MONITORING OF INDUSTRIAL SOUNDS, SEALS, AND BOWHEAD WHALES NEAR BP'S NORTHSTAR OIL DEVELOPMENT, ALASKAN BEAUFORT SEA, 2010: ANNUAL SUMMARY REPORT

by

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Greeneridge Sciences

& Applied Sociocultural Research

for

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*Cover Photograph***:** Ice field near location "C" on 27 July 2010 viewed from the bow of the ACS boat *Camden Bay* (photo by Katherine H. Kim).

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TABLE OF CONTENTS

CHAPTER 1:

INTRODUCTION, DESCRIPTION OF BP'S ACTIVITIES, AND RECORD OF SEAL SIGHTINGS, 2010[1]

by

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[1] Chapter 1 *In:* W.J. Richardson (ed.). 2011. *Monitoring of industrial sounds, seals, and bowhead whales near BP's Northstar Oil Development, Alaskan Beaufort Sea, 2010: Annual Summary Report.* LGL Rep. P1182. Rep. from LGL Alaska Res. Assoc. Inc. (Anchorage, AK), Greeneridge Sciences Inc. (Santa Barbara, CA) and Applied Sociocult. Res. (Anchorage, AK) for BP Explor. (Alaska) Inc., Anchorage, AK.

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. Facilities for waste grind and injection and for oil production and gas injection are also on the island. A drilling rig that had been on the island since 2000 was demobilized and removed from Northstar during the 2010 open-water season. 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 (17 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. Letters of Authorization (LoAs) issued under the previous (NMFS 2000) and current Northstar regulations (NMFS 2006) have required marine mammal and acoustic monitoring studies. These studies started in 1997,

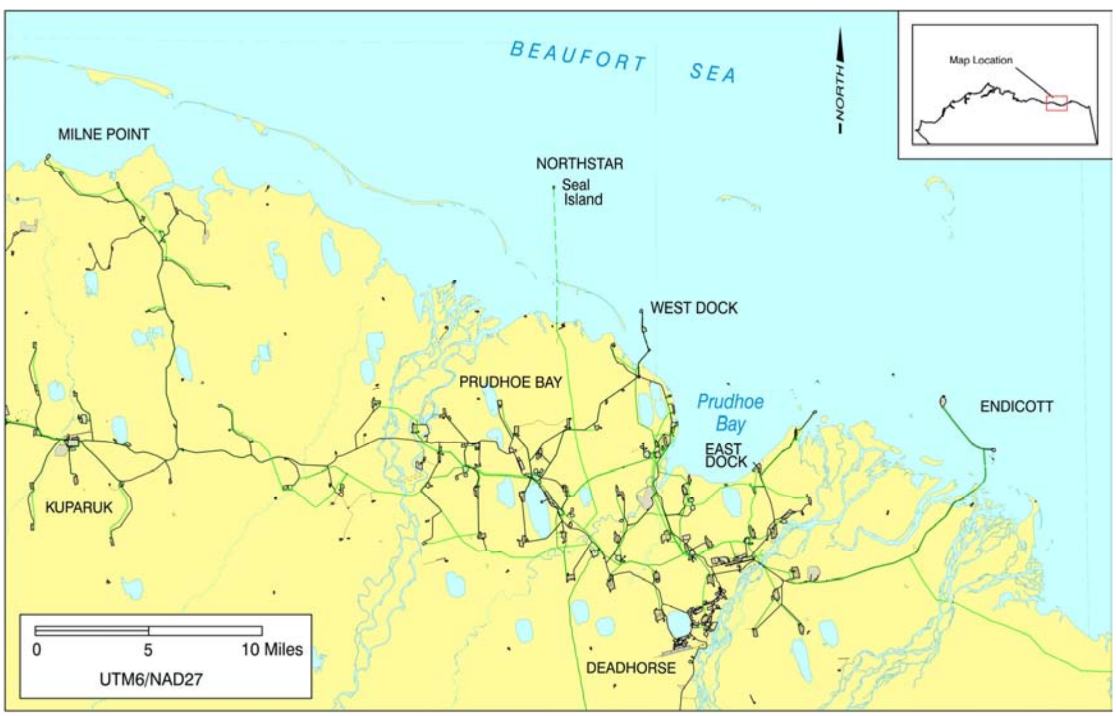

FIGURE 1.1. Location of the Northstar Development at Seal Island in the central Alaskan Beaufort Sea. Seal Island was an artificial gravel island constructed for exploration drilling in the 1980s. Northstar facilities were built on the eroded remnants of Seal Island in 2000.

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 through 6 Apr 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
27 Oct. 2009	BP requested renewal of the Regulations and LoA
28 Apr. 2010	BP requested issuance of an LoA for the 7 Jul. 2010 to 6 Apr. 2011 period

prior to any construction or formal monitoring requirement, and are ongoing. Monitoring results up to 2004 were described in Richardson (ed., 2008), and monitoring results for 2005 to 2009 were described in Richardson (ed., 2010). Specific 2009 results were described by Aerts and Richardson (eds., 2010). The present report describes the 2010 monitoring and its results.

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, various stakeholders during the annual open-water meetings convened by NMFS, various peer reviewers acting on behalf of journals, and others. The reviewers made many suggestions, most of which were later incorporated into data collection, analyses, and interpretation. In addition, the reviewers accepted BP's suggestion for a scaled back monitoring program 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 (in 2008) effects on bowhead behavior from airgun sounds would probably overshadow any effects from Northstar. Rather than analyze the 2008 data in detail, it was decided to repeat the augmented acoustic monitoring effort of 2008 in 2009, when no or only distant seismic survey activities were planned to take place. In fact, seismic survey activity in September 2009 was reduced and much more distant relative to 2008, but even so, sounds from distant seismic surveys were often detected in the migration corridor offshore of Northstar during September 2009. For 2009, we could not conclusively identify a specific relationship between offshore distance of bowhead whale calls and Northstar sound (McDonald et al. 2010).

During the 2010 open-water season, acoustic monitoring of bowhead whale calls reverted to a reduced level, consistent with the earlier recommendations of the SAC and recommendations from participants in the 2010 open-water meeting. Other aspects of the 2010 monitoring work, i.e., counts of seals near Northstar and documentation of the subsistence whale hunt at Cross Island, were continued as in other recent years. During 2010,

- personnel at Northstar counted seals near the island in a standardized way during the spring and early summer;
- underwater sounds near Northstar were monitored during the September whale migration season with a bottom-mounted recorder at a location near the island;
- calling bowhead whales in the southern portion of their migration corridor were monitored during September using a bottom-mounted Directional Autonomous Seafloor Acoustic Recorder (DASAR) at a location offshore of Northstar;
- the opinions of subsistence whalers based at Cross Island concerning the 2010 whale migration and whaling season were documented through interviews with the whalers and direct observations by a sociocultural researcher based on Cross Island during the 2010 hunt.

Counts of seals were made by Northstar personnel from mid-May through mid-July as in previous years. Results of seal counts in 2010 were compared with counts from 2005 through 2009.

The near-island and offshore acoustic recorders were deployed in 2010 at locations where similar recorders had been deployed during all autumn migration seasons since 2001. Types of acoustic data acquired at both sites were generally consistent with those obtained from those two sites in prior years, to allow comparison of the 2010 results with those from 2001 to 2009. However, whale calls were monitored at only one offshore site in 2010, in contrast to previous years, as localization of calling whales was not required in 2010. Bearings from the one call-monitoring station to the calling bowheads were determined in 2010 as in prior years using the directional capability of the DASAR (Greene et al. 2004).

The summary of whaler perceptions of the 2010 bowhead migration and hunt is based on similar procedures to those applied during the 2005 through 2009 seasons. Results from 2009 and from 2005–2009 combined were described by Galginaitis (2010a,b), respectively.

BP's 2010 activities and the seal counts are described later in this chapter. Chapter 2 summarizes the methods and results for the 2010 monitoring of Northstar sounds and whale calls offshore of Northstar. Chapter 3 summarizes the results of the 2010 whaling season at Cross Island.

This report satisfies annual reporting provisions of the regulations and LoAs 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.

The most recent comprehensive report concerning Northstar monitoring contained the monitoring results from 2005 to 2009. That report (Richardson [ed.] 2010) was submitted in August 2010 as required by the current Northstar regulations. Those regulations are in effect until April 2011. It is anticipated that an updated version of the most recent comprehensive report will be prepared after April 2011. That updated comprehensive report is expected to incorporate the results from 2010 summarized in this annual report along with the already-reported 2005–2009 results, and will also take account of peer review and other comments that BP expects to receive.

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 additional papers currently in press and in preparation (Table 1.2). Copies of the published papers are, with the permission of the relevant journals, included as Appendices to the first and/or second comprehensive report (Richardson [ed.] 2008, 2010). In addition, information on various aspects of the Northstar monitoring studies has been disseminated through numerous public presentations, e.g., to the annual open-water meeting convened by NMFS, BP

TABLE 1.2. Authors and titles of publications and manuscripts resulting from the Northstar marine mammal and acoustic studies program, 1999–2010.

Authors	**Title**	**Status**
Harris, R.E., G.W. Miller & 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 & 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 & 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. & 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 & 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 & 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. & 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 & 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. & 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 & 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. & 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 & M.W. McLennan. 2008.	Sounds and vibrations in the frozen Beaufort Sea during gravel island construction.	***J. Acoust. Soc. Am.*** 123(2): 687–695.
Streever, B., R.A. Angliss, R. Suydam & others. 2008.	Progress through collaboration: a case study examining effects of industrial sounds on bowhead whales.	***Bioacoustics*** 17 (1-3): 345–347.

TABLE 1.2. Continued.

Authors	Title	Status
Blackwell, S.B., T.L. McDonald, K.H. Kim, L.A.M. Aerts, W.J. Richardson, C.R. Greene Jr., & B. Streever	Directionality of bowhead whale calls measured with multiple sensors	***Mar. Mamm. Sci. (in press)***
McDonald, T.L., W.J. Richardson, C.R. Greene Jr., S.B. Blackwell, C.S. Nations, R.M. Nielsen, & B. Streever	Detecting changes in the distribution of calling bowhead whales exposed to fluctuating anthropogenic sounds.	***J. Cetac. Res. Manage. (in press)***
	In Preparation (titles and author lists are tentative)	
Richardson, W.J. T.L. McDonald, C.R. Greene Jr, S.B. Blackwell, & B. Streever	Distribution of bowhead whale calls near an oil production island at low and higher-noise times.	***In prep.***
Moulton, V.D., M.T. Williams, S.B. Blackwell, W.J. Richardson, R.E. Elliott & B. Streever.	Zone of displacement for ringed seals (*Phoca hispida*) wintering around offshore oil-industry operations in the Alaskan Beaufort Sea.	***In prep.***

managers, oil field workers, representatives from other energy companies, scientific conferences, universities in Alaska and elsewhere, and, to some degree, in Barrow.

OVERVIEW OF BP ACTIVITIES, NOVEMBER 2009 – OCTOBER 2010

This section describes BP's activities during the period 1 Nov. 2009 through 31 Oct. 2010. The ice-covered season is defined as the period from 1 Nov. 2009 through 15 June 2010, followed by the open-water season from 16 June through 31 Oct. 2010.

Transportation To and From Northstar Island

As in recent years, Bell 212 helicopters and a Griffon 2000TD hovercraft were used to transport personnel and equipment to and from Northstar Island during both the ice-covered and the open-water seasons. In addition, 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 Alaska Clean Seas (ACS) *Bay*-class boats and crew boats.

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). As in previous years, helicopters 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 2009/10 reporting period, helicopters made a total of 135.5 round trips to Northstar (Table 1.3). Nearly half of these trips were made in Sept. and Oct. 2010. Monthly totals were highest in Oct. 2010 and Nov. 2009. With the exception of Nov. 2009, very little helicopter traffic to Northstar occurred during the ice-covered period.

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; Table 1.4). Helicopter traffic to and from Northstar during the 2009/10 reporting period was reduced relative to all previous years since 2002/03 for both the ice-covered and open-water periods.

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

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 2009/10. A ½ round trip occurred when a helicopter or hovercraft (or other vehicle used for transport) left shore prior to midnight, and returned from the island after midnight or, occasionally, if the vehicle left the shore but did not complete the trip due to weather or other reasons.

	Ice-covered season			Open-water season	
Month	**Helicopter**	**Hovercraft**	**Month**	**Helicopter**	**Hovercraft**
November 2009	31	68.5	16-30 June 2010	2	83
December 2009	4	74	July 2010	20	130
January 2010	0	33.5	August 2010	0	65
February 2010	1	0	September 2010	11	34.5
March 2010	0	0	October 2010	55.5	33
April 2010	0	3			
May 2010	0	43			
1-15 June 2010	11	92.5			

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 2010, 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.

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. The hovercraft was first tested and used in spring 2003. na = not applicable. See Table 1.3 caption for description of a ½ round trip.

	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
2009/10	47	314.5	88.5	345.5

Griffon 2000 TD Hovercraft

A Griffon 2000 TD hovercraft was also used to transport personnel during both the ice-covered and the open-water periods (Fig. 1.3). The hovercraft made its first test trips in spring 2003, and since then has been used for transport of personnel and supplies. The hovercraft is powered by a 355 hp air-cooled Deutz diesel engine and is 11.9 m (39 ft) in length (Blackwell 2004; Blackwell and Greene 2005). The hovercraft is capable of carrying a payload of 2268 kg (5000 lb). During the 2009/10 ice-covered season, most hovercraft activity occurred during Nov. through Jan. and during May through early June. There were only three hovercraft round trips from Feb. through Apr. 2010, when most personnel transport was via pick-up trucks, SUVs, and buses operating on the ice-road. The hovercraft was used often during the 2010 open-water season. Of 660 round trips by the hovercraft from West Dock to Northstar in 2009/10, 314.5 round trips were during the ice-covered season and 345.5 during the open-water season (Table 1.4). Hovercraft traffic has been variable among years, ranging from 141 to 574 round trips per year during the ice-covered period, and from 188 to 560 round trips per year during the open-water period (Table 1.4).

Ice Road Transportation

As in previous years, an offshore ice road ~12 km (~7.4 mi) in length was built between West Dock and Northstar during the 2009/10 ice-covered season to transport personnel, equipment, materials, and supplies between the Prudhoe Bay facilities and Northstar Island. Ice-road construction started on 29 Dec. 2009 and construction activities transitioned to maintenance on 25 Feb. 2010. The ice road was officially declared open to light duty traffic on 13 Jan. and was officially closed to all traffic on 27 May 2010.

Tucker tracked vehicles (model 1600 Tucker-Terra; Fig. 1.4) were primarily used in 2010 to transport personnel and materials between West Dock and Northstar during ice-covered periods when the ice road did not permit standard vehicle traffic. These situations occurred mainly in the early-winter months prior to completion of the ice road and again during spring break-up when meltwater accumulating on the ice road prevented standard vehicles from safely transiting to and from the island. Tucker

FIGURE 1.3. Griffon 2000 TD hovercraft used for transporting personnel to and from Northstar.

FIGURE 1.4. Tucker tracked vehicle powered by a Cummins 6-Qsb 173 HP diesel engine.

vehicles are capable of carrying 15 people. Tucker tracked vehicles made a total of 67 round trips between West Dock and Northstar during the 2009/10 ice-covered season. Most Tucker trips to and from Northstar occurred in Dec. (20 round trips), Jan. (16 round trips) and May (17 round trips). The number of Tucker round trips to Northstar in 2010 was reduced compared to that in 2007/08 and 2008/09, and similar to 2005/06 (Table 1.5). No detailed records of round trips by Tucker or other tracked vehicles are available for the construction and early production years (2000–2003), other than that tracked vehicles (Hägglunds) were used frequently.

TABLE 1.5. Number of Tucker tracked vehicle round trips to Northstar Island by year, 2004–2010. See Table 1.3 caption for description of a ½ round trip.

Year	Tucker Round Trips
2004/05	25
2005/06	70
2006/07	37
2007/08	111.5
2008/09	127.5
2009/10	67

Standard vehicles, including vans, pick-up trucks, and buses, were the main method of transportation for Northstar personnel from 13 Jan. to 27 May 2010. A total of 3222 round trips were made during this period.

Tugs and Barges

During the 2010 open-water season. supply runs from West Dock to Northstar occurred mainly by tug and barge. The lengths of barges used to transport fuel and cargo to the island were typically ~46–61 m (160–200 ft) and the tug length was ~20 m (65 ft). On days with average levels of background sounds, sounds from tugs maneuvering at Northstar may 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 63.5 tug and barge round trips were made to and from Northstar during the 2010 open-water period. In 2010, more barge activity occurred in Aug. than in July or Sept. (Table 1.6). The total number of barge trips in 2010 was greater than in 2007–2009 and similar to the 2006 level of activity (Table 1.7). In the 2003 through 2010 period, the highest level of barge activity occurred in 2003 and the lowest in 2004 and 2005.

ACS and Crew Boats

Dedicated crew boats were used to transport personnel to and from Northstar during construction and initial operations, but after the hovercraft became available in 2003, a dedicated crew boat was not used again until 2010 (see below). After 2003, ACS *Bay*-class boats (Fig. 1.5) provided alternative transportation if the hovercraft could not be used. *Bay*-class boats are ~13 m (~42 ft) in length and are normally used as oil spill response vessels. In 2010 *Bay*-class boats were used for routine Northstar support only in Oct. (Table 1.6). The use of *Bay*-class boats in 2010 was reduced compared to most years from 2004 through 2009 (Table 1.7). Two additional trips by *Bay*-class boats were made during Sept. 2010 to support acoustic monitoring of Northstar and the bowhead whale migration (see “Acoustic and Bowhead Whale Migration Monitoring” below).

During the 2010 open-water season, BP operated the crew boat *American Resolution* (Fig. 1.6) to increase Northstar transportation capacity for activities associated with construction upgrades (Tables 1.6 and 1.7). The *American Resolution* is a single V-hulled aluminum landing craft with a length of 10 m (34 ft). Propulsion is accomplished by twin Volvo 63 engines rated at 370 HP each, and twin Kodiak 292 jet direct drives. The *American Resolution* can travel at a speed of 26 knots and is capable of transporting 30 people. Most crew boat activity was in Aug. followed by Sept. after which no further crew boat activity occurred.

TABLE 1.6. Number of round trips to Northstar by tugs/barges, ACS boats, and crew boat during the 2010 open-water season, by month. See Table 1.3 caption for description of a ½ round trip.

Month	Tugs/Barges	ACS boats	Crew Boat
June 16-30	0	0	0
July	16	0	37
August	25.5	0	108.5
September	20	0	86
October	2	15	0
Total	63.5	15	231.5

TABLE 1.7. Number of round trips to Northstar Island by tugs/barges, ACS boats and crew boats during the open-water season by year from 2003 through 2010. 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. See Table 1.3 caption for description of a ½ round trip.

Year	Tugs/Barges	ACS boats	Crew Boat
2003	82	--	N/A
2004	24	(22)	N/A
2005	21	(14)	N/A
2006	64	106	N/A
2007	40	137	N/A
2008	45	55	N/A
2009	44.5	65	N/A
2010	63.5	15	231.5

Activities at and near Northstar Island

Production Facilities

Oil production at Northstar began on 31 Oct. 2001 and has occurred almost continuously from that date through the present reporting period. Power generation and compressor equipment on the island in 2009/10 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.

FIGURE 1.5. ACS *Bay*-class boat; used for oil-spill response, to transport personnel to and from Northstar, and to support the Northstar acoustic monitoring program.

FIGURE 1.6. The crew boat *American Resolution* used to transport personnel to and from Northstar during 2010. Photo provided by Lori Murray.

Drilling and Pile-Driving

Drilling activities were conducted at one site at Northstar from Jan. through May 2010. The drill rig subsequently was demobilized and removed from the island via barges during the 2010 open-water period. No vibratory or impact pile driving associated with drilling activity occurred during the reporting period. However, vibratory pile driving did occur in association with construction and maintenance activities during the ice-covered and open-water periods, as discussed below.

Training Activities

A total of three articulated ARKTOS evacuation craft have been available as the island emergency escape vehicles since 2007 (Fig. 1.7). 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. These vehicles can operate both on ice and in water. ARKTOS training was performed on solid ice on 29 Mar. and 5 Apr. 2010. ARKTOS training also occurred in open water during the last two weeks of Sept. 2010.

Offshore oil spill training exercises were conducted on several occasions during the 2010 open-water season. Mini-barges with drum skimmers and pumps were deployed from West Dock on 19 and 26 July. ACS *Bay*-boats were used to deploy LORI brush skimmers and side skirts on 16 and 23 Aug. ACS boats were also used to deploy RO-boom from the island on 30 Aug. and 6 Sept.

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 Northstar pipeline for leaks or spills. Forward-looking infrared (FLIR) devices were 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 were used continuously to detect oil spills. No reportable conditions associated with the pipeline were recorded during the reporting period.

Reportable Spills

Nine reportable spills were recorded during the reporting period (Table 1.8). Spilled materials were cleaned up using various types of equipment and sorbents, and were recovered completely for each

FIGURE 1.7. Articulated ARKTOS evacuation craft used as Northstar's emergency escape vehicles.

TABLE 1.8. Record of material spilled at Northstar Island during the period 1 Nov. 2009 – 31 Oct. 2010. All spills were cleaned up using standard practices.

Date	Material Released	Did Release Reach Beaufort Sea or Sea Ice?
13 Dec.	Hydraulic fluid from NS-30 hydraulic panel totaling 4 gal., 2 in containment and 2 outside of containment.	No
9 Jan.	Hydraulic fluid from Airport Rentals dozer staged at PM2 on shore but was still considered Nstar; 2 gal. spilled on gravel pad.	No
5 Feb.	Hydraulic fluid from 163H CAT Blade doing snow removal on Nstar ice road, 1/4 gal.	No
24 Feb.	Hydraulic fluid from Kodiak snow blower doing snow removal on Nstar ice road, 20 gal.	Yes
15 Apr.	Hydrochloric Acid (HCl) from a pump van's check valve that was rigged up to a coil unit doing work on a well at Nstar, 0.1 gal (drip)	No
27 Apr.	Hydraulic fluid from Nstar hovercraft's Prop Pitch Assy lost bolt, 0.02 gal (mist)	No
2 May	Turbine wash water from overfilled container while doing wash on turbines, 1 gal.	No
22 May	Sulfuric Acid (H2S04) from failed battery in the Nstar loader, 0.06 gal.	No
24 Sept.	Diesel freeze protect leaked from flange on G&I header, 1 gal.	No

spill event. Hydraulic fluid was spilled on the ice road on 24 Feb. and contaminated snow/ice was removed. No spilled materials reached the Beaufort Sea during the reporting period and no clean-up activity was necessary after Northstar flare events.

Construction and Maintenance Activities

In early 2010, BP began an enhancement project on the southeast corner of Northstar to accommodate a new operations center that will be sea-lifted to the island in 2012. Removal of concrete blocks around the southeast corner began on 11 March. Installation of sheetpiles began on 1 April 2010; an APE model 200-6 vibratory impact hammer was used. Initial installation of 670 sheetpiles with the vibratory impact hammer was completed on 8 July. Maxi hauls (tractor/trailer dump trucks) were used to haul gravel to the island via the ice road from ~6 March to 7 May 2010. A roller compactor was used to consolidate the gravel as it was installed in the enhancement area on the southeast corner from late Mar. to early Apr. A redundant sheetwall consisting of 197 sheetpiles was installed inside the newly-installed outer wall in Oct. 2010 using the same APE model 200-6 vibratory hammer.

Construction of a new ramp for the ARKTOS vehicles and a new water intake system was scheduled to occur beginning in the late ice-covered period and to continue through the open-water period 2010. These activities were postponed and rescheduled for 2011.

The Nabors drill rig (Fig. 1.8) was demobilized and removed from Northstar beginning on 8 July. A Manitowok model 555 crane was used to load drill rig components onto barges for transport to West Dock. Transportation of the rig was coordinated with regular barge traffic that occurs annually to bring supplies and equipment to Northstar. The rig was transported on back hauls by the same barges, and dedicated barge traffic for rig transportation was not necessary. A crane with a clam-shell bucket, located on the island, was used for dredging of the Northstar dock area to remove silt deposition prior to demobilization of the drill rig.

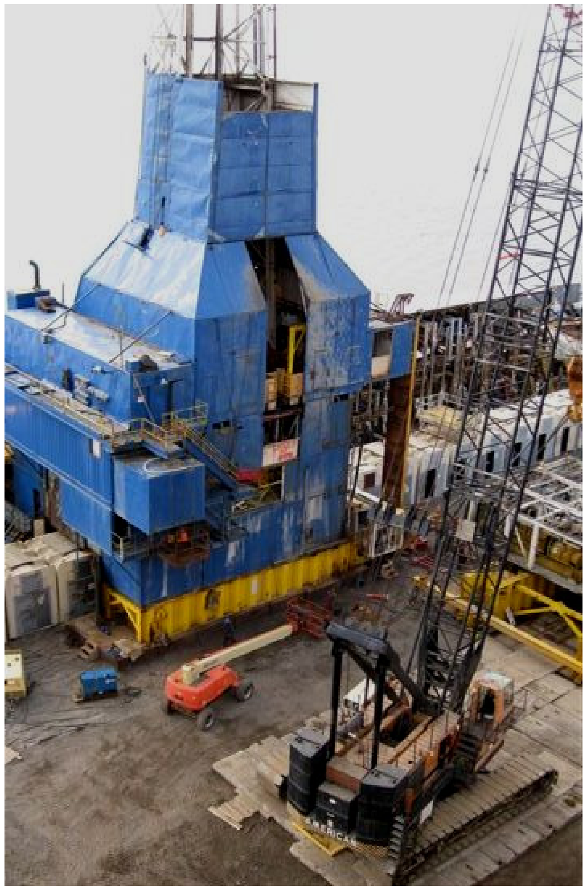

FIGURE 1.8. Demobilization of Nabors drill rig on Northstar Island, July 2010.

Acoustic and Bowhead Whale Migration Monitoring

This section provides a summary of the 2010 acoustic and bowhead whale monitoring activities associated with the Northstar project that required use of an ACS *Bay*-class boat in waters offshore of Northstar. Chapter 2 describes in detail the methods and results of these monitoring activities. The monitoring program planned and conducted in 2010 was less extensive than in 2000–2009, so the level of boat support required in 2010 was reduced.

Boat-based work in support of this monitoring was conducted on two dates: 2 and 30 Sept. 2010. On 2 Sept., the ACS boat *Gwyder Bay* was used to deploy five DASARs. Two DASARs were deployed 15 km (9.3 mi) northeast of Northstar and three were deployed ~430 m (~1410 ft) north of Northstar's northern shore. On 30 Sept., all DASARs were retrieved using the ACS boat *Mikkelsen Bay*. Health checks to confirm recording functionality were performed immediately following DASAR deployment on 2 Sept., and the time base and orientation of each DASAR were calibrated as part of deployment and retrieval activities on 2 and 30 Sept.

Non-Northstar Related Activities

The Bureau of Ocean Energy Management (formerly the Minerals Management Service and, before that, 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 the National Marine

Mammal Laboratory, and in 2008–2010 these surveys were extended across the northeast Chukchi Sea to document marine mammal distribution during the open-water (ice-free) months.

In 2010, Shell Offshore Inc. (Shell) used two vessels to conduct shallow hazard and site clearance surveys in Harrison Bay ~50 km (31 mi) west of Northstar Island, and in Camden Bay ~90 to 140 km (56 to 87 mi) east of Northstar (Reiser et al. 2011). In Harrison Bay, a small airgun array comprised of four 10–in^3 airguns with a total volume of 40 in^3 as well as higher frequency sources, including a sub-bottom profiler, side-scan sonar, and echosounders, were used. In Camden Bay, only the higher frequency sources were used. These activities were conducted periodically from ~13 Aug. to 9 Oct. Aerial surveys that were part of required mitigation for the shallow hazards surveys were conducted in the Beaufort Sea from 16 July to 10 Oct.

As in other recent years, five DASAR arrays were deployed by Greeneridge Sciences Inc. for Shell 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) from Harrison Bay to near Kaktovik.

The U.S. Geological Survey (USGS) in cooperation with the Geological Survey of Canada (GSC) used two vessels to conduct a marine geophysical survey in the Arctic Ocean north of Alaska from 12 Aug. to 4 Sept. 2010 (Beland and Ireland 2010). An airgun array with a total discharge volume of 1150 in^3 was used for acquisition of seismic survey data. Seismic survey activity generally occurred >100 km (62 mi) offshore in water generally >2000 m deep.

Various additional activities unrelated to Northstar likely occurred in the general area that are not reported here.

OBSERVED SEALS

This section summarizes Northstar seal sightings during the latter part of the ice-covered season and the start of the open-water season for 2005 through 2010. Observations were conducted from the 33-m (109-ft) high process module by Northstar Environmental Specialists on behalf of BP. The protocol for seal counts was initiated in 2005 and included

- counting the number of basking seals from 15 May to 15 July on a near-daily basis. Counts were done once each day, usually between 11:00 and 19:00 hr local time, for at least five days per week (when practicable). No counts were made if the cloud ceiling was less than 91 m (300 ft).
- using the roof of the Northstar process module to count seals within ~950 m (3116 ft) around the entire perimeter of the island covering an area of ~281 ha (695 acres).
- scanning with the naked eye and using binoculars to confirm suspected seal sightings. An inclinometer was used to estimate the distance to observed seals. Seals observed inside the area whose periphery was 2 degrees or more below the horizon were included in the count. (From the height of the observation platform, a 2º depression angle corresponded to a distance of ~950 m or 3116 ft.) If the depression angle was <2º as measured with the inclinometer, then the seal was outside the monitoring area.

Seal observations in 2010 were conducted from 15 May to 15 July as called for by the protocol. A total of 185 seals were observed (including presumed repeat sightings of the same animal on different days; Table 1.9). The total annual number of seal observations ranged from a low of 3 seals in 2007 to a high of 811 seals in 2009. The 2010 seal total count (185) and the mean daily sighting rate (3.0 seals/day) were intermediate relative to other years; the 2010 values were the 3rd lowest (and the 4th highest) values recorded during the 6-yr period from 2005 through 2010. Results of the seal counts suggest high inter-annual variability in number of seals sighted and mean daily sighting rates.

TABLE 1.9. Summary of seal data collected in the period 15 May to 15 July from 2005 to 2010.

Year	Total # of seals	Total obs. days	Mean # seals/day	Max. # observed	Standard deviation
2005	229	42	5.5	124	19.4
2006	54	48	1.1	4	1.2
2007	3	62	<0.1	1	0.2
2008	415	54	7.7	63	15.1
2009	811	61	13.3	87	24.6
2010	185	62	3.0	18	4.5

Most seals observed in 2010 were seen in June when they basked on ice (Fig. 1.9). Over the 6-yr period, sighting rates were highest at variable times in June and early July (Fig. 1.10). During each year with data, the seal sighting rate was low in the latter half of May and increased in early June (Fig. 1.10). In 2008 and 2009 the seal sighting rate continued to increase during the latter half of June. These relatively high sighting rates in late June of some years are reflected in the 6-yr average (Fig. 1.10). During most years, however, seal sighting rates declined during the latter half of June and continued to decline in July. Reports from Northstar do not provide evidence, or reason to suspect, that any seals were killed or injured by Northstar-related activities.

FIGURE 1.9. Seal near breathing hole, observed from the Northstar Process module on 11 June 2009.

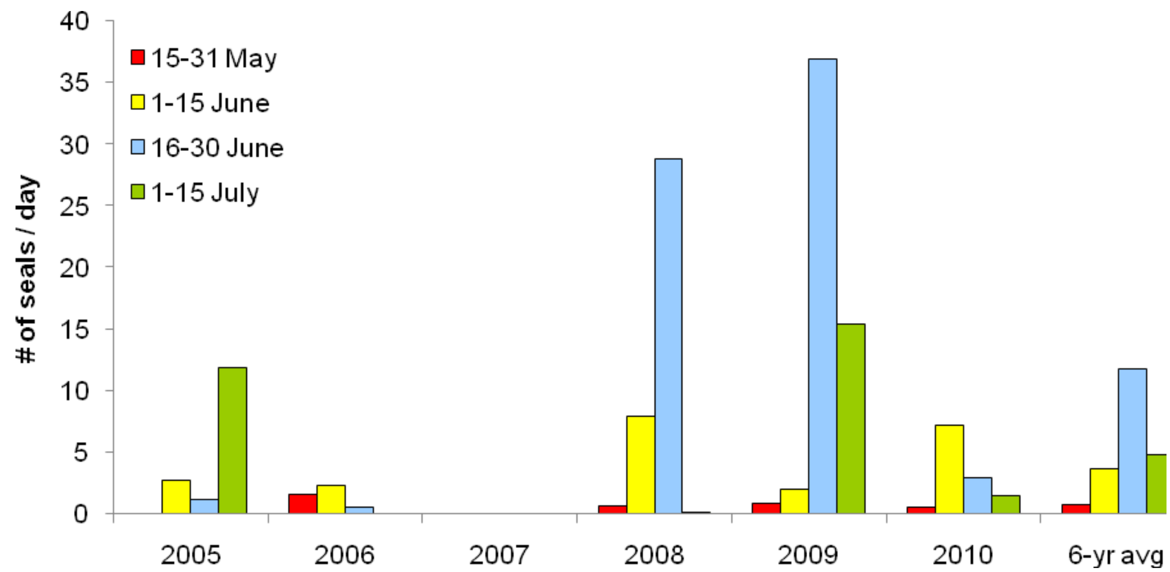

FIGURE 1.10. Average number of seals observed per day from Northstar Island, by half-month, from 15 May to 15 July during 2005 through 2010. In 2005 observations started on 3 June, so the number of seals in the period 15–31 May 2005 is unknown. Other “missing” bars (1–15 July 2006 and 2008, and all periods in 2007) indicate zero or near zero average numbers.

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CHAPTER 2:

ACOUSTIC MONITORING OF BOWHEAD WHALE MIGRATION, AUTUMN 2010[1]

by

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ABSTRACT

During the bowhead whale migration in Sept. 2010, Greeneridge Sciences Inc., on behalf of BP, implemented an acoustic monitoring program north-northeast of BP's Northstar oil development. Following two years of augmented acoustic monitoring efforts in 2008 and 2009, acoustic monitoring of bowhead whale calls in 2010 reverted to a reduced level as agreed by NMFS and stakeholders. In 2010, the acoustic monitoring plan focused on monitoring (1) sound levels emanating from Northstar and (2) the relative numbers and bearings to bowhead whale calls near Northstar, during the month of September.

To meet the aforementioned two objectives for 2010, underwater sounds associated with Northstar were monitored with a bottom-mounted recorder located near the island, and calling bowhead whales in the southern portion of their migration corridor were monitored using a directional seafloor recorder located offshore of Northstar. The near-island and offshore acoustic recorders were deployed in 2010 at locations where similar recorders had been deployed during all autumn migration seasons since 2001. Types of acoustic data acquired at both sites were generally consistent with those obtained from those two sites in prior years to allow comparison of the 2010 results with those from 2001 to 2009. Whale calls were monitored at only one offshore site in 2010, in keeping with the approved monitoring plan. Bearings from this one station to the calling bowheads were determined in 2010 as in prior years using the directional capability of the DASAR (Directional Autonomous Seafloor Acoustic Recorder).

As in years past, broadband sound near and offshore of Northstar was characterized by its dependence on wind speed (sea state) and by occurrence of transient high-level "sound spikes" caused by passing vessels. While baseline broadband levels continued to fluctuate in parallel with wind speed, baseline levels in 2010 were generally lower and less variable despite similar mean wind speeds to the previous two years. This may have been due to the dampening effect of unusually heavy ice near Northstar during the recording season. The frequency of occurrence of vessel spikes was slightly greater in 2010 compared with more recent post-construction years, probably as a consequence of the resumption and frequency of crew boat activities in 2010. Sounds from distant airguns and unidentified "pop" sounds, which were notable in 2008 and 2009, contributed little to the soundscape in 2010.

Whale call activity, on the other hand, was markedly different in 2010 than during most of the previous nine years of the Northstar acoustic monitoring study. The average daily call detection rate was the lowest of any year with comparable data (2001 to 2010) at only 12 calls/day. The bearing distribution of those calls was also striking, with detected whale calls located predominantly inshore and southeast of the offshore DASAR, largely due to a highly vocal bowhead or group of bowheads present on 29–30 Sept. Call type proportions were also unusual; simple calls comprised an extraordinary 97% of all calls with few (3%) of the calls being complex. Visual observations from aerial surveys and whalers appear to support the acoustic results. Aerial surveys observed no bowheads in the vicinity of Northstar during the DASAR recording period, and all sightings were at a greater distance from shore than the offshore DASAR. Whalers observed whales among nearshore ice but found most whales further offshore. Abnormally heavy local ice in 2010 may be responsible for some of these findings, possibly causing a dampening effect on surface-generated noise, moving the main migration corridor further offshore, and limiting acoustic detection capability due to propagation effects associated with shallow, ice-covered waters.

INTRODUCTION

A comprehensive summary of the results of the initial years of the acoustical and marine mammal monitoring program at Northstar (up to 2004) can be found in Richardson (ed., 2008). Results from continued monitoring in the 2005–2009 period are summarized in Richardson (ed., 2010). These results suggest that (1) there are no measurable effects on seals from Northstar activities, and (2) there are limited but statistically detectable changes in the distribution of localized bowhead whale calls near Northstar. The most readily detected effects on bowheads may be limited to the southernmost part of the migration corridor during periods with relatively noisy operations (generally boat and barge operations). The acoustic monitoring plan implemented in Sept. 2010 was reduced in scope to involve monitoring for changes in (a) sound levels emanating from Northstar and (b) the relative numbers of and bearings to bowhead whale calls near Northstar.

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 especially operational sounds from Northstar, with the exception of vessel-generated sounds, 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 (closest to Northstar) 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 calling bowhead whales in the southern (proximal) portion of the migration corridor during their autumn migration. Every year from 2001 to 2010, from late August/early September to late September/early October, cabled hydrophones or seafloor recorders were deployed ~450 m north of the island to obtain a continuous record of Northstar (and other) underwater sounds near the island. In addition, directional autonomous seafloor acoustic recorders (DASARs, Greene et al. 2004) were deployed offshore at varying numbers of locations: in arrays of DASARs at 10 locations (2001–2004 and 2008–2009), in arrays of 3–4 locations (2005–2007), and in 1 location (2010). These offshore DASARs were placed in the southern part of the migration corridor, ~6.5–38.5 km (~4–24 mi) northeast of Northstar. The offshore 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. Although the whale migration is known to continue well into October, the recorders were recovered in late September or early October each year before boat-based operations were curtailed by ice formation.

Analyses of the near-island sound records revealed 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 and resumed in 2010), 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 and under calm (sea state ≤1) and, thus, high detection range conditions, 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).

Analyses of the 2001–2004 call-location 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 a statistically significant tendency for the southernmost whale calls to be slightly farther offshore (McDonald et al. 2008, in press; Richardson et al. 2010, in press). 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. A similar analysis of call-location data from 2009 did not identify a specific relationship between offshore distance of bowhead whale calls and Northstar sound, possibly because of confounding by reactions of bowhead whales to sound pulses received from a seismic survey that was ongoing far to the east in 2009 as well as differences in analysis approach (McDonald et al. 2010).

Objectives

The overall objectives of the acoustic portion of the ongoing Northstar study are two-fold: acoustic monitoring of (1) Northstar sounds and (2) bowhead whales. In 2010, the specific tasks to achieve these objectives were as follows:

1. Deploy an acoustic recorder about 450 m (1476 ft) north of Northstar, in the same area where underwater sounds have been recorded during each late summer/early autumn season since 2001. This recorder was to be installed for ~30 days in September, corresponding with the deployment period for the offshore recorder (see below). The near-island recorder was to be used to record and quantify sound levels emanating from Northstar. At least one additional acoustic recorder was to be deployed to provide a reasonable level of redundancy.
2. Deploy a DASAR or similar recorder about 15 km or 9 mi north of Northstar, consistent with a location used in past years (as far as conditions allow). The data from the offshore recorder can provide information on the total number of calls detected, the temporal pattern of calling during the recording period, the bearings to calls, and call types. These data can be compared with corresponding data from the same site in previous years (known as location EB in 2001–2007 and C in 2008–2009). A second DASAR, or similar recorder, was to be deployed at the same location to provide a reasonable level of redundancy.

The methods used and the results obtained from the deployment of these nearshore and offshore DASARs are the subject of this chapter. This includes the computation of broadband, narrowband, and one-third octave band levels based on the data collected by two recorders, one located close to Northstar (~430 m or ~1410 ft away) and the other farther offshore (15 km or 9.28 mi from the island). It also reports on other sound sources, for example, impulsive sounds such as airgun pulses. Lastly, the report describes the bowhead whale calls detected at the offshore recorder, bearings to those calls, and call types.

METHODS

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 past Northstar. 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 in the following ways: (1) smaller size, lower profile, and lower weight, making handling easier and improving stability on the seafloor; (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; and (8) gain matching of the directional sensors, which leads to more accurate bearing data. 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 13 cm (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. Testing confirmed no change in acoustic sensitivity or performance. 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 the direction to a sound source. 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" 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 are 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 (more than required here) at a data bandwidth of 450 Hz.

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

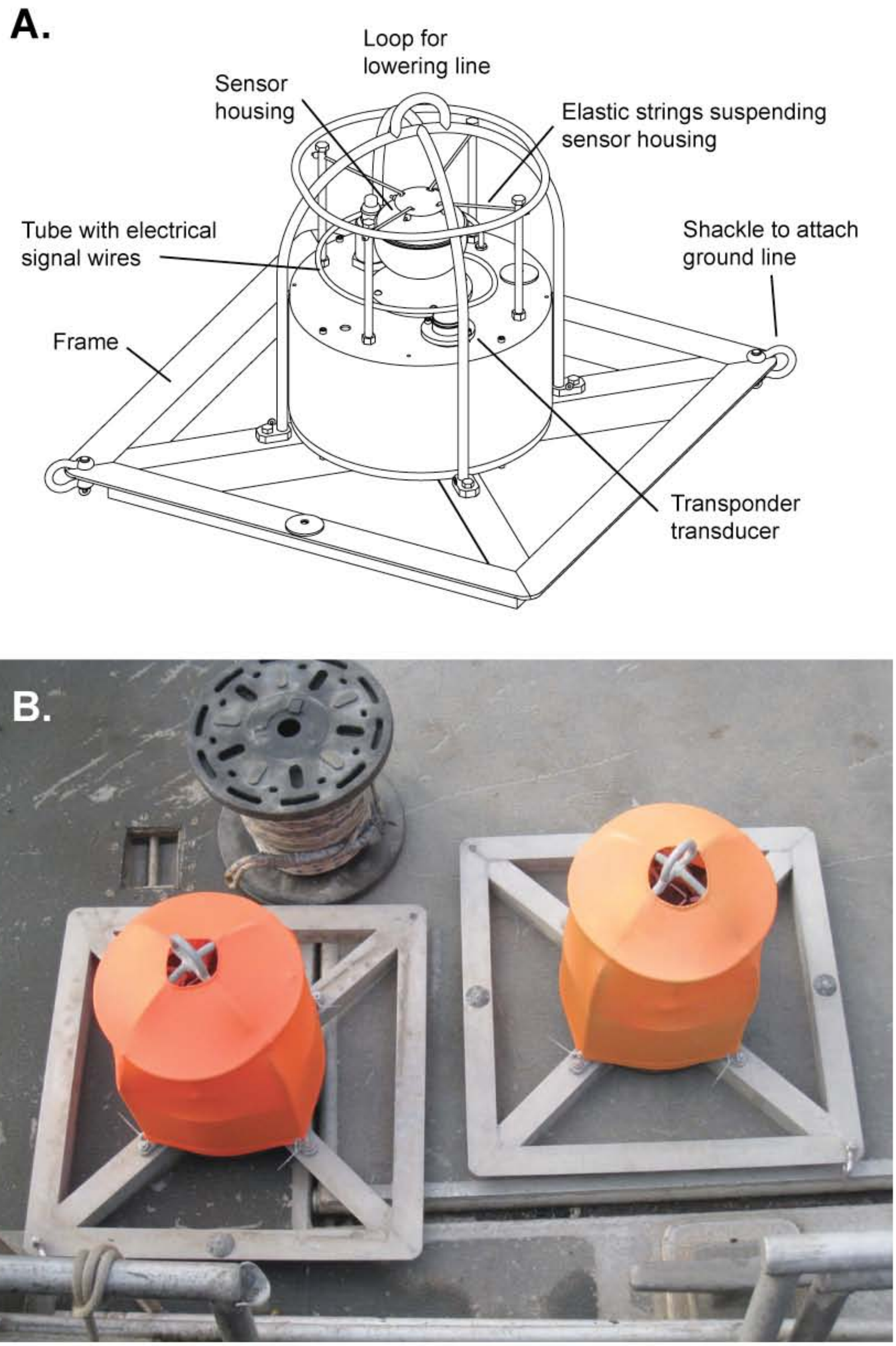

FIGURE 2.1. DASAR recorders. ***(A)*** Schematic diagram of the components of the DASAR-C recorder. ***(B)*** DASARs on the back deck of an ACS vessel awaiting deployment.

The DASAR hydrophone sensitivity is –149 dB re 1 V/μPa at 100 Hz and increases with frequency at a 6 dB/octave rate throughout the operating range. (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 overloads (saturates) when the instantaneous sound pressure exceeds 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).

2010 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.

Five DASAR installations took place on 2 Sept. 2010 from the ACS vessel *Gwyder Bay* (Fig. 2.2). Table 2.1 lists the deployment locations and recording start and end times for all DASARs. Two DASARs were deployed at location C, 15 km (9.3 mi) northeast of Northstar, which is the one offshore location where a functional DASAR has been deployed every autumn since 2001. One of the two served as a redundant backup recorder. The role of the offshore DASARs was to provide information on the total number of whale calls detected, the temporal pattern of calling during the recording period, the bearings to calls, and call types. These data can be compared with corresponding data from the same site in previous years (known as location EB in 2001–2007 and C in 2008–2010). In addition, three DASARs were deployed ~430 m north of Northstar (Fig. 2.3). The primary function of these near-island 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 401 m, 389 m, and 431 m (1316 ft, 1277 ft, and 1413 ft), respectively, from the center of the north shore of Northstar. NSa and NSb were separated by 142 m (468 ft), and NSb and NSc by 136 m (447 ft). Two of the three DASARs were deployed as backups to the third.

All five DASARs were successfully retrieved on 30 Sept. 2010 by the ACS vessel *Mikkelsen Bay*.

Health Checks

On 2 Sept., 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 2 Sept., soon after deployment.

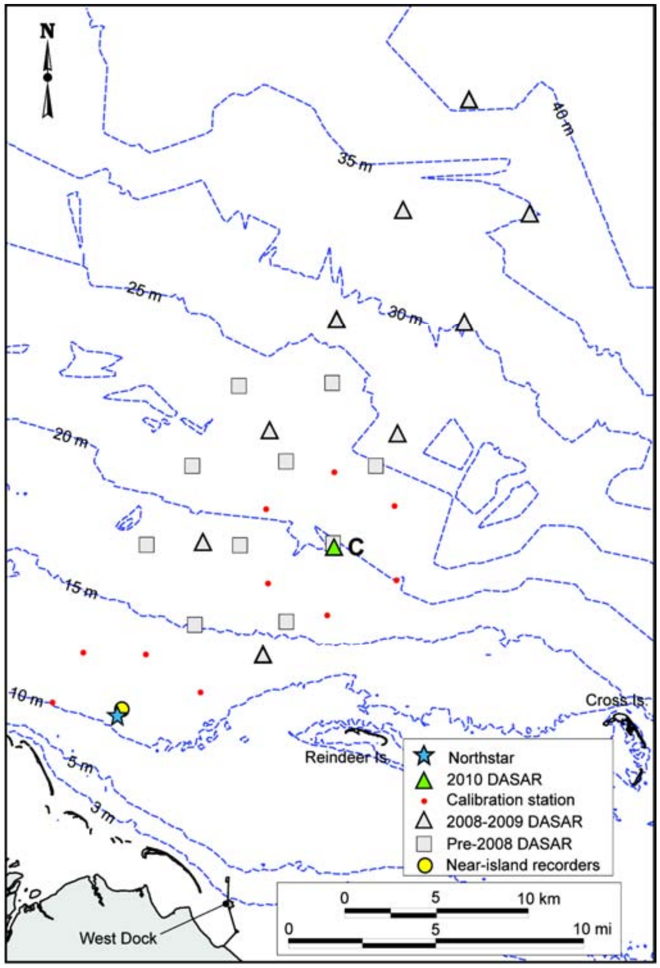

FIGURE 2.2. Locations of two offshore DASARs (two DASARs were deployed at location C) and 10 calibration stations with respect to Northstar Island, Sept. 2010. The three near-island DASARs are shown just north of Northstar (see Fig. 2.3). For comparison, DASAR locations used in 2001–2004 (a subset of these locations were used in 2005–2007), 2008, and 2009 are also shown.

TABLE 2.1. DASAR locations in 2010, 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. Location C in the array is the same as location EB in 2001–2007. DASAR units 50 and 47 were deployed offshore and are redundant of each other, both at location C. DASAR units 48, 51, and 49 were installed close to Northstar and are redundant of each other. * 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)	Distance from Northstar (mi)
C (=EB)	50	2 Sept. 12:01	2 Sept. 10:00	30 Sept. 11:40	70.577	148.396	22.2	14.65	9.11
C dupl.	47	2 Sept. 11:47	2 Sept. 10:00	30 Sept. 12:01	70.576	148.384	22.2	14.94	9.28
NSa	48	2 Sept. 07:07	2 Sept. 10:00	30 Sept. 13:55	70.495	148.694	12.3	0.40	1316 *
NSb	51	2 Sept. 07:20	2 Sept. 10:00	30 Sept. 13:31	70.494	148.691	12.3	0.39	1277 *
NSc	49	2 Sept. 07:33	2 Sept. 10:00	30 Sept. 14:14	70.494	148.688	12.3	0.43	1413 *

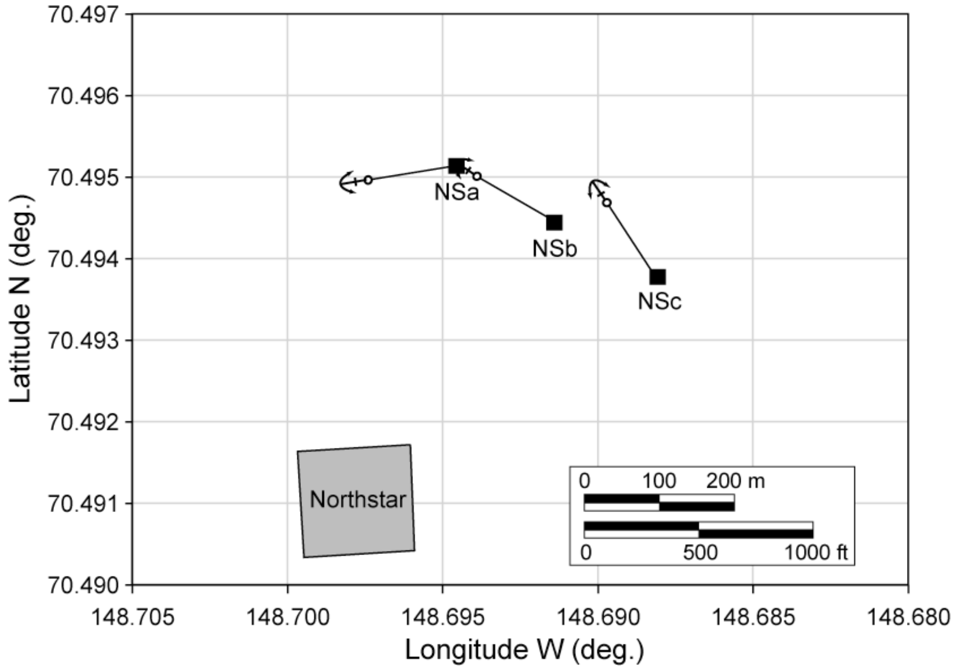

FIGURE 2.3. Locations of the three near-island DASARs (■) and their associated ground lines and anchors in relation to Northstar, Sept. 2010. The primary function of these DASARs was to provide a continuous acoustic record of sounds produced by Northstar and its attending vessels.

Time and Bearing Calibrations

On 2 Sept., the day of DASAR deployment, the clock and reference bearing of each DASAR were calibrated. Time and bearing calibrations were also performed on 30 Sept., before DASAR retrievals. On each of those two days, calibration transmissions were projected at six locations around the offshore DASAR and four locations around the near-island DASARs, resulting in a total of ten calibration locations (Fig. 2.2). *Time calibrations* are conducted because each DASAR's clock has a small but significant drift. The clock drift must 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 convert bearings to whale calls measured relative to the DASARs to bearings relative to True North.

Field calibrations (both time and bearing) 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 (± a small uncertainty in bearing). The calibration transmissions also allow us to synchronize the clocks in the 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.

Equipment used for calibrations included a model J-9 underwater sound projector, an amplifier, and a special "Calbox" with the stored waveform to be projected and a GPS receiver to control the timing of the sound source and to record the locations of each transmission. A spectrogram of the waveform used in 2010 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 pseudorandom noise (m-sequence with 255 states, 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 appended in 2009. The 4 s of pseudorandom noise is spectrally flat across the DASAR operating band (see Figure 2.4) and has the advantage over purely random noise of being reproducible. It was added in 2009 because its broadband character enables finer time resolution for calibration analyses. The source level of the projected sound was ~150 dB re 1 μPa @ 1 m. During calibration at a given station, a waveform transmission was initiated every 14 s and repeated 8 times at that calibration station before moving the *Bay*-boat to another station and repeating.

Analyses of Acoustic Data from DASARs

After retrieval on 30 Sept., 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 Greeneridge Sciences, where they were backed up and copied for analysis. Data were transferred to computers running MATLAB and custom analysis software and were equalized in post-processing. 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 enables 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).

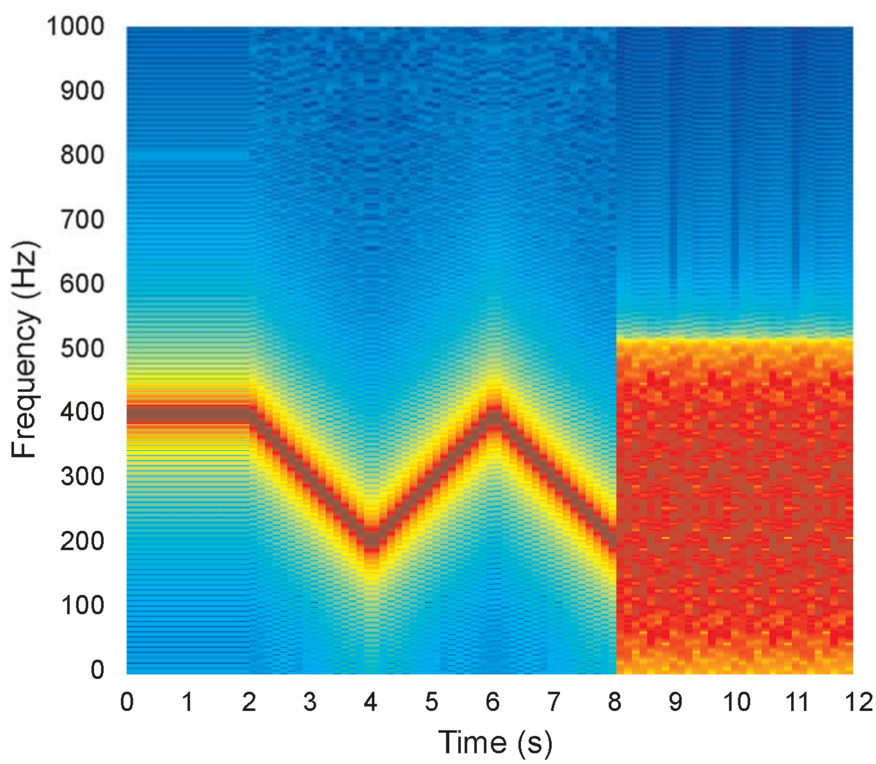

FIGURE 2.4. Spectrogram of the calibration waveform used in 2010.

Various analyses were performed to address the 2010 study objectives. Many of the analyses were the same as in 2008–2009 (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;
- Analyses of other sounds, such as impulsive sounds;
- Whale call analyses.

The results from these analyses are presented in the *Results and Discussion* section.

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. 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.

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. To calibrate both time and bearing, the calibration signals transmitted at DASAR deployment and retrieval must first be accurately detected in the DASAR acoustic records. This is accomplished by means of a matched filter, which proves especially useful when calibration signals are obscured by background noise. For time calibrations, the calibration signal's arrival time at the DASAR is determined after accounting for source-to-receiver travel time. The time error (the difference between true time and DASAR clock time) is characterized as a linear function and is used to correct the time measured by the DASAR clock to true time. For bearing calibrations, once calibration signals are identified in the acoustic records, the relative bearing of the DASAR to the known position of the calibration vessel is obtained. (Bearing calibration methodology is explained in more detail in *Annex 2.1* of Blackwell et al. [2010a].) This is done for all 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%, was analyzed. The 119 resulting 1-Hz spectra were averaged to derive a single averaged spectrum documenting narrowband levels for the one-minute period.

One-third octave band and broadband levels were derived from the aforementioned narrowband spectral densities. The bandwidth of a one-third octave band is 23% of its center frequency. Standard center frequencies for adjacent 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 series of 1-min averages separated by 4.37 minutes of the levels of low-frequency underwater sounds ~430 m from Northstar during the period 2 Sept.–30 Sept. 2010.

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, 5^{th}-percentile, 50^{th}-percentile, 95^{th}-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. Thus, it allowed general comparisons between years by identifying, for example, prominent tones or the dominant frequency ranges of industrial sounds.

During the 2008 and 2009 field seasons, 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 offshore 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 "minimum analysis" computations were repeated with the 2010 data.

Other Sounds

Pop Sounds—Analyses of the data collected in 2008 and 2009 showed that pops only occurred on the three near-island recorders (and not on any offshore array DASARs), the sounds likely originated from the northeastern corner of the island, and there was a strong positive association between wind speed and the presence and amplitude of pops. This supported the hypothesis that the pops were produced by movements of an underwater structure. For 2010, a manual search of the broadband acoustic records of the three near-island recorders was conducted to identify quiet times, noisy times, and times when levels were changing quickly. We then investigated time series and spectrograms of the omnidirectional channel at these times for signal characteristics associated with the pops. This manual search process revealed that there were very few identifiable pops in 2010. Consequently, no additional analyses were performed to detect and quantify pops.

Airgun Pulses—During the 2008 and 2009 field seasons, numerous airgun pulses not associated with Northstar were detected on the acoustic records of the offshore DASARs. Since airgun pulses have energy distributed over our entire analysis band of 10–450 Hz, they are a source of interference in the acoustic records. 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 2010 field season, we analyzed pulses in the record of DASAR C (the offshore DASAR) using software developed by Dr. Aaron Thode (Scripps Institution of Oceanography). This analysis allowed comparison of the number and received levels of airgun pulses detected on DASAR C in 2010 with those in 2009.

The process of automatically detecting and measuring acoustic properties of airgun signals took place in three stages: pulse detection, interval estimation, and level measurement. The first two stages (pulse detection and interval estimation) are described in detail in *Annex 2.2* of Blackwell et al. (2010a). Once pulses were identified, the software calculated the following five parameters for each detected pulse: (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 (in dB re 1 μPa); (4) pulse *sound exposure level level* (SEL), a measure of the energy in the pulse, defined as the squared instantaneous sound pressure integrated over the pulse duration (in dB re 1 $\mu Pa^2 \cdot s$); and (5) *background level*, as determined over ~0.5–1 s immediately preceding the pulse (in dB re 1 μPa). 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.

Whale Call Analyses

Analysis of whale calls was done manually by trained staff using software developed at Greeneridge Sciences and procedures similar to those 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. 2.5). The sounds recorded by the offshore DASAR during a given 1-min interval 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 "marking" the call in the records. The software then calculated several parameters such as the call's start time and bearing, its duration and bandwidth, signal and noise levels, and various call localization statistics. The lead analysts performed regular checks for consistency among analysts. In prior years, when an array of DASARs was deployed offshore, calls were often detected by more than one DASAR which allowed triangulation of the call's estimated position using a method described in Greene et al. (2004). The greater the number of DASARs detecting a given call, the greater the localization accuracy. With a reduced monitoring plan for 2010, an array of few recorders would yield correspondingly inaccurate localization estimates. Consequently, one offshore DASAR at location C was utilized in 2010, allowing estimation of a given call's bearing from DASAR C but not the call's location.

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

FIGURE 2.5. Eight of the 30 workstations at Greeneridge Sciences Inc. where analysts identify and localize whale calls.

(*Odobenus rosmarus divergens*), and gray whales (*Eschrichtius robustus*) as well as sounds of anthropogenic origin. These were not classified using the analysis software but were noted in separate logs.

During the whale call classification process, the bearing from DASAR C to each detected call was determined automatically, using information from the bearing calibrations (see section *Time and Bearing Calibrations* above). After all the calls were processed, two parameters were calculated for DASAR C 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 2.6 shows how to calculate these two parameters using example bearings to nine different calls. The vector 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 2.7).

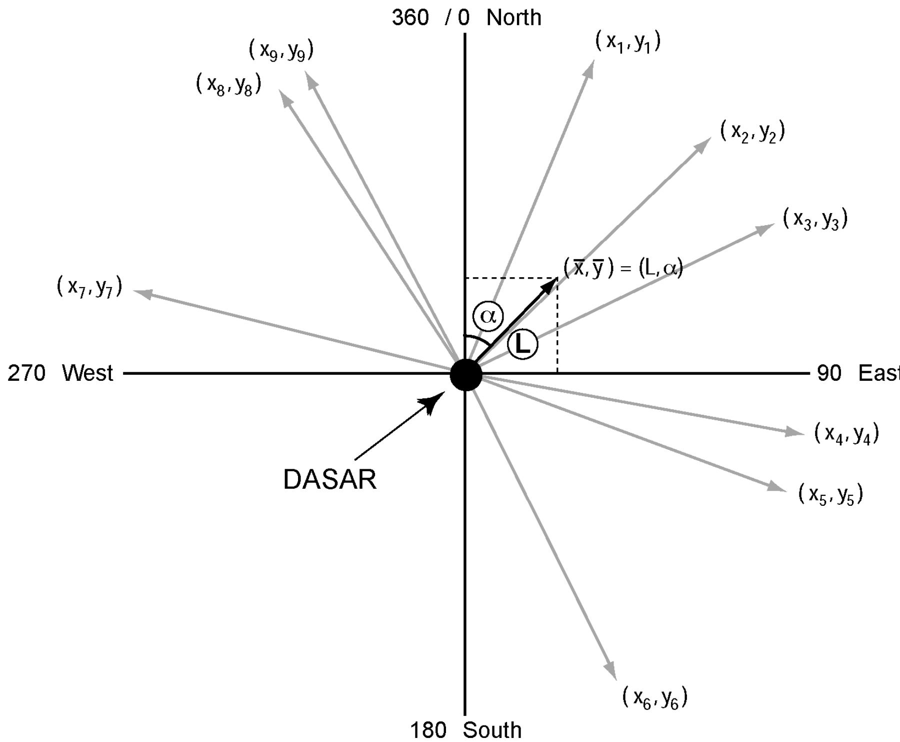

Figure 2.6. Average bearing calculation. The gray arrows are example bearings from a DASAR. Mean bearing angle $\alpha = \arctan(\bar{x}, \bar{y})$, where $\bar{x}$ and $\bar{y}$ are the average cosine and sine, respectively, of all bearings obtained at one DASAR during a season. Mean vector length, $L = \sqrt{\bar{x}^2 + \bar{y}^2}$, is a measure of the variation of individual bearings around the vector mean direction.

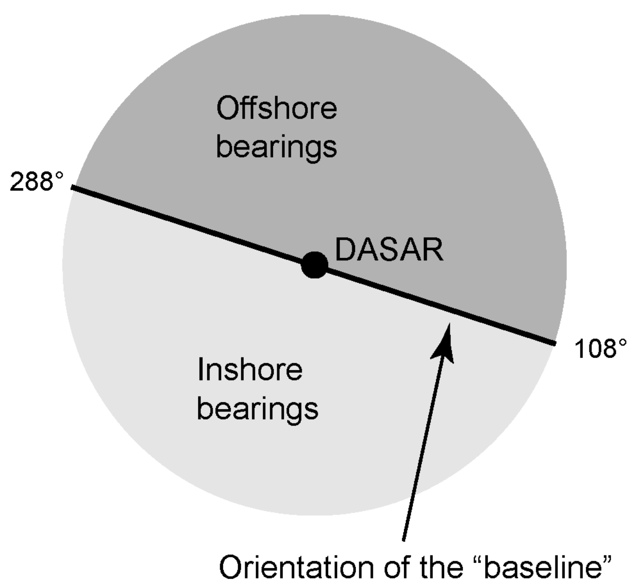

Figure 2.7. Definition of the “offshore” and “inshore” sectors in relation to the orientation of the baseline and DASAR location (filled circle in center). See text for details.

RESULTS AND DISCUSSION

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. To meet this objective, this section presents results from the analyses of sounds recorded near and offshore of Northstar throughout Sept. 2010. Measurements of underwater sounds generated by Northstar and within the whale migration corridor, as recorded by a near-island DASAR and an offshore DASAR, respectively, were compared with similar data from previous years. In addition to sounds of anthropogenic origin, we report on the number of whale calls detected, bearings to calls, and types of calls. Specifically, the results are presented in the following five sections:

(1) Broadband sound levels near Northstar and offshore;

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

(3) Other sound sources, for example, impulsive sounds such as airgun pulses;

(4) Whale call activity.

Broadband Sounds Near Northstar and Offshore

Broadband Sounds Near Northstar

Three DASARs were deployed ~430 m north of Northstar, with two of the instruments considered backups to the third. Data from these three recorders were in close agreement, with differences that were well within the variation one might expect based on sound reception at slightly different locations (see Fig. 2.3). As in 2009, 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 acoustic signals recorded on 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 previous *Methods* section). Figure 2.8B shows the received levels of broadband (10–450 Hz) sound as recorded in 2010 by DASAR NSc, located ~430 m northeast of Northstar (see Fig. 2.3). The range of broadband levels shown for 2010 is 90–136 dB re 1 μPa. This variation in received levels was correlated with wind speed, which is related to sea state. Figure 2.8A 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 2–30 Sept. 2010. The lowest sound levels in Fig. 2.8B are indicative of the quietest times in the water near the island and generally correspond to times with low wind speeds (compare with Fig. 2.8A). Conversely, times of high wind speed (e.g., 4 or 14 Sept.) usually correspond to increased broadband levels in the DASAR record. Mean hourly wind speed in 2010 (calculated over the period 31 Aug.–30 Sept.) was 6.9 m/s (15.3 mph). This is lower than that of the previous three years over the same period and at the same weather station: ~14 % lower than in 2009 (7.9 m/s or 17.7 mph), ~4% lower than in 2008 (7.2 m/s or 16.2 mph), and 45% lower than in 2007 (10.0 m/s

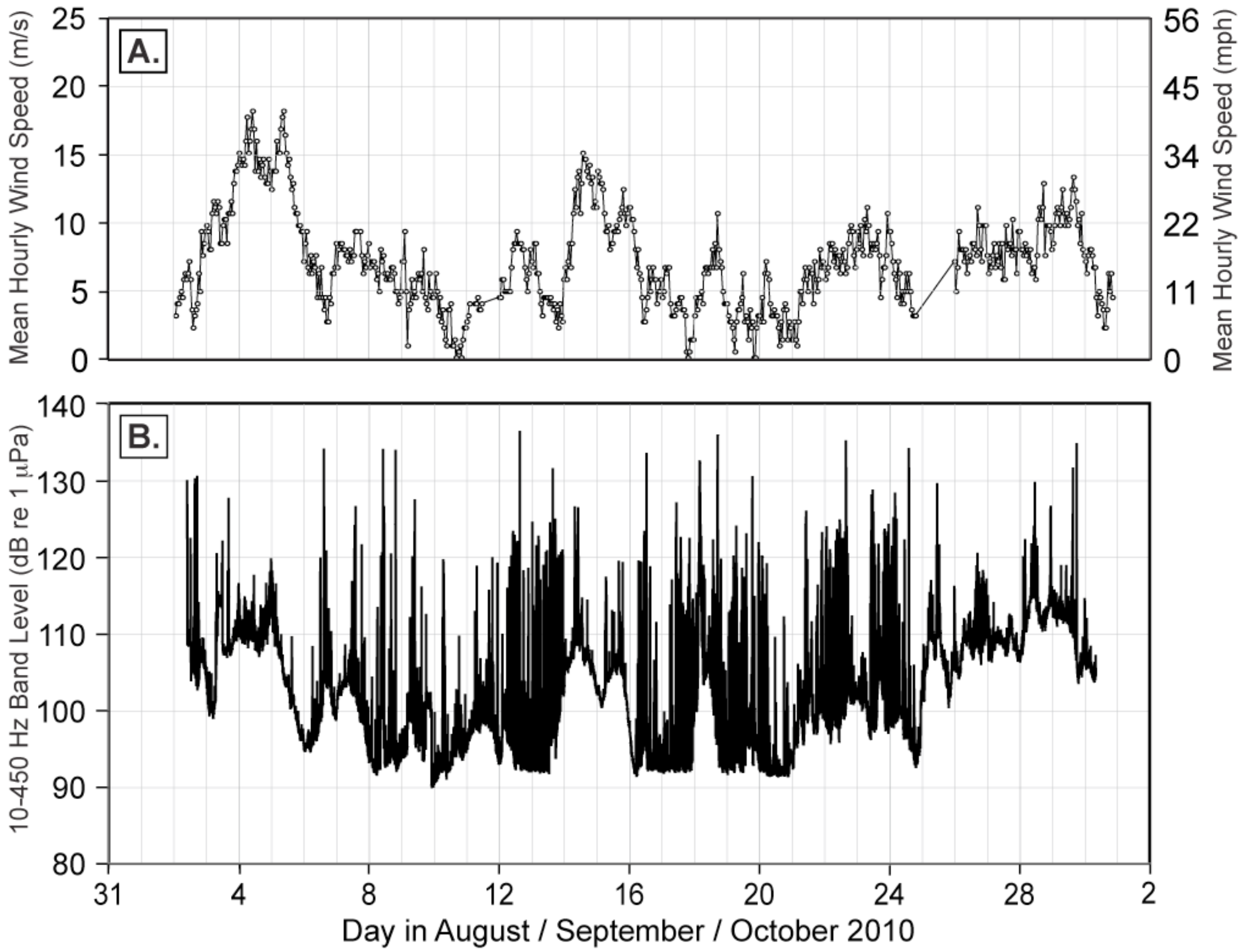

FIGURE 2.8. Variation in broadband levels of underwater sound near Northstar in relation to date and wind speed for 2–30 Sept. 2010. ***(A)*** Mean hourly wind speed as recorded by the Prudhoe Bay weather station (see text for more information). ***(B)*** Broadband (10–450 Hz) levels of underwater sound (1-min averages) near Northstar vs. time, as recorded by DASAR NSc, located ~430 m north of the island. Vertical spikes in the sound pressure time series are generally produced by vessels arriving at or departing the island.

or 22.3 mph). Figure 2.9 summarizes mean wind speed (31 Aug.–30 Sept.) in each year of the Northstar study, as recorded by the Northstar[3] (2001–2006) or Prudhoe Bay (2007–2010) weather station.

Figure 2.10 compares broadband levels, as recorded ~430 m northeast of the island, over ten seasons of monitoring (2001–2010). The number of "vessel spikes"[4] in 2010 was relatively high compared with those detected during other production years (2002 and later), commensurate with the

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[3] 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.

[4] 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 2.10, 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.

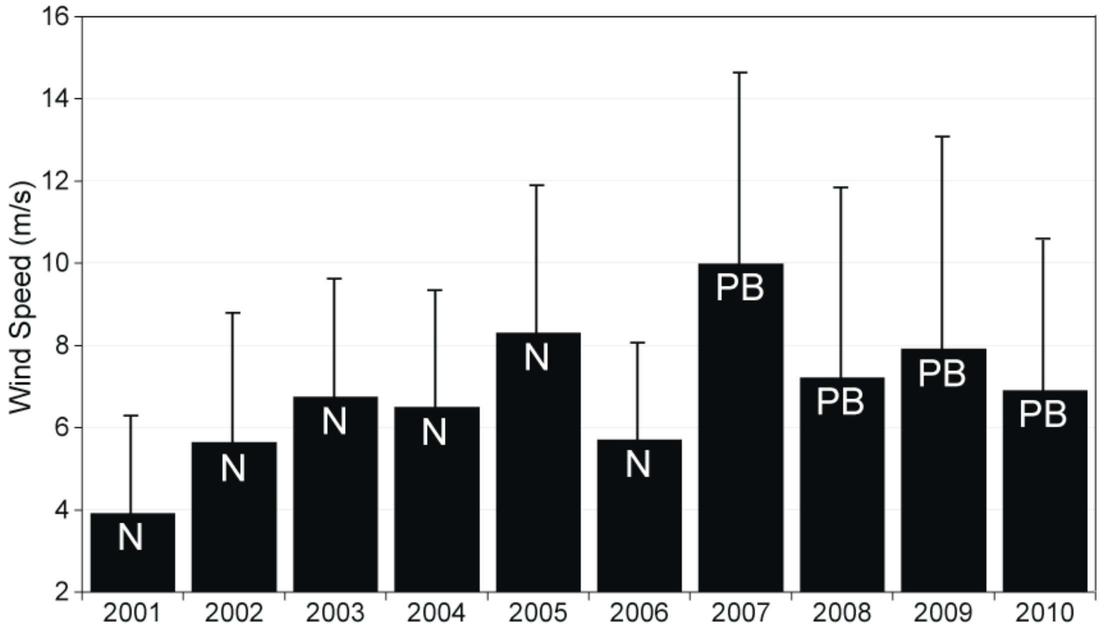

FIGURE 2.9. Mean wind speed for the period 31 Aug.–30 Sept. in 2001–2010, plus one standard deviation. Data for 2001–2006 were collected by the Northstar (N) weather station, and data for 2007–2010 were collected by the Prudhoe Bay (PB) weather station.

resumption of crew boat use in 2010 (see Table 1.7). On the other hand, "baseline" sound levels, where "baseline" refers to the lower

envelope of the standard-analysis-derived SPL time series, were lower overall in 2010 than in previous years. Baseline levels fluctuate in parallel with wind speed and, therefore, sea state, but it is possible that the dampening effect of unusually persistent ice in 2010 may have lessened wind-contributed sound. 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 2.2. Figure 2.11 illustrates how the percentiles of broadband sound in 2010 compare to previous years (2001–2009). Percentile levels of broadband sound near Northstar in 2009 were well within the range for 2001–2009. The maximum levels in Table 2.2 and Figure 2.11 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 in the recordings from 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 when they were more extensively analyzed (Blackwell et al. 2010b). 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 "Methods") and retaining the lowest value per 10-min period. The results of this analysis are shown in Figure 2.12, together with the standard analysis of Northstar sounds (1 min average every 4.37 min) that was shown in Figure 2.8. Mean received levels were 4.2 dB lower for the 2-s minimum analysis compared to the standard analysis (99.0 dB vs. 103.3 dB re 1 μPa, respectively). For comparison, in 2009, the difference between the minimum and standard broadband levels was 7.4 dB and,

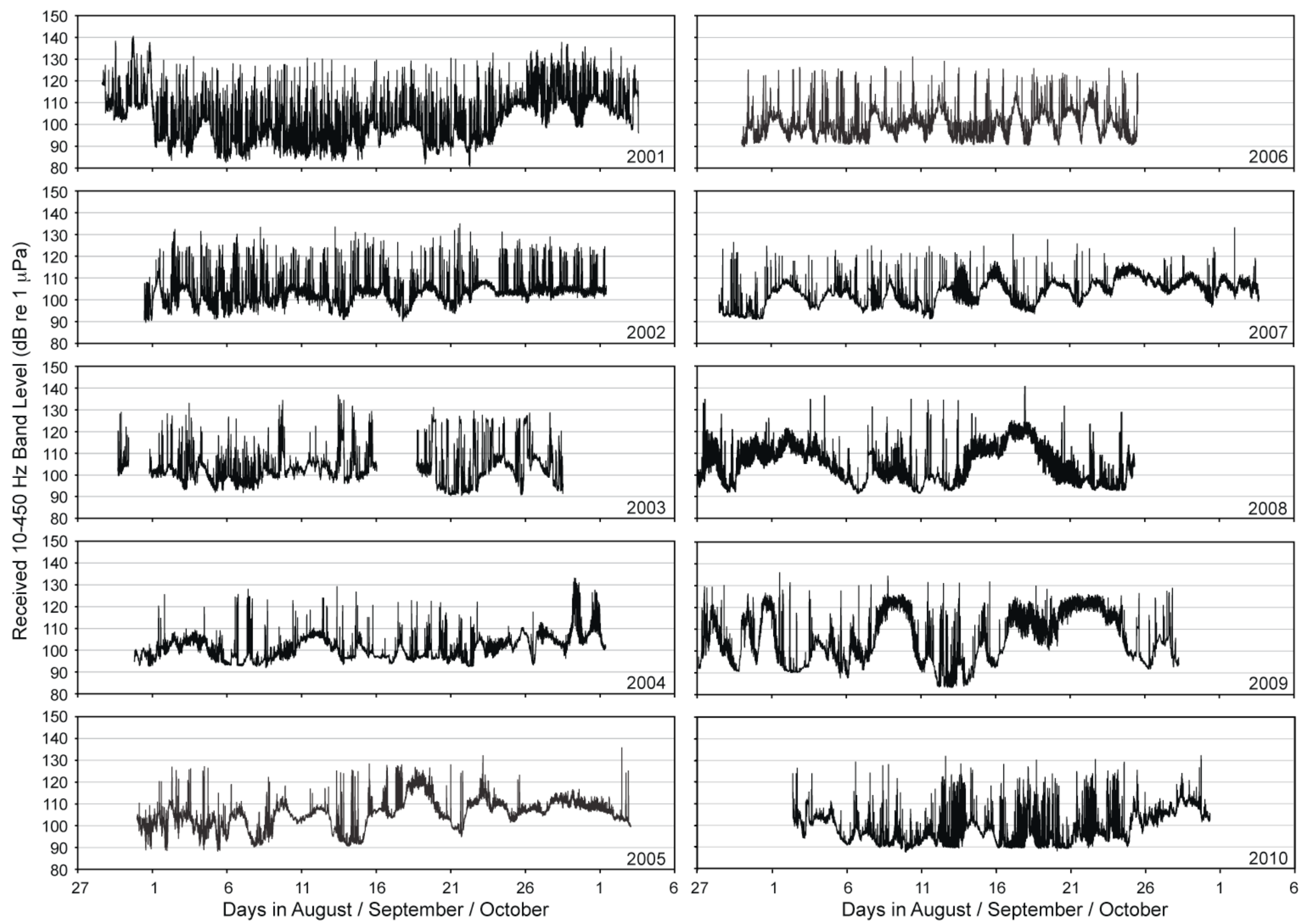

FIGURE 2.10. Sound pressure time series (10–450 Hz band; 1-min averages) for the entire 2001–2010 late summer / early autumn field seasons, as recorded ~450 m north to northeast of Northstar. The recorders were a cabled hydrophone in 2001, 2002, and the first part of 2003, and a DASAR for the second part of 2003 and 2004–2010.

TABLE 2.2. 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, 2001–2010. In 2010, data were recorded by DASAR NSc (2–30 Sept.). (For 2001–2009 sensor details and recording duration, refer to Table 3.1 *in* Blackwell et al. 2010a.) "Range" is the difference between maximum and minimum values. 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	2010
	CH #2	CH #2	CH #2	NS	NSa	NSb	NSc	NSb	NSc	NSc	NSc
Max	140.5	135.0	136.8	131.1	133.1	135.8	131.4	133.3	141.1	137.9	136.3
95th %ile	122.7	117.3	116.7	125.1	110.1	118.2	111.4	112.5	119.4	123.0	117.0
50th %ile	101.8	103.5	101.8	103.4	100.5	105.5	98.7	104.0	103.6	103.9	102.7
5th %ile	87.3	94.8	95.2	91.7	93.7	92.4	91.7	93.4	93.2	89.9	92.3
Min	80.8	89.7	91.8	90.4	92.0	88.0	89.8	90.9	91.0	83.6	90.0
Range	59.7	45.3	45.0	40.7	41.1	47.8	41.6	42.8	50.0	54.3	46.3

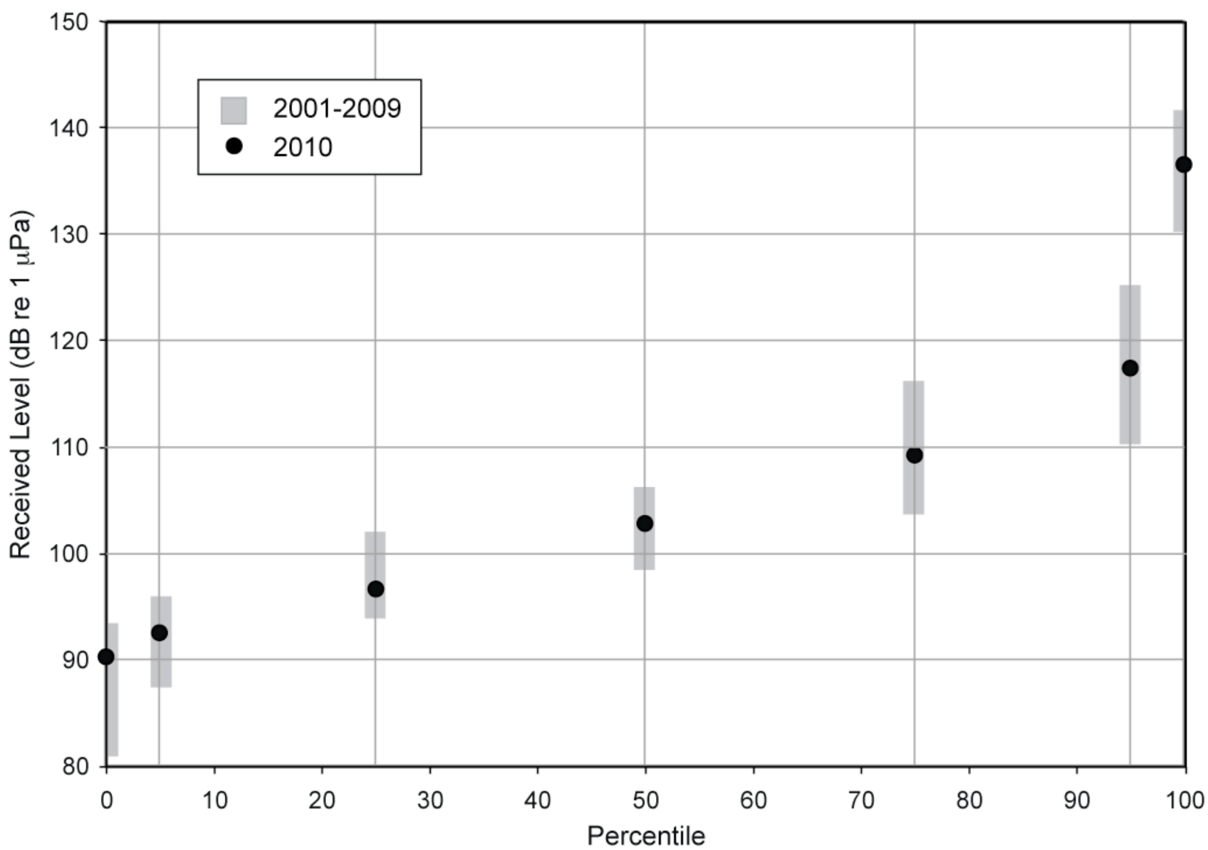

FIGURE 2.11. Percentile levels of broadband (10–450 Hz) sound at DASAR NSc in 2010 (black dots) compared to the range of values for the period 2001–2009 (gray bars). For each year the minimum, 5th, 25th, 50th, 75th, and maximum percentiles were calculated using data collected over the entire field season (7551–11,906 sampled minutes per year).

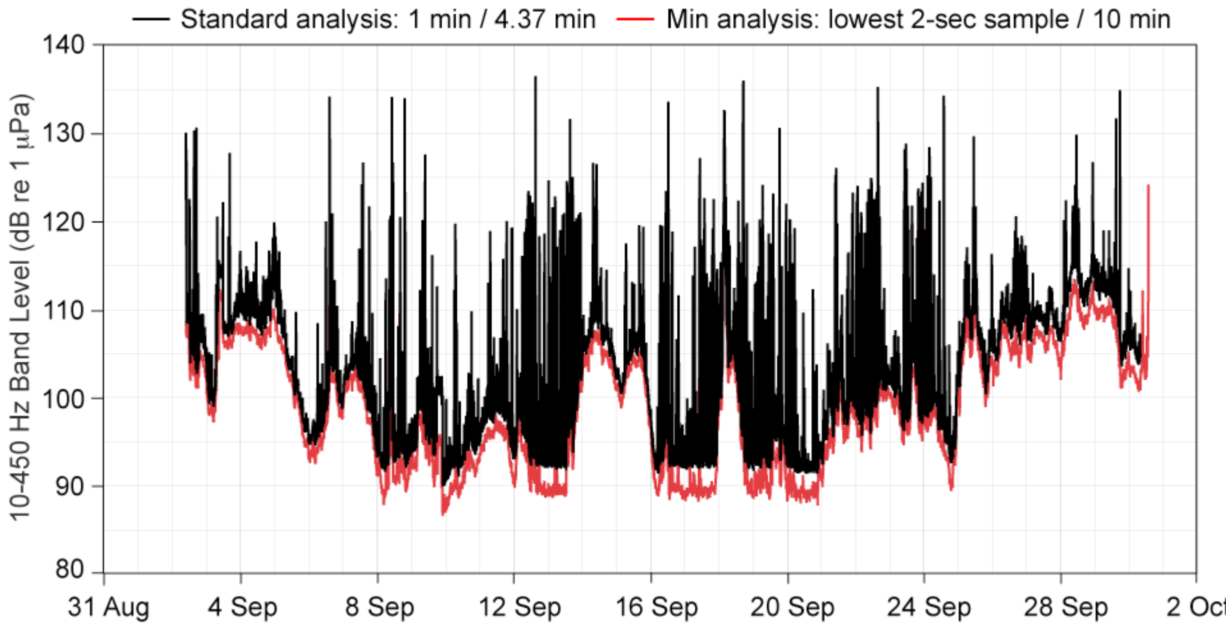

FIGURE 2.12. Broadband (10-450 Hz) levels of sound at DASAR NSc in 2010, as calculated two different ways: ***(1)*** "Standard method" (black line): average over one min every 4.37 min (see Fig. 2.8); ***(2)*** "Minimum method" (red line): lowest 2-s sample for every 10 min period. See text for more information.

in 2008, it 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 suggests that pops were less prominent, or virtually absent, in 2010.

Broadband Sounds Offshore

Sounds recorded by the offshore DASAR at location C/EB were analyzed in the same two ways as the near-island sounds shown in Figure 2.12, 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 *Methods* section for more details). These two types of broadband (10–450 Hz) levels for DASAR C are shown in Figure 2.13. Recall that DASAR C was 14.7 km (9.1 mi) from Northstar (Table 2.1). 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 baseline levels in Figure 2.13 parallel seasonal variations in wind speed (Fig. 2.13, top) and, also, the overall shape of the sound pressure time series near the island (Fig. 2.12). Mean broadband level (2–30 Sept.) for offshore DASAR C was 101.9 dB, i.e., the mean received level at the offshore DASAR was similar to that for the nearshore DASAR NSc (103.3 dB). Median broadband levels for DASARs C and NSc were the same at 102.7 dB. Given that the received levels did not decrease significantly with distance from the island, these results support the notion that Northstar was not a large contributor to sound levels either offshore or nearshore.

The DASAR arrays deployed in 2001–2009 were laid out in various configurations (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 observe the variability in broadband sound levels 14.7 km (9.1 mi) offshore of Northstar each autumn since 2001. This comparison is shown in Figure 2.14. Frequent vessel

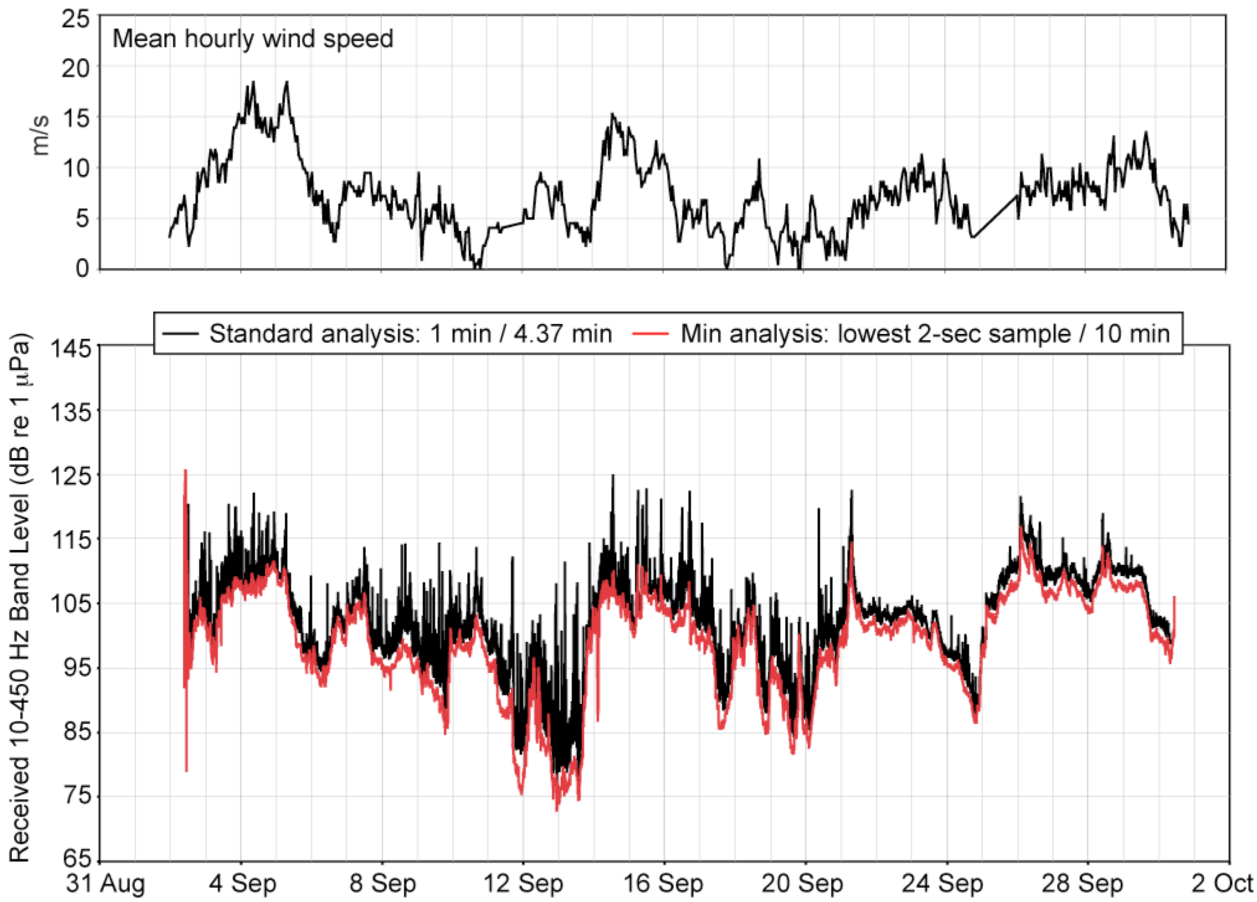

FIGURE 2.13. Broadband (10–450 Hz) levels of sound at offshore DASAR C (bottom plot), 2–30 Sept. 2010, as calculated using either the "standard method" (black line, average over one min every 4.37 min) or the "minimum method" (red line, lowest 2-s sample for every 10-min period). Mean hourly wind speed at the Prudhoe Bay weather station is also shown in the top plot.

spikes are prominent throughout most of the 2010 deployment period, a result of generally lower wind conditions (Fig. 2.9) enhancing detectability and increased reliance on vessels servicing Northstar, specifically, a crew boat that operated on average ~7 times per day between 19 July and 25 Sept. (see Table 1.7 and Fig. 2.15 below).

For each year, 2001–2010, percentile levels of broadband sound (maximum, 95th, 50th, and 5th percentile, and minimum) were computed over the entire field season for DASAR C / EB and are summarized in Table 2.3. Figure 2.16 shows percentile levels of broadband sound at C/EB in 2010 compared to the range of values in previous years. Minimum and maximum percentile levels of broadband sound were well within the range of previous years, but all other percentiles (5th, 25th, 50th, 75th, and 95th) were at or near the highest of all years (see Fig 2.16), rivaling those of 2005. The 2005 season was also characterized as a heavy ice year. It's possible that noise produced by ice present in 2005 and 2010 contributed to these heightened sound levels.

Figure 2.17 compares broadband sounds near Northstar with those recorded offshore by displaying the data for DASARs NSc and DASAR C 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

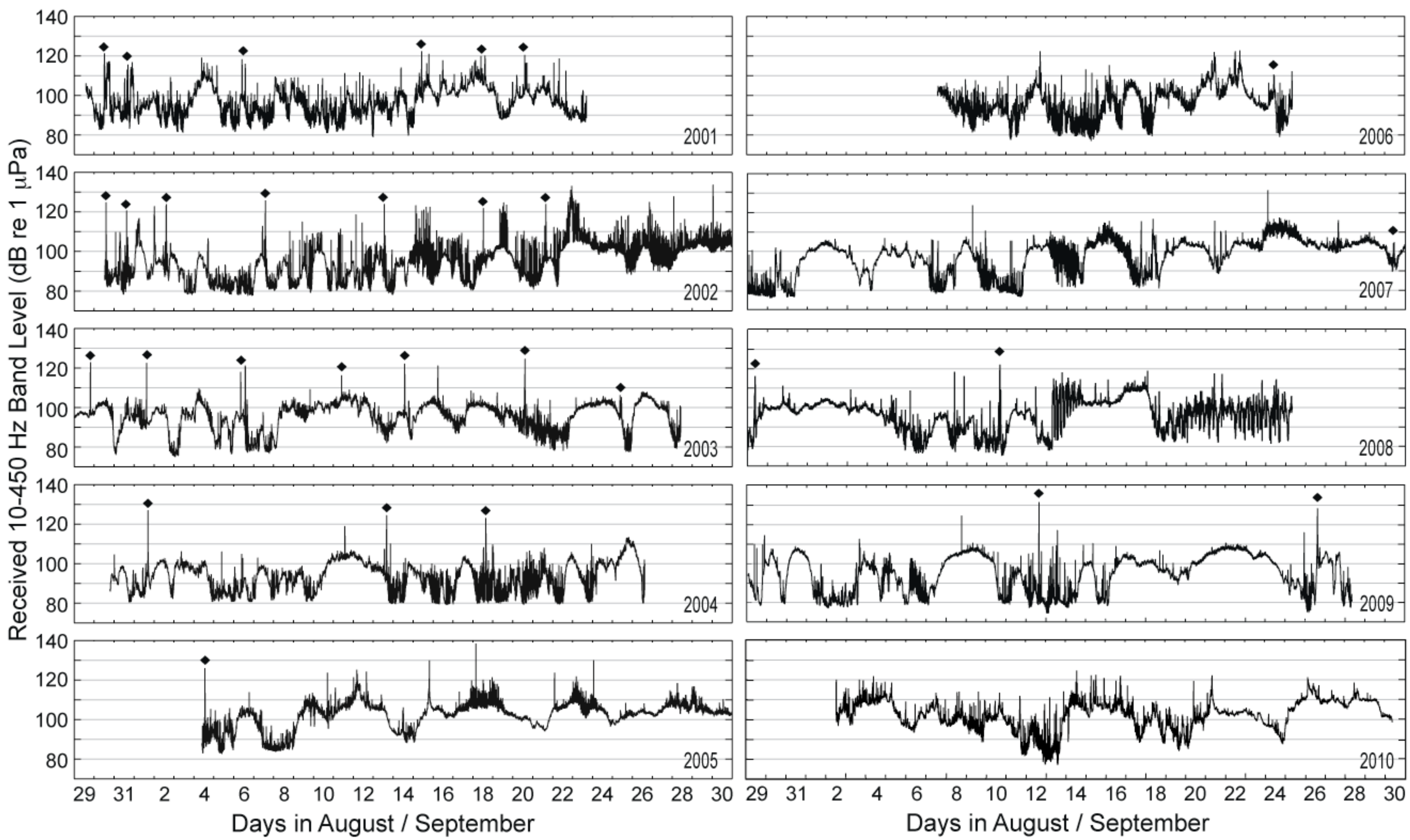

FIGURE 2.14. Broadband sound pressure time series (10–450 Hz band; 1-min averages) at a DASAR location 14.7 km (9.1 mi) from Northstar during ten consecutive years, 2001–2010. This DASAR location was known as EB in 2001–2007 and C in 2008–2009. Diamonds indicate sound spikes created by the acoustic crew's vessel during servicing of the array of DASARs.

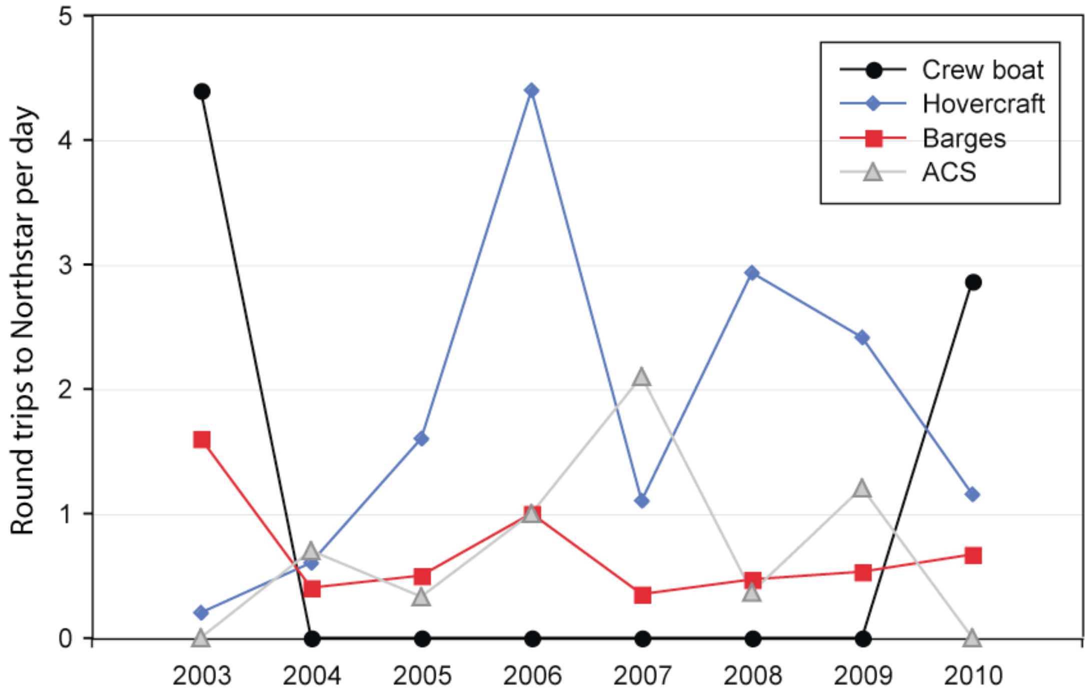

FIGURE 2.15. Daily mean number of round trips to Northstar by the crew boat, hovercraft, barges, and ACS vessels, 2003–2010. Each year, these numbers were calculated over the DASAR deployment duration, which varies from year to year, but is generally late Aug. to late Sept. (Records obtained from the Northstar Scheduler. The values for ACS vessels do not include trips the acoustics crew made in the vicinity of Northstar using an ACS "*Bay*" boat.)

another. The baseline levels near and offshore of Northstar were remarkably similar, and upward excursions of the sound level above the baseline were more frequent and stronger near Northstar, indicative of the great influence of Northstar service vessels under such conditions.

Statistical Spectra of Sounds Near Northstar and Offshore

To characterize the frequency composition of sounds near Northstar and offshore during the study period in 2010, percentile distributions of one-third octave band levels and spectral density levels were calculated for near-island DASAR NSc and offshore DASAR C. In both cases, the measurements were averages over 1 min. These plots provide 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 2.18 shows one-third octave bands and Figure 2.19 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

[5] **2009**: Figs. 3.10 and 3.11 in Blackwell et al. (2010b); **2008**: Fig. 3.10 in Blackwell et al. (2009); **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).

TABLE 2.3. Percentile levels, in dB re 1 μPa, of broadband (10–450 Hz; 1-min averages) underwater sound recorded offshore of Northstar Island during late summer / early autumn, 2001–2010. In 2010, data were recorded 2–30 Sept. by DASAR C (=EB in 2001–2007). "Range" is the difference between maximum and minimum values.

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
	EB	EB	EB	EB	EB	EB	EB	C	C	C
Max	122.4	135.4	124.5	126.8	138.4	122.9	131.5	130.9	133.1	124.6
95th %ile	108.5	107.7	104.1	103.9	110.8	108.4	108.8	108.6	107.4	111.8
50th %ile	95.5	95.2	96.5	93.1	103.1	95.4	100.4	97.0	96.0	102.7
5th %ile	85.2	81.1	80.2	81.1	87.2	81.8	79.2	80.2	79.6	87.3
Min	78.9	77.6	74.9	79.1	82.5	76.8	75.9	74.9	74.6	77.1
Range	43.5	57.8	49.6	47.8	55.9	46.1	55.6	56.0	58.5	47.5

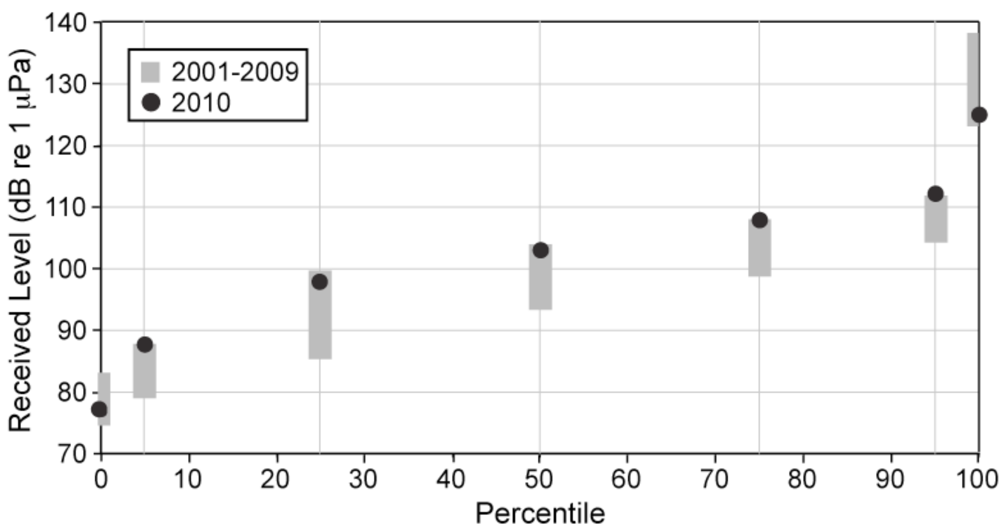

FIGURE 2.16. Percentile levels of broadband (10–450 Hz) sound at DASAR C (=EB in 2001–2007) in 2010 (black dots) compared to the range of values at the same site for the period 2001–2009 (gray bars). For each year the minimum, 5th, 25th, 50th, 75th, and maximum percentiles were calculated using 1-min average values collected over the entire field season (5862–11,906 sampled minutes per year).

30 Hz and 60 Hz—these peaks have been present every year of monitoring and are associated with generation of 60 Hz power. Also, as in previous years, the 87 Hz peak, which has been present in the near-island recordings since 2003, appeared only weakly in the 50th percentile data (Figure 2.19).

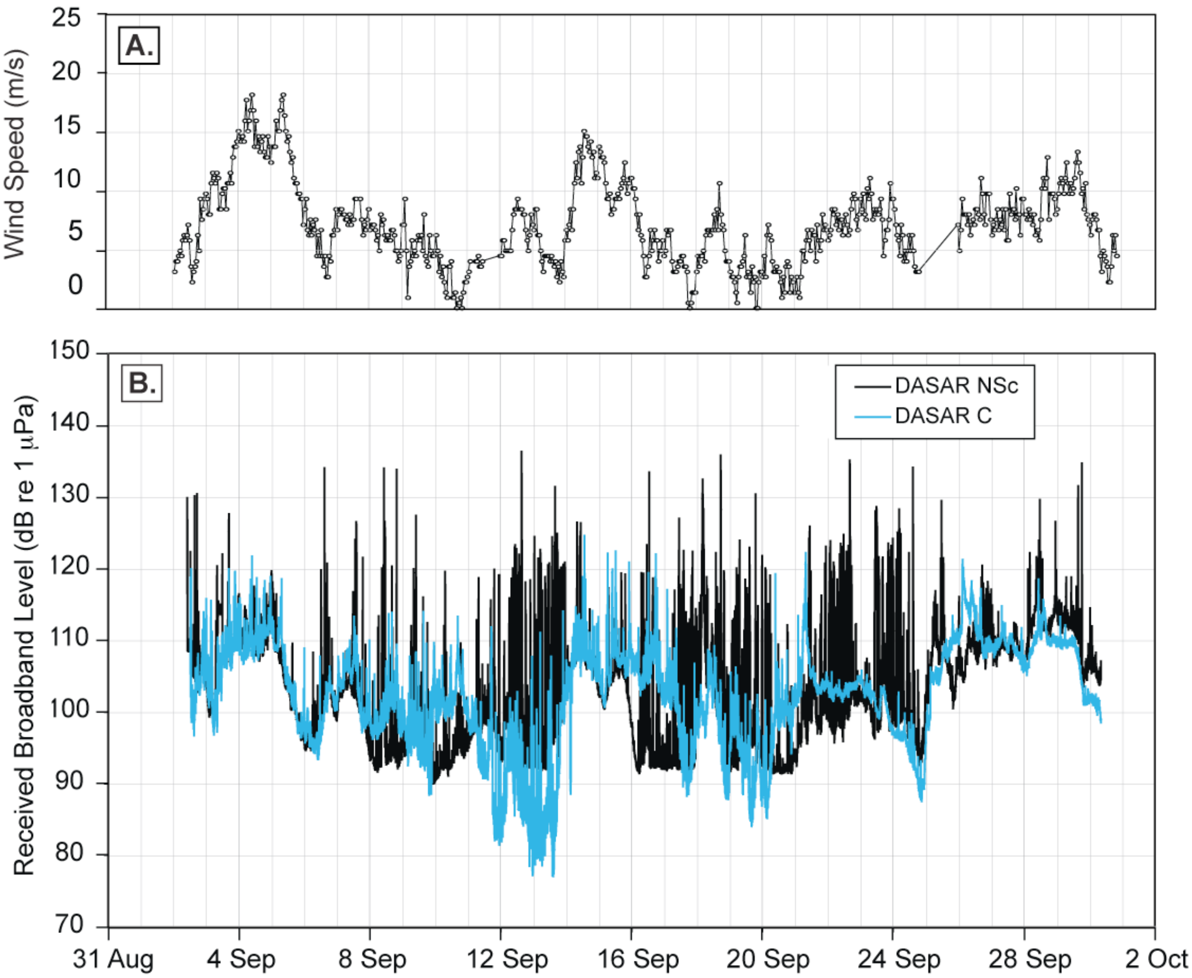

FIGURE 2.17. Sounds close to Northstar and in the DASAR array in relation to wind speed at Prudhoe Bay. ***(A)*** Mean hourly wind speed during the period 2–30 Sept. 2010, as recorded by the Prudhoe Bay weather station. ***(B)*** Broadband sound pressure time series (10–450 Hz band; 1-min averages) at DASAR NSc (~430 m north of Northstar) and DASAR C / EB (14.7 km or 9.2 mi northeast of Northstar) over the same time as in *(A)*.

Figure 2.18 shows percentile one-third octave band levels. The main difference between the top plot (near Northstar) and the bottom plot (offshore) 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 5^{th} percentile lines. The sound contained in these frequencies is largely of anthropogenic origin, at least when ambient noise levels are low. It is this observation that led to the definition of the industrial sound index *ISI_5band* in 2001 (Blackwell 2003).[6] Overall, one-third octave band levels are similar between Northstar and offshore DASARs with the exception of the maximum percentile which is elevated at Northstar (Fig. 2.18, top).

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[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.

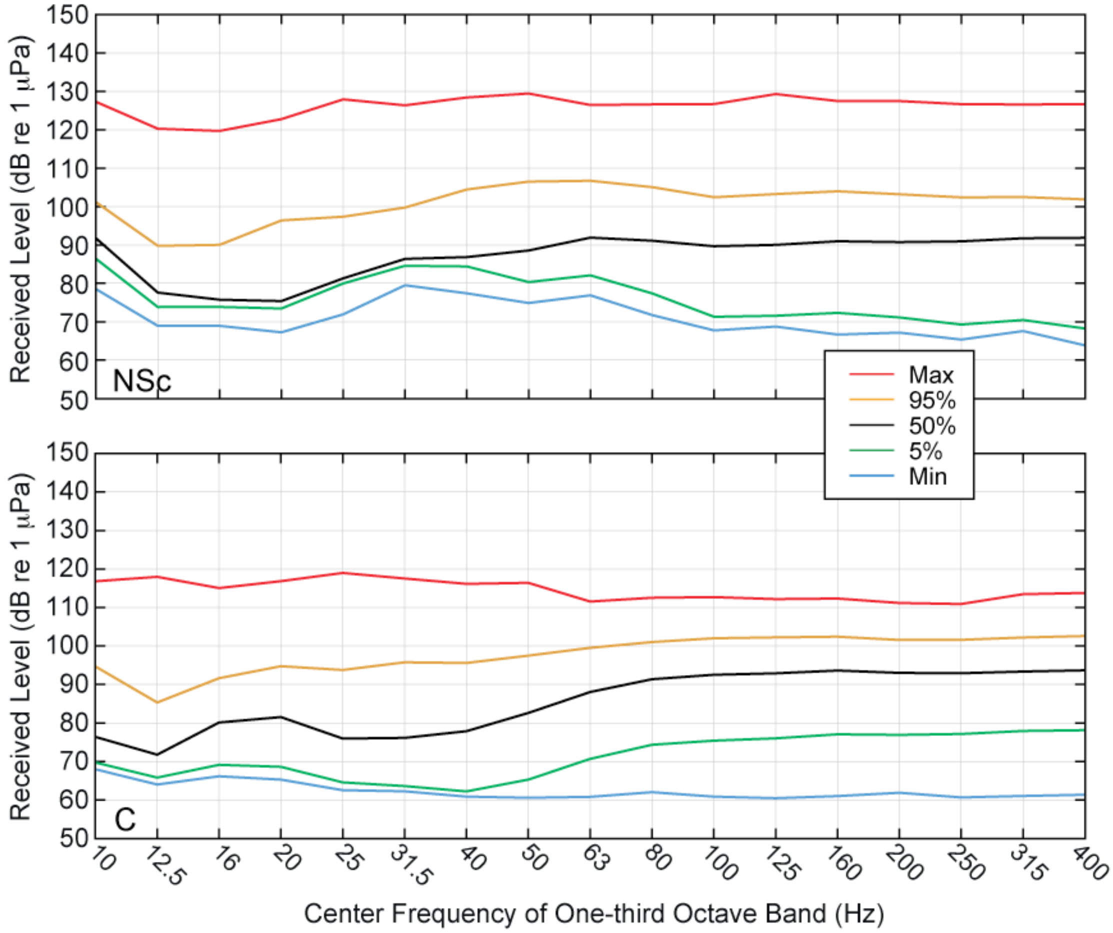

FIGURE 2.18. Percentile one-third octave band levels for sounds recorded by DASARs NSc (near-island, top) and C (offshore, bottom) during the period 2–30 Sept. 2010. In these plots the five curves show, for each frequency, the minimum, the 5^{th}, 50^{th}, 95^{th} percentiles, and the maximum of the 1-min averages. For both plots, the number of 1-min measurements used was 9173.

The same comparison can be made for the percentile spectral density levels shown in Figure 2.19. 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 DASAR C: (1) elevated percentile values (minimum, 5^{th}, 50^{th} and 95^{th}) near Northstar at low frequencies, in the range 10–60 Hz, and (2) observable tones, which in NSc's case can be identified in the minimum, 5^{th} percentile, and 50^{th} percentile lines, i.e., during quieter times when levels are lower than median.

Other Sound Sources

"Pop" Sounds

In 2008 and 2009, an impulsive popping sound was prominent on the near-island recorders. This sound was of short duration (~0.05 s), but its high amplitude, broad bandwidth, and rate of occurrence were such that it could 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. However, a manual

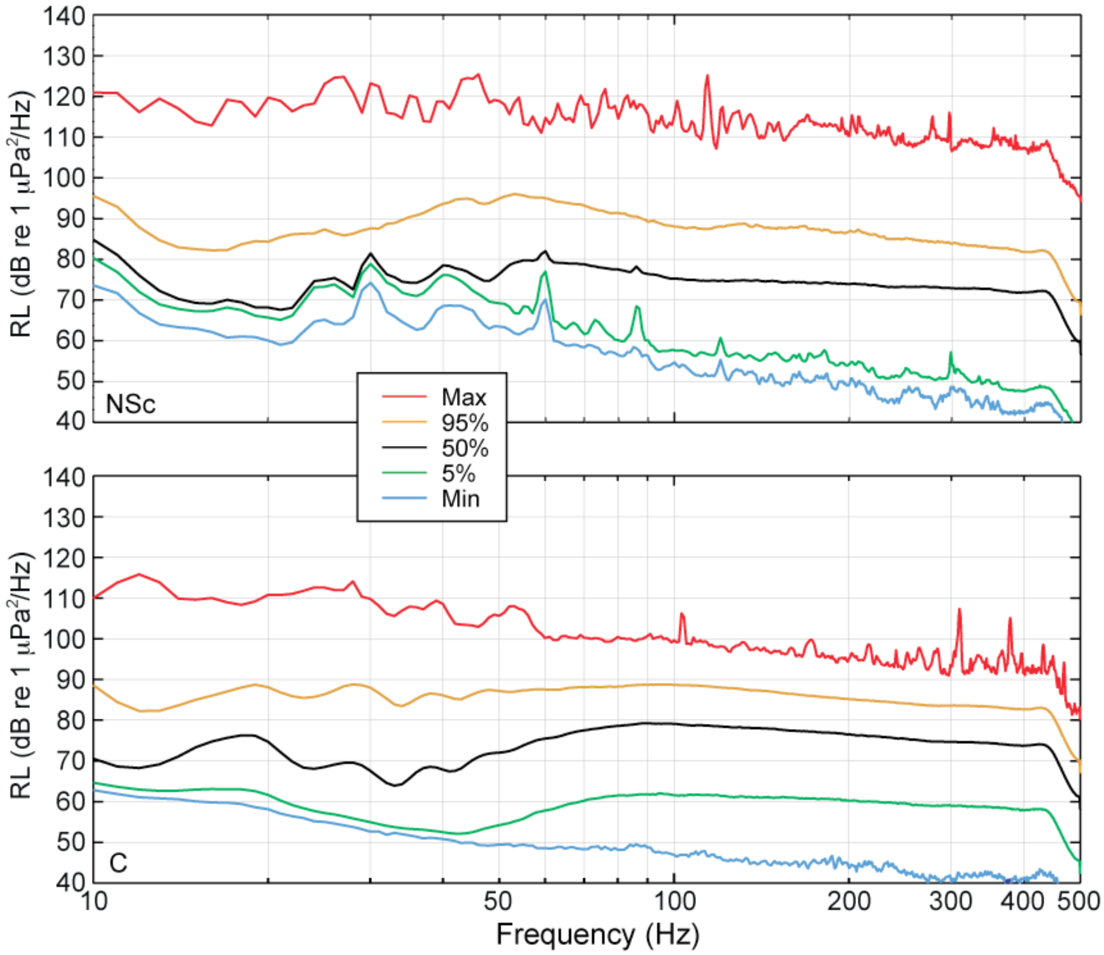

FIGURE 2.19. Percentile spectral density levels for sounds recorded by DASARs NSc (near-island, top) and C (offshore, bottom) during the period 2–30 Sept. 2010. In these plots the five curves show, for each frequency, the minimum, the 5th, 50th, 95th percentiles, and the maximum of the 1-min averages. For both plots, the number of 1-min measurements used was 9173.

search for pops in the near-island records of 2010 (see *Methods* section for details) revealed few occurrences of signals exhibiting 2008/2009 pop characteristics. Furthermore, differences were small between baseline broadband levels calculated by "standard" and "minimum" analysis methods for the near-island DASAR (Fig. 2.12), indicating that pops had little influence on the sound levels near Northstar in 2010.

The 2009 pop analyses found a strong positive association between wind speed and the presence and amplitude of pops in both 2008 and 2009. Coupled with bearing estimates from the three nearshore DASARs, which suggested that the pops were likely generated near or possibly offshore of the northeast corner of Northstar, it has been hypothesized that the pops may have been produced by an object or structure underwater, located close to the island, that moves when sea state increases. With this assumption, the lack of pops in 2010 could be related to the possible dampening effect of an ice field which persisted well into September and whose edge extended closer to shore during this time than in previous years.

Airgun Pulses

During the 2008 field season, ~147,000 sound pulses produced by airguns used for seismic exploration not associated with Northstar or other BP operations near Prudhoe Bay were detected on the DASAR deployed farthest from shore that year (known as DASAR J, refer to Fig. 2.2). The airgun pulses of 2008 constituted a strong confounding factor in achieving the objective of assessing the effects of Northstar sounds on bowhead whale behavior. During the 2009 field season, fewer (~65,000) airgun pulses were detected on DASAR J, and their received levels tended to be lower than in 2008. Although the contribution of these airgun pulses to overall sound levels was smaller in 2009 than it was in 2008, they were taken into account when assessing the effects of Northstar sounds on bowhead call behavior (McDonald et al. 2010).

Two main operations were known to us that were in relatively close proximity in Sept. 2010 and utilized acoustic sources in the DASAR frequency band. Shell conducted marine surveys in Harrison Bay ~50 km (31 mi) west of Northstar and in Camden Bay ~90 to 140 km (56 to 87 mi) east of Northstar (Reiser et al. 2011). The Harrison Bay shallow hazard survey used a 40 in^3 four-airgun array, as well as a variety of high-frequency (kHz range) sonar sources outside the DASAR frequency band. The Camden Bay survey also used a variety of high-frequency sources, but the only source within the DASAR frequency band was a vibratory coring system. To obtain a quantitative assessment of airgun pulses received near Northstar during the 2010 field season, the automated pulse detection software that was applied to DASAR J records of 2008 and DASAR J and C records of 2009 (Blackwell et al. 2010c) was applied to DASAR C records of 2010. The received levels of pulses at DASAR C in 2010 are shown in Figure 2.20. The number of pulses detected on DASAR C was 2862, mean SPL was 101.3 ± 13.7 dB (median SPL was 103.2 dB), and mean instantaneous peak level was 115.9 ± 8.0 dB. Pulse results of 2010 are not directly comparable to those of 2008 due to different receiver locations (C and J, respectively). However, DASAR C was analyzed for airgun pulses in both 2010 and 2009, and pulse levels were much higher in 2010. Median SPL excluding background noise was 102.1 dB for DASAR C in 2010 compared to 88 dB for the same location in 2009, while median SEL was 103.7 dB and 86 dB, respectively. The pulses detected in 2010 may have originated from the aforementioned airguns, coring system, and/or possibly other unidentified sources. Based on standard and minimum analyses of broadband levels (Fig. 2.13), these pulses contributed little to sounds at location C.

Whale Call Activity

The results of the Northstar whale call analyses are presented in the following three sections: (1) number of whale calls detected, (2) bearing analyses, and (3) call types. The procedures used to analyze these data are described in more detail in the previous *Methods* section.

Number of Whale Calls Detected

Every year since 2001, there has been a functional DASAR at location C (known as location EB in 2001–2007). Using call data from this location allows us to compare call counts over ten years. This comparison is shown in Table 2.4, which 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. A total of 340 bowhead whale calls were detected on the records of DASAR C during the 2–30 Sept. period in 2010. The number of calls per day in 2010 was on average 12 calls/day, the lowest in the ten-year history of the study (Table 2.4). This daily call detection rate is of the same order of magnitude as that of 2005 and 2006 field seasons, which were both heavy ice years when whales tend to swim on the outskirts of

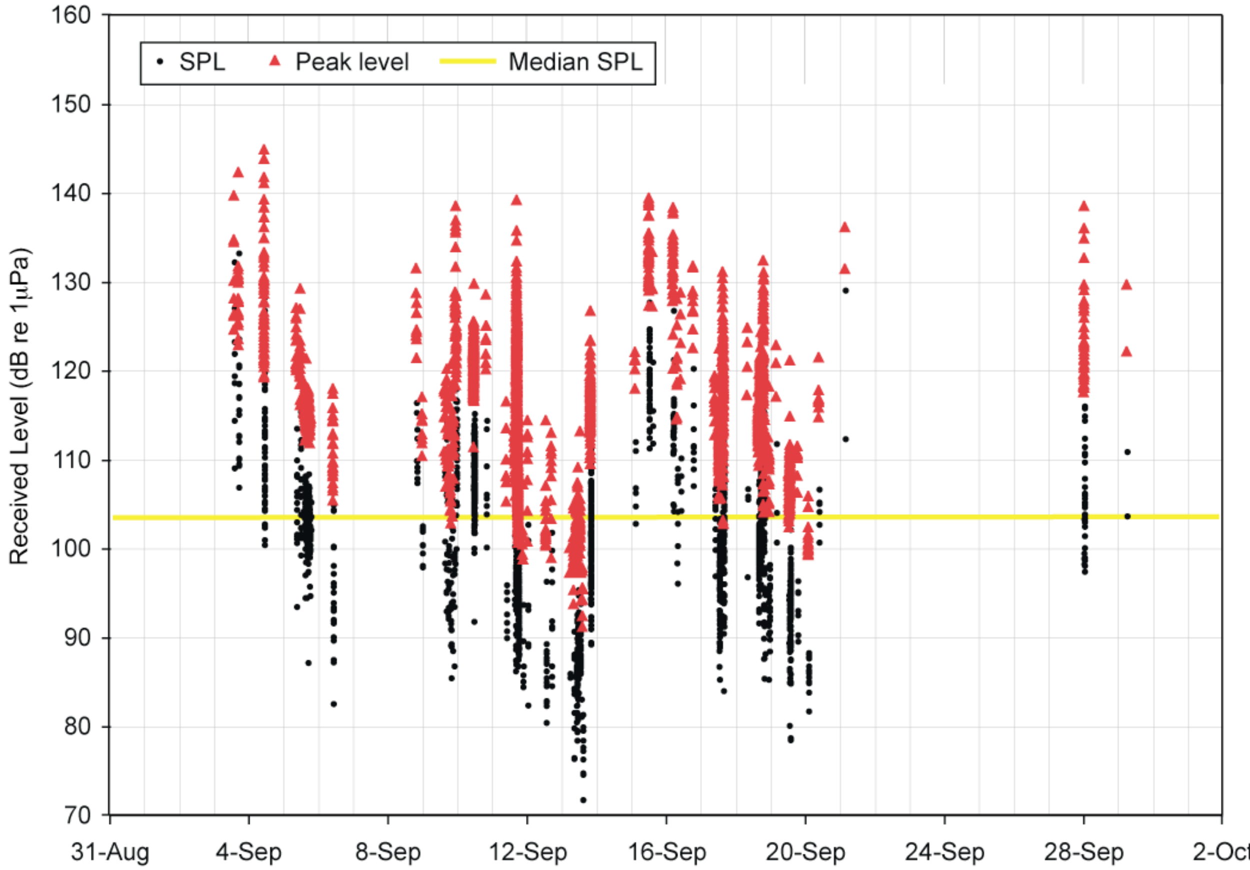

FIGURE 2.20. Levels of pulses, as received at DASAR C in 2010 (2–30 Sept.). Received sound pressure levels (SPLs) are shown with black dots, and instantaneous peak pressures are shown as red triangles. The yellow line denotes the median SPL of the pulses.

their traditional migratory path. The 2010 field season was also noted for heavy ice near Northstar such that DASAR deployment operations were postponed and a circuitous route to location C was necessary due to abundant ice lingering close to shore compared with previous years.

Hourly call detection rates for all offshore DASARs over the entire 2010 deployment period are shown in Figure 2.21. The highest call detection rate was 32 calls/hour on 18 Sept. between 15:00 and 16:00. This maximum rate was significantly higher than occurred on all but two other deployment days; hourly rates approaching the peak hourly rate of 18 Sept. were encountered near the end of the deployment period (28 Sept. and 30 Sept.). At all other times, hourly call detection rates were less than half the maximum rate.

Figure 2.22 compares daily numbers of calls detected by DASARs at location C / EB in 2010 (black line, visible mainly in the lower panel of Fig. 2.22) and in previous years. The pattern at location C in 2010 exhibited a peak beginning to emerge at the end of September but otherwise bore little resemblance to previous years. Other years with daily call detection rates consistently below 200 calls/day were 2005 and 2006. Heavy ice occurred (at least locally) in the Northstar area during the 2005, 2006, and 2010 field seasons.

TABLE 2.4. Year-to-year comparison of bowhead whale call counts at DASAR location C (2008–2010) 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
2010 (C)	340	28	12

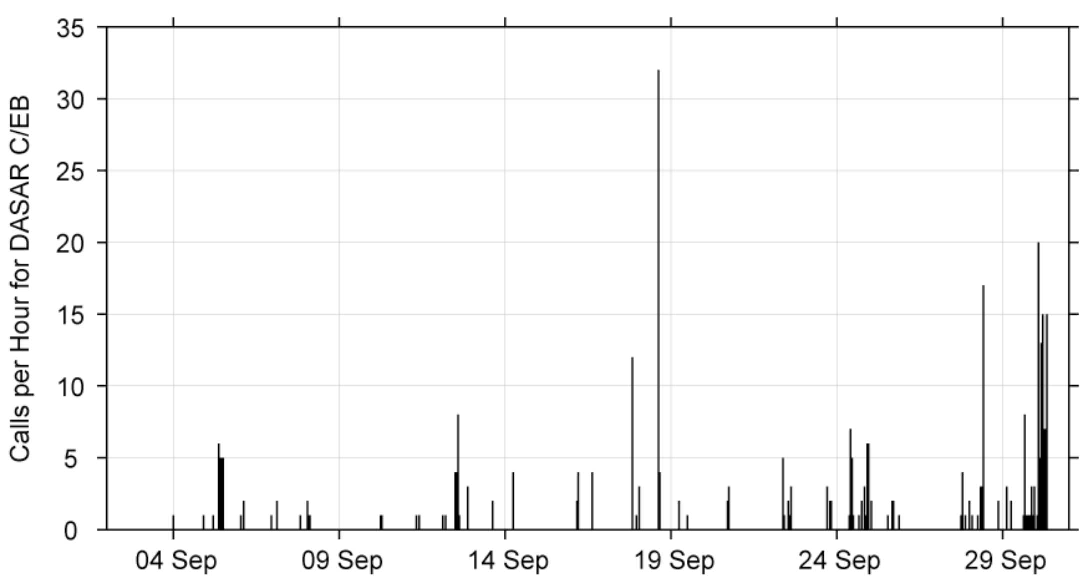

FIGURE 2.21. Hourly detection rate of whale calls as a function of time, 2–30 Sept. 2010. Total number of calls detected was 340. Tick-marks on X-axis represent midnight (local daylight time). The highest hourly call detection rate was 32 calls/hour on 18 Sept. between 15:00 and 16:00.

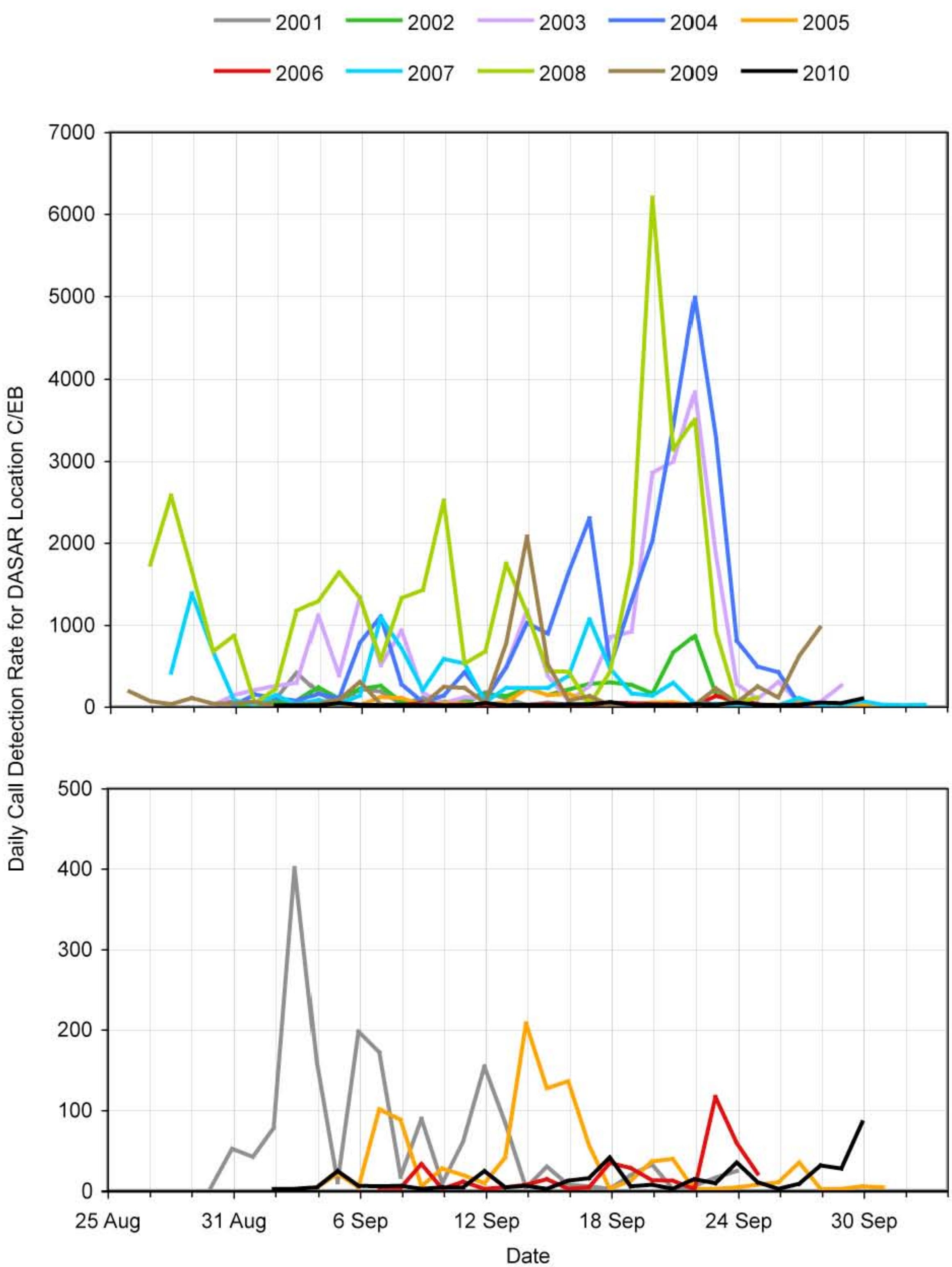

FIGURE 2.22. Daily number of bowhead calls detected by a DASAR at location C / EB by date over the 2001–2010 seasons (top panel), replotted with expanded vertical scale for years with low call detection rates (bottom panel). Note that, in 2001, 2005, 2006, and 2010, the total number of calls at location C / EB never exceeded 500 calls/day.

One possible explanation for the atypical call detection rates in 2010 is that the whales may have migrated further from location C / EB than in previous years. More details are in the *Bearing Analyses* section that follows. Another possibility is that signal (whale call) detectability was reduced in 2010 due to increased acoustic transmission loss as a result of

- scattering by ice along the source-to-receiver (i.e., whale-to-DASAR) propagation path, and
- absorption associated with increased sound interactions with the seafloor in shallower waters, assuming most whales whose calls were detected were closer to shore than in years past (see *Bearing Analyses* section below).

Furthermore, whale call analysts reported that 2010 was unusual in its high number of unidentifiable sounds, sounds that could not be positively classified as originating from whales. In the analysts' logs, such sounds were usually attributed to "boat", "motor", and "engine" noises or other industrial activity. Indeed, 2010 ice conditions forced additional maneuvering by vessel operators. Analysts' logs also included references to seals, walruses, gray whales, and unidentified marine mammals. Moreover, ice itself produces sound which could complicate detection and classification of whale calls.

Bearing Analyses

Table 2.5 summarizes the main results of the bearing analyses. Location C / EB is the one DASAR location for which ten consecutive years of bearing data exist. Considering all ten seasons (2001–2010), vector mean bearings to the whale calls detected by the DASAR at location C / EB were most often (in 8 of 10 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. 2.7), i.e., the year with the highest number of offshore calls in relation to the number of inshore calls. In 2010, the mean vector length of 0.24 was second only to 2005 for smallest mean vector length (i.e., greatest bearing variability). The O/I ratio of 0.7 in 2010 was the lowest of all ten years and, notably, identified 2010 as the only year to exhibit more calls inshore than offshore of DASAR C (Table 2.5).

TABLE 2.5. Results of the bearing analyses for location C (2008–2010) / 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. 2.6). O/I is the ratio of number of offshore versus inshore calls. See *Methods* section and Figure 2.7 for more information on O/I ratios, and Figures 2.2 and 2.3 for maps of DASAR locations.

Year	α (°)	L	O/I	*n*
2001	44	0.65	5.7	1624
2002	64	0.74	13.6	4317
2003	78	0.55	2.5	21,726
2004	69	0.42	2.4	26,546
2005	348	0.14	1.3	951
2006	33	0.46	4.0	331
2007	75	0.45	2.9	9076
2008	59	0.53	5.1	39,550
2009	65	0.70	5.6	6859
2010	115	0.24	0.7	340

Heavy ice remained in the vicinity of Northstar longer than usual in 2010, delaying DASAR deployment operations this year. The ice field extended so far inshore at the time of deployment that it limited vessel access to location C, which was only reached by a circuitous route, and persisted for sometime thereafter. Several studies (Moore 2000; Treacy et al. 2006) have shown a relationship between ice coverage and the distances of bowhead whales from shore during the migration. The median offshore distance has, in the past, tended to be larger in heavy ice years. That is consistent with the low number of calls detected in 2010 by DASAR C, which was located relatively close to the coast as compared with much of the normal bowhead migration corridor. This may appear inconsistent with the preponderance of calls inshore of DASAR C in 2010 but is explained in the following paragraph.

Figure 2.23 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 2010. 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.), expressed as a percentage of all call bearings determined via DASAR C / EB for that season. The 2010 plot shows that bearings in the range 135°–150° were most common. Related to its unusual O/I ratio, the distribution of bearings in 2010 was unlike the distribution for any other year in the 2001–2010 period. Low sample size combined with chance sampling effects may have contributed to the unusual distribution. In addition, most (84%) of the calls between 135° and 145° bearing occurred in a single brief time period, 29–30 Sept., indicative of one highly vocal bowhead or group of bowheads, as shown in Figure 2.24. Without this isolated group of calls, the directional distribution of bearings for 2010, seen in Figure 2.23, would resemble that of 2004 and 2005, also heavy ice years.

Call Types

Figure 2.25 shows a percentage breakdown of all bowhead whale calls detected by DASARs at location C / EB by call type for 2001–2010. Calls are broken down into two main categories: simple calls and complex calls. Simple calls are further broken down into four sub-categories: upsweeps, down-sweeps, 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. The call type analysis (Fig. 2.25) showed that the use of different call types in 2010 was within the range of previous years, with the notable exception of complex calls which occurred in a much smaller proportion than in all previous years. This finding is reiterated in Figure 2.26, which shows the percentage of simple versus complex calls in 2001–2010. Simple calls assumed an uncharacteristically larger proportion of calls in 2010 than in previous years, accounting for 97% of all calls in 2010.

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). It is conceivable that the atypical ice conditions of 2010 were in some way related to the preponderance of simple calls this year. The low number of calls and potential for chance sampling effects could also be a factor.

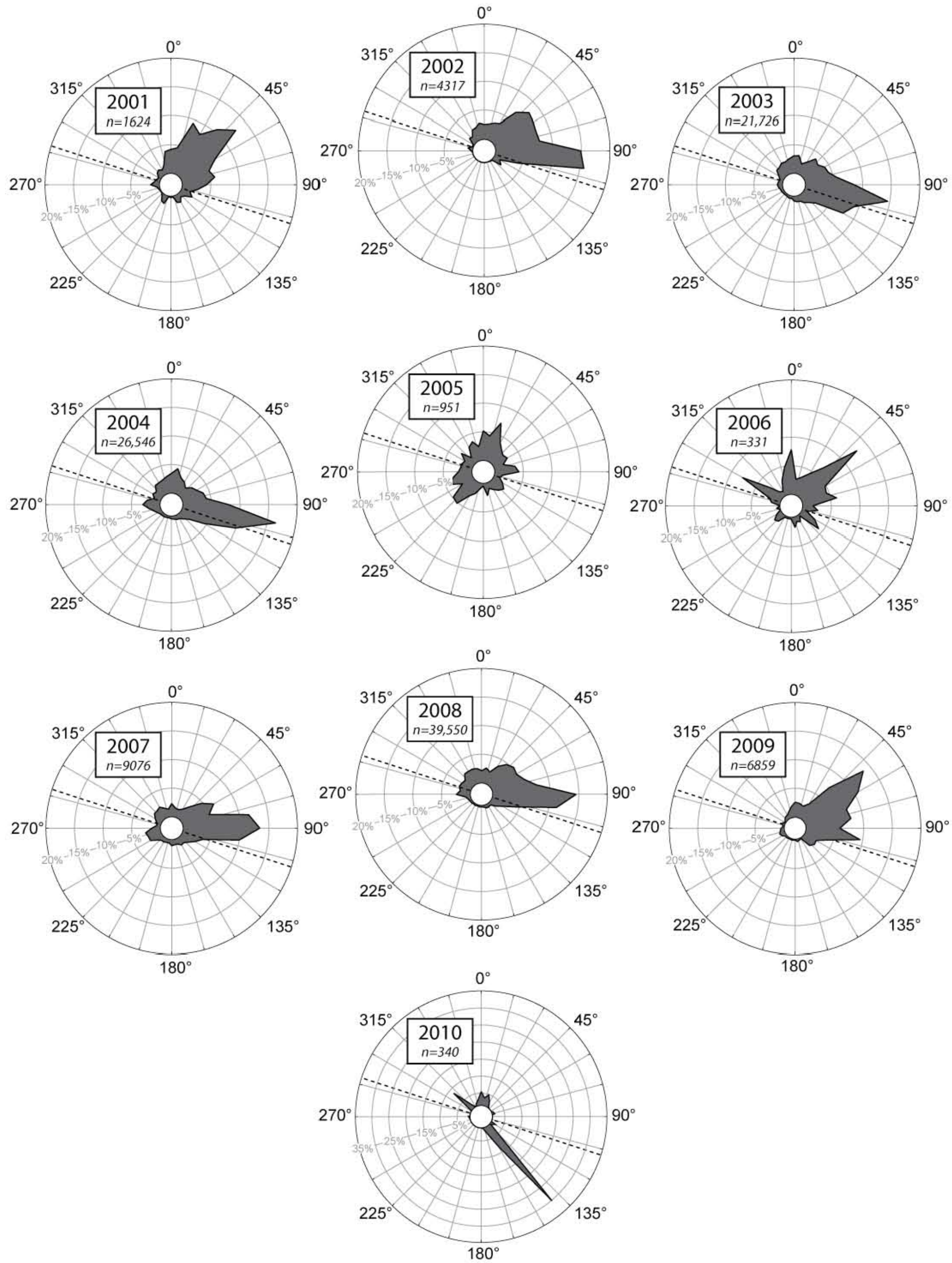

FIGURE 2.23. Directional distribution of bearings to bowhead whale calls detected via DASAR C/EB in 2001–2010. Results for each 10° sector are expressed as a percentage of all bearings obtained via the DASAR at location C/EB that year. Note the larger scale for percentage of bearings for 2010. The approximate orientation of the coast ("baseline", see Fig. 2.7) is shown as a dashed line through each DASAR. Sample sizes vary widely, from 331 in 2006 (over 18 days) and 340 in 2010 (28 days) to 39,550 in 2008 (30 days).

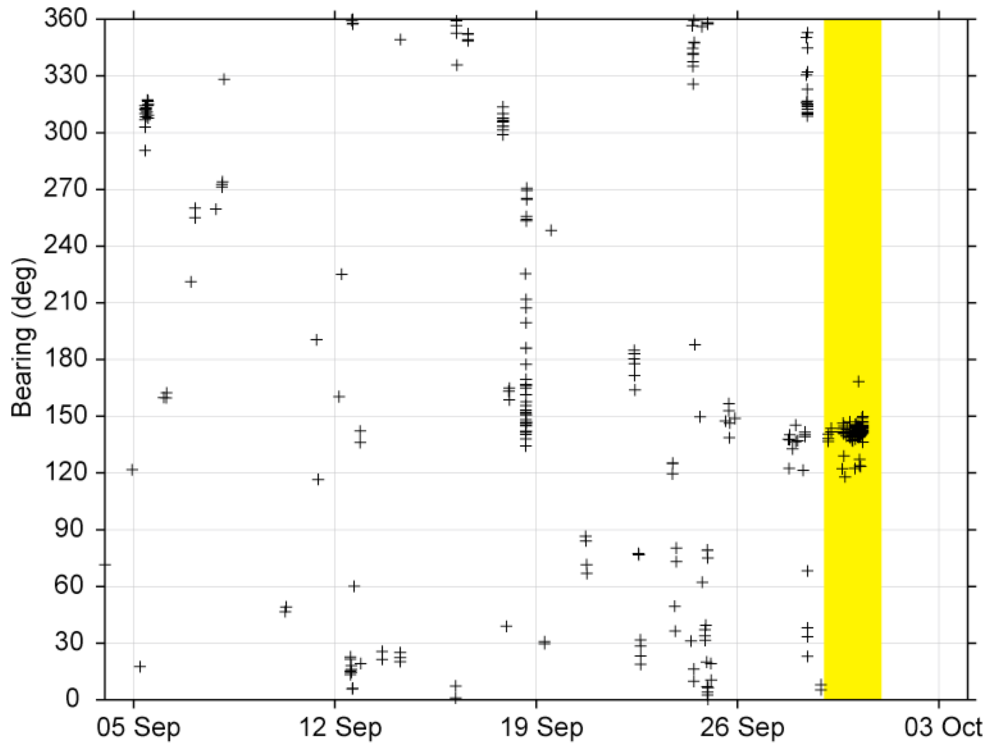

FIGURE 2.24. Whale call bearings from DASAR C as a function of time from 2–30 Sept. 0° and 360° correspond to North, 90° corresponds to East, and so on. The preponderance of calls at ~140° bearing (Fig. 2.23) is due to the highly vocal bowhead or group of bowheads detected at that bearing on 29–30 Sept (time period delineated in yellow).

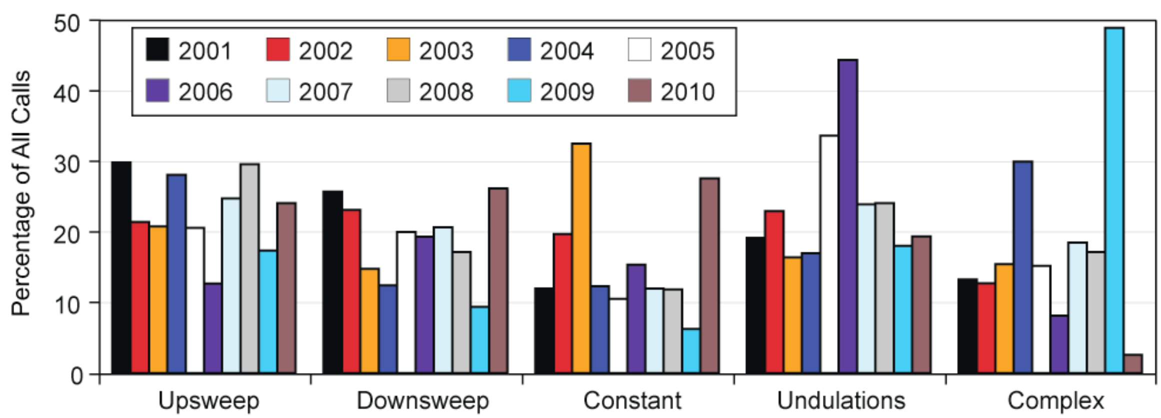

FIGURE 2.25. Percentage breakdown by call type in 2001–2010 for calls detected by DASARs at location C / EB. Simple calls include upsweeps, downsweeps, constant calls, and undulations.

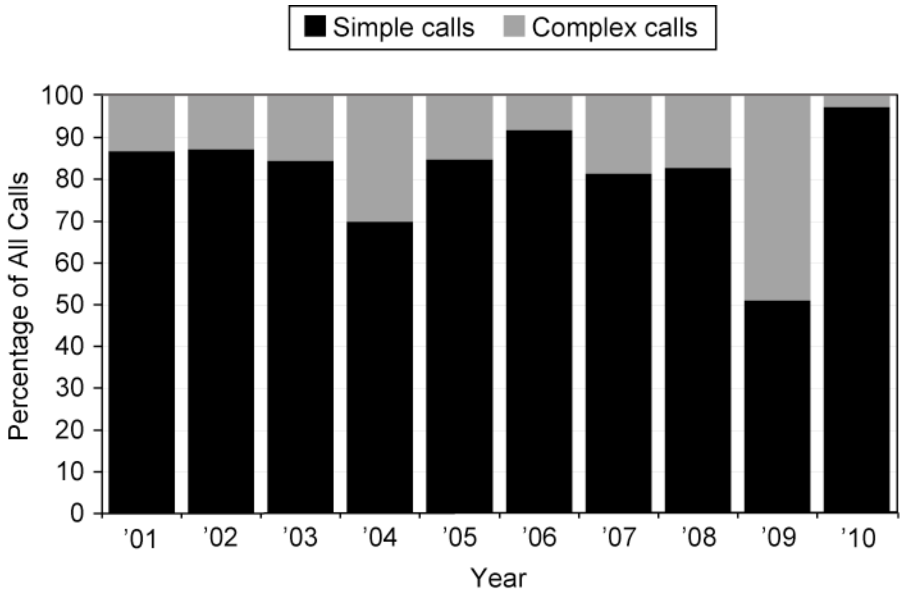

FIGURE 2.26. Percentage of simple (black bars) vs. complex (gray bars) call types in 2001–2010. Simple calls were by far the dominant call type in 2010.

In terms of whale call activity, the autumn of 2010 was a remarkable season among the ten autumns for which we have directly comparable data. The average daily call detection rate was the lowest found to date, at only 12 calls/day. The bearing distribution of those calls was also striking: for the first time in ten years, detected whale calls were predominantly inshore and southeast of DASAR C, largely due to a bowhead or group of bowheads vocalizing heavily over a brief two-day period. Call types were also unusual, with simple calls comprising a greater proportion (97%) of calls than in any other study year.

Visual observations appear to be consistent with the acoustic results. Aerial surveys conducted in a 24,990 km^2 (9648 mi^2) area roughly centered off Harrison Bay from 16 July to 9 Oct. sighted no bowheads in the vicinity of Northstar during the DASAR recording period, and all sightings were further offshore than DASAR C, with peak sighting rates observed 60–65 km (37–40 mi) from shore (Reiser et al. 2011). In addition, during 2010, whalers noted some bowheads in the nearshore ice but found most whales beyond (seaward of) the ice, fairly far offshore (see Chapter 3). Abnormally heavy local ice in 2010 may have moved the main migration corridor further offshore than in years past as well as limited acoustic detection of those whales located near shore due to propagation effects associated with shallow, ice-covered waters.

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CHAPTER 3:

SUMMARY OF THE 2010 SUBSISTENCE WHALING SEASON AT CROSS ISLAND[1,2]

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[2] All conclusions and opinions expressed in this report 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 recommended in 2005 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 for 2010 in large part by summarizing data acquired during the 2010 phase of the MMS/BOEMRE 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 2010, the whalers' observations of the general offshore distribution of whales, whale feeding behavior (if any), and "skittish" behavior.

In 2010, a total of six crews with a total of 14 boats whaled from Cross Island. Three crews traveled to Cross Island on 28 August, one crew on 29 Aug., and two crews on 30 Aug. Three crews (seven boats) scouted on 29 Aug. and landed a whale late in the day. Butchering took place 30 Aug. Five crews (11 boats) scouted on 31 Aug. and landed a whale. Four crews (nine boats) scouted on 1 Sept. and landed two whales to complete the 2010 Nuiqsut quota. Butchering occupied 2 through 5 Sept. One crew returned to Nuiqsut on 5 Sept., and the other five on 6 Sept. Weather conditions did not prevent whaling activities on any days. Whales were seen on all days when scouting occurred, although not in great numbers. Floating ice was encountered on every scouting day and some whales observed were near floating ice. The whalers reported seeing whales relatively close to Cross Island, although some whalers suggested that the floating ice made whales more difficult to spot, and most of the whales seen (and most of those chased and struck) were encountered in more open water, beyond the floating ice. The whalers did not report observing any boat traffic (commercial barges, ACS vessels, or private craft).

The 2010 Cross Island whaling season extended over 10 days, although the "open fire" period was only 5 days long and ended 1 Sept. Scouting for whales occurred on three of these days. Two days were devoted to travel, and five to butchering and packing. No days were "lost" due to weather. The full quota of four whales was landed. Strikes were made an average of 26.5 km (16.5 mi) NNE of Cross Island.

In summary, the 2010 Cross Island hunt was short and successful. The full quota of four whales was landed with only three days of scouting. Whales were seen and landed on all days when boats went scouting. No conditions negatively affecting whaling success were reported. Floating ice was present, but not an obstacle to whaling. No observations of other vessel traffic were reported. Weather did not prevent or delay any whaling activities. No "skittish" whale behavior was reported. No observations of whale feeding behavior were reported, but the one stomach examined was full. The level of effort expended by the whalers, in terms of boat hours on the water scouting for, chasing, and towing whales, was much lower in 2010 than in 2009, and is in the "low" range for the ten years documented by the BOEMRE project. The whalers expressed neither general nor specific concerns about BP's Northstar activities in 2010.

INTRODUCTION

During the autumn migration period of bowhead whales, subsistence hunters from Nuiqsut travel to Cross Island, a distance of 148 to 175 km (92 to 109 mi), 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, and is 27.4 km (17 mi) east of BP's Northstar production island. 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 Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE, formerly MMS) has sponsored a detailed study of the whaling activities at Cross Island (Galginaitis and Funk 2004, 2005; Galginaitis 2006a,b, 2007a, 2009a,b,d, 2010a, 2011). 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) data loggers have been placed on most 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 in 2005 that the ongoing MMS/BOEMRE (henceforth listed as "BOEMRE") 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 BOEMRE-supported program during 2005–2010, to compile the specific types of information mentioned by the SAC. Annual reports for 2005–2010 are provided by Galginaitis (2006c, 2007b, 2008a, 2009c, 2010b, this report), respectively. In addition, Galginaitis (2008b, 2010c) provided broader syntheses of the information available up to 2005 and up to 2009.

This chapter of BP's 2010 Annual Summary Report describes information provided by the Nuiqsut subsistence whalers about selected aspects of the 2010 whaling season. This included their assessment of the general offshore distribution of whales in 2010, 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 2010 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 2010 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, as referenced above.

METHODS

The objective of the BOEMRE 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 BOEMRE 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 BOEMRE-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 (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 2001–2010. 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 handheld 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 when 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. GPS units are, for the most part, situated in a mounting base attached to the boat rather than being hand-held.

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 2010 and previous whaling seasons. 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 on the topics specified above. For the 2010 Cross Island whaling season, GPS tracks for 89 percent (24 of 27) of the whaling trips were obtained and mapped. Interview and observational information for all 27 whaling trips supplemented the

GPS material. A more detailed description of the methodology can be found in Galginaitis and Funk (2004, 2005) and Galginaitis (2006a,b, 2007a, 2009a,b,d, 2010a).

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 BP's Endicott Development along the coast, 24.1 km (15 mi) NE 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 2010. 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 3.1 and 3.2 provide images of the equipment used for Cross Island whaling during the study years—darting gun, float, shoulder gun, and the boats used by the six crews.

Nuiqsut whalers state that "normally" they 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. The ideal model would be for a whale to be landed every other day, with butchering completed on the day between two whale landings, until the quota is completed. However, this ideal pattern has not been evident in recent years – primarily due to concerns about adverse weather conditions. 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,b). In ***2007***, they purposely landed two whales on one day in order to complete their quota and close the season due to 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 Sept. was large, all but the crew who landed that whale went scouting again on 12 and 13 Sept. (and landed another whale on 13 Sept.). In ***2010***, four whales were landed in the span of four days, immediately after the crews arrived at Cross Island, to take advantage of a period of good weather. A large whale was landed 29 Aug., 30 Aug. was devoted to butchering, a whale was landed and substantially butchered 31 Aug., and two whales were landed 1 Sept.

Nuiqsut whalers invariably use the term "scouting" rather than "hunting" to describe looking for whales to strike, and good fall 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 correspond with 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

FIGURE 3.1. Subsistence whaling equipment. *Top left to right:* NOAA archive illustration of darting gun (above) and shoulder gun (center and below); wrapping rope on float (to attach to darting gun); and cleaning shoulder gun. *Below:* Unloaded new whale bombs (quarters for scale); and some fragments of exploded bombs recovered from whales.

FIGURE 3.2. Whaling boats at Cross Island during the 2010 subsistence whaling season, clockwise from top left – Nukapigak boats preparing for scouting, Taalak boats, Aqarguin boats preparing for scouting, Oyagak boats, Napageak boats, Ipalook boats

ice floes. During the period of the BOEMRE-funded 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. In 2010 there was significantly more floating ice than in 2009, but in a restricted area that affected the towing of landed whales more than the conduct of the hunt itself (discussed below). Some whalers reported that the ice conditions may have affected their ability to spot whales, especially those close to Cross Island within the floating ice pack.

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 2010 season ranged from two to five persons (average of 3.6). Although solitary boats do take whales on occasion (for example the first two strikes by Nuiqsut whalers in 2007 were from 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 preferred minimum number of boats to have available for scouting whales on a given day, and in 2010 the average number of boats that went out scouting was 9.3 (the highest for the 10 years documented by the BOEMRE-funded project). When more boats are available, efficiency, safety and likelihood of a successful hunt are all increased.

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 them 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 (Fig. 3.1)

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 darting gun has attached a float to a whale (and at the same time shot a bomb into the whale). The first (darting gun) 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 (with minimal cleaning between shots), while the darting gun needs to be recovered from the water and cleaned before it can be used again.

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. However, 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). Most Nuiqsut whaling crews prefer to use black powder bombs.

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 BOEMRE-funded project (2001–present).

Once the whale is dead, all available boats usually assist in towing it back to Cross Island to be butchered. Sometimes, if the captains decide to try to land a second whale the same day, several boats will continue to scout for whales rather than joining the tow. This is a collective decision, and not one made by individual captains. Once a whale has been towed to Cross Island, 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 (and others) is done after the crew and whale products are in Nuiqsut.

The harvest of bowhead whales by crews from Nuiqsut is displayed in Table 3.1. Because Nuiqsut was resettled in 1973, years before 1973 are not included in this table.

THE 2010 WHALING SEASON

This section contains a general overview of the 2010 Cross Island whaling season. More detail on day-by-day whaling activity can be found in the 2010 Annual Report currently in preparation for BOEMRE (Galginaitis 2011). All point locations, times, and distances are approximate estimates. As noted above, no other vessel traffic was reported in the Cross Island area in 2010. The level of detail in this chapter is limited as there were no issues or problems during the 2010 whaling season to which more detailed information would be pertinent.

Six crews whaled from Cross Island in 2010. All had whaled at Cross Island previously. No crew whaled with only one boat, a large change from past years. Four crews whaled with two boats, and two crews whaled with three boats. One of the "3-boat" crews also used a fourth boat for logistical support. The other "3-boat" crew sent one boat back to Nuiqsut early, but only after all four whales had been landed.

TABLE 3.1. Recent harvest of bowhead whales near Cross Island.

Year	Whales			Notes
	Quota	Landed	Struck & Lost	
1973	NA	1	0	Butchered in water near Flaxman Isl./Canning R. delta
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
2010	4	4	0	Favorable whaling conditions

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. **Sources:** Compiled from AEWC records, personal communications with Nuiqsut whalers, and field notes from the 2001–2010 whaling seasons.

Chronology of the 2010 Whaling Season

As in previous years, the start of the Cross Island whaling season in 2010 depended primarily on weather conditions, reports of whale sightings near Cross Island, and the readiness of the whaling boats and crews. Most captains had initially planned to leave for Cross Island sometime during the weekend before Labor Day. As it turned out, since Labor Day was relatively “late” in 2010 (6 Sept.) and whales were already being sighted on their migration, all crews left for Cross Island about a week before Labor Day. The whalers completed landing their quota of four whales on 1 Sept. and the last crews left Cross Island on 6 Sept. Characteristics of the whales landed are summarized in Table 3.2. Weather conditions, time spent out boating (which includes all time spent out on the water from the first boat leaving Cross Island until the last boat returning), and times and dates of strikes are graphically summarized in Figure 3.3.

TABLE 3.2. Characteristics[1] of whales struck near Cross Island, 2010.

Date	Time Struck	Length	Sex	Whale ID	Miles from Cross Island	Bearing from Cross Island	Notes
29 Aug.	12:58	51’0”	F[2]	10N1	19.5	27˚	Ipalook, landed
31 Aug.	11:59	44’10”	M	10N2	13.1	20˚	Napageak, landed
01 Sept.	12:29	26’0”	F	10N3	21.1	30˚	Nukapigak, landed
01 Sept.	14:43	46’0”	F	10N4	12.1	26˚	Oyagak, 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) and positions are approximate and are derived from the recorded GPS tracks and/or radio logs, combined with whalers’ accounts. They are subject to correction or refinement, based on additional information sources not yet available.

[2] Whale 10N1 was pregnant.

Three crews traveled to Cross Island on 28 Aug., one on 29 Aug., and two on 30 Aug. Wind speed was 5 mph (8 km/h) or less for most of this period.

On ***29 August***, the three crews that had arrived on Cross Island the previous day went scouting for whales with seven boats, and landed a whale. The fourth crew arrived at Cross Island in time to assist with the last stages of the tow. Floating ice was encountered until about 12.5 miles (20 km) from Cross Island, and was especially thick within 5 or 6 miles of Cross Island. Beyond about 12.5 miles the water was mostly open water. The only whale seen on 29 Aug. was in open water about 18.1 miles NNE of Cross Island. All boats scouted to the NNE of Cross island, but did not closely coordinate their movements until the initial sighting of the whale. From that point on all boats were involved in the chase and landing of this whale. The whale was struck about 19.7 miles from Cross Island and killed about 18.3 miles from Cross Island. The tow back to Cross Island took about 7.5 hours, primarily due to the delays involved in finding a route back to Cross Island through the floating ice. The tow did not arrive at Cross Island until about 23:00, so the whale was left in the water until the next morning. Several whalers reported smelling, but not seeing, whales within the thicker pack ice about 5 or 6 miles from Cross Island. Several whalers also reported some possible sightings of whale blows in the distance during the day, but were not sure enough of them to report them as sightings. The general consensus was that the floating ice made it difficult to spot whales, and that whaling effort on following days would concentrate on the area of more open water beyond the floating pack ice. Crews reported seeing seals in proximity to the ice, but did not specify sighting locations.

On ***30 August***, no scouting took place, although conditions were generally favorable. The whale landed 29 Aug. was large, and on 30 Aug. all hands were needed for butchering.

On ***31 August***, five crews with 11 boats went scouting for whales, and landed the second whale of the season. Crews left primarily toward the N and NNE of Cross Island, and saw perhaps five whales (and lost track of them) before spotting and landing a different whale. Floating ice was again encountered until about 12 miles from Cross Island, and weather conditions continued to be favorable. The boat that first spotted the whale that was eventually landed also reported seeing three other blows in the distance. Until this whale was spotted about 09:37, no boat had been able to follow a whale for any significant period of time. Once this whale was spotted, eight of the boats coordinated to chase it. One crew (two boats) was independently scouting for other whales NE of Cross Island, and those two boats were joined by a boat from another crew that left Cross Island after the other boats. The crews of these three boats

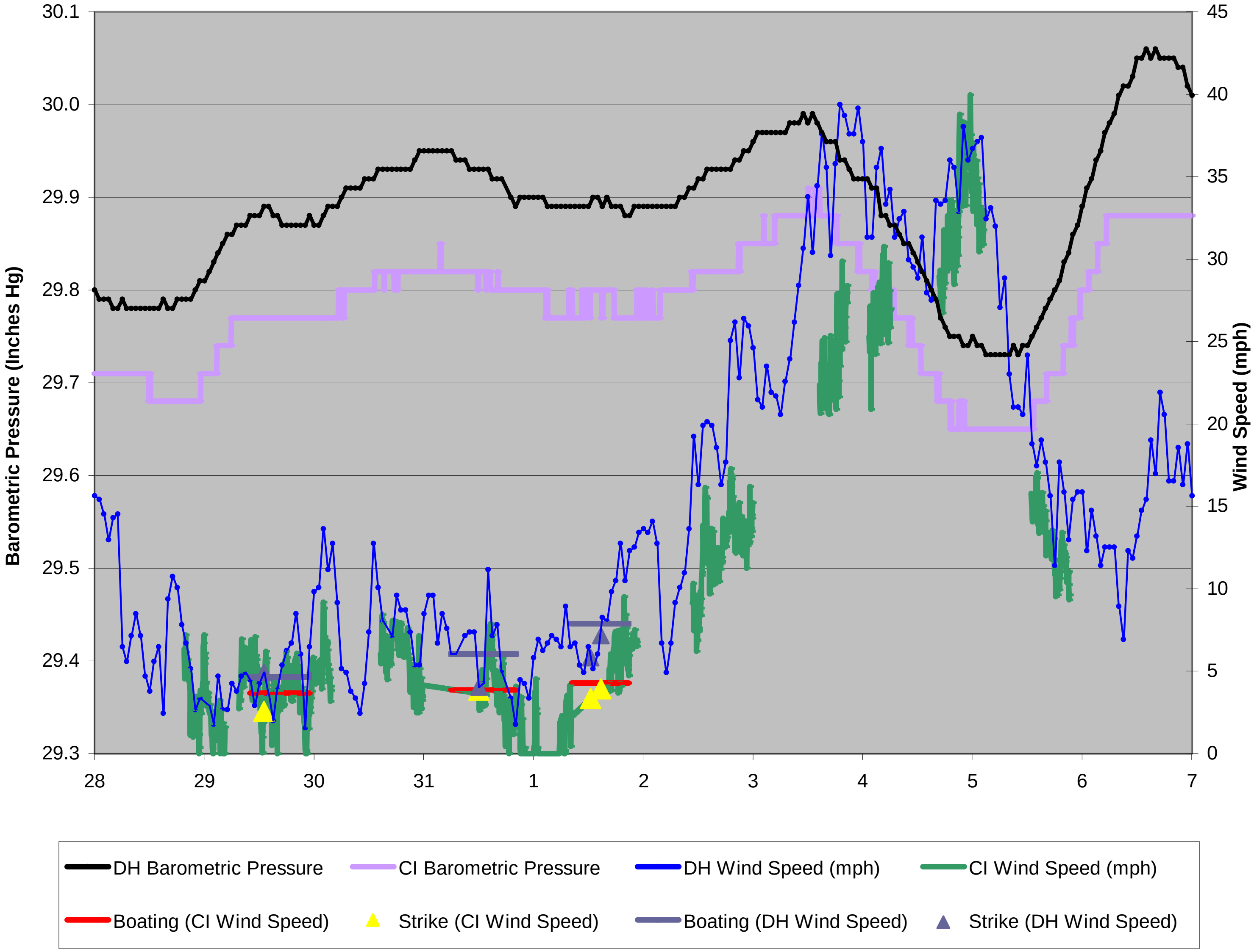

FIGURE 3.3. Summary of weather and bowhead strikes during the 2010 Cross Island subsistence whaling season. X-axis shows dates in Aug. and Sept., with tick marks at midnight (local daylight time). CI = Cross Island; DH = Deadhorse. "Boating" includes all time on the water.

spotted and started chasing a whale independently of the other group. However, once a boat in the larger group struck the whale they were chasing, these three boats broke off their chase and joined the other eight boats. The whale was struck about 13.1 miles from Cross Island and killed about 13,3 miles from Cross Island. The tow took about four hours, again primarily due to the need to find passage through the floating ice pack. The whale arrived at Cross Island about 17:19 and butchering progressed to the point where the carcass was opened before crews quit for the night. A total of perhaps 7 to 9 different whales were seen during the day, including 3 or 4 observed as blows in the distance. All whales observed were seen in open water at distances of 16 to 21 miles from Cross Island, in the northeast quadrant from Cross Island. Seals were also seen in proximity to the ice, but no specific sighting locations were noted.

On ***1 September***, four crews with nine boats scouted for whales, since butchering on the two landed whales was well advanced. Whaling conditions continued to be good and the whalers landed the last two whales of their quota. The first whale was small and winds were expected to increase the next day, so the captains decided to try for another whale that same day. [Winds did subsequently increase to a peak on 5 Sept, decreasing on 6 Sept. to levels that allowed the whalers to return to Nuiqsut.] One boat experienced mechanical problems on 1 Sept. and returned to the island early in the day, but was repaired and able to assist with the tow on the second whale landed. Floating ice was again encountered, but may not have extended as far from Cross Island (perhaps 6 to 8 miles rather than 12 as on the previous day). A total of seven whale sighting locations were documented, but it is possible (as for 31 Aug.) that more whales were observed than were reported. On the other hand, at least two crews reported seeing floating logs that could easily be mistaken for whales.

On the morning of 1 Sept., all boats left the island between 08:30 and 09:30 and went NNE, towards where they had seen whales before. Whale sightings were reported from about 14 to 21 miles from Cross Island, mostly in open water, with the qualification that there were also whales (especially the smaller ones) nearer the ice edge and perhaps within the floating ice pack. These whales were not enumerated or located more precisely, as this was more a general characterization of the season than a specific statement about this one day. Once the first whale was spotted, shortly before 10:00 about 14 miles NNE of Cross Island, all boats coordinated to chase the whale seen. Even though all boats were in the same general area, more than one whale may have been pursued (by different boats) at the same time. No whale was pursued for very long or seen more than 2 or 3 times until a whale was sighted about 12:21, about 21 miles NE of Cross Island. This is the location to which the whales previously spotted and chased had led the boats by that time. The 12:21 whale may have been spotted earlier, but 12:21 was the time when all boats were informed of its location and changed direction to assist with the chase. This small whale was struck about 12:29.

Once this whale was killed, about 21 miles NE of Cross Island, four boats (from two crews) tied on for the tow and four boats (from three crews) continued to scout for whales, primarily in the area to the south and east of where this whale had been secured. This scouting area was probably also selected (in part) so that these boats could assist with the tow if required. The latter four boats left this area at high speed about 14:20 and traveled to the SSW, towards a whale one of them had sighted about 14.4 miles NE of Cross Island (and 3 to 4 miles SSW of where the boats were at that time). This whale was struck about 14:43 and was secured about 12 miles NNE of Cross Island. The tow for the first whale lasted about 3.5 hours while that for the second was 5 to 6 hours. The tow for the second and larger whale went no faster than 4 mph while that of the smaller whale could go 7 to 8 mph at times.

All crews spent ***2–5 September*** butchering and packing. Wind speed started to increase 2 Sept. and reached a peak of 30 mph on 5 Sept. It is likely that, if the fourth whale had not been landed on 1 Sept., no further scouting would have taken place until 6 Sept. Most packing had been completed by the end of 5 Sept., and demobilization was scheduled for 6 Sept. One crew that had not landed a whale left Cross Island on 5 Sept. The other five crews left Cross Island on 6 Sept.

Discussion of Whaling in 2010

At least one crew was on Cross Island for parts of 28 Aug. through 6 Sept. in 2010, a total of 10 days. The only period of high winds, when conditions would not have been suitable for scouting for whales, occurred after the quota had been completed and before the whalers were ready to leave Cross Island. Thus, weather did not interfere with the Cross Island 2010 whaling season. Two days were devoted to travel. Scouting for whales took place on three days, and at least one whale was landed on each of these days. Butchering and packing accounted for the other five days. Table 3.3 summarizes selected descriptive measures of the 2010 Cross Island subsistence whaling season, and presents the comparable values for the previous study years (2001–2009).

Three crews had a whaling season of 10 days, one crew was on Cross Island for 9 days, one for 8 days, and one for 7 days. The "average" crew was thus on Cross Island for 9 days in 2010. Only two seasons since 2001 have had such short "average crew seasons" (Table 3.3) — 7.3 days in 2008 (when the length of the season was 14 days) and 10.4 days in 2007 (when the season was 13 days long). All other years had significantly higher values. Floating ice cover extended to about 12 miles from Cross Island for most of the season, and may have made spotting whales more difficult. Weather conditions were favorable for whaling as soon as the whalers reached Cross Island, and they were able to find and land whales in the open water beyond the floating ice pack. No encounters with non-whaling vessels were reported. These factors combined to make the season the shortest documented to date, although the amount of scouting ("on-the-water") effort per strike was higher than for some previous seasons and the "average crew" was on Cross Island for more days than in 2008.

The researcher (MSG) was on Cross Island for the entire 2010 whaling season and was able to collect GPS tracks and whaler accounts for all scouting days. Summary numeric information for boat trips and whale strikes for 2010 (and comparative information for 2001–2009) is provided in Table 3.4. For the overall season, there were 29 "boat days" with 30 different scouting trips (since there was 1 occasion when a boat made two different trips on a single day). Of these 30 tracks, 26 are represented by GPS information (87 percent). Most of the missing tracks were due to the GPS unit occasionally being left onshore or not being turned on. Two of the missing tracks, unfortunately, were for boats that had the first strike on whales. While the track itself was more-or-less represented by other boats at sea that same day (and in the same general area), the point information for these two first strikes is necessarily somewhat less precise than would otherwise be the case. Given the approximate nature of most point information for the BOEMRE project to date, however, this is not a major concern.

The number of boats scouting on any given day ranged from 8 to 11 and averaged 9.3. This is the highest value for the ten years documented by the study (Table 3.3). The number of whale sighting reports each day with scouting varied from 1 to 7 (Table 3.5). This is more a qualitative or relative measure, rather than a quantitative one, as it is subject to a number of limiting factors (see the discussion of "Offshore Distribution of Whales" below, and the general description of the 2010 Cross Island whaling season above).

Figure 3.4 shows all documented GPS tracks for all Cross Island boats on all days during the 2010 whaling season, color-coded by day, along with locations of strikes and other whale sightings.

TABLE 3.3. Selected observational measures of Cross Island subsistence whaling seasons, 2001–2010.

Metric	Type	Season									
		2001	**2002**	**2003**	**2004**[6]	**2005**[6]	**2006**	**2007**	**2008**[7]	**2009**[8]	**2010**
Whales Landed/Whales Struck & Lost	count	3/0	4/1	4/0	3/0	1/0	4/0	3/1	4/0	2/1	4/0
Length of Whales Landed, Total	total	120' 2"	142' 1"	134' 8"	110' 10"	40' 9"	140' 5"	120' 8"	126' 1"	69' 4"	167' 10"
Length of Average Whale Landed	average	40' 1"	35' 6"	33' 8"	36' 11"	40' 9"	36' 7"	40' 3"	31' 6"	34' 8"	42' 0"
Active Crews on Cross Is. (max.)	count	4	3	4	4	5	4	5	6	6	6
Scouting Boats on Cross Is. (max.)	count	7	9	10	8	8	7	9	12	11	14
Cross Is. Population	average	27.7	26.6	20.4	18.9	29.8	29.2	26	22 (36)	41.85	44.1
Length of Season[1]	count	24	23	19	30	27	21	13	14 (7)	20	10
Crew Days (total for all crews)[2]	count	90	58	53	77	105	84	52	44 (35)	115	53
Length of Season/Crew (days)[3]	average	22.5	19.34	13.25	19.25	21	21	10.4	7.3 (5.8)	19.2	8.8
Weather Days	count	8 or 9	4	8	10	11 to 15	4	3	6 (0)	5 (6)	0
# Days Scouting[4]	count	12	15	7	12	9	10	5	5 (5)	12 (10)	3
# Days Whales Seen[5]	count	9	9	7	6	7	8	4	5	10 (10)	3
Boats Scouting/Day	average	4.8	4.3	4.9	3.4	4	4.8	3.2	4.8 (5.4)	7.4 (8.6)	9.3
Boat Crew Size	average	3.9	3.6	2.9	3.6	4.4	4.3	4.2	3.8	3.6	3.5

[1] Number of days with at least one crew on Cross Island. Includes day of arrival at and departure from Cross Island.
[2] Crews do not necessarily arrive on or leave Cross Island on the same day. Each day when at least one crew member from each crew is on Cross Island counts as 1 crew day. For example, if members of 2 crews are on Cross Island on one day, and members of 3 crews are on Cross Island the next, the total would be 5 crew days for the two days.
[3] "Crew Days"/"Active Crews on Cross Is. (max.)".
[4] Number of days when at least one boat went out scouting for whales.
[5] Number of days when at least one crew saw whales while scouting from a boat. Blows seen from Cross Island on non-scouting days are not included.
[6] One crew went to Cross Island well before other crews, so total season measures may be somewhat misleading. Refer to Galginaitis 2006d, 2008c for details.
[7] Figures in parentheses ( ) are values excluding 7 days when only one crew was on Cross Island.
[8] Figures in parentheses ( ) are values reclassifying 2 marginal scouting days: 1 "weather" day and 1 "travel/preparation" day.

TABLE 3.4. Selected analytical measures of Cross Island subsistence whaling seasons, 2001–2010.

Metric	**Type**	**Season**									
		2001	**2002**	**2003**	**2004**[6]	**2005**[6]	**2006**	**2007**	**2008**[7]	**2009**[8]	**2010**[9]
# Boat Days[1]	count	57	65	34	41	35	48	16	29 (27)	89	29 (26)
# Boat Trips (possible # of GPS tracks)[2]	count	59	67	42	46	48	53	22	33 (31)	113	30 (27)
Actual # of GPS Tracks Collected	count	49	52	37	44	48	51	20	30	93	26 (24)
Length of Trip (miles)	average	84	64.3	37.2	45.3	60.7	60.8	30.1	32.1	61.6	70.1 (78.5)
Duration of Trip (hr:min)	average	9:43	7:58	4:31	6:51	7:07	8:13	5:39	5:03	6:43	10:14 (11:13)
Furthest Point from Cross Is. (miles)	average	23.6	19.5	11.6	12.1	19.1	22.2	10.4	8.3	15.8	18.8 (21.0)
Strike Distance from Cross Is. (miles)[3]	average	19.5	13.4	9.3	9.7	25.9	17	12	6.5	13.8	16.5
Strike Direction from Cross Is. (degrees)[3,4]	average	64°	67°	56°	36°	82°	59°	80°	05°	70°	26°
Total Seasonal Boat Effort (boat-hr)[5]	sum	572.9	533.6	162.9	301.2	341.3	427.1	124.3	158	751.7	307 (302.7)
Boat Hours/Strike	average	191	106.7	40.7	100.4	341.3	106.8	31.1	39.5	250.6	76.7 (75.7)

[1] Each boat scouting for whales on any given day counts as one "boat day". For example, if 2 boats scout on one day, and 4 boats on the next, the total is 6 boat days.

[2] Some boats made more than one scouting trip on a single day.

[3] Includes "struck and lost" whales in 2002 and 2007.

[4] Due north is 0 (and 360) degrees, due east is 90 degrees. Includes struck and lost as well as landed strikes.

[5] Yearly total equals aggregate sum of duration of all whaling trips by all boats. Includes estimates for missing information.

[6] One crew went to Cross Island well before other crews, so total season measures may be somewhat misleading. Refer to Galginaitis 2008b for details.

[7] Figures in parentheses ( ) are values excluding 7 days when only one crew was on Cross Island.

[8] Figures in parentheses ( ) are values reclassifying 2 marginal scouting days: 1 "weather" day and 1 "travel/preparation" day.

[9] Figures in parentheses ( ) are values excluding certain "marginal" data: 1 "boat trip" that only aided a tow and with no other information, 1 "boat trip" that only aided a tow and lasted only 98 minutes, and 1 "boat trip" that lasted 13 minutes and was terminated by engine trouble.

TABLE 3.5. Summary of "scouting days" during the 2010 Cross Island subsistence whaling season.

Date	Average Wind Speed While Scouting (mph)[a]	Boats Scouting	Whales Seen (#)[b]	Whales Seen (%)
29 Aug.	3.7/4.7	8	1	6.7
31 Aug.	3.9/6.0	11	7	46.7
1 Sept.	4.3/7.9	9	7	46.7
Totals (Boat Days/Whales)		28	15	100.1

[a] "Average Wind Speed" is given for both the Cross Island weather station and the Deadhorse weather station (since the Cross Island weather station had reported only for limited periods of time).

[b] "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).

Figure 3.5 compares the 2010 tracks, coded in silver, with the prior years documented for this project (2001–2009). The 2010 season appears to have been one where whales were available reasonably close to Cross Island, but only beyond the floating ice pack. Figure 3.5 clearly indicates that scouting tracks during the 2010 season show the same major pattern demonstrated by those for 2001–2009: a concentration in a "core use" area in the quadrant to the northeast of Cross Island.

Figure 3.6 displays the 2001–2009 GPS tracks grouped by level of scouting effort expended per strike, with three categories of effort, and 2010 displayed in a 4th color. Effort expended per strike during the 2010 season was greater than the lowest years documented to date, but less than the "intermediate" level of effort. The pattern of GPS tracks for 2010 appears to more closely resemble the intermediate effort grouping. Whalers traveled farther in 2010 than they did in 2003, 2007, or 2008 and about the same distances as in 2004, but not as far as they had in the other years since 2001. The pattern in 2010 is not quite like that of any prior year, probably due to the presence of the floating pack ice near Cross Island. Without this floating ice, the pattern may have more closely matched that of the grouping consisting of the years 2003, 2007, and 2008.

OBSERVED WHALE FEEDING BEHAVIOR IN 2010

Whalers did not report observing any whale feeding behavior, or any areas of "whale food", in 2010. No stomach samples were taken from bowheads landed in 2010, although four whales were landed. However, the stomach from the first whale landed was opened and was full of invertebrates. (This whale was also pregnant.) Stomachs from the other whales were not examined, as 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. The stomachs from these animals were either never seen or punctured during the butchering process.

That feeding whales were not observed by the Cross Island whalers during the 2010 season was not surprising. There had been few such reports in the previous years of the research. The whalers reported seeing relatively few whales, and only spent three days on the water. At least some whalers believed that

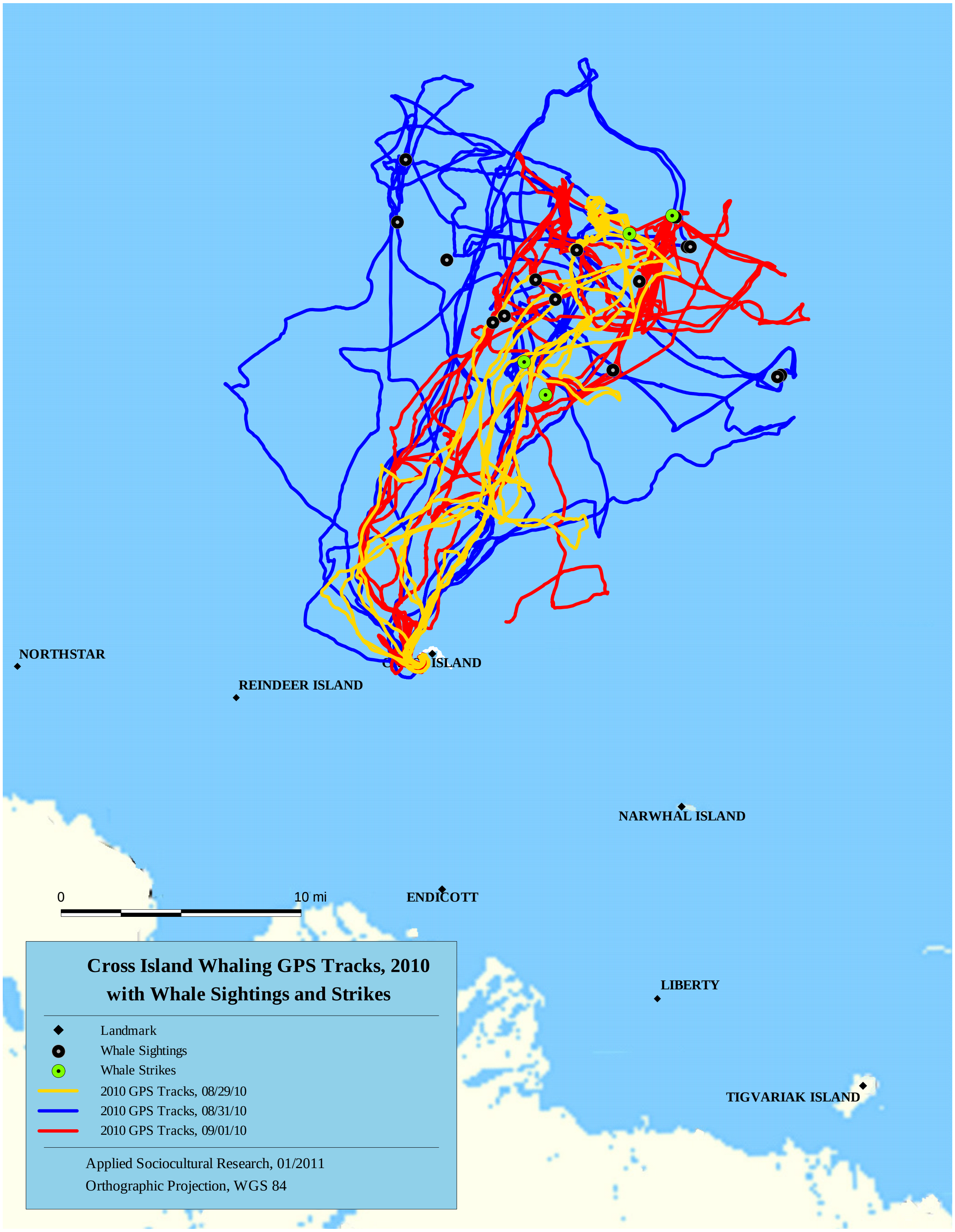

FIGURE 3.4. GPS tracks for Cross Island whaling in 2010, with whale sighting locations and strike locations.

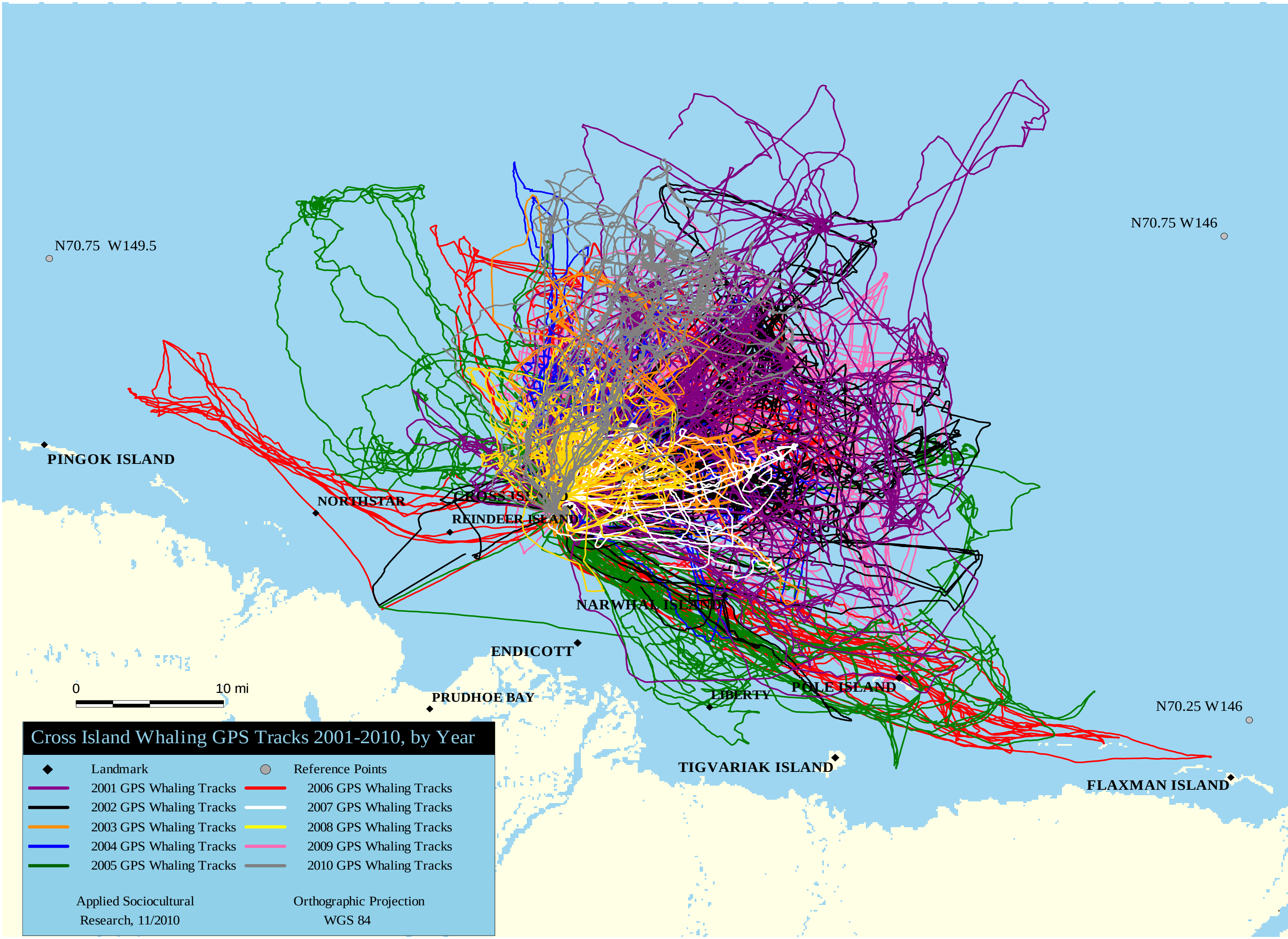

FIGURE 3.5. GPS tracks for Cross Island whaling by year, 2001–2010.

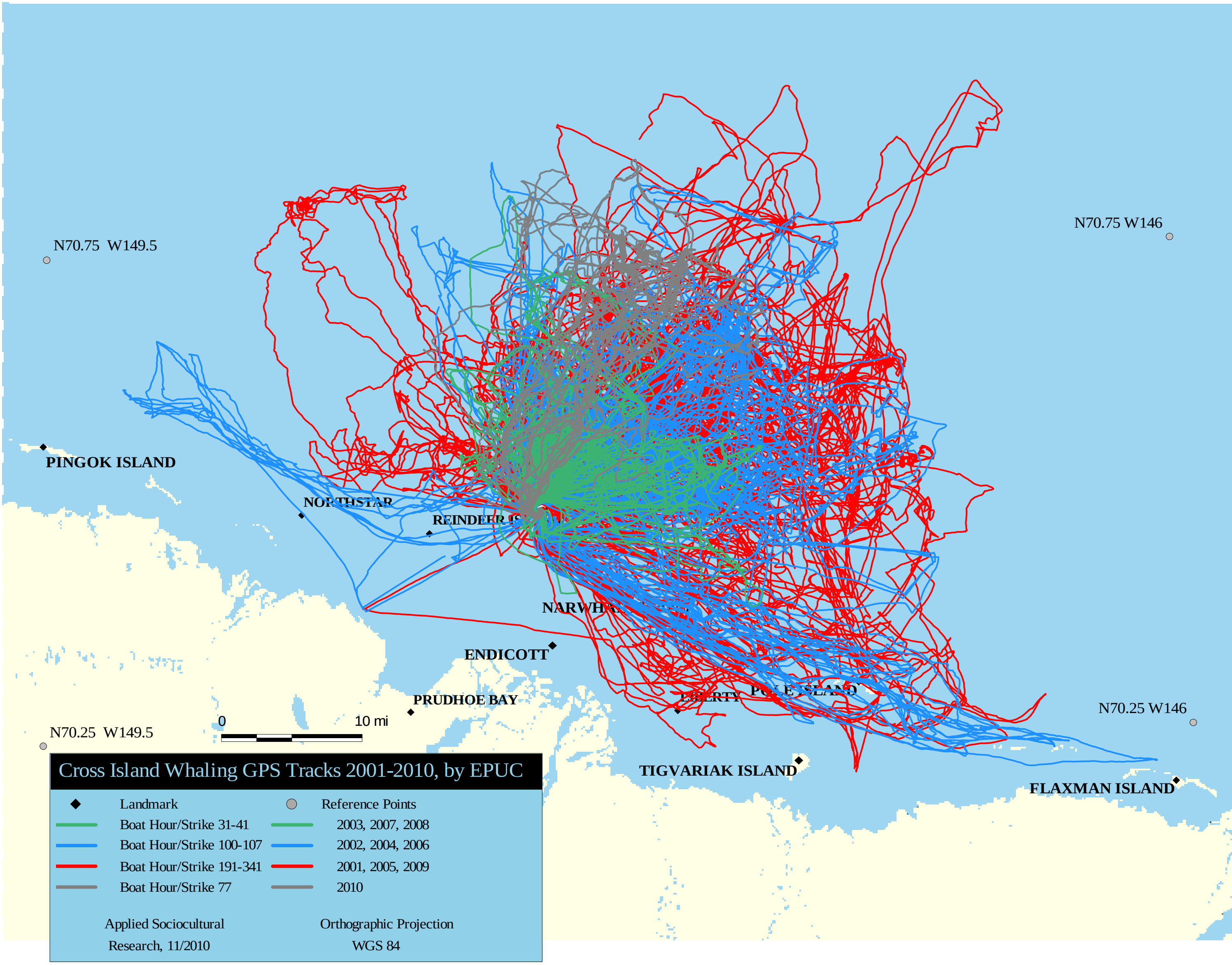

FIGURE 3.6. GPS tracks for Cross Island whaling, 2001–2010, with years grouped by boat-hours of effort/strike.

the whale migration in 2010 was relatively close to Cross Island, but that the floating ice made these whales more difficult to spot than whales out in the open water. Thus, it is likely that the whalers only saw a fraction of the whales actually present, and then only during the limited amount of time when the whalers were on the water. This does not necessarily mean that feeding did not occur around Cross Island in 2010, but does indicate that whale feeding activity, if it occurred, was generally not very obvious in that area when viewed from small boats. Previous reports have listed the following factors as contributing to the relative lack of whaler observations and reports of whale feeding:

- whale feeding is not commonly observed (or at least not reported) by Nuiqsut whalers near Cross Island (only two or three incidents, during only two of the previous nine 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;
- floating ice may have made it difficult to see many of the whales closer to Cross Island, reducing the number of possible observations; and
- a major part of the migration may have bypassed the area accessible to the whalers, as they used a relatively small portion of the total whale-search area documented during previous years of the study.

For the nine years of the study previous to 2010, only two or three whaler observations of whale feeding were reported and recorded. These were spectacular sightings of whales feeding on the surface with their mouths open, relatively close to Cross Island (within 16 km or 10 mi of Cross Island). These were described as "rare" events. This does not necessarily indicate that Nuiqsut whalers observed no whale feeding behavior on other occasions in 2001–2010 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 2001–2010, 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, the whalers 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. Also, some bowhead whales interrupt their feeding when a motor vessel approaches (Richardson and Malme 1993), and this response presumably reduces opportunities to observe bowhead feeding behavior from whaling vessels used near Cross Island.

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). The only whale stomach examined in 2010 was full of prey. 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 also be added that, since the development of Northstar, Nuiqsut whalers report that they rarely scout for whales in that area, and certainly Figure 3.5 demonstrates that has been the case since 2001.

"SKITTISH" WHALE BEHAVIOR DURING 2010

"Skittish" behavior has been characterized in previous reports, and the interested reader is referred to those documents. No skittish or "disturbed" whale behavior was reported in 2010, and no major difficulties in following whales, once seen, were noted. Some whalers did indicate that the floating ice near Cross Island may have made seeing whales near Cross Island more difficult than for whales in more open water. Whalers also stated that smaller whales tended to stay closer to floating ice than did larger whales. They attributed this to the more cautious nature of smaller whales, and the preference of larger whales for deeper water. They also suggested this as an explanation for their taking three whales longer than 40 feet. Since they were whaling in the deeper and more open water rather than in the shallower water with the floating ice pack, most of the whales they saw and had chances to strike were larger. Most of the small whales they saw were either in the ice or along the edge of the floating ice pack.

GENERAL OFFSHORE DISTRIBUTION OF WHALES, 2010

Nuiqsut whalers did not offer any general characterization of the whale migration near Cross Island in 2010. They agreed that they saw all varieties of whales and all size classes, with the smaller whales staying closer to the nearshore ice than did the larger ones. All agreed that whales in the ice were difficult to see, and all whales struck and landed were found in more open water beyond the floating ice pack. The whalers made the conscious decision to hunt in the open water since the low wind speed conditions allowed them to do so without encountering the waves and swells prevalent in open water in past years. Striking a whale near ice is risky since the whale can more easily escape by diving under ice that the boats must go around, if they can get to the other side of the ice at all. The whalers' sightings in 2010 were weighted almost completely towards the open water beyond the floating ice pack, for two reasons. First, the whalers spent most of their scouting time in the open water. Second, whales are harder to see when ice floes are present, so a smaller percentage of the whales actually present would be observed, compared to an equivalent period of scouting in open water.

With these caveats, the whalers' comments were consistent with the following generalizations about the situation in 2010. These generalizations are those of the author, and not the whalers, but are based on the author's experience at Cross Island and with his discussions with the whalers:

- The number of whales present was not perceived to be either more or less than "normal" or what would be expected. That is, there were adequate opportunities to strike and land whales.
- Whalers did not note many (and perhaps not any) large groups of whales. There were perhaps two mentions of cases where two bowheads may have appeared close together, and one report of three blows in the distance seen at the same time. There were no instances of whalers seeing "schools of whales" as has been typical of at least one day per season in other recent years. This could well have been a consequence of the presence of the floating ice, or of the limited number of days on the water in 2010.
- Whales were not noted to occur at a greater distance from Cross Island than "normal" or in other recent years. Yet, the average distance from Cross Island for whale strikes in 2010 was greater than for all but three of the previous nine documented years. This was probably due to (a) the presence of the floating pack ice out to 12 miles from Cross Island, (b) the whalers' assumption that whales in the ice would be, to all intents and purposes, not available to the whalers, and (c) the relatively calm and favorable conditions in the open-water beyond the ice. All the whale sightings whose locations were specified by the whalers were in the open water beyond the ice. The whalers did note that the smaller

whales were near the ice, and the larger whales were found in the open water. This pattern is consistent with the fact that 3 of 4 whales landed in 2010 were larger than the stated “preferred” size for whales to be taken (25 to 35 ft).

- Even in the open water areas, some whalers remarked that floating logs could have been mistaken for whales.
- At the same time, it is also likely that some possible whale sightings were not reported, especially those within the floating ice pack or near the ice edge.
- The lack of adverse weather conditions probably made the whalers less concerned with the distance of whales from Cross Island, as long as the whales were found in adequate numbers to provide an opportunity to fill the quota. This was the first season in memory where the quota was completed before Labor Day (the usual *start* date of the Cross Island whaling season).

NUIQSUT WHALERS’ REPORTS OF VESSEL ACTIVITIES, 2010

Nuiqsut whalers reported no observations of other vessels during the 2010 whaling from Cross Island. The season was the shortest so far documented by the BOEMRE-funded project, and the whalers only needed to scout for whales on three days. Although the Nuiqsut whalers retained (in 2010) their general concern about potential effects of BP’s Northstar activities on bowhead whales and whaling, no specific BP activities in 2010 elicited any expressions of concern from the whalers.

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Numerous people contributed greatly to whatever merit exists in this chapter. The cooperation and participation of the Nuiqsut whalers were indispensable for the success of this project, and I cannot thank them enough. Not only did they collectively provide all the raw data reported in this chapter, but specific crews have also served as my hosts on Cross Island for ten seasons—the Ahkiviana crew in 2002 and 2005–2007; the Napageak crew in 2004 and 2010; the Oyagak crew in 2003, 2008, and 2009; and the Kittick crew in 2001. The Nukapigak, Aqarguin, Ipalook, and Taalak crews have also been very helpful, both on Cross Island and in Nuiqsut. The AEWC and its staff have also been consistent supporters of the project. There are far too many individuals who have helped me in the last ten years to name individually, but I must single out three whaling captains who have strongly supported this research—the late Thomas Napageak Sr., Archie Ahkiviana, and Billy Oyagak. As representatives of the Nuiqsut Whaling Captains’ Association, they offered the first invitation for me to go out to Cross Island. The NWCA has, so far, renewed this invitation each year. The Bureau of Ocean Energy Management, Regulation and Enforcement (formerly Minerals Management Service), Alaska OCS Region, again provided funding for the basic 2010 research. BP 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. 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. W.J. Richardson of LGL for his inestimable help since the 2005 season and for suggestions concerning the draft, and Dr. Bill Streever of BP for his support and comments.

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