Monitoring of Industrial Sounds, Seals, and Bowhead Whales Near BP's Northstar Oil Development, Alaskan Beaufort Sea, 2005: Annual Summary Report

by

LGL

and

Greeneridge Sciences, Inc.

for

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Dept of Health, Safety & Environment

900 East Benson Blvd.

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MONITORING OF INDUSTRIAL SOUNDS, SEALS, AND BOWHEAD WHALES NEAR BP'S NORTHSTAR OIL DEVELOPMENT, ALASKAN BEAUFORT SEA, 2005: ANNUAL SUMMARY REPORT

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CHAPTER 1:
INTRODUCTION, DESCRIPTION OF BP'S ACTIVITIES, AND RECORD OF SEAL SIGHTINGS, 2005 [1]

by

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INTRODUCTION

BP Exploration (Alaska) Inc. (BP) is producing crude oil from the Northstar Unit in the Beaufort Sea, northwest of Prudhoe Bay (Fig. 1.1). Northstar is a gravel island connected to Prudhoe Bay facilities by two subsea pipelines and, seasonally, by an ice road constructed from West Dock Base of Operations. At BP's request, during 2000 the National Marine Fisheries Service (NMFS) promulgated regulations under section 101 (a) (5) of the Marine Mammal Protection Act to authorize incidental "taking" of small numbers of whales and seals as a result of Northstar activities through 25 May 2005 (NMFS 2000). In August 2004, BP requested that NMFS reissue those regulations for another 5-year period, and those regulations were renewed in March 2006 (NMFS 2006). The authorizations issued under the regulations have required monitoring studies. Several types of marine mammal and acoustic monitoring had been completed through 2004 (Richardson and Williams [eds.] 2004, 2005; Richardson [ed.] 2006).

During early 2005, those monitoring results were reviewed by the Science Advisory Committee (SAC) of the North Slope Borough, which met in Anchorage on 7 March 2005. The monitoring results through 2004 were also reviewed on 10–11 May 2005 at the meeting convened annually by NMFS to review monitoring studies in the Beaufort Sea. Based on the results up to 2004, it was concluded that the monitoring of both seals and bowhead whales could be modified in 2005, with the possibility of reinstating something similar to the previous whale monitoring program in a future year. Consistent with this recommendation, during 2005 personnel at Northstar counted seals near the island in a standardized way, underwater sounds near Northstar were monitored during the September whale-migration season, and calling bowhead whales were monitored offshore of Northstar. The acoustic and bowhead-call data were collected and analyzed in ways consistent with prior years to allow comparison of the 2005 results with the results from 2001–2004.

This report describes BP's activities during the November 2004 through October 2005 period, and it describes the results of the monitoring studies conducted during that year. Descriptions of BP's activities and the seal counts are included in this chapter. Chapter 2 provides the results of the acoustic measurements and the counts of calling bowhead whales.

The Science Advisory Committee 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." BP adopted that recommendation, and Chapter 3 of this report provides the results.

This report addresses BP's company goal of implementing studies intended to understand and minimize the environmental effects of BP operations. This report also satisfies annual reporting provisions of the Letter of Authorization issued by the National Marine Fisheries Service for incidental "taking" of whales and seals by Northstar activities.

The Science Advisory Committee and participants in the 2005 Beaufort Sea open-water meeting also recommended that various additional analyses of previous monitoring results be done. BP and its contractors agreed to this, and undertook to incorporate the results into an updated comprehensive report (UCR). This was to be a combined presentation of the monitoring results up to 2003 and those from 2004 (from Richardson and Williams [eds.] 2004, 2005), along with the additional analyses of the combined data. A draft of the UCR was completed in spring 2006 (Richardson [ed.] 2006), and further analyses of the 2001–2004 data are ongoing in summer 2006 for inclusion in a planned revision of the UCR.

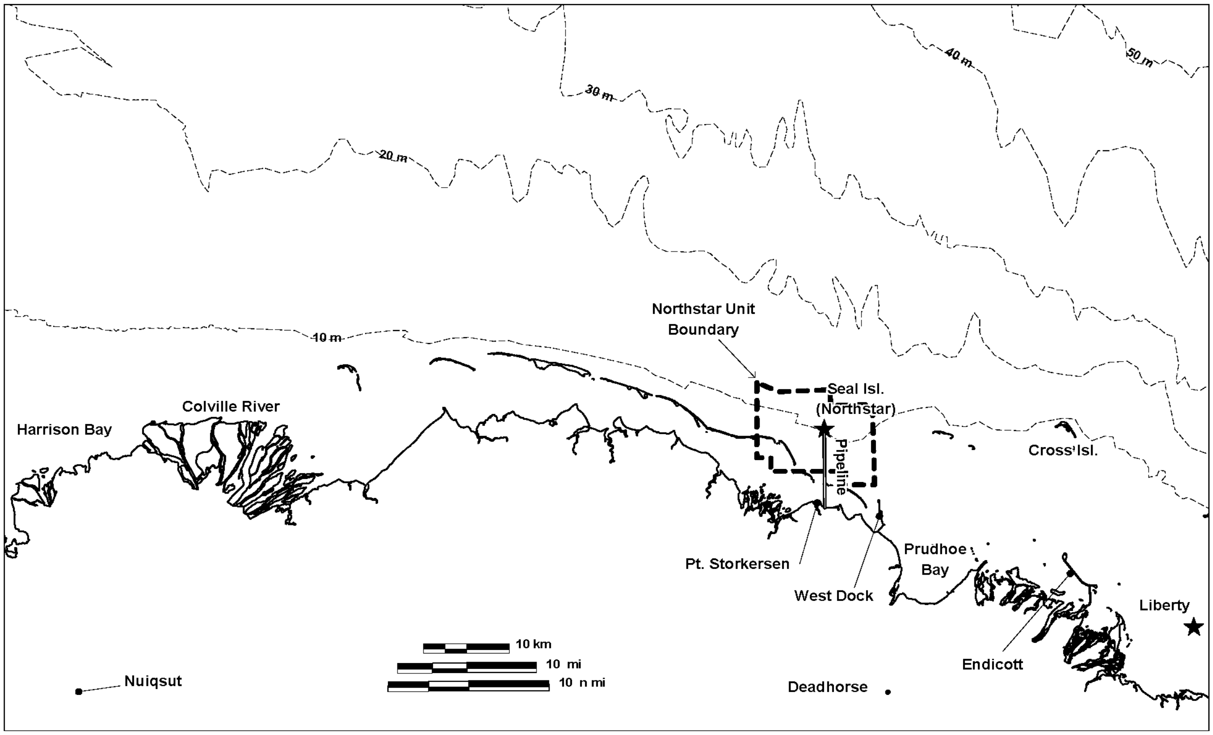

FIGURE 1.1. Location of the Northstar Development at Seal Island in the central Alaskan Beaufort Sea.

During the one year period summarized in this report, BP and its contractors also continued to work toward publication of the monitoring results in peer-reviewed journals. Four papers based on Northstar studies had been published prior to November 2004, the start of the present reporting period (Moulton et al. 2002, 2003; Blackwell et al. 2004a; Greene et al. 2004). Four more papers have subsequently been published (Blackwell et al. 2004b; Blackwell and Greene 2005, 2006a; Moulton et al. 2005). Additional papers are "in press" or "in review" by journals (Williams et al. in press; Blackwell et al. in review) or are in preparation.

BP ACTIVITIES, NOVEMBER 2004 – OCTOBER 2005

BP Activities, 2004-2005 Ice-covered Period

This section discusses BP's activities during the ice-covered period from 1 Nov. 2004 through 15 June 2005. For some activities, such as repairs to the protective barrier around the island, activities were begun during the ice-covered period but were completed during the subsequent open-water period. In that case, the discussion of the activity is in this section.

Ice Road Construction

One offshore ice road was built during the 2004–2005 ice-covered season. As during previous years, this ice road was built to transport personnel, equipment, materials, and supplies between the Prudhoe Bay facilities and Northstar Island. The ~12 km (7.4 mi) offshore ice road was built between West Dock and Northstar. Ice road construction began on 29 Nov. 2004 and was completed on 20 Dec. 2004. The ice road was used from 20 Dec. 2004 until it was officially closed on 21 May 2005.

Transportation To and From Northstar Island

Two Bell 212 ***helicopters*** were used to transport crew and materials to and from Northstar during the early and late parts of the ice-covered season of 2004–2005, when ice conditions prevented or limited on-ice transportation. Helicopters operated from Nov. 2004 to Feb. 2005 but not during March through May 2005. Helicopter use resumed during June 2005. The helicopters made 118 round trips to Northstar Island during the 2004–2005 ice-covered period (Table 1.1).

TABLE 1.1. Number of Bell 212 helicopter round trips to Northstar Island by month during the 2004–2005 ice-covered period.

Month	Helicopter Round Trips
November 2004	48
December 2004	19
January 2005	16
February 2005	5
March 2005	0
April 2005	0
May 2005	0
1-15 June 2005	30

During regular helicopter operations, recommended flight corridors and altitude restrictions were maintained, as in previous seasons (see Fig. 2.4 *in* Williams and Rodrigues 2004). For visual flight rule (VFR) conditions, standard flight altitude was 1500 ft (460 m), 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.

The helicopter routes were negotiated among the U.S. Fish and Wildlife Service (USFWS), NMFS, and BP to minimize impacts to waterfowl and marine mammals. The LoA issued by NMFS stated that helicopter flights to support Northstar operations must be limited to a corridor from Northstar Island to the mainland and, except when taking off, landing or limited by weather, must maintain a minimum altitude of 1000 ft (305 m). During poor weather or emergency conditions, pilots followed Federal Aviation Administration (FAA) altitude regulations and BP safety policy.

Hägglunds ***tracked vehicles*** were used to transport personnel and materials during Dec. 2004 and Jan. 2005. During that period, Hägglunds vehicles made 25 round trips to Northstar. A Mat Trak and a Tucker tracked vehicle each made two round trips, one in Dec. 2004 and one in Jan. 2005. ***Standard vehicles***, including vans, pick-ups, and buses, were the main method of transportation for Northstar personnel from 20 Dec. 2004 to 21 May 2005.

A ***Griffon 2000 TD Hovercraft*** was also used to transport personnel during the ice-covered period. The hovercraft was capable of carrying a payload of 2268 kg. The hovercraft was powered by a 355 hp air-cooled Deutz diesel engine and was 11.9 m (39 ft) in length (2004; Blackwell and Greene 2005, 2006b). The hovercraft was active from Nov. 2004 to Jan. 2005 but not from Feb. through April 2005. Hovercraft activity resumed in May and continued to the end of the ice-covered period and into the open-water period 2005. During the 2004–2005 ice-covered period, the hovercraft made 180 round trips to Northstar (Table 1.2).

TABLE 1.2. Number of hovercraft round trips to Northstar Island by month during the 2004-2005 ice-covered period.

Month	Hovercraft Round Trips
November 2004	22
December 2004	61
January 2005	37
February 2005	0
March 2005	0
April 2005	0
May 2005	14
1-15 June 2005	46

Chronology of Island Activities

Oil production at Northstar began on 31 Oct. 2001 and occurred almost continuously from then throughout the present reporting period. During the 2004–2005 ice-covered season, there was no impact pile driving or other activity that might have exposed seals to received levels of underwater sound exceeding 190 dB re 1 μPa (rms).

Power generation and compressor equipment on the island was unchanged from previous reporting periods. Solar® gas turbines powered generators that 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. Three gas-turbine-powered high-pressure compressors (model GE LM-2500) were also on the island. Two of the gas-turbine generators were in use at any one time for gas injection into the formations.

Drilling had been suspended through the 2004 open-water season, but resumed in Jan. 2005. Drilling activity, including rig set-up and break-down, occurred from 9 Jan. to 14 May 2005.

Maintenance activities to repair the block system and fabric barrier began on 28 May and were completed during the subsequent open-water period on 26 June 2005. Divers were used for underwater work throughout the duration of the procedure. Initial repair activities included melting ice using high pressure washers and a hot water sled. Blocks were removed and sandbags were positioned in areas where gravel had been washed away. A new fabric barrier was placed over the sandbags and the blocks were replaced and shackled together. Equipment used included a Manitowoc 888 crane, Volvo 150D loader, John Deere 650H excavator, Ingersoll-Rand zoom-boom, air compressors, Chinook 800 and Tioga heaters, and generators. A hot oil unit composed of 2 pumps and 3 holding tanks with a total capacity of 135 gallons was used to heat fluids.

Various test, training, and inspection activities occurred in the area intermittently through the winter and spring. No oil spill exercises were conducted on floating ice during the 2004–2005 ice-covered season. Training sessions for the Spill Response Team were given every Monday evening. The Fire Brigade underwent weekly training on Saturday evenings.

Six to 7 aerial surveys per month were conducted to inspect the pipeline. These surveys were done by twin-engine fixed-wing aircraft, either a Twin Otter (DHC-6) or a CASA 212 backup aircraft. No reportable conditions were recorded during the surveys.

There were 8 reportable Northstar-related spills during the 2004–2005 ice-covered season. Material spilled included methanol, corrosion inhibitor, diesel fuel, oxygen scavenger, and propylene glycol. Almost all of this material remained in containment and was recovered. Corrosion inhibitor was the only spilled material that was not contained. Non-contained corrosion inhibitor included 0.50, 0.50 and 0.10 gallons spilled on 21 Jan., 14 April, and 4 June 2005, respectively. All material spilled during this ice-covered season was cleaned up; none entered the water. No clean-up activity was necessary after Northstar flare events during the reporting period.

Equipment Used, 2004–2005

Transportation.—Two Bell 212 helicopters were used to transport crew and materials to and from Northstar. These are medium-sized helicopters (see Fig. 2.3 *in* Williams and Rodrigues 2004), each with two turboshaft engines, a 2-bladed main rotor, and a 2-bladed tail rotor.

Hägglunds tracked vehicles (model 206 SUSV; see Fig. 2.1 in Williams and Rodrigues 2004) were used to transport personnel and materials between West Dock and Northstar Island. Average transport speeds were typically 8–16 km/h (5–10 mph). The maximum allowable payloads are 380 kg (838 lbs) for the 4-person front car and 1250 kg (2756 lbs) for the 8-person personnel carrier. A Tucker tracked vehicle and a Mattrak also made occasional round trips to Northstar Island.

Busses, pick-ups, and vans were used for transportation of personnel over the ice road to Northstar Island from 20 Dec. 2004 to 21 May 2005.

A Griffon 2000TD hovercraft was used to transport personnel and cargo prior to the beginning of the 2004–2005 ice-covered period and hovercraft use continued into Jan. 2005. Hovercraft use was suspended during Feb. through April and resumed during May–June and into the 2005 open-water period.

Emergency Escape Exercises.—Two articulated ARKTOS evacuation craft are available as the island emergency escape vehicles. Each ARKTOS evacuation craft is 15 m (50 ft) long and 3.9 m (13 ft) high with a beam of 3.8 m (12 ft 9 in) (Fig. 2.15 *in* Williams and Rodrigues 2004). The maximum speed is 16 km/h (10 mph) on land or ice, and 11.1 km/h (6 knots) in water. Each ARKTOS is capable of carrying 52 people, 24 in the front section and 28 in the rear section. The ARKTOS evacuation craft were not used during the reporting period.

Ice Road Construction.—Bluebird rolligon-type pumpers (Fig. 2.2 *in* Williams and Rodrigues 2004) were used for ice-road flooding.

Power Generation and Gas Injection.—Five gas turbines are located at Northstar Island: three Solar® generators for power generation, and two GE LM-2500 high pressure compressors for gas injection. Each Solar® generator is a 13,000 hp (9700 kW) gas turbine, rated at 10,780 rpm and operating at 9500 rpm. Each high pressure compressor is a 30,000 hp (22,370 kW) gas turbine, rated at 10,000 rpm and running at 9000–9400 rpm; speed varied with the gas injection rate. There is also a low-pressure compressor driven by a 5000 hp (3730 kW) electric motor running at a constant speed of 3600 rpm.

BP Activities, 2005 Open Water Period

Transportation to and From Northstar Island

As during previous years and during the previous ice-covered period, Bell 212 ***helicopters*** were used to transport personnel and freight to and from Northstar Island during the 2005 open-water period. Helicopters made 103 round-trips from Deadhorse to Northstar during the period (Table 1.3). Helicopter use increased in October when freeze-up impaired use of barges and overcraft use declined.

TABLE 1.3. Number of Bell 212 helicopter round trips to Northstar Island by month during the 2005 open-water period.

Month	Helicopter Round Trips
16-30 June 2005	11
July 2005	12
August 2005	1
September 2005	9
October 2005	70

The ***hovercraft*** used during the ice-covered period was also used to transport personnel and freight during the 2005 open-water period. The hovercraft made 188 round trips from West Dock to Northstar during the 2005 open-water period (Table 1.4).

TABLE 1.4. Number of hovercraft round trips to Northstar Island by month during the 2005 open-water period.

Month	Hovercraft Round Trips
16-30 June 2005	38
July 2005	37
August 2005	45
September 2005	41
October 2005	27

Tug and barge activity to supply Northstar during the 2005 open-water period began on 27 July and the last trip occurred on 2 Oct. A total of 21 tug and barge trips was made to Northstar during the 2005 open-water period (Table 1.5).

TABLE 1.5. Number of tug and barge round trips to Northstar Island by month during the 2005 open-water period.

Month	Tug and Barge Round Trips
16-30 June 2005	0
July 2005	3
August 2005	10
September 2005	7
October 2005	1

Alaska Clean Seas (ACS) ***Bay-class boats*** made 14 trips to Northstar during the 2005 open-water period to transport personnel to and from the island. These 14 trips included 2 in Aug., 10 in Sept., and 2 in Oct. There were 5 additional trips by *Bay*-class boats in association with acoustic monitoring of the bowhead whale migration (see "Sound Measurements and Acoustic Monitoring" on p. 1-9).

Activities On and Near Northstar

Production Facilities.—Solar® generators, a diesel generator, high-pressure compressors, crude stabilizer pumps, and water injection pumps used during the previous ice-covered period remained in use during the open-water period.

Other On-Island Equipment.—A number of pieces of equipment were used on Northstar Island during the open-water period. A Manitowoc 888 crane, Polaris 6-wheeler, and compactors received occasional use, and a Caterpillar 966 loader, Volvo 150 front-end loader, Volvo A30 end dump, mechanic box truck, mobile aerial lifting platform, and light plants received intermittent use.

Drilling and Support.—No new wells were drilled during the reporting period. Well maintenance work was done using cables to lower equipment into existing wells.

Oil Spill Response Team Training Activities.—Offshore oil spill response training activities occurred on 19 and 26 Sept. Two 24 ft aluminum boats (*Irene* and *Kiwi*) were used to conduct these activities.

Emergency Evacuation Exercises.—The ARKTOS emergency evacuation vehicle was serviced and used during training activities during the 18 to 24 Aug. period. These activities occurred both on the island and in adjacent marine waters.

Oil Spill Inspections.—Aerial surveys to inspect the pipeline for leaks or spills were continued during the 2005 open-water period. Five to 7 surveys of the pipeline corridor were flown each month during the reporting period. No reportable conditions were recorded during the surveys.

Reportable Spills.—Five reportable spills occurred during the 2005 open-water period. Spilled material included lubricants, diesel, crude oil, produced water, and corrosion inhibitor (Table 1.6). No spilled material entered the water, and all spilled material was cleaned up.

TABLE 1.6. Reportable spills during the 2005 open-water season: dates, spilled material, and gallons in and out of containment.

Date	Description/Source	Gal. Out of Containment	Gal. In Containment
16 June	Lube oil from compressor seal leak	0.1	0.9
21 June	Hydraulic fluid from excavator fitting	1.5	0
4 Sept.	Diesel from TEG reboiler	0.5	0
6 Sept.	Crude and produced water from test header valve	1.0	0
25 Sept.	Corrosion inhibitor inside plant	0.0	0.06

Construction and Maintenance Activities

Maintenance activities to repair the island barrier were completed during the current open-water period. These activities were begun during the previous ice-covered period as described above.

Sound Measurements and Acoustic Monitoring

Boat-based work in support of acoustic monitoring of bowhead whale migration was done by Greeneridge Sciences on five dates from late Aug. to early Oct. 2005. A *Bay*-class boat was used to deploy 3 Directional Autonomous Seafloor Acoustic Recorders (DASARs) 390–520 m north of Northstar on **30 Aug**., and the vessel then did a reconnaissance farther offshore. On **4 Sept**., after ice moved away, 4 DASARs were deployed 9–15 km northeast of Northstar Island (Chapter 2). The DASARs were calibrated during the 4 Sept. deployment trip, and again during a third vessel trip on **25 Sept**. On **2 Oct**., the vessel traveled offshore in an attempt to retrieve the DASARs but could not do so because of poor weather and sea conditions. All DASARs were retrieved during the fifth vessel trip on **3 Oct**. In addition, open-water recordings were made at several locations up to ~8 n.mi. north of Northstar Island on 4 Sept. and 3 Oct. 2005. Chapter 2 describes the acoustic methods and results.

Non-Northstar Related Research

The U.S. Fish and Wildlife Service conducted low-level, aerial surveys for polar bears along the coast and barrier islands from Barrow to the Canadian border during the late fall using a turbine twin-engine Aero Commander aircraft. The surveys were flown on 13–14 and 21–22 Sept. and on 5–6 and 17–18 Oct. 2005. During each 2-day survey, the aircraft passed briefly through the Northstar area. The Minerals Management Service conducted its usual Bowhead Whale Aerial Survey Program (BWASP) during the bowhead migration season (Dr. C. Monnett, MMS, pers. comm.).

MMS also funded boat-based surveys to collect water, sediment, tissue, and plankton samples for physical and chemical analyses. This work occurred at various locations from the Northstar area east to Barter Island (Hardin 2005). The surveys were conducted from 26 July to 14 August 2005. Sampling in the Northstar area was conducted on 4, 10, and 11 August.

Additional research activities may also have occurred in the area.

OBSERVED SEALS

This section summarizes Northstar seal sightings for both the ice-covered and open-water periods covered by this report. Observations to detect seals were made from the roof of the process module on Northstar Island on 56 days from 3 June to 22 Aug. 2005. These observations were done by Northstar Environmental Specialists on behalf of BP. The surveyed area included a 950 m strip around the entire perimeter of the island, centered on the process module. An inclinometer was used to determine the edge of the search area. Observers were able to scan a 360° field of view covering an area of ~695 acres (281 ha). Initial observations of the 950-m strip around the island were made visually without the use of binoculars. Observers then used 10 × 42 binoculars to confirm suspected seal sightings. Most of the habitat around Northstar remained frozen prior to 27 June and ringed seals were observed basking at breathing holes in the ice. After 27 June, extensive cracks appeared as grounded ice began to thaw. No continuous ice sheet was present after mid-July although large ice flows, on which seals were occasionally observed, moved through the area.

No more than 4 seals were observed during any survey early during the period, when seal habitat remained frozen (Table 1.7). Larger numbers of seals were reported during break-up when seals were observed basking on passing ice floes. During break-up, the highest counts were 17, 30, and 124 seals observed on 8, 10, and 11 July, respectively. No seals were observed from Northstar after 15 July. All identified seals were ringed seals.

TABLE 1.7. Ringed seal counts from Northstar during 3 June through 22 August 2005. Sky codes are as follows: OO = Overcast, PS= Partly sunny, PC= Partly cloudy, CC = Clear. Data provided by Northstar Environmental Specialists on behalf of BP

Date	Local Time	Sky	Temp (°F)	Number	Comments
6/3/2005	11:30	OO	32	2	NW and W of Island
6/4/2005	11:00	P S	33	2	NE and W of Island
6/5/2005	13:00	P S	32	3	NW, NE, and W of Island
6/6/2005	11:30	OO	28	3	NW, NE, and W of Island
6/7/2005	13:30	P S	34	3	NW, NE, and W of Island
6/8/2005					
6/9/2005	12:05	P S	40	4	2 on NE (1 in Construction Moat); 2 on NW
6/10/2005	12:00	OO	34	3	1 on NE, 2 on NW
6/11/2005	12:30	OO	35	3	1 on NE, 2 on NW (Same places as prior days)
6/12/2005	12:15	OO	33	3	1 on NE, 2 on NW (Same places as prior days)
6/13/2005	13:00	OO	35	3	1 on NE (Same place as prior days)
6/14/2005	13:00	OO (FOG)	36	2	1 on NE, 1 on NW
6/15/2005	13:30	C C	35	2	1 on NE, 1 on NW
6/16/2005	13:00	OO	35	1	1 on NW
6/17/2005	13:30	C C	36	2	1 on NE, 1 on NW
6/18/2005	13:45	C C	35	2	1 on NE, 1 on NW
6/19/2005	12:45	OO	34	2	1 on SW approx. 100'; small pup. Raises head when hovercraft passes but then back to normal basking. 1 on NW side
6/20/2005	13:30	C C	36	1	1 Pup on SW
6/21/2005	13:00	OO	38	0	
6/22/2005	13:45	OO	31	2	1 Pup on SW. 1 on SE
6/23/2005	12:30	OO (FOG)	32	4	1 Pup on SW. 1 on SE. 1 on W. 1 on NW
6/24/2005	13:30	C C	36	2	1 Pup on SW. 1 on SE
6/25/2005	13:30	C C	36	1	1 Pup on SW
6/26/2005	13:30	OO	38	1	Ceiling<300',1 Pup on SW
6/27/2005	13:30	C C	43	0	
6/28/2005	13:30	C C	47	0	
6/29/2005	13:00	C C	46	0	
6/30/2005	13:20	OO	44	0	
7/1/2005	13:30	C C	48	0	

TABLE 1.7 (continued).

Date	Local Time	Sky	Temp (°F)	Number	Comments
7/2/2005	13:50	O O	35	2	Rain & light snow today. Small area of open water S of the island; seals were observed swimming.
7/3/2005	13:50	O O	32	2	Small area of open water S of the island; seals were observed swimming.
7/4/2005	13:30	O O	35	0	Rain
7/5/2005	13:40	O O	41	0	Rain
7/6/2005	13:30	O O	33	0	Thick Fog, Low Ceiling (<300') During Observation
7/7/2005	13:30	C C	38	0	
7/8/2005	14:30	O O	34	17	10 sighted basking on an ice flow passing on the NE; 7 sighted basking on an ice flow passing on the SW. Winds blowing from W @ 17 - 25 mph; lots of moving ice.
7/9/2005	13:00	O O	35	0	
7/10/2005	12:30	O O	37	30	30 sighted basking on an ice flow passing on the S/W. Ice has been flowing back and forth all day.
7/11/2005	12:30	O O	38	124	40 sighted basking on an ice flow passing on the East, 6 sighted basking on an ice flow passing on the North, 40 sighted basking on an ice flow passing on the West, 38 sighted basking on an ice flow passing on the S/W. The ice was flowing past in large chunks all day.
7/12/2005	12:30	O O	38	0	
7/13/2005	13:30	C C	39	2	S/E on ice flow basking
7/14/2005	13:00	O O	41	0	
7/15/2005	14:00	O O	41	1	Swimming south of the island
7/16/2005	1330	OO	37	0	
7/17/2005	1330	OO	35	0	Mostly open water with small ice chunks floating by
7/18/2005	1400	OO	38	0	Mostly open water with small ice chunks floating by
7/19/2005	1330	CC	32	0	Mostly open water with small ice chunks floating by
7/20/3005	1200	CC	38	0	

TABLE 1.7 (continued).

Date	Local Time	Sky	Temp (°F)	Number	Comments
7/30/2005	1500	OO	41	0	Mostly open water with small ice chunks floating by
8/1/2005	1230	PC	40	0	Mostly open water with small ice chunks floating by
8/5/2005	0900	OO	45	0	Open water
8/9/2005	1000	PC	55	0	Open water
8/13/2005	1300	OO	55	0	Mostly open water with small ice chunks floating by
8/16/2005	1300	OO	37	0	Mostly open water with small ice chunks floating by
8/18/2005	1500	OO	41	0	Open water
8/19/2005	0800	OO	33	0	Open water
8/22/2005	1000	OO	41	0	Open water

Only one potential seal response to Northstar activity was noted. On 19 June, a seal pup raised its head as the hovercraft traveled past at an unspecified distance and then returned to its normal basking position. Whether the seal was responding to the hovercraft or to some other stimulus is unknown.

Although no systematic studies of seals were conducted during this reporting period, there was no evidence, and no reason to suspect, that any seals were killed or seriously injured by Northstar-related activities during the winter of 2004–2005 or during the 2005 open-water period. During this time there was no impact pile driving or similarly noisy activity that could have exposed any marine mammals to underwater received levels ≥180 or 190 dB re 1 μPa (rms). There were no spills of liquid hydrocarbons that reached the water under the sea ice.

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CHAPTER 2:

ACOUSTIC MONITORING OF BOWHEAD WHALE MIGRATION, AUTUMN 2005 [1]

by

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ABSTRACT

During the bowhead whale migration in Sept. 2005, Greeneridge Sciences (on behalf of BP) implemented an acoustic monitoring program north-northeast of BP's Northstar oil development. Monitoring objectives in 2005 were modified relative to those in previous years, given that 2001–2004 results had suggested that the bowhead migration corridor offshore of Northstar likely was not strongly affected by varying activities at Northstar. In addition, the North Slope Borough's Science Advisory Committee (SAC) concurred that priority be put on additional analyses of the 2001–2004 data over additional data collection. The primary objectives in 2005 were two-fold: (1) Monitor sounds produced by Northstar and its associated vessels, and compare the levels and frequencies to those in previous years (2001–2004). (2) Count whale calls at one of ten locations ("EB") that have been used in previous years, and then compare the count with counts at the same location in previous years. The 2005 monitoring program was designed to detect significant changes in sounds produced by Northstar or in number of whales (as indicated by their calls) migrating along the southern part of the bowhead migration corridor.

Based on initial evidence that call counts were lower in 2005 than in prior years, data from backup instruments were analyzed to verify the initial results and to address expanded objectives. We compared call counts and call types as recorded in 2005 at three locations with corresponding data from the same sites in previous years. Also, we compared bearings to calls in 2005 vs. previous years.

On 4 September 2005, four DASARs (Directional Autonomous Seafloor Acoustic Recorders) were deployed at locations 9.3–15 km (5.8–9.3 mi) offshore of Northstar Island. These instruments recorded low-frequency sounds continuously for ~28 days. Simultaneously, near-island recordings were obtained from three DASARs placed 390–520 m (1280–1700 ft) from Northstar over ~33 days (30 Aug. to 3 Oct. 2005). The sounds received in 2005 by one of the near-island DASARs were analyzed as broadband signals (10–450 Hz) and as one-third octave and narrowband levels. Median broadband levels were higher than in previous years, most likely because mean hourly wind speed at Northstar during the 2005 field season was 24–113% higher than in 2001–2004. Vessel traffic to and from Northstar in 2005 was about the same as in 2004, but reduced compared to 2001–2003. Overall, industrial sounds from Northstar were about the same as in previous years, except for the reduced frequency of transient high-level sounds associated with boats.

In total, 1566 bowhead whale calls were recorded in ~28 days at DASAR locations EB, CC, and WB (or 54 calls per day of monitoring). This compares to 2927 calls in 2001 (124/day), 5216 calls in 2002 (226/day), 29,714 calls in 2003 (991/day), and 38,353 in 2004 (1344/day), based on data from the same three sites each year. The maximum call detection rate in 2005 was low, 112 calls per hour. Over 50% of the recorded calls occurred in mid-September (13–16 Sept.). The low call counts in 2005 might have been related to (1) the possibility that the main part of the bowhead migration corridor was farther offshore than in 2003 and 2004, and to (2) higher mean wind speeds in 2005. Higher wind speeds lead to higher ambient sound levels, which cause more calls to be masked (undetectable). High background noise levels also made identification and classification of calls more difficult than in previous years.

A comparison of bearings from DASAR EB in 2001–2005 showed that, in 2005, a higher proportion of the detected calls were inshore (vs. offshore) than in previous years. This result, combined with observations by Nuiqsut whalers, suggests that ice a few miles north of Northstar may have led a few whales to travel south of the ice (and through the DASAR array) while most whales traveled north of it, many of them beyond acoustic range. Higher background noise levels in 2005 appear to have reduced the effective monitoring radius and number of calls detected by the DASARs as compared to previous years.

INTRODUCTION

This chapter is a report on the acoustic monitoring of the bowhead whale migration near the Northstar development during the early autumn of 2005. Since 2000, the autumn migration of the bowhead whale has been monitored acoustically north of Northstar Island for a nominal 30 days during the month of September. Every year since 2001, continuous underwater recordings were obtained close to Northstar Island to determine the levels and frequency composition of sounds produced by the island itself and associated vessels. In 2000 to 2004, whale calls were monitored continuously by an array of Directional Autonomous Seafloor Acoustic Recorders (DASARs), deployed 6.5–21.5 km (4–13.4 mi) NNE of Northstar. After retrieval of the instrumentation, the whale calls recorded by the DASARs were localized by triangulation. The key objective of the monitoring in 2001–2004 was to estimate the offshore displacement of the southern edge of the bowhead migration corridor, if any, at times when higher-than-average levels of underwater sound were being emitted from Northstar Island and its associated vessels. We used quantile regression to compare the locations of whale calls after nominal (15–120 min) periods with low to high average ISI levels and when tones or transient sounds were present (see McDonald et al. 2006). Overall, the apparent southern (proximal) "edge" of the corridor was significantly ($P < 0.01$) associated with industrial sound output each year. The best estimates of the offshore deflection at times with high Northstar sound ranged from a low of 0.66 km (0.41 mi) in 2003 to a high of 2.24 km (1.39 mi) in 2004.

Based on the results achieved in 2001–2004[2], BP, the Science Advisory Committee (SAC) appointed by the North Slope Borough to review the work, and the team of scientists conducting the study concluded that monitoring as carried out in 2001–2004 did not need to be repeated every year. The 2005 effort described in this report is therefore a modified effort compared to the efforts in 2001–2004. Results from 2001–2004 are summarized in Greene et al. (2002, 2003a), and Blackwell et al. (2004, 2005). The methodology is described in Greene et al. (2003b, 2004).

BP's business rationale for the overall monitoring project, and for the specific bowhead monitoring task, was driven both by corporate policies and by regulatory requirements. BP corporate policies support studies that objectively assess environmental effects that may result from BP operations. In addition, monitoring the autumn migration of bowhead whales past Northstar was required, during the open-water season of 2005, to satisfy (a) provisions of the North Slope Borough zoning ordinance for Northstar, and (b) the monitoring requirements of a Letter of Authorization issued by NMFS to BP on 6 Dec. 2004 (NMFS 2004).

The specific objectives in 2005 were as follows:

(1) to measure near-island sounds about 450 m (1476 ft) north of Northstar using DASARs (one primary DASAR whose data were to be analyzed plus two spares for backup), and to compare the amplitude and frequency composition of the sounds with similar data collected in previous years;

(2) to install a small array of DASARs in three of the locations used in previous years (see below), analyze the data from one of these units to count whale calls as in previous years, and compare the whale counts at the chosen DASAR with whale counts obtained at the same location in 2001–2004.

Objective (1) provides an impartial record of the underwater sounds near the Northstar operation, which can be compared to equivalent records from previous years. For example, these data allow us to

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[2] Due to technical difficulties with the DASARs in 2000, the 2000 data set was incomplete and could not be used for a full scale analysis of the effects of Northstar on the bowhead whale migration.

detect changes in the frequency composition or received level of sounds produced by Northstar, compared to previous years. Objective (2) provides a means of identifying any unusual trends in the 2005 bowhead whale migration as compared to the previous four years. The project design and objectives for 2005 were approved by the SAC. A preliminary summary of the results was provided to the NSB and NMFS in January 2006 (Annex 2.1), and this report provides more details.

After the end of the 2005 field season, one DASAR ("EB", see below) was selected for analysis and the whale calls it detected were counted and classified. However, the number of calls detected by this DASAR was lower than call counts at the same location in previous years (2001–2004). BP requested ***additional analyses of the recordings from all DASARs deployed offshore in 2005***. The additional analyses, whose results are included in this chapter, added three main objectives to the two original objectives listed above:

(3) obtain whale call counts from all four DASARs deployed offshore in 2005, to determine whether the initial call count at one DASAR was representative;

(4) obtain bearings to whale calls and localization of calls, if possible. A comparison of the bearings or locations obtained in 2005 with those obtained in previous years should provide information on the distribution of the calling whales, i.e., the proportion of calls originating offshore vs. inshore of the locations of the DASARs deployed in 2005;

(5) compare the types of calls recorded at the DASAR locations used in 2005 with the call types recorded at the same locations in previous years.

METHODS

Summary of Methodology in 2001–2004 and Differences in 2005

Directional sensors from DIFAR (Directional Frequency and Recording) sonobuoys were used, along with digital recording equipment and batteries, to construct Directional Autonomous Seafloor Acoustic Recorders (DASARs). For a complete description, see Greene et al. (2004). The DIFAR sensor includes a compass, two horizontal orthogonal directional sensors, and an omnidirectional pressure sensor to sense an acoustic field. DASARs record at a sampling rate of 1 kHz onto a 25.38-GB disk drive. This allows for continuous sampling for up to 45 days and spans an acoustic range up to 500 Hz, adequate for bowhead vocalizations.

In ***2001–2004***, DASARs were deployed at 10 locations 6.5–21.5 km (4–13.4 mi) NNE of Northstar (see Fig. 2.1, filled triangles and open diamonds). The DASARs recorded continuously for the entire field season, usually late Aug./early Sept. until late Sept./early October (range 24 to 35 days). Whale calls were tallied on all DASAR records. When a whale call was recorded by two or more DASARs, a position for the calling whale was obtained by triangulation, using the DASAR bearing information.

A continuous record of sounds from Northstar Island and its attending vessels was also obtained by deploying several redundant recorders (either cabled hydrophones, ASARs[3] or DASARs) ~450 m (1476 ft) north of the island's north shore (see Fig. 2.1, open triangle). One minute of data was used every 4.37 min (or ~330 times per 24-h day) to calculate an Industrial Sound Index (ISI). The ISI was determined from the

[3] ASAR = Autonomous Seafloor Acoustic Recorder. These recorders are described in Greene et al. (1997) and Blackwell and Greene (2002). They include an omnidirectional hydrophone and do not have the directional capabilities of the DASARs.

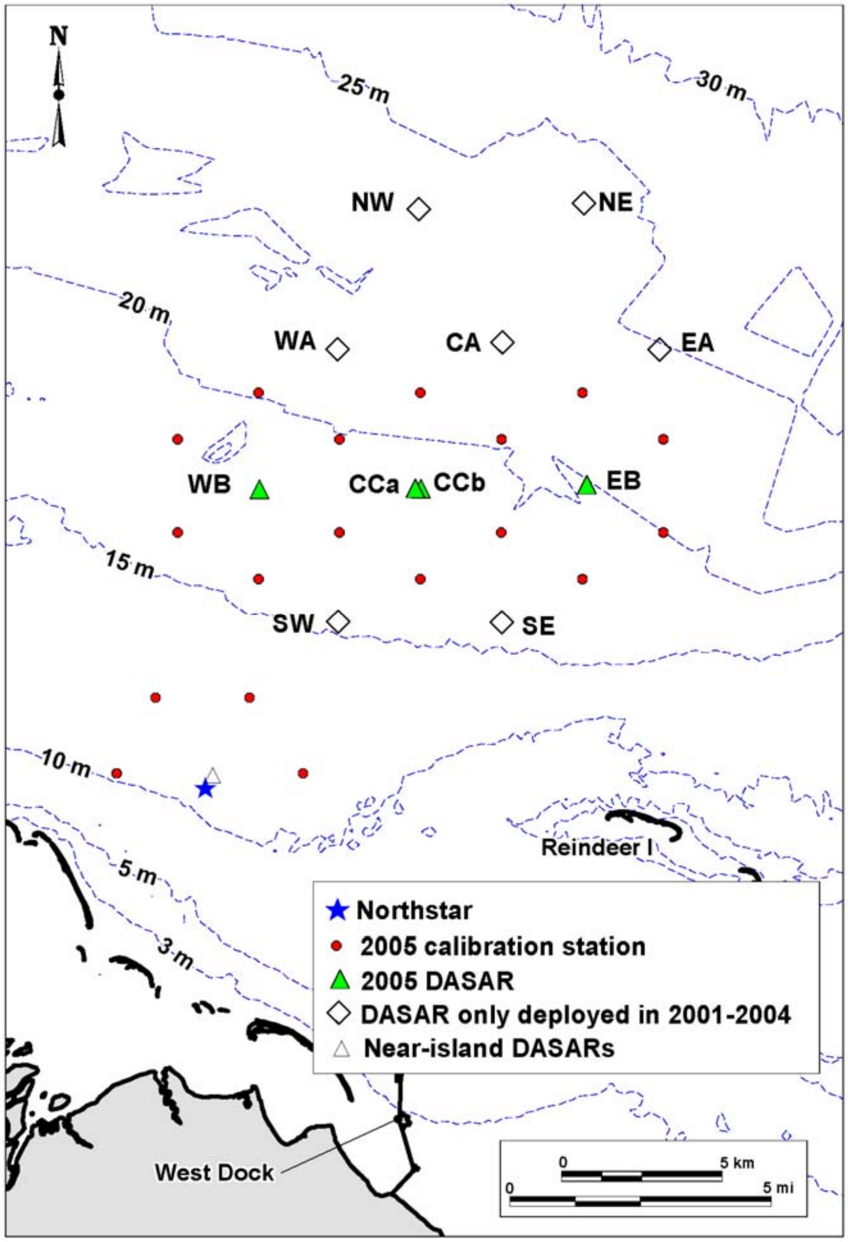

FIGURE 2.1. Locations of four array DASARs, 18 calibration stations, and three near-island DASARs (see Fig. 2.2) with respect to Northstar Island, Sept. 2005. DASARs were deployed at locations WB, CCa, CCb, and EB (green triangles) in 2005. The remaining DASAR locations (empty diamonds) were only used in 2001–2004.

sum of the mean-square sound pressures in the five one-third octave bands centered at 31.5, 40, 50, 63, and 80 Hz, i.e., including frequencies from 28 to 90 Hz. These five one-third octave bands were shown to contain most of the industrial sound energy emanating from Northstar.

2005 Field Deployments

The near-island sound monitoring in 2005 was identical to that in previous years. However, the array of DASARs that was deployed farther offshore was changed from 10 or 11 recorders at 10 locations to 4 recorders at 3 locations (see below).

On 30 Aug. 2005 an attempt was made to deploy DASARs from the ACS vessel *Harrison Bay*. There was dense pack ice about 2 n.mi. north of Northstar and consequently we were not able to reach the area where the array of DASARs had been deployed in prior years. The three near-island DASARs (NSa, NSb, and NSc) were deployed ~390 m, 410 m, and 520 m (1280–1706 ft) north of Northstar's north shore (Fig. 2.1, Fig. 2.2). Water depth was about 13 m. NSa and NSb were 136 m apart; NSb and NSc were 225 m apart (see Fig. 2.2). They started recording at ~21:00 local daylight time on 30 Aug. 2005 (Table 2.1).

On 4 Sept., another attempt was made at deploying four DASARs at offshore locations where DASARs had been deployed in prior years. The pack ice was still present north of Northstar but it had moved northward by a few miles and its southern edge had loosened up. The DASARs were deployed at locations WB, CC (2 DASARs, CCa and CCb) and EB, at distances 9.3–15 km (5.8–9.3 mi) NNE of Northstar Island (Fig. 2.1). These DASARs started recording at ~10:00 local time on 4 Sept. (Table 2.1).

After DASAR deployments on both 30 Aug. and 4 Sept., an acoustic transponder in each DASAR was interrogated to confirm that each DASAR was operating nominally. All seven DASARs recorded continuously at a 1 kHz sampling rate (10–500 Hz bandwidth) until they were retrieved on 3 Oct. 2005.

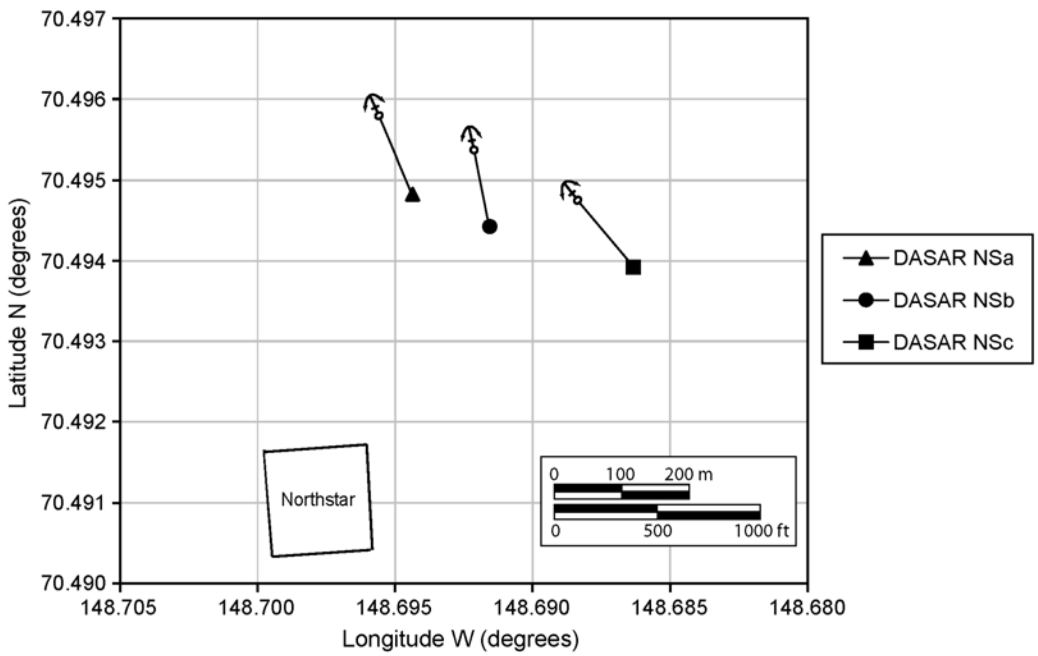

FIGURE 2.2. Deployment locations of DASARs (filled symbols) and their anchors near Northstar Island in 2005. All three DASARs were deployed on 30 Aug., retrieved on 3 Oct., and functioned throughout their deployment period.

TABLE 2.1. DASAR locations in 2005, with installation date and time, start and end of data collection, position, and water depth. All times are local Alaska Daylight Saving times. The "Data End" time is the last stable compass reading prior to recovery, while the DASAR was still sitting on the sea floor. DASAR units 1–4 were installed in the array; units 5, 6 and 8 were deployed close to Northstar (NS).

Location	Unit #	Installed (Date; Local Time)	Data Start	Data End	Latitude (deg N)	Longitude (deg W)	Depth (m)
WB	2	4 Sep 2005 9:25	4 Sep 2005 10:00:17	3 Oct 2005 11:15	70.574	148.659	19.5
CCa	1	4 Sep 2005 8:05	4 Sep 2005 10:00:24	3 Oct 2005 9:55	70.576	148.525	20.1
CCb	3	4 Sep 2005 9:00	4 Sep 2005 10:00:26	3 Oct 2005 10:40	70.576	148.530	20.1
EB	4	4 Sep 2005 8:30	4 Sep 2005 10:00:17	3 Oct 2005 9:20	70.578	148.387	23.2
NSa	5	30 Aug 2005 16:50	30 Aug 2005 21:00:21	3 Oct 2005 15:07	70.495	148.694	13.1
NSb	6	30 Aug 2005 16:57	30 Aug 2005 21:00:28	3 Oct 2005 15:27	70.494	148.692	13.1
NSc	8	30 Aug 2005 17:05	30 Aug 2005 21:00:24	3 Oct 2005 15:50	70.494	148.686	13.1

Calibration of the DASAR Clocks

Each DASAR contains a magnetic compass and clock. However, to provide greater precision in times (and bearings if used), the DASAR clocks and orientations were calibrated by projecting test sounds at known locations (Fig. 2.1) and known times, and receiving these sounds via the DASARs. These acoustic transmissions allow us to correct for slight drift in the clock built into each DASAR (Greene et al. 2003b, 2004). It is important to characterize and correct for this drift in order to obtain the correct times of the whale calls. (It is also necessary for synchronizing the data from various DASARs when triangulating calls.) Two sets of calibrations were performed during the 2005 field season, one on 4 Sept. after all DASARs were deployed and the second on 25 Sept. before retrieval. In 2005, transmissions were emitted at 14 locations surrounding the array DASARs and 4 locations surrounding the near-island DASARs (see Fig. 2.1). The same J-9 sound projector, amplifier, sound source, GPS timing, and projected waveform were used in 2005 as in 2003 and 2004. The projected waveform 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, and a 2-s linear sweep from 400 to 200 Hz. Figure 7.3 in Blackwell et al. (2006) shows a spectrogram of this waveform. The source level of the projected sounds was ~150 dB re 1 μPa-m. An entire ping transmission required 8 s, and there were 7 s between two consecutive pings, which initiated every 15 s. As in most previous years, recordings obtained while the acoustic crew's vessel was in the DASAR array were not analyzed.

Signal Analysis

Equalization Process

The acoustic sensors taken from sonobuoys provide increasing sensitivity as frequency increases from 10 Hz to over 1000 Hz (Fig. 2.3A). The sensitivity curve is specified to be within an envelope of high and low limits. At 100 Hz the limits are ±3 dB, with looser tolerances at higher and lower frequencies. The sensors are not required to be calibrated accurately, but the manufacturer does measure sensitivity to assure that it falls within the envelope at all frequencies. We have those measurements and used them in calculating the sensitivity of each DASAR. This means that our measurements of sound pressure levels are within ±3 dB.

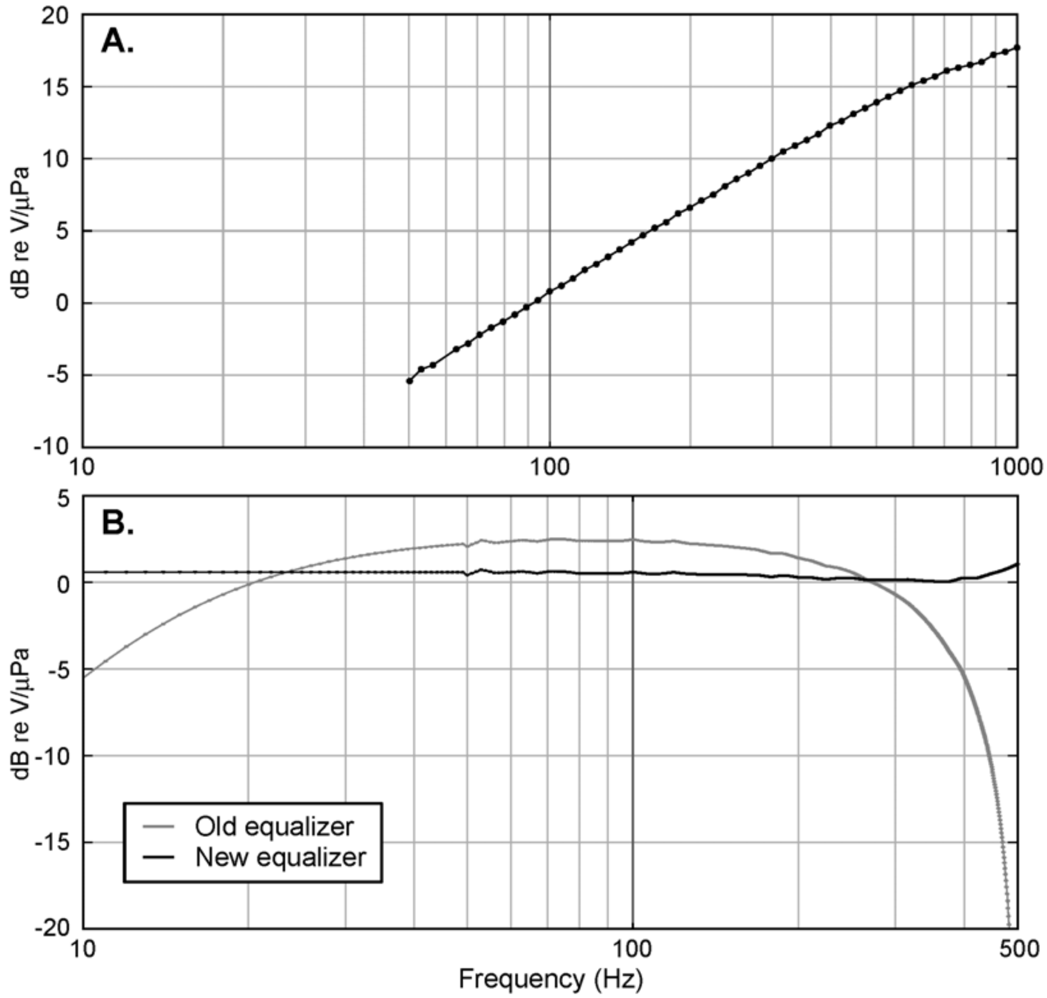

FIGURE 2.3. Equalization process. ***(A)*** Measured frequency response for a -53D sonobuoy sensor (serial number 1717, 135 dB added). ***(B)*** Corrected frequency response for the sonobuoy sensor shown in ***(A)***, using the old (gray line) and new (black line) equalization filters.

The upward slope of the response with increasing frequency requires equalization to flatten the overall response. Such flattening permits computing calibrated sound pressure levels, both on a spectral density basis and in frequency bands (one-third octave bands and the 10–450 Hz broad band being common in our analyses). That is, the response of the equalizing filter must emphasize the low frequencies and correspondingly de-emphasize the higher frequencies to flatten out the overall sensitivity curve. A digital filter was designed for this purpose and has been used for all the noise measurements based on DASAR sensors since 2001, whether in the array for call localization or whether used for near-island sound measurements. The filter was designed for high speed operation, resulting in errors averaging about 1.5 dB compared to an idealized equalizing filter. While we normally strive for calibration accuracies of better than 1 dB, this filter was acceptable given the original ±3 dB uncertainty in the sensors.

In 2005, a slower but more accurate digital equalization filter was designed and used. The overall frequency responses using the old and new equalizers are shown in Figure 2.3B. For 2005, differences in percentile levels of sound as derived with the old vs. the new filter were generally less than 1 dB.

Near-island DASARs

Data collected by the near-island DASARs were used to determine the sound spectrum (1 Hz intervals) for a one minute period every 4.37 min (262 s). This provided ~330 spectral measurements per 24-hr day. To derive each of these 1-min spectra, a series of 119 one-second-long data segments, overlapped by 50% and thus spanning 1 min, were analyzed. For each minute analyzed, the 119 resulting 1-Hz spectra were averaged to derive a single averaged spectrum for the 1-min period.

Those narrowband results were used to determine the corresponding broadband (10–450 Hz) and one-third octave band levels averaged over 1 min. This provided a measurement of the sound level in each band, averaged over a 1-min period, for each 4.37-min interval. These data provided an essentially continual record of the levels of low-frequency underwater sounds 400–500 m (~1310–1640 ft) from Northstar during the study period, 31 Aug.–2 Oct. 2005. The narrowband and one-third octave data were also summarized 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 frequency cells or one-third octave bands in the spectra, the values were sorted from smallest to largest, and the minimum, 5th-percentile, 50th-percentile, 95th-percentile, and maximum values for that frequency cell were determined.

The near-island DASAR data were analyzed at frequencies up to 450 Hz. In 2001, 2002, and the first part of the 2003 season, the island sound monitoring was done using cabled hydrophones. DASARs and the cabled hydrophone system collect comparable data, with one main difference: the sampling rate for the cabled hydrophone (2 kHz) was twice that for the DASARs (1 kHz). This means that the cabled hydrophone systems and DASARs provide acoustic data for frequencies up to 900 Hz and 450 Hz, respectively. To allow comparisons with data collected by DASARs, cabled hydrophone data from previous years were also analyzed for the 10–450 Hz bandwidth. These analyses have shown that there is little sound energy in the 450–900 Hz band. For example, levels in the 10–450 and 10–900 Hz bands (as represented by their minimum, 5^{th}, 50^{th}, and 95^{th} percentile levels, and maximum) differed by 0.4–0.7 dB on average in 2001–2003 (range 0.1–1.1 dB).

Industrial Sound Index.—For comparison with previous years (2001–2004), the near-island recordings in 2005 were used to define an "Industrial Sound Index" or ISI. The ISI was constructed by adding together the sound levels in one-third octave bands that appeared to be dominated by industrial components. A detailed rationale for the selection of particular one-third octave bands during 2001 and 2002 is presented in Blackwell (2003). The ISI for 2001–2004 was defined as the sum of the mean square pressures in the one-third octave bands centered at 31.5, 40, 50, 63, and 80 Hz, the "5-band ISI" (Blackwell 2003; Richardson et al. 2003). Total mean-square sound pressure (SPL) in the five one-third octave bands considered was computed as

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

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

Array DASARs

Whale call data from all four offshore DASARs (EB, CCa, CCb, and WB) were analyzed in the same way as they have been in the past (2001–2004, see Greene et al. 2002, 2003a; Blackwell et al. 2004, 2005). During the initial analysis whale calls were only tallied on DASAR EB's record, but calls recorded by the other three DASARs were subsequently tallied as well. The full DASAR record was examined minute by minute to count calls and to determine call types. A spectrogram was produced of each call (or suspected call). Based on the spectrogram and on listening to the call with headphones, analysts classified all calls into ***simple calls*** and ***complex calls***. The call classification was based on descriptions by Clark and Johnson (1984) and Würsig and Clark (1993):

- ***Simple calls*** were frequency modulated (FM) tonal calls or "moans" in the 50–300 Hz range. We distinguished (1) ascending or up calls, "/"; (2) descending or down calls, "\"; (3) constant calls, "–"; and (4) inflected calls, "∪" and "∩".
- ***Complex calls*** were infinitely varied and included pulsed sounds, squeals, growls with abundant harmonic content, and combinations of two or more simple and complex segments. Subcategories of complex calls could not be discerned consistently, so all subcategories were pooled.

In addition, the bearing from each DASAR to each detected call was determined. In 2001–2004, the bearings from various DASARs had been used to calculate positions of calling whales. However, in 2005 three out of the four array DASARs (WB, CCa, and CCb) and all near-island DASARs were moved on the seafloor by currents or surge one or more times during their deployment. Two examples are given in Figure 2.4. Consequently, only 1 of 4 offshore DASARs (EB, see below) provided reliable bearings to whale call locations. DASAR movement was evident based on differences in compass calibration data collected on two dates, and from changes in magnetic compass bearings logged aboard the DASARs:

- The DASAR clocks and compasses were calibrated twice during the 2005 season: on 4 Sept. right after DASAR deployment, and on 25 Sept., 7 days before DASAR retrieval. This provided accurate information about the orientation of each DASAR on those two days.

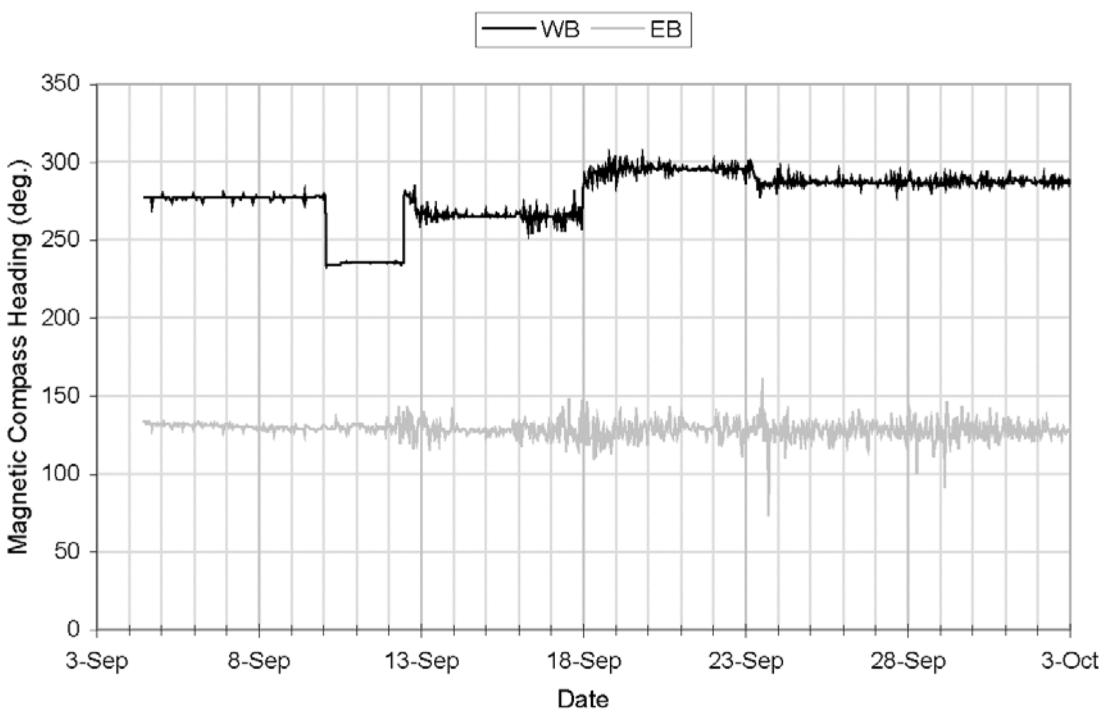

FIGURE 2.4. Magnetic compass heading vs. time for two array DASARs (WB and EB) over their entire deployment in 2005. DASAR WB experienced shifts in compass heading on 10, 12, 17, and 23 Sept. The compass heading for DASAR EB was the most stable of the array DASARs throughout the deployment period.

- Magnetic compass data logged at 46.6 min intervals indicated when the DASARs moved. However, at the high geomagnetic latitude of Northstar, compass bearings alone are too uncertain to determine the orientation of a DASAR on the seafloor.

The DASAR movement was caused by unusually high wind speeds that occurred commonly in Sept. 2005, and which resulted in higher sea states than in previous years (see below). If a DASAR is moved between successive calibrations, or after the last calibration, then its bearings are not sufficiently reliable to be used in localizing whale calls.

The calibration and compass data from DASAR EB in 2005 gave no indication that this DASAR moved during its deployment, so the computed bearings to whale calls were deemed valid. To better understand where whales were calling from in various years relative to the DASAR location, we compared bearings to whale calls from DASAR EB in 2005 with bearings to calls determined by a DASAR at the same location in previous years. ***Vector mean bearings*** and ***mean vector lengths*** (Batschelet 1981) were calculated for DASAR EB in 2001–2005, and for DASARs CC and WB in 2001–2004. Figure 2.5 shows an example of a mean bearing calculation using a set of 9 bearings. The vector mean bearing for each year indicates the general direction to the majority of calls for 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 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 proportions of calls "offshore" versus "inshore" (O/I ratio) were also calculated for DASAR EB in 2001–2005 and DASARs CC and WB for 2001–2004. Offshore calls were defined as those whose bearings from EB were between 298° and 98° True (including 360°/0°, true north), and inshore calls were defined as those with bearings between 118° and 278° (including 180°, south; Fig. 2.6). These ranges were determined by the orientation of the baseline (extending from 108° to 288° True), with a 20° buffer zone (centered on the baseline) between the offshore and inshore areas. Thus, calls with bearings in the ranges 98°–118° and 278°–298° were not included in the calculation of the O/I ratio (Fig. 2.6).

To provide information on ambient sound levels away from Northstar, data recorded by the DASAR farthest from the island (EB) were analyzed the same way as data from the near-island DASAR (see above).

RESULTS

This section is organized with five main sections describing

1. DASAR operations in 2005;
2. Calibration of the DASAR clocks;
3. Underwater sounds at Northstar, including temporal variation in broadband levels and ISI levels, spectral analyses, and comparisons with previous years;
4. Underwater sounds at offshore DASAR EB, including temporal variation in broadband levels, percentile levels of broadband sound, and comparisons with previous years;
5. Whale call analyses, including (a) the number of whale calls detected at all offshore DASARs and comparisons with previous years; (b) bearings to calls and O/I ratios for DASAR EB in 2005, including comparisons with previous years; (c) analysis of call types in 2005 and comparison with call types obtained at the same locations in previous years.

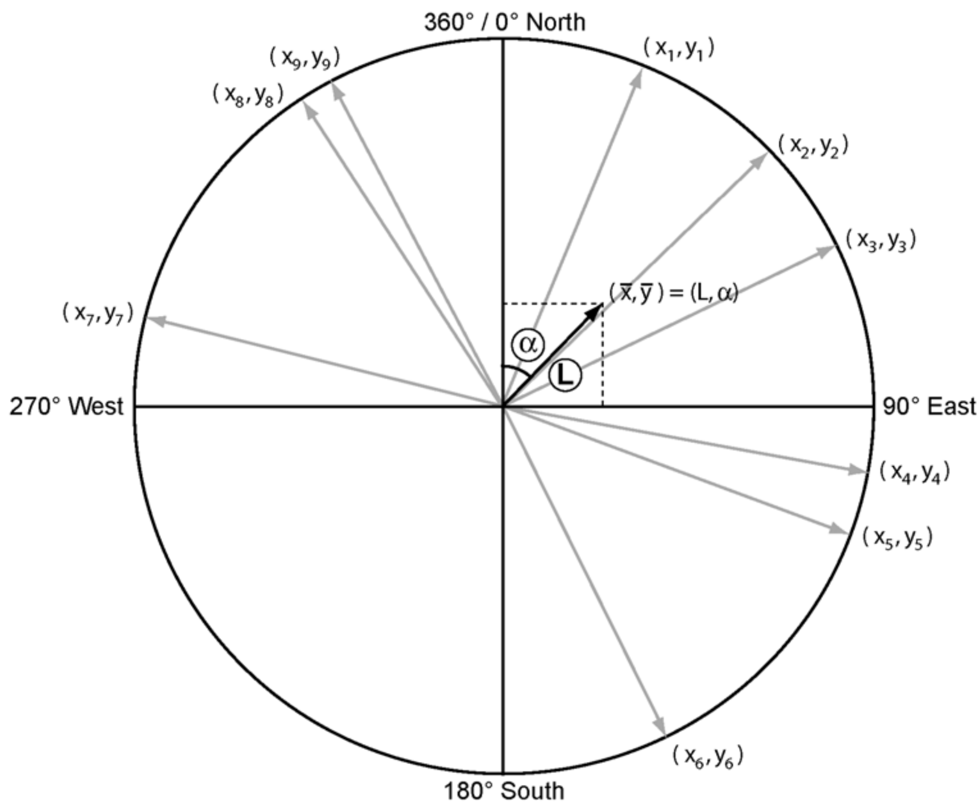

FIGURE 2.5. Average bearing calculation. The gray arrows are example bearings from a DASAR (located in the center of the circle). Mean bearing angle $\alpha = \arctan(\bar{x}, \bar{y})$, where $\bar{x}$ and $\bar{y}$ are the average cos and sin, respectively, of all bearings obtained at one DASAR during a season. Vector length L = $\sqrt{\bar{x}^2 + \bar{y}^2}$.

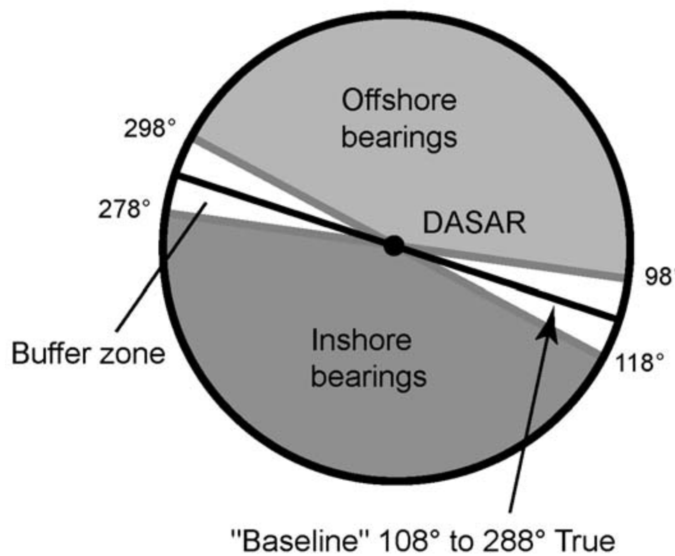

FIGURE 2.6. Definition of the "offshore" and "inshore" sectors in relation to the "baseline" and DASAR location (filled circle). See text for details.

DASAR Operations in 2005

All DASARs functioned throughout their deployment. The magnetic compass data indicated that six out of seven DASARs may[4] have experienced one or more changes in orientation during their deployment, which is a higher rate than in 2004. However, there was less compass variability in the array (offshore) DASARs than in those near Northstar, probably because the former are located in deeper water. To reduce the amount of possible turning, tabs were added to the DASAR bases before the 2004 season. The wind was particularly strong in 2005 and that is the likely cause of these movements. Mean hourly wind speed during the period 31 Aug.–30 Sept. was 24–113% higher in 2005 than in previous years (2001–2004, see Fig. 2.7 below).

Calibration of the DASAR Clocks

The results of the clock drift calibrations are presented in Table 2.2. Unlike the bearing calibrations, which improve noticeably with the number of pings used, the clock calibrations can be done using only a few pings. Therefore only the first ping from each calibration station was used for each of the two calibration days. The number of pings used to calibrate the array DASARs was higher than the number used for the near-island DASARs because the former are surrounded by more calibration stations (6 each versus 3, respectively; see Fig. 2.1). Clock drift for the various DASARs ranged from –2.2 to +0.2 seconds per day.

TABLE 2.2. DASAR clock drift rate in 2005. Clock drift is characterized by its rate or "slope", in seconds per day, and by the standard deviation of the residuals (in seconds).

			Clock drift	
DASAR	**Unit #**	**# Pings**	**S.D. of residuals (s)**	**Slope (s/day)**
WB	2	14	0.072	-1.634
CCa	1	13	0.200	-0.729
CCb	3	15	0.100	-2.013
EB	4	12	0.180	-1.423
NSa	5	6	0.082	0.196
NSb	6	6	0.150	-1.389
NSc	8	6	0.055	-2.167

Underwater Sounds at Northstar

Broadband Sounds

The sound levels recorded by the three near-island DASARs (NSa, NSb, and NSc) were in close agreement, with differences that are well within the variation one might expect based on reception at slightly

[4] Calibration data in previous years have shown that apparent shifts of the magnetic compass are not always confirmed by changes in the calibration reference directions.

different locations. We decided to use the data collected by DASAR NSb as this DASAR had the most stable compass bearings over its deployment and had thus been moved by currents the least. The signals from DASAR NSb were analyzed to determine the broadband (10–450 Hz) level of underwater sound based on a one-minute analysis every 4.37 minutes. The combined results are presented in Figure 2.7B for the period 31 Aug.–2 Oct. 2005. The range of broadband levels shown for 2005, 88–136 dB re 1 μPa, is similar to that reported for 2002, 2003, and 2004: 90–135, 90–137, and 92–133 dB re 1 μPa, respectively.

Broadband levels close to Northstar are determined by a combination of two factors: the level of sound-generating industrial activities (from Northstar and its associated vessels) and wind speed, which determines ambient sound levels. Mean hourly wind speed in 2005 was 8.3 m/s (18.6 mph) during the period 31 Aug.–30 Sept. This is 28% higher than in 2004 (6.5 m/s or 14.5 mph), 24% higher than in 2003 (6.7 m/s or 15.0 mph), 48% higher than in 2002 (5.6 m/s or 12.5 mph), and 113% higher than in 2001 (3.9 m/s or 8.7 mph). Figure 2.7A shows mean hourly wind speed as recorded by the Northstar weather station[5]. The lowest levels in Figure 2.7B are indicative of the quietest times in the water near the island, and generally correspond to times with low wind speeds. Conversely, times of high wind speed (e.g., 9–10, 12, 18, or 22–23 Sept.) usually correspond to increased broadband levels in the DASAR record (Fig. 2.7B). In 2005 there was an unusually close relationship between the mean wind speed and the minimum value of broadband sound on an hourly basis (r = 0.81, n = 743; in 2003 for example r = 0.46, n = 622). As in previous years this means that when wind speed was high so were average broadband (and ISI) levels. Figure 2.7D shows the relationship between mean hourly wind speed and the minimum hourly ISI value for the 2005 season.

Industrial Sound Index (ISI)

As in 2001–2004, the sum of sound components in the frequency range 28 to 90 Hz defined the ISI. The ISI for the 2005 study period is shown in Figure 2.7C as a function of time. As in previous years the ISI was closely related to the overall 10–450 Hz level, but the ISI tended to be a few decibels lower (as a consequence of excluding sound components at frequencies 10–28 Hz and 90–450 Hz.). Direct comparison of the two values showed that 1-min ISI values were, on average, 5.7 dB below 10–450 Hz broadband values in 2005. This difference was 5.0 dB in 2004 and 5.7 dB in 2003.

There was no oil production on 31 Aug.–5 Sept. due to problems with the turbines or compressors resulting in partial shutdowns. In addition, wind speeds were comparatively low (Fig. 2.7A) and the pack ice was only a mile or two seaward of the island. The presence of pack ice decreases sea state and thus ambient sound levels. These factors (combined) could explain the lower minimum levels early in the season compared to later, as evident in both the broadband levels (Fig. 2.7B) and ISI data (Fig. 2.7C).

Statistical Spectra of Island Sounds

To characterize the sounds near Northstar during the study period in 2005, statistical spectrum and one-third octave band levels were calculated for DASAR NSb (Fig. 2.8). Overall, these spectra are similar to those from previous years (see Fig. 7.13 in Blackwell et al. 2004 or Fig. 2.7 in Blackwell et al. 2005), but with some variations. For example, as in previous years, peaks were present at 60 and 87 Hz, but a peak at 30 Hz was more pronounced in 2005. Percentile levels of broadband sound as recorded by the near-island recorders in 2001, 2002, 2003, 2004, and 2005 are compared in Table 2.3 and Figure 2.9. In 2005, the minimum and 5th percentile were lower than in other years except 2001. Median and 95th percentile levels of sound recorded near Northstar in 2005 were 5.0 and 8.1 dB higher than in 2004, probably because of

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[5] Northstar weather data are available at http://www.resdat.com/mms/

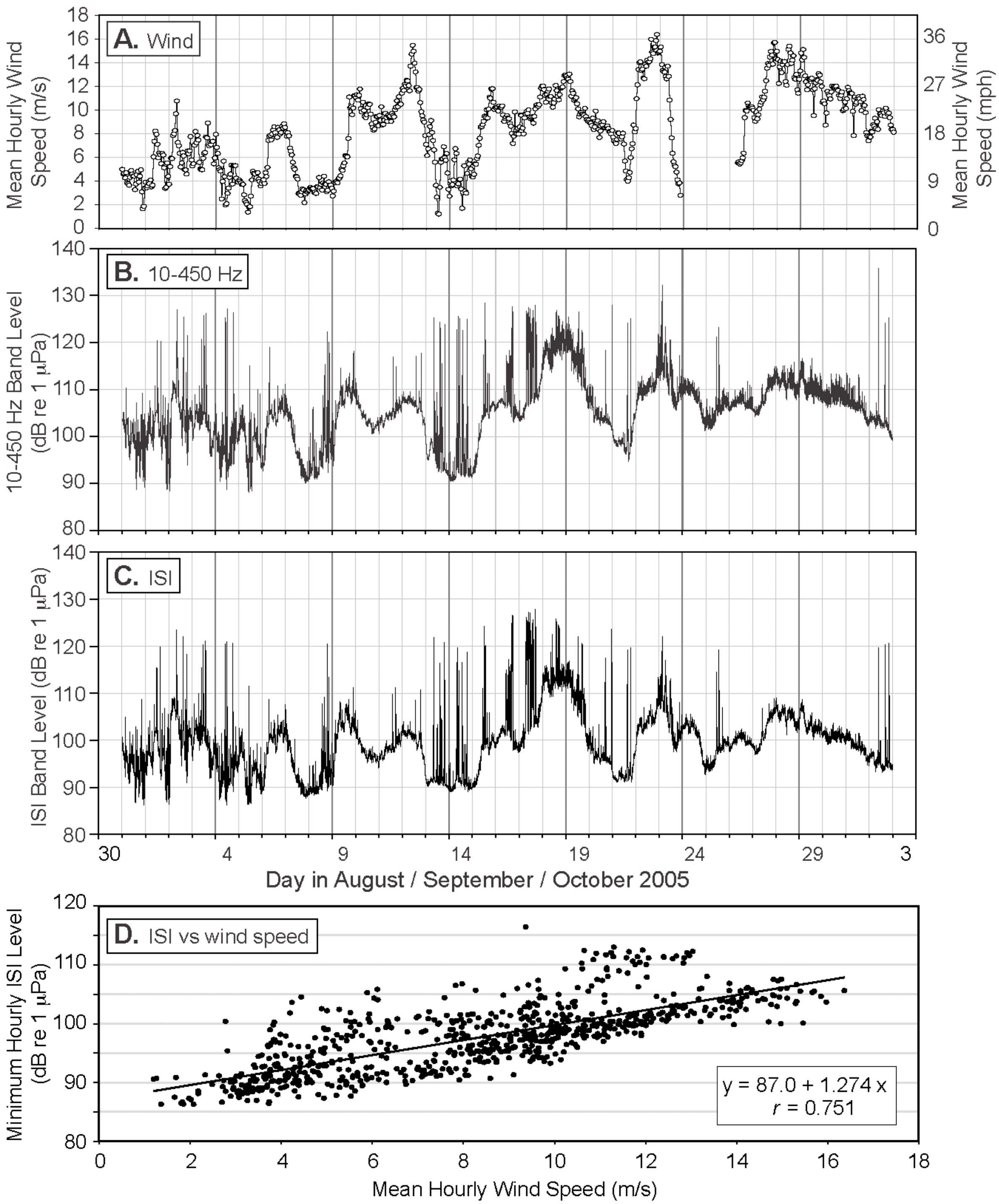

FIGURE 2.7. Variation in levels of underwater sound near Northstar in relation to date/time and wind speed, 30 Aug.–3 Oct. 2005. ***(A)*** Mean hourly wind speed as recorded by the Northstar weather station. Note that this weather station does not record north winds correctly, as the wind vane is shielded by a building in that direction. ***(B)*** Broadband (10–450 Hz) levels of underwater sound near Northstar vs. time, as recorded by DASAR NSb. This recorder was deployed 410 m (1345 ft) north of Northstar. ***(C)*** Corresponding ISI band level (~28–90 Hz). ***(D)*** Minimum hourly ISI level versus mean hourly wind speed for 2005.

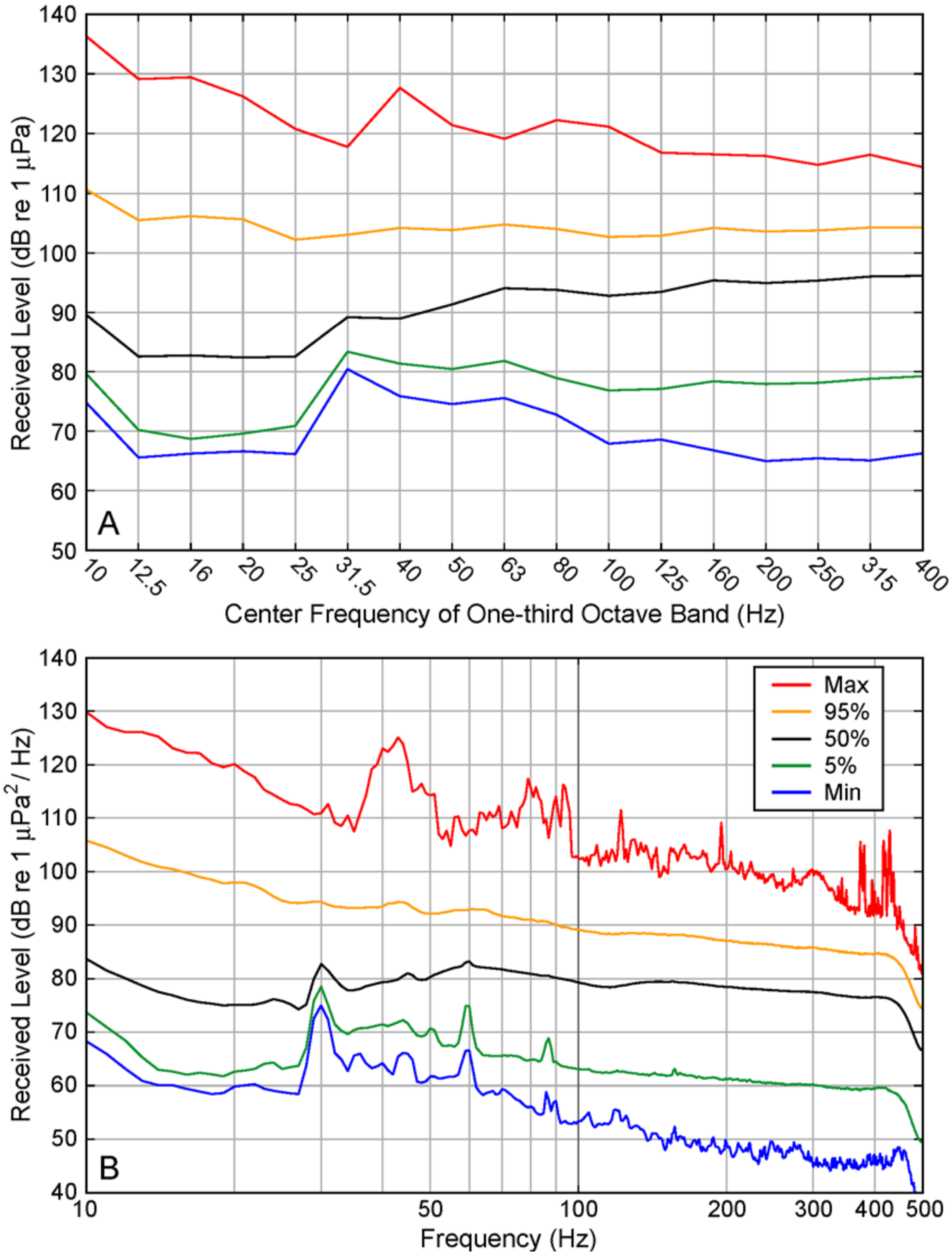

FIGURE 2.8. Statistical spectra for sounds recorded by DASAR NSb during the period 30 Aug.–3 Oct. 2005. ***(A)*** One-third octave band levels. ***(B)*** Sound spectral density levels. In both plots the five curves show, for each frequency, the minimum, the 5th, 50th, 95th percentiles, and the maximum. For both plots the number of 1-min measurements used was 10,999.

TABLE 2.3. Percentile levels of broadband (10–450 Hz) underwater sound recorded near Northstar Island in 2001–2005. In 2001 (1–21 Sept.) and 2002 (31 Aug.–23 Sept.) data were collected by cabled hydrophone (CH) #2. In 2003 data were recorded both by CH #2 (29 Aug.–16 Sept.) and DASAR NS (18–28 Sept.). In 2004 data were recorded by DASAR NSa (30 Aug.–1 Oct.). In 2005 data were recorded by DASAR NSb (1 Sept.–2 Oct.). "Range" is the difference between maximum and minimum. All hydrophones were at similar distances (420–550 m or 1378–1804 feet) north of Northstar. All levels are in dB re 1 µPa. For 2001–2004, values presented here differ very slightly from those presented in previous reports for two reasons: (1) the new equalizing filter was applied retroactively to all DASAR data; and (2) broadband levels are presented for the 10–450 Hz range instead of 10–500 Hz.

	2001	**2002**	**2003**		**2004**	**2005**
	CH #2	**CH #2**	**CH #2**	**DASAR NS**	**DASAR NSa**	**DASAR NSb**
Minimum	80.8	89.7	91.8	90.4	92.0	88.0
5th percentile	87.3	94.8	95.2	91.7	93.7	92.4
50th percentile	101.8	103.5	101.8	103.4	100.5	105.5
95th percentile	122.7	117.3	116.7	125.1	110.1	118.2
Maximum	140.5	135.0	136.8	131.1	133.1	135.8
Range	59.7	45.3	45.0	40.7	41.1	47.8

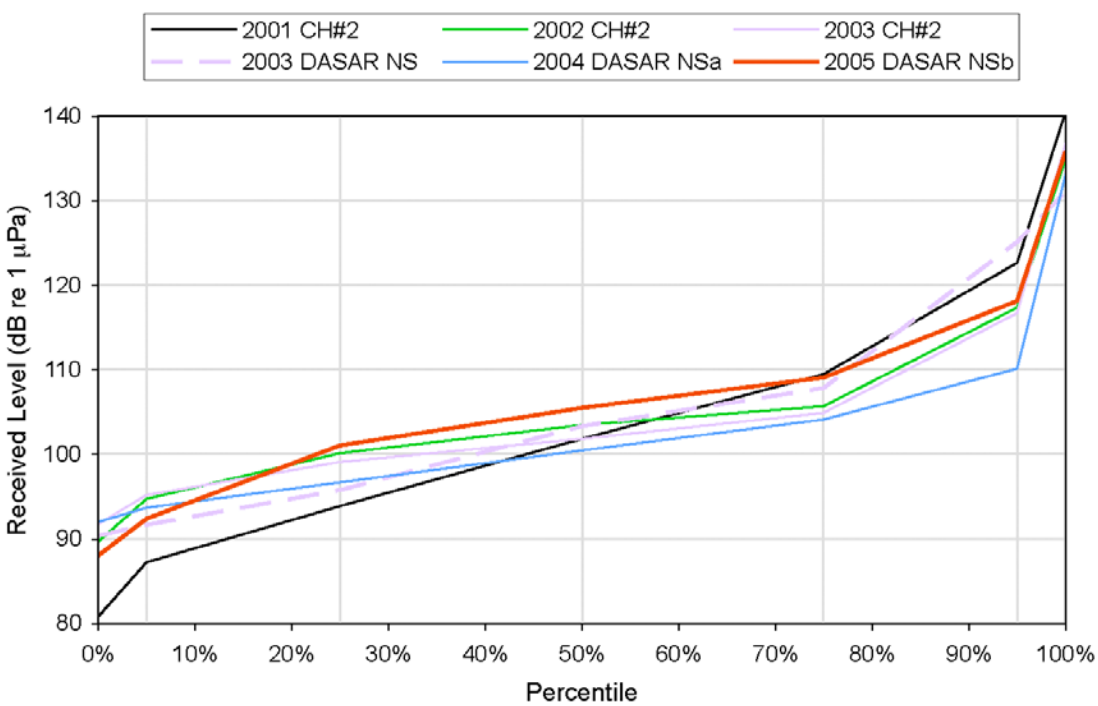

FIGURE 2.9. Minimum, 5th, 25th, 50th, 75th, and 95th percentiles, and maximum received levels of broad-band (10-450 Hz) sound at the near-island recorder (cabled hydrophone or DASAR) for 2001–2005. The number of 1-min measurements for each year was as follows: 11,486 for 2001, 7551 for 2002, 5162 for 2003 (CH), 3233 for 2003 (DASAR), 10,409 for 2004, and 10,999 for 2005.

higher wind-induced ambient levels. The 2005 median was higher than in all previous years. Maximum levels, which are principally determined by boats, were similar to those in previous years.

Specific Island Sound Sources

Vessels.—As in 2004, the crew boat was not used at all during the 2005 field season. Instead, personnel and goods were transported to the island with the hovercraft and, when weather conditions precluded its use, with helicopters. In addition, ACS vessels made a few runs to the island during Sept. 2005. The daily number of round trips by the hovercraft, ACS vessels, and the Northstar tug (River-class *Kavik River*) and barge are shown in Figure 2.10. These records were compiled by the Crowley Marine dispatcher's office at West Dock, the Whaling Communications Center, and the Northstar Scheduler.

- The *hovercraft* made a total of 53 round trips to Northstar during the 33 days shown in Fig. 2.10 (on average 1.6 trips/day). This is almost 3 times the use in 2004, which averaged 0.6 trips / day. High wind conditions precluded use of the hovercraft on 19 Sept. and 22 Sept.–2 Oct. As expected based on radiated sound measurements (Blackwell and Greene 2005), the arrivals and departures of the hovercraft at Northstar were not detectable on DASAR NSb's sound pressure time series (e.g., Fig. 2.7B).
- The Northstar *tug and barge* made 16 trips to Northstar in 33 days, i.e., an average of 0.5 trips/day. This is slightly higher than in 2004 (0.4 trips per day), but well below the average barge traffic in 2003 (1.6 round trips per day).
- ACS vessels (excluding the vessel used by the acoustics crew) made 11 round trips to Northstar in 33 days, an average of 0.33 trips per day, or about half the number in 2004 (0.7 trips/day). In addition to the ACS vessels used for island runs or oil spill response training, an ACS "Bay" boat was used by the acoustics crew to deploy, calibrate and retrieve the instrumentation in the array and close to Northstar (see gray shading in Fig. 2.10). This boat made a total of 4 trips to Northstar and the DASAR array during the period shown in Fig. 2.10 (1 Sept.–3 Oct.). An additional trip took place on 30 Aug., for a total of 5 ACS trips related to this project in 2005. This compares to 12, 8, 8, and 9 trips in 2001, 2002, 2003, and 2004, respectively.

Round trips to the island by the tug and barge and ACS vessels combined accounted for at least 81% of all the large "spikes" in DASAR NSb's sound pressure time series (Fig. 2.7B). We used the following procedure for this estimate. We defined a large spike as one with a maximum level above 115 dB re 1 μPa. In counting spikes, we ignored 16 and 17 Sept. because of the presence of another sound source (see below), which did not allow us to visually detect sound spikes on the sound pressure time series. We also ignored days when the baseline levels of sound were at or above 115 dB (for example 18 Sept.). Here, baseline refers to the lower edge of an "envelope" around the plotted sound pressure time series. The times of vessel arrival at and "departure" from Northstar were matched with the presence of spikes (or tight groups of spikes) on the sound pressure time series. Our estimate is a minimum estimate, since only the arrival and departure spikes were taken into account. For example, during a 5-hr stay at Northstar it is possible that the tug and barge performed some maneuvering at the island that may have created one or several spikes – these types of events were unknown and could not be taken into account.

Figure 2.11 shows broadband (10–450 Hz) levels of sound as recorded at the near-island recorders in 2001–2005. In all years vessels operating near Northstar (excluding the hovercraft) had a strong influence on overall sound levels. The number of "vessel spikes" in the sound pressure time series steadily decreased from 2001 through 2004, and then remained about the same in 2005. Baseline levels of sound were particularly high in 2005 because of the high average wind speeds.

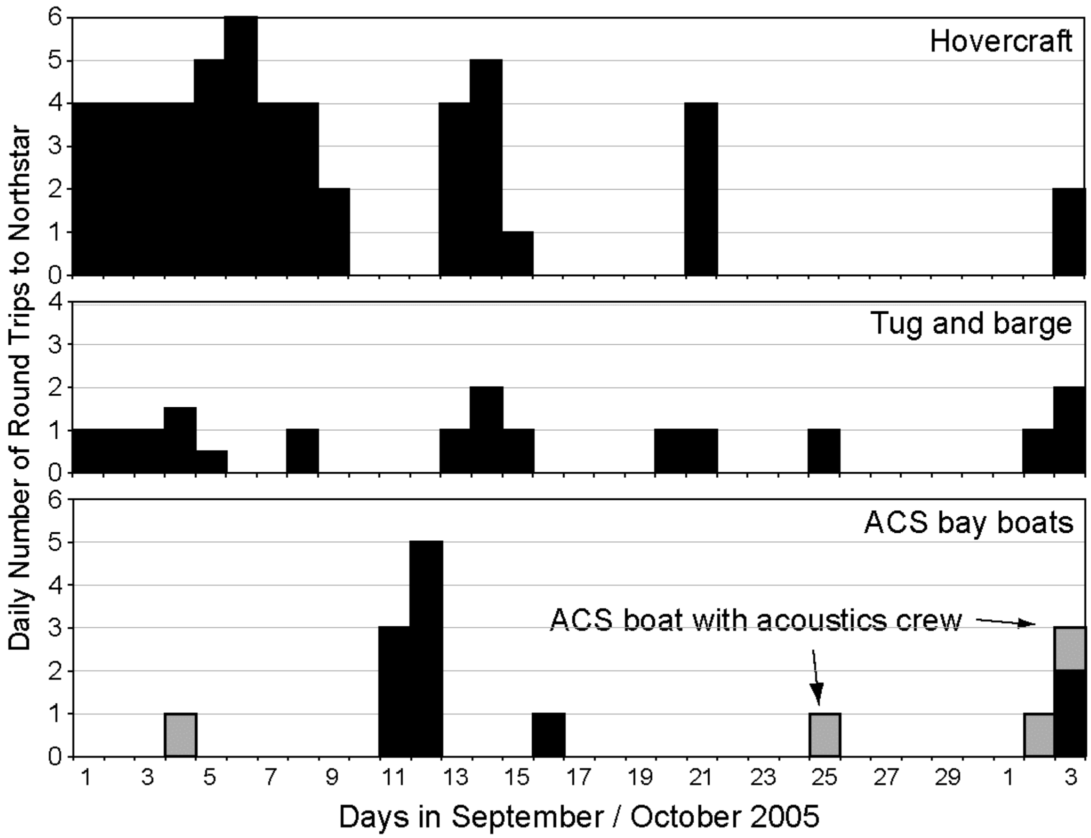

FIGURE 2.10. Daily number of round trips to Northstar Island by the hovercraft, the Northstar tug and barge, and ACS vessels (black shading = Northstar related, gray shading = acoustics crew) during the period 1 Sept.–3 Oct. 2005.

Other Island Sounds.—Spectrograms of island sound showed that on 16 and 17 Sept. an unidentified sound source operated on Northstar. It contained a fundamental frequency at 21–23 Hz and multiple harmonics thereof (up to ~150 Hz). Figure 2.12 shows a spectrogram for 17 Sept., in which the sound source operated for ~6 hours between 07:00 and 18:00. The frequency composition of this sound source is reminiscent of vibratory pile driving as seen in Sept. 2004 (see Fig. 2.11A in Blackwell et al. 2005). However, vibratory pile driving did not take place on Northstar during Sept. 2005. The most likely candidate is therefore a compactor, which was used as an attachment on a backhoe during the days in question. The fundamental frequency of this sound source (21–23 Hz) is outside the range of frequencies included in the ISI (28–90 Hz); however, three of its harmonics are included (see Fig. 2.12). Consequently ISI levels on 16–17 Sept. while the unidentified sound source was operating were generally <2 dB below the corresponding broadband levels (see Fig. 2.7B vs. C).

Underwater Sounds Offshore at DASAR EB

Figure 2.13 shows broadband (10–450 Hz) levels of sound as recorded offshore at DASAR EB in 2001, 2002, 2003, 2004, and 2005. DASAR EB was 15 km (9.3 mi) northeast of Northstar (Fig. 2.1). Spikes in sound levels that were caused by the presence of the acoustic crew's vessel offshore near the DASARs are marked with diamond symbols. Note that the acoustic crew's vessel did not produce a spike on the sound pressure time series during calibrations in the DASAR array on 25 Sept. 2005 (Fig. 2.13). This could be in

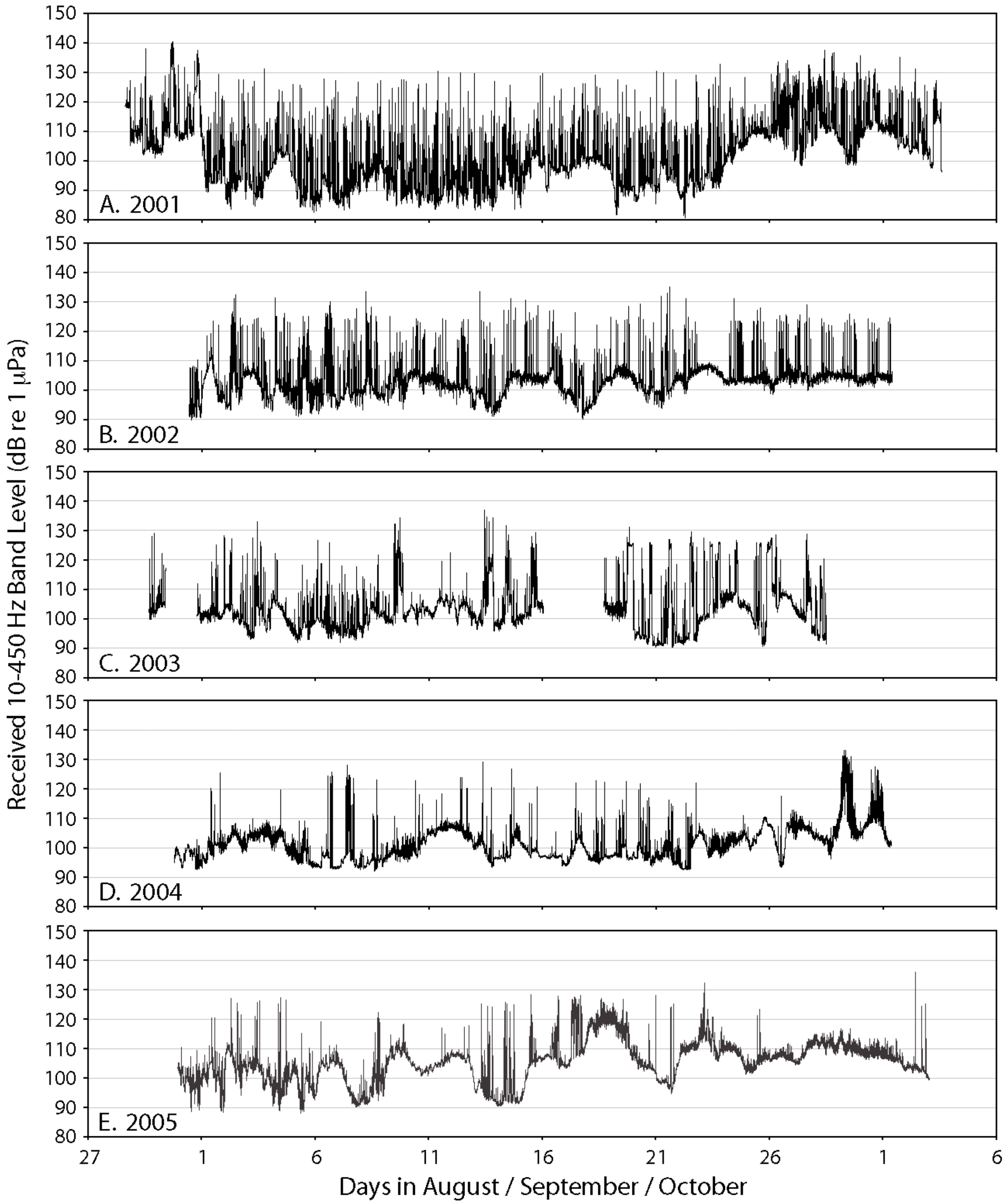

FIGURE 2.11. Sound pressure time series (10–450 Hz band level) for the entire 2001–2005 seasons, as recorded by the near-island recorders – a cabled hydrophone in 2001, 2002, and the first part of 2003, and a DASAR for the second part of 2003, and all of 2004 and 2005.

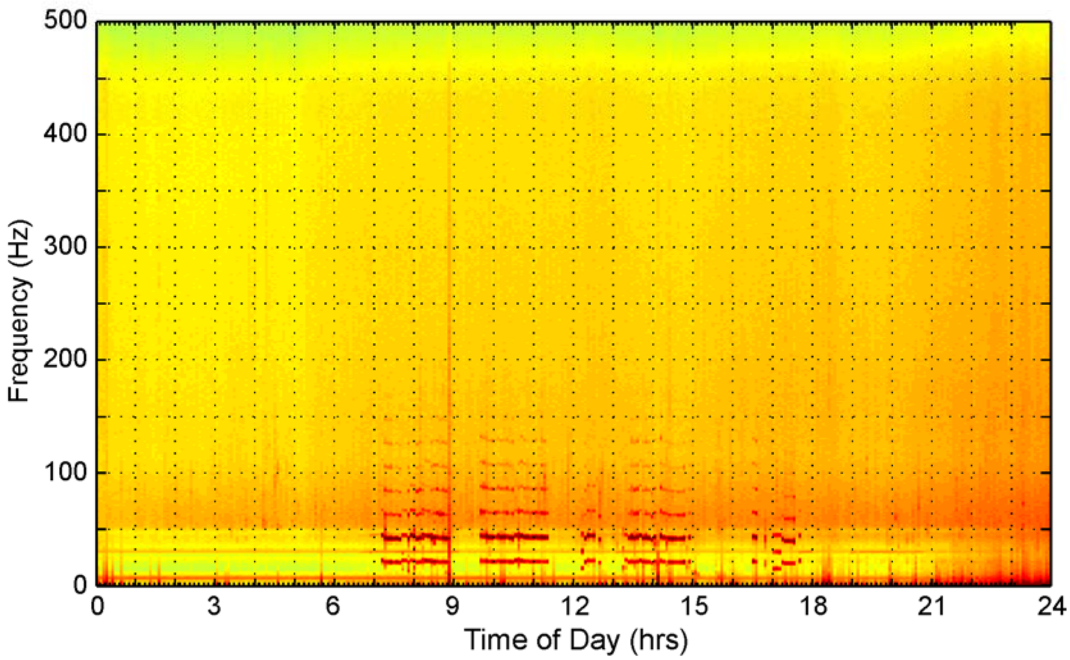

FIGURE 2.12. Spectrogram for 17 Sept. 2005, computed from data recorded by DASAR NSb located 410 m (1345 ft) from Northstar. Peak levels of sound, represented by red horizontal stripes, were caused by an unidentified sound source on Northstar, possibly a compactor attachment on a backhoe. The only other visible signs of industrial activity are a few tones below 50 Hz.

part because no health checks were performed on that day, so the vessel was always at least 3 km (1.9 mi) from any DASAR. Baseline[6] levels of sound at DASAR EB are mainly a function of sea state, and therefore wind speed. Wind-induced sound levels were particularly high during the latter part of the 2005 season: unlike any other year, the "baseline" (minimum measured levels) stayed above 94 dB re 1 μPa for at least 18 days in a row (Fig. 2.13, 15 Sept.–2 Oct.). Figure 2.14 shows percentile levels of underwater sound at DASAR EB, calculated each year over the entire season. In 2005, the various percentile levels plotted in Figure 2.14 were 1.9–8.5 dB above the maximum values for 2001–2004 combined, with the 25th, 50th, and 75th percentiles showing the biggest increases.

Whale Call Analyses

Number of Whale Calls Detected

A total of 1613 calls were detected on the records of DASARs EB, CCa, CCb, and WB combined during the 4 Sept. to 3 Oct. period in 2005. This is the lowest call count for these DASARs for any year from 2001 to 2005. Table 2.4 compares call counts in the different years. In 2005 there were two DASARs at location CC (CCa and CCb), so to allow meaningful comparisons with previous years we have only included one of the CC DASARs (CCa) in Table 2.4. The mean number of calls detected per day was calculated using only days when all three recorders were functioning normally (2001: 16 out of 35 days; 2002: 23 out of 24 days; 2003: 30 out of 30 days; 2004: 27 out of 33 days; 2005 29 out of 29 days). The percentages of calls detected at WB, CC, and EB add up to more than 100% because some calls were heard by two or three DASARs.

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[6] The ***baseline*** refers to the lower edge of an "envelope" around the plotted sound pressure time series.

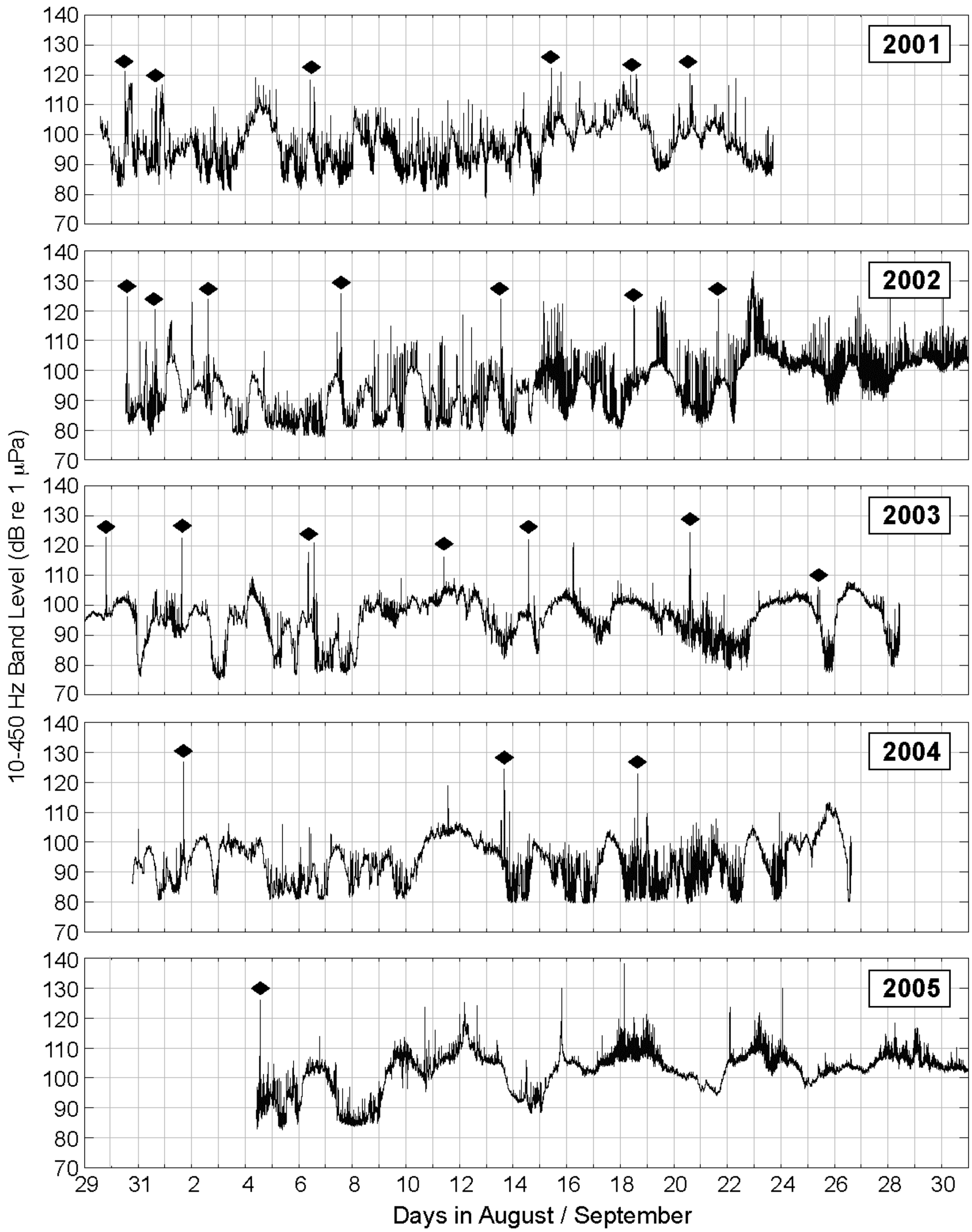

FIGURE 2.13. Broadband (10–450 Hz) SPLs vs. time as recorded by DASAR EB in 2001, 2002, 2003, 2004, and 2005. Diamonds indicate spikes (brief periods of higher-level sound) created by the acoustic crew's vessel during servicing of the array. Note that the acoustic crew's vessel did not create a large spike during calibrations on 25 Sept. 2005 (see text for details).

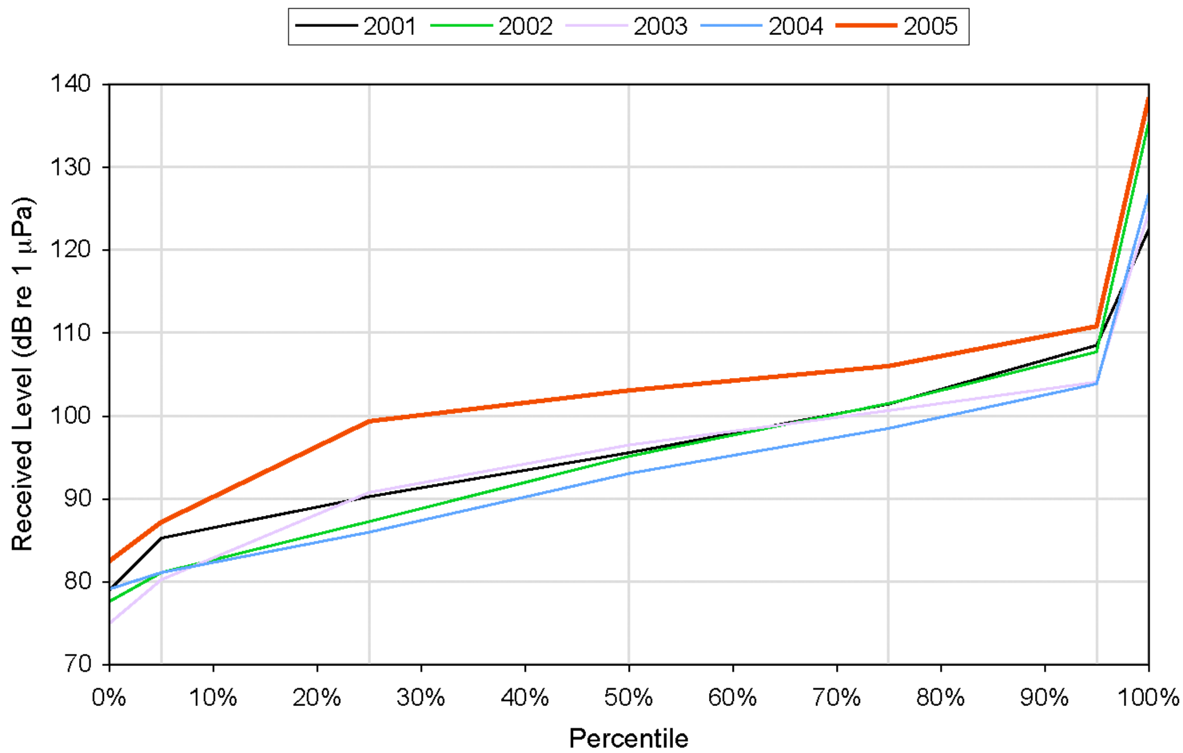

FIGURE 2.14. Minimum, 5th, 25th, 50th, 75th, 90th, and 95th percentiles, and maximum received levels of sound at DASAR EB for 2001–2005. The number of 1-min measurements for each year was as follows: 8276 for 2001, 11,165 for 2002, 10,016 for 2003, 8841 for 2004, and 9420 for 2005.

TABLE 2.4. Comparison of call counts via DASARs EB, CC (CCa in 2005), and WB combined in 2001–2005. Also shown for each year are mean number of calls detected per day (based on only those three DASARs), and percentages of those calls detected at each of the three DASAR locations. See text for details.[a,b]

Year	Total calls (WB, CC, EB)	Mean # calls per day [a,b]	Percentages of calls detected		
			EB	**CC**	**WB**
2001	2927	124	55.4	15.4	39.0
2002	5216	226	82.7	40.2	34.7
2003	29,714	991	73.1	55.6	37.7
2004	38,353	1344	69.2	64.4	55.4
2005	1566	54	40.8	37.2	39.8

[a] Mean number of calls per day for individual DASARs EB, CC and WB were as follows: **2001**, 94, 28 and 20, respectively; **2002**: 187, 91 and 79; **2003**: 724, 551 and 373; **2004**: 948, 831 and 706; **2005**: 22, 20 and 21. For each year, these values consider days when all 3 of these DASARs were operating. The 2005 EB figure (22) is the revised value from the reanalysis when data from 4 DASARs were examined together.

[b] In **2000**, the DASAR array was 1 n.mi. farther north than in 2001–2005, with no functional DASAR near EB. The two recorders closest to DASARs CC and WB were SW1 located 1850 m north of CC, and SW2 ~4650 m southwest of CC and southeast of WB (Greene et al. 2001). SW1 recorded 1177 calls over 11.7 days, or 100 calls per day; SW2 recorded 1012 calls over 5.7 days, or 177 calls per day.

In 2005 there were a total of 2415 separate call detections at the four offshore DASARs, and these were quite evenly split among the four recorders: 639 (26.5%) detections via EB, 583 (24.1%) via CCa, 570 (23.6%) via CCb, and 623 (25.8%) via WB. (The number of call detections is higher than the total number of whale calls shown in Table 2.4 because some of the calls were detected by more than one DASAR.) The percentages of calls detected by 1, 2, 3, and 4 DASARs were 65%, 22%, 12%, and 1%, respectively. The percentage of calls detected by a single DASAR was much higher in 2005 (65%) than in previous years. In 2004, for example, only 22% of calls were detected by only one DASAR (Blackwell et al. 2005). The low percentage of multiple-DASAR detections in 2005 was presumably partly a function of the lower number of DASARs used in 2005 and partly a function of the higher wind speeds and ambient noise levels in 2005 (see Fig. 2.14).

When the data from the three "extra" DASARs were analyzed, the data from EB were re-analyzed at the same time, and the results for EB reported here are from this reanalysis. The number of calls detected via EB during the reanalysis (639) was substantially lower than that detected during the initial 2005 analysis of data from EB alone (951). The drop in the number of calls detected at DASAR EB was related to difficulties in analyzing the 2005 data given the unusual noisiness of the records. The whale call analysts reported that 2005 was a more difficult year (as compared with 2001–2004) for detecting whale calls and for classifying them by call type. All DASAR records from 2005 included extended periods with unusually high amounts of ambient noise, which leads to more masking of calls. Expectedly, the proportion of calls detected by only one DASAR was higher than usual (see below). Figure 2.15 shows 1-min long spectrograms of the type the analysts see while analyzing the whale call data. In Figure 2.15A, ambient sound levels were typical. At least seven whale calls are easily identifiable on the spectrogram. In Figure 2.15B, ambient sound levels were high, as was common in 2005. There were at least three whale calls during this minute, but they are difficult both to see (on the spectrogram) and to hear. During the initial analysis of data from DASAR EB, the analysts were only focusing on a single DASAR. Because of the extremely low call counts, they were very motivated to find every sound on the DASAR record that could be interpreted as a whale call. During the reanalysis, when they were processing data from four DASARs simultaneously in the same manner applied in prior years, they were more discriminating. The reanalysis is believed to have provided results that are more comparable to those of prior years. This process highlights the fact that there is a degree of subjectivity in recognizing barely-detectable (faint) whale calls, and such calls predominate when background noise level is high as it often was in 2005. Overall, the level of subjectivity involved in identifying whale calls visually and aurally increases when records contain the level of ambient noise that was present in 2005.

In 2001, 2002, 2003, and 2004 DASAR EB detected 15.1%, 40.8%, 47.6%, and 40.0% of all calls detected by the DASAR array. Using these percentages, we can estimate the total number of calls that would have been detected in 2005 if all DASARs had been deployed based on the data in Table 2.4. It is reasonable to assume that the 639 calls detected at DASAR EB in 2005 constituted between 47.6% (2003 value) and 15.1% (2001 value) of all calls that would have been detected if the full DASAR array had been deployed in 2005. Thus, the total number of calls that might have been detected by an entire array of DASARs in 2005 would have been in the range 1342–4232.

Figure 2.16 shows the call detection rate for the entire 2005 season, considering calls from DASARs WB, CCa, and EB combined. The highest rate of call detection for the three DASARs combined was 112 calls/hour on 13 Sept. 2005. Most of the call detections occurred in mid-September (~12–17), with smaller peaks close to 7, 20, and 27 Sept.

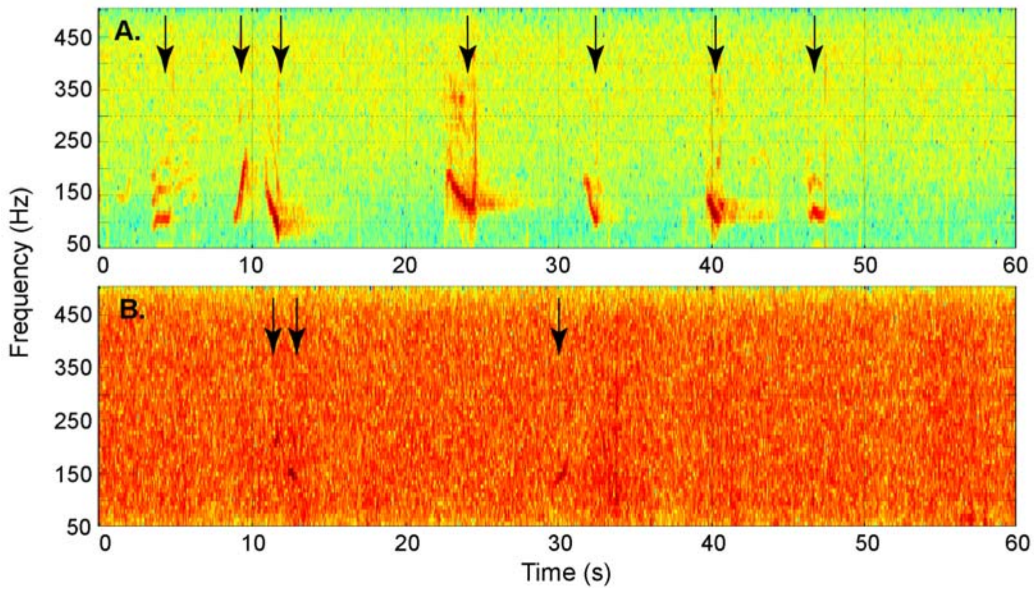

FIGURE 2.15. Spectrograms showing one minute of DASAR data containing whale calls (arrows) in different ambient sound conditions. ***(A)*** DASAR NW, 21 Sept. 2004 at 20:00:00, in average ambient sound levels; ***(B)*** DASAR EB, 16 Sept. 2005 at 06:55:00, in high ambient sound levels. See text for details.

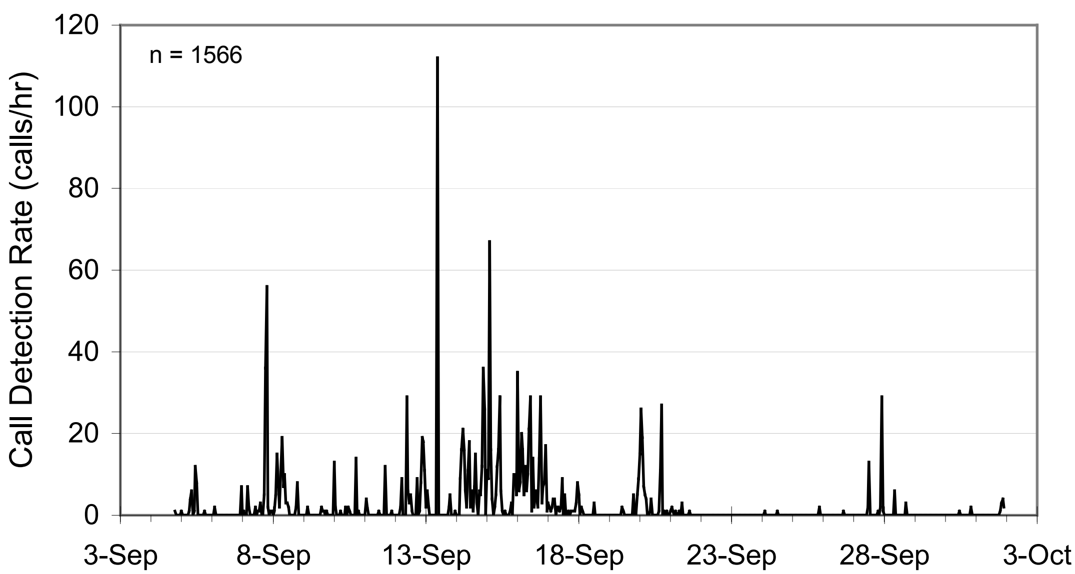

FIGURE 2.16. Hourly detection rate of whale calls as a function of time in September and October 2005. Includes all calls detected via DASARs EB, CCa, and WB except those occurring while the acoustic vessel was in the array. Total number of calls considered in this diagram was 1566. Tick-marks on X-axis represent midnight. The day with the highest call detection rate (13 Sept.) was also the day with the lowest mean hourly wind speed (see Fig. 2.7A).

Figure 2.17 compares daily number of calls detected by DASARs EB, CC(a), and WB combined in 2005 and in previous years. In 2001, most of the calls were detected in the first part of the season, before 15 Sept., whereas in 2002, 2003 and 2004 most of the calls were detected after 15 Sept. (This is the later part of our field season but the middle part of the bowhead migration period which extends until mid- to late-October). In 2005 the situation was intermediate, with the biggest surge in detected calls occurring in the middle of September; over 50% of the calls occurred during the period 13–16 Sept. Part of that "surge" corresponded to a time with low wind speed (Fig. 2.7A), when background noise was low. Under those conditions, calls from distant whales would be more likely to be detected. The two years with the largest call counts (2003 and 2004) showed three peaks (Fig. 2.17): a small peak in early Sept., a second peak in mid-Sept., and a third (and largest) peak on 21 Sept.

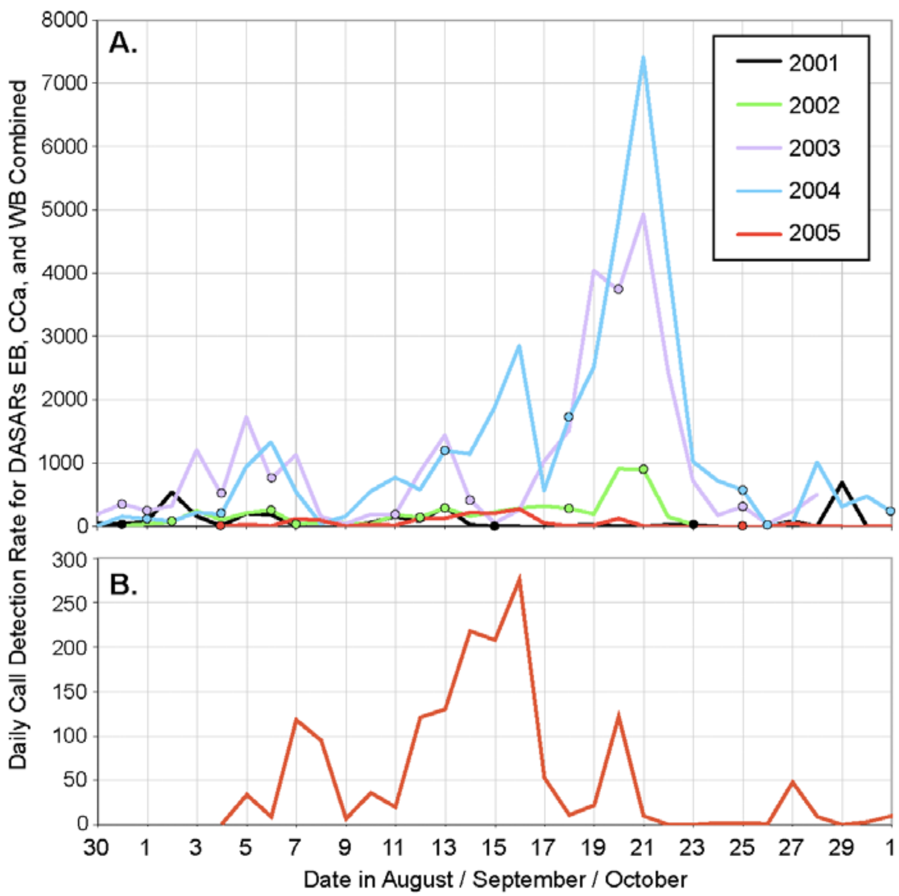

FIGURE 2.17. Daily number of calls detected by DASARs EB, CC(a), and WB combined for the entire 2001–2005 seasons. ***(A)*** 2001–2005, and ***(B)*** 2005 only, on an enlarged scale. Daily counts marked with a dot indicate days when the acoustic vessel went into the area of the DASAR array for servicing. In 2002–2005, the calls detected at those times were not counted, and those days are therefore "incomplete". In 2001, all calls were counted, regardless of the presence or absence of the acoustic vessel.

Figure 2.18 shows the number of whale calls detected by DASAR EB as a function of mean wind speed, for each hour of available data in 2002, 2003 and 2005. (2002 and 2003 are example years with low and high call counts, respectively.) Hours during which the acoustics vessel was in the DASAR array were not included. This Figure helps us to gauge the contribution of strong wind conditions to the low whale call counts in 2005. When wind speeds are high, ambient noise is high and the detectability of calls decreases, i.e., the range within which calls can be heard by a particular DASAR decreases. In 2003, hourly call counts at DASAR EB fell to near-zero at wind speeds above 12.1 m/s (27 mph). The percentage of samples with wind speeds above 12.1 m/s was about 3.5% in 2002 and 2003, and about 17% in 2005. At low wind speeds (0–6 m/s or 0–13.4 mph), ambient sounds are lower, and calls from whales at longer distances are more likely to be detected. For any one narrow range of wind speeds, call detection rates can be compared directly from one year to the next. Figure 2.18 shows that, for particular wind speeds, call detection rates were much lower in both 2002 and 2005 than in 2003.

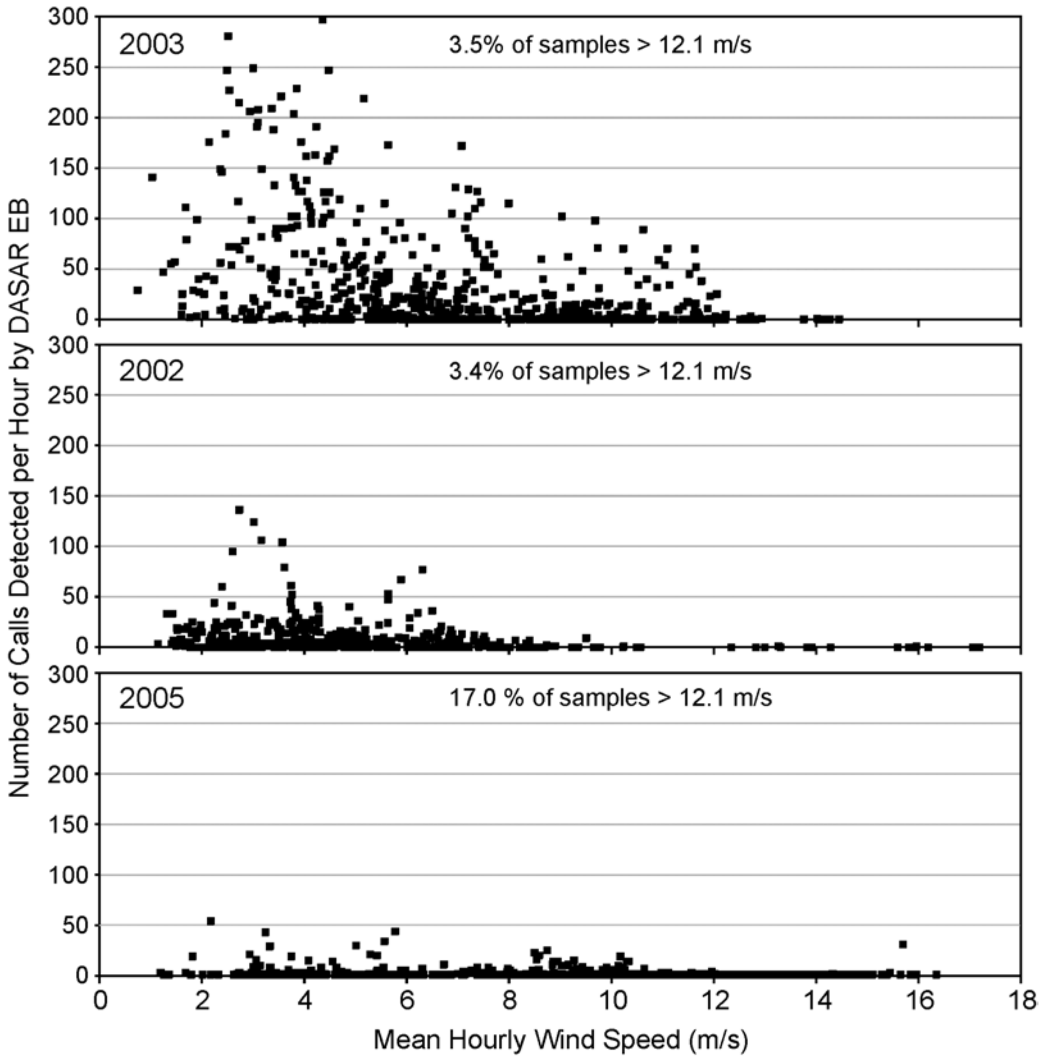

FIGURE 2.18. Hourly number of calls detected by DASAR EB as a function of mean hourly wind speed for 2002, 2003, and 2005. Hours when the acoustic vessel was in the DASAR array were not included.

The analysis of all the records from DASARs placed offshore in 2005 supports the general conclusion that 2005 was a low-count year. The number of calls detected by the combined DASARs EB, CC(a), and WB in 2005 was 53% of that in 2001, 30% of that in 2002, and 4–5% of the numbers detected in 2003 and 2004.

Bearing Analyses

Table 2.5 summarizes some of the main results of the bearings analyses. For 2005, bearings from CCa and WB could not be relied upon because those DASARs were moved by currents between successive calibrations of their compasses. Thus, only the results from EB are shown for 2005. For 2001–2004, bearing data from DASARs CC and WB provide a basis for comparison with results from EB (Table 2.5). Considering all five seasons (2001–2005), vector mean bearings to the whale calls detected by these DASARs were most often in the range NNW through N to E (i.e., offshore). The one exception was WB in 2001 (WNW). For all DASARs, 2002 was the year with the longest mean vector length (L), i.e., the strongest tendency for calls to be toward the NE–ENE direction from the DASARs. Predictably, 2002 was also the year with the highest O/I ratios, i.e., the highest number of offshore calls in relation to the number of inshore calls. In 2003 and 2004, the mean vector length L and the O/I ratios were smaller than in 2002 for all three DASARs, which supports the observation that the whales were migrating farther south in 2003 and 2004 compared to 2002.

TABLE 2.5. Results of the bearing analyses for DASARs EB, CC(a) and WB in 2001–2005. α is the vector mean bearing in degrees True, and L is the length of the mean vector (see Fig. 2.5). O/I is the ratio of number of offshore versus inshore calls. See text and Fig. 2.6 for definitions of offshore and inshore, and Fig. 2.1 for a map of DASAR locations.

	EB			**CC**			**WB**		
	α (°)	**L**	**O/I**	α (°)	**L**	**O/I**	α (°)	**L**	**O/I**
2001	44	0.65	6.5	61	0.39	2.0	286	0.40	0.5
2002	64	0.74	21.4	51	0.66	42.4	43	0.71	105.6
2003	78	0.55	2.9	66	0.54	6.4	54	0.49	6.2
2004	69	0.42	2.9	67	0.52	6.2	59	0.54	13.0
2005	348	0.14	1.3	-	-	-	-	-	-

The very small L value for 2005 as compared with other years indicates that there was much variation in the bearings to the calling whales, i.e., the calls detected by DASAR EB were more evenly spread in all directions than in previous years. In addition, the O/I ratio of 1.3 was among the smallest found for any of the three DASARs in any year. This result shows that only about 1.3× as many calls were detected offshore than inshore of DASAR EB in 2005, as opposed to 2.9× to 21.4× as many offshore vs. inshore of that site in previous years (Table 2.5).

Figure 2.19 shows the percentage distribution of all bearings obtained via DASAR EB in each year from 2001 to 2005. The bearings for each year were grouped into thirty-six 10° bins centered on multiples of 10° (i.e., 355°–4.99°, 5°–14.99°, etc.). The number of bearings in each bin is expressed as a percentage of the total number of call bearings determined via DASAR EB for that season. These plots emphasize the preponderance or rarity of bearings in certain directional sectors. For example, the 2002 plot shows that

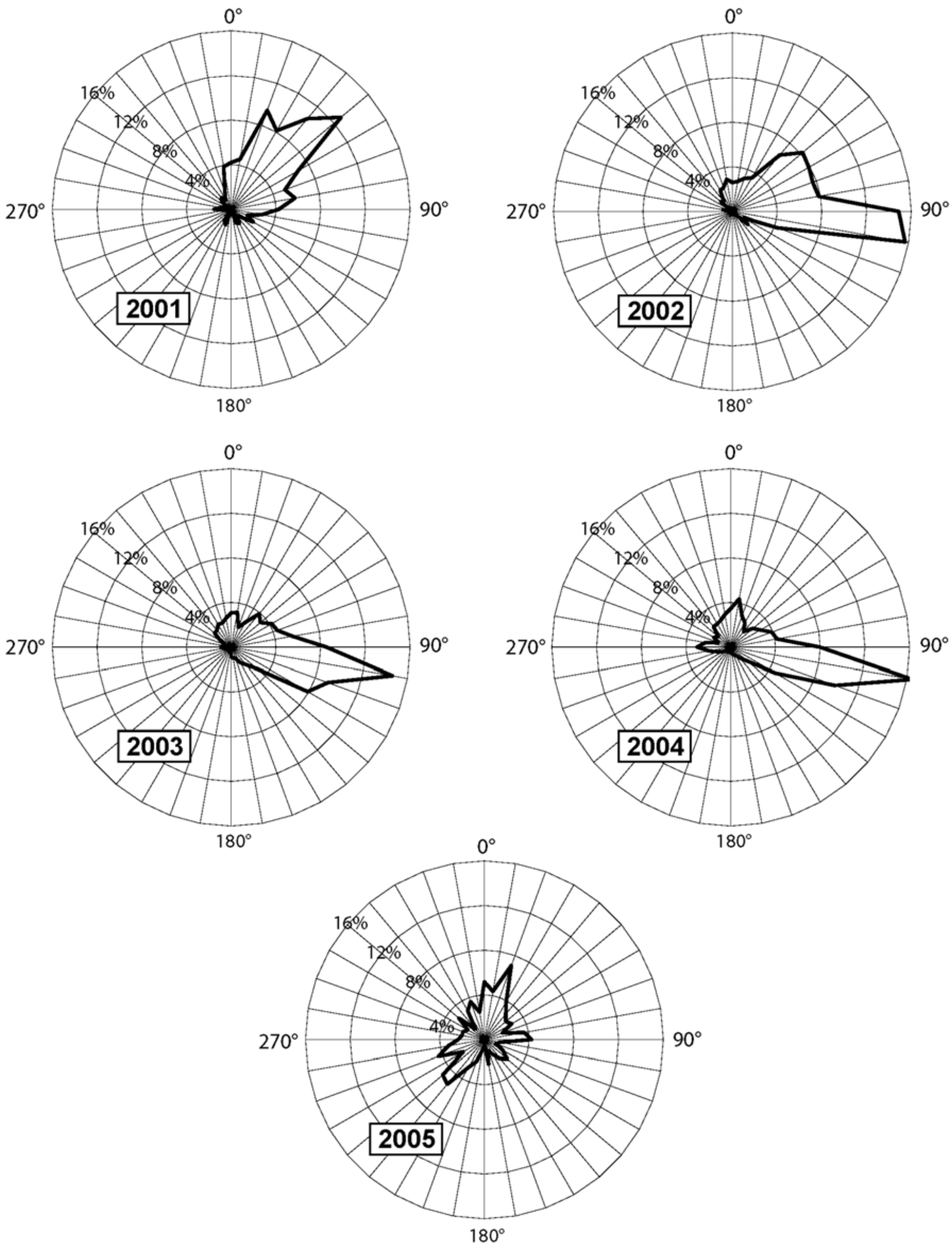

FIGURE 2.19. Directional distribution of bearings to bowhead whale calls detected via DASAR EB in 2001–2005. Results for each 10° sector are expressed as a percentage of all bearings obtained via DASAR EB that year. Sample sizes vary widely, from ~640 in 2005 to ~26,550 in 2004, and can be obtained from Table 2.4.

bearings in the range 140°–310° were rare that season, whereas bearings in the range 85°–105° were most common. The bearings to calls were more evenly spread around DASAR EB in 2005 than in any of the four previous years (Fig. 2.19), consistent with the low "L" value (=large variance in bearings) shown for 2005 in Table 2.5. Within each year, the distributions of bearings for DASARs CC and WB (not shown) were fairly consistent with those shown for DASAR EB.

Figure 2.19 shows that in 2001–2004 the vast majority of bearings to calls from DASAR EB were in the 20°–120° range, i.e., ~NNE to ESE. This is not what we would expect if the whale calls were omnidirectional and the whale calling rate was constant as they swam through the DASAR array past Northstar. This skew towards the east was also seen in DASARs CC and WB in 2001–2004 (not shown), except for DASAR WB in 2001 for which the skew was in the opposite direction (40% of bearings were in the 265°–275° range). It is unlikely that the DASARs would have a bias towards picking up signals from the east if the calls are equally strong "ahead of and "behind" the predominantly westbound whales. Thus, this uneven distribution of bearings probably reflects either some difference in whale behavior to the west vs. east of the DASAR, or directionality in the calls (i.e., a lower effective source level for propagation behind the whales). There is some equally indirect evidence of call directionality for bowheads migrating in spring (Clark et al. 1986). However, we have no specific evidence to distinguish the possibilities of call directionality vs. alteration in behavior (e.g., lower call rate) in more westerly areas. The effects of sounds from Northstar on bowhead calls in 2001–2004 are currently being investigated (Blackwell et al., Chapter 11 *in* Richardson [ed.] 2006).

It should be noted that in 2003, 2004, and (to a lesser degree) 2002, a large percentage of the bearings from DASAR EB to calls were directed approximately ESE of the DASAR (Fig. 2.19). Many of these calls were in directions that were within the 98°–118° range that was neither offshore nor inshore, but rather alongshore (and "upstream").

High background noise levels provide an alternative explanation for the low call counts in 2005. (It is also possible that whales call less when ambient sound levels are high, but we have no information on this.) High ambient noise masks an unknown percentage of calls that would otherwise have been detectable, and the poor quality of the resulting sound records makes the identification and classification of calls a challenge. The low call counts at DASAR EB in 2005, the difference between the first and second analysis, and testimonials from the whale call analysts all suggest that the high amount of background noise in 2005 limited what could be done by acoustic monitoring more than in previous years.

Call Types

Figure 2.20 shows a percentage breakdown of all calls detected by DASARs EB, CC(a), and WB by call type for 2001–2005. Simple calls are broken down into five categories: upsweep, downsweep, constant, and two types of undulation calls. The percentage of calls that were "simple" (i.e., 100% – % complex calls) varied from 82 to 87% in 2001–2003. In 2004 it dropped to 70%, and was 78% in 2005. Call type percentages in 2005 were within the ranges of values obtained in previous years.

Call type percentages were often different when based on data from only one of the DASARs (not shown) as compared with combined values from DASARs EB, CCa, and WB (Fig. 2.20). Similarly there are differences when comparing the call type breakdown for DASARs EB, CC, and WB combined (Fig. 2.20) with that for the entire array in 2001–2004 (*cf.* Blackwell et al. MS). For example, in 2002 and 2003 the percentage of complex calls as detected by the entire DASAR array was 30% and 27%, as compared to 13% and 18% in those respective years for EB, CCa and WB (Fig. 2.20). In 2001 inflected "∩" calls made

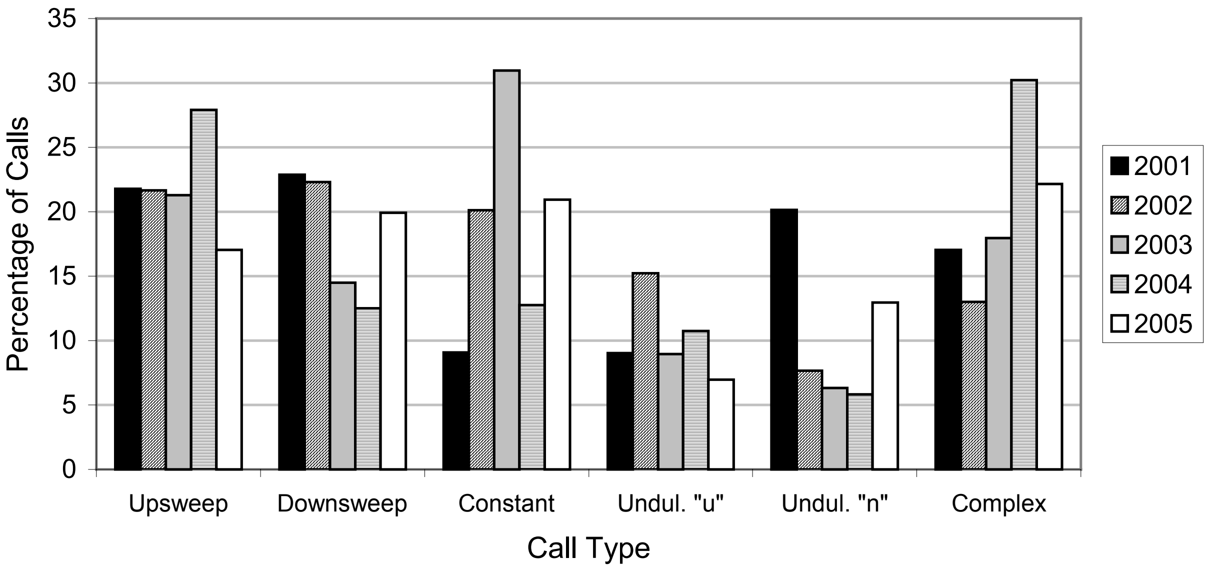

FIGURE 2.20. Percentage breakdown by call type in 2001–2005 for calls detected by one or more of DASARs EB, CC(a), and WB. Simple calls include upsweeps, downsweeps, constant calls, "∪" undulations, and "∩" undulations. Call sequences, which were detected only in 2004, were not included in these percentages.

up only 6% of calls for the entire array, but 20% of calls for DASARs EB, CCa, and WB combined (Fig. 2.20). We have no information on the biological significance or possible causes of these differences.

Since calls from DASAR EB in 2005 were analyzed twice we compared the call type percentages for the first vs. the second analysis. The percentages of upcalls and downcalls changed by ~1%. The percentages of constant and inflected calls changed by 6–7%. However, the identification of constant and inflected calls is ambiguous since there is essentially a continuum from an inflected "∪"call to a constant call to an inflected "∩" call. The percentage of complex calls also changed by ~7%. In view of the difficulties in the detection and identification of calls in 2005 (see Fig. 2.15), these differences may be a result of slight differences in categorization procedures from the original analysis to the re-analysis.

DISCUSSION

Underwater Sounds at Northstar

Figure 2.11 shows two main characteristics of underwater broadband sounds during September 2005 (as recorded 410 m or 1345 ft north of Northstar) compared to previous years:

- the number of boat-related "spikes" in received sound level during 2005 was similar to that during 2004, but less than in the preceding three years (2001–2003). In 2005 vessel traffic included the Northstar tug and barge, ACS vessels, and the hovercraft. Of these, only the tug and ACS vessels need to be considered, as the hovercraft does not produce a sound spike on the sound pressure time series of the near-island recorder (see Fig. 7.9 in Blackwell et al. 2004). The number of daily tug and barge round trips to Northstar in 2005 was about the same as in 2004, and the number of trips to Northstar by ACS vessels was reduced by 50%. Overall, at least 81% of the spikes during the 2005 season could be attributed to these two types of vessels.

- ambient sounds as caused by wind and wave action were unusually high in 2005 as compared to the previous four years, particularly in the second half of September. The presence of broken ice ~2 n.mi. north of Northstar in late August and early September helps explain the lower sound pressure levels at that time (Fig. 2.7, 2.11), as ice floes dampen wave action. Higher mean wind speeds are also a likely explanation for the heightened median and 95^{th} percentile levels in 2005 compared to 2004 (Table 2.3). The curves published by Knudsen et al. (1948) can be used to estimate the increase in broadband sound levels caused by a change in sea state. Mean wind speeds in 2001 and 2005 (the years with the lowest and highest mean wind speed values) correspond to sea states 2 and 3, respectively. According to the Knudsen et al. (1948) curves, this corresponds to an increase in broadband levels of 3–4 dB.

Table 2.3 and Fig. 2.9 also show that minimum broadband values were somewhat lower in 2005 than in 2004 but within the range of previous years. Maximum values were similar to previous years, which is to be expected since they are probably determined by the passage of a vessel overhead. The range (maximum – minimum) increased somewhat in 2005 compared to 2004, but remained well below the 2001 value.

The statistical spectra shown in Figure 2.8 are similar to those obtained in previous years (see Fig. 2.7 in Blackwell et al. 2005, Fig. 7.13 in Blackwell et al. 2004, Fig. 6.19 in Blackwell 2003, Fig. 7.19 in Blackwell and Greene 2002, and Fig. 7.31 in Blackwell and Greene 2001). The maximum spectra are excluded in this comparison, as they can be shaped by a single event and are therefore subject to much variation. Also, the rapidly dropping values at frequencies close to 500 Hz, seen in data collected by DASARs (whose sampling rate is 1 kHz), are an effect of the anti-aliasing filter applied to the data. Three peaks or tones below 100 Hz were present in all years (2001–2005): those at 30, 60, and 87 Hz. The number of tones and peaks at low frequencies was about the same in 2005 as in 2002–2004, whereas in 2001 (during island construction) they were noticeably more numerous. As in previous years, levels for the one-third octave bands centered at 31.5, 40, 50, 63 and 80 Hz tended to be elevated compared to neighboring bands (see minimum percentile in Fig. 2.8A).

Broadband (10–450 Hz) sound levels recorded 15 km (9.3 mi) from Northstar at the DASAR EB location (Fig. 2.13) were characterized by large fluctuations due to sea state and occasional tall “spikes” in sound levels. Many of these spikes were caused by the vessel servicing the array. Most likely some of the remaining spikes were caused by other vessels, such as those transiting between North Slope communities or those involved in other (non-BP) industrial activities (see Chapter 3). When industrial sound levels are low or absent, minimum sound levels in the sound pressure time series shown in Figure 2.13 are determined by ambient noise. In 2005 there were extended periods during which minimum sound levels were higher than any of the minima during 2001–2004.

Whale Calls and Locations

After four years during which the yearly number of detected whale calls at DASARs EB, CCa, and WB increased steadily (Table 2.4), the number of calls detected in 2005 was much lower. The number of calls detected by DASARs EB, CCa, and WB in 2005 was 54% of that in 2001, 30% of that in 2002, and 4–5% of the numbers detected in 2003 and 2004 (Table 2.4). All DASARs deployed in 2005 were functioning normally over their entire deployment as best we can determine. We therefore distinguish the following possible causes for this decline in numbers of calls detected:

- The location of the bowhead whale migration corridor varies from one year to the next and it could have been (mainly) farther offshore in 2005 compared to previous years. Since 1982, systematic aerial surveys have been done by or for the Minerals Management Service off the north coast of Alaska during the autumn migration period of the bowhead whales. Their data showed that in 2004 whales were sighted on average closer to shore than in previous years (1982–2001; Monnett and Treacy, 2005). Early in the 2005 season (early September) whales were sighted north of the area of drifting ice, i.e., several to many miles north of Northstar. Later in the season very few flights could take place because of the poor weather conditions. Thus sample sizes over the season were low and differences in distance from shore (in 2005 vs. previous years) may not be significant (C. Monnett, MMS, pers. comm.). When available, the MMS aerial survey data will be useful in documenting the overall position and width of the migration corridor in 2005 compared to 2001–2004. The analysis of the bearings to whale calls from DASAR EB in 2005 compared to previous years (2001–2004; see Fig. 2.19) indicates that many of the whales recorded were traveling inshore of this DASAR. However, few calls were detected in 2005, and the presence of ice in 2005 may have split the migration pathway, with most whales traveling north of the ice pack (mainly beyond acoustic range) and some whales traveling south of it (within range). Using aerial survey data, Moore (2000) and Treacy et al. (2006) have shown that bowheads tend to select shallow inner-shelf waters close to shore during years with moderate and light ice, and deeper slope habitat farther from shore in heavy ice conditions.
- The noticeably higher mean wind speed in 2005 created higher levels of ambient noise, which would lead to masking of a higher proportion of whale calls than in previous years. In 2003, a year with a large sample size, 12.1 m/s (27 mph) was the wind speed above which the call detection rate dropped to near 0. Figure 2.18 shows that in 2005 hourly wind speed was greater than 12.1 m/s 17% of the time, compared to ~3.5% of the time in 2002 and 2003. However, Figure 2.18 also shows that the call detection rate at low wind speeds (e.g., below 6 m/s) was much lower in 2002 and particularly 2005 than in 2003. The scarcity of detectable calls at times with low wind speeds in 2005 most likely corresponds to a lack of whales (or a lack of calling) near DASAR EB, and not to differential call detectability.
- Barging activities east of Prudhoe Bay in September 2005 might also have had an effect on the bowhead whale migration pathway. Vessel traffic not related to BP occurred on several days during which the DASARs were recording. Nuiqsut hunters reported seeing vessel activity on 3, 4, 5, 8, 14, and 21 Sept., and expressed concern at the potential disruptive effects of this non-BP vessel traffic on the 2005 whale hunt (see Chapter 3).

Anecdotal evidence also supports the hypothesis that the bowhead migration corridor was farther from shore in 2005. During boat-based work to service the DASARs in 2005 the acoustics crew saw no bowhead whales. Similarly, there were no visual observations of bowhead blows in either 2001 or 2002, whereas in 2003 and 2004 there were several (up to ~4) observations of bowhead blows on each day that the acoustics crew was in the DASAR array aboard an ACS vessel. In 2003, the Nuiqsut whalers landed their quota of four bowheads at Cross Island during a very short period (1–6 Sept.), consistent with the occurrence of many bowheads close to shore. The whaling season in 2004 was somewhat more extended (1–15 Sept.), and three whales were caught. Consistent with the above evidence, the acoustic localization data showed that the migration corridor was closer to shore in 2003 and 2004 than in 2001 and 2002 (Richardson et al. 2005). In 2005 the whaling season started around 1 Sept. but the whalers didn't catch their first (and only) whale until 14 Sept. (see Chapter 3 for details). They continued whaling until 24

Sept., when the Cross Island camp was dismantled and the whaling season was closed due to poor weather.

The call type analysis showed that the percentages of calls of the simple vs. complex types in 2005 were within the range of the previous four years. In 2004 the percentage of complex calls was much higher than in 2001, 2002, 2003, and 2005 (Fig. 2.20). This could be in part related to the large number of calls detected that year. Blackwell et al. (MS) showed that in 2004 the daily percentage of complex calls was positively correlated with the total daily number of calls. In other words the use of complex calls increased with the density of calls (and presumably of whales). Other authors (i.e., Würsig and Clark 1993; Richardson et al. 1995b) have reported an association between complex calls and socializing. If so, then the higher proportion of complex calls in 2004 was consistent with the idea that higher densities of calls (and presumably of whales) might be associated with more socializing. Behavioral associations for other types of bowhead calls are not known. Therefore it is not possible to assess the meaning or significance of other variations in the use of call types, like the increases in use of constant calls in 2003 or ∩-shaped undulation calls in 2005 (Fig. 2.20).

The acoustic monitoring effort in 2005 was a modified version of the project as implemented in 2001–2004. It provided the data needed to characterize sounds from Northstar Island during much of the 2005 bowhead migration period, including a comparison of their levels and frequencies with previous years. Counting whale calls at three DASARs in 2005 provided data that were directly comparable with previous years. Data collected in autumn 2005 showed that 2005 was an outlier year, with the lowest call counts and the highest wind speeds since the beginning of this study in 2001. These results show that, in some years, acoustic monitoring of the autumn migration of bowhead whales in the general Prudhoe Bay region can be limited by high background noise levels.

Relatively high wind speeds and ambient noise levels prevailed during parts of the 2005 autumn migration season. This factor, combined with the lower sound emissions from Northstar during routine production operations (as occurred in 2005), mean that Northstar sounds would have been (on average) less audible to bowhead whales than at some times in the past. The number of whales deflected offshore in response to Northstar operations in 2005 cannot be estimated by the methods that have been applied to the more extensive datasets acquired in 2001–2004. However, if the overall migration corridor in the central Alaskan Beaufort Sea was farther offshore in 2005 than in other recent years, then the number of whales deflected by Northstar-related sounds in 2005 was likely toward the low end of the range for 2001–2004. With an offshore migration corridor, especially in a year when Northstar sounds were less prominent as compared with some earlier years, relatively few whales would have been on migration paths that would bring them close enough to Northstar for deflection to be likely.

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ANNEX 2.1: SUMMARY OF NORTHSTAR BOWHEAD WHALE MONITORING WORK IN 2005

24 January 2006

Robert Suydam and Craig George
North Slope Borough
Dept. of Wildlife Management
PO Box 69
Barrow, Alaska 99723

RE: 2005 Northstar Bowhead Whale Monitoring Work

Dear Mr. Suydam and Mr. George,

Per our conversation in San Diego, I am writing to summarize the Northstar bowhead whale monitoring work accomplished in 2005.

As you know, 2005 was the first year of our modified monitoring program. Our primary goals were to: 1) record sounds from Northstar during September, allowing a comparison with past years; and 2) record bowhead calls during September from a single DASAR, allowing a comparison with past years. The sections below summarize different aspects of our work.

> ***Instrument Deployments for Northstar Recordings:*** To record sounds from Northstar, three DASARs were installed 390–520 meters (1280–1700 feet) north of the island on 30 August. Two of these DASARs were intended as backups. All three DASARs recorded continuously until they were retrieved on 3 October.
>
> ***Instrument Deployments for Bowhead Recordings:*** To record bowhead calls, four DASARs were installed on 4 September 9.3–15 km (5.8–9.3 mi) NNE of Northstar Island, in locations identified in previous Northstar reports as WB (1 DASAR), CC (2 DASARs—1 primary and 1 backup) and EB (1 DASAR). Ice conditions delayed deployment and limited our choice of locations for deployment. We chose to deploy the DASARS on 4 September as far offshore as ice conditions permitted, rather than further delaying deployment. Although we had hoped to deploy the DASARs in a triangular configuration, ice conditions forced us to deploy them in a line roughly parallel to shore. Also note that ice conditions in 2005 would not have allowed full deployment of the DASAR array used in past years. All four of these DASARs recorded continuously until they were retrieved on 3 October.
>
> ***Recordings near Northstar:*** Data from one of the three DASARs deployed 390–520 meters north of Northstar have been processed. Data from the other two backup DASARs deployed 390–520 meters north of Northstar will not be processed, but they will be archived.
>
> Median and 95th percentile levels of sound recorded near Northstar were 5.3 and 7.7 dB higher in 2005 than in 2004, probably because of higher wind-induced

ambient levels. Mean hourly wind speed in 2005 at the Northstar weather station was 8.3 m/s (18.6 mph) during the period 31 August to 30 September. This is 28% higher than the same period in 2004 (6.5 m/s or 14.5 mph), 24% higher than in 2003 (6.7 m/s or 15.0 mph), 48% higher than in 2002 (5.6 m/s or 12.5 mph), and 113% higher than in 2001 (3.9 m/s or 8.7 mph). The curves by Knudsen et al. (1948)[7] can be used to estimate the increase in broadband sound levels caused by a change in sea state. Mean wind speeds in 2001 and 2005 (the years with the lowest and highest mean wind speed values) correspond to sea states 2 and 3, respectively. According to the Knudsen et al. (1948) curves, this corresponds to an increase in broadband levels of 3–4 dB re 1 μPa.

Important components of island sounds are the spikes produced by vessel traffic to and from Northstar. In 2005, there was about the same amount of spike-producing vessel activity as in 2004. The frequency composition of industry sounds was similar to previous years.

Based on island recordings and activities, there is no reason to believe that industry sound levels were higher in 2005 than in previous years. In fact, high wind conditions likely masked industry sounds to a greater extent than would have occurred in past years, in effect shrinking the island's acoustic footprint.

Recordings at DASAR EB: DASAR EB was located 15 km (9.3 mi) NNE of Northstar. Of the 2005 DASARs, it was farthest from Northstar and the least influenced by industrial sounds.

Median levels of sound at DASAR EB in 2005 were 6.5–9.9 dB higher than in previous years (2001–2004). Again, this is most likely the result of the higher wind speeds in 2005.

Calls on DASAR EB were tallied and compared to the number of whale calls detected at the same DASAR location in previous years. A total of 951 calls were detected by DASAR EB during the 2005 season, or a mean of 34 calls per day of monitoring. This compares with 1,624 calls in 2001 (62/day), 4,317 calls in 2002 (180/day), 21,726 calls in 2003 (724/day), and 26,546 calls in 2004 (948/day).

We believe the lower call count in 2005 probably resulted from a combination of two factors: high background noise (masking the calls) and the possibility that the bowhead migration corridor was farther from shore. The acoustic data from prior years clearly show that the whales tended to be farther from shore in 2001 and 2002 (when the call counts were fairly low) than in 2003 and 2004 (when call counts were much higher). Given this, we suspect that the 2005 migration corridor was also farther offshore than in 2003 or 2004. That factor, along with the higher wind speeds and background noise levels in 2005, could account for the low number of calls detected in 2005. We hoped to learn more about the 2005 migration corridor through the BWASP study, but a preliminary discussion with MMS suggests that weather conditions limited BWASP surveys in 2005 in such a way that their data may not shed much light on the location of the migration corridor. We also hope to learn more based on discussions with native hunters, but these discussions have not yet been completed.

Recordings at DASARs WB, CCa and CCb: Our 2005 monitoring plan called for inter-annual comparison of whale calls recorded by a single DASAR unless calling rates were unusually low. The relatively low number of calls recorded in 2005

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[7] Knudsen, V.O., R.S. Alford, and J.W. Emling. 1948. Underwater ambient noise. *J. Mar. Res.* 7(3):410–429.

justifies further processing of call data from DASARs WB, CCa and CCb. This processing is currently underway and should be completed by late March. In addition to counting calls recorded by these three DASARS, bearing data will also be processed. Because the four offshore DASARs were deployed in a straight line rather than in a triangular configuration (because of ice conditions), our ability to localize calls will be limited, especially for calls east and west of the DASARs. Nevertheless, even limited localization may help us understand if calling whales were further offshore than was typical of past years.

Additional Analyses of Previous Years' Data: In keeping with recommendations made by the Scientific Advisory Committee, we continue to process data collected in previous years. To date, none of these analyses have led to meaningful changes in conclusions, but we still have a substantial amount of work to complete.

Attached is a copy of a draft paper on analyses of bowhead calling behavior that might interest you. We would welcome any comments you have on this draft paper.

In closing, I want to acknowledge and thank LGL and Greeneridge staff for their ongoing work on this project. Susanna Blackwell and Bill Burgess deserve special recognition for their patience and perseverance during many slow days when weather, either ice conditions or wind, delayed deployment and retrieval of DASARs in 2005.

Sincerely,

Bill Streever
Environmental Studies Leader

cc: Ken Hollingshead, NMFS
Brad Smith, NMFS
Pam Pope, BP Northstar HSE

CHAPTER 3:

SUMMARY OF THE 2005 SUBSISTENCE WHALING SEASON, AT CROSS ISLAND[1]

by

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ABSTRACT

The North Slope Borough's Science Advisory Committee has recommended that local and traditional knowledge of Nuiqsut whalers be incorporated into reports concerning BP's Northstar marine mammal and acoustic monitoring program. This chapter does so in large part by summarizing data acquired during the 2005 phase of the Minerals Management Service project "Annual assessment of subsistence bowhead whaling near Cross Island". Those data were supplemented by interviews with the whalers focussing on specific aspects of the 2005 season relevant to BP's Northstar monitoring program. The interviews concentrated on whalers' encounters with non-whaling vessels in 2005, and the whalers' observations of the general offshore distribution of whales, whale feeding behavior (if any), and "skittish" behavior. In 2005, the first whaling crew went to Cross Island on 30 August, and the fifth and last crew arrived on Cross Island 8 September. Overall, the 2005 Nuiqsut whaling season was marked by very poor weather and rough seas, which affected not only the whalers but also all other maritime activities. Few days were suitable for "scouting" by the whalers, and on only one day was a large number of whales seen. On most days suitable for scouting, whalers encountered non-whaling vessels, some engaged in support to the petroleum industry and others not, but none related to Northstar. The whalers concluded that barges directly affected their hunt on two days in 2005, and that such influences may have occurred on other days as well. Only one whale was taken by Nuiqsut whalers in 2005, on 14 September. Nonetheless, the whalers called a cease fire on 24 September because of the forecast of more bad weather and the possibility of imminent freezeup, and on 25 September all crews left for Nuiqsut. In summary, the 2005 Cross Island hunt was affected negatively by bad weather and pack ice. The 2005 hunt was also perceived by the whalers to have been affected by tug and barge traffic, but not by Northstar-related activities.

INTRODUCTION

During the autumn migration period of bowhead whales, subsistence hunters from Nuiqsut travel to Cross Island, 17.5 miles (28 km) east of Northstar, in order to hunt bowheads. 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 the associated industrial activities. There is considerable concern among the Nuiqsut hunters about the potential for vessel and aircraft traffic, and other industrial activities, to interfere with the hunt.

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

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

It was apparent that the ongoing MMS study provided a good starting point for the compilation of the types of traditional knowledge that the NSB's SAC had recommended be incorporated into BP's Northstar monitoring program. Consequently, BP agreed to augment the ongoing MMS-supported program during 2005 in order to compile the specific types of information mentioned by the SAC.

This chapter of BP's 2005 Annual Summary Report describes information provided by the Nuiqsut subsistence whalers on selected aspects of the 2005 whaling season. This included the general offshore distribution of whales in 2005, 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, the chapter begins with a discussion of the methods used for gathering the information in this section, a very general description of the equipment and methods used for fall subsistence whaling, and a brief summary of the 2005 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 2005 season, which sets definite limits on the conclusions that can be drawn. Some comparative information from previous years is mentioned briefly. An expanded version of this chapter, including additional information about whaling in prior years, appears in an "updated comprehensive report" on BP's Northstar monitoring work in 1999–2004 (Richardson [ed.] 2006). More details for prior years can be found in earlier reports prepared for MMS (Galginaitis and Funk 2004, 2005; Galginaitis 2006a, 2006b).

METHODS

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

Information on the level of hunting effort was collected by systematic observations by MSG, who was on Cross Island for most of the whaling season in each of 2001–2005. 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. The whalers were given instructions on how to record the GPS coordinates (track) of the boat's 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 is then mapped, and is 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 position at the time a whale or group of whales was seen. These whales may be quite close or miles away (depending on the conditions of the day).

This information was supplemented by subsequent conversations with each boat crew, while reviewing the mapped GPS information on a laptop computer with them. When reviewing tracks after their return, crew members would often identify locations where they saw whales, and these points were added to the GPS information. Some of these points were boat positions, and some were estimated positions of whales (and thus not on a boat track). Other points were reference coordinates and may represent past whale sightings, so they also may not be 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 focussed on those topics of particular concern to BP were conducted both on Cross Island and in Nuiqsut after the whaling season. These interviews were primarily with whaling captains or senior crew members who had encountered non-whaling vessels while scouting for bowheads. These interviews were guided by an informal protocol developed to document each such encounter within the context of that day's scouting/whaling activities. Thus there were no "sampling" issues *per se*—information was collected from all crews that had such encounters. A more detailed description of the methodology can be found in Galginaitis and Funk (2004, 2005) and Galginaitis (2006a).

SUBSISTENCE WHALING EQUIPMENT 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 following is intended to provide only enough detail to ensure that the subsequent material is understandable. For a broader review, see Stoker and Krupnik (1993) or Rexford (1997).

The community of Nuiqsut is located about 16 miles inland ("as the crow flies") on the Colville River. Nuiqsut crews whale only in the fall, at a location about 73 "direct" miles or 92 to 109 "water" miles from Nuiqsut, on Cross Island. Cross Island is located about 10 miles north of Endicott, 15 miles NW of West Dock, and 17 miles east of Northstar. There are currently four to six active whaling crews in Nuiqsut, some of which use more than one whaling boat. Whaling boats are generally 18 to 24 feet long, with either aluminum or fiberglass hulls, and single outboard motors of 80 to 250 horsepower. The by-laws of the Alaska Eskimo Whaling Commission specify the equipment to be used for the whale hunt, and the general manner in which it is to be conducted.

Nuiqsut whalers generally go scouting for whales on any day when the weather is suitable for finding and striking whales unless a whale was taken the prior day, in which case butchering usually has priority. Whalers invariably use the term "scouting" rather than "hunting". Good whaling weather is determined more by wind speed than anything else. Whalers prefer days with no wind, and winds up to 5 mph, or even 10 mph, are acceptable. Sea conditions generally correspond with wind speed. Scouting can occur even with higher winds, depending on the circumstances. Boats typically scout for whales with a complement of three or four people, although some boat crews are as small as two or as big as eight. Although single boats do take whales on occasion, it is not encouraged and Nuiqsut boats almost always scout for whales in pairs, in case of mechanical break downs or other emergencies. Whaling crews with two or three boats are willing to whale on their own, but it is commonly agreed that five to seven boats is a preferable number to have available for whaling on a given day. More boats would be useful, and the availability of fewer boats decreases the efficiency, safety, and overall chance for success of the hunt.

The whale is killed by the delivery of whale "bombs", which are in essence very large bullets with timed fuses (generally 4 to 8 seconds) that explode inside the whale. Inupiat whalers adopted this technology from the commercial Yankee whalers. The first bomb is usually delivered through the use of a darting gun, and a harpoon with attached float is deployed at the same time. AEWC bylaws state that the first strike must attach a float to the whale, but does not require that the first strike deliver a bomb. Thus a harpoon without a darting gun may be used for the first strike, although this is seldom the case. 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 10 or 15 feet, and ideally closer. Once the whale is struck, the harpoon head separates from the handles. 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 seconds 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 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 must be approached on the whale's left side, since the boat normally "catches up" to the whale from behind it to achieve a striking position.

Once Nuiqsut whalers spot a whale and determine that it is a proper whale to take (generally 25 to 35 feet long, and not a mother with calf), they will approach it at high speed so that it dives. They will then estimate where it will reappear (usually in 5 to 10 minutes, but sometimes longer) and once in that area will wait and search at low speed until the whale surfaces and is spotted. They will then approach it so that it dives again, and so on. 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 finally get close enough to the whale while it is on the surface to strike it on its left side with the darting gun.

The second weapon used to deliver whale bombs is the shoulder gun – very heavy, short barrel, high caliber "rifles" used to shoot the same sort of bomb as is used in the darting gun, only with fins or quarrels to help stabilize its flight in the air. The shoulder gun can only be used after a float has been attached to a whale, and is generally used only after one or more darting guns have delivered bombs. A good proportion of whales are killed by the first bomb. However, when multiple bombs are required, the shoulder gun is useful because it can be used to fire several bombs, as long as the barrel is cleaned after each shot.

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

THE 2005 WHALING SEASON

Five crews whaled from Cross Island in 2005, but some spent more time on Cross Island than others. The researcher (MSG) traveled to Nuiqsut on 27 August, as several crews indicated their target date for travel to Cross Island was 2 September. As it turned out, one crew took one boat to Cross Island on Tuesday 30 August. Their second boat remained in Nuiqsut, waiting for a part for repairs. Two more crews left Nuiqsut and reached Cross Island with three boats on 4 September. The researcher and a crew with two boats left for Cross Island on 5 September, and arrived early on 6 September (one of the boats had some fuel problems). The last crew arrived on Cross Island 8 September. All crews left Cross Island on 25 September even though only one whale had been taken. Conditions during the entire season had been quite poor and the weather forecast was for increasing winds and high seas for at least the next 4–7 days. As it was, conditions on 25 September were marginal for small boat travel between Cross Island and West Dock, and most boats took an indirect route (towards Endicott from Cross Island) so they would not take on too much water.

The whaling seasons for the five crews ranged in length from 18 to 27 days, counting travel days. The seasons for the individual crews were 27, 22, 22, 21, and 18 days. The whalers encountered a great deal of ice in 2005, which was a dramatic change from the previous four years. The weather was also very unfavorable in 2005, and was dominated by strong east winds of 15 to 45 miles per hour. Wind speed as recorded at Cross Island exceeded 15 miles per hour consistently on 9–12 Sept., 15–20 Sept., 21–23 Sept., and part of 24 Sept. These periods of strong winds were generally consistent with those evident from wind measurements at Northstar—see Figure 2.7A in Chapter 2.

At least one boat went out scouting for whales on 8 different days (and also went out one day without whaling equipment to hunt seals). The researcher was on Cross Island for only 5 of these days, but was able to collect GPS tracks and whaler accounts for all scouting days. The first crew scouted for whales on 8 days (and hunted for seals on another), but on 2 of those scouting days were by themselves. Two crews scouted for whales on 6 days, one crew on 5 days, and the last crew on 3 days. Each crew devoted 2 days or (in one case) 3 days to travel to and from Cross Island. Various boats were disabled at times due to mechanical problems of various sorts, but weather was a much more significant factor in limiting scouting effort. Weather prevented any scouting activity on at least 16 days, and ice and weather limited scouting activities to some extent even on those days when boats did go out scouting.

Crews spotted whales on most (but not all) scouting days, although—with one exception—not in the numbers seen in previous years. The one exceptional day was the one day in 2005 when a whale was taken by the Cross Island whalers (14 Sept.). Also, the call detection rate offshore of Northstar was relatively high that day, as compared with most other days during the 2005 monitoring season (see Fig. 2.13 and 2.14 in Chapter 2). The generally lower numbers of whales seen in 2005 as compared with other recent years were attributed for the most part to the heavy ice cover encountered on most days. The ice cover (and fog) also limited the areas that could be searched for whales (see discussion of offshore distribution of whales, below). Only one whale was taken, a 40’9” (12.4 m) male taken by the Napageak crew, about 27 miles (43 km) east of Cross Island.

The whalers encountered barges on at least three days when they were scouting for whales, and noted barge sightings on at least several other days. None of these barges were engaged in Northstar-related activities. Whalers reported that, on at least two of those days, barges significantly affected whale behavior and the conduct of the hunt. More detailed information on these barge sightings / interactions is provided below (see discussion of observed vessel activity, below). Whaler observations and reports of whale feeding behavior and “skittish” behavior are also briefly discussed below, in separate sections.

OBSERVED WHALE FEEDING BEHAVIOR IN 2005

There were no reports of whale feeding behavior during the 2005 Cross Island whaling season. This does not necessarily mean that feeding did not occur, or that Nuiqsut whalers did not observe it. However, it is an indicator that whale feeding activity was not very obvious in 2005. Possible explanations, not mutually exclusive, are as follows:

- Whale feeding is not commonly observed (or at least not reported) by Nuiqsut whalers near Cross Island (only one incident during the previous four years);

- Few whales were observed by whalers during the 2005 season;
- On most days when scouting was possible, ice conditions made it difficult to observe whales for more than the shortest periods of time;
- On most days when scouting was possible, swells and waves (due to wind) still made spotting and observing whales difficult;
- Barge and other vessel activity may have "spooked" the relatively few whales seen;
- A major part of the migration may have bypassed the area accessible to the whalers.

For the four years previous to 2005, only one observation of whale feeding was reported and recorded. This was a spectacular sighting of a whale feeding on the surface with its mouth open, about 7.8 miles (12.6 km) from Cross Island, bearing 34° true. The captain, a very experienced whaler, remarked that this was the first time he had seen this. This does not necessarily indicate that Nuiqsut whalers did not observe whale feeding behavior on other occasions in 2001–2005 when they were out scouting. However, it probably means that such observations were not common. If other sorts of feeding behavior had been observed during 2001–2005, they would probably have been reported.

Most feeding by bowhead whales is below the surface and difficult to recognize via surface observations; however, there have been some previous observations of bowheads feeding actively at the surface in the Canadian and Alaskan Beaufort Sea, with mouths open (Würsig et al. 1984, 1989; Richardson and Thomson [eds.] 2002). The first whale taken by a Nuiqsut crew, in 1973, was reported to have been feeding on the bottom near Flaxman Island. Some other whales landed at Cross Island have been found to have recently-consumed food in their stomachs (Lowry and Sheffield 2002; Lowry et al. 2005).

"SKITTISH" WHALE BEHAVIOR DURING 2005

Nuiqsut whalers saw relatively few whales in 2005, compared to previous years. In most cases they were not able to follow or chase whales long enough to have a good opportunity for a strike.

In some cases whalers indicated that whales were traveling fast, not staying on the surface very long, and changing direction in unpredictable ways when first sighted. In other cases they indicated that a whale that had been traveling at normal migration or traveling speed suddenly began to take evasive action – more than would be expected simply from the approach of the whalers' boats. The 9/14/05 and 9/21/05 accounts in Annex 3.1 are examples. Whalers interpreted such "spooked" behavior by whales as reactions to encounters with barges and other vessels in the area. This interpretation was based on the whalers' previous encounters with similar bowhead behavior in the presence of vessels. The whalers noted that the one day and area where they found a large number of whales behaving in a normal (unspooked) way was NW of Cross Island in an area with no other vessel traffic (at least none that they knew of) on 9/14/05. While chasing whales, whalers directly observed changes in the behavior of several whales that they believe were related to the presence and activities of other (non-whaling) vessels in the area. Whalers did not suggest any alternative explanations for the "spooked" behavior of so many of the whales that they saw SE and E of Cross Island.

Ice conditions prevented whalers from searching NW of Cross Island in 2005 except during part of one day. However, ice conditions were not mentioned as a possible reason for why some whales behaved in a more "spooked" way than in previous years. As discussed in the next section, ice and weather were the major factors that whalers suggested made whales more difficult to find in 2005. Ice and weather were not considered to be factors that would make whales behave in a more "skittish" manner. However, especially to the SE of Cross Island inside the ice pack, Nuiqsut whalers reported that—once whales were found—they were often difficult to follow and chase because of "skittish" or "spooky" behavior induced, they thought, by other (non-whaling, non-Northstar) vessel activity in the area.

In 2001, whalers also reported that whales seemed more skittish than normal. However, in 2001 (unlike 2005) they suggested several possible explanations, some industrial and some natural: oil and gas activities, other local vessel activity, killer whales or air or vessel traffic east of Cross Isl., and ice conditions in Canadian waters. None of these, other than vessels not associated with Northstar, were suggested as alternative explanations in 2005. Environmental conditions in the two years were very different. In 2001 there was almost no ice and the whales found by whalers were quite distant from Cross Isl. (Acoustic monitoring in 2001 also found that bowheads were farther offshore in that year than in some subsequent years—specifically 2003 and 2004: Richardson et al. 2004; Richardson and Williams [eds.] 2005; Blackwell et al. MS.) Whalers went far to the NW and NE of Cross Island when scouting for whales in 2001. In 2005, whalers were for the most part effectively confined to the SE of Cross Isl. by ice.

General Offshore Distribution of Whales

Whalers remarked that 2005 was a year of very poor whaling conditions. Winds were consistently high (above 10 miles per hour) and ice conditions prevented whalers from reaching the areas where they had consistently found whales in the past (except for part of one day). Thus it was no surprise that whalers saw relatively fewer whales in 2005 than in previous years. The whalers did not suggest that there were actually fewer whales in the area. Rather, they theorized that the wedge of pack ice that prevented them from going much north of Cross Island was encouraging most of the migrating whales to stay well north of Cross Island, in more open water (supporting the 2005 acoustic monitoring results reported in Chapter 2). This ice allowed the whalers to travel most easily to the SE of Cross Island, and this is the direction that most of their scouting trips took (Fig. 3.1). This was a pattern very different from other recent years, when most trips were either NW or NE of Cross Island, with a few more easterly and only a very few with a southerly component (Fig. 3.2). Most scouting activities (and almost all Nuiqsut whale strikes) in other recent years have been north of Cross Island (Fig. 3.2; see also Figures 3.5–3.8 in Annex 3.2 at the back of this chapter).

In 2005, scouting trips to the SE of Cross Island did allow the whalers to find a few whales. However, the whalers' primary objective was stated to be to go SE far enough to reach the eastern end of this pack ice so that they could eventually turn north into more open water. They succeeded in doing so on 9/14/05 (Fig. 3.3) and found whales essentially due east of Cross Island, in an area where the hunters had taken whales in previous years. That was the one location and date in 2005 when the Nuiqsut whalers were successful in taking a whale.

There were difficulties with this strategy, however. These whales were quite distant from Cross Island (27 miles or so) and the tow would prove to be quite long. The two choices for the tow were

- to try to retrace the hunters' path to the whales, which had been south and then northeast on the shore side of the ice pack, or
- to travel more directly west on the ocean (or relatively open-water) side of the ice pack, with the hope that they could then find their way south or southeast through the ice pack to Cross Island.

Before reaching the whales 27 miles to the east, the crews of three boats had turned back to Cross Island, as they thought that they had already traveled too far from Cross Island, in conditions that would not allow them to successfully harvest and recover a whale. After stopping back at Cross Island to refuel, they

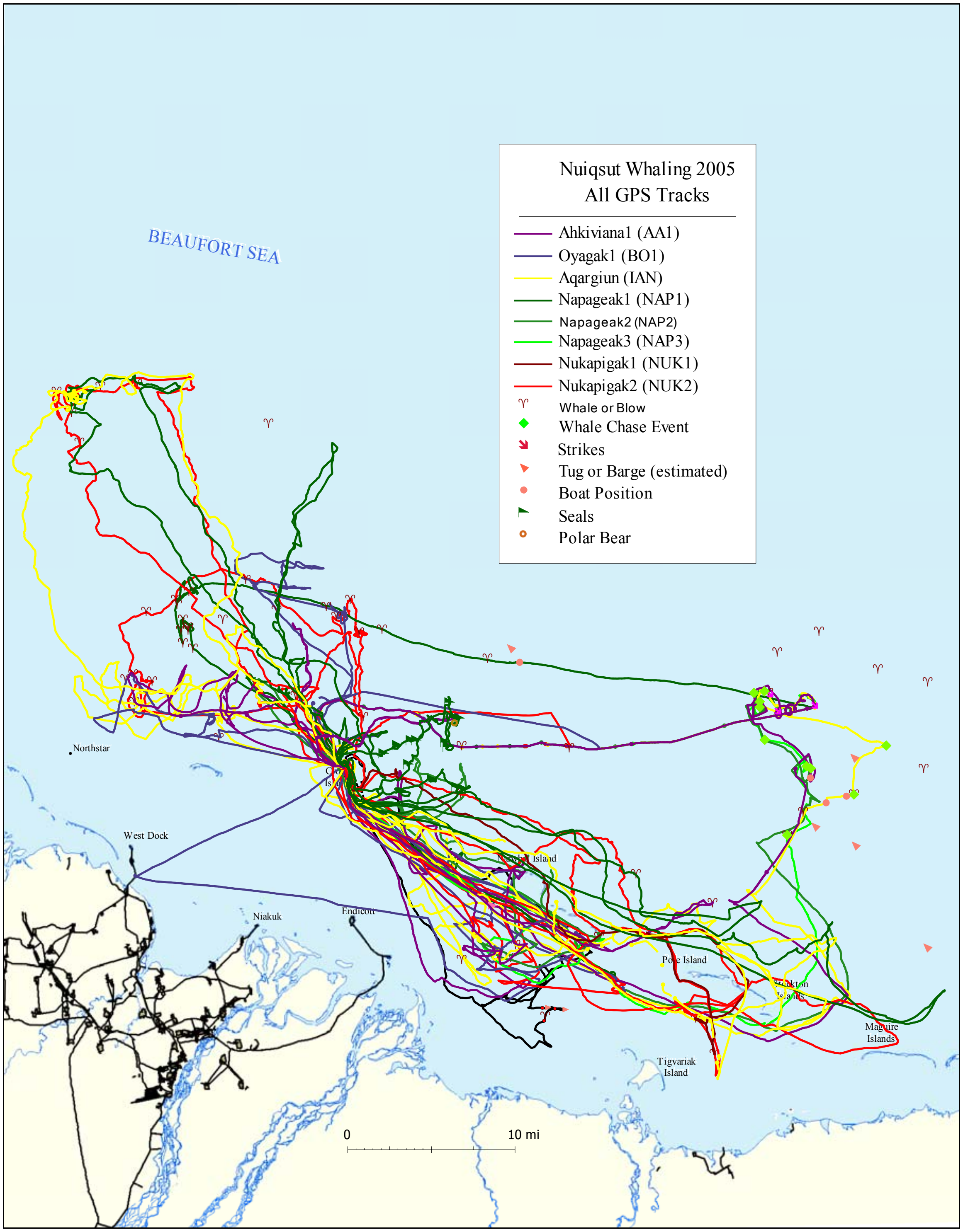

FIGURE 3.1. Nuiqsut whaling, 2005: All GPS tracks.

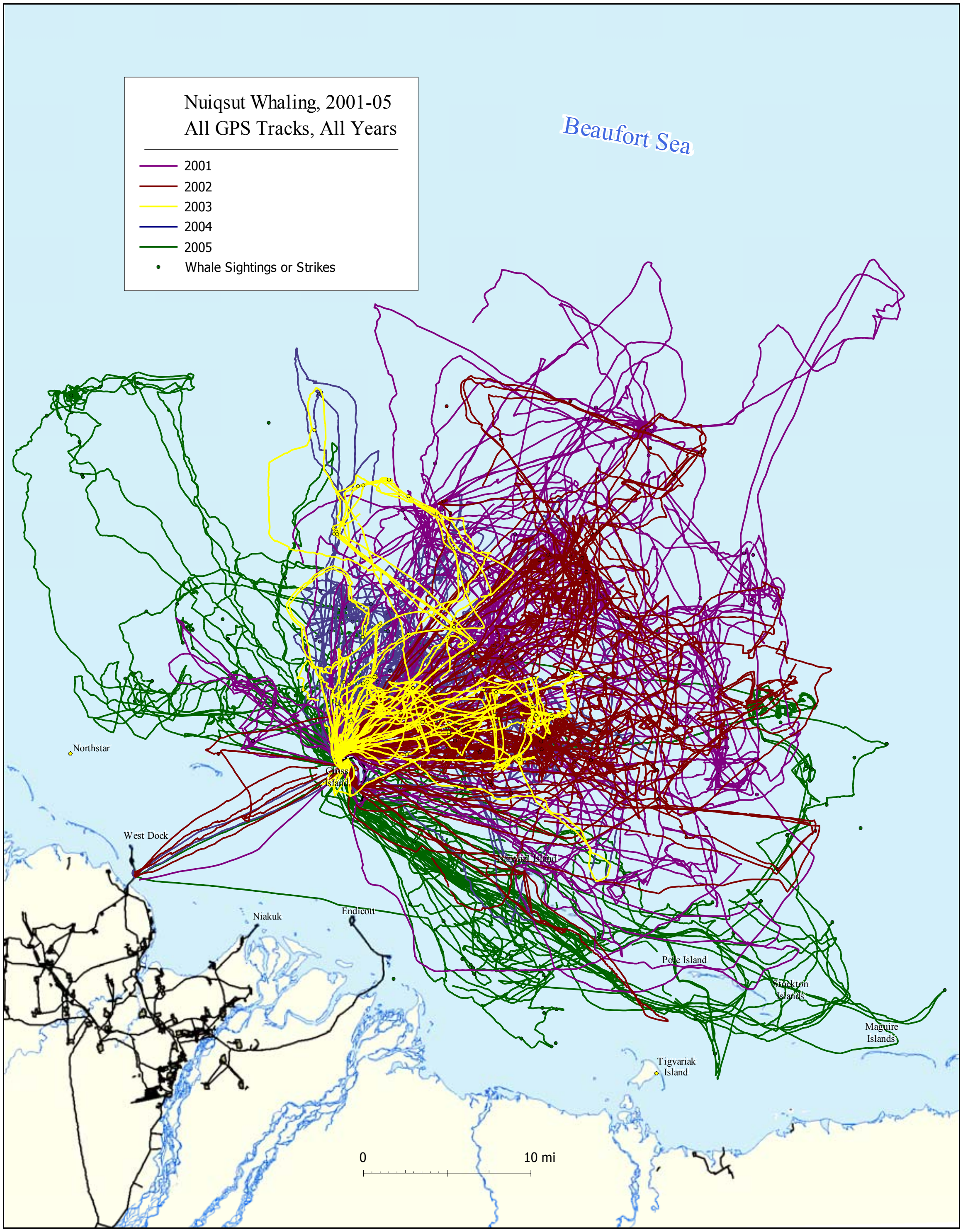

FIGURE 3.2. Nuiqsut whaling, 2001–2005: All GPS tracks, all years.

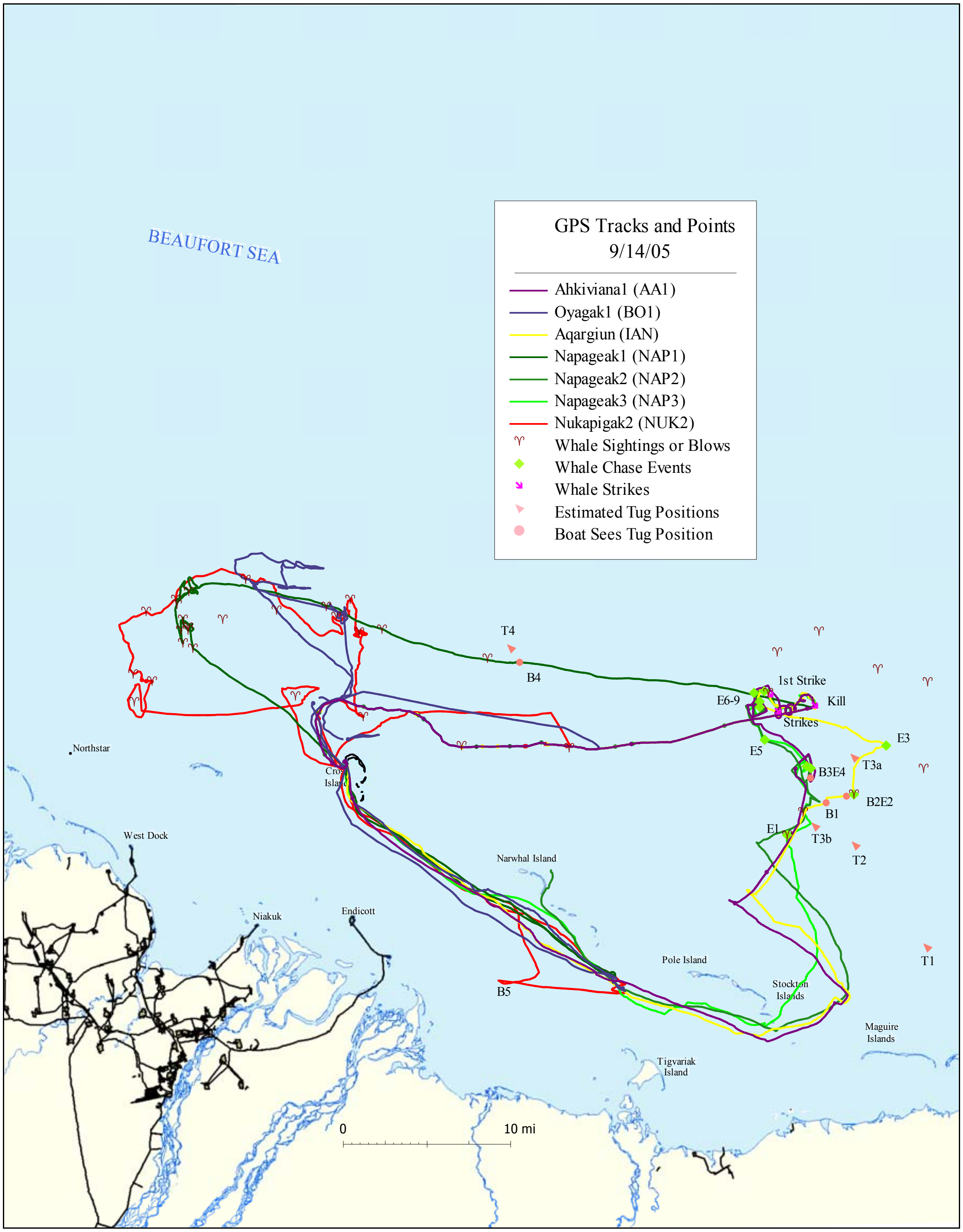

FIGURE 3.3. Nuiqsut GPS tracks, 9/14/05.

tried to go NW to see if they could penetrate the ice pack that way into more open water (Fig. 3.3). They succeeded in doing so and found a great number of whales within 10–15 miles NW of Cross Island, in an area where Nuiqsut whalers often find whales. This confirmed their idea that the whales were on the north side of the ice pack. Because the other four boats were already chasing a whale SE of Cross Island, and might need assistance with the tow if they were successful, the boats to the NW of Cross Island were told not to strike any whales. The NW boats did continue to chase whales to be in position to strike in case a decision to take two whales in one day was made. The SE whale, when it was finally killed, proved to be moderately large, and the tow was anticipated to be rather long and difficult. Thus, the decision not to strike a second whale had been prudent. The NW boats returned to Cross Island and then went out to help with the tow of the SE whale. Their trip to the NW did have the benefit that it enabled the tow to proceed with a reasonable expectation that the hunters could find a way through the pack ice to Cross Island from a position north or a little northwest of Cross Island. Thus, the tow could take a relatively direct route back to Cross Island. Even so, the whale did not arrive at Cross Island until very early on 9/15.

In general, Nuiqsut whalers report that significant ice cover allows whales to "hide" and thus makes them more difficult to spot. Significant ice cover also allows whales that are seen to escape more easily; it makes them more difficult to follow. Whales can dive under ice, whereas boats must travel around it. Thick ice cover, such as that encountered near Cross Island in 2005, may also direct most of the migration farther north into more open water, while at the same time effectively preventing Nuiqsut whalers from reaching or accessing those areas. When Nuiqsut whalers were able to reach the more open water to the north of the ice pack, they did find whales and were able to follow and chase them. However, on those few days when Nuiqsut whalers could penetrate the ice pack to reach open water NW of Cross Island, weather (wind) prevented them from being able to scout, except on 9/14/05. After the whale taken on 9/14/05, weather prevented all scouting activity until 9/21/05. Even on 9/15 the wind was 16.5 miles per hour from the east. Whalers tried to go north, but encountered "surf waves" that made conditions too dangerous for scouting. They thus concentrated their efforts on the open water SE of Cross Island again, and did find whales (although not in large numbers, and not as nearly as many as had been seen NW of Cross Island on 9/14).

Nuiqsut whalers believe that the migration of whales in 2005 was similar to that of previous years, but that ice and weather conditions prevented the whalers from reaching and seeing most of the whales. They also believe that many of the whales that they did see, at least in the area SE and E of Cross Island, were affected by non-whaling vessel activity in the area, and that this had a detrimental effect on the success of their subsistence whaling (see following section).

NUIQSUT WHALERS' REPORTS OF VESSEL ACTIVITIES, 2005

Annex 3.1, at the end of this chapter, summarizes the specific observations made by Nuiqsut whalers, during the 2005 Cross Island whaling season, of activities by vessels other than whaling vessels. (Henceforth, all references to "vessels" refer to vessels other than whaling vessels.) This information was recorded by a researcher staying with the whalers on Cross Island. Summaries are included only for those days on which vessel activity was reported, or for days on which whale scouting activity occurred. For days that are not listed, neither activity was reported. Blows of whales were spotted from Cross Island on several days when whaleboats did not go out scouting due to adverse conditions. The log compiled by the Whaling Communications Center has also been consulted to verify some of the details of timing and locations. Based on the daily information in Annex 3.1, the following summary has been compiled, attempting to draw some generalizations from the daily information.

Whalers reported seeing activity by vessels on six separate days during the 2005 whaling season, five of which were days when the whalers were actively scouting for whales (9/03, 9/05, 9/08, 9/14 and 9/21 were "scouting days"; 9/04 was not). Figures 3.3 and 3.4 show the details for two of those dates, 9/14 and 9/21. On another "scouting day", whalers did not see vessel activity but were informed that such activities were scheduled (9/13). None of the vessels encountered were engaged in support for Northstar. Whalers accounts of these encounters became more detailed later in the season, perhaps because the researcher was not on Cross Island until 9/06 and also perhaps because the whalers became increasingly sensitive to the potential disruptive effects such vessel encounters could have on their whaling activities. Whalers also had few good opportunities to approach or strike whales early in the season, as conditions for finding whales were not very good. Relatively few whales were seen prior to 9/14, and those whales that were seen were seen for relatively brief periods of time. How much of this can be attributed to vessel activity in the area as opposed to adverse environmental conditions is difficult to assess, and Nuiqsut whalers did not express developed statements in this regard. Given the conditions, they perceived that vessel traffic may have been a factor on days prior to 9/14 (specifically 9/05 and 9/08, and maybe 9/13), but the scarcity and brevity of whale sightings could not be definitely attributed to that vessel traffic.

However, whalers report that vessel activity directly affected the conduct of their hunt on 9/14 and 9/21 (see Annex 3.1 and Fig. 3.3, 3.4). It is not possible to demonstrate that, in the absence of vessel activity, the Nuiqsut whalers would have taken more than one whale, and they did not make that assertion. It would not be culturally appropriate for a whaler to state that a harvest was likely, under any circumstances. However, within the cultural constraints of not taking the harvest of any animal for granted, it was fairly clear that the whalers thought that their chances for taking more than one whale would have been substantially increased without the interference posed by the vessel traffic. This is MSG's interpretation of the various whalers' accounts. An earlier kill to the east of Cross Island on 9/14 might have allowed an attempted strike at a second, smaller whale to the NW of Cross Island on that day. Chances for a strike on 9/21 were apparently quite promising prior to the appearance of a barge (Fig. 3.4; Annex 3.1), although of course success can never be assumed.

The major environmental difference between the 2005 whaling season and the prior years documented by the MMS "Annual Assessment of Subsistence Bowhead Whaling Near Cross Island" (2001–2004) is that, in 2005, ice and weather confined the whalers' scouting activities primarily to nearshore waters SE of Cross Island. The same ice and weather conditions also made these nearshore waters the preferred operating areas for non-whaling vessel traffic. Interactions among vessels, whales, and whalers are likely in such a situation, although perhaps not inevitable. Vessel traffic encountered by the Nuiqsut whalers in the area east of Cross Island in September 2005 was not associated with BP's Northstar Development, 17.5 miles (28 km) west of Cross Island.

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

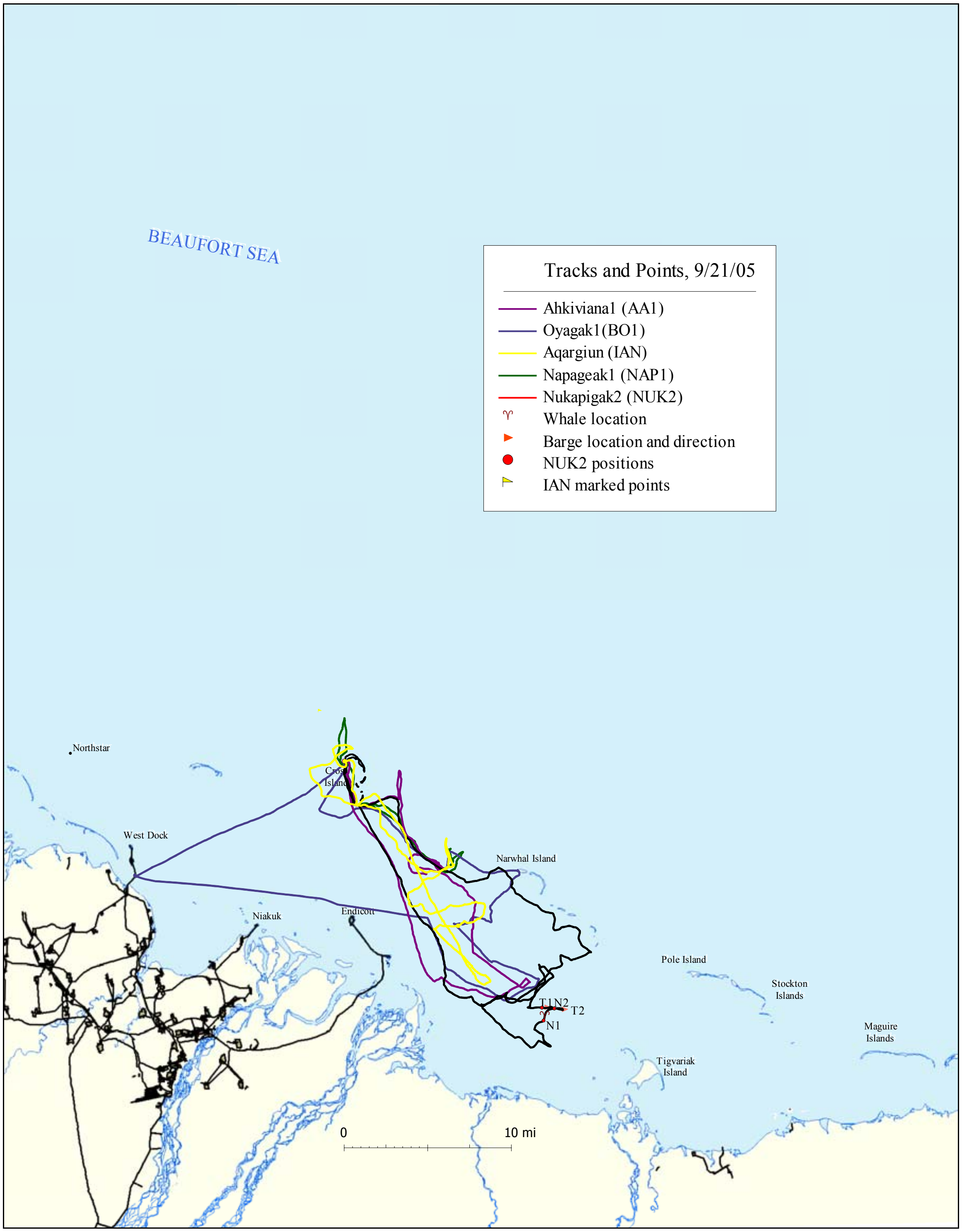

FIGURE 3.4. Nuiqsut GPS tracks, 9/21/05.

However, concerning Northstar in particular, whalers have not reported effects on their hunt from its development and production activities, although its noise and potential oil spills are still of concern for the disruptive effects they might have. BP has made consistent efforts to decrease the risk of spills and to reduce the effects of vessel and air traffic to Northstar as much as possible. Northstar is to the west of Cross Island and "downstream" in terms of both the direction of autumn bowhead migration and the locations where Nuiqsut whalers normally scout for whales. Hence, the Nuiqsut whalers do not expect Northstar to be as problematic in terms of direct effects on whaling as would development to the north and east of Cross Island (Ahmaogak 2002: 5, 14). This is not inconsistent with the conclusions of the acoustic monitoring near Northstar in 2001–2004. That study has found a statistically significant, but small, deflection effect in the southern part of the bowhead migration route offshore of Northstar (west of Cross Island) at times when noise from Northstar was at its highest levels (McDonald et al. 2006). Nuiqsut whalers, however, prefer not to whale near industry facilities, if they can avoid doing so. In 2005, whalers explicitly indicated that they turned away from Northstar rather than approach it too closely. The closest approach was 2.5 miles, and in general whaling boats maintained a distance of at least 4–5 miles away. Nuiqsut whalers also indicate that Barrow whalers, though far from Northstar, may have been subject to some of its effects, as Northstar is east (and "upstream" in terms of the bowhead migration) from Barrow.

ACKNOWLEDGEMENTS

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ANNEX 3.1: DAILY ACCOUNTS

This Annex 3.1 summarizes specific observations made by Nuiqsut whalers of activities by vessels other than whaling vessels during the 2005 Cross Island whaling season. This information was recorded by a researcher (MSG) staying with the whalers on Cross Island. Summaries are included only for those days on which vessel activity was reported, or for days on which whale scouting activity occurred. For days that are not listed, neither activity was reported. Crews and boats are indicated by acronyms for convenience. These are the same acronyms as are used in the legends of the Figures 3.3 and 3.4:

- AA refers to the Ahkiviana crew
- BO refers to the Oyagak crew
- IAN refers to the Aqargiun crew
- NAP refers to the Napageak crew
- NUK refers to the Nukapigak crew
- Numbers after the above acronyms refer to a specific boat for multi-boat crews. The number 1 boat is usually the boat with the captain on it. Only the Aqargiun crew was a single-boat crew.

8/31/05

Only NAP1 out, hunting for seals (did not take whaling gear along in boat). Saw many seals, but no whales. Did not report seeing any vessel activity.

9/02/05

Only NAP1 out. Saw many seals, but no whales. Did not report seeing any vessel activity.

9/03/05

Only NAP1 out scouting. Saw only one whale, and only 1 or 2 people on the boat saw it. They did see a barge during their trip as well (position not noted on the GPS track).

9/04/05

NUK2, on the way from Nuiqsut to Cross Island, saw a barge. Position not marked or indicated on track. They reported it [when they arrived at West Dock] and were told by Security that it was probably the Kaktovik fuel barge. No boats were out scouting on 09/04.

9/05/05

AA1 and AA2, on the way from Nuiqsut to Cross Island, saw a barge; position not marked or indicated on track. Barge heading west? Four boats (from three crews) scouted for whales on 9/05. Three of the boats saw the same whale south of Pole Island. NAP1 did not see any whales, although it looked in the same area where it saw a whale on 9/03 (SE towards Pole Island).

9/07/05

IAN, NAP1, NUK1, and NUK2 out scouting. NAP1 saw no whales. The other boats all saw the same, single whale (or rather, its blow). They all saw many seals. Much ice, no reported other vessel activity.

9/08/05

IAN boat reported a barge at 1:53 PM (point Barge_153). No indication of how far away the barge was or in what direction. Barge was east of Endicott. Com Center determined that it was a Crowley barge and had departed from West Dock for Badami (heading east). Four boats went scouting on 9/08. No whales were spotted to the SE of Cross Island on 9/08. The AA1 boat did hear a blow (or blows) in the ice to the east of its easternmost position (10:44 AM). Ice and fog limited where the boats could go. NAP1 went more north than the other boats and saw a whale to the north of Cross Island (east of where NUKs had seen a whale on 9/07). They saw this whale in the late afternoon, well north (25+ miles) and west of where IAN saw the barge.

9/09/05

No boats went scouting. An officer of the Nuiqsut Whaling Captains Association (NWCA) called the NSB Planning Department to discuss two issues – the barges harassing all the animals in the open water inshore of the barrier islands (the only open water there was) and the polar bears harassing the whalers on the island.

9/13/05

Six boats (from five crews) out scouting. A plane flies over Cross Island at 8:34 AM and is determined to be a FWS polar bear survey plane. At 9:15 AM Com Center advised the whalers of planned industry boat movements for the day – a trip from West Dock to the north of Northstar (ice reconnaissance) and the *Agvik* going towards Cape Simpson. Boats did see whales on 9/13. BO1 saw a whale about 7.5 miles west of Cross Island (initially thought to be black ice), another about 4.6 miles west of Narwhal Island (southeast of Cross Island), and another about 7 miles SW of Narwhal Island (pretty much south of the other whale). IAN (and NAP1 and perhaps other boats) were chasing a whale south of Narwhal Island in the early evening – 5:40 to 6:30 PM or so. The NUK2 boat apparently saw a whale SW of Cross Island in the morning. No barge activity observed by the whalers.

9/14/05 (Figure 3.3)

Seven boats (from five crews) out scouting. All initially went SE, but three turned back about 20 miles from Cross Island, thinking that the whales being seen by other boats were too far away, given the ice conditions. These three boats then went NW of Cross Island. The other four boats continued SE and saw whales about 27 miles from Cross Island (Fig. 3.3), but much farther out (outside of the barrier islands) than whales had been seen on prior days. They were able to find the eastern end of the ice pack and head north into more open water. Whalers (NAP3, NAP2, IAN, AA1) had scouted the areas SE of Cross Island and S of Pole Island where they had seen whales before, but did not see any until about 9.4 miles NE of Pole Island (11:44 AM or so). They attributed the lack of animals in this area to possible vessel activity in the area, since the whalers were following a "path" of calmer water to the NW, similar to the path of a vessel that could have been in front of them most of the morning. The tug and barges that they later spotted probably generated this hypothesis, but it could not have been the same tug since the tug observed was first seen to the south and/or east of the whalers (see accounts below). For the boats SE of Cross Island, the action started when—at about 11:44—the NAP2 and NAP3 boats spotted some blows (point E1 on Fig. 3.3) and went to the NE, where they found several whales. They called the AA1 and IAN boats and all four in effect chased different whales, but in the same general area.

The IAN whale was the smallest and went off to the east, whereas the others went more north. About 12:30 (point B1) the IAN boat heard what would turn out to be the Canadian barge, but at first thought that it could have been a helicopter. About 12:40, while still chasing the whale, they saw what appeared to be some "black ice" to the south and realized that it was a tug with two large barges (point B2 was the boat's position, point T2 the tug's estimated position). They estimated the distance as 4 miles. At the same time the whale they had been chasing made a 90 degree turn and went straight north (point E2). The IAN boat went to high speed and followed until about 12:53, when they went to slow speed to wait for the whale to surface again, whereupon they could resume the chase. They slowly searched this area until 1:16 PM or so, at which point they concluded that the whale had given them the slip (point E3), at least partially due to the noise and interference of the Canadian tug. The IAN boat then went to help the NAP1 and NAP2 (and by that time AA1) boats chase their whales.

The whale next largest in size was chased by the NAP2 and AA1 boats. They chased this whale NW, then NE, and finally S and apparently had a good striking opportunity about 12:38 PM, but the boat stalled at a critical moment and the chance was lost, and the whale dove (point E4). They regrouped and were searching the area at low speed, waiting for the whale to resurface. They spotted the Canadian tug at about 12:46 (boat position B3; tug's position uncertain, but probably somewhere on a line between—or in an area defined by— T3b and where first placed by AA1 at T3a). They turned north, away from the tug, and continued at slow speed in hopes of seeing the whale when (and if) it resurfaced. They never saw signs of this whale again. They searched and waited in the area until about 1:05 PM, at which point they went to join the NAP3 boat in pursuit of the one whale still in sight (point E5). NAP3 called the other boats to come help chase after NAP3 spotted a blow presumed to be one of the whales the boats had been chasing. The failure of this whale to resurface nearby was also attributed at least in part to interference from the Canadian tug.

The NAP3 boat was chasing a larger whale at this same time, somewhat to the north of the other boats. At about the time they first saw the Canadian tug, 12:48 PM, the whale they were following also dove. The NAP3 boat searched in a circle and waited until 1:05 PM for the whale to resurface, at which time the NAP3 crew saw a blow about 2.7 miles NW of their position (point E5). NAP3 saw it because they were further north than the other boats. They assumed at the time that it was the whale that they had been chasing, although the time submerged and the distance traveled were both somewhat greater than would be expected. However, a whale "spooked" by a tug could act in this way. This could also have been a different whale. In any event, NAP3 spotted this whale and called the other boats and all went to chase it. About 1:45 a boat had a chance to strike, but the harpooner's throw was low and missed. This and other sightings were marked by points E6-9. About 2:15 the NAP3 boat struck the whale and put a float on it (point "1st Strike"). At some point a second float was put on the whale, and additional bombs (shoulder gun shots) were placed about 2:42 PM (point "Strikes"). The kill was announced at 4:04 PM (point "Kill"). The relatively long time between the first strike and the kill was attributed in part to the whale being "spooked" by the Canadian barge so that it was difficult to approach. There were some equipment failures as well. At least one crew believes that the Canadian barge added at least two hours and 12+ miles to the hunt, by its "spooking" the whales the boats were chasing.

In sum, the boats that went to the SE of Cross Island did succeed in landing a whale, but had spotted only a few whales before seeing the barge. After the tug passed to the west, the whalers saw quite a few other whales and blows during the chase of the whale they landed. That is, once the tug was gone, signs of whales were very evident. The exact line of travel of the tug cannot be determined precisely from the information obtained, but is as generally indicated in Figure 3.3. The Canadian tug was heading generally NW. It was south of the whaling boats while they were chasing whales and well west of them at the time the whale was killed. The boats to the NW of Cross Island, with no barge in the area, saw lots of whales all day, until encountering the Canadian tug (boat position B4, tug estimated position T4) on their way to assist the boats now east of Cross Island with killing and towing the whale. After that point, they saw only a single whale. The whalers concluded that, since the barge had not reached the NW area as yet, the whales were not spooked and the boats to the NW of Cross Island (NAP1, BO1, NUK2) could go right to the whales.

Boats (NAP1, NUK2, BO1) were seeing whales and following them to the NW of Cross Island from about 12:00 PM (noon) on. These whales were 11.5 to 14 miles from Cross Island (NW). The boats had encountered thick ice when traveling north, but between 6 and 10 miles out, the ice coverage thinned out. Water conditions were conducive to scouting and many whales were seen.

Specific locations of the Canadian barge were not documented (marked by waypoints) by the boats on the water. However, whalers from all four boats participating in the active hunt (NAP3, NAP2, AA1, and IAN) later indicated on their tracks where they thought they were (and estimated where the barge was) when they saw it. Note that these records imply that IAN saw [or more probably heard] the barge between about 12:07 and 12:15 PM (estimated from the GPS track), well before AA1 reported it on the VHF radio. The IAN boat was the northernmost boat at 12:15 but was east of the other boats as well.

Some later information obtained from the IAN crew was as follows: When they first saw the whale, it was "playing around" and going slow, taking its time. The next time they saw it blow it was going very fast, due north. It came up about 4 or 6 times "real fast", and then went down still going due north for several miles. It went down again and IAN looked for it for several miles but never saw it again. After it was first disturbed [by the barge, they think], it popped up ¼ of a mile later and headed due north [away from the barge]. They lost track of this whale. AA1 had said they were chasing a whale (with NAP3, after losing track of the one they had been chasing with NAP2), so IAN went west to join the other boats, as described above. IAN indicated that they would have had a chance at the first whale they had seen if it had not been spooked [by the barge]. All crews involved indicated that this chase (and kill) were significantly influenced by the presence of the tug and barges.

One boat crew indicated that they saw the barge to the east of them when they had started to go north into open water east of Pole Island (tug estimated position T1). They did not indicate their boat's position. This observation was not documented in the Whalers' Communication Center log, nor was it recorded in notes made during the 2005 whaling season. The other three boat crews did not see the tug until about 12:40 or 12:48, when they were chasing whales and the tug was much closer. However, they also said that it was possible that the fourth boat did see the tug earlier and that they (the other boat crews) simply did not notice. The position noted for the tug by the fourth boat is consistent with later locations estimated by the other boats. They said the tug was to the east of them and was skirting the edge of the ice, headed in a northeast direction (similar to that of the whale boats once they were east of Pole Island but had not yet seen any blows or whales, south of point E1). The position noted on the figure is very approximate, however, as neither the time nor the distance were remembered with great precision.

9/19/05

No scouting. An NWCA representative called NSB Planning about the barge situation, and they talked with NWCA officers as well. A tentative meeting between NSB Planning and the Nuiqsut whalers on Cross Island was set up for Thursday 9/22 (but later canceled due to weather conditions).

9/20/05

No scouting. Com Center informs Nuiqsut whalers (9:17 AM) that the white plane with red stripes will be doing a whale count today and is preparing to take off towards Kaktovik. At 10:22 the Com Center calls to any barges operating in Michelson Bay to respond – but none do. Not clear that barges are operating.

9/21/05 (Figure 3.4)

Five boats (from five crews) went out scouting. At 11:34 AM the FWS polar bear survey plane asked for permission to fly over Cross Island. The whalers asked him to stay away – but the ceiling was so low that the mission is aborted anyway. He was looking for some place to fly but there is fog everywhere.

About 1:00 PM, NUK2 reported seeing a barge – "We saw a whale and there is a barge right in front of us" and they give their coordinates as N70 16 34.16 W147 26 45.4. The whale (symbol only, no label) was very close to NUK2 (point N1) when they spotted it. Very soon after they saw the whale, they also saw the tug and barge (point T1) emerge from the fog almost directly north of the whale, about ½ to ¾ mile from their boat. They then lost track of this whale and there was intermittent talk about the barge situation, through at least 3:00 PM (NSB Planning took part in this talk on VHF radio before heading back to Barrow). The wind started to pick up and most boats return to Cross Island by 5:00 PM.

NUK2 on their encounter with the barge: Once they found the current they followed it. They saw 4 "whale birds" in the current and followed sort of a zigzag course. Someone "asked the whale birds where the whales were" and the birds took off again and the NUKs started to smell something and followed the birds. The fog was to the north, maybe ½ mile away. The birds landed and the NUKs saw the whale in a clear area [to the south of the fog] and they could see the land (mountains) and Pole Island to the east. The whale came up and went down about 3 times and then went down. They then speeded up in the boat to go to the whale, and saw the boat/barge coming out of the fog. They reached the position where the whale had been, but were distracted by the tug and barge appearing at about the same time and did not notice which way the whale had headed. (Whalers can often tell which way a whale is headed by the way its flippers are oriented, and/or the trail of bubbles that it leaves; when it dives it leaves a sort of whirlpool and "trail".) The boat was headed east away from the fog and towards the clear area and the sunshine. It was going fast to the SE. A location labeled N1 is the boat's position when the crew first spotted the tug and barge about 12:56 PM at point "T1". The estimated position of the whale is unlabeled, but marked with the whale symbol.

After the whale submerged the NUK2 boat started to go towards the barge in order to record its identification number and other information (about 1:03). NUK2 got to within 1/8 mile of the barge (boat position "N2", estimated tug position of "T2") when the Communications Center said that they knew it was a Crowley barge. NUK2 backed off at this point and went to look for the whale again, but they never saw it again. This was the only whale they saw all day. NUK2 continued looking for the whale to the west, and could see the tug continuing to the east and north, back into the fog. At this point the whale was already spooked and gone – about 1:17 PM (the estimated position of the barge was not given, but was east of "T2"). The NUK2 crew repeated that they were following the current and only saw the whale once. It popped up 3 or 4 times really fast and was acting scared – it acted like a "spooked" whale. Once they saw the barge, they never saw the whale again and then went north, and inside of the fog. They said that the whale must have gone north or they would have seen it, but it was so foggy that they could see nothing so they went back south to the current. They met up with AA1 (at about 2:37PM) and talked about the current and headed SW together. Fog started to roll in but it was still clear to the south (they could see the land) so they went back to the current again and again could smell something – but saw only 1 bearded seal and lots of ducks. They followed the ice towards Narwhal Island (north and then northwest) and saw seals. The ice extended in a band SE of Cross Island for about 8 miles and they saw seals along that ice.

9/23/05

On this date, Canadian barge transported portable generators and other relief supplies from West Dock to the whalers on Cross Island. Conditions are such that smaller vessels cannot go out, and aircraft cannot fly.

Annex 3.2: GPS Tracks for Nuiqsut Whaling in 2001-2004

The following four maps show the GPS tracks for whaling in 2001, 2002, 2003, and 2004, as documented by Galginaitis and Funk (2004, 2005) and Galginaitis (2006a).

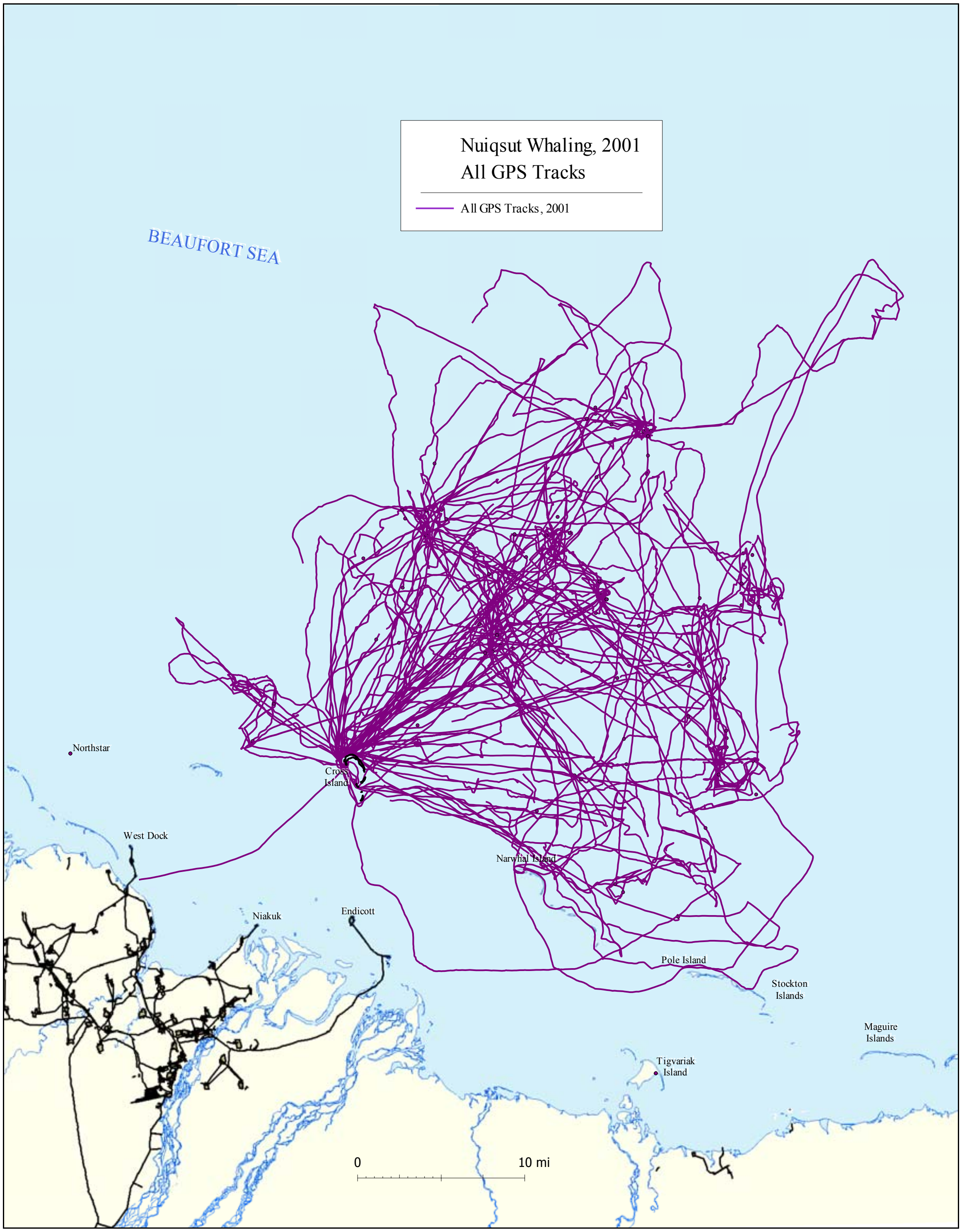

FIGURE 3.5. Nuiqsut whaling, 2001: All GPS tracks.

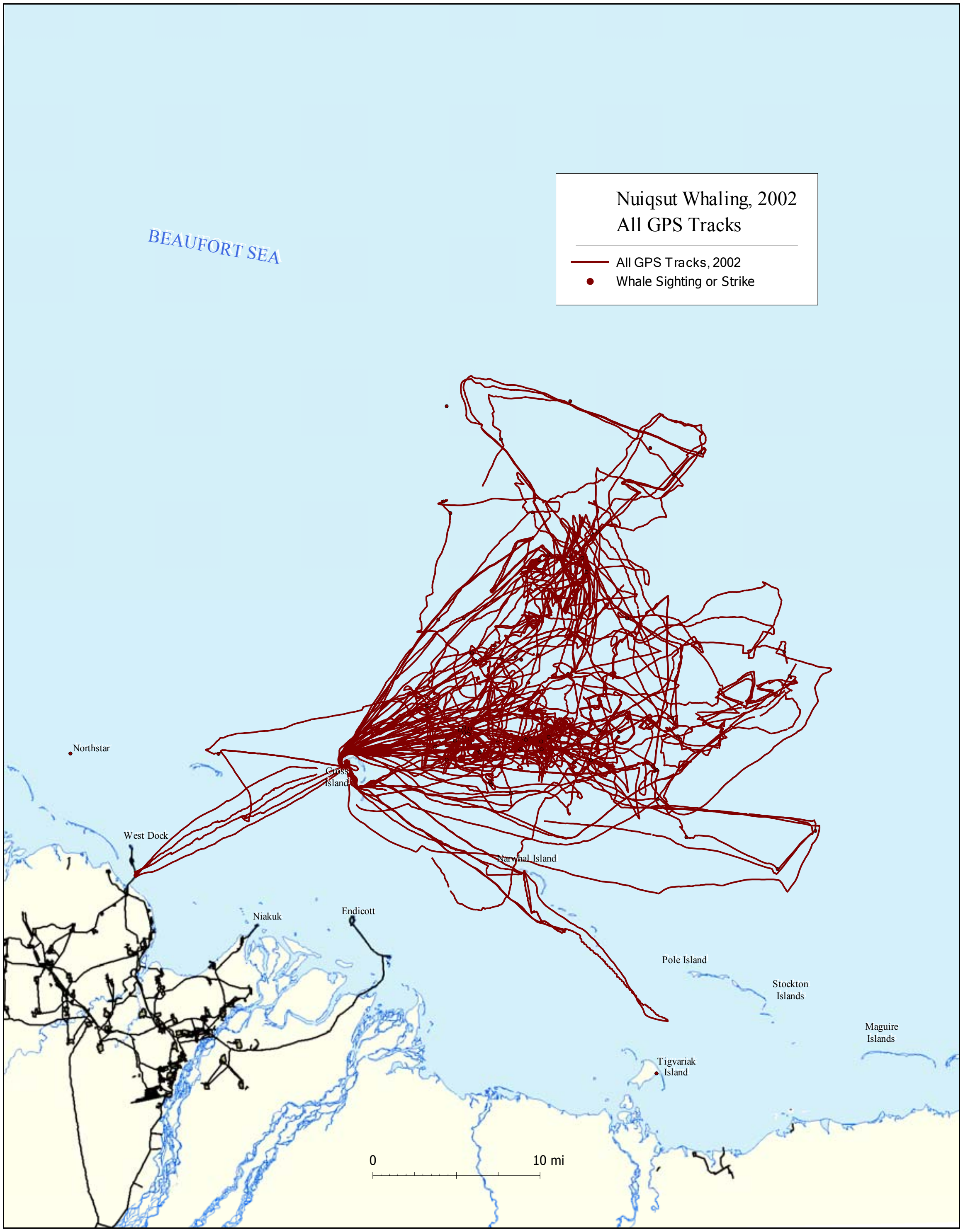

FIGURE 3.6. Nuiqsut whaling, 2002: All GPS tracks.

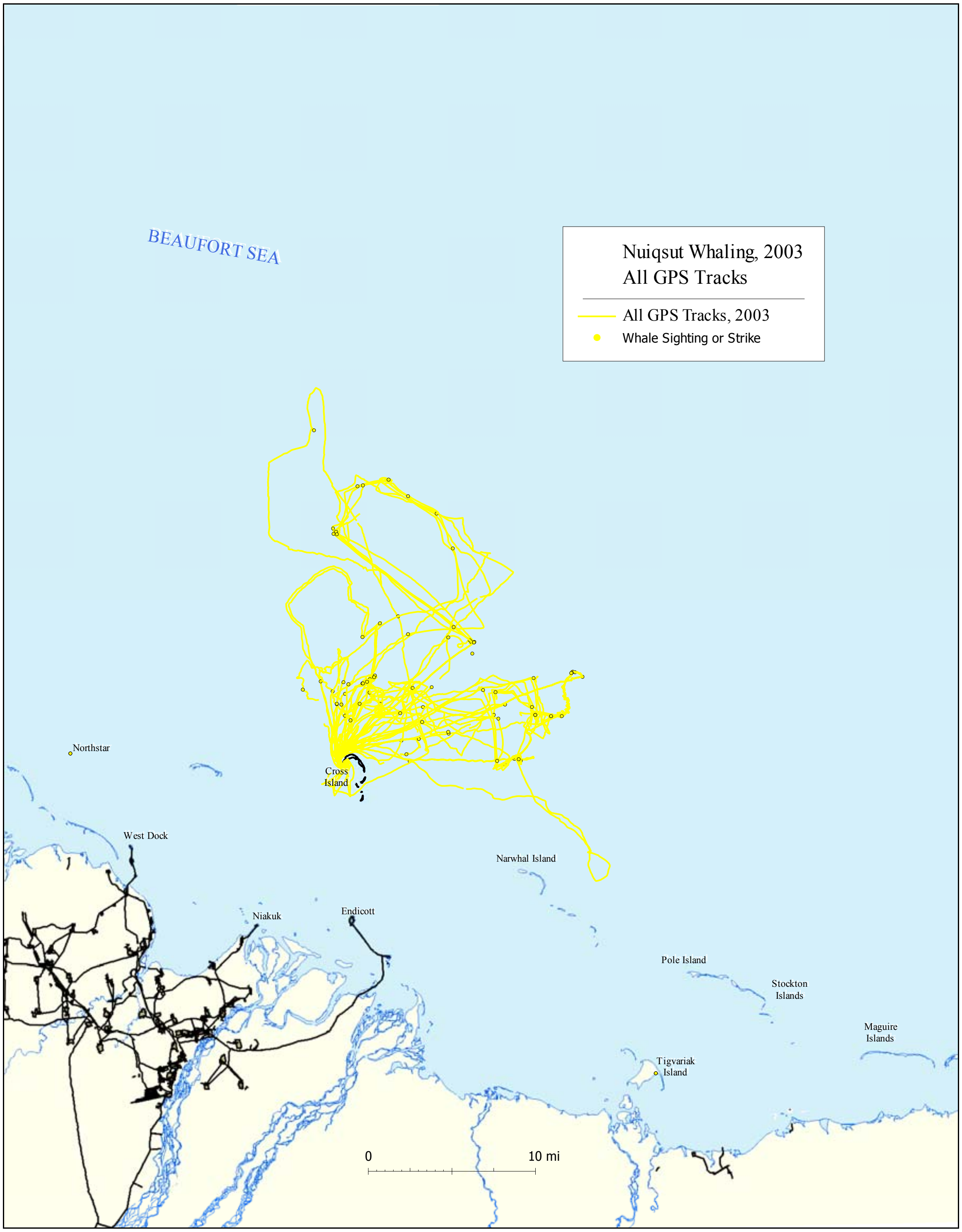

FIGURE 3.7. Nuiqsut whaling, 2003: All GPS tracks.

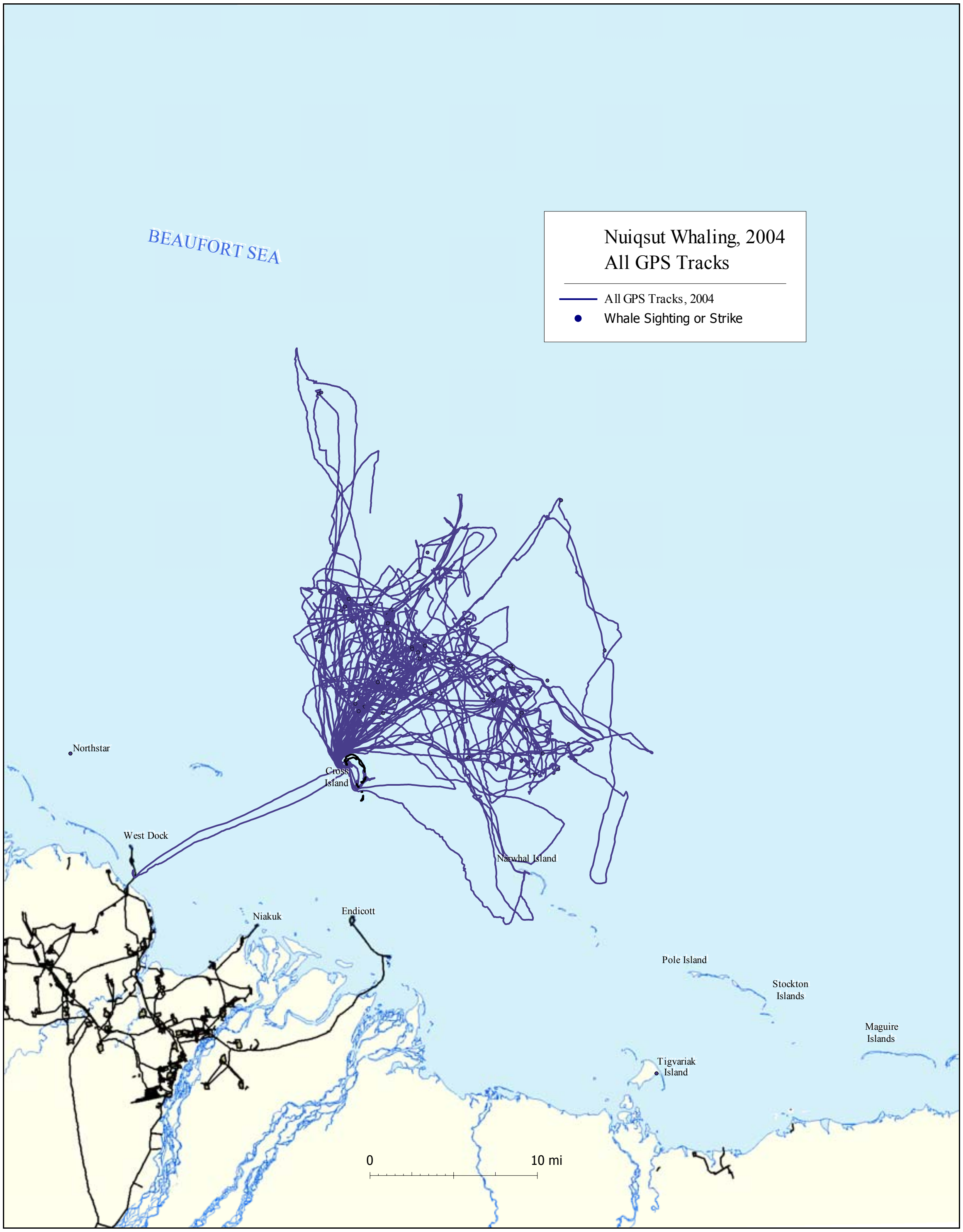

FIGURE 3.8. Nuiqsut whaling, 2004: All GPS tracks.