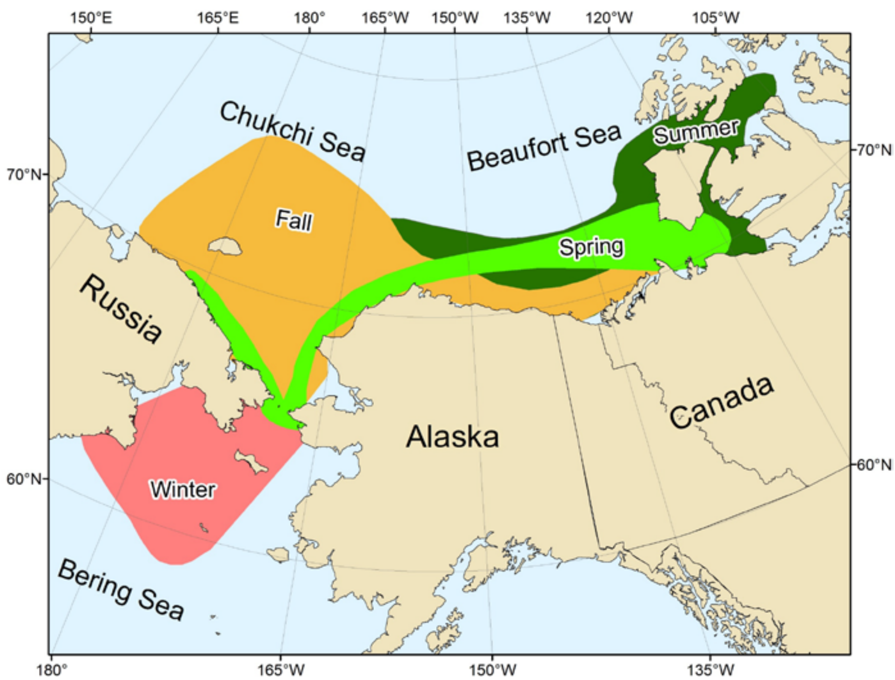
OCS Study
BOEM 2013-01110

Satellite Tracking of Bowhead Whales

Movements and Analysis from 2006 to 2012
Final Report



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Satellite Tracking of Bowhead Whales:

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Project Organization Page

Authors:
Lori T. Quakenbush (B.S., M.S.) is a Fish and Wildlife Biologist IV and Program Leader for the Arctic Marine Mammal Program within the Alaska Department of Fish and Game. Her role in this project was that of Principal Investigator and Project Manager and her activities included coordination, communication, contracting, permitting, tagging, presentations, report writing, and manuscript preparation.

Robert J. Small, PhD. is a Wildlife Scientist I and the Statewide Marine Mammal Program Leader within the Alaska Department of Fish and Game. His role in this project was that of Principal Investigator and his activities included coordination, contracting, permits, tagging in Canada, report and manuscript preparation.

John J. Citta, PhD. is a Biometrician II with the Arctic Marine Mammal Program within the Alaska Department of Fish and Game. His role in this project was data management, archive, and analysis, weekly map production and distribution, and presentation, report, and manuscript preparation.

Key Project Personnel:
John "Craig" George, PhD. is a Senior Wildlife Biologist for the North Slope Borough (NSB), Department of Wildlife Management. He is a bowhead whale expert and his role in this project was to coordinate project and tagging activities in the NSB, communicate with the AEWC and Whaling Captain's Associations, and prepare manuscripts.

Mads Peter Heidi-Jørgensen, PhD. is a Senior Scientist with the Greenland Institute of Natural Resources and is an expert in tagging large whales in Greenland, Canada, Russia, and South America. His group with includes Mikkel and Anders Villum Jensen have developed and provided the tags and some of the tag deployment equipment. Mikkel and Anders Jensen also deployed tags and trained others in tag deployment.

Lois Harwood is a Wildlife Biologist with the Arctic Aquatic Research Division, Department of Fisheries and Oceans Canada. She provided coordination, contracting, permitting, personnel, and secured funding for tagging operations in Canada.

Harry Brower, Jr., Lewis Brower, Billy Adams, George Tagarook, Eddie Arey, Tom Akeya, and Clarence Irrigoo are Alaskan Subsistence whalers who were key participants as taggers and boat drivers.

James Pokiak, Charles Pokiak, Angus Alunik, Dennis Arey, Larry Arey, Pat Kasook, Buddy Gruben, Douglas Panaktalok are Canadian hunters and trappers who were key participants as taggers and boat drivers.

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Appendix E-6. Quakenbush, L.T., J.J. Citta, J.C. George, H. Brower, Jr., L. Harwood, R. J. Small, and M.P. Heide-Jørgensen. 2011. How many industrial activities do individual bowhead whales from the Western Arctic stock encounter annually? 19th Biennial Conference on the Biology of Marine Mammals, 28 November – 2 December, Tampa, FL. (Abstract and oral presentation).

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Executive Summary

Bowhead whales (*Balaena mysticetus*) are the most important species for many subsistence communities along the coasts of the Beaufort and Chukchi seas and for Bering Sea island communities for their nutritional and cultural importance. Bowhead whale summer and fall habitats coincide with areas of oil and gas activity and interest, therefore information is needed to better understand bowhead feeding areas and migration routes in order to plan lease sales, permit development activities, and design effective mitigation measures. Within a five-year (2006-2010) satellite telemetry study, we have combined satellite tag technology and the tag deployment skills of Native subsistence whalers to greatly increase our knowledge of bowhead whale movements and behavior in a relatively short period of time. During this study we provided information on the movements and timing of spring migration, rate of travel, ice conditions and use of leads along the spring migration route and at spring destinations. We also documented interactions with seismic operations and summer movements beyond the known range of the western Arctic stock of bowhead whales. We documented fall use of the Barrow area, fall migration behavior through Chukchi Lease Sale Area 193, and intensive use of the northern Chukotka coast as well as the timing and route into the Bering Sea for winter. Most tagged bowhead whales spent the winter in the western Bering Sea in heavy ice and did not commonly frequent polynyas, the marginal ice zone, or near shore areas. Diving data indicated that bowheads dove frequently to the bottom in winter and may be feeding. This final report is for the subsequent 3-yr study (2010-2013) in which we have continued the cooperative efforts with Native subsistence whalers, the Alaska Eskimo Whaling Commission, the North Slope Borough, the Greenland Institute of Natural Resources, the Department of Fisheries and Oceans Canada, and the local Canadian Hunters and Trappers Associations to further describe the year-round movements and behavior of the western Arctic stock of bowhead whales. Specifically, we have expanded our sample sizes to better address summer movements, fall migration especially in the Beaufort Sea, and to further evaluate the inter-annual variability of feeding areas and migration routes. We also deployed an oceanographic tag to associate water temperature and salinity with bowhead diving behavior and we began tagging from St. Lawrence Island to lessen potential biases in our data due to tagging location. In addition to bowhead whales, we also tagged, biopsied, and photographed gray whales in the Bering and Chukchi seas to learn more about gray whale movements and use of the study area. During the eight years of these studies we have developed a solid working relationship with subsistence whalers and our other partners and we are prepared to continue this relationship for the next five years to learn more about bowhead whales by using oceanographic tags and by developing an acoustic tag that will add to our understanding of bowhead behavior relative to noise. We will also focus on the variability of movements from year to year and how bowhead whales interact with industrial activities.

Introduction

During the first five years of this study (2006–2010) we learned about the movements and timing of bowhead whales during the fall migration across the Chukchi Sea and the amount of time whales spent in the Chukchi Lease Sale Area (Quakenbush et al. 2010a). We also learned about their winter range in the Bering Sea, the timing of its use, sea ice conditions in winter, and when the spring migration begins (Citta et al. 2012). We found that summer movements were more complicated than generally believed. We learned that at least one bowhead traveled far to the north and east, entered the Northwest Passage, and used an area frequented by the eastern Arctic bowhead stock (Heide-Jørgensen et al. 2011). Another bowhead, tagged near Barrow during the fall migration, did not pass Barrow the following spring but spent the summer in the Russian Chukchi Sea (Citta et al. 2012; Quakenbush et al. 2012). We also identified areas we believe to be important for bowhead feeding; the suitability of these areas for feeding appears to be dependent upon oceanographic conditions, which may be ephemeral. In addition to movements of whales tagged in 2010–2012, this report includes new analyses of whales tagged previously.

Objectives for this study include learning more about the inter-annual variability of movements, oceanographic conditions conducive for feeding, and behavior relative to industry activities. We also explored whether tagging whales at other locations, such as St. Lawrence Island, resulted in different movements or behavior.

Goals and Objectives

This study was designed to provide data to address the objectives listed below and for data to be integrated with concurrent research on oceanographic conditions relative to variability in bowhead whale feeding behavior and habitat utilization.

Overall Objective: The overall objective of this study is to work with subsistence whalers to deploy satellite transmitters on bowhead whales in order to collect data that can be used to accomplish the following specific objectives.

Objective 1**:** Test the general hypothesis that all bowhead whales in the western Arctic stock make seasonal migrations between the Bering Sea and feeding grounds in western Canada.

Objective 2**:** Test the related hypothesis that occasional concentrations of bowhead whales feeding in nearshore waters of the Beaufort Sea east of Barrow are a product of delays in migration by whales returning from summering in Canada.

Objective 3: Test the alternative hypothesis that the above occasional concentrations of whales feeding east of Barrow are composed of whales that generally summer in the eastern Chukchi Sea and only enter the southwestern Beaufort Sea periodically, and under certain oceanographic conditions.

Objective 4: To the extent possible, test the hypothesis that the above concentrations of whales consist of representative proportions of demographic (sex and age, i.e., size) groups as observed in the western Arctic population.

Objective 5**:** Test the hypothesis that the above concentrations of bowhead whales consist of individuals that are only present in the aggregations for hours to days as opposed to weeks to months.

Objective 6**:** Estimate the rate and timing of travel of whales during migration across the Beaufort Sea.

Objective 7: To the extent possible, document and describe the general pattern of year-round movements by bowhead whales, the degree to which migrating whales make use of specific polynyas or channels, and estimate for individual whales time budgets of time spent in specific geographic regions and/or functional habitat areas.

Objective 8: Instrument other species of baleen whales when encountered during bowhead tagging efforts when practical.

Methods

Coordination

Meetings, workshops, other communication. Meetings with the Alaska Eskimo Whaling Commission (AEWC), local whaling captains, and the North Slope Borough have been fundamental to this tagging project. We also participated in the Synthesis of Arctic Research (SOAR) meeting to develop plans for manuscripts that would incorporate data from tagged bowheads with data from other studies such as oceanographic and acoustic projects.

Tagging

We continued to use a system of tag deployment and attachment developed by the Greenland Institute of Natural Resources (i.e., Mads Peter Heide-Jørgensen and his assistants, Mikkel and Anders Jensen) that had been used successfully with bowhead whales in Canada and Greenland and North Pacific right whales (*Eubalaena japonica*) in the Bering Sea (Heide-Jørgensen et al. 2001, Heide-Jørgensen et al. 2003) and humpback whales in the South Pacific (see Figure 1 in Hauser et al. 2010). We used three types of transmitters; the first recorded only the locations of whales (SPOT transmitters), the second recorded location and diving information (SPLASH and Splash10 transmitters), and the third recorded dive profiles and oceanographic information (i.e., temperature and salinity; CTD transmitters). All transmitters use the ARGOS system of satellites. SPOT and SPLASH tags are manufactured by Wildlife Computers, Inc. (Redmond, WA, USA) and CTD tags are manufactured by the Sea Mammal Research Unit by the University of St. Andrews in Scotland. Between 2006 and 2008, SPOT tags were set to transmit 300 times per day, while SPLASH tags were set to transmit 350 times per day. We found 300 transmissions per day to be sufficient; after 2008, both SPOT and SPLASH tags were set to transmit 300 times per day. Tags were set to transmit all hours of the day and all days of the week; there was no “duty cycle” or “dead time.” Tags only send data when at the surface and more than one transmission is required by Argos satellites to calculate a location. The number of transmissions received from tags was variable and likely depends upon the position of the tag on the whale in addition to the tag settings.

The SPOT transmitter was housed inside a stainless steel cylinder (20 mm diameter) that was attached to a stainless steel anchor shaft with a cutting head and flexible barbs (5 cm long) along the shaft to impede expulsion from the blubber (Hauser et al. 2010). The anchor shaft and cylinder was 27.5 cm long and implanted beneath the whale’s skin, ~24.0 cm into the blubber, leaving ~3.5 cm of the cylinder outside of the skin and a short (15 cm) antenna extended from the top. The transmitter, housing, and anchor shaft weighed 240 g.

The SPLASH transmitter (8.5 x 5 x 2.5 cm) was deployed external to the whale's skin by a similar stainless steel anchor shaft with a cutting head and flexible barbs (4 cm long) along the shaft that implanted beneath the whale's skin. The transmitter was mounted to a steel plate that swiveled on the shaft allowing the transmitter to move to the position of least hydrodynamic resistance. This transmitter and anchor weighed 300 g. The total length of the transmitter and anchor shaft was 23.5 cm. When attached to a whale, 21 cm of the tag projected into the blubber, 2.5 cm remained above the skin, and a short (16 cm) antenna extended from the top. The transmitter and anchor weighed 294 g. Splash10 tags (discussed below) are the same size and shape as the SPLASH tags.

The CTD transmitter (also discussed below) was approximately 7 cm wide by 5 cm tall by 10 cm long and was deployed on a swivel shaft similar to that used on SPLASH and Splash10 transmitters. Anchor dimensions were virtually identical to that of SPLASH and Splash10 tags.

Tag capabilities are ever improving and we are exploring how new tag technology can be applied to bowhead studies. During this project, we deployed two new tag platforms: 1) Splash10 tags; and 2) a CTD tag.

The new SPLASH tags are called "Splash10" tags. SPLASH tags transmitted dive data in compressed and simplified histogram form, while the new Splash10 tags collect more detailed dive information. Specifically, Splash10 tags collect three new forms of data:

1) *Time Series Depth-Temperature Profiles* are messages with paired depth and temperature readings for the deepest dive in a 6-hr period. This setting collects paired depth and temperature readings in a time-series with 10 second spacing. These messages are sometimes very large if dives are very long.
2) *Depth-Temperature Profiles* record the minimum and maximum temperatures observed at 8 depths. The depths are chosen dynamically to include the minimum and maximum depths detected, and 6 other intermediate depths arranged equally between the minimum and maximum. Hence, they provide more detail than a dive histogram, which covers a 6-hr period, but not as much data as a true time-series.
3) *Dive Behavior* records the maximum depth and duration of a dive, along with its general shape. Possible shapes include "square," "V," or "U" shapes. Additionally, "V" and "U" shapes can be skewed right or left. This setting also records how much time is spent at the surface.

Each setting requires a differing amount of battery resources and messages are of different length. The *Time Series Depth-Temperature Profiles* are long messages that are difficult to transmit to a satellite. The *Depth-Temperature Profiles* and the *Dive Behavior* messages are compressed data that are easier to transmit. As such, we decided to deploy one tag (B12-4) that specified the *Time Series Depth-Temperature Profiles* and one tag (B12-03) that specified both the *Depth-Temperature Profiles* and *Dive Behavior*. We are currently reviewing the data from these tags to assess how best to parameterize new tags for our purposes.

The other new tag we deployed was a CTD (i.e., *C*onductivity, *T*emperature, *D*epth) tag. The CTD tag records linked readings for location, salinity, temperature, and depth. In effect, this tag was designed to collect salinity and temperature profiles along the track of a whale.

We attached the SPOT tags to whales using a 2 or 4-m long fiberglass pole system (Heide-Jørgensen et al., 2003), an airgun (ARTS, Air Rocket Transmitter System, see Heide-Jørgensen et al., 2001), or a crossbow. The pole was used as a jab-stick to tag whales at a distance of 2–4 m. The pole system included a biopsy tip (manufactured by CETA-DART, Denmark), a 2.5 cm-long stainless steel hollow cylinder 0.6 cm diameter with internal barbs, designed to obtain a skin biopsy during tag deployment that could be analyzed to determine gender of tagged whales. When using the ARTS, the SPOT tag was placed into a plastic cylindrical projectile that was loaded into the aluminum barrel of the airgun and propelled at the whale using compressed air from a SCUBA tank (Heide-Jørgensen et al. 2001). Penetration depth was controlled by a stopper on the plastic projectile when using the airgun and by a plastic device that holds the transmitter onto the pole. SPLASH and CTD tags do not fit into the barrel of the ARTS and were deployed only by using the fiberglass pole system (Heide-Jørgensen et al. 2003). All tags were deployed from aluminum boats (~5.5–6.1 m long) with outboard motors. In 2012, all tags were deployed using the pole system.

Genetic Analyses

Bowhead Whales. A biopsy rod with replaceable tips was mounted on each deployment pole so that a skin sample was collected as the tag was deployed (Heide-Jørgensen et al. 2003). DNA was extracted and analyzed to determine sex by genetics experts at the National Marine Fisheries Service, Southwest Fisheries Science Center for gender analysis and then archived. Genetic material from this archive was also used to assess stock structure within the western Arctic population of bowhead whales as requested by the International Whaling Commission.

Gray Whales. The same biopsy rod with replaceable tips system mounted on the deployment poles used for bowheads was also used for gray whales so that a skin sample was collected as the tag was deployed (Heide-Jørgensen et al. 2003). Additional biopsies were collected from gray whales that were not tagged by attaching biopsy tips to arrow shafts fired from crossbows. Both methods have been used successfully to attain biopsies in this and other studies (e.g., Heide-Jørgensen et al. 2003). DNA was extracted and analyzed to determine sex by genetics experts at the National Marine Fisheries Service, Southwest Fisheries Science Center for gender analysis and then archived. Genetic material from this archive was also used to assess stock structure within the eastern and western stocks of gray whales as requested by the International Whaling Commission.

Photo-identification

In addition to tagging and biopsy of gray whales we also took photographs using the standard protocol provided by David Weller of the National Marine Fisheries Service (NMFS) for the catalogs used to photographically identify individuals (Weller et al. 1999). We used a Canon EOS digital camera, with a 300 mm lens, set to 400 ISO and shutter speed of 1/1200 or faster if conditions warranted. Photos were taken of left and right flanks from the dorsal ridge back as well as photos of the ventral flukes when possible. Photos were recorded in fine, high quality JPEG and RAW formats to maximize image quality. Copies of all gray whale photos were shared with David Weller and Aimee Lang (NMFS) and with John Calamabokitis (Cascadia Research), for comparison with individuals in other catalogs.

Mapping
To keep all interested parties informed of tagged whale movements, maps were made on a weekly basis and sent to an extensive mailing list (there are ~230 recipients on the list) that includes many whalers and other subsistence hunters as well as agency personnel. ArcGIS version 9.2 (ESRI 2006) is used for all mapping. These maps and information about the project are also posted at the Alaska Department of Fish and Game's (ADF&G) website: http://www.wildlife.alaska.gov/index.cfm?adfg=marinemammals.bowhead. Recent maps are also archived at: http://www.adfg.alaska.gov/index.cfm?adfg=marinemammalprogram.bowheadmaps.

Movement Analyses
Analyses in this report are not confined to data collected between 2010 and 2012. To gain a more complete understanding of whale movements and distribution, we included data from all whales tagged between 2006 and 2012.

Data Management and Location Processing. Location data were collected using the ARGOS system (Harris et al. 1990) and a copy of the raw data is archived at ADF&G in Fairbanks. Transmitter locations were estimated based upon the number of times the transmitter communicated with Argos satellites when the whale was at the surface. Location error was estimated by the Argos system and characterized by "location classes" (see the Argos User's Manual for a complete description; available online from argos-system.org/manual/). Location classes are only an approximate representation of location accuracy (e.g., Vincent et al. 2002). Instead of using only the locations representing the highest accuracy (2 or 3), we chose to use all available location classes (B, A, 0, 1, 2, 3) and a filter developed by Freitas et al. (2008) in R version 2.5.1 (available online from R-project.org) to remove less accurate locations. The filter has separate velocity and angular components.

Bowhead whale locations that resulted in swim velocities of >1.94 m/s were removed unless they were within 5 km of the previous location. The threshold velocity of 1.94 m/s was based on direct measurements during spring migration and literature review indicating this velocity is the maximum observed migration speed of bowheads not fleeing vessels or assisted by currents (Zeh et al., 1993). The angular component of the filter is used to remove locations with a high degree of location error that fall far from the line of travel, but still within the threshold velocity. These locations are essentially outliers and they create "spikes" or acute deviations in the line of travel (e.g., Freitas et al. 2008, Keating 1994). For location i, this deviation is measured as the angle between locations i-1, i, and i+1. We used the default settings within the Freitas et al. (2008) filter; i.e., within 2.5 km of the track line, locations resulting in angles <15°were removed and locations between 2.5 and 5 km of the track line were removed if they resulted in angles <25° (see the manual for Package 'argosfilter' for more detail, available online at cran.R-project.org). We then removed locations that fell on land to establish the final set of locations used to determine bowhead whale migratory paths and areas of concentrated use.

Analysis of Time Spent Within Petroleum Areas. We used all telemetry data collected between 2006 and 2013 to quantify when tagged whales were present within petroleum areas. Transmitter locations were filtered as described above. When calculating the number of calendar days that whales transmitted within various oil and gas exploration/lease areas we pooled all study years (i.e., 1 January 2008 and 1 January 2009 are both simply "1 January"). Pooling across years yields a more general understanding of when whales might be detected within a petroleum area. However, charts should be interpreted cautiously. Annual variation in the movements of whales might be confounded with how many whales are tagged each year. Hence, documenting the range of days that whales are present within an area is more important than the actual number of whales.

We examined bowhead whale use of the following petroleum areas (Fig. 1):

1. Alaskan Chukchi Sea: We examined use within all of Lease Sale Area 193 and specifically within the leased blocks.
2. Central Alaskan Beaufort Sea, Prudhoe Bay
3. Central Alaskan Beaufort Sea, Camden Bay
4. Canadian Beaufort Sea, Mackenzie-Tuktoyaktuk
5. Russian Chukchi Sea: Russia's main oil and gas company, Rosneft, recently signed an agreement with ExxonMobil to explore three areas for liquefied natural gas (LNG) reserves (Appendix A). These areas include Severo-Vrangelevskiy 1, Severo-Vrangelevskiy 2, and Yuzhno-Chukotsky (Fig. 1).

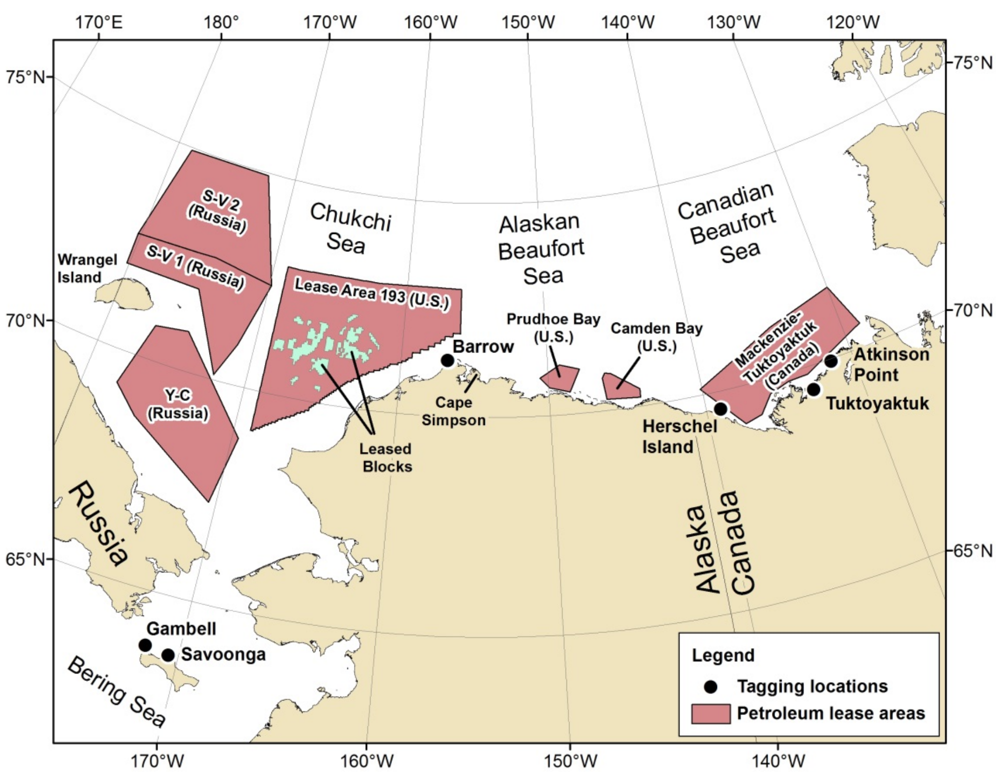


Figure 1. Locations where bowhead whales were tagged (black circles) and petroleum exploration/development lease areas (red polygons) within the Chukchi and Beaufort seas.

Safety
Safety plans and emergency contacts were specific to each tagging effort. We purchased some safety equipment, used additional safety equipment purchased during the previous study, and trained personnel in its use. Safety equipment included floatation suits, first aid kits, VHF radios, satellite phone, personal satellite-linked locator beacons, and GPS units. Tagging near Barrow also included a formal float plan filed with the NSB Search and Rescue Team.

Results

Coordination
We worked closely with the AEWC, the local whaling captain's associations, the North Slope Borough (NSB), the Greenland Institute of Natural Resources, the Department of Fisheries and Oceans (DFO) Canada and the local Hunters and Trappers Committees, and BOEM. See Table 1 for project history by month and year. We maintained a webpage on the State of Alaska, Division of Wildlife Conservation website that was updated weekly with whale movements and explained the project (http://www.wildlife.alaska.gov/index.cfm?adfg=marinemammals.bowhead). We also sent maps to an extensive list of interested entities including individual whalers and whaling captains, NOAA Fisheries biologists, NSB, BOEM, and DFO.

We began this phase of the study by sponsoring a workshop for the Alaska Eskimo Whaling commission (AEWC) and the North Slope Borough to review the accomplishments of the 5-yr study that had just ended. Using the information from the workshop and input and recommendations from AEWC commissioners we developed a new study plan that was approved by the AEWC (Appendix B).

Table 1. Project history from 1 June 2010 to 25 August 2013.

Month	Year	Event
June	2010	Project awarded the U.S. Secretary of the Interior, Partners in Conservation Award for 2010. Tagged whale goes up Chukotka coast and does not pass Barrow in spring or summer.
July		Final Report to BOEMRE (2010-033) on first 5 years finalized.
August		Tagged 11 bowheads and 1 gray whale near Herschel Island and Tuktoyaktak Peninsula, Canada.
September		Presented project update to Barrow Whaling Captains in Barrow. Paper on fall movements in the Chukchi published in Arctic. *Fall and winter movements of bowhead whales* (Balaena mysticetus) *in the Chukchi Sea and within a potential petroleum development area.* Arctic 63(3):289–307.
October		Presented project update to AEWC.
December		Workshop with AEWC to evaluate project and develop new study plan.
January	2011	Oral presentation: *Bowhead inter-annual variability and exceptional movements of western Arctic bowhead whales from satellite telemetry, 2006–2010* at the Alaska Marine Science Symposium in Anchorage.

		Update to BOWFEST at their annual meeting in Anchorage.
February		Submitted manuscript to journal Arctic on winter movements. Lecture to Univ. of Alaska, School of Fisheries and Ocean Sciences. Lecture to Univ. of Alaska Marine Mammal Class. Update to AEWC at Mini-Convention in Barrow.
July		Presented Workshop Summary and Draft Study Plan to AEWC. Study plan was modified and approved. Paper accepted for publication by Arctic. *Winter movements of bowhead whales* (Balaena mysticetus) *in the Bering Sea.*
August		Tagged 5 gray whales near Barrow.
September		Tagged 1 gray whale near Barrow. Joint paper on Western Arctic tagged bowhead overlapping with Eastern Arctic tagged bowhead in summer 2010. *The Northwest Passage opens for bowhead whales.* Biology Letters doi:10.1098/rsbl.2011.0731
October		Update to AEWC in Anchorage.
November		Trained one whaling crew in Gambell and one in Savoonga for tagging.
December		Oral presentations at Society for Marine Mammalogy Conference in Tampa, Florida. Citta presented *Does the winter range of bowhead whales overlap commercial fisheries in the Bering Sea?* Quakenbush presented *How many industrial activities do individual bowhead whales from the from the Western Arctic stock encounter annually?*
January	2012	Oral presentations at the Alaska Marine Science Symposium in Anchorage Quakenbush presented *Western Arctic bowhead whale movements and habitat use throughout their range: 2006–2011 satellite telemetry results* and Citta presented *Does the winter range of bowhead whales overlap commercial fisheries in the Bering Sea?*
March		Paper on *Winter movements of bowhead whales in the Bering Sea* published in Arctic 68(1):13-34. Attended Synthesis Of Arctic Research (SOAR) meeting and outlined two bowhead papers; 1) identify bowhead hotspots and describe associated oceanography, 2) use oceanography to explore annual variability in fall migration behavior in Chukchi Sea.
April		Savoonga whaling crew deployed 2 tags on bowheads.
May		Gambell whaling crew deployed 2 tags on bowheads.
June		Presented bowhead study results (oral and written) to the Science Committee of the International Whaling Commission in Panama City, Panama (Quakenbush et al. 2012).
July		AEWC voted to continue tagging at Barrow in summer/fall due to plans for drilling in Chukchi and Beaufort seas this year. This vote allows for tags in addition to the purposes approved in the study plan in July 2011.
August		Gambell whaling crew tagged 1 gray whale near Gambell and assisted with biopsies and photographs of other gray whales.
September		Two bowheads tagged near Barrow (first CTD tag and first advanced Splash10 tag)
October		Update to AEWC in Anchorage.

November		Oral presentation *Industrial activities and western Arctic bowhead whales: what we have learned from satellite telemetry* at U.S.-Canada Oil and Gas Conference in Anchorage.
December		Manuscript on crab/pot fisheries and bowhead wintering areas submitted. Poster: *Industrial activities and western Arctic bowhead whales: what we have learned from satellite telemetry* for the Alaska Marine Science Symp. Shared data for use in planning shipping through Bering Strait. Shared data for use in three SOAR projects.
January	2013	Prepared 2012 annual report to BOEM.
February		Visited Gambell and Savoonga to plan tagging in spring 2013.
March		Prepared Draft Final Report.
May		Submitted Draft Final Report. Manuscript titled "*Interactions of bowhead whales and winter pot fisheries in the Bering Sea*." accepted by Marine Mammal Science.
June		Paper on *Interactions of bowhead whales and winter pot fisheries in the Bering Sea* published Marine Mammal Science doi 10.1111/mms.12047
July		Revised Draft Final Report
August		Submitted Final Report

Tagged Whales and Tag Performance

Bowhead whales. A total of 17 bowheads were tagged during this study between June 2010 and December 2012 (Table 2). Eleven whales were tagged near the Tuktoyaktak Peninsula, Canada, three were tagged near St. Lawrence Island, Alaska, and three where tagged near Barrow, Alaska. The sizes of the bowheads tagged ranged from 8.2–15.2 m; the largest was tagged near Barrow, Alaska, in September (Table 2). Of the 17 tagged, biopsies were collected from 10 and gender was determined for six; four are pending.

Of the 17 tags deployed on bowhead whales; 11 were SPLASH tags, two were Splash10 tags, three were SPOT tags, and one was a CTD tag. Tags deployed in 2010 lasted an average of 162 days (range = 0 to 380 days). No tags were deployed in 2011, and SPOT and Splash-type tags deployed in 2012 averaged 113 days (range = 0 to 232). The CTD tag was expected to last 60–90 days and it lasted 33 days (Table 2).

Gray Whales. A total of six gray whales were tagged during this study between June 2010 and December 2012. All were tagged in Alaska; five were tagged near Barrow and one was tagged near St. Lawrence Island (Table 2). Also included in Table 2 are details for the only other gray whale tagged (in 2009) during the initial study period (2006–2010). Tag durations for gray whales were less than for bowhead whales, averaging 36 days (range = 0 to 100 days). We expected shorter deployments than what is typical for bowhead whales because gray whales feed along the seafloor. Frequent rubbing on the bottom may damage or dislodge tags, resulting in shorter deployments.

Table 2. Bowhead whales tagged with satellite transmitters in Alaska and Canada between August 2010 and September2012 and gray whales tagged in Alaska and Canada between September 2009 and August 2012.

Whale Id	Date tagged	Location	Approx. length (m)	Sex	Tag type	Tag duration (days)
Bowhead						
B10-05	23-Aug-10	Tuk.	9.1	Unk	SPLASH[1]	30
B10-06	25-Aug-10	Tuk.	9.1	Unk	SPLASH	30
B10-07	25-Aug-10	Tuk.	9.9	Unk	SPLASH	4
B10-08	25-Aug-10	Tuk.	10.7	Unk	SPLASH	387
B10-09	25-Aug-10	Hershel	9.1	F	SPOT[2]	188
B10-10	27-Aug-10	Tuk.	9.1	Unk	SPLASH	0
B10-11	27-Aug-10	Tuk.	12.2+	M	SPLASH	281
B10-12	27-Aug-10	Tuk.	11.4	F	SPLASH	144
B10-13	27-Aug-10	Tuk.	10.7	F	SPLASH	78
B10-14	30-Aug-10	Tuk.	12.2	M	SPLASH	257
B10-15	30-Aug-10	Tuk.	12.2	F	SPLASH	380
--	20-Apr-12	Savoonga	8.2	F	SPOT	0
B12-01	24-Apr-12	Savoonga	12.2 +	Unk	SPLASH	232
B12-02	29-Apr-12	Gambell	13.7	Unk	SPOT	143
B12-03	10-Sep-12	Barrow	13.7	M	Splash10[4]	113
B12-04	10-Sep-12	Barrow	15.2	M	Splash10	274
B12-05	21-Sep-12	Barrow	13.7	M	CTD[5]	33
Gray						
G09-01	3-Sep-09	Atkinson	9.9	F	SPLASH	100
G11-01	15-Aug-11	Barrow	8.4	F	SPOT	13
G11-02	17-Aug-11	Barrow	9.1	M	SPOT	13
G11-03	17-Aug-11	Barrow	9.9	M	SPOT	45
G11-04	17-Aug-11	Barrow	9.9	F	SPOT	0
G11-05	18-Aug-11	Barrow	10.7	M	SPOT	16
G11-06	29-Sept-11	Barrow	8.4	Tbd	SPOT	6
G12-01[6]	12-Aug-12	Gambell	9.1	F	SPOT	65

[1] SPLASH = Tag that provides locations and dive histograms. [2] SPOT = Tag that provides locations only. [3] Tbd = Gender to be determined when DNA results are available. [4] Splash10 = Tag that provides location, dive histograms, and other, more, specific dive records (see Methods). [5]CTD = *C*onductivity, *T*emperature, and *D*epth tag that provides location and detailed dive profiles with information on water temperature and salinity. [6]This whale was also photographed and included in the photo-identification catalog.

Sex Ratio of Tagged Whales

Bowhead Whales. The majority of tagged whales of known sex are male (63%; Table 3). More males than females were identified within the tagged sample at Atkinson Point (*n* = 3), Barrow (*n* = 26), and Shingle Point (*n* = 4). More females than males were identified within the tagged sample at Herschel Island (*n* = 1) and Tuktoyaktuk (*n* = 5).

It is unclear what finding more males than females in the sample indicates about our sampling methods. Thirty-seven percent of tagged whales (24 of 65) could not be identified to sex and sample size within most tagging sites is very small. Only the sample at Barrow is large (*n* = 27). However, the pattern observed at Barrow (70% males) is similar to that observed across the entire sample (63%). While there might be more females than males at Tuktoyaktuk, Shingle and Atkinson points are in the same general area. Hence, it is unlikely that sex ratios are really different between Tuktoyaktuk, Shingle Point, and Atkinson Point. If we pooled these samples, there would be a slight male bias (54% male; 7 of 13). Because the pattern of male bias seems to be common to most of our tagging areas, it is unlikely that it reflects population segregation. Rather, we suspect that our avoidance of females with calves results in a male biased sample.

Table 3. Number of tagged bowhead whales with genetic sex determination by tagging location. For whales where sex is to be determined (Tbd), samples are pending analysis at the laboratory. The percentage of males is calculated only for whales of known sex.

Location	**#Female**	**#Male**	**#Unknown**	**#Tbd**	**%Male**
Alaska					
Barrow	8	19	15		70%
Gambell			1		-
Savoonga	1		1		0%
Canada					
Atkinson Point	1	2	1		67%
Hershel Island	1				0%
Shingle Point	1	3	1		75%
Tuktoyaktuk	3	2	5		40%
Total	**15**	**26**	**24**	**0**	**63%**

Behavior of Tagged Bowhead Whales by Sex and Age

Sex and Age Segregation. To assess if whales congregating near Barrow show evidence of sex or age segregation, we examined all whales of known sex and length with satellite locations within 150 km of Barrow. This distance, 150 km, is large enough to include the area whales frequent near Barrow, which we have identified as one of several hotspots (See area #3 in Figure 29). Sex was determined from genetic analysis of skin biopsies and age was based upon whale length. Based upon the work of Koski et al. (1993), we define "mature" whales as those at least 13 m in length and "immature" whales as those less than 13 m in length.

To date, most tagged whales are immature (26 of 41, 63%). Our entire tagged sample of known sex whales consists of 11 immature females, 4 mature females, 15 immature males, and 11 mature males. However, fewer whales are in the sample that transmitted within 150 km of Barrow. Whales transmitting within 150 km of Barrow include 9 of 10 immature females, 13 of 15 immature males, 3 of 4 mature females, and 6 of 8 mature males. Hence, sample sizes are small, especially for mature whales.

The pattern of use near Barrow is generally the same for immature females and males (Fig. 2). Immature whales of both sexes pass Barrow from approximately 18 April to 5 May. Traditional knowledge from Barrow says that the migration begins in early April with mid-sized whales passing by in the nearshore lead (Huntington and Quakenbush 2009). In mid-April lots of small whales pass by for several days and then a second wave, consisting of mid-sized whales, typically arrives in early May after a gap of two or three days from the first wave. The second wave has many whales, and lasts about a week (Huntington and Quakenbush 2009). One whaling crew has seen the same recognizable whale on 23 April year after year suggesting that individuals may have a personal pattern (Huntington and Quakenbush 2009). In the fall, immature whales are generally present between the end of August to approximately the first week in November. Traditional knowledge from Barrow says that bowhead whales return to the area near Point Barrow in late August, though some large whales were seen 20–30 miles offshore in open water in early August one year. Generally, the large whales come first in the fall migration, followed by mid-sized whales, with small whales coming last. This pattern is less distinct in fall than is the three-wave pattern in spring (Huntington and Quakenbush 2009).

Patterns for mature tagged whales are much less certain, due to small sample size. In the spring, mature tagged males passed Barrow between 21 April and 5 May (much like immature whales). However, one mature male (B10-01) and one mature female (B10-03) migrated past later in the spring (between 24 and 25 May); both were tagged near Barrow. According to traditional knowledge, the final wave in spring is of large whales, including cows with calves, which arrive in mid-May and continue into June (Huntington and Quakenbush). Currently our sample sizes are insufficient to say how the age classes may differ in their migration timing. In general, mature whales arrive at Barrow in the fall during the same window of time that immature whales are present. Mature females were present between 22 August and 2 September, while mature males were present between 9 September and 19 October (Fig. 2). Again, due to small sample sizes, we cannot conclude that the pattern of use by mature whales differs from that of immature whales.

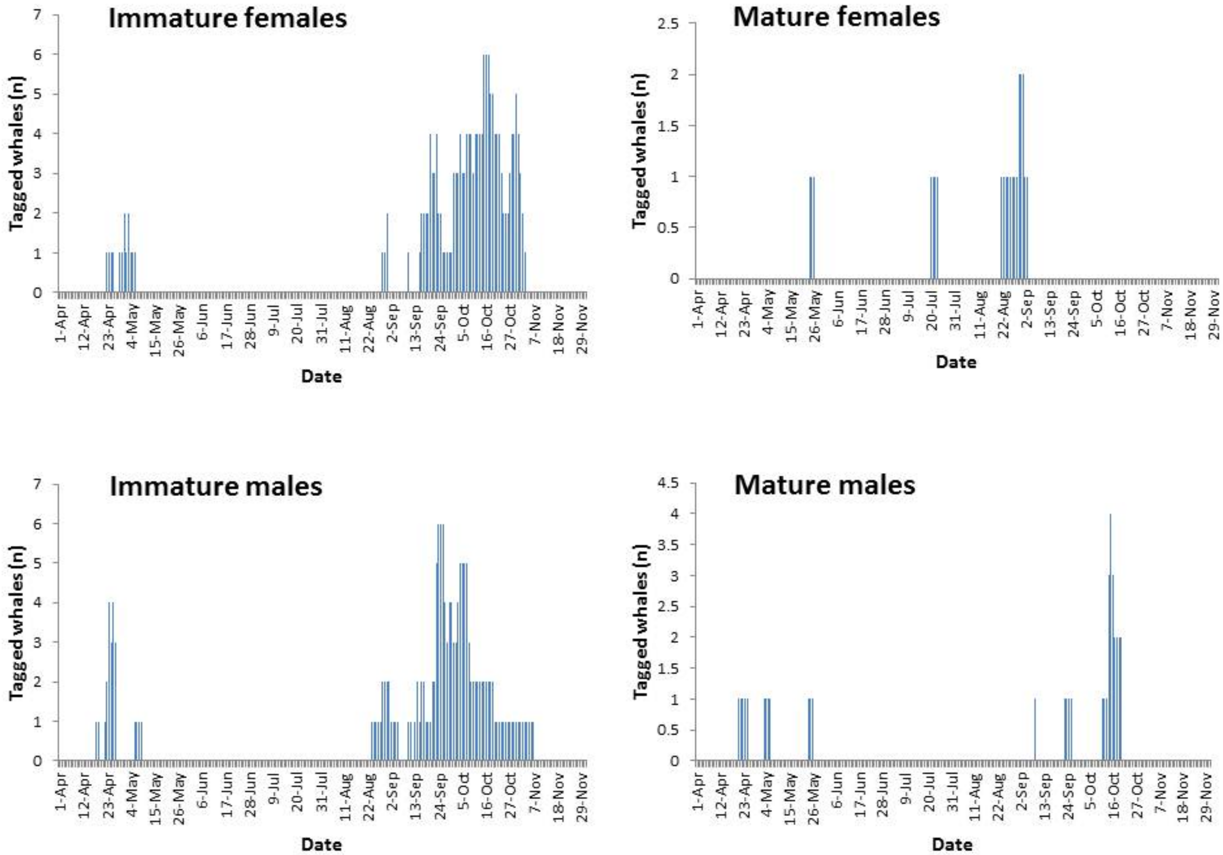


Figure 2. Number of tagged bowhead whales present within 150 km of Point Barrow by sex and age class. Sex was determined genetically from skin biopsies and whales ≥13 m in length were classified as mature.

One mature female (B10-03) was within 150 km of Barrow between 21 and 23 July 2010, after the spring migration but prior to the fall migration (Fig. 2). While there is not enough data to suggest that whales found near Barrow prior to the fall migration are only mature whales, there might be evidence to suggest that mature whales are more likely to make non-traditional or “unexpected” movements. For example, both whales that traveled up into the Canadian Arctic, north of Banks Island, were mature males (B06-01 and B10-01) (Figs. 3–5). We have also observed two whales migrate across the Beaufort and Chukchi seas, to Russia, well in advance of the typical fall migration. In 2010, B10-03 crossed the Chukchi to the Russian coast in late August (blue track in Fig. 4). In 2012, B12-02, a whale tagged near Gambell, followed the normal spring migration pattern, but left Amundsen Gulf in early June traveling west and then northwest to spend July 2012 in the Arctic Ocean as far north as 78˚N latitude (Fig. 5). B10-03 was a mature female and B12-02 was a mature whale of unknown sex. However, the two whales (B08-07 and B08-12) we observed making round trips from Amundsen Gulf to an area approximately 200 km north of Barrow and back before fall migration (see Fig. 25 in Quakenbush et al. 2010b) were both immature males. Hence, while mature whales may be more likely to make long distance movements prior to the fall migration, immature whales may also make similar movements. We need more data to determine whether .movement patterns differ by sex and age affect.

Gray Whales. In addition to the eight gray whales (four females, three males, one to be determined) that were tagged during this and our previous study, we also collected biopsies and photographs of five other gray whales (three females, one male and one unknown) near Gambell, AK, in August 2012. These gray whales will be genetically and photographically identified as individuals for matching with genetics and photos collected by other researchers at other locations in order to understand more about where they go during other times of year. We have determined the sex of 11 of 12 gray whales biopsied (one is still to be determined); seven were females and four were males (36% male).

Bowhead Whale Movements and Behavior by Season

Satellite telemetry continues to be a valuable tool for tracking movements over long distances and time periods. Additional years have allowed us to identify inter-annual variation in fall movements across the Chukchi Sea and unexpected movements by some individuals high into the Canadian Arctic (Heide-Jørgensen et al. 2011). During the initial study period (2006–2010), few whales were tracked westward across the Beaufort Sea during the fall migration. The tags deployed in Canada in 2010, during this study period (2010–2012), greatly improved our sample size for that region and time period.

Summer/Fall (July–September) High Arctic, Beaufort Sea, and Chukchi Sea. Two bowhead whales have made long distance movements outside of the migration period and into Canadian High Arctic waters. One whale (B06-01) tagged in spring 2006 made a 1,400 km round trip from Amundsen Gulf to the north end of Banks Island and back (Fig. 3) (Quakenbush et al. 2010b, Heide-Jørgensen et al. 2011) and another, tagged in spring 2010, left Amundsen Gulf passed through Prince of Wales Strait between Banks and Victoria islands into Viscount Melville Sound (Fig. 4) where it overlapped in space with a bowhead whale from the Eastern Arctic stock tagged in West Greenland (Fig. 5) (Heide-Jørgensen et al. 2011).

Other complicated summer/fall movements have been identified. To date, after the spring migration to Amundsen Gulf, we have observed two tagged whales (B08-07 and B08-12) make round trips from Amundsen Gulf to Barrow and back before fall migration (see Fig. 25 in Quakenbush et al. 2010b). Kaktovik whalers see the first whales in the fall in late July or early August but the main migration begins in late August (Huntington and Quakenbush 2009). Because Kaktovik is done whaling and engaged in subsistence activities on land before the fall migrations ends, they could not say when that occurs.

We have also observed two whales migrate across the Beaufort and Chukchi seas, to Russia, well in advance of the typical fall migration. In 2010, B10-03 crossed the Chukchi to the Russian coast in late August (blue track in Fig. 6). In 2012, B12-02, a whale tagged near Gambell, followed the normal spring migration pattern, but left Amundsen Gulf in early June traveling west and then northwest to spend July 2012 in the Arctic Ocean as far north as 78˚N latitude (Fig. 7).

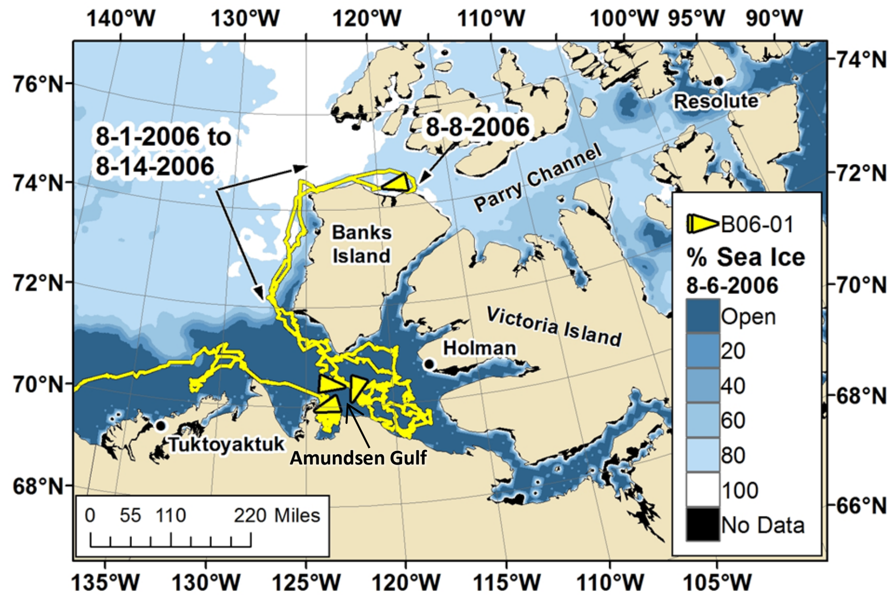


Figure 3. Track of satellite tagged bowhead whale B06-01 from Amundsen Gulf to the north end of Banks Island and back in summer.

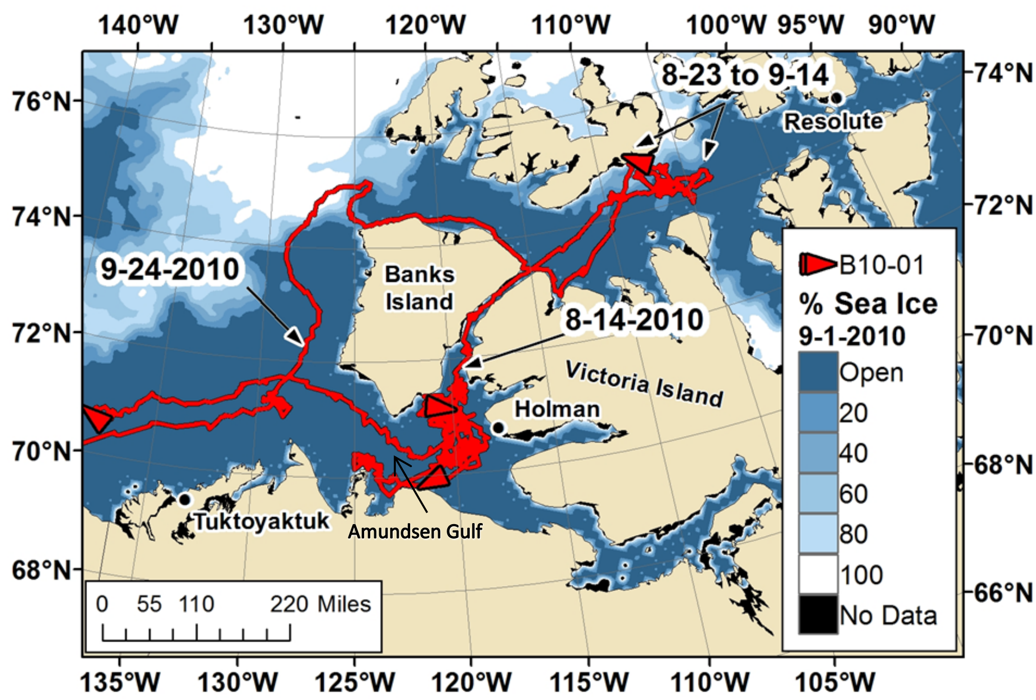


Figure 4. Track of satellite tagged bowhead whale B10-01 that left Amundsen Gulf passed through Prince of Wales Strait between Banks and Victoria islands into Viscount Melville Sound where it overlapped in space with a bowhead whale from the Eastern Arctic stock tagged in West Greenland (Heide-Jørgensen et al. 2011).

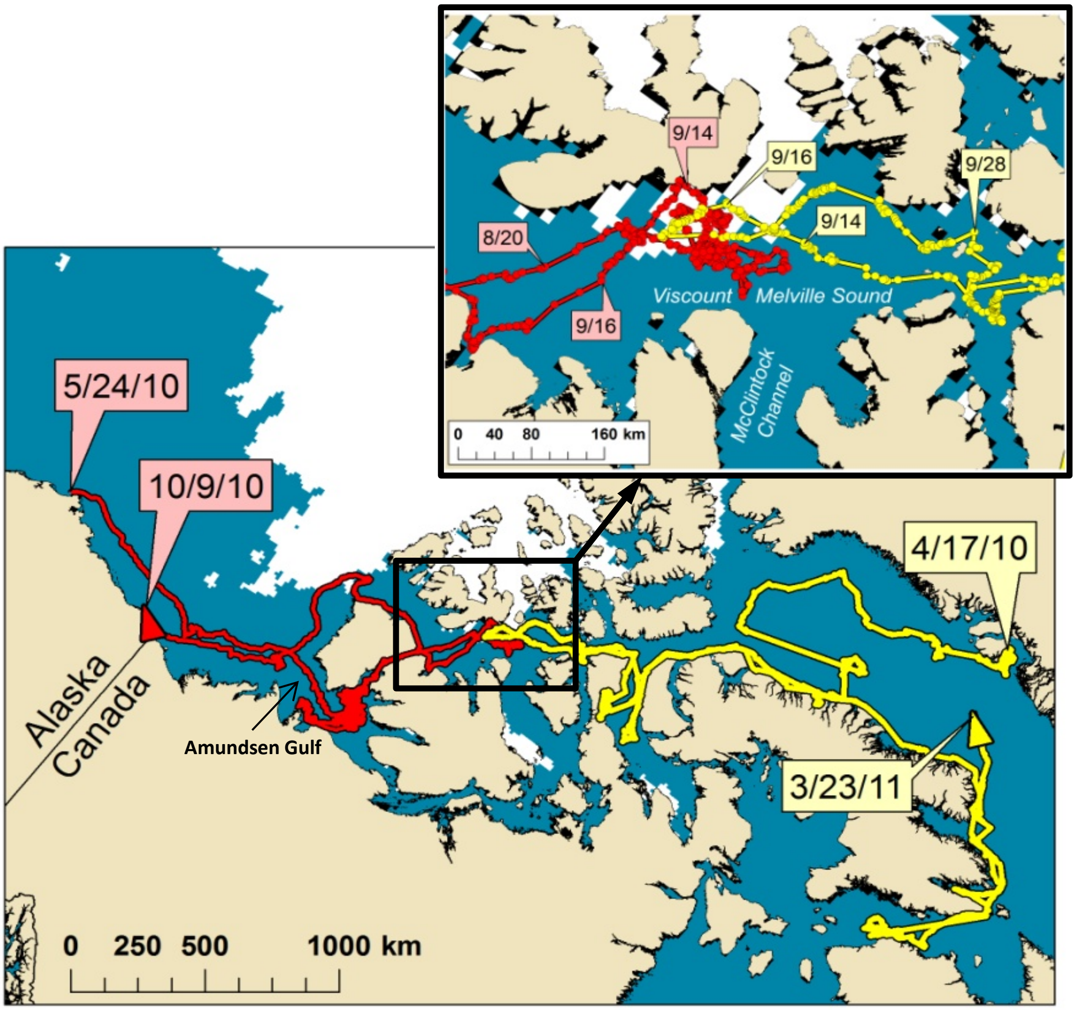


Figure 5. Tracks of two tagged bowhead whales that entered the Northwest Passage in September 2010. One whale from the Western Arctic stock traveled north and east while a second whale from the Eastern Arctic stock traveled north and west to Viscount Melville Sound (Heide-Jørgensen et al. 2011).

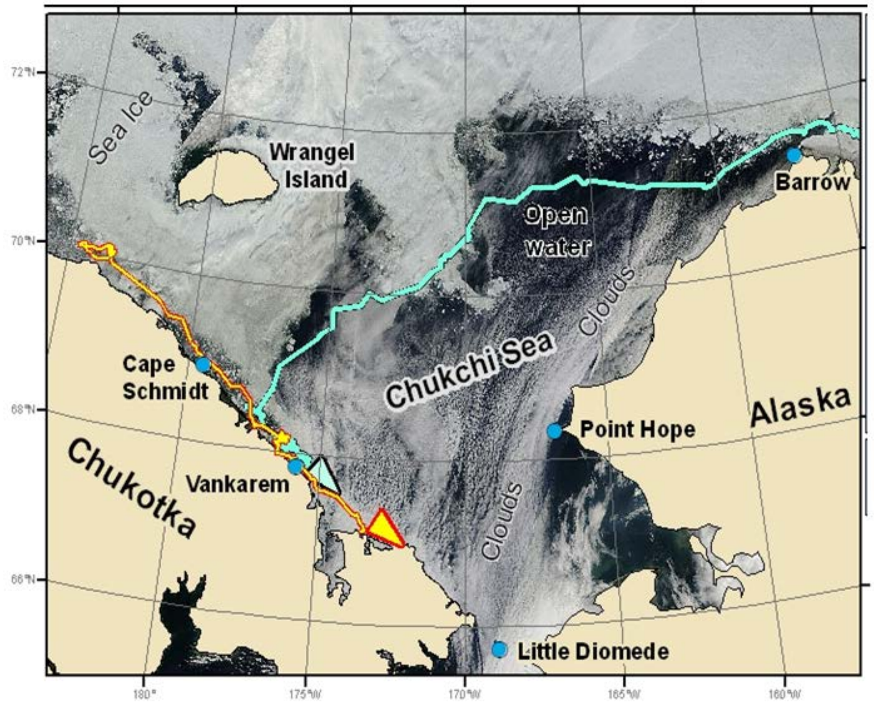


Figure 6. Bowhead whale B09-09 (yellow track); the only tagged whale to migrate north along the Russian coast in spring and spend the summer in the Chukchi Sea. This whale was joined in summer (late August) 2010 by B10-03 indicating summer use of the Chukchi Sea.

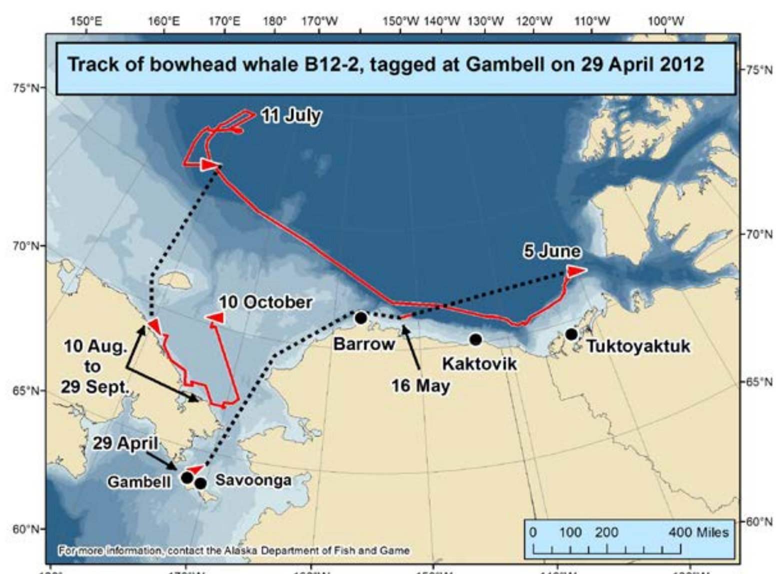


Figure 7. Farthest north summer movements of a tagged bowhead whale (B12-02) to greater than 78˚ N latitude in July 2012.

One whale (B09-09) tagged near Barrow in August 2009 summered in the Chukchi Sea in 2010 (Quakenbush et al. 2010b, 2012; Citta et al. 2012). B09-09 migrated later in the spring than the other tagged whales, leaving the Bering Sea ~26 May, and traveled up the Chukotka coast (Fig. 8). Between mid-June and 30 August, when it last transmitted, B09-09 remained in the Chukchi Sea (yellow track in Fig. 6; Fig. 8), and is the only tagged whale that has not passed Barrow and traveled through the Beaufort Sea to the Amundsen Gulf region during the spring.

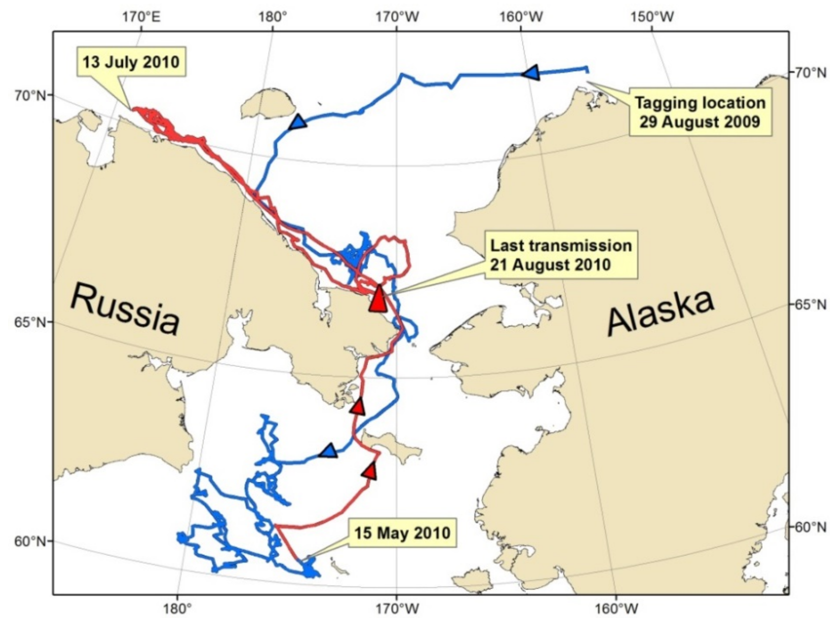


Figure 8. Complete track of B09-09; the only tagged whale that did not pass Barrow in the spring on the way to the Canadian Beaufort Sea and instead spent spring and summer in the Chukchi Sea mostly in Russian waters. Blue track is 29 August 2009–15 May 2010. Red track is 16 May 2010–29 August 2010.

During the fall migration, all but one tagged bowhead whale traveled within 50 km of shore in the Alaskan Beaufort Sea. Kaktovik whalers see whales very close to shore that stop to feed, but others travel farther offshore, moving steadily westward (Huntington and Quakenbush 2009). When the leader of a group of feeding whales shows its flukes when it dives it is telling the others it is time to go. Bowheads do not come close to shore every year, but whales have long been found nearshore as indicated by Arey Island's Iñupiaq name, Nalagiagviq, which means "place to listen for whales." (Huntington and Quakenbush 2009). The only whale traveling farther offshore was B06-01, tagged in 2006 (see yellow track in Fig. 9); this whale traveled within 90 km of shore.

Kaktovik whalers do not see a strong pattern of whales regarding the timing of passage by size of whales (Huntington and Quakenbush). While larger whales may tend to come by first, whales of all sizes are seen throughout the migratory period. They do not see the really big whales that are seen at Barrow probably because they travel more than 20 mi from shore. Females with calves are first seen in mid-September and are not the first to be seen (Huntington and Quakenbush 2009). Passage time from Demarcation Point to Point Barrow averaged 16 days (range = 5 to 43 days).

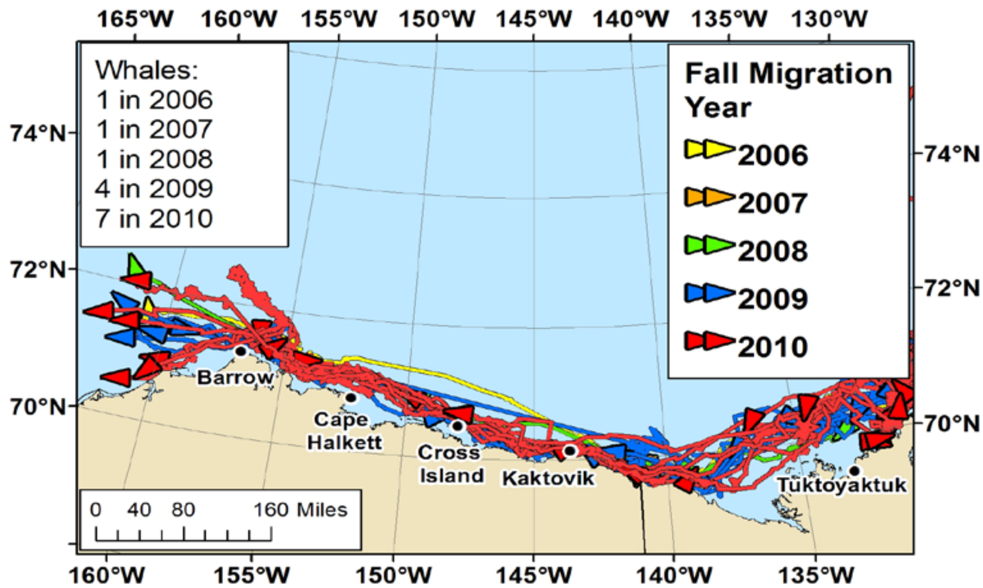


Figure 9. Tracks of tagged bowhead whales traveling westward across the Beaufort Sea during fall migration.

General Use of Beaufort Lease Sale Areas. Many tagged bowheads spent much of the summer feeding in the Canadian Beaufort Sea, much of that time within the active Mackenzie-Tuktoyaktak oil and gas exploration area (Figs. 1 and 10). In fall, whales left the Canadian Beaufort Sea traveling west, where they passed through the leased blocks in Camden Bay followed by the Prudhoe Bay leases on the way to the Chukchi Sea leases (Fig. 10).

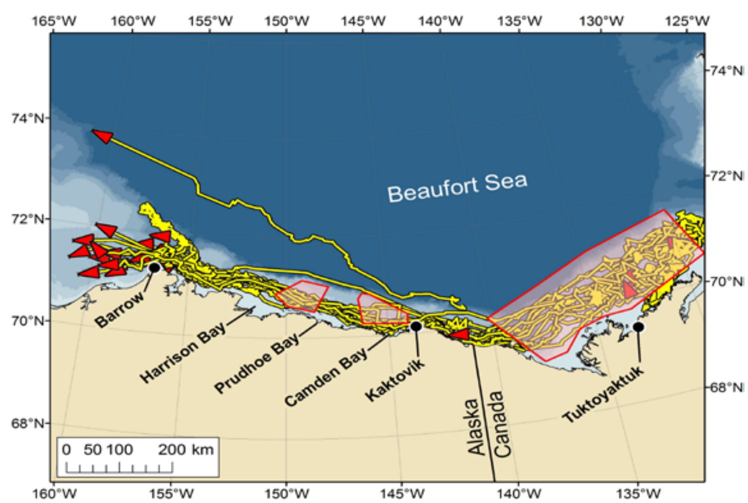


Figure 10. Tracks of tagged bowhead whales in Canada and westward across the Beaufort Sea during fall migration (all years) relative to the locations of oil and gas lease sale areas (outlined in red).

Fall (August–December) Chukchi Sea. Movements of tagged whales in the Chukchi Sea during fall 2006–2008 were published in Quakenbush et al. (2010a). Additional years of data including those from this study period have shown that there is inter-annual variability in how and when bowhead whales migrate through the Chukchi Sea (Fig. 11). Prior to this study period, tagged whales were consistent in crossing the Chukchi Sea fairly directly and then moving slowly southward along the Chukotka coast before moving into the Bering Sea (Figs. 11, 12). In 2012, however, most bowheads lingered in the central Chukchi Sea and entered the Bering Sea more directly, without spending time along the northwestern Chukotka coast (Fig. 13). Only B12-02 visited the north-western Chukotka coast (red track in Fig. 12). This whale moved into the Chukchi Sea in early July, prior to the typical fall migration and visited the northwestern Chukotka coast between 10 and 22 August. This whale then moved to the central Chukchi Sea in September and October, when the other whales tagged in 2012 were also present in the central Chukchi Sea.

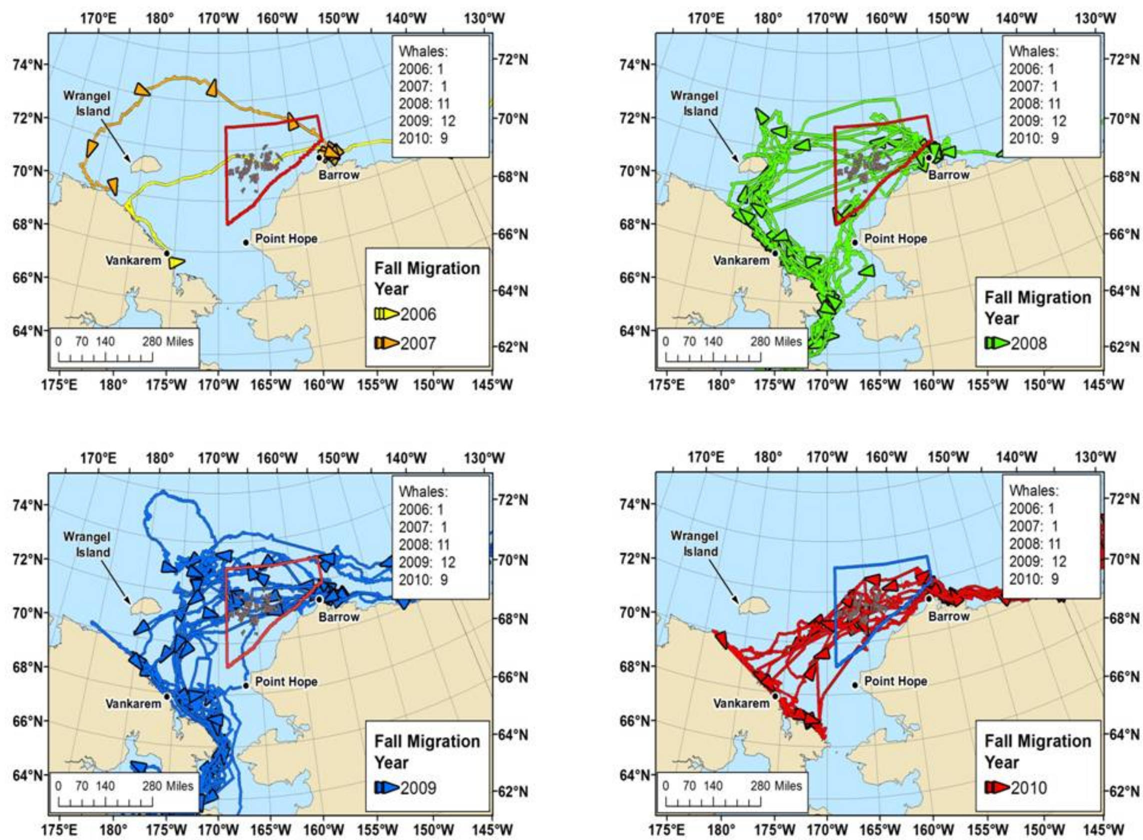


Figure 11. Tracks of satellite-tagged bowhead whales showing different paths across the Chukchi Sea by year but consistent use of the Russian coast in August through December, 2006 through 2010. The oil and gas lease sale area is outlined in red (or blue) and the leased blocks appear inside the outline in gray.

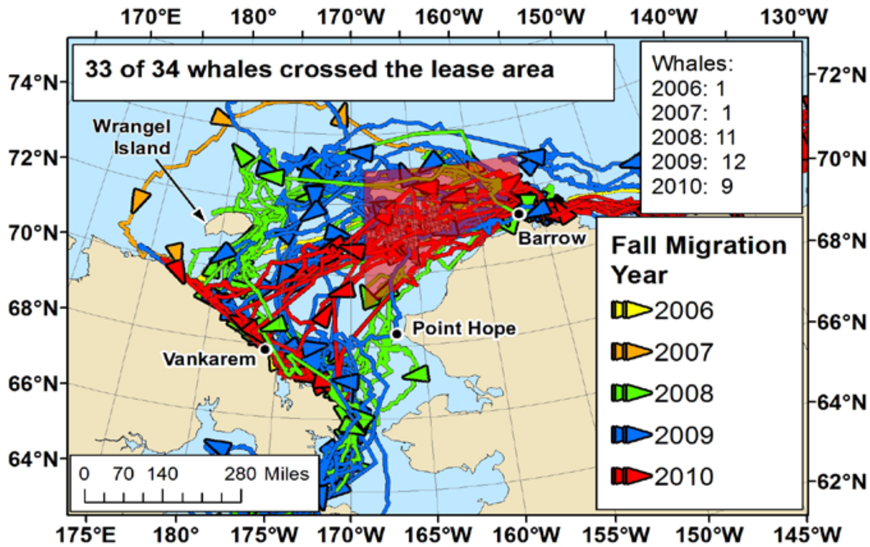


Figure 12. Tracks of 32 satellite-tagged bowhead whales in the Chukchi Sea from August through December, 2006–2010 relative to Chukchi Lease Sale 193 (shaded in red).

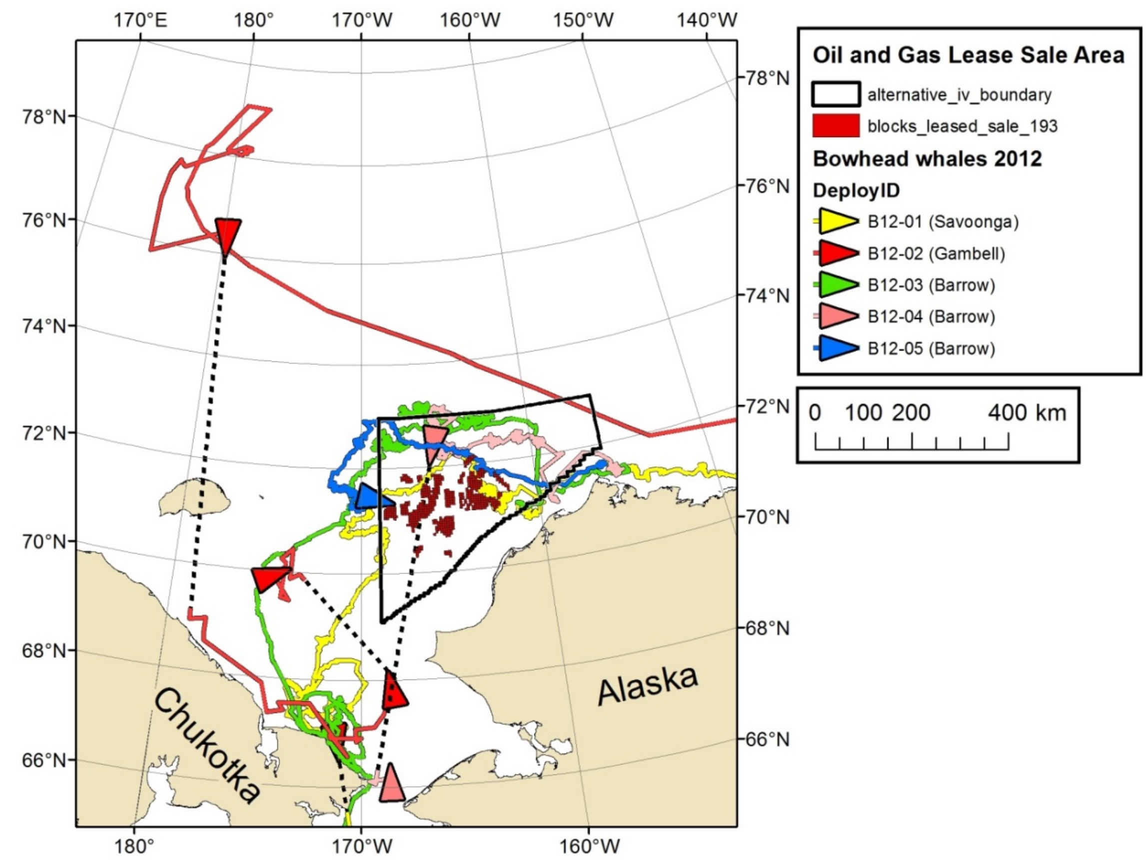


Figure 13. Fall tracks of tagged bowhead whales in the Chukchi Sea in 2012.

General Use of Chukchi Lease Sale Area including during drilling. Prior to 2012, virtually all whales (33 of 34) crossed the lease sale area, but no whales spent significant time within the sale area (Fig. 12). Whales typically crossed the Chukchi Sea quickly and then traveled slowly southward along the Chukotka coast, eventually into the Bering Sea. In contrast to this, most whales in 2012 lingered within the Chukchi Sea lease sale area (Fig. 13), co-occurring with drilling operations by Shell at the Burger Prospect (Fig. 14). Whales remained in the central Chukchi Sea until sea ice formed along the northwestern coast of Chukotka. Whales then traveled to the coast of Chukotka near Bering Strait and entered the Bering Sea in early December (Fig. 13).

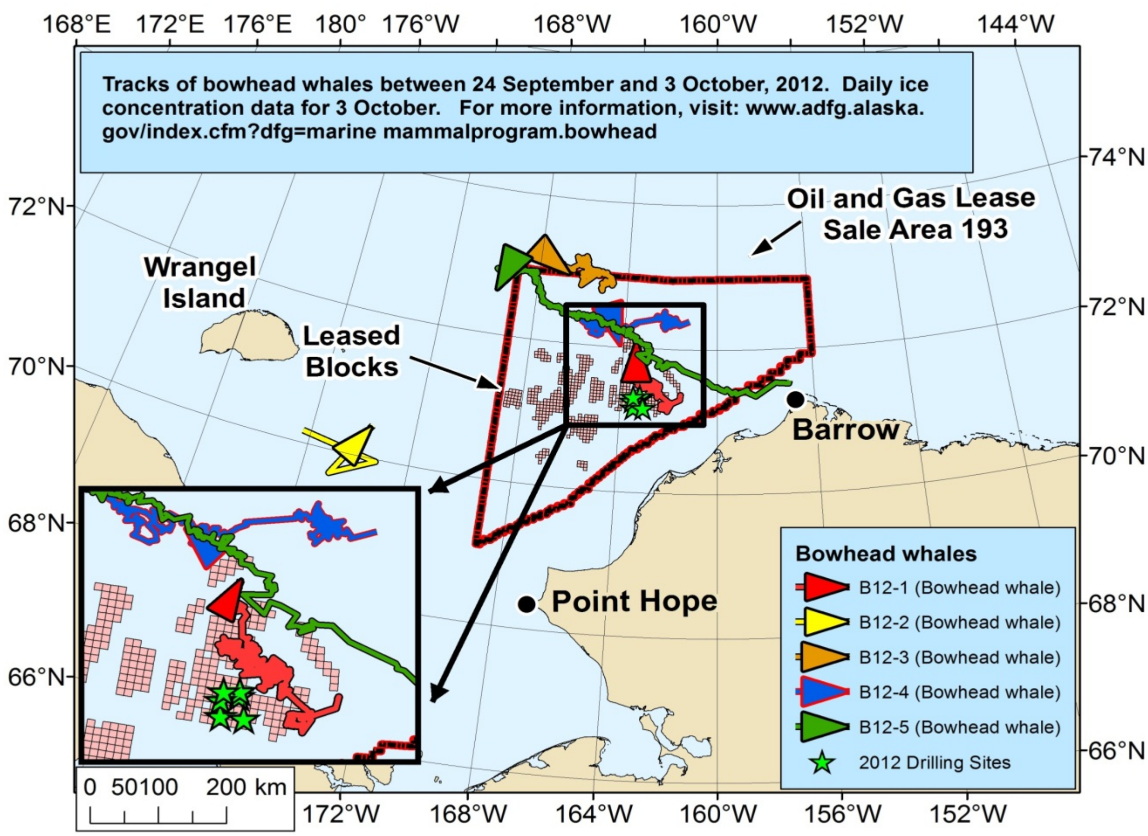


Figure 14. Tracks of tagged bowhead whales within Chukchi Sea Lease Sale Area during drilling in 2012. Drilling occurred at only one of the green stars.

Winter (December-March) Bering Sea. Winter movements of 11 tagged whales in 2008/09 and 10 in 2009/10 were published in Citta et al. (2012). In the first winter, tagged bowheads remained in the Anadyr Strait area in the western Bering Sea (Fig. 15). In the second winter, tagged bowheads were found in that same area and farther east to St. Matthew Island (Fig. 15). Bowheads remained inside the ice edge during both winters. Additional winter information was collected for three tagged whales in 2012/13. In 2012, one tagged whale (B12-3) traveled as far east as 164˚W longitude and 58˚N latitude (near Bristol Bay in the Bering Sea (Fig. 16).

In the winter, St. Lawrence Island whalers first see whales along the fast ice north of Savoonga in December about two days before they are seen in Gambell. The predominant winter movement of bowheads past St. Lawrence Island is west of the island (Noongwook et al. 2007), which corresponds to movements of the tagged whales where only one passed west of the island (Fig. 15).

Tagged whales used offshore areas of heavier, yet fractured, ice despite the availability of areas with open water near shore (Figs. 17 and 18). Within a random sample of bowhead locations, only 1 of 102 locations (i.e., ~1%) fell within an open water area (polynya) during the winter of 2009/08 (Citta et al. 2012). Only 3 of 53 locations (~6%) fell within polynyas during the winter of 2009/10.

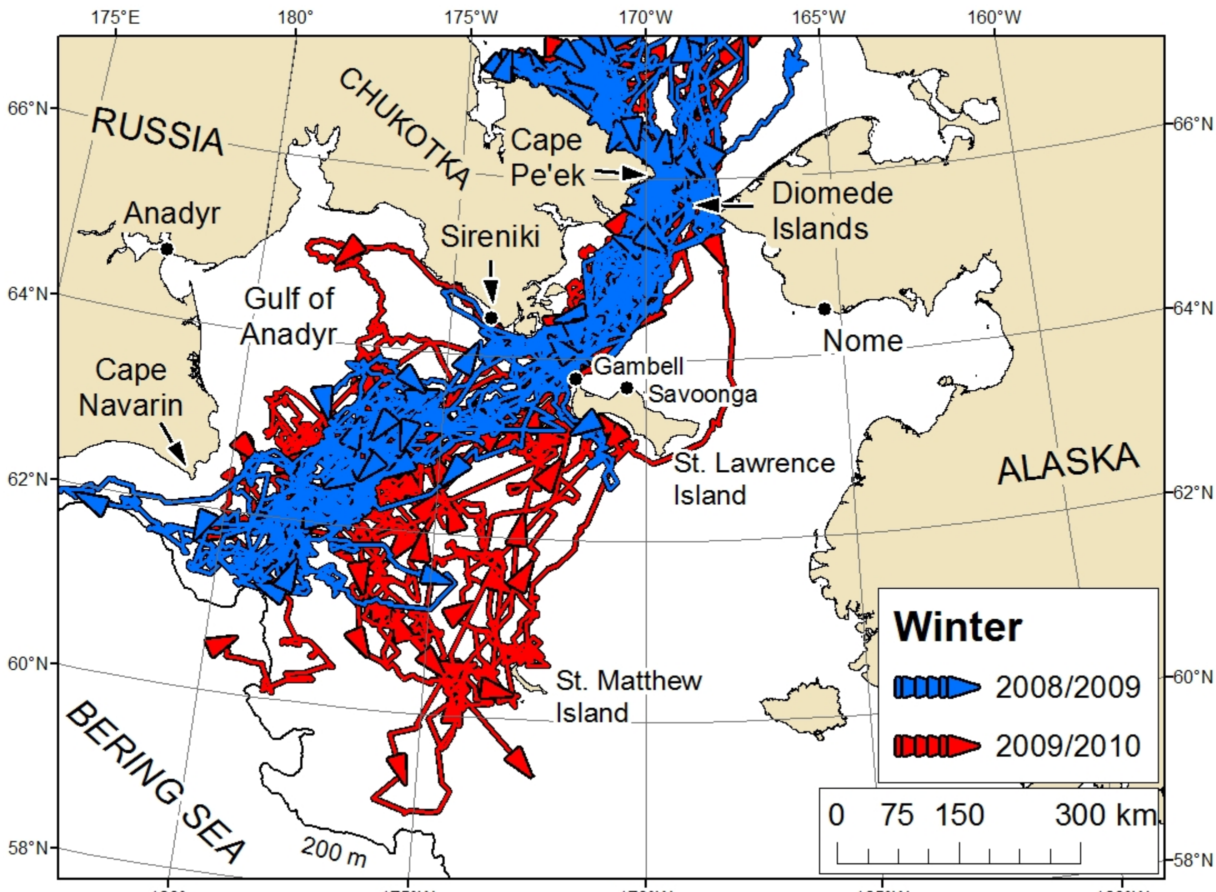


Figure 15. Tracks of tagged bowhead whales within the Bering Sea during the winters of 2008/09 (n=11) and 2009/10 (n=10). Figure 3 in Citta et al. 2012.

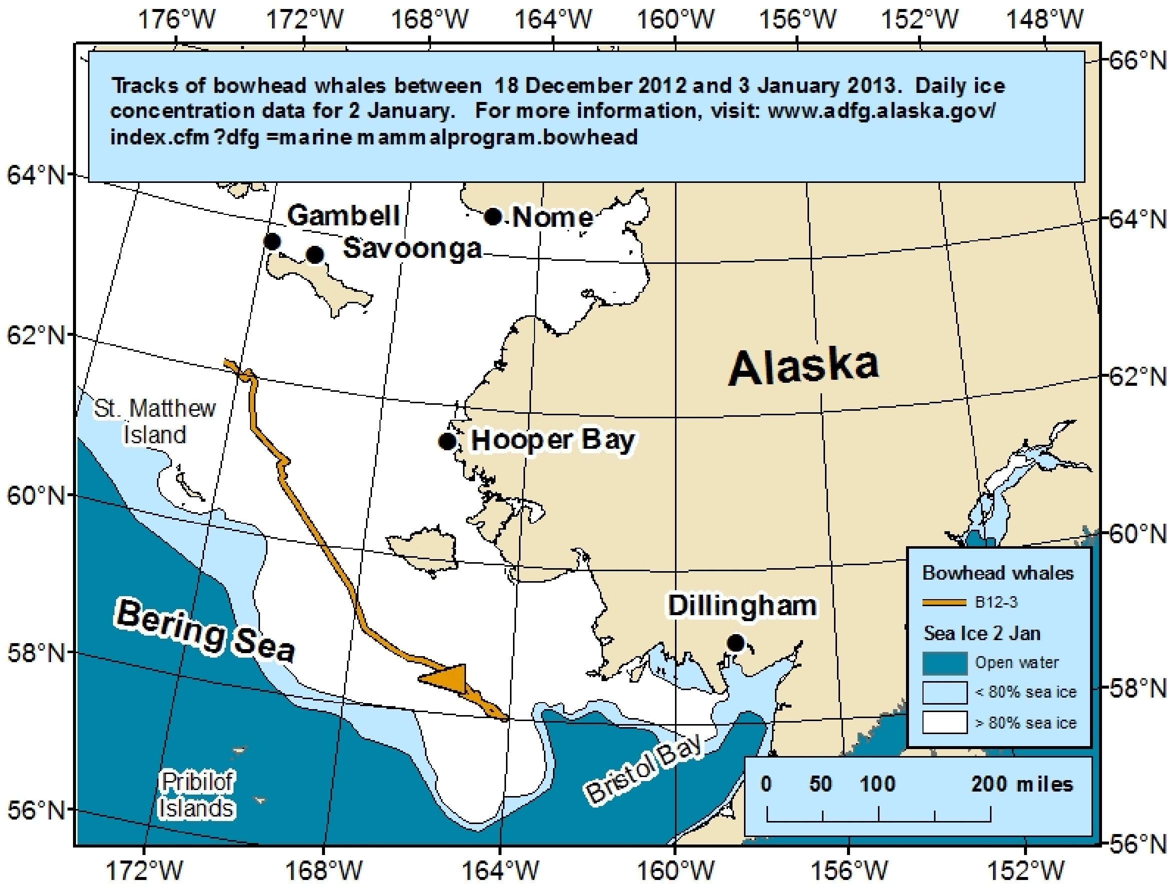


Figure 16. Track of B12-3 in late December 2012 and early January 2013 showing its farthest east location.

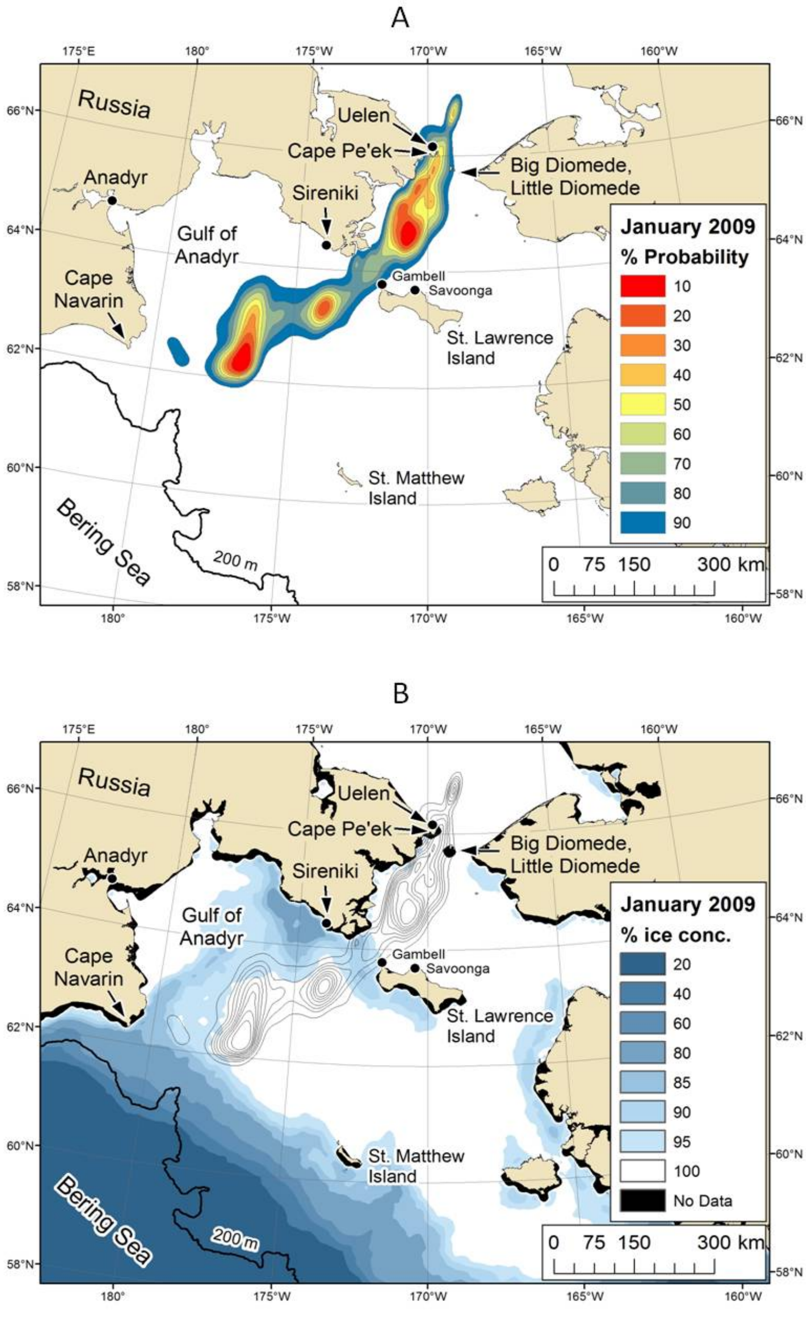


Figure 17. Contours showing probability of use (%) by bowhead whales and average Advanced microwave Scanning Radiometer-Earth observing system (AMSR-E) ice concentration in January 2009. The ice concentration maps include non-shaded contours for probability of use, illustrating how probability of use overlaps ice concentration.

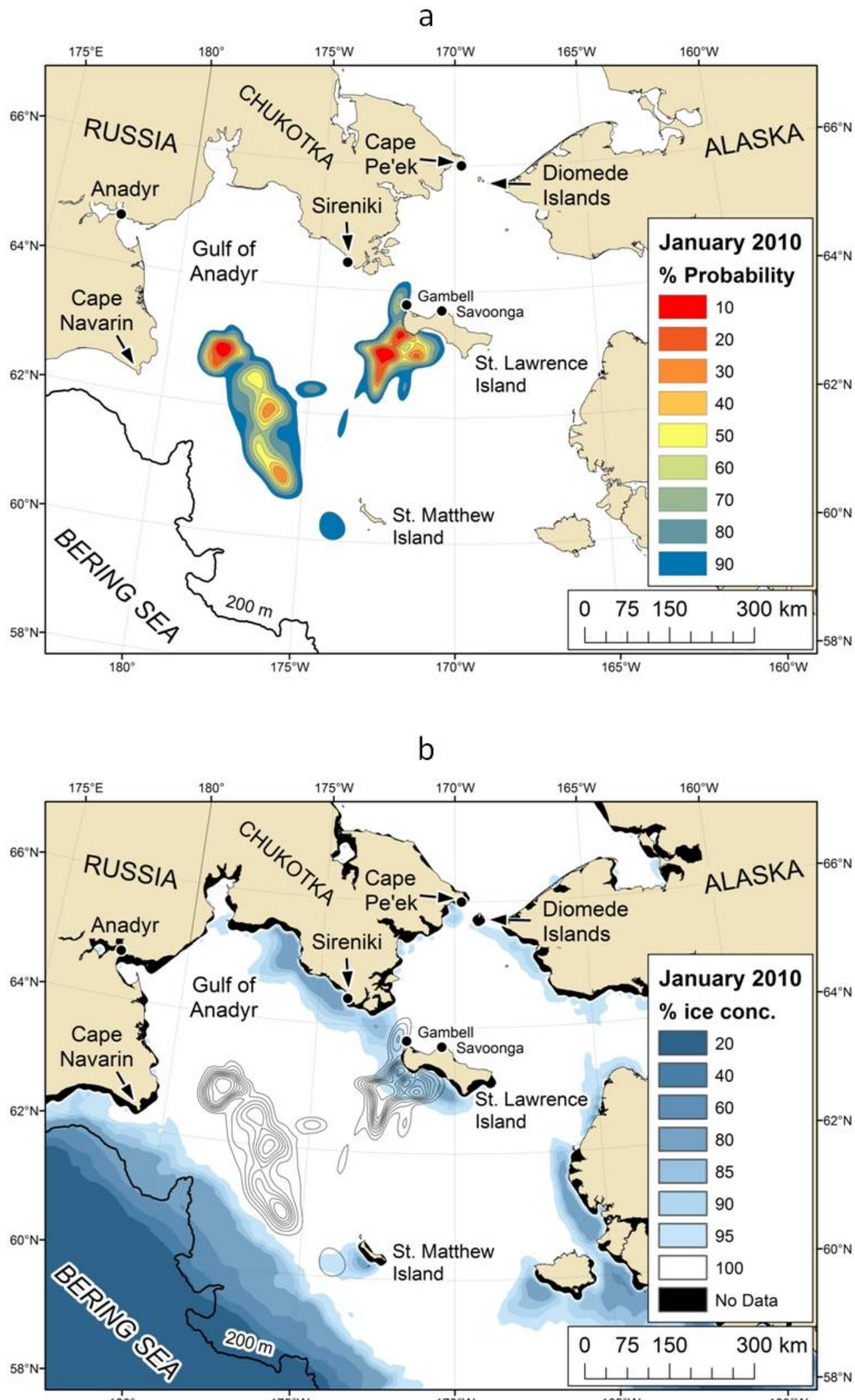


Figure 18. Contours showing probability of use (%) by bowhead whales and average Advanced microwave Scanning Radiometer-Earth observing system (AMSR-E) ice concentration in January 2010. The ice concentration maps include non-shaded contours for probability of use, illustrating how probability of use overlaps ice concentration.

Spring (April-June) Bering, Chukchi and Beaufort Seas. Tagged bowhead whales left the Bering Sea between 31 March and 27 April in 2009 (n = 7). In 2010, 5 of 6 tagged bowhead whales left the Bering Sea between 10 and 22 April. One whale (B09-09) migrated much later (26 May). Prior to reaching Bering Strait all tagged whales traveled north by passing west of Saint Lawrence Island. This pattern is also described by whalers from St. Lawrence Island (Noongwook et al. 2007). Some whales passing near shore of Pugughileq (Southwest Cape), the spring whaling location of the Village of Savoonga, travel west toward the Russian coast. Whales passing to the west more offshore turn northwest and pass Gambell. This is known because pulses of whales seen close to shore at Pugughileq are not seen from Gambell, and pulses of whales seen at Gambell are not seen first at Pugughileq (Noongwook et al. 2007). Although not seen recently, some whales must have traveled by to the east because there are bones at archeological sites there (Noongwook et al. 2007). In Bering Strait, whales passed by both to the east (n = 8) and to the west (n = 3) of the Diomede Islands and three whales did not transmit often enough when passing to determine where they passed the Diomede Islands (Citta et al. 2012, Quakenbush et al. 2012).

Until 2010, tagged whales traveled north along the Alaska coast mostly east of the eastern boundary of the Chukchi lease sale area (Fig. 19) towards Point Barrow then on to Amundsen Gulf, Canada (Fig. 20). Whale B09-09, however, migrated later in the spring than the other tagged whales, leaving the Bering Sea ~26 May and traveled up the west side of the Chukchi Sea instead of the east side (Fig. 21). By 14 June 2010 this whale was west of Wrangel Island (Fig. 8) (Quakenbush et al. 2010b, 2012). Between mid June and 21 August 2010, B09-09 remained in the Chukchi Sea (Fig. 8) and this is the only whale tagged during the spring in any year that has not passed Barrow and entered the Beaufort Sea.

Traditional knowledge from Barrow includes bowheads seen as early as February but they usually arrive in mid-April (Huntington and Quakenbush 2009).

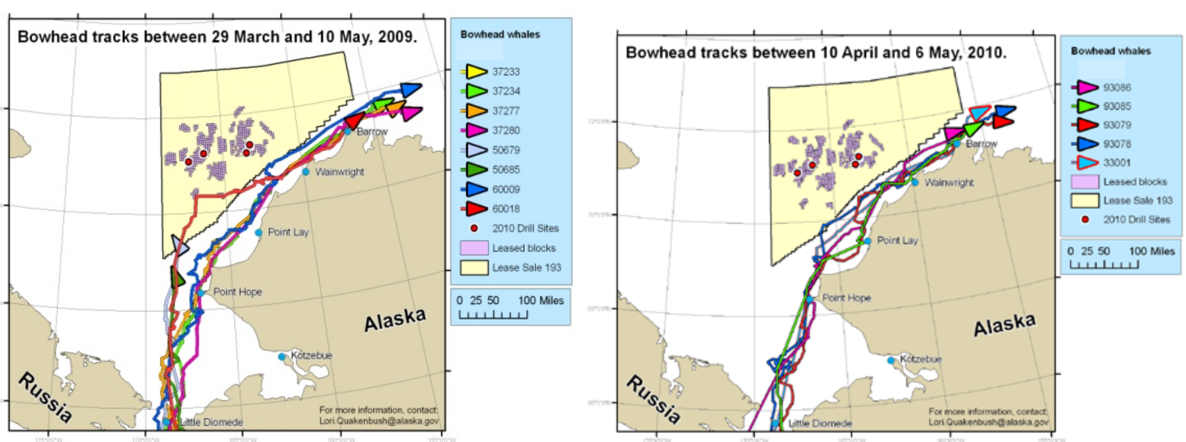


Figure 19. Tracks of tagged bowhead whales on spring migration through the Chukchi Sea in late March through early May, 2009 and 2010.

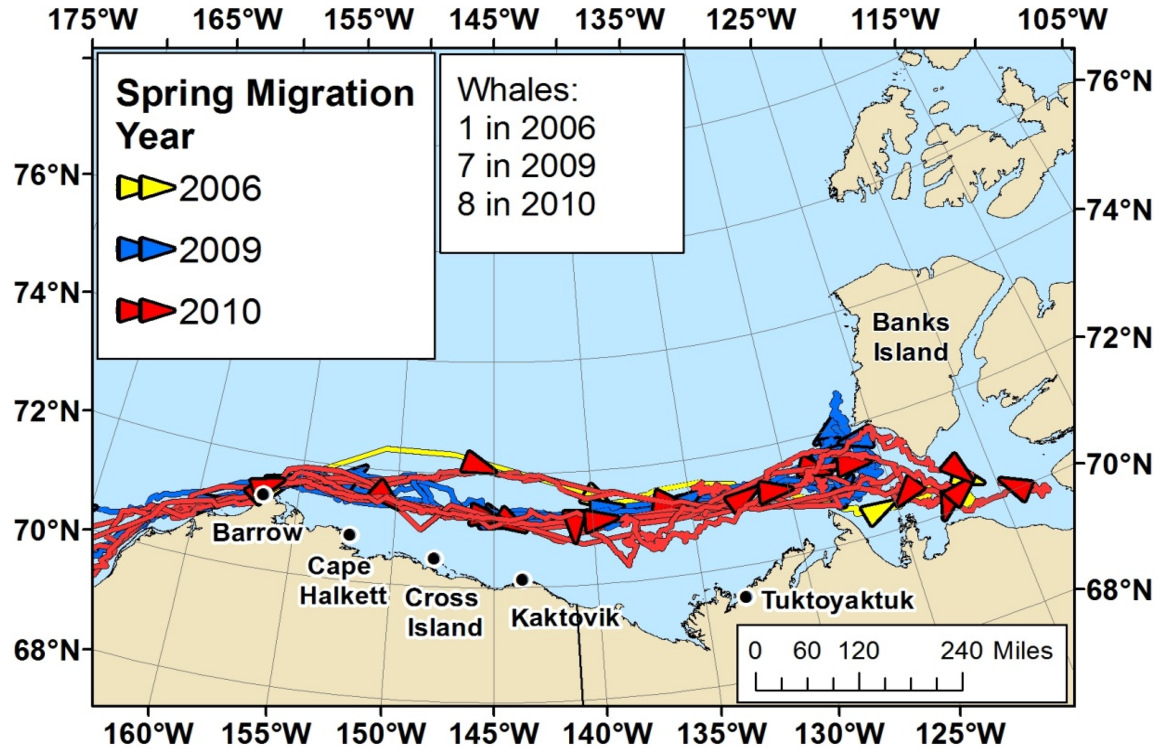


Figure 20. Tracks of tagged bowhead whales on spring migration through the Beaufort Sea in May 2006, 2009, and 2010.

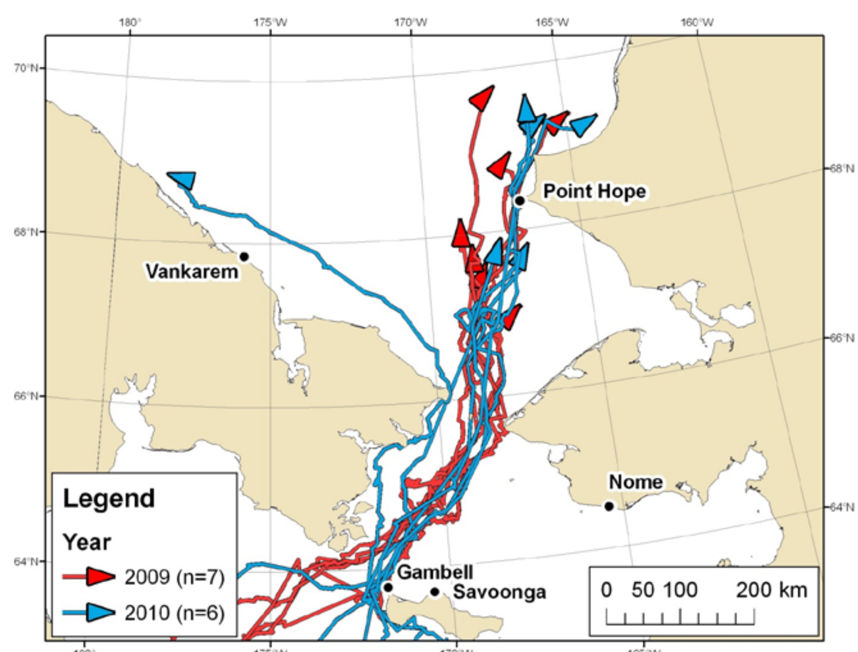


Figure 21. Tracks of bowheads whales leaving the Bering Sea on spring migration including the only tagged whale (B09-09) to travel northward along the western Chukchi Sea coast.

Bowhead Whale Presence and Timing within Petroleum Areas
We were able to document the timing of use of proposed and active petroleum areas for 63 tagged bowhead whales (Fig. 22). We were able to track 57 of these during the fall migration period (July–December) and show by histograms the days that tagged whales were present in each active petroleum area (Fig. 23) and each potential petroleum area (Fig. 24). Histograms should be interpreted cautiously because annual variation in the movements of whales might be confounded by how many whales are tagged. Hence, documenting the range of days that whales are present within an area is more important than the actual number of whales.

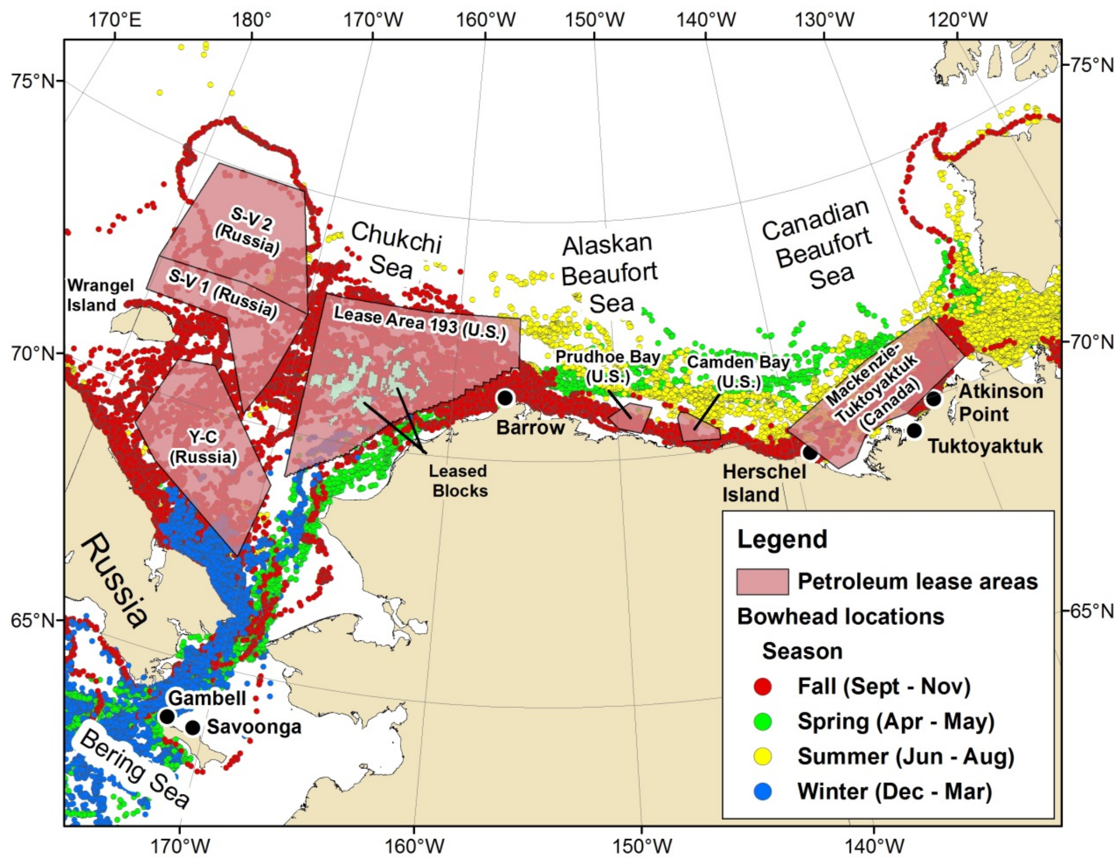


Figure 22. Locations by season for 63 bowhead whales with satellite transmitters (colored circles) between July and December, 2006–2012, relative to active and proposed petroleum areas.

Chukchi Sea Lease Area 193. The route of the spring migration follows the Alaska coast to Point Barrow and few whales entered Area 193 or the leased blocks (Fig. 19). During the spring migration, whales transmitted within Area 193 between 16 April and 5 May (Fig. 23). The main period that tagged whales were present within Area 193 was in fall from approximately 28 August to 26 November, although some whales were sporadically present from 6 July to 25 December. On average, tagged whales were present within Area 193 for 10 days (range = 1 to 36 days, *n* = 45 whales).

Residence patterns within the leased blocks were similar to those within the larger area (Fig. 23). Because the leased blocks represent a small area, fewer whales were found within the block boundaries. During the spring migration, a single whale entered a leased block on 18 April. Tagged whales were present within the leased blocks on most days between 3 September and 25 November. A single whale tagged in 2010 was present within the leased blocks on 23 and 24 July. Because the leased blocks are relatively small, residence times in the greater lease area are probably more representative of when whales might be found within leased blocks than the data from leased blocks alone. During the fall migration, 40 of 41 tagged whales (97.6%) entered the lease area (Table 4).

Beaufort Sea, Prudhoe Bay. The spring migration is typically offshore of Prudhoe Bay (Fig. 20); hence, no tagged whales transmitted from the Prudhoe Bay area in spring. Tagged whales were located within the Prudhoe Bay area between 19 July and 28 October (Fig. 23). Generally, only a single transmitter was located within the Prudhoe Bay area at any given time. The average number of days individual whales transmitted from this area was 2.0 (range = 1 to 3 days; n = 16 whales). The low number of days individual whales were present was likely because whales were migrating through this area, rather than lingering or feeding. Two transmitters were located within this area on 12 September, 13 September, 26 September, 3 October, and 4 October. Hence, the main migratory pulse likely occurs in September and early October. During the fall migration, 15 of 18 whales (83.3%) entered the Prudhoe Bay petroleum area (Table 4).

Beaufort Sea, Camden Bay. As with the Prudhoe Bay area, the spring migration path is typically offshore of Camden Bay (Fig. 20). No tagged whales transmitted within the Camden Bay area until 26 July. Sporadic transmissions lasted until 26 October (Fig. 23). The average number of days individual whales transmitted from this area was 2.2 (range = 1 to 6 days; n = 13 tagged whales). One whale remained within the Camden Bay area for five days and one remained for six days (both in 2010). Hence, while most whales simply migrate through the Camden Bay area, we observed a few whales (2 of 13) spend five or six days within the area. While some whales may stop briefly to feed here, whales generally do not spend a significant amount of time here.

During the fall migration, 13 of 18 whales (72.2%) entered the Camden Bay petroleum area (Table 4). Of the whales that migrated through the Beaufort Sea, three of four that did not enter the Camden Bay petroleum area passed inshore of the area (Fig. 24).

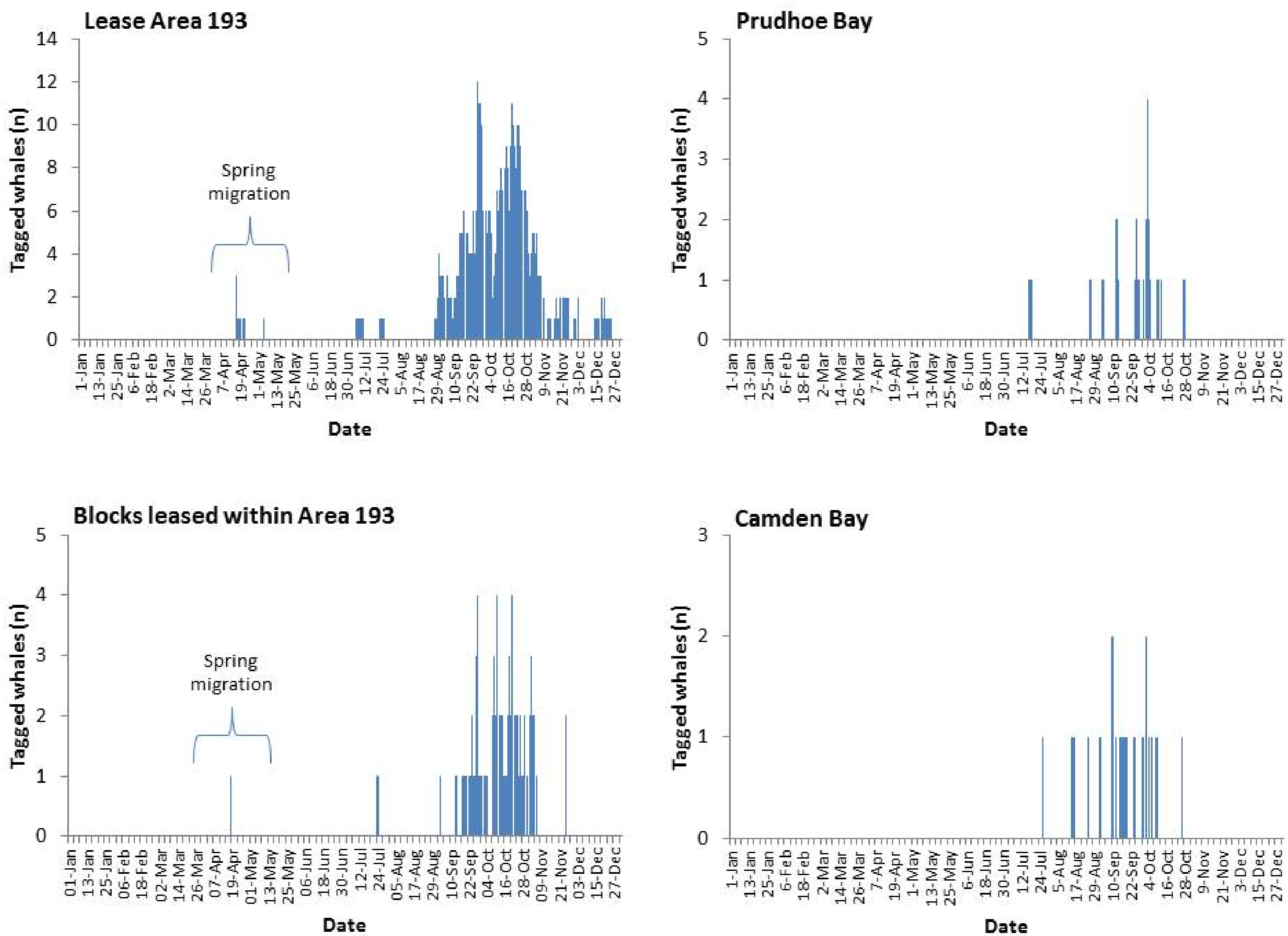


Figure 23. Count of tagged whales present within petroleum areas in Alaskan waters by day of year.

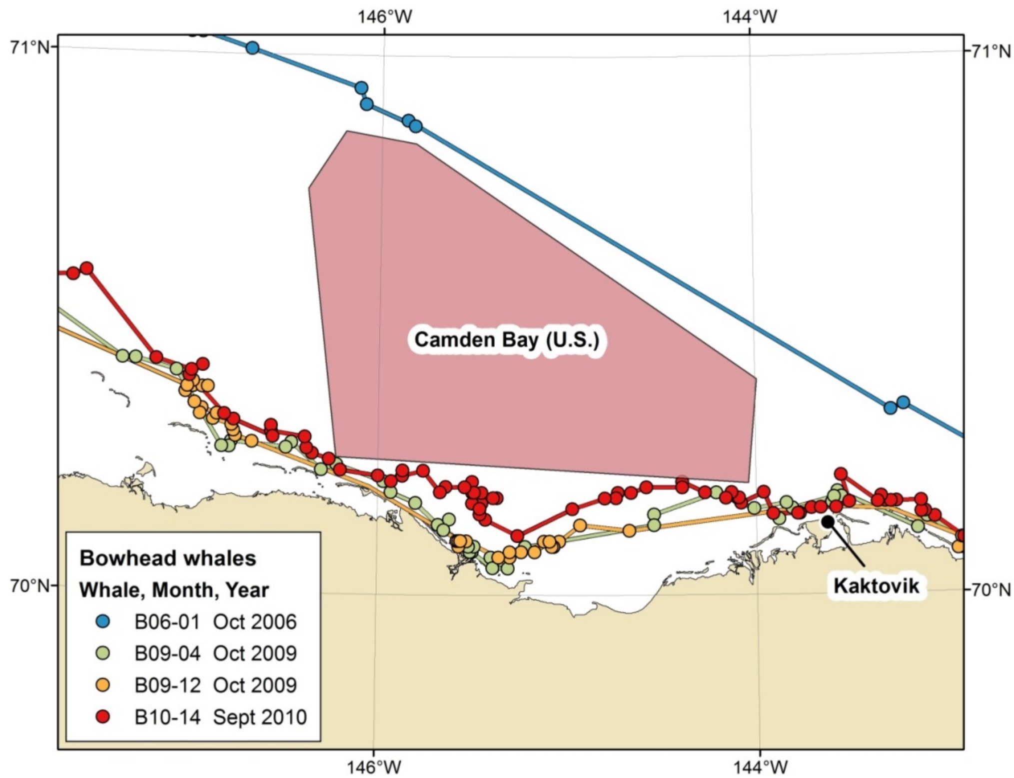


Figure 24. Locations (colored circles) for four whales that did not pass through the Camden Bay petroleum area during the fall migration. Three of four whales passed inshore of the petroleum area. Locations for the eleven whales that did pass through the area are not shown on this map.

Beaufort Sea, Mackenzie-Tuktoyaktuk. The Mackenzie-Tuktoyaktuk oil and gas area lies on the eastern boundary of the western Arctic stock's summer range in Amundsen Gulf, Canada (Fig. 22). Bowhead whales occurred within this area in two distinct time periods (Fig. 25). First, tagged whales arrived in the Mackenzie-Tuktoyaktuk area on 1 May while en route to Cape Bathurst and Amundsen Gulf. Whales generally passed through this area by 19 June. Second, whales return to the Mackenzie-Tuktoyaktuk area in summer and remain there until the fall migration. Tagged whales returned to this area on 27 June and were present until 25 October.

Whales spent an average of 21 days within this area (range = 1 to 68 days; n = 35 whales). This number should be considered a minimum estimate, however because tags that were deployed the previous fall and survived long enough to enter this area often stopped transmitting within this area. Presumably whales were present after the tags stopped transmitting. In addition, a number of whales were tagged within this area and were present for some time before they were tagged. Ten whales were tagged near Tuktoyaktuk between 23 and 30 August 2010. Hence, the spike in the number of whales present in the Mackenzie-Tuktoyaktuk area around 29 August is due to this tagging event (Fig. 25).

During the fall migration, 30 of 31 tagged whales (96.8%) entered the Mackenzie-Tuktoyaktuk petroleum area (Table 4).

Chukchi Sea, Proposed Russian Lease Areas. To date, tagged bowhead whales have only entered the proposed Severo-Vrangelevskiy 1 (SV-1) and Severo-Vrangelevskiy 2 (SV-2) lease areas during the fall migration. Tagged whales were present within the more northern SV-1 area between 5 September and 17 November, and were present for an average of 4 days (range = 1 to 14; *n* = 25 whales). Tagged whales were present within SV-2 between 15 August and 31 October (Fig. 24), and were present for an average of 17 days (range = 2 to 55; *n* = 8 whales).

The Yuzhno-Chukotsky (Y-C) lease area is located farther south and prior to the typical fall migration, three different whales spent time there between 26 July and 15 October; B09-09, B10-03, and B12-02. Two of these, B10-03 and B12-02, migrated across the Beaufort and Chukchi seas, to Russia, well in advance of the typical fall migration. In 2010, B10-03 crossed the Chukchi Sea to the Russian coast in late August (blue track in Fig. 6). In 2012, B12-02, a whale tagged near Gambell, Alaska followed the normal spring migration pattern, but left Amundsen Gulf, Canada in early June traveling west and then northwest to spend July 2012 in the Arctic Ocean as far north as 78˚N latitude (Fig. 7). B09-09 tagged near Barrow in August 2009 summered in the Chukchi Sea in 2010 (Fig. 8).

Whales following the typical fall migration pattern began to arrive in the Y-C area around 16 October and were present until 19 December (Fig. 25). Tagged whales were present within the Y-C area for an average of 6 days (range = 1 to 17 days; *n* = 33 whales). During the fall migration, 25 of 33 tagged whales (75.8%) entered SV-1, while 8 of 34 (23.5%) entered SV-2, and 33 of 35 (94.3%) entered Y-C (Table 4).

Potential for Cumulative Effects. We were able to assess how many active petroleum areas were encountered during the entire fall migration for 15 whales. The average number of active petroleum areas individual whales passed through was 3.3 (range = 0 to 4) active petroleum areas. The average number of active and proposed petroleum areas individual whales passed through was 5.0 (range = 1 to 6).

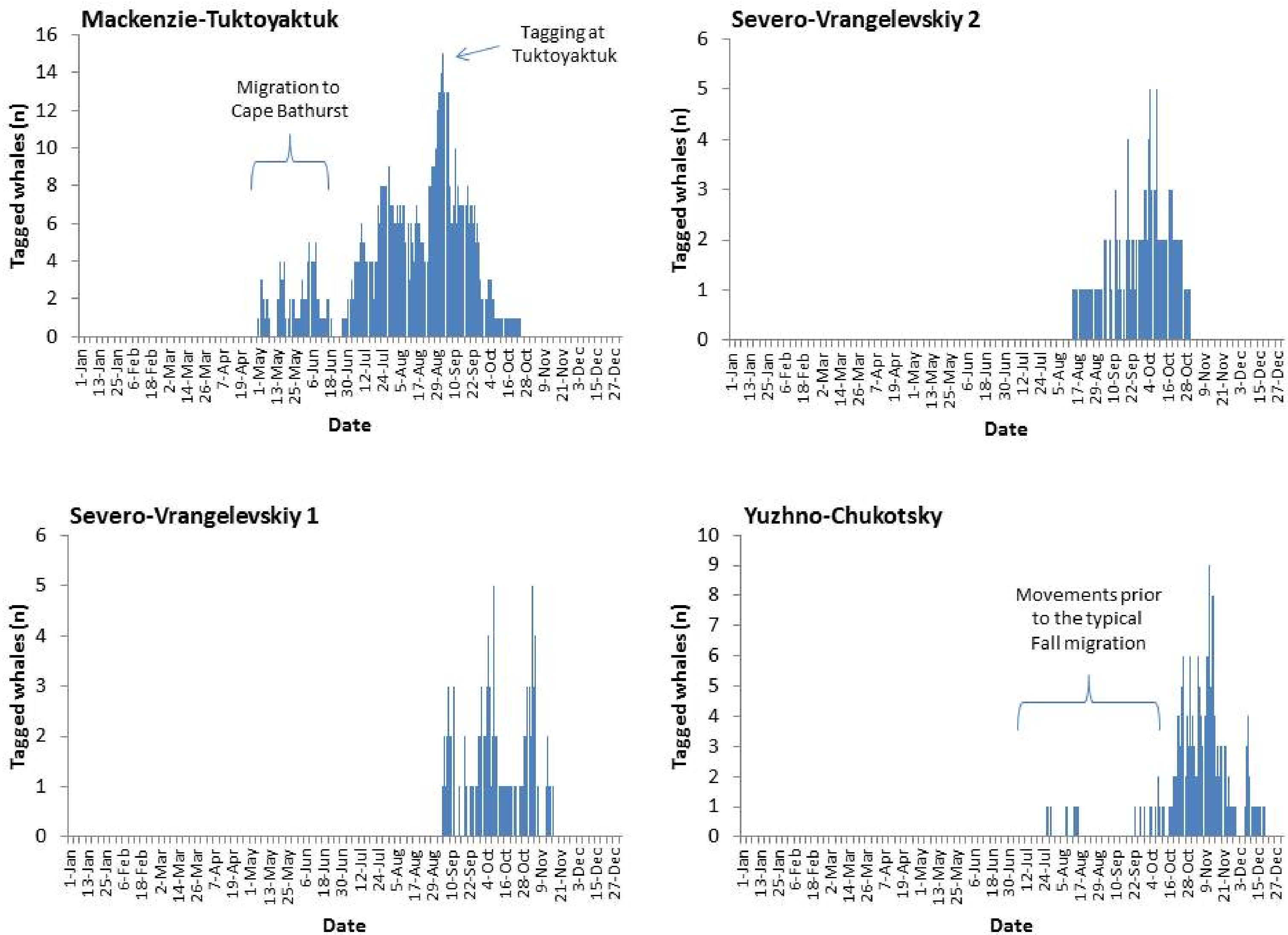


Figure 25. Count of tagged whales present within petroleum areas in Canadian and Russian waters by day of year.

Table 4. Summary of how many whales entered each petroleum area during the fall migration. For each whale and area, "Yes" indicates that satellite locations were collected within the petroleum area, "No" indicates that the whale passed the petroleum area and did not transmit from within the area boundary, and "-" indicates that entry into the area is unknown. Only locations between July and December are considered.

Whale ID	Year	Active petroleum areas				Proposed petroleum areas		
		Area 193	Prudhoe	Camden	Tuk	SV-2	SV-1	Y-C
B06-01	2006	Yes	No	No	Yes	No	Yes	Yes
B07-02	2007	-	-	-	Yes	-	-	-
B07-06	2007	-	-	-	Yes	-	-	-
B07-10	2007	Yes	-	-	-	Yes	-	-
B08-01	2008	Yes	Yes	Yes	Yes	No	Yes	Yes
B08-01	2009	-	-	-	Yes	-	-	-
B08-02	2008	Yes	-	-	-	Yes	Yes	-
B08-03	2008	Yes	-	-	-	No	Yes	Yes
B08-05	2008	Yes	-	-	-	-	-	-
B08-06	2008	Yes	-	-	-	No	Yes	Yes
B08-07	2008	Yes	-	-	-	No	Yes	Yes
B08-07	2009	Yes	No	Yes	Yes	Yes	Yes	-
B08-08	2008	Yes	-	-	-	Yes	Yes	Yes
B08-09	2008	Yes	-	-	-	No	Yes	No
B08-10	2008	Yes	-	-	-	No	No	No
B08-11	2008	Yes	-	-	-	Yes	Yes	Yes
B08-12	2008	Yes	-	-	-	-	-	Yes
B08-12	2009	-	-	Yes	Yes	-	-	-
B08-13	2008	Yes	-	-	-	-	-	Yes
B08-14	2008	-	-	-	-	-	-	Yes
B08-14	2009	-	-	-	Yes	-	-	-
B09-01	2009	Yes	-	-	-	Yes	Yes	Yes
B09-02	2009	Yes	-	-	-	-	Yes	Yes
B09-03	2009	Yes	-	-	-	Yes	Yes	Yes
B09-04	2009	Yes	Yes	No	Yes	No	Yes	Yes
B09-04	2010	-	-	-	Yes	-	-	-
B09-05	2009	Yes	Yes	-	Yes	No	Yes	Yes
B09-05	2010	-	-	-	Yes	-	-	-
B09-06	2009	Yes	-	-	-	-	Yes	-
B09-09	2009	Yes	-	-	-	No	Yes	Yes
B09-09	2010	No	No	No	No	No	No	Yes
B09-12	2009	Yes	Yes	No	Yes	-	Yes	-
B09-13	2009	Yes	-	-	-	No	No	Yes

Table 4. Continued

Whale ID	Year	Active petroleum areas				Proposed petroleum areas		
		Area 193	Prudhoe	Camden	Tuk	SV-2	SV-1	Y-C
B09-13	2010	Yes	Yes	Yes	Yes	No	-	Yes
B09-15	2009	Yes	-	-	-	No	-	Yes
B09-15	2010	-	-	-	Yes	-	-	-
B09-16	2009	Yes	-	-	-	No	-	Yes
B10-01	2010	Yes	Yes	Yes	Yes	No	No	Yes
B10-03	2010	Yes	Yes	-	Yes	No	No	Yes
B10-04	2010	-	-	-	Yes	-	-	-
B10-05	2010	-	Yes	Yes	Yes	-	-	-
B10-06	2010	-	-	Yes	Yes	-	-	-
B10-07	2010	-	-	-	Yes	-	-	-
B10-08	2010	Yes	Yes	Yes	Yes	No	Yes	Yes
B10-08	2011	-	-	-	Yes	-	-	-
B10-09	2010	Yes	-	-	-	No	No	Yes
B10-11	2010	Yes	Yes	Yes	Yes	No	Yes	Yes
B10-12	2010	Yes	Yes	Yes	Yes	No	No	Yes
B10-13	2010	Yes	Yes	Yes	Yes	No	Yes	Yes
B10-14	2010	Yes	Yes	**No**	Yes	No	Yes	Yes
B10-15	2010	Yes	Yes	Yes	Yes	No	Yes	Yes
B10-15	2011	-	-	-	Yes	-	-	-
B12-01	2012	Yes	Yes	Yes	Yes	No	No	Yes
B12-02	2012	-	-	-	-	-	-	Yes
B12-03	2012	Yes	-	-	-	No	Yes	Yes
B12-04	2012	Yes	-	-	-	-	-	-
B12-05	2012	Yes	-	-	-	Yes	Yes	-
Whales that enter		40	15	13	30	8	25	33
Tracked whales		41	18	18	31	34	33	35
Percent entering		**97.6%**	**83.3%**	**72.2%**	**96.8%**	**23.5%**	**75.8%**	**94.3%**

Seismic Analyses
The activity associated with oil and gas exploration that has the greatest potential for harm is seismic testing due to the high noise levels associated with it. Many seismic arrays tow 36 airguns and noise levels can be as high as 190 dB. There is little information about how noise affects bowhead whale communication, navigation, and movements. Whalers know that whales are sensitive to noise. In Kaktovik, a thermos falling over in the boat was enough to make them dive and swim away (Huntington and Quakenbush 2009). Wainwright whalers have been told since they were young boys at whaling camp to keep quiet so that the whales would not be disturbed while setting the migratory path for the other whales to follow (Quakenbush and Huntington 2010). In 1968, there was seismic testing offshore of Wainwright during the spring migration. The whalers saw no whales, not even a blow, that spring. Barrow provided whale meat and maktak to Wainwright for Thanksgiving and Christmas (Quakenbush and Huntington 2010). When a test well was drilled offshore near Point Barrow, whales diverted their migration around the area, even though no drilling occurred during the migration. The noise from the idle drill ship was still sufficient to affect the whales. After the drilling ceased and the rig was removed, the whales reverted to normal behavior in the area within a couple of years. Whalers of St. Lawrence Island use sails to power their boats when whaling because whales alone or in small groups are sensitive to noise. When large numbers of whales are present their less sensitive to noise (Noongwook 2007).

Although we now know that tagged bowheads encounter multiple active petroleum areas during summer and fall we have found few incidences where tagged bowhead whales overlap in space and time with seismic operations. We provided a preliminary analysis of a tagged whale in 2006 that was within a seismic operation near Tuktoyaktak (Quakenbush et al. 2010, Citta et al. abstract/poster Appendix C). We recently acquired more detailed data on this seismic operation and will be able to conduct a more detailed analysis in the future.

We also worked with Shell to compare location and timing of seismic operations in the Chukchi Sea with tagged bowhead whales to look at overlap in Lease Area193 and did not find any overlap. We also looked at overlap in the Prudhoe Bay petroleum area and did not find any. The most likely area of overlap may be in the Tuktoyaktuk area in 2010 when 11 tagged whales were present.

Dive Behavior
We have not conducted detailed analyses of the dive data from the SPLASH or Splash10 tags, yet. Preliminary examinations, however, show that except for Barrow Canyon, bowheads often dive to the bottom when they are over the Continental Shelf. Whalers near Kaktovik see bowheads pause to feed at the passes between barrier islands and where the water flowing out of the lagoon mixes with the ocean water. There are depressions in the sea floor at these places and bowheads are seen there with mud on their stomachs (Huntington and Quakenbush 2009).

CTD tag deployment. One Conductivity (*i.e.*, salinity), Temperature, and Depth (CTD) tag was deployed at Barrow on 21 September 2012. The tag was designed to last 90 days to minimize weight and size. The tag transmitted 33 days and yielded 17 CTD profiles, 171 dive profiles, and 187 locations along Barrow Canyon and over the shelf (Fig. 25, lower right). Although the tag did not transmit as long as we expected, the quality and quantity of the data collected by this tag is promising.

For examples of data produced by this tag, we present two bowhead whale dive profiles paired with CTD profiles of those dives. The first set of dive and CTD profiles were collected northeast of Point Barrow in Barrow Canyon. In summer and fall, the Alaska Coastal Current carries Alaska Coastal Water (ACW) through Barrow Canyon. Colder, saltier Winter Water (WW) occurs both below and offshore of the Alaska Coastal Current, forming distinct vertical and horizontal hydrographic fronts. There is another front located where WW grades into warmer Atlantic Water (AW), usually around 200–250 m depth (e.g., Pickart 2004, Pickart et al., 2005; Nikolopoulous et al., 2009; von Appen and Pickart, 2012). Plotting the temperature, salinity and depth data collected by the tag in Barrow Canyon show the three distinct water masses (Fig. 26). The upper left panel in Figure 26 shows that water temperature (red line) is fairly warm near the surface, but then drops to approximately -1˚C. Below 100 m the temperature gradually warms. Plotting this information in a Temperature-Salinity plot (lower left chart in Fig. 26) helps identify individual water masses. ACW is generally warm (1–3 °C) and fresh with a salinity range of ~30–31 practical salinity units (PSU). WW is generally cold (< 0 °C) with a higher salinity range of 32–33.5 PSU. AW is warmer (>0 °C) but saltier than WW (>33.5 PSU) (Steve Okkonen, *pers comm*). Hence, it appears that the boundary between WW and AW occurred at ~150 m when the whale was present. Interestingly, many of the dive profiles collected in this area show that the whale frequented this depth that defined the interface between WW and AW (see upper right chart in Fig. 26). Perhaps zooplankton were being concentrating at this hydrographic front providing a layer of prey for bowheads.

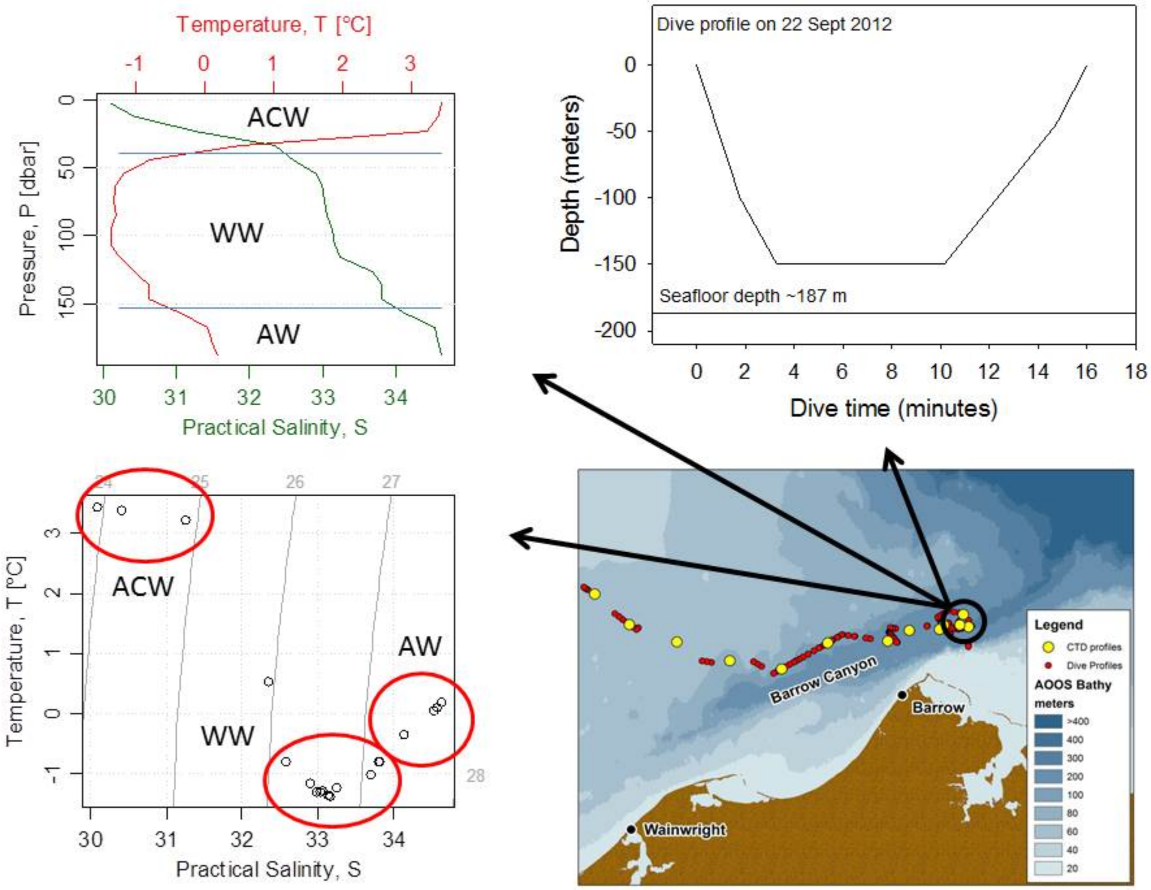


Figure 26. Example of CTD and dive profiles for an area within Barrow Canyon. The temperature and salinity plots show that the area within ~50 m (dbar = m) of the surface is dominated by Alaska Coastal Water (ACW). Between 50 and 150 m, Winter Water (WW) from the Chukchi shelf dominates. Around 150 m, warmer, saltier Atlantic Water (AW) dominates. A dive profile (upper right chart) shows that during a 16 min dive, the whale spent 6 min near the lower boundary of WW and AW. Perhaps zooplankton were concentrated at the hydrographic front between WW and AW.

The second example is for a location northwest of Barrow Canyon over the continental shelf of the Chukchi Sea (Fig. 27). The temperature and salinity plots show that ACW dominates the water column. The dive profile shows a dive lasting 15 min; ~11 min of this dive are spent at or near the seafloor, located at 45 m depth. Diving to the bottom was commonly observed in dive profiles over the Chukchi Shelf.

We have three CTD tags that we hope to deploy this spring and fall. We hope to collect oceanographic data within the Cape Bathurst polynya (Canada) in the spring and along the Chukotka coast (Russia) in fall, both areas are likely important to bowhead whales for feeding.

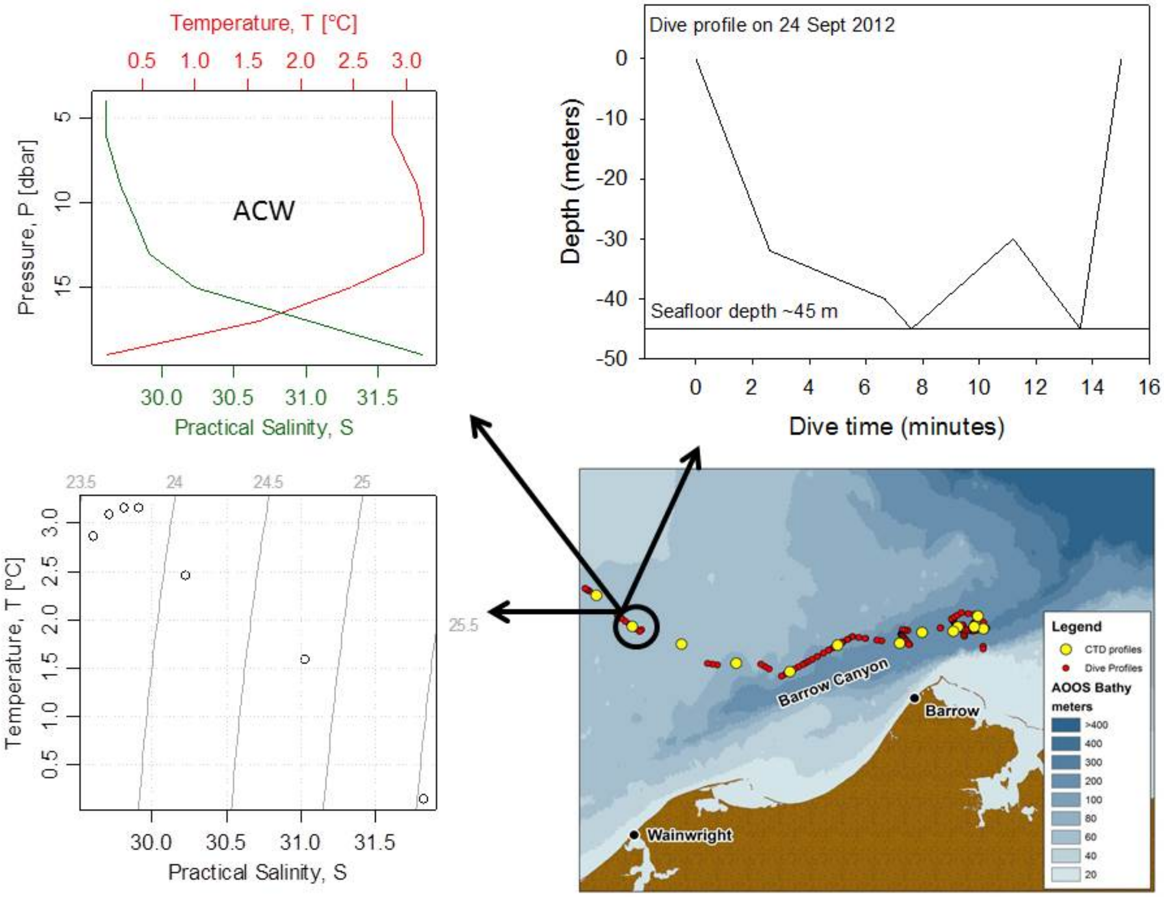


Figure 27. Example CTD and dive profiles for an area on the Chukchi Sea shelf. Temperature and salinity plots show that the water column was dominated by Alaska Coastal Water (ACW). The dive profile (upper right chart) shows that the whale dove for 15 min and spent ~11 min at or near the seafloor. Most of the dive profiles collected over the Chukchi Shelf indicated that the whale spent significant time at or near the seafloor.

Tag development and deployment

During this study period, tag development included use of Splash10 and CTD tags, both which collect better dive information. We expanded our deployment locations to include Canada and St. Lawrence Island; this helped ensure that our data were not biased by tagging location. We purchased four CTD tags and deployed one. CTD tags provided detailed data on individual dives and link ocean temperature and salinity to dive depth. This information will be valuable in identifying the physical properties of water where bowheads spend time and will help to identify feeding conditions and areas.

To date, we have tracked nine whales for >365 days. The number of tags with this longevity has clarified that our limiting factor is not tag retention but battery power. During the next phase of this study (2012–2017) we will be programming SPOT tags to last up to two years of tracking.

Accomplishment of Objectives and Tasks

Overall Objective: The overall objective of this study is to work with subsistence whalers to deploy satellite transmitters on bowhead whales in order to collect data that can be used to accomplish the following specific objectives.

Between 2010 and 2012 we worked with subsistence whalers from Tuktoyaktuk, and Aklavik in Canada and from Barrow, Kaktovik, Pt. Hope, Gambell, and Savoonga.

***Objective 1*:** Test the general hypothesis that all bowhead whales in the western Arctic stock make seasonal migrations between the Bering Sea and feeding grounds in western Canada.

To date, all tagged whales have wintered in the Bering Sea. Except for one, all whales migrated from the Bering Sea, directly to the Canadian Beaufort Sea. Whale B09-09 (Fig. 8) migrated into the Chukchi Sea on 25 March 2010 and remained there until it stopped transmitting in August. This whale did not go to western Canada to feed in 2010. Conclusion – most, but not all, bowhead whales in the western Arctic stock make seasonal migrations between the Bering Sea and feeding grounds in western Canada.

***Objective 2*:** Test the related hypothesis that occasional concentrations of bowhead whales feeding in nearshore waters of the Beaufort Sea east of Barrow are a product of delays in migration by whales returning from summering in Canada.

If food is present near Point Barrow due to the "krill trap" conditions described by the BOWFEST project (Ashjian et al. 2010, Okkonen et al. 2011) bowhead whales could come from several directions to take advantage of it. Whales that passed west of Barrow could come back (see Fig. 3 in Quakenbush et al. 2010a) and whales on migration from Canada could stop. Additional possibilities include whales summering in the Chukchi Sea could go to Barrow (see Objective 3 below) and whales traversing the Beaufort Sea during summer could move in from the north (see Fig. 25 in Quakenbush et al. 2010b). To date, however, all satellite tagged bowhead whales observed at Barrow in the summer and fall, first migrated to the Canadian Beaufort (Amundsen Gulf) in spring.

Objective 3: Test the alternative hypothesis that the above occasional concentrations of whales feeding east of Barrow are composed of whales that generally summer in the eastern Chukchi Sea and only enter the southwestern Beaufort Sea periodically, and under certain oceanographic conditions.

Although we cannot say for sure, our data so far does not support the hypothesis that the concentration of whales feeding near Barrow in summer comes from whales summering in the Chukchi Sea. We have tagged only one whale that summered in the Chukchi and it did not spend time near Barrow, although it was tagged there the preceding August.

Objective 4: To the extent possible, test the hypothesis that the above concentrations of whales consist of representative proportions of demographic (sex and age, i.e., size) groups as observed in the western Arctic population.

In general, the whales tagged near Barrow have tended to be males. We have tagged a total of 42 bowhead whales near Barrow, 24 are of known sex and 16 of the 24 (67%) were males (Table 2). We have tagged more immature whales (n = 25) than mature whales (n = 12) overall. Immature whales tend to spend time near Barrow in the summer and fall from the end of August to early November, which is similar to when mature whales are there; end of August to mid October. Sample sizes are too small for mature whales to determine if use of the Barrow area differs by sex. Although our sample sizes are small for some sex/age groups, males, females, immature and adults all spend time near Barrow in summer and fall.

Objective 5**:** Test the hypothesis that the above concentrations of bowhead whales consist of individuals that are only present in the aggregations for hours to days as opposed to weeks to months.

In order to address this objective, we analyzed residence time, defined as the sum of days individual tagged whales were within 150 km of Barrow within each month. We separated the whales tagged near Barrow in the month they were tagged from whales tagged near Barrow during a different month or tagged elsewhere. This is important because whales tagged near Barrow likely have residence times that are biased low for the month of tagging because they were present for an unknown length of time before being tagged (Table 5).

In the spring (April and May), tagged bowheads spent less time near Barrow than in the fall (September–October). The average residence time in the spring is 3–4 days but ranged from 1–11 days. We have very little data for the summer months of June and July; the data available for August are for whales tagged within that month, likely biasing August residence times low (upper Table 5). The August data suggest that tagged whales spent at least 5 days near Barrow with a minimum range of 2–10 days. In September and October the average was more than a week (7.4 and 11.9 days, respectively) and the range extended to 31 days (Table 5).

Table 5. Average number of days whales spend within 150 km of Barrow by month. Whales tagged at Barrow may have residence times that are biased low for the month of tagging because they may have been present before being tagged. Hence, we present whales tagged at Barrow within the month of tagging separately from those present in subsequent months or initially tagged elsewhere. For example, if a whale was tagged at Barrow in May, the data are likely biased low and are in the upper part of the table ("Month tagged at Barrow"). If the whale was within 150 km of Barrow in later months, the data are unbiased and are presented in the lower part of the table ("Unbiased data").

		Month							
Month tagged at Barrow		**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
	n	1	2	-	-	10	16	4	-
	Mean (d)	1	3	-	-	5.1	5.3	6.5	-
	Range (d)	-	3	-	-	2-10	1-10	2-14	-
Unbiased data		**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
	n	10	6	1	1	-	15	16	4
	Mean (d)	4.4	3.3	1	4	-	7.4	11.9	3.3
	Range (d)	2-11	1-4	-	-	-	1-17	3-31	1-7

***Objective 6*:** Estimate the rate and timing of travel of whales during migration across the Beaufort Sea.

Across all years, tagged whales took an average of 8 days (range = 6 to 18 days) to cross the Alaskan Beaufort Sea in spring. The earliest date tagged whales passed Point Barrow was 16 April and the latest date tagged whales past Demarcation Point was 30 May (a span of 44 days).

The fall migration occurs over a longer period of time and is more variable. Passage time from Demarcation Point to Point Barrow averaged 16 days (range = 5 to 43 days). The earliest date tagged whales passed Demarcation Point was 18 August and the latest date tagged whales passed Point Barrow was 4 November (a span of 78 days).

While there are two migratory periods (spring and fall) in which the majority of tagged whales crossed the Alaskan Beaufort Sea, a small number of tagged whales were present in the Alaskan Beaufort Sea between the migrations. Hence, it is likely that there is a low density of bowhead whales within the Alaskan Beaufort Sea between April and November (Fig. 28).

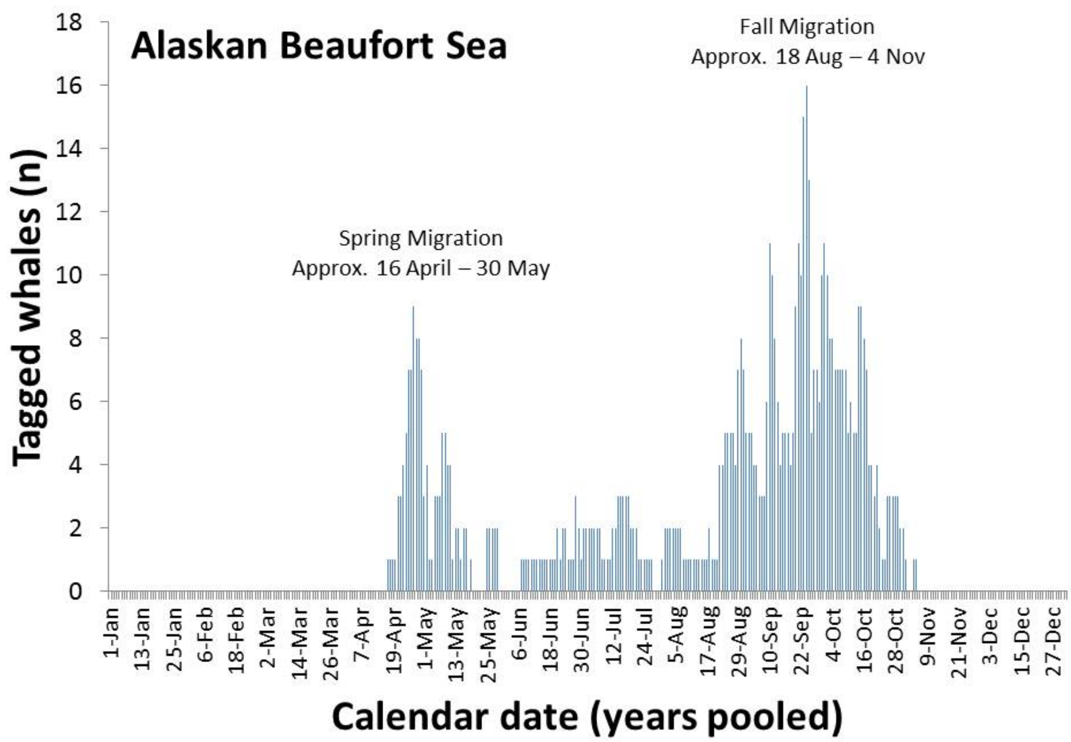


Figure 28. Timing of bowhead whale presence in the Alaskan Beaufort Sea as determined from satellite telemetry 2006–2012. Note that there are two migratory periods (spring and fall) during which the number of tagged whales is increased; however, there are some tagged whales in the Alaskan Beaufort Sea all summer.

Objective 7: To the extent possible, document and describe the general pattern of year-round movements by bowhead whales, the degree to which migrating whales make use of specific polynyas or channels, and estimate for individual whales time budgets of time spent in specific geographic regions and/or functional habitat areas.

We have documented the general pattern of year-round movements by bowhead whales and identified some unexpected movements that broaden the range in which bowheads could be found in any given year (Fig. 29). Other than the spring lead system in the Chukchi Sea, bowheads do not appear to use leads, polynyas or channels regularly for migration. We have pooled all of our data to identify areas throughout their range where bowheads spend time (Fig. 30).

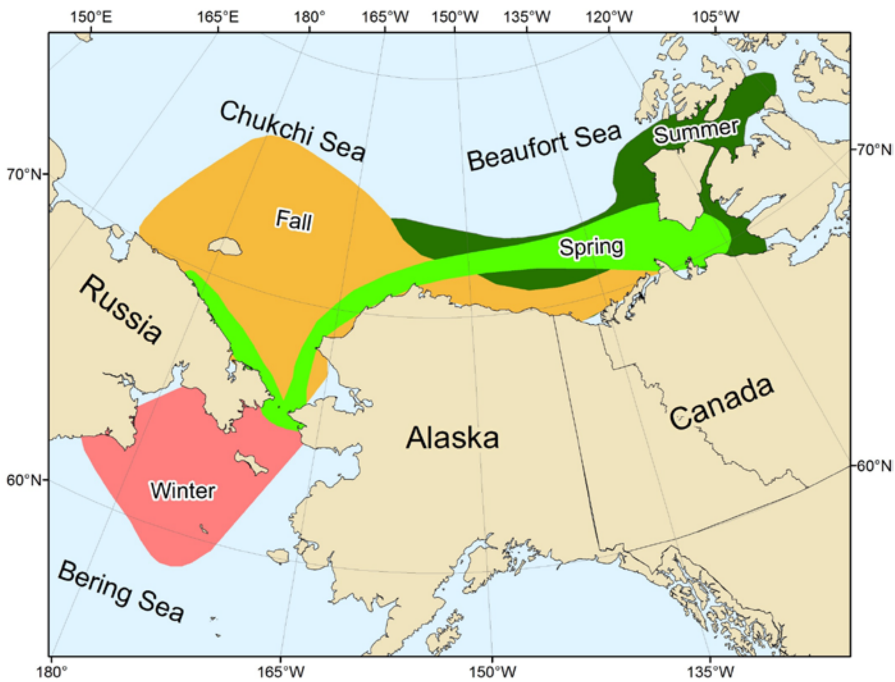


Figure 29. Seasonal areas of use by bowhead whales as determined from satellite telemetry 2006–2012.

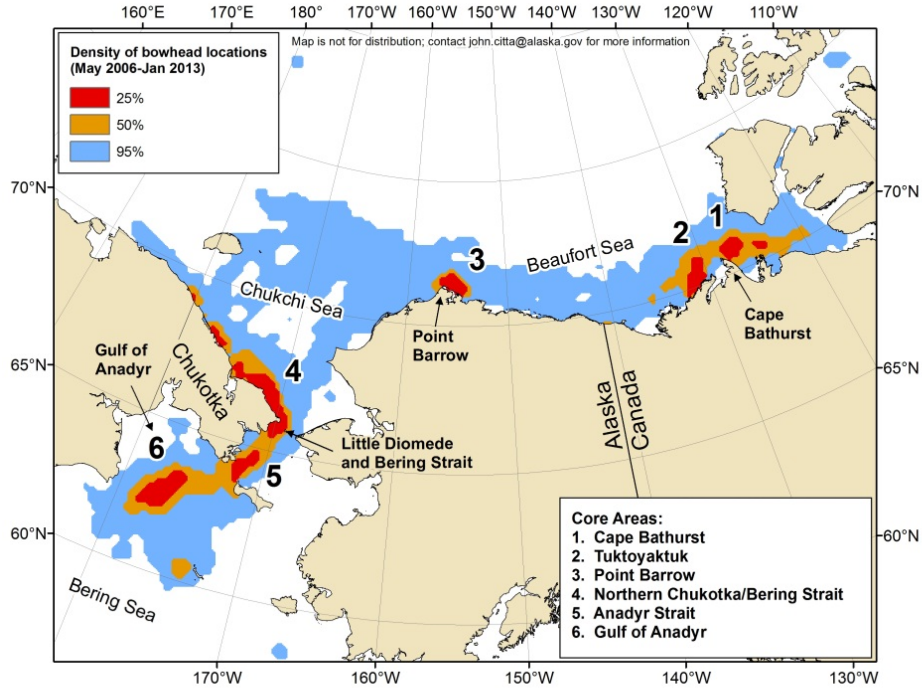


Figure 30. Tagged bowhead locations by density using pooled location data (2006–2012). The highest density areas are in red.

Objective 8: Instrument other species of baleen whales when encountered during bowhead tagging efforts when practical.

Gray whales. Eight gray whales were tagged during this study: one in 2009, six in 2011, and one in 2012 (see Table 2). Tagged gray whales ranged in size from 8.4–10.7 m; three were males, four were females, and the sex of one has yet to be determined. Movements of seven tagged gray whales are shown in Figure 31; one tagged gray whale did not transmit any locations (G2011-04). Although most tags on gray whales have not lasted as long as those for bowhead whales (average = 33 days; range = 0 to 100 days) we have collected useful information on summer behavior and some documented some long distance movements. In addition to trying to extend the longevity of tag deployments, we collected biopsies and photographs of five gray whales to genetically and photographically identify them for matching at other locations in order to better understand where gray whales go during other times of year (Appendix D).

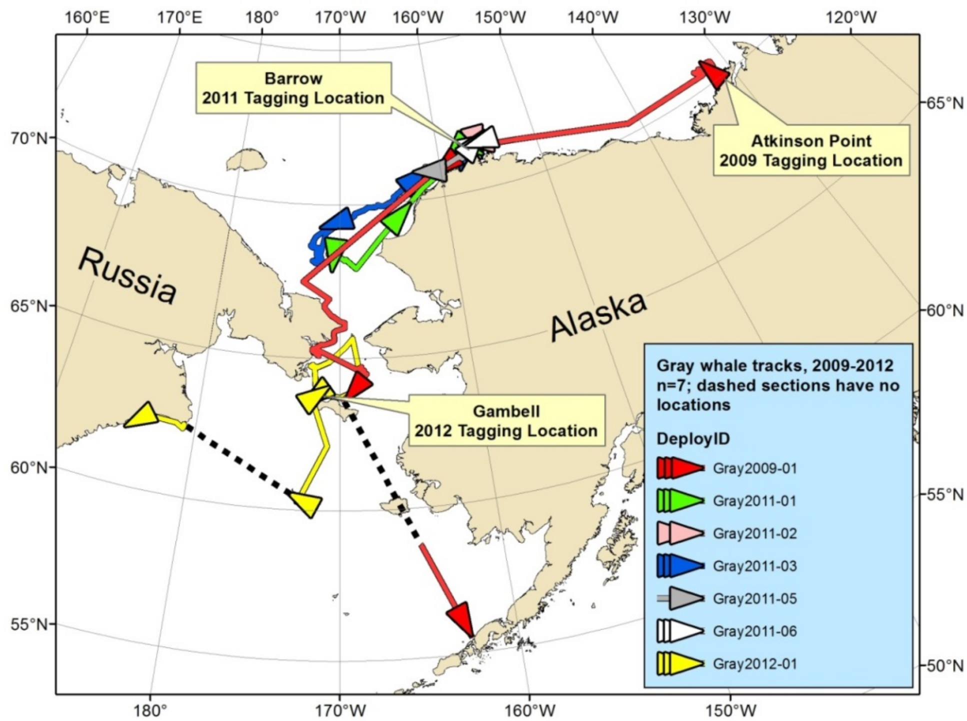


Figure 31. Tracks of gray whales tagged in 2009, 2011, and 2012.

Task 1 – Data Review and Hypothesis Development. We continue to review available data on bowhead whales. In addition to examining our own data, we peer review manuscripts and read published literature on bowhead whale movements and behavior from all stocks in order to refine and develop working hypotheses.

Task 2 – Experimental Design and Field Work. We continued to develop our collaborations originally established during "The Planning Phase" of this study in 2005 and during Phase I of this study (2006–2010). We worked with the AEWC to develop a new study plan, which they approved in 2011. We worked with taggers in Canada to tag 12 bowheads near Tuktoyaktuk to increase our understanding of fall migration patterns and movements east of Barrow. We trained whalers from Gambell and Savoonga to tag whales near St. Lawrence Island. Alaska Native whalers participated in many aspects of this study. Although we took a very conservative approach to avoiding conflicts with subsistence whaling by trying to separate tagging periods from the whaling season, in several instances the whaling communities decided to designate a tagging crew that was allowed to work during the whaling season. The tagging crew coordinated with the whaling crews and usually looked for whales farther offshore than whaling crews.

To date we have been able to track nine whales for >365 days. The number of tags with this longevity has clarified that our limiting factor was not retention but battery power. During the next phase of this study (2012–2017) we will be expanding our tracking longevity to beyond one year, deploying CTD tags for more specific dive and oceanographic data, developing an acoustic tag for studying bowhead vocalization rates relative to ambient noise, including industrial noise.

Task 3 – Data Analysis and Reporting. We have used findings from this study to test and refine hypotheses. We provided weekly maps of tagged whales and in 2012 we changed our map schedule to accommodate a weekly meeting that BOEM and NMFS held with industry in order to provide the most recent locations of tagged bowhead whales for near real time evaluations of bowhead whales and industry. We have published two manuscripts on this project to date. A third manuscript is in press and two more are currently being drafted (see below). We also regularly report findings at meetings and conferences (see Table 1). During the next phase of this study (2012–2017) we will continue to analyze data and address objectives.

Task 4 – Integration of Findings with other Tasks. During 2012, we participated in a Synthesis of Arctic Research (SOAR) workshop and developed two outlines for manuscripts that incorporate oceanography and ice data with bowhead movements to better understand causes of variability in bowhead whale feeding areas along their migratory route.

The first manuscript titled "Oceanographic and Other Factors Associated with Western Arctic Bowhead Whale "Hotspots'" will combine areas where tagged bowheads spend time with the corresponding oceanographic, weather (e.g., winds), and sea ice conditions in order to determine what conditions concentrate prey and provide feeding habitat for bowhead whales. We developed a "hotspot" map pooling data for all years (Fig. 30), which identifies six core areas. In order to understand when each core area is important we also developed graphs showing when each area was used (Fig. 32).

We have accommodated many requests for our tagging data to augment other projects and efforts. For example, we have contributed to the U.S. Coast Guard efforts for planning shipping lanes in Bering Strait and we have provided reports to the International Whaling Commission for discussions on general movements and stock structure. We are also contributing to a manuscript combining telemetry data from multiple marine mammal species and current shipping traffic to illustrate the overlap between shipping and marine mammals in Bering Strait. We make our maps and other products available through our website and many consulting companies and other entities use them for their reports.

The second manuscript titled "Oceanographic and Other Factors Associated with Bowhead Whale Movements in the Chukchi Sea" will combine bowhead tracks with oceanography, winds, and sea ice conditions by year to try to determine the cause of observed inter-annual variability in the fall migration across the Chukchi Sea.

In addition to the above manuscripts that we are directly responsible for we have also contributed data for a SOAR manuscript titled "*What sound environments do bowhead whales annually encounter in the Bering, Chukchi, and Beaufort seas?*" We provided the average number of days a tagged bowhead whale spent in specific areas by month. The areas were defined by acousticians using data from passive acoustic buoys.

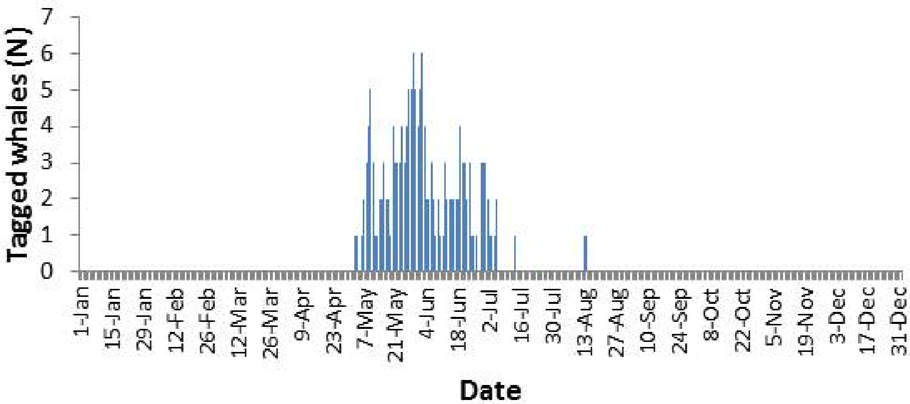
Task 5 – Data Management and Archival. We continue to maintain an archive of all data collected during all phases of this study. Our data archive and access policy is consistent with standards adopted by BOEM, the National Oceanographic Data Center, NOAA, and other federal agencies.

Task 6 – Local Coordination, Outreach and Permitting. We hold a Federal Marine Mammal Research Permit from NMFS and an Institutional Animal Care and Use Committee (IACUC) approved protocol for our cetacean research in the U.S. For research conducted in Canadian waters we also obtain research and IACUC permits required in Canada. We coordinate with the North Slope Borough when tagging near Barrow and with the local Whaling Captain's Associations for each community where tagging occurs. In Canada, we coordinate with the Department of Fisheries and Oceans and with the local Hunter's and Trapper's Associations.

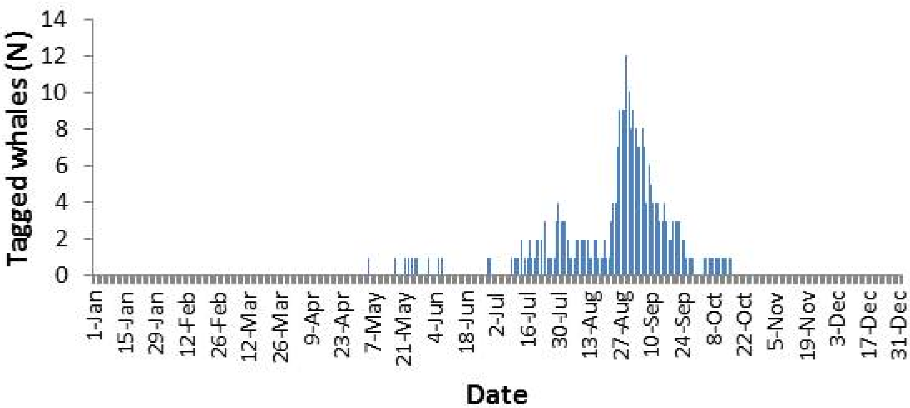
Our primary method of outreach consisted of sending weekly project updates and maps to a list of interested persons, including whalers, scientists, and managers. Updates included a map with the most recent tagged whale locations, a description of sea ice conditions, and a description of any additional pertinent information. We often get responses and discussion among recipients in real time when maps are sent. The e-mail list includes many subsistence hunters and whalers as well as agency personnel. Maps are then posted on the ADF&G website, where they are available along with other information about the bowhead tagging project. We also prepared posters and gave presentations in interested coastal communities.

Task 7 – Logistics/Safety Plan. Safety plans are developed specific for each tagging effort based on the local logistics, infrastructure, and measures already in place. Safety equipment is present and inspected to ensure it is in working order. A safety boat accompanies each tagging boat. Radio communication is established between boats and with a contact on shore. In addition to marine VHF radios, radio beacons, satellite telephones are on board tagging boats. In the Barrow area, a "float plan" is filed with the North Slope Borough Search and Rescue office prior to departure.

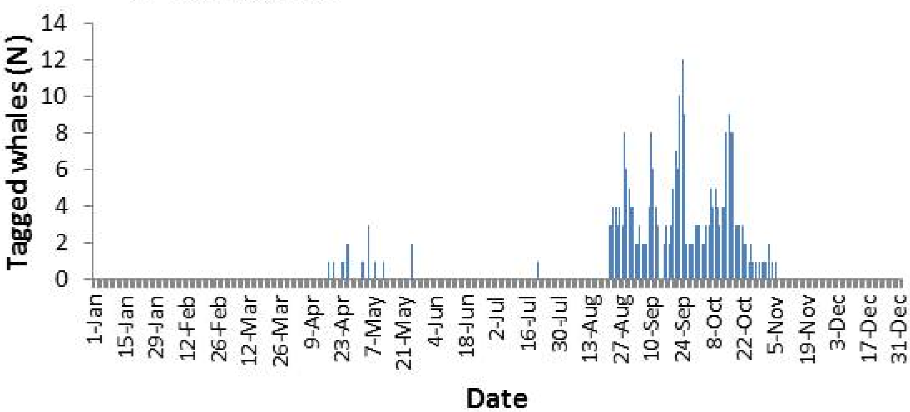
1. Cape Bathurst



2. Tuktoyaktuk



3. Point Barrow



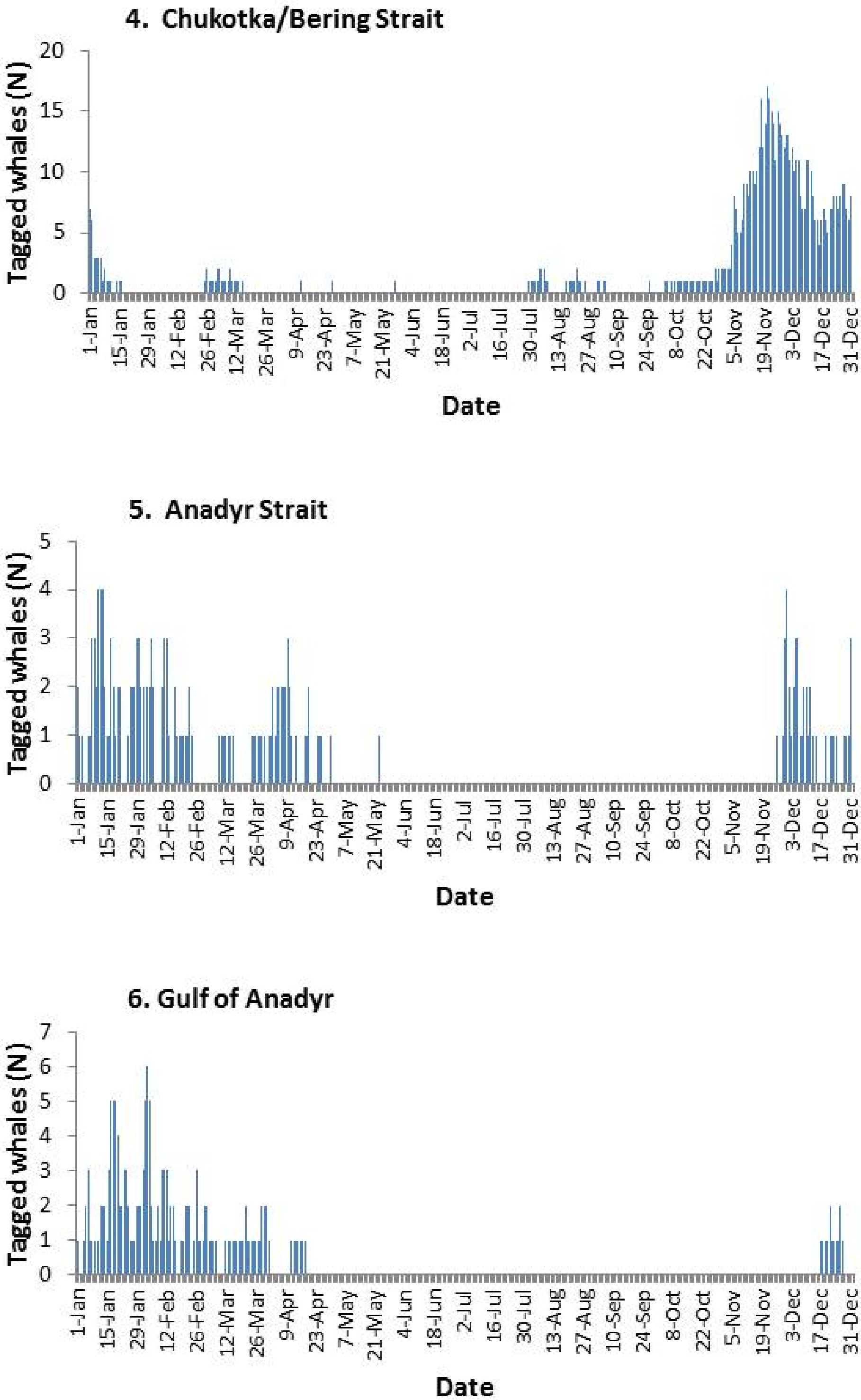


Figure 32. Timing of use of core areas by tagged bowhead whales. Data pooled from all years (2006–2012).

Discussion

Coordination

Collaboration between the AEWC, NSB, Captain's associations, individual whalers, Canadian hunters, DFO, and BOEM personnel was highly conducive for tagging and exchanging information during the first five years of this study and we continued this collaboration during 2010–2012. A new Study Plan was designed, modified, approved, and executed by the partners. Decisions about where and when to tag were made with AEWC and the local whaling captains associations prior to tagging operations. How tagging occurred relative to subsistence whaling was also left to the captains. One of our objectives was that tagging would not interfere with subsistence whaling and in order to achieve that we proposed to avoid the whaling season and deploy tags at other times or places. The AEWC, the Barrow whaling captains, and the Gambell and Savoonga whaling captains, however, felt that there were ways that tagging could occur during whaling that would not interfere. For example, in spring near Barrow when the lead is narrow and the whalers are waiting for the lead to open wide enough so that a struck whale will not be lost under the ice, the whalers felt that whales that came up in the narrow leads could be tagged from the ice edge. In Gambell and Savoonga, crews dedicated to tagging where chosen and the tagging activities were coordinated by the captains and tags were deployed during whaling without complaint.

In order to keep the AEWC informed of the study progress and for them to relay questions and concerns we made regular oral presentations at AEWC meetings and provided handouts for AEWC commissioners. In order to keep as many people informed as possible we sent weekly maps of the locations and movements of tagged bowheads to partners and anyone that expressed an interest in receiving them. The e-mail list contains >250 addresses; many people also forward our maps to their own list of addresses.

Upon receiving maps, recipients often replied to the list with their thoughts, questions, or other information about current whale observations. This often stimulated a mini-discussion that provided valuable real time information with perspective on the movements of the tagged whales relative to the rest of the population. For example, when we sent out a map showing when the first tagged whales were entering the Bering Sea, hunters on St. Lawrence Island informed us that they were already observing whales and were whaling. Hence, when whales were first spotted from St. Lawrence Island, the closest tagged whales were still 250 km to the north. This type of information is extremely valuable in helping us determine how well tagged whales represent the population and serves as an important reminder that the tagged whales do not represent all whales. This is also why we added the traditional knowledge component to the study.

After the maps are distributed to the e-mail list they are placed on the ADF&G website for people without e-mail addresses. We know that the website is checked regularly because we receive inquiries if we are slow to post a map. We also post publications, analyses, posters, and other products on our webpage. These products are used by many entities for environmental assessments, biological opinions, incidental harassment applications and authorizations, in oil company reports, and in species and habitat maps.

We coordinated with the research conducted by another BOEM project, BOWFEST, and provided updates regarding the tagging project at their annual meetings. We also provide data on tagged whale locations and movements that were relevant to their research near Barrow.

Tagged Whales, Biopsy and Tag Performance
The amount of data collected from each tag varies greatly and is dependent on many factors, some of which are impossible to identify with certainty. During this study period (2010–2012) we have had good success with tag longevity and performance for our standard tags. We also tried a new tag (CTD) that was larger, heavier, and used more battery power; it lasted 33 days and provided excellent oceanographic and dive data with much more detail than previous tags. We check all tags thoroughly before deployment by dunking them in salt water and testing battery strength.

In spring 2012, we had one bowhead tag that was deployed near St. Lawrence Island that never transmitted. During deployment the plastic piece that connects the tag to the pole came off the pole and remained on the tag possibly blocking transmissions from the antenna.   We believed that it would come off eventually and the tag would begin to transmit, but it never did. Another tag deployed near St. Lawrence Island (B12-2) transmitted only sporadically and, although it lasted 143 days (Table 2), there were several gaps in the track that we cannot explain.

During this study (2010–2012), we deployed 17 transmitters on bowhead whales and six on gray whales. The success of this program continues to be largely due to cooperation with native whalers. Whalers are familiar with how best to approach and harpoon bowhead whales and are able to place tags at the highest point on the whale’s back and seat the anchors completely and perpendicular to the surface of the whale. We think that high, perpendicular tag placement leads to better rates of transmission and full seating of the anchors leads to longer tag attachment.

DNA from skin biopsies collected during tagging has allowed us to determine gender for 6 of 11 bowhead whales in 2010 (two males and four females) and, 4 of 6 in 2012 (pending analysis). Gender was determined for all seven gray whales tagged (3 males and 4 females) and for all five of the gray whales that were biopsied without being tagged (one male and four females).

Gray Whale Photo-identification. Movements of a gray whale tagged near Sakhalin Island, Russia, on 4 October 2010 raised questions regarding the discreteness of gray whale stocks. This whale, identified by photographs to be a 13 yr-old male, was thought to be part of the small (~130) endangered Western Pacific population. On 11 December, however, it left the Sakhalin area and migrated across the Okhotsk Sea, the Bering Sea, and the Gulf of Alaska and was headed toward the breeding grounds of the Eastern Pacific population. The transmissions ended within 20 km of the central Oregon coast. Photo-id catalogs of the two stocks were compared and matches were found indicating that this individual had been photographed within the ranges of both stocks. Until this event, gray whales summering in the Bering and Chukchi seas were thought to belong to the Eastern Pacific population but it is possible there is more movement between the Eastern and Western Pacific groups than scientists realized. In order to determine the wintering grounds of gray whales that summer in the Bering and Chukchi seas we are taking photographs to compare with existing catalogs. Photo-catalogs exist for both the eastern and western Pacific groups; matching photos from the Bering and Chukchi seas will contribute greatly to understanding the movements of gray whales across the Pacific.

Conclusions

This project continues to collect important information about bowhead whales throughout their range. We have continued to work with Native subsistence whalers to develop new study objectives and to deploy tags. We continue to work with tag manufacturers to improve tag data and longevity. We shared our results with subsistence whalers and their communities, scientists, oil company personnel, agency personnel, and other interested parties by sending out weekly maps and information updates. We maintained an active website that allowed public access of our data products. This website was used by many entities for diverse purposes, including species and habitat maps, environmental assessments, biological opinions, incidental harassment applications and authorizations. We published three papers in peer-reviewed scientific journals and made numerous oral and poster presentations and conferences, symposia, and meetings (Appendix E).

This project has contributed a greater understanding of the distribution, movements, and biology of bowhead whales. These include, but are not limited to:

1. Further documentation of the year-round distribution of western Arctic bowhead whales, including extensive summer movements, variations in wintering areas, and the migratory routes that connect these areas.

2. Documentation of areas where whales spend time, and are likely feeding. These areas include Cape Bathurst and Tuktoyaktuk in Canada; Point Barrow in Alaska; and Northern Chukotka and the Gulf of Anadyr in Russia; and Bering Strait and Anadyr Strait in Russia and Alaska. We have documented the timing of movements and calculated kernel densities for these areas (see Results and Discussion).

3. The western Beaufort Sea from Barrow to Cape Simpson was the only area within the Alaskan Beaufort Sea where tagged bowhead whales spent much time indicating an important feeding location within the Alaska Beaufort Sea. Although oceanographic factors that concentrate krill may not be favorable every year our combined data do not indicate any other feeding areas in the Alaska Beaufort Sea.

4. We have identified migratory corridors that bowheads use to travel between feeding areas. Both the spring migratory corridor between the Bering Strait and Cape Bathurst in Amundsen Gulf and the fall migratory corridor between Hershel Island and Barrow have been relatively distinct and consistent among years. The fall migratory corridor between Barrow and the Bering Strait, however, is more variable. We think this is related to prey availability, which is also related to the timing of whale movements. Krill is concentrated by oceanographic factors, which vary in space and time. This results in complex movement patterns as individual whales travel to different feeding areas at different times.

5. We have documented bowhead movements within all oil and gas lease sale areas in the Chukchi and Beaufort seas including their presence in the vicinity of active seismic and drilling operations. Based on movements and behavior of tagged bowhead whales from all years, the greatest potential for anthropogenic disturbances from industrial activities including shipping occur near Cape Bathurst in May and June, Tuktoyaktuk in late August to early September, Point Barrow in late August to late October, northern Chukotka/Bering Strait in October to early January and the outer Gulf of Anadyr in December through March. Ships traveling through the narrow area west of Little Diomede Island from mid November to the end of December would have high potential for encountering many bowhead whales.

6. We deployed tags near St. Lawrence Island and found movements similar to whales tagged near Barrow and Tuktoyaktuk, although the sample size was small (n = 2).

Recommendations

1. In order to increase the likelihood that tagged whales represent the population as a whole, and in order to gain a year-round understanding of bowhead whale movements and distribution, tagging should continue from as many locations and during as many different times of year as possible. Specifically:

    a. Increasing the sample size of tagged whales at all tagging locations will make identifying separate concentrations of whales more likely. For example, whale B09-09 was tagged in Barrow in late August of 2009, but migrated to Chukotka in the spring of 2010. More summering areas may be identified as more tags are deployed.

    b. Although we have increased our sample size to observe fall movements of 15 bowhead whales across the Beaufort Sea, we have found no additional areas of importance where bowheads are spending significant time between Tuktoyaktuk and Barrow. There is great interest in oil and gas exploration in this region and we expect an increase in industrial activity, therefore more information may still be needed regarding bowhead whale movements and feeding behavior for the Alaskan Beaufort Sea. Tagging more whales near St. Lawrence Island and Barrow in the spring and tagging more whales in Canada in the fall will address this need.

    c. Deploy tags near St. Lawrence Island to determine if whales tagged there are similar in their movements and behavior to those tagged near Barrow and in Canada. To target whales summering in Chukotka, we suspect it is more efficient to tag whales migrating past St. Lawrence Island in the spring than from Barrow in the fall.

2. Conduct a comprehensive analysis of bowhead whale interactions with seismic activities.

Bowhead whale tracks that spatially and temporally overlap with seismic operations need to be analyzed to learn about bowhead whale behavior near seismic activities. Oil and seismic companies need to be forthcoming with their seismic information in order for this analysis to occur.

3. Investigate the combination of satellite telemetry and acoustic technology to directly monitor noise levels that bowhead whales are exposed to and how their vocalization rate changes with those levels. This knowledge could then be used to interpret passively monitored acoustic information.

4. Continue to deploy tags that are capable of measuring temperature and salinity, important factors that relate to how krill concentrate.

5. Conduct a comprehensive analysis of how whale movements and feeding areas shift by year. Understanding annual variability is important for understanding the full range of bowhead movements, behavior, and habitat use. Furthermore, we cannot predict how whales will respond to climate change and changing ice conditions until we know what influences their current distribution.

Acknowledgments

This cooperative project involved contributions and hard work from many organizations, agencies, and individuals. The Alaska Eskimo Whaling Commission (the late Arnold Brower, Sr., Harry Brower, Jr., and Ray Koonook), North Slope Borough (John “Craig” George, Billy Adams, Robert Suydam, and Ambrose Leavitt), Barrow and Kaktovik Whaling Captain’s Associations (Eugene Brower, Fenton Rexford, Joe Kaleak, George Tagarook, and Eddie Arey), Barrow Arctic Science Consortium (Lewis Brower), Aklavik and Tuktoyaktuk Hunters and Trappers Committees (Dennis Arey, Larry Arey, Pat Kasook, Buddy Gruben, Douglas Panaktalok, Mikkel Panaktalok, Max Kotokak, Sr., Charles Pokiak, and James Pokiak), and Department of Fisheries and Oceans Canada (DFO) (Lois Harwood, Kevin Bill, Tim Leblanc, Patrick Ryan, Terry Stein, Angus Alunik), and Dr. Stephen Raverty of the BC Animal Health Center all assisted with field operations. The Greenland Institute of Natural Resources (Mads Peter Heide-Jørgensen, Mikkel and Anders Villum Jensen) contributed to tag development and deployment. Funding for this research was provided by the Bureau of Ocean Energy Management with support and assistance from Charles Monnett and Jeffery Denton. Much of the operations in Canada were funded by the Fisheries Joint Management Committee, Ecosystem Research Initiative (DFO), and Panel for Energy Research and Development with extensive support and coordination from Lois Harwood. Bowhead whale research has been conducted in the U.S. under a Marine Mammal Protection Act permit issued to National Marine Fisheries Service (No. 782-1719) and under the Alaska Department of Fish and Game’s Animal Care and Use permit Nos. 06-16 and 09-21. In Canada, research was conducted under Department of Fisheries and Oceans Scientific License No. S-07/08-4007-IN, S-08/09-4000-IN, S-09/10-4005-IN-A1 and Animal Care Protocols FWI-ACC-2007-2008-013 and FWI-ACC-2008-031, and FWI-ACC-2009-019.

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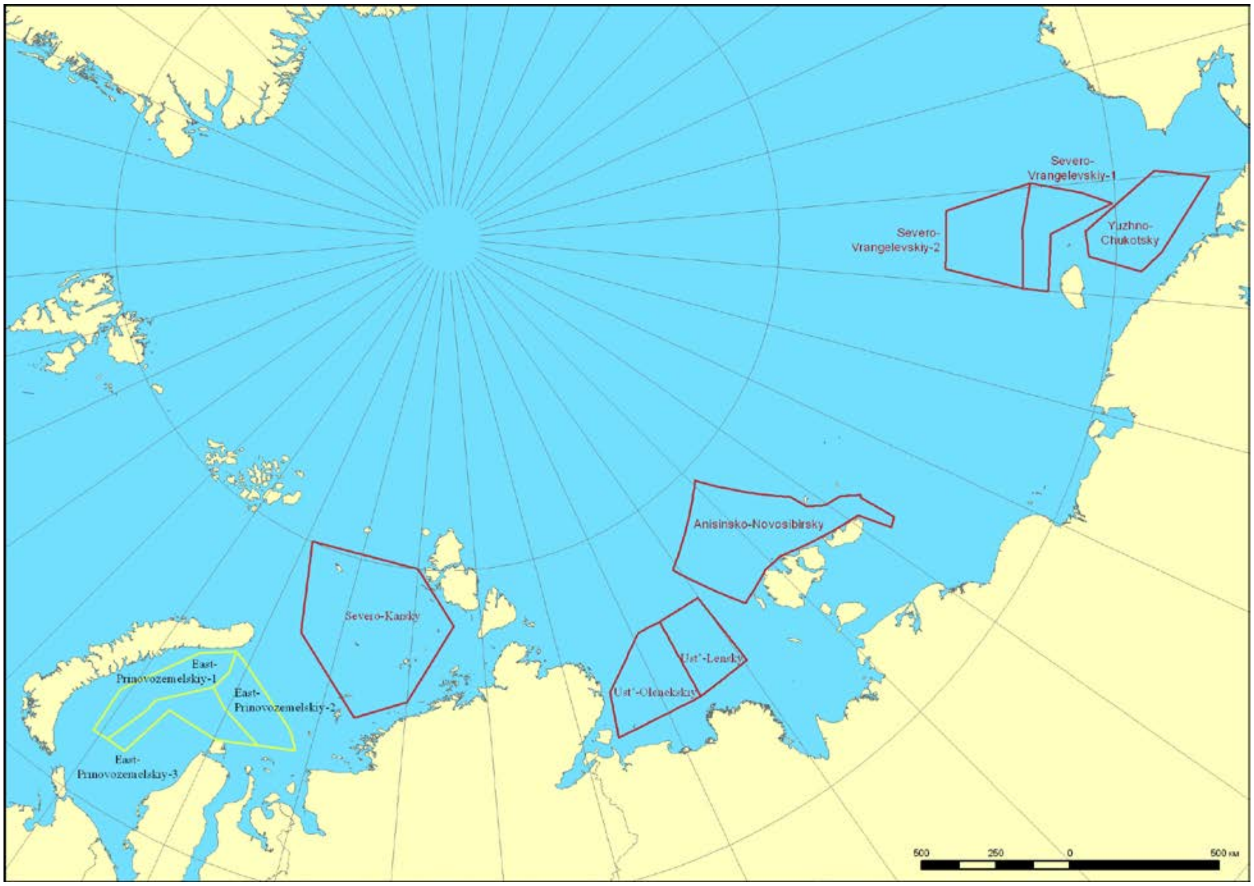
Appendix A. Announcement of Proposed Oil and Gas Leases in the Russian Chukchi Sea.
Found at: http://www.rosneft.com/news/pressrelease/130220133.html



Name of the license block	Sea	Acreage, sq.km*	Acreage, acres*	Water depth, m*
1. East Prinovozemelskiy-1 2. East Prinovozemelskiy-2 3. East Prinovozemelskiy-3	Kara	125,904	31.1 M	10-440
4. Severo-Karsky	Kara	196,000	48.4 M	20-480
5. Ust' Olenekskiy	Laptev	64,103	15.8 M	19-90
6. Ust' Lensky	Laptev	46,851	11.6 M	15-90
7. Anisinsko Novosibirsky	Laptev	140,981	34.8 M	20-2000
8. Severo-Vrangelevskiy-1 9. Severo-Vrangelevskiy-2	Chukchi	115,176	28.4 M	40-370
10. Yuzhno Chukotsky	Chukchi	73,197	18.0 M	40-70

*estimated

February 13, 2013

Rosneft and ExxonMobil Expand Strategic Cooperation

- Companies to add seven Arctic license areas covering approximately 600,000 square kilometers (150 million acres) in the Chukchi, Laptev and Kara seas
- Rosneft is provided with an option to acquire a 25 percent interest in Point Thomson natural gas and condensate project in Alaska operated by ExxonMobil
- Companies to jointly study potential for LNG project in Russian Far East.
- Moscow, Russia – February 13, 2013. Rosneft and ExxonMobil have agreed to expand their cooperation under their 2011 Strategic Cooperation Agreement to include approximately additional 600,000 square kilometers (150 million acres) of exploration acreage in the Russian Arctic, and potential participation by Rosneft (or its affiliate) in the Point Thomson project in Alaska. They have also agreed to conduct a joint study on a potential LNG project in the Russian Far East.
- The agreements, which include plans to explore seven new blocks in the Chukchi Sea, Laptev Sea and Kara Sea, were signed by Igor Sechin, president of Rosneft and Stephen Greenlee, president of ExxonMobil Exploration Company, in the presence of Russian President Vladimir Putin.
- The license blocks include Severo-Vrangelevsky-1, Severo-Vrangelevsky-2 and Yuzhno-Chukotsky blocks in Chukchi Sea, Ust' Oleneksky, Ust' Lensky and Anisinsko-Novosibirsky blocks in Laptev Sea and Severo-Karsky block in Kara Sea, which are among the most promising and least explored offshore areas globally.
- A separate Heads of Agreement was signed providing Rosneft (or its affiliate) with an opportunity to acquire a 25 percent interest in the Point Thomson Unit which covers the project of developing a remote natural gas and condensate field on Alaska's North Slope. It is estimated that Point Thomson contains approximately 25 percent of the known gas resource base in Alaska's North Slope.
- Rosneft and ExxonMobil also executed a Memorandum of Understanding to jointly study the economic viability of an LNG development in the Russian Far East, including the possible construction of an LNG facility. The companies will form a joint working group which is expected to commence work in the coming weeks to study the viability of an LNG project using available natural gas resources.

Commenting on the agreements signed, Igor Sechin said, “The agreements signed today bring the already unprecedented scale of Rosneft and ExxonMobil partnership to a completely new level. The acreage in the Russian Arctic subject to geological exploration and subsequent development increased nearly six-fold. That means the enormous resource potential of Russian Arctic offshore fields will be explored and developed in the most efficient manner with the application of cutting-edge technologies and expertise of our strategic partner, ExxonMobil, using state-of-the-art environmental protection systems. Participation in the Point Thomson project will increase Rosneft’s access to the latest gas and condensate field development technologies used in harsh climatic conditions”.

- Greenlee said the agreement builds on the ongoing successful cooperation between the companies.
  “This expansion is an illustration of the strength of the partnership that exists between ExxonMobil and Rosneft,” said Greenlee. “We look forward to working together on these new projects.”
- The companies are committed to using global best practices and state-of-the-art safety and environmental protection systems for the Arctic operations. The work will be supported by the recently signed Declaration on the Russian Arctic Shelf Environmental protection. Also, ExxonMobil and Rosneft will work together through an Arctic Research Center to provide a full range of research and design services to support their cooperation on Arctic projects.
- Rosneft and ExxonMobil continue to implement a program of staff exchanges of technical and management employees to help strengthen relationships between the companies.
- License areas factsheet

- **Rosneft Information Division**
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  www.rosneft.com

  February 13, 2013

Appendix B. Quakenbush, L. and J. Citta. 2011. Satellite Tracking of Bowhead and Other Whales: Further Studies, 2011–2015. Study Plan as approved by the Alaska Eskimo Whaling Commission on 22 July. 5 pp.

Study Plan

Satellite Tracking of Bowhead and Other Whales: Further Studies, 2011–2015

As approved by:
The Alaska Eskimo Whaling Commission
22 July 2011

Submitted by:
Lori Quakenbush and John Citta
Alaska Department of Fish and Game
Fairbanks, Alaska

July 2011

Introduction

Bowhead whales (*Balaena mysticetus*) were designated as an endangered species in 1973 due to depletion by commercial whaling during the late 1800s. The population has recovered considerably since then and the current estimate is ~10,000 (Zeh and Punt 2005). Bowheads are an important subsistence and cultural resource for coastal people of northern Alaska and Russia and their harvest is managed by a quota system approved by the International Whaling Commission and implemented, in Alaska, by the Alaska Eskimo Whaling Commission (AEWC). Oil and gas leasing, exploration, development, and production are ongoing in the Alaskan Beaufort Sea, and leasing and exploration are ongoing in the Canadian Beaufort Sea and in the Chukchi Sea. International shipping is expected to increase and some fisheries may be expanded as the open water season lengthens. These activities will occur within the range of the Bering-Chukchi-Beaufort stock of bowhead whales. In order to minimize the impacts of industrial activities on bowhead whales we need to better understand bowhead migration routes and timing, and identify important habitats (e.g., feeding and summering areas) so that lease sale areas and industrial activities can be designed to minimize effects on bowhead whales. Between 2006 and 2010 we deployed 57 satellite transmitters on bowhead whales in Alaska and Canada and collected information on migration routes, migration timing, swim speed, diving behavior, residence times in portions of the range, as well as some responses to industrial activity (Quakenbush et al. 2010a, b). The study was designed cooperatively with the AEWC, the North Slope Borough, the Minerals Management Service (MMS, now Bureau of Energy Management, Regulation and Enforcement), and the Alaska Department of Fish and Game; it was funded by MMS. We have evaluated our accomplishments relative to our original study objectives and we have developed a study plan for the next 5 years to focus on objectives that have not been fully met.

Methods

In December 2010, we held a workshop with the AEWC and North Slope Borough personnel in Anchorage to evaluate our accomplishments relative to our study objectives in order to identify objectives that have not been met and to determine whether additional study is recommended (Appendix A). We used the summary from the workshop to develop this draft study plan for review, modification, and approval by the AEWC.

Study Plan, 2011–2015

Do satellite transmitters (tags) harm bowhead whales? An important topic of discussion at the workshop was whether the tags harm the whales. Although we have tagged 57 bowhead whales we have not been able to examine the tag site after deployment. No tagged whales have been harvested. Billy Adams reported seeing a tag ~20 days after deployment and it looked the same as when it was deployed (i.e., flush with the skin). The tracks from the tagged whales tell us that their movements are what are expected from healthy whales. Individual whales tagged in fall near Barrow have been tracked for more than 365 days. The long retention time of many of the tags suggest that the tag site is not becoming infected. An infection would affect the skin and surrounding tissue and cause the tag to fall off. If the tags were irritating to the whales they would likely be rubbed off on the bottom or on the ice. A study of penetrating tags used on humpback whales (*Megaptera novaeangliae*) compiled the sightings of seven tagged whales and found that all seven were observed at least 20 years after tagging and five of the seven have been observed for more than 30 years (Mizroch et al. 2011). This study was published recently and was not available to discuss at the workshop.

Overall Study Objectives:
Work with subsistence whalers during all aspects of this study and make sure research activities do not interfere with subsistence whaling activity.

Use satellite telemetry and the methods developed during the previous study to further investigate movements, timing, important habitats, and interactions with industry. Specifically:

Bowhead whales
Objective 1: Tag at St. Lawrence Island beginning in 2011 until 10 or more tags are deployed.
Movements of whales tagged near Barrow and in Canada have not been representative of when and where bowheads are seen near St. Lawrence Island. In addition, by tagging whales near St. Lawrence Island we may document more whales going west in spring and not passing Barrow. Tagging whales in the Bering Sea may also help answer the question about where the whales that show up at Barrow in July come from. Movements of tagged whales near St. will be combined with traditional knowledge.

Objective 2: Tag small (~30 ft long) and large (>40 ft long) whales at Barrow.
More males have been tagged then females. Few small (only 4) and few large females (only 4) have been tagged. Although we cannot determine the sex of a whale before it is tagged (unless it has a calf), we can determine size. Thus, we could focus on small and large whales in order to get more tags on these age classes and some of them should be females, which would increase our female sample too. Tagging small whales near Barrow would also help answer the question of whether the sizes are mixed near Barrow in summer (boat or aerial surveys could answer this question, too). Tagging any bowheads near Barrow in July may tell us whether these whales go east into the Beaufort Sea where they may encounter oil and gas activities before migrating west in the fall.

Objective 3: Document the affects of tags on whales.
We will document affects of tags on whales by trying to re-sight and photograph tagged whales.

Objective 4: Analyze existing data on interactions with seismic and other industrial activities.
We will analyze and report on interactions with industry collected from previously tagged whales.

Objective 5: Develop a tag that records sounds that bowheads hear and sounds they make.
Hydrophones placed near seismic operations have shown that when airguns turn on, bowhead call numbers go down. This could mean that bowheads leave the area or that they stop calling. A tag that records sound (acoustic tag) could tell us which happens. If bowheads stay in the area they could be physically injured by the high noise levels and methods other than increasing the noise level slowly so bowheads can move away before seismic operations start would need to be developed to protect bowheads.

Objective 6: Add a temperature probe to the tag anchors to record internal temperature.
The tags we use record water temperature and we could add a sensor in the anchor that would record the temperature deeper in the blubber under the skin at the site of the probe. This information would help with studies of energetics, which is how much food (energy) a bowhead needs to eat to live and reproduce.

Objective 7: Deploy tags that measure changes in ocean temperature and salinity.
This information would help us understand why bowhead whales stop in some places to feed but not others. It is believed that krill (bowhead food) collects in places where water with different temperature or salinity meet (fronts). These fronts are similar to eddies on a river and krill collects in these eddies, much like debris collects in eddies on rivers.

Objective 8: Develop a tag with both satellite and VHF capability.
The VHF part of the tag would allow us to find the tagged whale from an airplane so we could document the number of other bowheads with it. We could use the satellite tag to track the whale and when it travelled to an area we could reach with an airplane we could fly out and find it. This would help us determine how well the tagged whales represent whales that are not tagged. VHF capability may also help accomplish Objective 3 by allowing us to identify and photograph the tag to determine its affect on the whale.

Gray whales
Gray whales are more common in the Chukchi and Beaufort seas now than in the past and their movements, important habitats, and how they interact with industrial activities is unknown and important. Our research permit and our funding allows for this project to include tagging and biopsies of gray whales.

Objective 1: Tag gray whales near Barrow and St. Lawrence Island.
We can use similar tags with shorter anchors for gray whales and begin to collect similar information about their movements. We can use the same biopsy methods to determine the sex of the gray whales tagged.

Humpback whales
A few humpback whales have been seen each year in the Chukchi Sea and their movements, important habitats, and how they interact with industrial activities is also unknown and important. Our research permit and our funding allows for this project to include tagging and biopsies of humpback whales.

Objective 1: Biopsy humpback whales near Barrow and St. Lawrence Island.
We can begin to study humpback whales by collecting biopsies for sex and genetics. We can use biopsy tips on crossbows to determine the sex of the whale biopsied.

Discussion

We have completed 5 years of research on bowhead whales using satellite telemetry and working with subsistence whalers. We have learned a tremendous amount about bowhead whales that is already being used to plan shipping lanes and develop mitigation to protect bowhead whales. Our tagging project received the Secretary of the Interior Partners in Conservation Award for its outstanding contributions and unprecedented collaborations among government and Native organizations. The award acknowledged that the success of the project was largely due to the efforts of Native subsistence whalers.

Due to the past success of the project, the funding agency, the Bureau of Energy Management, Regulation and Enforcement (formerly MMS) will continue the funding to pursue unanswered questions regarding bowhead whales and to pursue similar studies of gray and humpback whales. In order to continue the studies we submit this study plan for the review, modification, and approval of the AEWC.

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Appendix C. Citta, J. J., L. T. Quakenbush, R. J. Small, and J. C. George. 2007. Movements of a tagged bowhead whale in the vicinity of a seismic survey in the Beaufort Sea. 17th Biennial Conference on the Biology of Marine Mammals, 29 November – 4 December 2007, Cape Town, South Africa. (Abstract and poster)

ABSTRACT: The western Arctic stock of bowhead whales (*Balaena mysticetus*) is critical for the nutritional and cultural health of Alaska Natives and it is important in the marine ecosystem as a consumer of zooplankton. Most bowheads winter in the Bering Sea and summer in the eastern Beaufort Sea where they are vulnerable to possible effects from oil and gas exploration, development, and production. Marine seismic surveys are commonly used during oil and gas exploration and have the potential to disrupt bowhead communication, feeding, and migration. Such surveys often include mitigation measures intended to minimize potential effects of seismic activity on marine mammals; however, the efficacy of such measures is unknown. In 2006, we documented movements of a satellite-tagged bowhead whale in the vicinity of an active seismic survey, north of the Mackenzie River Delta, Canada. We examined how the whale's velocity, turn angle relative to the seismic ship, and the dispersion in turn angles were related to distance from the seismic ship. We found no statistical relationship between whale behavior and distance from the seismic ship and suspect this is largely due to the ship shutting down seismic operations when the whale came closest. On 19 September, when the whale was closest (9.2 km) to the ship, the whale deviated course. Marine observers aboard the ship then halted the survey and shutdown the airguns in response to sighting other closer bowhead whales, during which time the satellite-tagged whale crossed the projected path of the seismic ship.

Movements of a Tagged Bowhead Whale in the Vicinity of a Seismic Survey in the Beaufort Sea

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John C. George, North Slope Borough, Department of Wildlife Management, P.O. Box 69, Barrow, Alaska, 99723, USA; craig.george@north-slope.org

ABSTRACT: The western Arctic stock of bowhead whales (*Balaena mysticetus*) is critical for the nutritional and cultural health of Alaska Natives and it is important in the marine ecosystem as a consumer of zooplankton. Most bowheads winter in the Bering Sea and summer in the eastern Beaufort Sea where they are vulnerable to possible effects from oil and gas exploration, development, and production. Marine seismic surveys are commonly used during oil and gas exploration and have the potential to disrupt bowhead communication, feeding, and migration. Such surveys often include mitigation measures intended to minimize potential effects of seismic activity on marine mammals; however, the efficacy of such measures is unknown. In 2006, we documented movements of a satellite-tagged bowhead whale in the vicinity of an active seismic survey, north of the Mackenzie River Delta, Canada. We examined how the whale's velocity, turn angle relative to the seismic ship, and the dispersion in turn angles were related to distance from the seismic ship. We found no statistical relationship between whale behavior and distance from the seismic ship and suspect this is largely due to the ship shutting down seismic operations when the whale came closest. On 19 September, when the whale was closest (9.2 km) to the ship, the whale deviated course. Marine observers aboard the ship then halted the survey and shutdown the airguns in response to sighting other closer bowhead whales, during which time the satellite-tagged whale crossed the projected path of the seismic ship.

INTRODUCTION: In September of 2006, a satellite-tagged bowhead whale was in the vicinity of a 2D seismic operation for 17 days (Fig. 1). The survey was conducted by GX Technology Corporation using the *M/V Discoverer*, a 72 m Ice Class C vessel towing a 40 airgun array, of which a maximum of 36 airguns were firing (total discharge volume of 3,220 cubic inches). On this survey, specific mitigation measures included: 1) shutting down airguns when bowhead whales were observed within designated safety zones (~ 1 km where noise levels were predicted to be > 180 dB) and 2) following shutdowns, activating one airgun at a time to allow whales to move away as the sound levels increased slowly (Harris et al. 2007). The purpose of this project was to examine how whale behavior varied as a function of distance from the seismic ship.

METHODS: To remove unlikely whale locations from the dataset, we filtered locations using the speed filter described by MacConnell et al. (1992) with a velocity threshold of 5.9 m/s, the maximum speed Richardson and Finley (1989) observed a bowhead whale fleeing a ship. For each whale location, we calculated distance to the seismic ship, the whale's velocity approaching the nearest location to the ship ($v_{1,2}$), the whale's velocity leaving the nearest location to the ship ($v_{2,3}$), and the whale's change in direction (θ_2) relative to the ship's location (Fig. 2). We predicted that the whale would turn away from the ship and its velocity would increase as the ship came closer to the whale. If whale movement was random, when the whale was far from the ship we expected the distribution of turn angles to be uniform with high dispersion. As the ship approached the whale, we expected the distribution of turn angles to have a mean near 180° and a low amount of dispersion, indicating that the whale's movements were consistent with attempts to move away from the ship. We split the data into four distance categories: 1) ≤ 25 km; 2) 26 to 50 km; 3) 51 to 100 km; 4) > 100 km. Because the whale was located few times in close proximity to the ship, we relied on non-parametric comparisons. To compare whale velocity in the four distance categories we used a Kruskal-Wallis test in SAS 9.1 (SAS Institute 2004) using PROC NPAR1WAY. To determine if the distribution of turning angles changed in mean direction or dispersion between distance categories, we used Rao's Test for Homogeneity (Jammalamadaka and SenGupta 2001) in package CircStats in R (R Development Core Team 2007).

The M/V Discoverer towing a seismic array.

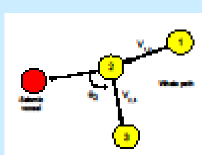

Figure 2. Example of velocity and angular statistics calculated for whale location number 2.

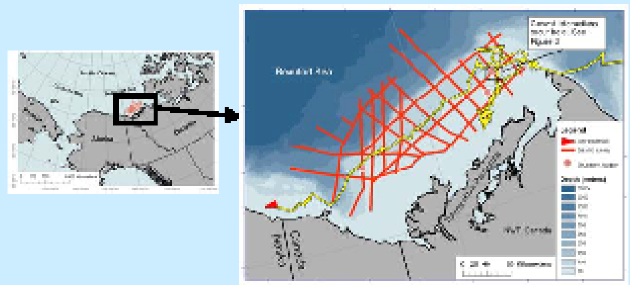

Figure 1. Overlay of the bowhead whale and seismic survey tracks.

RESULTS: The whale was located 160 times during the seismic survey. The minimum distance between the whale and the seismic ship was 9.2 km. The whale was located eight times in the first distance category (≤25 km), 10 times in the second category (26 to 50 km), 10 times in the third category (51 to 100 km), and 132 times in the fourth category (> 100 km). Neither metric of whale velocity differed by distance category (p=0.67 for $v_{1,2}$; p=0.85 for $v_{2,3}$) and the distance categories did not differ in either their mean direction (p=0.16) nor dispersion (p=0.52).

We found visual evidence, however, that the whale avoided the seismic ship on 19 September. On this day, marine mammal observers on the ship sighted a mother-calf pair of bowhead whales ~ 500 m from the ship; consequently the airguns were shut-down and the survey was halted for ~ 3.5 hours. The whale maintained a distance of ~ 9.2 km from the ship and then crossed in front of the ship during the shut-down (Fig. 3). Animations of the whale and the seismic survey can be viewed at: ftp://ftpr3.adfg.state.ak.us/JCitta/.

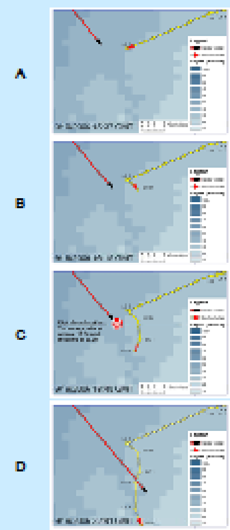

Figure 3. Sequential maps depicting the closest interaction between the whale and the seismic survey.

DISCUSSION: This is the first documented interaction between a satellite-tagged bowhead whale and a seismic ship. We found evidence that this whale maintained a minimum distance of 9.2 km from the seismic ship, which is a much greater distance than the designated 1 km 'safety zone' used to trigger shut-downs. However, this is considerably less than the 20 km deflections noted for migrating bowheads in the mid-Beaufort Sea (Richardson 1999). Based upon our statistical analyses, it does not appear the seismic survey affected overall whale behavior, as the whale remained in the area after the seismic survey ended, presumably feeding, and then migrated into the Chukchi Sea, off the coast of Chukotka, Russia. Hence, we conclude that the seismic operation did not permanently disrupt the feeding or migratory behavior of this whale.

ACKNOWLEDGEMENTS: Cooperators include the Alaska Department of Fish and Game, the North Slope Borough, the Alaska Eskimo Whaling Commission, the Barrow and Kaktovik Whaling Captains Association, the Greenland Institute of Natural Resources, the Aklavik Hunters and Trappers Committee, and the Department of Fisheries and Oceans Canada. Information on the seismic survey was provided by, GX Technology. This project is funded by the U.S. Department of the Interior, Minerals Management Service. Bowhead tagging was conducted under NFMS permit number 782-1719-04.

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2012 Photos of Gray Whales in Western Alaskan Waters

Gambell August 2012

Alaska Department of Fish and Game
Arctic Marine Mammal Program

Lori Quakenbush
Lori.Quakenbush@alaska.gov
(907) 459-7214

Right

Left

Fluke

ID
ER12GAM-93080

First/Last year seen
2012

First photographed
Gambell

Genetic Sample?
Yes

Sex
Female

Right

Left

Fluke

ID
ER12GAM-001

First/Last year seen
2012

First photographed
Gambell

Genetic Sample?
Yes

Sex
Female

Right

Left

Fluke

ID
ER12GAM-002

First/Last year seen
2012

First photographed
Gambell

Genetic Sample?
Yes

Sex
Female

Right

Left

Fluke

ID
ER12GAM-003

First/Last year seen
2012

First photographed
Gambell

Genetic Sample?
Yes

Sex
Male

Right

Left

Fluke

ID
ER12GAM-004

First/Last year seen
2012

First photographed
Gambell

Genetic Sample?
Yes

Sex
Female

Right

Left

Fluke

ID
ER12GAM-P005

First/Last year seen
2012

First photographed
Gambell

Genetic Sample?
No

Sex
?

Right

Left

Fluke

ID

First/Last year seen

First photographed

Genetic Sample?

Sex

Appendix E-1. Project Update to Barrow Whaling Captains' Association

Satellite Tracking of Bowhead Whales

Project Update to BWCA – 27 September 2010

Recent Accomplishments: In May 2010, four large whales were tagged near Barrow (size ranged from 45–60 ft.). These whales were tagged by a crew that included Billy Adams, Anthony Kippi, Carl Kippi, Joe Sage, and Max Adams, Jr., Eleven tags deployed in Canada in August 2010. One near Hershel Island with assistance of George Tagarook and Sam Gordon and 10 near Tuktoyaktuk deployed by James and Charles Pokiak. Two whales tagged in October 2009 tagged by Harry Brower, Jr (#93079 and #93081) and two whales tagged in May 2010 by Anthony Kippi (#93080 and #93084) and are still on the air (see Figure 1).

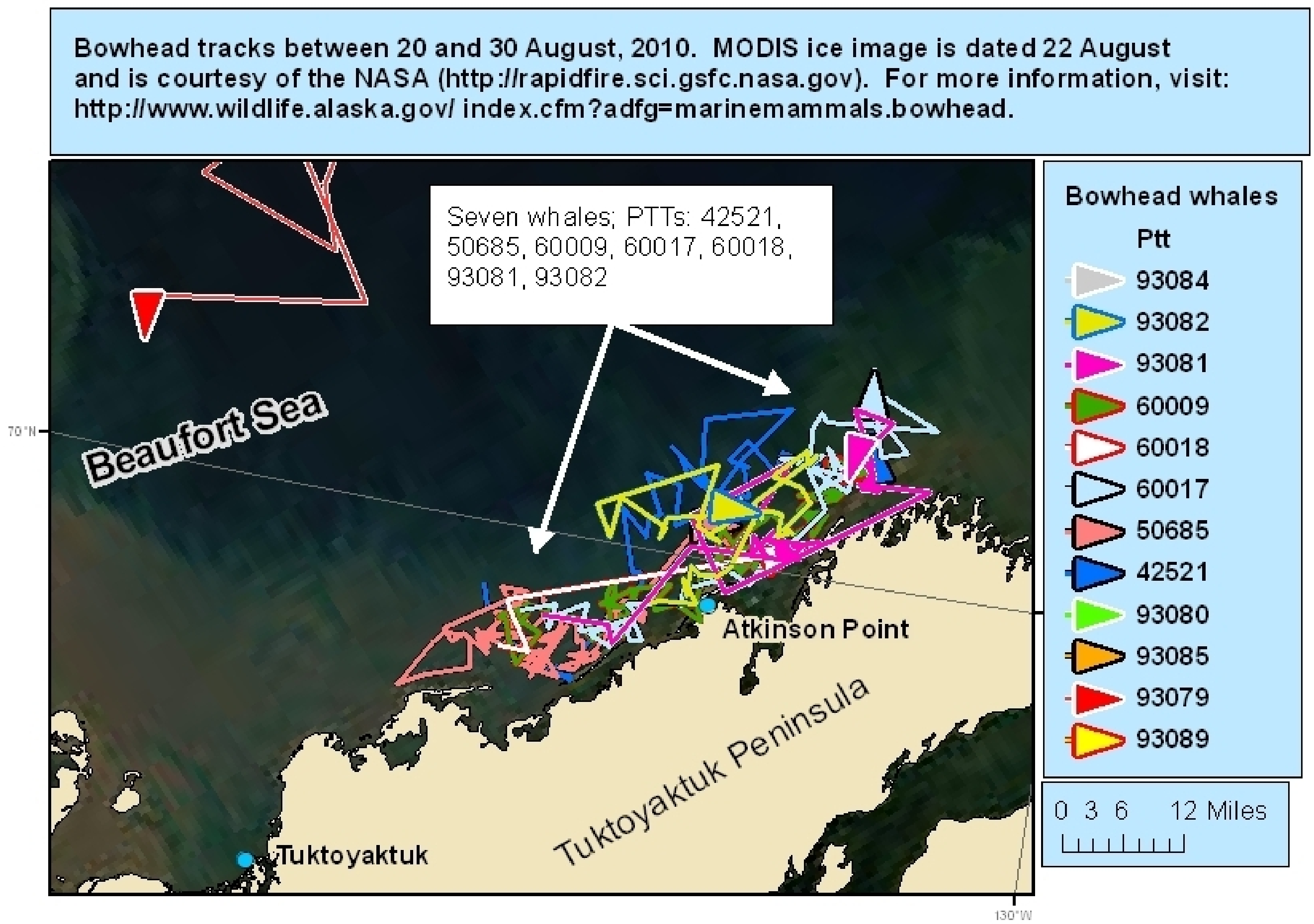

Figure 1. Area along Tuktoyaktuk Peninsula where 10 bowhead whales were tagged in August 2010. The northernmost whale (#93079, red arrow), a 56 ft female, was tagged near Barrow in October 2009 by Harry Brower, Jr. The whales tagged in August 2010 ranged from 30-40 ft in length. One additional whale was tagged near Hershel Island to the west of the map in this figure.

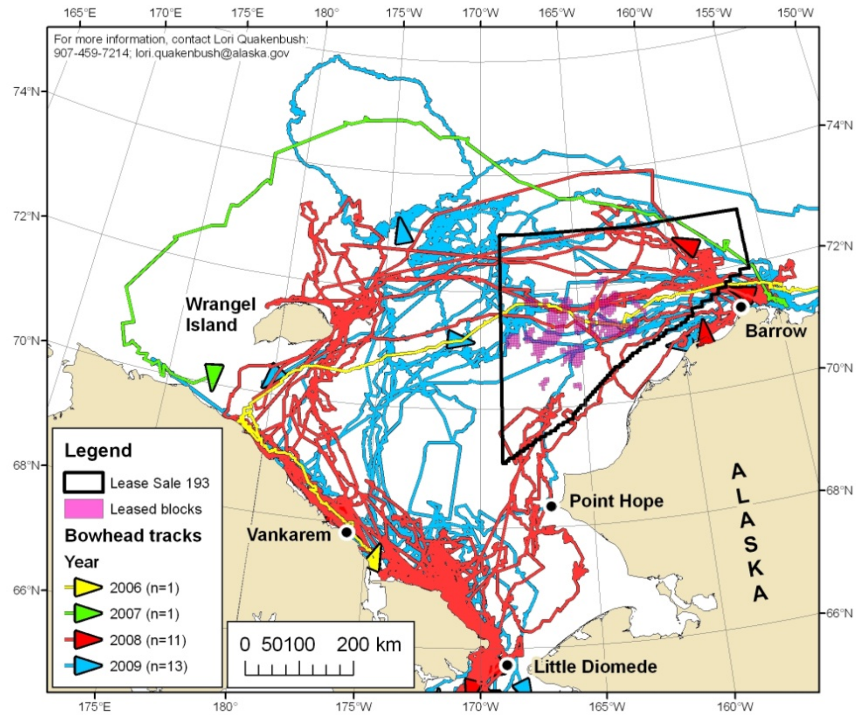

Figure 2. Map of all tracks by year of tagged bowhead whales that traveled through the Chukchi Sea in late summer and fall. All tagged whales except one in 2009 is believed to have traveled through Lease Sale Area 193.

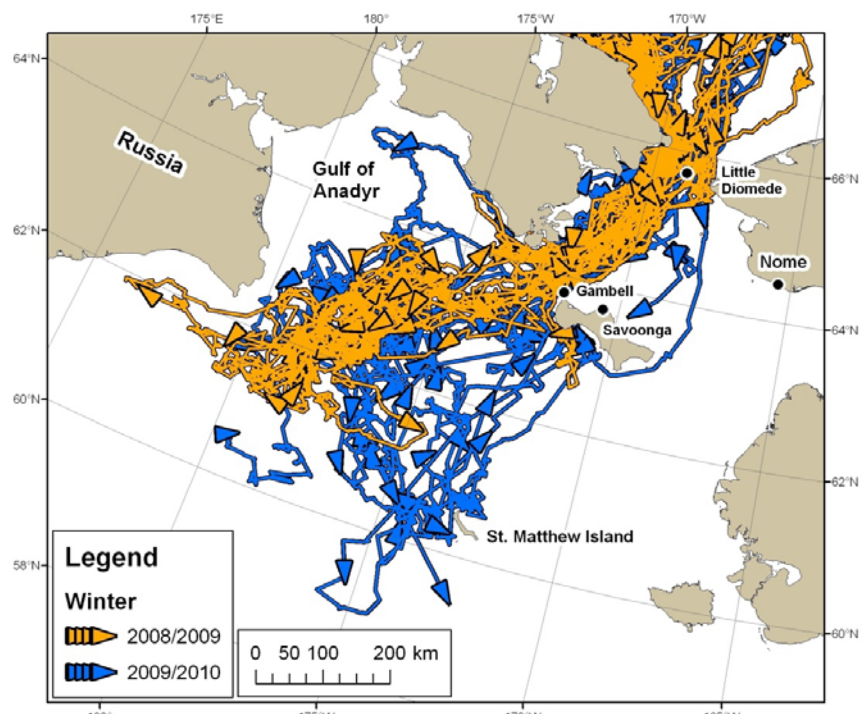

Figure 3. Map of all tracks by year of tagged bowhead whales in the Bering Sea in winter. There was greater use of the area between St. Lawrence and St. Matthew islands in the winter of 2009/2010.

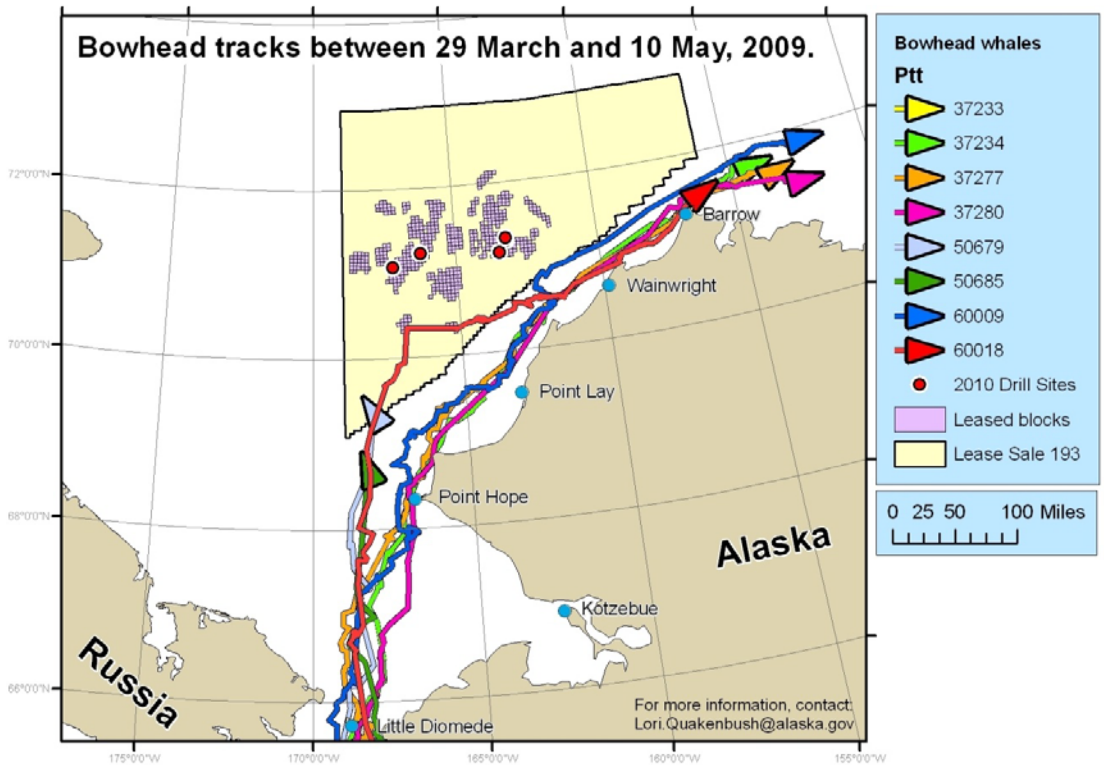

Figure 4. Tracks of eight tagged bowhead whales in spring 2009 relative to Lease Sale Area 193.

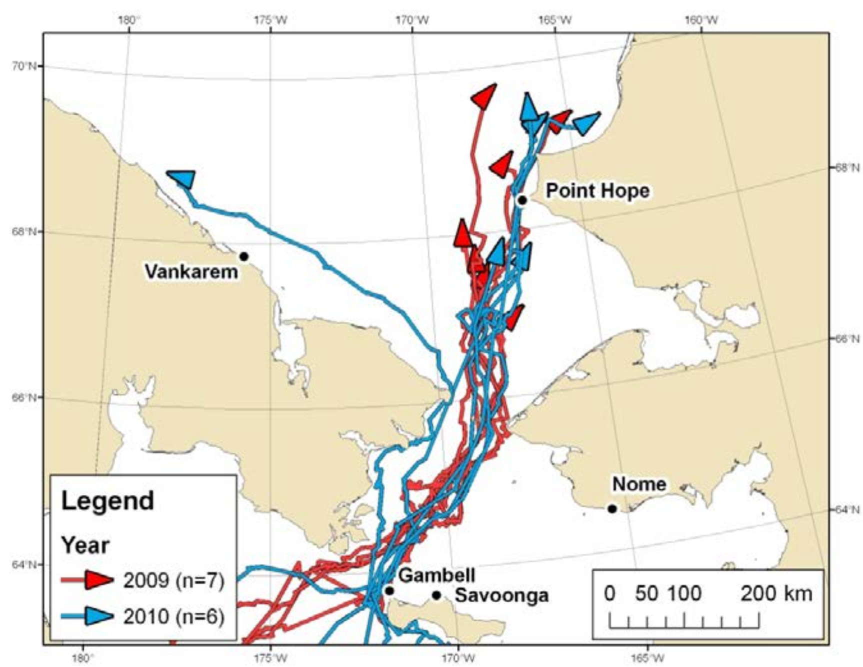

Figure 5. Tracks of 13 tagged bowhead whales in spring 2009 and 2010. The whale (# 93089) that traveled northwest along the Chukotka coast stayed in the Chukchi all summer. This whale was ~40 ft of unknown sex and was tagged by Lewis Brower near Barrow 29 August 2009.

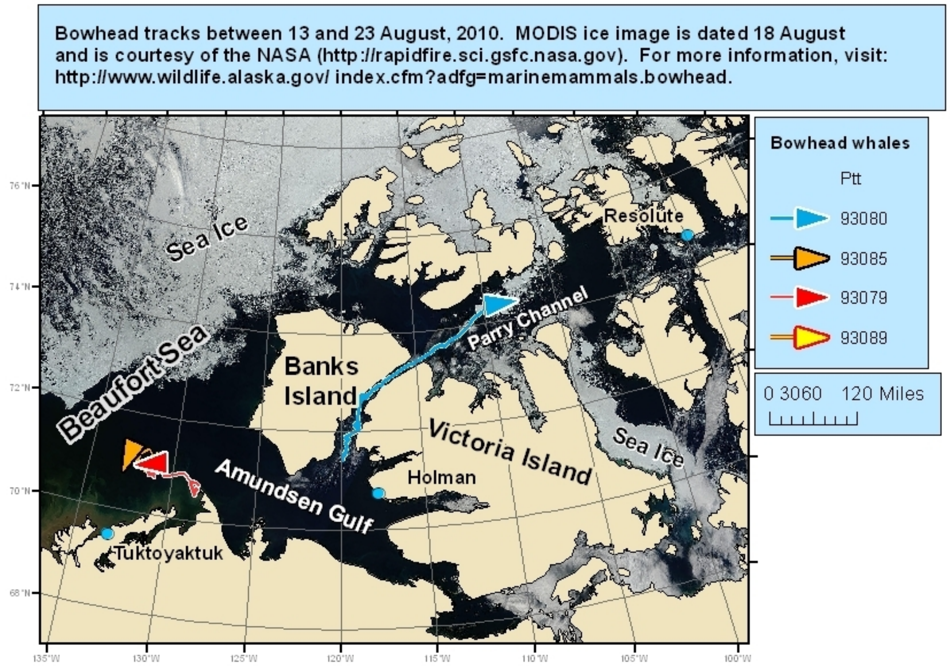

Figure 6. Path of whale #93080 through Prince of Wales Strait into Parry Channel. This is a 50 ft whale tagged near Barrow in May 2010.

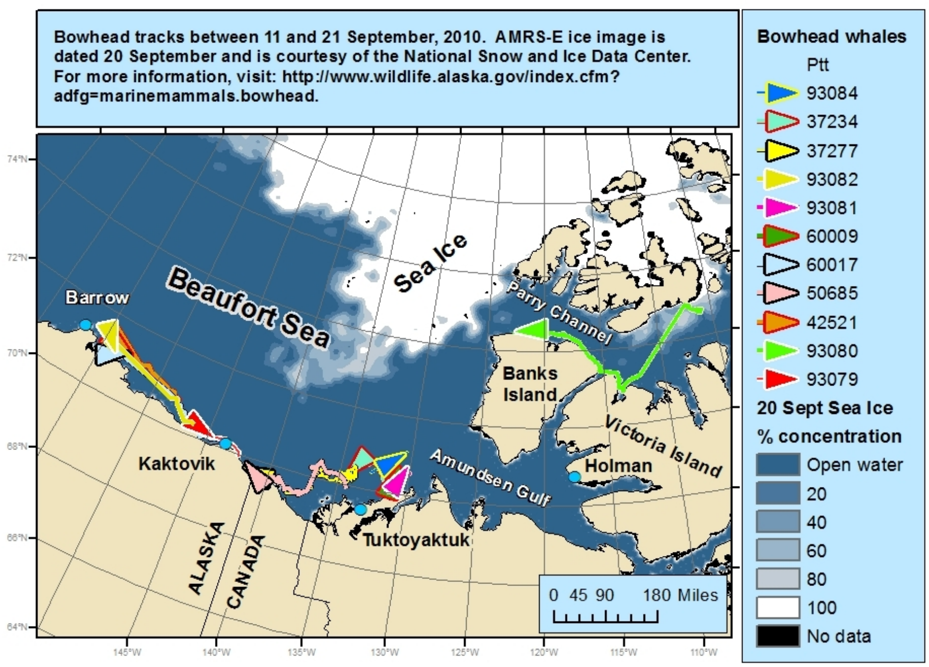

Figure 7. Map of location of 11 bowhead whales in September 2010. Two of these (#93079 and #93081) were tagged near Barrow in October 2009 and two (#93080 and #93084) were tagged near Barrow in May 2010. The others were tagged near Tuktoyaktuk in August 2010.

Prepared by Lori Quakenbush (907) 459-7214 or toll free 1-800-478-7346. E-mail: lori.quakenbush@alaska.gov. Visit the website for the latest bowhead maps: http://www.wildlife.alaska.gov/index.cfm?adfg=marinemammals.bowheadmovements

Appendix E-2. Bowhead Tagging Workshop and Summary Results.

Bowhead Tagging Workshop Agenda <u>and Summary</u>

Westmark Hotel, 720 West 5th Ave

7 December 2010, 9am-4:30 pm

AGENDA

8:30 am ***Coffee***
9:00 am Welcome, Introductions, Invocation

9:15 am History of Tagging Project and the Purpose of this Workshop

Process
Concerns (injury from tags, sample size, TEK)
Purpose – to evaluate tagging project and develop new objectives

9:30 am Review of Original Objectives

1) Work with subsistence whalers to deploy satellite transmitters on male and female bowheads of all sizes to document the general pattern of year-round movements.

    a. Determine whether ALL bowhead whales make seasonal migrations between the Bering Sea and the eastern Beaufort Sea.
    b. Determine if concentrations of bowheads feeding near Barrow in summer are whales returning from the eastern Beaufort Sea.
    c. Determine if bowhead whales feeding near Barrow in summer are of mixed sizes and sexes.
    d. Determine if wintering concentrations of whales are of mixed sizes and sexes.

2) Use satellite tagging to document migration relative to how behavior and timing are related to ice conditions, water depth, and industrial disturbance.
    a. Determine if bowheads only migrate in leads or when ice conditions are light to medium.
    b. Determine if industrial disturbances change migration routes or timing.
    c. Determine if bowheads stop to feed during migration.
    d. Determine if bowheads follow a particular water depth contour when migrating.

3) Document the timing of migration and rate of travel.

4) Estimate residence time for individual whales at specific locations (e.g. feeding areas).
    a. Estimate residence time for individual whales feeding near Barrow.
    b. Estimate residence time for individual whales feeding in the eastern Alaskan Beaufort Sea.

Bowhead Tagging Workshop Agenda – Page 2

9:45 am What did we do?

Number of tags by location, by year, by season
Number of whales tagged by sex, size, location

10:00 am Overview - What have we learned?

Longevity of tags
Effects of tags
Spring movements
Summer movements

10:30 am ***Break***
10:45 am Continue Overview - What have we learned?

Fall movements
Winter movements
Important areas
Interactions with seismic operations
Differences in movements and important areas between years
Potential interactions with shipping lanes
Potential interactions with crab fishing

12:00 ***Lunch***
1:30 Evaluation – Did we accomplish our original objectives?
See objectives above.

2:30 What do we still need to know?

3:00 ***Break***
3:15 What are our new priorities/objectives?

4:30 ***Adjourn***

Materials available:
Final Report
TEK Reports
Arctic paper

Bowhead Tagging Workshop Summary

Participants:

Harry Brower, Jr.	Barrow
Rossman Peetook	Wainwright
Joseph Kaleak	Kaktovik
Oran Knox	Kivalina
Ronald Ozeena,	Diomede
Luther Komonasek	Wales
Isaac Kiligvak	Pt. Hope
Julius Rexford,	Pt. Lay
Merlin Koonooka,	Gambell
Billy Adams,	Barrow, NSB-DWM
Grace Leavitt,	AEWC, Staff.
Johnny Aiken,	AEWC Executive Director
Nolie Alcantara	AEWC Staff
Jessica Lafevre,	AEWC Council
Craig George,	NSB-DWM
John Citta,	ADF&G
Lori Quakenbush,	ADF&G

Welcome, Introductions, Invocation by Rossman Peetook

History of Tagging Project and the Purpose of this Workshop

Process- Received AEWC approval to conduct tagging if we included Traditional Knowledge (TEK) regarding bowhead movements and if any harm was seen from the tags the project would be re-evaluated.

Concerns (injury from tags, sample size, TEK) – Injury from the tags is still not known because bowheads are not often seen after tagging and no tagged bowheads have been harvested. Early in the project when tags were not staying on very long, we thought that they were falling out, possibly due to tissue damage surrounding the tag, but now that we have had 4 tags stay on for more than a year it is not likely they are causing tissue because that would cause them to be rejected. Billy Adams mentioned that he saw the tag on a whale that had been tagged 3 weeks prior and the tag was flush with the body and looked like it did when it was first tagged. A study on penetrating tags used on humpback whales compiled the sightings of seven tagged whales and found that all seven were observed at least 20 years after tagging and five of the seven have been observed for more than 30 years (Mizroch et al. 2011). This study was published recently and was not available to discuss at the workshop.

The number of tagged whales is small relative to the whole population but we have learned a lot from each tag. TEK has added greatly to the information on bowhead whales we have collected from the tags. TEK was collected at Kaktovik, Barrow, and Wainwright (Huntington and Quakenbush 2009a, Huntington and Quakenbush 2009b).

Purpose of the workshop – to evaluate tagging project and develop objectives for future

Review of Original Objectives

1) Work with subsistence whalers to deploy satellite transmitters on male and female bowheads of all sizes to document the general pattern of year-round movements.

   We have worked with whalers to deploy tags on male and female bowhead whales of most sizes. We have not tagged many small (4) or large females (4) and do not currently have a permit to tag cows with calves.

   a. Determine whether ALL bowhead whales make seasonal migrations between the Bering Sea and the eastern Beaufort Sea.

      Not all bowhead whales make seasonal migrations between the Bering Sea and the eastern Beaufort Sea; one tagged whale went up the Russian coast into the Chukchi Sea for the summer and did not pass Barrow in the spring. This means that the population estimate is low because the count is at Barrow in the spring and some whales do not pass by but stay in the Chukchi during the count.

   b. Determine if concentrations of bowheads feeding near Barrow in summer are whales returning from the eastern Beaufort Sea.

We do not know if bowheads near Barrow in summer have returned from eastern Beaufort, some could be whales that went to the Russian coast in spring and summered in the Chukchi. A few of the tagged whales returned from the eastern Beaufort in midsummer to area offshore of Barrow. We need to tag more whales to answer this question.

c. Determine if bowhead whales feeding near Barrow in summer are of mixed sizes and sexes.

Both males and females were tagged near Barrow in August. No tags have been deployed in July. Of 12 tags deployed near Barrow in August; 3 were female, 4 were male, and 5 were of unknown sex. All 12 were 36 – 50 ft long. So, we can say the sexes are mixed but we have not tagged small whales near Barrow in summer. We need to try to tag small whales near Barrow to answer this question.

d. Determine if wintering concentrations of whales are of mixed sizes and sexes.

Of the mix of sizes and sexes tagged so far, it appears that they winter together in the Bering Sea. We may see finer scale segregation if more females and females with calves are tagged.

2) Use satellite tagging to document migration relative to how behavior and timing are related to ice conditions, water depth, and industrial disturbance.

a. Determine if bowheads only migrate in leads or when ice conditions are light to medium.

Bowheads do not only migrate in leads, they also migrate east across the Beaufort Sea in heavy ice in spring when leads are north-south.

b. Determine if industrial disturbances change migration routes or timing.

We may have overlap with tagged whales and industrial disturbances (i.e., seismic) during migration in Camden Bay and possibly elsewhere in the Alaskan Beaufort Sea that needs to be analyzed.

We have analyzed the interaction of a tagged whale and a seismic operation that occurred in a feeding area prior to migration in the Canadian Beaufort Sea in 2006. We are looking for more of these interactions to analyze.

c. Determine if bowheads stop to feed during migration.

Spring. We have not seen tagged whales stop during spring migration, although they may feed some while they are migrating. Tagged whales move quickly through the Chukchi and Beaufort seas in spring. The one whale (B09-09) that went to Russia in later spring may have been feeding as it moved much more slowly along the Chukotka coast in late May-early June than the tagged whales that migrated past Barrow.

Fall. We have seen evidence of slow movements (stopping) with changes in direction that indicate possible feeding near Barrow, near Wrangell Island, and especially along the northern coast of Chukotka in the fall time. The tracks across the Alaskan Beaufort Sea during the fall migration have not been fully analyzed; however, we have not seen tracks that show bowheads spending much time in one place (stopping) between the Mackenzie Delta and Barrow, except that one or two whales paused briefly at Herschel Island.

d. Determine if bowheads follow a particular water depth contour when migrating.

We have not done a complete analysis; however, it does not look like tagged whales follow a depth contour when migrating in spring or fall.

3) Document the timing of migration and rate of travel.

Information regarding the timing of migration, rate of travel, and dive duration has been collected and it is currently being analyzed. During the spring whale census, bowhead whales travel at 2.49 miles per hour. Average dive duration is only 8.4 minutes, but all whales make some long dives between 36 and 72 minutes in duration. Our analyses show that assumptions of whale behavior used during the Barrow whale census are correct. In 2009 and 2010, tagged whales passed Barrow when there were no watches because of weather or lead conditions. But in 2011, all tagged

whales passed Barrow while the survey was active. This indicates that the survey for 2011 was well-timed.

4) Estimate residence time for individual whales at specific locations (e.g. feeding areas).
    a. Estimate residence time for individual whales feeding near Barrow.

       Residence time for individual tagged whales in fall near Barrow is about 8 days.

    b. Estimate residence time for individual whales feeding in the eastern Alaskan Beaufort Sea.

       We have not seen tagged bowheads moving slowly and changing directions frequently (movements that are evidence of feeding) in the Alaskan Beaufort Sea. So, we cannot answer the question of how long bowheads spend feeding in the eastern Beaufort Sea with the information we have so far. Using the data we have the residence time is the time it takes for whales to pass through the Alaskan Beaufort Sea.

What did we do?

Number of tags by location, by year, by season

57 total tags deployed, 37 near Barrow, 20 in Canada

3 in 2006; 10 in 2007; 15 in 2008; 15 in 2009; and 14 in 2010

7 in spring, 50 in fall (however some of the 50 lasted through the following spring)

Number of whales tagged by sex, size, location

<u>Sex</u> - 22 males, 14 females, 20 unknown (no biopsy)

<u>Size, Sex, Location</u> – (one female at Barrow was <30 ft)

17 males, 7 females at Barrow

6 males, 6 females in Canada

30-35 ft (total = 25)

10 were males (7 Barrow, 3 Canada)

4 were females (all Canada)

11 were unknown (5 Barrow, 6 Canada)

36-40 ft (total = 13)

3 were males (2 Barrow, 1 Canada)

5 were females (3 Barrow, 2 Canada)

5 were unknown (4 Barrow, 1 Canada)

41-45 ft (total = 9)

6 were male (5 Barrow, 1 Canada)

2 were female (all Barrow)

1 was unknown (all Barrow)

46-50 ft (total = 6)

3 were males (2 Barrow, 1 Canada)

1 was female (all Barrow)

2 were unknown (1 Barrow, 1 Canada)

>50 ft (total = 2)

None were males

1 was female (Barrow)

1 was unknown (Barrow)

Overview - What have we learned?

Longevity of tags

29 tags lasted 3 months

15 lasted 6 months

4 lasted 12 months

Effects of tags

The effect of tagging is unknown; however, tag longevity suggests they are not causing infection. If tags caused infection, they would not stay attached to the whale.

Spring movements

We have a good idea of when bowheads leave the Bering Sea and most pass between the Chukchi Lease Area and shore on the way to Barrow. One of 13 tagged whales tracked during the spring stayed in the Chukchi Sea and did not pass Barrow.

We do NOT think we have a good idea of movements near St. Lawrence Island and believe we need to tag there to get better representation of movements in that area.

Summer movements

We have observed some unexpected summer movements including:

1) **Two whales moved north from Amundsen Gulf into the High Canadian Arctic, north of Banks Island.**
2) **After the spring migration to Canada, 2 whales travelled to an area north of Barrow in summer and returned to Canada. This is the first data showing bowheads move back and forth across the Beaufort Sea in summer in addition to the spring and fall migration.**
3) **Movements across the Chukchi Sea earlier than fall migration. One whale crossed the Chukchi Sea in July and one in mid-August. A few whales passed Barrow going west in the fall but then returned to Barrow.**
4) **One whale stayed in the Chukchi Sea for the summer.**
5) **We have not seen tagged whales spend much time near shore in the Alaskan Beaufort Sea in summer.**

Fall movements

We have good data on fall movements across the Chukchi Sea and have analyzed much of it including the use of the Lease Sale Area 193. We also have good data on fall movements across the Beaufort Sea, however we have not analyzed it in detail yet.

Winter movements

We have good data for winter movements relative to ice coverage. We have 3 years of movements in and out and have analyzed two of them. We saw some differences in between winters in where bowheads were in winter, but they did not use open water areas or areas south of the ice edge in either winter.

Important areas

We have identified some important areas probably for feeding including Amundsen Gulf (Canada) in spring and summer, Barrow (Alaska) in fall, the northern coast of Chukotka (Russia) in fall, and the Bering Sea in winter (Russian and U.S. waters).

Other areas that may also be important in some years include areas north of Banks Island and east of Wrangel Island.

Interactions with seismic operations

We have analyzed movements of one tagged whale in the vicinity of a marine seismic operation in the oil and gas exploration area near Tuktoyaktuk Canada in 2006. The seismic program occurred in September 2006 and was conducted in a known bowhead feeding area. The tagged whale changed directions during an approach of the ship, however the tagged whale remained in the area during the seismic operation until the seismic program was completed and the ship left. The tagged whale migrated at a similar time and along a similar route as other tagged whales across the Beaufort Sea. This same tagged whale passed by the same ship engaged in another seismic operation in the Chukchi Sea in October 2006. We have looked for other interactions between tagged whales and seismic operations in the Chukchi in 2007–2009 but did not find any.

We have not looked at 2010 data yet.

Differences in movements and important areas between years

We have seen differences in where bowheads cross the Chukchi Sea in fall. For example, in 2008 and 2009 most whales went west to Wrangel Island then south to the Chukotka coast. In 2010, most whales went southwest to the Chukotka coast before reaching Wrangel Island. The two whales that travelled north of Banks Island could be an indication that there is an important area there in some years. Where whales go in Amundsen Gulf in spring varies due to the position of the ice edge when they arrive.

Possibly more important than the differences in areas is the similarities of areas used. It appears that Amundsen Gulf in spring and summer, Barrow in early fall, and the northern Chukotka coast in late fall and early winter are very consistently important.

Potential interactions with shipping lanes

Shipping lanes are being planned in anticipation of an increase in large ships passing through the Bering Strait for the Arctic Circle Route to Russia and Europe (west) and the Northwest Passage to Canada and the Atlantic (east). Tracks of the tagged whales have shown that it is likely that much of the Western Arctic population is moving south along the Chukotka coast through the western portion of the Bering Strait (between Big Diomede and Russia) in November and December. In spring, it is likely that the bowheads will have migrated prior to the shipping season, although local ships supporting oil and gas exploration may arrive before whales migrate if icebreakers are used.

Potential interactions with crab fishing

Many whalers have asked us whether crab fishing in the Bering Sea happens near wintering bowheads. There are 3 different crab fisheries (Tanner, snow, and king). There is no direct overlap between the two because bowheads stay inside the ice and the crabbers try to stay away from the ice. But, the ice can move over the crab gear and move it and lost pot gear can entangle whales.

Evaluation – Did we accomplish our original objectives? See annotated objectives above.

We fully accomplished many of our objectives, partially accomplished some, and have yet to accomplish others.

What do we still need to know?

1) **Are the tags causing any harm to the whales?**
2) **We have tagged fewer females and no females with calves. What if females with calves go to different places and we have not identified those places as important?**
3) **The bowheads tagged so far have not travelled around St. Lawrence Island in the way that the whalers see them.**
4) **How often do whales come in contact with seismic operations and other industrial activities not just in Alaska, but also Canada and Russia?**
5) **Where do bowheads that feed near Barrow in summer come from?**
6) **How well do tagged whales represent all whales in the population?**

What are our new priorities/objectives?

1) **Encourage whalers to collect any tags found in harvested whales by removing a block of tissue around the tag (without taking the tag out of the maktak). We can learn how the tag affects the tissue by examining it in place.**

2) **Work on modifying our research permit to allow tagging of females with calves. Continue to tag in order to track more females.**
3) **Work with Gambell and Savoonga Whaling Captains to tag whales near St. Lawrence Island to track whale movements there and to see if whales tagged there have different movement patterns.**
4) **Analyze existing data to see how many different industrial activities a tagged whale encounters in one year. Develop an acoustic tag that will record the sound that bowheads hear and the sounds they make.**
5) **Whales tagged near St. Lawrence Island in spring could provide data to determine where bowheads feeding near summer come from.**
6) **Put VHF/Satellite tags on and fly out to tagged whales and see how many other whales are with each tagged whale.**
7) **Put oceanographic satellite tags on that measure salinity and temperature. We could learn what the ocean conditions are where bowheads spend time (likely feeding).**
8) **Tag and biopsy gray whales to learn about their movements, feeding areas, and stock structure in the Bering, Chukchi, and Beaufort seas.**

General concerns, issues, comments:

MMS did not use our information from the tagged whales in the Chukchi 193 Environmental Impact Statement. Why are we doing this study and why is MMS funding it if they don't use the information to evaluate the effects of activities? Maybe we should put a hold on the tagging until MMS starts to use the information. It is very frustrating that they don't recognize the information. It is discouraging how we have to start over every year when we deal with the federal government.

It is important to continue tagging for a few more years because of shipping, climate change, ESA listings; there are lots of changes happening.

The research permit did not allow females with calves to be tagged. If tags are safe we may want to know more about movements of females with calves.

Shipping is a concern.

We still don't know how tags affect whales.

Oil and gas activities in Canada affect our bowheads.

We need tags that record sound to study noise.

Does seismic, or submarines, or other activities make whales go more offshore than normal.

There was site clearance seismic work near Cape Halkett this year that could have affected whale movements.

There were about 100 bowheads in early September near Cooper Island. It got windy and water got murky. Bowheads were north of where the water was clear.

In 2010, the first whales near Barrow were seen 30 August.

There were lots of gray whales near Barrow. Bowheads stay farther offshore and away from gray whales. Maybe bowheads don't like gray whales.

We don't see gray whales near Wales.

How are bowheads using currents?

Fall migration is on Russian side in Bering Strait.

Wainwright harvested a whale on 7 October 2010, 15 mi. from Wainwright. Saw lots of small whales. This is the first fall harvest in many years.

Statoil conducted 2 and 3-D seismic in Chukchi between 20 August and 1 October 2010.

Why aren't there any bowheads on the west side of St. Lawrence Island? Could be that the currents are different and the food is less available.

Seismic operators are looking to use icebreakers after the whales leave.

What are the cumulative effects of multiple seismic and other operations in the Chukchi, Alaskan Beaufort, and Canadian Beaufort seas.

Can you identify resting areas where whales are floating with the current or at the surface next to the ice?

In 1987, the ice was heavy and whales tried to migrate north but came back south.

Analyze more ice detail.

Time-area closures could be designed to protect important habitats only when they are in use. The closures could be designed as limited use areas, such as special management areas or as marine protected areas. Maybe ocean zoning like coastal management zoning could be designed to protect important bowhead habitats.

The North Slope Borough has joined a research agreement with Shell and that may help to get the locations of ships doing seismic programs.

Blackwell et al. 2010 had DASARS out during seismic that showed it was quiet (no whale calls) during operation of the airguns. Acoustic tags that record the bowhead calls could tell us if the whales go quiet when the guns are loud.

Some elders say to quit playing with the animals, they are our food, never harm the animal, never play with the animals.

TEK is powerful.

Some people don't understand the process, we need more outreach.

References

Huntington, H.P., and L.T. Quakenbush. 2009a. Traditional knowledge of bowhead whale migratory patterns near Kaktovik and Barrow, Alaska. Report to the Eskimo Whaling Commission and the Barrow and Kaktovik Whaling Captains. 14 pp.

Huntington, H.P., and L.T. Quakenbush. 2009b. Traditional knowledge of bowhead whale migratory patterns near Wainwright, Alaska. Report to the Eskimo Whaling Commission and the Wainwright Whaling Captains. 9 pp.

Mizroch, S.A., M.F. Tillman, S. Juraz, J.M. Straley et al. 2011. Long-term survival of humpback whales radio-tagged in Alaska from 1976 through 1978. Marine Mammal Science 27(1):217–229.

Appendix E-3. Quakenbush, L.T., J.J. Citta, J.C. George, R. Small, H. Brower, Jr., M.P. Heide-Jørgensen, and L. Harwood. 2011. Bowhead inter-annual variability and exceptional movements of western Arctic bowhead whales from satellite telemetry, 2006–2010. Alaska Marine Science Symposium, 17–21 January, Anchorage AK. (Abstract and oral presentation).

Inter-annual Variability and Exceptional Movements of Western Arctic Bowhead Whales from Satellite Telemetry, 2006–2010

Lori Quakenbush[1], John Citta[1], John C. George[2], Robert Small[3], Harry Brower, Jr.[2, 4], Mads Peter Heide-Jørgensen[5], and Lois Harwood[6]

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[2]North Slope Borough, Barrow AK, USA; [3]Alaska Department of Fish and Game, Juneau AK, USA, [4]Alaska Eskimo Whaling Commission [5]Greenland Institute of Natural Resources, Copenhagen Denmark, [6]Department of Fisheries and Oceans, Yellowknife, NT, Canada;

A cooperative research project began in 2005 to study the movements and habitat use of the western Arctic stock of bowhead whales (*Balaena mysticetus*). Satellite-linked transmitters were deployed on 58 bowhead whales (2006–2010) by Alaskan and Canadian subsistence whalers. Tagging in consecutive years allowed us to examine variability among years, illuminating important aspects of bowhead ecology. For example, whales entered the Bering Sea over a longer time period in 2008/09 (65 d) than in 2009/10 (20 d), and whales in 2008/09 spent more time in the western, versus central, Bering Sea and were farther from the marginal ice edge. As more tags were deployed, we observed movements that were not expected, including: 1) in spring 2010 one whale migrated west to the Chukchi Peninsula, not east to the Canadian Beaufort; 2) two whales (one in 2006 and one in 2010) travelled north of Banks Island before returning to the Beaufort Sea prior to fall migration; and 3) after migrating to the Canadian Beaufort, four whales returned to Barrow (offshore) during summer instead of during fall; one of these whales travelled to the Chukchi Peninsula prior to the fall migration. These movements, whereas exceptional within our tracking data, are unlikely to be rare for the population as a whole and in some cases are corroborated by local observations. Satellite tracking over multiple years will allow us to assess variability in movements and habitat use to assess how bowhead movements may be influenced by currents, ice, underwater noise, and other factors.

Alaska Marine Science Symposium, 18–22 January 2011, Anchorage AK

Appendix E-4. Quakenbush, L. and J. Citta. 2011. Satellite Tracking of Bowhead and Other Whales: Further Studies, 2011–2015. Draft Study Plan for review, revision and approval by the Alaska Eskimo Whaling Commission. 5 pp.

Draft Study Plan

Satellite Tracking of Bowhead and Other Whales: Further Studies, 2011–2015

For Review, Revision, and Approval by:
The Alaska Eskimo Whaling Commission

Submitted by:
Lori Quakenbush and John Citta
Alaska Department of Fish and Game
Fairbanks, Alaska

June 2011

Introduction

Bowhead whales (*Balaena mysticetus*) were designated as an endangered species in 1973 due to depletion by commercial whaling during the late 1800s. The population has recovered considerably since then and the current estimate is ~10,000 (Zeh and Punt 2005). Bowheads are an important subsistence and cultural resource for coastal people of northern Alaska and Russia and their harvest is managed by a quota system approved by the International Whaling Commission and implemented, in Alaska, by the Alaska Eskimo Whaling Commission (AEWC). Oil and gas leasing, exploration, development, and production are ongoing in the Alaskan Beaufort Sea, and leasing and exploration are ongoing in the Canadian Beaufort Sea and in the Chukchi Sea. International shipping is expected to increase and some fisheries may be expanded as the open water season lengthens. These activities will occur within the range of the Bering-Chukchi-Beaufort stock of bowhead whales. In order to minimize the impacts of industrial activities on bowhead whales we need to better understand bowhead migration routes and timing, and identify important habitats (e.g., feeding and summering areas) so that lease sale areas and industrial activities can be designed to minimize effects on bowhead whales. Between 2006 and 2010 we deployed 57 satellite transmitters on bowhead whales in Alaska and Canada and collected information on migration routes, migration timing, swim speed, diving behavior, residence times in portions of the range, as well as some responses to industrial activity (Quakenbush et al. 2010a, b). The study was designed cooperatively with the AEWC, the North Slope Borough, the Minerals Management Service (MMS, now Bureau of Energy Management, Regulation and Enforcement), and the Alaska Department of Fish and Game; it was funded by MMS. We have evaluated our accomplishments relative to our original study objectives and we have developed a study plan for the next 5 years to focus on objectives that have not been fully met.

Methods

In December 2010, we held a workshop with the AEWC and North Slope Borough personnel in Anchorage to evaluate our accomplishments relative to our study objectives in order to identify objectives that have not been met and to determine whether additional study is recommended (Appendix A). We used the summary from the workshop to develop this draft study plan for review, modification, and approval by the AEWC.

Study Plan, 2011–2015

Do satellite transmitters (tags) harm bowhead whales? An important topic of discussion at the workshop was whether the tags harm the whales. Although we have tagged 57 bowhead whales we have not been able to examine the tag site after deployment. No tagged whales have been harvested. Billy Adams reported seeing a tag ~20 days after deployment and it looked the same as when it was deployed (i.e., flush with the skin). The tracks from the tagged whales tell us that their movements are what are expected from healthy whales. Individual whales tagged in fall near Barrow have been tracked for more than 365 days. The long retention time of many of the tags suggest that the tag site is not becoming infected. An infection would affect the skin and surrounding tissue and cause the tag to fall off. If the tags were irritating to the whales they would likely be rubbed off on the bottom or on the ice. A study of penetrating tags used on humpback whales (*Megaptera novaeangliae*) compiled the sightings of seven tagged whales and found that all seven were observed at least 20 years after tagging and five of the seven have been observed for more than 30 years (Mizroch et al. 2011). This study was published recently and was not available to discuss at the workshop.

Overall Study Objectives:
Work with subsistence whalers during all aspects of this study and make sure research activities do not interfere with subsistence whaling activity.

Use satellite telemetry and the methods developed during the previous study to further investigate movements, timing, important habitats, and interactions with industry. Specifically:

Bowhead whales
Objective 1: Tag at St. Lawrence Island beginning in 2011 until 10 or more tags are deployed.
Movements of whales tagged near Barrow and in Canada have not been representative of when and where bowheads are seen near St. Lawrence Island. In addition, by tagging whales near St. Lawrence Island we may document more whales going west in spring and not passing Barrow. Tagging whales in the Bering Sea may also help answer the question about where the whales that show up at Barrow in July come from.

Objective 2: Tag small (~30 ft long) and large (>40 ft long) whales at Barrow.
More males have been tagged then females. Few small (only 4) and few large females (only 4) have been tagged. Although we cannot determine the sex of a whale before it is tagged (unless it has a calf), we can determine size. Thus, we could focus on small and large whales in order to get more tags on these age classes and some of them should be females, which would increase our female sample too. Tagging small whales near Barrow would also help answer the question of whether the sizes are mixed near Barrow in summer (boat or aerial surveys could answer this question, too). Tagging any bowheads near Barrow in July may tell us whether these whales go east into the Beaufort Sea where they may encounter oil and gas activities before migrating west in the fall.

Objective 3: Request to change our research permit to allow tagging females with calves.
Our current research permit does not allow for tagging of females with calves. Although we know from the whalers, from the count at Barrow, and from the aerial surveys that the females with calves migrate later in spring, we do not know whether females with calves go to different places in summer and winter. In addition we do not know much about their fall migration route and timing.

Objective 4: Analyze existing data on interactions with seismic and other industrial activities.
We will analyze and report on interactions with industry collected from previously tagged whales.

Objective 5: Develop a tag that records sounds that bowheads hear and sounds they make.
Hydrophones placed near seismic operations have shown that when airguns turn on, bowhead call numbers go down. This could mean that bowheads leave the area or that they stop calling.

A tag that records sound (acoustic tag) could tell us which happens. If bowheads stay in the area they could be physically injured by the high noise levels and methods other than increasing the noise level slowly so bowheads can move away before seismic operations start would need to be developed to protect bowheads.

Objective 6: Add a temperature probe to the tag anchors to record internal temperature.
The tags we use record water temperature and we could add a sensor in the anchor that would record the temperature deeper in the blubber under the skin at the site of the probe. This information would help with studies of energetics, which is how much food (energy) a bowhead needs to eat to live and reproduce.

Objective 7: Deploy tags that measure changes in ocean temperature and salinity.
This information would help us understand why bowhead whales stop in some places to feed but not others. It is believed that krill (bowhead food) collects in places where water with different temperature or salinity meet (fronts). These fronts are similar to eddies on a river and krill collects in these eddies, much like debris collects in eddies on rivers.

Objective 8: Develop a tag with both satellite and VHF capability.
The VHF part of the tag would allow us to find the tagged whale from an airplane so we could document the number of other bowheads with it. We could use the satellite tag to track the whale and when it travelled to an area we could reach with an airplane we could fly out and find it. This would help us determine how well the tagged whales represent whales that are not tagged.

Gray whales
Gray whales are more common in the Chukchi and Beaufort seas now than in the past and their movements, important habitats, and how they interact with industrial activities is unknown and important. Our research permit and our funding allows for this project to include tagging and biopsies of gray whales.

Objective 1: Tag gray whales near Barrow and St. Lawrence Island.
We can use similar tags with shorter anchors for gray whales and begin to collect similar information about their movements. We can use the same biopsy methods to determine the sex of the gray whales tagged.

Humpback whales
A few humpback whales have been seen each year in the Chukchi Sea and their movements, important habitats, and how they interact with industrial activities is also unknown and important. Our research permit and our funding allows for this project to include tagging and biopsies of humpback whales.

Objective 1: Biopsy humpback whales near Barrow and St. Lawrence Island.
We can begin to study humpback whales by collecting biopsies for sex and genetics. We can use biopsy tips on crossbows to determine the sex of the whale biopsied.

Discussion

We have completed 5 years of research on bowhead whales using satellite telemetry and working with subsistence whalers. We have learned a tremendous amount about bowhead whales that is already being used to plan shipping lanes and develop mitigation to protect bowhead whales. Our tagging project received the Secretary of the Interior Partners in Conservation Award for its outstanding contributions and unprecedented collaborations among government and Native organizations. The award acknowledged that the success of the project was largely due to the efforts of Native subsistence whalers.

Due to the past success of the project, the funding agency, the Bureau of Energy Management, Regulation and Enforcement (formerly MMS) will continue the funding to pursue unanswered questions regarding bowhead whales and to pursue similar studies of gray and humpback whales. In order to continue the studies we submit this study plan for the review, modification, and approval of the AEWC.

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Appendix E-5. Citta, J.J., L.T. Quakenbush, J.C. George, H. Brower, Jr., R. J. Small, and M.P. Heide-Jørgensen. 2011. Does the winter range of bowhead whales overlap commercial fisheries in the Bering Sea? 19th Biennial Conference on the Biology of Marine Mammals, 28 November – 2 December, Tampa, FL. (Abstract and oral presentation).

Does the winter range of bowhead whales overlap commercial fisheries in the Bering Sea?

Citta, John J.[1]; Quakenbush, Lori T.[1]; George, John C.[2]; Brower, Harry[2]; Small, Robert J.[3]; Heidi-Jorgensen, Mads Peter[4]

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How often bowhead whales (*Balaena mysticetus)* become entangled in commercial fishing gear is unknown, although rope scars are identified on approximately 10% of harvested whales and a dead whale wrapped in 'pot' gear, apparently causing its death, was found in July 2010. Rope scars are believed to result from entanglement in pot gear set in the Bering Sea; however, the relative positions of bowhead whales and the pot fishery was unknown until recent satellite tagging studies. In the winters of 2008–09 and 2009–10, the distribution of 20 tagged bowhead whales overlapped the locations of pot gear set for Pacific cod (*Gadus macrocephalus*) and blue king crab (*Paralithodes platypus*), yet the fisheries concluded before whales migrated into the overlap area. The snow crab (*Chionoecetes opilio*) fishery extends from January to April and provides the greatest potential for bowhead whales to encounter active pot gear. However, whales generally remained in areas with > 90% sea ice concentration, which is too concentrated for crab boats. Although the distribution of pot gear in Russian waters is unknown, Russian fisheries are equally limited by sea ice. Hence, bowhead whales generally frequent waters too ice-choked for commercial fishing boats in winter and "ghost" gear (*i.e.*, lost fishing gear) may be the main source of entanglement. Because this stock of whales is increasing, it is unlikely that fishery induced mortality limits the population. However, entanglement rates should be monitored as they may increase if the location of the pot fishery shifts as ice conditions change.

Appendix E-6. Quakenbush, L.T., J.J. Citta, J.C. George, H. Brower, Jr., L. Harwood, R. J. Small, and M.P. Heide-Jørgensen. 2011. How many industrial activities do individual bowhead whales from the Western Arctic stock encounter annually? 19th Biennial Conference on the Biology of Marine Mammals, 28 November – 2 December, Tampa, FL. (Abstract and oral presentation).

How many industrial activities do individual bowhead whales from the Western Arctic stock encounter annually?

L.T. Quakenbush, J.J. Citta, J.C. George, H. Brower, Jr., L. Harwood, R. J. Small, and M.P. Heide-Jørgensen

The Western Arctic stock of bowhead whales (*Balaena mysticetus*) are exposed to increasing numbers and sources of industrial activities during their migrations, yet the cumulative effects of these exposures have not been evaluated. A recent satellite tagging study tracked bowhead whales (2006–2010) to determine their minimum annual encounter rate with these activities. Most tagged whales made a >6,000 km annual circuit, from the Bering Sea (winter grounds) through the Chukchi and Beaufort seas to the Canadian Beaufort Sea (summer grounds) and back. Their path takes them through industrial activities conducted by Russia, the U.S., and Canada. Bowhead whales winter near fisheries that may be a source of line entanglements and they pass twice through the narrow Bering Strait where international shipping is concentrated and increasing. Whales pass through oil and gas activities underway in U.S. waters of the Chukchi Sea, and some spend up to 3 months feeding within active oil and gas exploration areas in the Canadian Beaufort Sea. On their return, they pass near or through active oil and gas exploration and development areas in the Alaskan Beaufort Sea. All whales passed through at least two active industrial areas (one in the U.S. and one in Canada) and one whale encountered three seismic surveys. Whale movements relative to fisheries and shipping show that as these activities increase the potential effects to whales could increase as well. This population has been growing, therefore the current level of activities and their cumulative effects has not prevented population growth; however, all industrial activities are expected to increase, which will increase the frequency of encounters by bowheads and the probability of potential consequences. In addition, other effects such as altered movement patterns are of concern to subsistence hunters. These data demonstrate that individual bowhead whales encounter multiple industrial activities annually.

Oral presentation at the 19th Biennial Conference on the Biology of Marine Mammals, 28 November – 2 December, Tampa, FL.

Appendix E-7. Citta, J. J., L. T. Quakenbush, J. C. George, H. Brower, R. J. Small, and M. P. Heide-Jorgensen. 2012. Does the winter range of bowhead whales overlap commercial fisheries in the Bering Sea? Alaska Marine Science Symposium, 16–20 January, Anchorage, AK. (Abstract and poster).

Does the winter range of bowhead whales overlap commercial fisheries in the Bering Sea?

Citta, John J.[1]; Quakenbush, Lori T.[1]; George, John C.[2]; Brower, Harry[2]; Small, Robert J.[3]; Heidi-Jorgensen, Mads Peter[4]

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How often bowhead whales (*Balaena mysticetus)* become entangled in commercial fishing gear is unknown, although rope scars are identified on approximately 10% of harvested whales and a dead whale wrapped in ‘pot’ gear, apparently causing its death, was found in July 2010. Rope scars are believed to result from entanglement in pot gear set in the Bering Sea; however, the relative positions of bowhead whales and the pot fishery was unknown until recent satellite tagging studies. In the winters of 2008–09 and 2009–10, the distribution of 20 tagged bowhead whales overlapped the locations of pot gear set for Pacific cod (*Gadus macrocephalus*) and blue king crab (*Paralithodes platypus*), yet the fisheries concluded before whales migrated into the overlap area. The snow crab (*Chionoecetes opilio*) fishery extends from January to April and provides the greatest potential for bowhead whales to encounter active pot gear. However, whales generally remained in areas with > 90% sea ice concentration, which is too concentrated for crab boats. Although the distribution of pot gear in Russian waters is unknown, Russian fisheries are equally limited by sea ice. Hence, bowhead whales generally frequent waters too ice-choked for commercial fishing boats in winter and “ghost” gear (*i.e.*, lost fishing gear) may be the main source of entanglement. Because this stock of whales is increasing, it is unlikely that fishery induced mortality limits the population. However, entanglement rates should be monitored as they may increase if the location of the pot fishery shifts as ice conditions change.

Appendix E-8. Quakenbush, L., J. Citta, J.C. George, R. Small, M.P. Heide-Jørgensen, L. Harwood, and H. Brower, B. Adams, L. Brower, G. Tagarook, J. Pokiak, and C. Pokiak. 2012. Western Arctic bowhead whale movements and habitat use throughout their range: 2006–2011 satellite telemetry results. Alaska Marine Science Symposium, 16–20 January, Anchorage, AK. (Abstract and oral presentation).

Western Arctic Bowhead Whale Movements and Habitat Use throughout their Range: 2006–2011 Satellite Telemetry Results

Lori Quakenbush[1], John Citta[1], John C. George[2], Robert Small[3], Mads Peter Heide-Jørgensen[4], Lois Harwood[5], and Harry Brower[2], Billy Adams[2], Lewis Brower[6], George Tagarook[7], James Pokiak[8], and Charles Pokiak[8].

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In 2005, the Alaska Department of Fish and Game began a cooperative research project to study movements and habitat use of the western Arctic stock of bowhead whales (*Balaena mysticetus*). In collaboration with the Alaska Eskimo Whaling Commission, the North Slope Borough, the Greenland Institute of Natural Resources, and the Department of Fisheries and Oceans Canada, with core funding from the Minerals Management Service, 59 satellite transmitters were deployed on bowhead whales in Alaska and Canada between 2006 and 2010. The majority of the whales were instrumented in waters near Point Barrow, Alaska, and near the Tuktoyaktuk Peninsula in Canada by Native subsistence whalers. Six tags have transmitted for more than a year, allowing a complete description of annual movements in the Bering, Chukchi, and Beaufort seas. Thirty tags have transmitted for more than three months covering significant portions of the annual migratory cycle. Tagging in consecutive years has allowed us to examine variability in movements, wintering areas, and the timing of migration among years. We have identified several areas of concentrated use throughout the range of bowhead whales, and have documented interactions with industrial activities and potential conflicts with shipping. We plan to begin tagging near St. Lawrence Island, Alaska to investigate whether the location of tagging is a factor in bowhead movements. Future analyses include bowhead movements relative to industrial activities and oceanographic factors that influence movements and foraging behavior of this stock of bowhead whales.

Oral presentation at the Alaska Marine Science Symposium, 16–20 January 2012, Anchorage AK

Appendix E-9. Quakenbush, L.T., , L. Harwood, J.J. Citta, J.C. George, R. J. Small, M.P. Heide-Jørgensen, H. Brower, B. Adams, L. Brower, J. Pokiak, C. Pokiak, and G. Tagarook. 2012. Industrial activities and western Arctic bowhead whales: what we have learned from satellite telemetry. U.S.-Canada Oil and Gas Forum, 13–15 November, Anchorage, AK. (Abstract and Oral presentation).

Industrial activities and western Arctic bowhead whales: what we have learned from satellite telemetry

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Offshore industrial activity is increasing within the range of the western Arctic stock of bowhead whales (*Balaena mysticetus*); however, how often individual whales encounter activities, and whether multiple encounters occur, has not been known. A satellite tagging study, funded by MMS/BOEM, tracked bowhead whales (2006–2010) to determine movements and habitat use, and minimum annual encounter rates of individuals with industrial activities. Most tagged whales made a >6,000 km annual migration, from the Bering Sea (winter range) through the Chukchi and Beaufort seas to the Canadian Beaufort Sea (summer range), and back. Their migration takes them through active oil and gas lease areas in U.S., Canadian, and (possibly) Russian waters. In summer, most whales (36 of 37) spend up to 3 months feeding in the Canadian Beaufort Sea, where 2D and 3 D seismic surveys have been conducted since 2006. In fall, whales pass near or through active oil and gas exploration and development areas in the Alaskan Beaufort Sea. Each year, all tagged whales passed through at least one active industrial area and most (36 of 37) passed through two (one in the U.S. and one in Canada). One whale was documented within three seismic survey areas. The current level of activity has not prevented this population from growing; however, industrial activity is expected to increase, which will increase the frequency bowhead whales encounter industrial disturbances, which may have negative population-level consequences. Other potential effects are of concern to subsistence hunters, such as altered movement patterns. This study has demonstrated that individual bowhead whales currently encounter multiple industrial activities annually. Future studies will include the use of acoustic tags to determine individual bowhead call rates relative to ambient noise levels. Understanding bowhead call behavior will aid the interpretation of passive acoustic data currently collected near seismic and drilling sites.

Appendix E-10. Quakenbush, L.T., , L. Harwood, J.J. Citta, J.C. George, R. J. Small, M.P. Heide-Jørgensen, H. Brower, B. Adams, L. Brower, J. Pokiak, C. Pokiak, and G. Tagarook. 2013. Industrial activities and western Arctic bowhead whales: what we have learned from satellite telemetry. Alaska Marine Science Symposium, 21–25 January, Anchorage, AK (Abstract and Poster).

Industrial activities and western Arctic bowhead whales: what we have learned from satellite telemetry

L.T. Quakenbush[1], L. Harwood[2], J.J. Citta[1], J.C. George[3], R. J. Small[4], M.P. Heide-Jørgensen[5], H. Brower[3], B. Adams[3], L. Brower[6], J. Pokiak[7], C. Pokiak[7], and G. Tagarook[8]

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Technical Summary: BOEM Publication 2013-01110

Study Title: Satellite Tracking of Western Arctic Bowhead Whales

Report Title: Satellite Tracking of Bowhead Whales – Movements and Analysis from 2006–2012

Contract Number: M10PC00085, BOEM **Study Number:** 2013-01110
Sponsoring OCS Region: Alaska
Applicable Planning Areas: Beaufort and Chukchi
Fiscal Years of Project Funding: 2010–2013

Completion Date of Report: August 2013
Cost by fiscal year; FY 2010: $100,000; FY 2011: $350,000; FY 2012: $250,000
Cumulative Project Cost: $700,000
Project Manager: Lori Quakenbush
Affiliation: Alaska Department of Fish and Game
Address: 1300 College Road, Fairbanks, AK 99701
Principal Investigators: Lori Quakenbush and Robert J. Small
Key Words: Bowhead whale, Beaufort Sea, Chukchi Sea, Bering Sea, feeding, satellite telemetry, movements, migration, petroleum exploration areas

Background: The western Arctic (or Bering-Chukchi-Beaufort) stock of bowhead whales (*Balaena mysticetus*) is of high importance due to the nutritional and cultural role of bowhead whales to coastal Alaska Natives of the Bering, Chukchi, and Beaufort seas, their role in the marine ecosystem, and because their range overlaps with areas identified for potential oil and gas development and shipping. Movement patterns and feeding areas of this stock of bowhead whales, however, are not well understood. Increasing our understanding of bowhead whale movements, habitat use, and behavior will aid in resource planning and bowhead conservation.

Objectives: The overall objective of this study was to work with subsistence whalers to deploy satellite transmitters on bowhead whales of different sex and age in order to document and describe the general pattern of year-round movements. Specific objectives included using satellite telemetry to document 1) the pattern of year-round movements, 2) behavior during migration relative to migration routes and the environmental characteristics along those routes (e.g., polynyas, leads, bathymetry, ice conditions, industrial disturbances), 3) document the timing of migration and the rate of travel, 4) determine whether bowhead whales found near Point Barrow in summer came from summering in the Chukchi Sea or were returning early from Canada, and 5)instrument other species to address movements and behavior.

Description: We worked with Native whalers from Alaska and marine mammal hunters from Canada to attach satellite transmitters to bowhead and gray whales during a three year period, 2010–2013 to document movements and identify important habitats during all seasons. This work is a continuation of a five year study from 2005 to 2010.

Significant Conclusions: We have documented bowhead movements within all oil and gas lease sale areas in the Chukchi and Beaufort seas including their presence in the vicinity of active seismic and drilling operations. Based on movements and behavior of tagged bowhead whales from all years, the greatest potential for anthropogenic disturbances from industrial activities including shipping occur near Cape Bathurst in May and June, Tuktoyaktuk in late August to early September, Point Barrow in late August to late October, northern Chukotka/Bering Strait in October to early January and the outer Gulf of Anadyr in December through March. Ships traveling through the narrow area west of Little Diomede Island from mid-November to the end of December would have high potential for encountering many bowhead whales. We have identified migratory corridors that bowheads use to travel between feeding areas. Both the spring migratory corridor between the Bering Strait and Cape Bathurst in Amundsen Gulf and the fall migratory corridor between Hershel Island and Barrow have been relatively distinct and consistent among years. The fall migratory corridor between Barrow and the Bering Strait, however, is more variable. We think this is related to whales responding to prey availability. Krill is concentrated by oceanographic factors, which vary in space and time. This results in complex movement patterns as individual whales travel to different feeding areas at different times.

We have documented areas where whales spend time, and are likely feeding. These areas include Cape Bathurst and Tuktoyaktuk in Canada; Point Barrow in Alaska; and Northern Chukotka and the Gulf of Anadyr in Russia; and Bering Strait and Anadyr Strait in Russia and Alaska

Study Results: From 2010 to 2012 we worked with Native whalers from Alaska and marine mammal hunters from Canada to attach 17 satellite transmitters to bowhead whales (11 near Tuktoyaktak, 3 near Barrow and 3 near St. Lawrence Island) for a total of 63 bowhead whales tagged since the project began in 2006. We combined information from all whales tagged to document movements and behavior. We documented the annual distribution of western Arctic bowhead whales, including summering and wintering areas, and the migratory routes that connect these areas. We have incorporated traditional knowledge information collected by us and others into our final report. We described how tagged bowhead whales move through Oil and Gas Lease Sale Areas in Canada and Alaska and in proposed areas of Russian waters in the spring and fall. Eight gray whales were tagged and five were photographed and added to photo-identification catalogs for the eastern Pacific stock.

Study Products: We provided weekly e-mails of maps and updates on the State of Alaska website. We made presentations to the Alaska Eskimo Whaling Commission, the International Whaling Commission, and at scientific meetings including the Society for Marine Mammal Conference, Alaska Marine Science Symposium, and the U.S.-Canada Oil and Gas Conference. We produced annual reports, a publically available report to the International Whaling Commission, and four peer-reviewed publications.

160°E
170°E
180°
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160°W
150°W
140°W
70°N
65°N
60°N
180°
170°W
160°W
Beaufort Sea
Hanna Shoal
Wrangel Island
Herald Shoal
Point Barrow
Wainwright
Icy Cape
Cape Schmidt
Chukchi Sea
Point Hope
Kivalina
Chukotka
Vankarem
Little Diomede Island
Cape Serdtse-Kamen
Russia
Uelen
Bering Strait
Alaska
St. Lawrence Island
Bering Sea
0 100 200 400 km