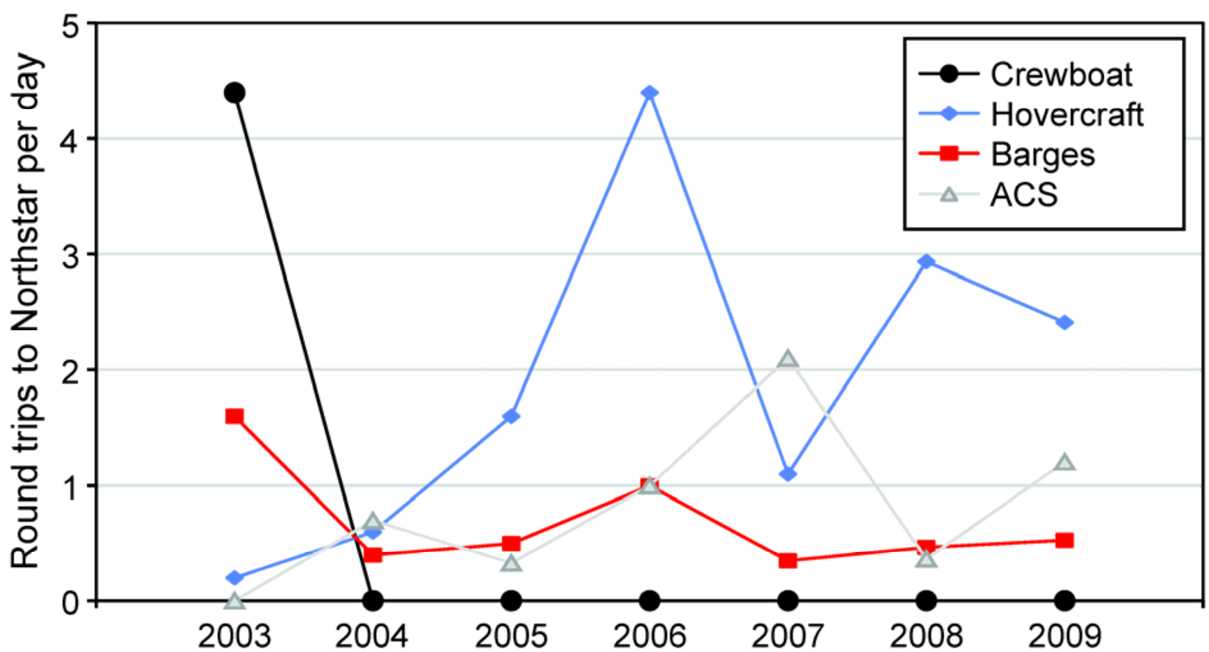

FIGURE 3.19. Daily mean number of round trips to Northstar by the crewboat (not used after 2003), the hovercraft, barges, and ACS vessels, 2003–2009. Each year, these numbers were calculated over the DASAR deployment duration, which varies from year to year, but is generally late Aug to late Sep.

We investigated how far vessel spikes created at Northstar were detectable on DASAR sound records offshore by choosing a day when wind speed was low and there was some well-defined activity at Northstar. There was such a day on 25 Sep, with mean hourly wind speed < 5 m/s (Fig. 3.1A) and the arrival, maneuvering, and departure of a barge in midday, which produced some of the higher sound levels over the season (Fig. 3.1B). Figure 3.20 shows the sound pressure time series (one sample / 4.37 min) on 25 Sep 2009 for DASARs NSc, A, and C. The tug and barge approached Northstar around 11:45 and left the island around 15:45. The tug's activities while at Northstar led to an increase in broadband levels of 10–15 dB above background, and up to ~30 dB above background shortly before the tug's departure from the island.

Figure 3.21 shows spectrograms for the same date and times at DASARs NSc, A, C, and E. Whereas the sound pressure time series in Figure 3.20 shows the broadband levels as a function of time, the

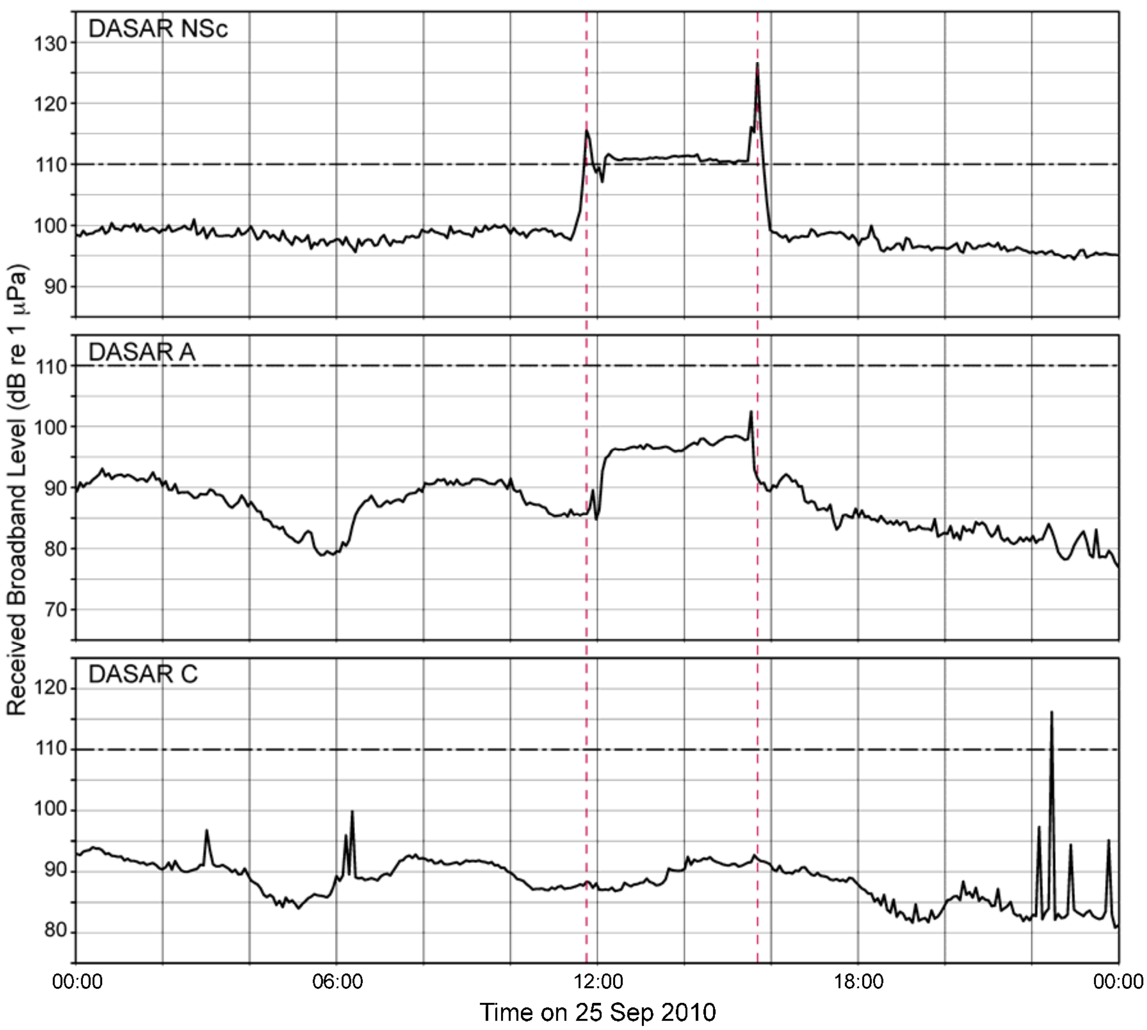

FIGURE 3.20. Broadband (10–450 Hz) sound pressure levels (1-min averages) during 25 Sep 2009 at near-island DASAR NSc (top), as well as array DASARs A (middle) and C (bottom). DASARs A and C were located 8.6 km and 14.8 km (5.4 mi and 9.2 mi) from Northstar, respectively. Spikes created by the arrival and departure of a tug and barge at Northstar are visible in the top plot and are marked with dashed lines. A "plateau" of higher sound levels can be seen between the spikes, corresponding to the maneuvering of the tug and barge at the island. To facilitate comparisons, a dash-dotted line has been placed in each plot at received levels of 110 dB re 1 μPa. See text for more information.

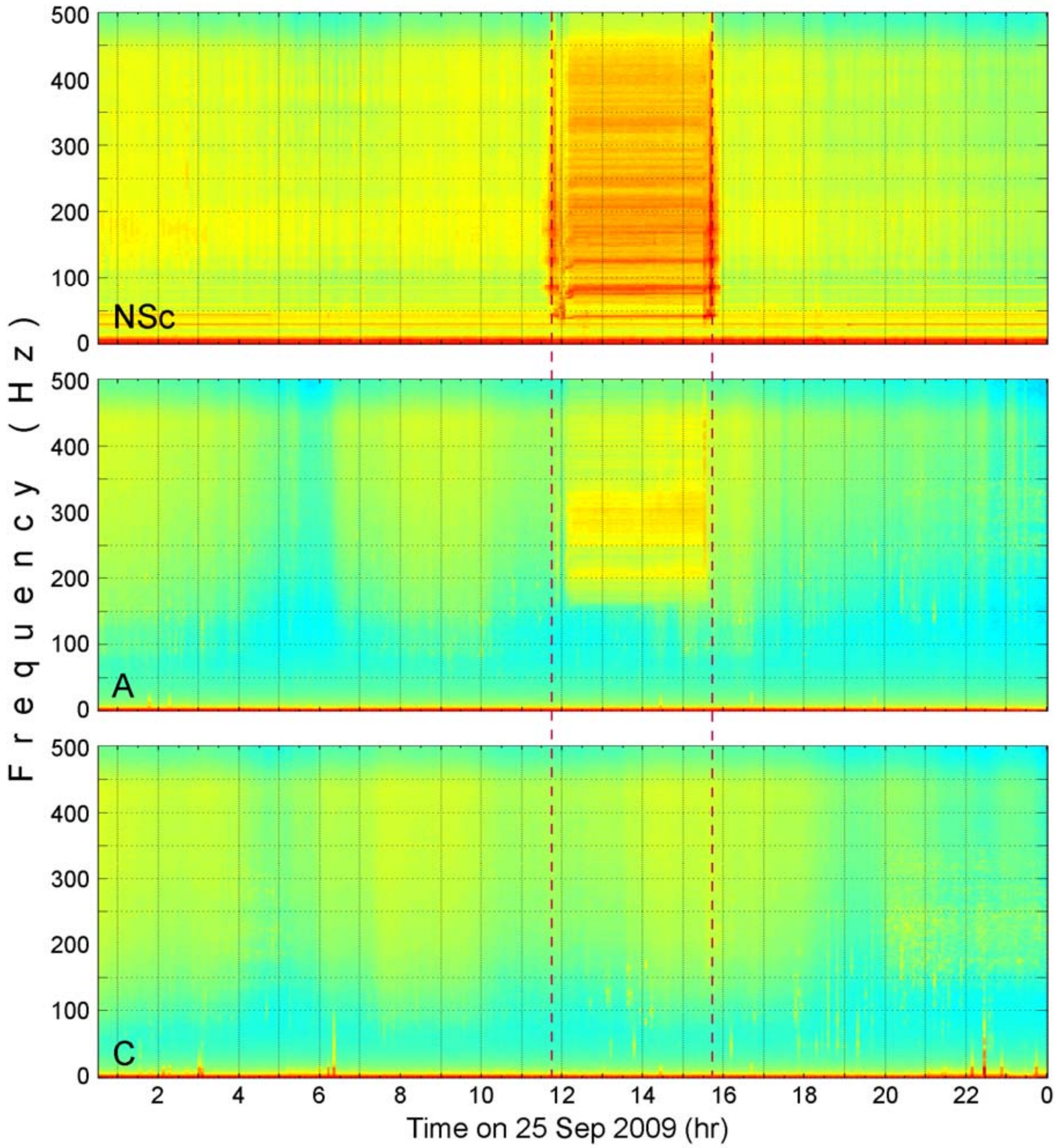

FIGURE 3.21. Spectrograms of data collected by near-island DASAR NSc, and array DASARs A and C, 25 Sep 2009. Color on the spectrograms varies with received levels of sound, from low (blue) to high (red). The red vertical dashed lines have been placed in the same locations as in Figure 3.20, at the times of the highest sound levels on the near-island recorder. See text for further information.

spectrograms give information on the spectral composition of the sound. Again, the activities at Northstar are clearly visible at DASAR NSc and at array DASAR A, but difficult to distinguish farther offshore.

At DASAR A, located 8.6 km from Northstar, the general increase in sound levels during the tug/barge activities is still visible in the sound pressure time series (Fig. 3.20), but with lower levels (~ 97 dB re 1 μPa for the central "plateau" period instead of ~110 dB) and dampened peaks. At DASAR C (Fig. 3.20, bottom plot), located 14.8 km from Northstar, it is difficult to distinguish elevations in received levels that can be attributed to tug activities at Northstar. Similarly, heightened levels in the frequency range 150–450 Hz are visible on the spectrogram for DASAR A (Fig. 3.21), but no longer at DASAR C.

The hovercraft was used for transport of goods and personnel to the island whenever possible in 2009. As in previous years, the arrival or departure of the hovercraft was not associated with any characteristic and predictable increases in the 1-min averages calculated every 4.37 min at DASAR NSc, 450 m offshore of Northstar[8].

"Pop" Sounds

During visits to Northstar on 11 June and 16 July 2009, no pops were heard using the listening system described in Chapter 2. On 11 June other sounds, including sounds made by divers working in the moat around the island, were audible to the field crew, confirming that the listening system was functioning properly. On 16 July the presence of pops was investigated at four different stations around the island. Wind speed was ~22 knots from the NE with a Sea State of 4 and 5 ft swells, which would have led to a fair amount of sound from waves slapping the hull of the vessel, so any existing pops could conceivably have been masked by background noise. Pops were also not heard while listening on the leeward (west) side of the island, where noise from wind and waves was lower.

Based on the data collected during the 2008 field season, the locations for the source(s) of the pops were estimated utilizing the bearing measurement capabilities of three nearshore DASARs. This suggested that the pops were likely generated within or close to the perimeter of Northstar, possibly offshore of the northeast corner of the island. Thus, an *Acousonde*™ [9] acoustic data logger was deployed on three different days in close proximity to Northstar: 35–135 m from the NE corner of the island. Acoustic data collected during these three *Acousonde* deployments in 2009 (on 25 Aug, 12, and 26 Sep) were analyzed for the presence of pops. Similarly, the acoustic records of near-island DASAR NSb in 2008 and 2009 were analyzed in their entirety (~29 and ~33 days, respectively) for the presence of pops. A peak detector with a 7 Pa threshold (i.e., set to detect acoustic transients with peak pressure ≥136.9 dB re 1 μPa) was used on all acoustic records and the results of these analyses are summarized in Table 3.2.

One of the principal goals of this investigation was to estimate the highest received levels in the water close to Northstar, if one assumed that the sound source was located near Northstar's northeastern corner. Received SPL (rms) and instantaneous peak values for the largest pop in each acoustic record are presented in Table 3.2. To estimate the received level of a pop at a given location, one requires a model for acoustic transmission loss between the source (pop) and receiver (*Acousonde* or DASAR NSb). An attempt was made to associate pops on the *Acousonde* records with the same pops on DASAR NSb in 2009, in order to derive a simple transmission loss model based upon direct measurement of transmission loss between the two receivers. However, on 25 Aug (the first *Acousonde* deployment), DASAR NSb had not yet begun recording, and on 12 and 26 Sep (the second and third *Acousonde* deployments), no pops were detected on DASAR NSb at about the same times (accounting for sound travel time) as they occurred on the *Acousonde* records, even after lowering the threshold level of the peak detector. Thus, a 15log(R) transmission loss model, determined empirically for sound sources in the vicinity of Northstar (Blackwell and Greene 2006), was used to estimate the highest potential received SPL at Northstar's northeastern corner. Assuming the

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[8] Examination of the raw sound pressure time series as received at near-island DASAR NSc have in the past revealed tones produced by the hovercraft, for periods of 1–2 min during the hovercraft's arrival at or departure from Northstar. However, these tones were faint, and not strong enough to increase the one-min broadband levels by a noticeable amount.

[9] Information on the *Acousonde* can be found on the website http://www.acousonde.com

TABLE 3.2. Summary of results obtained using a peak detector to identify "pops" on *Acousonde* and DASAR acoustic records. The highest SPL and highest instantaneous peak values are only given for the strongest pop in each acoustic record. The estimated SPL at Northstar's NE corner is calculated using the SPL (rms) for the largest pop in each record, the distance between the recorder and the NE corner of the island, and a 15log(R) transmission loss. See text for more information.

	Acousonde data			DASAR data	
Date	25 Aug	12 Sep	26 Sep	2008	2009
Distance from recorder to NE corner of Northstar (m)	135	35	45	348	351
# of hours of data analyzed	6.1	7.4	9.6	704.7	801.4
# of pops exceeding 7 Pa threshold	32	1	1	52,248	131,352
ANALYSES OF LARGEST SINGLE POP IN EACH ACOUSTIC RECORD:					
Time of pop with highest sound levels	14:01:35	11:56:19	17:21:55	17 Sep 08 10:47:45	31 Sep 09 18:58:24
Highest SPL (dB re 1 μPa)	138.0	135.2	132.0	144.5	142.3
Highest instantaneous peak (pk) (dB re 1 μPa)	145.6	142.5	137.3	149.0	149.3
Estimated SPL at Northstar's NE corner (dB re 1 μPa) assuming 15log(R)	170.0	158.4	156.8	182.6	180.5
Number of pops with SPL >180 dB at Northstar's NE corner (extrapolated SPL)	0	0	0	1	1
Duration of pulses with SPL >180 dB at Northstar's NE corner (ms)	0	0	0	44	54

pops originated at or near Northstar, the estimated SPL in the water at Northstar's NE corner was in the range 157–183 dB re 1 μPa (Table 3.2). The cases in which this estimate exceeded 180 dB were for DASAR NSb in 2008 (182.6 dB re 1 μPa, duration 44 ms) and 2009 (180.5 dB, duration 56 ms). However, none of the remaining pops detected on DASAR NSb's acoustic records (52,247 and 131,351 pops, respectively) resulted in an estimate above 180 dB re 1 μPa. The 15log(R) transmission loss model was derived from measurements taken in deeper water off Northstar, so it is theoretically possible that these calculated received levels at Northstar's NE corner are underestimated, since even greater transmission loss would be expected in the shallower waters at the island's edge.

Another goal of this investigation was to locate and identify, if possible, the source of the pops. We compared the number of pops detected on the *Acousonde* and DASAR NSb records during the same periods on 12 and 26 Sep. (One pop was identified on each of these two days on the *Acousonde* records, see Table 3.2.) On 12 Sep the peak detector got a number of hits on the record of DASAR NSb, but these turned out all to be related to vessel noise. On 26 Sep no pops were detected on NSb. Therefore, this comparison yielded little additional information as to the location and identity of the pops.

Based on analysis of the 2008 data (Blackwell et al. 2009), there was some preliminary evidence that pops were more prevalent on days with higher wind speeds, which would support the hypothesis that they were produced by the movements of an underwater structure. By applying the peak detector to the entire acoustic record from DASAR NSb in 2008 and 2009, we obtained data to address this question. Figure 3.22 shows peak pressure levels from pops for the entire 2008 and 2009 seasons, together with mean hourly wind

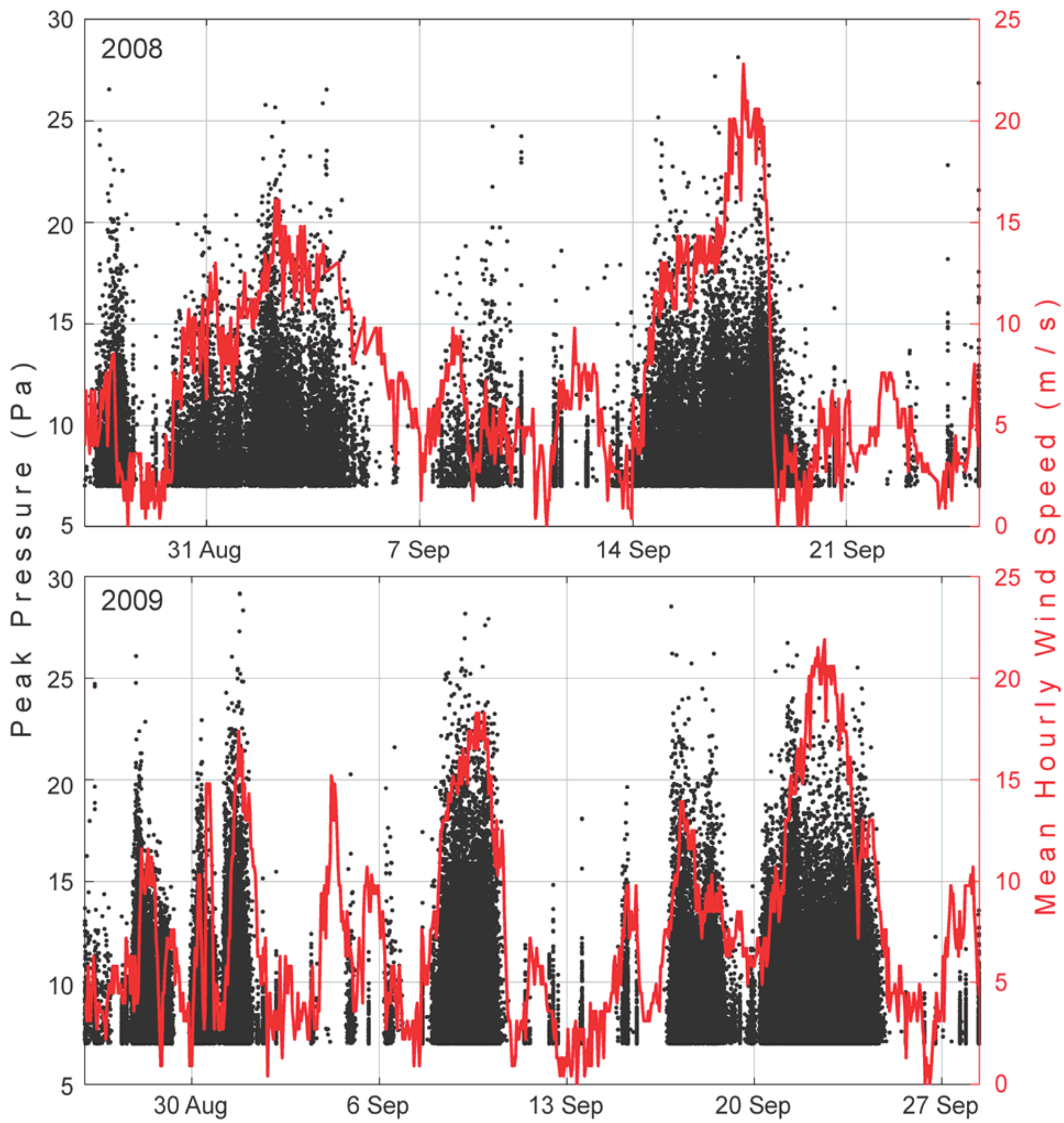

FIGURE 3.22. Presence and received levels of pops (black dots) on records of near-island DASAR NSb in 2008 (top) and 2009 (bottom) in relation to mean hourly wind speed (red line). A peak pressure of 7 Pa (136.9 dB re 1 μPa) corresponds to the threshold level of the peak detector. Wind speed was measured at the Prudhoe Bay weather station so is only roughly indicative of wind speed near DASAR NSb.

speeds obtained from the Prudhoe Bay weather station. Even though this relationship was not quantified, there appears to be a strong positive association between wind speed and the presence and amplitude of pops in both years. This may explain why so few pops were detected on the *Acousonde* records in Sep 2009: both days (12 and 26 Sep) experienced some of the lowest wind speeds of the season.

AIRGUN PULSES

During the 2009 field season, sound pulses produced by airguns in use for seismic exploration not associated with Northstar or other BP operations near Prudhoe Bay were detected by the call analysts on the acoustic records of array DASARs. According to the analysts' notes, the occurrence of airgun pulses on the DASAR records increased with distance from shore, i.e., airgun pulses were least common at DASAR A and most common at DASAR J. If airgun pulses were detected by near-island DASAR NSc, they were very rare—a manual search yielded one possible airgun pulse at a barely detectable level. There were two main operations known to us that involved the use of airguns during September 2009, one far to the north of the DASAR array in deep water (non-BP) and one far to the east (BP Canada). Both operations were located hundreds of km from the DASAR array.

To provide a relative comparison of the number and received levels of airgun pulses in 2009 compared with 2008, we analyzed the records of DASAR J with an automated pulse detector operating in the same manner for the two years (see Chapter 2). The number of airgun pulses detected was 64,692 for 2009 (26 Aug–27 Sep, or 33 days) and 146,967 for 2008 (27 Aug–24 Sep, or 29 days). The number of pulses presented here for 2008 is higher than that (90,582) presented for the same period in Blackwell et al. (2009). The reason for this is that the algorithm used by the pulse detector for finding airgun pulses was improved by incorporating bearing information, which led to a higher number of pulses being detected than were found during the run performed in January 2009. The actual numbers of airgun pulses received in the DASAR array during both years were likely higher than these numbers. During the automated search for pulses, the threshold signal to noise ratio (SNR) in the algorithm was set at 8 dB, a high-enough level that non-airgun sounds were excluded, but weak airgun pulses were also excluded by this analysis.

Figure 3.23 shows received levels of airgun pulses at DASAR J in 2008 (top) and 2009 (bottom). For each 10-min period with detected airgun pulses, Figure 3.23 shows (1) the median received sound pressure level (black dots), and (2) the 95th percentile of the maximum instantaneous peak values (red triangles). The number of pulses detected per 10-min period was on average 33 pulses ± 17 pulses in 2009 (mean ± S.D.) and 49 pulses ± 22 pulses in 2008. In 2008, 72% of all 10-min periods included in the 29 days analyzed (27 Aug–24 Sep) contained one or more airgun pulses. In 2009 this percentage was lower: 41% of all 10-min periods included in the 33 days analyzed (26 Aug–27 Sep) contained one or more airgun pulses. Table 3.3 summarizes received SPLs, SELs, and instantaneous peak levels of airgun pulses detected at DASAR J in 2008 and 2009. Overall, received airgun pulse levels averaged higher in 2008 than in 2009, with median SPLs ~7 dB higher in 2008. They were also more variable in 2008, as is shown in Figure 3.23 and by the fact that the 95th percentile of max SPL was 15 dB higher in 2008 than 2009 (Table 3.3). The 95th percentile of the maximum instantaneous peak was also ~15 dB higher in 2008 (140 dB vs. 125 dB in 2009).

DISCUSSION

Broadband Sound Levels Near Northstar

In all years, broadband levels at the island have been much influenced by wind and wave action, but superimposed on this natural variability are the effects of industrial activities. Figure 3.3 and the data presented in Table 3.1 describe how broadband (10–450 Hz) levels of underwater sound, as recorded ~450 m north of Northstar, have changed over nine fall seasons of monitoring. The median broadband level of sound, as recorded ~450 m north of Northstar, was 103.9 dB re 1 μPa in 2009. This is close to the value in 2008 (103.6 dB) and within the range as recorded for all previous years (98.7–105.5 dB). Values for the 75th percentile, however, were higher than in previous years (Fig. 3.4). We have no specific explanation for this increase.

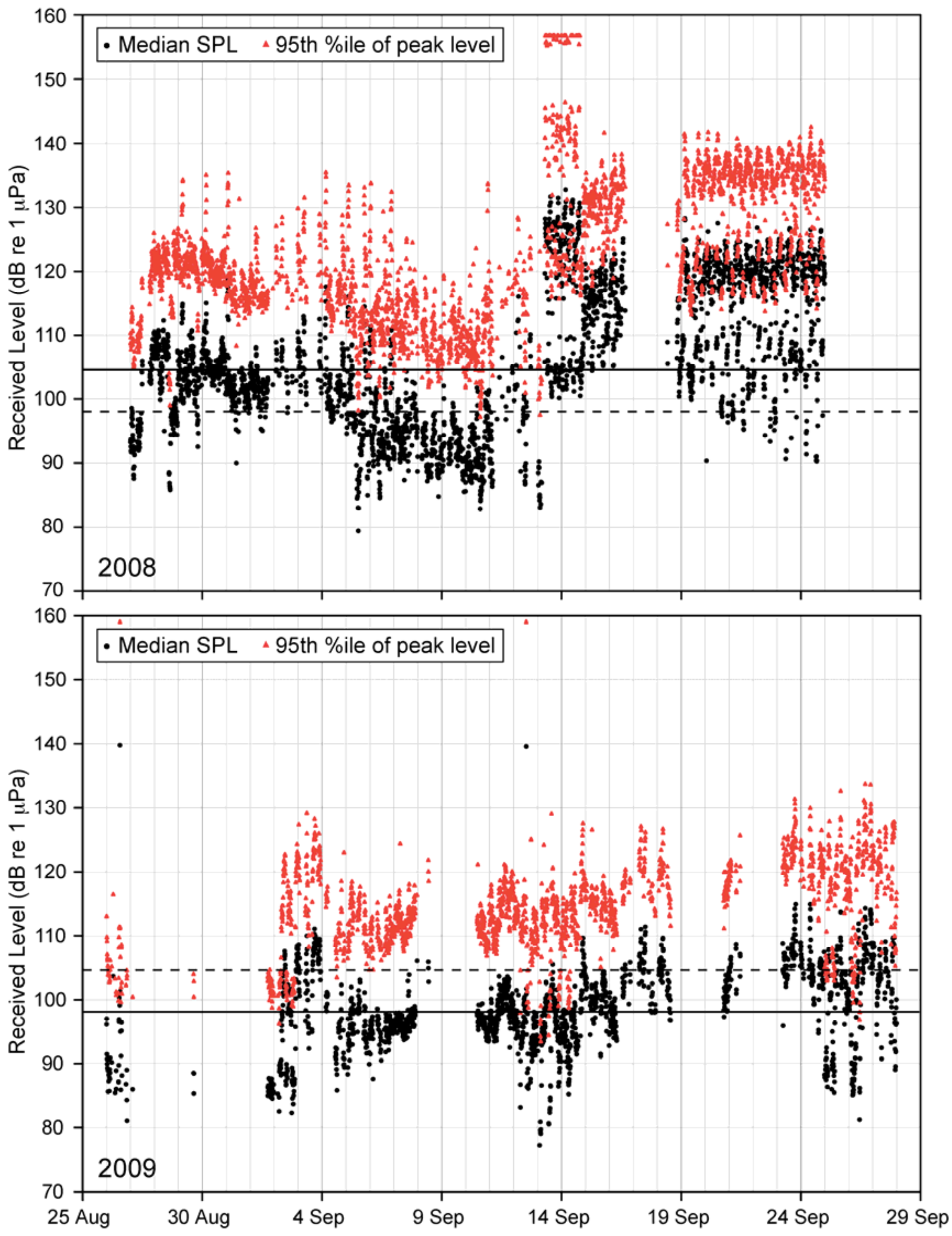

FIGURE 3.23. Levels of sound from airgun pulses, as received at DASARs J (most offshore) in 2008 (top, 27 Aug–24 Sep) and 2009 (bottom, 26 Aug–27 Sep). Data are summarized over 10-min periods. Median received sound pressure levels (SPLs) are shown with black dots, and the 95th percentile of instantaneous peak pressures are shown as red triangles. The black line in each plot shows the median SPL; the dashed line shows the median SPL for the "other" year (2009 in the 2008 plot and 2008 in the 2009 plot).

TABLE 3.3. Summary statistics for airgun pulses detected in 2008 and 2009 and analyzed by 10-min periods: total number of airgun pulses detected, number of overloaded pulses, number of 10-min periods with at least one detected airgun pulse, median SPL, 95th percentile of maximum SPL, mean SNR, median SEL, and 95th percentile of maximum instantaneous peak. The number of overloaded pulses is not included in the total sample size. All dB units are re 1 μPa except for (*) which are dB re 1 $\mu Pa^2 \cdot s$.

	DASAR J 2008	DASAR J 2009
Sample size	146,967	64,692
# overloaded pulses	43	0
# 10-min periods with at least one airgun pulse	3020	1938
Median SPL (excluding background)	105 dB	98 dB
95th percentile of max SPL	127 dB	112 dB
Mean signal to noise ratio	17 dB ± 10 dB	11 dB ± 7 dB
Median SEL	107 dB *	100 dB *
95th percentile of max instantaneous peak	140 dB	125 dB

When examining sound pressure time series, such as those shown in Figure 3.3, one of the more striking differences between years is the variation in the density of "vessel spikes". Even though a few of these spikes can be attributed to other activities of a transient nature, at least 80–90% of the spikes are caused by vessels going to and from Northstar. From 2001 to 2005 the average number of vessel spikes decreased progressively from year to year (Fig. 3.3). Starting in 2003, the total number of trips to Northstar by spike-producing vessels can be estimated by adding together values shown in Figure 3.19 for the crew boat, the tug and barge, and ACS vessels. This shows that there was an increase in the number of round-trips / day in 2006 and 2007, followed by a decrease in 2008 to an average of 0.8 round-trips / day (Fig. 3.19). The 2009 value was somewhat higher (1.7 round-trips / day) but still well below the peak in 2006 (2.5 round-trips / day).

Even when vessels were absent, there was more short-term variability in sound levels near the island (DASAR NSc) in 2009 than in most previous years—compare for example the 2009 plot in Fig. 3.3 with that from 2004, 2005, or 2007. Again, this could be due to the presence of pops on the near-island records (see below). The same hypothesis and some supporting evidence (Blackwell et al. 2009) were put forth for the 2008 data, which showed a similar pattern of short-term variability in the records collected by the near-island recorders.

Starting in 2008, two different types of broadband levels were calculated for all DASARs: the "standard" broadband analysis, in which an entire minute of data was analyzed every 4.37 min, and the "minimum" analysis, in which broadband levels were computed over 2 s every second, and only the lowest value per 10-min period was stored. If many pops or airgun pulses were detected we expected the difference between the "standard" and "minimum" values to be greater. In 2009 the average difference at DASAR NSc between the "standard" and "minimum" values was 7.4 dB, which is higher than in 2008 (5.9 dB), possibly because many more pops were detected in 2009 than in 2008 (~131,000 vs. ~52,000). As a comparison, in 2007 (a year without pops) this difference was 3.4 dB.

The *ISI_5band* measure was developed to characterize the sound components most closely related to industrial activities. The bandwidth of *ISI_5band* (28–90 Hz) includes island operational sounds (generators, compressors and the like) as well as the sounds from vessels. It also inevitably includes sounds from wind and waves, which affect sound levels at all frequencies. The salient observation about *ISI_5band* values at the near-island DASAR in 2009 is that they differed from the broadband background sound in the 10–450 Hz range by a greater amount than in years without pops. Pops (see below) contain most of their energy outside the 28–90 Hz band. Therefore, they contribute to broadband levels but not (or little) to *ISI_5band* levels, resulting in a greater difference between mean broadband and mean *ISI_5band* levels. This difference was 7.8 dB in 2009 and 8.7 dB in 2008, another year with pops. Corresponding values in 2003–2006 were in the range 4.2–5.7 dB, but had increased to 6.7 dB in 2007. Although these popping sounds are from an unconfirmed source, they are likely to be island-related and therefore are a component of the industrial sound that was not well represented by *ISI_5band*.

"Pop" Sounds

In 2008, and again in 2009, we detected an impulsive popping sound that was prominent on the near-island recorders. This sound was of short duration, but its amplitude and rate of occurrence were such that we expected it to have some effect on the descriptive statistics of Northstar sound. Pops seem to have been more frequent in 2009—a peak detector used on the record of near-island DASAR NSb in 2009 identified ~2.5 times the number of pops that were detected on the 2008 record.

Analyses of the 2009 data confirmed a suspicion expressed in 2008 (Blackwell et al. 2009) that the pops were related to sea state (and therefore wind), i.e., the frequency of occurrence and received level of the pops increased with increasing wind speeds (Fig. 3.21). We do not have any further information on the source of the pops, but based on the available information it seems reasonable to suggest that pops could be produced by an object or structure underwater, located close to the island, that moves when sea state increases.

Northstar Sounds Recorded Offshore

One of the specific objectives in 2009 was to "increase the understanding of received levels of sound from Northstar farther offshore". This was done by comparing the level of certain sound types (e.g., vessels, or tones) recorded at the near-island DASAR with the same sound types recorded by the array DASARs at different distances offshore. However, it rapidly becomes clear that Northstar is not the only sound source in the area. Industrial indices such as *ISI_tone* or *ISI_transient*—designed to be indices of Northstar sound—also include some sound from other sources and become indices of non-Northstar sound beyond a certain distance from the island.

Median broadband levels in the offshore array (Fig. 3.6) were lower than at Northstar by ~8–11 dB, which is similar to previous years. Median broadband levels did not differ much across the north–south extent of the array (93.3–94.4 dB) except for somewhat higher values at the DASAR farthest north, J (96.4 dB). This is in contrast to 2008, when there was a pattern of increasing mean broadband levels with increasing distance from shore. In 2008, the higher levels of offshore industrial activity were suggested as the most likely explanation for this trend (Blackwell et al. 2009). In 2009, offshore industrial activities were reduced compared to 2008 and, insofar as known to us, consisted mainly of relatively limited supply and support vessel traffic. There were some airgun activities in 2009, but much less than in 2008 and far enough from Northstar (hundreds of km) that they would have a minor influence on broadband levels such as we measure them.

Most types of large equipment used at Northstar, such as generators, engines of various sorts, vibratory pile-drivers, compactors, etc., are likely to produce tones (Spence 2006) that propagate into the water. In addition, tones are produced by vessels. The *ISI_tone* measure provides information on the presence and amplitude of tones close to Northstar and in the offshore array. Near-island DASAR NSc had the highest proportion of *ISI_tone* values>0 and the highest mean *ISI_tone* value over the 2009 season (Fig. 3.14). If the presence of tones was mainly attributable to Northstar, then one would expect decreasing numbers of tones with increasing distance from Northstar. However, array DASARs A, C, E, G, and J, representing the full north-south extent of the array, all had about the same percentage of samples for which *ISI_tone* = 0 (96–98.5%). In addition, mean *ISI_tone* values over the whole season varied throughout the array, being lowest at DASARs A and G and highest at DASAR J, therefore seemingly unrelated to Northstar. More likely, Northstar tones are not detectable beyond the southern-most DASARs in the array and most tones detected in the DASAR array are produced by vessels.

Vessel spikes are a prominent feature in the sound pressure time series (Fig. 3.3). In 2008, spikes from tugs were at least some of the time detectable in the sound pressure time series offshore as far as DASAR E, 21.5 km (13.4 mi) from Northstar (Blackwell et al. 2009). In 2009 we found that spikes and maneuvering by a tug at Northstar on 25 Sep (Fig. 3.20) were easily identifiable on the record of DASAR A (8.6 km or 5.4 mi away), but were not readily identifiable on the sound pressure time series of DASAR C (14.8 km or 9.2 mi away). The same result was found by examining spectrograms of the DASAR data on 25 Sep (Fig. 3.21): the tug activities were recognizable at DASAR A, but not farther offshore.

Non-Northstar Sounds: Airgun Pulses

During the 2009 field season (26 Aug–27 Sep), nearly 64,700 airgun pulses with SNR ≥ 8 dB were detected at array DASAR J, the farthest from Northstar. Being located in the deepest water of all DASARs deployed in this study (Table 2.1), location J is likely to have recorded the highest number of airgun pulses originating or propagating from farther offshore (it did so in 2008, see Blackwell et al. 2009). This is about 44% of the number of airgun pulses that were detected in 2008 (~147,000), but it is still considerable. Received SPLs (rms) of airgun sound at DASAR J averaged ~98 dB, which is ~7 dB lower than in 2008. The lower levels in 2009 are consistent with the fact that the seismic surveys were being conducted at greater distances from the DASARs than were some of the 2008 seismic surveys.

To evaluate the contribution of airgun pulses to overall sound levels, broadband levels were calculated in two different ways for the array DASARs: the "standard way" (mean over 1 min every 4.37 min and thus including airgun pulses) and the "minimum way" (lowest 2-s average over 10 min and thus excluding airgun pulses). In 2009, the minimum values were similar to the lower edge of the range of values derived by the standard method (Fig. 3.6). This is in contrast to 2008, when airgun activities were present much closer to the DASAR array than they were in 2009. The Figure equivalent to Fig. 3.6 but for 2008 data (Fig. 3.6 in Blackwell et al. 2009) shows a gap between the minimum and standard lines, which during airgun activities could differ by as much as 25 dB. The contribution of airgun operations to sounds in the array was therefore smaller in 2009 than it was in 2008, but will need to be taken into account when assessing the effects of Northstar sounds on bowhead whale behavior in 2009. Bowhead whales have been shown to react to airgun sounds by deflecting or by changing their calling behavior, or both (Richardson et al. 1986, 1999; Ljungblad et al. 1988; Blackwell et al. 2008). We therefore plan to add measures of the airgun pulses as additional covariates in the overall analysis that will be presented as a chapter in the draft 2010 comprehensive report covering the years 2005–2009, to be submitted to NMFS in August 2010.

SUMMARY BULLETS

- Median broadband levels of sound as measured at the near-island DASAR NSc were within the range of previous years, but 75th percentile levels were higher than in 2001–2008.
- Based on vessel traffic records, the number of round trips to Northstar by vessels that produced "sound-spikes" increased in 2009 compared to 2008, but remained below 2007 levels.

- Pops were detected on the near-island DASAR in higher numbers than in 2008. Their frequency of occurrence and amplitude were related to wind speed, and therefore sea state. Pops had an influence on the sound levels close to Northstar. They were suspected of (1) causing more short-term variability in sound levels near the island (as seen in 2008); (2) increasing the difference between standard 1-min broadband levels and "minimum" levels; (3) increasing the difference between standard broadband levels and *ISI_5band* levels;
- Mean broadband levels for array DASARs did not change consistently with distance from Northstar but were somewhat higher for the northernmost DASAR (J).
- Tone-producing equipment was operating more frequently at Northstar in 2009 than in 2008. Values for *ISI_tone*, which is an index of the presence and amplitude of tones from machinery and vessels, was highest at Northstar and variable in the DASAR array. Many tones detected in the DASAR array were likely not produced by Northstar.
- Sound spikes from a tug maneuvering at Northstar were readily identifiable on the sound pressure time series of DASAR A (8.6 km or 5.4 mi away), but not on that of DASAR C (14.8 km or 9.2 mi away) or farther offshore.

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ANNEX 3.1: SUMMARY TABLE OF VARIOUS BROADBAND SOUND MEASURES

The table below summarizes mean and median values for various broadband measures calculated at near-island DASAR NSc and array DASARs A, C, E, G, and J, in 2009 (26 Aug–28 Sep). Both means and medians are shown since the differences between the two suggest a skewed amplitude (dB) distribution of the sound. Differences within or between specific columns are also shown. All values are in dB re 1 μPa. BB = broadband, Min = minimum, Std = standard. Samples sizes for each DASAR are as follows: 10,986 for standard broadband values and *ISI_5band* values (one 1-min sample every 4.37 min), and 4799 samples for minimum broadband values (one 2-s sample every 10 min).

Values in column G are the differences between mean broadband levels obtained using the "standard" analysis (one-min samples every 4.37 min) and those obtained using the "minimum analysis" (smallest 2-s sample per 10-min period). **Values in column H** are the differences between mean broadband levels obtained using the "standard" analysis (one-min samples every 4.37 min) and mean *ISI_5band* levels. **Values in column I** are the differences between mean broadband levels at Northstar and each of the array DASARs. **Values in column J** are the differences between mean *ISI_5band* levels at Northstar and each of the array DASARs.

Columns:	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
							Columns involved:			
DASAR	Std BB analysis [mean]	Std BB analysis [median]	Min analysis [mean]	Min analysis [median]	*ISI_5band* [mean]	*ISI_5band* [median]	A - C	A - E	A	E
NSc	105.5	103.9	98.1	98.3	97.8	95.0	7.4	7.8		
A	93.3	94.4	89.7	91.6	80.0	77.3	3.6	13.3	12.2	17.8
C	94.4	96.0	91.8	94.0	79.4	76.8	2.6	15.0	11.1	18.4
E	94.0	94.4	91.0	92.3	80.2	77.4	3.0	13.8	11.5	17.6
G	93.6	94.3	90.8	92.1	78.6	75.1	2.8	15.0	11.9	19.2
J	96.4	96.4	93.5	94.0	87.2	86.6	2.9	9.2	9.1	10.6

CHAPTER 4:

ACOUSTIC LOCALIZATION OF MIGRATING BOWHEAD WHALES NEAR NORTHSTAR, AUTUMN 2009[1]

by

Katherine H. Kim[a], Susanna B. Blackwell[a], William C. Burgess[a], Charles R. Greene, Jr.[a], and Lisanne A.M. Aerts[b]

[a]Greeneridge Sciences, Inc.
6160-C Wallace Becknell Road, Santa Barbara, CA 93117
Phone: (805) 967-7720; e-mail: khkim@greeneridge.com

[b]LGL Alaska Research Associates, Inc.
1101 East 76th Avenue, Suite B, Anchorage, AK 99518
Phone: (907) 562-3339; e-mail: alaska@lgl.com

for

BP Exploration (Alaska) Inc.
Dept. of Health, Safety & Environment
900 East Benson Blvd., P.O. Box 196612
Anchorage, AK 99519-6612

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ABSTRACT

Calls from migrating bowhead whales near Northstar were recorded and localized using an array of 10 directional autonomous seafloor acoustic recorders (DASARs) offshore of Northstar for ~33 days (26 Aug–28 Sep). The primary objective of the study was to assess the effects of Northstar production activities, especially underwater sounds, on the southern edge of the distribution of calling bowhead whales during their autumn migration. In this chapter, we report on the number of whale calls detected, bearings to calls, the estimated locations of calls, and the types of calls.

In 2009, there were a total of 97,662 call detections from the records of the 10 array DASARs, representing a total of 19,772 different bowhead whale calls. The highest number of calls was detected by DASAR F, close to the center of the array. About 89% of the calls were detected by two or more DASARs, and over 4% of the calls were detected by all 10 DASARs concurrently; 16,825 calls were successfully localized. The highest hourly call detection rate was 466 calls per hour and occurred on 13 September. In addition to this peak in call detection rate, there was an increase in call detection rate in late September as was also apparent in most other years. DASARs have been deployed at location C (referred to as EB in 2001–2007) every year since 2001. Therefore, data collected at that location are a good basis for comparisons across years. Call detection rates at DASAR C in 2009 averaged 205 calls/day, the median detection rate of the study's nine years, when call detection rates ranged from as few as 18 calls/day in 2006 to as many as 1337 calls/day in 2008. The vector mean bearing to calls from DASAR C was 65° in 2009, similar to the vector mean bearings from that location in 2002, 2003, 2004, 2007, and 2008. Call type percentages recorded at DASAR C in 2009 differed markedly from previous years, with simple and complex calls occurring approximately equally; in past years of this study, simple calls were more common than complex calls. In short, the number of calls detected was within the range of call detections since systematic monitoring began in 2001, call distribution was similar to that in most previous years, and the proportion of complex calls was higher compared to all prior study years.

INTRODUCTION

The overall aim of this study is to assess the effects of Northstar production activities, as manifested in underwater sounds, on the distribution and behavior of calling bowhead whales in late summer and early autumn. An acoustical approach was used to locate calling bowhead whales near Northstar, and in earlier years a dose-response analysis was used to determine whether the distribution of calling whales was related to Northstar sounds. Statistical analyses of the 2001 to 2004 data showed that, with increased levels of certain types of Northstar sounds, there was a northeastward shift in the locations of whale calls in the southern (inshore) part of the whale migration corridor (Richardson et al. 2008). This shift could be the result of whales deflecting away from the island, of the whales near Northstar changing their calling rates in response to increased sounds, or possibly of a change in a whale's heading, given newfound evidence of directionality in bowhead whale calls (Blackwell et al. 2010, in preparation). Because estimated locations of calling bowhead whales constitute the primary data on whale distribution, understanding the nature of whale calls is important in interpreting the results.

Detailed analyses of the 2009 data are underway, seeking to identify and characterize any change in the distribution of bowhead whale calls that is related to Northstar sounds. The results of these analyses will be incorporated into a comprehensive report on Northstar monitoring in 2005 to 2010, to be submitted to NMFS in August 2010. The current chapter presents the results from preliminary analyses of whale calls recorded in and near the offshore DASAR array during the late summer/early autumn of 2009, and compares these results with those from previous years. It provides information on annual variation in the number of calls detected, their distribution, their bearings from the Northstar area, and the use of various call types.

The results of the Northstar whale call analyses are presented in the following three sections: (1) Number of whale calls detected; (2) Bearing analysis and whale call locations; and (3) Call types. The Methods used to acquire these data are described in more detail in Chapter 2.

NUMBER OF WHALE CALLS DETECTED

A total of 19,772 bowhead whale calls were detected on the records of the 10 array DASARs (A though J) during the 26 August–28 September period in 2009. These 19,772 calls were represented by a total of 97,662 call detections on one or more of the 10 array DASARs. A call that is detected at several DASARs is counted as a single call. The previous year, 2008, was notable for having the highest number of call detections in the history of the study (average of 1337 calls/day), whereas the number of calls detected per day in 2009 (average of 205 calls/day) ranked in the middle relative to all study years (Table 4.1).

Hourly call detection rates for all offshore DASARs over the entire deployment period are shown in Figure 4.1. The highest call detection rate was 466 calls/hour on 13 September at 20:00. This maximum rate was significantly higher than occurred on the vast majority of deployment days, when detection rates were typically below 150 calls/hour. In 2009, there was only one other noteworthy peak in call detection rates at ~300 calls/hour occurring at the end of the deployment period in late September (27–28). A peak in call detection rate during mid-late September was also apparent in most previous years (see Fig. 4.4, later).

TABLE 4.1. Year-to-year comparison of bowhead whale call counts at DASAR location C (2008, 2009) and EB (2001–2007). Also shown for each year is the length of the recording season (which depends on the deployment period and functionality of the DASAR), and the mean number of calls detected per day. When dividing the total number of calls by the season length, discrepancies in the listed mean number of calls per day may arise from rounding error.

Year	Total calls detected at C/EB	Length of DASAR recording season (days)	Mean # calls per day
2001 (EB)	1624	25	65
2002 (EB)	4317	24	180
2003 (EB)	21,726	30	724
2004 (EB)	26,546	27	989
2005 (EB)	951	29	33
2006 (EBa)	331	18	18
2007 (EBa)	9076	36	250
2008 (C)	39,550	30	1337
2009 (C)	6859	33	205

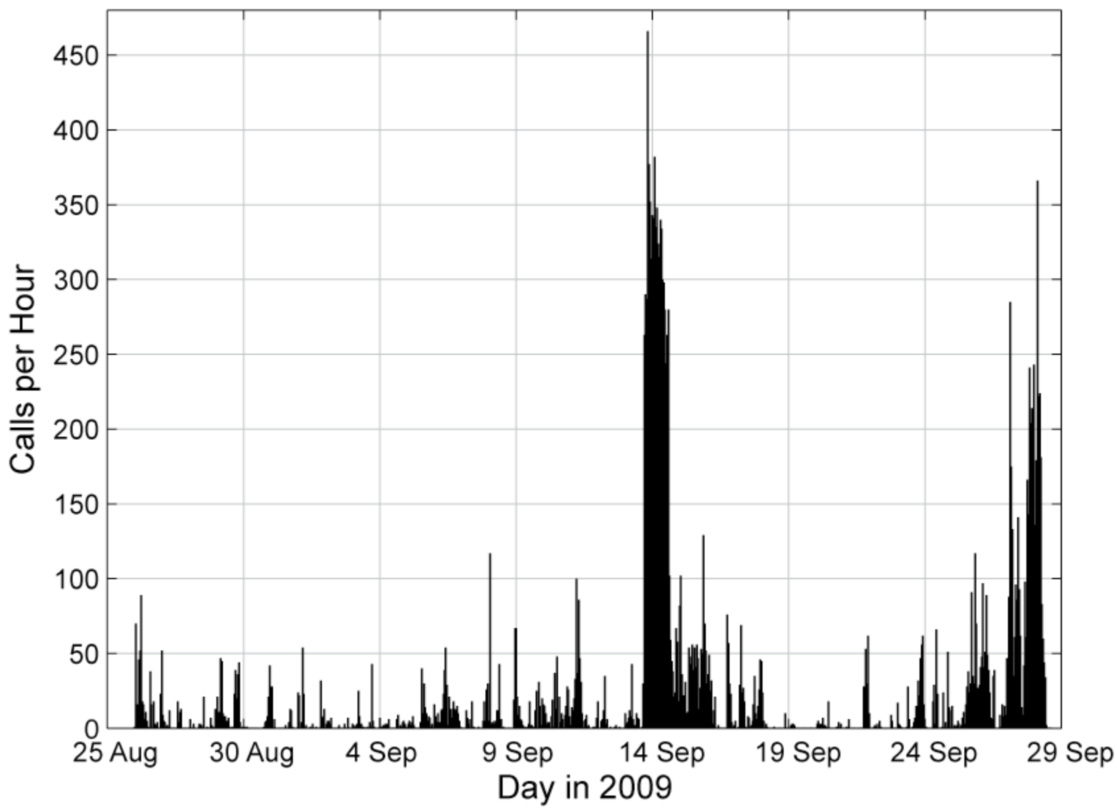

FIGURE 4.1. Hourly detection rate of whale calls as a function of time in late August to late September 2009. Total number of calls considered in this diagram was 19,772. Tick-marks on x-axis represent midnight (local daylight time). The highest hourly call detection rate was 466 calls/hour on 13 September between 20:00 and 21:00.

Visual observations of migrating bowhead whales were attempted from the ACS *Bay*-class boat *Mikkelsen Bay* anchored at 70°38.945′ N, 148°23.972′ W, near the middle of the offshore DASAR array. The purpose was to test the feasibility of collecting visual data on bowhead whales that would allow a meaningful comparison with acoustically detected whales. Based on peak call detection rates in previous years of the study, these visual observations were planned for five days in the period 17–24 September. Due to weather conditions, visual observations were only conducted for 8 hours on 19 September, and no bowhead whales were observed (see Annex 4.1 for more information). Unfortunately, the peak call detection rate in 2009 occurred slightly earlier in September than in previous years, presumably contributing to the lack of sightings.

Figure 4.2 shows that call detections did not exhibit a uniform distribution across the 10 offshore DASARs but were more numerous at the DASARs in the middle and northern part of the array farthest from shore. Specifically, the highest call detection rates occurred at DASARs F, G, H, and I, located ~25 to 35 km (16 to 22 mi) from Northstar. This region of maximum call detection was farther offshore than in 2008, when the highest call detection rates occurred at DASARs D, E and F, located ~18 to 25 km (11 to 16 mi) offshore of Northstar. The mean number of detections per call was 4.9 over the entire 2009 field season, meaning that an average of ~five DASARs detected each call. Figure 4.3 shows the distribution of calls heard by different numbers of DASARs, ranging from 1 (call detected by only one DASAR; no localization) to 10, i.e., call detected by all DASARs in the array. A total of 874 individual calls were

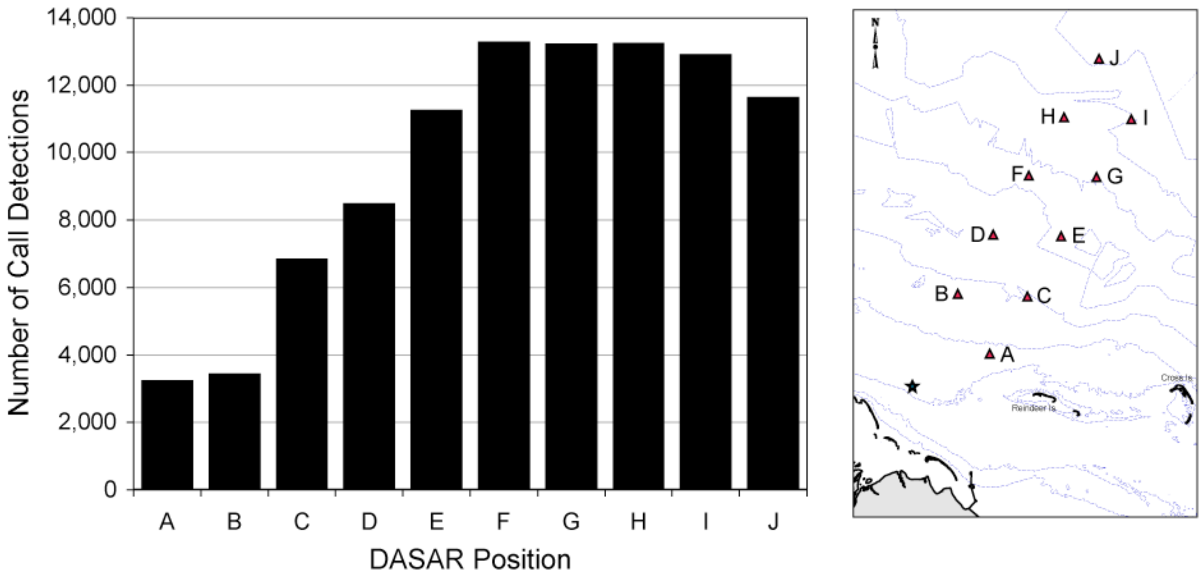

FIGURE 4.2. Number of bowhead call detections per DASAR location in 2009, for offshore DASARs. DASAR A is southernmost, DASAR J is northernmost, and DASARs are listed (from left to right) in the order of increasing distance from shore. The map shows Northstar (star) and the 10-DASAR array.

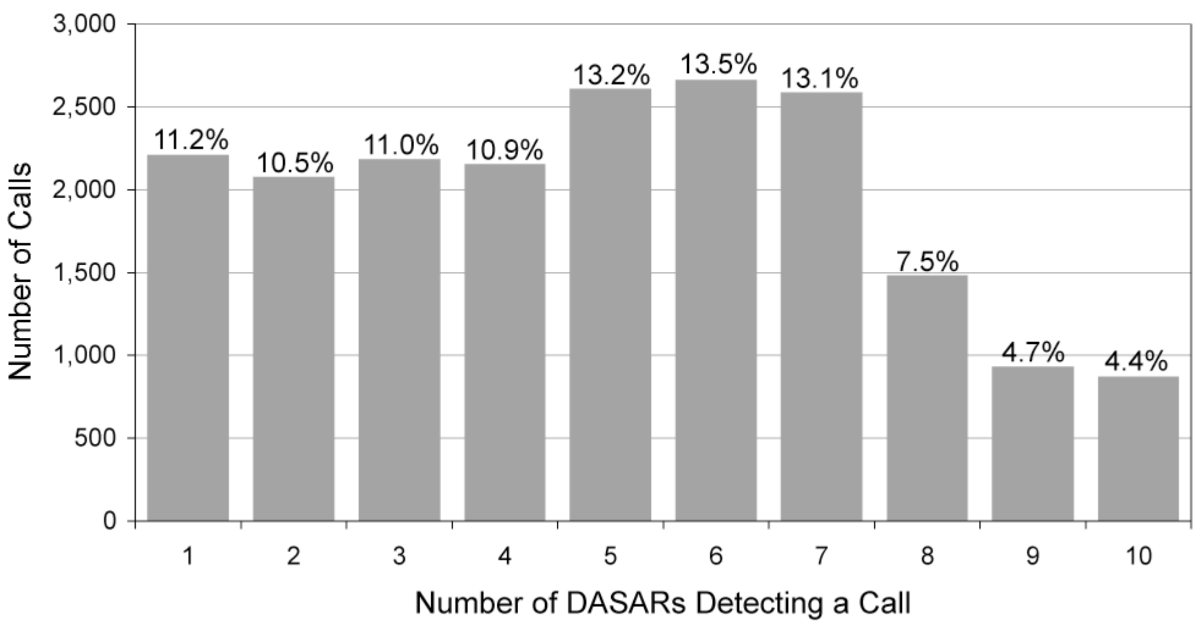

FIGURE 4.3. Number of bowhead calls detected by 1–10 DASARs in the offshore array, 26 August–28 September 2009. Corresponding percentages are shown above the bars.

detected by all DASARs concurrently. Since the offshore array is 32 km (19.9 mi) in its greatest dimension (DASAR A to DASAR J), those calls would have been audible over at least 16 km (9.9 mi). In 2009, 11.2% of calls were detected by only one DASAR. This percentage is lower than in earlier years when data from a ten-DASAR array with a different configuration were analyzed: e.g., corresponding values in 2002, 2003, and 2004 were 19%, 19%, and 22%, respectively (Greene et al. 2003; Blackwell et al. 2006a, 2006b). In 2008, when the array configuration was the same as in 2009, the percentage of calls detected by only one DASAR was similar to that in 2009, specifically, 14.3% (Blackwell et al. 2009).

Every year since 2001 there has been a functional DASAR at location C, which was called location EB in 2001–2007 and hereafter is referred to as location C/EB. Using call data from this location allows us to compare call counts over eight years. This comparison is shown in Table 4.1, and includes the mean number of calls per day to allow for the fact that DASARs were deployed for varying numbers of days in different years. In years when redundant DASARs were deployed at C/EB, we have only included counts from one of the DASARs. The daily call detection rate in 2009 (205 calls/day) was lower than in 2003, 2004, 2007 and 2008, and higher than in 2001, 2002, 2005 and 2006 (Table 4.1) and, thus, falls at the median of all study years.

Figure 4.4 compares daily numbers of calls detected by DASARs at location C/EB in 2009 and in previous years. The pattern at location C in 2009 was similar to the pattern seen in all DASARs combined (see Fig. 4.1), i.e., the highest peak was on 13 September and a secondary peak began to emerge at the end of September. The peak around mid-September occurred earlier in the deployment season compared with the peaks in 2002, 2003, 2004, and 2008, when maximum call detection rates occurred ~1 week later.

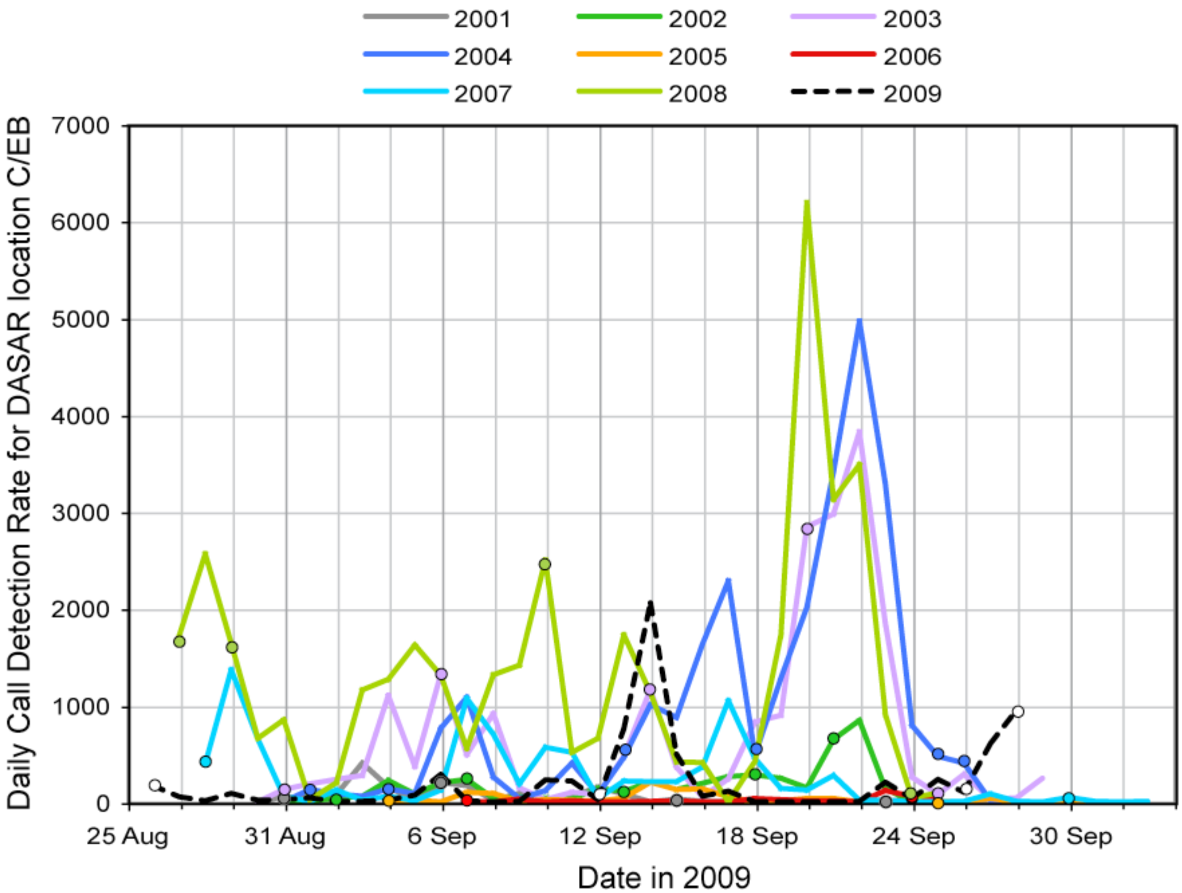

FIGURE 4.4. Daily number of bowhead calls detected by a DASAR at location C and EB for the entire 2001–2009 seasons. Note that, in 2001, 2002, 2005, and 2006, the total number of calls at location EB never exceeded 1000 calls/day. Daily counts marked with a dot indicate days when the acoustic research vessel went into the area of the DASAR array to service the DASARs. In 2002–2007, the calls detected at those times are not included and those days are, therefore, “incomplete”. In 2001, 2008, and 2009, all calls were counted, regardless of the presence or absence of the acoustic vessel.

A comparison of the number of calls detected in 2009 with previous years supports the general conclusion that 2009 was a year with average whale call counts. The different array configuration in 2009 compared to years before 2008 makes a direct comparison difficult, but call count statistics at DASAR location C/EB confirm this trend.

BEARING ANALYSES AND WHALE CALL LOCATIONS

In 2009, nearly 89% of the 19,772 whale calls were recorded by two or more DASAR. When a call is detected by two or more DASARs, its location can usually be estimated. In 2009, a total of 16,825 calls were localized. Figure 4.5 shows the estimated locations of these calls in relation to Northstar and the ten-DASAR array. Accuracy of the position estimates generally increases as a call is heard by more DASARs. In addition, confidence in the position estimates decreases with increasing distance from the DASARs; this decrease is quite steep beyond a distance of 6–10 km (4–6 mi) from the periphery of the DASAR array. In general, bearings to distant calls well outside the DASAR array are known quite accurately, but their estimated distances may be quite imprecise. Furthermore, the degree to which bearings are in line with the long axis of the array can affect localization accuracy since the greater the effective array aperture, the greater the localization accuracy.

Table 4.2 summarizes the main results of the bearing analyses. Location C/EB is the one DASAR location for which nine consecutive years of bearing data exist. Considering all nine seasons (2001–2009), vector mean bearings to the whale calls detected by the DASAR at location C/EB were most often (in 8 of 9 years) within the northeastern quadrant, i.e., offshore to the northeast or east-northeast. The longest mean vector length (L), indicative of the least variable bearings, was in 2002. Also, 2002 was the year with the highest O/I ratio (see Fig. 2.10), i.e., the year with the highest number of offshore calls in relation to the number of inshore calls. In 2009, the mean vector length, 0.70, rivaled that of 2002. Out of nine years, the O/I ratio in 2009 was the third highest, with 5.6× more calls offshore than inshore of DASAR C (Table 4.2).

Figure 4.6 shows the percentage distribution of all bearings to bowhead whale calls as obtained by the DASAR at location C/ EB in each year from 2001 to 2009. The bearings for each year were grouped into thirty-six 10° bins centered on multiples of 10° (i.e., 355°–4.99°, 5°–14.99°, etc.). The number of bearings in each bin is expressed as a percentage of the total number of call bearings determined via DASAR C/EB for that season. These plots emphasize the preponderance or relative rarity of bearings in certain directional sectors. For example, the 2009 plot shows that bearings in the range 135°–325° were relatively uncommon that season, whereas bearings in the range 45°–55° were most common. The distribution of bearings in 2009 was very similar to the distribution in 2001, which was a year when the southern edge of the whale migration corridor was relatively far offshore (Blackwell et al. 2007).

CALL TYPES

Figure 4.7 shows a percentage breakdown of all bowhead whale calls detected by DASARs at location C/EB by call type for 2001–2009. Calls are broken down into two main categories: simple calls and complex calls. Simple calls are further broken down into four sub-categories: upsweeps, downsweeps, constant frequency calls, and undulated calls. Until 2007, undulated calls were split into ∪-shaped and ∩-shaped undulated calls, but some undulated calls fit neither of these categories. Consequently, a third category of "other" undulated calls was created. To facilitate comparison among years, undulated calls are treated here as one category. Figure 4.8A shows that the call breakdown at DASAR C in 2009 was similar to the overall call breakdown at all 2009 DASARs. Figure 4.8B shows the percentage of simple versus complex calls in 2001–2009. Complex calls assumed an uncharacteristically larger proportion of calls than in previous years, accounting for approximately half, 49%, of all calls in

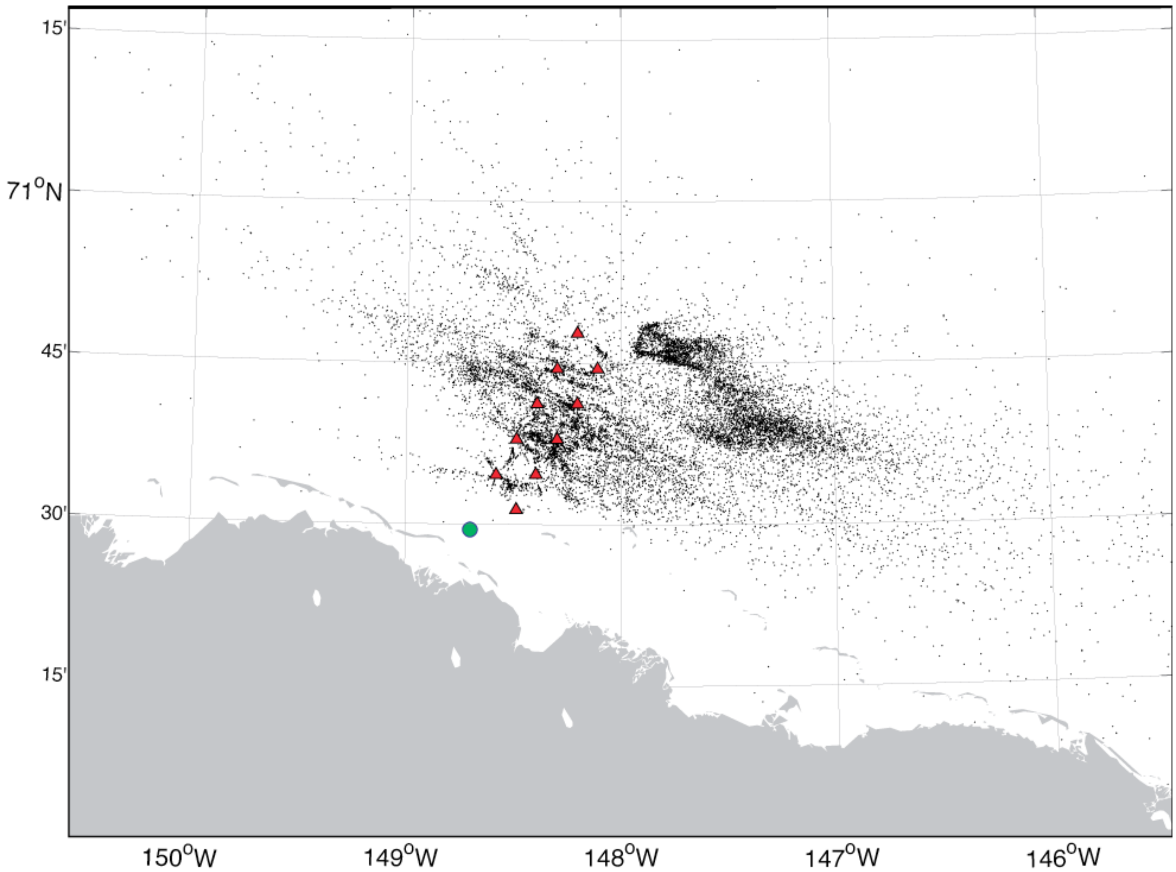

FIGURE 4.5. Estimated locations of all whale calls that were detected by two or more offshore DASARs in 2009. Northstar is shown as a green circle and the DASAR locations as red triangles. Calls recorded by the near-island DASARs were not used in the location estimations. Location accuracy increases with the number of DASARs used for each position calculation and decreases with distance from the array. For calls far outside the periphery of the DASAR array, bearing from the array is estimated quite accurately, but distance from the array is quite uncertain.

TABLE 4.2. Results of the bearing analyses for location C (2008, 2009)/EB (2001–2007). α is the vector mean bearing in degrees with respect to True North, and L is the length of the mean vector (see Fig. 2.9). O/I is the ratio of number of offshore versus inshore calls. See Chapter 2 *Methods* and Figure 2.10 for more information on O/I ratios, and Figure 4.2 and 4.5 for maps of DASAR locations.

Year	α (°)	L	O/I
2001	44	0.65	5.7
2002	64	0.74	13.6
2003	78	0.55	2.5
2004	69	0.42	2.4
2005	348	0.14	1.3
2006	33	0.46	4.0
2007	75	0.45	2.9
2008	59	0.53	5.1
2009	65	0.70	5.6

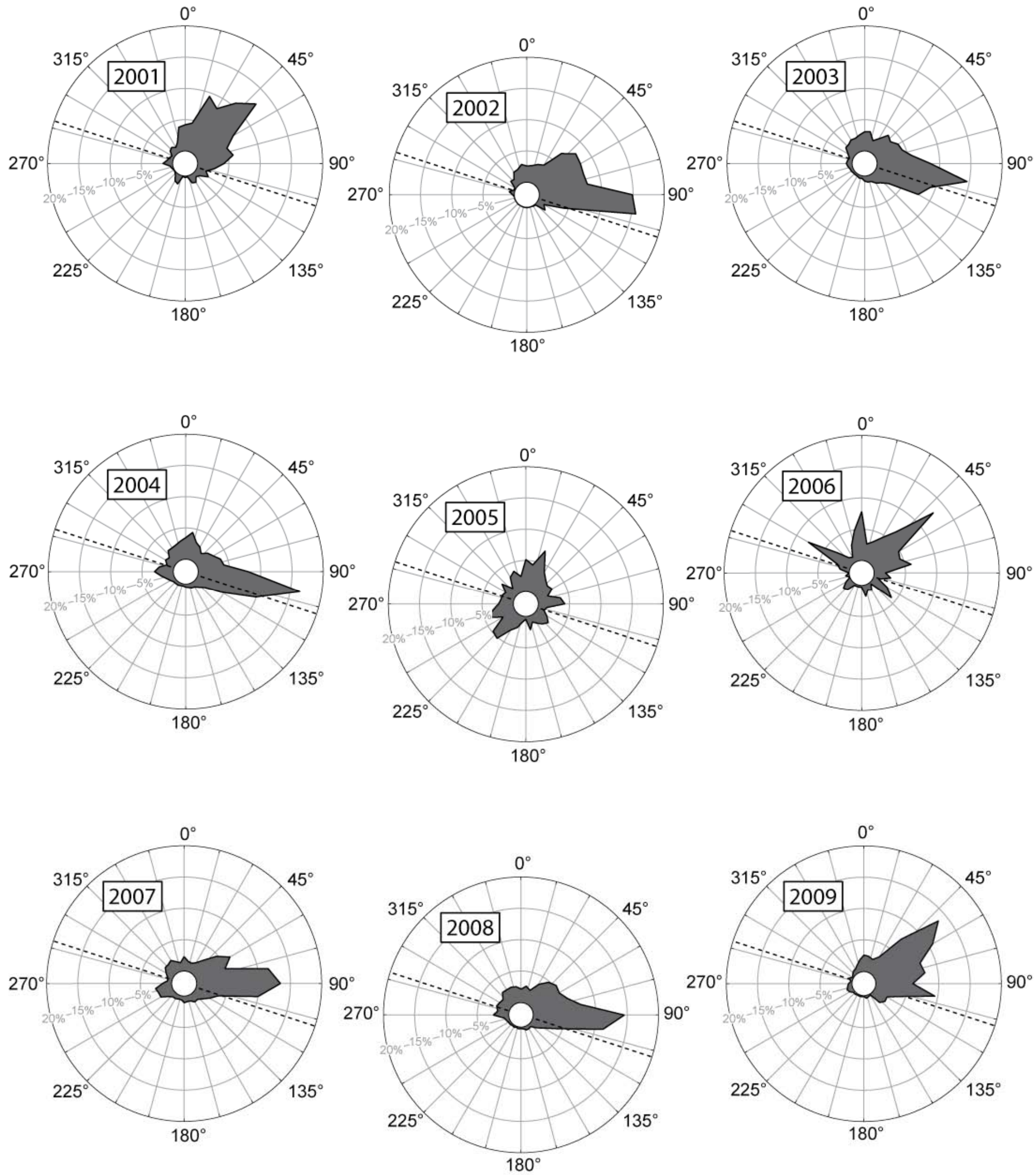

FIGURE 4.6. Directional distribution of bearings to bowhead whale calls detected via DASAR C/EB in 2001–2009. Results for each 10° sector are expressed as a percentage of all bearings obtained via the DASAR at location C/EB that year. The orientation of the baseline (see text) is shown as a dashed line through each DASAR. Sample sizes vary widely, from 332 in 2006 to 39,550 in 2008 (6859 in 2009).

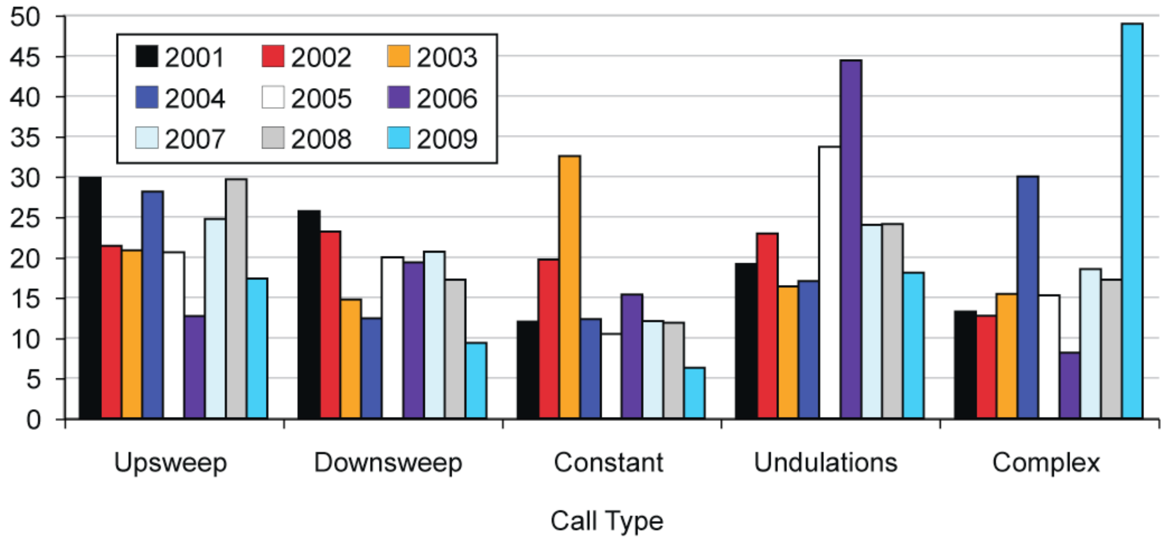

FIGURE 4.7. Percentage breakdown by call type in 2001–2009 for calls detected by DASARs at location C/EB. Simple calls include upsweeps, downsweeps, constant calls, and undulations.

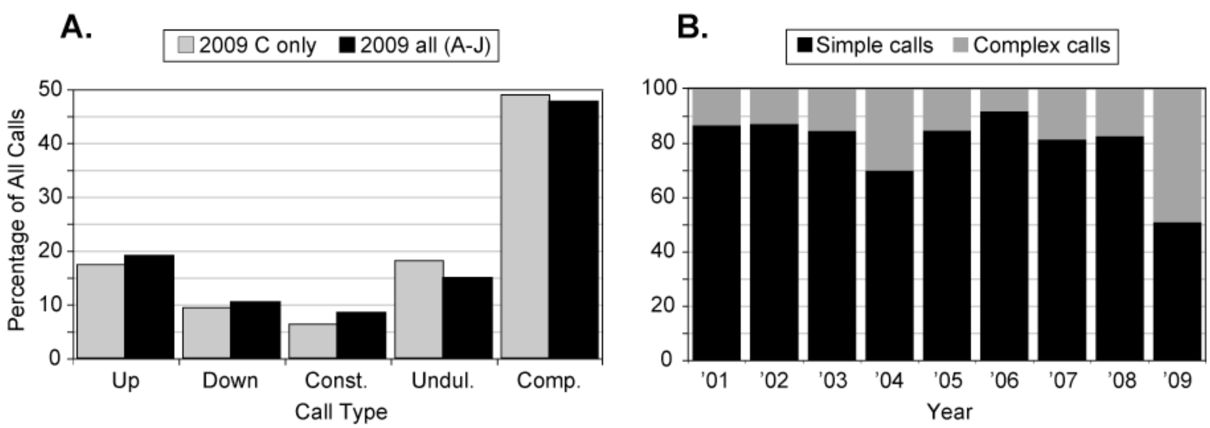

FIGURE 4.8. Comparisons of percentage breakdowns by call type for DASAR C vs. other DASARs in 2009, and among years. ***(A)*** Call types detected in 2009 by DASAR C (gray bars) versus all array DASARs (black bars). Simple calls include upsweeps, downsweeps, constant calls, and undulations. ***(B)*** Percentage of simple (black bars) vs. complex (gray bars) calls in 2001–2009. Simple and complex calls occurred in equal proportion in 2009.

2009. Likewise, the remaining 51% of simple calls comprised a smaller percentage of calls compared with 70% to 92% in 2001–2008.

DISCUSSION

After an initial year of partially successful acoustic monitoring operations in 2000, the fall migration of bowhead whales has been monitored acoustically offshore of Northstar Island since 2001. In the four years 2001–2004, a rather consistent procedure was used. In 2005–2007, the procedure was changed on the basis of the results obtained during 2001–2004. The 2008 and 2009 seasons were similar to 2001–2004 with regard to the number of DASARs, but the configuration of the array was different, with DASARs extending farther offshore than in 2001–2004 (both configurations are shown in Fig. 2.2, Chapter 2).

The distribution of estimated call locations in 2009, shown in Figure 4.5, bears similarities to the distribution seen in 2001, but with a higher number of calls detected in 2009 than in 2001. As seen in 2001 (and other years), more calls were detected to the east of the center of the array than to the west (see Fig. 4.5). The distribution of calls detected by different DASARs, shown in Figure 4.2, suggests that in 2009 the bowhead migration corridor was farther offshore (concentrated around DASARs F, G, H, and I) than in 2008. This is consistent with the observations of Nuiqsut whalers that whales were relatively far offshore during the 2009 fall hunt (see Chapter 5).

The distribution of bearings to whale calls from DASAR C in 2009, as shown in Table 4.2 and in Figure 4.6, was also most similar to the distribution in 2001. In these years, the majority of bearings were in the 45°–55° range, i.e., the calling whales were predominantly to the northeast of DASAR C/EB.

The call type analysis (Fig. 4.7, 4.8) showed that the use of different call types in 2009 was within the range of previous years, with the notable exception of complex calls which occurred in a much higher proportion compared to simple calls than in previous years. Changes in the percentage use of different call types from one year to the next are difficult to interpret because little is known about the behavioral significance of specific types of bowhead calls. Some studies suggest that complex calls are related mostly to social behavior (Würsig and Clark 1993; Richardson et al. 1995).

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ANNEX 4.1: VISUAL OBSERVATIONS OF BOWHEAD WHALES FROM THE ACS *BAY* BOAT *MIKKELSEN BAY*

The purpose of collecting visual observations on migrating bowhead whales in the middle of the DASAR array was to test if these data would allow a meaningful comparison with acoustically detected bowhead whales. Although the acoustic data show year-to-year variation in the timing and magnitude of peaks in detection of calling bowhead whales (Fig. 4.4), the week of 17–25 September seemed to be the most appropriate choice for visual observations because in most years a peak in bowhead call detection occurred during this period.

In 2008, visual observations were conducted for a total of 22 hours over 3 days by a marine mammal observer stationed on the process module at Northstar Island. From this location, bowhead whales at the surface should have been observable to a distance of ~5 km (3 mi) offshore of Northstar during favorable weather conditions. Most bowheads migrating west in autumn are much farther offshore than this, and as such visual observations from the Northstar process module were not considered to be useful. In 2009, it was decided to change the approach and to conduct visual observations from an ACS *Bay*-class boat anchored in the middle of the DASAR array.

Three marine mammal observers were present on the boat, with at least two observers on watch for bowhead whales at any time during daylight hours (Fig. 4.9). These observers were Patrick Easterday (Nuiqsut) and Charles Hopson (Barrow) from LCMF, and Lisanne Aerts from LGL Alaska. Due to poor weather conditions (wind speeds of 32 km/h [20 mph] or more), visual observations were conducted on only one day, specifically 19 September. On this day, the wind speed was ~16 km/h (10 mph). The *Mikkelsen Bay* anchored at a location just NE of DASAR D at 70°38.945′ N, 148°23.972′ W. Visual observation attempts on 20 and 24 September were cancelled due to bad weather conditions, such as wind speeds in excess of 32 km/h (20 mph) and high sea swells.

One marine mammal observer was located on the bridge or at the bow of the *Mikkelsen Bay* and scanned an area of ~180^o in front of the vessel while a second marine mammal observer was located on the deck and scanned an area of ~180^o behind the vessel. Observations were made with the naked eye or with a reticle binocular (Fujinon 7 × 50) to confirm sightings and estimate distance.

On 19 September, observations were made during a total of 8 daylight hours, from 09:40 to 17:40 AKDT. During this period, no bowhead whales (or other cetacean species) were sighted. There were 15 sightings of ringed seals at distances of ~5–100 m (16–328 ft) from the boat. These sightings included repeat sightings of possibly 3 or 4 seals, including a juvenile. Visibility was generally 10 km (6 mi) or more, with occasional fog reducing visibility to 5 km (3 mi). The distance to which whales at the surface could be detected reliably on that day was estimated to be 1.5 to 2 km (0.9 to 1.2 mi) to from the vessel. (A detectability curve could not be calculated due to the lack of sightings.)

Although visual observations were planned to coincide with historically high calling periods, the peak in call detection rate in 2009 occurred slightly earlier in September than in previous years. Results from the call analyses revealed that on 19 September a total of 10 bowhead calls were detected. Of these 10 calls, 6 calls could be localized, but none of these calls were detected during daylight hours when visual observations took place. In a general way, the lack of visual observations of bowheads in the middle of the array is consistent with the lack of acoustic detections and localizations at that place and time. However, due to the absence of any visual sightings, results do not provide useful information on the feasibility of comparing visual observations from an ACS *Bay*-class boat in the middle of the array with the acoustic call detections.

FIGURE 4.9. Charles Hopson and Patrick Easterday watching for marine mammals from the back deck of the *Mikkelsen Bay* on 19 September ***(A)***, and Charles Hopson watching for marine mammals from the bow of the boat ***(B)***.

CHAPTER 5:

SUMMARY OF THE 2009 SUBSISTENCE WHALING SEASON AT CROSS ISLAND[1,2]

by

Michael S. Galginaitis

Applied Sociocultural Research
519 West 8th Ave, Suite 204, Anchorage, AK 99510
Phone: (907) 272-6811; e-mail: msgalginaitis@alaska.net

for

BP Exploration (Alaska) Inc.
Dept. of Health, Safety & Environment
900 East Benson Blvd, P.O. Box 196612
Anchorage, AK 99519-6612

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[2] All conclusions and opinions expressed in this chapter are those of the author and do not necessarily represent those of either BP or the Nuiqsut whalers.

ABSTRACT

The North Slope Borough's Science Advisory Committee has recommended that local and traditional knowledge of Nuiqsut whalers be incorporated into reports concerning BP's Northstar marine mammal and acoustic monitoring program. This chapter does so in large part by summarizing data acquired during the 2009 phase of the Minerals Management Service project "Annual assessment of subsistence bowhead whaling near Cross Island". Those data were supplemented by data analysis and additional interviews with the whalers focusing on topics relevant to Northstar. The interviews concentrated on whalers' encounters or concerns with non-whaling vessels in 2009, the whalers' observations of the general offshore distribution of whales, whale feeding behavior (if any), and "skittish" behavior.

In 2009, a total of six crews with a total of 11 boats whaled from Cross Island. Five crews traveled to Cross Island on 27 August, with the sixth crew traveling on 28 August. A few boats scouted on 28 and 29 August, but most crews spent these days on preparing equipment and fixing cabins on Cross Island. Conditions on 30 and 31 August were not suitable for scouting for whales. Most boats scouted on 1–4 September, 6–7 September, and 11–13 September. Conditions (mainly high wind and sea swells) prevented scouting on 30–31 August, 5 September, and 8–10 September (although one boat did scout briefly on 10 Sep). Whales were seen on most days when scouting occurred (but not on 28 Aug and 10 Sep). However, conditions on most days made seeing whales very difficult, some reported sightings may be less certain than others, and relatively few whales were seen. The lack of ice during the 2009 whaling season also often contributed to adverse sea states (the presence of large rolling swells) even on some days with little wind. The whalers concluded that there were relatively few whales in the area, and the ones they saw behaved as if they were "spooked". The whalers observed various types of boat traffic (commercial barges, ACS vessels, or private craft) on four different days, with two different sightings on one day. One of these encounters was on 12 September with the ACS vessel *Mikkelsen Bay* while it was servicing the DASARs in the Northstar array (see also Chapter 2, section "Time and Bearing Calibrations"). The *Mikkelsen Bay* returned to West Dock directly after its crew was contacted by the Communication Center. There was no consensus on why so few whales were seen or why they were "spooky", but factors discussed included vessel traffic, sea state and lighting conditions, the possible presence of killer whales, and possible changes or variation in the path or timing of bowhead whale migration. The whale call analyses based on the 2009 DASAR records were consistent with observations by the whalers in that, compared to 2008, significantly fewer calls were detected and the migration path was slightly further north (see Chapter 4). The whalers ended their season on 13 September due to deteriorating conditions and other factors. Four crews returned to Nuiqsut on 14 September and two crews on 15 September.

The 2009 Cross Island whaling season extended over 20 days. Scouting for whales occurred on 12 of these days. On two of these days only one or two boats went scouting, due to marginal conditions. Weather or sea conditions prevented crews from whaling on five days. Three days were devoted to traveling between Nuiqsut and Cross Island or preparing for whaling or butchering. Nuiqsut whalers used only three of their four strikes. A whale was struck and lost on 6 September and single whales were landed on 11 and 13 September. Strikes were made an average of 22 km (14 mi) ENE of Cross Island, with individual strikes 17.2 km [10.7 mi] east; 18.7 km [11.6 mi] ENE; and 31.7 km [19.7 mi] ENE).

In summary, the 2009 Cross Island hunt was challenging; only three of Nuiqsut's four strikes were used, and only two bowheads were landed. Although whalers were able to scout for whales on most days, overall sea-state and weather conditions often made it difficult to reliably observe whales and relatively few whales were seen. The whalers thought that the whales they did see were behaving strangely. Whalers reported two instances of observed whale feeding. Weather and sea conditions prevented any

scouting activity on five days, and effectively prevented it on a sixth day. There were 12 days when boats went scouting for whales, under variable and sometimes marginal conditions that made detection of whales difficult. The absence of ice increased the adverse effect of wind, and even on relatively calm days large swells sometimes made scouting somewhat difficult. More than in previous years of this study, the whalers had a season-long concern with non-whaling vessel traffic, and spotted vessels when they were whaling on four different days. The level of effort expended by the whalers, in terms of boat hours on the water scouting for, chasing, and towing whales was much higher in 2009 than in any year for which comparable information is available.

INTRODUCTION

During the autumn migration period of bowhead whales, subsistence hunters from Nuiqsut travel to Cross Island, 28 km (17.5 mi) east of Northstar, in order to hunt bowhead whales. In recent years, a quota of four whales has been allotted to the Nuiqsut hunters. Cross Island is relatively close to the Prudhoe Bay area and its associated industrial activities. There is considerable concern among the Nuiqsut hunters about the potential for vessel and aircraft traffic, and other industrial activities, to interfere with the hunt.

The North Slope Borough's Science Advisory Committee (SAC) reviewed the results of BP's Northstar marine mammal and acoustic monitoring program during early 2005. One of their recommendations was to use Traditional Knowledge (TK) in future monitoring. Specifically the SAC recommended that observations by subsistence whale hunters at Cross Island should be integrated into the Northstar monitoring study. The SAC noted that "Such observations might include general offshore distribution of whales, feeding behavior, 'skittish' behavior, number of vessels and reaction to them. We recommend that TK observations be summarized in a section of the Northstar annual report."

Since 2001, the Minerals Management Service has sponsored a detailed study of the whaling activities at Cross Island (Galginaitis and Funk 2004, 2005; Galginaitis 2006a,b, 2007a, 2009a,b). Each year since 2001, Galginaitis has spent much or all of the autumn whaling season at Cross Island with the Nuiqsut whalers, documenting their activities and interpretations of events. As part of this work, GPS (Global Positioning System) dataloggers have been placed on whaling vessels to document the tracks of the whalers as they scout for whales. Systematic observations and interviews with the whalers supplement the GPS data. The whalers have been very cooperative in supporting this work, and in providing detailed information.

It was apparent that the ongoing MMS study provided a good starting point for the compilation of the types of traditional knowledge that the NSB's SAC had recommended be incorporated into BP's Northstar monitoring program. Consequently, BP has augmented the ongoing MMS-supported program during 2005–2009, to compile the specific types of information mentioned by the SAC (Galginaitis 2006c, 2007b, 2008a,b, 2009c, this report).

This chapter of BP's 2009 Annual Summary Report describes information provided by the Nuiqsut subsistence whalers on selected aspects of the 2009 whaling season. This included the general offshore distribution of whales in 2009, any observations of feeding behavior of whales, observed "skittish" behavior of whales, the number of vessels (aside from whaling vessels) encountered at sea, and observed whale reactions to those vessels. To provide broader context, this chapter begins with a discussion of the methods used for gathering the information in this chapter, a very general description of the equipment and methods used for fall subsistence whaling, and a brief summary of the 2009 subsistence whaling season at Cross Island. That introductory summary mentions some factors that may limit the conclusions that can be drawn, e.g., lack or scarcity of observations, indeterminate causes, or possible multiple cause-effect linkages. This chapter deals almost entirely with the 2009 season, which sets definite limits on the conclusions that can be drawn. Some comparative information from previous years is mentioned briefly. More details for prior years can be found in earlier reports prepared for MMS and for BP (Galginaitis and Funk 2004, 2005; Galginaitis 2006a,b,c, 2007a,b, 2008a,b, 2009a,b,c).

METHODS

The objective of the MMS Cross Island project is to describe Cross Island whaling using measures that document year-to-year variability in whaling and, when sufficient time series data are available, will allow tests of hypotheses on the causes of this variability. Concern about potential effects of oil and gas development on whaling is the prime motivation for the MMS project, but it is recognized that other factors can strongly affect Cross Island whaling and thus need to be considered as well. These other factors include weather and ice conditions, equipment problems, whalers' decisions, and non-industrial human activities. During the MMS-sponsored project, information is collected on level of hunting effort, including how many boats go out each day, crew size, how much time is spent on the water, lengths of trips in miles, and furthest point away from Cross Island during each trip. Information is also collected on the abundance and distribution of whales, including the number and location of whales observed and/or struck by the whalers.

Information on the level of hunting effort was collected by systematic observations by the author of this chapter (MSG), who was on Cross Island for most of the whaling season in each of 2001–2009. This information was supplemented by conversations with all of the boat crews. Further information on the hunting effort, and on the abundance and distribution of whales, was obtained by issuing Garmin hand-held GPS (Global Positioning System) units to all boats operating from Cross Island. The whalers were given instructions on how to record the GPS coordinates (track) of each boat trip, and how to mark waypoints of significance, including whale sightings and strikes, sightings of vessels other than whaling vessels, and other pertinent observations. This information was then mapped, and the results form the basis for the Figures included in this report. It should be noted that whaling crews mark relatively few points when on the water, and the points they do mark represent the boat's positions at times a whale or group of whales was seen, or some other significant event took place. Whales sighted may be quite close or miles away, depending on the conditions during that day.

The information collected with the GPS units was supplemented by subsequent conversations with the whalers in English and reviews of the mapped GPS information with each boat crew. During this review of boat tracks shortly after the whalers returned from their trips, crew members would often remember and identify locations where they saw whales, and these points were added to the recorded GPS information. Some of these points were boat positions, and some were estimated positions of whales (and thus not necessarily located on a boat track). Other points were reference coordinates and may represent past whale sightings, so they also may not be located on boat tracks. MSG did not accompany the whalers in their boats while they were hunting, since it is not permissible for any non-Native to participate actively in hunting marine mammals.

Supplemental systematic interviews that focused on those topics of particular concern to BP were conducted both on Cross Island and in Nuiqsut after the whaling season. These interviews were primarily with whaling captains or senior crew members who had encountered non-whaling vessels while scouting for bowheads or who had other significant information to share. These interviews were guided by an informal protocol developed to record such information within the context of the documentation of that day's scouting/whaling activities. Thus there were no "sampling" issues *per se*—information was sought from all crews for all whaling trips, and especially for those encountering other vessels or who had other significant information they were willing to share. However, during the 2009 season, one captain declined to participate in the research, so most GPS and supplemental information is lacking for one boat. A more detailed description of the methodology can be found in Galginaitis and Funk (2004, 2005) and Galginaitis (2006a,b, 2007a, 2009a,b).

SUBSISTENCE WHALING EQUIPMENT, METHODS, AND CONSTRAINTS

A basic understanding as to how subsistence whaling is conducted by Nuiqsut whalers is important in interpreting how those activities might be affected by industry activities. The information in this section is intended to provide only enough detail to provide an adequate context for the results of this report. For a broader review, see Stoker and Krupnik (1993), Rexford (1997), Brewster (2004), or the first two chapters of Wohlforth (2004).

The community of Nuiqsut is located about 25.7 km (16 mi) inland ("as the crow flies") on the Colville River. Nuiqsut crews harvest whales only in the fall. Their whaling location is Cross Island, about 117 "direct" km (73 mi) or 148 to 175 "water" km (92 to 109 mi) from Nuiqsut. Cross Island is located about 16.1 km (10 mi) north of Endicott, 24.1 km (15 mi) NW of West Dock, and 27.4 km (17 mi) east of Northstar. There are currently seven active whaling crews in Nuiqsut. Six of these whaled in 2009. There are also some additional identified crews that have not whaled since at least 2000. Whether a crew goes out during any specific season depends upon the captain's personal and economic circumstances. Some crews use more than one whaling boat. Whaling boats are generally 5.5 to 7.3 m (18 to 24 ft) long, with aluminum or fiberglass hulls, and single outboard motors of 70 to 250 horsepower. The bylaws of the Alaska Eskimo Whaling Commission (AEWC) specify the equipment (weapons, harpoon, float) to be used for the whale hunt, and the general manner in which it is to be conducted. Figures 5.1 and 5.2 provide images of the equipment used for Cross Island whaling in 2009 (and previous study years)—darting gun, float, shoulder gun, and the boats used by the six crews.

Nuiqsut whalers generally scout for whales on any day when the weather is suitable for finding and striking whales unless a whale was taken the previous day, in which case butchering usually has priority. However, this pattern may be changing. In 2006, Nuiqsut crews landed single whales on three successive days, apparently because the whales were relatively small and the whalers wanted to take advantage of a period of good weather for scouting (Galginaitis 2007a, 2007b). In 2007, they purposely landed two whales on one day in order to complete their quota and close the season given the unpredictable weather conditions for whaling (Galginaitis 2008a, 2009a). In 2008, Nuiqsut whalers landed four whales in the space of five days, again because they wanted to take advantage of relatively good weather conditions after a period of unfavorable weather and before conditions deteriorated again (Galginaitis 2009b). In 2009, although the whale landed on 11 September was large, all but the crew who landed that whale went scouting on 12 and 13 September (and landed another whale on 13 Sep). Whalers invariably use the term "scouting" rather than "hunting" to describe looking for whales to strike. Good whaling weather is determined more by wind speed and sea conditions than anything else. Whalers prefer days with no wind, but winds up to 8 to 16 km/h (5–10 mph), or even higher, can be acceptable. Sea conditions generally are related to wind speed, but scouting can occur even with higher winds, depending on the circumstances. Ice cover generally moderates the effect of wind by dampening wave height, especially when the ice edge is not too far from shore but also to some extent when there are floating ice floes. During the period of the MMS research (2001 to present) the ice edge has always been quite distant from shore, and significant ice floes have been mostly absent. There were some large ice floes present in 2001, fewer in 2002, and almost none of significance since then. In 2005 and 2006, localized consolidated pack ice along the north shore of Cross Island limited the area where Nuiqsut whalers could hunt for whales. In 2009 the ice edge was far from shore and there was little floating ice.

FIGURE 5.1. Left to right, top to bottom: NOAA archive photo showing whaling gear, cleaning shoulder gun, wrapping rope on float (to attach to darting gun), unloaded new whale bombs (quarter for scale), some fragments of exploded bombs recovered from whales.

FIGURE 5.2. Whaling boats at Cross Island during the 2009 subsistence whaling season, clockwise from top left: Napageak boat prepared for scouting; Oyagak2 and Oyagak1 at Cross Island; Aqarguin boat at Cross Island; Taalak1 and Taalak2 anchored at Cross Island; Nukapigak 1, Nukapigak3, and Nukapigak2 at Cross Island; Ipalook1 (foreground) and Ipalook2 leaving Nuiqsut for Cross Island.

Boats typically scout for whales with a complement of three or four people, although since 2001 boat crews have ranged in size from two to seven, and during the 2009 season ranged from three to five persons. Although solitary boats do take whales on occasion (for example the first two strikes by Nuiqsut whalers in 2007 were conducted by boats scouting alone), this is not encouraged. Nuiqsut boats almost always scout for whales with at least one other boat, in case of mechanical break down or other emergencies. Whaling crews with two or three boats are willing to whale without the support of other crews, and this is one reason for a single crew to use more than one whaling boat. It seems that five to seven boats is a preferable number to have available for scouting whales on a given day, and in 2009 the average number of boats that went out scouting was 7.4 (8.6 if two marginal days are excluded). When fewer boats are available, the efficiency, safety, and likelihood of a successful hunt are all decreased.

Once Nuiqsut whalers spot a whale and determine that it is a proper whale to take, generally 7.6 to 10.7 m (25 to 35 ft) long and not a mother with a calf, they approach it at high speed so that it dives. They then estimate where it is likely to reappear (usually in 5 to 10 min, but sometimes longer) and once they reach that area wait and search at low speed until the whale surfaces and is spotted. They then repeat the process. The objective is to tire the whale so that it must stay on the surface for longer periods of time, until one of the boats can get close enough to strike the whale on its left side with the darting gun. The whale is killed by the delivery of whale "bombs", which are in essence very large explosive bullets with timed fuses (generally 4 to 8 s) that allow the bombs to penetrate inside the whale before they explode. Inupiat whalers adopted this technology from the commercial Yankee whalers. Lytle (1984) presents a full review of this technology and its development. The whale bombs are delivered to the whale via two methods: a darting gun attached to a harpoon, or a shoulder gun.

During fall whaling, the first bomb is delivered via a darting gun, which at the same time deploys a harpoon with an attached float. The harpoon and darting gun are both attached to a long wooden handle. This is thrown from the boat at the whale, usually at a distance of no greater than 3–4.6 m (10–15 ft), and ideally closer. Once the whale is struck, the harpoon separates from the handle. A trigger rod fires the darting gun and shoots the bomb into the whale. An internal hammer ignites the bomb's fuse once it hits and penetrates the whale's skin and the bomb explodes 4 to 8 s later (depending on how long a fuse was used). The darting gun remains on the handle and thus floats in the water until it can be recovered. It must be dried and cleaned before being used again. In extreme cases this can be done on the water, but is usually done on shore. Thus, most darting guns are effectively one-shot weapons. Each whaling boat has at least one, and sometimes two, darting guns on board.

The second weapon used to deliver whale bombs is the shoulder gun. A shoulder gun is essentially a very heavy, short barreled, smooth bore, high caliber shotgun-like device that shoots the same sort of black-powder bomb as is used in the darting gun, only with metal fletches or fins to help stabilize its flight in the air. In the fall, the shoulder gun can only be used after a float has been attached to a whale with a darting gun. The first bomb kills some whales. However, when multiple bombs are required, the shoulder gun is useful because it can be used to fire more than one shot.

Until recently, all Nuiqsut whalers used the "traditional" black powder bombs—a technology adopted from the commercial Yankee whalers. All captains, or a trusted member of a captain's crew, load and assemble these bombs each year, often only after reaching Cross Island, due to the hazards involved. As discussed above, the black powder projectiles fired by the darting gun and shoulder gun are essentially the same. The more recently developed "super bomb" can only be used on a darting gun, with a specially modified barrel. It is manufactured in Norway, uses penthrite instead of black powder, and is designed to kill whales faster than a black powder bomb. It is a product of the interest in developing more efficient weapons for subsistence whaling, but development has been somewhat delayed due to the relatively small demand and its somewhat complicated operation compared to the black powder bomb (Øen 1995; Sadler and Grønvik 2003; AEWC 2006).

The darting gun is always thrown from the right side of the boat, since it is attached to a line and the float, and this line is always rigged on the right side of the boat. If the darting gun were thrown to the left of the boat, the float line would then stream across the boat at high speed, endangering the crew and the structural integrity of the boat. Thus the whale is usually approached and struck on the whale's left side, since the boat normally "catches up" to the whale from behind it in order to achieve a striking position. Nuiqsut whalers report that whales are sometimes approached and struck from the front, but that this is unusual and has not occurred at Cross Island during the course of the MMS project (2001–present).

Once the whale is dead, all available boats usually assist in towing it back to Cross Island to be butchered. It is hauled up onto the beach with mechanical assistance. All cutting is done with an assortment of knives with long handles. The initial butchering and division into crew shares is done on Cross Island, but further division among crew members is done after the crew and whale products are in Nuiqsut.

The harvest of bowhead whales by crews from Nuiqsut is displayed in Table 5.1. Because Nuiqsut was resettled in 1973, years before 1973 are not included in this table.

THE 2009 WHALING SEASON

This section contains a general overview of the 2009 Cross Island whaling season. Annex 5.1 provides more detail on a day-by-day basis for both whaling activity and other vessel traffic noted in the Cross Island area.

Six crews whaled from Cross Island in 2009. All had whaled at Cross Island previously. Two crews whaled with one boat, three whaled with two boats, and one crew whaled with three boats. One of the "two-boat" crews was joined late in the season by a "support" boat. This was the only crew in 2009 that used a boat for logistic support. As in previous years, the start of the Cross Island whaling season depended primarily on weather conditions, reports of whale sightings near Cross Island, and the readiness of the whaling boats. The whalers were perhaps a little more intent on starting the season early rather than late because of recent experiences with poorer weather in the second half of September. The whalers struck and lost one whale, landed two others, and did not use their fourth strike, as summarized in Table 5.2. Weather conditions, time spent out scouting, and time and date of strikes are summarized graphically in Figure 5.3.

Five crews left Nuiqsut for Cross Island on 27 August in order to get things ready for whaling and to build or repair their cabins. Two crews were relatively newly formed and had "borrowed" cabins the previous year, and wanted to construct cabins of their own. The cabins for three other crews (one not whaling in 2009) had been damaged by polar bears since the 2008 season, and needed to be cleaned and repaired. Other structures on the island that had not been recently used had also been damaged. The sixth crew traveled from Nuiqsut to Cross Island on 28 August. Two boats went scouting on 28 August, but one was out for only 12 minutes, to check a potential sighting seen from the island (it was negative). Winds were 8 to 27 km/h (5 to 17 mph), so conditions, while not optimal, were at least marginally acceptable. The other boat remained out about 4 hours 11 minutes and reported no whale sightings. Winds were about the same on 29 August and three crews (four boats) went scouting, with trips of 3.5 to almost 11 hours, and reported a total of two whale sightings. The other three crews remained on shore. Wind speeds on 30–31 August prevented anyone from whaling. Although wind speed dropped as low as 8 km/h (5 mph) on 30 August, it peaked at 56 km/h (35 mph) and sea states were too rough. On 31 August wind speed peaked at nearly 64 km/h (40 mph).

TABLE 5.1. Recent harvest of bowhead whales near Cross Island.

Year	Whales			Notes
	Quota	Landed	Struck & Lost	
1973	NA	1	0	
1982	1	1	0	
1986	2	1	0	
1987	2	1	0	
1989	3	2	2	Oil industry vessel disturbance noted by whalers
1990	3	0	1	Oil industry disturbance noted, also rough seas
1991	3	1	2	Poor weather, adverse ice conditions
1992	3	2	1	
1993	3	3	0	Very favorable whaling conditions
1995	4	4	0	
1996	4	2	0	
1997	4	3	1	
1998	4	4	1	
1999	4	3	0	
2000	4	4	0	Very favorable whaling conditions
2001	4	3	0	Whalers report whales tended to be “skittish”
2002	4	4	1	
2003	4	4	0	Poor weather
2004	4	3	0	Poor weather
2005	4	1	0	Very poor weather, adverse ice conditions, disruption
2006	4	4	0	Adverse ice conditions first half of season
2007	4	3	1	Overall poor weather, little ice, whales close
2008	4	4	0	No ice, generally poor weather, and rough/variable sea conditions; whales close to Cross Island
2009	4	2	1	No ice; swells and some difficult sighting conditions; whales relatively distant

Notes: Years of no harvest and no “struck and lost” are not listed. This does not imply that no whaling effort was made in those years. “Quota” was not applicable prior to 1978. It is not clear from the records (or informants) when the quota for Nuiqsut increased to 2 whales and then to 3 whales (1983–1991 documentation is not definitive). Values provided for these years are best guesses based on inconsistent information.

Sources: Compiled from AEWC records, personal communications with Nuiqsut whalers, and field notes from the 2001–2008 whaling seasons.

TABLE 5.2. Summary characteristics[1] of whales struck near Cross Island, 2009.

Date (mm/dd/yy)	Time Struck	Length	Sex	Whale ID	Miles from Cross Island	Bearing from Cross Island	Notes
09/06/09	21:11	NA	NA	NA	10.7	50˚	Nukapigak, Struck and Lost
09/11/09	07:59	49’0”	F	09N1	11.6	79˚	Taalak, Landed
09/13/09	10:34	20’4”	F	09N2	19.7	79˚	Nukapigak, Landed

[1]All characteristics are from direct observations or GPS records made on the day of the activity, other than the WhaleID number. WhaleID numbers are assigned by the North Slope Borough Department of Wildlife Management (NSB DWM). Times (local daylight) are approximate and are derived from the recorded GPS tracks and/or radio logs, combined with whalers’ accounts, as are the distances from Cross Island.

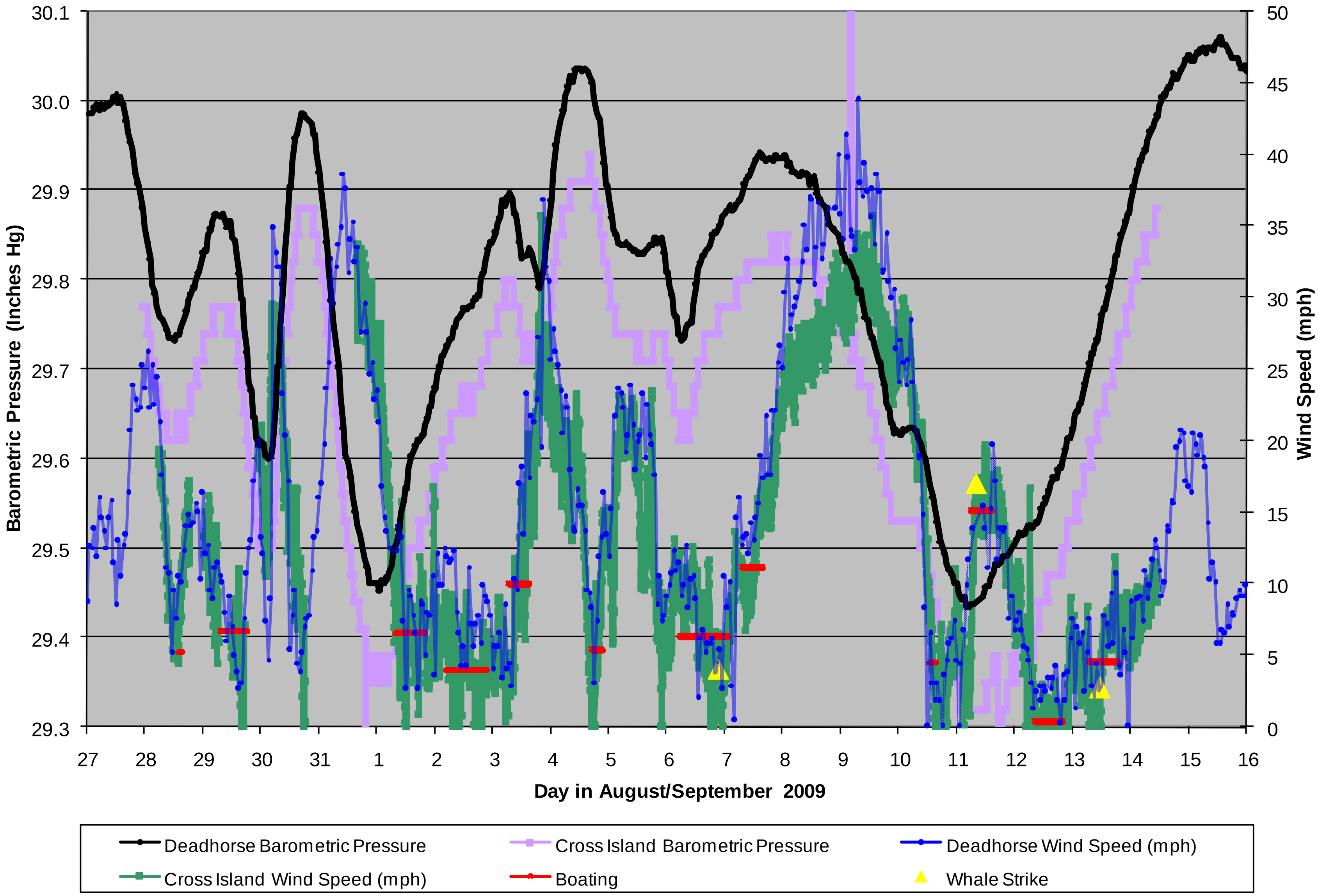

FIGURE 5.3. Temporal summary of the 2009 Cross Island subsistence whaling season in relation to weather.

Conditions on 1–4 September were more suitable for scouting for whales, with wind speed generally less than 16 km/h (10 mph). (Although it increased to over 56 km/h [35 mph] at midnight on 3–4 Sep, it decreased to less than 8 km/h [5 mph] late in the afternoon.) Of the 11 whaling boats on Cross Island, eight went scouting during all four days. Of those that did not, one was disabled, one went out the first three days (conditions on 4 Sep were marginal), and the third went out two days. These were the days when the most whale sightings were reported (36 of 53 total), and these four days (mostly 1–3 Sep) accounted for 64 percent of all the whale sightings reported for the 2009 season (but see the "Distribution of Whales" discussion below). The longest individual trip times were over 11 hours on 1 September and over 15 hours on 2 September, but only 5.5 hours on 3 September and 4 hours on 4 September. Winds on 5 September were generally over 32 km/h (20 mph) and no boats went out scouting.

Winds moderated on 6 September and 10 boats (all but the disabled boat) went scouting and spent from 5 to 17.5 hours on the water. They reported a total of 5 whale sightings, and a whale was struck late in the day. It was left once it became too dark to safely continue to pursue it. Its position was marked on several of the whalers' GPS units. Conditions on 7 September were more marginal, with wind speeds averaging over 16 km/h (10 mph), but nine boats went out scouting. They first looked for the whale struck the day before, but only found an oil slick in the area where they had left it. They continued scouting and most boats spent from 6 to 8 hours on the water. Two whale sightings were reported. Winds speeds were very high on 8–10 September, peaking at almost 72 km/h (45 mph) at midnight on 8–9 September. One boat went scouting on 10 September, once the wind speed was below 8 km/h (5 mph), but only stayed out 2.5 hours and near the island. That crew did not report any whale sightings.

Ten boats went scouting on 11 September, with the wind speed was less than 8 km/h (5 mph). The wind speed soon increased, but a whale was seen, followed, struck and landed about 2 hours after the first boat had left Cross Island that morning. Because the whale was large (15 m [49 ft]) and seas were rough, all boats were needed to help with the tow. However, conditions were too harsh for the smaller boats to do so safely so, instead of helping with the tow, they returned to Cross Island to make preparations to haul the whale onshore. The tow required about 6 to 6.5 hours and reached Cross Island in mid-afternoon.

Butchering progressed to a stage where eight boats—all but those from the crew that landed the whale and the disabled boat from another crew—could go out scouting on 12 and 13 September. Conditions on those days were reasonably good for scouting, with wind speeds generally less than 5 mph. Few whales were seen, perhaps four each day. A whale was struck and landed on 13 September. Since this was a small whale, three boats towed it to Cross Island while the other boats stayed out to look for another whale. Although several crews may have had potential opportunities to make a strike, no other whale was struck. Once all the boats returned to Cross Island the captains talked with each other and decided to call a "cease fire" and end their season. Conditions were such (not seeing many whales, whales fairly skittish) that the crews did not want to risk being stuck on Cross Island by an extended period of bad weather. Four crews that had completed their butchering and packing tasks left on 14 September. The last two crews left on 15 September. One was the crew who landed the whale on 13 September and so had more butchering chores than did the other crews. The other was the crew with the disabled boat, which they fixed either late 14 September or early 15 September, in time to go back to Nuiqsut without being towed.

Data from the project's weather station at Cross Island provided information on the weather conditions from when it began to receive wind speed readings up at 05:39 on 28 August through 10:54 on 14 September. During this period, crews went out scouting for whales on 12 days, as described above. Wind speeds recorded at Cross Island corresponded well with those recorded at Prudhoe Bay for this period (Fig. 5.3). Although the magnitudes may have varied slightly between the two locations, the overall patterns were the same—winds increased and decreased at the same times. It is clear that whalers go out scouting when wind speeds tend to be lower (8 km/h [5 mph] or so) and that the exceptions are primarily due to increases in wind speed when the whalers are already out on the water (3 Sep, 7 Sep, and especially 11 Sep). Whales also tend to be struck when wind speed is lower (6 Sep and 13 Sep). Whalers remember that the wind came up on 11 September after the whale was struck, so it is possible that the wind speed at Cross Island increased sooner than it did out on the water where the whalers were. In any case, the whale landed on 11 September was seen and approached when wind speeds were lower.

At least one crew was on Cross Island for parts of 27 August through 15 September, a total of 20 days. There were several periods of high winds when conditions were not suitable for scouting for whales, on 30–31 August, 5 September, and 8–10 September (although one boat tried to scout on 10 Sep). This were 5 or 6 weather days. Three days were devoted to travel or other chores. Scouting occurred on 12 days, but one should probably be considered a "weather" day. A summary would be 20 days total, with 11 scouting days, 6 weather days, and 3 days for travel and other chores.

Two crews had a whaling season of 20 days, three crews were on Cross Island for 19 days, and one crew for 18 days. The "average" crew was thus on Cross Island for 19.2 days in 2009. Ice cover was mostly absent, which exacerbated the effects of the wind that was always a factor and the swells that persisted throughout the season (independent of the wind speed at any given time). These factors combined to make scouting for whales difficult in general. Whales were difficult to see, and when they were seen, difficult to follow and approach. The situation in 2009 was in marked contrast to that in 2008, when the "average" crew was only on Cross Island for 7.3 days and conditions for scouting were much better than in 2009. In 2007 there was a 13-day season (10.4 days for the "average" crew; Galginaitis 2009a), in 2006 a 21-day season (21 days for the "average" crew; Galginaitis 2007a), and in 2005 a 27-day season (21 days for the "average" crew; Galginaitis 2006b). For 2001–2007, the average length for the overall whaling season was 22.4 days, while the length of season for the "average" crew in this period was 16.4 days (Galginaitis 2009b). Thus the 2009 season was a little shorter than the average 2001–2008 season in terms of overall length, but a little longer in terms of "average" crew season length.

The researcher (MSG) was on Cross Island for the entire 2009 whaling season except for the last day, and was able to collect GPS tracks and whaler accounts for all scouting days. For the overall season, there were 89 "boat days" with 112 different scouting trips (since there were 23 occasions when a boat made two different trips on a single day). Of these 114 tracks, 95 are represented by GPS information (83 percent). One captain who declined to participate in the research accounted for most of these "missing" tracks: 12 tracks from 8 different days (two tracks on each of 4 days). In addition, seven other tracks were not collected. For five of these either "tracking" had been turned off or the GPS itself was off. The systematic lack of information from one crew is unfortunate and places some limits on the interpretation of the data that were collected, but does not substantially change the overall understanding of the 2009 Cross Island subsistence whaling season.

The number of boats scouting on any given day ranged from 1 to 11, but was eight or more on most scouting days, and the number of whale sighting reports each day with scouting varied from 0 to 15 (Table 5.3). (There were zero sightings on the two days when conditions were marginal but 1 or 2 boats went out scouting anyway.) It is possible that some of the sightings reported for the early days in the season (1 Sep through 3 Sep) may have been "false positives", because of the difficult conditions of the 2009 season. As an example, on 28 August some whalers thought that they saw a whale from Cross Island, and the IP2 boat went out to investigate. They reported that it was not a whale, but instead was an *anałuq* (explained as "a shallow area where waves come together from different directions and raise a

TABLE 5.3. Summary of "scouting days" during the 2009 Cross Island subsistence whaling season.

Date in 2009	Average Wind Speed While Scouting (mph)	Boats Scouting	Whales Seen (#)[a]	Whales Seen (%)
28 Aug	5.2	2	0	0.0
29 Aug	6.6	4	2	3.8
1 Sep	6.6	9	8	15.1
2 Sep	4.0	10	15	28.3
3 Sep	10.0	9	8	15.1
4 Sep	5.4	9	3	5.7
6 Sep	6.3	10	5	9.4
7 Sep	11.1	9	2	3.8
10 Sep	4.5	1	0	0.0
11 Sep	12.3[b]	10	2	3.8
12 Sep	0.32	8	4	7.5
13 Sep	4.5	8	4	7.5
	Totals (Boat Days/Whales)	89	53	

[a]"Whales Seen" is an estimate based on the reported sightings from the whalers, radio reports from the whalers, and Communications Center log entries. These have been compared with GPS tracks, where available, to judge whether sightings are of the same or different whales, or if some sightings may not have been reported. It is likely that not whale sightings were reported, and that some reported sightings (especially for days of many such reports) were not "real" sightings (see discussion in text).

[b]"Wind Speed" for 11 September is the average from when the first boat left Cross Island to go scouting until the whale was struck. Average until whale was killed was 13.3 mph. Average until towed to Cross Island was 15.1 mph.

spray that looks like a blow, and the backwash exposes the shallow land and looks like the black of a whale"). Some whalers suggested that swells seen from a distance by personnel in a small boat in the open ocean could give the same illusion. The NAP boat was the only other boat scouting on 28 August (for about 4 hours) and that crew reported no whale sightings. For the first days when most boats went out, some boats reported seeing several whales while other boats reported seeing none, while chasing after the boats that did. They referred to it as "chasing boats". It seems likely that for 1–3 September at least some of the reported sightings were actually more examples of *anałuq* or a similar thing. While some crews reported a few blows, most of the whalers agreed that most of the possible whales that they were seeing did not exhibit blows—and blows are usually the most noticeable feature of a whale unless the whale is very close. The blow is generally light in color ands thus contrasts with its surroundings. In the absence of blows, whalers must rely on actually seeing the black whale ("seeing the muktuk"). During the first several days there were relatively many reported single sightings of possible whales that were not resighted; subsequently whalers reported fewer sightings as whales. Thereafter, the whalers tended to refer to them as "something black" and reported a whale sighting only if they went to investigate and saw something again. Similarly, after 3 September, boats did not tend to "chase" other boats until there was a fairly strong indication that there had been a more definite sighting. In essence, this was a recalibration as to what constitutes a "sighting" under difficult conditions. An alternative interpretation is that there were more whales in the area on 1–3 September than on the other days, however, this was not apparent from the hourly whale call detection rate (Chapter 4, Fig. 4.1). Thus, the few days with a higher number of reported whale sightings likely did not mean that there were actually a large number of whales in the area on those days.

The whalers described the entire season as one where they saw few whales because of several factors:

- They believed that there were relatively few whales in the area, in that they seldom saw more than one whale at a time, and never saw a large number of whales at the same time;
- The whales that were present were considered “spooked” in that they were, in general, swimming fast (for bowheads), did not emit a visible blow when they surfaced, and usually surfaced only once and then went down without showing their flukes;
- Physical conditions (large swells, lighting that minimized contrast) made spotting the whales that were present difficult;
- Non-whaling vessel traffic may have been a factor affecting whale behavior; and
- Other factors, such as the possible presence of killer whales, could also have affected the whales.

Some whalers drew a comparison to 2001 and 2002, when whales had also been described as skittish or spooked. One remarked that, just as in 2001/2002, they had seen sheens of oil or grease, as if killer whales had been eating marine mammals. No one had reported seeing a killer whale during any of the study years, however.

Figure 5.4 shows all documented GPS tracks for all Cross Island boats on all days during the 2009 whaling season, color-coded by day, along with locations of strikes and other whale sightings, and the 2009 BPXA DASAR array. Figure 5.5 compares the 2009 tracks, coded in pink, with tracks from the prior years documented for this project (2001–2008). The GPS tracks for 2001–2007 are displayed in black. The GPS tracks for 2008, the year when Nuiqsut whalers landed their whales closer to Cross Island than in any other study year, are displayed in yellow. Figure 5.5 clearly indicates that scouting tracks during the 2009 season closely resembled those for 2001–2007, in terms of the “core” use area: the quadrant to the northeast of Cross Island. Whalers did not travel quite as far as they did in 2001, but the 2009 pattern corresponds closely to that of 2002, which was a comparison suggested by the whalers during the 2009 season. Nuiqsut whalers had to travel much farther from Cross Island in 2009 than in more recent years (2007–2008) and 2001 was the only recent year when the whalers traveled farther from Cross Island. The whaling effort in 2009, as measured by time spent on the water, was much greater than in any prior year documented by the project (2001–2008). During the year with the most similar effort, 2005, only one whale was struck (and landed) due to ice and sea-state conditions that prevented the whalers from approaching whales on all but one day. Considering the period since 2001, in terms of scouting effort the years most similar to 2009 were 2001 and 2002, and those were also years when whalers saw relatively few whales; remarked that the whales were behaving as if they were spooked; and noted that whales were farther away from Cross Island than in more “normal” years. The offshore distribution of bowheads in 2001–2002 was also evident from the locations of calling whales offshore of Northstar, which tended to be farther from shore in 2001–2002 than in various subsequent years (Blackwell et al. 2007). That is, this information is consistent with and supports the description of the 2009 season as one where whales were farther away from Cross Island than in most years and were behaving in ways that made them more difficult to see and approach (discussed below). Combined with the environmental conditions that made whales difficult to spot (large swells, lack of contrast) it is not surprising that landing whales was more difficult in 2009 than in most prior years—and certainly the most difficult for any season in the 2001–2009 period when ice was not a factor (ice was a factor in 2005).

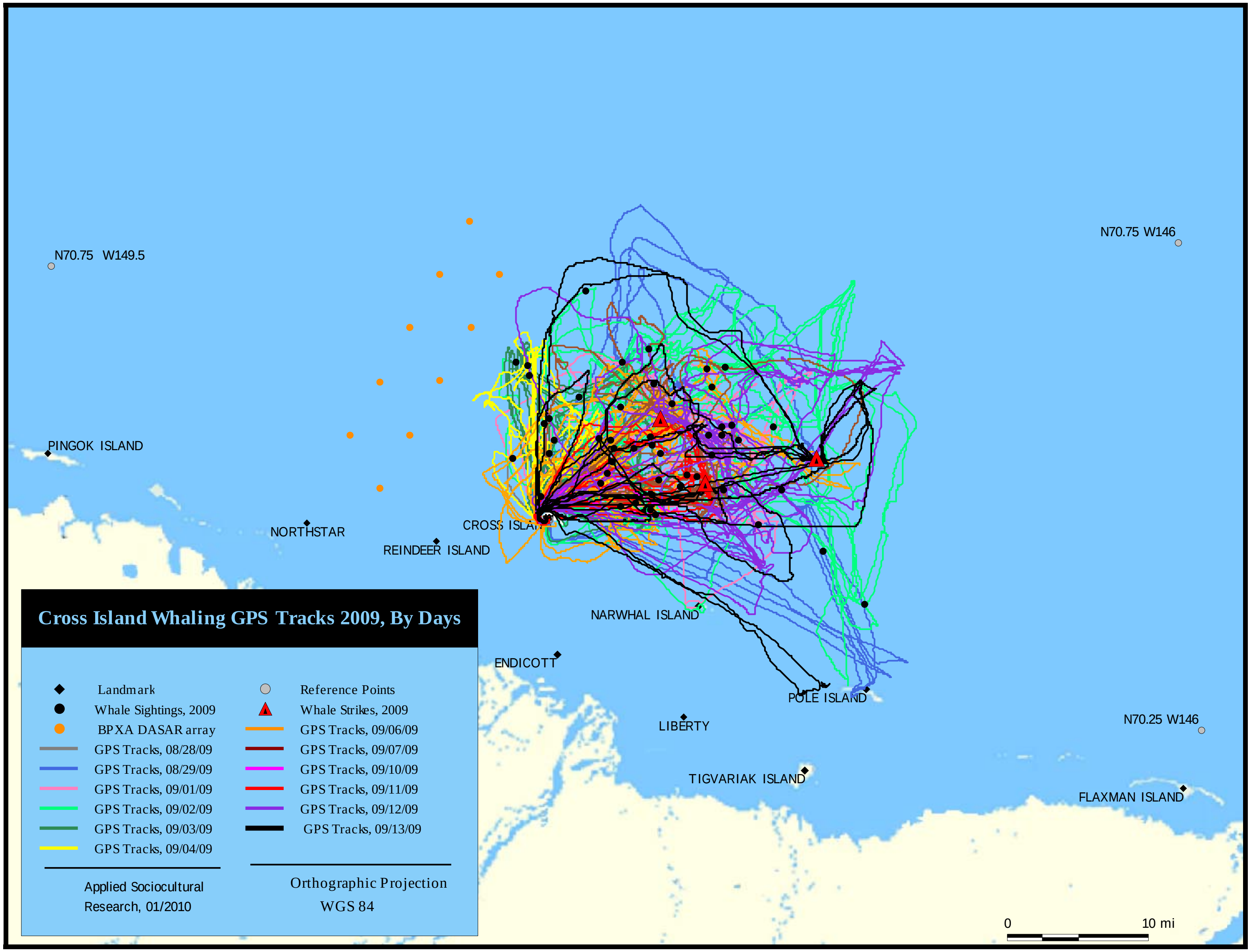

FIGURE 5.4. Cross Island whaling GPS tracks for 2009, by days.

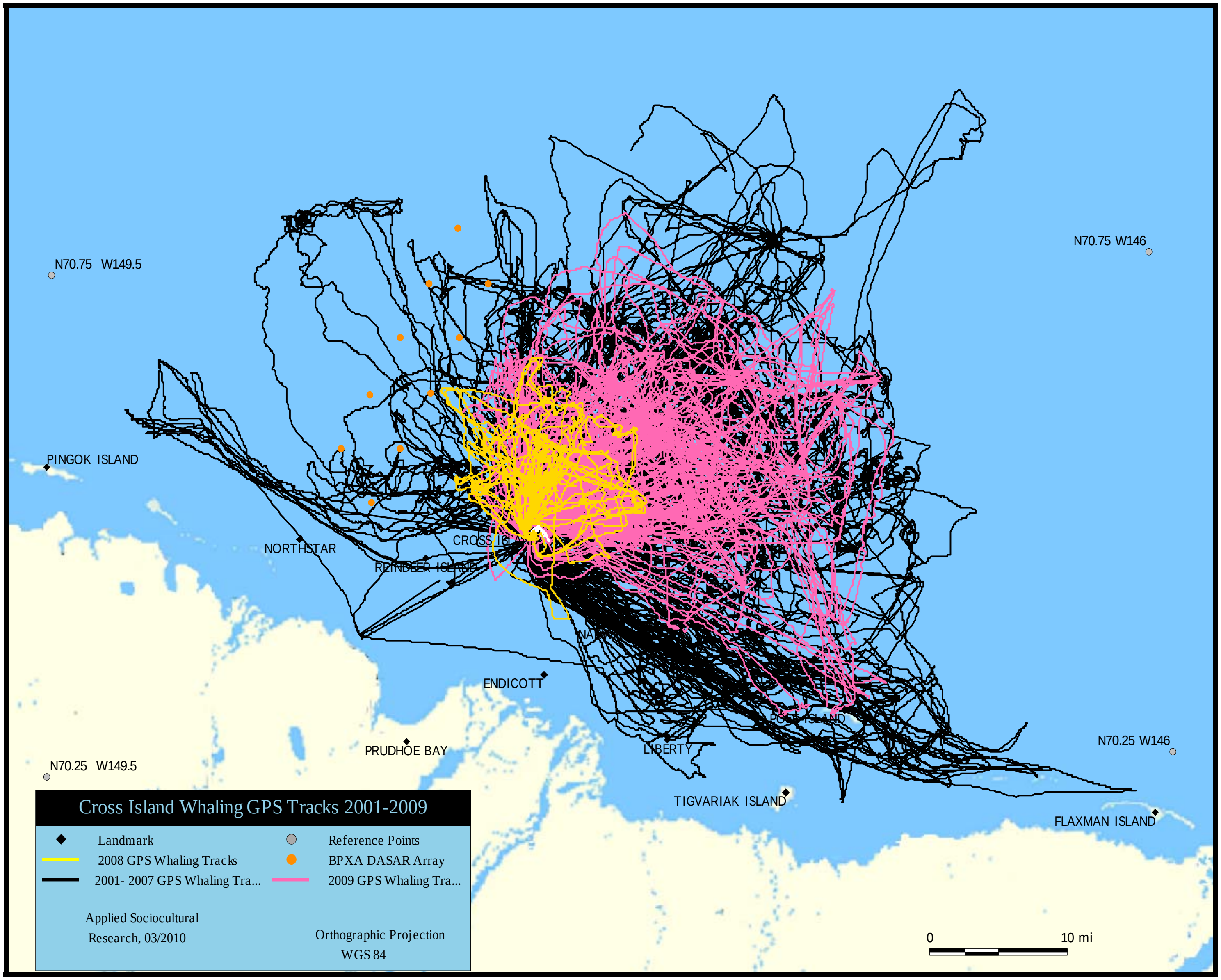

FIGURE 5.5. Cross Island whaling GPS tracks, 2001–2009. BPXA DASAR locations are as deployed in 2008 and 2009.

OBSERVED WHALE FEEDING BEHAVIOR IN 2009

Whalers reported seeing whales feeding on the surface with their mouths open on one or two different days in 2009, but did not mark these locations at the times of the observations. The fieldnotes are somewhat confused, and it may be that there were two different reports of one whale, given the relative rarity of such reports during prior seasons. However, the information currently available suggests two separate observations. On 1 September, feeding was seen about 22.5 km (14 mi) ENE of Cross Island, and on 2 September it was seen about 10.5 km (6.5 mi) ENE of Cross Island. In addition, one boat reported seeing “whale food” in a streak or stream so red that it almost looked like blood. This observation was at a location about 4 to 7 km (2.5 to 4.5 mi) north of Cross Island on 1 September. However, that crew did not spot any whales in the area with concentrated whale food. On 29 August, one boat reported “dead krill” in the current NE of Narwhal Island, but did not report seeing any whales in that area. Whale birds (phalaropes), which are commonly associated with the presence of zooplankton concentrations near the surface and are used by the whalers as a sign that whales may be in the area, were explicitly noted on two days: 29 August and 1 September. No whales were reported in association with them, but on 1 September it was noted that where whalers saw many whale birds, they saw few seals, and vice versa. It is likely that whale birds were also seen on other days, as whalers tend not to report them as systematically as they do whales and other marine mammals (either to the researcher or the Communications Center operator). During a visit by the researcher to Nuiqsut in March 2010, one whaling captain characterized the 2009 season as one during which they observed “lots of small species in the water” on many days. He was referring to food items that whales and other animals are known to eat.

No stomach samples were taken from bowheads landed in 2009, although two whales were landed. The first whale landed was large and the butchering process required that emphasis be placed more on speed than delicacy when removing the viscera, in order to prevent spoilage of the parts intended for human consumption. Thus, the stomach for this whale was never available for sampling. The second whale landed was small and the stomach would have been available, but the researcher was not at the butcher site when the viscera were removed and disposed of in the bone yard. Attempts to find the stomach in the bone yard, at night, were not successful as the remains of the small whale were mixed with those of the older (and riper) large whale.

That feeding whales were observed during the 2009 season was somewhat surprising. There had been few such reports in the previous years of the research. This does not necessarily mean that feeding did not occur in those prior seasons, but it is an indicator that whale feeding activity is generally not very obvious around Cross Island. It may be that food sources were more abundant around Cross Island in 2009 than in previous years. In 2009, whalers saw relatively few whales for the effort they expended, and were usually unable to determine the activity of the whales since most whales were seen only once and not seen again. Most whale sightings were of single whales, and no large groups whales were seen at the same time. Conditions were not favorable for seeing whales in general, due to factors such as swells, waves, lack of contrast, and skittish whale behavior. Thus to recognize one or two cases of feeding whales was extraordinary (and the whalers themselves described it as “a rare sight”). Previous reports have listed the following factors as contributing to the relative lack of whaler observations of whale feeding:

- whale feeding is not commonly observed (or at least not reported) by Nuiqsut whalers near Cross Island (only one incident during the previous eight years);
- most feeding by bowhead whales is known to occur below the surface (e.g., Würsig et al. 1989) where it would be invisible to people in small boats;

- on most or all days when scouting was possible, swell and waves (due to wind) made spotting and observing whales difficult;
- barge and other vessel activity may have "spooked" whales (and Nuiqsut whalers reported seeing more non-whaling vessels in 2009 than in previous years, at least several of which they thought affected whale behavior or subsistence whaling activity); and
- a major part of the migration may have bypassed the area accessible to the whalers, as they stayed relatively close to Cross Island (compared to the other years of the study).

For the eight years of the study previous to 2009, only one observation of whale feeding was reported and recorded. This was a spectacular sighting of a whale feeding on the surface with its mouth open, about 12.6 km (7.8 mi) from Cross Island, bearing 34º True. The captain, a very experienced whaler, remarked that this was the first time he had seen this. This does not necessarily indicate that Nuiqsut whalers observed no whale feeding behavior on other occasions in 2001–2008 when scouting for whales. It probably means that such observations were not common or that it is not easy to determine if whales are feeding. Nuiqsut whalers tend not to speculate on what an animal ***may*** be doing—if they are unsure they will usually not say anything. If other obvious feeding behavior had been observed during 2001–2008, it probably would have been reported. Nuiqsut whalers do believe that whales feed near Cross Island, especially when whales appear to be staying in the area rather than swimming directly through it. When whaling, however, they are often not in a position to make such observations due to less than ideal weather and sea conditions, or the need to concentrate on the immediate tasks of whaling.

Most feeding by bowhead whales is below the surface and difficult to recognize via surface observations. There have been some previous observations of bowheads feeding actively at the surface in the Canadian and Alaskan Beaufort Sea, with mouths open (Würsig et al. 1985, 1989; Richardson and Thomson [eds.] 2002). The first whale taken by a Nuiqsut crew, in 1973, was reported to have been feeding on the bottom near Flaxman Island. Some other whales landed at Cross Island have been found to have recently-consumed food in their stomachs (Lowry and Sheffield 2002; Lowry et al. 2004). One of the whales taken in 2006 was also reported to have had mud on its jaw, and one of the two stomachs that were examined was quite full (Galginaitis 2007a). Nuiqsut whalers report that Camden Bay is regularly used as a feeding area by bowhead whales when migrating, and as a resting area when there are high winds and rough water. One whaler recounted that in 1997 there were many gray whales feeding near Reindeer Island, and that year a Nuiqsut crew landed a bowhead whale close to where Northstar now is. He said that since the development of Northstar the whalers have not seen any feeding whales in those areas. It must be added that since the development of Northstar, Nuiqsut whalers report that they rarely scout for whales in that area, and certainly Figure 5.5 demonstrates that has been the case since 2001.

"Skittish" Whale Behavior During 2009

For several reasons, Nuiqsut whalers reported that whales were difficult to see and follow in 2009. First, there did not seem to be many whales near Cross Island. Second, large waves and swells (high sea states) and low contrast light conditions made it difficult to see whatever whales were present. Third, the behavior of the whales also contributed to making them harder to see. Whalers summarized these behaviors as whales acting "skittish or "spooked" and seemed to include a constellation of behaviors under this term:

- Swimming at a fast speed rather than staying in the area;
- Surfacing only one time between dives, and not exhibiting a visible "blow" when surfacing;
- Not showing flukes when diving, but simply sinking down under the water;

- Not being able to spot a whale again after it dives.

Note that this is only a general description of most whales seen in 2009, and does not necessarily contradict the reports of two feeding whales and several that were sleeping or resting when they were first seen.

In the context of skittish behavior, one captain remarked on the evening of 2 September that all the whales seen up to that point had behaved in a similar way to the only whale landed in 2005. He described this as a whale that appeared to be coming from the Camden Bay area and as exhibiting spooked behavior (fast speed, single surfacings). The whalers had also encountered a barge in the area where they chased this whale. During the 2009 season the whalers experienced several vessel encounters while scouting (see section below) and so were quite sensitive to the possibility that whales were spooked by this vessel.

Other whalers compared the 2009 season to 2002 and 2001, in terms of skittish (and more general) whale behavior. These were seasons that whalers characterized as years when they saw few whales, with whales farther from Cross Island than “normal”, and with whales exhibiting skittish behavior–the same way that they characterized the 2009 season. For 2001 they suggested several possible explanations for the skittish behavior (Galginaitis 2006c). Although Nuiqsut whalers cited industry activities as one possible explanation or factor, they said that other explanations were also possible. These other factors or possible factors were ice conditions to the east of Cross Island, possible presence of natural predators such as killer whales, barge traffic related to the Kaktovik water and sewer project, or other air or vessel traffic to the east of Cross Island. Note that two of these, while not related to oil industry activities, are related to other human economic activities. For 2009, the whalers directly observed more barges and other vessels in their immediate whaling area than in 2001 or 2002, and some whalers believed that the vessel activity was likely a cause of skittish whale behavior in 2009. Other whalers were not convinced that this vessel activity was the most important factor, although it certainly was considered a possible contributing factor, and one that they wanted eliminated.

General Offshore Distribution of Whales, 2009

Cross Island whalers reported that in 2009 whales were relatively distant from Cross Island and not very numerous. The frequency and distribution of whale calls detected by the DASARs offshore of Northstar in 2009 support this general observation. Chapter 4 of this document (Table 4.1) indicates that the number of whale calls detected was lower in 2009 than in 2008, 2004, and 2003. The number of whale calls detected in 2009 was similar to that in 2007 and higher than in 2001, 2002, 2005, and 2006. The years 2005 and 2006 may not be directly comparable to the other years due to the presence of ice for the entire or most of the season. This trend is consistent with the Nuiqsut whalers’ overall characterization of their whaling seasons. The whalers reported that in 2001 and 2002 the whales were farther from Cross Island and (within their search area and periods) fewer in numbers than they had typically encountered in years prior to 2001, as well as in subsequent years up to 2008. They also explicitly characterized the 2003 and 2004 seasons as a return to more typical patterns. The distribution of whale calls in 2001–2002 also showed those to be years when the migration corridor tended to be relatively far offshore, and 2003–2004 as years when the corridor was closer to shore (Blackwell et al. 2007). The whalers characterized 2005 as a season where ice packed against the barrier islands kept the whales far offshore. For the first half of the 2006 whaling season ice also prevented the whalers from finding whales because they were relatively far from Cross Island. Weather complicated the 2007 and 2008 hunting seasons, but the whales were close to Cross Island, especially in 2008 (Fig. 5.5).

The contrast between the 2009 and 2008 seasons is especially apparent both from the whalers’ observations and from the whale call distributions (*cf.* Chapter 4). Whalers explicitly noted the similarity in distribution, number, and behavior of whales encountered during the 2009 season and those of the 2001 and

2002 whaling seasons. The overall pattern of the whalers' 2009 GPS tracks graphically supports this characterization (Fig. 5.5). The 2009 whaling tracks encompass almost the entire quadrant northeast of Cross Island within which most of their documented landed whales were found. Only a few tracks of the 2001 and 2002 season that are most distant from Cross Island extend beyond the 2009 tracks. (See Galginaitis and Funk [2004] or Galginaitis [2008b] for specific GPS tracks in 2001 and 2002.) The 2008 tracks, on the other hand, are much more compressed and indicate that in 2008 the whalers stayed closer to Cross Island than in any other year during which the Cross Island hunt was studied. This is completely consistent with the 2008 and 2009 whale call data from the Northstar DASAR array, with a record high number of call detections in 2008 and a much lower number of call detections in 2009 (see Chapter 4, Table 4.1).

As described above, during the 2009 season the Nuiqsut whalers frequently discussed among themselves why they were seeing so few whales. Multiple factors were no doubt in play, and those they posited included poor sighting conditions (weather and sea state conditions), "spooky" whale behavior, commercial vessel activities in or to the east of the whaling area, and a "late" migration (usually expressed as "we may be too early"). In this regard, it is interesting to note that the Northstar acoustical monitoring stations, operational from 26 August to 28 September, detected only two or three periods with high rates of whale detection, on 13–14 September and 27–28 September (Chapter 4, Fig. 4.1). The whalers closed their season on 13 September, and the last crew left Cross Island 15 September. It appears that the 2009 bowhead whale migration peaked after the whalers had closed their season and left Cross Island. As an alternative, some whalers later suggested (during the researcher's follow-up trip to Nuiqsut in March 2010) that the 2009 bowhead migration had been early, so that the whalers had "missed" the pulse of small to mid-size animals that they normally target, although these were the whales that the Barrow hunters encountered. One whaler hypothesized that many of the biological cycles, including the bowhead migration, had advanced by as much as a month.

The other measures documenting the 2009 Cross Island whaling season are fairly consistent with the idea that the hunt did not occur during the peak of 2009 whale migration. The total number of bowheads reported as sighted by the whalers during the 2009 whaling season was comparable to most prior study years, but in 2009 the whalers rarely saw more than one animal at a time, and never any large groups of whales. The average strike distance, length of trip (both in terms of distance and time), and the maximum distance that boats traveled from Cross Island were very similar in 2009 to the averages of all seasons combined. Cross Island whalers scouted for whales on 12 days during the 2009 season. They reported whale observations on 10 of these days. For the two days when they did not report any whales, only one or two boats went out scouting and conditions for whaling were marginal. Thus, while whalers saw whales on most days during the 2009 season, they did not see large numbers of whales—an average of ~5 whales on the days when they did see whales. Most whales were seen as single individuals and were encountered only once. A few whales were seen in pairs, but no large groups or "schools of whales" such as were seen in 2007 or 2008 were seen in 2009.

About half of the reported whale sightings in 2009 were encountered at distances of more than 16 km (10 mi) from Cross Island. Given that the whale sighting reports are incomplete, and that several other measures of 2009 Cross Island whaling activity were "average" compared to previous years (rather than exceptional), these measures do not strongly support the conclusion that whales may have been relatively farther from Cross Island in 2009 than in other years. However, the information on "whaling success" and physical conditions during the 2009 whaling season provides clarification to this issue. The years for which Nuiqsut whalers did not use their full quota of four strikes were 2001, 2004, 2005, and 2009. Of the nine study years, these years rank 1, 3 and 5 in terms of "boat hours" of effort (total number of hours boats were on the water engaged in whaling activities) per landed whale, and 1, 3 and 6 in terms of effort per strike. This information supports the observation that whales were hard to find in 2009, and the more general statement that Cross Island whalers will travel as far from Cross Island as conditions permit in order to find whales. For some years conditions limit this range much more than for other years. For example, in 2001 there were few whale sightings and they were far from Cross Island, but the whalers were able to scout 40 km (25 mi) or more from Cross Island (Galginaitis 2009d). Even so, they only used three strikes (average distance 31 km [19.5 mi]). In 2008, whalers were restricted to about 13–16 km (8–10 mi) from Cross Island, since beyond that point swells and other physical conditions made it difficult, if not impossible, to see and follow whales (Galginaitis 2009b). Because whales were found close to Cross Island, the whalers were able to land a full quota of four whales (average distance 10.5 km [6.5 mi]).

Measures of "whaling success" and "whaling on-the-water effort" clearly indicate that 2009 was far from an average season, and have direct implications for a discussion of the offshore distribution of whales in 2009. For 2009, total effort was 752 boat hours or 251 boat hours/strike used. Previously the season with the highest level of expended effort had been 2001, with 573 total boat hours and 191 boat hours/strike used, and in that year whalers on average traveled 39 km (24 mi) from Cross Island. The year 2009 contrasts especially with the seasons with the lowest documented level of expended effort, which were also the most recent years prior to 2009. "Total boat hours" was only 158 in 2008 and 124 in 2007, and "boat hours/strike used" was only 40 in 2008 and 31 in 2007. Whalers on average traveled 13 km (8 mi) from Cross Island in 2008, and 16 km (10 mi) from Cross Island in 2007. A more detailed discussion of the "whaling effort" measurement for 2001–2008 can be found in Galginaitis (2009d, p.76–81), and in Galginaitis (2010).

NUIQSUT WHALERS' REPORTS OF VESSEL ACTIVITIES, 2009

Annex 5.1, at the end of this chapter, summarizes the specific observations of non-whaling vessel activities as noted by Nuiqsut whalers during the 2009 Cross Island whaling season. It also includes observations on whaling activities. All references to "vessels" in this section refer to vessels other than whaling vessels. The researcher (MSG), who was staying with the whalers on Cross Island, recorded this information, checked it with the Deadhorse Communication Center Call Log, and also discussed it (including a preliminary form of Figure 5.6) during a trip to Nuiqsut in early March 2010. Summaries are included only for those days on which vessel activity was reported, or for days on which whale scouting activity occurred. Based on the daily information in Annex 5.1, the following brief discussion has been compiled, attempting to draw some generalizations about the reported effects of vessel traffic and industrial activities on the 2009 Cross Island subsistence whaling season.

In strong contrast to the 2008 season, there were two instances in 2009 when the whalers filed Vessel Conflict Incident reports about vessels that they encountered while out scouting for whales. These incidents occurred on 1 September and 2 September. Whalers reported other instances when they observed vessels while they were out whaling (3 Sep and 12 Sep), but in those cases did not file Vessel Conflict Incident reports through the Deadhorse Com Center. It is not clear why reports were not filed in the latter cases, or if such reports were filed directly with AEWC. It may be that the whalers were frustrated by the process of logging complaints to no apparent purpose, since the complaints did not seem to affect the non-whaling vessel traffic.

One incident listed in Table 5.4 involved Northstar-related activities. A whaling boat encountered the ACS *Bay*-class boat *Mikkelsen Bay* on 12 September when it was servicing the DASAR array offshore Northstar. The whaling boat contacted the Deadhorse Com Center, which in turn contacted the *Mikkelsen Bay*. Upon this notification, the crew of that vessel terminated their activities and returned to West Dock, with a short stop at Northstar to retrieve an acoustic recorder. The *Mikkelsen Bay*'s movements were confined to the area from West Dock to Northstar and the BPXA DASAR array offshore of Northstar (Fig. 5.6).

TABLE 5.4. Non-whaling vessels encountered by Cross Island whaling vessels.

Date	Time	Vessel or Incident	Other Notes
1 Sep	12:19	*Seneca* barge (Crowley)	NE of Cross Island, traveling to the west. Vessel Conflict Incident report filed with Deadhorse Com Center and AEWC about 12:38pm (Hickey 2009a). First seen from Cross Island and then reported by whaling vessels out on the water.
2 Sep	05:59	*Avik* barge (Crowley)	Several miles south of Cross Island, reported by whaling vessels out on the water and Vessel Conflict Incident filed (Hickey 2009b).
2 Sep	20:40	*Begger* (private yacht)	Roughly 10 km (6 mi) north of Cross Island, reported by whaling vessel on the water. Vessel Conflict Incident files with the Deadhorse Com Center about 21:13 (Hickey 2009b).
3 Sep	06:58	Unidentified barge	Whalers reported that the barge was about 8 km (5 mi) away from them, straight North, and was "kind of loud", so they went east away from the barge. They think that the barge was going toward Barrow (west overall) and was moving pretty fast. They reported it to the Deadhorse Com Center but no Vessel Conflict Incident was filed.
12 Sep	14:12	*Mikkelsen Bay* (ACS vessel)	Reported by whaling vessel on the water. The *Bay*-class vessel was moving west, so the whaling vessel turned around and went the other way (SE) to join the other whalers. Reported to the Deadhorse Com Center which in turn contacted the *Mikkelsen Bay.* The *Mikkelsen Bay* immediately aborted its activities in the Northstar DASAR array and returned to West Dock, with a short stop at Northstar. It is not clear from the researcher's notes whether the other boats had also encountered a vessel (or seen this one) earlier in the day.

Note: This table lists only those vessel encounters made known to the researcher and so is not necessarily complete. It also is not a complete listing of all non-whaling vessel traffic in the Cross Island area during the 2009 whaling season.

The other incidents all involved vessels whose owners and operators were not parties to the Conflict Avoidance Agreement (CAA), and were actually traversing the area (most or all from east to west) at various distances from Cross Island.

The estimated positions of four of these vessel sightings are displayed in Figure 5.6 in relation to the reported whale sightings for the 2009 Cross Island subsistence whale season and the BPXA DASAR array. Precise locations of these vessels sightings were not obtained, except for the *Mikkelsen Bay*, for which exact coordinates were available. Where possible, vessel positions have been estimated from the locations of the whaling boats from which the vessels were seen, or from nearby boats when no track was available for a given whaling boat. One of the captains estimated the position for the *Avik* (seen 2 September), since no GPS information was available for the whaling boat that reported the *Avik*; that whaling boat was the only one that was out scouting at the time (it was the first boat to go out scouting that day). The *Seneca* (seen 1 September) is also mapped where a whaling captain estimated it was first spotted, much closer to Cross Island than the researcher had first mapped it. No GPS information of even an imprecise nature was available for this sighting. The main point of Figure 5.6 is to indicate that the observed vessels were in the area where Cross Island whalers were looking for, and spotting, whales, although no whales were seen in these areas at the specific times when non-whaling vessels were present.

In any event, Cross Island whaling was potentially more affected by commercial, industrial, and private vessel traffic in 2009 than in any previously documented season (2001–2008), at least in terms of the number of such encounters and the volume of vessel traffic observed. In 2005, there was an incident that probably directly and adversely affected the active pursuit of a bowhead whale. During 2009, none

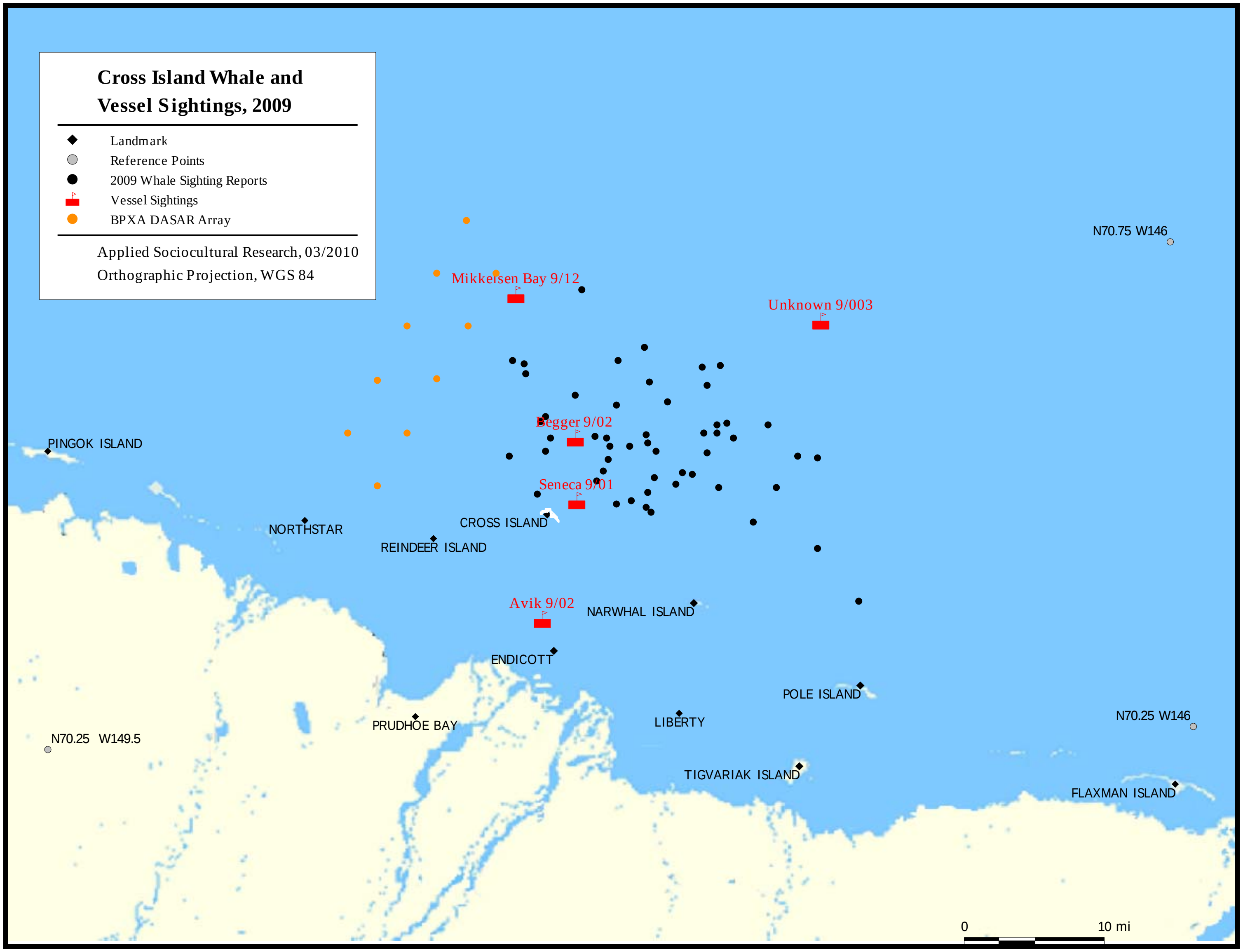

FIGURE 5.6. Cross Island whale and vessel sightings, 2009.

of these incidents affected the immediate pursuit of whales, but in a more general way potentially contributed to the disturbance of whales and their generally skittish behavior, making it more difficult to see and approach them. AEWC and the whalers have long been aware that the vessels operated by entities that are not parties to the CAA may have adverse effects on whaling activities. Until a mechanism is developed to include such vessels in at least the reporting and communication requirements (via the Deadhorse Com Center), this will continue to be the case. Most whalers seemed to think that the 1 September incident (and vessel traffic to the NE of Cross Island in general) was the most important concern and had the potential to most affect their whaling activities.

Nuiqsut whalers have some generalized perceptions as to how industrial activities affect their hunt, based on their experiences with such activities. The proximity of onshore development facilitates the logistical support of Cross Island whaling, and Nuiqsut whalers make frequent supply runs (weather permitting) between Cross Island and West Dock. Logistical support and emergency assistance from industry are at times requested by the whalers. However, whalers perceive offshore oil and gas activities as potentially adverse to whaling, primarily because of noise and/or potential spills and accidents.

Insofar as Northstar activities are concerned, whalers report experiencing some immediate and direct effects on their hunt from its development and production activities, although oil spills and noise are their major concerns because of the potential disruptive effects they could have. Nuiqsut whalers typically avoid searching for whales near Northstar, although in years with adverse ice conditions they will search in that area since it tends to be accessible when other areas are not (e.g., in the 2005 and 2006 seasons). During 2009, one whaling boat encountered the ACS boat the *Mikkelsen Bay* offshore of Northstar while scouting by itself, and turned back to the east after the encounter. This incident may reinforce the whalers' preference not to whale near industry facilities, if they can avoid doing so. Nuiqsut whalers report that this preference has had the effect of making the area around Northstar a "no whaling" zone for them, and they note that in 1997 (before Northstar was built) a whale was taken in that area. In 1997, they had to hunt in this area west and NW of Cross Island because ice and other conditions had prevented them from accessing the area to the NE of Cross Island. They also report that, prior to the development of Northstar, they had observed whales feeding in the area of Reindeer Island (especially numerous in 1997), but that they have not seen this since the development of Northstar.

BP has made efforts to decrease the risk of spills and to reduce the effects of vessel and air traffic associated with Northstar as much as practicable (see Chapter 1 of this report). Northstar is to the west of Cross Island and "downstream", in terms of the westward bowhead migration, from the areas where Nuiqsut whalers normally scout for whales. Thus, the hunters do not expect Northstar to be as problematic, in terms of direct disturbance and interference effects on whaling, as development to the north and east of Cross Island would be (Ahmaogak 2002: 5, 14).

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Napageak Sr., Archie Ahkiviana, and Billy Oyagak. As representatives of the Nuiqsut Whaling Captains' Association (NWCA), they offered the first invitation for me to go out to Cross Island. The NWCA has, so far, renewed this invitation each year. The Minerals Management Service, Alaska OCS Region, again provided funding for the basic 2009 research. BP again provided supplemental funding for additional data collection, interviewing, and analysis. The industrial consortium that operated the Whaler Communication Center in Deadhorse supplied logistical assistance in transporting project equipment and supplies to Cross Island, and allowed me to examine and compile information from the 2009 Deadhorse Communication Center Call Log. Any errors or misinterpretations are of course solely my responsibility and not the responsibility of those from Nuiqsut, and the North Slope generally, who have contributed so much of their time and knowledge in trying to educate me. Also, I thank Dr. Bill Streever of BP and Dr. Lisanne Aerts of LGL Alaska for suggestions concerning the draft, and Dr. W.J. Richardson of LGL for his inestimable help since the 2005 season.

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ANNEX 5.1: DAILY CROSS ISLAND BOAT AND VESSEL ACCOUNTS, 2009

22 August, Saturday

American Discovery made a day trip to Cross Island from West Dock to take some pictures (after obtaining permission to do so). The *Arctic Wolf* traveled from West Dock to Cross Island for the setup of the generator, delivery of the gasoline and diesel supplies, telephone work, and other mobilization tasks. Because of the lateness of the day and the large number of polar bears seen on Cross Island, the *Arctic Wolf* stayed at Cross Island overnight and most of the mobilization work was actually done on 23 August. One or more Nuiqsut whalers served as polar bear watch for the mobilization effort.

27 August, Thursday

Of the six crews and eleven whaling boats that participated in the 2009 Cross Island subsistence whaling season, five crews and eight boats traveled from Nuiqsut to Cross Island on 27 August. Once they arrived at Cross Island they unpacked, cleaned their cabins, and inventoried the state of the equipment on the island. Some cabins had been damaged by polar bears and needed repairs in addition to cleaning. Most crews still had to prepare their *aviqpus* (floats) and bombs. Several more communal tasks also needed completion before a whale could be successfully landed and butchered. At least one new tow-line had to be prepared (eventually two new ones were made). An “eye” had to be prepared on the new cable that had been installed on the winch. The skid plate that the winch was mounted on had to be straightened, and to straighten the skid plate the winch house had to be moved a bit so that the loader could reach the skid plate. Some crews started preparing floats and bombs the day they arrived, but all the other tasks were deferred until at least the next day. No boats went scouting for whales on 27 August.

28 August, Friday

28 August started fairly windy, but by noon was calmer, although very foggy. The whalers talked about going out to look for whales but realized that they had quite a bit to do before they would be ready to actually land a whale. Thus, most crews did not go out scouting for whales, although conditions were reasonably favorable to do so. The *Arctic Wolf* made a trip from West Dock to Cross Island with a light plant for the butcher site, some food supplies, and a load of mattresses.

The NAP boat made the only extended scouting trip for this day. They indicated that waves and swells were moderate, and visibility was acceptable – although there was still quite a bit of fog. Their trip of 46.4 miles was mainly to the east of Cross Island, but also included a short search west of the island, and was conducted primarily at relatively high cruising speeds. There were about ten short periods of low speed when they were looking at potentially interesting areas that had drawn their attention for one reason or another. The NAP crew did not report seeing any whales, however, and did not draw any special attention to any of these areas when talking about their track. The only other boat to go out was the Ipalook2 boat, and it went out only because someone saw what could have been a whale very close to Cross Island. They went out to see if this was a whale and returned almost immediately (a trip of 12 to 15 minutes) once they determined that the dark spot they had seen was a low-lying island appearing and disappearing in the waves and swells (*anałuq*). This sort of “false positive” sighting seems to have been evident for the duration of the season. That is, by the end of the 2009 season the whalers reported the generally prevalent conditions for the 2009 season (large swells, skittish whales with few or no blows, low contrast lighting conditions for sightings) were the reasons for few whale sightings. In many cases they were uncertain if a whale had been sighted or not.

29 August, Saturday

More crews had prepared floats and bombs by 29 August, although the other (and larger) communal tasks remained undone. Three crews (four boats) went out scouting. One boat made two trips, but with only a short interval between them in order to refuel. The boats all left within a space of 40 minutes (7:17 to 7:56 am) and coordinated their activities for the entire period they were out, and all returned to Cross Island for the day within a period of 25 minutes (17:56 to 18:21). They all headed NE from Cross Island, in the direction where most whales have been landed in the past. Two blows were reported, both by the BO2 boat. The BO2 boat indicated that they saw the first blow about 4.5 miles from Cross Island (about 8:31am). This sighting was bracketed by two points where the BO2 boats reported a "whale smell". This blow was seen only once and no other details were provided. The second blow was sighted by the BO2 boat at 9:15am. This was about 8.5 miles North of Cross Island. The other boats immediately changed course to go towards the BO2 boat to help follow this whale, but this whale/blow was not seen again and by 9:35am or so all boats turned to the north and started to look in that direction. The BO2 boat crew indicated that this was a big blow (maybe 8-feet), and hence a big whale, but they only saw it once and could not tell what direction it was going. Because of the size of the blow, they thought it was a different whale than the first one. While no other whale or blow sightings were noted, all boats reported seeing lots of whale birds, seals, and oogruks. Many such points could have been located and whalers pointed out only a few of these. Some boats also mentioned dead krill in the current near Narwhal Island. Most boats returned to Cross Island between 6:00pm and 6:20pm.

30 August, Sunday

All boats on shore.

31 August, Monday

All boats on shore.

1 September, Tuesday

Nine boats went out scouting on 1 September. The first boat left Cross Island about 7:41am and the last about 8:29am. Conditions were marginal or even rough at the start with 5 foot waves, but it started to calm down after lunch and was "real calm" about 3pm. It was calmer in the east than in the west (but the boats spent most of their time in the east). While the whalers were out scouting for whales, the Arctic Wolf made a trip from West Dock to Cross Island with a load of lumber and other supplies for the whalers.

The BO2 boat was the first boat out and saw a whale about 1.5 miles from Cross Island at about 7:52am. This sighting encouraged the other crews to launch as soon as they could get ready. The BO2 boat reported that they only saw this whale once. When they saw it the whale was just floating in the water and they thought that it may have been sleeping. The whalers report that when whales sleep they just float like this one was. As they approached it the whale just went down and disappeared. It did not dive and they never saw a blow, and they could not tell what direction it may have gone. They also never saw it come up. This was the general pattern for the day – whalers would see a whale (or something black) and would approach it only to have it "go down" or disappear. They would not see a blow, and would not see the whale or object again. After seeing this whale, the BO2 boat headed east, following currents in places, until IP1 saw something at about 11:37am. The only other whale they saw was at about 11:50am, while on their way towards the IP1 boat, when they saw a whale in front of them and reported that they were going to it. It went down and they never saw it again.

The BO1 boat started by following the BO2 boat (leaving the island about 17 minutes later). However, one of their crew members became ill and they returned to the island to drop him off. They reported seeing a whale about 12 miles from Cross Island. They went out scouting a second time, heading north for about 8 miles and then E or NE. They reached about 14.7 miles from Cross Island and then started back to Cross Island in a fairly straight line. Up to that point they had "zig-zagged in order to search a wider path" since the whales were hard to spot and they could not see any blows. They turned back top Cross Island once it started to get windy. On the way back to Cross Island they looked for whales but saw none. They had to slow down while returning to Cross Island because of the size of the swells and the characteristics of the boat.

The IAN boat saw a whale about 8 miles from Cross Island and the other boats changed course to help look for it. As with other whales seen on 9/01, this whale was seen only once and "had no blow."

Both IP crew boats left Cross Island together, but the IP1 had to return to Cross Island to drop off an injured crew member (bruised ribs from a prior day's activities). After heading out again, IP1 Looked in areas where the other boats had seen whales, and then joined IP2. The IP boats then responded to the sightings of other boats, but did not see these whales. The other whalers again only saw these whales once, and after they could not be found all the boats headed towards Narwhal Island. There IP1 saw two whales playing around – or rather, one that was sort of breeching out of the water vertically while the other was floating on the surface some distance from it. They looked in that area for awhile, turned around, and could not see anything, so they turned north towards the reported position of a whale spotted by the NUK boats. They never saw this whale (and the NUKs saw it only once). IP1 then turned north towards two whales that TAL2 and NUK3 had seen while IP2 went to Narwhal Island, and then north for about 10 miles, and then ENE to join IP1 (and the other boats) in the most NE part of the day's travel. IP1 was following a current for a while and then went to check out the "20 mile current", where they also met up with IP2 and transferred 15 gallons of gas to IP2. IP1 then went towards where NUK3 had spotted a whale but again IP1 did not see it themselves. At this point both the IP boats were low on gas, so they headed back to Cross Island. They indicated that otherwise they may have stayed out longer.

The Taalak crew boats spent the entire day in close proximity to each other. The captain reported that they did not see anything (meaning whales) all day. Soon after leaving Cross Island in the morning, about 4 miles north, they encountered a "streak" of whale food that extended to the NE. They slowed down and followed this but saw no whales. One crew member remarked that the water was so red that he thought it was blood, but it was not. On the way back to Cross Island, the Taalak boats were further north and west than the other boats and were headed in the general direction of Northstar. One of the crew members of TAL1 thought that he may have seen a couple of blows in the direction of Northstar. TAL1 (but not TAL2) went about 3.4 miles from this reported sighting in the direction of Northstar, but did not see any sign of whales, and so turned and returned to Cross Island. They were still about 15 miles from Northstar when they turned for Cross Island. The captain reiterated that he himself did not see any signs of whales all day, but that every turn in his boat's track except the last represented a reported sighting by another boat to which he had responded. The TAL2 boat also saw few or no whales – reporting that one crew member saw two different whales that they think were probably the same as those seen by the NUK3 boat, in the general area of tal2_090109a. Conditions were reported about the same as for other boats – pretty rough when they went out, but calming down as they went along. There were swells all day, although the last part of the day to the SE was calm and it was even calmer in the west. However, when they turned SE to head back to Cross Island, conditions became rougher.

Most of the discussion of the NUK boats activities was based on the track for NUK3. Early in the day the two boats were not traveling together, however, as the whalers wanted to cover more area since they were having such a problem resighting whales when they resurfaced (and in fact were not able to do so). NUK3 reported seeing "maybe 3 or 4 whales and then a blow towards Narwhal Island" and NUK1 reported seeing the two whales sighted in the east. They only located these sightings in a very general way, and were more interested in discussing two more general, interrelated, and vitally important issues – the strange behavior of whales so far during the 2009 whaling season and the problem of tug and barge traffic interfering with fall subsistence whaling activities.

While most of the whalers were out scouting for whales, one crew member who stayed on the island noticed a tug and barge (identified as the *Seneca*) NE of Cross Island at about 12:19pm. Once this was drawn to their attention, the whalers saw it as well and requested (strongly) that it change course and travel inside of the barrier islands. The barge was on its way to Barrow and the whalers were very concerned about the potential effects it could have on the behavior of the migrating whales. Once the whalers returned to Cross Island there was much discussion about why there were so few whale sightings, why they could not resight the few whales that they were seeing, if this was an indication of "strange" whale behavior, and if tug and barge traffic could be a factor or cause behind these observations. All agreed that there were few whale sightings, few or no whale blows were observed, and no whale was seen more than once. The various (non-exclusive) explanations offered were that there were simply few whales in the area, or that the whales were spooked or behaving in a strange way, or that conditions were such that spotting whales was difficult and "false positives" (false whale sightings) were likely. There was no consensus on the relative weight that should be given to each of these factors. Some whalers thought that there were still relatively few whales, difficult spotting conditions, quite a few false whale sighting reports, and maybe some "spooky" whale behavior (possibly due to barge traffic, but also possibly related to other factors such as the presence of killer whales). Other whalers thought it more likely that most sightings were real, that all whales seen were "spooked," and that barge traffic was a major factor in the difficulties they were experiencing.

2 September, Wednesday

All crews except NAP went out scouting on 2 September, with all possible boats. All spent considerable time on the water, from about 9.5 hours to somewhat over 15. Five boats (three crews) made two trips, with short stops on Cross Island to refuel between the two (IAN, IP1, IP2, TAL1, TAL2). Five boats (two crews) did not need to refuel and made only one long trip for the day (BO1, BO2, NUK1, NUK2, NUK3).

The first sighting of the day was reported by the IAN crew, of a barge (the Crowley barge *Avik*) to the south of them heading to West Dock, but still too close to the whaling area (about the 6:06-6:14am). This point could not be marked, since the IAN track was not collected and it was the only boat out at the time, but was probably reasonably close to Cross Island. It was not reported whether the barge was inside of the barrier islands or not. However, the Deadhorse Communication Center summarized the contact as follows:

The call was taken at approximately 5:59 am by the on-duty operator at the Deadhorse Com Center. Edward Nukapigak reported that a barge, later identified as the *Avik* (Crowley barge 160-4), was traveling several miles south of Cross Island and displaced a grouping of bowhead whales that were being tracked by the Nuiqsut Cross Island bowhead crews. The barge was contacted by the Com Center and moved out of the area. Crowley was again notified of the Com Center call-in protocol by Mr. Hickey (via email to Carolyn Macdonald) and Waska William Jr. (North Slope Borough Planning Dept.) also notified Crowley (Greg in Barrow) to stay clear of Cross Island and inside the Barrier Islands when possible.

IAN reported several whale sightings as well – about 9:01am, 10:10am, 11:40am, and 14:05am.

The first whale sighting was reported by NUK1 or NUK3 about 6.3 miles North of Cross Island (6:33am). NUK3 left Cross Island and headed north, and continued north after seeing this whale. They may have been following this whale, but more likely lost track of it. The next sighting, also by NUK3, was 16 miles North of Cross Island at about 7:48am. These were the only sightings reported by the NUK3 boat, although they scouted until about 9:29pm. They may have seen some of the other whales reported by other crews later in the day (about 16 and 20 miles from Cross Island), but did not remark on them. After they saw their second whale, they continued to the east (in response to a sighting by IAN) and then south to a point about 5.5 miles north of Pole Island (probably in the company of IAN). They then essentially retraced their path to the area of an earlier IAN sighting. They then responded to a sighting report by BO1 to their SW, and after losing track of this whale returned to Cross Island with most of the other boats.

Shortly after the NUK3 sighting, TAL2 reported a sighting at 7:58am and 11.2 miles WNW of Cross Island. TAL2 thought this whale went then east, so TAL2 went east but evidently never saw the whale again, since they turned west again about 8:16am. TAL2 turned east again about 8:57, in response to the sighting of whales to the east. The TAL boats continued east until leaving at high speed in response to the IAN sighting about 10:10am. When the IAN boat saw a whale about 10:10am, it appears that all boats except the BO boats went to assist them – IP1 and IP2 from the north, NUK2 and NUK3 (and probably NUK1) from the west, and TAL1 and TAL2 from the NW. TAL1 developed motor problems and had to return to Cross Island, and TAL2 accompanied TAL1 for part of this trip, and then resumed independent scouting about 12:01pm when they saw some promising signs for whales and TAL1 was reasonably close to Cross Island (9 miles). TAL1 reached Cross Island about 1:54pm.

The whale seen by IAN was soon lost and may not have been seen again at all. The IAN boat and the IP boats seem to have left the immediate area in a southerly direction about 11:10am or so. NUK3 (and probably NUK1) left the area about 11:20am to head towards Pole Island. The NUK2 boat remained searching in the area until 11:30am, when it turned south and proceeded at high speed to join the IAN boat. IAN had reported seeing many whale birds about 11:30am, and at 11:40am reported a whale sighting. However, since the NUK2 boat actually looked for IAN and the other boats near Narwhal Island, NUK2 did not join the other boats until about 2:36pm. IAN, the IP boats, NUK3, and probably NUK1 scouted to the south, towards Pole Island. They do not seem to have seen this whale again, as there are no reports of other sightings. The boats proceeded mostly at “scouting speed” and appear to have been in reasonable proximity to each other. They were in close enough to each other to provide mutual assistance in the event of sightings. They probably was a whale while the boats were proceeding north, after going south to a point about 6 miles from Pole Island, and then turning and proceeding almost due north. The BO boats had joined the other boats in this area, having traveled at high speed from the north starting about 12:10pm until about 12:49pm when they reached the other boats. They then proceeded south to Pole Island and then north with the other boats. When IAN reported seeing a whale at 2:05pm, BO2 reported sighting a different whale at the same time. The boats were at scouting speed (in a NW or W direction) looking for these whales but did not report seeing them again.

The next whale sighting reported was about 4:13pm, 14.6 to 15.6 miles from Cross Island, by NUK1. It was first seen by IAN and NUK1. The BO and IP boats responded to the sighting, as did NUK2. The NUK2 and NUK3 boats were scouting together when this sighting was made. The NUK2 boat went to help find/chase this whale, while the NUK3 boat continued north at scouting speed.

About 4:36 the BO2 boat turned for Cross Island, to refuel and then go to West Dock to pick up a crew member at West Dock who needed transport to Cross Island. About 4:59pm BO1 saw a whale about 5.5 miles from Cross Island. BO2 was only 2.8 miles from Cross Island, but turned around to help find and chase this whale and the NUK2 boat came to help the BO boats from the NE, joining them at about 5:19pm. All the other boats either eventually joined (NUK1, NUK3, IP2) the BO boats in this general area or returned to Cross Island to refuel and then went out again to help the other boats (IP1, IAN, and the TAL1 and TAL2 boats once the TAL1 motor was fixed). The NUK2 boat stayed with the BO boats until about 5:50pm, when it headed back to Cross Island for the day. When the TAL boats went out on their second trip, both initially went north to join the IAN and NUK1 boats. About 5 miles north of Cross Island they split. TAL1 continued at high speed north to join IAN and NUK1 about 5:53pm while the TAL2 boat went SE at scouting speed to join the BO and other boats. TAL1 (and it is assumed the IAN and NUK1 boats) then went south at scouting speed in the general direction of the other group of boats. About 4:42 the NUK3 boat had turned to the west and southwest. This brought his boat into the same area as the other boats had searched just after 4pm, but by that time those boats had lost track of their whale and had moved on to help BO1 with the whale they had seen closer to Cross Island. NUK3 continued scouting in this area until about 6:02pm, when they headed south at high speed towards where the most of the other boats were scouting (the IAN, NUK1, and TA1 boats were to NUK3's west). They reached the general area of the other boats about 6:45pm.

TAL1 reported spotting a whale at 6:49 pm and turned west to try to follow it. About 7:05pm the TAL1 boat (and it is assumed the IAN and NUK1 boats) decided to join the other boats and went "on top of the water" at high speed and slowed down in that general area at about 7:18pm. They either lost track of their whale (or never saw it again) or were called to go help the other boats. Soon after this, at 7:25pm it was reported that two groups of boats were chasing whales – IAN, NUK1, and TAL1 in one group and the BO boats, TAL2, IP1, and NUK3 in another. All boats in the "BO whale group" almost immediately changed direction at high speed for a position west of where one of the other boats had thrown a harpoon. It appears that the bomb did not explode and that the darting gun missed the whale, but all boats continued to concentrate on this whale. About 7:47:30 TAL1 had a potential opportunity to strike this whale again, but was not quite able to obtain the proper position, and they eventually lost track of this whale. It does not appear that the whale was definitively seen once it dived about 8:48pm (NUK3 sighting) or perhaps even 8:10pm. Boats headed back to Cross Island at different times. BO1 and BO2 went back at high speed about 8:08, so that they could then go to West Dock to pick up a crew member. IP1 headed west to Cross Island at scouting speed about 8:21, and once they were beyond the range of where they thought it likely to see the whale they had been chasing again, went to high speed at about 8:41. The NUK3 and TAL2 boats were scouting for this whale in fairly close cooperation with TAL1 and headed back to Cross Island in the company of TAL1 (9:15 and 9:08 respectively). The IP2 boat had left this area about 7:08pm to go refuel at Cross Island and did not return to help scout for the whale until about 7:55. They were scouting south of TAL1 and probably in the company of IAN when IAN reported seeing a vessel to the NE of Cross Island. This vessel's position was not well documented (but NW of where the whalers had been looking for the whale they were following). IP2 had gone from scouting speed to high speed about 8:34 and was following a course parallel to that of its course out from Cross Island. Just after 8:40, when IAN reported seeing the barge, IP2 altered course to the NW so that it returned to Cross Island from the NE, possibly gaining a better view of the object IAN and they had observed. It is possible that they saw the barge as early as 8:34, prompting their high speed, but no detailed account from the whalers was obtained. This vessel was actually a privately-owned 57' vessel traveling about 6 miles north of Cross Island and was instructed to move further out to sea by the Communications Center.

3 September, Thursday

Conditions were not particularly good for scouting, and seemed to worsen as the day went on. Nine boats went out scouting (14 boat trips – 5 boats made two trips each). All of the "two trip" boats came in for lunch and went out again in about an hour. All boats were back at Cross Island for the day by 3:11pm, so all second trips were quite short. No whales or potential whale sightings were seen in the afternoon.

The IP1 and IP2 boats were the first boats out, at 6:32am, as the captain had decided the night before to go out early unless conditions were very bad. The other seven boats all went out between 8:46 and 9:23, since conditions did not appear to be very good. Also, the first thing that the IP boats had seen was a barge at 6:58am. The barge was not identified and its position was documented only in an approximate fashion. The IP boats had left Cross Island heading ENE and were about 5 miles from Cross Island when they saw the barge. They reported that the barge was about 5 miles due north of them, was heading to the west and moving "pretty fast" and was quite loud. For this reason they decided to travel almost due east, directly away from the barge [and implying that this would give them the greatest chance to encounter whales not disturbed by the barge]. They proceeded east at 8-10 mph until about 7:04am (about 1.1 miles after seeing the barge) and dropped to scouting speed (3-4 mph). IP2 reported seeing a whale, but did not specify the time or place – but saw it soon before going to join IP1 since that boat also saw a whale. At 7:23am the IP boats saw a second whale. They were able to follow this whale for some distance, but eventually lost track of it. They then went at scouting speed towards the IAN boat, which had reported seeing a whale. The IP boats scouted in this area for nearly an hour. No points were marked, although IP2 located two whales or blows that were seen, but only one time each. These could have been the same whale, but were discussed as being different whales. They then scouted north and at 9:50am IP1 saw a whale and were able to follow it for a while. They saw a blow from this whale at 9:58. They saw another blow at 10:17am that they thought was the same whale. They continued north, following the whale birds and saw another blow to the north (but did not locate it – unsure if it was really an additional blow).

The TAL1, TAL2, and NUK1 boats all left Cross Island at the same time (9:23am) in a generally northern direction. TAL spotted a whale 5.5 miles from Cross Island at about 9:47am. TAL2 and NUK1 headed more north or NNW, as TAL2 had spotted a whale about 6.9 miles from Cross Island at about 9:56am. It is possible that the TAL1 and TAL2 whales were the same whale, but they were reported as different whales. TAL2 and NUK1 ended up north of Cross Island 10-12 miles between 10:30 and 11:00. The other seven boats were all east (BO2, BO1) or NE (IP1, IP2, NUK3, TAL1) of Cross Island. All the "eastern" boats except for BO2 headed towards TAL2 and NUK1 at high speed at about 10:31, as they had reported that they were seeing quite a few whales. The BO2 boat clearly was following some promising signs, but did not report any sightings and after scouting for a period of time and winding up about 9 miles due east of Cross Island at 11:46 just returned to Cross Island at high speed. All the boats from the east (except BO2) arrived in the vicinity of TAL2 and NUK1 between 10:45 and 10:59. The wind was increasing markedly, however (from less than 5 mph to 35 mph by early afternoon). Even though there had been two more sightings of what was thought to be the same whale conditions had deteriorated so much that by somewhat after 11am all boats had started back to Cross Island at scouting speed (conditions may have precluded higher speeds). Most boats had returned to the island by 12:43. The TAL1 boat and the NUK3 boat stayed out a bit longer to take an additional look at the area 6 to 7 miles NE of Cross Island. They were joined in this area after lunch by the NAP crew (using the IP1 boat), IP2, IAN, NUK1, and TAL2 (a few went more north than east). None reported any sightings. All boats were back on the island by 3:13pm.

4 September, Friday

Conditions for most of the day precluded scouting, due to high winds. In the late afternoon the winds abated and at least one boat was scouting between 5:00pm and 9:12pm, with individual boat trips ranging from 2 hours 42 minutes to four hours 1 minute. Most boats left Cross Island between 5pm and 5:30. BO1, BO2, IP1, IP2, and TAL1 headed NE. NUK1 headed almost due east. NUK3 headed NW. TAL2 did not leave Cross Island until about 6pm and headed north (towards NUK3). There were three primary sightings that influenced where other boats went – NUK1 east of Cross Island at about 6:02pm, NUK3 NW of Cross Island at about 6:09pm, and IP1 north of Cross Island at about 7:55pm.

The NUK1 boat headed east, saw the first whale of the day (or a blow) but probably only saw it once. The BO1, BO2, IP1, IP2, and TAL1 boats that had headed NE from Cross Island all responded and turned towards the NUK1 boat when it spotted a whale. The IP1 and IP2 boats broke off to the NW and

NUK3 when they saw "their" whale. BO1, BO2, and TAL1 continued to the area of NUK1 but never saw that whale. NUK1 and TAL1 then scouted in a NW direction until about 7:25 when TAL2 spotted "something black" to the NW of them and TAL1 responded by traveling there at high speed while NUK1 continued at scouting speed. BO1 scouted in the area east of Cross Island a bit more, and decided to head back to Cross Island about 7:50pm due to conditions being marginal for the BO1 boat. The BO2 boat was responding to the NUK3 whale sighting but slowed and scouted in the area SE of Cross Island, and headed back to Cross Island when BO1 did. NUK3 had headed NW from Cross Island and saw two blows, and a little after that a whale about 4.7 miles from Cross Island. Although many boats responded to this sighting, this whale was seen only once. The boats in this area then dispersed to the north, with TAL2 being the most western and reporting a sighting about 7:25. This was not a definitive sighting and only the IP2 boat went over to look as well, and nothing more was seen. About 7:55pm IP1 saw a whale and the TAL boats helped search the area, but again the whale was seen only once. Other boats (NUK1, IP2) later searched the same area and reported no sightings.

Conditions were not good for spotting whales, and the whalers reported that the whales they did see were traveling fast and acting in a "spooked" way. They were traveling with their tails down, and no one had seen a whale dive and show its flukes this season (a "normal" way for a whale to dive, and noting how the flukes are positioned is on one way to judge the direction a submerged whale will be swimming). There was quite a bit of discussion among the whalers as to the cause of the observed behavior of the whales, which one captain said was very similar to what they observed seven years ago [probably referring more to 2001 than 2002, but the two years were similar with 2001 being somewhat more extreme than 2002]. In 2001 (and to a lesser extent 2002) few whales were seen and all that were seen seemed to be spooked, were traveling fast, and difficult to approach. In that year, killer whales or some other source of disturbance was posited as a cause. For 2009, the whalers added barge traffic as a potential cause, since they had already seen quite a few barges while they were out scouting.

5 September, Saturday

No boats went scouting for whales, because of winds close to 25 mph. The *Arctic Wolf* made a trip from West Dock to Cross Island with gasoline and other supplies for the whalers.

6 September, Sunday

Conditions were marginal for scouting, but ten boats did scout for at least part of the day. Two boats, IP1 and IP2, essentially stayed out all day – 16.5 and 17.5 hours (although IP2 did make a very brief stop back at Cross Island to drop off a crew member and pick up a replacement). Two boats, BO1 and BO2, only scouted in the evening – about 5pm to 10pm or so. One boat, NUK2, went out only in the morning (5:30am to 11:12am). The other five boats took two separate trips, one in the morning (leaving 5:30 to 6:22am and returning around noon) and one in the evening (leaving 5:10 to 7:12pm and returning around midnight or 1:00am the next day). A few whales were seen, but not many, and a whale was struck late in the day but not landed. Since it was not found on the next or subsequent days, it was recorded as a struck and lost whale.

The NUK crew (NUK1, NUK2, NUK3) was the first crew to leave Cross Island, at 5:33am. The IAN boat left about 5:52am. NUK2 only went out in the morning. In the morning, these boats went north, then east and SE, then back NW, west, and back south or SE to Cross Island. The farthest they went from Cross Island was about 8.4 miles. NUK3 reported a whale about 7:50am, about 6.1 miles from Cross Island. When they slowed down where they estimated that the whale they had seen had been when they spotted it, they were 4.6 miles from Cross Island. This whale does not seem to have been followed for any great distance or time. After scouting in this area all NUK boats headed back to Cross Island at scouting speed. NUK2 used higher speeds than the other two boats and arrived at Cross Island about

11:12am. The other two boats arrived at 12:14pm and 12:28. The track from the IAN boat was not collected.

The TAL crew (TAL1 and TAL2) left Cross Island about 6:22am and headed north. About 7:00am TAL2 reported that "something splashed over here" and both TAL1 and TAL slowed down and searched SE and then north at slow speed (1-3 mph) until about 7:30. Neither boat reported seeing a whale. They then continued SE at higher speed (8-12 mph) until 7:52, which they increased speed to 20-25 mph about 7:52, towards the NUK3 whale sighting. They searched this area but could find no further trace of the whale. They then turned WNW towards where other boats had gone. TAL1 went further north than TAL2 and both started SW back to Cross Island about 11:00am at 16-20 mph (not top speed, but faster than their scouting speed of 1-4 mph) and arrived back at Cross Island somewhat before noon.

The Ipalook boats (IP1 and IP2) left Cross Island at 7:20am and 7:03am respectively and were the only boats to essentially stay out scouting most of the day. They headed south and then east from Cross Island. They were generally at more than scouting speed until they were about 5 miles from Cross Island, when they slowed to scouting speed. About 8:35am IP1 turned north towards NUK3 and the other boats and IP2 returned to Cross Island by going NE (to drop off an ailing crew member and pick up a replacement). IP1 maintained scouting speed while IP2 went at high speed. IP2 reached Cross Island at 9:20am and then left again almost immediately. They headed NE towards IP1 at about 8 mph, a fast scouting speed. They slowed for a short closer look about 10:50am, and then went to high speed at about 11:00am until they met up with IP1 about 11:19am. IP1 had changed course slightly to the west to meet IP2 and had been maintaining a fast scouting speed until they met, at which point they matched speeds at about 20 mph, implying that they may have seen something to the NE. Both boats slowed to scout slowly about 11:31am and IP2 reported seeing a walrus. About 11:43 both boats resumed scouting speed (4-6 mph) to the east. IP2 reported seeing many whale birds about 12:09pm and repeated the observation about 12:12pm and slowed to less than 1 mph to search the area and wait for about 10 minutes (as did IP1). Both then resumed scouting to the east and south, and then eventually back west. IP1 may have seen something about 2:11pm, but neither boat reported a sighting, so if they did see something they were not sure about it. They continued west until about 3:35pm and then headed north again, with IP1 to the east of IP2. About 3:41pm IP1 remarked (over the radio) that it was getting calmer, and this may have influenced the decision of other crews to try scouting in the evening. They proceeded to the east until about 4:46pm, when they turned to the NW and scouted an area of approximately 4 square miles for about an hour. IP1 marked a point about 4:48pm that probably represents a whale sighting. While scouting this area IP1 talked with the BO crew (on Cross Island) and they agreed that when the BO crew went out scouting again that they would scout together in the direction of Narwhal Island. Thus, when the IP boats had searched for about an hour (until 6pm or so) they headed SE at scouting speed towards Narwhal and Pole Islands. They only turned east about 7:42pm when TAL1 reported seeing a whale. They had no other reported sightings before turning east, and all subsequent points pertained to the chase of the whale spotted by TAL1.

The BO boats both left Cross Island about 4:50pm and headed east at scouting speed – probably towards the IP boats. They did not report any sightings and turned back east when TAL1 reported a whale sighting. Their subsequent points all pertained to the chase of this whale, which they left early due to an injury to a crew member.

NUK1 and NUK3 left Cross Island to go scouting at 7:12pm. They headed NW and had just slowed to scouting speed (and seen a large bearded seal about 7:38pm) when they headed NE at high speed about 7:42pm – apparently in response to TAL1 sighting a whale. About 8:14pm both NUK1 and NUK3 changed course to the SW towards coordinates from the IAN boat. They briefly searched this area from about 8:30pm-8:34pm. They left at high speed towards the east where the other boats where all chasing the whale first seen by TAL1 at 7:45pm.

The TAL boats left Cross Island in the evening about 6:07pm and 6:11pm. They both headed east, with TAL1 at somewhat higher speed than TAL2, and TAL2 generally at 8-10 mph. At about 7:01pm TAL2 reported they “saw something black” and immediately turned north and towards TAL1. TAL1 reduced speed and searched their immediate area (east and north) until about 7:22pm, and TAL2 also briefly looked in this area when they approached TAL1. They did not see any follow up sightings and continued to scout north. At 7:41pm TAL1 saw a whale or something. At 7:45pm there was a report of a definite sighting of a whale going west. They had seen the dive and flukes, but no blow. The other boats all changed course at high speed to help with this whale. The whale was next sighted at 7:58pm, perhaps by the IAN boat or one of the TAL boats. The whale was seen again by TAL2 at 8:04pm and by an unidentified boat at 8:08pm. The BO2 boat was in the area and saw the whale to the east at 8:11pm. The two BO boats, the two TAL boats, and IP2 were in close proximity at this stage of the chase, and the IP2 boat soon joined them. They followed the whale south (about 8:19pm), ENE (8:24pm), and then north (8:31pm). They then headed at high speed to the SSW a little over half a mile (8:34pm) and scouted this area for six or seven minutes, when they then headed back NNE about 1.2 miles (8:43pm). Most of the boats (TAL1, TAL2, NUK1, NUK3, and IP2 fanned out and continued ENE to NE at about 8 mph. IP1, BO1, and BO2 reduced speed to less than 1 mph and scouted more in the immediate area – IP1 to the north and the BO boats to the south. About 8:56 one of the BO boats (probably BO2) spotted the whale. All the other boats followed after the BO boats. Probably about 8:59 a crew member on BO1 was injured and BO1 dropped out of the chase to take him back to Cross Island. BO1, and all other boats, were ready to strike should the chance arise. BO1 was the first boat in the area, and may have been in a position to strike before the injury occurred. The next nearest boats were IAN (who spotted the whale at 9:07pm), NUK3, and NUK1. NUK3 sped up at from his location at 9:07pm, slowed and changed direction about 9:09pm, and struck the whale at 9:11pm.

IP1 marked several points after this, but the interpretation of some of them is problematic. There are also some points that can be located from the Communications Center log or field notes from radio messages. At 9:27pm the NUK crew was wanting to put another bomb in the whale. Events of the chase are not totally clear, however. The whalers kept contact with the whale until at least 10:05pm or so. NUK3 indicated they were still tracking the whale at 9:44pm. However, it appears that they lost track of the whale shortly after this, as the float had come off and most of the boats began scouting in a NW direction, and at 10:20pm whalers were discussing where to look. It was getting too dark to see and at 10:31 NUK3 heard the whale blow. TAL2 marked the last place they saw the whale at about 10:24pm. This probably was not the last such sighting, as people continued looking and at 10:59pm NUK3 saw the whale behind his boat. At 11:01pm NUK3 tried to put another float on the whale. They either missed or this float also came off, as NUK3 indicated at 11:08pm that they were right by the whale and the float had come off. IP1 marked where they last saw the whale at 11:38pm.

7 September, Monday

The day had relatively good conditions. The wind was less than 10 mph when the boats went out and conditions were reported to be good. However, then the waves got bigger and the wind increased, especially once the boats started back to Cross Island. For the smaller boats or those that did not cut through the waves that well, conditions were rough. The first objective was for boats to look for the whale struck the previous day. Nine boats went scouting. IAN left at 7:25am, NUK1 and NUK3 about 8:05am, and NO1, BO2, IP1, IP2, TAL1, and TAL2 between 8:43am and 9:22am. All returned to Cross Island between 3:09pm and 3:39, an indication that there was consensus that they were not seeing many whales and that conditions were not favorable. Some crews also wanted to make logistical trips to West Dock.

NUK1, NUK3, IP1, IP2, and most likely IAN all headed NE from Cross Island, to the approximate location of where they had left the whale struck on 9/06. TAL2 headed north. BO1, BO2, and TAL1 headed east. The boats that looked for the whale struck yesterday did not see it, but did encounter an oily sheen on the water, which they said often indicated where a whale had been struck or “down current” from such a strike. They also reported a strong smell of whale in the area of the strike. TAL1 went much further east (to an area north of Pole Island) than the BO boats (which remained north of Narwhal Island). TAL1 then circled north and west and was then in the general area of the “northern boats.” NUK3 marked a point about 12:19 and may have seen a whale traveling east, but did not report it to the researcher or the Com Center. They did not see anything afterwards, and when BO2 sighted a whale to the SE, all of the “northern boats” boats responded to the BO2 whale sighting (12:24pm) by changing direction and heading to that area. NUK3 and the IP boats were at high speed while NUK1 was at 10-15 mph. Thus the other three boats arrived in the area of the BO2_090709a sooner (12:48pm) than did NUK1 (1:20pm). There were several repeat observations of the whale – 12:35pm, 12:42pm, and 12:54pm. There were not more certain sightings of this whale, although the boats remained in the area at slow scouting speed until 1:30pm (and some boats a bit later). All boats were heading east towards Cross Island by 1:23pm, but maintained scouting speeds. About 1:55pm NUK1 evidently saw something and all boats responded by changing course and speed towards NUK1. Five of the boats were south to WSW of NUK1, one was SSE, and one was east (position of the IAN boat is unknown). This whale was not resighted (and there may have been some doubt about the initial sighting), and all boats resumed an eastward course towards Cross Island by 2:24pm (most by 2:15). There was general consensus that all sightings were of the same whale, although it was going different directions at different times, and for most sightings only one boat (and sometimes only one crew member) saw it. Most boats maintained scouting speeds until between 3:00 to 3:30pm, and then sped up until they reached Cross Island.

8 September, Tuesday

Winds increased from about 15 mph on 7 September to about 35 mph on 8 September, and no boats went scouting for whales.

9 September, Wednesday

Winds increased to almost 45 mph on 9 September, and no boats went scouting for whales.

10 September, Thursday

It had been very windy 9/08 and 9/09 (30 to almost 45 mph) and 9/10 started with lower, but still high, winds of 20 to 25 mph. These fell to near zero to 5 mph in mid-day, but with sharply falling barometric pressure and thick fog. Only the IP2 boat went out scouting, as IP1 was borrowed by the NAP crew to go to Nuiqsut to pick up a motor for their boat (since their motor was not repairable on the island). IP2 spent most of the trip at 10 mph or more, and never slowed to less than 6 mph, and reported no sightings. The trip was from 12:50pm to 3:23pm, also an indication that conditions were not good for seeing whales, and not expected to improve. The TAL1 boat made a trip to West Dock for water and to pick up boxes, and the IP2 boat did go out in the evening to help the IP1 boat on its way back from Nuiqsut.

11 September, Friday

Ten boats went out scouting – all but the NAP boat (still disabled). Eight boats went out between 5:55am and 6:31am. IP1 and IP2 were the last boats out at about 7:16am and 7:33am, in response to the BO boats seeing a whale NE of Cross Island and the TAL and NUK boats seeing a whale ENE of Cross

Island. The BO boats had headed NW from Cross Island, while the TAL and NUK boats had headed east and then a bit north after they saw a whale. When IP1 left Cross Island it headed east towards the TAL/NUK boats. IP2 left Cross Island to the NE towards the BO boats. The IP2 boat only paused briefly in this NE area and joined the BO boats in traveling at high speed to the east to join the other boats from the north. They had evidently lost track of the whale the BO crew had been chasing (more details below on this BO whale and the NUK/TAL whale). It is assumed that the NUK3 boat had a track similar to that of NUK2, but the GPS for NUK3 was never turned on.

IAN and NUK1 were the first boats out at about 5:55am and headed east. NUK2 and NUK3 left about 6:00am and also headed east. All of these boats were in the same area when one of the NUK boats saw a whale about 7:10am. BO1 and BO2 were the next boats out at about 6:18am and headed NE (probably to search a different area than the IAN and NUK1 boats). They turned to the east and increase their speed about 7:11am, when NUK1 reported their sighting. BO1 saw a whale, probably about 7:27am, to the east. BO1 and BO2 slowed to look for this whale. This is also about the time IP2 left Cross Island and this sighting is probably why IP2 headed towards the BO boats rather than the NUK/TAL boats, as had IP1 when it left Cross Island about 7:16am. The BO boats scouted to the east from about 7:30am to 7:57am, when one of the BO boats saw the whale again to the west of them. They did not see this whale again, and continued west at "fast scouting speed" until about 8:05am, at which point they both increased speed and headed towards the TAL/NUK boats. This is about the time that the IP2 boat joined the BO boats.

Information on the chase of the NUK/TAL whale is not very detailed. NUK1 headed east from 5:55am (when they left Cross Island) until about 7:01am, when they turned SE. About 7:10am they saw a whale. About 7:20am the whale was probably seen again going to the north. IAN and NUK3 were probably with the NUK1 and NUK2 boats, but the other boats were still heading towards them and are not yet in the area. NUK2 probably saw the whale again about 7:27am. The TAL1 and TAL2 boats reached this area about 7:29am. At about 7:37 one of the TAL boats probably saw the whale again. All of the boats in the area headed mostly south until about 7:41am, when the whale was apparently seen again and all boats sped to the west for a short distance. IP1 joined these boats about 7:54am and they all followed the whale south. TAL1 reported striking the whale about 7:59am. The boats then followed the whale south, with boats trying to place more bombs to kill it. The BO1, BO2, and IP2 boats joined the other boats between 8:32am and 8:38am. TAL1 put a second float on the whale about 8:39am (or perhaps as early as 8:04am). The whale was officially declared dead about 8:52am.

The coordinates given for the strike were N70 31.157 W147 29.2545 but these coordinates were given by the TAL2 boat and using all the information available an alternative strike point has been estimated as N70 31.289 W147 29.323. These two points are about 0.2 mile apart. The kill location coordinates were given as N70 29.898 W147 28.317. The distance between the strike and kill points is about 1.6 miles.

The wind increased greatly just before the whale was struck. Thus, although the graphic summary of 2009 Cross Island whaling activity shows the average wind speed while boats were out scouting on 9/11 as about 15 mph, most of that time was during the tow, after the kill. Average wind speed prior to the strike was 12.3 mph. Average wind speed after the strike was 16.1 mph. Six boats participated in the tow – TAL1, TAL2, NUK1, IP1, IP2, and BO2. Conditions were too rough for BO1 to help with the tow and other boats had other reasons to return to Cross Island ahead of the tow. The tow reached Cross Island about 2:20pm. The whale was a female and 49'0" long.

12 September, Saturday

Eight boats went scouting on 9/12, with the TAL boats staying to butcher the whale they had landed the day before, and the NAP crew's boat still being disabled. Conditions were favorable for scouting, with the wind less than 5 mph for the entire day. Seven of the boats left in the morning between 8:30am and 9:26am, and returned between 6:40pm and 7:55pm. One boat had a shorter trip from about 12:15pm to 7:14pm, and another boat actually took two trips as it came back to Cross Island to refuel. Whalers saw more whales than on the previous day, but it is not certain that all were documented on the tracks or in the discussions with the whalers, and overall relatively few whales were seen.

All boats left Cross Island headed NE or ENE. The pattern of the tracks was influenced by the first whale sightings of the day, which were made by the one boat for which there is no track. The first sighting was about 9:45am and all boats out at the time responded to it. Most boats scouted the area heading NE, although IAN stayed in the area and to the NW. NUK3 either stayed with IAN or NUK1. When IAN spotted a second whale at about 11:54am all boats except NUK3 responded by heading towards it at high speed (IP2 leaving Cross Island about 12:15pm). This sighting was about 4.6 miles NW of the first sighting and was assumed to be a different whale. NUK3 continued to the NW and west. Most boats did not stay in this area very long, and the BO boats never reached it, since BO2 saw a whale at about 12:19pm while heading towards the IAN boat and changed course towards it. The other boats joined the BO boats in this area or further to the east. Boats scouted east, NE, and NW of the initial area of sighting and saw the whale again. From this point all boats (except NUK3) followed this whale to the east. They could not see a blow, but the whale was coming up only once and then diving again, rather than the normal pattern of several short dives and appearances followed by a longer dive. The boats followed it east until they judged that it was too far from Cross Island. About 4:00pm BO1 (and the other boats) turned to the SW. They were all at high speed and headed towards Narwhal Island, probably to scout the area north of Narwhal Island. In the meantime, NUK3 had traveled to the NW and about 2:12pm reported seeing a boat. About 2:25 NUK3 reported that the vessel was the *Mikkelsen Bay* and gave his coordinates. Probably because of the boat, NUK3 then turned to the SE and headed towards the other boats. About 2:50pm NUK3 reported seeing a bearded seal. NUK3 did not report any other sightings, and traveled mostly at high speed, but did periodically slow down to scouting speed for brief periods of time before reaching the area of the other boats at about 3:43pm. NUK1 reported seeing a whale about 4:17pm. Other boats also saw this whale. IP2 indicated that they saw a big whale with no blow. This point seems to have been the last sighting of the whale first seen by NUK1. Boats then scouted a bit to the east, SE, and NE before most boats turned back towards Cross Island between about 5:30pm and 6:00pm, some at scouting speed and others at high speed. NUK1 and NUK3 stayed in the area longer than the other boats and then also returned to Cross Island.

13 September, Sunday

Conditions were good for scouting on 9/13, with winds generally less than 5 mph (although stronger than the day before). Seven boats went out scouting as the day before – those that went out the day before except for NUK2. NUK2 later went out to help with the tow of a landed whale. Four boats made two trips each, returning to Cross Island primarily to refuel. All left in the morning between 6:51 am and 7:26am, and returned in the evening between 4:30pm and 6:38pm. NUK3 struck and landed a whale, and the three NUK boats towed it into Cross Island about 4:30pm (IP1 helped tow part way but left the tow about 1:37pm, just before NUK2 joined the tow about 2:48pm).

IP1 and IP2 left Cross Island headed north for 16 or 17 miles and then turned east. BO1, BO2, NUK1, NUK3, and probably IAN headed NE or ENE. BO1 spotted a whale about 8:05am. This sighting did not attract other boats, however. IP1, IP2, and NUK1 stayed to the north of the BO boats, while NUK3 had been going faster and was well to the east of them. IAN may have been near NUK1 or NUK3. The BO boats may have been able to follow their whale for a while, but when NUK3 reported seeing a whale about 10:00am IP1, IP2, and NUK1 (and IAN) immediately increased speed to join NUK3. BO1 and BO2 delayed doing so until 10:18am or so, staying in an area at low speed to see if they could pick up the trail of the whale they had been following. Since they did not see this whale again, they also then went east at high speed to join in chasing the NUK3 whale. The NUK3 boat radioed their coordinates to the other boats about 10:09am. The reported time for that NUK3 struck the whale is 10:35am but it seems likely that it may have been a bit earlier. Similarly, the Communications Center recorded that the NUK3 boat used their shoulder gun about 10:39am when it seems likely to have been a little earlier. The whale was declared dead no later than 10:55am. The whale was seen to be a small whale (later measured as a 20’4” female), so that if possible the whalers wanted to land a second whale as well. BO1 (and presumably the IP2 boat, since they were very close together) saw a different whale about 10:49am and instead of helping with the tow went after this whale.

The accounts of the chase of the whale that was landed are somewhat difficult to reconcile in detail. There were at least two whales together, but whether they were together at all points in the chase is not clear. Some boats saw two whales sooner than did other boats. It is not clear if the whale that BO1 saw was the second whale or a third whale. In any event, BO1, BO2, IP1, IP2, and probably IAN followed this whale north at high speed at 10:58 – soon after the NUK3 whale was declared dead. IP1 turned back to the NUK3 whale about 11:11am to help with the tow, as the NUK1 and NUK3 boats wanted at least one other boat to help them. They called the NUK2 boat to come out to help but due miscommunications NUK2 did not meet the tow until 2:54pm or so. The boats that followed the BO1 whale north made a loop about 6.1 miles to the NE, but seem to have lost track of it and then headed back to Cross Island to refuel. On the way back to Cross Island BO1 saw something about 2:00pm, and BO1 made an “extra” loop about 5.1 miles to the NW. BO1 did not report sighting anything of interest. This delayed BO1’s return to Cross Island and, with conditions getting more marginal, BO1 did not make a second trip.

On the tow back to Cross Island, IP2 saw a whale at about 1:36pm and left the tow to look around at about 1:40pm, but did not report seeing anything of interest. IP2 then returned to Cross Island at high speed, rather than rejoining the tow, since by that time NUK2 had tied in to the tow and the tow was not that far from Cross Island.

BO2 made a second trip of about 2 hours to the north and NE, and reported no sightings. IP1 and IP2 made second trips of 3.5 and 2.5 hours to the east, to areas where whales had been seen before. They also reported no sightings of interest.

The captains decided to call a “cease fire” and end their season, even though they had one strike left. They did not specifically indicate the reasons why, but the relative lack of whales and somewhat difficult whaling conditions (wind and swells) were certainly important factors. Also, some crew members had been on Cross Island for over two weeks and had run out of subsistence leave, or had other employment or personal obligations. The captains arranged for the demobilization barge to pick up the butchered whale and equipment on 14 September (Tuesday).

14 September, Monday

Most crews had finished their butchering chores by the end of 14 September, but the NUK crew still had some of their crew shares to box, and the NAP crew still had to work on their boat. The four other crews (IAN, BO, IP, TAL) left Cross Island for Nuiqsut on 14 September and arrived in Nuiqsut.

15 September, Tuesday

The NUK and NAP crews left Cross Island for Nuiqsut and arrived in Nuiqsut.

MEMORANDUM

Date: September 1, 2009

To: AEWC, Deadhorse Com Center, Kaktovik Com Center

From: William Hickey, AES Beaufort Sea Com Center Project Mgr.

Subject: For-the-Record: Report of Vessel Conflict with Cross Island Subsistence Bowhead Hunt

• On September 1, 2009, Isaac Nukapigak contacted the Deadhorse Com Center to report a vessel conflict in the Cross Island area. The call was taken at approximately 12:38 pm by Emily Panigeo, the on-duty operator at the Deadhorse Com Center. Mr. Nukapigak reported that the barge "*Seneca*" (barge 250-10), operated by Crowley, was traveling northeast of Cross Island and displaced a grouping of bowhead whales that were being tracked by the Nuiqsut Cross Island bowhead crews. Reportedly, the barge caused the whales to disperse while transiting through the area.

• After the call, Ms. Panigeo hailed the vessel *Seneca* using VHF Channel 16 and announced to the vessel radio operator that they disrupted the bowhead whales in the area. The *Seneca* crew reportedly contacted the Crowley North Slope Operations Manager, located in Deadhorse, by phone. The Crowley staff in Deadhorse directed the *Seneca* to leave the area immediately to avoid any further conflicts with the bowhead hunters of Cross Island.

• Emily contacted William Hickey at 1:25 pm to report the incident. Mr. Hickey confirmed with Emily that the incident was properly logged into the Deadhorse Com Center Call Log Book. Between 1:40 pm and 1:56 pm, Mr. Hickey contacted the Crowley offices in both Anchorage and Deadhorse to discuss the incident. In Anchorage, Mr. Hickey was directed to speak with Bill Hill (Director of Business Development). Mr. Hill was not available so Mr. Hickey left a voice message with Mr. Hill summarizing the incident and requesting a discussion of the matter at his earliest convenience. Mr. Hickey spoke to Jim Deal with Crowley in Deadhorse and Mr. Deal concurred with the communication scenario described by Ms. Panigeo. Since the Crowley North Slope Operations Manager, Randy Daniels, was not available Mr. Hickey asked Mr. Deal to pass on the message to call Mr. Hickey when convenient.

• Since Crowley is not a signatory to AEWC's 2009 Conflict Avoidance Agreement, they are not required to radio the Com Centers on a routine basis (i.e., every 6 hrs). Crowley routinely provides vessel schedule information by email to both the Deadhorse and Kaktovik Com Centers. Mr. Hickey recommended to Mr. Deal that, in the future, it would be preferable for Crowley vessels to contact the Com Centers by VHF radio via Channel 16 when in proximity to Cross Island or Barter Island given that the bowhead season is underway.

*Please contact Mr. Hickey at 907-339-7617 to discuss this incident further.

MEMORANDUM

Date: September 3, 2009

To: AEWC, Deadhorse Com Center, Kaktovik Com Center

From: William Hickey, AES Beaufort Sea Com Center Project Mgr.

Subject: For-the-Record: Report of Vessel Conflicts with Cross Island Subsistence Bowhead Hunt (*Avik* and *Begger* incidents)

• On September 2, 2009, the Deadhorse Com Center reported two isolated vessel conflicts in the Cross Island area. Both of these incidents are also noted in the 9/2/09 Daily Report for the Com Center Program.

• The first call was taken at approximately 5:59 am by Emily Panigeo, the on-duty operator at the Deadhorse Com Center. Edward Nukapigak reported that a barge, later identified as the "*Avik*" (Crowley barge 160-4), was traveling several miles south of Cross Island and displaced a grouping of bowhead whales that were being tracked by the Nuiqsut Cross Island bowhead crews. The barge was contacted by the Com Center's Ms. Panigeo and moved out of the area. Crowley was again notified of the Com Center call-in protocol by Mr. Hickey (via email to Carolyn Macdonald) and Waska William Jr. (North Slope Borough Planning Dept.) also notified Crowley (Greg in Barrow) to stay clear of Cross Island and inside the Barrier Islands when possible.

• The second call was taken at approximately 9:13 pm by Elizabeth Ipalook, the on-duty operator at the Deadhorse Com Center. Isaac Nukapigak reported that a vessel, later identified as the *Begger* (privately owned, 57' boat), was traveling roughly 6 miles north of Cross Island heading west and was disturbing bowhead whales that were being tracked by the Nuiqsut Cross Island bowhead crews. The vessel was contacted by the Com Center's Ms. Ipalook and moved out of the area.

• Since Crowley and the private vessel owner *Begger* are not signatories to AEWC's 2009 Conflict Avoidance Agreement, they are not required to radio the Com Centers on a routine basis (i.e., every 6 hrs). Crowley routinely provides vessel schedule information by email to both the Deadhorse and Kaktovik Com Centers. The crew of the *Begger* was not aware of the active whale hunt or the Com Center Program (although the Com Centers are addressed in the U.S. Coast Guard's regional Notice-to-Mariners).

*Please contact Mr. Hickey at 907-339-7617 to discuss this incident further.