BOWHEAD WHALE FEEDING ECOLOGY STUDY

(BOWFEST)

IN THE WESTERN BEAUFORT SEA

2008 Annual Report

A project provided to:
Environmental Studies Program
Alaska Outer Continental Shelf Region
Minerals Management Service
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INTRODUCTION

The Bowhead Whale Feeding Ecology Study (BOWFEST) was initiated in May 2007 through an Interagency Agreement between the Minerals Management Service (MMS) and the National Marine Mammal Lab (NMML). The study is being conducted through grants and contracts to scientists at Woods Hole Oceanographic Institute (WHOI), University of Rhode Island (URI), University of Alaska Fairbanks (UAF), University of Washington (UW), Oregon State University (OSU), as well as through employees at NMML. Field work is being coordinated with the North Slope Borough (NSB), Alaska Eskimo Whaling Commission (AEWC), Barrow Whaling Captains' Association (BWCA), Alaska Department of Fish and Game (ADFG), and MMS. Marine mammal studies are as permitted under NMML's Permit No. 782-1719.

This study focuses on late summer oceanography and prey densities relative to bowhead whale (*Balaena mysticetus*) distribution over continental shelf waters between the coast and 72°N and between 152º -154º west longitudes, which is north and east of Point Barrow, Alaska. 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 2008. This is the second of three proposed years of field work for this program.

AERIAL SURVEYS OF BOWHEAD WHALES IN THE VICINITY OF BARROW, ALASKA, AUGUST-SEPTEMBER 2008

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Abstract

The aerial survey component of BOWFEST is designed to 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, aerial photography provides information on residence times (through reidentification of individual animals) and sizes of whales (through photogrammetry). 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 27 August to 16 September 2008 over continental shelf waters from 157° W to 152° W and from the coastline to 72° N, with most of the effort concentrated between 157° W and 154° W and between the coastline and 71° 44'N. There were 56 sightings of bowheads (an estimated 163 whales) during 42.7 flight hours (approximately half of the 70 available flight hours due to fog and high winds). Most of these sightings were on or near the 20 m isobath. Two Canon EOS-1DS Mark III cameras were used to photograph bowhead whales; 256 pictures were taken with a 55 mm lens for photogrammetry, and 307 pictures were taken with a 70-200 mm lens for photo-identification. Unlike in 2007 when nearly all bowheads appeared to be feeding as indicated by mud plumes and multiple swim directions, in 2008 aerial observers identified only 4 of the 56 bowhead sightings as feeding. Examination of the photographs will provide more precise records of how many whales were feeding as evidenced by mud on the body, open-mouths, and the presence of feces. "Traveling" was the most commonly recorded behavior, indicating that bowheads were most likely migrating through the study area. Collecting additional years of data as well as integrating aerial information with other projects will help elucidate the extent to which bowheads feed near Point Barrow in the summer.

Introduction

Most bowhead whales of the Bering-Chukchi-Beaufort (BCB) stock migrate 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 eastern Beaufort Sea, traveling northwesterly towards Barrow and west across the Chukchi Sea throughout September and October (Moore & Reeves, 1993).

Although bowheads are more commonly seen off Barrow during the spring and autumn migrations, there have also been reports of whales feeding near Barrow in summer (July to September). There is no documentation as to whether these animals are still traveling from the Chukchi Sea following the spring migration, traveling towards the Chukchi Sea prior to the autumn migration, or residing between the Chukchi and Beaufort seas throughout the summer. BOWFEST was established to determine the relative scale of feeding near Barrow in the summer and the consistency of this behavior relative to location within the study area, year, and age class (using whale size as a proxy for age). In addition, the ecological relationship between feeding bowhead whales and relevant oceanographic parameters -- such as bathymetry, currents, temperatures, and ice conditions -- are being examined to assess whether oceanographic features indirectly affect the location of bowhead feeding aggregations by influencing prey distribution. Accordingly, the aerial survey component of BOWFEST 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, aerial photography provides information on residence times (through reidentification of individual animals) and sizes of whales (through photogrammetry).

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 inner section of the study area (violet) was approximately 7,276 km^2 and the larger, outer section (yellow) was approximately 12,152 km^2.

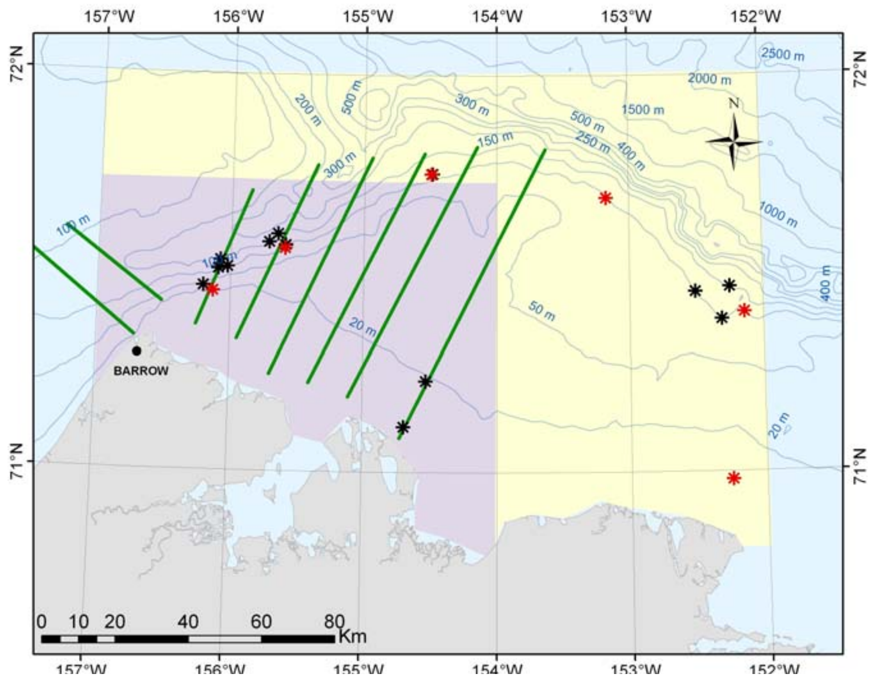

Figure 1. Two-part study area (inner violet section and outer yellow section) relative to pre-set oceanographic tracklines (green) and acoustic moorings (asterisks: red=2007, black=2008).

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 inner 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. 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%. Decreasing the detection probability caused the proportion of effort allocated to the inner 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 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. 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. The entire study area contained approximately 8,746 km of trackline, 5,923 km in the inner section and 2,824 km in the outer section (Figure 2). Based on the allocation of effort and the flight hours available, the tracklines in the inner section were spaced 1.2 km apart while lines in the outer section were spaced 4.2 km apart. The placement of the first survey line in the inner section of the study area (closer to Barrow) was determined by random selection. In this case, the first transect line was placed 0.75 km and 3 km from the northwest corner of the inner and outer portions of the study area and oriented at a 66° angle. Subsequent tracklines were parallel to the first trackline and spaced 1.2 km apart for the inner area and 4.2 km apart for the outer area.

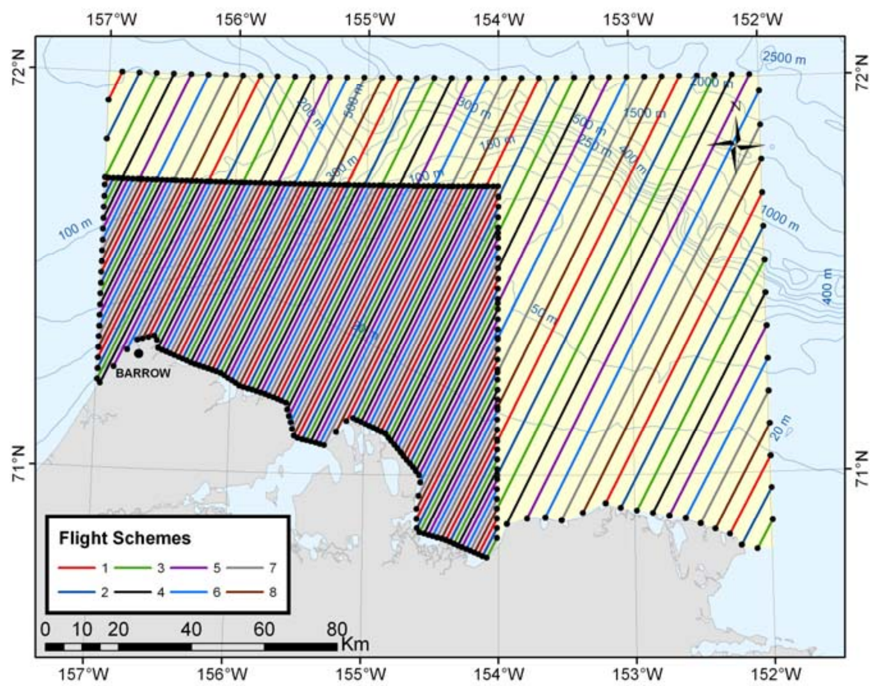

Figure 2. Two-part study area with proposed tracklines for the 2008 BOWFEST aerial survey.

In order to prevent overlap in survey effort due to tightly spaced tracklines, eight sampling schemes were devised (Fig. 2 & 3). The first scheme (Scheme 1) was created by selecting the first line from the west side of the study area and every eighth line thereafter. Using the same method, beginning with the second through seventh lines from the west side of the study area, the seven remaining schemes were created. As a result, tracklines were spaced approximately 9.6 km and 33.6 km apart in the inner and outer sections of the study area (Fig. 3).

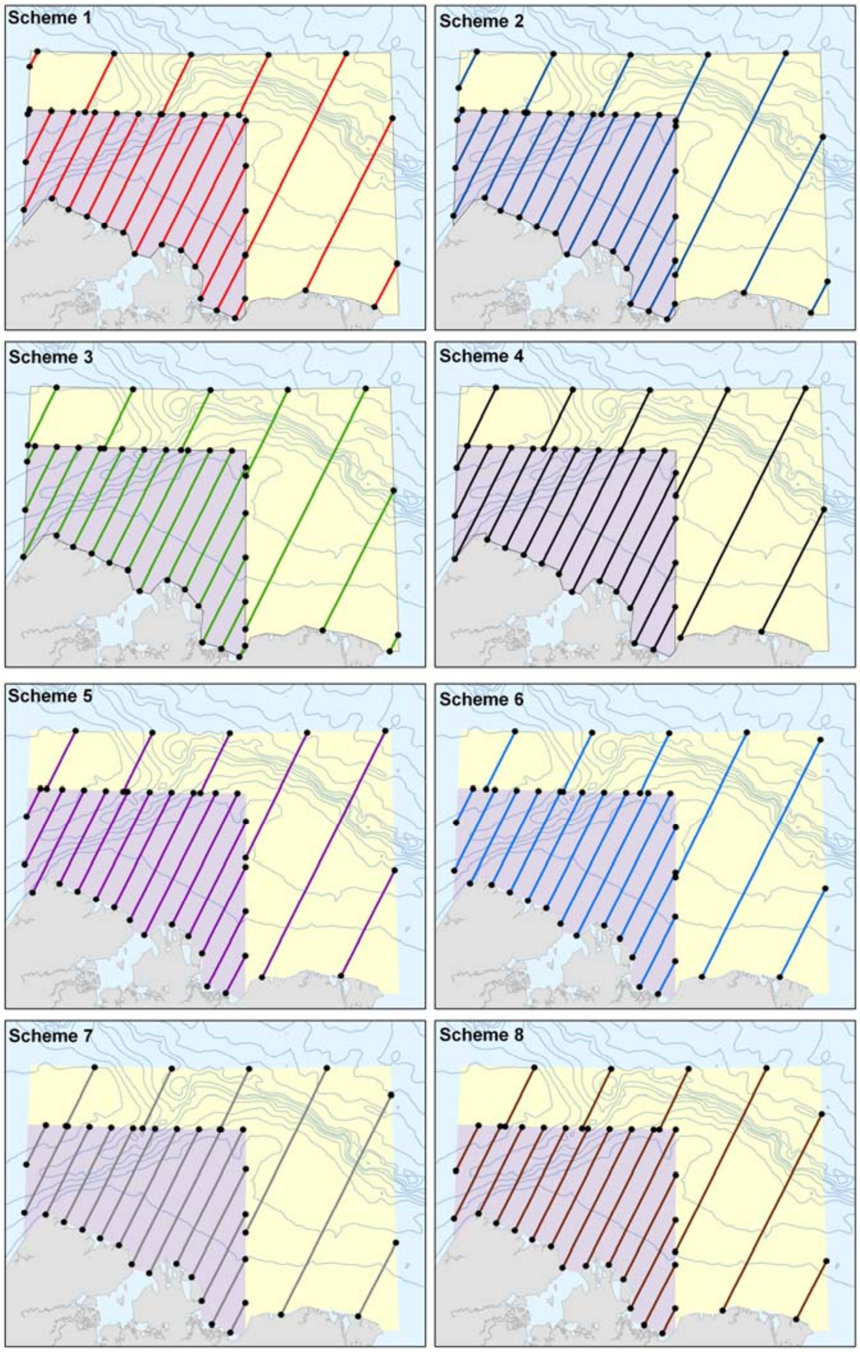

Figure 3. The eight individual survey schemes for the 2008 BOWFEST aerial survey.

Survey Protocol

BOWFEST aerial surveys were flown in a NOAA Twin Otter (N48RF) equipped with twin engines, high wings, and more than 6 hours of flying capacity. In addition, the aircraft had 2 large bubble windows and an open belly window/camera port for vertical photography. An intercom system allowed communication among observers, pilots, and data recorder while a 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. Visibility quality within the given inclinometer angle was documented as one of five subjective categories from excellent to useless; areas where observers rated visibility quality as poor or useless on both sides of the aircraft were considered off effort and, thus, unsurveyed. Date, time, sighting observer, inclinometer angle, group size, and species were recorded for all marine mammals; in addition, for large whale sightings, observers reported calf number, travel direction, sighting cue, dominant behavior, group composition, reaction to plane, and number of nearby vessels.

The target survey altitude was 305 m (1000 ft), although a lower altitude (900 ft) was sometimes used for aerial photographic passes (allowed under NMML Permit No. 782-1719-07). The northeast/southwest tracklines were flown sequentially west to east (opposite the bowhead whales' autumn migration route) in order to minimize 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 deviated from the trackline only when an observer reported a bowhead whale or an unidentified large cetacean sighting (in order to obtain an adequate identification). After a bowhead was reported, the trackline was typically 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 Canon EOS-1DS Mark III cameras were used simultaneously over an open belly port for vertical photography (Figure 4A). A 70-200 mm lens (primarily set at 200 mm) was used to provide larger images of whales for purposes of identifying individual animals. This lens was equipped with image stabilization technology and was set to autofocus throughout the survey. Since this camera was held over the belly port aimed vertically down rather than oblique, the images can also be used to obtain relative whale lengths in the event that a whale was not captured by the photogrammetry camera (Figure 4B).

The second camera, with a 55 mm fixed lens (no magnification), was used for photogrammetry in order to best estimate whale lengths. This lens was manually focused and taped to impede rotation. The camera was housed in a Forward Motion Compensation (FMC) mount (installed on the left side of the belly port) which uses a rocker mechanism to counter the forward velocity of the relative ground speed and was integrated with an autonomous radar altimeter (Honeywell AA300 model) in order to collect precise altitudes each time the camera was fired (Figure 4C). Unlike the handheld camera for photo-identification, this mounted camera was fired using a custom built data acquisition system that automated the retrieval of data including altitude, time of camera firing, frame number, aircraft speed, and focal length of the camera lens. Immediately prior to a whale appearing beneath the plane, a keystroke on the computer triggered the camera to continuously fire so that each consecutive image overlapped the previous photo by 60%, adjusted for altitude. Both cameras recorded RAW format, 21.0 megapixels (5616 x 3744) images and were set to shutter priority, 400-800 ISO sensitivity, and a shutter speed of 1/1000s or faster.

Photo by Craig George, 2008 Photo by Dave Rugh, 2008 Photo by Dave Rugh, 2008

Figure 4. A) The NOAA Twin Otter (N48RF) with open belly port. B) The handheld Canon EOS-1DS Mark III with 70-200 mm lens used for photo-identification. C) The Canon EOS-1DS Mark III with 55 mm lens housed in the FMC mount on the left side of the belly port.

Photographic passes were typically made after completing the trackline on which the bowhead sighting was initially reported. After breaking trackline 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 the observers felt that most whales in the area had been photographed. During each photographic pass, the forward observer provided a countdown to alert the photographer(s) when a whale was about to appear under the aircraft.

In addition to photographing bowhead whales, photographs were taken of two calibration targets (one over land and the other over water) using the same two cameras (Canon EOS-1DS

Mark III) and lenses (55 mm and 70-200 mm). The land 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 abandoned airstrip north of Barrow near the former Naval Arctic Research Lab's aircraft hangar.

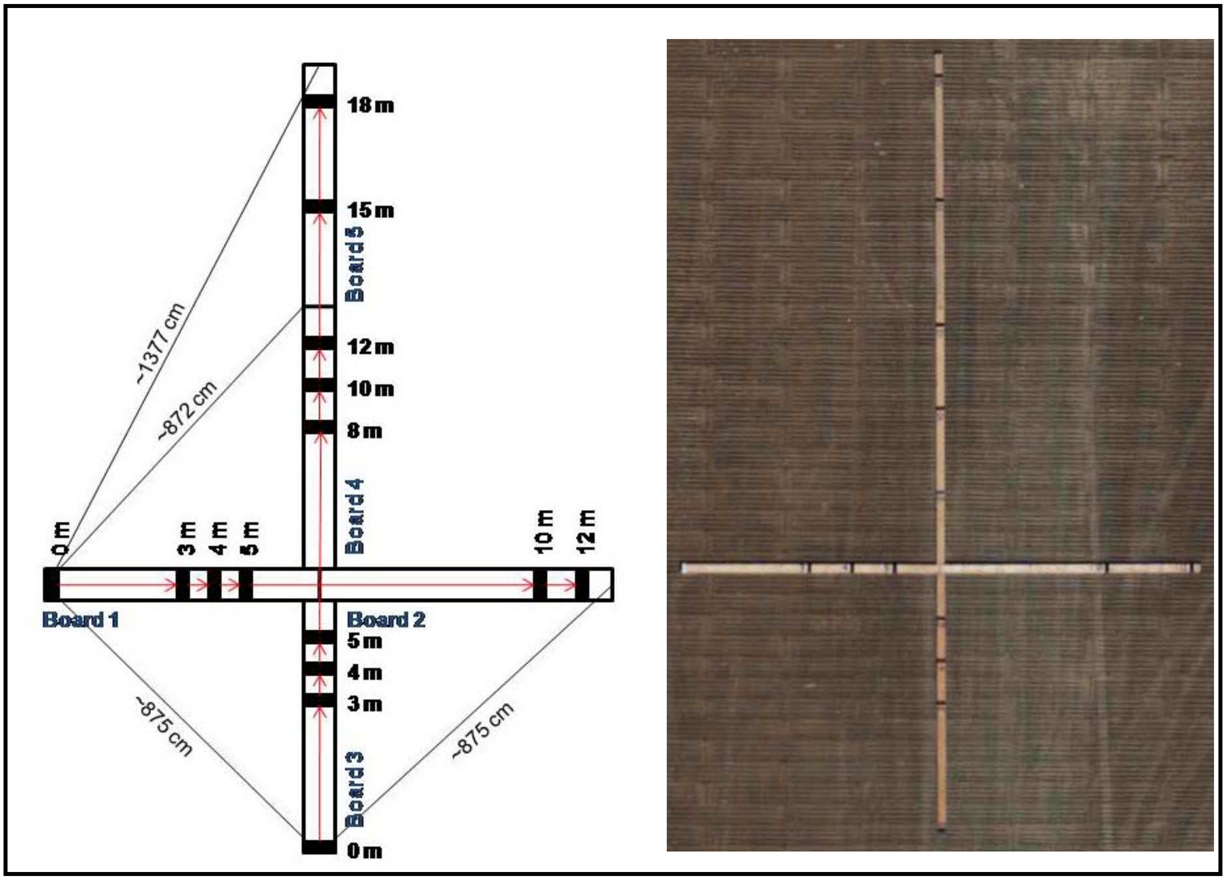

Figure 5. Diagram (left) and aerial image (right) of the land-based calibration target.

A second, floating water target was developed by David Rugh, Julie Mocklin, and Noah Lawrence-Slavas in order to detect possible discrepancies between radar altimeter performance over land and water. The target consisted of 200 ft non-stretch rope attached to an array of floats (4 large and 1 small) followed by a 36 inch drogue needed to keep the line straight and reduce undulations (Figure 6). The drogue was attached to the rope by a 5/16" swivel to allow free rotation. This apparatus was then towed by a 27-foot motor boat in an area where bowheads were often seen, approximately 30 km northeast of Barrow.

Figure 6. Aerial photograph of the 27-foot motor boat towing the water-borne calibration target.

To test the performance of the autonomous radar altimeter, photographs of both calibration targets were taken at 100 ft intervals from 700 to 1300 ft. Since the lengths between marks on the targets are known precisely, altimeter readings can be corrected. This correction factor can then be applied to photographs of bowhead whales to provide more accurate body length estimates. Vertical photography removes angle as a variable when applying aircraft altitude to the calculation of distance between the camera and the target.

After each survey, all photographs were geo-referenced 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 so that the program could interpolate latitude and longitude and embed this position information in the exif data of each photograph. Since RoboGeo uses time to link photographs to the tracklog position, we synched the date and time on both cameras with the date and time on the GPS unit at the beginning of each survey. Once geo-referenced, all images and associated metadata were sent to LGL 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 2008 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

<u>Survey effort</u>

Aerial surveys were conducted in the BOWFEST study area on 8 days between 27 August and 16 September 2008. All flights were based out of Barrow, each ranging from 1.1 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 42.7 hours (8,100.5 km) were flown. Of the 34.3 hours spent on search effort over water, 16.7 hours (3,082.7 km) were flown on systematic transects and 17.6 hours (3,282.3 km) were flown searching off transects such as when transiting between transect lines, circling animals, or photographing whales (Figures 7A & 7B). An additional 0.7 hours were spent flying over and photographing the two calibration targets, and 7.7 hours (1,602.6 km) were flown in suboptimal conditions (when the visibility quality on both sides of the aircraft was poor or useless, the aircraft was over land, or when deadheading to a location without search effort) (Table 1). Due to logistical difficulties (fuel and weather) the boat crews collecting oceanographic samples and tagging whales typically did not travel long distances from Barrow. As a result, the aerial surveys were primarily concentrated in the inner section of the two-part study area with only ~10% of the search effort in the outer section.

Throughout the entire 2008 BOWFEST field season, only 6.0 hours (1,206.4 km) were flown in poor or useless viewing conditions and, thus, were considered unsurveyed (Table 1). The 6.0 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 11 of the possible 20 survey days, poor weather conditions precluded us from flying.

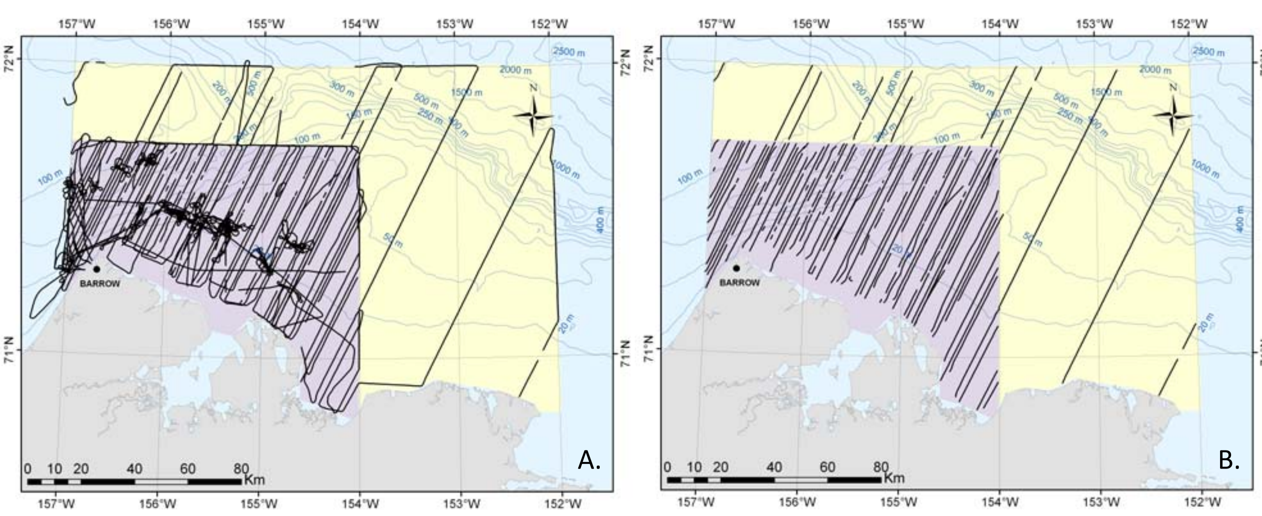

Figure 7. A) All search effort, including transect, circling, and photo effort and B) dedicated transect effort during the 2008 BOWFEST survey.

Table 1: Allocation of survey effort (distance and time) for the 2008 BOWFEST aerial survey

EFFORT SUMMARY	DISTANCE (KM)	TIME (MINS)
On Effort - Trackline	3082.74	1003
On Effort - Deadhead	1867.27	593
On Effort - Photo Mode	1122.50	363
On Effort - Circling	292.60	97
Total On Effort	6365.11	2056
Off Effort - Over Land	202.08	56
Off Effort - Bad Weather	1206.39	360
Off Effort - Deadhead	194.10	47
Total Off Effort	1602.57	463
Calibrating Targets	132.79	42
Totals	**8100.47**	**2561**

Six of the eight devised survey schemes (schemes 1, 2, 3, 5, 6, and 8) were flown during the 2008 BOWFEST survey. Approximately 610.7 km of Scheme 1 (57%) was flown on 5, 15, and 16 September, and an additional 780.2 km was flown on effort while circling, photographing, or transiting between tracklines (Table 2; Figure 8). Schemes 2 (29 August), 3 (30 August), 5 (6 September), and 6 (11 September) were each flown once, covering approximately 29%, 16%, 39%, and 52% of each scheme, respectively. Two separate flights were flown on Scheme 8 on the same day in order to cover the entire scheme. As a result, we completed 90.7% of the transects in Scheme 8. Of the 8,746.1 km of designated trackline, only 35.2% were completed. Schemes 4 and 7 were not flown.

Table 2: Allocation of search effort per survey scheme.

Flight Scheme	Off Transects km	Off Transects mins	On Transects km	On Transects mins	Transects Availible (km)	% Transects flown
1	780.2	254	610.7	200	1077.5	56.7
2	322.4	103	314.0	103	1088.6	28.8
3	434.6	137	178.1	58	1106.9	16.1
4	0.0	0	0.0	0	1103.7	0.0
5	559.9	180	431.1	139	1101.0	39.2
6	532.9	172	567.8	186	1095.8	51.8
7	0.0	0	0.0	0	1091.0	0.0
8	652.5	208	981.1	318	1081.6	90.7
Totals	**3282.3**	**1053.7**	**3082.7**	**1003.4**	**8746.1**	**35.2**

Figure 8. Aircraft tracklines (black lines) per survey scheme (colored lines) flown during the 2008 BOWFEST field season. Each of these 6 schemes was flown once with the exception of Scheme 1 (attempted 3 times due to poor survey conditions).

Photographic effort

Bowhead whales were photographed on six of the eight survey days. In total, we spent 6.1 hours (1122.5 km) photographing bowheads. Within this time, 256 pictures (418 bowhead images) for photogrammetry (PGRAM) and 307 pictures (471 bowhead images) for photo-identification (PID) were taken (Table 3; Figure 9). An additional 75 pictures of the land and water calibration targets were taken (37 using the photo-identification camera and 38 using the photogrammetry camera). Although there were 889 bowhead whales counted on a total of 563 photographs, the number of unique bowhead whales will be less after accounting for duplicate images.

Table 3: Allocation of photographic effort for the 2008 BOWFEST aerial survey.

Date	Method*	Bowhead Pictures	Bowhead Images**	Calibration Pictures
29-Aug	PGRAM	9	12	0
	PID	7	10	0
30-Aug	PGRAM	15	25	0
	PID	7	9	0
5-Sep	PGRAM	12	14	0
	PID	19	22	0
6-Sep	PGRAM	143	230	0
	PID	179	264	0
11-Sep	PGRAM	17	28	0
	PID	33	64	0
13-Sep	PGRAM	60	109	38
	PID	62	102	37
	Total	**563**	**889**	**75**

* PGRAM = Photogrammetry, PID = Photo-identification
** Total number of individual bowheads counted from all pictures (i.e. 1 picture may have 3 or more bowhead images).

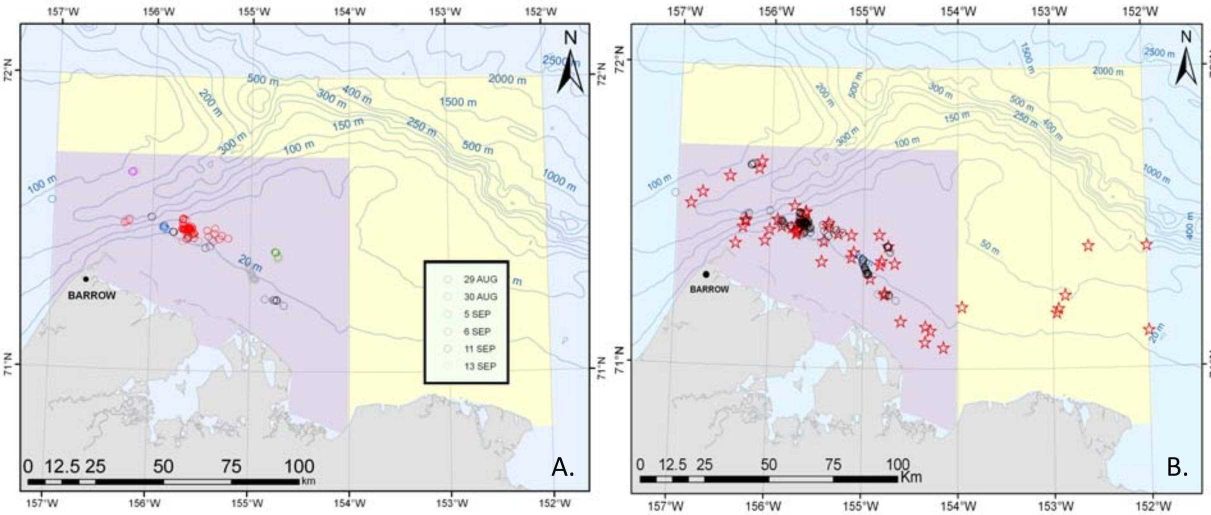

Figure 9. A) Locations where bowhead whales were photographed per survey day, and B) photographic locations (black circles) relative to all bowhead sightings (red stars).

<u>Sighting Summary</u>

There were 56 bowhead sightings of 126 animals seen throughout the duration of the 2008 BOWFEST survey. After breaking trackline to circle/photograph the whales, an additional 37 animals were counted, bringing the total number of bowheads to163 (Tables 4 & 5). Unlike in 2007, when nearly all bowheads appeared to be feeding as indicated by mud plumes and multiple swim directions, only 4 of the 56 bowhead sightings were reported by the observers as feeding. (Examination of the photographs will later document how many bowheads had mud on their bodies, and therefore were probably feeding). “Traveling” was the most commonly recorded behavior, indicating that bowheads were most likely migrating through the study area. The most bowhead whale sightings were made on 6 September (23 sightings of 62 animals) and 13 September (14 sightings of 50 animals) (Table 4, Figure 10). The higher number of bowheads sighted on these two days may be a result of low sea state rather than representing truly higher numbers of whales in the area. Figure 11 shows that the majority of survey effort on 6 and 13 September was completed during relatively calm sea states (Beaufort < 3). By comparison, the sea state on 15 and 16 September was predominantly greater than five, and no bowhead whales were seen.

In addition to bowhead whales, there were 22 sightings of gray whales (39 whales), 2 sightings of belugas (2 whales), 4 sightings of ringed seals (6 seals), 9 sightings of bearded seals (9 seals), 87 sightings of unidentified seals (141 animals), 13 sightings of unidentified large cetaceans (13 animals), and 4 sightings of 5 polar bears seen on land (Table 5, Figure 12). The frequent encounter of high sea states and relatively high survey altitude (1000 ft) made identifying seals to species level difficult, resulting in a large number of unidentified seals.

Table 4: Summary of bowhead sightings and numbers of bowheads counted during the 2008 BOWFEST aerial surveys. Counts may include resightings between days.

Date	# Sightings	# Animals
29-Aug-2008	2	5
30-Aug-2008	3	16
05-Sep-2008	5	12
06-Sep-2008	23	62
11-Sep-2008	9	18
13-Sep-2008	14	50
15-Sep-2008	0	0
16-Sep-2008	0	0

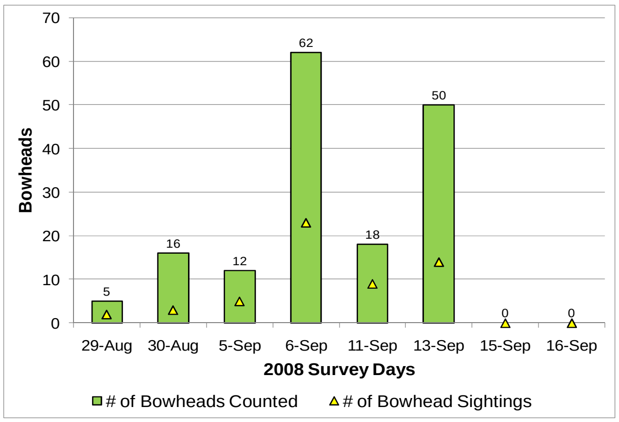

Figure 10. Number of bowhead sightings (yellow triangles) and bowheads counted (green bars) per survey day.

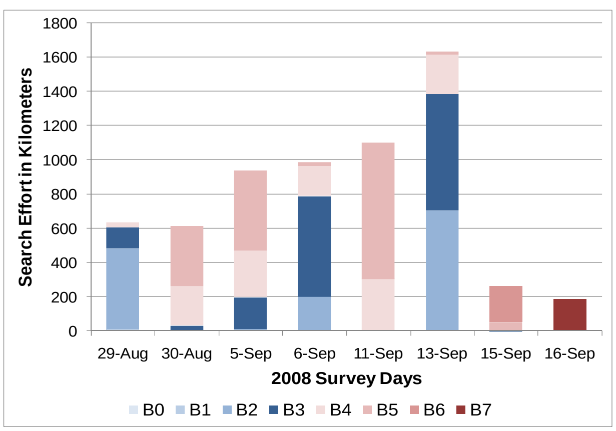

Figure 11. Search effort per survey day categorized by Beaufort Sea State (B).

Table 5: Summary of marine mammal sightings and numbers of marine mammals counted during the 2008 BOWFEST aerial survey. Asterisk indicates increased counts made while circling.

Common Name	Scientific Name	# Sightings	# Animals
Bowhead Whale	*Balaena mysticetus*	56	126 (163*)
Gray Whale	*Eschrichtius robustus*	22	39
Beluga Whale	*Delphinapterus leucas*	2	2
Ringed Seal	*Phoca hispida*	4	6
Bearded Seal	*Erignathus barbatus*	9	9
Unid Seal	---	87	141
Unid Large Cetacean	---	13	13
Polar Bear	*Ursus maritimus*	4	5
Totals		**197**	**341 (378*)**

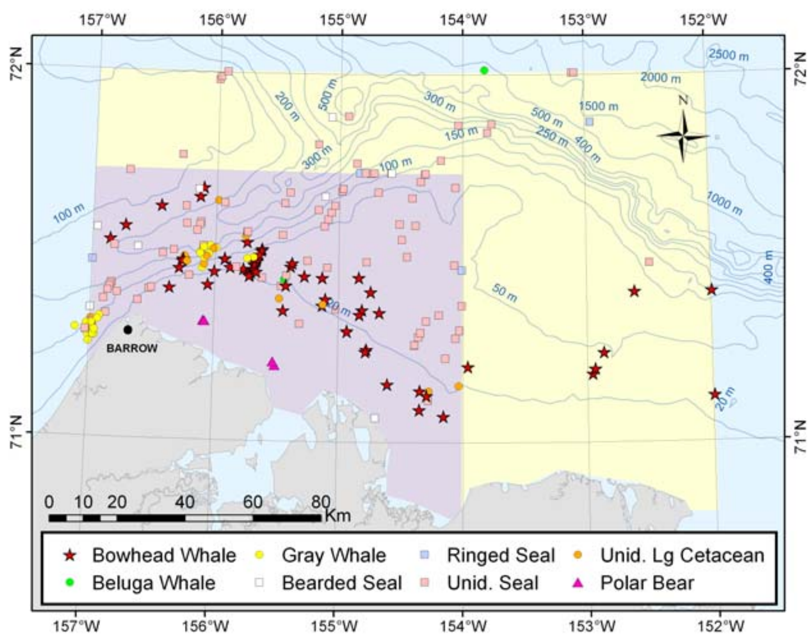

Figure 12. Map showing locations of all marine mammal sightings.

2008 Daily Reports

<u>August 27-28</u>

No flights were flown on these days due to low visibility and low ceilings (overcast 300-600ft) in the study area. The aerial survey team took advantage of the downtime by setting up equipment in the aircraft and making sure all programs were running smoothly.

August 29

The BOWFEST survey began with a 4.9 hour (950.5 km) flight using the tracklines from Scheme 1 (Flight 1). The ceilings near Barrow were predicted at 6,500 feet with greater than 10 miles of visibility. However, we encountered large patches of fog as we flew west from Barrow. As a result, we deadheaded to the eastern portion of the study area to look for holes in the fog. We were able to complete a couple of more tracklines in the eastern section of the small study area before fog rolled in and caused us to head back to Barrow. In total, poor weather interfered with viewing conditions during 1.5 hrs of the 4.9 hours on Flight 1.

Despite the intermittent patches of fog, there were two sightings of 5 bowhead whales north-northeast of Point Barrow. Once the sightings were made (Group 1), we completed the trackline and surveyed up the next trackline before breaking effort to circle and photograph the whales. We spent approximately 28 minutes photographing the group, collecting 16 photographs (7 for photo-identification and 9 for photogrammetry) before resuming trackline effort.

In addition to bowhead whale sightings, there were also 1 beluga whale sightings (1 animal), 1 ringed seal sighting (1 animal), 3 bearded seal sightings (3 animals), 9 unidentified seal sightings (11 seals), and 3 unidentified large cetacean sightings (3 animals).

August 30

Ceilings were approximately 1200 feet over the western portion of the study area. Winds were 15-20 knots over the water, creating high sea states and poor visibility during parts of the survey. Despite conditions, we flew 3.9 hours (746.9 km) on Scheme 3 (Flight 2). During this time, we encountered lower and lower cloud ceilings as we completed tracklines to the east and, with no improvement in sea state, we ended Flight 2 and headed back to Barrow.

Less than 10 minutes from starting Flight 2, the initial bowhead sighting was made (1 animal), and approximately 12 minutes were spent in photo mode before resuming trackline effort. The second bowhead sighting (1 animal) was made on the next trackline to the east, and an additional 14 minutes were spent taking photographs. The final sighting (2 animals) was made about an hour later approximately 30 km northeast of Barrow. After circling and photographing the whales for 30 minutes, we counted an additional 12 whales, bringing the total number of whales to 14 for this sighting. All bowheads seen on this day were traveling. However, later examination of the photographs revealed the presence of a calf hidden in the wash next to one of the travelling bowheads. In total, 22 photographs were taken (15 for photogrammetry and 7 for photo-identification).

In addition to the 3 bowhead sightings, there were 2 gray whale sightings (2 animals), 1 ringed seal sighting (1 animal), and 2 polar bears sighted on land (Tapkaluk Islands).

September 1 - 4

There were no flights these days due to high winds (20-25 knots), scattered showers, low ceilings (400-800 ft), and fog.

September 5

The northwest part of the BOWFEST study area was covered by dense, low clouds. We flew above the clouds until we found an opening well to the north. After flying a couple of tracklines in the northern part of our study area, we were able to work our way south in and out of fog, under a thick ceiling. We flew a total of 6.3 hours (1,171.6 km) using Scheme 1 tracklines. Of the total flight time, 5.1 hours (941.5 km) were spent actively searching for animals.

The first bowhead whale sighting (1 animal) was made approximately 30 km northeast of Barrow, in the same location bowheads were sighted on previous flights. Because of fog, we did not break trackline to circle or photograph the animal. Two tracklines to the east, the second bowhead whale group (2 animals) was sighted. We broke trackline and spent approximately 21 minutes photographing the group. Once completing the photographic passes, the total number of the animals in this group was 3, rather than the 2 animals counted previously. An additional 3 bowhead whales were sighted another two tracklines to the east (approximately 60 km northeast of Barrow). After spending 30 minutes photographing the animals, an additional 5 bowheads were counted, bringing the total number of animals in this group to 8. One of the bowheads seen on this day was playing and rolling with a log. The remaining 11 of the 12 total bowheads sighting on this day were traveling. During this flight, we collected a total of 31 photographs (12 for photogrammetry and 19 for photo-identification).

The only animals sighted other than bowhead whales were 3 unidentified seals (4 animals).

September 6

The majority of the tracklines within the inner section of the study area were completed with fair or good viewing conditions. Ceilings varied from 700-1000 feet with scattered fog over the water. We flew 6.4 hours (1201.9 km) on Scheme 4, 5.3 hours (990.9 km) of which were on dedicated search effort (Flight 4).

The first bowhead whale sighting (3 animals resting at the surface) was made 30 km north of Barrow. After we spent 23 minutes circling whales in an attempt to take photographs, we lost the animals in the fog and decided to resume trackline effort. Two tracklines to the east (about an hour later), a series of 4 bowhead whale sightings (Group 2) were reported (4 animals; 2 traveling and 2 milling at the surface) and a little less than thirty minutes was spent photographing this group. Bowhead whales were sighted (Groups 3-8) on each trackline thereafter, parallel to one another. Group 3 consisted of 5 animals (4 milling and 1 traveling) and was not photographed. Group 4 (approximately 40 animals) was very dynamic and exhibited a number of behaviors including milling, tail slapping, mating, and log-playing. Groups 5, 6, 7, & 8 (10 animals) were sighted on consecutive tracklines thereafter and the whales exhibited no evidence of feeding but were mostly traveling. A mother and calf pair was observed in Group 5. A total of 1.8 hours was dedicated to photographing whales, resulting in 322 photographs (143 photogrammetry and 179 photo-identification pictures) of the estimated 62 bowhead whales (23 sightings) seen throughout the duration of the flight.

Other sightings made during Flight 5 include: 1 gray whale (1 animal), 1 beluga whale (1 animal), 2 bearded seals (2 animals), 13 unidentified seal (13 animals), 1 unidentified large cetacean (1 animal), and 3 polar bears sighted on land.

September 7-10

There were no flights on these days due to low ceilings (200-800 ft), scattered fog, light snow, and freezing drizzle.

September 11

The majority of the tracklines within the inner section of the study area were completed. However, some areas had patchy coverage and compromised visibility due to fog, icy windows, and high sea states (Beaufort 4-5). This flight lasted 6.7 hours (1,249.5 km) of which 1,100.6 km (6.0 hours) was on dedicated search effort (Flight 5). We completed the majority of the tracklines on Scheme 6 within the inner section of the study area.

As was typical on previous survey days, the initial bowhead sighting (2 animals traveling) was made approximately 30 km northeast of Barrow. We completed the next trackline to the east, where the second group of bowheads (9 animals) were sighted, before breaking trackline for photographs. Approximately 49 minutes were spent photographing these two groups. Although “travel” and “unknown feeding activity” were the initial behaviors recorded with the sighting, after circling for photographs, we observed bowheads breaching and covered with mud. Once resuming effort, a third group of 4 bowheads were sighted, 2 of which were touching each other in perpendicular orientation, and we photographed the group for 13 minutes. An additional two groups of bowheads (3 animals) were sighted on tracklines to the east (within 15 km from shore), but no additional photographs were taken. A total of 50 photographs (17 for photogrammetry and 33 for photo-identification) were taken of Groups 1, 2, and 3.

In addition to the 18 bowheads sighted, 2 gray whales sightings (2 animals) and 3 unidentified large cetacean sightings (3 animals) were also made during this flight.

September 12

There was no flight today due to scattered, broken, and overcast cloud layers (200-700 ft), fog, rain, and snow showers.

September 13

Two flights (Flights 6 & 7) were flown, completing all tracklines within Scheme 8. Weather and visibility conditions were optimal with high ceilings (2000-3500 ft) and low sea states (Beaufort 2-3). We began Flight 6 at 9:35 am and completed the tracklines within the inner section of the study area in approximately 6.7 hours. Of the 1,281.3 km flown on this flight, 950.9 km (5.1 hours) were flown while on dedicated search effort. During this flight, multiple passes were flown over each of two calibration targets (a land and a water target) at 100 foot intervals from 700 to 1300 feet. A total of 75 photographs were taken of the calibration targets. After a brief break, we flew a second, 4.2 hour (837.0 km) flight (Flight 7) in order to complete the tracklines in the outer section of the study area. Because much of this flight was spent deadheading to and from the outer section of the study area, only 3.2 hours (599.0 km) were spent searching for animals.

The first group of bowheads (2 animals) was sighted in the location 30 km northeast of Barrow. Only 6 minutes (two photo passes) were spent photographing this group. Two tracklines to the east, another bowhead sighting (1 animal resting) was reported. Although 12 minutes were spent on photo mode, no photographs were taken. Group 3 (2 whales traveling) was sighted on the next trackline to the east but was not photographed in an effort to finish the tracklines. Parallel to this group, on the next trackline, we sighted a large group (30 animals) of bowhead whales. Although the initial behavior recorded with the sighting was “traveling”, we later observed milling activity and mud indicating that the group had most likely been feeding. In addition, we observed log-play behavior. Because of the large number of animals in the area, 39 minutes was spent photographing Group 4. Another group of 6 bowhead whales were sighted near the southeastern corner of the inner part of the study area but no pictures were taken due to time constraints. During the second flight, an additional 5 groups of bowheads (9 whales all of which were resting or traveling) were sighted 30-60 km from shore. In an effort to finish the tracklines in Scheme 8 and to examine the overall distribution of bowhead whales within the BOWFEST study area, no photographs were taken during the second flight. During Flights 6 & 7, 122 photographs (60 for photogrammetry and 62 for photo-identification) were collected.

In addition to the 49 bowheads sighted during the two flights, there were 3 gray whale sightings (11 animals), 4 bearded seals (4 animals), 62 unidentified seals (113) animals, and 6 unidentified large cetaceans (6 animals).

<u>September 14</u>

Although the weather forecast was favorable for flying, there was no flight today due to mechanical problems on the plane.

<u>September 15</u>

Motivated by a need to find whales for the tagging team before the end of the season, we flew 2.4 hours (465.9 km) on Scheme 1 despite sub-optimal weather conditions. Only 1.4 hours (260.0 km) were flown on search effort, of which 26 minutes were on trackline. Flight 7 was shorter than planned due to light fog, glare, and very high sea states (Beaufort 4-6). Two gray whales feeding northeast of Barrow were the only animals sighted during this flight.

<u>September 16</u>

This flight (Flight 9) was shorter than planned (1.1 hours) due to glare and very high sea states (Beaufort 6-7). Due to poor coverage of Scheme 1 tracklines on the previous flight, we attempted the same tracklines again. However, only 27 minutes were spent flying due to poor conditions in the designated study area. We flew west to see if conditions improved in the Chukchi Sea, but with no overall improvement in visibility, we headed back to Barrow. Due to forecasted high wind and low ceilings through Sep 19, this was the last flight of the 2008 BOWFEST aerial field season.

Three gray whales were sighted less than 10 km offshore Barrow in the Chukchi Sea.

Discussion

Bowhead whales are commonly seen migrating past the Barrow area in spring and autumn (Moore and Reeves, 1993). Bowheads are also seen in the Barrow area during the summer; however, sightings here are relatively rare compared to summer sightings in the eastern Beaufort Sea. 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 demarcation line at 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 bowheads taken near Point Barrow indicate that feeding is a major activity: 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 westward out of the Eastern Beaufort Sea in early September, we expected to find more bowheads towards the end of the BOWFEST field season than in the beginning. Indeed, this pattern is roughly indicated in Figure 10. This was in contrast to sightings in 2007 when the only bowheads we encountered were in the first two days of the survey (23 and 24 Aug); none were seen in September (as late as 11 Sept).

Although most bowheads appeared to be feeding in 2007 as evidenced by mud plumes, open mouths, and the presence of feces, the bowheads seen in 2008 were predominantly traveling through the area. Observers reported only a few clear indications of feeding whales; however, photographic examination may show that many of the whales were muddied from feeding. In addition, in 2008 nearly all the bowhead whale sightings were located at or near the 20 m isobath, suggesting that the animals may use bathymetry as a migratory guide through the area, as it seems gray whales do (Rugh et al. 2001).

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 18,000 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 2008 BOWFEST survey will help evaluate the overall health of the BCB population of bowhead whales. 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.

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PHOTOGRAPHIC ANALYSIS OF FEEDING WHALES

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Background

Aerial photographic surveys of the Bering-Chukchi-Beaufort (BCB) population of bowhead whales have been conducted intermittently for over the past 30 years. In that time, scientists have amassed over 18,000 images which are now housed at the National Marine Mammal Laboratory (NMML) in Seattle and LGL, ltd. environmental research associates, in Canada. The utility of photo-identification as a research tool has been well documented, and applications include mark-recapture abundance estimation (Rugh, 1990; da Silva *et al.* 2000; Schweder, 2003), survival analysis (Zeh *et al.* 2002), calving intervals (Miller *et al.* 1992; Rugh *et al.* 1992), and measurement of individual growth rates (Koski *et al.* 1992; 1993). The primary objective of the current study is to conduct photographic analyses of bowhead whales to glean information about the feeding ecology of the BCB population.

Bowhead whales have three documented feeding strategies (surface feeding, water-column feeding, and epibenthic feeding (Würsig *et al.* 1989)), which can occasionally be evidenced in photographs when whales have open mouths or are swimming in echelon formation (surface feeding), feces is seen (any of the strategies), or mud shows on the body (epibenthic feeding). A preliminary review of available photographs of bowheads indicates that open mouths and defecation are not captured photographically very often, and echelon feeding behavior is fairly rare. On the other hand, whales that are covered in mud make up the bulk of our photographic evidence of feeding, which is why this study is focused on this particular feeding strategy. This research builds upon unpublished work by Robyn Angliss (Angliss *et al.* 1993, per. comm.), and though visual assessments of bowhead whale feeding strategies are well documented (Ljungblad *et al.* 1986; Würsig *et al.* 1989), no published research has focused on analyzing photographs for clues to feeding behavior.

Objectives

1) Analyze and compare photographs from May/June off Barrow in 1985, 1986, 2003, 2004 and near Barrow in August/September (2006-2009) for evidence of feeding.
2) Determine the proportion of whales that show evidence of epibenthic feeding relative to whales with no evidence of mud on their dorsal surface.
3) Test these results for temporal and spatial trends in epibenthic feeding.

Methods and Results

An Access scoring database has been created to enter scores for evidence of feeding as visible in aerial photographs taken directly above bowhead whales. The scoring system was tested at length with several different testers from NMML to ensure repeatability of the system. Thereafter, a simplified test was developed and administered during the 2008 field season. A set of 15 images was shown to various bowhead experts including leading experts from NMML, LGL, NSB, and local Barrow whalers to ensure that there is general agreement regarding the designation of feeding whales. The results were promising: there was 74.1% general agreement on whether a whale was muddy, clean, or the photo was indeterminable, and there was 85.9% agreement with Julie when she determined that a whale was muddy. The agreement rates were even higher when the images that Julie scored as indeterminable were not included (these were the most contentious images). By using only images with a clear determination made by Julie, there was 85.6 % general agreement with Julie (including other people's uncertainty), 94.5% agreement with Julie when she determined that a whale was muddy, and 100% when she determined a whale to be clean. Systematic photoanalysis has not yet begun for photographs taken in 2008, but a quick review reveals that quite a few whales during this survey season show evidence of epibenthic feeding (see Fig. 1), despite the fact that active feeding behavior was rarely evident during our aerial surveys.

Figure 1. Examples of bowhead whales with mud on their dorsal surfaces, especially around the head area.

Discussion

One of the primary purposes of BOWFEST is to document bowhead whale distribution relative to ecological features, and in particular to document where bowheads are feeding. The best available evidence of feeding has been through aerial observations of feeding behavior (echelon formation, skim feeding with open mouths, mud plumes, defecation, or mud on the whale), and aerial photography has proven to be an excellent tool for documentation and verification. Although most of these feeding behaviors are not seen often, it is not at all rare to see mud on the dorsal surface of bowheads in aerial photographs. The current study examines aerial photographs among thousands of images collected over the past three decades, many during the spring migration near Barrow or the summer in the eastern Beaufort Sea, and now a growing collection of photographs from the BOWFEST study area in summer.

Mud seen on bowhead whales has been a puzzle for a long time, but through the collective insights from whalers and biologists, it is now resolved that the best explanation for the mud is that the whales get it from the seafloor during bouts of epibenthic or benthic feeding. In multiple images of some reidentifiable whales, the mud is noticeably rinsed off. Experiments are being conducted to test the rate of flushing and the tenacity of the mud, but this, of course, will vary by location and whale speed. However, the evidence so far indicates that muddy whales probably fed fairly close to where they were photographed. Therefore, aerial images of muddy whales can provide a map of feeding activity in the BOWFEST study area.

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PASSIVE ACOUSTIC WHALE MONITORING

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A mix of acoustic recorders and moorings were used this season to passively monitor bowhead whales (summarized in Figure 1 and Table 1): AURAL (Autonomous Underwater Recorder for Acoustic Listening, Multi-Électronique, Rimouski, QC, Canada) recorders on deep moorings along the 100m isobath, EAR (Environmental Acoustic Recorder, Oceanwide Science Institute, Honolulu, HI) recorders on short-term movable moorings, and EAR recorders on UAF (University of Alaska at Fairbanks) mooring frames (Okkonen).

AURAL recorders

All AURAL recorders (Figure 2b) were deployed on deep water moorings (Figures 3a and 4) by Kate Stafford on the *USCGC Healy* 08-04 cruise (8-13 August, 2008). These deployments were piggy-backed with another project, so vessel time on the *Healy* came at no cost to BOWFEST. All four overwintering units (BF07_2-5) were retrieved, and three were redeployed along with a new instrument that was purchased for the 2008 field season. Lack of ship time prevented the fourth overwintering unit to be redeployed, and so it was returned back to Seattle. In addition to these BOWFEST moorings, two identical AURAL moorings were deployed for a NOPP funded project[1]. As shown in Figure 1, the final configuration of these AURAL recorders is a triad array (BF08_1-3, spaced ~ 3-4 km apart) to the west, a single mooring to the north (NOPP_A1) and a triad array (BF08_5-6 and NOPP_A2, spaced ~9-10 km apart) to the east. These recorders were programmed to record at a sample rate of 8192 Hz on a duty cycle of 9 minutes on/ 21 minutes off in order to record for a year's duration. All retrieved recorders contained data, but unfortunately because of an error in the 2007 version of the AURAL programming software the units recorded for 8 months instead of a full year. These recordings are currently being analyzed by Kate Stafford and David Mellinger. Preliminary analysis has found definite recordings of bowheads, belugas, bearded seals, walrus, air guns, ships, and ice noise. Spectrogram examples of these sounds can be found in Figures 5 and 6.

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[1] Ashjian, CJ, Campbell, RG, George, JC, Moore, SE, Okkonen, SR, Sherr, BE, Sherr, EB and Stafford, KM. Episodic upwelling of zooplankton within a bowhead feeding area near Barrow, AK. NOPP (National Ocean Partnership Program), 2008.

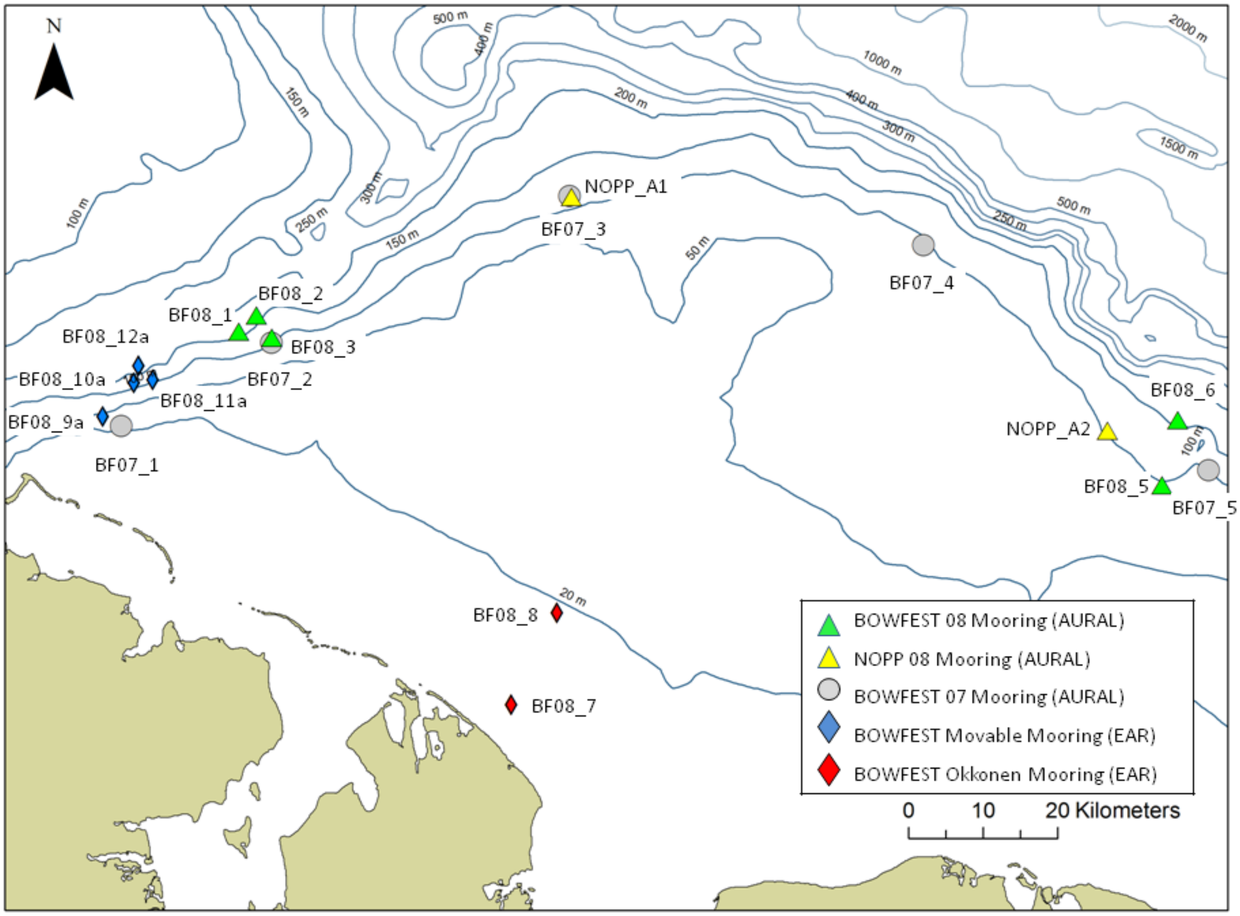

Figure 1. Locations of passive acoustic recorders deployed and retrieved during the 2008 BOWFEST field season.

Table 1. Information on passive acoustic recorder moorings deployed during the 2008 BOWFEST season.

ID	Latitude	Longitude	Water depth (m)	Mooring type	Recorder type	Deployment date	Sampling Rate (Hz)	Duty Cycle (min on/ min off)	Retrieval date	Number hours recorded
BF07_1	70.9800	-152.2500	15.1	Okkonen	AURAL	17-Aug-07	8192	Continuous	MIA	MIA
BF07_2	71.4000	-152.1400	108	Deep	AURAL	16-Aug-07	8192	10/20	8-Aug-08	1824
BF07_3	71.6900	-153.1700	104	Deep	AURAL	16-Aug-07	8192	10/20	8-Aug-08	1824
BF07_4	71.7500	-154.4900	100	Deep	AURAL	16-Aug-07	8192	10/20	12-Aug-08	1824
BF07_5	71.5600	-155.5900	110	Deep	AURAL	16-Aug-07	8192	10/20	9-Aug-08	1824
BF07_6	71.4500	-156.1300	16	Okkonen	AURAL	12-Aug-07	8192	10/20	11-Sep-07	648
BF08_1	71.5749	-155.7104	110	Deep	AURAL	8-Aug-08	8192	9/20	-	-
BF08_2	71.5958	-155.6456	173	Deep	AURAL	8-Aug-08	8192	9/20	-	-
BF08_3	71.5681	-155.5878	118	Deep	AURAL	13-Aug-08	8192	9/20	-	-
BF08_5	71.3825	-152.3098	92	Deep	AURAL	9-Aug-08	8192	9/20	-	-
BF08_6	71.4635	-152.2460	134	Deep	AURAL	9-Aug-08	8192	9/20	-	-
BF08_7	71.1138	-154.6887	9.57	Okkonen	EAR	19-Aug-08	12500	60/4.9	10-Sep-08	0
BF08_8	71.2292	-154.5258	18.75	Okkonen	EAR	19-Aug-08	12500	60/4.9	10-Sep-08	483
BF08_9a	71.4631	-156.2025	17.6	Movable	EAR	28-Aug-08	40000	60/15.6	10-Sep-08	242
BF08_10a	71.5065	-156.0911	100	Movable	EAR	6-Sep-08	40000	60/15.6	13-Sep-08	133
BF08_11a	71.5114	-156.0221	100	Movable	EAR	6-Sep-08	40000	60/15.6	13-Sep-08	133
BF08_12a	71.5282	-156.0768	115	Movable	EAR	6-Sep-08	40000	60/15.6	13-Sep-08	133

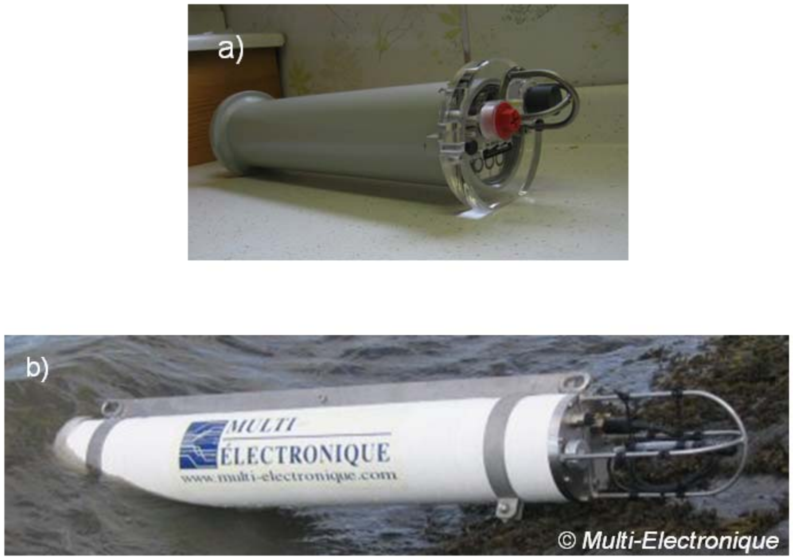

Figure 2. Passive acoustic recorders deployed during the 2008 BOWFEST field season: a) EAR; b) AURAL.

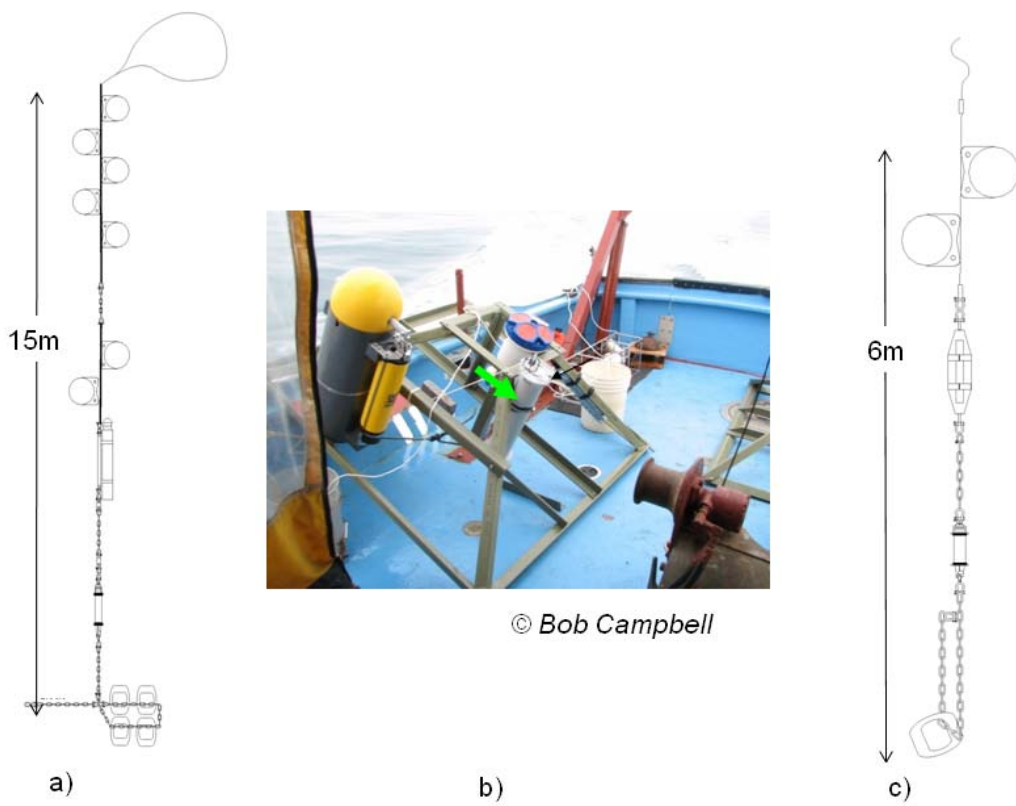

Figure 3. Moorings used during the 2008 BOWFEST field season: a) Deep moorings deployed from the <u>USCGC Healy;</u> b) Mooring frame deployed from the <u>Annika Marie</u> (EAR recorder marked with arrow); and c) movable mooring deployed from the <u>Iipuk</u> and <u>Little Whaler</u> boats.

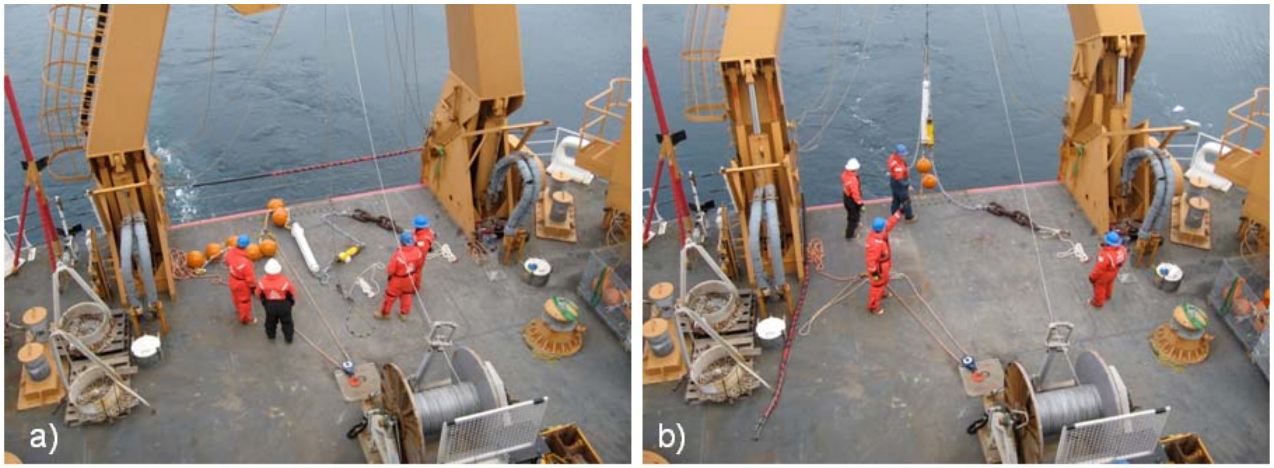

Figure 4. Deployment of deep AURAL mooring from the Healy.

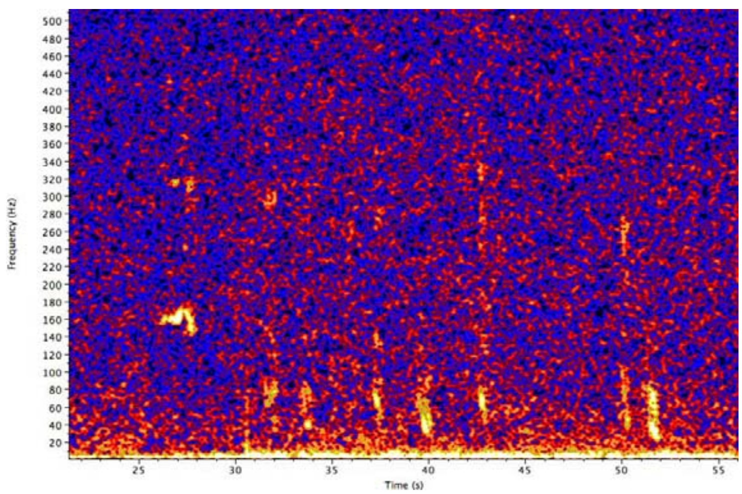

Figure 5. Spectrogram showing an example of the bowhead calls recorded on AURAL recorders during the 2007-2008 deployment.

Because there are over seven-thousand hours of data to be analyzed, our work is currently focused on developing a robust bowhead whale call detector that will be able to distinguish between bowheads and the ubiquitous bearded seal sounds.

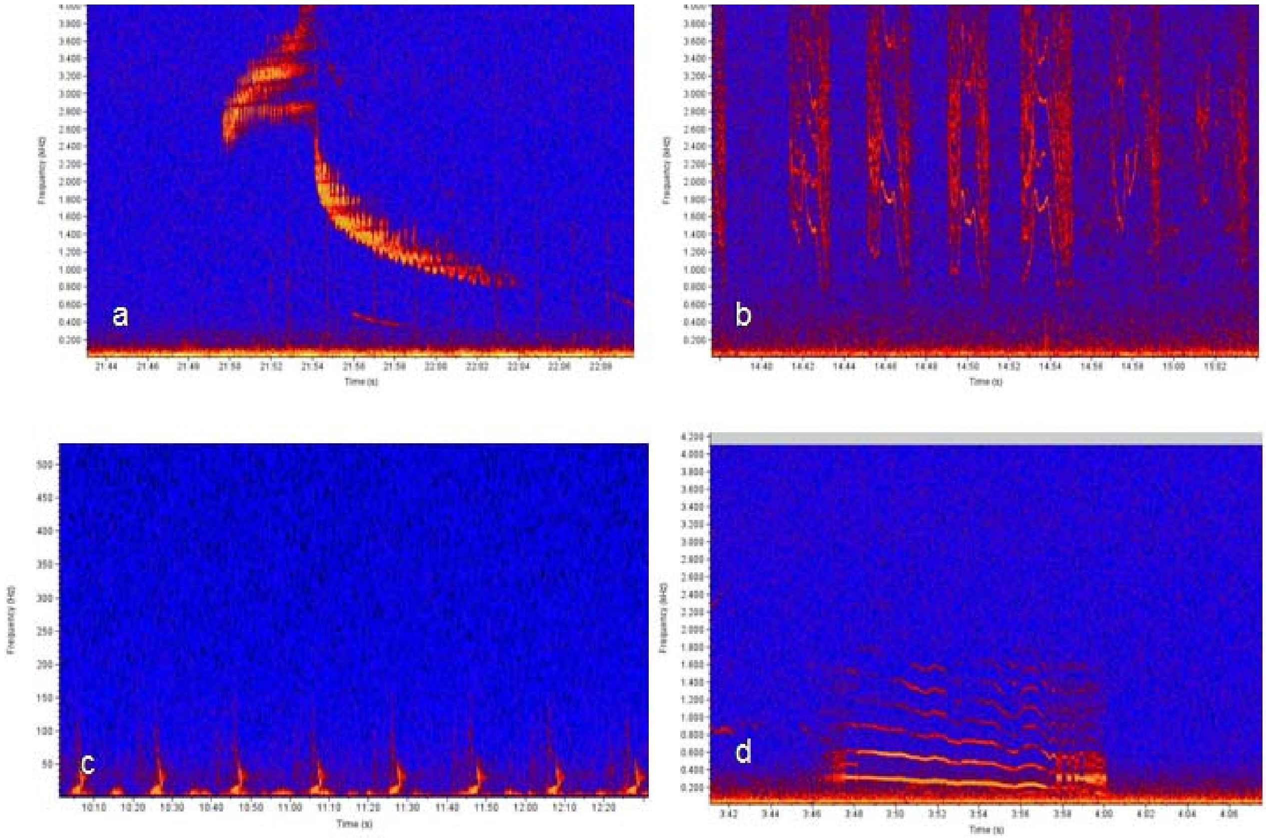

Figure 6. Spectrograms of other types of sounds recorded on AURAL recorders during the 2007-2008 deployment: a) bearded seal; b) beluga whale; c) airgun; and d) ice noise.

The final AURAL from 2007 (BF07_1) was not recovered. This recorder was deployed on a UAF mooring frame (Figure 3b) in August of 2007, and its mid-October 2007 recovery was cancelled because of ice conditions. Attempts by Steve Okkonen to recover this mooring in August 2008 were unsuccessful, and so this recorder is considered to be lost.

EAR recorders

Two EAR recorders (Figure 2a) were sent to Prudhoe Bay to be deployed on the *Annika Marie's* transit from Deadhorse to Barrow. These recorders were deployed in shallow water on UAF mooring frames (Figure 3b) on 19 August 2008 and were retrieved on 10 September 2008. Both recorders were programmed to record at a sampling rate of 12.5 kHz on a duty cycle of 60 minutes on/4.9 minutes off. It was necessary to record on a duty cycle since the EAR units are not capable of continuous recording. After opening the units for downloading the data it was discovered that the computer chip in the inshore unit (BF08_7) had been knocked out of its socket on route to Prudhoe Bay from Seattle. A quick scan of the hard drive revealed that no data were recorded on this unit during its deployment. Fortunately, the offshore unit (BF08_8) was verified to contain recordings.

The remaining four EAR recorders were deployed on movable moorings (Figure 3c) as a single mooring and a triad array. All units were programmed to record at a sample rate of 40 kHz on a duty cycle of 60 minutes on/ 15.6 minutes off (again, the duty cycle was a requirement of the EAR unit). These moorings were designed to bridge the gap between the long-term deep water arrays and the fine scale acoustic sampling of WHOI RATS arrays. They can be deployed by hand from small boats (Figure 7b) so they can be recovered and redeployed in a new area if the whales shift location during the field season. This ease of handling also means that the recorders can be deployed in shallow water because they can be retrieved before the ice comes in. Furthermore, although they cannot capture fine scale whale movements like the RATS array, they can remain deployed for weeks at a time, increasing the chances of making behavioral/acoustic correlations.

There were two main goals for these movable EAR recorders during the 2008 field season. First, we needed to determine if an array of these recorders could be used to effectively track bowhead whales. To this end, calibration signals were made by striking a submerged metal tube with a metal rod. These signals were made in several places within the array and for several days (Table 2) during its deployment. Analysis of the data will show whether or not the estimated source locations are reasonably close to the GPS position of the boat. In addition, field notes were taken on the positions and behavior of gray (mostly) and bowhead whales found in the vicinity of the array, and those data will also be compared to the acoustic recordings (Notes were taken during vessel surveys on the Sauvgak boat (Billy Okpeaha and Henry Elavgak) and the *Little Whaler* boat (Eugene Brower). Second, we wanted to increase local Inupiat involvement in the BOWFEST program, and felt that these recorders could be integrated into the local-run vessel surveys (NSB-DWM). Two locals (Billy Okpeaha and Henry Elavgak) were trained on mooring assembly (Figure 7a) and operation of the acoustic releases (Figure 7c). Craig George and Josh Bacon of NSB-DWM, and Lewis Brower of BASC also received the training. The boats used to deploy the moorings were the NSB-DWM's *Iipuk* (with the assistance of Okpeaha, George, and Bacon) and Eugene Brower's *Little Whaler* (with the assistance of Brower, George, and Zach). The *Little Whaler* was also used to retrieve all the moorings at the end of the season. A combined total of 38 hours was spent at sea on these three boats (Table 2). Note that there were only two dedicated acoustics days, with the rest serving double and triple duty with the vessel survey and satellite tagging efforts. Unfortunately, most good weather days coincided with hunting responsibilities, and so Berchok and George went out with Eugene Brower to deploy and retrieve the moorings. For next season, we hope to identify a local who can be trained on the system, go along with either boat crew during deployments and recoveries, and collect detailed behavioral data during the vessel survey efforts.

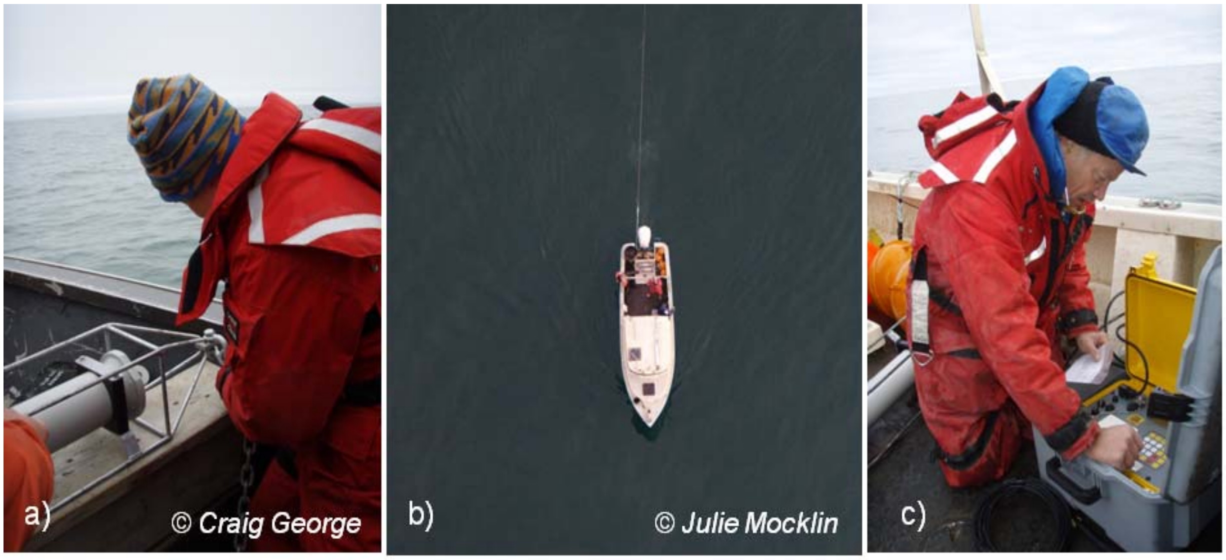

Figure 7. Movable EAR array small boat work: a) Connecting EAR cage to mooring (Iipuk boat) b) Little Whaler boat c) Sending release code to mooring (Little Whaler boat).

Table 2. Small boat time at sea for the passive acoustic component of BOWFEST.

Date	Boat Used	Hours on Water	Survey Cruise?	BOWFEST Acoustic Tasks Completed
28-Aug	*Iipuk*	3.5	N	Single movable mooring deployed
6-Sep	*Little Whaler*	5	N	Movable triad array deployed, array calibration
8-Sep	*Little Whaler*	8.1	Y	Observations made around triad array, array calibration
9-Sep	*Sauvgak*	6.2	Y	Observations made outside array
10-Sep	*Little Whaler*	7.9	Y	Recovered single movable mooring, array calibration.
13-Sep	*Little Whaler*	7.5	Y	Recovered the movable triad array, satellite tagging, aerial altimeter floating target calibration
TOTAL		***38.2***		

Presentations

K.M. Stafford, S.E. Moore, C.L. Berchok, and D.K. Mellinger (2009). "Acoustic sampling for marine mammals in the Beaufort Sea July 2007-March 2008," Acoustical Society of America, 157th Meeting, Portland, Oregon, 18-22 May 2009 (*invited paper*).

Mooring and Broad-scale Oceanography

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Introduction

This was another successful field year for the oceanographic mooring and broad-scale oceanography component. Both programs were greatly enhanced by our companion NOPP program which provided an outstanding ship (*USCGC Healy*) and technical support for the mooring deployments (NOPP moorings) and turnarounds (BOWFEST deep moorings; Stafford/Okkonen) as well as a substantial portion of the operating costs of the *R/V Annika Marie* and the logistic support (shipping, supplies, lodging, meals) for the field team in Barrow. The use of the *USCGC Healy* and the assistance of our colleagues R. Pickart and J. Kemp in the mooring program cannot be overemphasized; the BOWFEST program benefited greatly from this collaboration.

Fieldwork

For both components, preparation for the upcoming field season began during the spring with calibration of sensors and acquisition and organization of gear. There were two main activities in the field this year: 1) Mooring turnaround and deployment from a cruise on the *USCGC Healy*, 7-13August, in conjunction with fieldwork for a companion NOPP project (Ashjian, Okkonen, Campbell, Stafford, Moore); and 2) Oceanography and bowhead whale prey distribution (broad- and fine-scale) and short-term mooring deployments on the Beaufort Shelf during August – September. Equipment for the mooring cruise was shipped to Seattle and loaded onto the *USCGC Healy* on 2-3 June. K. Stafford participated in that cruise. The equipment for the shallow water moorings was shipped to Deadhorse, Alaska, to be loaded onto the *R/V Annika Marie* for deployment during the transit of the boat from Deadhorse to Barrow for fieldwork. The remaining field equipment was shipped, or had been stored, in Barrow. Oceanography field team members included Carin Ashjian, Bob Campbell, Steve Okkonen, and Phil Alatalo. Arrangements for lodging and transportation in Deadhorse were coordinated with the CH2MHill Polar Services (as part of our companion NOPP project). Charter of the *R/V Annika Marie* was set up by CH2MHill for the NOPP project with the BOWFEST project procuring additional weather and working days through a separate charter with Oceanic Research Services, Inc. through WHOI. Laboratory, lodging, and staging facilities in Barrow were procured through a paid-for-service agreement with the Barrow Arctic Science Consortium (BASC).

Short-Term Moorings

Bottom-mounted moorings (Figure 1), each instrumented with an upward-looking RDI ADCP and a SeaBird microcat (Figure 2), were deployed in mid-August on the western Beaufort shelf to investigate the relationship between the overlying wind field, shelf currents, and the presence of zooplankton. Moorings were deployed along transect lines used in the 2005/2006 NSF-funded SNACS study and are identified by Transect # (e.g., Line 3 and Line 8) and water depth. The westernmost mooring, deployed at the edge of Barrow Canyon, was supported by our companion NOPP project and complements the research of BOWFEST. All three moorings were recovered in mid-September. Elevated acoustic backscatter, recorded by the ADCPs and suggesting diel migration, was interpreted as a proxy for the presence of zooplankton.

On 22 August, two UAF divers were unsuccessful in their attempt to locate the Line 3 shelf-break mooring that was not recovered in Sept. 2007. The divers were hampered by the absence of an acoustic homing signal and a very deep (10') benthic boundary layer that obscured visibility almost completely. Also on that date, two local boats led by Lewis Brower (BASC) dragged for a mooring deployed at Sanigaruak Pass in 2007 which overwintered but were unsuccessful in their recovery efforts.

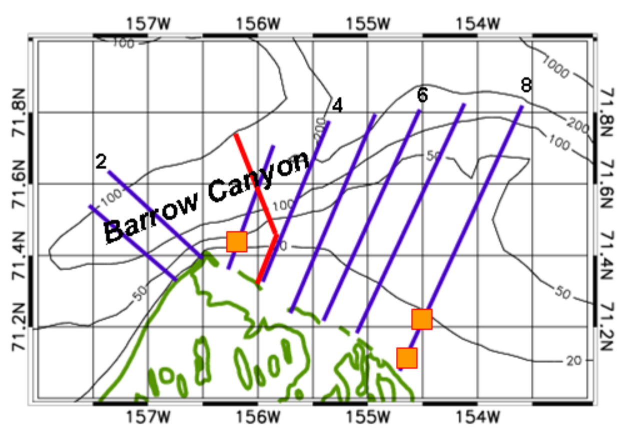

Figure 1. Shelf mooring locations (orange squares). One mooring was deployed along SNACS Line ,3 and two were deployed along SNACS Line 8 with one at 10 m (Line 8-10) and the second at 20 m (Line 8-20). Blue lines indicate transect lines surveyed during the SNACS program.

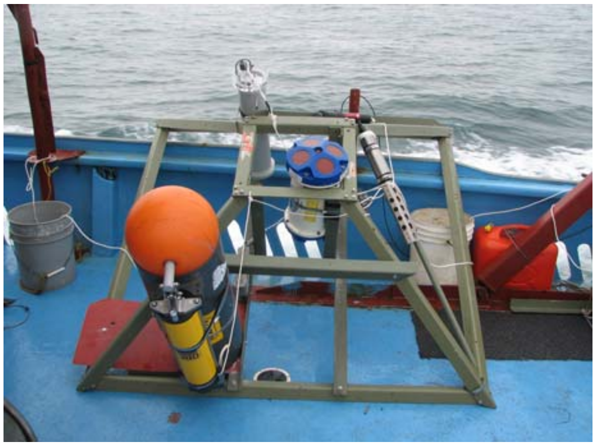

Figure 2. Typical configuration of moorings deployed on the western Beaufort shelf.

Preliminary Results

A close association between wind and current direction and elevated levels of vertically migrating backscatter, presumably from krill, was observed in the records from the short-term mooring deployed at the edge of Barrow Canyon. During the first portion of the record, winds were mostly to the east. Backscatter is usually low with no diel vertical migration signal. Winds began to blow from the east-southeast on about 30 August (Figure 3). A protracted period of winds from the east began on 29 August. Currents started to flow to the west, promoting upwelling along the edge of the canyon, with a delay of 3 days. Acoustic backscatter plots showing elevated backscatter events peaking a couple of hours after midnight suggest that diel migration of zooplankton begins around three days after the onset of E-SE winds on the evening of 1 September. Similar associations between acoustic backscatter and wind/currents also were observed at the shallow-water moorings along SNACS Line 8. Results of the mooring work will be presented in a poster at the 2009 Alaska Marine Science Symposium.

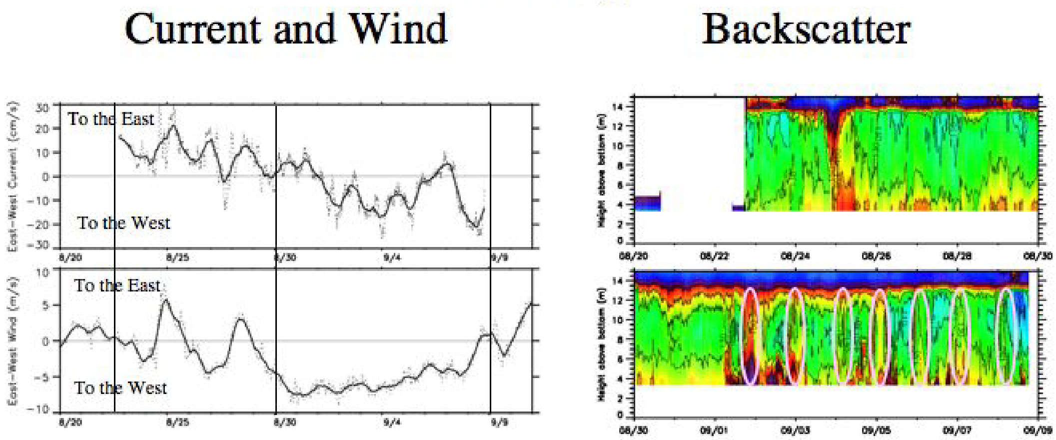

Figure 3. (Upper Left) East-West component of current over the deployment period, smoothed with a 13-hour boxcar filter. (Lower Left) East-west component of the winds, measured at Barrow, also smoothed with a 13-hour boxcar filter. (Right) Vertical sections of relative acoustic backscatter (counts) from the two weeks of the deployment. Upper panel corresponds to a period between first two vertical bars on wind-velocity plots; lower panel corresponds to the period between the second two vertical bars.

Broad-Scale Oceanography Component

The charter for the *R/V Annika Marie* was for 17Aug. – 20 Sept. 2008, with the end date weather dependent (Table 1, Appendix 1). The first 5 working days and 5 weather days, as well as mobilization and demobilization days and expenses and transit days, were supported by our companion NOPP project. The boat transited from Prudhoe Bay on 18-19 Aug. and returned to Prudhoe Bay on 12-13 Sept. Mobilization and demobilization of equipment to/from the boat in Barrow was accomplished on 20 Aug. and 11 Sept, respectively. During the period of 21 Aug. - 10Sept, the *Annika Marie* worked for 11 days and could not work because of bad weather for 10 days. During the transit from Prudhoe Bay to Barrow, two shallow moorings were deployed near Cape Simpson (see above). Surveys concentrated on three sampling lines that had been sampled during 2005-2007, with complete or partial surveys of Line 2 (twice), Line 4 (four times), and Line 3 (once) (Figure 4). Sampling along the 15 m isobath to the east was conducted on two days. Additional sampling at the shelf break near Line 4, where bowhead whales had been observed, was conducted on two days. The mooring at Barrow Canyon was recovered on 8Sept, and the moorings near Cape Simpson were recovered on 10 Sept. Sampling at Barrow was suspended and equipment demobilized from the *Annika Marie* on 11 Sept. because of forecasts of foul weather. (See Appendix I for daily calendar).

Table 1. Number of hours on the water by the R/V Annika Marie, activities, and participants. Kopplin and Pollock are the R/V Annika Marie captain and relief captain, respectively. Science team members are Ashjian, Campbell, Okkonen, and Alatalo. Mob = Mobilization; DeMob = Demobilization.

Date (2008)	Number of Hours	Activity	Personnel
18-Aug	5	Transit	Campbell, Okkonen , Kopplin, Pollock
19-Aug	17	Transit	Campbell, Okkonen , Kopplin, Pollock
20-Aug	0	Mob Barrow	Ashjian, Alatalo, Campbell, Okkonen , Kopplin, Pollock
21-Aug	19.25	Work	Ashjian, Alatalo, Campbell, Okkonen , Kopplin, Pollock
22-Aug	7.75	Work	Okkonen, Kopplin, Pollock, 2 UAF Divers
23-Aug	17.75	Work	Ashjian, Alatalo, Campbell, Okkonen , Kopplin, Pollock
24-Aug	0	Weather	
25-Aug	15.75	Work	Ashjian, Alatalo, Campbell, Okkonen , Kopplin, Pollock
26-Aug	8	Work	
27-Aug	0	Weather	
28-Aug	9.75	Work	Ashjian, Alatalo, Campbell, Okkonen , Kopplin, Pollock
29-Aug	7.25	Work	Ashjian, Alatalo, Campbell, Okkonen , Kopplin, Pollock
30-Aug	0	Weather	
31-Aug	0	Weather	
1-Sep	0	Weather	
2-Sep	0	Weather	
3-Sep	0	Weather	
4-Sep	0	Weather	
5-Sep	4.25	Work	Ashjian, Alatalo, Campbell, Okkonen , Kopplin, Pollock
6-Sep	14.25	Work	Ashjian, Alatalo, Campbell, Okkonen , Kopplin, Pollock
7-Sep	0	Weather	
8-Sep	11.25	Work	Ashjian, Alatalo, Campbell, Okkonen , Kopplin, Pollock
9-Sep	9.5	Work	Ashjian, Alatalo, Campbell, Okkonen , Kopplin, Pollock
10-Sep	13.75	Work	Ashjian, Alatalo, Campbell, Okkonen , Kopplin, Pollock
11-Sep	0	DeMob Barrow	Ashjian, Alatalo, Campbell, Okkonen , Kopplin, Pollock
12-Sep	10	Transit	Campbell, Okkonen , Kopplin, Pollock
13-Sep	6	Transit	Campbell, Okkonen , Kopplin, Pollock

Overall, the oceanographic sampling was highly successful despite the poor weather. Eighty-nine 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. Sampling at discrete stations was conducted using a CTD, plankton nets, Video Plankton Recorder (VPR), and Nisken bottles to collect water samples for determination of chlorophyll *a* and nutrient concentrations and for flow cytometry analyses to enumerate the abundances of phytoplankton and cocooid cyanobactera (an indicator of Pacific Water). 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 four years of our observations (Years 1 and 2 of BOWFEST 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 bowhead whales during their fall migration.

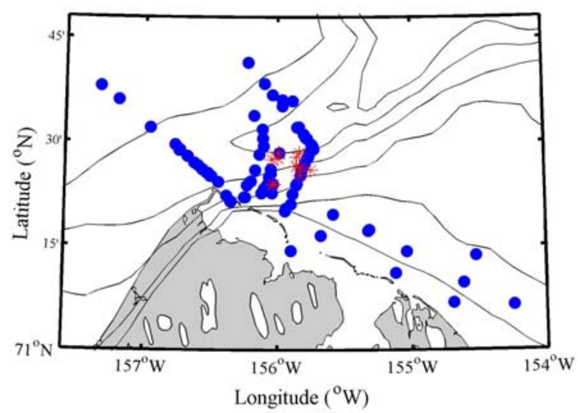

Figure 4. Locations of stations (blue dots) and bowhead whales observed from the R/V Annika Marie (red asterisks). Continuous transects surveyed with the Acrobat vertically profiling vehicle and the acoustic Doppler current profiler not shown.

Preliminary Results

Ocean temperatures were much colder this year, closer to conditions observed in 2006 than in 2005 and 2007 (Figures 5 & 6). Significant year-to-year variability in the temperature-salinity characteristics of the waters sampled within the Barrow Canyon-western Beaufort shelf study area has been observed over the past four years (2005-2008). The 2005 and 2007 surveys encountered very warm Pacific Water, whereas the 2006 and 2008 surveys encountered much cooler Pacific Water. The presence of extensive sea ice cover in 2006 is reflected in the prevalence of sea ice meltwater.

Winds were low and from the W and N during the first portion of our 2008 field season, precluding upwelling of water and krill along the Beaufort Shelf (Figure 3). However, upwelling favorable winds were experienced from 30 Aug. – 8 Sept. (elevated velocity and from the E), during which period we were unable to work because of the adverse weather. Visual examination of the plankton from the net tows revealed krill were observed following the period of east wind; the net samples must be enumerated before abundance estimates can be made.

Bowhead whales were observed from the boat along the 15-20 m isobath to the NE of Barrow, in a location similar to where whales were observed in 2006. These observations coincided with days when krill appeared to be present in elevated abundances. Chlorophyll was fairly low, generally less than 2 µg/l; however, the cells that were present were large and clogged the zooplankton nets. An extremely thick layer of high-fluorescing phytoplankton was observed below the pycnocline in Barrow Canyon, with still elevated abundances of low-fluorescing phytoplankton (*Chaetoceros debilis*) in the upper water column as well (observed with the Video Plankton Recorder (VPR)). This high abundance of phytoplankton clogged the plankton nets (even the coarse 500 µm mesh net), precluding effective sampling in Barrow Canyon with the nets (although copepod and other plankton and particle abundances were obtained with the VPR). One very exciting observation was that no coccoid cyanobacteria were observed in any of the water samples, regardless of the water type in which the sample was collected (Figure 7). This confirmed our observations in 2005 that coccoid cyanobacteria are indicators of the presence of warm Pacific Water, since warm Pacific Water was not present in 2006 and 2008 but was present in 2005 when high abundances of the cyanobacteria were present (Sherr and Sherr, unpublished). Results of the mooring work will be presented in a poster at the 2009 Alaska Marine Science Symposium.

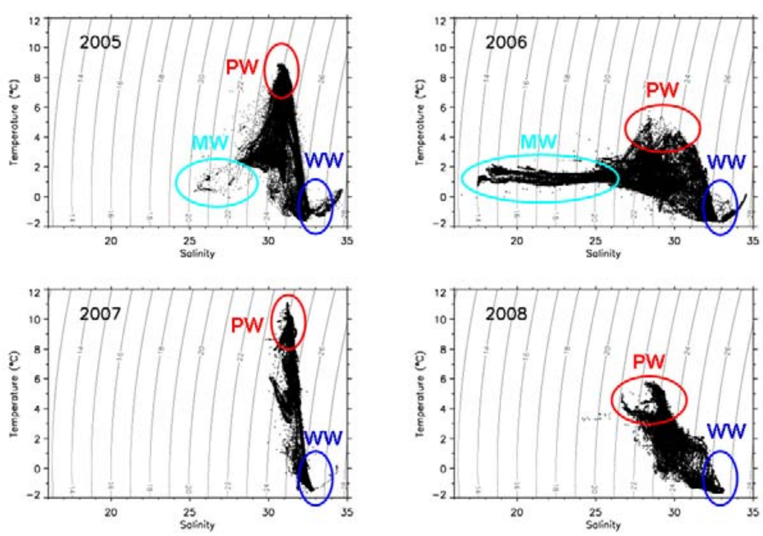

Figure 5. Temperature-salinity plots of each year's Acrobat and individual cast CTD data. Water masses are Pacific Water (PW), Winter Water (WW), and Meltwater (MW). Curved lines are isopycnals (constant sigma-t)

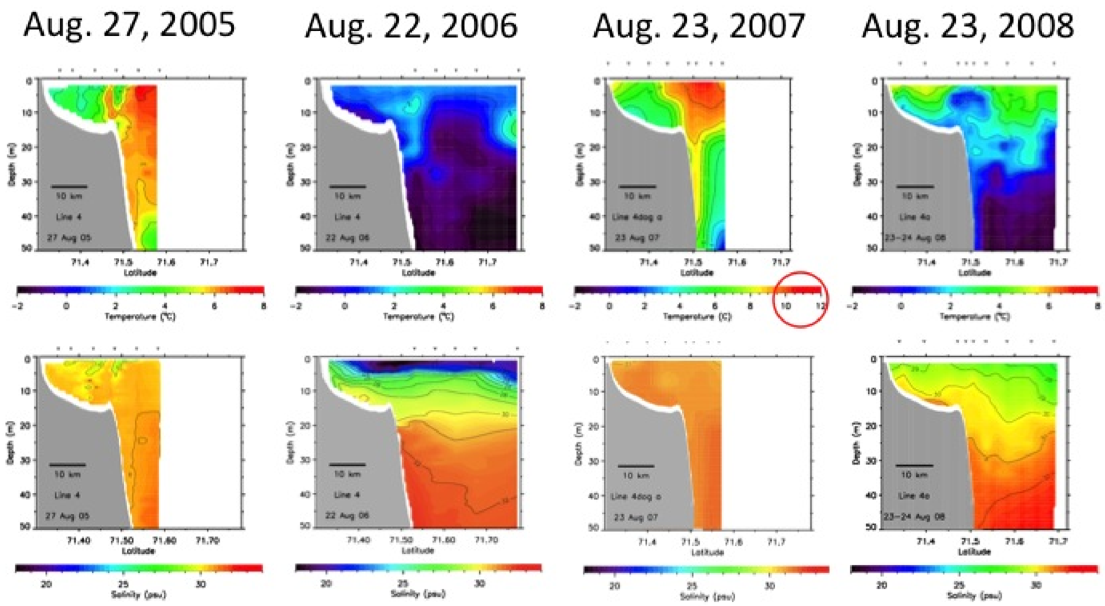

Figure 6. Temperature (upper row) and salinity (lower row) sections across Barrow Canyon for four years.

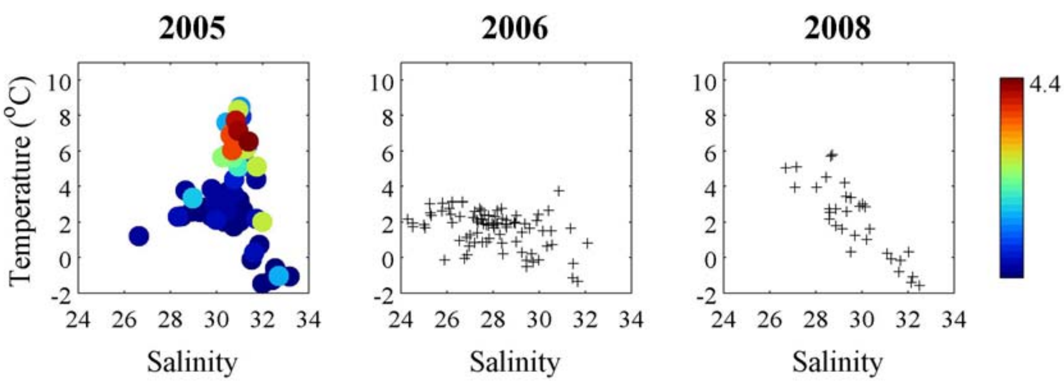

Figure 7. Abundance (1000s/ml) of coccoid cyanobacteria as a function of the temperature and salinity of each water sample. T-S relationships and water masses for each year are as described in Figure 6. "+" indicates that no coccoid cyanobacteria were present. Data from our collaborators B. Sherr and E. Sherr through the NSF SNACS and NOPP programs. Because of a funding gap, no data are available for 2007.

Data Analysis, Synthesis, and Presentations

Analysis of data and samples from 2007 is nearing completion. We made progress on synthesis during weather days while we were in Barrow. Analysis of data and samples from 2008 is ongoing, with 2008 zooplankton samples still to be counted (an excess of work at our counting center has precluded their being counted to date; counting should commence in March).

Based on the four years of accumulated physical and biological data, we have advanced a hypothesis whereby the shelf near Barrow provided a favorable feeding environment for the bowhead whale during its fall migration. The mechanism involves a combination of winds, currents, and krill distribution (Figure 8). During periods of winds from the east, currents move to the west along the Beaufort Shelf, the Alaska Coastal Current (ACC) is pushed to the NW and away from Barrow Canyon, some shelf water escapes the shelf around Pt. Barrow, and upwelling occurs along the Beaufort shelf to the NE of Barrow, bringing krill onto the shelf. The krill are somewhat diffuse when first brought onto the shelf. During a subsequent period of winds from the S or SW or weak winds, currents on the shelf become weaker and less directed, and the ACC moves up tight against the eastern edge of Barrow Canyon, trapping shelf water, and krill, on the shelf and concentrating the krill along the 15-20 m isobath. This is the location where bowhead whales frequently are observed feeding.

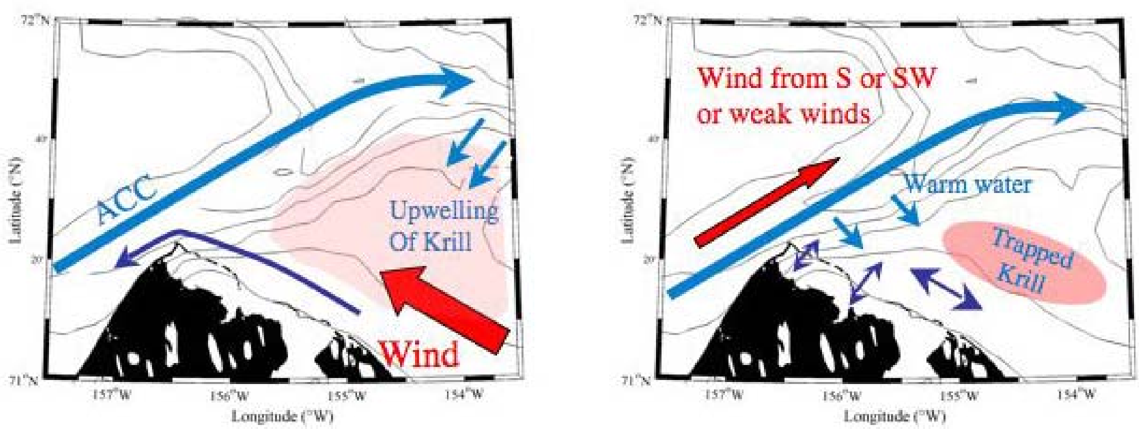

Figure 8. Schematics demonstrating the two-step mechanism whereby krill are concentrated on the Beaufort Shelf near Barrow, providing a favorable feeding environment for the bowhead whale. Blue: Currents; Red: Winds; Pink: Krill; ACC: Alaska Coastal Current.

Results from the 2007 fieldwork, together with results from 2005 and 2006 from the NSF-funded SNACS program, were presented in several posters at the Alaska Marine Science Symposium in January 2008 (see list below) as well as at the 2008 Ocean Sciences Meeting in Orlando FL (>4000 registrants). Results, including 2008 fieldwork, also were presented at the

U.S.-Canada 2008 Oil and Gas Forum in October and the 11th Annual MMS Information Transfer meeting, both in Anchorage at the end of October, as well as at the Symposium on Arctic Sea Ice and Climate, an international symposium held in November at the Woods Hole Oceanographic Institution.

C. Ashjian attended the Barrow Whaling Captains Association meeting in September just after the end of the field season and discussed our findings during 2007 and thanked the captains for their support. The Barrow Whaling Captains continue to be very supportive of our project and interested in our results.

Presentations

Ashjian, C.J, Braund, S.R., Campbell, R.G., George, J.C., Moore, S.E., Okkonen, S.R. Sherr, B.F., Sherr, E.B. 2008. Environmental variability and bowhead whale distribution on the Alaskan Beaufort Shelf near Barrow, AK. Ocean Sciences Meeting, March 6, 2008, Orlando, FL. Oral Presentation.

Ashjian, C.J, Campbell, R.G., George, J.C., Moore, S.E., Okkonen, S.R. Sherr, B.F., Sherr, E.B. 2008. Environmental variability and bowhead whale distribution on the Alaskan Beaufort Shelf near Barrow, AK. Alaska Marine Science Symposium, Jan. 21-23, 2008 Anchorage, AK. Poster.

Moore, S.E., George, J.C., Ashjian, C.J. Cetacean habitats and Behavior Offshore Northwestern Alaska: Comparisons across Two Decades. Alaska Marine Science Symposium, Jan., 21-23, 2008, Anchorage, AK. Poster.

Okkonen, S., Ashjian, C.J., Campbell, R.G. Intrusion of warm Bering/Chukchi Waters onto the Shelf in the Western Beafort Sea. Alaska Marine Science Symposium, Jan. 21-23, 2008, Anchorage, AK. Poster.

Ashjian, C. Bowhead Whale Feeding Variability in the Western Beaufort Sea – Feeding Observations and Oceanographic Measurements and Analyses. U.S. and Canada Northern Oil and Gas Research Forum: Current Status and Future Directions in the Beaufort Sea, North Slope and Mackenzie Delta. Oct. 29, 2008, Anchorage AK. Invited.

Ashjian, C. Episodic Upwelling of Zooplankton within a Bowhead Whale Feeding Area near Barrow, AK. MMS Alaska OCS Region Eleventh Information Transfer Meeting, Oct. 20, 2008, Anchorage, AK. Invited.

Ashjian, C. Climate Variability, Oceanography, Bowhead Whale Distribution, and Iñupiat Subsistence Whaling near Barrow, AK. Symposium on Arctic Sea Ice and Climate, Nov. 5, Woods Hole, MA. Invited.

Okkonen, S. Biophysical Domains on the Western Beaufort Shelf. Minerals Management Service, Anchorage, Alaska. Dec. 3, 2008. Oral presentation.

Publications

A manuscript based on field work conducted in 2005-2007 "Intrusion of warm Bering/Chukchi waters onto the shelf in the western Beaufort Sea," authors Okkonen, Ashjian, Campbell, Maslowski, Clement-Kinney, and Potter, was submitted to *JGR-Oceans* in April. Reviews were received, and the paper was revised and resubmitted.

Two manuscripts based on fieldwork conducted in 2005 and 2006 "Bowhead whale distribution and feeding in the western Alaskan Beaufort Sea during late summer, 2005-06 are nearing completion and will be submitted as companion papers to the journal *Arctic*. Although not focusing on the Bowhead Whale Feeding Study data, this paper is a contribution of the larger effort by our team to understand the importance of this region to the bowhead whale.

Tagging and Fine-scale Oceanography

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Field operations for tagging and fine-scale oceanography took place from 27 August to 20 September 2008. 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) a small ~18 ft boat contracted by BASC (referred to as the Tagging Boat); 2) a larger 22 ft. aluminum boat contracted by BASC (referred to as the Donovan Boat); 3) the MMS *Launch 1273*; and 4) the *R/V Annika Marie*.

The Tagging Boat, *Launch 1273*, and the Donovan Boat spent a combined total of 139 hours on the water over 5 days of acceptable weather (Table 1). Despite our longer field season this year, we spent 25% less time on the water in 2008 than in 2007 (192 total hours in 2007) because of two prolonged periods of high east winds at the beginning and end of our 2008 field season. Unlike 2007, bowhead whales were present in the study area and were encountered on each day we were on the water. The whales were extremely difficult to approach within 10 m to allow deployment of the suction-cup attached archival tags. In general, the whales were surfacing for short intervals, remaining submerged for long periods of time, and moving long distances between surfacings. For the first two days at sea, we used an aluminum-hulled boat equipped with a 2-stroke engine as our tagging boat (Rialy Kalayauk's boat), and were unsuccessful in getting within even 20-30 m of any whale. Fearing that the 2-stroke engine was far too loud for close approaches, we switched to another tagging boat equipped with a much quieter 4-stroke engine (Lewis Brower's boat). We were only successful in approaching 2 whales during our last day on the water, September 13. The first animal we approached within tagging distance on September 13 was a small bowhead that was actively feeding in the area. The whale reversed course immediately in front of us, which allowed us to get close enough to apply the suction-cup attached tag. The tag remained attached for less than 2 minutes. We approached a second animal just 25 minutes later and it surfaced close to our boat, but we were just out of reach of the tagging pole. We attempted to tag this animal, but the tag hit the side of the animal and did not attach.

An analysis of the photos taken during these close approaches revealed that the bowhead whales we attempted to tag had particularly rough skin (Figure 1). There are numerous small divots, bumps, and scrapes on the skin that interrupts water sheeting off of the animals back when it surfaces (Figures 1a and 1b). These irregularities can be clearly seen in close-up shots of the animals' back (Figure 1c). It is likely that this rough skin is responsible for the premature detachment of the suction-cup on the first whale approached on 13 September. In contrast to our experience thus far with bowhead whales, we have achieved long suction-cup attachments on North Atlantic right whales because their skin is comparatively much smoother (Figure 1d). It is very likely that suction-cup attachment is not going to be an effective means to tag bowhead whales in the study area.

Because of our disappointing results approaching and tagging bowhead whales with a suction-cup attached tag, we have been developing an alternative tag attachment since returning from the field that will allow deployment at greater range. The tag will consist of nearly the same instruments and transmitters as used in the suction cup tag (time-depth recorder, acoustic transmitter, radio transmitter), but will not allow for measurement of pitch and roll. These components will be set in cylindrical foam floatation that, in turn, will be housed in a durable plastic housing. The tag will be fired as a projectile from a compressed air gun at ranges of 10-20 m. The tip of the housing will be a 6.4-mm (0.25-inch) diameter stainless steel solid core ringed needle designed to implant into the skin and blubber of a whale. The tag housing will act as a low-drag external float that is anchored by the dermal attachment (needle). A "stop" (e.g., a disk many times the diameter of the needle) will be attached to the needle to control the depth of penetration during deployment and to prevent any further inward migration after deployment. The archival tag will be attached to the needle via a severable tether so that after a specified period of time (several hours), the tag can detach and be recovered. The needle is designed to be easily shed by the skin within a few weeks.

The initial design of the tag and fabrication of prototypes will be completed in January 2009, and testing with sections of North Atlantic right whale skin and blubber will be conducted during February-March. Test deployments on humpback whales during May of 2009 in the Gulf of Maine are planned so that holding power, tagging reaction, and long-term healing can be monitored in this heavily photographed population. We hope to use this new attachment on North Pacific right whales in the Bering Sea during July and August of 2009, so that the method can be perfected prior to use on bowhead whales. Dr. Baumgartner has developed a protocol for this work, and had gained the approval of his Institutional Animal Care and Use Committee (see attached documentation). He has applied for a modification to his own federal permit to allow the use of the dermal attachment on endangered whales, but the permit modification request is unlikely to be approved in time for any fieldwork in 2009. As a contingency, Dr. Baumgartner is seeking permission to work as a co-investigator under the permit of Dr. Bruce Mate, who currently has 25 takes per year to deploy implantable satellite tags on bowhead whales. Dr. Mate is amenable to having Dr. Baumgartner work under his permit and use these takes. Dr. Baumgartner has also requested to use 5 of Dr. Mate's humpback whale takes for the pilot work in May 2009, and Dr. Mate has expressed a willingness to allow these takes to be used provided they do not exceed his annual limit. In discussions with the federal permit office, use of the dermal attachment will be considered equivalent to satellite tagging (albeit less invasive), so that existing satellite tagging takes can be used for this work.

Table 1. Number of hours spent on the water in 2008 by the three vessels participating in the suction-cup tagging and fine-scale oceanography operations.

Date	Launch 1273	Tagging boat	Donovan boat	Comments
27-Aug				Arrival
28-Aug				Setup
29-Aug				Setup
30-Aug				Setup
31-Aug				Poor weather
1-Sep				Poor weather
2-Sep				Poor weather
3-Sep				Poor weather
4-Sep				Poor weather
5-Sep				Poor weather
6-Sep	12.0	9.0	9.0	At sea
7-Sep				Poor weather
8-Sep	10.5	7.5	7.5	At sea
9-Sep	10.0	7.0	7.0	At sea
10-Sep	7.0	8.5	8.5	At sea
11-Sep				Poor weather
12-Sep				Poor weather
13-Sep	14.5	10.5	10.5	At sea
14-Sep				Poor weather
15-Sep				Poor weather
16-Sep				Poor weather
17-Sep				Poor weather
18-Sep				Pack up
19-Sep				Pack up
20-Sep				Depart
Totals (hrs)	54.0	42.5	42.5	

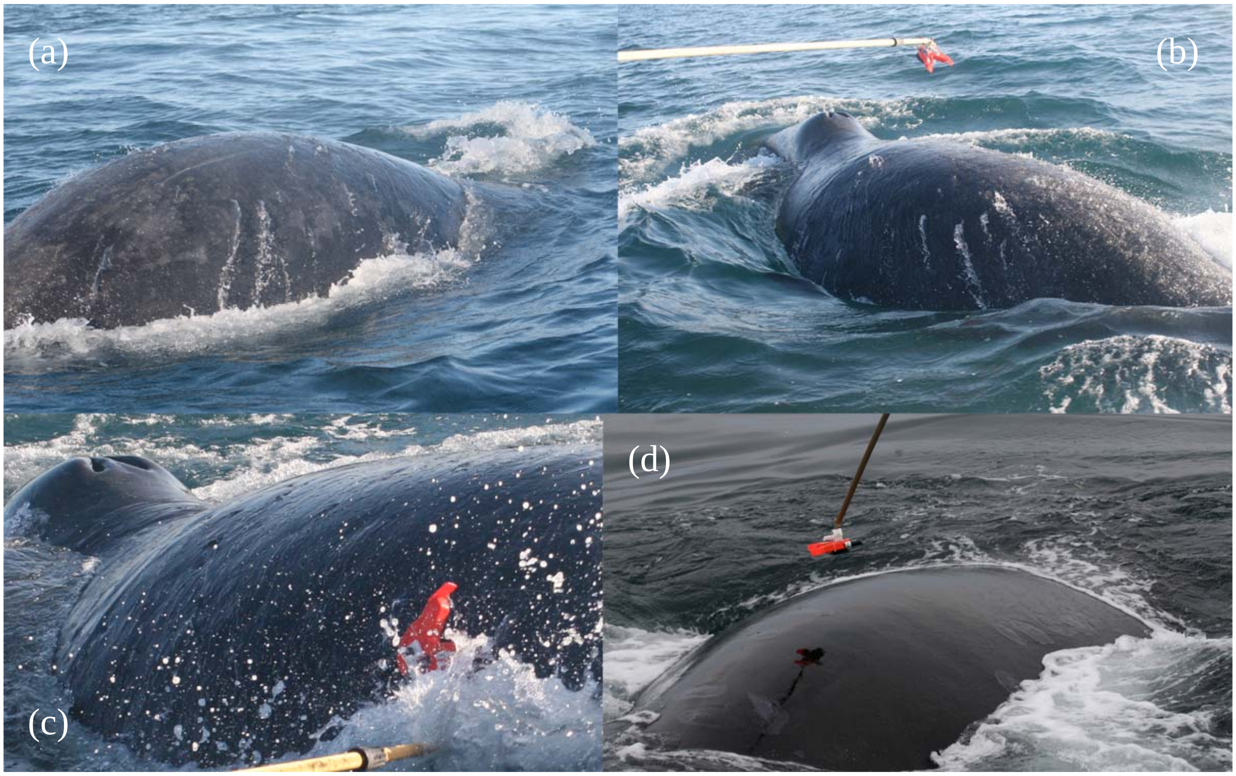

Figure 1. (a) First bowhead whale approached and tagged on 13 September 2008. (b) Second bowhead whale approached on 13 September, but tagging was unsuccessful. (c) Close up of skin of the whale in (b). (d) Tagging of a North Atlantic right whale. Note the irregularities in the bowhead whale skin that cause uneven water sheeting in (a) and (b). In contrast, the North Atlantic right whale skin is much smoother.

NORTH SLOPE BOROUGH RESEARCH:
EXAMINATIONS OF BOWHEAD STOMACH CONTENTS AND LOCAL BOAT SURVEYS

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Background

Studies of the bowhead whale area at Barrow have been ongoing for three years beginning with the National Science Foundation's (NSF) SNACs program. Examinations of bowhead stomach contents have been underway for over 30 years, beginning in the 1970s under NOAA-NMML and since 1981 by the North Slope Borough (NSB). Currently MMS is funding a multi-year bowhead whale feeding study (BOWFEST) via NMML. Its purpose is to expand and continue the feeding ecology research begun under the NSF. Information from this study will be used by the Minerals Management Service (MMS) for pre- and post-lease analysis and documentation under the National Environmental Policy Act (NEPA) for Beaufort Sea and Chukchi Sea Lease Sales.

The following report reports on the North Slope Borough (NSB) Department of Wildlife Management's and Alaska Department of Fish and Game (ADFG) activities with the BOWFEST study during 2007 through spring 2008. The NSB and ADFG work includes sampling stomachs of landed whales, boat based surveys, project coordination, logistical assistance, and boat-based observations of feeding whales.

Objectives

1. Gather distribution data on bowhead whales in the study area (Barrow to Cape Simpson and offshore ~20 km) via local boat-based surveys before the official "field season" starts on 15 August.
2. Document bowhead whale prey amounts and types in the stomachs of whales landed during the subsistence hunt of bowhead whales at Barrow and Kaktovik.
3. Document locations and basic behavior of feeding whales from a boat-based platform.

Results

<u>Local Boat-Based Bowhead Whale Surveys</u>

Local whale hunters (Eugene Brower, Billy Okpeaha, Henry Elavgak, Zachariah Ahmakak, Lewis Brower) were hired to locate bowhead whales, determine their behavior, assist with deploying acoustic oceanographic instruments, and other projects as assigned.

In all, a total of 18 surveys were conducted from 15 August to 13 September. Six of the 18 surveys were hunting forays conducted by hunters associated with project, prior to the official start (15 August) of the study (Figure 1; Table 1 and 2). These surveys were included because reliable GPS tracks existed and the hunters were confident about their recollection of bowhead sightings. With the inclusion of earlier hunting forays, the surveys spanned from 20 July to 13 September 2008. [In the July and early August surveys only sightings of bowhead whales were documented.]

During the period from 20 July to 13 September, a total of 48 bowhead whales were seen plus 6 additional "possible" bowhead sightings which may have been gray whales[i]. Gray whales were the most common whale seen with 54 recorded sightings however this is a minimum as not all gray whales were recorded. Essentially all gray whales were seen west of 156 W longitude. Other sightings include: two possible minke whales, two walrus, and four swimming polar bears (a single animal and a sow with 2 cubs) were seen in the survey area. Seal were generally ubiquitous through the area and not consistently recorded.

Sea ice was mostly absent in the study area after 15 August. The sea ice in the area earlier appeared to consist of entirely first-year ice, no multiyear ice was seen.

Table 1. Preliminary tally of whale, walrus and polar bear sightings during local boat surveys during fall 2008.

Species	**Number seen**
Polar Bear	4
Bowhead	48
Bowhead and or Gray	6
Bearded Seal	3
Gray Whale	54
Minke?	2
Unidentified Whale	2
Walrus	2

Table 2. Table of sighting surveys and effort for 2008.

Survey-ID	Length (km)
20JULY-LB	139.4
23JULY-BO	101.7
3AUG-CG	40.5
5AUG-EB	16.5
8AUG-LB	258
16AUG-BO	133.8
16AUG-CG	33.3
18AUG-BO	100.6
19AUG-BO	162
20AUG-BO	90.2
22AUG-LB	165.3
8SEPT BO	77.3
8SEPT-EB	101
8SEPT-CG	139
9SEPT-BO	136.5
10SEP-EB	113.5
13SEP-EB	126.8
Total	**1936.2**

Prior to the official start of the study, two bowheads were reported [by Billy Okpeaha] north of Point Barrow in late July, but then nearly a month past before bowheads were seen again on 28 August (Figure 1). We are fairly confident based on our surveys and limited aerial surveys, that very few bowheads were present in the western BOWFEST study area between late July and late August. Following that, relatively low numbers of bowheads were seen scattered around the BOWFEST study area. The largest whales were seen north of Point Barrow in deep water. Most bowhead whales appeared to be migrating west through the study area during late August and early September, but a few feeding groups were noted (Figure 2).

By the third week of September, large numbers of bowheads were seen in the vicinity of the Tapkaluk Islands and Cooper Island during tagging operations on 20 and 23 September. During these operations, Harry Brower commented there were "500 whales" in the area on 23 September that appeared to be feeding. Whale tagging was possible at this late date because the start of fall whaling was delayed until 4 October (2008). The longstanding agreement with the Barrow Whaling Captain's Association has been to cease tagging and other research operations one week prior to the fall hunt.

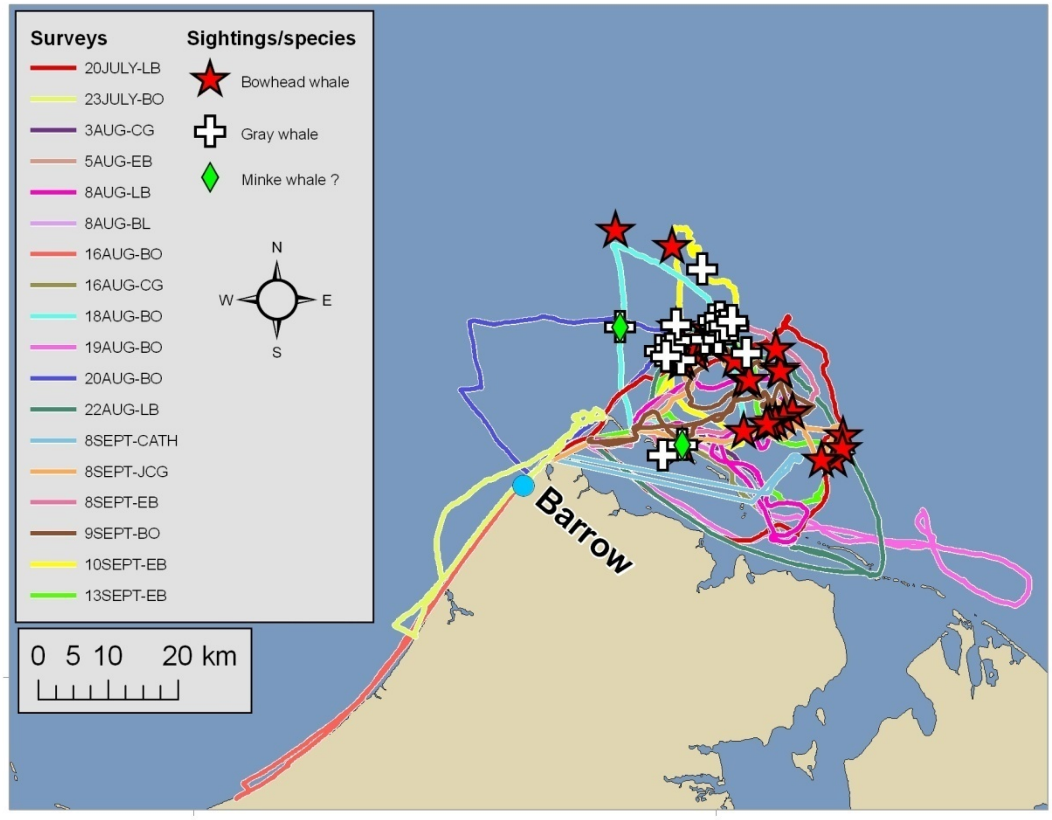

Figure 1. Locations of sightings of cetaceans seen during local boat-based surveys and effort tracks (graphics provided by John Citta).

Figure 2. A small group of bowhead whales feeding north of Cooper Island (photo by Henry Elavgak).

This study has shown the utility of using local boat-based surveys and local knowledge to locate bowheads, determine their behavior, and to deploy small scientific instruments in nearshore Arctic waters. Positive aspects of this approach include: 1) hunters are familiar with the region and distribution of marine mammals, 2) they understand the local waters and safety hazards, 3) they can refer to a large body of traditional knowledge to interpret their observations, and data from earlier hunting forays are available, 4) and the costs are modest compared with aircraft and large vessel charter.

Limitations include: 1) the use of small boats (< 9 m) confines surveys to nearshore areas (< ~25 miles offshore); 2) space for scientific equipment is limited; and 3) personnel space is limited. Improvements and modifications for future surveys might include: 1) structured transects; 2) revised data collection techniques; and 3) enhanced GPS data-capture approaches.

Satellite Tagging

The DWM and BOWFEST team participated along with Lori Quakenbush and local whale hunters in the satellite tagging efforts. Four Barrow residents are currently on the tagging permit: Harry Brower, Craig George, Lewis Brower, and Robert Suydam. The result was a very successful season with 14 tags deployed at Barrow in October 2008.

Stomach Examinations

Bowhead whale stomachs of landed whales were examined during 2008 from the spring and autumn whale hunt at Barrow and the autumn hunt at Kaktovik (see Table 3). Tissues samples were also collected from these animals (Table 4). Preliminary analysis of autumn suggests that bowhead stomachs contained mainly copepods at Kaktovik and euphausiid-like prey at Barrow. Whale 08B11 was unusual in that the stomach was full of almost fresh euphausiid-like prey with very little associated fluid (Figure 3).

Based on NSB-DWM field notes, two (12%) of nine whales harvested near Barrow during April-May were feeding (Table 5). However, at least 75% of the eleven bowhead whales examined during October were feeding (one fall whale stomach was not examined) (Table 3). At Kaktovik, one whale harvested and examined during September was feeding, one whale was not feeding, and one whale was nursing.

Figure 3. Photo of the stomach from whale 08B11, this stomach was unusual in that the stomach contained fresh undigested euphausiid-like prey with very little fluid.

<u>Submitted Papers</u>

A manuscript has been prepared and submitted to Journal *Arctic* describing the initial results from the original NSF funded bowhead whale feeding research at Barrow Alaska in 2005 and 2006. It has been tentatively accepted pending revision. Sue Moore is taking the lead. This paper will provide excellent background information for the current BOWFEST project. The paper reference:

Moore, S.E., George, J.C., Sheffield, G., Bacon, J., and Ashjian, C.J. and the SNACS Team. *In Prep*. Bowhead whale distribution and feeding near Barrow, Alaska during late summer, 2005-06. Submitted to *Arctic*.

In Kaktovik, field notes of the condition of each stomach examined revealed:

- 08KK1: Stomach contained approximately 12 liters of milk. Sample collected.
- 08KK2: Stomach cut open accidentally during butchering. Approximately 48 liters of a watery red liquid containing undigested copepods and several amphipods were spilled. Sample collected.
- 08KK3: Stomach contained several liters of frothy clotted material, no prey items were present. Sample collected.

Currently, frozen stomach samples from 21 whales harvested during 2008 near Barrow and Nuiqsut were received, and are currently archived at the ADF&G Nome office. Further work in the laboratory will provide details on the types of invertebrate prey consumed.

An analysis of stomach contents from all whales landed since 2001 is underway by Sheffield and colleagues. The last comprehensive summary of the feeding habits of bowhead whales was published in Lowry et al. (2004) for whales landed between 1978 and 2001.

Table 3. Bowhead whales harvested near Barrow, Kaktovik, and Nuiqsut during 2008.

ID Number	Village	Date	Sex	Total Length (m)	Stomach
08B1	Barrow	Apr. 27	F	8.7	Examined
08B2	Barrow	Apr. 28	M	8.8	Examined
08B3	Barrow	May 7	M	9.2	Examined
08B4	Barrow	May 7	F	8.7	Examined
08B5	Barrow	May 8	F	9.2	Examined
08B6	Barrow	May 8	M	8.6	Examined
08B7	Barrow	May 8	M	9.2	Examined
08B8	Barrow	May 10	F	8.4	Examined
08B9	Barrow	May 11	M	8.4	Examined
08B10	Barrow	Oct 5	M	12.4	Examined
08B11	Barrow	Oct 6	F	8.9	Examined
08B12	Barrow	Oct 6	M	9.3	Examined

08B13	Barrow	Oct 9	M	10.6	Examined
08B14	Barrow	Oct 9	F	13.6	Examined
08B15	Barrow	Oct 9	M	12.7	Examined
08B16	Barrow	Oct 14	F	8.1	Examined
08B17	Barrow	Oct 14	M	9.0	Not examined
08B18	Barrow	Oct 14	F	8.3	Examined
08B19	Barrow	Oct 19	F	8.2	Examined
08B20	Barrow	Oct 22	F	8.7	Examined
08B21	Barrow	Oct 23	M	8.3	Examined
08KK1	Kaktovik	Sep. 6	M	7.2	Examined
08KK2	Kaktovik	Sep. 7	M	12.8	Examined
08KK3	Kaktovik	Sep. 13	M	9.8	Examined
08N1	Nuiqsut	Sep. 5	F	9.9	Examined
08N2	Nuiqsut	Sep. 6	F	9.0	Examined
08N3	Nuiqsut	Sep. 8	F	8.8	Examined
08N4	Nuiqsut	Sep. 9	F	10.7	Examined

Table 4. Tissues collected from bowhead whales harvested near Kaktovik during September 2008 and the recipient of those tissues.

	08KK1	08KK2	08KK3
Stomach contents	ADF&G; NSB-DWM	ADF&G; NSB-DWM	ADF&G; NSB-DWM
Blood	NSB-DWM	NSB-DWM	NSB-DWM
Blubber	NSB-DWM	NSB-DWM	NSB-DWM
Tongue	NSB-DWM	-	NSB-DWM
Kidney	NSB-DWM	NSB-DWM	NSB-DWM
Liver	NSB-DWM	NSB-DWM	NSB-DWM
Spleen	NSB-DWM	NSB-DWM	NSB-DWM
Muscle	NSB-DWM	NSB-DWM	NSB-DWM
Lung	NSB-DWM	NSB-DWM	NSB-DWM
Eyeball(s)	NSB-DWM	NSB-DWM	NSB-DWM
Testis	-	NSB-DWM	NSB-DWM
Heart	NSB-DWM	NSB-DWM	NSB-DWM
Bladder	-	NSB-DWM	-
Skin	NSB-DWM	NSB-DWM	NSB-DWM
Body fat	NSB-DWM	NSB-DWM	-
Intestine	NSB-DWM	NSB-DWM	NSB-DWM
Baleen	NSB-DWM	NSB-DWM	NSB-DWM

NSB-DWM = North Slope Borough, Department of Wildlife Management (Barrow)
UAM = University of Alaska Museum (Fairbanks)

*Table 5. Status of bowheads harvested near Barrow (spring) and Kaktovik (fall) during 2008 and examined for evidence of feeding. Feeding status based on field notes pending laboratory analysis is indicated by *. Sample sizes are indicated in parentheses.*

	Barrow – spring	Barrow – fall	Kaktovik – fall
	n=9	n=11	n=3
Feeding	11% (1)	75% (9)	33% (1)
Not feeding	78% (7)	-	33% (1)
Uncertain	11% (1)	25% (3)	-
Nursing	-	-	33% (1)
Unexamined		(1)	

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PRELIMINARY LIST OF SYSTEMATIC SURVEYS INVOLVING BOWHEAD WHALES IN THE U.S. BEAUFORT AND CHUKCHI SEAS 1975 – 2008

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As a part of BOWFEST, a review and summary table were compiled of all prominent scientific surveys involved in systematically recording bowhead whale occurrence in the waters north of Alaska in the U.S. Beaufort and Chukchi seas. In its current form, this list is meant to be a preliminary working document and as such is not all-encompassing. Rather, it is meant to provide a framework from which to solicit feedback that can be used to refine, improve and build upon this information and its utility to interested parties. Studies involving bowheads in the U.S. Beaufort and Chukchi seas are numerous and are difficult to identify, locate, obtain and compile as they include many obscure and/or unpublished reports, datasets, etc. However, such information represents the "best available information" needed to address NEPA, ESA, MMPA, etc. requirements with respect to bowhead whales. Given the current and growing numbers of studies involving bowheads and industrial activities in this region, there is a need to integrate and track the studies, particularly with respect to potential cumulative effects of anthropogenic impacts.

The long-term goal of this review is to provide a comprehensive list of studies that both systematically and opportunistically searched for and/or detected bowhead whales in the BCSPA and to update this list over time. The intent is to provide one comprehensive source that provides a foundation for the integration of past and ongoing bowhead studies relative to industrial activities, mitigation, and management. It is also meant to assist and improve the flow of scientific information between interested entities and the public. For example, during 2008, over 30 studies involving bowhead whales were conducted in the U.S. Beaufort and Chukchi seas, and there is a need to integrate and track this information. Another goal of the review is to identify existing databases as well as data needs and gaps in research on bowheads relative to offshore industrial operations. These include past, ongoing, proposed, and cumulative activities.

A number of comprehensive reviews have been conducted on various aspects regarding bowhead studies occurring in the U.S. Beaufort and Chukchi seas (e.g., Burns et al. 1983; Oliver 1987; Richardson et al. 1989, 1995; Marquette 2002). However, an up-to-date list synthesizing past and ongoing systematic and non-systematic survey and sighting/detection studies on bowhead whales is currently not available. This information is directly relevant to fulfilling the goals of current inter-disciplinary efforts to study bowhead ecology (e.g., BOWFEST, BWASP, COMIDA) vis-à-vis ongoing, proposed and anticipated offshore oil and gas activities in the BCSPA.

Information was compiled into an Excel spreadsheet that can be used to readily identify and search basic survey components to assess the relevance of data to the task at hand and to follow-up on further study details. This compilation includes data derived from aerial surveys for whale distribution, aerial photography, ice- and shore-based census efforts, and vessel-based studies that systematically recorded whale sightings or acoustic detections. Studies include monitoring efforts conducted in association with offshore oil and gas exploration, development, and operations.

The summary table contains columns with the following information: first year of study, all study years, method (e.g., aerial survey), funding source (e.g., Minerals Management Service), principal investigator(s)/point of contact(e.g., Charles Monnett, MMS), research team (e.g., MMS), project name (e.g., Bowhead Whale Aerial Survey Project), short description (e.g., transect surveys), general location (e.g., western Beaufort Sea), timeframe (e.g., August to mid-October), and where the data were reported (list of annual reports and publications). Input is solicited for information that may improve, correct, clarify, etc., preliminary information presented in this working draft table. The table is intended to be finalized as a first-stage review in early 2009.

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[i] Note, literally hundreds of bowhead were seen in late September during satellite tagging exercises.