
**BOWHEAD WHALE FEEDING ECOLOGY STUDY
(BOWFEST)
IN THE WESTERN BEAUFORT SEA**

2010 Annual Report

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94 East 36th Avenue, 3rd Floor
Anchorage, Alaska 99508-4363



Submitted through: National Marine Mammal Laboratory
Alaska Fisheries Science Center, F/AKC4
7600 Sand Point Way, NE, Seattle WA 98115-0070
Phone: 206-526-4037; FAX 206-526-6615



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BOWHEAD WHALE FEEDING ECOLOGY STUDY (BOWFEST) Annual Report for 2010

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 BOEMRE. 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 152° -157° 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 2010. This is the fourth of five proposed years of field work for this program.

SECTION I - AERIAL SURVEYS OF BOWHEAD WHALES NEAR BARROW IN LATE SUMMER 2010

Kimberly T. Goetz, David J. Rugh, Linda Vate Brattström, and Julie A. Mocklin

National Marine Mammal Laboratory
Alaska Fisheries Science Center
National Marine Fisheries Service, NOAA
7600 Sand Point Way NE
Seattle, Washington 98115

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). Using a NOAA Twin Otter, scientists from the National Marine Mammal Laboratory (NMML) conducted aerial surveys from 31 August-18 September 2010 in the BOWFEST study area (continental shelf waters between 157° W and 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 102 sightings of bowheads (an estimated 383 whales) during 32.8 flight hours (47% of the 70 available flight hours; the survey was limited due to fog and high winds). Three Canon EOS-1DS Mark III cameras with Zeiss 85mm f 1/4 lenses were used for photography; all three cameras were in a forward motion compensating mount. Both a radar and laser altimeter provided altitudes. A total of 352 pictures were taken when over bowhead whales, counting fires from all three cameras. Several (18%) of the bowhead sightings were described as feeding, based on quick assessments by aerial observers, but photo examination in the lab 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.

Introduction

Most bowhead whales of the Bering-Chukchi-Beaufort (BCB) stock migrate through the Barrow area in the spring (generally April to June) and fall (September and October) (Moore & Reeves 1993). However, there have also been reports of whales feeding near Barrow in summer (July to September). BOWFEST was established to determine the 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 how oceanographic features might affect bowhead feeding aggregations by influencing prey distribution. Accordingly, the aerial survey component of BOWFEST was 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).

Methods

Study Area and Trackline Design

A trackline scheme was designed to provide different intensities in search effort across a two-part study area. The study area covers continental shelf waters from 157° W to 152° W and from the Alaska coastline to 72° N (Fig. I-1). The inner section of the study area (yellow) is 7,276 km², and the larger, outer section (green) is 12,152 km² (total = 19,428 km²). In order to determine how to relegate survey effort within these two areas, five years of data (2000-2005) from the MMS-funded Bowhead Whale Aerial Survey Project (BWASP) were used to calculate bowhead whale density (whales per unit effort) within the BOWFEST study area. According to the BWASP data, the density of bowhead whales in the inner section was approximately six times greater than in 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 study area to obtain a detection probability sufficient for determining relative densities of whales. Since oceanographic data become more difficult to collect with increased distance away from Barrow and much of the intent of BOWFEST is to compare ecological parameters relative to whale distribution, we decreased the effort for the larger section to focus on the inner area with more overlap of the whales and other BOWFEST researchers. Trackline orientation was based on the pre-determined oceanographic tracklines which ran in a northeasterly direction (66° True), approximately perpendicular to the coast. Line-transect methodology described in Buckland et al. (1993) helped 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 within a season. The entire study area contained approximately 5,011 km of trackline: 3,554 km in the inner section and 1,457 km in the outer section (Fig. I-2). Tracklines in the inner section were spaced 2 km apart while lines in the outer section were spaced 8 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 2010, the first transect line was placed 1.5 km from the northwest corner of the inner and outer portions of the study area. We purposely used the same random value (1.5 km) to calculate placement of the first line in both sections of the study area in order to align the tracklines in the outer study area with the tracklines in the inner study area. This method, simplified flight logistics and minimized transit time between tracklines. Subsequent tracklines were parallel to the first trackline and spaced 2 km apart for the inner area and 8 km apart for the outer area.

In order to prevent overlap in survey effort due to tightly spaced tracklines, four sampling schemes were devised (Fig. I-3). The first scheme (Scheme 1) was created by selecting the first line from the west side of the study area and every fourth line thereafter. Using the same method, beginning with the second through fourth lines from the west side of the study area, the three remaining schemes were created. As a result, tracklines were spaced approximately 8 km and 32 km apart in the inner and outer sections of the study area, respectively (Fig. I-3).

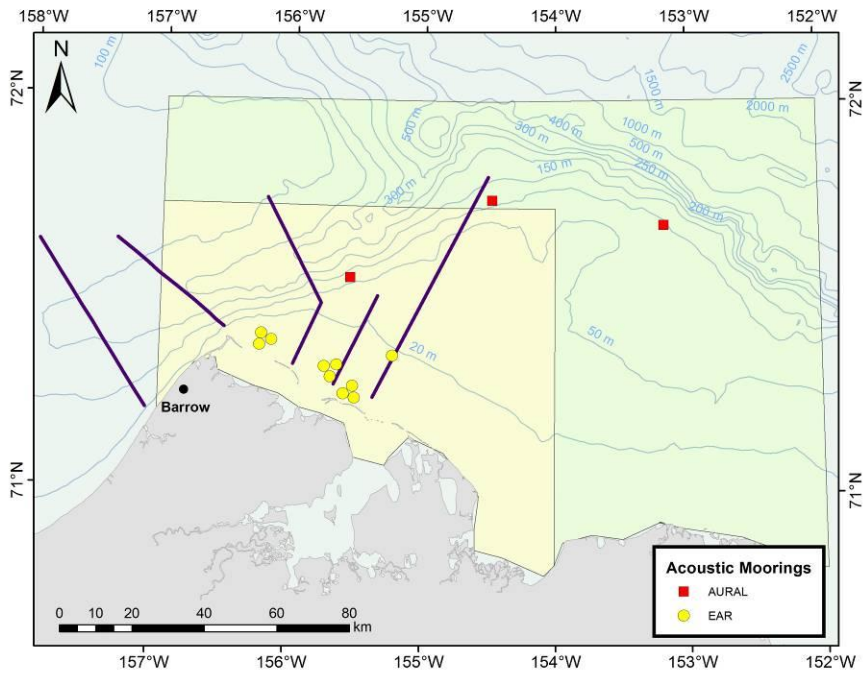


Figure I-1. Two-part study area (inner yellow section and outer green section) relative to pre-set oceanographic tracklines (purple) and acoustic moorings.

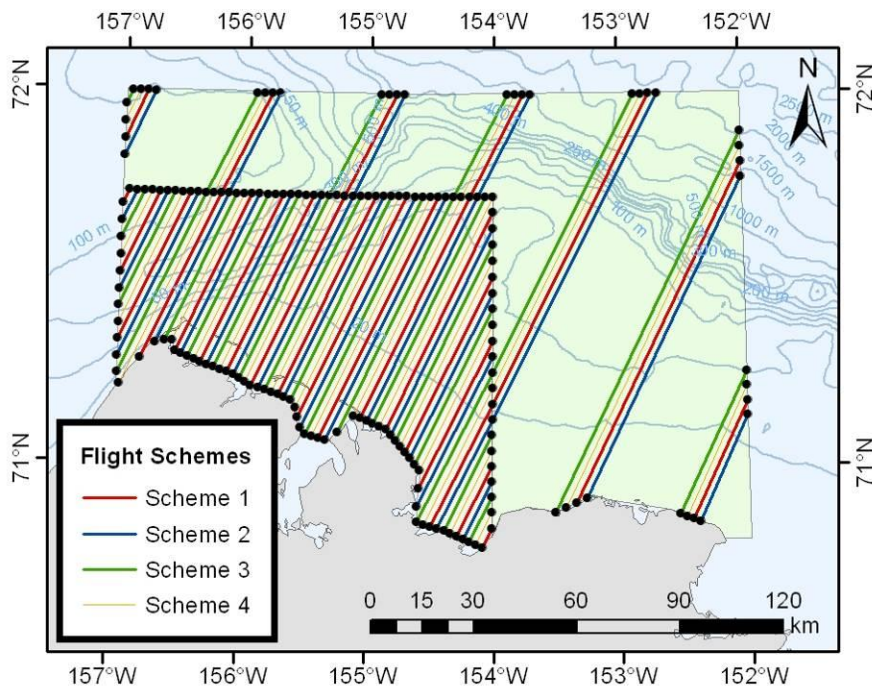


Figure I-2. Two-part study area with tracklines designed for the 2010 BOWFEST aerial survey.

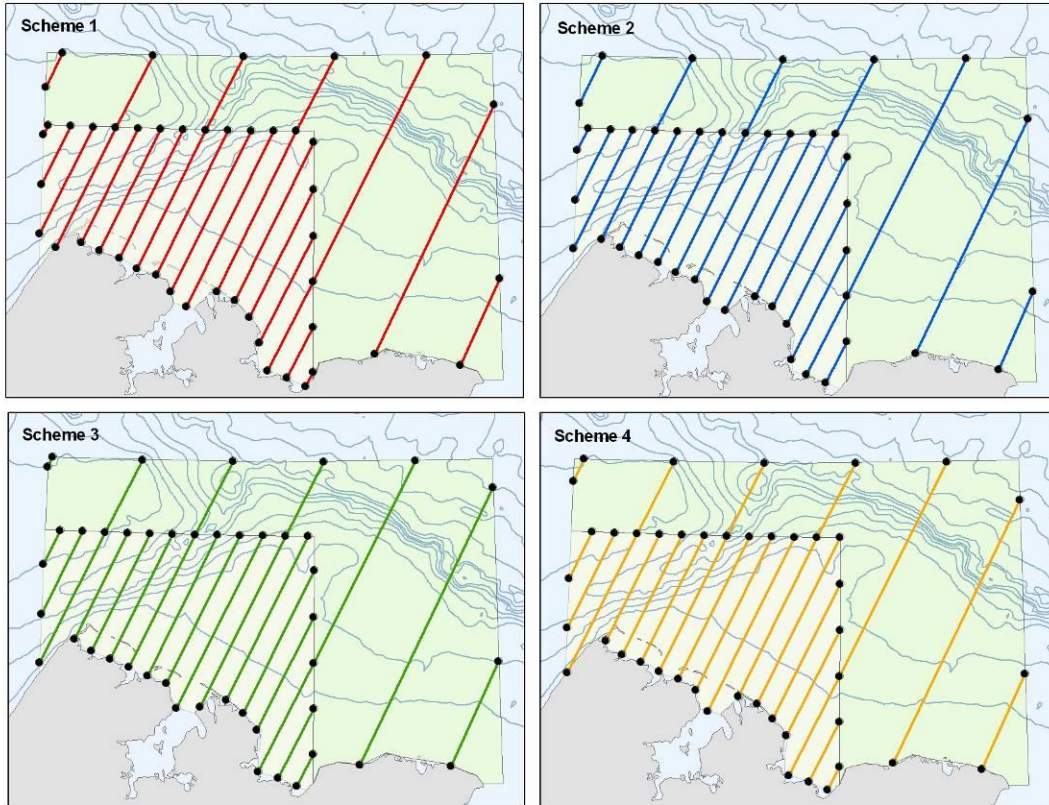


Figure I-3. The four survey schemes for the 2010 BOWFEST aerial survey.

Survey Protocol

BOWFEST aerial surveys were flown in a NOAA Twin Otter (N56RF) equipped with twin engines, high wings, and approximately 5 hours of flight endurance. In addition, the aircraft had two large bubble windows for the left and right observers 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. Survey altitude was generally near 310 m (1000 ft); most aerial photographic passes were made at 213 m (700 ft), as allowed under NMML Permit No. 782-1719-09. The northeast/southwest tracklines were flown sequentially west to east (opposite the bowhead whales' autumn migration direction) in order to minimize the probability of resighting the same whale(s).

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 (on or off), crew position, and photo data into an Access database. Location data (latitude, longitude, speed, altitude, and heading) were automatically recorded every five seconds; 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 the best of one of five subjective categories from excellent to useless; for example, a record of “ 20° good” would mean that from the trackline out to 20° (0.8 km), sighting opportunities were good, and farther from the trackline ($<20^\circ$) the visibility worsened and was not recorded. Areas along the trackline 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.

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 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.

In addition to an autonomous radar altimeter (not connected to the pilot’s altimeter) and GPS barometric altimeter, in 2010 a laser altimeter (Universal Laser Sensor) was tested, providing altitudes precise to within a few centimeters. The laser altimeter was mounted aimed vertically near the center camera so that it could accurately determine the distance between the photogrammetric camera and a target.

Photographic Protocol

Three Canon EOS-1DS Mark III cameras with Zeiss 85mm f 1/4 lenses were used simultaneously over an open belly port designed for vertical photography (Fig. I-4A). Lenses were focused to infinity and taped to impede rotation. The cameras were housed in a Forward Motion Compensation (FMC) mount which uses a rocker mechanism to counter the forward velocity of the relative ground speed. The cameras were integrated with an autonomous radar altimeter (Honeywell AA300 model) in order to collect precise altitudes each time the cameras were fired (<http://www.aerialimagingolutions.com/fmcmount.html>; Fig. I-4B). The mounted cameras were fired using a custom built data acquisition system that automated the retrieval of data including altitude, time of camera firing, frame number, 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. All three cameras recorded RAW format, 21.0 megapixels (5616 x 3744) images and were set to shutter priority (1/1000 or faster shutter speed) with ISO at 400-800 sensitivity.

Photographic passes were typically made after completing the trackline on which the bowhead sighting was initially reported. Several 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.

Photo by Craig George, 2008



Photo by Kim Goetz, 2010



Figure I-4. A) The NOAA Twin Otter (N57RF) with open belly port. B) The three Canon EOS-1DS Mark III cameras with 85 mm lens housed in the FMC mount.

In addition to photographing bowhead whales, photographs were taken of calibration targets using the same camera system. 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) (Fig. I-5). The calibration target was laid out on an abandoned airstrip north of Barrow near the former Naval Arctic Research Lab's aircraft hangar.

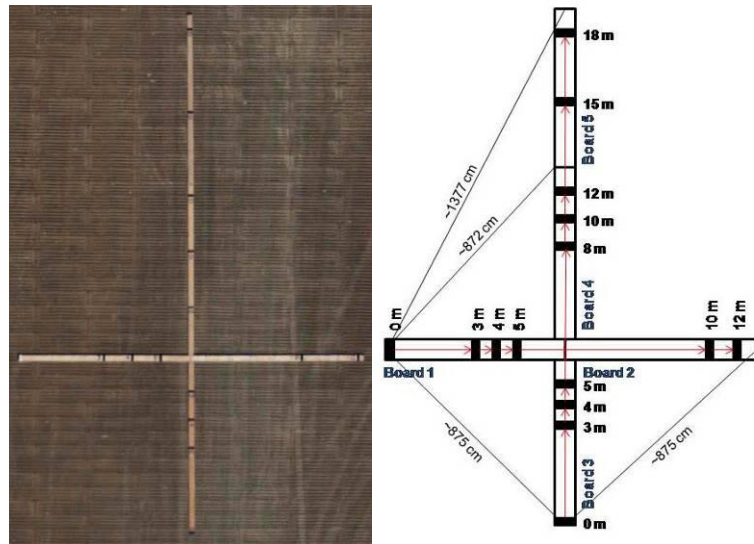


Figure I-5. Aerial image (left) and diagram (right) of the land-based calibration target.

To test the performance of the autonomous radar altimeter, laser altimeter, and GPS barometric altimeter, photographs of the calibration target were taken at 33 m (100 ft) intervals from 170 to 500 m (500 to 1500 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 JPGs. Both the GPX file and the JPGs were used as inputs for RoboGEO so that the program could interpolate latitude and longitude and embed this position information into the exif metadata of each photograph. Since RoboGeo uses time to link photographs to the tracklog position, we synchronized the date and time on all 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 by 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 will be compared to each other to determine if individual whales were photographed multiple times. Following this comparison, these whale images will be compared to others collected in previous years to establish when and where individual whales have been seen before.

Results

Survey effort

Aerial surveys were conducted in the BOWFEST study area on 8 days between 1-18 September 2010, including one flight dedicated solely to photographing calibration targets. All flights were based out of Barrow, each ranging from 0.9 to 5.3 hours in duration. Although 70 flight hours were originally scheduled for the project, fuel availability, fog, low ceilings, and high winds limited flying conditions on many days such that only 32.8 hours were flown. Of the 28.4 hours spent on search effort over water, 16.1 hours (3061 km) were flown on systematic transects and 11.5 hours (2236 km) were flown searching off transects such as when transiting between transect lines, circling animals, or photographing whales (Fig. I- 6). An additional 0.8 hours were spent flying over and photographing calibration targets, and 0.9 hours was spent deadheading without search effort (Table I-1). Due to logistical difficulties (fuel limitations 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 concentrated in the inner section of the two-part study area.

Throughout the entire 2010 BOWFEST field season, only 1.7 hours were flown in poor or useless viewing conditions and, thus, were considered unsurveyed (Table I-1). These 1.7 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 6 of the possible 13 survey days, poor weather conditions precluded us from flying.

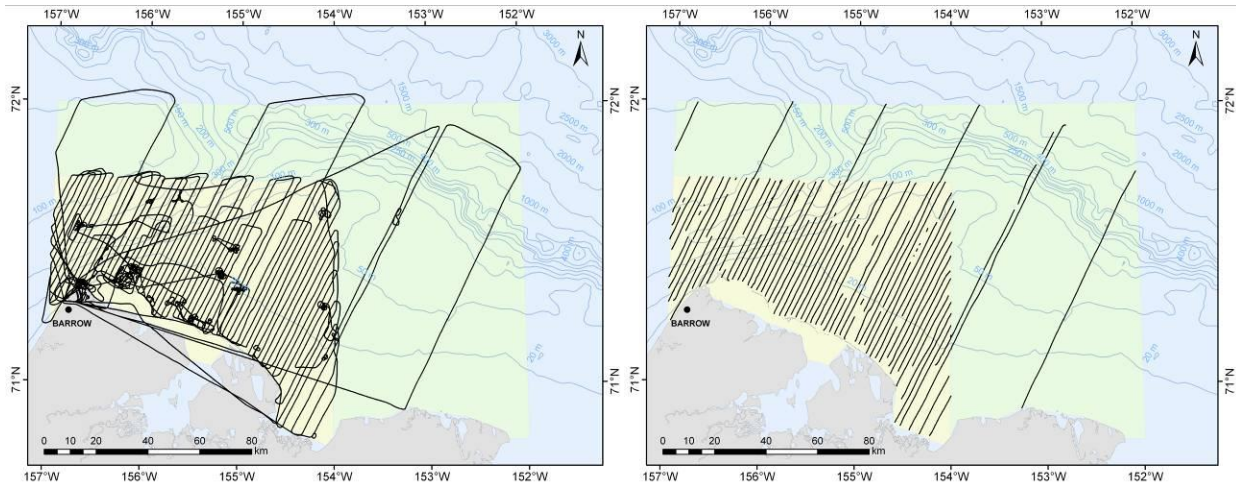


Figure I-6. All search effort, including transect, circling, and photo effort (left) and dedicated transect effort (right) during the 2010 BOWFEST survey.

Table I-1: Survey effort (distance and time) for the 2010 BOWFEST aerial survey.

EFFORT SUMMARY	DISTANCE (KM)	TIME (HRS)
On Effort - Trackline	3060.45	16.09
On Effort - Deadhead	1585.58	7.82
On Effort - Photo Mode	464.28	2.64
On Effort - Circling	186.25	1.04
Total On Effort	5296.56	27.59
Off Effort - Over Land	443.41	1.96
Off Effort - Bad Weather	369.98	1.65
Off Effort - Deadhead	196.60	0.89
Total Off Effort	1009.99	4.50
Calibrating Targets	158.53	0.76
Totals	6465.08	32.85

All four of the devised survey schemes were flown during the 2010 BOWFEST survey. Approximately 810 km of transects were flown in Scheme 1 (65%) on 6 and 8 September, and an additional 833 km were flown on effort while circling, photographing, or transiting between tracklines. Scheme 2 was nearly completed during two flights on 12 September, covering approximately 90% of the Scheme. We surveyed Scheme 3 on 13 and 15 September, completing 48% of the designated tracklines, primarily in the smaller section of the study area. Similarly,

approximately 41% of Scheme 4 tracklines were flown on 17 September 2010 (Table I-2; Fig. I-7). Of the 5011 km of designated trackline within the four schemes, approximately 61% were completed.

Table I-2: Search effort per survey scheme in 2010.

Flight Scheme	Off Transects		On Transects		Transects Available (km)	% Transects flown
	km	mins	km	mins		
1	833.3	153.3	809.8	257.2	1251.6	64.7
2	544.0	158.5	1128.5	353.0	1251.4	90.2
3	283.9	88.4	603.1	191.5	1255.1	48.1
4	317.2	150.8	519.1	163.7	1252.8	41.4
Totals	1978.4	551.0	3060.5	965.3	5010.9	61.1

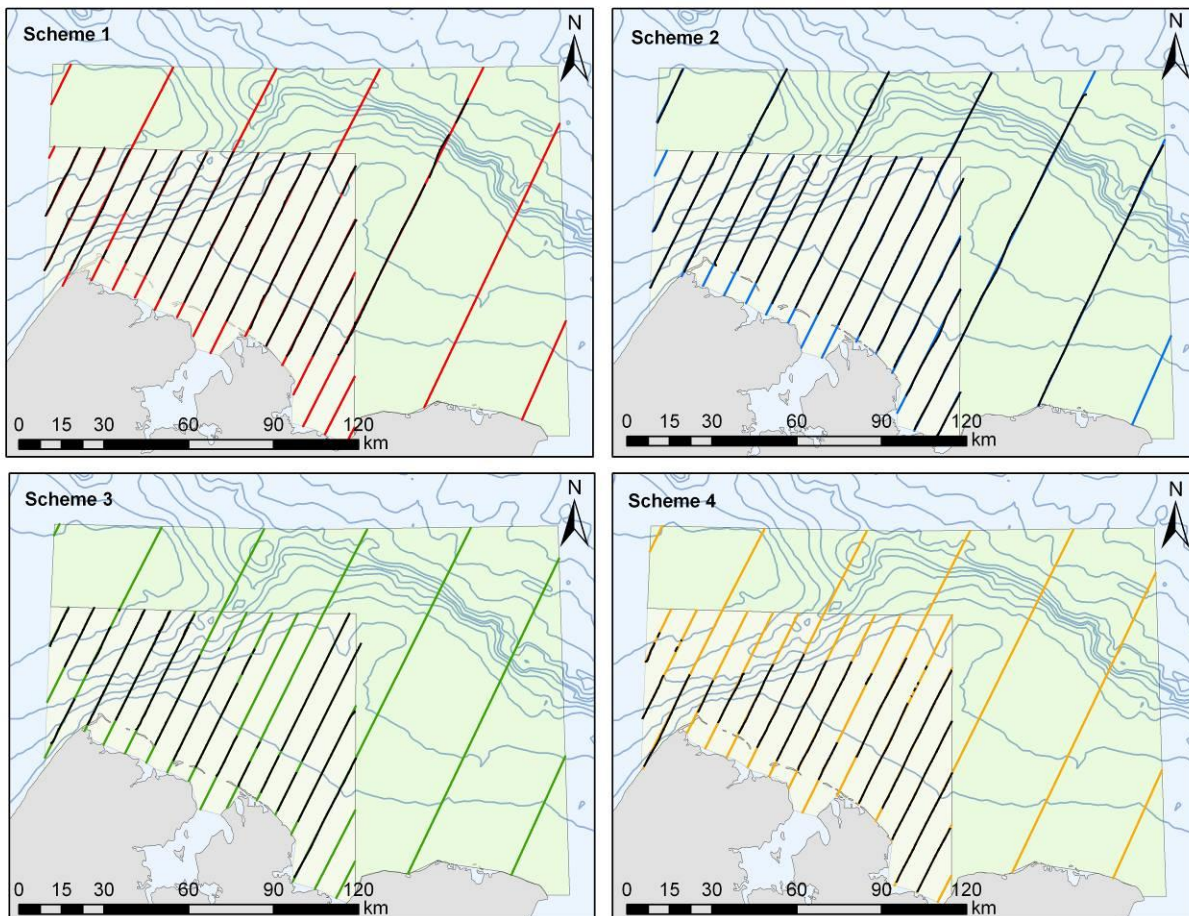


Figure I-7. Tracklines flown (black lines) per survey scheme (colored lines) during the 2010 BOWFEST field season.

Sighting Summary

There were 83 bowhead whale sightings of 216 animals seen on transect throughout the 2010 BOWFEST survey. An additional 19 sightings of bowheads (28 animals) were sighted while deadheading between designated tracklines and thus may be repeat sightings. After circling/photographing the bowheads, an additional 117 animals on trackline and 22 off trackline were counted, bringing the total number of bowheads sighted to 333 on trackline and 50 off trackline for a grand total of 383 (Table I-3). Unlike the 2007 field season, when nearly all bowheads appeared to be feeding as indicated by mud plumes and multiple swim directions, only 18 of the 102 bowhead sightings were positively identified as feeding in 2010. (Examination of the photographs will later document how many bowheads had mud on their bodies, and therefore were probably feeding). This observed behavior was similar to 2008 and 2009 in which “traveling” was the most commonly recorded behavior, indicating that bowheads were most likely migrating through the study area, perhaps feeding along the way. Most bowhead whale sightings were made on 17 September (42 sightings of 183 animals) (Fig. I-8). Figure I-9 shows that only 44% of the survey effort was completed during relatively calm sea states (Beaufort \leq 3).

Table I-3: Summary of marine mammal sightings and numbers of marine mammals counted during the 2010 BOWFEST aerial survey. The bowhead whale count with asterisks (*) include whales seen while the aircraft was circling and not on transects.

Common Name	Scientific Name	Sightings	Count
Bowhead Whale	<i>Balaena mysticetus</i>	102	244(383*)
Gray Whale	<i>Eschrichtius robustus</i>	6	10
Beluga Whale	<i>Delphinapterus leucas</i>	2	5
Ringed Seal	<i>Phoca hispida</i>	8	40
Bearded Seal	<i>Erignathus barbatus</i>	3	3
Walrus	<i>Odobenus rosmarus</i>	1	2
Polar Bear	<i>Ursus maritimus</i>	16	23
Unid Large Cetacean		1	1
Unid Pinniped		1	1
Unid Seal		60	85
Totals		200	414 (553*)

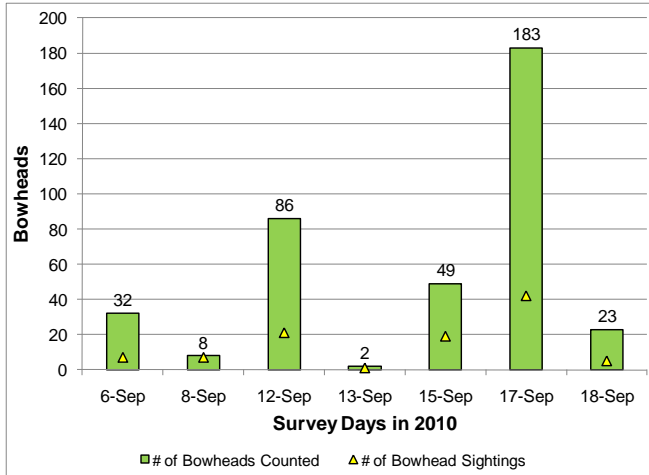


Figure I-8. Number of bowhead sightings (yellow triangles) and bowheads counted (green bars) per survey day. Counts may include resightings between days.

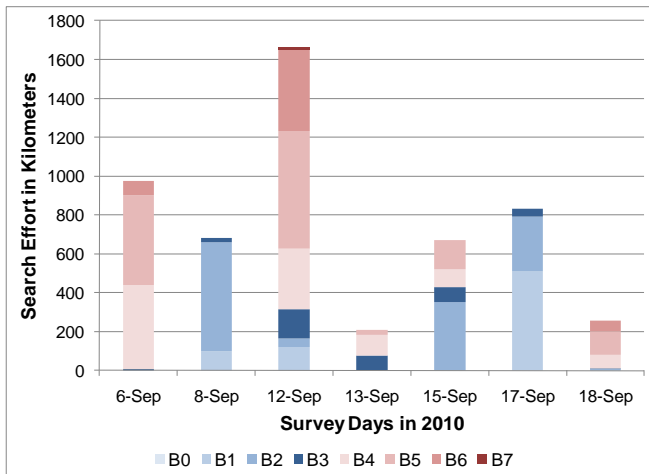


Figure I-9. Aerial survey effort conducted under varying Beaufort sea states.

In addition to bowhead whales, there were 6 sightings of gray whales (10 whales), 2 sightings of beluga whales (5 animals), 8 sightings of ringed seals (40 seals), 3 sightings of bearded seals (3 seals), 1 sighting of 2 walrus, 16 polar bear sightings (23 animals), 60 sightings of unidentified seals (85 animals), 1 unidentified pinniped (1 animal), and 1 unidentified large cetacean sighting (1 animal) (Table I-4, Fig. I-10). The frequency 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 I-4: *Photographic effort for the 2010 BOWFEST aerial survey.*

Date	Bowhead Pictures	Bowhead Images*	Calibration Pictures
1-Sep	0	0	39
6-Sep	63	76	0
8-Sep	5	5	0
12-Sep	107	308	0
13-Sep	3	4	0
15-Sep	31	38	0
17-Sep	121	223	0
18-Sep	22	35	0
Total	352	689	39

*Total number of individual bowheads counted from all pictures (e.g., one picture may have 2 or more bowhead images).

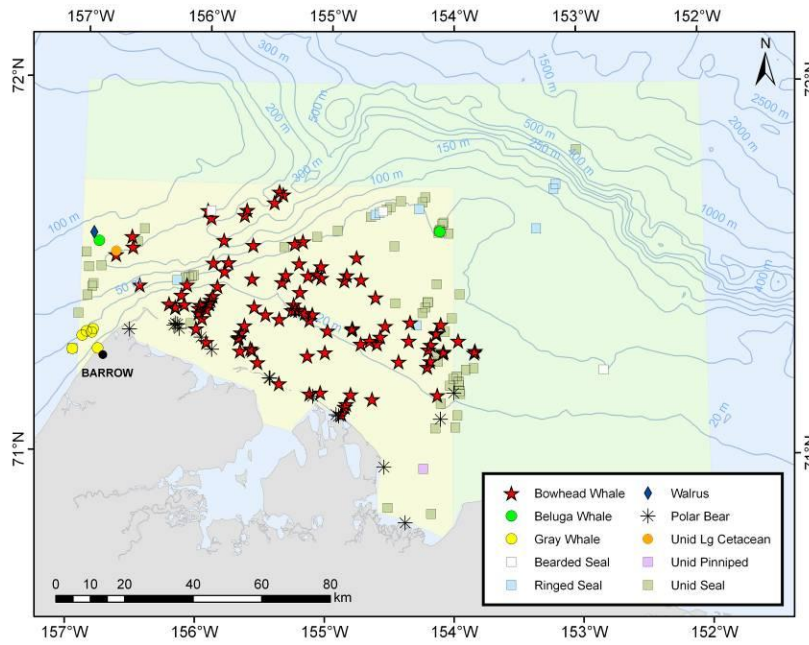


Figure I-10. *Map showing locations of all marine mammal sightings during the 2010 BOWFEST field season.*

Photographic effort

Bowhead whales were photographed on 7 of the 8 survey days. In total, we spent 2.6 hours photographing bowheads, resulting in 352 pictures (689 bowhead images) from all three cameras (Table I-4; Fig. I-11). An additional 39 pictures were taken of the calibration target. Although there were 689 bowhead whales counted in the photographs, the number of unique bowhead whales will be less after accounting for duplicate images.

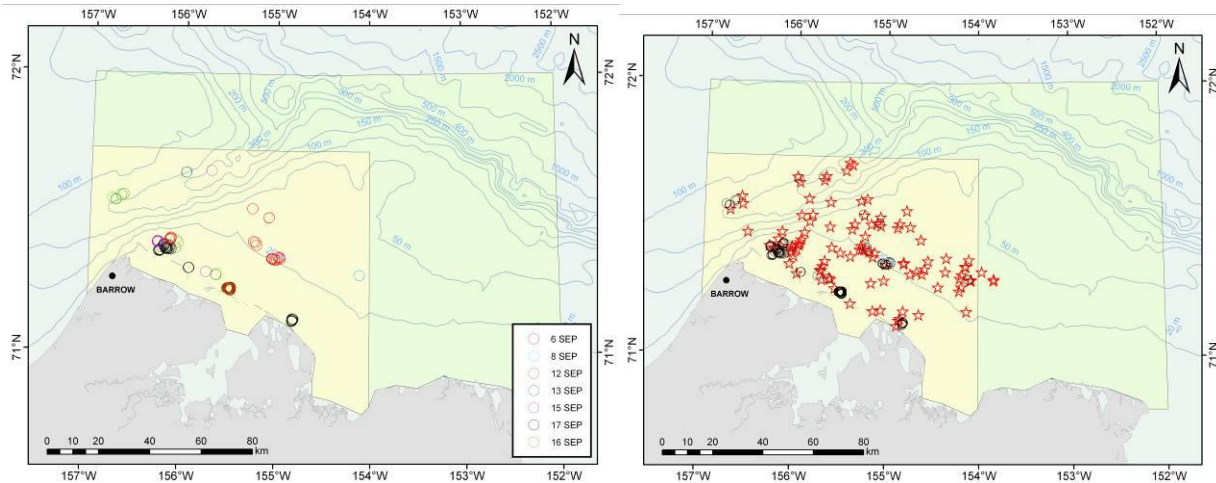


Figure I-11. Locations where bowhead whales were photographed per survey day in the left figure; and photographic locations (black circles) relative to all bowhead sightings made during these aerial surveys in 2010 (red stars) in the right figure.

Preliminary results from tests of the radar, laser and GPS barometric altimeters were promising. The tests showed high agreement among all three altimeters (no significant difference) (Fig. I-12). This is important for BOWFEST since we currently rely upon an old, expensive and borrowed radar altimeter. It would be cost prohibitive to replace the radar altimeter if we needed to, so continuing this analysis is imperative to ensure we have found a suitable replacement.

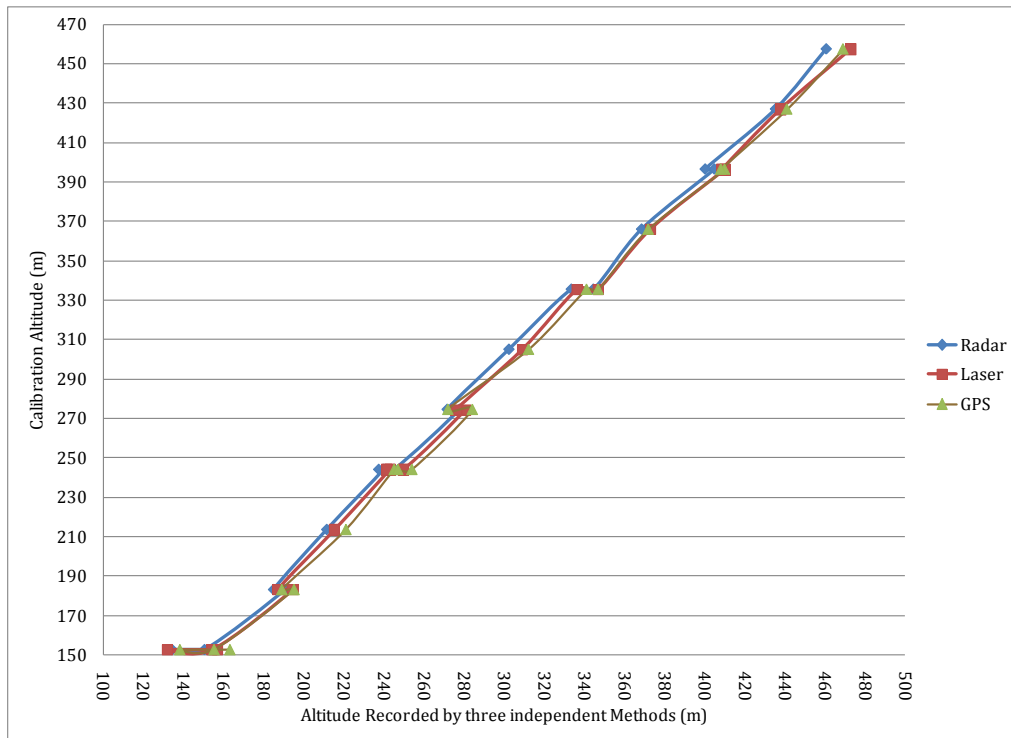


Figure I-12. Graph showing close agreement among all three altimeters tested during the 2010 BOWFEST field season.

2010 Daily Reports

August 26

Aerial observers arrived in Barrow, but problems with fuel availability delayed the arrival of the aircraft. Aerial photogrammetric equipment, such as the triple-camera FMC mount, autonomous altimeter, laser altimeter, and interfacing equipment, was installed in Seattle in mid-June prior to surveys of Steller sea lions, fur seals, and harbor seals.

August 30

The aircraft (N56RF) arrived in Barrow in the evening. No fuel available in Barrow.

August 31

Field equipment was installed on the aircraft, aerial operations were refined, and the crew had a safety briefing. Still no fuel available in Barrow.

September 1

Flight 1 over the calibration targets; however, because the aircraft had to fly to Deadhorse for refueling, there was insufficient fuel to conduct a survey.

September 2-5

Lack of refueling options in Barrow and fog/low ceilings prevent any attempt at flying surveys.

September 6

Fuel now available in Barrow. Flight 2 covered the western portion of the inner survey area of Scheme 1. Viewing conditions were generally good to fair with periodic fog and Beaufort ranging between 4 and 6.

September 7

No flight due to fog and low ceilings.

September 8

Flight 3 covered the remainder of Scheme 1 except some areas obscured by fog. In order to assist the bowhead tagging team, we flew along the 20 m isobath (where bowheads are often sighted) from Point Barrow to the start of our tracklines. We were able to finish the tracklines in the smaller box of Scheme 1 and one line in the larger box before encountering fog. Viewing conditions were generally good with sparse patches of light fog. The sea state was remarkably low and never rose above Beaufort 3.

September 9-11

No flights due to fog or low ceilings.

September 12

Flight 4 & 5 covered nearly the entire two-part study area. Viewing conditions were generally good, but thick haze/mist limited the view in some areas. Beaufort sea state was high throughout most of the smaller portion of the two part study area (4-7) and lower within the larger part (1-4).

September 13

Flight 6 attempted scheme 3. Fog became more prevalent throughout the BOWFEST study area and very little on-effort data were collected. Over half the time spent on trackline was classified as “off effort” due to heavy fog. Deteriorating weather conditions near Barrow forced us to terminate the flight after only two hours.

September 14

No flight due to thick fog and low ceilings.

September 15

Flight 7 covered the inner study area of scheme 3. While we encountered patches of light fog throughout much of the study area, visibility was good enough to allow fairly thorough coverage. Most of the tracklines in the smaller section of the study area were completed. Visibility was generally fair or better with Beaufort sea states between 2 & 5.

September 16

No flight today due to persistently low clouds.

September 17

Flight 8 covered the inner study area of scheme 4. A fog bank prevented us from surveying the northern reaches of the inner study area; otherwise, viewing conditions were generally good with remarkably low sea states (Beaufort 1-3). We were able to complete almost all the tracklines in the inner study area.

September 18

Flight 9 searched for bowhead whales for photographic purposes. No designated tracklines were completed. Cloud ceilings were initially high, but dropped throughout the duration of the survey. High winds (20-25 knots) caused high sea states for most of the survey (Beaufort 3-6).

Discussion

Bowhead whales are often seen in the Barrow area during the summer; however, sightings are relatively rare here compared to the eastern Beaufort Sea where most of the BCB stock is known to spend the summer (Moore & Reeves 1993). 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. Although our aerial sighting data suggested an increase in bowhead sightings through the 2008 field season, the reverse was true in 2007 when the only bowheads we encountered were in the first two days of the survey (23 and 24 August) and none were seen after that (as late as 11 September). Also, in 2009, there was no suggestion of an increase in sightings through the field season. In 2010, the number of bowheads sighted varied throughout the survey and there was no obvious trend in sighting rates.

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, 2009, and 2010 were predominantly traveling through the area. Observers reported only a few clear indications of feeding whales; however, photographic examination provides a more exacting documentation of how many whales were muddied from feeding. In 2007-2009, the majority of 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). However, in 2010, bowheads were scattered throughout the inner section of the survey area.

There is substantial evidence that bowheads feed during the fall migration. Although past studies (Lowry & 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 fall migrations (Lowry et al. 2004, Mocklin 2009). 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. 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). Photographic evaluations support this as well, 61% of images in spring showed evidence of feeding, and 99% of images in late summer did (Mocklin 2009). Thus, feeding appears to be both more extensive and more frequent during the fall migration than the spring migration.

To learn more about the consistency of bowhead feeding aggregations seen near Barrow during the summer, photographs collected during the BOWFEST aerial survey will be evaluated for recognizable individuals. 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. Reidentifying 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) (Rugh et al. 2003, 2009). The data collected from photographic images during the BOWFEST aerial surveys 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.

Acknowledgments—The Bureau of Ocean Energy Management, Regulation and Enforcement (formally Minerals Management Service) funded the BOWFEST program; in particular, Chuck Monnett provided guiding support and inspiration to get this large research program underway. NOAA’s Aircraft Operation Center provided the aircraft and crew. Our pilots in 2010, Bradley Fritzler and Rob Mitchell, filled a critical role in keeping the aircraft at the preferred altitude while flying intricate patterns over moving whales. Rob Miletic provided mechanical support for the aircraft. Wayne Perryman loaned us a radar altimeter and provided technical advice, and Don LeRoi loaned us the FMC mount and assisted with the camera mount installation. Craig George provided the calibration target. This study was conducted under MMPA Scientific Research Permit No. 782-1719-09.

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SECTION II - PASSIVE ACOUSTIC MONITORING IN THE WESTERN BEAUFORT SEA

Catherine Berchok¹, Kate Stafford², David K. Mellinger³, Sharon Nieuwkerk³,
Sue Moore⁴, J. Craig George⁵, and Frederick Brower⁵

¹National Marine Mammal Lab, AFSC, NOAA Fisheries Service,
7600 Sand Point Way NE, Seattle, WA 98115

²Applied Physics Lab, University of Washington, 1013 NE 40th St., Seattle, WA 98115

³Cooperative Institute for Marine Resources Studies, Oregon State University,
2030 S. Marine Science Drive, Newport, OR 97365

⁴NOAA/S&T-PMEL, 7600 Sand Point Way NE, Seattle, WA 98115

⁵North Slope Borough Department of Wildlife Management, PO Box 69, Barrow, AK 99723

Background and Introduction

For 2010, there were three components to the field work: Long-term AURAL (Autonomous Underwater Recorder for Acoustic Listening, Multi-Électronique, Rimouski, QC, Canada) recorders on deep moorings along the 100 m isobath, a short-term EAR (Ecological Acoustic Recorder, Oceanwide Science Institute, Honolulu, HI) recorder deployed on a UAF (University of Alaska at Fairbanks) mooring frame (Okkonen), and short-term EAR recorders deployed on movable moorings.

AURAL Recorders

Due to time constraints aboard the USCGC *Healy*, the long-term BOWFEST mooring work was shared with the BOEMRE (Bureau of Ocean Energy Management, Regulation, and Enforcement) funded CHAOZ (Chukchi Acoustics, Oceanography, and Zooplankton study) cruise on the F/V *Alaskan Enterprise* (24 August -20 September, 2010).

The acoustic mooring portion of BOWFEST again benefited from the fact that Kate Stafford (APL-UW), Carin Ashjian (WHOI), and Steve Okkonen (UAF) received National Ocean Partnership Program grants that require ship time aboard the USCGC *Healy* in the Beaufort Sea. The chief scientist of this annual cruise, Dr. Bob Pickart (WHOI), allowed time for the BOWFEST moorings to be serviced on his cruise. Sharon Nieuwkerk (CIMR/OSU) was onboard the *Healy* during the 10-03 leg (September 6-26, 2010) to supervise the deployments and recoveries. Moorings BF10_AU_02 & BF10_AU_03 were deployed, while moorings BF09_AU_05 and BF09_AU_06 were retrieved (Fig. II-1, Table II-1). Kate Stafford's (APL-UW) NOPP and NSF (AON) funded AURAL recorders, whose data will complement the NMML data set, were also turned around on the *Healy* by Nieuwkerk (Fig. II-1). All 2010 AURAL recorders were programmed to record at a sampling rate of 8192 kHz on a duty cycle (9 min on, 11 min off) in order to record for an entire year.

Mooring work on the F/V *Alaskan Enterprise* included the turn-around of BF09_AU_01 (to BF10_AU_01), as well as recovery attempts (dragging) on the three BOWFEST moorings (BF08_AU_01-03) lost off Barrow Canyon during the 08-09 season (Fig. II-1, Table II-1). Since the CHAOZ cruise was already in the area for a crew transfer, we spent two days attempting to

recover the lost moorings using our winch and a string of dragging hooks (Fig. II-2) to ‘lasso’ the moorings.

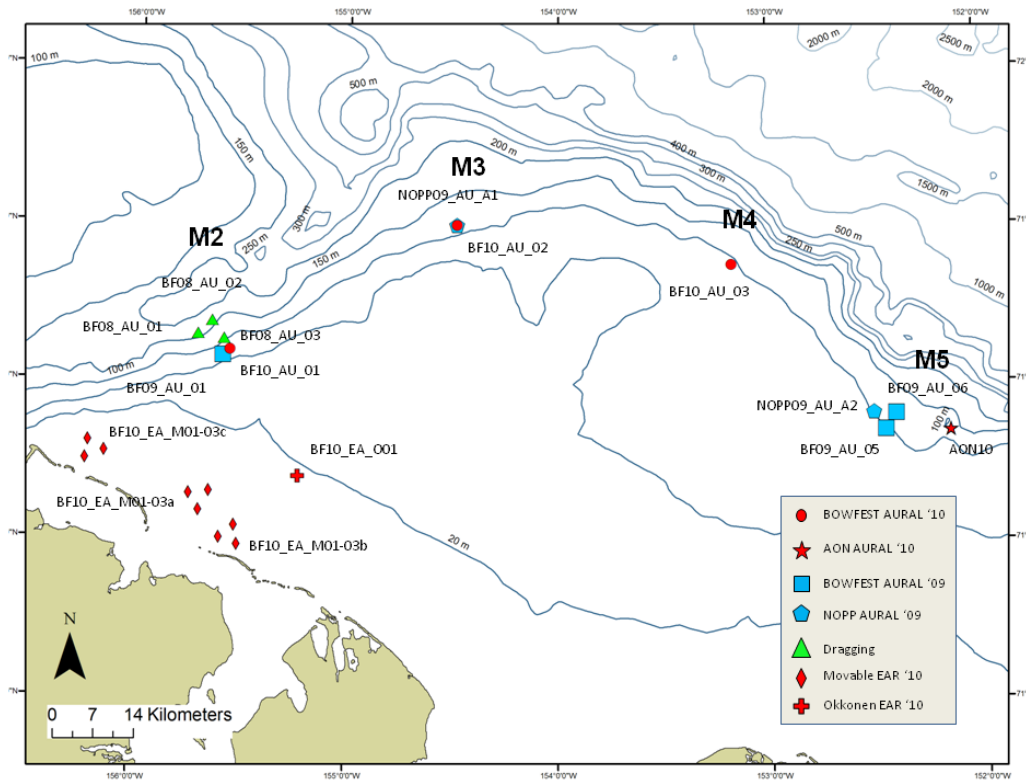


Figure II-1. Locations of passive acoustic recorders during the 2010 BOWFEST field season. The AON and NOPP moorings are external to the BOWFEST project, but their data will be included in our analysis. Note that the 2008 moorings referred to in the text were in the same location as NOPP09-AU-A2 and BF09_AU_06 shown here. The M# labels represent mooring clusters, which will simplify inter-annual comparison.

Figure II-2. Dragging hooks used to attempt recovery of lost moorings.



Table II-1: Passive acoustic recorder moorings deployed, retrieved, or dragged for during the 2010 BOWFEST field season.

Moorings	Latitude	Longitude	Water depth (m)	Deployment date	Sampling Rate (Hz)	Duty Cycle (min on/ min off)	Retrieval date	Recorder Type	Comments
BF08_AU_01	71.57485	-155.71038	110	8-Aug-08	8192	9/20	-	AURAL	On side in mud
BF08_AU_02	71.60323	-155.64692	173	8-Aug-08	8192	9/20	-	AURAL	Moved 1 nm over past 2 years
BF08_AU_03	71.56807	-155.58780	118	13-Aug-08	8192	9/20	-	AURAL	Lost
BF09_AU_01	71.54172	-155.59185	66	5-Aug-09	8192	9/20	-	AURAL	
BF09_AU_05	71.42500	-152.45005	137	2-Aug-09	8192	9/20	13-Sep-10	AURAL	
BF09_AU_06	71.44995	-152.40007	125	2-Aug-09	8192	9/20	13-Sep-10	AURAL	
BF10_AU_01	71.55038	-155.55850	72	8-Sep-10	8192	9/11	-	AURAL	
BF10_AU_02	71.75052	-154.48297	100	12-Sep-10	8192	9/11	-	AURAL	
BF10_AU_03	71.68800	-153.17398	105	12-Sep-10	8192	9/11	-	AURAL	
BF10_EA_O01	71.35150	-155.22910	19	19-Aug-10	12.5k	60/5	16-Sep-10	EAR	Okkonen Mooring
BF10_EA_M01a	71.32198	-155.74095	15	24-Aug-10	40k	30/8	8-Sep-10	EAR	Movable array #1
BF10_EA_M02a	71.29552	-155.69443	15	24-Aug-10	40k	30/8	8-Sep-10	EAR	Movable array #1
BF10_EA_M03a	71.32640	-155.64763	15	24-Aug-10	40k	30/8	8-Sep-10	EAR	Movable array #1
BF10_EA_M01b	71.25258	-155.59502	15	13-Sep-10	40k	30/8	17-Sep-10	EAR	Movable array #2
BF10_EA_M02b	71.27257	-155.52538	15	13-Sep-10	40k	30/8	17-Sep-10	EAR	Movable array #2
BF10_EA_M03b	71.24238	-155.51035	15	13-Sep-10	40k	30/8	17-Sep-10	EAR	Movable array #2
BF10_EA_M01c	71.40228	-156.22037	15	17-Sep-10	40k	30/8	23-Sep-10	EAR	Movable array #3
BF10_EA_M02c	71.37360	-156.23275	15	17-Sep-10	40k	30/8	23-Sep-10	EAR	Movable array #3
BF10_EA_M03c	71.38628	-156.14387	15	17-Sep-10	40k	30/8	23-Sep-10	EAR	Movable array #3

One mooring was never located. This was the mooring that was released during the 2009 field season by Berchok and Brower on the *Little Whaler*, but was never seen on the surface (even with Rugh, Goetz, and Mocklin overhead in the aerial survey plane searching the area). It is now thought that the mooring worked its way off the anchor over the past year and is now free-floating somewhere at sea. The other two moorings were located and re-surveyed to more accurate positions: one had moved one mile over the past two years, and one appeared to be deeply imbedded in the mud. The ‘walking’ mooring was hooked twice, but was lost each time when bringing it back to the surface. The other mooring was not hooked. Discussions were made with the chief engineer and the captain on ways to improve the dragging method for next year.

Short-term EAR Moorings

Again we are grateful to Steve Okkonen (UAF) for agreeing to attach our EAR recorder (BF10_EA_O01) to one of his short-term mooring frames. The recorder was deployed from mid-August through mid-September (Fig. II-1, Table II-1), and recorded at a sampling rate of 12.5 kHz on a duty cycle of 60 minutes on/4.9 minutes off.

Frederick Brower (NSB) led the movable mooring operations in 2010. He was able to make three deployments of a three-unit array (BF10_EA_M01-03 a-c: Fig. II-1, Table II-1). All units recorded on a duty cycle of 30 min on/ 8 min off at a sampling rate of 40 kHz. We will get a copy of the data at the upcoming BOWFEST meeting in Anchorage, but from email correspondence it is known that two of the instruments from the ‘b’ array never started recording.

A change to the anchor system (gravel-filled burlap sacks) was made this year in order to reduce shipping costs to Barrow. The new system worked well except for one mooring that had its bag break open. Luckily, the mooring was found adrift by Brower and recovered.

Data Analysis and Synthesis

[Note: Because deployment locations and array configurations of the AURALs have changed slightly since the beginning of BOWFEST, we are framing the results in terms of mooring clusters (indicated by the 'M' labels on Figure II-1)].

Stephanie Grassia (NMML) has begun analysis of the AURAL data starting with the 2007-2008 moorings. Data were analyzed yes/no/maybe for bowhead calls in three hour bins, meaning that as soon as a bowhead call was detected, the analyst moved to the next three hour bin. If no (or indeterminate) calls were detected, then the analyst had to process all of the data in that bin. See SoundChecker section below for a brief description of the analysis program developed in-house. She has finished the 2007-08 M3 AURAL (see Figure II-1 and results below), and is currently working on the 2007-08 M2 unit.

Kate Stafford (APL-UW) has analyzed her 2008-2009 NOPP data (2008-09 M3 & M5 – see Figure II-1 and results below) for the presence of bowheads, belugas, bearded seals, and airguns. Because her NOPP-A2 mooring flooded in 2008, she analyzed our BF08_AU_06 mooring (Fig. II-1, M5) as a proxy. She counted the number of half-hour segments with the presence of calls/airguns per day. These data were converted into the same analysis interval as the NMML data to allow comparison in the results section below.

We will be combining all bowhead results with Stafford's airgun and ice data results and hope to have a publication out by spring 2012. We are trying to obtain funding for a graduate student to analyze the BOWFEST recordings for the presence of beluga calls. Manolo Castellote, a NMML postdoc working on Cook Inlet belugas, will help to oversee the analysis. We also have an undergraduate NOAA Hollings Scholar, Dana Wright, arriving this spring to analyze the Okkonen EAR mooring data from 2007-2010 for temporal trends in bowhead whale presence. David Mellinger and Sara Heimlich (CIMR/OSU) continue to work on a paper on their bowhead whale detection/classification work.

SoundChecker Analysis Program

The SoundChecker program was developed in response to the sheer magnitude of passive acoustic data recordings that need to be analyzed, the enormous overlap of the acoustic repertoires of many Alaskan marine mammal species, and the lack of any semblance of a stereotyped call for most of the species. Despite reports of other institutions having developed effective bowhead whale call detection algorithms, further inquiry has revealed that these organizations employ large teams of analysts to essentially hand browse their data for bowhead calls, many times analyzing only a fraction of the recordings. In the cases where auto-detectors are used, these analysts are still needed to verify the results.

We are finding it extremely difficult to come up with autodetection parameters that effectively catch the majority of a particular call type in all locations for all recorder types and seasons, without catching a majority of calls from other species as well. The amount of effort required to effectively ground truth a particular autodetection run, in addition to still having to process a majority of the files, has led us to just use a brute force method of manual analysis. However, the SoundChecker program has the option of running on data sets that have already been run through an autodetector (or set of autodetectors).

The trouble with any spectrogram based sound analysis program is the amount of computational time needed to generate the spectrograms. This time increases as the frequency band of interest increases. SoundChecker, written in the MatLab programming language, operates on image files (Portable Network Graphics (PNG) format) that can be generated ahead of time (typically overnight), so no time is wasted waiting for the spectrogram to appear during the analysis sessions.

Figure II-3 shows the interface window for the SoundChecker program. It consists of the spectrogram image whose title indicates the data/time/location of the sample, an information bar that shows what species/call type/analysis interval is being used as well as a counter to protect the analyst's sanity, and a variety of action buttons. In use all of the time are the Yes/No/Maybe buttons. Once the analyst decides if a species or call type is present they select one of those buttons and the program jumps to either the next image file for No/Maybe answers or the first image file of the next time interval for Yes answers. There is also an option to go back to a previous image if a correction is needed. If a shorter analysis interval is desired, it is simple to re-run that recorder at the shorter interval – the images already assigned to Yes/No/Maybe will be skipped over, allowing for faster re-analysis.

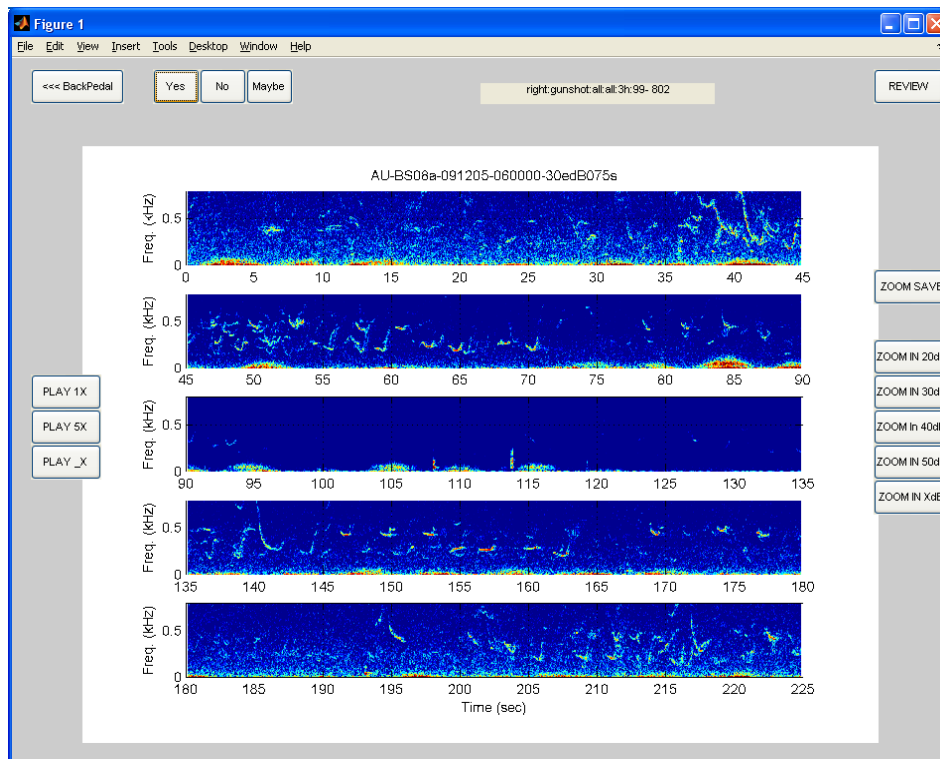


Figure II-3. SoundChecker analysis interface. Spectrogram shown is for the Bering Sea PMEL M8 mooring deployed in 2009 and represents 225s of recordings starting at 07:00:00 UTC on 17 December 2009. The upper information bar shows that this analyst is looking for right whale gunshot calls in 3hr analysis intervals and is 802 spectrograms into their analysis session. Present are bowhead whale and ice seal calls. SoundChecker was written in the MatLab programming language.

Since many sounds are difficult to determine just visually, there is a set of playback buttons that can be used on sections of the image file selected by drawing a box with the cursor. To this end, there is also a set of zoom buttons that allow for more detailed (or with better contrast) views of selected sections of the image. The zoom-save button allows an image file and its related wave file clip to be saved to our expanding library folder of known species calls and our increasingly expanding folders of unknown signals. Furthermore, there is a review mode button (See Figure II-4) that lets the analyst jump back to a specific time/date image and retain the playback/zoom functions without altering the Yes/No/Maybe responses. This is particularly helpful during the many meetings we hold to try and determine the source of many of the signals detected.

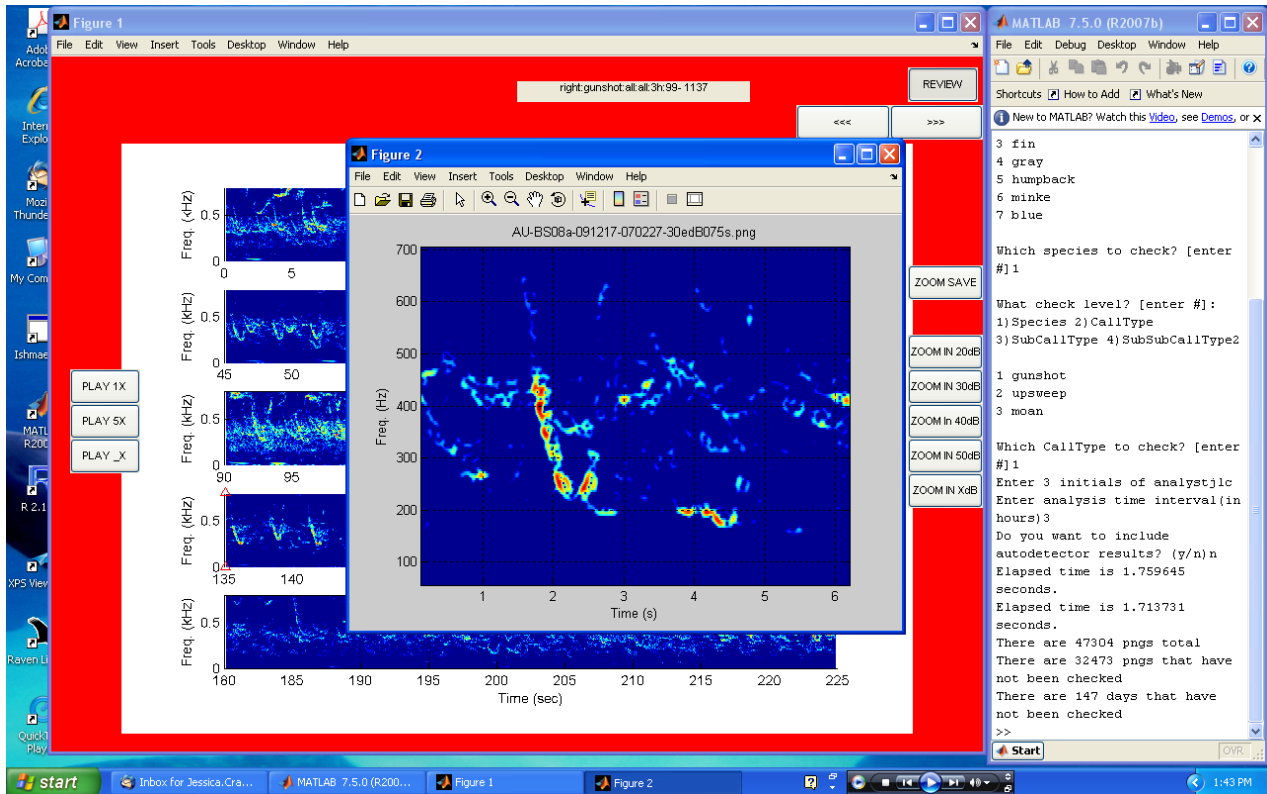


Figure II-4. SoundChecker analysis interface in review mode with a zoom option selected. Spectrogram shown is for the Bering Sea PMEL M8 mooring deployed in 2009. The zoom clip shows some bowhead calls occurring at approximately 07:02:27 UTC on 17 December 2009. SoundChecker was written in the MatLab programming language.

So far, this method is proceeding faster than expected, with the worst case recorders taking around 3 weeks for one analyst to process a year's worth of data. The benefit we are finding with this method is that because we can view an entire 3-4 minute chunk of data at a time, we are getting a good overview of all the call types that are out there – not just those in a particular frequency band or those with particular characteristics. Furthermore, viewing the call in this longer-term context is extremely helpful for making decisions on the signal source.

Because the results from this analysis are in a consistent form, further analysis of the results can be automated, including plot generation and correlation to other biophysical parameters.

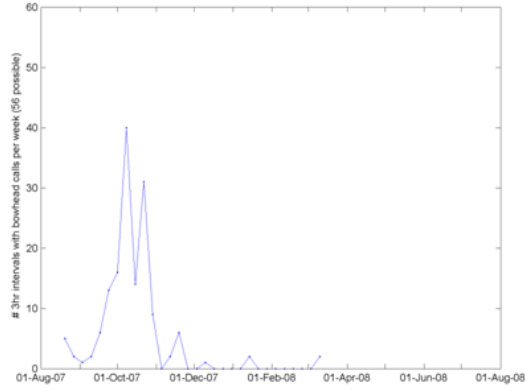
Results

[Note: Because deployment locations and array configurations of the AURALs have changed slightly since the beginning of BOWFEST, we are framing the results in terms of mooring clusters (indicated by the 'M' labels on Figure II-1)].

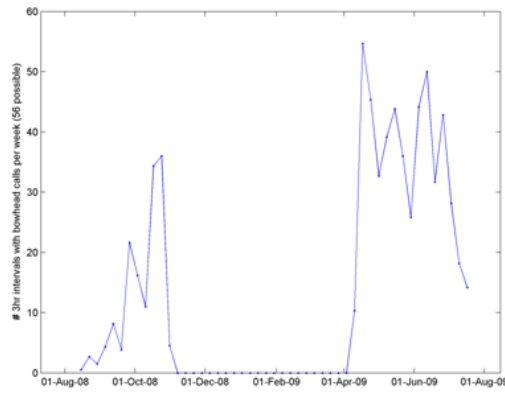
The seasonal pattern of bowhead calls can be seen in Figure II-5, which compares the results for the M3 cluster across deployment years (2007-08 vs. 2008-09) as well as across clusters (M3 vs. M5). The 2007-08 M3 cluster AURAL stopped recording in March, but the same October/November peak can be seen in both years and both locations. For the 2008-09 AURAL s that recorded for the full year – a second larger peak in bowhead calling can be seen peaking in May-July. Figure II-6 shows the daily bowhead calling distribution for the M3 cluster (2007-08). For this figure, the number of days where a bowhead call was detected in each three-hour bin are summed and plotted.

The remaining figures show the results of the M3 and M5 clusters (2008-09) for other sounds detected on those AURALs. There is quite a difference between mooring clusters for the onset of the peak in bearded seal calls (Fig. II-7), with calls peaking almost two months earlier at the M3 cluster. Calling terminates abruptly on both clusters, however, at the end of July. This drop off corresponds directly with the seasonal decrease in ice concentration (Fig. II-8). Beluga whale calls (Fig. II-9) show differences in calling levels but similar calling peak time periods between clusters. Very little difference was seen between airgun detections at both mooring cluster sites (Fig. II-10).

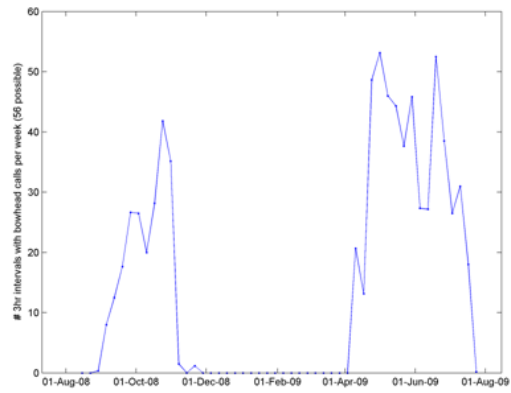
07-08



08-09



M3



M5

Figure II-5. Results of bowhead call analysis on the 2007-08 M3 mooring cluster and 2008-09 M3 and M5 mooring cluster AURALs. See text for analysis details. Data are presented as number of three-hour intervals with bowhead calls detected per week (with a maximum of 56 intervals possible per week).

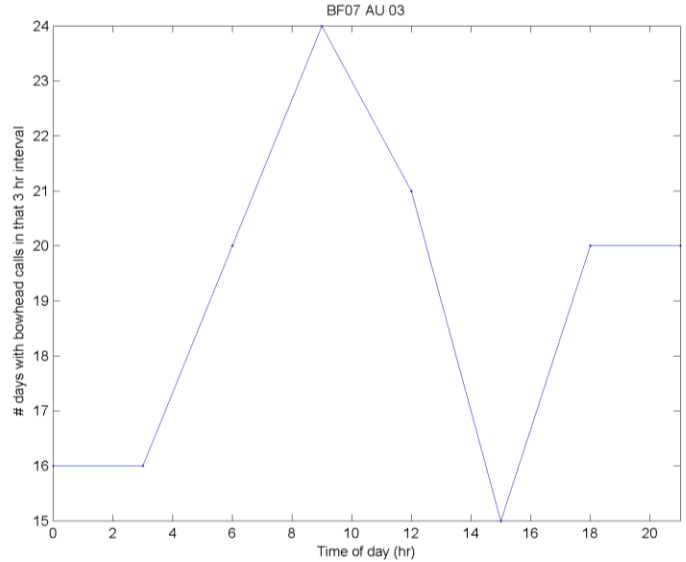


Figure II-6. Daily pattern of bowhead calling at the 2007-08 M3 mooring cluster. See text for analysis details. Data were analyzed in three-hour intervals.

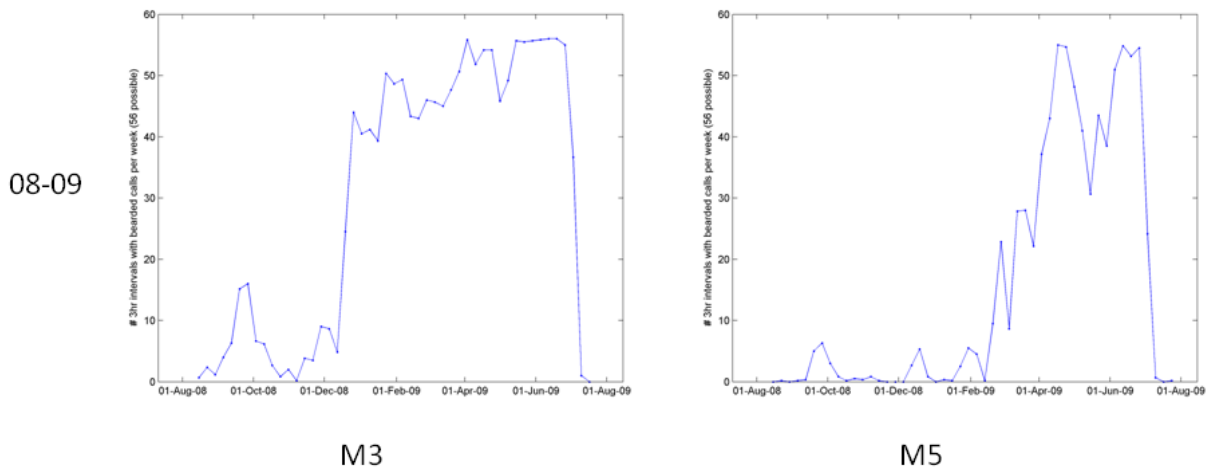


Figure II-7. Results of bearded seal call analysis on the 2008-09 M3 and M5 mooring cluster AURALS. See text for analysis details. Data is presented as number of three-hour intervals with bearded seal calls detected per week (with a maximum of 56 intervals possible per week). The sharp drop-off in July is an actual cessation in calling and not an analysis artifact. This drop off corresponds directly with the seasonal decrease in ice concentration.

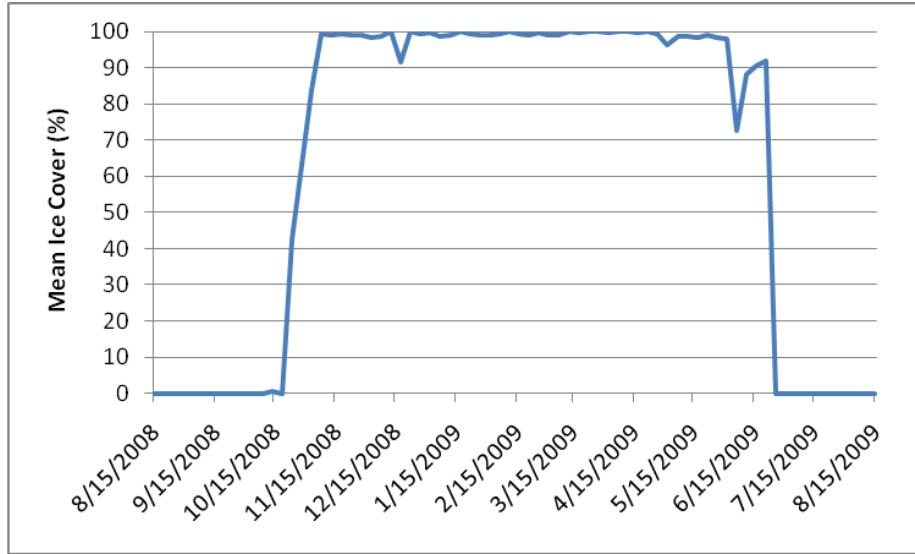


Figure II-8. Mean Ice concentration in 2008-09 at the M5 mooring cluster.

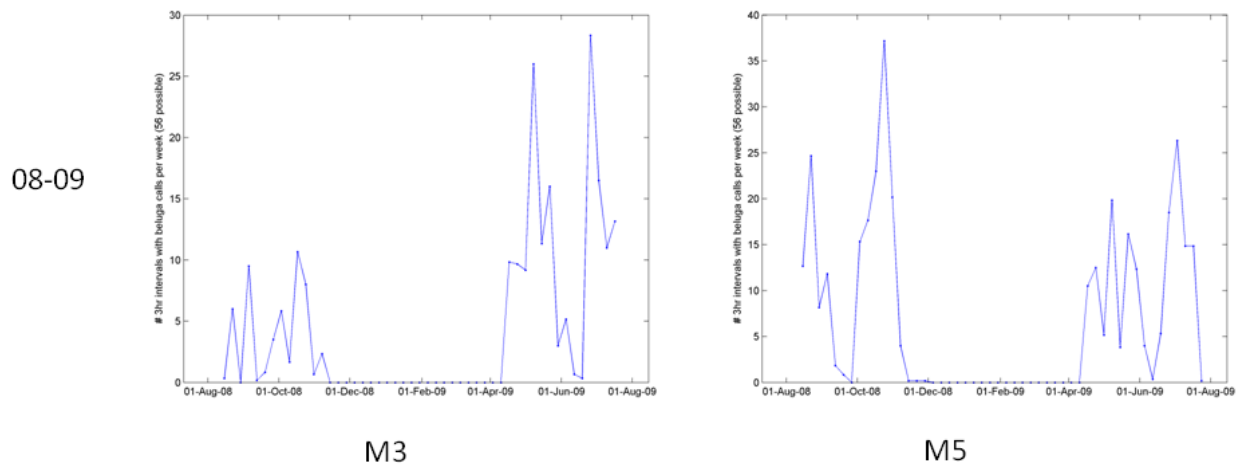
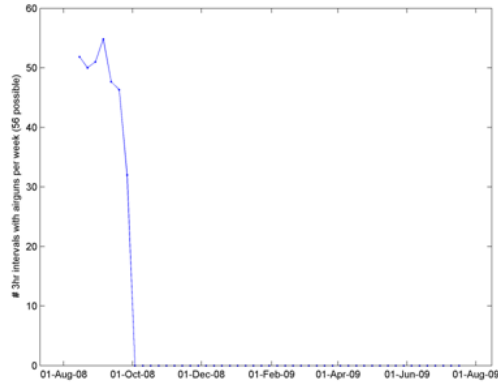
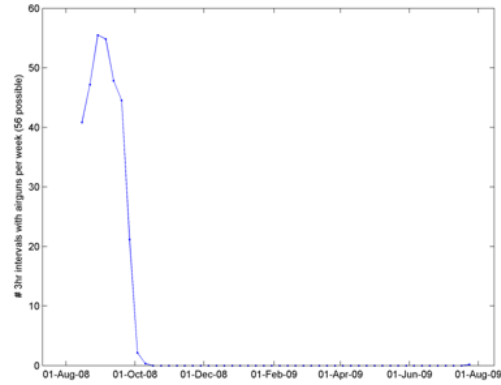


Figure II-9. Results of beluga call analysis on the 2008-09 M3 and M5 mooring cluster AURALS. See text for analysis details. Data are presented as number of three-hour intervals with beluga calls detected per week (with a maximum of 56 intervals possible per week).

08-09



M3



M5

Figure II-10. Results of airgun analysis on the 2008-09 M3 and M5 mooring cluster AURALS. See text for analysis details. Data are presented as number of three-hour intervals with airguns detected per week (with a maximum of 56 intervals possible per week). The sharp drop-off in October is an actual cessation in airgun detections and not an analysis artifact.

SECTION III - MOORINGS AND BROAD-SCALE OCEANOGRAPHY

Carin Ashjian¹, Robert Campbell², and Stephen Okkonen³

¹ Department of Biology, Woods Hole Oceanographic Institution, Woods Hole, MA 02543

² Marine Scientist, Graduate School of Oceanography, University of Rhode Island, Narragansett, RI 02882

³ Institute of Marine Science, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, Fairbanks, AK 99775-7220

Introduction

This was another successful field year for the oceanographic mooring and broad-scale oceanography component. Both programs were greatly enhanced by our companion National Oceanographic Partnership (NOPP) and NSF-supported Arctic Observing Network (AON) projects. This was the final field year of the NOPP project that provided an outstanding ship (USCGC *Healy*) and technical support for the recovery of the two year-round NOPP moorings and deployment of a BOWFEST mooring on the far side of Barrow Canyon. The AON project provided a substantial portion of the operating costs of the R/V *Annika Marie* and of 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.

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*, September 18 & 19, 2010, 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 loaded onto the USCGC *Healy* in Seward, AK in July. The equipment for the shallow water moorings and the CTD was shipped to Deadhorse, AK 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 to Barrow, AK. Oceanography field team members included Carin Ashjian, Bob Campbell, Steve Okkonen, and Phil Alatalo. Arrangements for lodging and transportation in Deadhorse were made by Phil Alatalo. The R/V *Annika Marie* was chartered from Oceanic Research Services, Inc. by WHOI with funds from both BOWFEST and AON. Laboratory, lodging, and staging facilities in Barrow were procured through a paid-for-service agreement with the Barrow Arctic Science Consortium.

MOORING COMPONENT

Stephen Okkonen

Four oceanographic moorings were deployed during the 2010 field season to investigate the relationship between the overlying wind field, local currents, and the presence of zooplankton. Deployment locations are indicated by blue asterisks in Figure III-1. Moorings B-D (Table III-1) were deployed by the R/V *Annika Marie* for the BOWFEST project while Mooring A, deployed by the USCGC *Healy* for the AON project, complements the objectives of the

BOWFEST project. Moorings C and D were recovered during the third week of September near the end of the BOWFEST oceanographic fieldwork near Barrow.

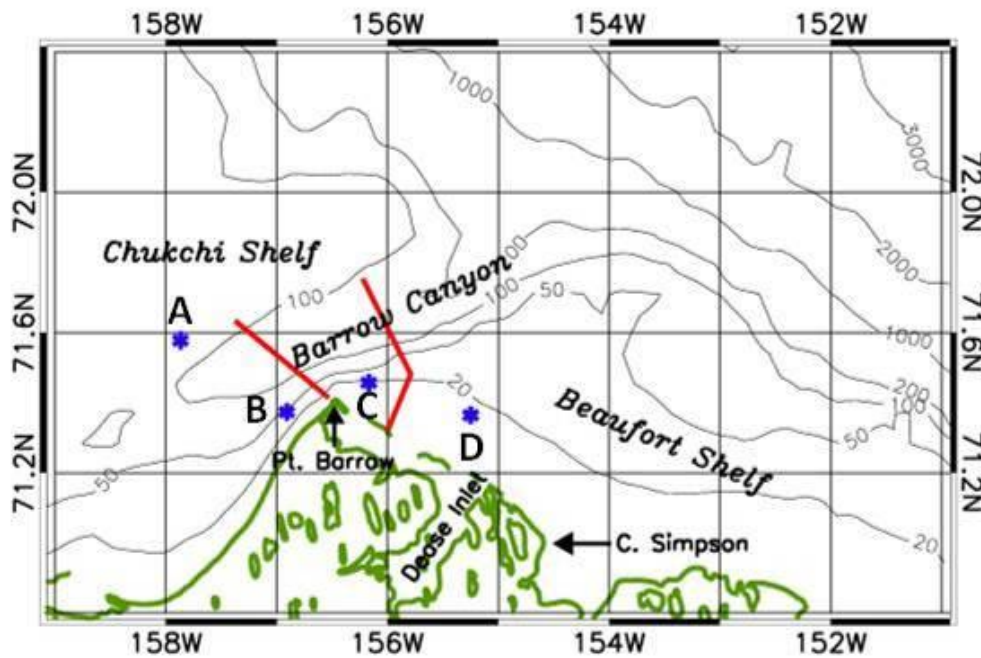


Figure III-1. 2010 oceanographic mooring deployment locations.

Table III-1: Mooring characteristics.

Mooring	Depth	Instrumentation	Deployment	Recovery
A	70m	Current speed & direction, temperature, salinity	10 September 2010	Summer 2011
B	70m	Current speed & direction, temperature, salinity	19 August 2010	Summer 2011
C	15m	Current speed & direction, temperature, salinity	19 August 2010	13 September 2010
D	19m	Current speed & direction, temperature, salinity	18 August 2010	16 September 2010

Initial Results

Moderate-to-strong winds occurred during the shelf mooring deployment period (Fig. III-2). Moderate-to-strong (>5 kts) upwelling-favorable winds (blue vectors in top panel) from the east occurred during most of the week of 21-27 August and during most of the week of 1-7 September. A brief period of weak winds (red vectors top panel) occurred between 29-31 August

and an extended period of generally weak winds occurred during most of the remainder of deployment period for moorings C and D (8-16 September).

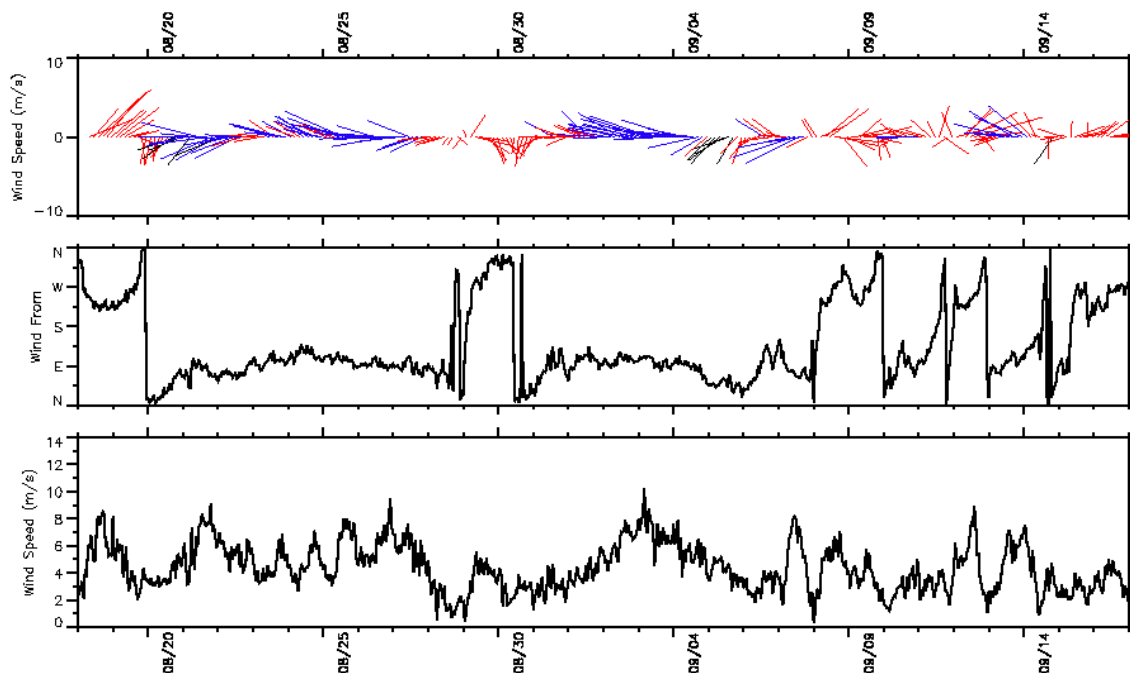


Figure III-2. Winds at Barrow in 2010, showing vectors (top), direction (middle), and speed (bottom). Blue vectors depict winds that promote upwelling onto the western Beaufort shelf. Red vectors depict weak wind conditions that lead to aggregation of krill on the western Beaufort shelf.

Figure III-3 shows a map of the salinity field at 10-m depth as determined from multiple CTD (conductivity-temperature-depth) casts taken (9-13 September) during this extended weak-wind period. A tongue of somewhat lower salinity water is seen to encounter more saline waters along the barrier islands of Elson Lagoon. The location of mooring D (red diamond) is seen to lie within the salinity front. Because fronts are convergence zones, the presence of krill at the mooring D location during this weak-wind period might be expected.

Figure III-4 shows this to be the case. This time series of relative acoustic backscatter within the water column above mooring D shows well-defined occurrences of diel vertical migration (DVM; elevated acoustic backscatter centered on celestial midnight) of zooplankton during 7-13 September. The occurrence of krill on the Beaufort shelf during this weak wind period is consistent with our conceptual ‘krill trap’ model.

Interestingly, the apparent low numbers of krill (much weaker DVM events) during the weak wind period 28 August-1 September and no prior local reports of krill washup events during the summer suggest that krill had not yet been advected to the Barrow area.

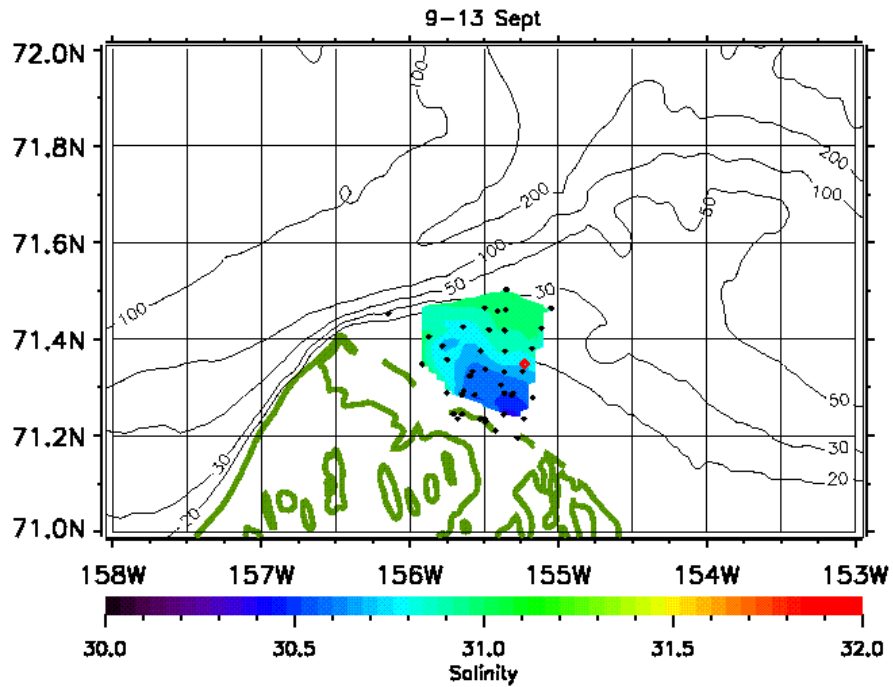


Figure III-3. Map of salinity at 10-m depth for the period 9-13 September 2010. The location of mooring D is shown by the red diamond. Black diamonds show the locations of CTD casts from which the salinity measurements were acquired.

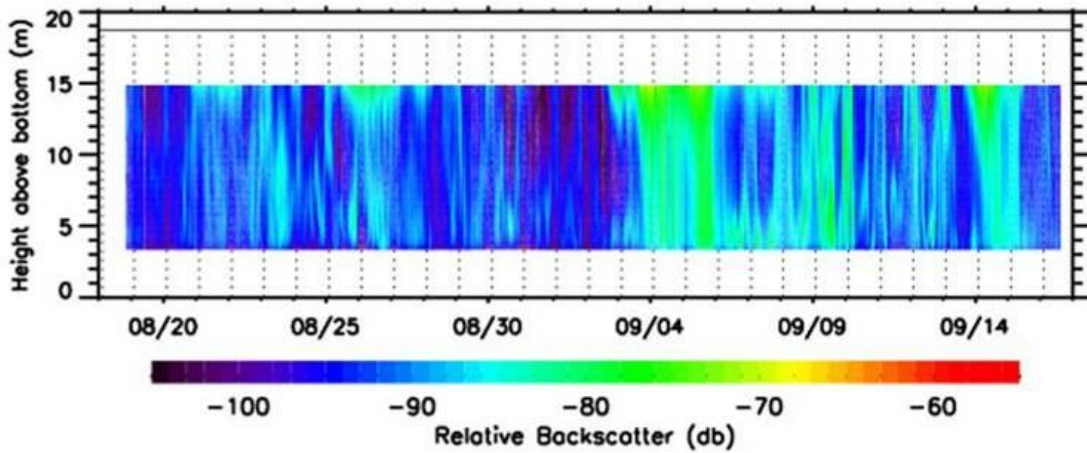


Figure III-4. Relative acoustic backscatter at mooring site D. Vertical dotted lines indicate celestial midnight. Elevated relative acoustic backscatter signals centered on celestial midnight are indicative of diel vertical migration of zooplankton.

BROAD-SCALE OCEANOGRAPHY COMPONENT
Carin Ashjian, Robert Campbell, and Stephen Okkonen

The charter for the R/V *Annika Marie* was August 17-September 20, 2010, with the end date weather dependent (Table III-2). Six working days and 6 weather days, and mobilization days, expenses, and transit days were supported by our companion AON project. The boat transited from Prudhoe Bay on August 18-19 and returned to Prudhoe Bay on September 18. Mobilization of equipment to/from the boat in Barrow was accomplished on August 20 and September 17, respectively and in Prudhoe Bay on August 17 and September 19. From August 21-September 17, there were 14 working days and 14 weather days.

Table III-2: R/V Annika Marie hours on the water by activity and participants.

Date	Hours	Comment	People
17 Aug	0	Mob	Campbell, Okkonen, Kopplin, D'Aoust
18-Aug	11	Transit	Campbell, Okkonen , Kopplin, D'Aoust
19-Aug	7	Transit	Campbell, Okkonen , Kopplin, D'Aoust
20-Aug	0	Mob Barrow	
21-Aug	12	Line 2	Campbell, Okkonen , Kopplin, D'Aoust, Ashjian, Alatalo, Morgan
22-Aug	4	Line 4 (failed)	Campbell, Okkonen , Kopplin, D'Aoust, Ashjian, Alatalo, Morgan, L. George
23-Aug	13.5	Line 4	Campbell, Okkonen , Kopplin, D'Aoust, Ashjian, Alatalo, Morgan
24-Aug	15	Line 1	Campbell, Okkonen , Kopplin, D'Aoust, Ashjian, Alatalo, Morgan
25-Aug	0	Weather	
26-Aug	0	Weather	
27-Aug	0	Weather	
28-Aug	0	Weather	
29-Aug	11.5	Line 2	Campbell, Okkonen , Kopplin, D'Aoust, Ashjian, Alatalo, Morgan
30-Aug	18	Line 6	Campbell, Okkonen , Kopplin, D'Aoust, Ashjian, Alatalo, Morgan
31-Aug	8	Line 2	Campbell, Okkonen , Kopplin, D'Aoust, Ashjian, Alatalo
1-Sep	0	Weather	
2-Sep	0	Weather	
3-Sep	0	Weather	
4-Sep	0	Weather	
5-Sep	0	Weather	
6-Sep	1	Work	Campbell, Okkonen , Kopplin, D'Aoust, Ashjian, Alatalo, Morgan
7-Sep	0	Weather	
8-Sep	13.5	Line 4	Campbell, Okkonen , Kopplin, D'Aoust, Ashjian, Alatalo
9-Sep	14	Lines 5 & 6	Campbell, Okkonen , Kopplin, D'Aoust, Ashjian, Alatalo
10-Sep	13	Lines 5 & 6	Campbell, Okkonen , Kopplin, D'Aoust, Ashjian, Alatalo
11-Sep	8	Inshore	Campbell, Okkonen , Kopplin, D'Aoust, Ashjian, Alatalo, Suydam
12-Sep	0	Weather	
13-Sep	11.5	Mooring	Campbell, Okkonen , Kopplin, D'Aoust, Ashjian, Alatalo
14-Sep	0	Weather	
15-Sep	0	Weather	
16-Sep	12	Mooring	Campbell, Okkonen , Kopplin, D'Aoust, Ashjian, Alatalo, Moore, C. George
17-Sep	7.5	Line 4, Plover	Campbell, Okkonen , Kopplin, D'Aoust, Ashjian, Alatalo, DeSouza
18-Sep	12	Transit	Campbell, Okkonen , Kopplin, D'Aoust

Three moorings were deployed on August 18 and 19; one each was recovered on September 13 and 16 (see mooring section). Surveys concentrated on three sampling lines that had been sampled during 2005-2009, with complete or partial surveys of Line 1 (once), Line 2 (three times), Line 4 (three times), Line 5 (once), and Line 6 (twice) (Fig. III-5). One of the samplings of Line 2, on September 1, was conducted at night to sample in darkness. Line 1 sampling is also a component of the 2010 Distributed Biological Observatory repeat transect sampling (designed by an international group of researchers as a means to gain repeated sampling at a common location). Additional sampling off of the lines was conducted inshore along the Elson Lagoon Barrier Islands and near where feeding bowhead whales were observed. From August 19 – September 6, Tawna Morgan from ABR Inc. accompanied us to collect underway bird and mammal observations. We also were able to bring several Barrow scientists (Craig George, Robert Suydam, Leandra DeSouza), Sue Moore from NOAA, and a local college student (Luke George) out for a day trip each (Table III-2).

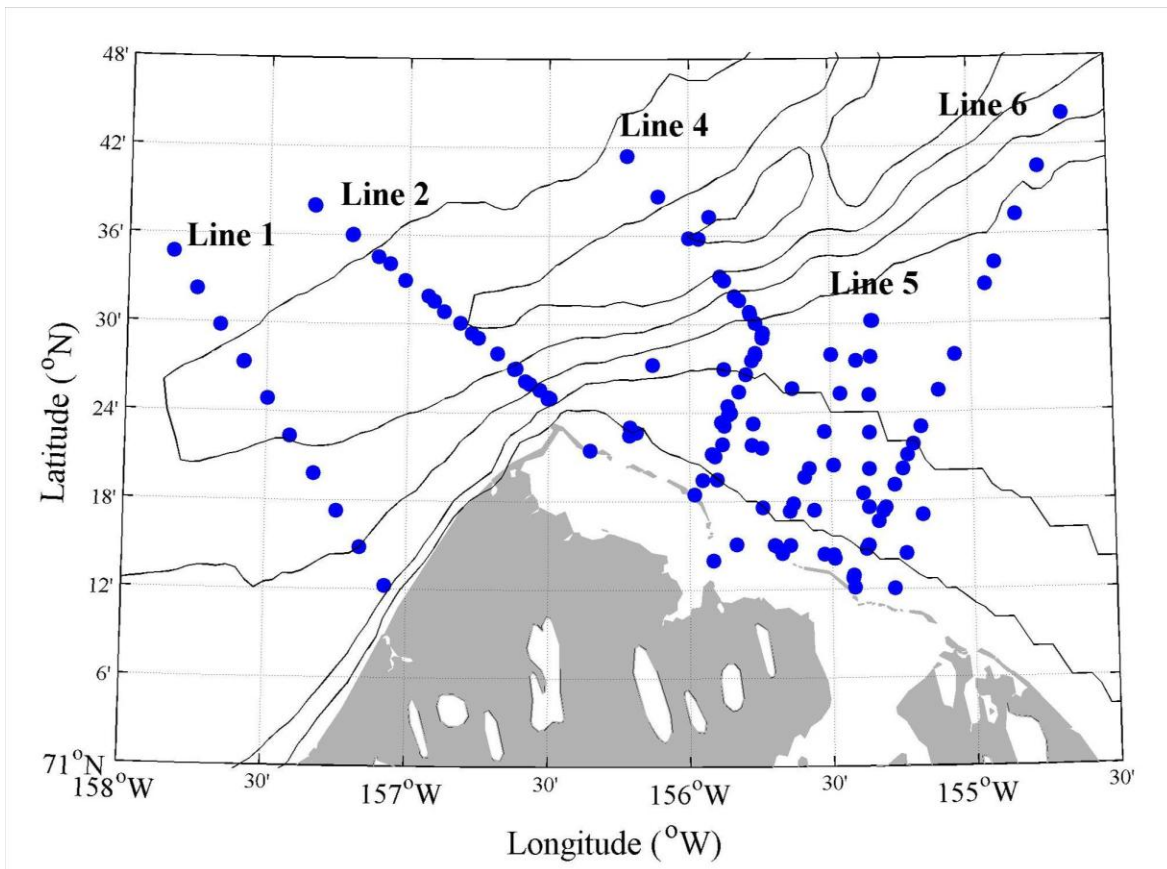


Figure III-5. Locations of stations sampled in 2010. Underway sampling using the Acrobat towed vehicle and the ADCP also was conducted on the outbound legs of most samplings of Lines 2, 4, and 6. Line 1 was included as a component of the international 2010 Distributed Biological Observatories.

The oceanographic sampling was highly successful. One hundred twenty-six (126) stations were sampled, 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. Sampling at discrete stations was conducted using a CTD, ring nets, a Tucker Trawl, and Niskin bottles to collect water samples for determination of chlorophyll *a* and nutrient concentrations, for flow cytometry analyses to enumerate the abundances of phytoplankton and coccoid cyanobacteria (an indicator of Pacific Water), and for microscopic analysis for microplankton composition and abundance (a component of our companion NSF-funded Arctic Observing Network project). Bird (August 19-September 6) and marine mammal (entire period) distributions were also recorded.

Plankton composition from a subset of the ring net tows is presently being enumerated. A subset of the Tucker trawls has been analyzed using silhouette analysis (Davis and Wiebe, 1985) for krill abundance, size distribution, and biomass. Additional samples will be analyzed in the coming months. Samples for extracted chlorophyll concentration have been analyzed and can be used to ground-truth the fluorescence measurements from the CTD and Acrobat fluorometers. As part of our AON project, samples for nutrient concentration and microbial composition and concentration have been analyzed; samples for microzooplankton composition and abundance are in the process of being analyzed.

Preliminary Results

Considerable interannual variability in physical and biological oceanography has been observed between the six years of our observations. In particular, this year saw quite warm water but lower abundances of krill on the shelf and high abundances of chaetognaths, ctenophores and medusae, and small copepods. Defining and understanding this variability and how it is associated with larger scale atmospheric and oceanographic conditions is critical to achieving a better understanding of the importance and persistence of the western Beaufort Shelf as a feeding environment for the bowhead whales during their fall migration.

Ocean temperatures this year were similar to those observed during 2005 (Fig. III-6), with warmest ocean temperatures at ~8°C. 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 six years (2005-2010) (Fig. III-6). The 2005, 2007, 2009, and 2010 surveys encountered very warm Pacific Water (>>4 °C), 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; meltwater was also observed in 2008 but not significantly in the other four years.

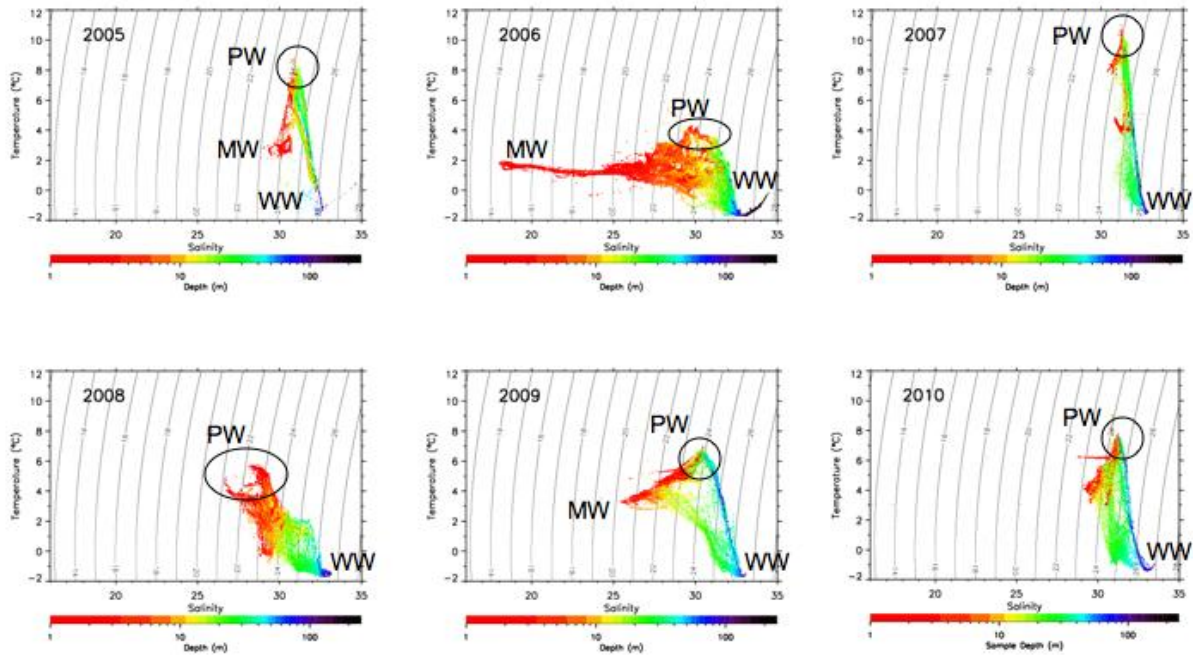


Figure III-6. Temperature-Salinity plots of each year's aggregate (Acrobat and individual cast) CTD data. Representative water masses are Pacific Water (PW), Winter Water (WW), and Meltwater (MW). Curved lines are isopycnals (constant σ_t). Color indicates water depth at each data location.

Variable ocean conditions were also observed during this summer's field season. A comparison of hydrographic conditions along Line 4 (Fig. III-7) shows that the isotherms and isohalines were generally steeper over the southern flank of Barrow Canyon during the occupation of this line on September 8 than on August 23. As such, this indicates that northeastward flow associated with the ACC was somewhat stronger at the time of the September 8 sampling. In the September sections, water on the inner shelf is seen to be relatively cooler and less saline than water on the middle to outer shelf, with warmer Pacific water on the middle to outer shelf. This salinity gradient is also observed in the Figure III-3 salinity map.

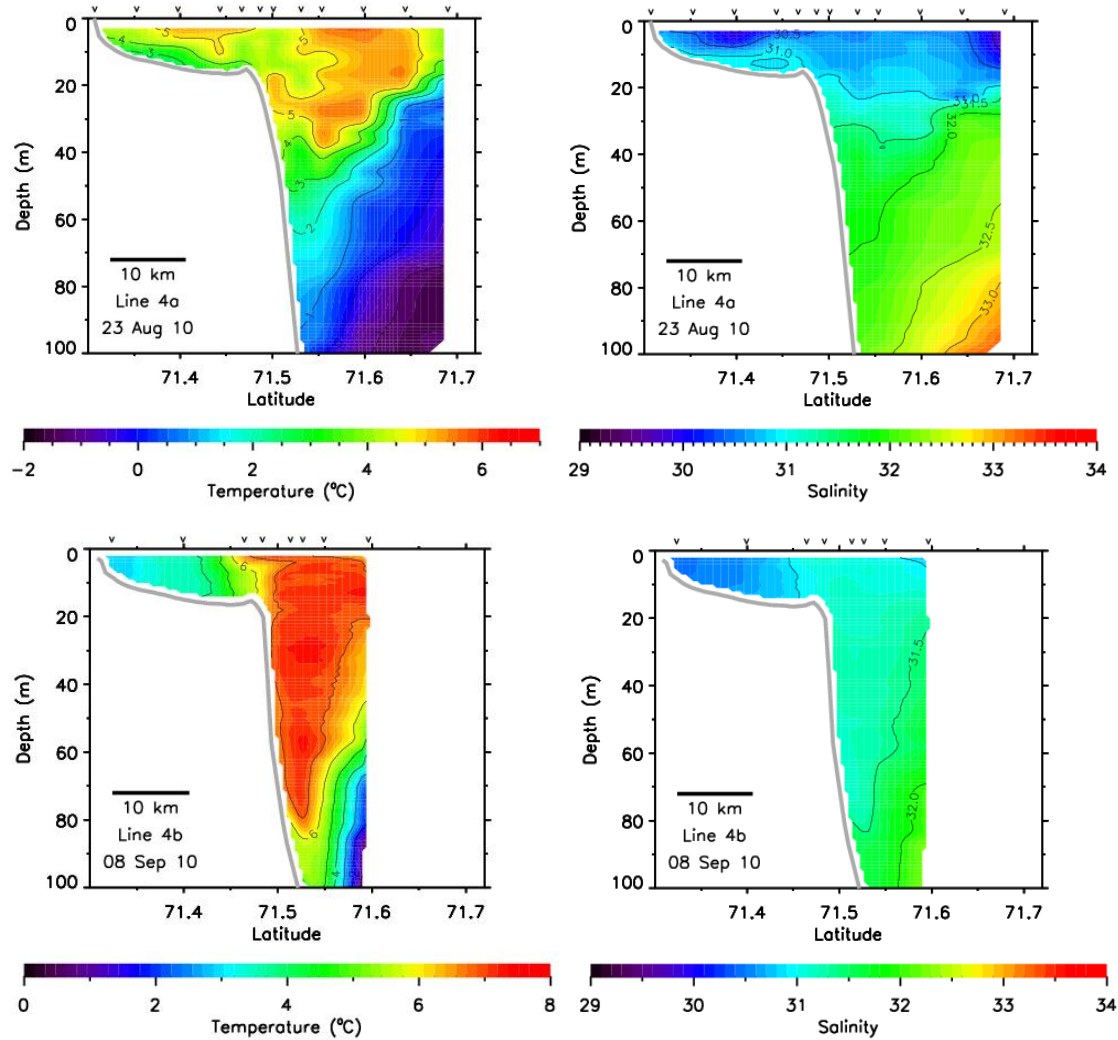


Figure III-7. Temperature and salinity sections across Line 4 from August 23 (upper row) and September 8 (lower row), 2010.

As noted above, several upwelling events occurred during the sampling period that would be expected to bring high abundances of krill onto the shelf (Fig. III-2). However, high abundances of krill were not, qualitatively, observed on the shelf through much of the sampling period. Only during the last 10 days (September 7 and on) were krill collected on the shelf in any abundance. This corresponds to the pattern deduced from diel vertical migration (DVM) in the moored ADCP record (Fig. III-4), where significant DVM was observed starting in September. The plankton community was notable in that it contained high abundances of chaetognaths, ctenophores, small copepods, and medusae. Even when krill did become abundant, medusae and ctenophores were still very abundant and dominated the plankton biomass at many locations.

The high abundances of ctenophores/medusae also precluded use of the towed ADCP to detect layers of krill since backscatter from ctenophores/medusae and krill cannot be reliably

differentiated. At locations where bowhead whales were observed feeding on the shelf, particularly on September 13-17, krill were collected but ctenophores/medusae remained abundant. We speculate that low transport of Bering Sea water, and intrinsic krill, northwards may have delayed the arrival of substantial numbers of krill in the Barrow region until later in September.

Feeding bowhead whales were observed on several occasions and we were able to sample in their vicinity. Analysis of these plankton samples presently is ongoing. In support of Linda Vate Brattström's poster for the Alaska Marine Science Symposium, plankton samples collected near whales on September 11 (when echelon formations of surface feeding bowhead whales were observed to the north of Cooper Island) have been analyzed. The whales were observed feeding within relatively cold shelf water. Krill also were observed in abundance in the cold shelf water. Based on these limited data, and on qualitative examination of the samples, krill abundance appears to be lower in the warm, Pacific Water located on the western end of the shelf and along the shelf break (Fig. III-8). Analysis of plankton samples is ongoing and further refinement of these observations will be possible in the near future.

September 11, 2010- Total Water Column Abundance of Krill

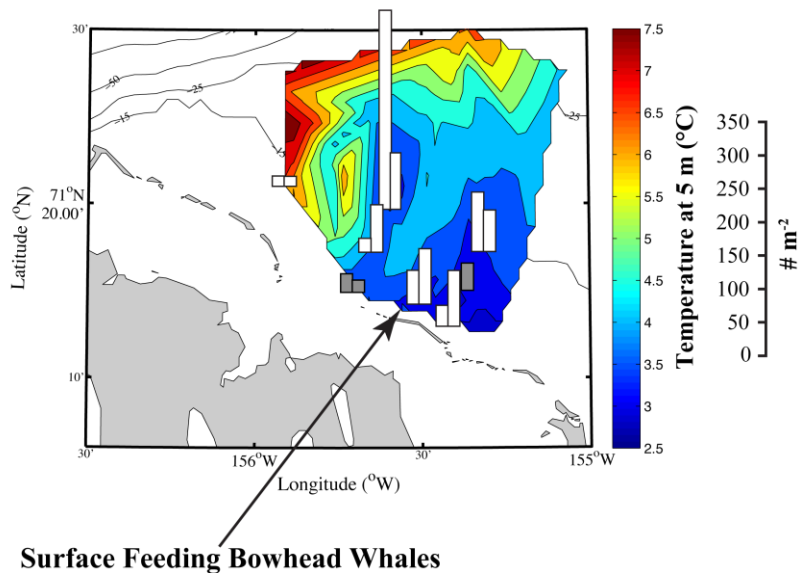


Figure III-8. Water column abundances of krill sampled on Sept. 11, 2010 when echelon feeding bowhead whales were observed during oceanographic sampling. Water temperature at 5 m depth is shown as the colored contours. Stations where abundant krill furcilia (smaller, younger stages) were observed are indicated with the gray histograms; stations where furcilia were rare and where most krill were larger juvenile or adult stages are shown in white. At many locations, abundance estimates from two nets are shown, demonstrating high small-scale spatial variability. At the whale feeding location, krill were distributed uniformly throughout the water column (not shown). Whales were observed feeding in cold, fresh shelf water where krill also were abundant, with fewer krill in the relatively warm, salty water of Pacific origin to the western end of the region. Qualitative examination of samples still to be analyzed indicates that this pattern is consistent across the shelf. Samples were collected with a $\frac{1}{4}$ m² Tucker Trawl equipped with 333 and 500 μ m mesh nets.

Other Activities

In addition to the fieldwork and ensuing data analysis, the team has presented results of the research in several forums throughout the year. A presentation focusing on the 2005 and 2006 SNACS (Study of the Alaskan Coastal System) project that included results from BOWFEST work as well was made at the international State of the Arctic Meeting that was held in Miami, FL in March 2010 and that was attended by national and international scientists, program managers, and policy makers (Ashjian et al. 2010a). Aspects of the research were included in an analysis of inter-annual variability in ocean conditions (both biology and physics) near Barrow that was presented orally (Ashjian et al. 2010b) to an audience of over 100 national and international scientists and as posters (Okkonen et al. 2010a,b) at the 2010 Ocean Sciences Meeting in Portland, OR and 2010 American Geophysical Union Fall Meeting in San Francisco, CA. An updated oral presentation will be made at the Arctic Session of the Alaska Marine Science Symposium on January 19, 2011 (Ashjian et al. 2011). A poster describing recent hypotheses regarding the source of krill near Barrow will be presented at the Alaska Marine Science Symposium on January 18, 2011 (Okkonen et al. 2011). Ashjian also was invited to present results from the entire BOWFEST program at the mid-summer quarterly meeting of the Alaska Eskimo Whaling Commission in Fairbanks AK.

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SECTION IV - TAGGING AND FINE-SCALE OCEANOGRAPHY

Mark Baumgartner

Department of Biology,
Woods Hole Oceanographic Institution,
Woods Hole, MA 02543

Introduction and Methods

Our objectives for the 2010 fieldwork were to (1) attach archival tags to bowhead whales, and (2) intensively sample oceanographic conditions and prey distribution in proximity to the tagged whales. Two vessels were used for this operation, one for each objective: (1) a small ~20 ft boat contracted by BASC (the tagging boat, driven by Lewis Brower or Billy Adams), and (2) the MMS *Launch 1273*. As in 2009, we used a dermal attachment short-term tag developed specifically for this project (Fig. IV-1).

The new tag was designed to overcome: (1) difficulties in approaching bowheads at close enough range for tagging, and (2) irregularities in the skin that made suction-cup tags ineffective. The new tag is fired from a compressed-air launcher instead of using the older pole deployment method, which increases the range of deployment considerably. The attachment consists of a solid core needle that is designed to implant in the epidermis and blubber. The implanted needle acts as an anchor for the recoverable archival tag that is attached to it via a severable tether. The tether passes through a corrosive foil release that is designed to allow detachment of the tag from the anchor after a specified time (1-3 hours). After attachment, the tagged whale is tracked via a high-frequency pinger incorporated in the tag and a hand-held directional hydrophone and receiver used to provide bearing and approximate distance to the pinger from the tagging boat. When the whale surfaces, the position is noted by the tagging boat, radioed to the *Launch 1273*, and a cast is conducted at that position with a vertical profiling instrument package consisting of a conductivity-temperature-depth instrument, chlorophyll fluorometer, turbidity sensor, and a video plankton recorder.

Results

Field operations for tagging and fine-scale oceanography took place from August 18 to September 21, 2010. During 15 days at sea, we tagged 8 bowhead whales, 6 of which had attachments lasting between 45 minutes and 2.3 hours (Table IV-1). A total of 42 casts with the vertical profiling instrument package were conducted in proximity to the tagged whales (Table IV-1). The tagged whales tended to travel over relatively large distances while tagged, ranging from 7 to 21 km (Fig. IV-2; Table IV-1). Swimming speeds during these events ranged from 3.2 to 4.9 knots. While some of the tagged whales remained very close to the surface while traveling (e.g., events 8 and 10; Fig. IV-3), others made repeated dives to the sea floor (e.g., events 6, 7, and 9; Fig. IV-3). Event 6 was notable both for the total distance traveled as well as the amount of time the whale spent at depth. This whale was tagged in a large feeding aggregation just off of Plover Point.

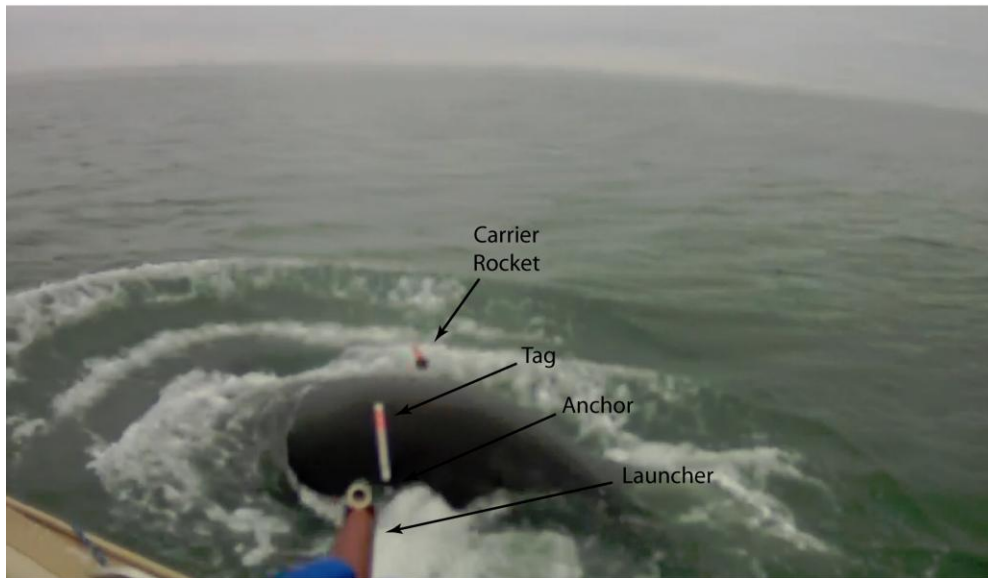


Figure IV-1. (top) Close approach to bowhead whale immediately prior to tagging with short-term dermal attachment tag (event 7). Note launcher in the foreground. (bottom) Successful attachment of projectile dermal attachment tag showing separation of dermal anchor, tag, and carrier rocket after contact with the whale. Images taken from video camera mounted two inches from tagger's right eye.

Table IV-1: Results for each bowhead whale tagged in 2010, including date, attachment duration (in minutes and hours), total distance traveled (in kilometers), average swimming speed (in kilometers per hour and knots), and the number of casts conducted near the tagged whale with the vertical profiling instrument package.

Event*	Date	Duration (min)	Duration (hr)	Distance (km)	Speed (km/hr)	Speed (knots)	No. casts
3	9/9	12	0.2	2.4	6.9	3.7	2
4	9/16	11	0.2	1.7	5.9	3.2	2
5	9/16	65	1.1	11.0	8.2	4.4	5
6	9/17	137	2.3	21.3	9.0	4.9	10
7	9/17	45	0.8	6.5	5.8	3.2	5
8	9/18	88	1.5	13.8	9.0	4.8	6
9	9/18	129	2.2	17.8	8.0	4.3	7
10	9/19	116	1.9	15.1	6.8	3.7	5
Total/Average:		603	10.2	89.6	7.5	4.0	42

*Events 1 and 2 were gray whales.

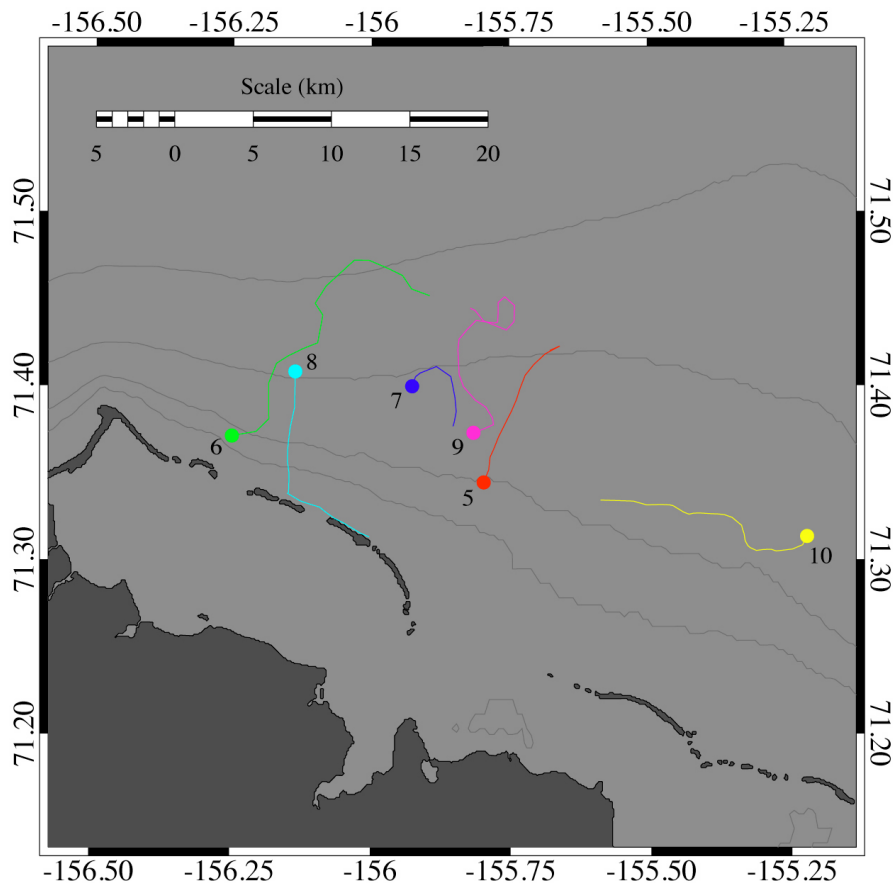


Figure IV-2. Map of tagging locations and tracks of the 6 tagged whales for which the tag remained attached for 45 minutes or more. Tagging events are labeled next to tag attachment location (filled circle).

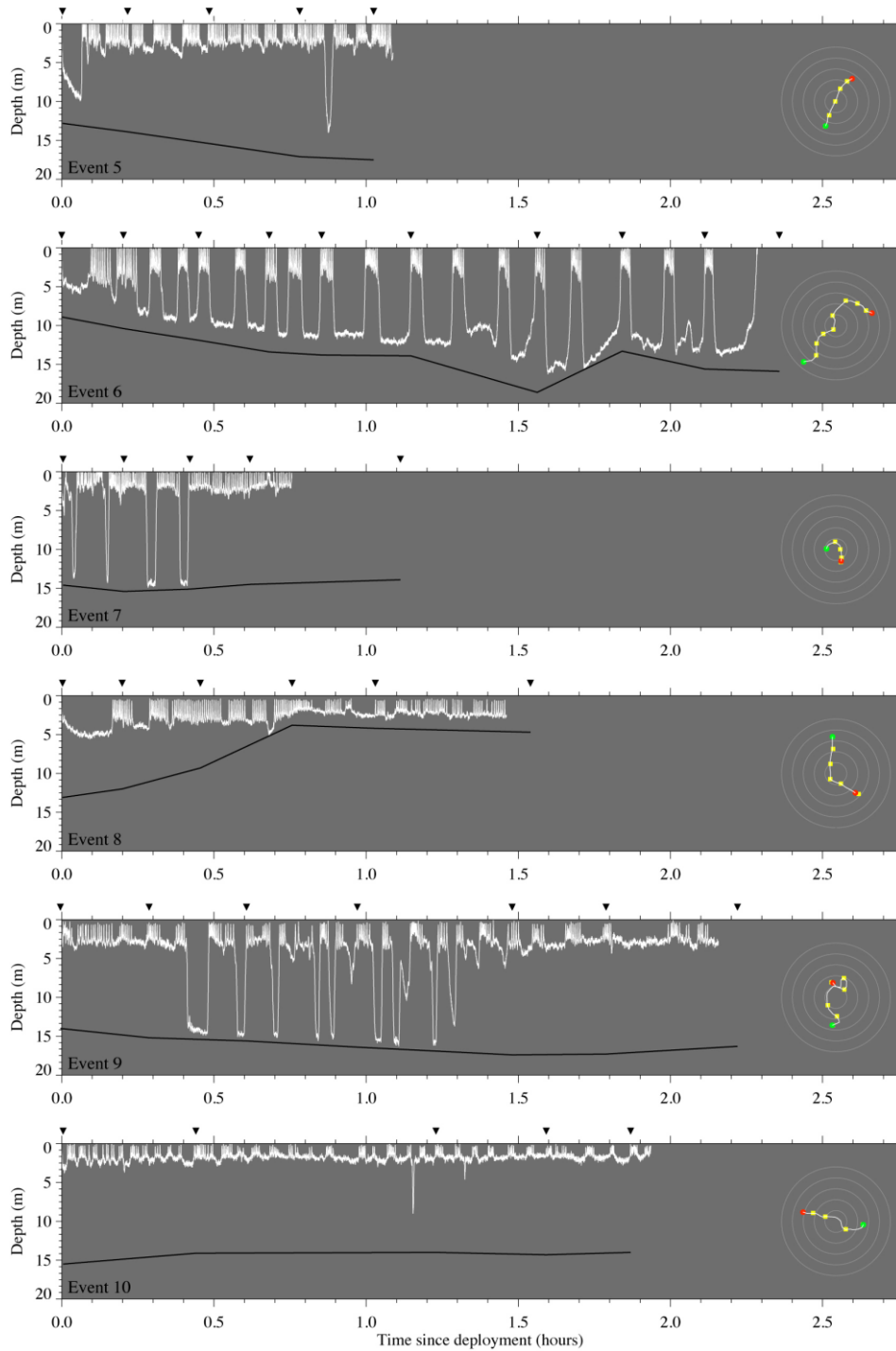


Figure IV-3. Dive behavior of 6 tagged whales for which the tag remained attached 45 minutes or longer. Dive profile is shown as a white line and the sea floor is shown as a black line. The movements of the tagged whales are also shown in the inset map to the right (tagging location indicated with a green dot, tag detachment location indicated with a red dot, and the circles are shown in 2 km increments). Times and locations of vertical profiles shown as inverted triangles above the time series plot, and as yellow squares in the inset map.

Upon tagging, it began traveling to the north-northeast with several other animals. During the entire time we tracked the animal, it was traveling in the same direction as other animals nearby (within ~1 mile) as well as several animals well ahead of the tagged animal. These observations have led us to hypothesize that bowheads sometimes travel in acoustically coordinated groups that spread out over many miles of ocean, and each animal in the group “prospects” for highly aggregated patches of prey. The diving pattern observed during event 6 appears to be searching behavior, and presumably the animals within several miles of the tagged animal were conducting similar searches of their own. We hypothesize that when a highly concentrated prey patch is found, the whale acoustically advertises this to nearby animals, thus forming the aggregations of tens of bowheads that were observed on several occasions by both the BOWFEST ships and aircraft.

It is unlikely that any of the tagged bowhead whales were actively feeding during the time we tracked them. Observations from the video plankton recorder collected in proximity to the tagged whales indicated that zooplankton abundance was quite low. Gelatinous zooplankton (e.g., hydromedusae and ctenophores) were more abundant near the tagged whales (Fig. IV-4), but they were also numerically more abundant than euphausiids and large copepods across the entire study area (see results of broadscale oceanography component). The abundance of euphausiids and large copepods, the two main prey items of bowheads on the Beaufort Sea shelf, were well below concentrations that could be considered profitable for a feeding whale (Fig. IV-5). From the diving and movement behavior of the tagged whales, there was no evidence of bowheads feeding on any of these taxa during the tagging events. Bowhead whale movements did not appear to be associated with any fine-scale oceanographic features on the shelf (Fig. IV-6). Colder and fresher conditions prevailed to the east (events 5, 9 and 10), and warmer saltier water likely of Pacific origin (see broadscale oceanography results) were predominant in the western part of the study area (events 6 and 8); however, the tagged whales were found in both of these conditions and in some cases, crossed over the boundary between these two water masses (events 7, 8 and 9). Both along-shelf (event 10) and cross-shelf (events 5, 6 and 9) movements were observed (Fig. IV-2).

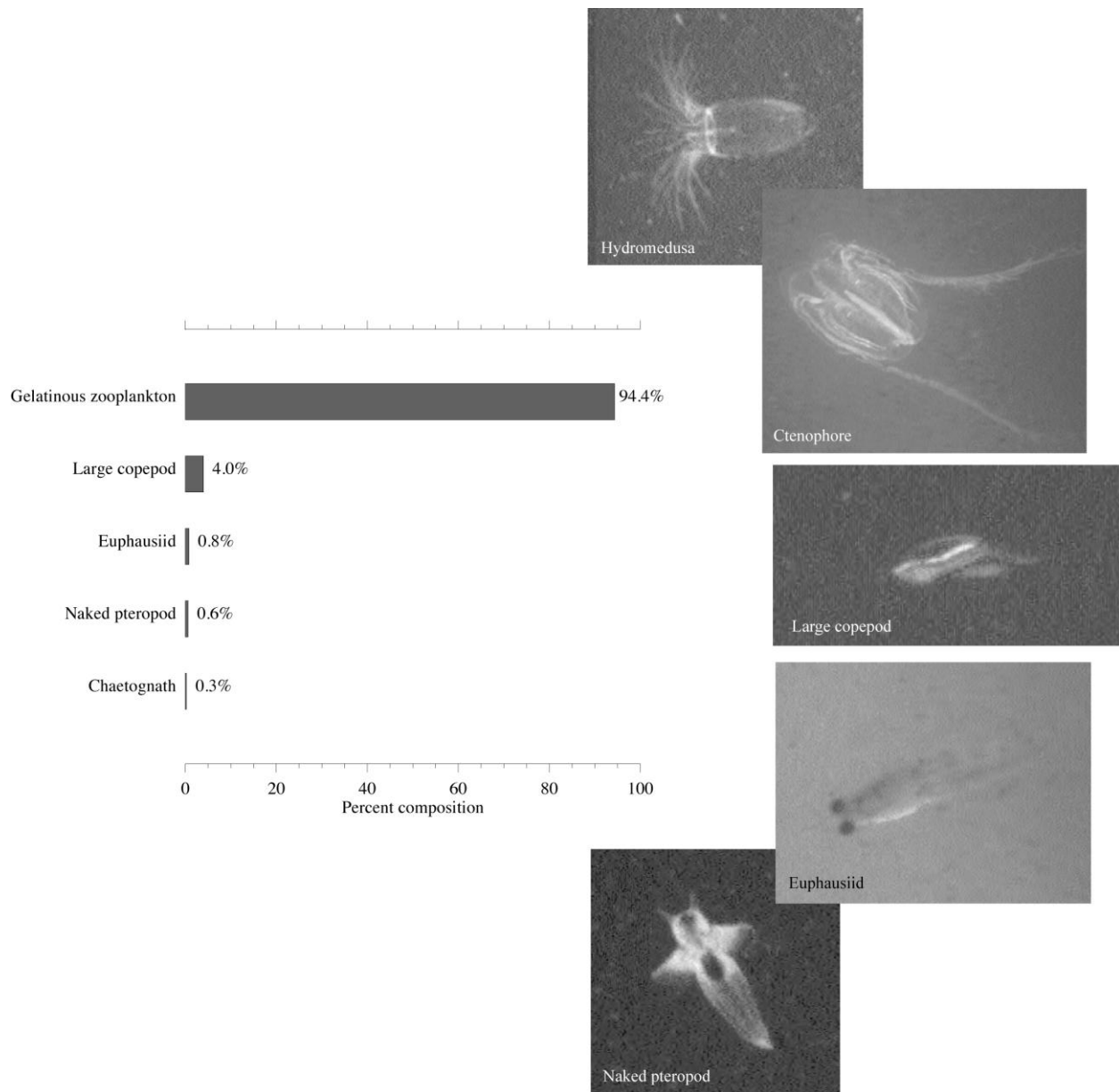


Figure IV-4. Zooplankton community composition near tagged bowhead whales in September 2010 off Barrow, Alaska derived from video plankton recorder (VPR) casts. Images from the VPR representing most taxa are shown (gelatinous zooplankton include hydromedusae, ctenophores, and jellyfish). Images not shown at similar scales.

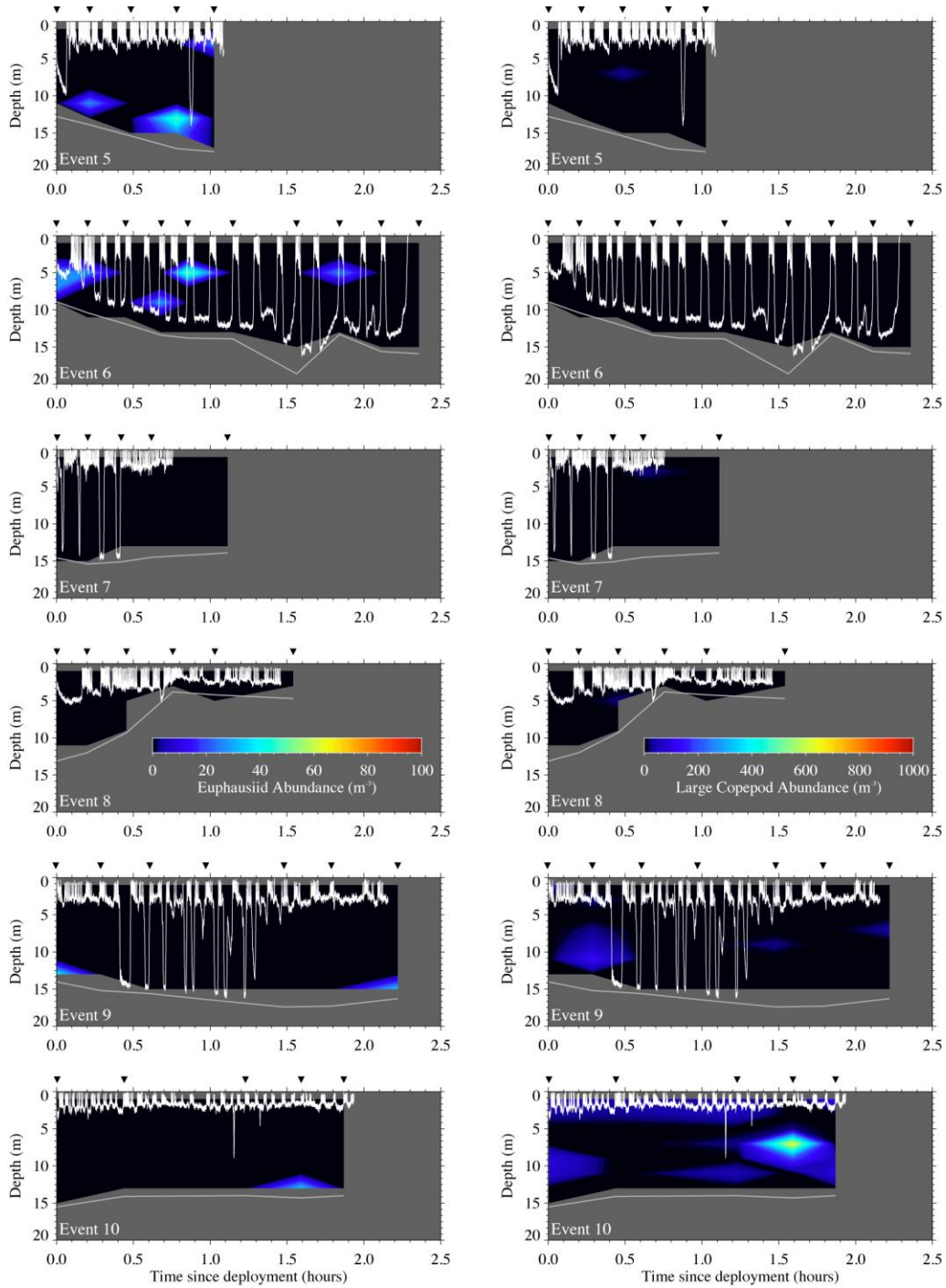


Figure IV-5. Dive profiles for each tagging event as shown in Figure IV-3 with the abundance of euphausiids (left panels) and large copepods (right panels), the main prey of bowhead whales in the Beaufort Sea, shown in color. Note that low prey abundance and a complete lack of correspondence between diving behavior and prey distribution suggests none of the tagged whales were actively feeding during the period they were tracked. Times of vertical profiles shown as inverted triangles above each plot.

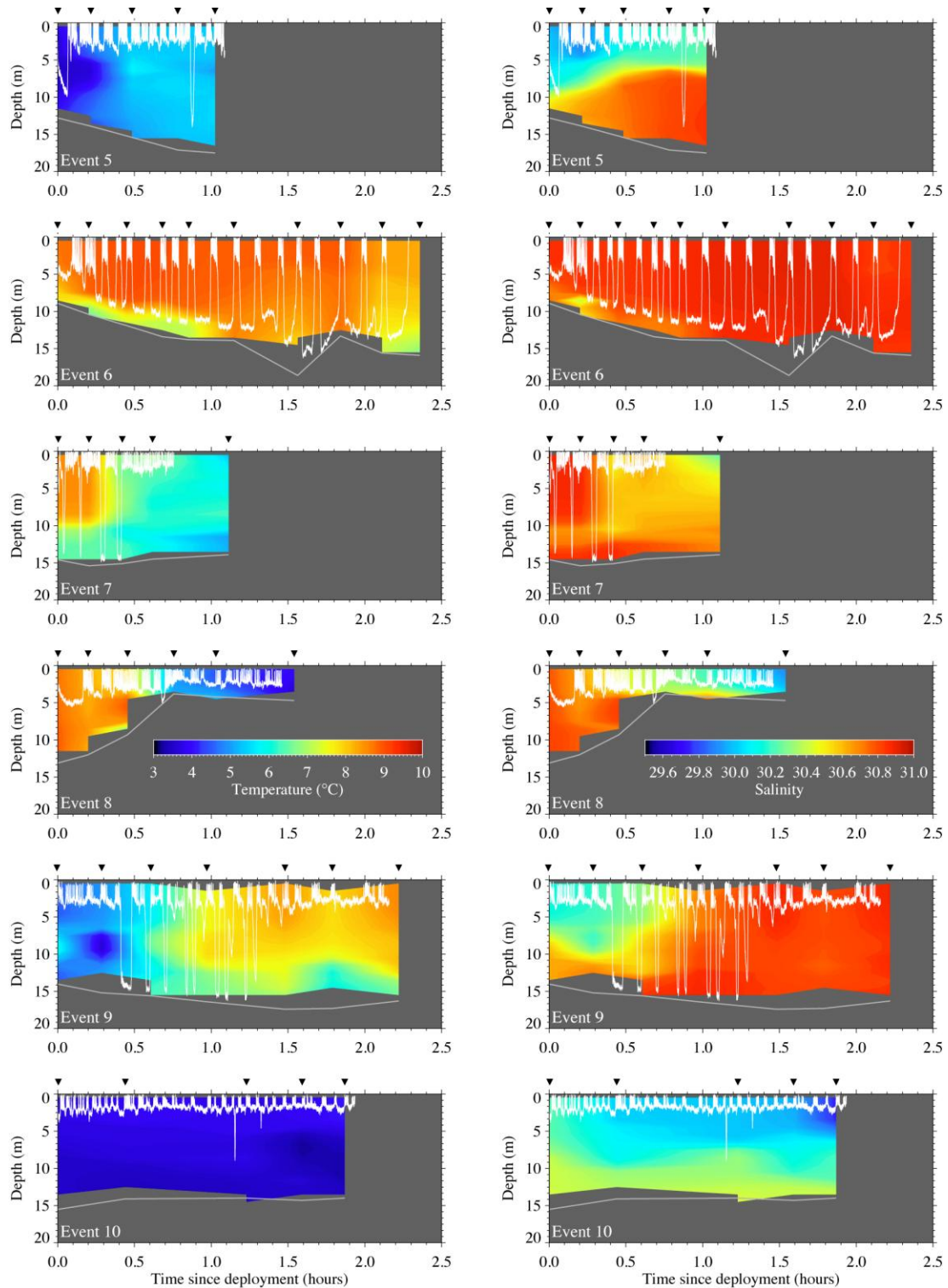


Figure IV-6. Dive profiles for each tagging event as shown in Figure IV-3 with the distribution of temperature (left panels) and salinity (right panels) along the tagged whales' track shown in color. Times of vertical profiles shown as inverted triangles above each plot.

SECTION V - NORTH SLOPE BOROUGH RESEARCH

Craig George¹, Gay Sheffield², and Lara Dehn³

¹North Slope Borough, Department of Wildlife Management

²Alaska Department of Fish and Game

³University of Alaska Fairbanks

Introduction

Bowhead whale feeding studies have been ongoing at Barrow for over 30 years and for six years beginning with the National Science Foundation's (NSF) SNACs (Study of the Northern Alaskan Coastal System) program in 2004 and Bureau of Ocean Energy Regulation, Management and Enforcement (BOEMRE, formerly MMS) funding. Currently BOEMRE 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 and better understand the oceanographic mechanisms and ecology of bowhead feeding in this area. Information from this study will be used by BOEMRE for pre- and post-lease analysis and documentation under the National Environmental Policy Act (NEPA) for Beaufort Sea and Chukchi Sea Lease Sales. The study will also add to the general body of knowledge regarding the feeding ecology of bowheads and other large cetaceans.

The following report details the North Slope Borough (NSB) Department of Wildlife Management's (DWM) activities with the BOWFEST study through fall 2010. The NSB's work includes sampling alimentary tracks of landed whales, boat-based whale surveys, project coordination, logistical assistance, boat-based behavioral observations of feeding whales, and more recently, bowhead digestion and energetics.

Objectives

1. Gather distribution data on bowhead whales in the study area 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.
3. Document locations and basic behavior of feeding whales from a boat-based platform.
4. Document locations and basic behavior of whales in the BOWFEST area using boat-based platform.
5. Conduct a pilot study on bowhead digestive efficiency.

Results

Stomach Examinations 2010

Examinations of stomach contents (and/or feces) of whales harvested by Eskimo hunters were made at the coastal communities of Barrow, Wainwright, and Kaktovik as well as Gambell and Savoonga on St. Lawrence Island (Fig. V-1). Of 36 harvested whales, postmortem exams were conducted on a total of 32 whales and samples from 27 were collected. Sampling was as follows: Barrow (Spring, n=8; Fall, n= 8) and Kaktovik (Fall, n=3), Wainwright (Fall, n=1), and St. Lawrence Island (Spring, n=5; Fall, n=2).



Figure V-1. Coastal communities from which diet samples were collected from subsistence harvested bowhead whales.

Spring 2010

Barrow. Biological examinations were conducted on all 14 whales with 12 examined for evidence of feeding during spring 2010 at Barrow. Spring stomach samples were prepared in the lab and prey grossly identified. Only two whales from Barrow contained any identifiable prey (one with a *Calanus* copepod; one with Arctic cod bones (*Boreogadus saida*)).

Saint Lawrence Island. Intestine and/or stomach contents were collected on 5 out of 8 whales landed during the spring 2010 hunt and a full suite of biological samples were collected. Preliminary examinations of these whales suggested feeding was occurring during spring and fall. Analysis of diet samples from Saint Lawrence whales was not conducted due to budgetary constraints but will be included in subsequent reports.

Fall 2010

Kaktovik. Tissue samples were collected and stomach examinations were conducted on all 3 whales harvested at Kaktovik in fall 2010. Stomach contents were grossly examined in the field and currently remain frozen for further investigation. Of the 3 whales harvested at Kaktovik during 2010, preliminary analysis indicates one whale stomach (10KK1) was empty with >8 liters of clear brown fluid (Fig. V-2) and one stomach (10KK2) contained > 4 liters of dark red liquid, blood clots, sand, and a sand tube casing of the worm *Pectinaria hyperborean*. Of note, hunters reported that the rostrum of 10KK2 was covered in a layer of mud suggesting it was feeding or in an inverted position on the seafloor before it was approached by hunters. The

stomach of the last harvested whale (10KK3) contained the remains of a brittle star and approximately one liter of red fluid with a greasy sheen.

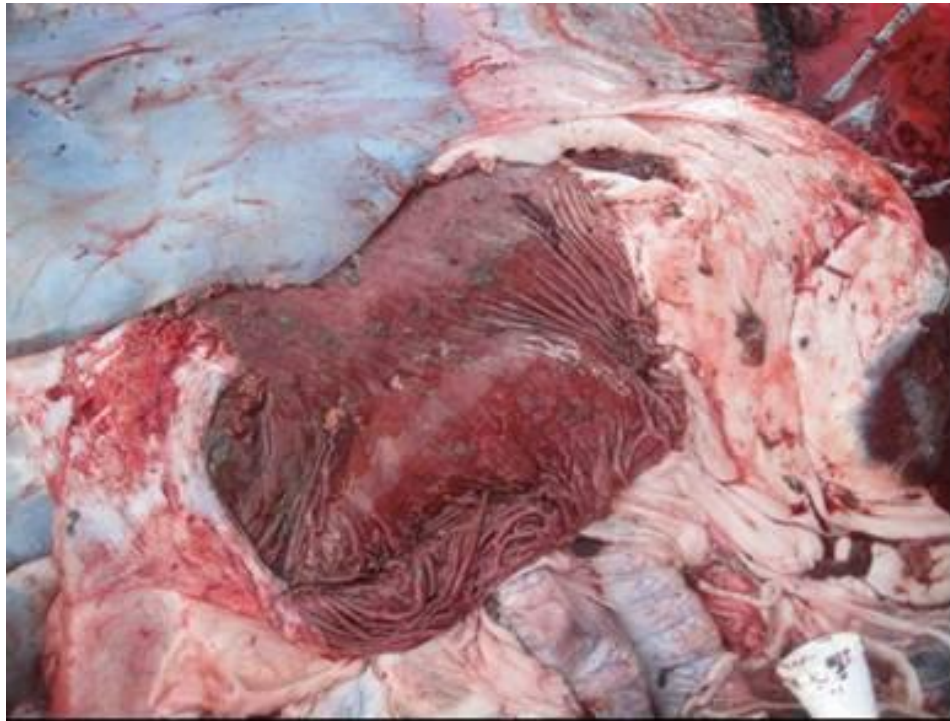


Figure V-2. Photo of stomach from whale 10KK1 which was likely not feeding at the time of death. The stomach contained blood clots, mud, and organic debris. During postmortem exams, it is uncommon for whales harvested Kaktovik to have empty stomachs.

Barrow. At Barrow, 8 whales were landed during the fall 2010 hunt and a full suite of biological samples collected. Preliminary examinations of their stomachs suggested only moderate feeding took place in the Barrow area. Analysis of stomach contents from fall Barrow whales was not conducted due to budgetary constraints but will be conducted in 2011.

Saint Lawrence Island. Intestine and/or stomach contents were collected on 2 whales landed during the fall hunt and a full suite of biological samples were collected. Preliminary examinations of these whales suggested feeding was occurring during spring and fall. Analysis of diet samples from Saint Lawrence whales was not conducted due to budgetary constraints but will be included in subsequent reports.

Feeding status for 2009-2010 at Barrow and Kaktovik

Unlike other villages, since the late 1970s whales have been routinely examined at Barrow and Kaktovik by biologists with regard to feeding status.

Analysis of Barrow bowhead stomachs indicated that in spring of 2009, 2 of 2 whales (100%) examined were feeding, another 2 whales were unexamined. In fall, 13 of 13 (100%) were feeding, however, another 2 whales were unexamined. Of the whales examined during fall of 2009 at Kaktovik, 2 of 3 were feeding (67%) and one whale's status was considered inconclusive with <10 prey items identified.

Analysis of Barrow bowhead stomachs indicated that in spring of 2010, 0 of 12 whales (0%) examined were feeding and 2 (17%) were inconclusive with <10 prey items identified. The stomachs of 2 harvested whales were unexamined. Of the 8 whales examined for evidence of feeding during the fall 2010 harvest at Barrow, 7 (88%) contained some prey, with copepods occurring in at least 5 of those samples. We have no quantitative prey analysis for the fall Barrow stomach examinations; however, the stomachs were relatively empty compared with past fall seasons. Copepods appeared to be the primary prey at Barrow in 2010 unlike most past seasons in which euphausiids were the dominant prey (Lowry *et al.*, 2004).

Of the whales examined during the fall 2010 harvest at Kaktovik, 1 stomach was empty (33%) and 2 (67%) were inconclusive with <10 prey items identified. One of the *most interesting* aspects of the 2010 fall season is the *paucity* of identifiable prey in the stomachs from Kaktovik and, to a lesser extent, Barrow. For whale 10KK2 (Kaktovik), the presence of sand, a worm casing, and a brittle star, as well as the hunter reports of mud on the rostrum suggest a benthic feeding strategy for this animal. Thus, based on stomach examinations, bowhead feeding activity near Kaktovik was relatively modest compared with past seasons.

Another interesting note in 2010 was the fact that Wainwright landed a whale for the first time ever during the fall hunt on 7 October (10WW3, female, 7.5 m). This was the first time within the memory of any living elders that a whale was taken in the fall, it was harvested northeast of the village. Local hunters and a visiting NSB Public Health Office/Veterinary Clinic veterinarian examined and sampled the whale and a stomach sample was obtained. The stomach was full and contained mostly copepods.

Boat Surveys

We collected boat-survey information on date, whale location, number and behavior from a number of sources (Table V-1; Figs. V-3 and V-4). We have records for a total of 64 surveys conducted by the boats associated with the study; however, tracks were not collected for every survey. These included surveys by local boats chartered by the DWM, BOWFEST vessels such as Launch 1273 and R/V *Annika Marie*, and vessels used for the NOAA/NSB gray whale biopsy study. While bowhead sightings were recorded as early as 28 June, BOWFEST-funded local boat surveys were initiated on 27 July and continued through 24 September; these surveys accounted for approximately half (30 of 64) of the survey effort.

Table V-1: Boat surveys for bowhead whales during the summer/fall 2010 season.

Platform	# Surveys
BOWFEST Local Boat Surveys	30
Gray Whale Biopsy/Surveys	13
R/V <i>Annika Marie</i>	8
Launch 1273/Baumgartner	8
UAF (Eichen, Petrich)	4
Local Private Boat (unfunded)	1
Total	64

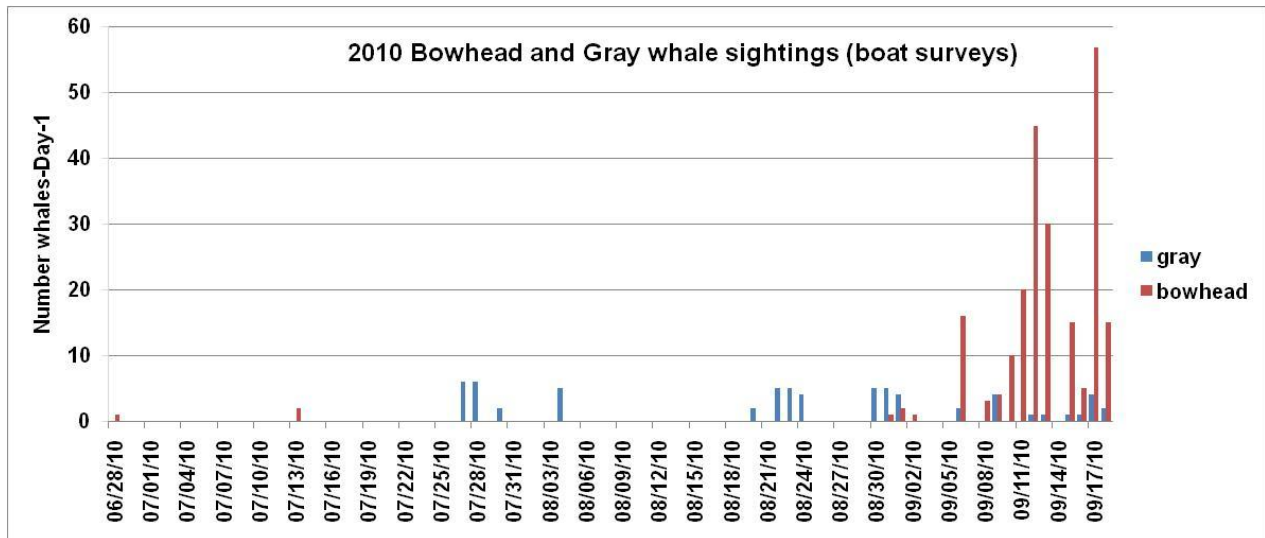


Figure V-3. Numbers of bowhead and gray whale sightings by date for BOWFEST 2010. Note the steady numbers of gray whales seen through the season while bowheads were not abundant until September in the BOWFEST study area.

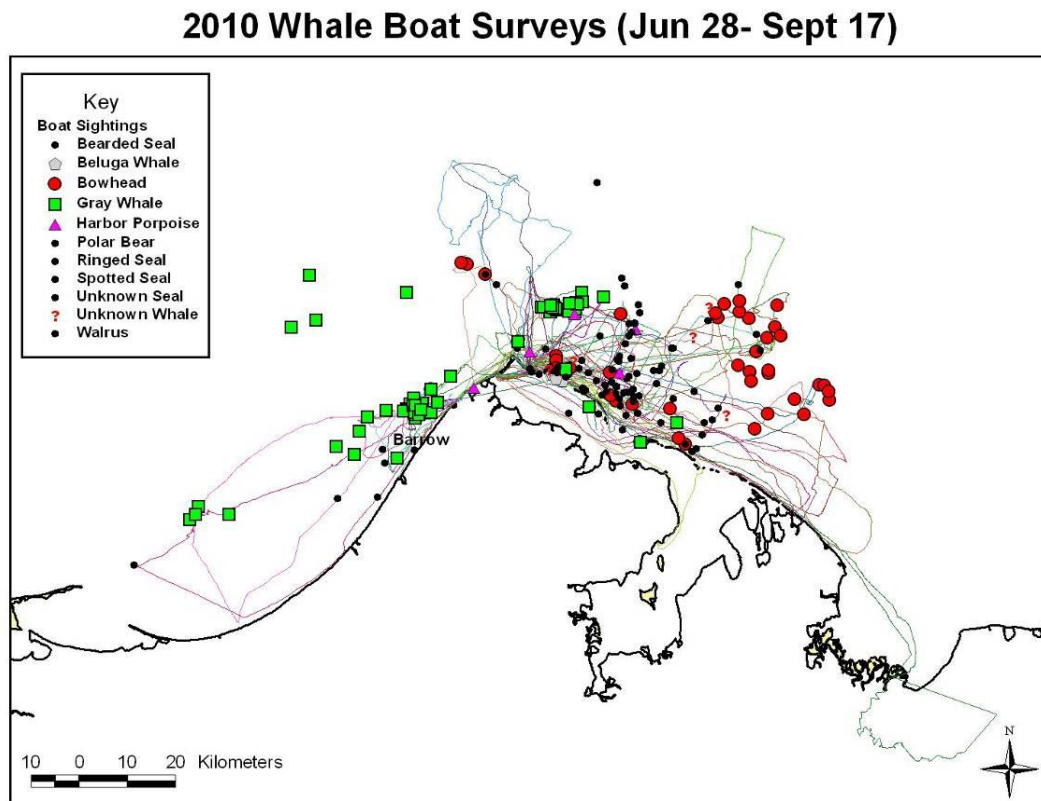


Figure V-4. Plot of positions of marine mammals seen during BOWFEST surveys in 2010.

Preliminary tallies indicate 213 bowhead whales were seen in approximately 51 sightings (Table V-2, Fig. V-4). A total of 149 gray whales were seen in 70 sightings and more belugas were seen (n=127) than in past years. Belugas were seen feeding inside Elson Lagoon in July and through August and September during boat surveys in Elson and elsewhere. In fact, on 25 July, Robert Suydam (pers. comm.) reported seeing over 500 belugas near Plover Point mostly inside the Lagoon. They were likely feeding. More harbor porpoise (n=10) were seen in 2010 than in past years.

Table V-2: Marine mammals seen near Barrow during boat surveys in 2010.

Species	No. Seen	No. Sightings
Bowhead whale	213	51
Bearded seal	42	33
Gray whale	149	70
Harbor porpoise	10	5
Polar bear	6	2
Ringed seal	12	10
Spotted seal	3	3
Unid. seal	44	44
Unid. whale	4	5
Walrus	1	1
Beluga whale	127	4

The total survey track-distance for all 2010 surveys was over 5,700 km (this did not include track distances for R/V *Annika Marie*), which was much greater than in 2009.

Bowhead and Gray Whale Distribution in the Barrow Area 2010

The first bowhead whale sighting for the open water season was on 28 June by local seal hunters in the ice floes just west of Barrow. Similarly 2 bowheads were seen on 11 July by NOAA and NSB seal biologists north of Point Barrow. Then a long period without *any* bowhead sightings ensued (essentially all of August) with bowheads not seen again until 1 September (Fig. V-3).

Gray whales, however, were seen throughout the study period in fairly steady numbers (Fig. V-3) and predictable locations (Fig. V-5). Bowheads were seen on essentially every survey in September. The highest densities of bowheads occurred in mid-September, most of which were feeding. While there was some uncertainty about the availability of strikes for the fall hunt, surveys were ended on 24 September based on our agreement with the Barrow Whaling Captains Association to stop work a week before the typical hunt start date of 1 October.

Despite increased effort in 2010, the relative distribution and abundance of bowheads in the Barrow area was much lower during the summer period (July and August) in 2010 than in 2009. In 2009, bowheads were seen essentially all summer. Unlike 2009, there were no reported euphausiid wash-ups in 2010 and the WHOI plankton tows (see Ashjian et al., this document) indicated lower euphausiid densities which might explain the low bowhead numbers in the area during summer.

2008-2010 Bowhead and Gray Whale Sightings

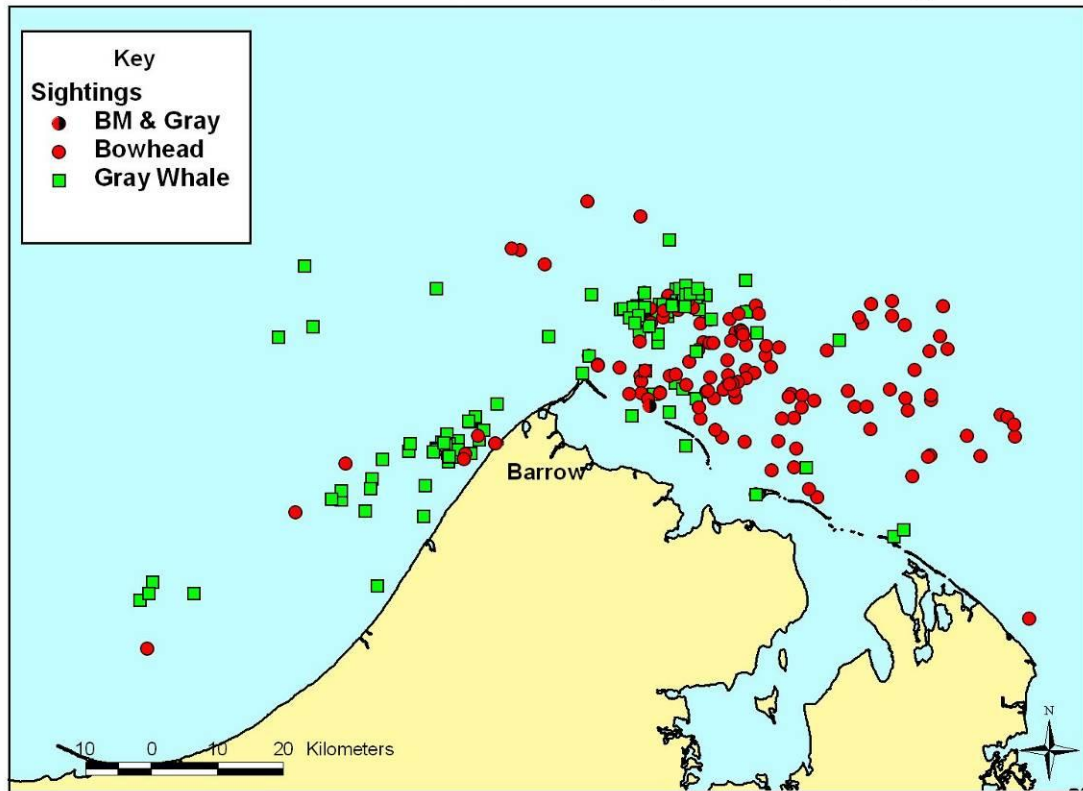


Figure V-5. Map showing positions of bowhead and gray whales for 2008 to 2010 BOWFEST surveys. Note the segregation between the two species with bowheads more common to the east and few gray whales seen east of 156 Longitude (10 miles east of Point Barrow).

Habitat Partitioning

Gray whales and bowheads appear to feed in somewhat different areas within the BOWFEST study area. Gray whales were consistently seen in small groups primarily north of Point Barrow and west of the village of Barrow in 2010 throughout the summer. However, as in past years, few gray whales were seen east of 156 Longitude (about 10 miles east of Point Barrow), whereas bowheads commonly fed in these waters (Fig. V-5). Bowheads likely feed in waters east of Point Barrow due to oceanographic factors with entrain euphausiids in these areas (Ashjian et al., 2010). Why gray whales feed in specific areas is not well understood but is likely associated with the availability of benthic prey.

Digestive Efficiency Analysis

Samples of digestive contents were taken along the alimentary tract of bowhead whales and included (in order of food passage from oral opening) forestomach, fundic chamber, pyloric chamber, duodenum, and colon. Full suites of samples were available from 5 whales harvested in fall 2009. Partial sample sets were obtained from additional 16 whales harvested in fall 2009, spring 2010, and fall 2010. Contents were frozen at -20C until analysis at UAF. In addition, fresh euphausiid prey was collected in Barrow in September 2009. Blood was sampled from the

palatal rete as soon as possible after death, spun, and serum frozen in cryovials at -20C until analysis at UAF (conducted by Lara Dehn).

Blood chemistry profiles were measured using an Abaxis VetScan Classic. Parameters analyzed included albumin (ALB), alkaline phosphatase (ALP), alanine aminotransferase (ALT), amylase (AMY), aspartate aminotransferase (AST), blood urea nitrogen (BUN), calcium (Ca), creatine kinase (CK), creatinine (CRE), gamma-glutamyl transferase (GGT), globulin (GLOB), glucose (GLU), potassium (K), magnesium (Mg), sodium (Na), phosphate (PHOS), total bilirubin (TBIL), and total protein (TP).

Percent water of prey and alimentary tract contents was determined as loss of mass during the freeze-drying procedure. Contents of different compartments were then lipid-extracted using chloroform:methanol in a modified Soxhlet procedure after Schlechtriem et al. (2003). Tissue nitrogen content was measured using a CNS 2000, Leco Combustion analyzer and ash content was determined via combustion in a muffle furnace at 550°C for 8 hours. The subtractions of ash content from dry matter allows for calculation of organic matter in the sample and further subtraction of lipid provides lean dry mass. Crude protein contents can then be calculated from lean dry mass assuming all nitrogen is bound to protein. In addition, fresh euphausiids and alimentary tract contents were analyzed for total caloric value using bomb calorimetry (Parr Model 1281). Digestive efficiencies were calculated based on “start” proximate composition of euphausiid prey to “end” composition of colon contents.

Crude protein of ingesta dropping from forestomach and fundic chamber to pyloric chamber is shown in Figure V-6. During the following passage through the alimentary tract protein is not further taken up by the digestive mucosa. This indicates that protein digestion is occurring in the forestomach, likely due to microbial fermentation and amino acid absorption by bacterial fauna similar to ruminants. However, measurement of protein contents in the gut can be biased due to sloughing of digestive tract lining and consequent analyses of “modified” gut contents. This scenario is likely for whale 09B8 where crude protein drops from the forestomach to the fundic chamber, but then increases to again in the pyloric chamber and duodenum. Overall, crude protein drops from 45% (fresh) to 20% (colon), resulting in an approximate efficiency of protein digestion by bowhead whales of 55%.

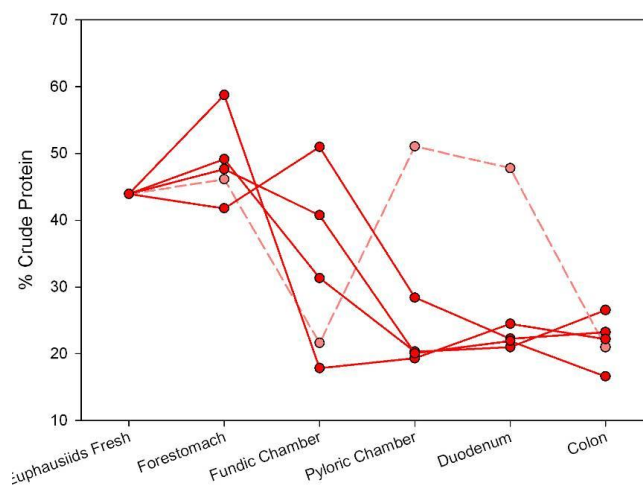


Figure V-6. Crude protein content by location in the gastrointestinal tract.

While lipids are released in the forestomach, proximate analyzes of gut contents did not show lipid uptake by bowhead whales until the duodenum (Fig. V-7). This is consistent with typical mammalian digestion under the action of pancreatic lipase in the duodenum. Herwig et al. (1984) described volatile fatty acid release in bowhead whale forestomachs. It is likely that volatile fatty acids are released from chitin fermentation by forestomach fauna, explaining not only the release of lipids and wax esters from crustacean prey, but also the drop in protein observed from the forestomach to the pyloric chamber. Overall, lipid digestion by bowhead whales is approximately 60% efficient, dropping from ~50% in fresh euphausiids to ~20% lipid in colon contents. Due to the high caloric density of lipids, this trend is repeated in total caloric contents of different stomach compartments and drops from 5.3kcal/g (22.4kJoules/g) in fresh euphausiids to 2.5cal/g (10.8kJoules/g) in colon contents (Fig. V-8).

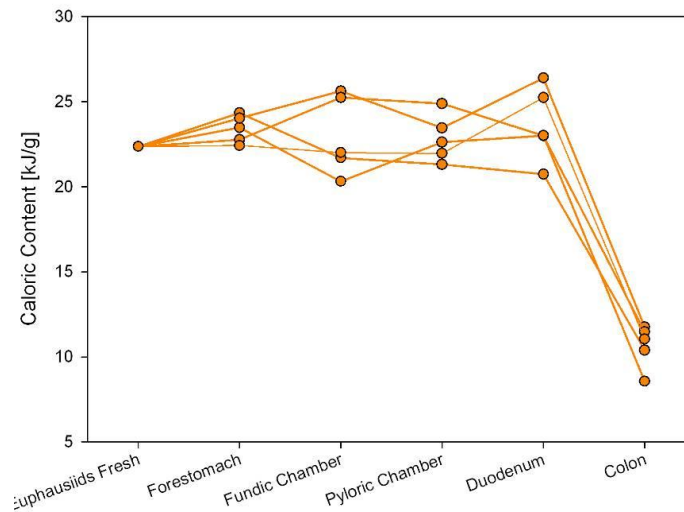


Figure V-7. Percent lipid for bowheads by location in the gastrointestinal tract.

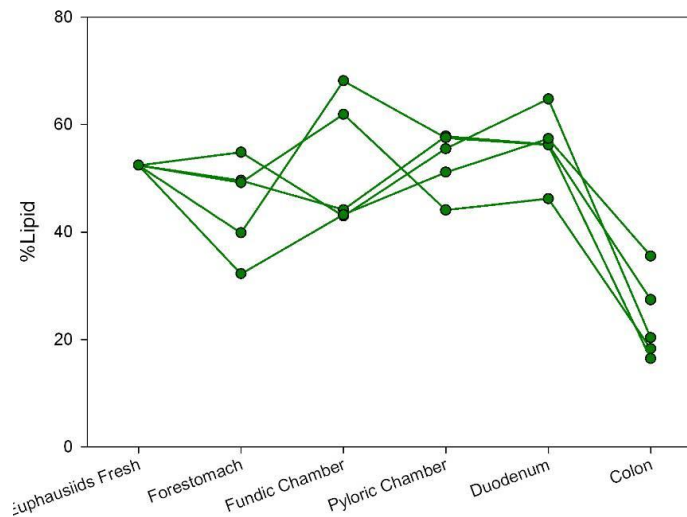


Figure V-8. Caloric content for bowheads by location in the gastrointestinal tract.

Caloric extraction from euphausiid prey is therefore approximately 50% with most calories gained from lipid uptake. It should however be mentioned that different prey, i.e., copepods might be digested differently, even though overall composition is roughly similar to euphausiids (Davis, 1993). In addition, lipid content of Arctic zooplankton is highly seasonal. Zooplankton have the highest lipid contents in fall (in preparation for winter dormancy) and emerge in the spring to replenish their diminished resources. This could be the reason that bowhead whales limit their food intake in the spring as the effort of prey acquisition might calorically more expensive than digestion of this “low-quality” zooplankton can provide in return. Interestingly, caloric contents of the colon was significantly higher in spring ($p < 0.0001$) compared to either fall season (Fig. V-9). Whales harvested in spring 2010 were characterized as non-feeding. It is possible that the gut lining is undergoing proliferation and sloughing of old mucosa in bowheads during this time, leading to a higher density of calories in the colon that are not prey-based.

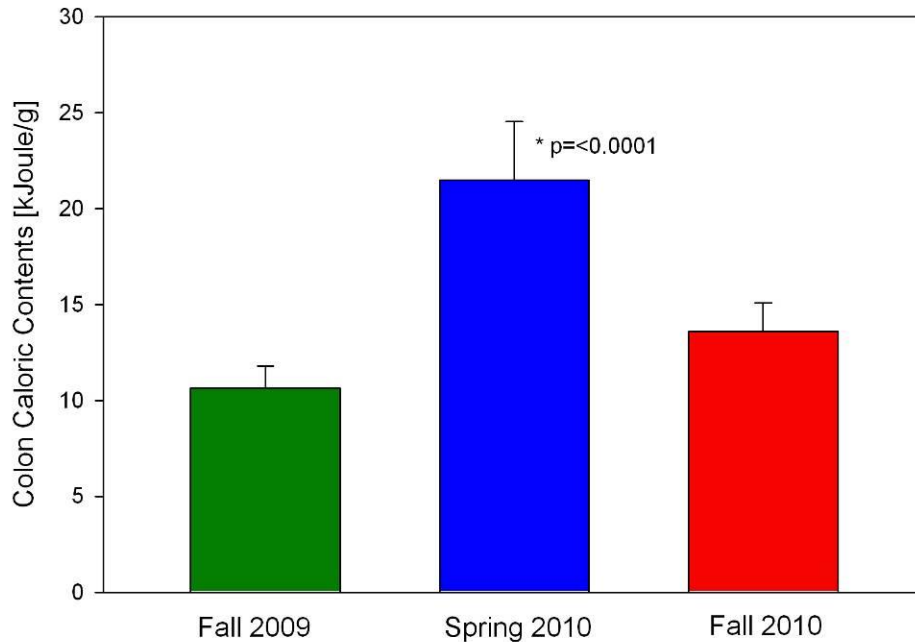


Figure V-9. Colon caloric content (KJoule/gram) by season.

Finally, principle components analysis of blood chemistry parameters revealed separation between feeding status of bowhead whales and was co-correlated with harvest season (Fig. V-10). The first two principal components (PC1 and PC2) explained 50 % of the variability between feeding and fasting bowhead whales. Variables with the most weight in PC1 were GLOB, BUN, and GGT. The separation in PC2 was largely driven by a positive loading of ALP, AMY, CRE, and GLU. Although somewhat counter-intuitive, this indicates that fasting bowhead whales tend to have higher levels of glucose and enzymes associated with production of bile (ALP) and pancreatic juices (AMY). Creatinine is a waste product of muscle breakdown and higher levels could be indicative of muscle catabolism. However, fasting adapted marine

mammals, such as bowhead whales, will avoid muscle catabolism (Castellini and Rea, 1992) and other associated indicators of muscle breakdown (e.g., BUN, CK, and AST) do not support extensive muscle wasting. Fasting hyperglycemia was also observed in Northern elephant seals (*Mirounga angustirostris*) and glucose recycling via the Cori cycle has been suggested (Keith and Ortiz, 1989; Champagne et al., 2005). The amino acid alanine can be broken down to pyruvate and the molecule can in turn be used for gluconeogenesis in the liver to support brain function while relying on only minor levels of ketones. This could then also account for higher levels of CRE in fasting bowheads. Alternatively, fasting whales are relying on their substantial fat reserves and the breakdown of triglycerides results in a glycerol backbone to be used in gluconeogenesis.

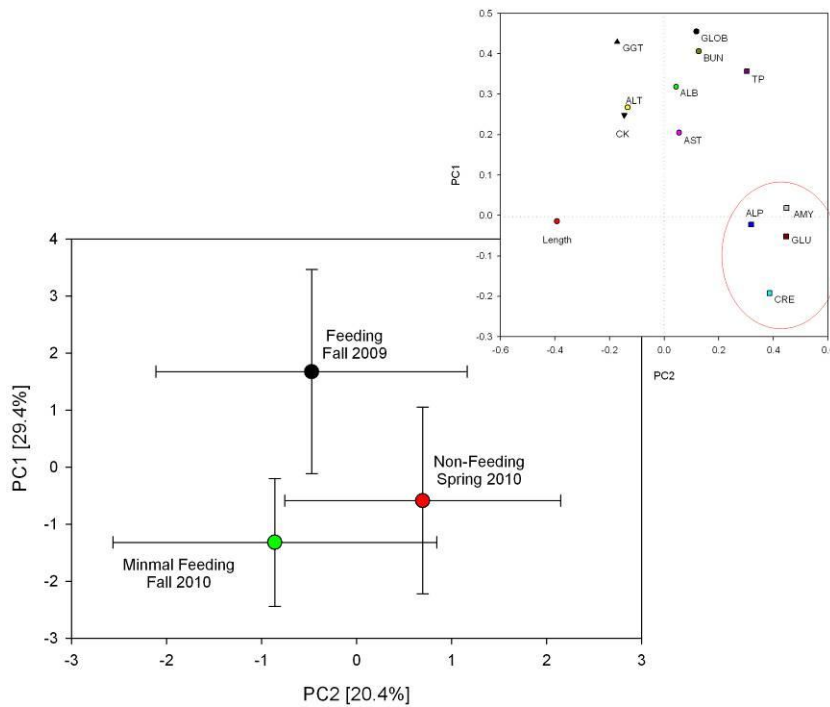


Figure V-10. Principle components analysis for bowhead whale blood by harvest season.

Other Activities

The following manuscript describing the distribution, behavior, and information on local zooplankton occurrence as indicated by stomach contents from harvested whales in Barrow during 2005-2006 was published by the scientific journal *Arctic* in 2010:

Moore, S.E., J. C. George, G. Sheffield, J. Bacon, C. J. Ashjian. 2010. Bowhead whale distribution and feeding near Barrow, Alaska, in late summer 2005-06. *Arctic* 63(2):195-205.

Acknowledgements—We thank the Barrow, Kaktovik and Saint Lawrence whaling communities for supporting and participating in this study. We thank Charles Monnett in particular and BOEMRE for vision and funding for BOWFEST and the NSB DWM staff for their assistance. We appreciate the dedication, patience, and careful handling of the data by Barbara Tudor and Cyd Hans during the project. Rob DeLong did a fine job helping analyze data and produced the maps in this report. The Barrow Arctic Science Consortium provided valuable assistance with boat logistics. Boat captains who were particularly helpful include: Fred Brower, Billy Adams, Harry Brower, Billy Okpeaha, and others.

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SECTION VI - SUMMARY OF SYSTEMATIC BOWHEAD SURVEYS CONDUCTED IN THE U.S. BEAUFORT AND CHUKCHI SEAS 1975-2008

Mari A. Smultea¹, Dagmar Fertl², David J. Rugh³, and Cathy Bacon⁴

¹Smultea Environmental Sciences (SES), 29333 SE 64th St., Issaquah, WA 98027 (msmultea@msn.com),

²Ziphius EcoServices, 8112 Springmoss Dr., Plano, TX 75023,

³National Marine Mammal Laboratory, 7600 Sand Point Way NE, Seattle, WA 98115,

⁴SES, 1616 Quails Nest Dr., Fort Worth, TX 76177

Introduction

As part of the 2007-2011 Bowhead Whale Feeding Ecology Study (BOWFEST) coordinated by NMFS' National Marine Mammal Laboratory for BOEMRE, we conducted a comprehensive review of all prominent scientific surveys that systematically recorded bowhead whales (*Balaena mysticetus*) in the U.S. Beaufort and Chukchi seas from 1975-2008. This review represents the "best available information" on bowheads needed to support environmental risk assessments, environmental impact assessments, and other pre-and post-leasing decision documents for potential gas and oil leasing in the Beaufort and Chukchi Sea Planning Areas. A general map of such past, ongoing and proposed activities is presented in Figure VI-1 to illustrate the extent and general geographic locations of these activities.

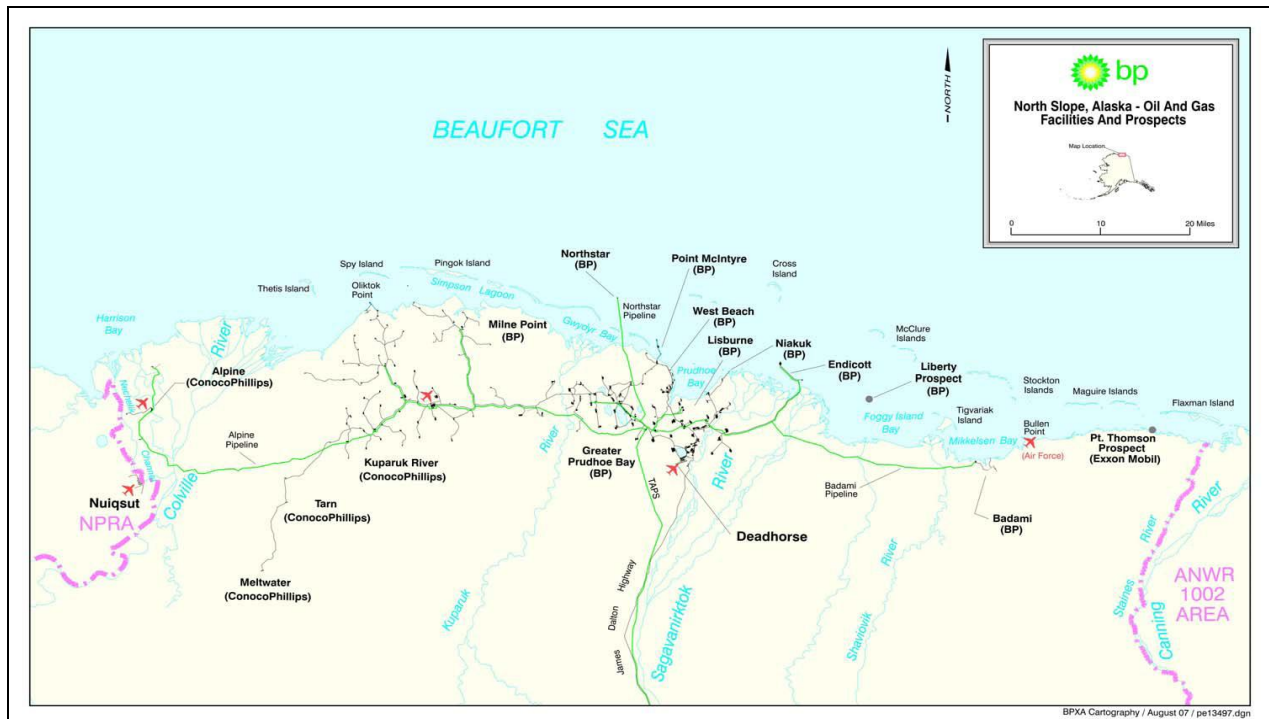


Figure IV-1. Map of selected historical, current and proposed oil and gas production activities in the U.S. Beaufort Sea. Associated marine mammal monitoring programs have contributed to systematic studies of bowhead whales along with projects funded by many other entities.

Given the cumulative number of such studies and the predicted continued growth of industrial activities in this region, our goals were to provide: (1) a summary for historical comparisons; (2) a format to integrate and track the studies; and (3) a publicly available starting point to identify data of relevance to ongoing work.

Methods

To address our goals, we compiled and synthesized a list of past and current visual/acoustic detection studies that systematically recorded bowhead whales in the U.S. Beaufort and Chukchi seas. This compilation included data derived from aerial surveys (both manned and unmanned) for whale distribution, aerial photography, ice- and shore-based census/tracking efforts, vessel-based and tagging efforts, and monitoring associated with offshore oil and gas exploration, development and operations. Studies were retrieved via online web searches, library database searches, personal communications, reviewing the literature cited sections of reports, publications and books, and by soliciting scientists for copies of their resumes and *curriculum vitae* that included lists of published peer-reviewed journal articles as well as reports. Our primary goal was to identify studies and to list a sample of publications associated with the studies. Thus, we did not provide an exhaustive list of all publications and reports associated with each study, rather we provided a list of those that were readily available. We also determined whether there were pdfs readily available for the cited literature.

Results

Studies involving bowheads in the U.S. Beaufort and Chukchi seas are numerous; they include many obscure and/or unpublished reports/datasets that are difficult to locate. In just 2008 and 2009, there were nearly 45 studies involving bowheads in this region. Compilation of such information is directly relevant to fulfilling goals of current inter-disciplinary efforts to study bowhead ecology vis-à-vis ongoing, proposed and anticipated offshore oil and gas activities in the Beaufort and Chukchi seas.

The results of our review are provided in Table VI-1 as a chronological listing of systematic studies of bowhead whales in the U.S. Beaufort and Chukchi Seas. For each study, we provide information on the first year of the study, the study period, the primary study methods, the funding source, the name of the Primary Investigator (PI)/Point of Contact (POC), the research team name, the project title, a general description of the study, the study location, a general description of the study, the timeframe, and a list of the some of the publications and reports generated though the study. The information is meant to provide a base from which interested parties can search for more detailed information regarding the research conducted. Examples of major entities funding bowhead whale systematic surveys and monitoring efforts include the U.S. Minerals Management Service, U.S. Bureau of Land Management, U.S. and Canadian Oil/Gas Industry, National Marine Mammal Laboratory (NMFS), North Slope Borough, Alaska Eskimo Whaling Commission, University of Alaska, Alaska Department of Fish and Game, University of Oregon, National Science Foundation, Fisheries and Oceans Canada, and Indian and Northern Affairs, Canada.

Table VI-1. List of Systematic Scientific Studies of Bowhead Whales Conducted in the U.S. Beaufort Sea and Chukchi Seas 1975-2008. Table acronyms in alphabetical order: ADFG = Alaska Department of Fish and Game, AEWC = Alaska Eskimo Whaling Commission, AUV = Autonomous Underwater Vehicle, BOWFEST = Bowhead Whale Feeding Ecology Study, BP = British Petroleum, COMIDA = Chukchi Offshore Monitoring in Drilling Area, DWM = Department of Wildlife Management, JIP = Joint Industry Program, MMS = U.S. Minerals Management Service, NMML = National Marine Mammal Laboratory, NMFS = National Marine Fisheries Service, NOAA = National Oceanic and Atmospheric Administration, NOPP = National Ocean Partnership Program, NOSC = Naval Ocean Systems Center, NSB = North Slope Borough, NSF = National Science Foundation, SIO = Scripps Institute of Oceanography.

First Yr of Study	Study Years	Method	Funding Source	PI / POC	Research Team	Project Title	Description	General Location	Time-Frame	Some Reports and Publications	Notes
1975	1975, 1976, 1977, 1978, 1979, 1980, 1981, 1984, 1985, 1986, 1987, 1989, 1990, 1991, 1992	Aerial survey	NMML	D. Rugh, H. Braham, T. Albert	NMML, NSB	Bowhead & white whale migration, distribution, abundance in Bering, Chukchi, and Beaufort seas	Develop reliable technique for counting bowhead whales to determine population size; supported ice-based census during same years	Vicinity of Pt Barrow, Bering, Chukchi, Beaufort	Spring	Braham et al. 1977, 1979a,b, 1980a,b, 1981, 1984; Krogman et al. 1989, Braham and Krogman 1978	
1976	Annually 1976 - 1988; 1992, 1993, 1999, 2000,	Ice-based visual survey	NSB-DWM, NOAA-AEWC, BP Exploration AK, Ilisagvik College, NSF	C. George	NSB DWM	Observations of bowhead whales during spring migration	Ice-based censuses of W Arctic stock of bowhead; first 2 yrs examined logistics of counting from ice as the whales passed near Pt Barrow during	Vicinity of Pt Barrow	Mid-April to mid-June	Braham et al. 1979a,b; Braham et al. 1980a,b, 1984; Braham and Krogman 1977; Carroll and	Of surveys in 1999-2001, only 2001 data were useful (pers. Comm., J.C. George, Dec 2008); acoustic censuses conducted simultaneously

First Yr of Study	Study Years	Method	Funding Source	PI / POC	Research Team	Project Title	Description	General Location	Time-Frame	Some Reports and Publications	Notes
	2001						spring migration			Smithhisler 1980; Johnson et al. 1981; Ljungblad 1981; Marquette et al. 1982; Dronenburg et al. 1982, 1984, 1986; Krogman et al. 1985, 1986, 1989; Zeh et al. 1983; Ljungblad et al. 1986a, 1987; George et al. 1995, 2004	during some years beginning in 1984 (see First Year 1984, PI Chris Clark)
1977	1977, 1978	Shore-based visual survey	NMML	D. Rugh	NMML	Census and monitoring of bowhead whale migration from Pt Hope & Cape Lisburne	Shore-based visual survey	Pt Hope & Cape Lisburne	April to mid-June	Rugh and Cabbage 1980	
1978	1978	Vessel survey	NMML	M. Dahlheim	NMML	Vessel survey for bowhead whales in the Bering and Chukchi Seas	See Project Title	Chukchi & Bering seas	June-July	Dahlheim et al. 1980	

First Yr of Study	Study Years	Method	Funding Source	PI / POC	Research Team	Project Title	Description	General Location	Time-Frame	Some Reports and Publications	Notes
1978	1978 - 1988, 1992, 1993, 2000, 2001	Acoustic including arrays & pop-up buoys	See Project Title	C. Clark	NSB, AEWC, NMML, NOSC, Cornell Univ.	Acoustic censusing of spring bowhead migration	Part of effort to census bowhead population from ice-based sites off Pt Barrow in spring	Pt Barrow	Mid-April through May	Braham et al. 1977, 1979a,b; Cummings and Holliday 1985; Ko et al. 1986; Sonntag et al. 1986; Clark et al. 1986a, b, 1996; Clark and Ellison 1988, 1989, 2000; George et al. 1989; Zeh et al. 1988a,b	
1979	Annually 1979 - 2009	Aerial survey (systematic & non-systematic) & acoustic	MMS, NMML	D. Rugh, J. Clarke, S. Moore, C. Monnett, J. Montague, S. Treacy, C. Cowles, D. Ljungblad	NOSC, MMS, NMML	Bowhead Whale Aerial Survey Project (BWASP)	Obtain data on distribution, migration, and abundance and monitor late-summer and fall migration in Beaufort & Chukchi relative to oil & gas exploration; acoustic data obtained from sonobuoys launched from aircraft	W Beaufort & NE Chukchi seas	Mid-June through mid-Nov (varied by year)	Ljungblad 1981 ; Ljungblad et al. 1980 , 1982 , 1983 , 1984 , 1985a,b,c , 1986a,b , 1987 , 1988 ; Moore et al. 1989 ; Treacy 1988a, b , 1989 , 1990a, b , 1991 , 1992 , 1993 , 1994 , 1995 , 1996 , 1997 , 1998 , 2000 .	Beaufort aerial survey 1979-1987 early Aug - late Oct with NOSC & subcontracts to SEACO; after April 1987, just MMS; 1988-2008 late Aug/early Sept - mid-Oct; 1982 - 1984 second aircraft flew random surveys for MMS in Beaufort to monitor seismic ship activity & search for bowheads near

First Yr of Study	Study Years	Method	Funding Source	PI / POC	Research Team	Project Title	Description	General Location	Time-Frame	Some Reports and Publications	Notes
										2002a,b , 2005 ; Treacy et al. 2006 ; Moore and Clarke 1991 , 1992 ; Moore 1992 ; Landino et al. 1994 , Clarke et al. 2010 , Monnett and Treacy 2005	seismic ships, with third aircraft in 1983; Chukchi surveys flown occasionally from 1982-1986 but in 1987 & 1989-1991 dedicated systematic surveys from mid-Sept to early Nov. Chukchi surveys recommenced in 2008 only in June, Aug & Oct. (pers. Comm. J. Clarke Dec 2008)
1980	1980, 1981, 1982, 1983, 1984, 1985	Aerial, acoustic, vessel	MMS	W.J. Richardson	LGL	Monitoring bowhead whale behavior in presence & absence of industrial stimuli, including playbacks	Baseline & exposure studies assessing importance of E Alaskan Beaufort Sea to feeding bowhead whales & effects of industrial activities; included systematic aerial surveys	E Beaufort Sea	July-Sept	Richardson 1982, 1983, 1984, 1985, 1986, 1987; Richardson et al. 1985, 1986, 1990, 1991; Würsig et al. 1984, 1985, 1986, 1989	Included assessing effects of aircraft overflights
1981	1981	Aerial	Dome Petroleum Ltd. & Sohio AK Petrol Co.	R. Davis & W.J. Richardson	LGL	Distribution, numbers and productivity of the Western Arctic stock of	Distribution, relative abundance, movements of bowheads on summer range in E Beaufort Sea, determine length	E Beaufort & Amundsen Gulf, Canadian Beaufort	Summer, fall	Davis et al. 1982a, b	

First Yr of Study	Study Years	Method	Funding Source	PI / POC	Research Team	Project Title	Description	General Location	Time-Frame	Some Reports and Publications	Notes
						bowhead whales in the eastern Beaufort Sea and Amundsen Gulf, summer 1981	composition of population				
1981	1981, 1982, 1983, 1984, 1985, 1986, 1987, 1989, 1990, 1991, 1992, 1994, 1998, 1999, 2000, 2003, 2004, 2005	Aerial photo-grammetry & photo ID	BP, CIAP, DIAMD & DSS, MMS, NMML-NMFS, NSB-DWS, SOHIO, SWEPI	D. Rugh, B. Koski	NMML-NMFS, LGL, Univ WA, Cascadia Res. Coll., NSB	Bowhead whale abundance through photographic analysis	Analyses include photos taken from 1976-2005 during aerial surveys by NMML & LGL	Canadian Beaufort, Beaufort Sea off Pt Barrow	Spring, fall	Cubbage and Rugh 1981, 1982; Cubbage et al. 1984; Cubbage and Calambokidis 1984,1987; Nerini and Rugh 1986; Nerini et al. 1987; Richardson et al. 1987, 1990, 1991, 1994, 1995; Withrow and Goebel-Diaz 1989; Rugh 1990, 2008; Da Silva et al. 2000; Angliss et al. 1995; Zeh et al. 2002; Schweder 2003;	Photographs permit calculation of bowhead whale population estimate required for AWMP management procedure; also photographed bowheads in Bering Sea in Sept 2006

First Yr of Study	Study Years	Method	Funding Source	PI / POC	Research Team	Project Title	Description	General Location	Time-Frame	Some Reports and Publications	Notes
										Schweder et al. 2009a, b; Brandon et al. 2005, 2007; Koski et al. 2005. 2006a, b, 2007a, b; Rugh and Wade 2005; Brandon and Wade 2004, 2006; Rugh and Koski 2007; Zeh et al. 2002; Sadykova and Schweder 2009, 2010; Schweder and Sadykova 2009	
1982	1982	Aerial survey	Dome Petroleum Ltd, & Gulf Canada Resources, Inc.	L.A. Harwood	Environmental Sciences Ltd (ESL)	Bowhead whale monitoring study in the southeast Beaufort Sea	Aerial surveys to monitor effects of industrial activities on bowheads	SE Beaufort Sea	July-Sept	Harwood and Ford 1983	
1983	1983, 1984, 1985, 1986	Aerial survey	Indian & N Affairs Canada	L.A. Harwood	Environmental Sciences Ltd (ESL) & LGL & GA Borstad Ltd	Beaufort bowhead whale monitoring study	Abundance and distribution of bowhead whales in relation to industrial activity	SE Beaufort Sea	July-Sept	Harwood and Borstad 1985; McLaren and Davis 1985; Duval 1987; Ford et al. 1987; ESL	

First Yr of Study	Study Years	Method	Funding Source	PI / POC	Research Team	Project Title	Description	General Location	Time-Frame	Some Reports and Publications	Notes
										Sciences Limited, LGL Limited, and Environmental and Social Systems Analysts Ltd. 1986; Thomson et al. 1986	
1983	1983, 1984, 1985, 1986	Aerial survey	Indian & N Affairs Canada		Pallister Resource Management Ltd			SE Beaufort Sea	July-Sept	Harwood and Borstad 1985; McLaren and Davis 1985; Duval 1987; Ford et al. 1987a, b	
1985	1985	Vessel, acoustic, aerial	UNOCAL	P. McLaren	LGL	Bowhead whales and underwater noise near a drillship operation in the Alaskan Beaufort Sea, 1985.	See project title	Alaskan Beaufort Sea	Summer, fall	McLaren et al. 1986	
1986	1986	Aerial	Shell Western E&P Inc		LGL	Bowhead Whale Feeding in the Eastern Alaskan Beaufort Sea	Systematic aerial surveys as part of study to investigate responses of migrating bowheads to an exploratory offshore	Near Hammerhead & Corona drillsites in Camden Bay, Beaufort Sea	2 Sept-9 Oct	Richardson and Thomson 2002	

First Yr of Study	Study Years	Method	Funding Source	PI / POC	Research Team	Project Title	Description	General Location	Time-Frame	Some Reports and Publications	Notes
							drilling operation				
1989	1989, 1990, 1991, 1994	Aerial, visual & acoustic ice-based monitoring (ice edge & pack ice)	MMS	W.J. Richardson	LGL	Acoustic Effects of Oil Production Activities on Bowhead and White Whales Visible During Spring Migration Near Pt. Barrow, AK	Monitor distribution & behavior of bowheads, belugas, and seals to playback of industrial sounds from ice edge & pack ice; ice-based visual & acoustic monitoring; sonobuoy drops from Twin Otter	Near Pt. Barrow, Beaufort Sea	Spring	Richardson et al. 1990, 1991, 1995; Patenaude et al. 2002	
1990	1990, 1991	Aerial, vessel & acoustic monitoring	Shell Western E&P Inc & Chevron USA, Inc	J. Brueggeman	Ebasco Envntl.	Chukchi Sea 1990 & 1991 Marine Mammal Monitoring Programs	Monitored effects of offshore drilling and icebreaker activities on marine mammals	Chukchi Sea	29 June - 5 Oct	Brueggeman et al. 1991a, 1992	
1991	1991	Vessel monitoring	Western Geophysical	J. Brueggeman	Ebasco Envntl.	Marine Mammal monitoring program relative to seismic vessel operations in the Beaufort Sea, 1991	Vessel-based monitoring for marine mammals during seismic operations	Beaufort Sea	Summer	Brueggeman et al. 1991b	
1992	1992	Satellite tag	MMS	Bruce Mate	Oregon State Univ.	Satellite-monitored movements of radio-tagged bowhead	See project title	Tagged in Canadian Beaufort off Mackenzie	30 Aug - 6 Sept	Krutzikowsky and Mate 2000; Mate et al. 2000	Tagged 12 juvenile bowheads

First Yr of Study	Study Years	Method	Funding Source	PI / POC	Research Team	Project Title	Description	General Location	Time-Frame	Some Reports and Publications	Notes
						whales in the Beaufort & Chukchi seas during the late-summer feeding season and fall migration		River Delta			
1992	1992, 1993, 1994, 1995, 1996	Vessel surveys	NSF	S. Moore	Joint Japanese-Russian-American (SAIC, NSB, Univ AK Fairbanks)	Marine mammal surveys in & near Chukotka Peninsula and Chukchi Sea	Vessel-based surveys conducted during Japanese-Russian-American Chukchi Sea Circulation Study Cruises	Chukchi Sea	Autumn	Melnikov et al. 1998b ; Moore et al. 1995	Surveys included extensive area of Chukchi Sea
1992	1992, 1993	Aerial, vessel, acoustic	ARCO Alaska, Inc.	J. Hall, K. Brewer	Coastal & Offshore Pacific Corp. (COPAC)	Marine mammal monitoring for Kuvlum drilling site	Systematic aerial line surveys focused around the drilling site to study distribution & relative abundance of bowheads to exploratory offshore drilling operation	Kuvlum in Camden Bay area	Mid-Aug - Sept	Brewer et al. 1993; Hall et al. 1994	
1996	1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003	Aerial, vessel-based, & acoustic monitoring & ice-based seal monitoring of lair use	BP Exploration (Alaska) Inc.	W.J. Richardson	LGL	Marine Mammal & Acoustical Monitoring of BPXA's Seismic Program in the Alaskan Beaufort Sea,	Intensive localized monitoring of distribution & behavior of bowheads over small geographic area focused on seismic surveys	Alaskan Beaufort Sea		Richardson 1998, 2004; Richardson and Williams 2004; Manly et al. 2007	

First Yr of Study	Study Years	Method	Funding Source	PI / POC	Research Team	Project Title	Description	General Location	Time-Frame	Some Reports and Publications	Notes
						1997					
1996	1996, 1997, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009	Aerial, vessel, acoustic	BP Alaska	B. Streever, L.A.M. Aerts, W.J. Richardson	LGL, Greeneridge Sciences Inc., Applied Sociocultural Research	Monitoring marine mammals relative to BP's Northstar oil development & operations, Alaskan Beaufort Sea	Monitoring distribution & behavior of bowheads, belugas, & seals relative to BP's Northstar oil production construction, development & operations, including monitoring of industrial sounds, seals, and whale calls	Northstar Alaskan Beaufort		Richardson 1997, 1998, 1999, 2000, 2006, 2007, 2008; Richardson and Williams 2001, 2002, 2003, 2004, 2005; Aerts & Richardson 2008, 2010	Anchorage, AK, and Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD.
1997	1997, 1998	Aerial & vessel-based visual & acoustic monitoring	Western Geophysical	W.J. Richardson	LGL, Greeneridge Sciences	Marine mammal & acoustic monitoring of Western Geophysical's open-water seismic program in the Alaskan Beaufort Sea	Monitor effects of open-water seismic on marine mammals	Alaskan Beaufort Sea	24 July - 11 Oct	Richardson 1998, 1999	
1998	1998, 1999, 2000	Aerial	MMS	W.J. Richardson	LGL	Aerial surveys during feeding study	Systematic aerial surveys to assess importance of E Alaskan Beaufort Sea to bowheads.	E Alaskan Beaufort Sea	Sept	Richardson and Thomson 2002	
2001	2001	Vessel,	WesternGeco,	W.J.	LGL	Marine mammal	See Project Title	Alaskan		Richardson and Lawson	

First Yr of Study	Study Years	Method	Funding Source	PI / POC	Research Team	Project Title	Description	General Location	Time-Frame	Some Reports and Publications	Notes
		aerial	BP	Richardson		monitoring of Western Geco's open-water seismic program in the Alaskan Beaufort Sea, 2001.		Beaufort Sea		2002	
2002	2002, 2003	Vessel	Encana Oil & Gas (USA) Inc., and Lynx Enterprises	G. Green	Foster Wheeler Env'tl. Corp.	Marine mammal monitoring program McCovey exploration prospect	Objective to document presence & behavior of marine mammals in vicinity of steel drilling caisson; incidental sightings of bowheads	McCovey Prospect, US Beaufort Sea	Summer, fall, winter	Green and Hall 2003, Green et al. 2003	
2005	2005	Vessel-based monitoring	NSF	B. Haley, W.J. Richardson	LGL	Marine mammal monitoring during Univ. AK Fairbanks' marine geophysical survey across the Arctic Ocean, Aug–Sep 2005	Marine mammal monitoring during seismic geophysical survey	Trans-arctic from Barrow to Norway	5 Aug - 26 Sept	LGL 2005; Haley and Ireland 2006	No bowheads seen
2005	2005, 2006, 2007	Vessel-based monitoring	ASRC Lynx Enterprises, Inc., & FEX L.P.	G. Green	Tetra Tech EC, Inc.	Marine mammal monitoring program FEX barging project 2005,	Vessel-based monitoring for marine mammals from two supply barges in conjunction with barging operations supporting onshore oil	Cape Simpson to Prudhoe Bay, US Beaufort Sea	31 July- 24 Aug 2007	Green and Negri 2005, 2006; Green et al. 2007	

First Yr of Study	Study Years	Method	Funding Source	PI / POC	Research Team	Project Title	Description	General Location	Time-Frame	Some Reports and Publications	Notes
						2007	& gas exploration involving transportation of equipment. Opportunistic sightings of bowheads				
2006	2006	Vessel-based monitoring	NSF	B. Haley, W.J. Richardson	LGL	Marine geophysical survey by the USGC Healey of the Western Canada Basin, Chukchi Borderland, and Mendeleev Ridge, Arctic Ocean, July-August 2006	Marine mammal monitoring during seismic geophysical survey	Crossed Chukchi & Beaufort to Arctic Ocean	July-Aug 2006	LGL 2006	
2006	2006 (see also 2007, 2008)	Vessel	GX Technology	D. Ireland	LGL	Marine mammal monitoring and mitigation during open water seismic exploration by GX Technology in the Chukchi Sea, Oct-Nov 2006	See project title	Chukchi Sea	Oct-Nov 2006	Ireland et al. 2007a	

First Yr of Study	Study Years	Method	Funding Source	PI / POC	Research Team	Project Title	Description	General Location	Time-Frame	Some Reports and Publications	Notes
2006	2006	Vessel, aerial, acoustic	Conoco Phillips Alaska, Inc., & GX Technology	D. Funk	LGL, Greeneridge Sciences Inc., Applied Sociocultural Research	Joint monitoring program in the Chukchi & Beaufort seas, July-Nov 2006	Aerial surveys conducted E of Barrow as part of Study of Northern Alaska Coastal System (SNACS) "Environmental Variability, Bowhead Whale Distributions and Inupiat Subsistence Whaling" study funded by NSF. Aerial surveys conducted in collaboration with C. Monnett (MMS)	Chukchi & Beaufort seas	July-Nov 2006	Funk et al. 2007	
2006	2006, 2008	Aerial, vessel, acoustic	Shell Offshore Inc.	M. Macrander, D. Funk, H. Patterson	LGL, Greeneridge Sciences Inc.	Baseline & seismic marine mammal monitoring and mitigation during open water seismic exploration by Shell Offshore Inc. In the Chukchi & Beaufort seas	Aerial & vessel surveys & 35 acoustic recorders (dasars)	Beaufort & Chukchi seas, Chukchi Sea: 0-25 mi from coast	July-Sept 2006, July-Nov 2007	Patterson et al. 2007, Funk et al. 2008, Ireland et al. 2009, Funk et al. 2010, Christie et al. 2009, Thomas et al. 2010	Per D. Rugh
2006	2006	Vessel	Conoco Phillips Alaska, Inc.	D. Ireland	LGL	Marine mammal monitoring and mitigation during open	See Project Title	Chukchi Sea	July-Oct 2006	Ireland et al. 2007b	

First Yr of Study	Study Years	Method	Funding Source	PI / POC	Research Team	Project Title	Description	General Location	Time-Frame	Some Reports and Publications	Notes
						water seismic exploration by ConocoPhillips Alaska Inc. In the Chukchi Sea, July-October 2006					

Summary

Our intent has been to *provide a comprehensive resource* to serve as a foundation for the integration of past and ongoing bowhead studies relative to industrial activities, mitigation, and management. It is meant to assist and improve the flow of scientific information between interested entities and the public, leading eventually to an integration of research on bowhead whales.

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BOWFEST PRESENTATIONS AND MEETINGS IN 2010

- 2010 Jan 18-22: Alaska Marine Science Symposium, Anchorage. The following presentations were based, at least in part, on BOWFEST research:
- Ashjian, C., R. Campbell, S. Okkonen, B. Sherr, and E. Sherr. Year-to-year variability of ocean biology at a bowhead whale feeding hotspot near Barrow, AK: 2005-2009. Poster presentation.
 - Rugh, D., C. Ashjian, M. Baumgartner, C. Berchok, R. Campbell, J.C. George, K. Goetz, D. Mellinger, J. Mocklin, S. Okkonen, G. Sheffield, M. Smultea, and K. Stafford. The Bowhead Whale Feeding Ecology Study (BOWFEST). Poster presentation.
 - Mocklin, J., D. Rugh, and S. Moore. Using aerial photography to investigate evidence of feeding by bowhead whales. Oral presentation.
 - Okkonen, S., C. Ashjian, and R. Campbell. Multi-platform observations of circulation features associated with the Barrow area Bowhead whale feeding hotspot. Poster presentation.
 - Smultea, M., D. Rugh, and D. Fertl. Review of systematic surveys involving bowhead whales in the U.S. Beaufort and Chukchi seas 1975-2009. Poster presentation.
 - Stafford, K. M., C. L. Berchok, D.K. Mellinger, and S.E. Moore. Ambient noise in the Alaskan Beaufort Sea 2007-2009. Poster presentation.
- 2010 Feb 17: Mini-symposium at the Alaska Fisheries Science Center, carried over from the Alaska Marine Science Symposium:
- Rugh, D., C. Ashjian, M. Baumgartner, C. Berchok, R. Campbell, J.C. George, K. Goetz, D. Mellinger, J. Mocklin, S. Okkonen, G. Sheffield, M. Smultea, and K. Stafford. The Bowhead Whale Feeding Ecology Study (BOWFEST). Poster presentation.
 - Mocklin, J., D. Rugh, and S. Moore. Using aerial photography to investigate evidence of feeding by bowhead whales. Oral presentation.
 - Smultea, M., D. Rugh, and D. Fertl. Review of systematic surveys involving bowhead whales in the U.S. Beaufort and Chukchi seas 1975-2009. Poster presentation.
- 2010 Feb 22: Ocean Sciences Meeting, Portland, Oregon.
- Ashjian, C.J., Campbell, R.G., Okkonen, S.R., Sherr, B.F., Sherr, E. B. Year-to-year variability of ocean biology across Barrow Canyon and the western Beaufort Shelf: 2005-2009. Oral presentation.
 - Okkonen, S.R., Ashjian, C.J., Campbell, R.G. Year-to-year variability of late summer hydrography across Barrow Canyon and the western Beaufort Shelf: 2005-2009. Poster presentation.
- 2010 Mar 11: BOWFEST described in the Multicultural Initiative in Marine Science: Undergraduate Participation (MIMSUP) at AFSC.
- 2010 Mar 16-19: International State of the Arctic Meeting, Miami, FL
- Ashjian, C.J., Braund, S.R., Campbell, R.G., George, J.C., Kruse, J.A., Maslowski, W, Moore, S.E., Nicolson, C.R., Okkonen, S.R., Sherr, B.F., Sherr, E.B., Spitz, Y.H.

Environmental Variability, Bowhead Whale Distributions, and Iñupiat Subsistence Whaling near Barrow, AK. Oral Presentation.

2010 Mar 24: BOWFEST overview presented to 100 attendees at the Open Water Meetings in Anchorage.

2010 Aug: Ashjian presents proposed research at an AEWG meeting in Barrow.

2010 Sept 3: BOWFEST PIs meet in Barrow to discuss the future of the program.

2010 Sept 3: BOWFEST PIs meet with NSB Mayor, Edward Itta.

2010 Dec 16: American Geophysical Union Fall Meeting.

Okkonen, S.R., Ashjian, C.J., Campbell, R.G. Sea ice as a tracer for circulation features associated with the Barrow area Bowhead whale feeding hotspot. Poster presentation.