BOWHEAD WHALE FEEDING ECOLOGY STUDY
(BOWFEST)
Annual Report for 2007

INTRODUCTION

The National Marine Mammal Lab received NOAA clearance on 7 May 2007 to accept funds from Minerals Management Service (MMS) for a five-year $5.095M study of bowhead whale feeding ecology (BOWFEST). This study focuses on late summer oceanography and prey densities relative to whale distribution over continental shelf waters within 100 miles north and east of Point Barrow, Alaska. Through NOAA's cooperative institutes, researchers have been included from Woods Hole Oceanographic Institute, University of Rhode Island, University of Alaska Fairbanks, University of Washington, and Oregon State University. Field work is being coordinated with the North Slope Borough, Alaska Eskimo Whaling Commission, Barrow Whaling Captains' Association, Alaska Department of Fish and Game, and Department of Interior's MMS. Marine mammal studies are as permitted under NMML's Permit No. 782-1719.

Aerial surveys and acoustic monitoring provide information on the spatial and temporal distribution of bowhead whales in the study area. Oceanographic sampling helps identify sources of zooplankton prey available to whales on the continental shelf and the association of this prey with physical (hydrography, currents) characteristics which may affect mechanisms of plankton aggregation. Prey distribution will be better understood by examining temporal and spatial scales of the hydrographic and velocity fields in the study area, particularly relative to frontal features. Results of this research program may help explain increased occurrences of bowheads feeding in the Western Beaufort Sea (US waters), well west of the typical summer feeding aggregations in the Canadian Beaufort Sea. Increased understanding of bowhead behavior and distribution is needed to minimize potential impacts from petroleum development activities.

The following reports describe field work and the respective analyses conducted under BOWFEST funds in 2007. This is the first of three proposed years of field work for this program.

Aerial Surveys of Bowhead Whales in the Vicinity of Barrow, Alaska, August-September 2007

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Abstract

In 2007, the Bowhead Whale Feeding Ecology Study (BOWFEST) was developed to mitigate the impact of future oil and gas development in northern Alaska's offshore waters by examining the relationship between bowhead whales and their environment. This multiyear study involves a coalition of scientific parties to gather data from oceanographic samples, boat observations, tagging operations, acoustic monitoring, and aerial surveys in an area northeast of Point Barrow where feeding bowheads are inconsistently reported during the summer. The aerial survey component of this multidisciplinary study will document patterns and variability in the timing and locations of bowhead whales as well as provide an estimate of temporal and spatial habitat use. In addition, photographic identification and photogrammetry will provide information on residence times and sizes of individual whales. With the consideration of acoustic mooring locations, preset oceanographic transects, bathymetric gradients, and distance from the base of operations (Barrow), a two-part study area and aerial trackline sampling scheme was devised. Using a NOAA Twin Otter, scientists from the National Marine Mammal Laboratory (NMML) conducted aerial surveys from late August to mid September 2007 over continental shelf waters from 157° W to 152° W and from the Alaska coastline to 72° N. Since the fall migration across the central Beaufort Sea typically begins in early September, we expected to find the majority of whales (both feeding and migrating) late in the field season. Instead, there were 16 sightings of bowheads (an estimated 49 whales) seen during 11 flight hours 23-24 August, and no whales were seen during 20 hours 6-11 September. Two Nikon D200 cameras were used to photograph bowhead whales; 158 pictures were taken with a 55 mm lens for photogrammetry, and 161 pictures were taken with a 180 mm lens for photo-identification. The majority of bowheads seen in August appeared to be feeding. This bowhead research project was terminated in mid-September out of respect for local whaling operations. Collecting additional years of data as well as integrating information with other projects will help elucidate whether bowheads feeding near Point

Barrow in the summer and the apparent late migration observed in 2007 were typical or anomalous.

Introduction

There are five stocks of Bowhead whales (*Balaena mysticetus*) found exclusively in arctic and sub-arctic waters (Burns et al. 1993; Rugh et al. 2003). The Bering-Chukchi-Beaufort (BCB) stock is of particular concern due to increased anthropogenic activities along their migratory route from the wintering grounds in the northern Bering Sea to the summering grounds in the eastern Beaufort Sea. In addition, these whales are hunted by Eskimos at several coastal villages along the migratory route, and bowheads travel over active and proposed areas of oil and gas development. Due to the severe depletion of this species caused by commercial whaling in the early 20th century, all bowhead stocks are currently listed as endangered under the Endangered Species Act (ESA), though numbers in the BCB stock are steadily rising.

Most of the BCB stock migrates annually from the Bering Sea, through the Chukchi Sea, to the eastern Beaufort Sea. During the spring migration, bowheads typically arrive in the Barrow area in early April and continue migrating past Barrow until mid-June. By early September, bowheads start leaving the central Beaufort Sea, traveling northwesterly towards Barrow and west across the Chukchi Sea throughout September and October (Moore & Reeves, 1993). During the migration back to the Bering Sea, bowheads swim in shallow waters along the Chukchi Peninsula (Moore & Reeves, 1993).

Although bowheads are more commonly seen in the central Beaufort Sea during the spring and autumn migrations, there have been several reports of whales feeding near Barrow in July and August. Whether these animals are traveling to the Beaufort Sea late during the spring migration, traveling to the Bering Sea early during the autumn migration, or reside in the area throughout the summer is unknown. A scientific study is needed to determine the relative scale of feeding near Barrow in the summer and the consistency of this behavior relative to season, year, and age class. In addition, the ecological relationship between feeding bowhead whales and relevant oceanographic parameters -- such as bathymetry, currents, temperatures, and ice conditions -- should be examined to assess whether oceanographic features indirectly affect the location of bowhead feeding aggregations by influencing prey distribution. Inconsistent reports of bowheads feeding in the western Beaufort Sea during the summer (a time when most whales are reported feeding in the eastern Beaufort Sea), and increased investment of oil and gas companies in developing this area, Point Barrow is an ideal location to study the influence of physical, ecological and anthropogenic factors on the feeding behavior of these animals.

In 2007, the Bowhead Whale Feeding Ecology Study (BOWFEST) was developed to examine the relationship between bowhead whales and their environment. This multiyear study involves a coalition of scientific parties to gather data from oceanographic samples, boat-based observations, tagging operations, acoustic monitoring, and aerial surveys relative to whale distribution over continental shelf waters within 100 miles north and east of Point Barrow. The aerial survey component of this multidisciplinary study will document patterns and variability in the timing and locations of bowhead whales as well as provide an estimate of temporal and spatial habitat use. In addition, photographic identification and photogrammetry will provide information on residence times and sizes of individual whales.

Methods

Study Area and Trackline Design:

After examining mooring locations, preset oceanographic transects, bathymetric gradients, and distance from the base of operations (Barrow), a two-part study area and aerial trackline sampling scheme was devised. The extent of the study area covered continental shelf waters from 157° W to 152° W and from the Alaska coastline to 72° N (Figure 1). The smaller section of the study area was approximately 7,276 km^2 and the larger, outer section was approximately 12,152 km^2.

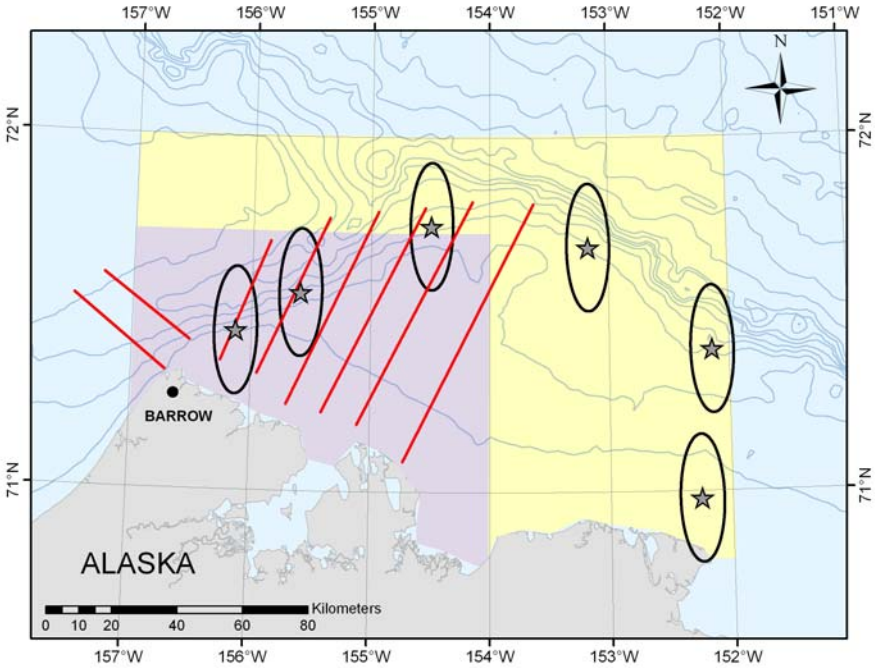

Figure 1. Two-part study area (smaller violet section and larger yellow section) relative to pre-set oceanographic tracklines (red) and acoustic moorings (gray stars) with 20 km auditory radii (black rings).

Five years of data (2000-2005) from the Bowhead Whale Aerial Survey Project (BWASP), operated by Minerals Management Service (MMS), were used to calculate bowhead whale density (whales per unit effort) within the BOWFEST study area. This helped to stratify and ultimately to determine the distribution and quantity of survey effort relegated to each section. According to the BWASP data, the density of bowhead whales in the smaller section was approximately six times greater than the larger section of the study area. Using equations 7.1, 7.2, and 7.4 from Buckland et al. (1993), we calculated the total effort needed in each of the two sections of the BOWFEST study area to obtain the same detection probability as the BWASP data. However, this method resulted in the allocation of 40% of the total survey effort to the lager section of the study area. Since oceanographic data becomes more difficult to collect with increased distance away from Barrow, we arbitrarily decreased the detection probability used to calculate effort for the larger section by 50 percent. Decreasing the detection probability caused the proportion of effort allocated to the smaller section to increase by 8%, thus, assigning the majority of the survey effort to this area. Trackline orientation was based on the pre-determined oceanographic tracklines which ran in a northeasterly direction at approximately a 66° True.

Line transect methodology described in Buckland et al. (1993) was utilized to calculate total survey effort for each section of the study area based on available survey hours for this project. Because the survey was not conducted over a continuous period due to logistics in aircraft scheduling (aircraft were available only on 21-27 August and 3-13 September), separate trackline sampling schemes were devised for August and September. Sampling schemes consisted of shifting the trackline array short distances to the east or west, removing the likelihood that any tracklines would be flown twice. For the August portion of the survey, the entire study area contained approximately 1330 km of trackline, 944 km in the smaller section and 386 km in the larger section (Figure 2). Based on the allocation of effort and the flight hours available, the tracklines in the smaller section were spaced 7.5 km apart while lines in the larger section were spaced 30 km apart. The placement of the first survey line in the smaller section of the study area (closer to Barrow) was determined by randomly selecting a number between 1 and 7.5. In this case, the first transect line was placed 5 km from the northwest corner of the smaller portion of the study area and oriented at a 66° angle. Subsequent tracklines were parallel to the first trackline and spaced 7.5 km apart. Because the transects in the larger section of the study area were spaced 30 km apart, four times the distance separating the tracklines in the smaller section, every fourth transect in the smaller section was extended to create the outer tracklines. This process simplified the flight scheme by eliminating offset tracklines between the two sections of the study area.

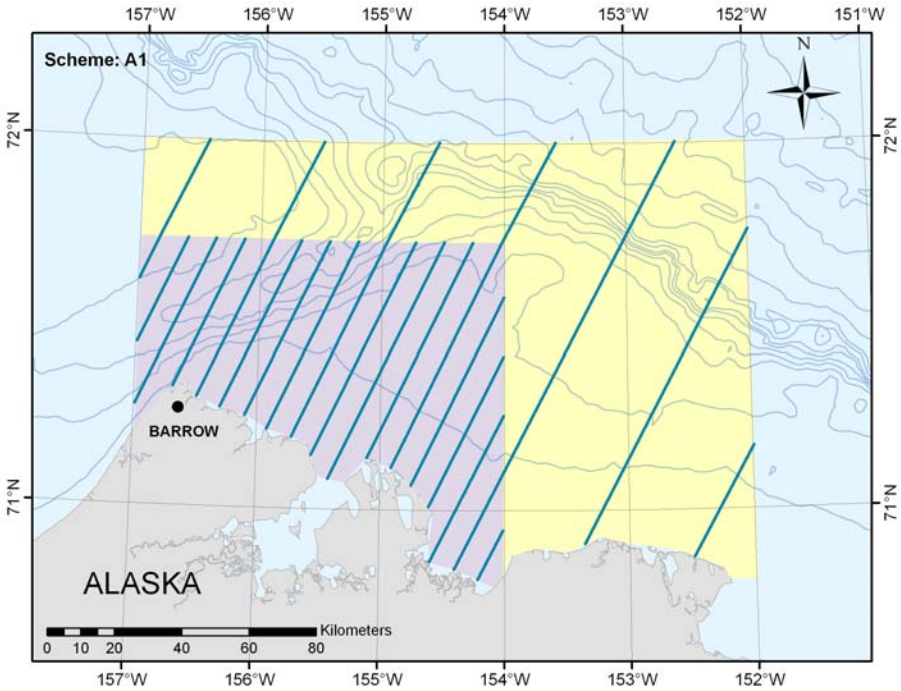

Figure 2. Two-part study area with proposed tracklines (scheme A1) for the August portion of the 2007 BOWFEST aerial Survey.

The hours remaining after completing the August portion of the survey were used to calculate the maximum survey effort available for the September flights. For the September portion of the survey, the entire study area contained approximately 4658.5 km of trackline, 3227.4 km in the smaller section and 1431.0 km in the larger section. Since the total trackline distance relative to the study area was much higher in September than in August, spacing between tracklines was much smaller; 2.2 km in the smaller section and 8.3 km in the larger section. Similar to the method used in August, a random number between 1 and 2.2 was used to determine the placement of the first trackline in the inner portion of the study area. In this case, the first line was placed 2 km from the northwest corner and oriented in the same direction as the August tracklines. All transect lines thereafter were spaced 2.2 km apart. Unlike in August, however, the placement of the first trackline in the outer portion of the study area was also randomly chosen, creating staggered tracklines between the two sections of the study area. The first line in this section was placed 3 km from the northwest corner of the larger section of the study area. Subsequent tracklines were placed 8.3 km apart (Figure 3).

In order to prevent overlap in survey effort due to tightly spaced tracklines, four sampling schemes were devised (S1, S2, S3, S4). The first scheme (S1) was created by selecting the first line from the west side of the study area and every fourth line thereafter. Using the same method, beginning with the second, third, and fourth lines from the west side of the study area, the three remaining schemes were created. As a

result, tracklines were spaced approximately 9 km and 33 km apart in the smaller and larger sections of the study area (Figure 4).

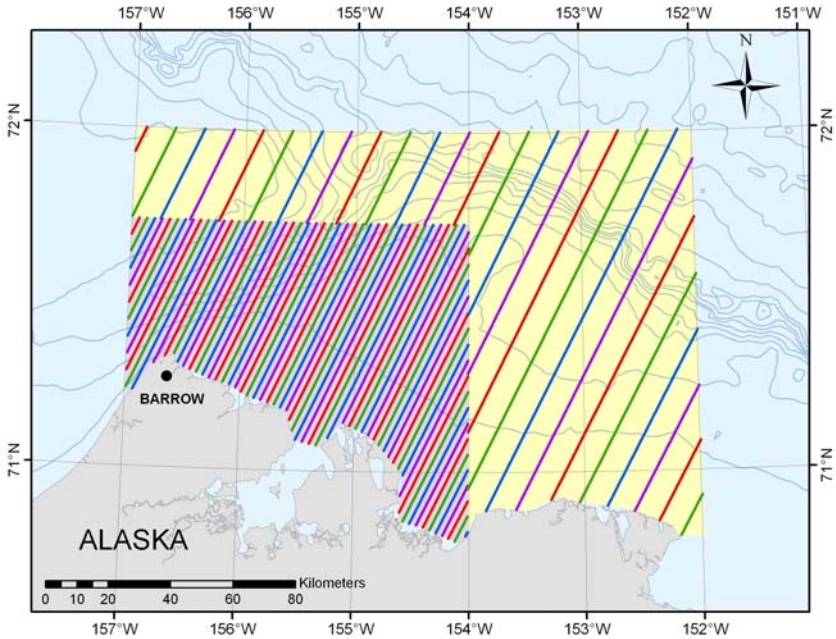

Figure 3. Two-part study area with proposed tracklines for the September portion of the 2007 BOWFEST aerial Survey.

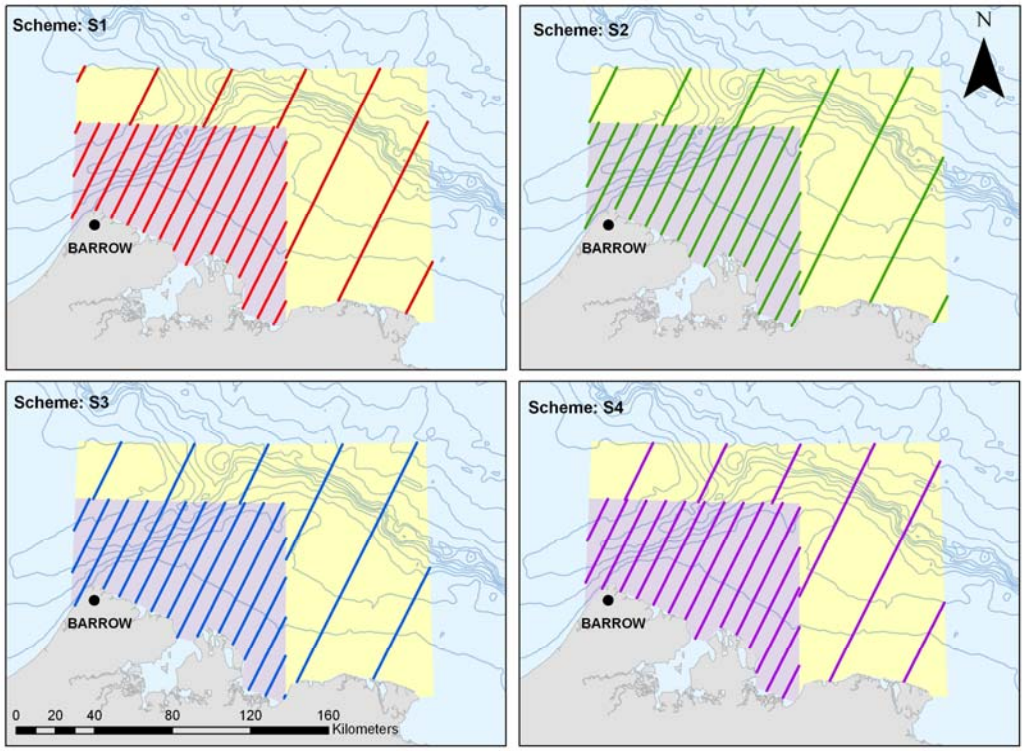

Figure 4. The four individual survey schemes (S1, S2, S3, & S4) for the September portion of the 2007 BOWFEST aerial Survey.

Survey Protocol:

The BOWFEST aerial survey was flown in two NOAA Twin Otters (N56RF used 21-27 August and N48RF used 3-13 September). Both aircraft were equipped with twin engines, high wings, and more than 6 hours of flying capacity. In addition, each airplane had 2 large bubble windows and a belly window/camera port covered with Plexiglas for vertical photography. An intercom system allowed communication among observers, pilots, and data recorder while a handheld VHF radio allowed communication with vessels, such as when reporting whale locations.

A laptop computer, interfaced with a custom built aerial survey program and a portable Global Positioning System (GPS – Garmin 76 CSx) recorded sighting position, weather, effort, crew position, and photo data into an Access database. Location data (latitude, longitude, speed, altitude, and heading) were automatically recorded every five seconds while all other entries were entered manually. In addition, each start and stop of a transect leg was recorded. Specific data entries for weather included: overall percent ice cover, ice type (categorized using the Observers Guide to Sea Ice http://response.restoration.noaa.gov/book_shelf/695_seaice.pdf), sky condition, and sea state (on a Beaufort scale) as well as glare, visibility angle, and visibility quality for each side of the aircraft. Observers used an inclinometer (0° = horizontal; 90° = straight down) to accurately determine the searchable distance out each side of the aircraft; areas where visibility angles were greater than 20 degrees (< 0.8 km from the trackline) on both sides of the aircraft were considered unsurveyed. Visibility quality within the given inclinometer angle was documented as one of five subjective categories from excellent to useless. Date, time, sighting observer, inclinometer angle, group size, species, and reaction to plane were diligently recorded for all marine mammals; in addition, for bowhead whale sightings, observers reported calf number, travel direction, sighting cue, dominant behavior, group composition, and number of nearby vessels.

The target survey altitude was 310 m (1000 ft), although a lower altitude (750 ft) was sometimes used for aerial photographic passes (allowed under NMML Permit No. 782-1719). Tracklines were flown east to west in August in order to maximize flight time (the pilots permitted longer flights if Barrow was in sight). However, in September, we adjusted our flying protocol to fly tracklines west to east. Although the method used in September would possibly result in shorter flights, flying west to east (opposite the bowhead whales' autumn migration route) minimized the probability of resighting the same whale(s) within the same day.

Immediately upon sighting a marine mammal, each observer reported the group size and species to the data recorder. As the aircraft passed abeam of the sighting, the observer informed the recorder of an inclinometer angle and whether or not there was an observable reaction to the aircraft. The plane only deviated from the trackline when an observer reported a bowhead whale or an unidentified cetacean sighting. After a bowhead was reported, the trackline was completed before going off effort to begin

photographic passes. This method allowed for a routine reporting of bowhead whales on the trackline and minimized confusion in reporting sightings while off-effort.

Photographic Protocol:

Two Nikon D200 cameras were used simultaneously over the belly port for vertical photography. A 55 mm fixed lens (no magnification) was used for photogrammetry in order to best estimate whale lengths. The second camera had a 180 mm fixed lens to provide larger images of whales for purposes of identifying individual animals. However, since this camera was held over the belly port, aimed vertically down rather than oblique, the images were also used to obtain whale lengths, if possible. Both cameras recorded 12 bit raw format images and were set to manual focus, shutter priority, 800 ISO sensitivity, and a shutter speed greater than 1/1000s.

Photographic passes were made only after completing the trackline on which the bowhead sighting was initially reported. After breaking effort, a single pass was made directly over the bowhead group in order to obtain a precise location. Several additional passes were flown over each group until both photographers felt confident that all whales had been photographed. During each photographic pass, the recorder provided a countdown to alert the photographers when a whale was about to appear under the aircraft.

In addition to photographing bowhead whales, photographs were taken of a calibration target using the same two cameras (Nikon D200s) and lenses (55mm and 180mm) as used for photogrammetry of whales. The target, provided by Craig George, North Slope Borough (NSB), consisted of painted 2" x 10" boards with precisely measured intervals that were visible at survey altitude (1000 ft) (Figure 5). The calibration target was laid out on an old airstrip north of Barrow. Because of apparent irregularities in the available altimeters, all whale and calibration photographs were taken at either 1000 ft or 750 ft according to the aircraft’s radar altimeter. The aircraft’s radar altimeter and the GPS barometric altimeter provided altitudes over whales and the calibration target. Since the length of the target is known, estimated lengths of bowhead whales can be obtained by correcting for errors in altitude. Photogrammetric procedures seek to minimize variables to improve the accuracy of whale length measurements. Thus, vertical photography removes angle from consideration when applying aircraft altitude to the calculation of distance between the camera and the target. Measuring the size of images of the target relative to given altitudes and lens can provide corrections for the aircraft altimeter. This can then improve the accuracy of altitudes measured over whales and, subsequently, the accuracy of estimating whale lengths.

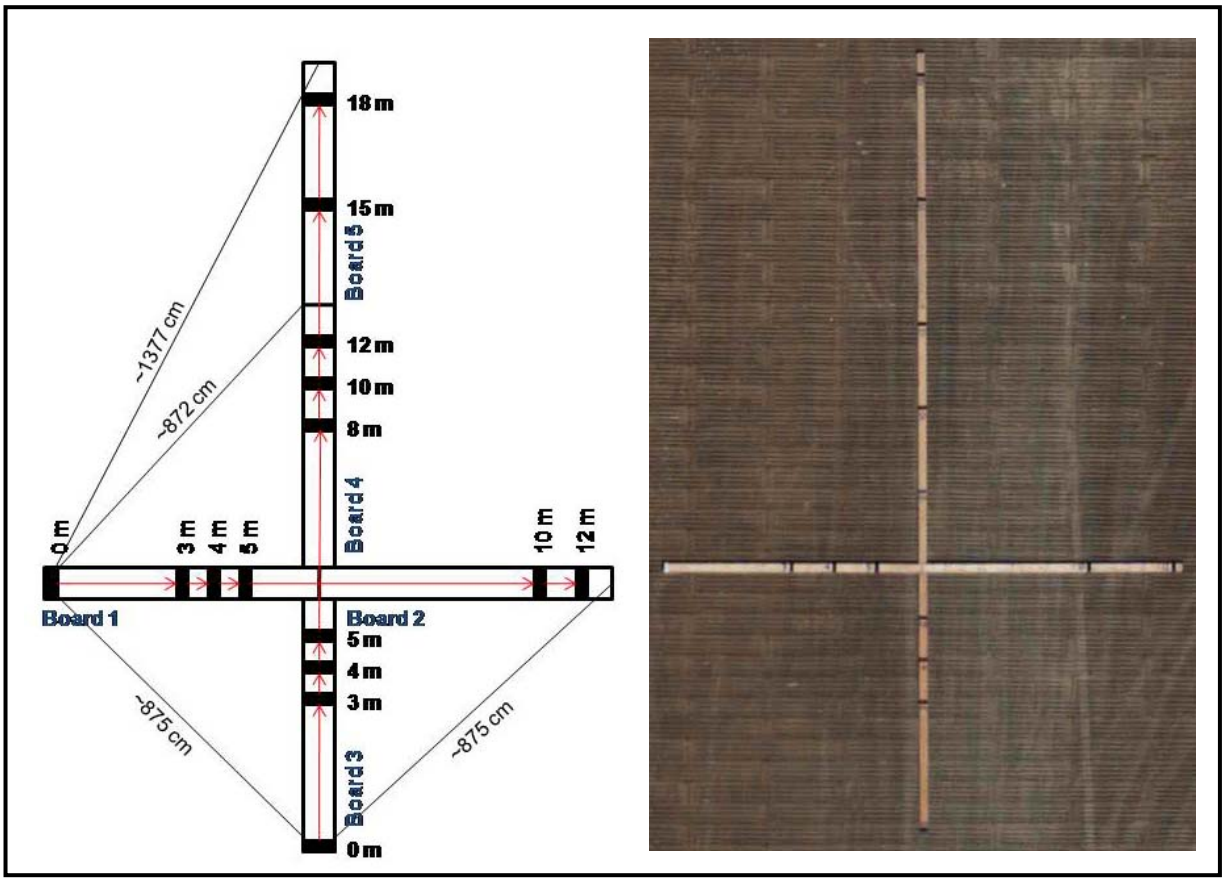

Figure 5. Diagram (left) and aerial image (right) of the calibration target used in the 2007 BOWFEST aerial survey

After each survey, all photographs were georeferenced using RoboGEO. The GPX file was downloaded from the GPS unit and raw images were converted to TIFFs. Both the GPX file and the TIFFs were used as inputs for RoboGEO in order for the program to interpolate the latitude and longitude and to embed this position information in the exif data of each photograph. Since RoboGeo uses time to link photographs to the tracklog position, the date and time on both cameras were synched to the data and time on the GPS unit at the beginning of each survey. In addition, the date and time on the GPS unit were photographed with both cameras at the beginning and end of each flight to correct for any drift in time between the GPS and camera prior to georeferencing. Once georeferenced, all images were sent to LGL Environmental Research Associates for analysis of whale lengths.

Processing images for photo-identification of individual whales begins with cropping and labeling images into a standard format. These images are then archived in the large collections maintained at NMML and LGL. Each whale image is categorized according to identifiability, and the photo is quality rated according to an established

protocol (Rugh et al. 1998). All images collected in 2007 will be compared to each other to determine if some individual whales were photographed multiple times. Following this comparison, these whale images will be compared to others collected in previous years to establish when and where individual whales have been seen before.

Results

Survey effort

Aerial surveys were conducted in the BOWFEST study area on 6 days between 22 August and 12 September 2007; two flights were flown 22-26 August and five additional flights were flown 5-12 September. All flights were based out of Barrow, each ranging from 2.0 to 6.7 hours in duration. Although 70 flight hours were originally scheduled for the project, fog, low ceilings, and high winds limited flying conditions on many days such that only 30.8 hours (5863.5 km) were flown – 12 flight hours in August and 18.8 hours in September (Figure 6). Of the 30.6 hours spent on search effort over water (9 in August and 27.5 in September), 12.5 hours (2305.8 km; 2096.5 km in the smaller section and 209.28 in the larger section of the study area) were flown on systematic transects (Figure 7). The remaining 18.1 hours were flown searching off transects, such as when limited by visibility conditions, transiting between transect lines, circling animals, photographing whales or a calibration target, or deadheading. In total, we surveyed approximately 5,827 km of water. The majority of survey effort (3521 km or 60.4%) was collected while searching off transects (Table 1).

Only 0.86 hours were flown in suboptimal conditions (visibility angle greater than 20° on both sides of the aircraft) throughout the entire BOWFEST survey (Table 1). Although the flight time in September was nearly twice that of August, survey time lost to unsuitable weather conditions in August was more than three times as great. While on transects, 26 km (0.14 hours) were flown in suboptimal conditions and, as a result, were considered unsurveyed. Even though it appears that poor weather conditions were rarely encountered, the 0.86 hours does not take into consideration the numerous times we changed course, deviated from transects, or altered our elevation to avoid low ceilings, precipitation, or fog. In addition, on three of the five possible survey days in August and four of the eight possible survey days in September, poor weather conditions precluded us from flying.

Four of the five devised survey schemes (Figures 2 & 4) were flown during the 2007 BOWFEST survey; one scheme in August (A1) and three in September (S1, S2, and S3). Scheme A1 was flown on 23 & 24 August (Flights 1 & 2) (Figure 8). Of the 2000 km flown in August (both on and off scheme A1 transects), approximately 49% was on designated transects (Table 2). On 6 & 7 September (Flights 3 & 4), we flew the first September scheme, S1 (Figure 9). Only slightly less than the August flights, we flew 1831.8 km of which 46% were on transects. On 9 September, we flew one flight (Flight 5) on scheme S2 (Figure 10), covering a total of 458.9 km, 22% of which were on

the designated transect lines. Finally, on 11 September we flew a total of 1536.4 km in two flights (Flights 6 & 7) (Figure 11). Although we flew 75% of transects on scheme S3, 93% of the transects were flown in the smaller section of the two-part study area. Due to bad weather, scheme S4 was not flown.

Table 1: Allocation of survey effort (time and distance) for the August and September portions of the 2007 BOWFEST aerial survey

Effort Type	August		September		Total	Total
	hr	km	hr	km	hr	km
In Flight	10.56	2003.16	20.23	3860.32	**30.79**	**5863.48**
Over Water	10.52	1999.99	20.06	3827.00	**30.58**	**5826.99**
Off Transect	7.01	1353.49	11.06	2167.71	**18.07**	**3521.20**
On Transect	3.50	646.50	9.00	1659.29	**12.50**	**2305.79**
Suboptimal* Conditions	0.66 (0.09)	101.61 (17.38)	0.20 (0.05)	36.19 (8.63)	**0.86 (0.14)**	**137.80 (26.01)**

* Numbers in parenthesis indicate suboptimal conditions while surveying on transect

Table 2: Allocation of effort per survey scheme for the 2007 BOWFEST aerial survey

Flight Scheme	Off Transects		On Transects		Transects Available (km)	% Transects Flown
	hr	km	hr	km		
A1	7.01	1353.49	3.50	646.50	1329.96	48.61
S1	6.65	1305.19	2.86	526.59	1150.76	45.76
S2	1.04	201.62	1.38	257.25	1179.65	21.81
S3	3.37	660.90	4.76	875.45	1173.61	74.59
Total	**18.07**	**3521.20**	**12.50**	**2305.79**	**4833.98**	**47.70**

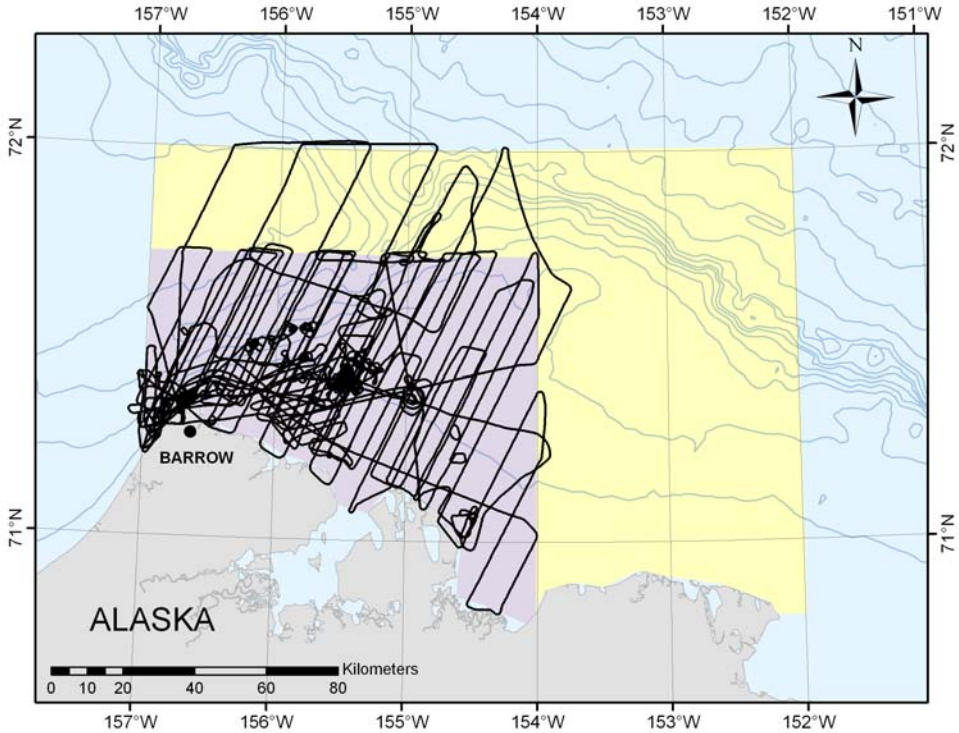

Figure 6. Total survey effort for the 2007 BOWFEST survey.

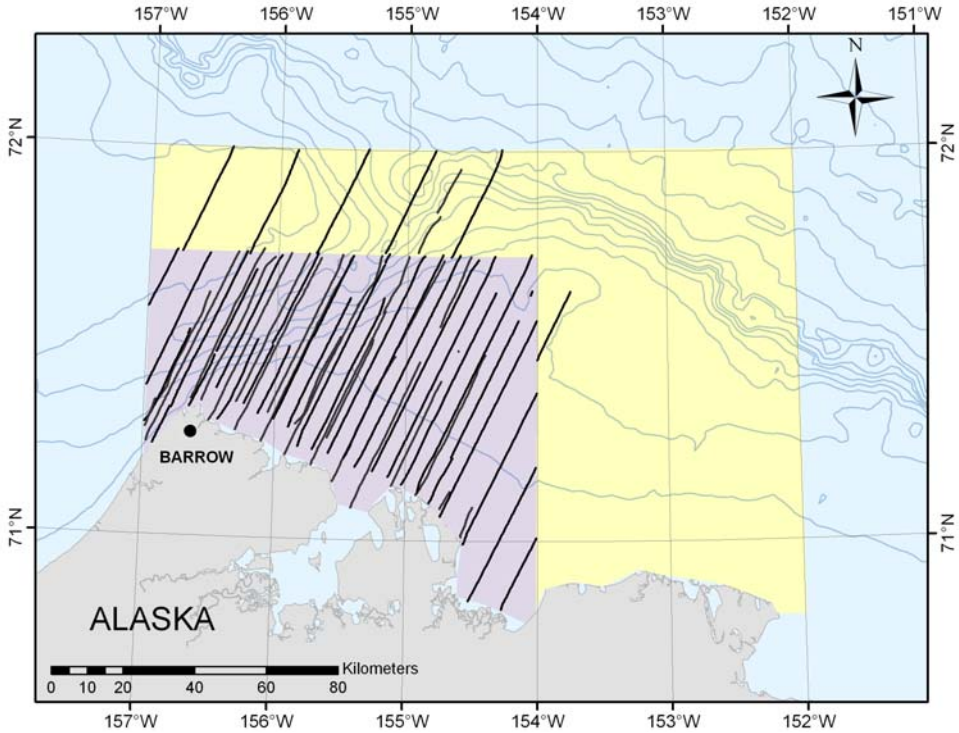

Figure 7. All on-effort tracklines flown during the 2007 BOWFEST survey.

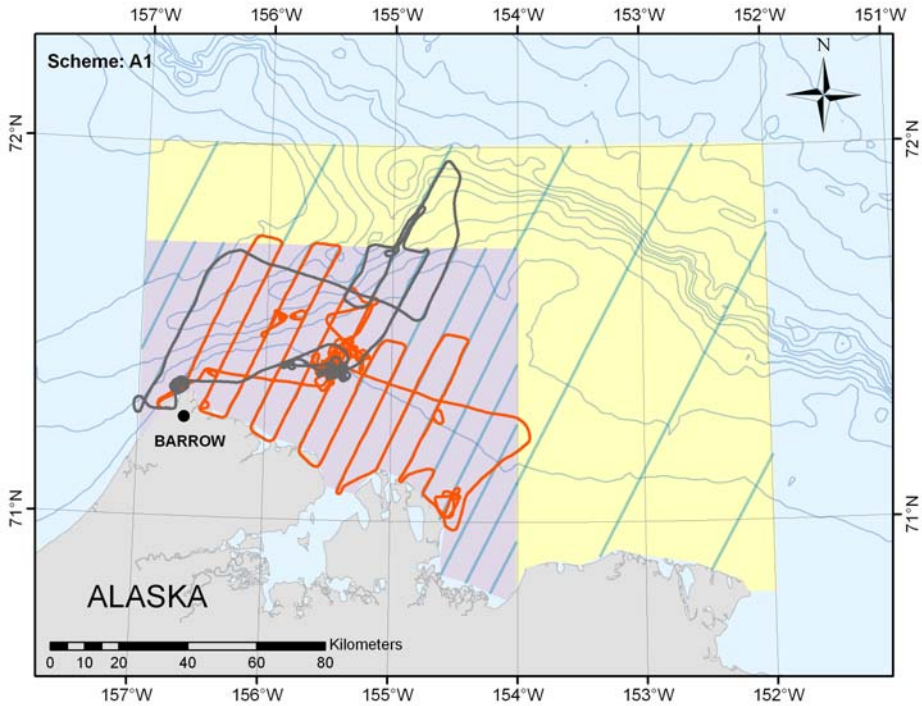

Figure 8. Scheme A1 transects (blue) with flights 1 (orange) & 2 (gray) flown on 23 & 24 August 2007.

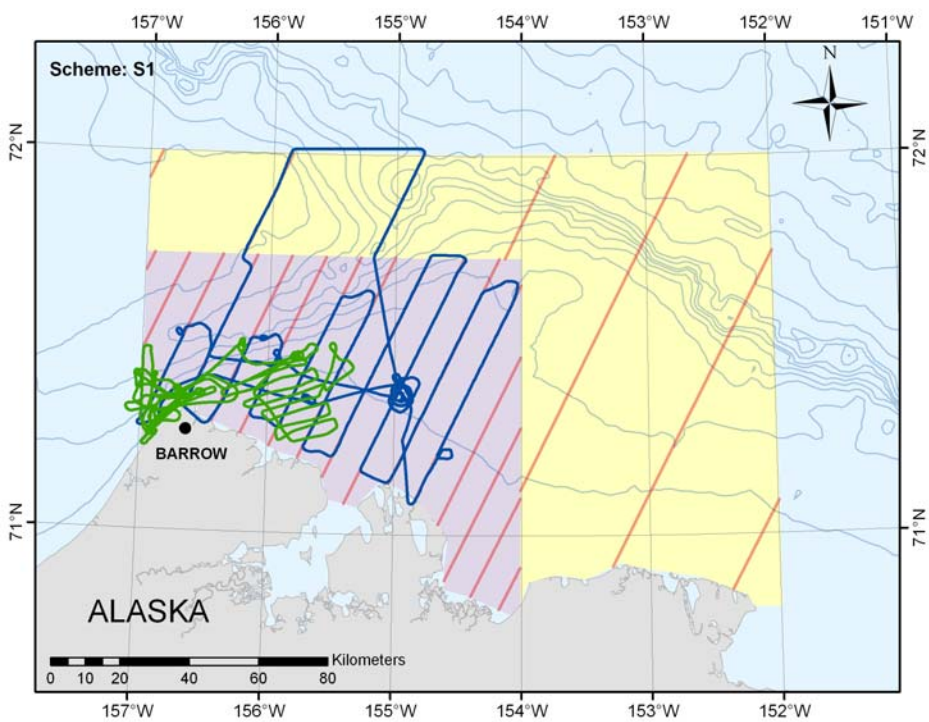

Figure 9. Scheme S1 transects (red) with flights 3 (green) & 4 (blue) flown on 6 & 7 September 2007.

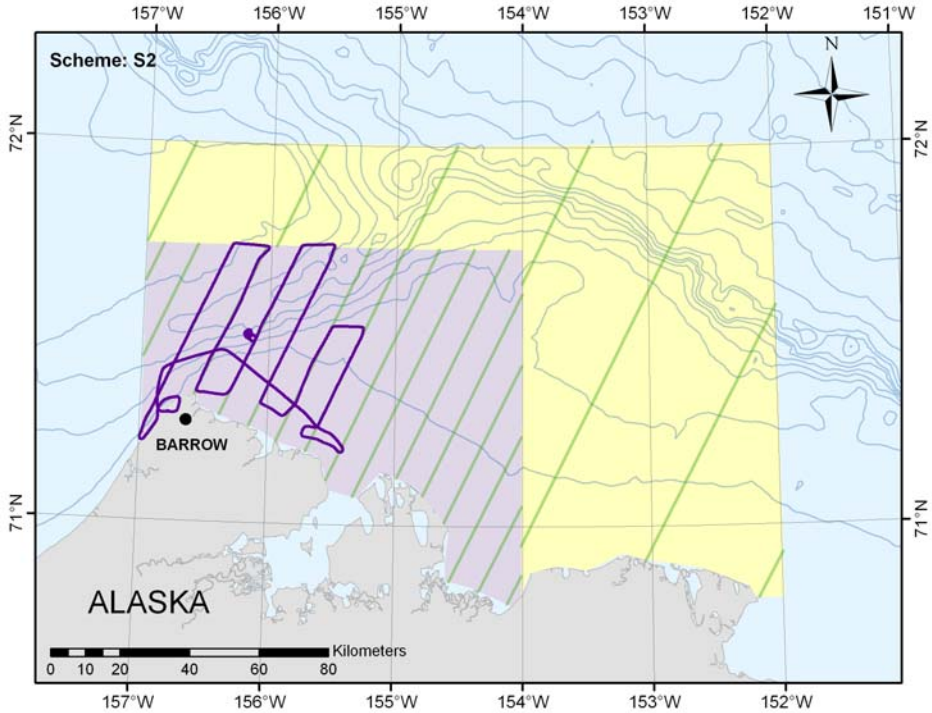

Figure 10. Scheme S2 transects (green) with flight 5 (purple) flown on 9 September 2007.

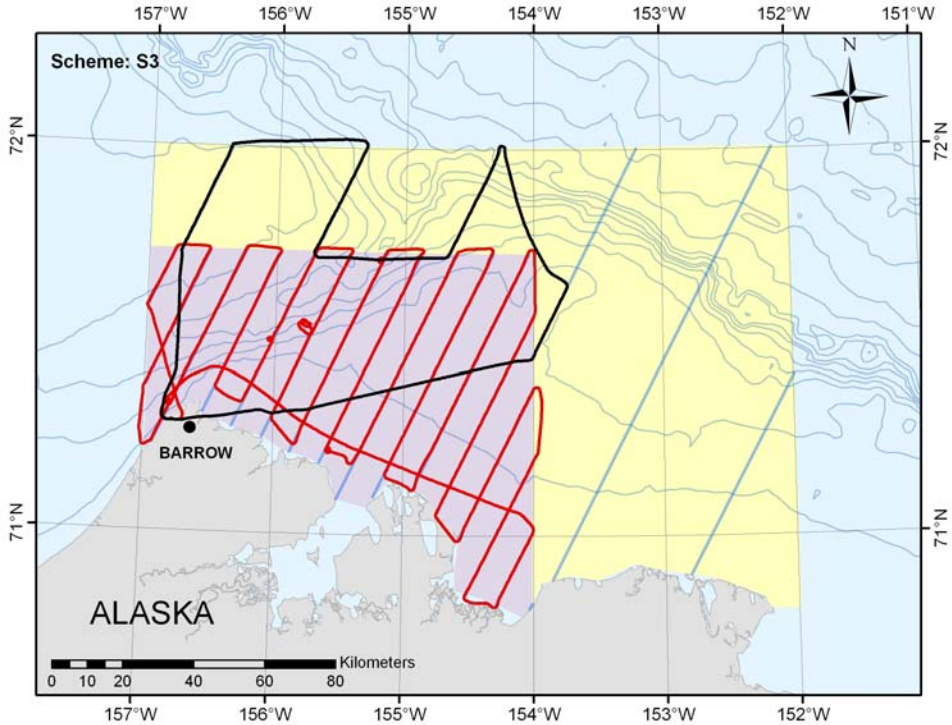

Figure 11. Scheme S3 transects (blue) with flights 6 (red) and 7 (black) flown on 11 September 2007.

Photographic effort

Since no bowhead whales were seen during the September portion of the survey, all bowhead photographs were taken 23-24 August. On 23 August, we spent approximately 1.7 hours (295 km) photographing bowhead whales. Within this time, 147 pictures (183 whale images) for photogrammetry (PGRAM) and 147 pictures (165 whale images) for photo identification (PID) were taken (Table 3). On 24 August, 1.4 hours (243 km) were spent on photographic effort, including 0.94 hours used to photograph a calibration target (29 photographs) and 0.44 hours to photograph bowhead whales. On 24 August, we collected 11 pictures for photogrammetry (16 whale images) and 14 photos for photo-identification (16 whale images). Although there were 380 bowhead whales counted on a total of 319 photographs, the number of unique bowhead whales will most likely be less after accounting for duplicate images.

Although the target settings for both cameras were manual focus, 800 ISO sensitivity, and 1/1000s shutter speed, adjustments were made as necessary. Examination of the photographic exif data revealed that the exposure program varied between shutter priority, aperture priority, and manual. ISO sensitivity was constant at 800, and exposure time ranged from 1/80s to 1/6400s.

Table 3: Allocation of photographic effort for the 2007 BOWFEST aerial survey

Date	Method	Time (hrs)	Distance (km)	Whale Pictures	Whale Images	Calibration Pictures
23-Aug	PGRAM	1.66	294.87	147	183	0
	PID			147	165	0
24-Aug	PGRAM	1.37	242.75	11	16	9
	PID			14	16	20
	Total	**3.03**	**537.63**	**319**	**380**	**29**

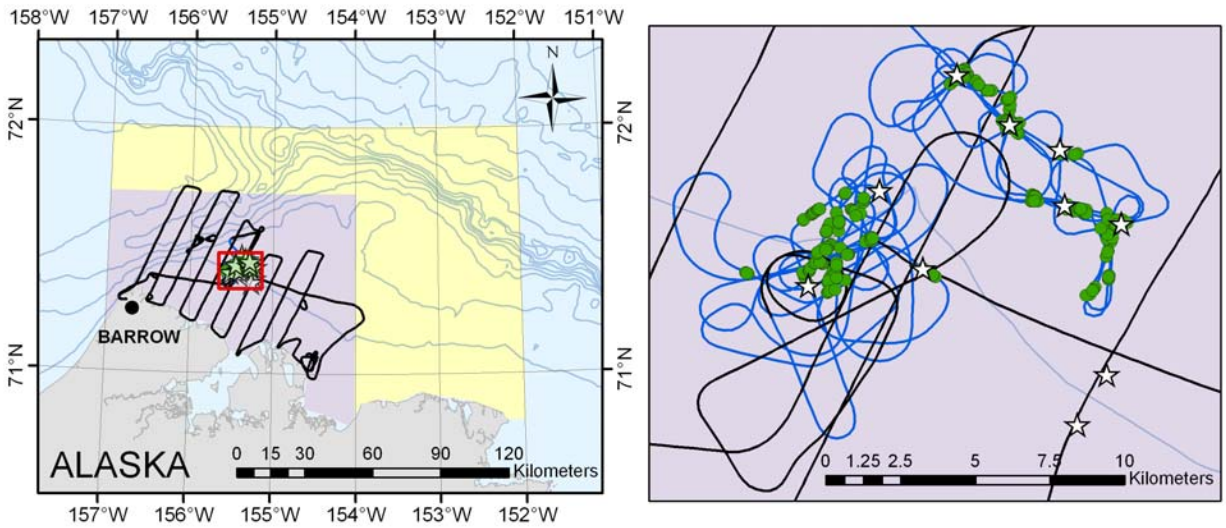

Figure 12. Map of flight 1 on 23 August 2007 with marked bowhead locations (left) and zoomed inset showing photographic effort (blue), locations of bowhead whale groups (white stars), and positions where photographs were taken for photogrammetry and photo-identification (green circles) (right).

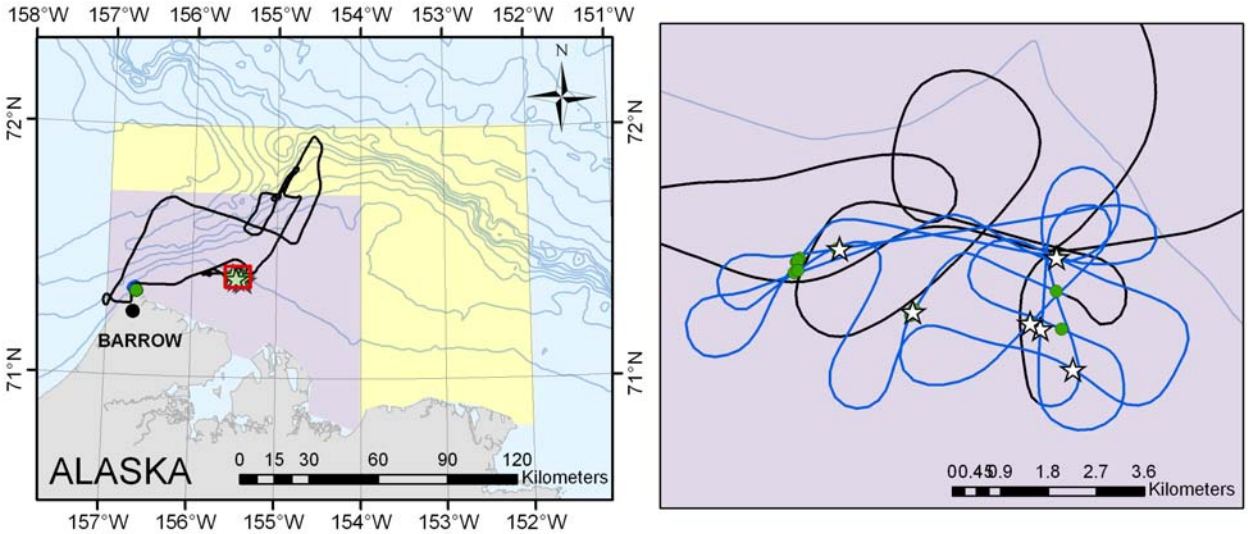

Figure 13. Map of flight 2 on 24 August 2007 with marked bowhead locations (left) and zoomed inset showing photographic effort (blue), locations of bowhead whale groups (white stars), and positions where photographs were taken for photogrammetry and photo-identification (green circles) (right).

Sighting Summary

Although no bowhead whales were seen in September, on 23 August there were 10 bowhead sightings (approximately 40 whales), and on 24 August, there were 6 sightings (approximately 9 whales; Table 4, Figure 14). Based on the multidirectional positioning of whales as well as the presence of mud plumes, most of the bowheads sighted appeared to be feeding. No bowhead whales appeared to be migrating through the area.

In addition to bowhead whales, there were 17 sightings of belugas (29 whales), 20 sightings of gray whales (29 whales), 65 sightings of walrus (255 animals), 32 sightings of bearded seals (90 seals),73 sightings of ringed seals (119 seals), 10 sightings of unidentified pinnipeds (12 animals), and 1 polar bear seen on land (Table 4, Figure 15).

Table 4: Summary of sightings and numbers of marine mammals seen during aerial surveys in the BOWFEST study area in August and September 2007. Counts may include resightings between days

Common Name	Scientific Name	Sightings	Count
Bowhead Whale	*Balaena mysticetus*	16	49
Beluga Whale	*Delphinapterus leucas*	17	29
Gray Whale	*Eschrichtius robustus*	20	29
Walrus	*Odobenus rosmarus*	65	255
Bearded Seal	*Erignathus barbatus*	32	90
Ringed Seal	*Phoca hispida*	73	119
Unidentified pinniped	---	10	12
Polar Bear	*Ursus maritimus*	1	1

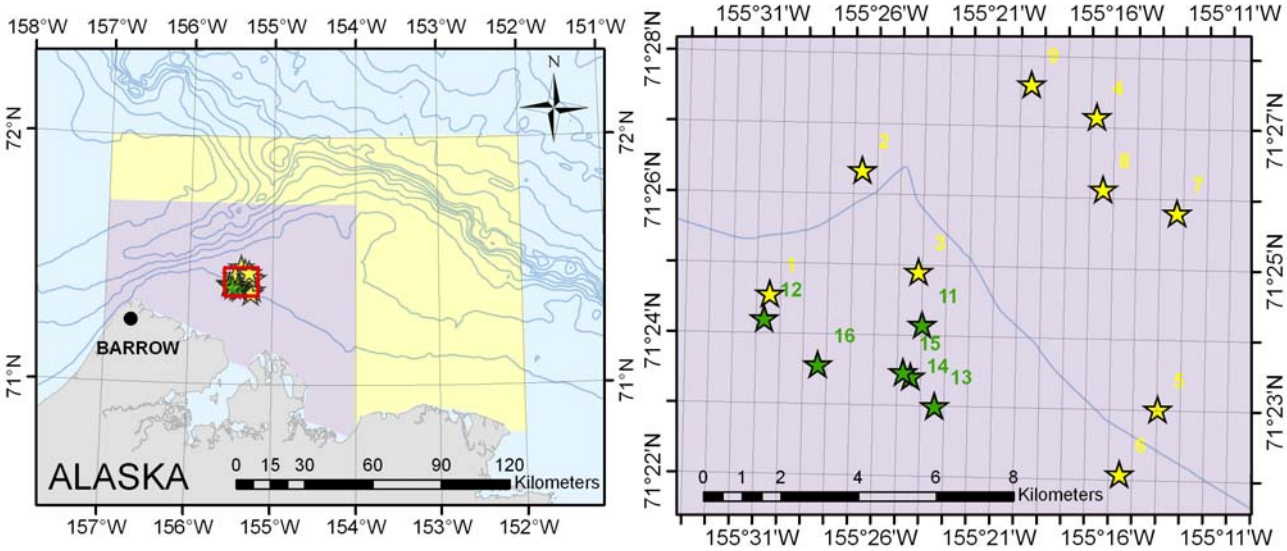

Figure 14. Map of study area with locations of all bowhead whale groups sighted during the 2007 BOWFEST survey (left) and zoomed inset showing bowhead whale groups 1-10 seen on 23 August (yellow stars) and group 11-16 seen on 24 August (green stars). Note: stars do not represent the original sighting location but rather when the plane was directly over each of the whale groups.

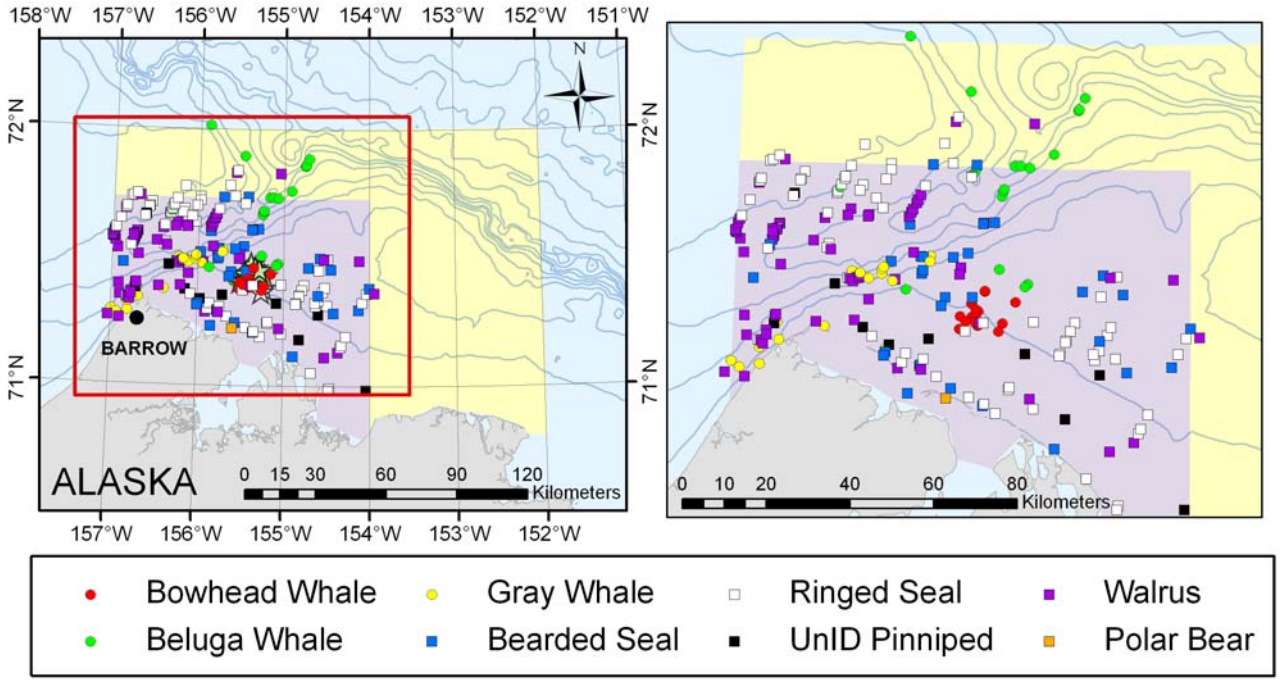

Figure 15. Map of study area (left) and zoomed inset (right) with locations of all marine mammal sightings during the 2007 BOWFEST survey.

2007 Daily Reports

August 22

Low ceilings precluded us from flying. The scientific team took advantage of the down time by setting up equipment in the aircraft and attending safety briefings. In addition the aerial survey team met with scientists from Woods Hole Oceanographic Institute (WHOI) to discus photographic methods.

August 23

The BOWFEST survey began with a 6.7 hour (1280.4 km) flight in the designated study area (Flight 1). Due to low ceilings in the morning, the flight was delayed until 15:00. After takeoff, we planned to deadhead to the furthest transect line of scheme A1 (Figure 2) in the lower right corner of the study area. However, approximately 14 minutes after takeoff, we sighted the first of several bowhead whales in the area. Rather than continuing to the furthest transects, we spent 1.7 hours photographing the whales. Once we were confident most of the bowheads had been photographed, we continued flying to the furthest transect line. Due to low ceiling and fog, we were unable to reach the outer section of the study area. Instead, we flew transects in the smaller portion of the study area, starting with the eastern transects and working our way back towards Barrow. While we were unable to complete any transects in the larger, outer section of the study area, we flew 52% of the available transect lines in the smaller portion of the study area. In total, poor weather interfered with viewing condition during 27.2 km of flight 1, 9.7 km of which were while flying transects.

There were 10 bowhead whale sightings representing approximately 40 animals. Seven of the sightings were made on transect and the remaining three were made during transit. The actual whale locations (marks taken when the whale was directly below the plane) were in proximity to one another and were within a relatively small area between 155.22° and 155.48° longitude and 71.37° and 71.48° latitude (~123 km^2). In addition to bowhead sightings, there were also 4 beluga whale sightings (4 animals), 4 gray whale sightings (8 animals), 14 bearded seal sightings (16 animals), 23 ringed seal sightings (40 animals), 1 walrus sighting (1 animal), and 3 unidentified pinniped sightings (3 animals).

August 24

While there was some fog in the morning, weather conditions improved enough to permit a 3.8 hour (720 km) survey flight in the late afternoon (Flight 2). Before beginning a systematic survey, we deadheaded to the old Barrow airstrip where the calibration target was assembled. After spending nearly an hour photographing the calibration target, we headed to the location where bowheads were sighted during Flight 1. Fourteen minutes later, the first bowhead sighting was made. There were 5 additional bowhead whale sightings, all of which were between 155.39° and 155.51°

longitude and 71.38° and 71.40° latitude (~12.3 sq km). We spent 0.44 hours photographing the whales for photogrammetry and photo-identification. The 6 bowhead whale sightings represented approximately 9 animals, all of which were sighted on transect and appeared to be feeding. While the whales were in the same vicinity, they appeared more concentrated than on the previous flight. In addition to bowhead whale sightings, there were 10 beluga whale sightings (21 animals), and 1 gray whale sighting (1 animal).

On August 24, similar to the previous day, we attempted to complete transects on scheme A1. However, due to the late start, periodically poor weather conditions, and time spent photographing bowhead whales and the calibration target, relatively little time (0.85 hours) was spent flying transects. In fact, only 11.9% of the total transect lines were completed. Unlike the first flight, however, some transects flown on the second flight were in the larger, outer section of the study area. Approximately 74 km were flown in poor weather conditions, 66.7 km of which were while flying on transect.

August 25-26

There were no flights due to heavy fog and low ceilings.

August 27

The August portion of the survey ended. The scientific party flew back to Seattle while the flight crew changed personnel and aircraft in preparation for the September portion of the survey.

September 5

There were no flights due to heavy fog and low ceilings.

September 6

We flew the first flight of the September portion of the BOWFEST survey (Flight 3; 4.0 hour; 784 km). Due to low ceilings and fog in the morning, we did not begin the survey until late afternoon. However, after takeoff, the weather gradually worsened with increased distance from shore, precluding us from flying the scheme S1 transect lines as planned. Instead, we flew an ad hoc pattern of lines adapted to the available weather clearings. Most of the survey was flown at an altitude less than 600 feet. At times, we minimized poor viewing conditions by flying below the survey protocol of 1000 feet. As a result, bad weather interfered for only 4.2 km.

Although no bowhead whales were seen during Flight 3, there were 3 gray whale sightings (5 animals), 6 walrus sightings (21 animals), and 1 unidentified pinniped sighting (1 animal).

September 7

We began Flight 4 mid day. Because transects were not flown on the previous flight, we attempted to fly scheme S1 transects for the second time. After takeoff, the first few hours of the survey were spent flying transects west to east. During the 5.5 hour flight over water, 2.8 hours (520.4 km) were flown on transects, covering roughly 45% of the total tracklines (56.7% of the inner tracklines and 18.5% of the outer tracklines). After leaving the tracklines, we transited to the location of the *Annika Marie* (a survey ship used in the BOWFEST project to collect oceanographic samples) to help identify an unknown whale species from the air. We circled the area for approximately 0.5 hours and identified a gray whale but no bowheads. Suboptimal conditions interfered with viewing conditions for only 8 km while on transect.

Much like Flight 3, no bowhead whales were seen during Flight 4. However, there were 4 gray whale sightings (4 animals), 2 bearded seal sightings (2 animals), 11 ringed seal sightings (16 animals), 11 walrus sightings (30 animals), and 2 unidentified pinniped sightings (3 animals)

September 8

There were no flights due to heavy fog and low ceilings.

September 9

Motivated by a need to find whales for the tagging team and good weather in the late afternoon, Flight 5 began later than usual. Beginning at 18:40, we flew 2.4 hours over water, 1.4 hours of which were on scheme S2 transect lines. We flew 22% of the tracklines, all within the small section of the study area. Starting in the western part of the study area, we flew six transect lines to the east (some only partial due to fog) before following the coastline approximately 8-16 km (5-10 miles) offshore back to Barrow. Poor weather conditions were rarely a factor, interfering with the search for only 8 km, most of which was off-transect.

Once again, there were no bowhead whale sightings. The entire flight yielded only 1 beluga whale sighting (1 animal), and 3 gray whale sightings (4 animals).

September 10

There were no flights due to heavy fog and low ceilings.

September 11

Taking advantage of the good weather, we flew two flights (6 & 7). In total, we flew 8.1 hours (1536.4 km) over water, completing approximately 75% of scheme S3 transects. We began Flight 6 by flying the westernmost transects and gradually worked our way towards the east before returning to Barrow. During this flight, we completed

93% of the transects in the smaller portion of the study area. Although our goal was to complete the tracklines in the outer portion of the study area on Flight 7, we only completed 33% of the available tracklines due to heavy fog. During this 2 hour flight, suboptimal viewing conditions impacted 16 km of the survey, none of which was on transect.

As with all preceding September flights, there were no bowhead whale sightings on 11 September. However, there were 3 beluga whale sightings (4 animals), 5 gray whale sightings (7 animals), 16 bearded seal sightings (72 animals), 39 ringed seal sightings (63 animals), 47 walrus sightings (203 animals), 4 unidentified pinniped sightings (4 animals), and 1 polar bear sighting (1 animal).

September 12

There were no flights due to heavy fog and low ceilings.

September 13

On this day the aerial survey project was terminated and the crews left Barrow.

Discussion

While bowhead whales are often seen traveling to and from the eastern Beaufort Sea during the spring and autumn migrations, reports of bowheads remaining in the Barrow area throughout the summer are relatively rare. Based on Traditional Ecological Knowledge (TEK), aerial observations, and bowhead stomach contents, Lowry and Frost (1984) identified two feeding areas in US waters; one between the US/Canadian border and Barter Island and another between Pitt Point and Point Barrow. Although past studies (Lowry and Frost 1984, Carroll et al. 1987) concluded that bowheads feed only occasionally during the spring migration, recent research has confirmed that bowheads are feeding frequently during both the spring and autumn migration (Lowry et al. 2004). Data collected from the stomach contents of whales taken near Point Barrow indicate that feeding is a major activity of bowhead whales throughout the Beaufort Sea: food was found in the stomachs of three-quarters of the animals examined in September-October and one-third of those taken in the spring (Lowry et al. 2004). Thus, feeding appears to be both more extensive and more frequent during the autumn migration than the spring migration.

Since the BCB stock of bowhead whales begins migrating back to the Bering Sea in early September, we expected to find more bowheads during September than the August portion of the 2007 BOWFEST survey. On the contrary, all of the bowheads seen during this survey (approximately 50) were found 23-24 August and none during the four days flown in September. Most of these bowheads appeared to be feeding as evidenced by mud plumes, open mouths, the presence of feces, and frequent turns in a small area. Several whales also had mud on their dorsal surfaces, indicating that they

had been near the sea bottom, presumably collecting epibenthic prey (Angliss et al. 1993). In addition, researchers from the *Oshoro Maru* 2007 summer cruise between the Bering and Chukchi Seas, reported an aggregation of 30 bowhead whales approximately 80 miles north of Cape Lisburne (Sekiguchi Cruise Report – Leg 3, 2007). These whales were spread out and headed in random directions indicating possible feeding behavior.

In order to learn more about the consistency of bowhead feeding aggregations seen near Barrow during the summer, photographs collected during the BOWFEST aerial survey are being analyzed. Aerial photography has been used over the past three decades to identify individual bowhead whales (Koski et al. 2007), and to date there are over 17,000 whale images in the catalog held both at LGL in Ontario and at NMML in Washington. Reidentifiying bowhead individuals provides information on: 1) residence times (duration of individuals within the study area from day to day); 2) behavior (individual whales seen feeding or not feeding on different days, and associations between certain individuals); 3) local abundance (by using mark/recapture techniques for a group of whales photographed across several days); 4) the probability of returning to the area (when whales are recognized across several years). Furthermore, resightings of bowheads in this study can provide information applicable towards survival analysis (Zeh et al. 2000), calving intervals (Rugh et al. 1992; Miller et al. 1992), growth rates (Koski et al. 1992), population dynamics (whale lengths are an indicator of maturity classes) (Koski et al. 2006), and stock structure (via resighting rates within and between various seas). The data collected from photographic images during the 2007 BOWFEST survey will provide information useful in evaluating the overall health of the BCB population of bowhead whales. Furthermore, information on bowhead distribution and habitat use within the BOWFEST study area will provide a foundation for assessing the potential impact of industrial development on bowhead whales near Barrow.

Acknowledgments

Minerals Management Service funded the BOWFEST program; in particular, Chuck Monnett provided guiding support and inspiration to get this large research program underway. NOAA's Aircraft Operation Center provided the aircraft and crew. Our pilots, Jason Mansour, Wally Pierce, and Nicole Cabana, filled a critical role in keeping the aircraft at the preferred altitude while flying intricate patterns over moving whales. Ron Pauley was paramount in providing mechanical support for the aircraft. Wayne Perryman and Don LeRoi were kind enough to lend us a radar altimeter and provide technical support. Craig George assisted the aerial survey project as an observer and provided the calibration target. Jeremiah Lambrecht helped transport and assemble the calibration target. This study was conducted under MMPA Scientific Research Permit No. 782-1719.

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Passive Acoustic Monitoring

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Six hydrophone packages were purchased from Multi-electronique for deployment in the Beaufort Sea. All of the instruments had 100 Gb harddrives. Two of the instruments were deployed in shallow water on mooring frames in early August while the other four were deployed on the Annika Marie's transit from Deadhorse to Barrow AK (Fig 1). The two shallow water moorings were programmed to record continuously at a sample rate of 8192 Hz while the deep water instruments were on a recording schedule of 10 min on/20 min off in order to record for a year's duration (Table 1).

The Cape Halkett mooring (M6) was recovered on 11 September 2007. The Barrow mooring (M1) was due to be recovered after whaling season, or roughly mid-October. Unfortunately, ice set in over the Barrow mooring and it could not be recovered this year. We hope that it, and the other instruments on the frame will be recovered as soon as ice cover recedes enough in 2008. It is, however, possible that this mooring may not be recovered due to possible ice damage.

Figure 1. Bowhead whale feeding study hydrophone deployment locations

Table 1. Information for hydrophones deployed for the bowhead whale feeding study

Hydrophone ID	Date deployed	Latitude	Longitude	Depth (m)	Sampling plan	Date recovered
M-1	8/17/07	70.98	-152.25	15.1	continuous	
M-2	8/17/07	71.40	-152.14	108	10/30 min	
M-3	8/17/07	71.69	-153.17	104	10/30 min	
M-4	8/17/07	71.75	-154.49	100	10/30 min	
M-5	8/17/07	71.56	-155.59	110	10/30 min	
M-6	8/16/07	71.45	-156.13	16	continuous	9/11/07

Preliminary results from Cape Halkett mooring

Just over one month of data were recorded on the hydrophone at M6 (8/12/07-9/14/07). These data were scanned for bowhead whale calls but no sounds that could be definitively attributed to bowheads were found. Other identifiable sounds recorded included bearded seals (Fig 2) and wave noise.

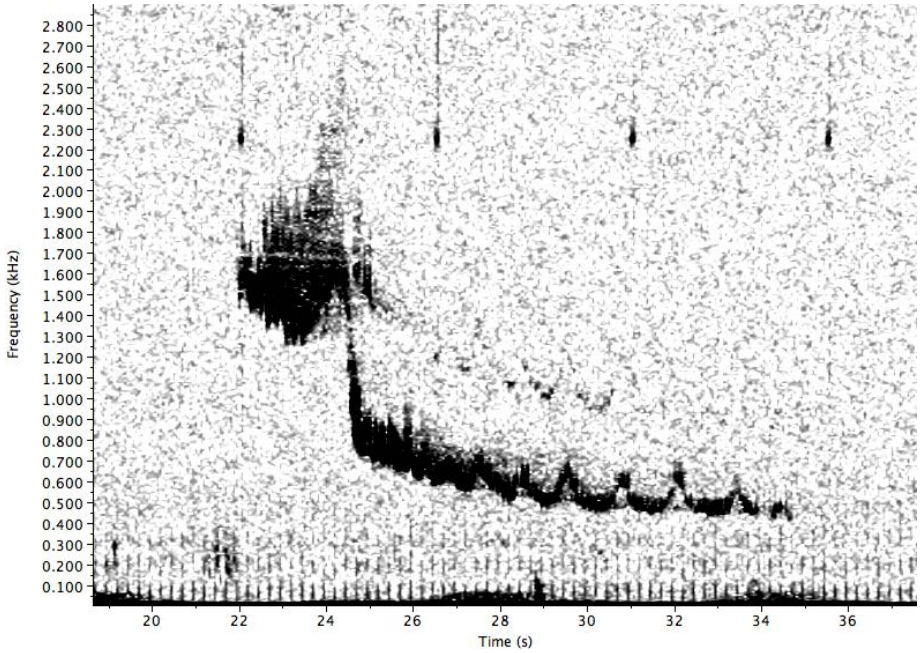
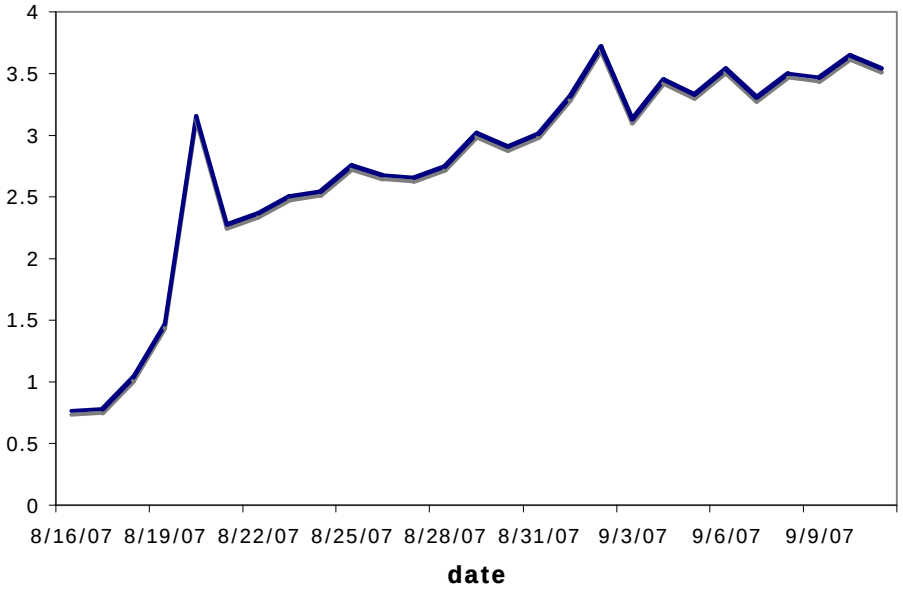


Figure 2. Example of bearded seal song recorded at Cape Halkett on 10 September 2007.

In addition to recording acoustic data, the hydrophones also record the water temperature at the time each file is written. Figure 3 shows the mean daily water temperature during the deployment at Cape Halkett.



Mooring and Broad-scale Oceanography

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Shallow water moorings were deployed by a local Barrow boat on 9 August 2007, each equipped with a CTD and acoustic current meter, in Ekilukruak Entrance (near Cooper Island) and in Eluitkak Pass (near Pt. Barrow), to measure exchange between Elson Lagoon and the nearshore Beaufort Sea. A shallow water mooring equipped with an acoustic recorder, CTD, and ADCP was also deployed by a local boat at a location ~10 km northeast of Pt. Barrow on 8 August 2007 (M1; Figure 1). These moorings are to be recovered along with a mooring at Sanigaruak Pass (see next section) after fall whaling concludes in early/mid-October 2007.

The charter for the *R/V Annika Marie* was for Aug. 15-Sept. 15, 2007. During the period of August 15-September 12, the *Annika Marie* worked for 13 days and could not work because of bad weather for 16 days. The boat transited from Prudhoe Bay to Barrow from Aug. 15-16, deploying five moorings during the transit (two working days). One shallow, short-term mooring, equipped with an acoustic recorder, ADCP, and CTD, was deployed near Cape Halkett (M6) and four long-term (year) moorings (M2-M5), equipped with acoustic recorders, were deployed along the shelf break. A shallow short-term mooring, equipped with a CTD and RCM-11 current meter, was deployed in Sanigaruak Pass on August 25th. Four of the SNACS transect lines were surveyed (Figure 1); three of the lines were surveyed twice (seven working days). Additional sampling off of the transect lines was conducted on two days. Sampling at Barrow was suspended and equipment demobilized from the *Annika Marie* on Sept. 10th because weather forecasts indicated that Sept. 11th would provide the only opportunity before Sept. 15th to recover the Cape Halkett mooring (M6). The *Annika Marie* left Barrow on Sept. 10th, recovered the Cape Halkett mooring on Sept. 11th, and returned to Prudhoe Bay that night (two working days), demobilizing there on Sept. 12th.

Overall, the oceanographic sampling was highly successful despite the poor weather. Sixty-four stations were conducted, including many with multiple types of instrument deployments or collections. The Acrobat towed vehicle (temperature, salinity, chlorophyll and CDOM fluorescence, optical backscatter) and the acoustic Doppler current profiler (ADCP) were towed along most lines except where weather precluded their use. The repeated sampling of transect lines permitted us to better

identify the role of wind in defining the oceanography on the shelf and in providing a favorable prey environment for bowhead whales. In addition, considerable interannual variability in physical and biological oceanography has been observed between the three years of our observations (Year 1 of the Bowhead Feeding Study (this work) and the two years of the Bowhead SNACS project). Defining and understanding this variability and how it is associated with larger scale atmospheric and oceanographic conditions is critical to achieving a better understanding of the importance and persistence of the western Beaufort Shelf as a feeding environment for the bowhead whales during their fall migration.

Okkonen was in Barrow 1-10 December 07 and, with the assistance of BASC personnel, recovered the Plover (71° 21.24'N, 156° 21.23'W) and Cooper (71° 13.24'N, 155° 49.76'W) oceanographic moorings that were deployed in Elson Lagoon in August 07. The Deese (71° 11.24'N, 156° 25.57'W) mooring was not recovered. A recovery of the Deese mooring will again be attempted in July/August 08 after the ice melts in the lagoon.

Since the field season, analysis of the oceanographic data is underway. Nutrient and chlorophyll analysis is completed, permitting calibration of the fluorometers on both the CTD and the Acrobat. Enumeration of the zooplankton net samples is underway at the University of Rhode Island and the Atlantic Reference Center in New Brunswick, Canada (these are the same laboratories that analyzed the zooplankton samples for the NSF-funded SNACS program). Preliminary analysis of the acoustic Doppler current profiler data has been accomplished. Preliminary comparisons of the current meter data from the Plover and Cooper moorings with contemporaneous Barrow winds show that non-tidal flows through the passages between the barrier islands of Elson lagoon are well correlated with winds from the east and west quadrants. Winds from the southeast push lagoon waters to the northwest end of the lagoon, promoting outflow through the passage west of Plover Island and inflow through the pass west of Cooper Island. Conversely, winds from the west push lagoon waters to the southeast end of the lagoon, promoting outflow through the passage west of Cooper Island and inflow through the pass west of Plover Island. These results are essentially the same as determined from the current meter moorings deployed at these same locations in summer 2006.

Results from the observational program will be presented in posters at the upcoming Alaska Marine Science Symposium in January 2008.

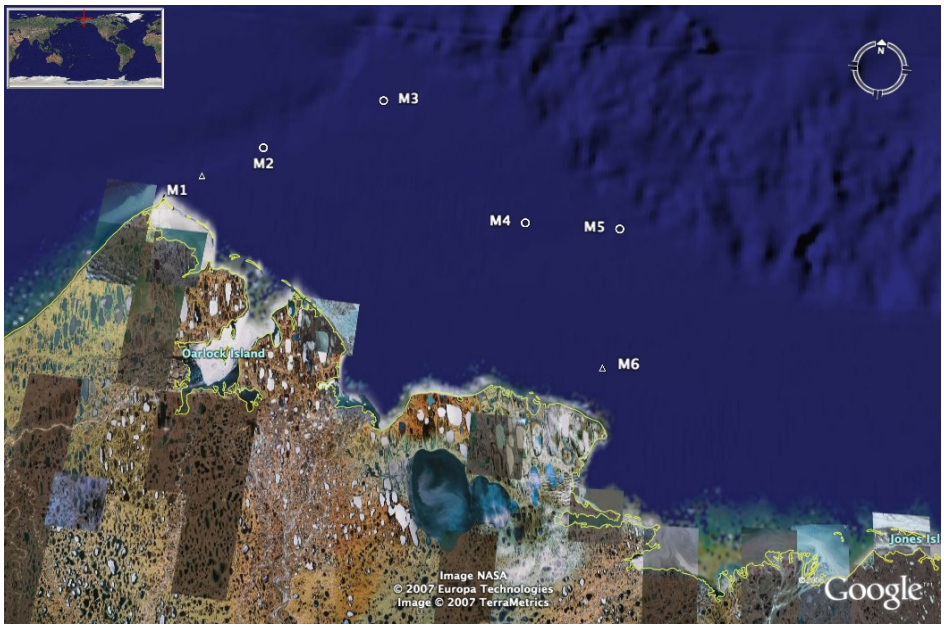

Figure 1. Locations of the moorings equipped with acoustic recorders.

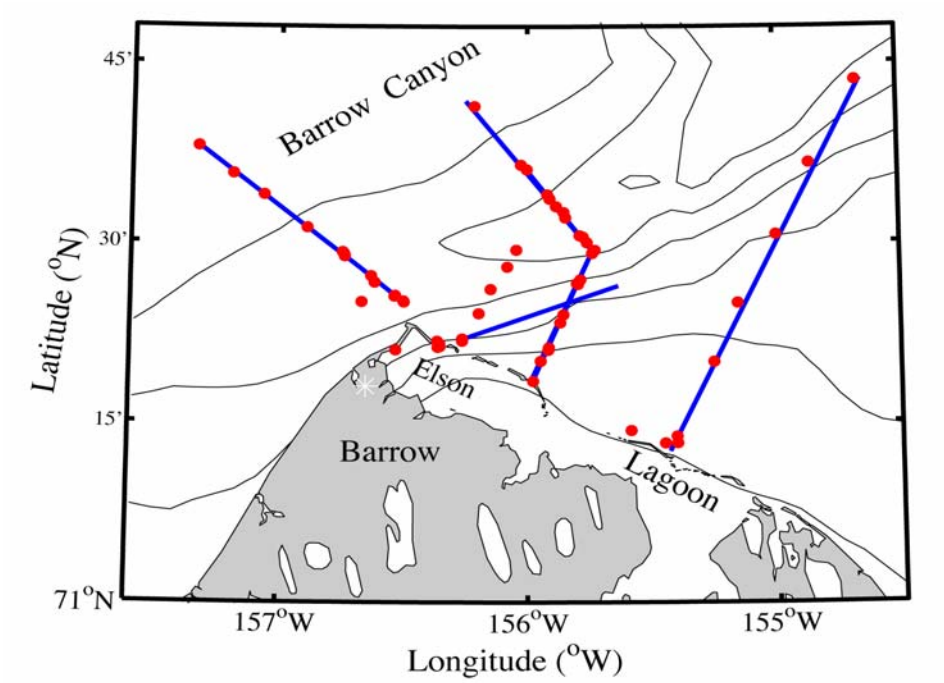

Figure 2. Locations of stations (red dots) and continuous sampling with the Acrobat and ADCP (blue lines). Each of the long lines was surveyed at least twice.

Tagging and Fine-scale Oceanography

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Field operations for the tagging and fine-scale oceanography took place from August 27 to September 11, 2007. Our objectives for the fieldwork were to: 1) attach suction-cup attached archival tags to bowhead whales; 2) intensively sample oceanographic conditions and prey distribution in proximity to the tagged whales; 3) deploy and tend a 3D tracking and passive acoustic monitoring array of free-floating buoys around the tagged whales; and 4) coordinate tagging activities with the large-scale sampling group (Ashjian et al.) so that they could conduct simultaneous cross-shelf transects in the vicinity of the tagged whales. Four vessels were used for this operation, one for each objective: 1) an 18 ft. Lund supplied by the North Slope Borough Department of Wildlife (referred to as the Wildlife Boat); 2) the MMS *Launch 1273;* 3) a contracted 22 ft. aluminum boat (referred to as the Donovan Boat); and 4) the *R/V Annika Marie*.

The Wildlife Boat, *Launch 1273*, and the Donovan Boat spent a combined total of 192 hours on the water searching for bowhead whales over 9 days of acceptable weather (Table 3). Typically, 2 people sailed aboard the Wildlife Boat, 4 aboard the *Launch 1273*, and 3 aboard the Donovan Boat; therefore, we expended over 600 man-hours searching for bowhead whales during the field study. This total does not include the search effort conducted by the *R/V Annika Marie* during her large-scale oceanography work. Despite this effort, we encountered no aggregations of whales. On two occasions, a single bowhead whale was briefly sighted, but we were unable to relocate the animal to commence tagging operations. Because of this lack of whales, no tagging or fine-scale oceanography work could be conducted.

Table 3. Number of hours spent on the water in 2007 by the three vessels participating in the tagging and fine-scale oceanography operations.

Date	*Launch 1273*	Wildlife Boat	Donovan Boat	Comments
27-Aug				Poor weather
28-Aug	12	8	8	
29-Aug				1273 captain unavailable
30-Aug	14	8	8	
31-Aug				Poor weather
1-Sep				Poor weather
2-Sep				Poor weather
3-Sep	6	3	3	
4-Sep	9.5	6.5	6.5	
5-Sep	2.5	1.5	1.5	
6-Sep	6	4	4	
7-Sep	13	10.5	10.5	
8-Sep				Poor weather
9-Sep				Poor weather
10-Sep	8	6	6	
11-Sep	10	8	8	
Total	81	55.5	55.5	

Bowhead Whale Harvest Sampling

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The Alaska Department of Fish and Game (ADF&G) was subcontracted by the National Marine Mammal Laboratory (NMML) to conduct harvest monitoring and tissue sampling of bowhead whales taken by subsistence whalers near Kaktovik, Alaska, during 2007. Accordingly, Gay Sheffield (ADF&G) was stationed at Kaktovik from 1-13 September. She made contact with all whaling captains, the Kaktovik mayor, and other residents to discuss objectives, techniques, and updates of the bowhead sampling project. Dr. Cheryl Rosa of the North Slope Borough Department of Wildlife Management (NSB-DWM) was in Kaktovik for a portion of the whaling season and ensured compatibility in data collection protocols with the North Slope Borough's efforts.

Three bowhead whales were harvested, butchered, and sampled within hours of death (Table 4). The stomach of each whale was examined as soon as possible. An estimate was made of the total volume of the stomach contents, and a sample of the contents was collected from the forestomach, when possible. Samples of stomach contents were frozen for identification of prey items. Identification work will be done in the laboratory in Fairbanks. Other biological samples were provided to the NSB-DWM for ongoing studies and/or archived at the University of Alaska Museum (UAM) for future studies (Table 5).

In the laboratory, samples were gently rinsed in freshwater in a 1.0 mm screen with a 0.5 mm screen layered underneath. Prey items were sorted macroscopically into major taxonomic groups and examined microscopically. Several prey vouchers have been sent to the University of Alaska taxonomy experts for identification to the lowest taxonomic level possible.

No significant technical, schedule, or cost problems were encountered.

Table 4. Bowhead whales harvested near Kaktovik during September 2007.

ID Number	Date	Sex	Total Length
07KK1	3 Sept	Male	8.3 meters
07KK2	10Sept	Female	8.1 meters
07KK3	11 Sept	Female	9.0 meters

Table 5. Tissues collected from bowhead whales harvested near Kaktovik during September 2007 and the recipient of those tissues.

	07KK1	**07KK2**	**07KK3**
Stomach contents	ADF&G	ADF&G	ADF&G
Blood	NSB-DWM	NSB-DWM	NSB-DWM
Blubber	NSB-DWM	NSB-DWM	NSB-DWM
Tongue	UAM	-	UAM
Kidney	NSB-DWM; UAM	NSB-DWM; UAM	NSB-DWM; UAM
Liver	NSB-DWM; UAM	NSB-DWM; UAM	NSB-DWM; UAM
Spleen	NSB-DWM; UAM	NSB-DWM; UAM	NSB-DWM; UAM
Muscle	NSB-DWM; UAM	NSB-DWM; UAM	NSB-DWM; UAM
Lung	NSB-DWM	NSB-DWM	NSB-DWM; UAM
Eyeball(s)	NSB-DWM	NSB-DWM	NSB-DWM
Testis	NSB-DWM	-	-
Pancreas	NSB-DWM	-	-
Ovaries	-	NSB-DWM	NSB-DWM
Urine	-	NSB-DWM	NSB-DWM
Feces	NSB-DWM	-	NSB-DWM
Skin	NSB-DWM	NSB-DWM	NSB-DWM
Baleen	NSB-DWM	NSB-DWM	NSB-DWM