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Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 2009

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

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Bowhead Whale with Calf
Beaufort Sea, Alaska
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Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 2009

Prepared by:
Janet T. Clarke, Cynthia L. Christman, Stephanie L. Grassia,
Amelia A. Brower and Megan C. Ferguson
National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE, F/AKC3, Seattle, Washington 98115-6349

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Email of corresponding authors: janet.clarke@saic.com and megan.ferguson@noaa.gov

ABSTRACT

This report describes field activities and data analyses for aerial surveys of bowhead whales (*Balaena mysticetus*) conducted during fall 2009 (1 September – 18 October) in the Beaufort Sea, between 140°W and 157°W, south of 72°N.

During September and October 2009, ice cover was extremely light. In September, ice was limited to the eastern offshore region of the study area and covered < 10% of the surface in that region; all remaining areas were ice-free. Freeze-up began in the nearshore areas of the eastern half of the Alaskan Beaufort Sea (between barrier islands and shore and in shallow areas seaward of the barrier islands) by mid-October, shortly before the field season ended. Most of the study area remained ice-free when the field season ended on 18 October.

A total of 18 survey flights were conducted. There were 77 sightings of 384 bowhead whales. Additionally, 439 belugas (*Delphinapterus leucas*), 1 harbor porpoise (*Phocoena phocoena*), 1 walrus (*Odobenus rosmarus*), 43 bearded seals (*Erignathus barbatus*), 933 unidentified pinnipeds, and 43 polar bears (*Ursus maritimus*) were observed. Total flight time was 93 hours, which included 43 hours of transect survey effort.

Sighting rates (number of whales per transect km surveyed) of bowhead whales were highest in Blocks 12, 3, and 1, while sighting rates of belugas were highest in Blocks 12, 11, 9, and 8. Sighting rates per depth zone were highest for bowhead whales in the shallowest depth zone (≤ 20 m) in both the central/eastern (140°-154°W) and western (154°-157°W) Alaskan Beaufort Sea. Sighting rates per depth zone for belugas were highest in the 201-2,000 m zone in both the central/eastern and western Alaskan Beaufort Sea. Large groups of feeding bowhead whales were seen in Block 12 on 13 October.

Median distance from locations of sightings of bowhead whales to a normalized shoreline in 2009 was 6.6 km (range from 3 to 57 km) in the East Region (140°-148°W), and 16.9 km (range from 5 to 87 km) in the West Region (148°-156°W). Median depth at sightings was 21 m (range from 11 to 56 m) in the East Region, and 17 m (range from 9 to 245 m) in the West Region. Compared to other light ice years (i.e., 1982, 1986, 1987, 1989, 1990, 1993-2008), sightings were significantly closer to shore and in shallower water in the West Region; there were too few sightings in the East Region in 2009 to conduct meaningful analyses.

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INTRODUCTION

In 1953, the Outer Continental Shelf Lands Act (OCSLA) (43 USC 1331-1356) charged the U.S. Secretary of the Interior with the responsibility for administering minerals exploration and development of the Outer Continental Shelf (OCS). The Act empowered the Secretary to formulate regulations so that its provisions might be met. The OCSLA Amendments of 1978 (43 USC 1802) established a policy for the management of oil and natural gas in the OCS and for protection of the marine and coastal environments. The amended OCSLA states that the Secretary of the Interior shall conduct studies in areas or regions of sales to ascertain the "environmental impacts on the marine and coastal environments of the outer Continental Shelf and the coastal areas which may be affected by oil and gas development" (43 USC 1346).

Subsequent to the passage of the OCSLA, the Secretary of the Interior designated the Bureau of Land Management (BLM) as the administrative agency responsible for leasing submerged federal lands and the Conservation Division of the U.S. Geological Survey for classification and evaluation of submerged federal lands and regulation of exploration and production. In 1982, the U.S. Minerals Management Service (MMS) assumed these responsibilities.

To provide information used in environmental impact statements and environmental assessments under the National Environmental Policy Act (NEPA) of 1969 (42 USC 4321-4347), and to assure protection of marine mammals under the Marine Mammal Protection Act (MMPA) of 1972 (16 USC 1361-1407) and the Endangered Species Act (ESA) of 1973 (16 USC 1531-1543), the BLM funded numerous studies involving acquisition and analysis of marine mammal and other environmental data.

In June 1978, the BLM entered into an Endangered Species Act Section 7 consultation with the National Marine Fisheries Service (NMFS). The purpose of the consultation was to determine the likely effects of the proposed Beaufort Sea Oil and Gas Lease Sale on endangered bowhead (*Balaena mysticetus*) and gray whales (*Eschrichtius robustus*). NMFS determined that insufficient information existed to conclude whether the proposed Beaufort Sea sale was or was not likely to jeopardize the continued existence of bowhead and gray whales. In August 1978, NMFS recommended studies to the BLM that would fill the information needs identified during the Section 7 consultation. Subsequent Biological Opinions for leasing and exploration in the Beaufort Sea (Sales 71, 87, and 97) and the 1988 Arctic Region Biological Opinion (ARBO) used for Beaufort and Chukchi Sea sales (Sales 124, 126, 144, and 170), recommended continuing studies of whale distribution and OCS-industry effects on bowhead whales (USDOC, NOAA, NMFS 1982, 1983, 1987, and 1988) and monitoring of bowhead whale presence during periods when geophysical exploration and drilling are occurring. The current ARBO, issued by NMFS in 2006 for leasing and exploration in the Beaufort Sea, also recommends that whale distribution studies during the fall migration continue, along with acoustic monitoring studies to describe the impact of exploration activities on the migration path of bowhead whales in the Beaufort Sea.

Following several years when drilling was limited to the period 1 November through 31 March (USDOI, MMS 1979), variable 2-month seasonal-drilling restrictions on fall exploratory activity in the joint Federal/State Beaufort Sea sale area was implemented. The MMS (Alaska OCS Region) adopted an endangered whale monitoring plan that required aerial surveys. The Diapir Field Sale 87 Notice of Sale (NOS) (1984) states that "Bowhead whales will be monitored by the Government, the lessee, or both to determine their locations relative to operational sites as they migrate through or adjacent to the sale area" (USDOI, MMS 1984). Subsequent lease sales in the Beaufort Sea (Sales 97, 124, 144, 170, 186, 195, and 202) did not include a seasonal drilling restriction, but the NOS for each contained an Information to Lessees clause that "MMS intends to continue its area wide endangered whale monitoring program in the Beaufort Sea during exploration activities" (USDOI, MMS 1988, 1991, 1996, and 1998). Information gathered is used to help determine the extent, if any, of adverse effects on the species.

From 1979 to 1987, the MMS (formerly BLM) funded annual monitoring of endangered whales in arctic waters under Interagency Agreements with the Naval Ocean Systems Center and through subcontracts to SEACO, Inc. (Ljungblad et al. 1987). The MMS used agency personnel to perform fieldwork and reporting activities for the Beaufort Sea on an annual basis from 1987 to 2006 (Treacy 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 2000, 2002a, 2002b, Monnett and Treacy 2005, and USDOI, MMS 2008). In 2007, an Interagency Agreement between MMS (U. S. Department of the Interior) and NMFS (specifically, the National Marine Mammal Laboratory [NMML], Alaska Fisheries Science Center) was established to authorize NMML to conduct the Bowhead Whale Aerial Survey Project (BWASP) surveys and assume partial responsibility for the management of the project. In 2008, full responsibility for all aspects of the BWASP surveys and related tasks was adopted by NMML (Clarke et al. 2011). The MMS is now the Bureau of Ocean Energy Management, Regulation, and Enforcement (BOEMRE).

The goals of the ongoing project are to

1) Define the annual fall migration of bowhead whales, significant inter-year differences, and long-term trends in the distance from shore and water depth at which whales migrate.

2) Monitor temporal and spatial trends in the distribution, relative abundance, habitat, and behaviors (especially feeding) of endangered whales in arctic waters.

3) Provide real-time data to MMS (now BOEMRE) and NMFS on the general progress of the fall migration of bowhead whales across the Alaskan Beaufort Sea, for use in protection of this endangered species.

4) Provide an objective, wide area context for management interpretation of the overall fall migration of bowhead whales and site-specific study results.

5) Record and map beluga distribution and incidental sightings of other marine mammals.

6) Determine seasonal distribution of endangered whales in planning areas of interest to MMS.

METHODS AND MATERIALS

Study Area

The BWASP annual survey program has been based on a design of north/south transects distributed randomly within established geographic blocks overlapping or near Beaufort Sea sale areas offshore of Alaska, an area commonly referred to as the North Slope. The present study included Beaufort Sea Survey Blocks 1 through 12 (Fig. 1) between 140°W and 157°W, south of 72°N, and north of the shoreline of Alaska, with occasional surveys west of 157°W in the Chukchi Sea (Survey Block 13).

A large-scale Beaufort Gyre moves waters clockwise from the Canadian Basin westward in the deeper offshore regions. Seaward of the gyre is the eastward-flowing Beaufort undercurrent, which flows subsurface in areas where bathymetry is 51 to 2,000 m (Aagaard 1984). In the nearshore shallow waters of the Beaufort inner shelf (≤ 50 m depth), currents tend to follow local wind patterns. In winter, currents are not substantial even when winds are strong. In summer, currents are much stronger and may flow either east or west, depending on prevailing winds. Based on analysis of modeled sea level and ice motion, wind-driven motion in the Arctic was found to alternate between anticyclonic and cyclonic circulation, with each regime persisting from 5 to 7 years (Proshutinsky and Johnson 1997, Johnson et al. 1999).

In the Beaufort Sea, landfast ice forms during the fall and may eventually extend up to 50 km offshore by the end of winter (Norton and Weller 1984). The pack ice, which includes multiyear ice averaging 4 m in thickness, with pressure ridges up to 50 m thick (Norton and Weller 1984) becomes contiguous with the new and fast ice in late fall, effectively closing off the migration corridor to westbound bowhead whales. From early November to mid-May, the Beaufort Sea normally remains almost completely covered by ice considered too thick for whales to penetrate. In mid-May, a recurring lead can form just seaward of the stable fast ice, followed by decreasing ice concentrations (LaBelle et al. 1983) and large areas of open water in summer. In recent years, the minimum area of the summer ice pack has been shrinking, setting records for new minimums in several years including 2007, 2008, and 2009 (National Snow and Ice Data Center 2007, 2008, and 2009). The open water season has lengthened and the southern edge of the ice pack has been farther from Alaskan shorelines. The decrease in sea ice extent has been correlated with an increase in Arctic Ocean cloud cover (Eastman and Warren 2010).

Local weather patterns affect the frequency and effectiveness of all marine aerial surveys. The study area is in the arctic climate zone, with mean temperatures at Alaskan Beaufort Sea coast locations ranging from -0.9°C to -0.1°C during September and from -9.7°C to -8.5°C during October (Brower et al. 1988). Mean temperatures measured at Barrow since 1972 have increased by 2.9°C (5.2°F), likely due to circulation changes (increased warm air advection from southern latitudes) or increased infrared back-radiation due to increased cloudiness, water vapor or CO_2 (Wendler et al. 2009). Precipitation across the North Slope occurred an average of

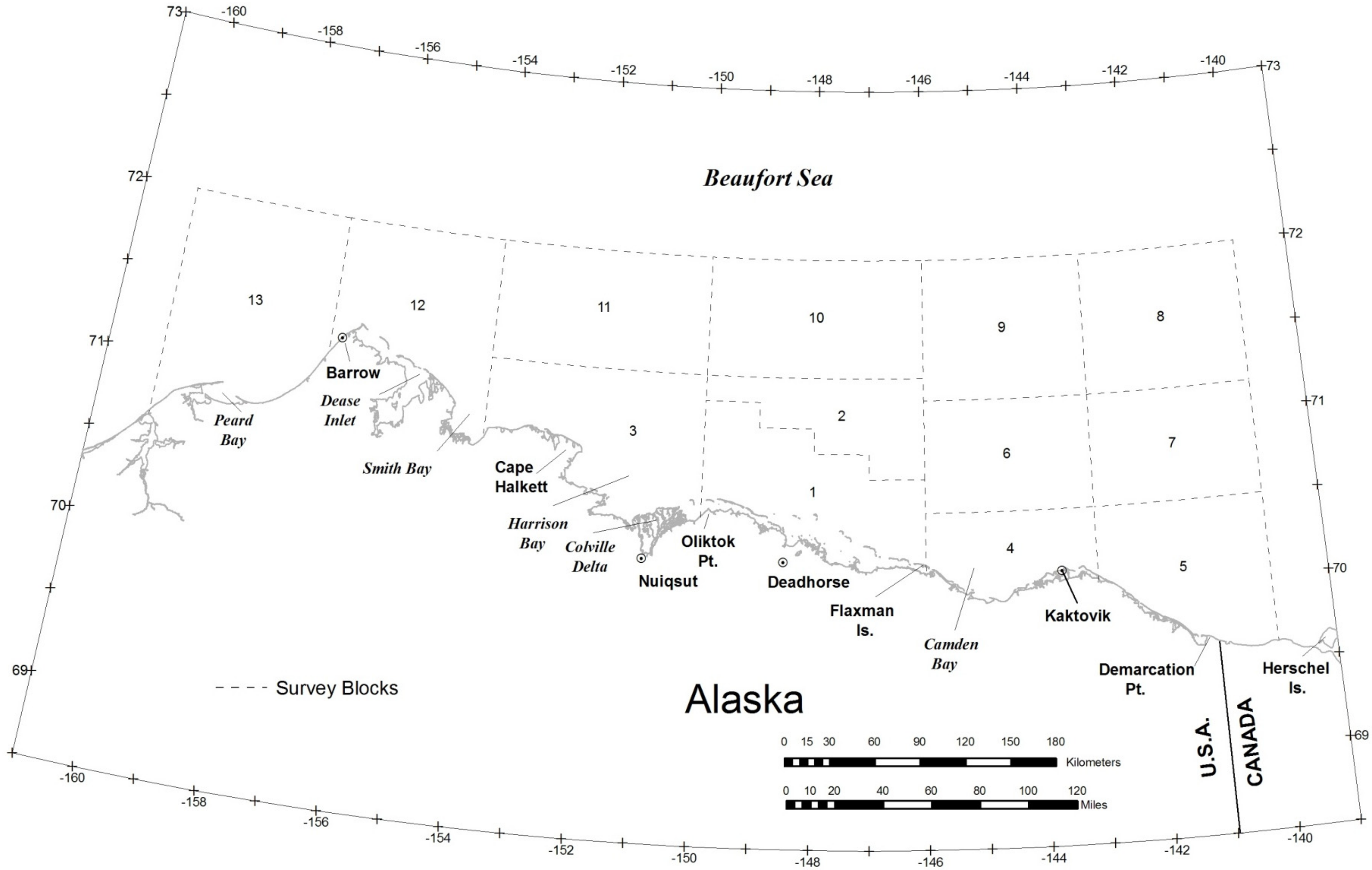

Figure 1. -- Study area showing Survey Blocks.

10-34% of the time during September (snow or rain) and 13-43% during October (almost all snow), with the heaviest precipitation at Barrow and Barter Island during both months (Brower et al. 1988). Mean wind speed in the same communities is from 5 to 6 m/s during September and 5 to 7 m/s during October (Brower et al. 1988). Wind speeds in September and October are generally higher than during other times of the year, perhaps because open water and cooling land mass increase thermal instability (Wendler et al. 2009). Wind direction is predominantly easterly, which also drives the Beaufort Gyre, but winds occasionally reverse and shift to being westerly. The occurrence of storms during which at least one hourly reading of wind speed was > 15 m/s (approximately Beaufort wind force 7) has also increased since 1972 (Wendler et al. 2009). Highest annual mean wind speeds at Barrow were recorded since the early 1990s; the mean annual wind speed in 2006 was approximately 5.2 m/s (Fig. 3 in Wendler et al. 2009).

Sea state also affects visibility during aerial surveys. Surface waters in the Beaufort Sea are driven primarily by wind. Ocean waves are generally from northerly or easterly directions during September and October. Prior to 1997, significant wave heights were reduced by a factor of 4 from heights that would otherwise be expected during the open-water season because pack ice limited fetch. Since 1997, large expanses of open water have been present during some or all of the survey. Corresponding wave heights have been considerably higher during periods of high wind.

Equipment

The project aircraft was a de Havilland Twin Otter Series 300 equipped for arctic operation and aerial surveys of whales. The U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Aircraft Operations Center (AOC), provided administrative support in managing the aircraft contract and provided the aircrew and aircraft. Onboard equipment, data collection, and post-field analyses replicated equipment and standard procedures developed and used in past years (1979-2008). These methodologies are described in detail elsewhere (e.g. Monnett and Treacy 2005; USDOI, MMS 2008; Clarke et al. 2011).

The aircraft was equipped with two medium-sized bubble windows behind the cabin bulkhead and two larger bubble windows forward of the aft-bulkhead that afforded complete trackline viewing. The pilot and copilot seats provided good forward and side viewing. Each observer was issued a hand-held clinometer for measuring the angle of inclination to sighting locations. Observers and pilots were linked with a common communication system. The aircraft's maximum time aloft under normal survey load was extended to approximately 7 hours through the use of a supplemental onboard fuel tank.

A laptop computing system was used aboard the aircraft to store and analyze flight and observational data. The computer system was connected to a Garmin Global Positioning System (GPS) with an external antenna, independent of the aircraft GPS. Latitude, longitude, and flight altitude from the GPS were transmitted to the computer through a standard serial connection. Data were backed up to an onboard external hard drive. A custom mapping program developed by MMS project personnel permitted observers to view the aircraft’s trackline in real time.

Onboard safety equipment included an impact-triggered emergency locator transmitter installed in the aircraft, an 8-person search and rescue life raft equipped with an emergency survival kit, a portable personal locator beacon, a portable ICOM A3 Sport aircraft-band transceiver, and orange survival suits. All personnel underwent regular aircraft egress, wilderness first aid, and other safety trainings as required by AOC and NMML. Observers and pilots wore orange Mustang Constant Wear Aviation Dry Suit System MSF300 and Switlik personal flotation vests outfitted with personal locator beacons and other safety gear.

The U.S. Department of the Interior, National Business Center, Aviation Management "Automated Flight Following" (AFF) system was used by Anchorage-based Aviation Management personnel for "satellite-tracking" the project aircraft over the Alaskan Beaufort Sea. Aviation Management obtained current flight information in the form of maps for real-time visual tracking of the survey aircraft. An Iridium satellite phone was used to communicate aircraft position to Aviation Management each hour. In addition to these flight-following systems, the onboard transponder was set at a discrete identification code for radar tracking by air-traffic-control personnel.

Aerial Survey Design

Aerial surveys were based out of Deadhorse, Alaska, from 1 September through 18 October 2009. The field schedule was designed to monitor the progress of the fall bowhead whale migration across the Alaskan Beaufort Sea. All bowhead whale observations were recorded, along with incidental sightings of other marine mammals.

Daily flight patterns were based on sets of unique transect grids, computer-generated for each Survey Block or set of two Survey Blocks (for blocks oriented together on a north-south axis). Transect grids were derived by dividing each Survey Block into sections 30 minutes of longitude across. One of the minute marks along the northern edge of each section was selected at random and then connected by a straight line to a similarly selected endpoint along the southern edge of the same section. This procedure was followed for all sections of the Survey Block. These transect legs were then connected alternately at their northernmost or southernmost ends to produce one continuous flight grid within each Survey Block.

The selection of Survey Blocks to be flown on a given day was nonrandom, based on reported or observed weather conditions over the study area and avoidance of recently surveyed areas. Weather permitting, the project attempted to distribute effort fairly evenly across the entire study area. A semimonthly flight-hour goal for each Survey Block was allocated proportionately for Survey Blocks east of 154°W. This was based on relative abundance of bowhead whales as determined from earlier fall migrations (1979-1986). Such allocations greatly favored survey coverage in inshore Survey Blocks 1 through 7 and 11 (Fig. 1) since bowhead whales were rarely sighted north of these blocks in previous surveys. The purpose of these survey-effort allocations was to increase the sample size (n) of whale sightings within the primary migration corridor, thus increasing the power of statistical analysis within these inshore blocks. Only data from transect legs were used to analyze the migration axis.

Survey Flight Procedures

During a typical flight, a search leg was flown to the target Survey Block, whereby a series of transect legs were flown, followed by a search leg back to Deadhorse. Transects were joined together by short search legs. Circling was initiated to further investigate cetacean sightings. Surveys generally were flown at a target altitude of 458 m, but could be flown as low as 305 m. Weather permitting, the higher altitude was maintained in order to maximize visibility and to minimize potential disturbance to marine mammals. When cloud ceilings were less than 305 m or the wind force was above Beaufort 5, survey flights were redirected to Survey Blocks with better conditions. Survey flights were aborted when conditions consistently did not meet minimum altitude (305 m) or wind force (Beaufort 5) requirements.

Primary observers were stationed on either side of the aircraft at bubble windows that permitted an unobstructed field of vision from the trackline directly below the aircraft to the horizon. The data recorder was primarily responsible for data entry but also functioned as a secondary observer. The data recorder was stationed at an aft bubble window, although some aircraft configurations had a flat window at the data recorder position. A clinometer was used to measure the angle of inclination to each sighting when the initial sighting location was abeam of the aircraft. Only sightings from primary observers were recorded as on transect; sightings by the data recorder, pilots, or occasional fourth observer were recorded as on search.

When cetaceans were encountered while surveying a transect line, the aircraft sometimes diverted from transect for brief (< 10 minute) periods and circled the whales to verify species, observe behavior, obtain better estimates of group size, and determine whether calves were present. Any new sightings of whales made while circling were recorded as on circling rather than as on transect. Sightings made off transect were recorded as on search.

Survey effort over land or in areas where visibility was zero was designated deadhead and not incorporated into further analyses.

Data Entry

Customized, menu-driven data entry software developed by MMS and Resource Data Incorporated (RDI) project personnel was used to record all data in database format (MS-Access 97). Location data (date, time, latitude, longitude, altitude, and aircraft heading) and environmental conditions (sky conditions, visual impediments, visibility left and right, percent ice coverage, ice type, and wind force) were recorded at sightings, turning points, when environmental conditions changed, or otherwise at intervals of 5 minutes (in time). A complete data sequence was recorded for cetacean sightings, including location data, environmental conditions, reason for entry, species, total number (as well as low, high, and best estimate of group size), observer, swim direction (magnetic), clinometer angle, calf number, behavior, sighting cue, group classification, habitat, swim speed, whether it was a repeat sighting, and response to aircraft. Reduced data sequences were used when recording other marine mammals. Position data only (date, time, latitude, longitude, and altitude) were automatically recorded every 30 seconds (in time) to provide a more complete record of the flight track.

The behavior, swim speed, and swim direction for observed whales represent what the pod as a whole was doing at the time it was first sighted. Behaviors were entered into 1 of 15 categories as noted during previous surveys (Table 1). The default behavior was "swimming", entered whenever an alternate behavior was not observed. Swimming speed was subjectively estimated by observing the time it took a whale to swim one body length. An observed swimming rate of one body length per minute corresponded to an estimated speed of 1 km/hr. One body length per 30 seconds was estimated at 2 km/hr, and so on. Swimming speed was recorded by relative category (i.e., still, 0 km/hr; slow, 0-2 km/hr; medium, 2-4 km/hr; or fast, > 4 km/hr). Group composition included categories single, pair, mixed group, etc., and was designed to provide additional information on group dynamics. Swim direction was recorded relative to the aircraft's heading, and then converted to actual swim direction via a module incorporated into the data collection software.

Wind force was recorded according to the Beaufort scale outlined in *Piloting, Seamanship, and Small Boat Handling* (Chapman 1971). Ice type was identified using terminology presented in Naval Hydrographic Office Publication Number 609 (USDOD, Navy 1956). Average ice cover over a 1-2 km lateral distance from the aircraft was estimated as a single percentage, regardless of ice type.

General Data Analyses

Preliminary field data analysis was performed by a computer program that provided daily summations of marine mammals observed, plus calculation of time and distance on transect, search, circling, and deadhead portions of the flight. The program provided options for editing the data file, calculating summary statistics on sightings and effort, and plotting the paths of one or more flights by Beaufort sea state.

The water depth at each bowhead whale sighting in the 1982-2009 database was derived from the International Bathymetric Chart of the Arctic Ocean (IBCAO) containing grid cells 2.5 km square (http://www.ngdc.noaa.gov/mgg/bathymetry/arctic/arctic.html).

Maps were prepared with application software (ArcGIS) based on Universal Transverse Mercator Zone 6 (central meridian = 147°W, reference lat. = 0.00000, false easting = 500000.00000, false northing = 0.00000, spheroid = GRS 80, scale factor = 0.99960). The natural coastline was adopted from the State of Alaska, Department of Natural Resources.

Environmental information, including wind speed and direction, ceilings, visibility, temperature, dew point, ice cover, and sea surface temperature was collected from numerous National Weather Service web sites and several other weather and climate-related web pages for the duration of the field season. Data were collected and stored electronically for both specific locations (e.g., Deadhorse, Barter Island, Kuparak, Alpine, and the weather station at West Dock) and for the Beaufort Sea region.

Table 1. -- Operational definitions of observed whale behaviors.

Behavior	Definition
Breaching	Whale(s) launching upwards such that half to nearly all of the body is above the surface before falling back into the water, usually on its side, creating an obvious splash.
Cow-Calf	Calf nursing; cow-calf pairs swimming within 20 m of each other.
Diving	Whale(s) changing swim direction or body orientation relative to the water surface, resulting in submergence; may or may not include lifting the tail out of the water.
Feeding	Whale(s) diving repeatedly in a fixed area, sometimes with mud streaming from the mouth and/or defecation observed upon surfacing. Feeding behavior is further defined as synchronous diving and surfacing or echelon-formations at the surface with swaths of clearer water behind the whale(s), or as surface swimming with mouth agape.
Flipper-Slapping	Whale(s) floating on side, striking the water surface with pectoral flipper one or many times; usually seen within groups or when the slapping whale is touching another whale.
Log-Playing	Whale(s) milling or thrashing in association with a floating log.
Mating	Ventral-ventral orientation of two whales, often with one or more other whales present to stabilize the mating pair. Mating is often seen within a group of milling whales. Pairs may appear to hold each other with their pectoral flippers and may entwine their tails.
Milling	Whales moving slowly at the surface in close proximity (within 100 m) to other whales, often with varying headings. Also one whale slowly changing its heading.
Resting	Whale(s) floating at the surface with head, or head and back exposed, showing no movement; more commonly observed in heavy-ice conditions than in open water.
Rolling	Whale(s) rotating on the longitudinal axis, sometimes associated with mating.

Spy-Hopping	Whale(s) extending head vertically out of the water such that up to one-third of the body, including the eye, is above the surface.
Swimming	Whale(s) proceeding forward through the water propelled by tail.
Tail-Slapping	Whale(s) floating horizontally or head-downward in the water, waving tail back and forth above the water and striking the water surface; usually seen in group situations.
Thrashing	Whale(s) exhibiting rapid flexure or gyration in the water.
Underwater-Blowing	Whale(s) exhaling while submerged, thus creating a visible bubble.

Sea ice concentrations were derived from the Beaufort Sea Ice Analysis provided by the National Ice Center in Suitland, Maryland. The Beaufort Sea Ice Analysis shows average ice concentrations over the prior 2 to 3-day period based on visual, infrared, and synthetic-aperture-radar satellite imagery combined with reconnaissance, ship, and shore observations. Polygons of ice concentrations in the Beaufort Sea bracketing the field season were downloaded from the National Ice Center web site for the western Arctic (http://www.natice.noaa.gov) and imported into ArcGIS. Total sea ice concentrations, regardless of ice type, were edited from these polygons and specially coded to distinguish 0%, 1 to 19%, 20 to 39%, 40 to 59%, 60 to 79%, 80 to 94%, or 95 to 100% ice cover.

Survey effort and observed bowhead whale distribution were plotted semimonthly over the Beaufort Sea study area. Fall sightings of belugas, as well as incidental sightings of other marine mammals, were depicted on separate maps. Common and scientific names used for marine mammals in this report are taken from Rice (1998).

Whale sightings were shown on distribution maps regardless of the type of survey leg (transect, search, or circling) being conducted or the prevailing environmental conditions (sea state, ice cover, etc.) when the sightings were made. As with previous reports in this series (e.g., Monnett and Treacy 2005; USDOI, MMS 2008; Clarke et al. 2011), same-day repeat sightings or sightings of dead marine mammals were not included in summary analyses or maps. Where tables and figures exclude certain data, such exclusions are indicated in the captions.

Analysis of the Bowhead Whale Migration Corridor

The bowhead whale migration corridor was examined using the mean and median distance from shore and the median depth at sighting for whales sighted on transects (Houghton et al. 1984). Treacy (1998) found that median and mean bowhead whale distance from shore values were only slightly different. Therefore, annual mean distance from shore was plotted in relation to the cumulative mean distance from shore for previous years starting in 1982, as described in greater detail below. Further comparisons of various subsets of data were based on statistical analyses of median distance from shore and depth at sighting, via the nonparametric Mann-Whitney U-test. This nonparametric test was used for these data because distributions generally did not fit assumptions necessary to use the two-sample t-test. The variances were not equal between subsets of data for both depth and distance from shore; in addition, the depth data were considerably skewed and the distance from shore data were slightly skewed, so neither distribution strictly met the assumption of normality. When assumptions of the t-test are seriously violated, the Mann-Whitney U-test may be more powerful than the two-sample t-test (Hodges and Liehman 1956, Zar 1984). Statistical tests were undertaken using *Statistica*™ StatSoft, Version 5.1 and ArcGIS, Version 9.3. Median distance from shore and depths for bowhead whale sightings in 2009, a light ice year, were compared with analogous values for combined data from previous years having light ice coverage (i.e., 1982, 1986, 1987, 1989, 1990, and 1993-2008).

All bowhead whale sightings made while on transect, regardless of distance from the transect line, were included in this report. Distance from shore and water depth at bowhead whale sightings were analyzed for two regions (Fig. 2), the boundaries of which correspond roughly to oceanographic patterns and the offshore extent of sampling, described in more detail below. Selected isobaths (10 m, 20 m, 30 m, 40 m, 50 m, 60 m, 100 m, 500 m, 1,000 m, 1,500 m, 2,000 m, 2,500 m, 3,000 m, and 3,500 m), derived from IBCAO data, were also included in Figure 2 for visual reference.

Oceanographic patterns common to waters off northern Alaska are reviewed in Moore and DeMaster (1997). In brief, cold saline Bering Sea water and warm fresh Alaskan coastal water enter the Alaskan Beaufort Sea through Barrow Canyon. Both water masses are identifiable on the outer shelf (seaward of 50 m) as the eastward flowing Beaufort undercurrent (Aagaard 1984). Bering Sea water has been traced at least as far east as Barter Island (~143°W), but the Alaskan coastal water mixes with ambient surface waters as it moves eastward and is not clearly identifiable east of Prudhoe Bay (~147°-148°W). Therefore, the delineation between East-West Regions for this analysis occurs at 148°W, based upon association with the general distribution patterns of these water masses.

The northern extent of each region is based upon survey effort. The East Region extends from 140°W to 148°W and northward from the shore to 71°10' N, except between 146°W and 148°W where the region extends to 71°20' N. The northern boundary for this region corresponds with boundaries of Survey Blocks 2, 6, and 7 (Fig. 1), blocks with sufficient survey effort to support analyses (Treacy 1998). The West Region extends from 148°W to 156°W and northward from shore to 72°N, except between 148°W and 150°W where the region extends to 71°20' N due to the layout of Block 2. The northern boundary for this region corresponds with boundaries of Survey Blocks 2, 11, and 12 (Fig. 1). The eastern boundary (140°W) is the easternmost longitude of the Survey Blocks. The western cutoff at 156°W limits the analysis to bowhead whales seen in the Alaskan Beaufort Sea and avoids the influence of Barrow Canyon on bowhead whale depth distribution.

The shoreline used for the distance from shore analysis was ‘normalized’ from the actual Beaufort Sea shoreline to provide a standardization of distance-from-shore measures regardless of the mapping software being used to depict the distribution data. The ‘normalized’ shoreline was defined by straight-line connections between 11 points at specific shoreline or barrier island locations across Alaska’s North Slope between 156°W and 140°W (Fig. 2). The points used to ‘normalize’ the shoreline are as follows:

71.317°N, 156.000°W
70.883°N, 153.900°W
70.917°N, 153.115°W
70.817°N, 152.200°W
70.430°N, 151.000°W
70.550°N, 150.167°W
70.450°N, 147.950°W
69.967°N, 144.700°W
70.150°N, 143.250°W
69.650°N, 141.000°W
69.617°N, 140.000°W

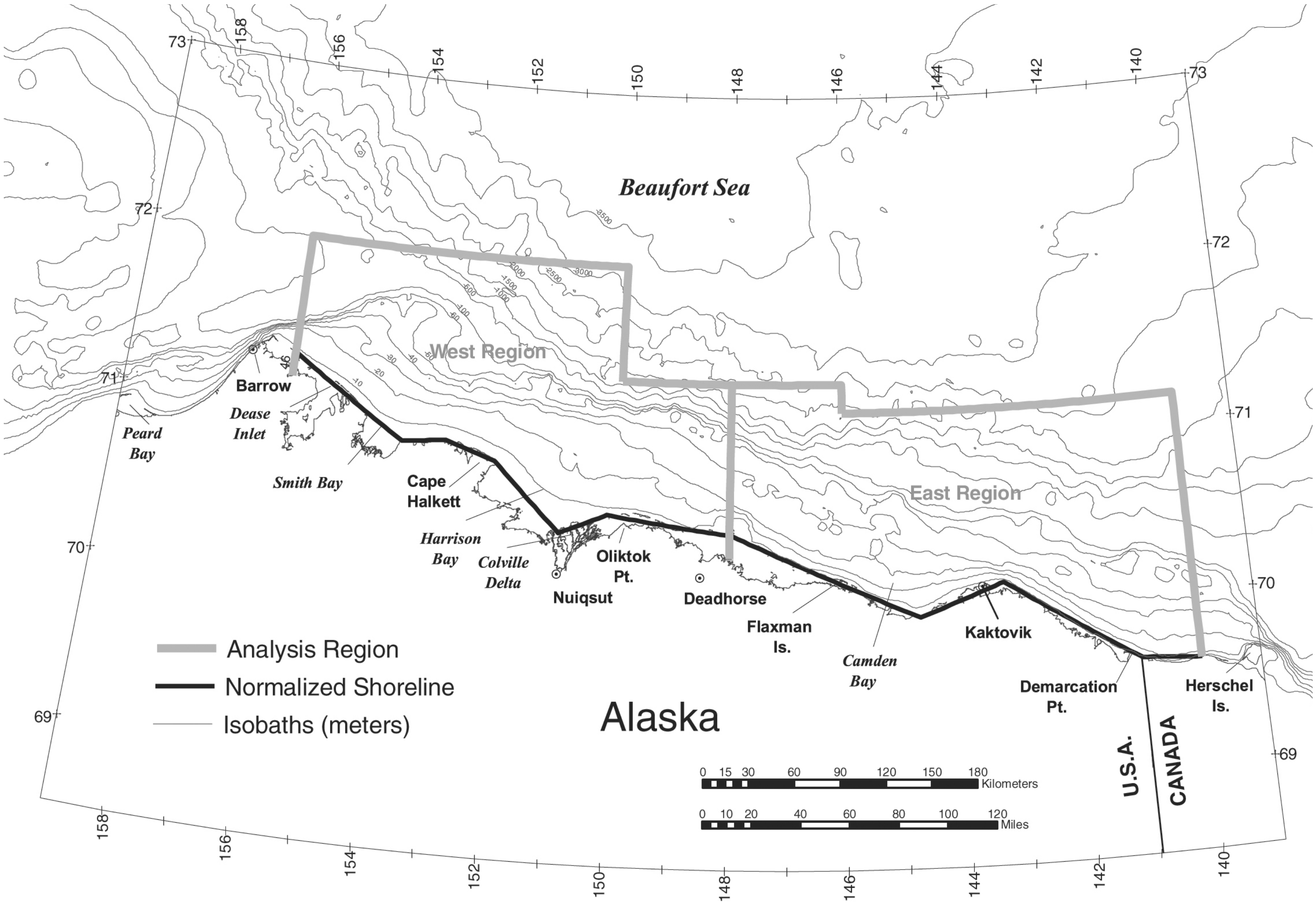

Figure 2. -- East and West Regions showing a normalized shoreline and selected IBCAO isobaths.

Two data subsets from BWASP 2009 were analyzed and are described below:

- All bowhead whale sightings on transect, regardless of behavior recorded. The analysis of this subset assumed that *all* bowhead whales in the Alaskan Beaufort Sea were migrating from the Canadian Beaufort Sea, where most bowhead whales are assumed to spend summer months, through the Alaskan Beaufort Sea enroute to wintering areas in the Bering Sea. Under this assumption, any feeding, milling, or resting behavior observed was considered temporary, and all whales were considered "migratory".

- All bowhead whale sightings on transect, *excluding* whales that were observed feeding, milling, or resting. These behaviors might be considered "non-migratory" and may influence, at least temporarily, the migratory path.

Analyzing the bowhead whale migration corridor based on sighting data only may be biased because survey effort is often variable both within and across years. For example, there may be more sightings in areas with greater transect effort and fewer sightings in areas with less transect effort, which biases the analysis. Analytical methods are being developed to base future migration corridor statistics on encounter rates, which will factor in variable survey effort and thereby remove the potential for bias.

Sighting Rate and Relative Occurrence Analysis

Sighting rates quantify relative occurrence while accounting for heterogeneity in survey effort across the study area. Sighting rates were derived for three different spatial scales. Estimated total effort (transect, search, and circling combined, in kilometers) and transect effort only (in kilometers) per Survey Block were calculated to determine annual sighting rates (WPUE = number of whales per unit effort) for bowhead whales and belugas. Although Survey Blocks are arbitrary geographic areas, they provide a basis for inter-annual cross-comparisons. Effort over land, between barrier islands and the mainland, and north of the study area (north of 72°N) was not included in this sighting rate analysis. Estimated transect effort (km) per depth zone (≤ 20 m, 21-50 m, 51-200 m, and 201-2,000 m) were computed separately for two subareas. One subarea spanned 154°W to 157°W, and includes Barrow Canyon and its surrounding area, which has noticeably different bathymetry than the rest of the BWASP study area (Fig. 2). The other subarea for the depth zone analysis spanned 140°W to 154°W, an area incorporating a well-defined continental shelf and slope. An additional sighting rate analysis was conducted at a finer-scale (5' latitude by 15' longitude), which used a grid matrix consisting of approximately equilateral grid cells superimposed across the study area. Bowhead whale sighting rates on this finer scale were calculated as the number of transect sightings per unit transect effort (SPUE) for each grid cell. An index of relative occurrence of feeding and milling behaviors, quantified as SPUE, was also calculated for the finer scale grid. The finer-scale grid analysis includes transect effort within the barrier islands and north of 72°N. Sighting rates were not corrected for availability or perception bias (Buckland, 2001).

RESULTS

Environmental Conditions

Sea ice coverage in the Alaskan Beaufort Sea was extremely light during the BWASP 2009 survey period. For purposes of inter-year comparisons of bowhead whales and other marine mammal distribution and occurrence, 2009 is considered a light ice year. Sea ice extent in 2009 receded to the third lowest level since satellite measurements began in 1979 (National Snow and Ice Data Center 2009). For most of September, ice persisted in the far eastern offshore Survey Blocks (Blocks 7, 8, 9, and 10) (Fig. A-1 to A-4) only, with all other areas ice-free. From late September to early October, new ice started to form offshore (Fig. A-5). In mid-October, however, the ice edge moved farther offshore (Fig. A-6 to A-7), where it remained through the end of the survey season. Ice percentage and sea state for each bowhead whale sighting are presented in Appendix B. The absence of sea ice in most of the study area in 2009 led to higher than preferred sea state conditions on many potential survey days.

Survey Effort

The fall field season was from 1 September to 18 October 2009 (Table 2). There were 18 flights, of which 11 were in September and 7 were in October. Over 20,000 km were flown during 93 hours; 32% of total survey effort was on deadhead (non-useable survey time). The average survey flight was 1,125 km, ranging from 541 to 1,967 km. A total of 8,894 km of transect lines were flown in 43 hours. Transect effort constituted 44% of the total kilometers flown and 47% of the total flight hours. Survey flight lines are summarized by semimonthly period in Figures 3 through 6. Coverage in early September was very good in the eastern and offshore part of the study area (Fig. 3). Although not regularly surveyed in recent years, surveys were conducted in Blocks 8, 9, and 10 because conditions were favorable and because data from the MMS-sponsored bowhead whale satellite-tagging project indicated that at least two whales had transited between Canada and Barrow and back again in August in this offshore part of the BWASP study area (Quakenbush et al. 2010). Survey coverage in late September was less than normal (Fig. 4) due to very poor conditions, including fog, high winds, blowing snow, and widespread icing. Survey coverage in early October focused on the far eastern and western portions of the study area (Fig. 5). There was only one flight in the latter half of October (Fig. 6). The BWASP aerial survey season ended on 19 October when the survey aircraft left the North Slope ahead of a large storm. Survey coverage was greatest in Blocks 1, 3, and 12, and lowest in Blocks 8, 9, 10, and 11. Flight lines and associated sea states are presented for individual flights in Appendix C.

Table 2. -- Aerial survey effort in the Beaufort Sea, 1 September-18 October 2009, by survey flight. Semimonthly totals may not exactly match the sum for the time period due to rounding error.

Day	Flight no.	Transect (km)	Circling (km)	Search (km)	Deadhead (km)	Total (km)	Transect (hr)	Total (hr)
1 Sep	1	1,013	17	101	70	1,201	5.0	5.9
2 Sep	2	1,117	47	175	66	1,404	5.5	6.9
3 Sep	3	650	47	197	476	1,370	3.2	6.5
5 Sep	4	701	21	593	74	1,390	3.4	6.5
6 Sep	5	507	82	391	136	1,117	2.5	5.4
14 Sep	6	0	0	0	583	583	0.0	2.3
16 Sep	7	322	0	47	796	1,165	1.6	4.9
19 Sep	8	72	0	112	556	739	0.4	3.2
25 Sep	9	23	32	85	402	541	0.1	2.4
28 Sep	10	701	33	156	81	971	3.4	4.7
29 Sep	11	221	49	136	269	675	1.1	3.0
1 Oct	12	569	21	259	649	1,498	2.7	6.8
2 Oct	13	259	19	397	191	867	1.3	4.0
6 Oct	14	830	36	265	425	1,555	3.9	7.0
10 Oct	15	198	8	287	267	760	1.0	3.3
12 Oct	16	672	63	385	848	1,967	3.2	8.4
13 Oct	17	546	178	355	436	1,515	2.6	6.8
18 Oct	18	494	95	230	120	938	2.4	4.5
Semimonthly Effort Summary								
1-15 Sep		3,987	214	1,458	1,405	7,064	19.5	33.6
16-30 Sep		1,340	114	534	2,104	4,092	6.6	18.2
1-15 Oct		3,073	325	1,948	2,816	8,162	14.6	36.3
16-18 Oct		494	95	230	120	938	2.4	4.5
Total		8,894	748	4,170	6,444	20,256	43.1	92.6

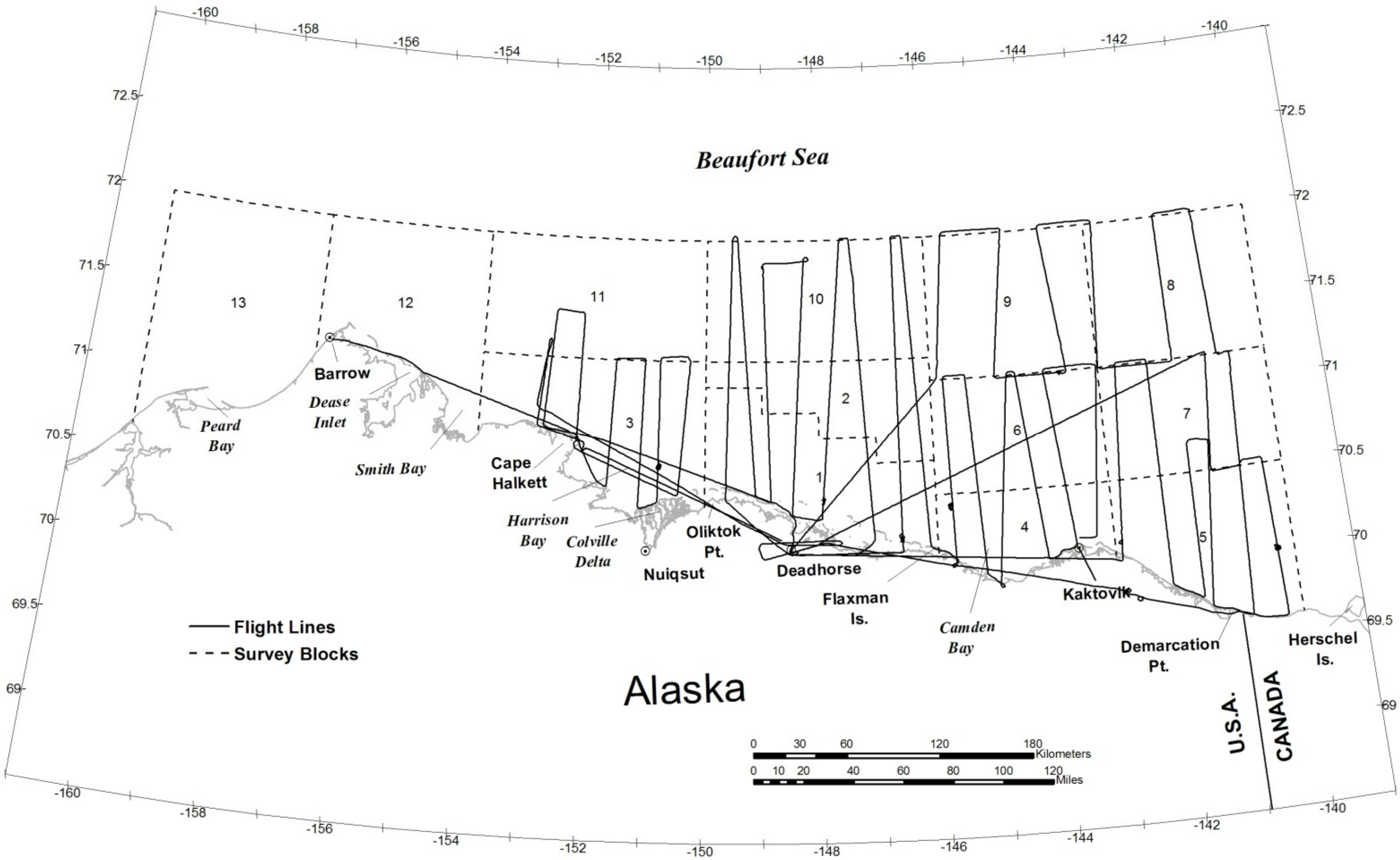

Figure 3. -- Combined flight tracks, 1-15 September 2009.

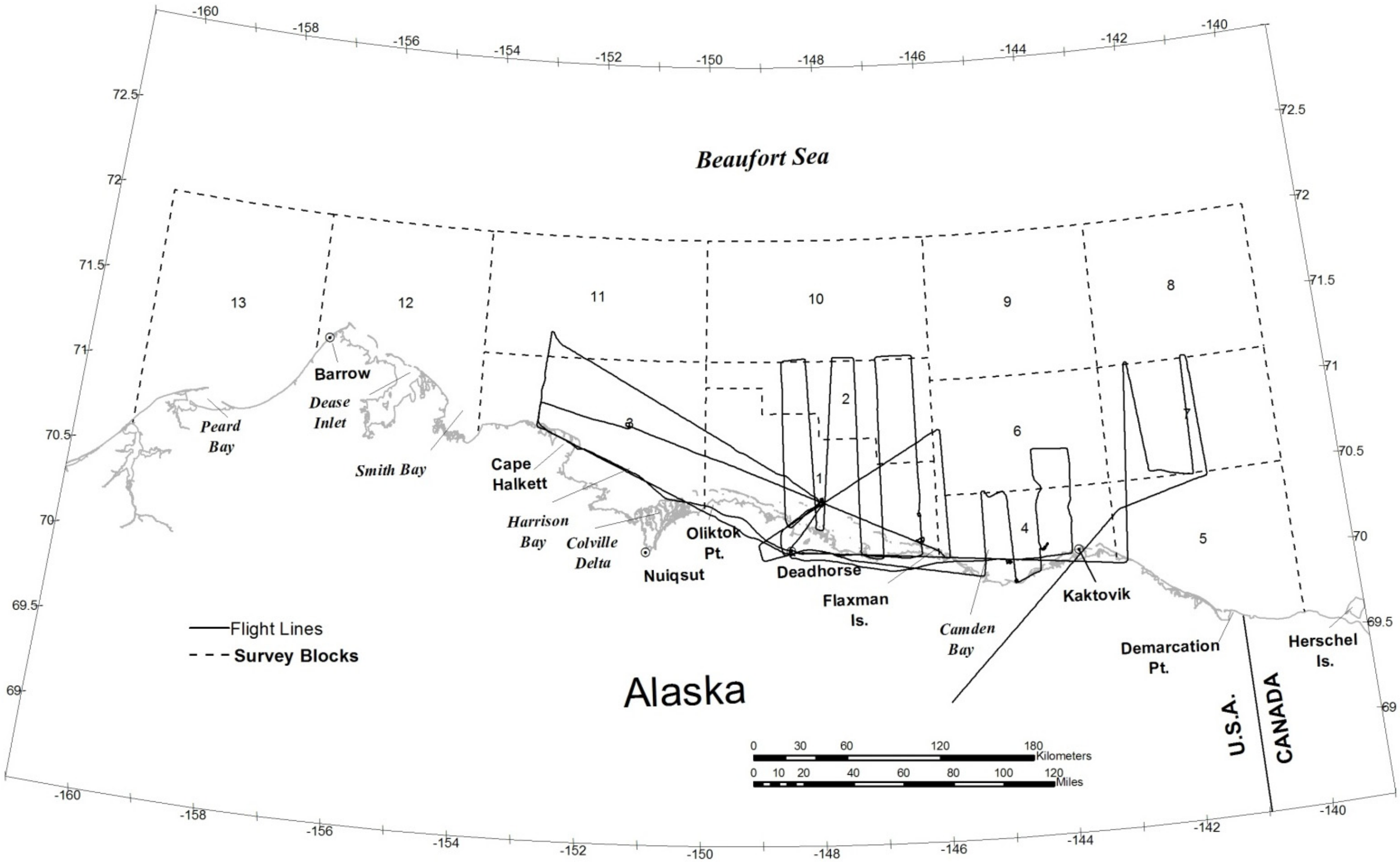

Figure 4. -- Combined flight tracks, 16-30 September 2009.

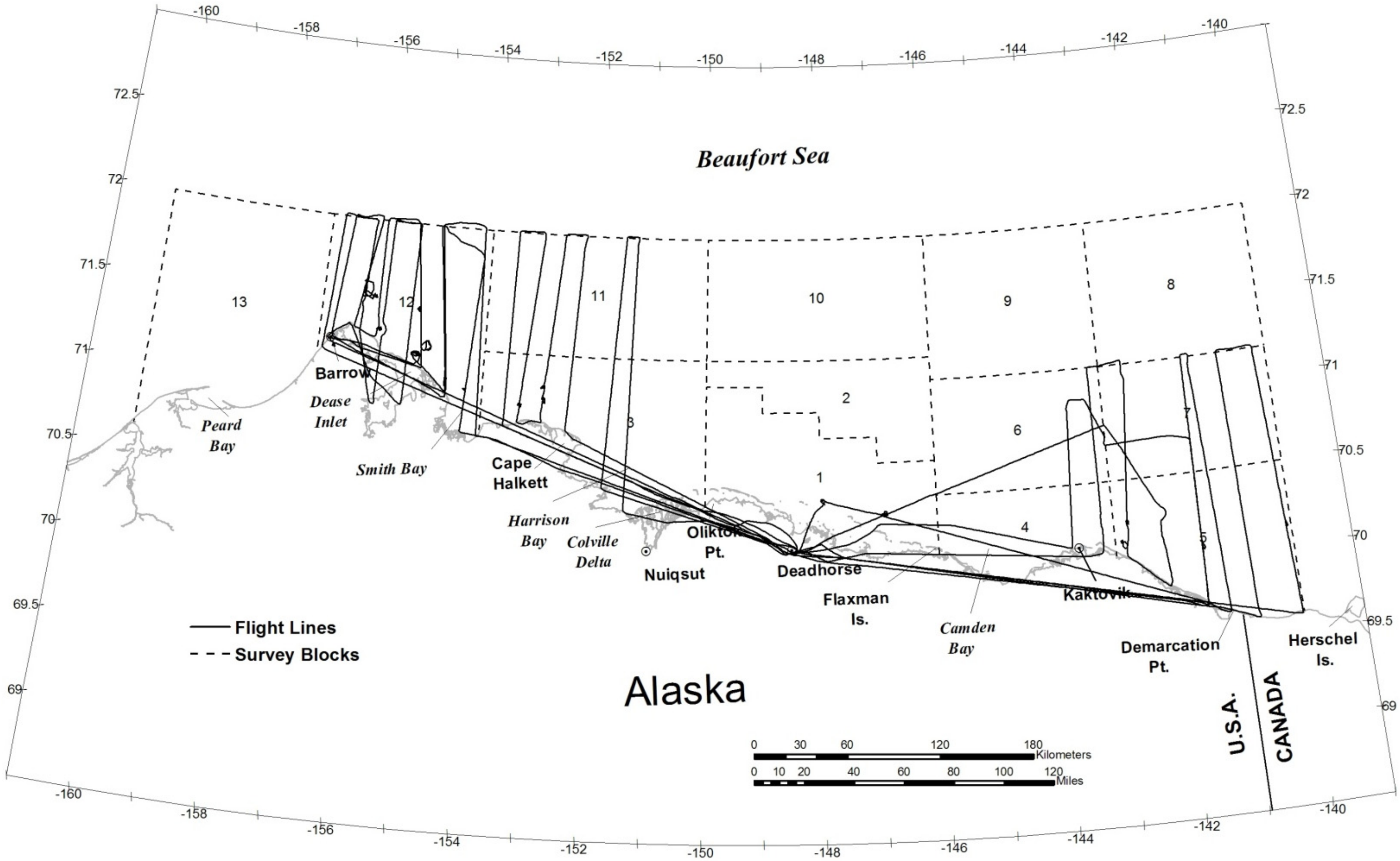

Figure 5. -- Combined flight tracks, 1-15 October 2009.

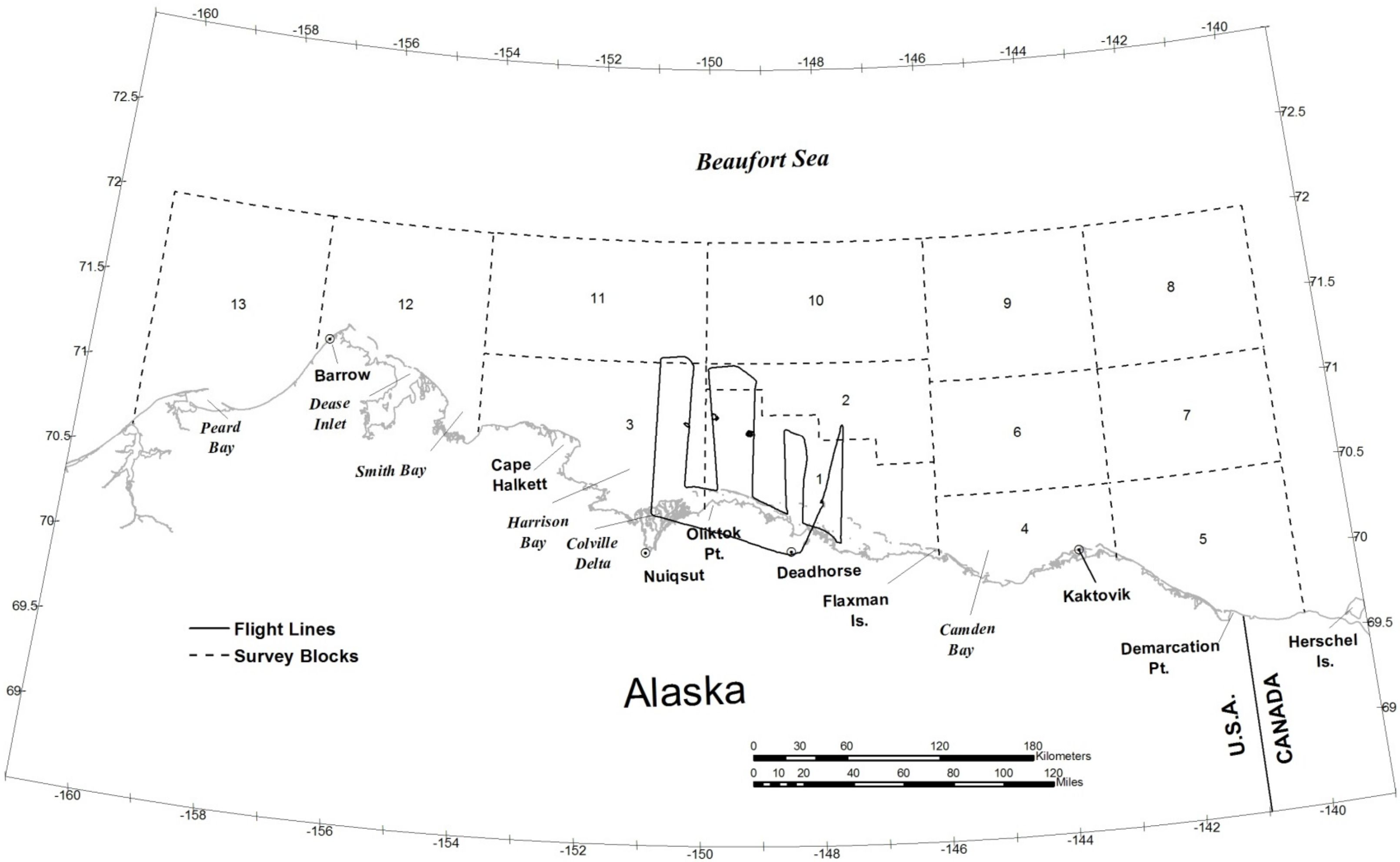

Figure 6. -- Combined flight tracks, 16-18 October 2009.

Bowhead Whale Observations

Sighting Summary

During the fall 2009 surveys, 77 sightings of 384 bowhead whales were observed in the study area (Table 3). Bowhead whales were distributed throughout the nearshore regions of the survey area (Fig. 7). Bowhead whales were not seen in offshore Blocks 8, 9, 10, and 11, despite surveys conducted there in excellent weather. The greatest number of sightings occurred in Block 12, east of Point Barrow. Block 12 contained 81% (312 whales) of the total bowhead whales observed in 2009. Out of the 384 bowhead whales, 14 were identified as calves (Appendix B). The resulting seasonal calf ratio (number of calves/total whales) is 0.036. Locations of bowhead whale sightings are shown by semimonthly period in Figures 8 through 11.

Sighting Rates

In fall 2009, bowhead whales were seen from Point Barrow to Canada. Areas of highest fine-scale sighting rates (no. of transect sightings/transect km surveyed in 5 km grid cells) were north and west of Smith Bay (Block 12), between Smith Bay and Cape Halkett (Block 3), and north of Flaxman Island (Block 1) (Fig. 12). There were 55 bowhead whale sightings on transect, ranging from 1 whale per sighting (n = 24) to 24 whales per sighting. The highest number of sightings on transect was in Block 12 with 30 sightings, followed by Block 3 with 10 sightings. The largest group of bowhead whales on transect (24 animals) was observed on 13 October northwest of Smith Bay in Block 12.

Highest sighting rates per Survey Block were in Block 12 (0.092 bowhead whales on transect/transect km flown), Block 3 (0.023 bowhead whales on transect/transect km flown) and Block 1 (0.013 bowhead whales on transect/transect km flown) (Table 4). Sighting rates using all bowhead whale sightings per Survey Block were similar to sighting rates using bowhead whales seen on transect only, except in Block 12. This is likely due to the influence of a single survey in Block 12 on 13 October, when 70% of all whales seen (208 whales out of a total 297 whales) were sighted during search or circling. Survey Block sighting rate analyses for light ice years in the 1980s and early 1990s (e.g., Ljungblad et al. 1987; Treacy, 1988, 1990, 1991, 1994, 1995, 1996, 1997, 1998) analyzed total number of bowhead whales/survey hour flown, and did not remove non-surveyable time periods (due to lack of suitable visibility) or time spent surveying inside the barrier islands and north of 72°N. Nonetheless, the pattern of highest sighting rates per year is similar across all years. In recent light ice years (2006-2008), highest sighting rates were generally in coastal Survey Blocks (1, 3, 4, 5, and 12), and were usually correlated with large groups of bowhead whales in feeding or milling aggregations (Clarke et al. 2011).

Sighting rates for bowhead whales in both the central/eastern (140°-154°W) and western (154°-157°W) Alaskan Beaufort Sea subareas were highest in the ≤ 20 m depth zone (Table 5). Transect survey effort in this depth contour (1,327 transect km) accounted for only 15% of the

Table 3. -- Summary of marine mammal sightings, 1 September-18 October 2009, by survey flight (number of sightings/number of individuals).

Day	Flight no.	Bowhead whale	Beluga	Harbor porpoise	Unidentified cetacean	Bearded seal	Walrus	Unidentified pinniped	Polar bear
1 Sep	1	0	0	0	0	0	0	0	1/1
2 Sep	2	0	0	0	0	3/3	0	53/274	1/1
3 Sep	3	2/2	0	0	0	6/8	0	26/222	0
5 Sep	4	0	9/27	0	0	0	0	1/2	0
6 Sep	5	9/12	0	0	1/1	0	0	0	1/1
14 Sep	6	0	0	0	0	0	0	0	0
16 Sep	7	0	0	0	0	0	0	0	0
19 Sep	8	0	0	0	0	0	0	0	1/1
25 Sep	9	0	0	0	0	0	0	0	3/8
28 Sep	10	3/11	1/1	0	1/1	6/7	0	38/63	5/9
29 Sep	11	5/5	0	0	0	0	0	14/14	0
1 Oct	12	12/12	1/1	1/1	0	3/3	0	38/69	0
2 Oct	13	5/6	0	0	0	2/2	0	13/14	0
6 Oct	14	9/29	10/22	0	0	9/9	1/1	111/157	0
10 Oct	15	0	0	0	0	1/1	0	2/2	0
12 Oct	16	3/5	3/5	0	0	3/3	0	32/47	1/7
13 Oct	17	26/297	24/367	0	0	5/5	0	20/46	0
18 Oct	18	3/5	2/16	0	0	2/2	0	14/23	1/15
Semimonthly Sighting Summary									
1-15 Sep		11/14	9/27	0	1/1	9/11	0	80/498	3/3
16-30 Sep		8/16	1/1	0	1/1	6/7	0	52/77	9/18
1-15 Oct		55/349	38/395	1/1	0	23/23	1/1	216/335	1/7
16-18 Oct		3/5	2/16	0	0	2/2	0	14/23	1/15
Total		77/384	50/439	1/1	2/2	40/43	1/1	362/933	14/43

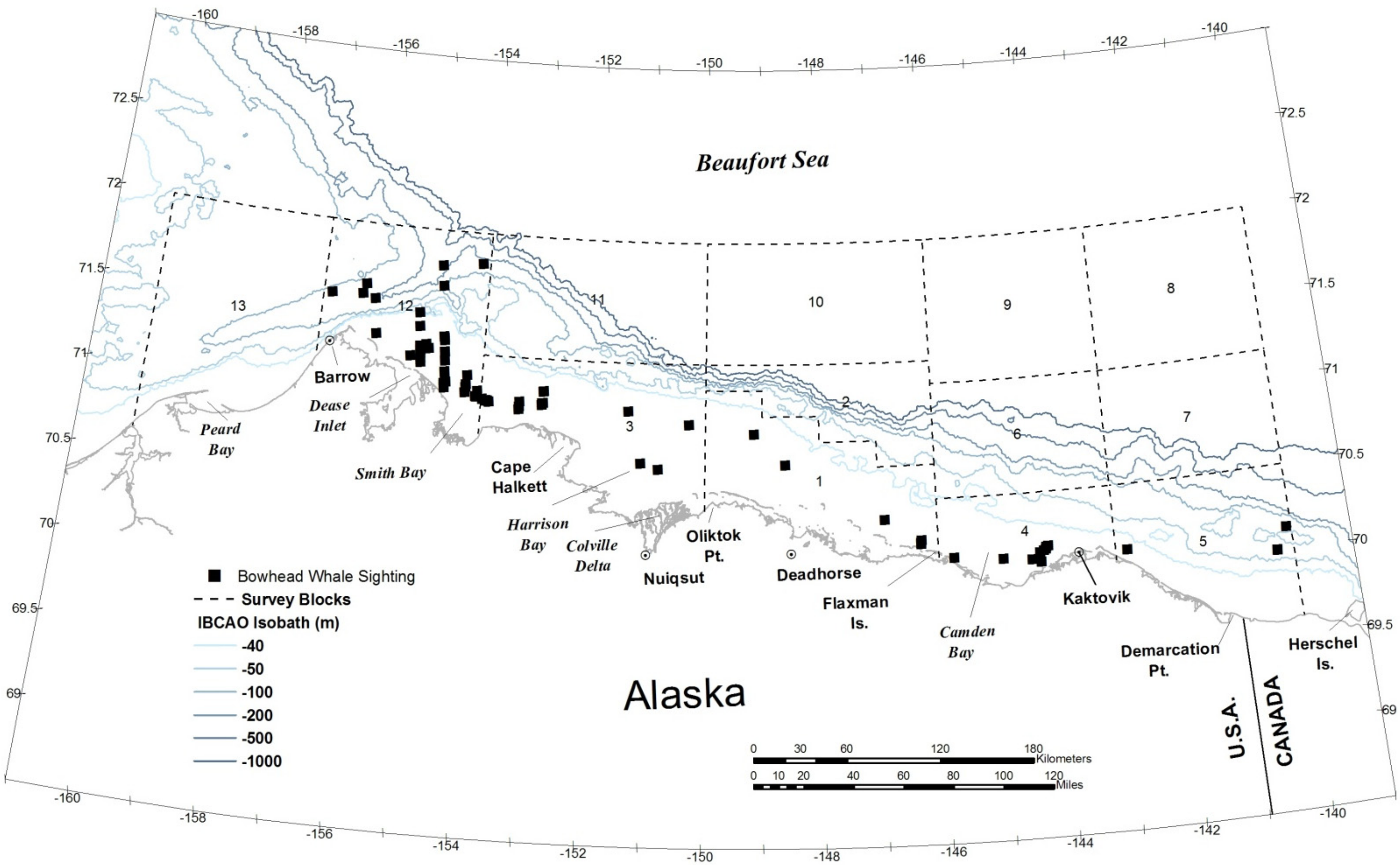

Figure 7. -- Bowhead whale sightings, fall 2009.

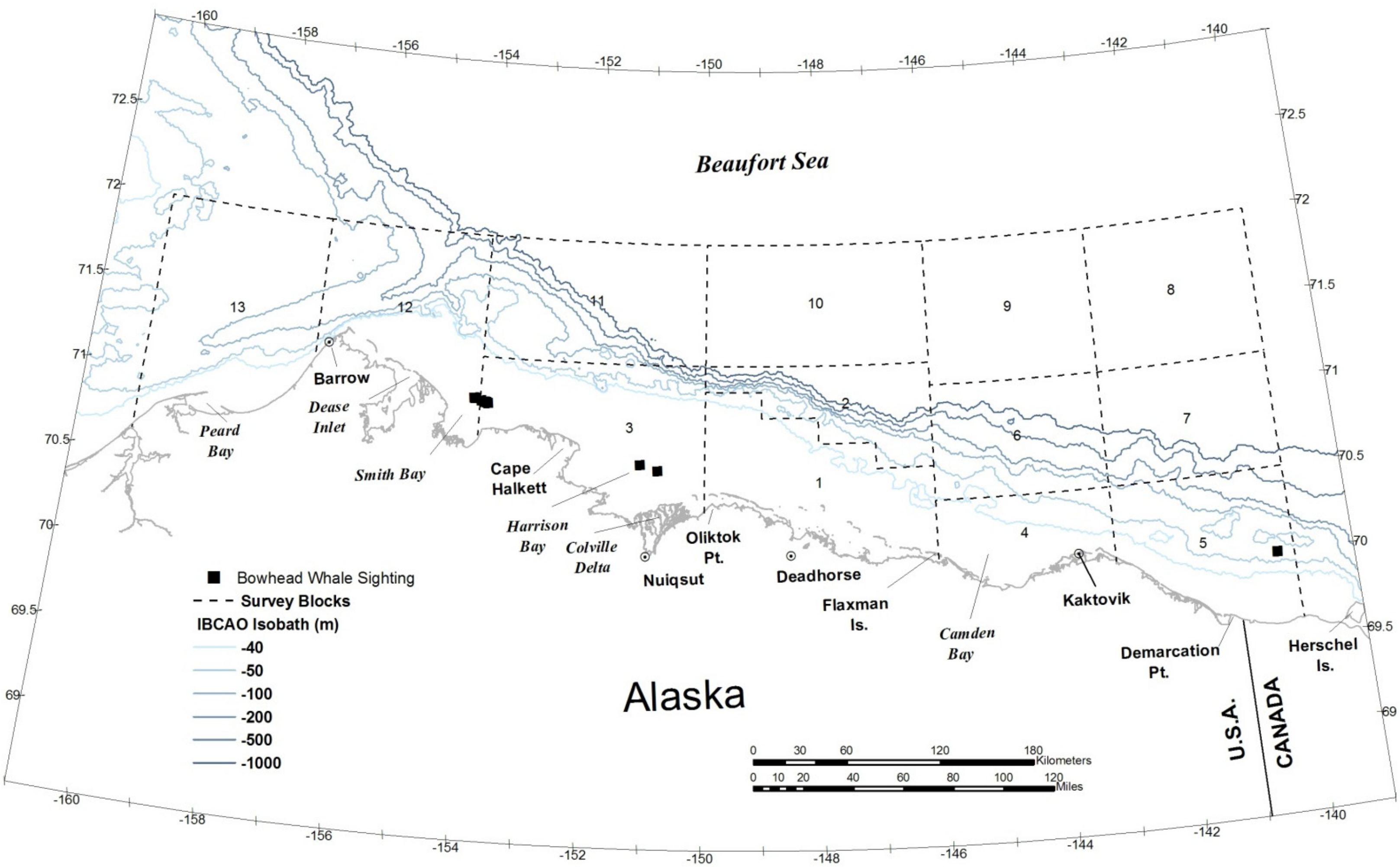

Figure 8. -- Bowhead whale sightings, 1-15 September 2009.

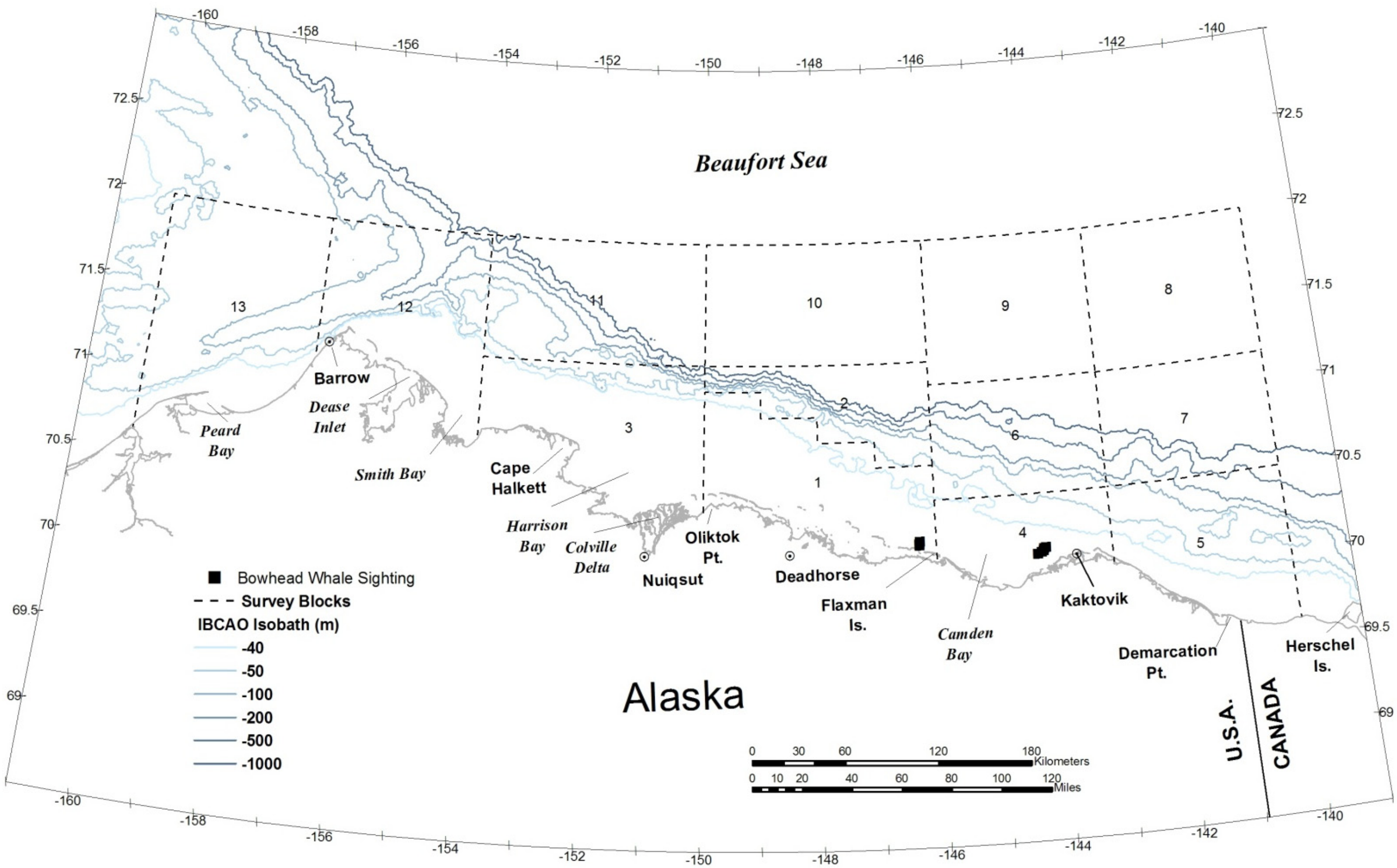

Figure 9. -- Bowhead whale sightings, 16-30 September 2009.

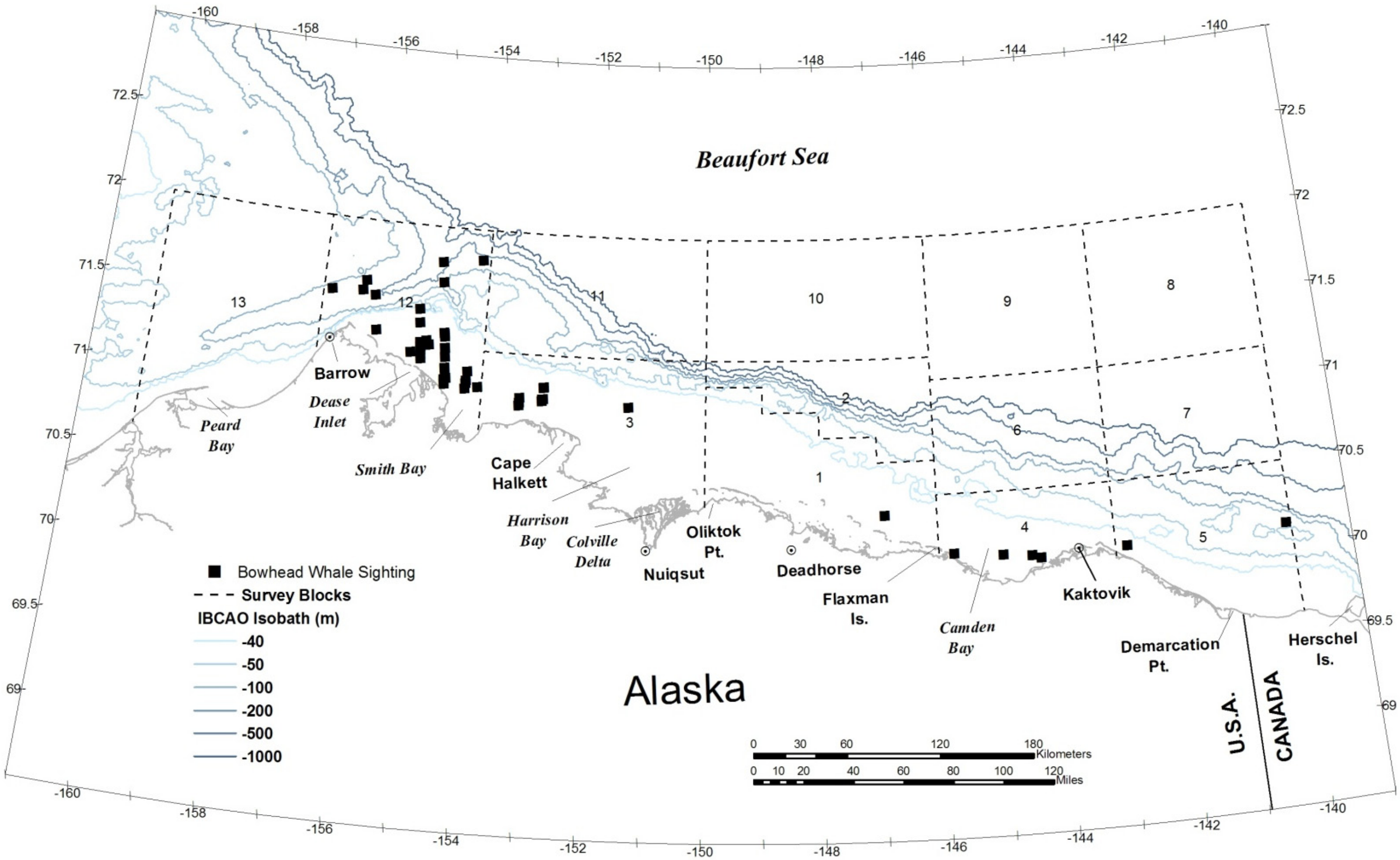

Figure 10. -- Bowhead whale sightings, 1-15 October 2009.

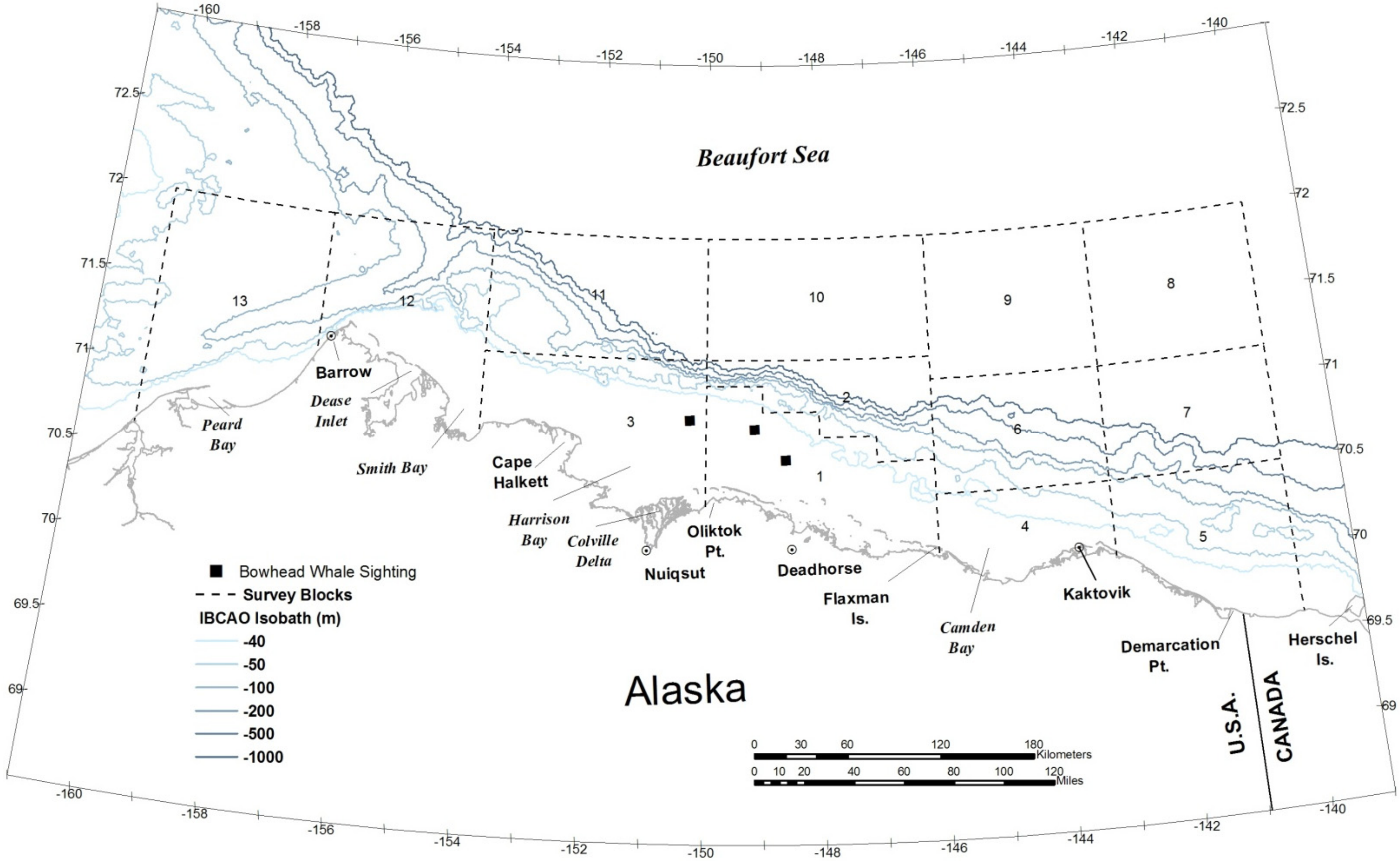

Figure 11. -- Bowhead whale sightings, 16-18 October 2009.

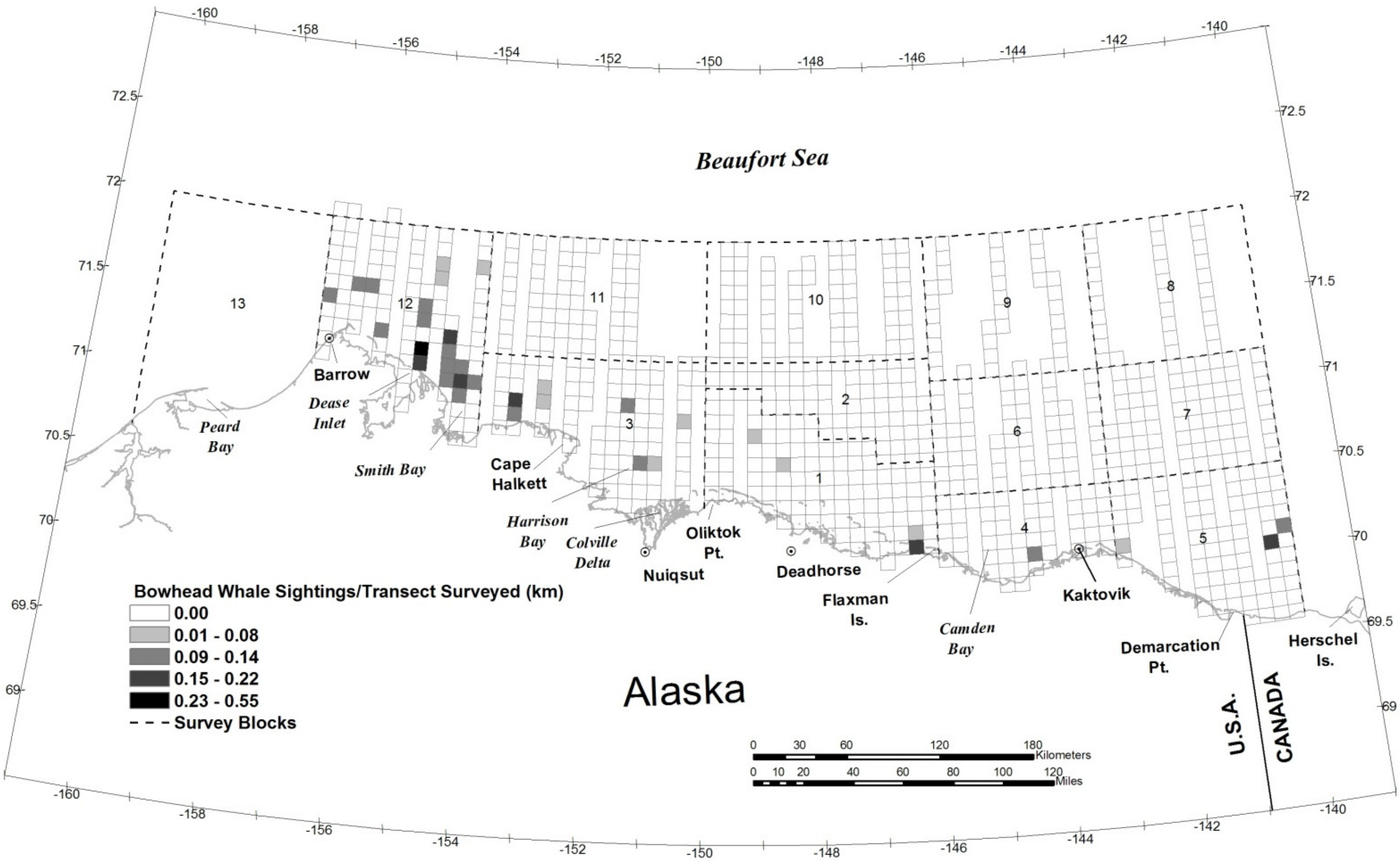

Figure 12. -- Sighting rates of bowhead whales, fall 2009 (bowhead whale sightings on transect/km of transect surveyed).

Table 4. -- Sighting rate (whales per km surveyed) per Survey Block for all bowhead whales and bowhead whales on transect, fall 2009.

Block	Total effort (km)*	Total bowheads (no. animals)	Transect effort (km)*	Transect bowheads (no. animals)	Transect WPUE
1	1,709	16	1,059	14	0.0132
2	872	0	714	0	0.0000
3	1,968	40	1,028	24	0.0233
4	1,250	9	580	1	0.0017
5	1,406	7	1,044	7	0.0067
6	999	0	626	0	0.0000
7	1,244	0	1,001	0	0.0000
8	375	0	281	0	0.0000
9	351	0	278	0	0.0000
10	608	0	569	0	0.0000
11	532	0	497	0	0.0000
12	1,580	312	1,087	100	0.0920
Total	12,895	384	8,764	146	0.0167

* Total and transect effort (km) do not match values in Table 2 because effort between barrier islands and the mainland was not included in this sighting rate analysis by block.

Table 5. -- Sighting rate (whales per km surveyed) per depth zone for bowhead whales on transect, fall 2009.

	West of 154°W			East of 154°W		
Depth zone	Tr-km*	No. bowheads	WPUE	Tr-km*	No. bowheads	WPUE
≤ 20 m	305	71	0.2329	1,022	31	0.0303
21-50 m	252	19	0.0754	2,202	11	0.0050
51-200 m	525	8	0.0152	1,226	4	0.0033
201-2,000 m	114	2	0.0175	1,628	0	0.0000
> 2,000 m	0	0	0.0000	1,701	0	0.0000
Total	1,196	100	0.0836	7,779	46	0.0059

* Tr-km – kilometers on transect; WPUE – whales per unit effort

total transect effort, while 70% of all bowhead whales (102 whales out of 146 total) were observed at those depths.

Sighting rates for the western Alaskan Beaufort Sea (154°-157°W) were considerably higher than those calculated for the central/eastern part of the study area, likely due to the influence of sightings during a single survey in October when feeding bowhead whale aggregations were seen.

Table 6. -- Semimonthly summary of bowhead whales observed, by percent ice cover present at sighting location, fall 2009.

Percent Ice Cover	1-15 Sep	16-30 Sep	1-15 Oct	16-18 Oct	Total
0	14 (100%)	16 (100%)	163 (46%)	5 (100%)	198 (51%)
1-5	0 (0%)	0 (0%)	186 (53%)	0 (0%)	186 (48%)
Total	14	16	349	5	384

Habitat Associations

Weekly ice coverage for the Alaskan Beaufort Sea during fall 2009 is included in Appendix A, and the percentage of ice cover visible from the aircraft at each bowhead whale sighting is included in Appendix B. All bowhead whales were observed in 5% or less sea ice cover (Table 6). Bowhead whales were not seen in offshore Survey Blocks, which were the only areas where sea ice coverage greater than 5% was present.

Behaviors

Behaviors of 359 bowhead whales observed during fall 2009 are summarized in Table 7. The behavior most often recorded (64%) was feeding. Swimming was recorded for 91 whales (23%). Most swimming whales for which swim direction was recorded were heading west or northwest (mean = 248° True, median = 267° True, range = 64°-358° True). Feeding and milling were recorded only in Blocks 3 and 12 in 2009, and all feeding behavior in Block 12 was observed on one date (13 October). Sighting rates of feeding and milling whales observed on transect are shown in Figure 13.

Block 12 is a well-documented bowhead whale feeding ground (Moore and Reeves 1993) and is the site of the MMS-sponsored Bowhead Whale Feeding Ecology Study (BOWFEST). Preliminary results from BOWFEST indicate that sustained winds from the east promote upwelling of krill from deeper waters onto the Beaufort shelf (Ashjian et al. 2010), whereupon the wind-driven, northwestward-flowing shelf current carries the krill toward Barrow. When easterly winds weaken and change to blow from the south, the northeastward-flowing Alaska Coastal Current moves adjacent to the southern edge of Barrow Canyon, thereby blocking the northwestward, alongshore movement of krill. This phenomenon results in the aggregation of krill at the western end of the Beaufort shelf near Barrow. The oceanographic response to the sequence of upwelling-favorable winds followed by weak southerly winds produces conditions conducive to energetically efficient feeding by bowhead whales.

Surveys were conducted in Block 12 on two occasions during BWASP 2009, with very different results (Fig. 14). On 1 October, 12 individual bowhead whales were seen during very good survey conditions (Beaufort 1 to 3, 5-10 km visibility) in two distinct areas. Most sightings were within the 20 m contour just north of Smith Bay, while two sightings were north of Point Barrow

Table 7. -- Semimonthly summary of bowhead whales observed, by behavioral category, fall 2009. Behavior was not recorded for all sightings.

Behavior	1-15 Sep	16-30 Sep	1-15 Oct	16-18 Oct	Total
cow with calf	0 (0%)	0 (0%)	0 (0%)	4 (80%)	4 (1%)
dive	0 (0%)	0 (0%)	4 (1%)	0 (0%)	4 (1%)
feed	2 (14%)	0 (0%)	246 (70%)	0 (0%)	248 (64%)
mill	0 (0%)	0 (0%)	11 (3%)	0 (0%)	11 (2%)
rest	1 (7%)	0 (0%)	0 (0%)	0 (0%)	1 (< 1%)
swim	1 (7%)	16 (100%)	73 (20%)	1 (20%)	91 (23%)
none recorded	10 (71%)	0 (0%)	15 (4%)	0 (0%)	25 (6%)
Total	14	16	349	5	384

in the Barrow Canyon area. None of the whales were reported feeding or milling, and nearly all whales were swimming in a westerly direction. On 13 October, 297 bowhead whales were observed during very good survey conditions (Beaufort 1 to 3, 5-10 km visibility). Several sightings were within the 20 m contour between Smith Bay and Point Barrow, with a few sightings offshore in deeper water. Most (87%) of the whales were reported as feeding or milling, including one group estimated at greater than 180 whales. Sightings of feeding and milling bowhead whales on 13 October were ~15-20 km northwest of the sighting locations of non-feeding bowhead whales on 1 October.

Wind conditions prior to these two sighting events were noticeably different. Information on wind speed and direction, as well as other environmental variables, were collected three times per day from the National Weather Service, Alaska Aviation Weather Unit web site (http://aawu.arh.noaa.gov/) for Barrow, and plotted for several days preceding the BWASP bowhead whale sighting events in Block 12. Winds prior to the 1 October sighting event (12 non-feeding singleton whales) were variable, but predominantly easterly and ~10 knots or less for the two days prior to 1 October (Fig. 15). Winds prior to the 13 October sighting event (> 200 feeding whales) were also predominantly easterly but in excess of 20 knots on 7 October at Barrow, and remained greater than 15 knots until 11 October. Winds were weak (5-7 knots) and from the south by 13 October when the large aggregation of feeding whales was seen. Therefore, it would appear that BWASP 2009 bowhead whale sightings in Block 12 are consistent with the predicted mechanism of zooplankton aggregation and availability proposed by Ashjian et al. (2010).

Marine mammal observers and flight crew watched for sudden overt changes (e.g., an abrupt dive, course diversion, or cessation of initial behavior observed) in whale behavior that may indicate a response to the survey aircraft. One bowhead whale (< 1% of all whales observed) responded to the aircraft.

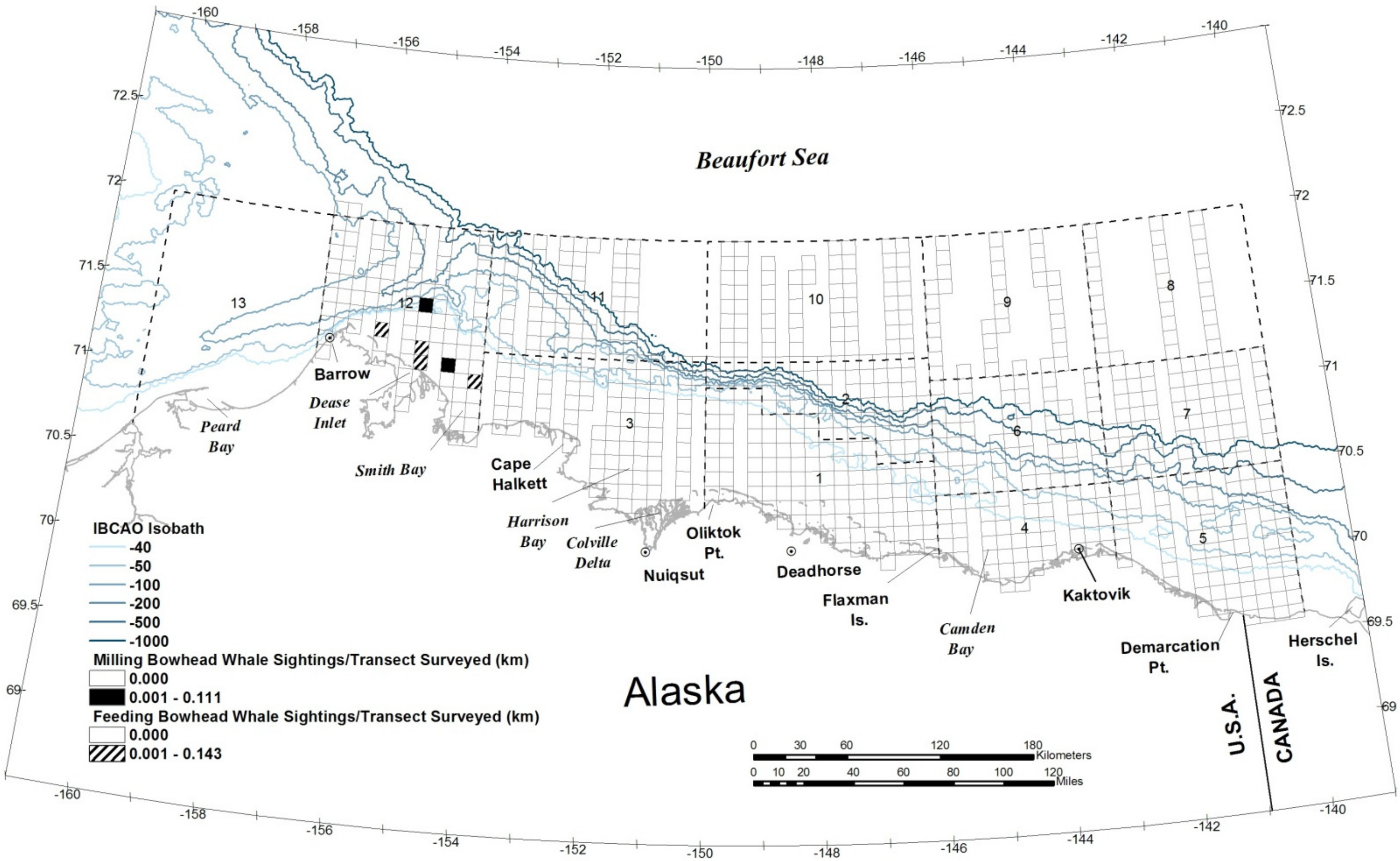

Figure 13. -- Sighting rates of milling and feeding bowhead whales, fall 2009 (bowhead whale sightings on transect/km of transect surveyed). Isobaths are in meters.

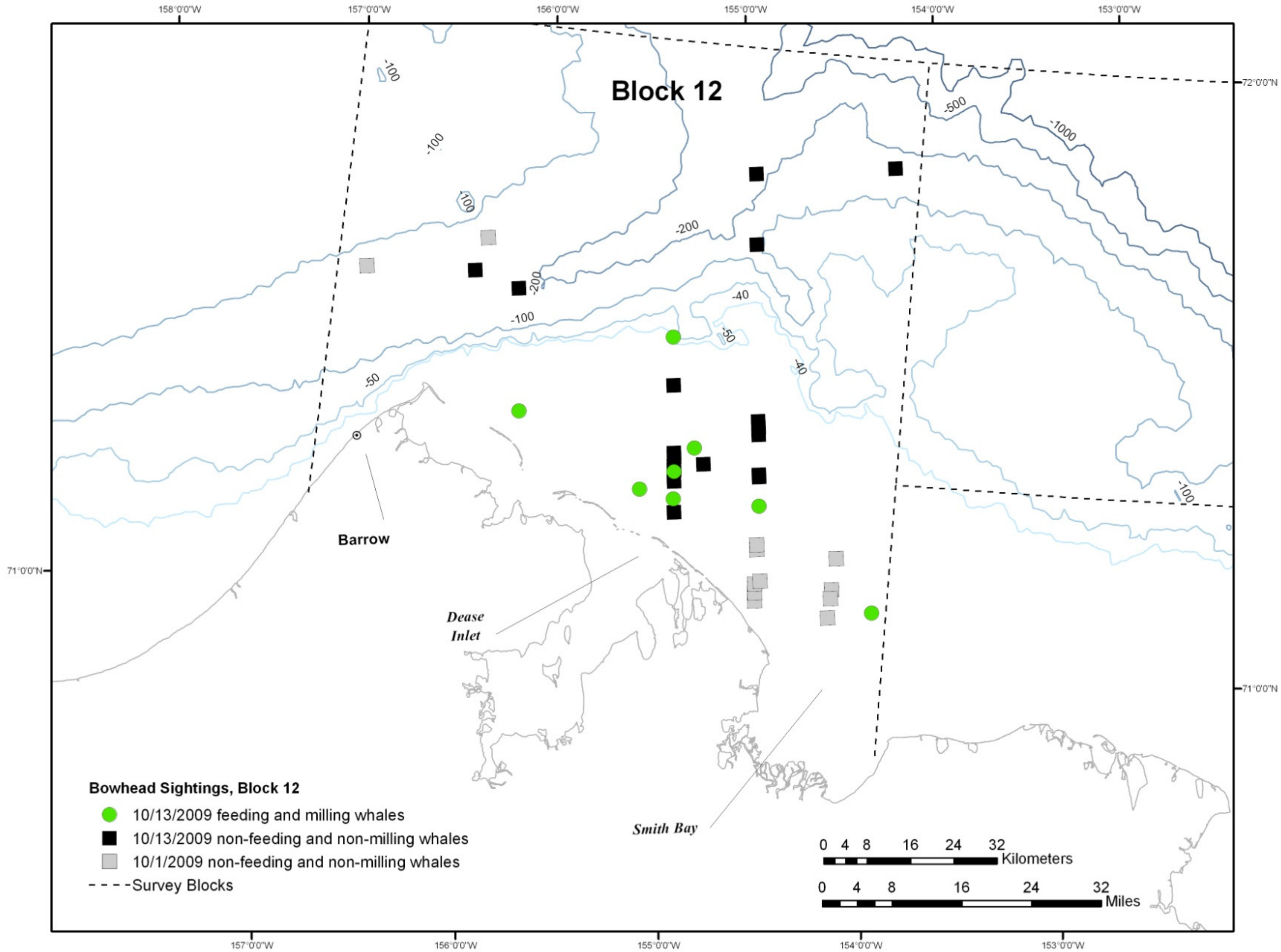

Figure 14. -- Bowhead whale sightings in Block 12 on 1 and 13 October 2009. Isobaths are in meters.

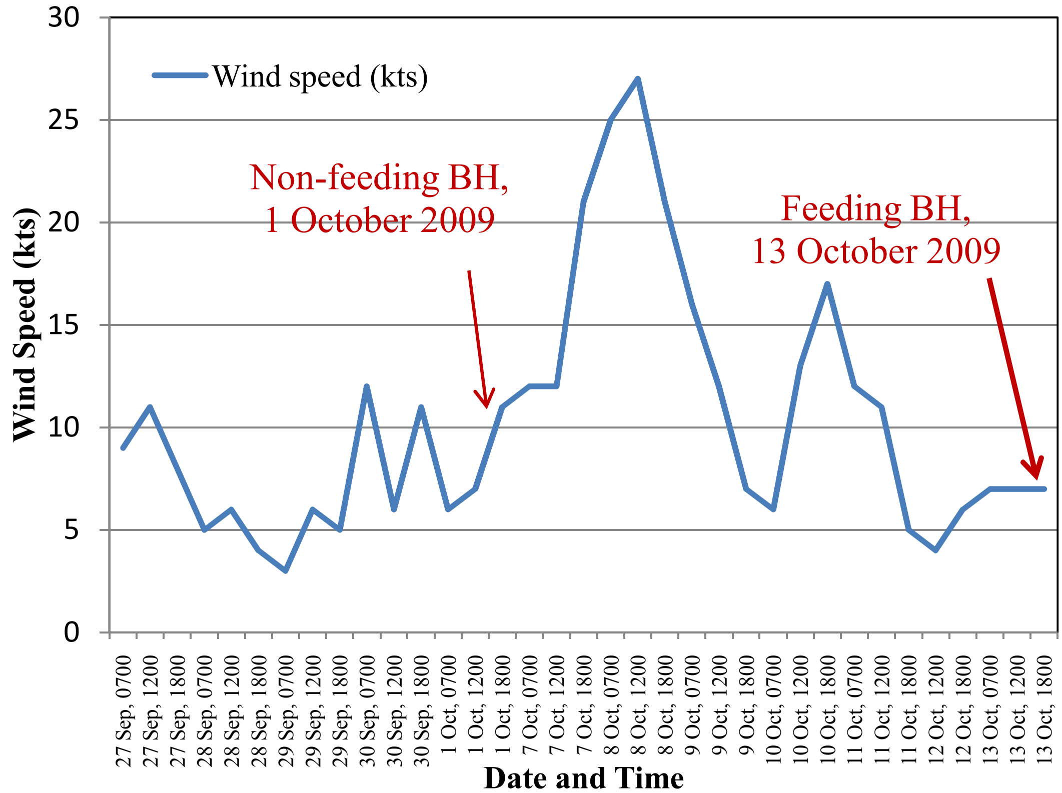

Figure 15. -- Wind speeds measured at Barrow prior to 1 and 13 October 2009. BH = bowhead whale.

Distance from Shore

Distances from shore of fall 2009 bowhead whale transect sightings were measured, using ArcGIS, as the distance due north of a normalized shoreline. Mean distance of locations of *all* bowhead whale transect sightings to a normalized shoreline in 2009 was 20.2 km (SD = 21.1) in the East Region, and 23.1 km (SD = 17.1) in the West Region (Table 8, Fig. 16). Mean distance of locations of “migrating” bowhead whale transect sightings (i.e., excluding those sightings of feeding, milling, or resting whales) was 24.2 km (SD = 17.8) in the West Region (Fig. 17). A Mann-Whitney U-test of significant difference between medians indicates no difference between distances of all whales versus distances of only those whales considered “migrating” in the West Region (Z = -0.281, P = 0.7790). Comparison of migrating bowhead whales with all bowhead whales in the East Region was not undertaken because only one of the nine sightings on transect was recorded as non-migrating (i.e., was feeding, milling, or resting).

Table 8. -- Central-tendency statistics for distance from shore (km) and depth (m) at bowhead whale transect sightings (September-October), by year and region, 1982-2009.

			Distance from shore (km)				Depth (m)			
Year	Region	TrSi	Median	Mean	SD	Min-Max	Median	Mean	SD	Min-Max
1982*	East	29	35.4	35.2	7.44	25-52	42	43	6.29	35-57
	West	27	40.1	41.4	15.47	14-84	31	92	207.03	14-1041
1983	East	14	84.8	83.4	14.91	57-115	804	916	718.72	65-1953
	West	15	47.5	56.4	25.14	24-122	68	313	597.95	21-2166
1984	East	23	33.3	35.8	22.43	2-98	44	77	104.86	18-508
	West	36	42	41.4	17.71	8-73	40	48	33.24	13-189
1985	East	10	28.1	29.3	14.62	2-56	39	38	7.31	23-51
	West	7	49.5	51.2	28.07	13-86	36	193	348.59	16-975
1986*	East	30	23.4	24.7	15.06	1-55	41	38	18.22	7-92
	West	19	34.3	36.8	21.29	4-80	28	78	117.51	10-490
1987*	East	34	30.5	32.9	17	6-79	39	53	45.72	15-223
	West	8	28.3	27.9	15.5	6-46	26	23	10.04	8-32
1988	East	6	26.2	29.1	20	5-66	49	92	123.39	23-343
	West	8	57.6	58.5	5.96	50-67	50	50	6.57	41-63
1989*	East	6	49.38	58.3	24.72	31-91	61	196	219.75	47-509
	West	17	33	28	15.82	7-64	20	19	8.2	6-34
1990*	East	93	31.6	31.5	12.53	8-78	42	48	33.05	20-285
	West	6	33.1	36.8	12.66	25-60	32	33	11.47	20-51
1991	East	15	51.3	52.5	20.23	22-79	55	122	108.45	35-387
	West	6	42.3	48.8	19.97	29-76	42	97	94.29	26-230
1992	East	12	36.1	39.2	11.94	24-60	54	51	6.07	40-59
	West	13	57.1	53.5	14.71	23-74	51	54	27.82	14-121
1993*	East	55	26.1	29	15.79	6-81	41	58	96.59	11-717
	West	35	23.9	28.1	12.38	11-62	20	23	9.29	11-49
1994*	East	32	27.3	35.1	18.57	12-74	47	80	175.67	31-1038
	West	3	17.9	22.3	11.6	14-35	12	22	16.74	12-41
1995*	East	94	27.2	29.8	14.93	3-99	42	52	68.74	15-628
	West	44	35.9	41.1	24.43	6-108	31	107	259.75	7-1233
1996*	East	13	27.9	26.3	10.45	14-53	29	38	9.16	15-48
	West	15	39.9	39	15.22	19-63	35	37	16.93	19-82
1997*	East	35	9.3	13.8	11.33	3-43	22	24	11.97	11-50
	West	145	23.6	25.6	11.33	1-57	20	25	21.42	5-189
1998*	East	103	20.4	22.1	12.61	3-68	32	34	12	7-83
	West	113	18.5	23.6	17.53	1-120	15	38	170.85	5-1815
1999*	East	68	36.4	35.3	11.5	1-59	50	51	20.94	8-171
	West	68	33	36.2	16.21	8-74	31	43	42.94	11-210

			Distance from shore (km)				Depth (m)			
	Region	TrSi	Median	Mean	SD	Min-Max	Median	Mean	SD	Min-Max
2000*	East	26	34	39.3	20.86	13-100	41	82	122.01	28-559
	West	19	9.3	16.2	18.23	1-78	11	32	81.58	4-367
2001*	East	16	31.5	29.7	112.2	12-48	46	43	8.73	27-53
	West	2	na	41.9	42.31	12-72	29	29	26.17	10-47
2002*	East	16	14.8	19	16.62	2-61	29	28	13.13	0-50
	West	23	33.9	35.6	12.31	10-57	24	27	12.17	11-61
2003*	East	33	34.7	29.8	19.3	4-65	40	39	16.75	12-92
	West	41	30.5	32.4	18.38	7-86	23	58	74.28	8-291
2004*	East	67	21.5	24.2	11.63	2-73	39	43	48.36	6-423
	West	60	23.1	23.5	10.4	1-66	20	31	35.68	4-211
2005*	East	19	28.1	26.4	14.15	3-45	42	39	12.39	12-57
	West	27	38.3	39.8	20.37	5-74	33	59	71.51	10-285
2006*	East	45	34.3	39.3	22.42	4-92	44	196	445.99	8-1868
	West	46	39.2	37.2	19.63	3-74	32	40	34.06	7-204
2007*	East	49	21.8	23.2	14.43	1-74	34	43	54.2	14-403
	West	6	25.7	25.7	64.8	15-35	23	23	8.55	12-35
2008*	East	25	21.3	20.5	10.65	6-38	29	27	7.68	12-40
	West	37	18.4	22.6	13.92	3-57	15	17	6.91	3-33
2009*	East	9	6.6	20.2	21.1	3-57	21	30	19.77	11-56
	West	42	16.9	23.1	17.06	5-87	17	30	44.67	9-245

TrSi – number of bowhead whale sightings on transect
SD – standard deviation
* – light ice years

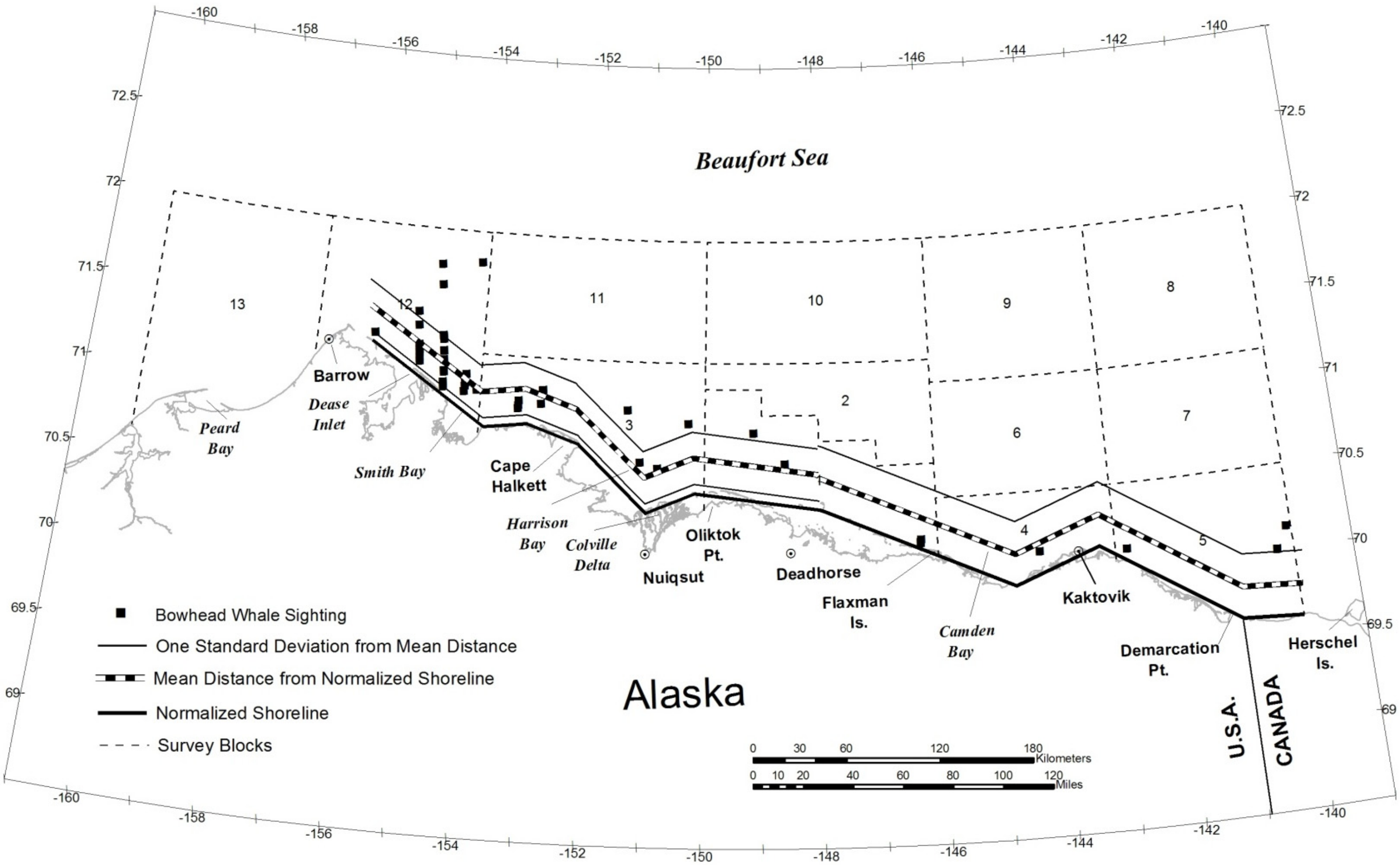

Figure 16. -- Bowhead whale sightings on transect, fall 2009, showing mean distance from a normalized shoreline.

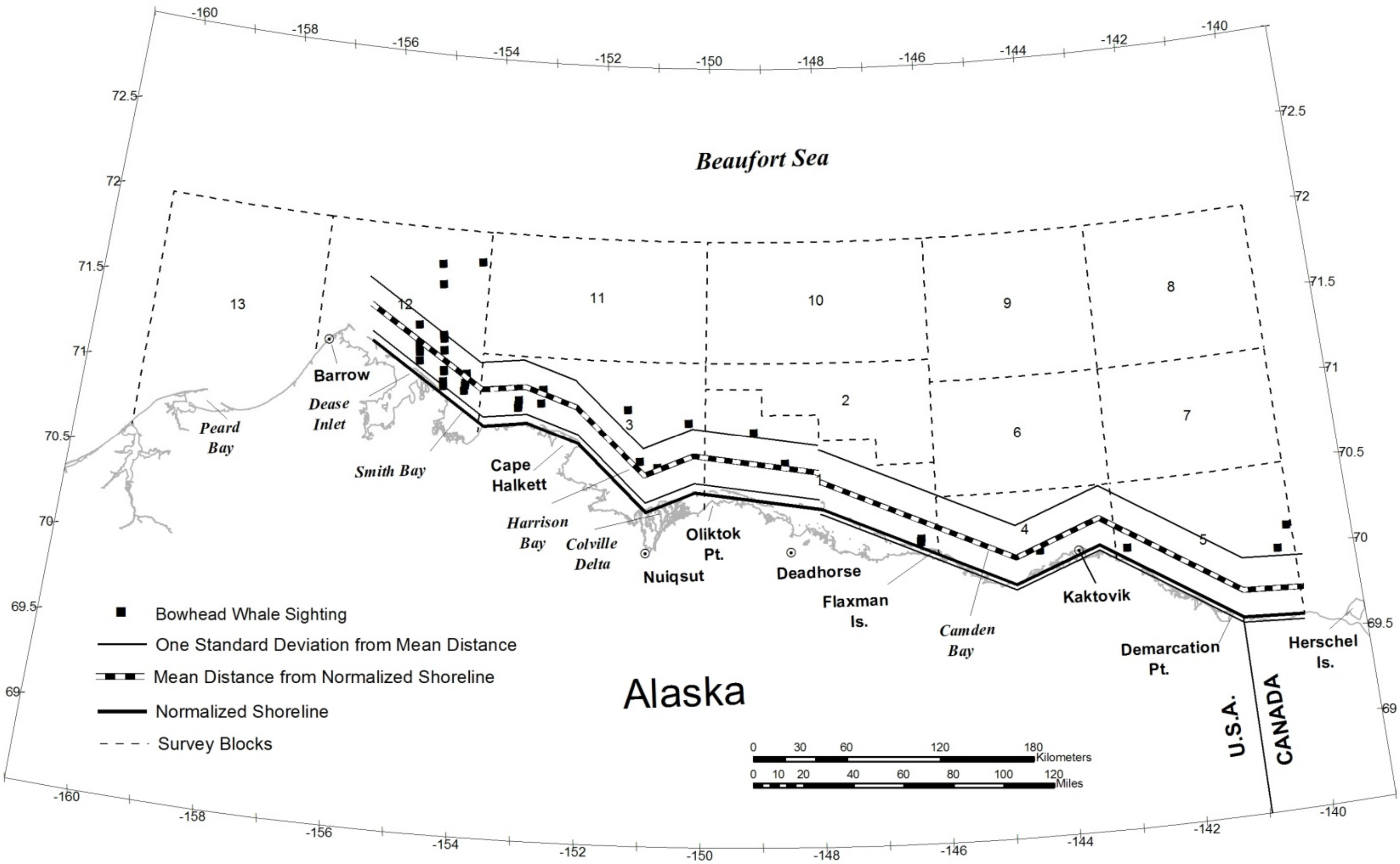

Figure 17. -- Bowhead whale sightings on transect excluding feeding, milling and resting whales, fall 2009, showing mean distance from a normalized shoreline.

Depth at Sighting

Mean depth at sightings of *all* bowhead whales on transect was 30 m (SD = 19.8, range 11-56 m) in the East Region, and 30 m (SD = 44.7, range 9-245 m) in the West Region (Table 8). Mean depth of "migrating" bowhead whales on transect (i.e., excluding those sightings of feeding, milling or resting whales), was 32 m (SD = 47.9, range 9-245 m) in the West Region. A Mann-Whitney U-test of significant difference of medians indicates no difference between depths of all whales versus depths of only those whales considered "migrating" in the West Region (Z = -0.085, P = 0.9321). As with distance from shore, comparison of "migrating" only bowhead whales with all bowhead whales in the East Region was not necessary because sample size was insufficient.

Based on the lack of significant difference between all bowhead whale sightings in 2009 and sightings limited to those whales considered "migrating," additional analyses of the bowhead whale migration corridor incorporated all sightings and were not limited to only those animals considered actively "migrating".

Distribution of Migrating Bowhead Whales, 2009, Relative to Previous Light Ice Years

In order to evaluate whether significant displacements occurred in the bowhead whale migratory corridor during 2009, estimates of median depth at sighting and distance of sightings from a normalized shoreline were compared with data from previous years having light ice coverage (i.e., 1982, 1986, 1987, 1989, 1990, and 1993-2008). Median distance from shore during previous light ice years for bowhead whale sightings was 26.5 km in the East Region and 26.8 km in the West Region; the median water depth at sightings was 40 m in the East Region and 22 m in the West Region.

In 2009, bowhead whales in the East Region were closer to shore (6.6 km vs. 26.5 km) and in shallower water (21 m vs. 40 m) than in previous light ice years, but these differences were not statistically significant, likely because the sample size was very small in 2009 (n = 9).

In the West Region, bowhead whales were significantly closer to shore (16.9 km vs. 26.8 km, Z = -3.188, P = 0.0014) and in shallower water (17 m in 2009 vs. 22 m, Z = -2.453, P = 0.0142) in 2009 compared with previous light ice years.

Other Marine Mammal Observations

No gray whales were observed in fall 2009.

There were 50 sightings of 439 belugas in fall 2009 (Fig. 18). Belugas were seen along the slope and in offshore Blocks 8 and 9, but the greatest numbers were seen in the Barrow Canyon area of Block 12, where sighting rate was highest (0.335 belugas on transect per transect km flown; Table 9). Sighting rate per depth zone was highest in the 201-2,000 m contour for both the central/eastern and western subareas of the BWASP region (Table 10). Belugas are usually

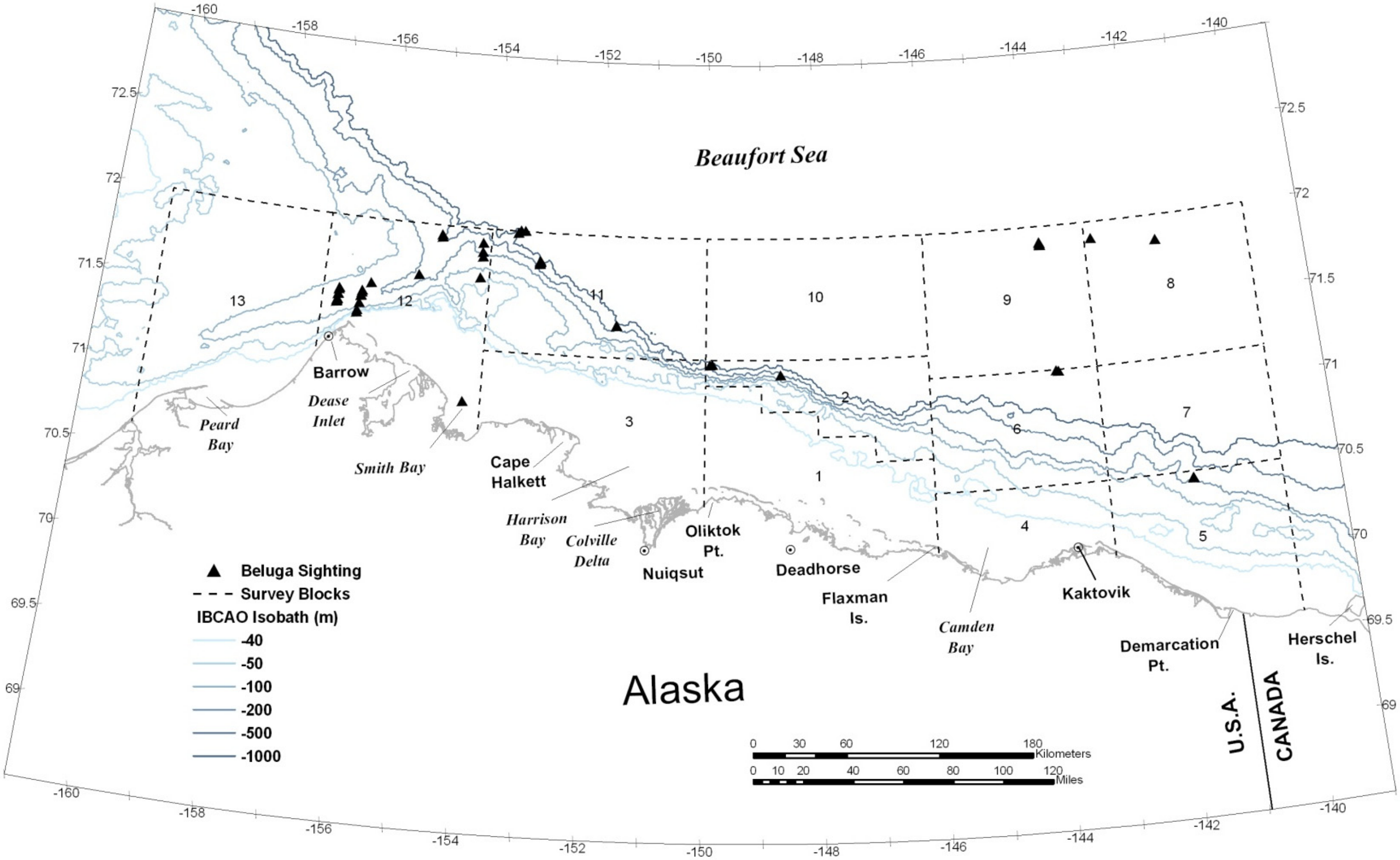

Figure 18. -- Beluga sightings, fall 2009.

Table 9. -- Sighting rate (whales per km surveyed) per Survey Block for all belugas and belugas on transect, fall 2009.

Block	Total effort (km)*	Total belugas (no. animals)	Transect effort (km)*	Transect belugas (no. animals)	Transect WPUE
1	1,709	0	1,059	0	0.0000
2	872	17	714	1	0.0014
3	1,968	0	1,028	0	0.0000
4	1,250	0	580	0	0.0000
5	1,406	5	1,044	5	0.0048
6	999	11	626	0	0.0000
7	1,244	0	1,001	0	0.0000
8	375	7	281	7	0.0249
9	351	9	278	9	0.0323
10	608	0	569	0	0.0000
11	532	22	497	20	0.0402
12	1,580	368	1,087	364	0.3349
Total	12,895	439	8,764	406	0.0463

* Total and transect effort (km) do not match values in Table 2 because effort between barrier islands and the mainland was not included in this sighting rate analysis by block.

Table 10. -- Sighting rate (whales per km surveyed) per depth zone for belugas on transect in the eastern/central and western Alaskan Beaufort Sea, fall 2009.

	West of 154°W			East of 154°W		
Depth zone	Tr-km*	No. belugas	WPUE	Tr-km*	No. belugas	WPUE
≤ 20 m	305	0	0.0000	1,022	0	0.0000
21-50 m	252	7	0.0278	2,202	0	0.0000
51-200 m	525	223	0.4248	1,226	0	0.0000
201-2,000 m	114	134	1.1754	1,628	26	0.0160
> 2,000 m	0	0	0.0000	1,701	16	0.0094
TOTAL	1,196	364	0.3043	7,779	42	0.0054

* Tr-km – kilometers on transect; WPUE – whales per unit effort

associated with ice (Moore et al. 2000), however most (94%) belugas seen in 2009 were in ice-free water as there was no ice cover in most of the study area during the survey period. Belugas seen offshore in Blocks 6, 8, and 9 were associated with ice cover > 30%. Beluga sighting rates were similar to those observed prior to 2007 (Fig. 19); very few belugas were seen during BWASP surveys in 2007 and 2008, possibly due to the retreat of the summer sea ice beyond the extent of BWASP surveys.

There was one sighting of a harbor porpoise on 1 October 2009, at 71.691°N, 156.828°W.

There was one sighting of a walrus on 6 October 2009, at 71.734°N, 152.716°W, swimming in an ice-free area.

Bearded seals (40 sightings of 43 seals) and unidentified pinnipeds (362 sightings of 933 seals) were seen during fall 2009 and were distributed across the Alaskan Beaufort Sea (Figs. 20 and 21). Few pinnipeds were seen in areas where water depths were less than 40 m in the western Alaskan Beaufort Sea (west of ~148°W), although distribution in the eastern part of the study area was in all depths. Unidentified pinnipeds included sightings of small pinnipeds that could not be identified to species due to the altitude of the aircraft (> 1,000 feet), and likely included spotted (*Phoca largha*) and ringed (*Pusa hispida*) seals. The distributions of ringed and spotted seals overlap in the Alaskan Beaufort Sea (Boveng et al. 2009, Angliss and Allen 2009); behaviors and physical characteristics observable from survey altitude are not distinguishable enough to allow positive species identification (D. Rugh and D. Withrow, NMML-AFSC, 7600 Sand Point Way NE, Seattle, WA 98115, pers. commun., 8 December 2009).

There were 14 sightings of 43 polar bears seen on 8 of 18 flights from 1 September to 18 October 2009; some of the bears may have been seen repeatedly (Fig. 22). All but one polar bear were sighted near or on shore, between Flaxman Island and just west of Cape Halkett. A single bear was sighted approximately 140 kilometers north of the barrier islands (71.850°N, 148.974°W), swimming in an ice-free area. Multiple bears were seen on Cross Island on several days: 8 bears on 25 September, 9 bears on 28 September, 7 bears on 12 October, and 15 bears on 18 October. All other bear sightings were singles.

Accomplishments

Results from the 2009 BWASP field season were presented by NMFS personnel at several venues, including:

Clarke, J.T. and M.C. Ferguson. 2010. Aerial surveys for bowhead whales in the Alaskan Beaufort Sea: BWASP update 2000-2009 with comparisons to historical data. Paper SC/62/BRG14 presented at the International Whaling Commission Scientific Committee Meetings, Morocco, June 2010. 11pp. (in preparation for journal submission).

Clarke, J., C. Christman, M. Ferguson and L. Morse. 2010. Bowhead Whale Aerial Survey Project (BWASP) Status Update in 2009. Poster: Alaska Marine Science Symposium, Anchorage, AK, January 2010.

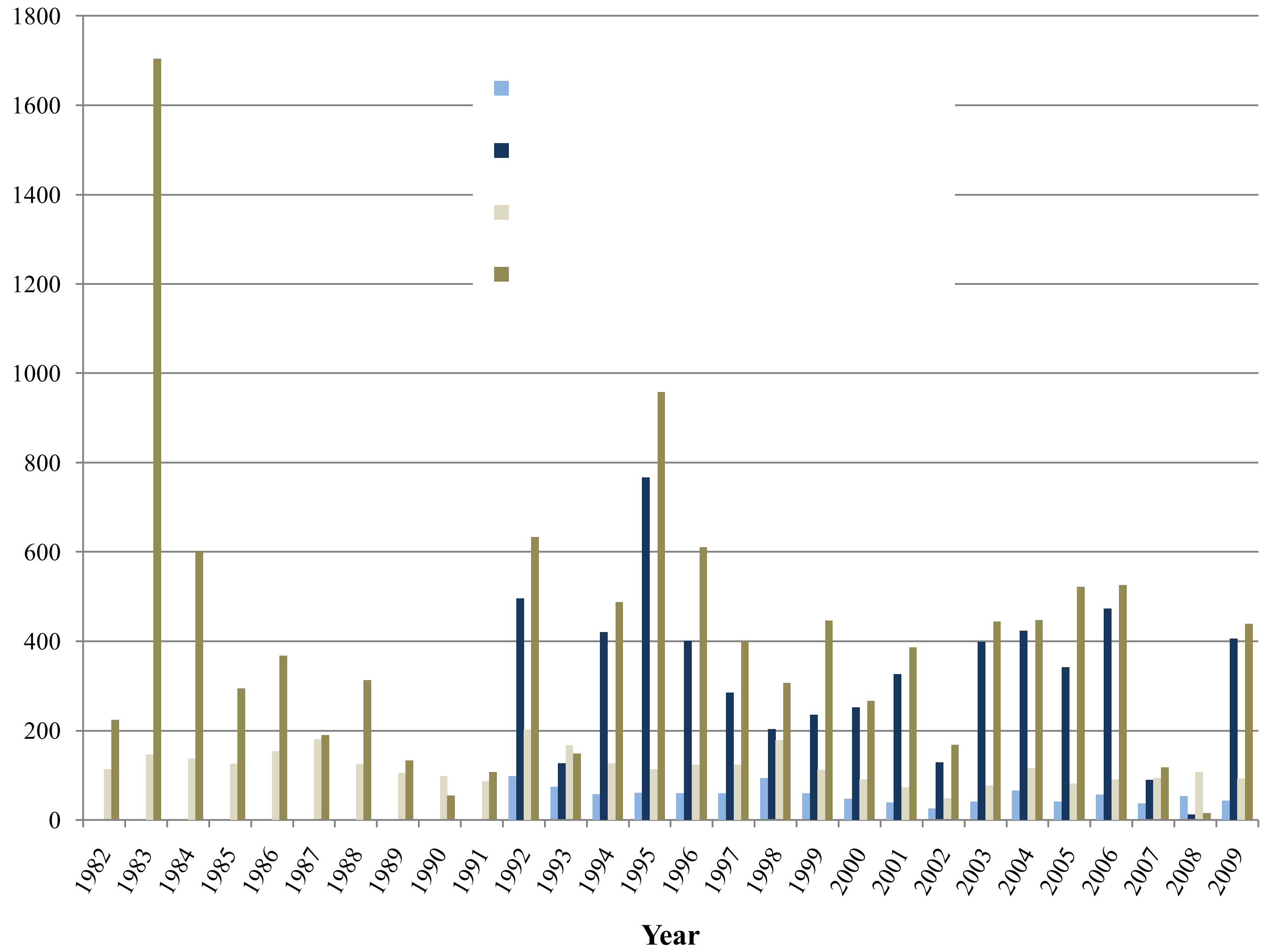

Figure 19. -- Number of belugas and annual effort (hr), total and transect only, 1982-2009. Transect data not available for 1982-1991.

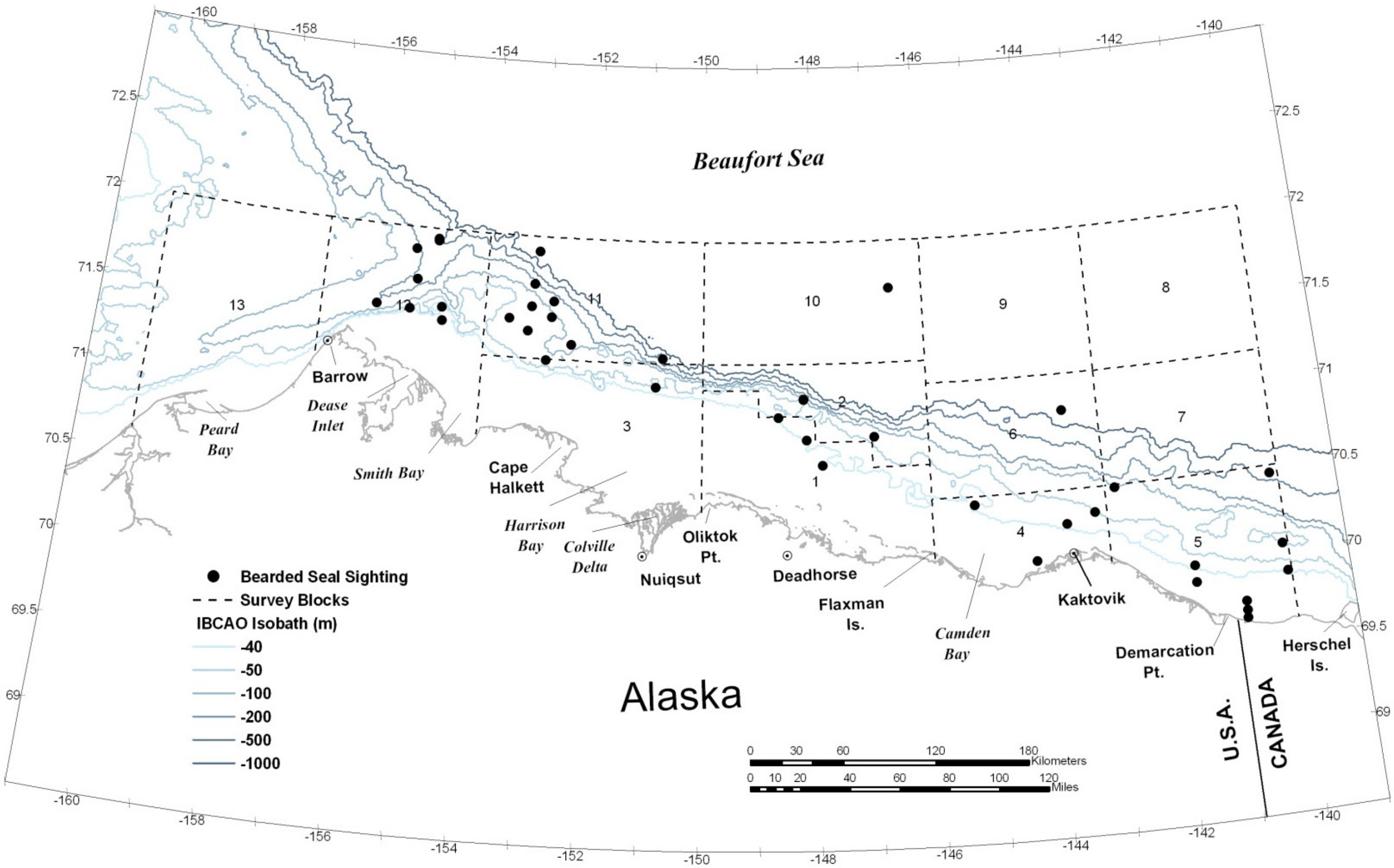

Figure 20. -- Bearded seal sightings, fall 2009.

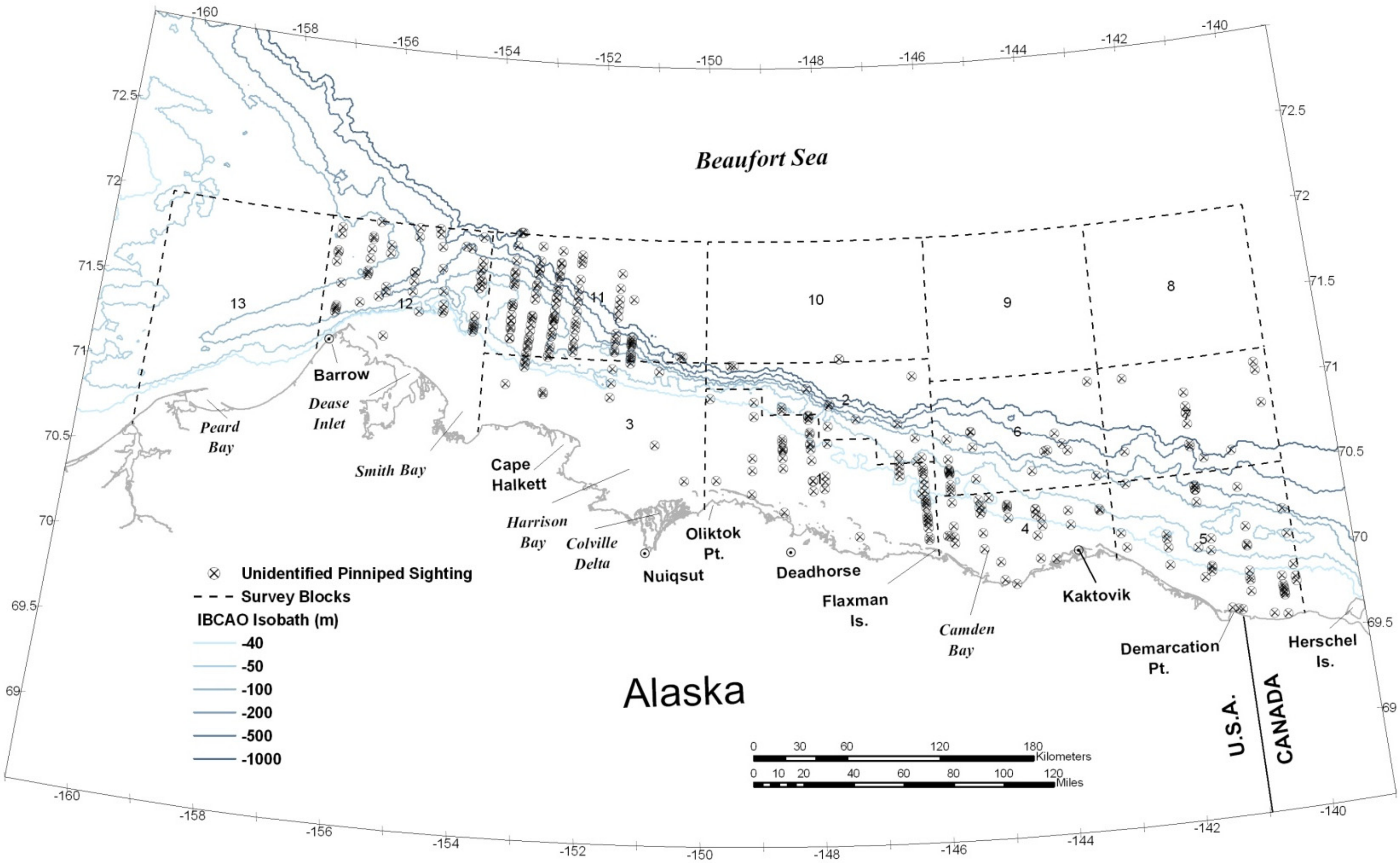

Figure 21. -- Unidentified pinniped sightings, fall 2009.

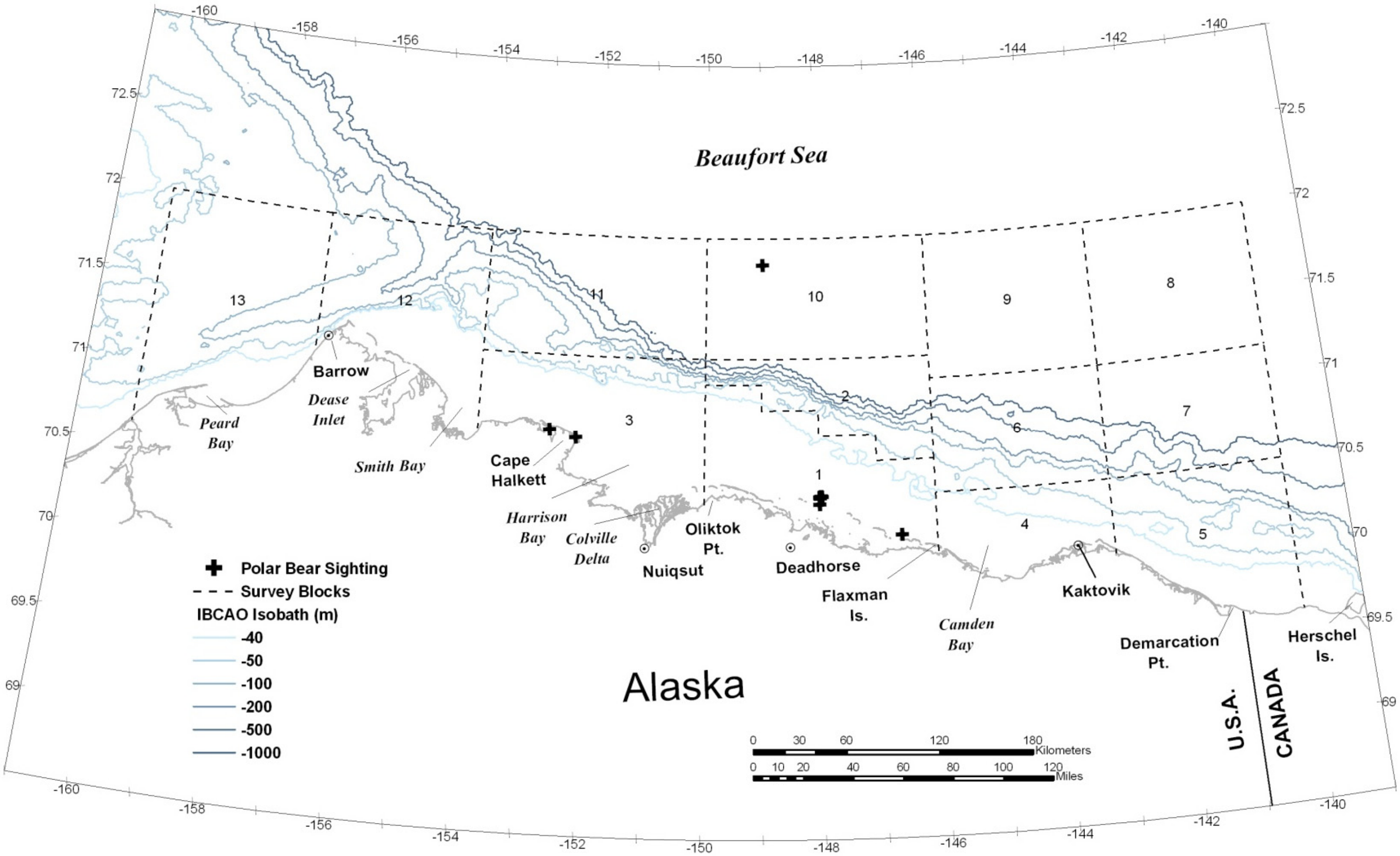

Figure 22. -- Polar bear sightings, fall 2009.

Ferguson, M. and J. Clarke. 2010. COMIDA and BWASP aerial surveys conducted by NMML, 2009. Presentation: Arctic Seismic Open Water Meeting, Anchorage, AK, May 2010.
Ferguson, M. and J. Clarke. 2010. COMIDA and BWASP aerial surveys conducted by NMML, 2009. Presentation: BOWFEST workshop, Anchorage, AK, January, 2010.

BWASP data were incorporated into analyses by other researchers, including:

Ashjian, C.J., S.R. Braund, R.G. Campbell, J.C. George, J. Kruse, W. Maslowski, S.E. Moore, C.R. Nicolson, S.R. Okkonen, B.F. Sherr, E.B. Sherr and Y. Spitz. 2010. Climate Variability, Oceanography, Bowhead Whale Distribution, and Inupiat Subsistence Whaling Near Barrow, Alaska. *Arctic* 63 (2): 179-194.
Givens, G.H., J.A. Hoeting and L.Beri. 2010. Factors that influence aerial line transect detection of Bering-Chukchi-Beaufort Seas bowhead whales. *J. Cetacean Res. Manage*. 11(1): 9-16.

DISCUSSION

Conclusions

Ice conditions in 2009 were very light, and similar to conditions observed in 2007 and 2008. Bowhead whale sightings were significantly closer to shore and in shallower water in the West Region of the Alaskan Beaufort Sea compared to previous light ice years, as shown via central tendency statistics and visual comparison (Fig. 23). The statistical trend for more coastal locations of bowhead whales in the West Region could be explained by higher concentrations of bowhead whale prey near the coastline (compared to past years), leading to an increased density of feeding whales. Analyses in the East Region in 2009 were compromised by low sample sizes. Bowhead whale depth preference, based on sighting rates uncorrected for availability or perception bias, was for very shallow waters (≤ 20 m), underscoring the importance of shallow nearshore areas in fall. Bowhead whale feeding was observed only in the western part of the BWASP study area, where a large aggregation of feeding bowhead whales was observed on 13 October.

Survey effort in 2009 was uneven, with the majority of effort in early September and October. Poor weather conditions in mid-and late September had a negative impact on survey effort. Surveys were conducted in offshore Survey Blocks 8, 9, and 10 for the first time in several years and, despite excellent conditions, no bowhead whales were seen.

Small groups of belugas were seen offshore in Blocks 6, 8, and 9. Distribution of beluga sightings in 2009 was similar to that documented in previous light ice years (Fig. 24), including the “channeling” of belugas through the Barrow Canyon area into the Chukchi Sea. Beluga depth preference in the eastern and central Alaskan Beaufort Sea, based on sighting rates uncorrected for availability or perception bias, was for slope and basin waters (> 200 m), which is consistent with what Moore et al. (2000) found for beluga data collected in the 1980s.

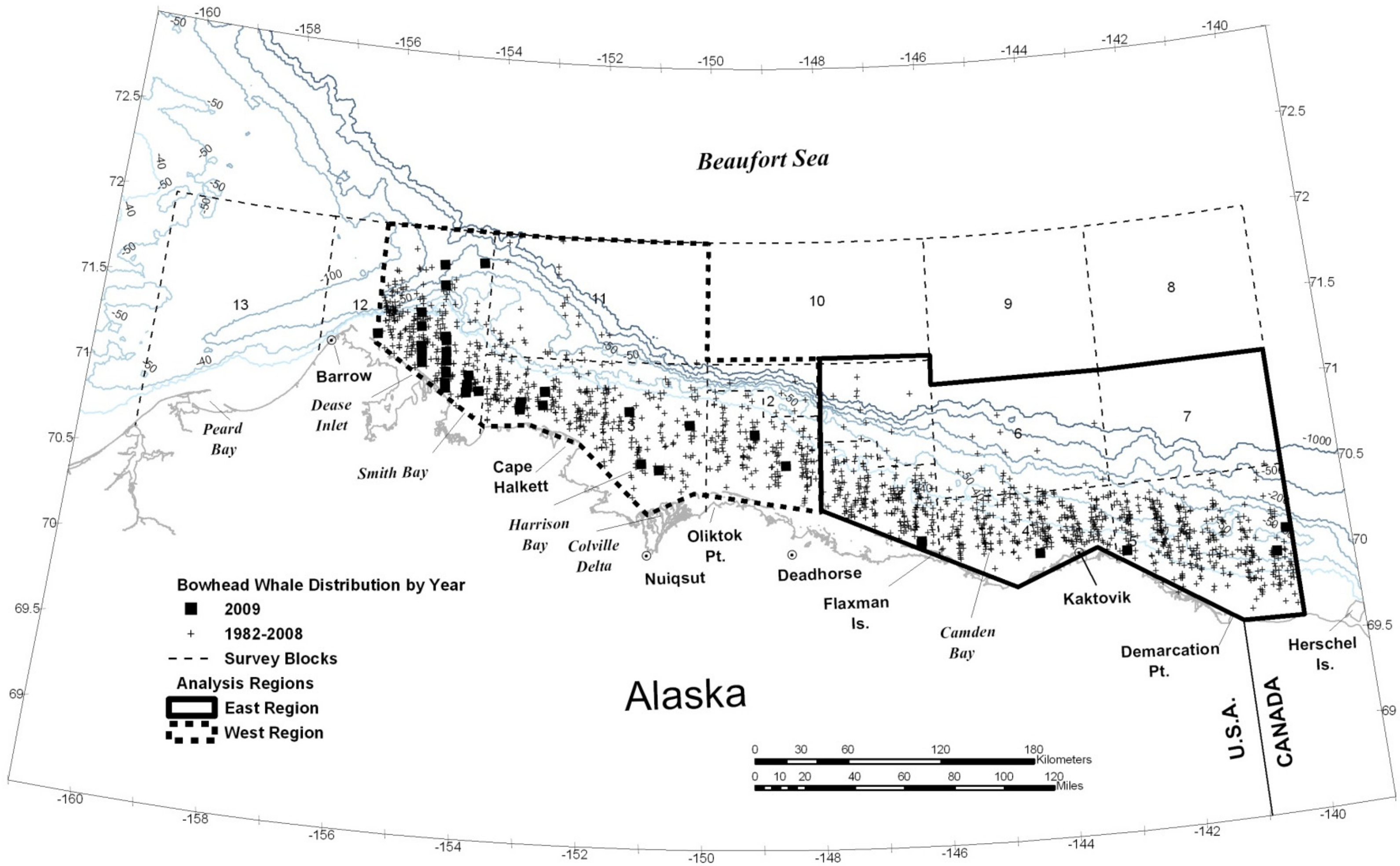

Figure 23. -- Bowhead whale sightings on transect in light ice years, by analysis region, 1982-2009.

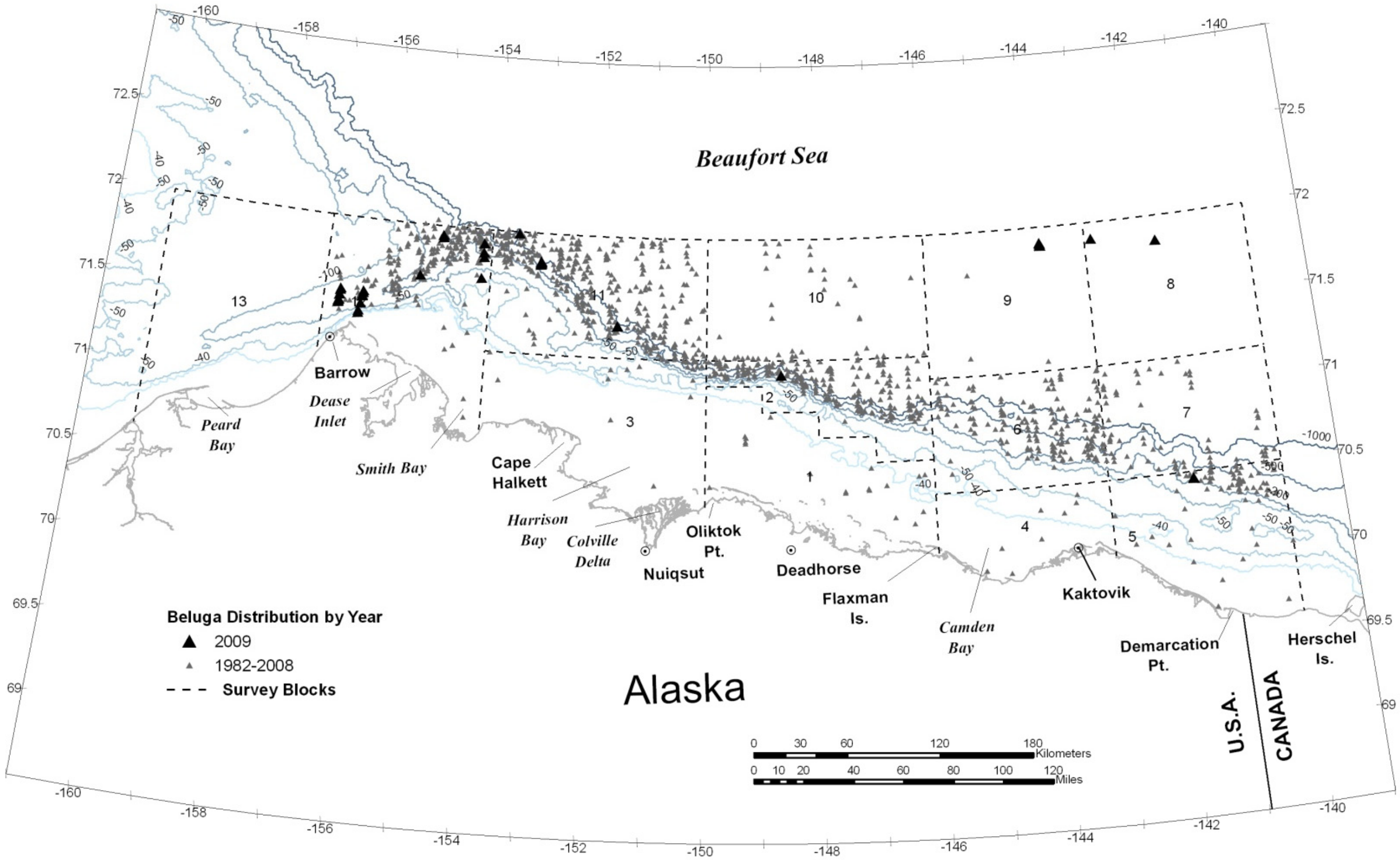

Figure 24. -- Beluga sightings on transect in light ice years, 1982-2009.

Management Use of Real-Time Field Information

The MMS issues various types of permits to industry for gas and oil exploration, including vessel geophysical permits for on-water exploration using an array of deep-seismic airguns; vessel geological-geophysical permits for shallow-seismic exploration using an airgun; on-ice geophysical permits using VIBROSEIS technology; both vessel and on-ice geological permits for obtaining core samples; and permits to drill for gas and oil. Although there was no offshore oil and gas activity in the Alaskan Beaufort Sea in 2009, BWASP aerial survey data were made available to representatives of oil companies, the North Slope Borough Department of Wildlife Management and the general public on a near real-time basis to encourage data transfer and enhance management via a web site maintained by NMML, (http://www.afsc.noaa.gov/nmml/cetacean/bwasp/index.php).

Management Use of Interannual Monitoring

The MMS bowhead whale monitoring study began in 1979 and has continued every year up to the present. While some aspects of this study have been updated, the data recorded have remained remarkably consistent (especially data from 1982-2009), thus permitting many direct comparisons across years. Such continuous, long-term, area-wide, aerial monitoring of a large whale migration is indeed unique. In addition to the accomplishments specifically mentioned in the results, the BWASP historical dataset has been used by industry, government and academic entities (e.g., Manly et al. 2007, Schick and Urban 2000).

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Numerous NMML personnel provided support to the survey team or assisted with technical, administrative, or logistical aspects of the study. Phil Clapham, Dave Rugh, Kim Shelden, and Janice Waite provided logistics and program support. Observers included Jeff Childs, Cynthia Christman, Megan Ferguson, Gary Friedrichsen, Stephanie Grassia, Amy Kennedy, Laura Morse, and Katie Sweeney. Mike Hay of RDI provided much needed assistance with data analysis, mapping, and report preparation.

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Phil Clapham, Dave Withrow and Kim Shelden (NMFS) reviewed the report. The NMFS Alaska Fisheries Science Center (AFSC) Publications Unit was instrumental in preparing this report for publication.

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APPENDIX A: FALL 2009 ICE CONCENTRATION MAPS

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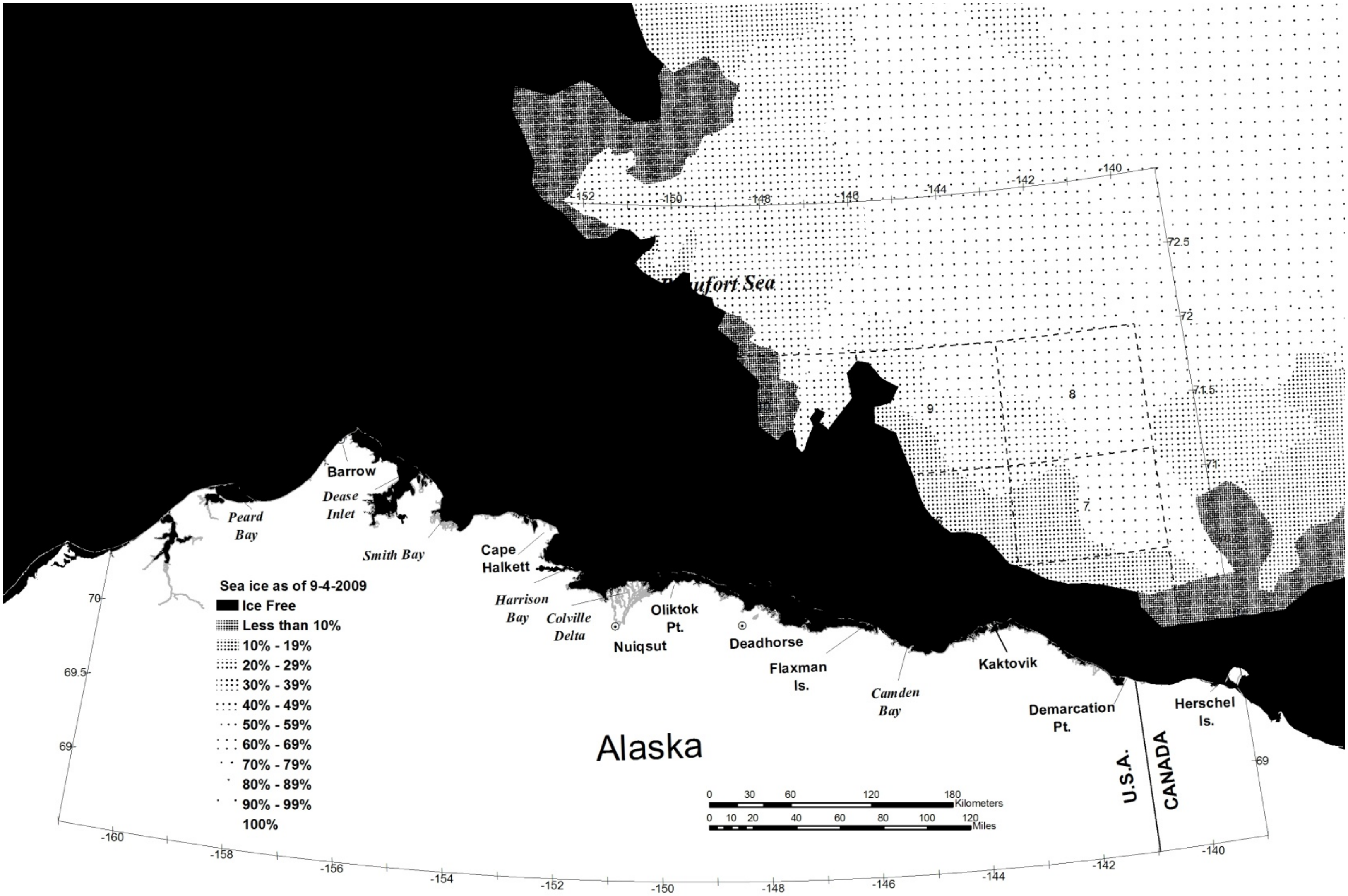

Figure A-1. -- Ice concentrations in the Alaskan Beaufort Sea, 4 September 2009.

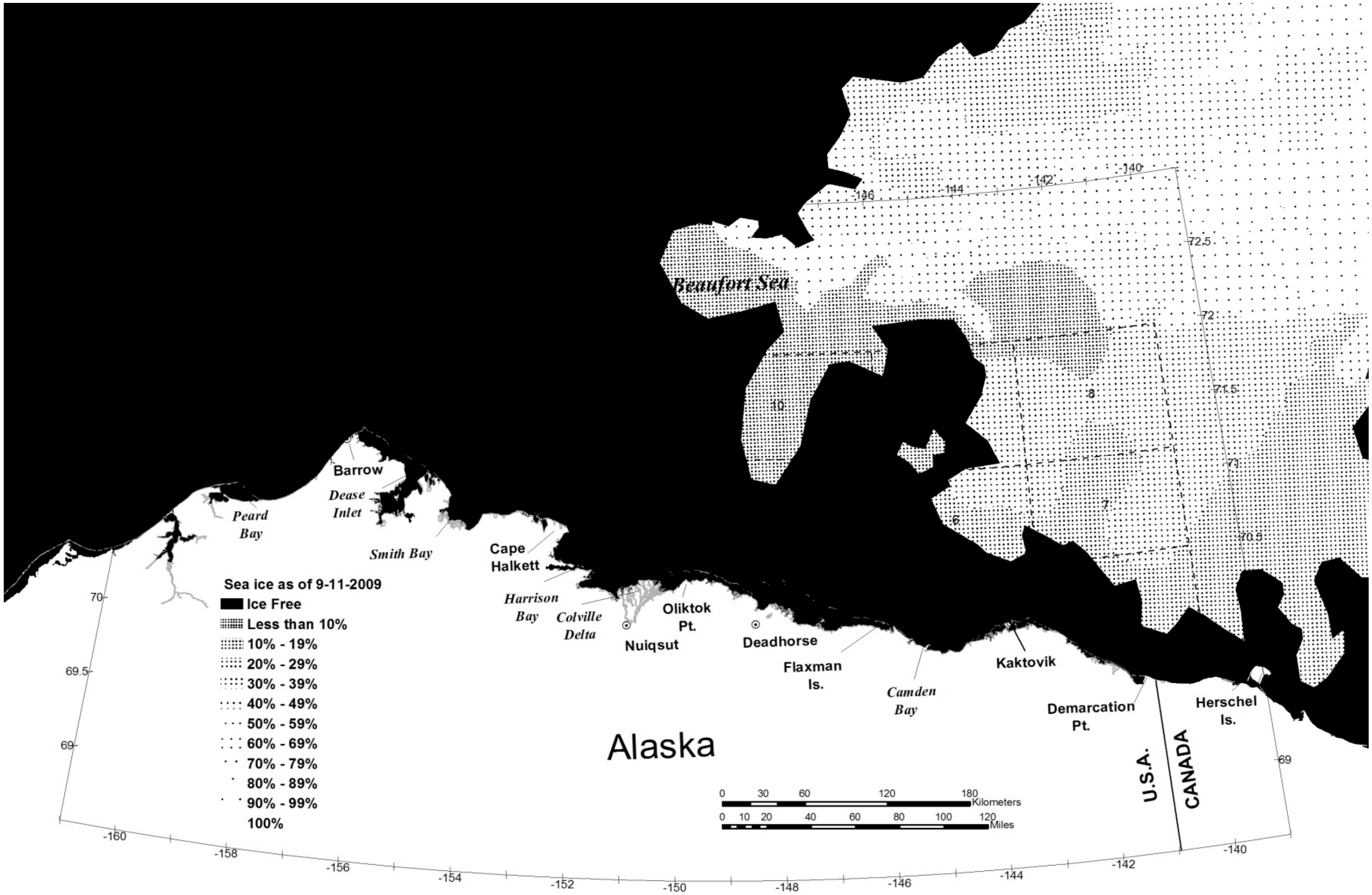

Figure A-2. -- Ice concentrations in the Alaskan Beaufort Sea, 11 September 2009.

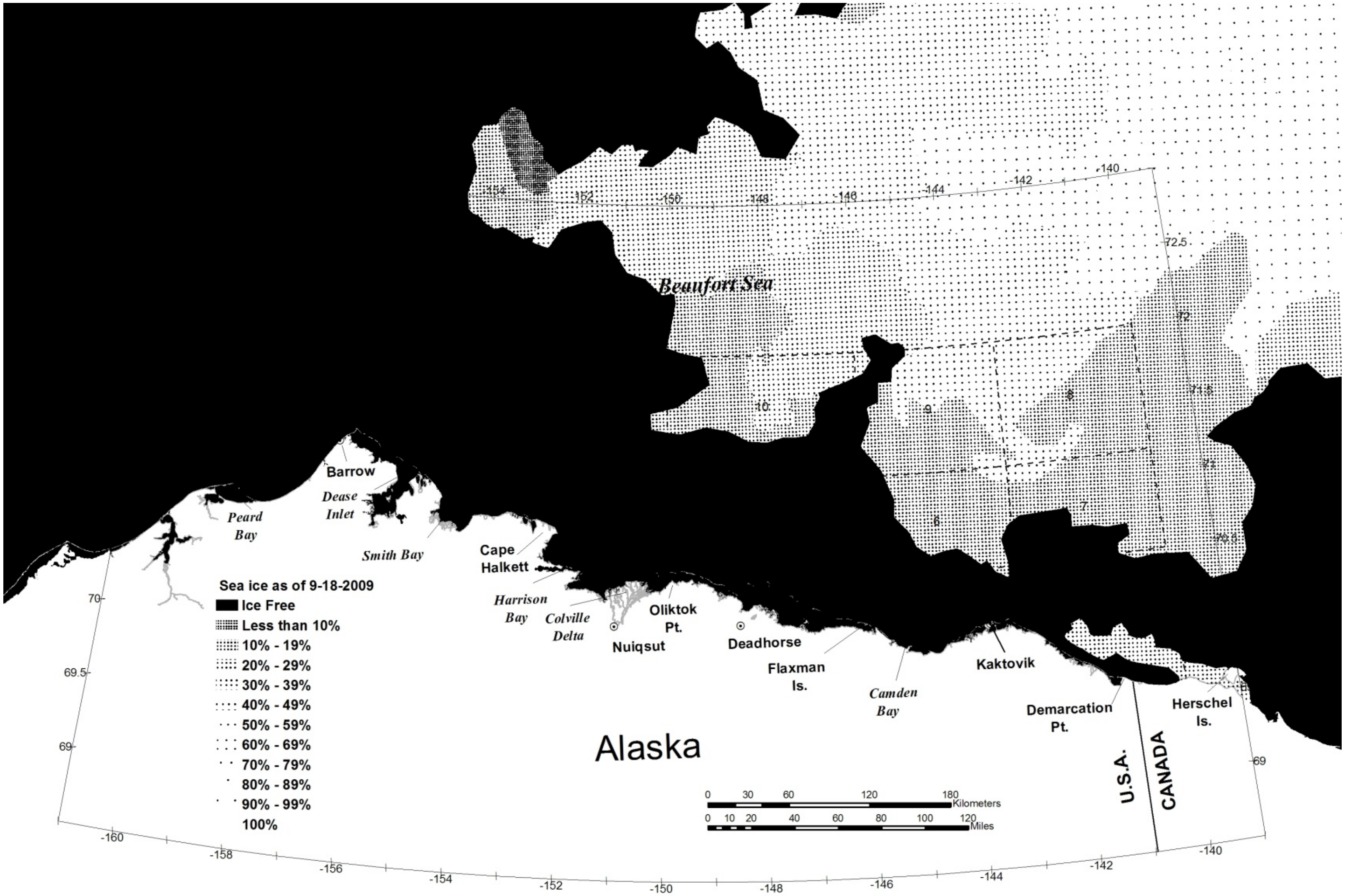

Figure A-3. -- Ice concentrations in the Alaskan Beaufort Sea, 18 September 2009.

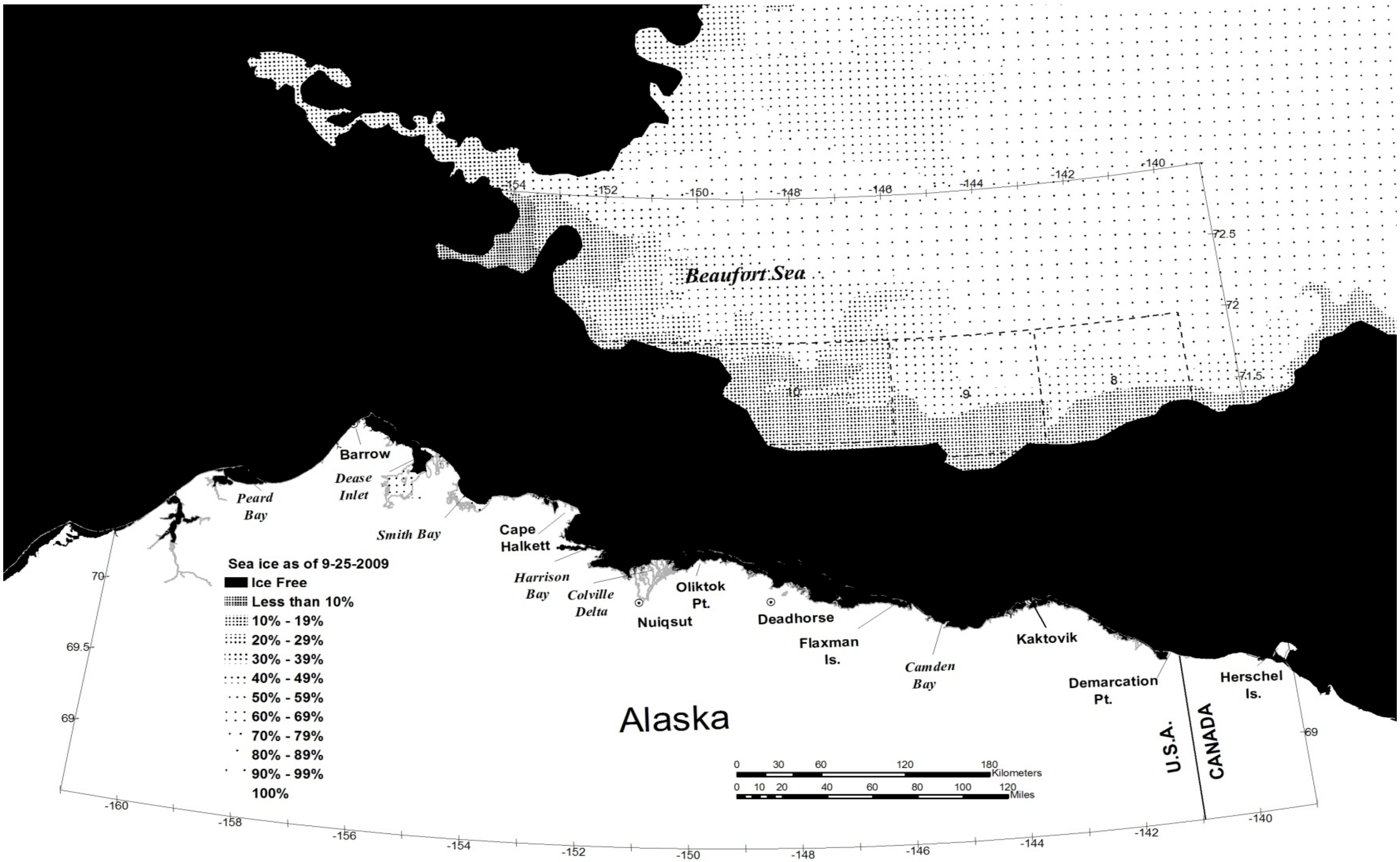

Figure A-4. -- Ice concentrations in the Alaskan Beaufort Sea, 25 September 2009.

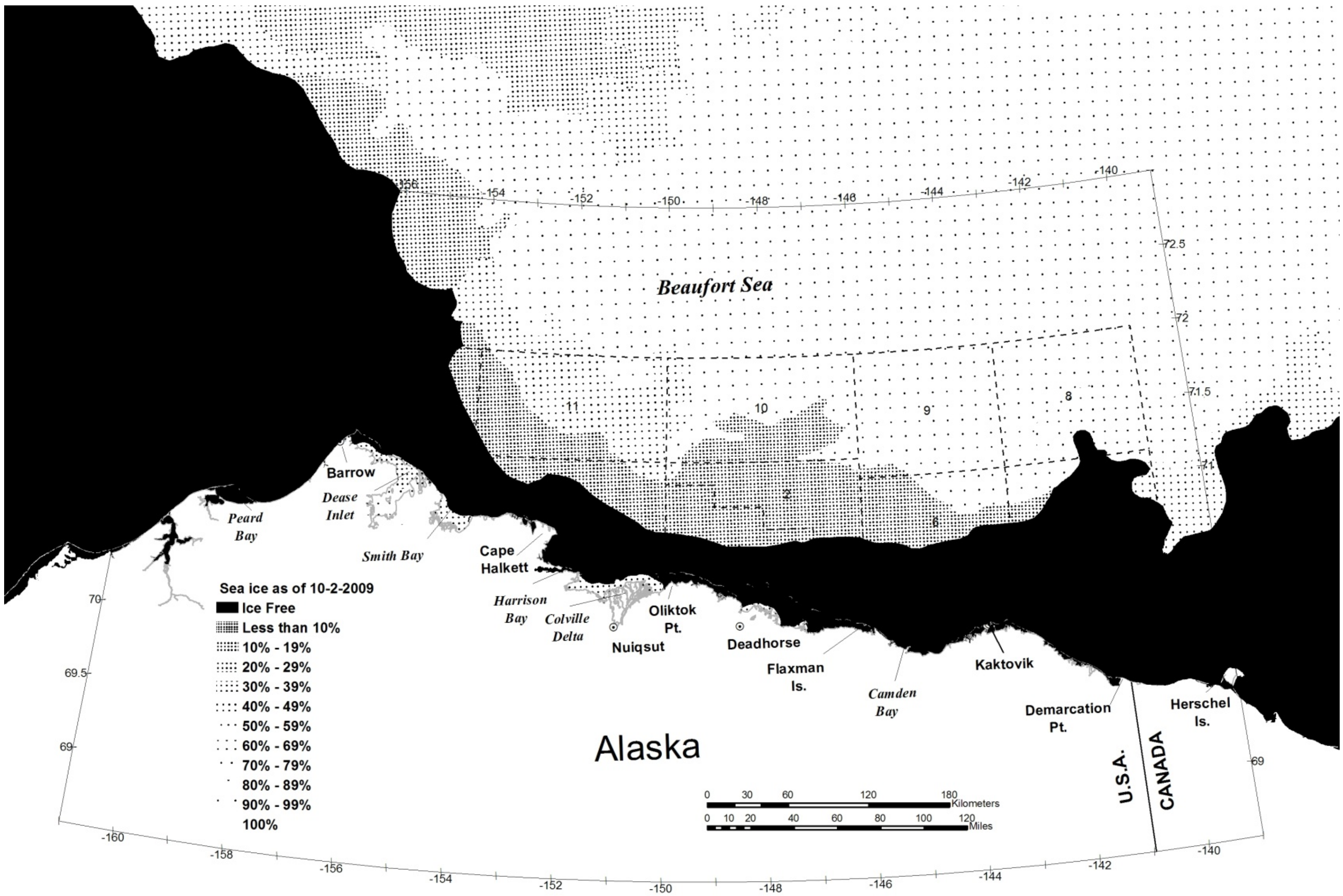

Figure A-5. -- Ice concentrations in the Alaskan Beaufort Sea, 2 October 2009.

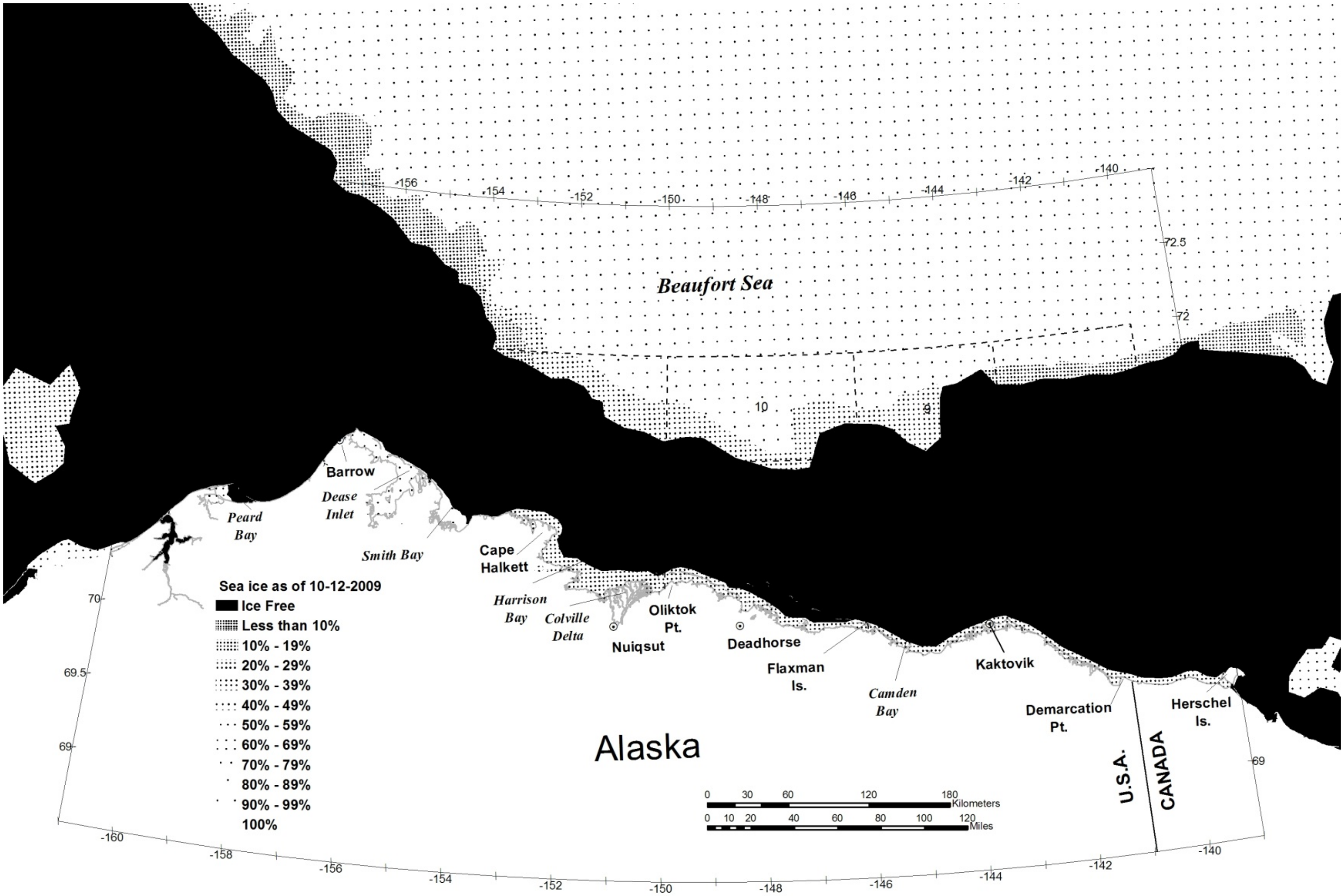

Figure A-6. -- Ice concentrations in the Alaskan Beaufort Sea, 12 October 2009.

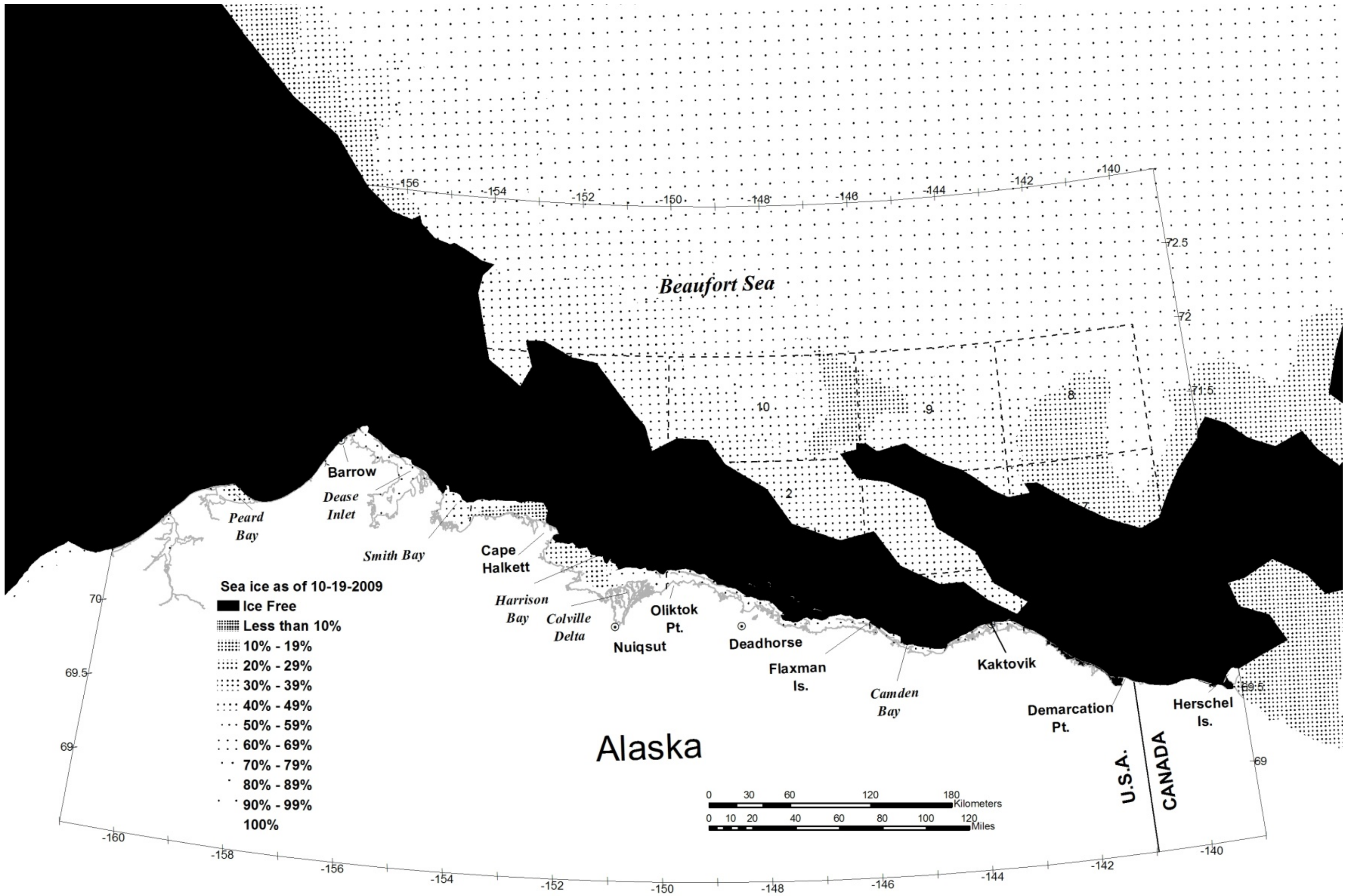

Figure A-7. -- Ice concentrations in the Alaskan Beaufort Sea, 19 October 2009.

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APPENDIX B: FALL 2009 BOWHEAD WHALE SIGHTING DATA

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Flight No	Day	Total Whales	No of Calves	Latitude	Longitude	Behavior	Compass Heading	Ice (%)	Beaufort Sea State
3	3 Sep	1	0	70º00.4'	140º17.1'	swim	358º	0	1
3	3 Sep	1	1	70º00.3'	140º17.1'	rest	*	0	1
5	6 Sep	1	0	70º43.2'	151º08.1'	*	271º	0	4
5	6 Sep	1	0	70º41.1'	150º49.3'	*	270º	0	4
5	6 Sep	2	0	71º01.9'	153º51.4'	*	19º	0	4
5	6 Sep	2	0	71º02.1'	153º53.1'	*	18º	0	4
5	6 Sep	1	0	71º02.2'	153º54.3'	*	229º	0	4
5	6 Sep	2	0	71º02.7'	153º58.7'	feed	*	0	4
5	6 Sep	1	0	71º03.3'	154º05.0'	*	108º	0	4
5	6 Sep	1	0	71º03.3'	154º05.2'	*	348º	0	4
5	6 Sep	1	0	71º03.4'	154º06.4'	*	348º	0	4
10	28 Sep	4	0	70º14.4'	146º17.6'	swim	*	0	2
10	28 Sep	5	0	70º14.8'	146º17.6'	swim	*	0	2
10	28 Sep	2	0	70º15.6'	146º17.0'	swim	*	0	2
11	29 Sep	1	0	70º08.8'	144º17.0'	swim	*	0	3
11	29 Sep	1	0	70º09.4'	144º12.8'	swim	*	0	3
11	29 Sep	1	0	70º11.0'	144º07.9'	swim	*	0	3
11	29 Sep	1	0	70º10.6'	144º10.1'	swim	283º	0	3
11	29 Sep	1	0	70º09.9'	144º10.5'	swim	281º	0	3
12	1 Oct	1	0	71º34.3'	156º50.9'	swim	272º	0	3
12	1 Oct	1	0	71º38.5'	156º14.1'	swim	272º	0	3
12	1 Oct	1	0	71º05.4'	154º40.4'	swim	263º	0	3
12	1 Oct	1	0	71º06.2'	154º40.6'	swim	265º	0	3
12	1 Oct	1	0	71º07.1'	154º40.8'	*	266º	0	3
12	1 Oct	1	0	71º07.4'	154º39.2'	swim	*	0	3
12	1 Oct	1	0	71º10.5'	154º41.1'	swim	115º	0	3
12	1 Oct	1	0	71º11.0'	154º41.2'	swim	235º	0	3
12	1 Oct	1	0	71º10.3'	154º16.5'	dive	304º	0	3
12	1 Oct	1	0	71º07.2'	154º17.1'	swim	244º	0	3
12	1 Oct	1	0	71º06.3'	154º17.3'	swim	64º	0	3
12	1 Oct	1	0	71º04.4'	154º17.7'	dive	274º	0	3
13	2 Oct	1	0	70º08.9'	145º44.6'	swim	334º	0	4
13	2 Oct	1	0	70º07.6'	144º54.6'	swim	246º	0	5
13	2 Oct	1	0	70º06.7'	144º25.2'	swim	275º	0	3
13	2 Oct	1	0	70º07.1'	142º47.9'	swim	282º	0	3
13	2 Oct	2	0	70º07.0'	142º47.9'	swim	282º	0	3
14	6 Oct	1	0	71º02.5'	153º18.7'	swim	335º	0	2
14	6 Oct	8	1	71º00.9'	153º19.1'	swim	*	0	2
14	6 Oct	1	0	70º60.0'	153º19.3'	dive	2º	0	2
14	6 Oct	3	0	71º02.0'	152º54.6'	swim	*	0	3

Flight No	Day	Total Whales	No of Calves	Latitude	Longitude	Behavior	Compass Heading	Ice (%)	Beaufort Sea State
14	6 Oct	8	0	71º02.5'	152º53.2'	swim	*	0	3
14	6 Oct	1	0	71º02.6'	152º54.2'	*	*	0	3
14	6 Oct	4	1	71º06.5'	152º53.5'	swim	*	0	3
14	6 Oct	1	0	71º06.7'	152º53.4'	*	164º	0	3
14	6 Oct	2	1	71º01.1'	151º22.3'	swim	271º	0	2
16	12 Oct	1	0	70º05.6'	144º16.1'	dive	230º	0	2
16	12 Oct	2	1	70º23.2'	146º53.8'	swim	287º	0	2
16	12 Oct	2	0	70º08.0'	140º05.0'	swim	267º	0	2
17	13 Oct	2	0	71º35.2'	156º17.0'	swim	*	0	3
17	13 Oct	1	0	71º33.8'	156º02.8'	swim	*	0	3
17	13 Oct	6	0	71º21.8'	155º58.5'	feed	*	0	2
17	13 Oct	5	1	71º30.7'	155º13.1'	mill	*	0	2
17	13 Oct	2	0	71º25.9'	155º11.5'	swim	174º	0	2
17	13 Oct	3	1	71º19.2'	155º09.3'	*	*	0	2
17	13 Oct	1	0	71º18.8'	155º09.2'	swim	264º	0	2
17	13 Oct	2	1	71º18.0'	155º08.9'	*	*	0	2
17	13 Oct	6	0	71º17.5'	155º08.8'	swim	*	0	2
17	13 Oct	7	0	71º17.4'	155º08.8'	feed	*	0	2
17	13 Oct	1	0	71º18.4'	154º59.9'	swim	*	0	2
17	13 Oct	20	0	71º19.9'	155º03.2'	feed	*	0	2
17	13 Oct	2	1	71º16.4'	155º08.5'	swim	181º	0	2
17	13 Oct	24	0	71º14.7'	155º08.1'	feed	*	0	2
17	13 Oct	2	0	71º13.4'	155º07.6'	swim	*	0	2
17	13 Oct	186	0	71º15.3'	155º18.9'	feed	*	2	0
17	13 Oct	6	0	71º14.8'	154º41.6'	mill	*	0	1
17	13 Oct	3	0	71º17.7'	154º42.5'	*	*	0	1
17	13 Oct	4	0	71º17.9'	154º42.6'	*	*	0	1
17	13 Oct	1	0	71º21.8'	154º43.7'	swim	*	0	1
17	13 Oct	2	1	71º22.6'	154º44.0'	swim	264º	0	1
17	13 Oct	2	0	71º23.1'	154º44.3'	swim	82º	0	1
17	13 Oct	1	0	71º40.6'	154º49.8'	swim	174º	0	3
17	13 Oct	2	1	71º47.5'	154º52.0'	swim	264º	0	3
17	13 Oct	3	1	71º49.3'	154º08.1'	swim	268º	0	2
17	13 Oct	3	0	71º05.2'	154º04.4'	feed	*	0	1
18	18 Oct	2	1	70º56.9'	150º17.3'	cow/calf	273º	0	1
18	18 Oct	2	1	70º53.8'	149º08.9'	cow/calf	302º	0	2
18	18 Oct	1	0	70º43.0'	148º36.1'	swim	300º	0	3

*Not recorded.

APPENDIX C: FALL 2009 DAILY FLIGHT SUMMARIES

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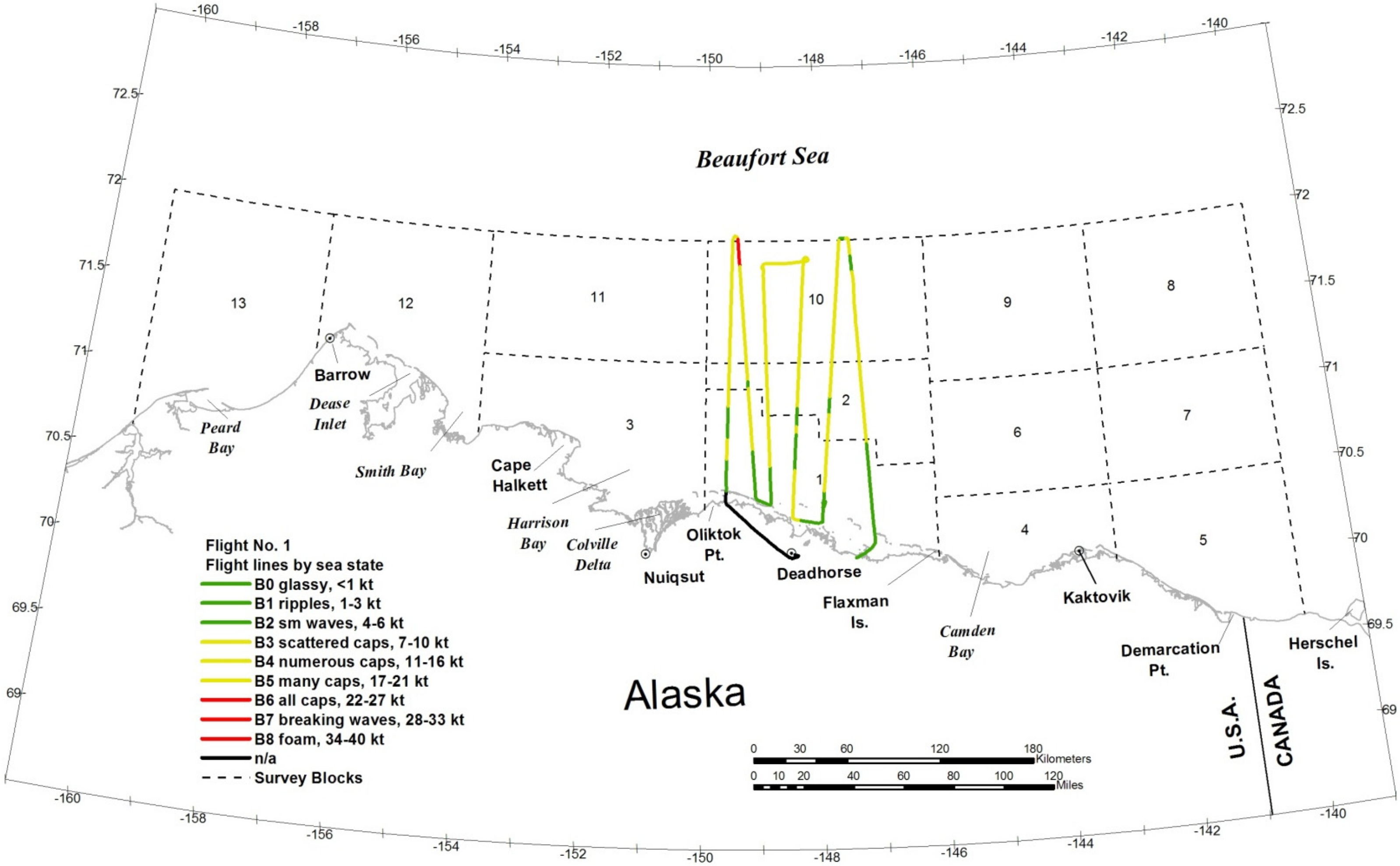

Figure C-1. -- Flight 1 survey track depicted by sea state, 1 September 2009.

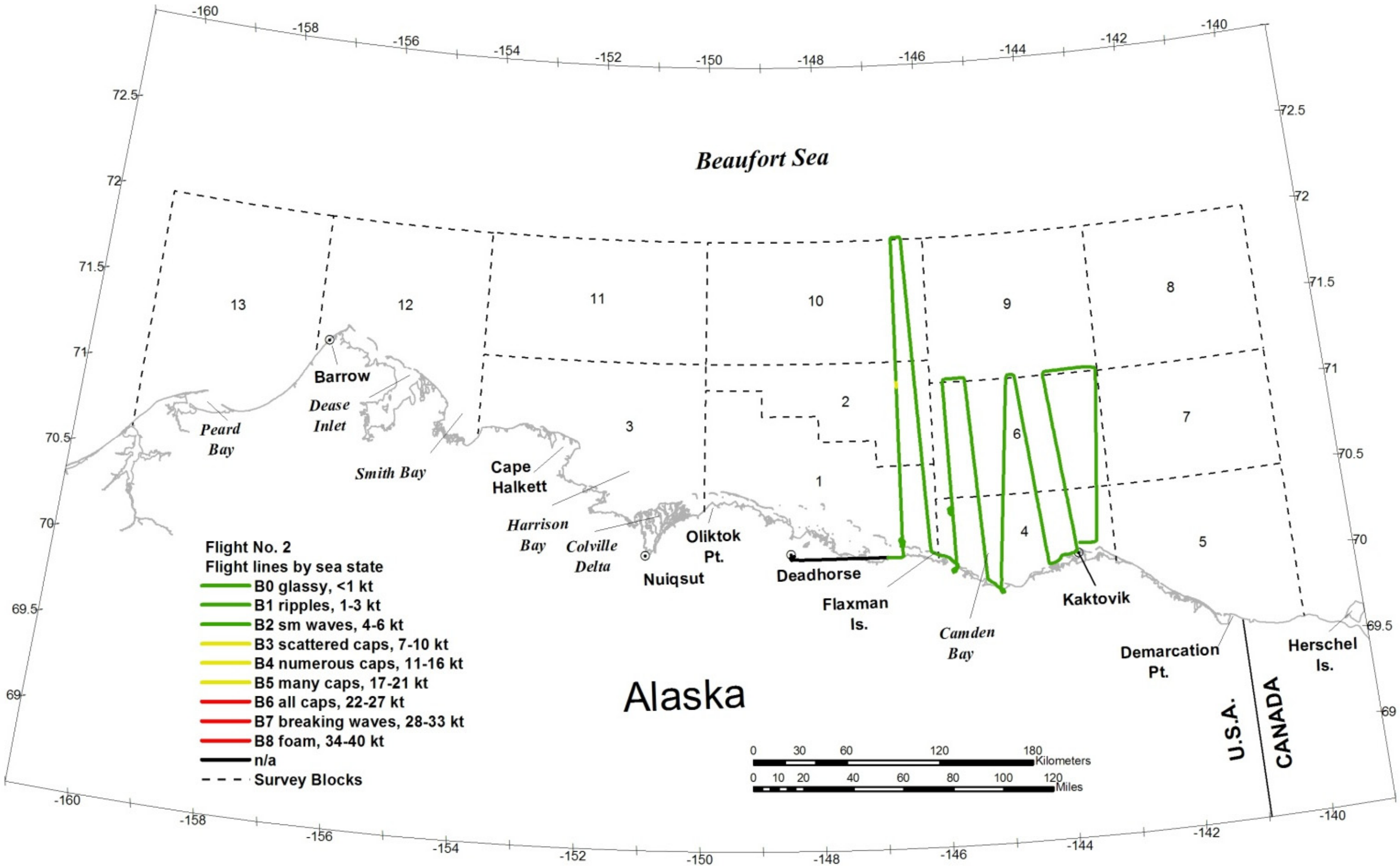

Figure C-2. -- Flight 2 survey track depicted by sea state, 2 September 2009.

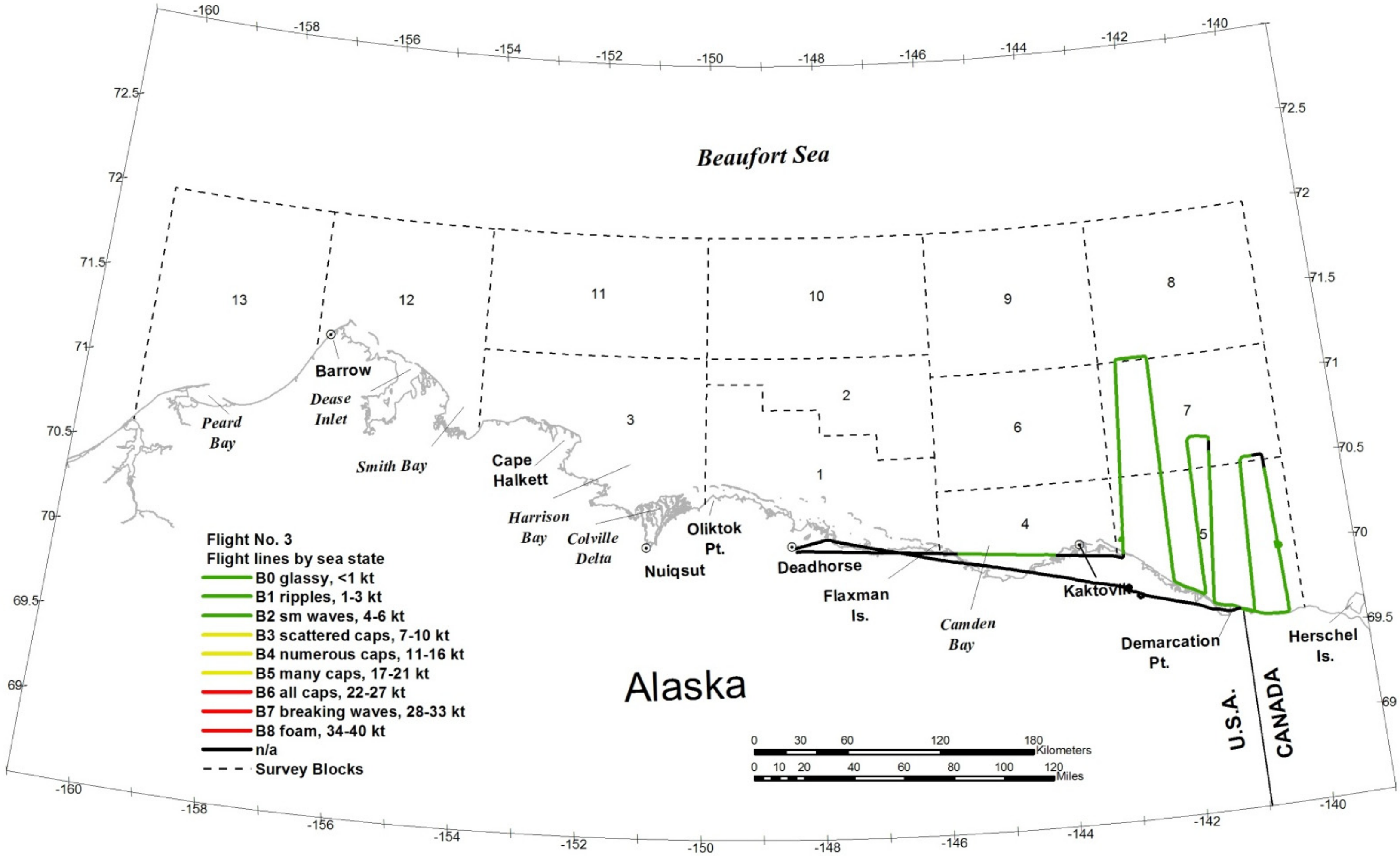

Figure C-3. -- Flight 3 survey track depicted by sea state, 3 September 2009.

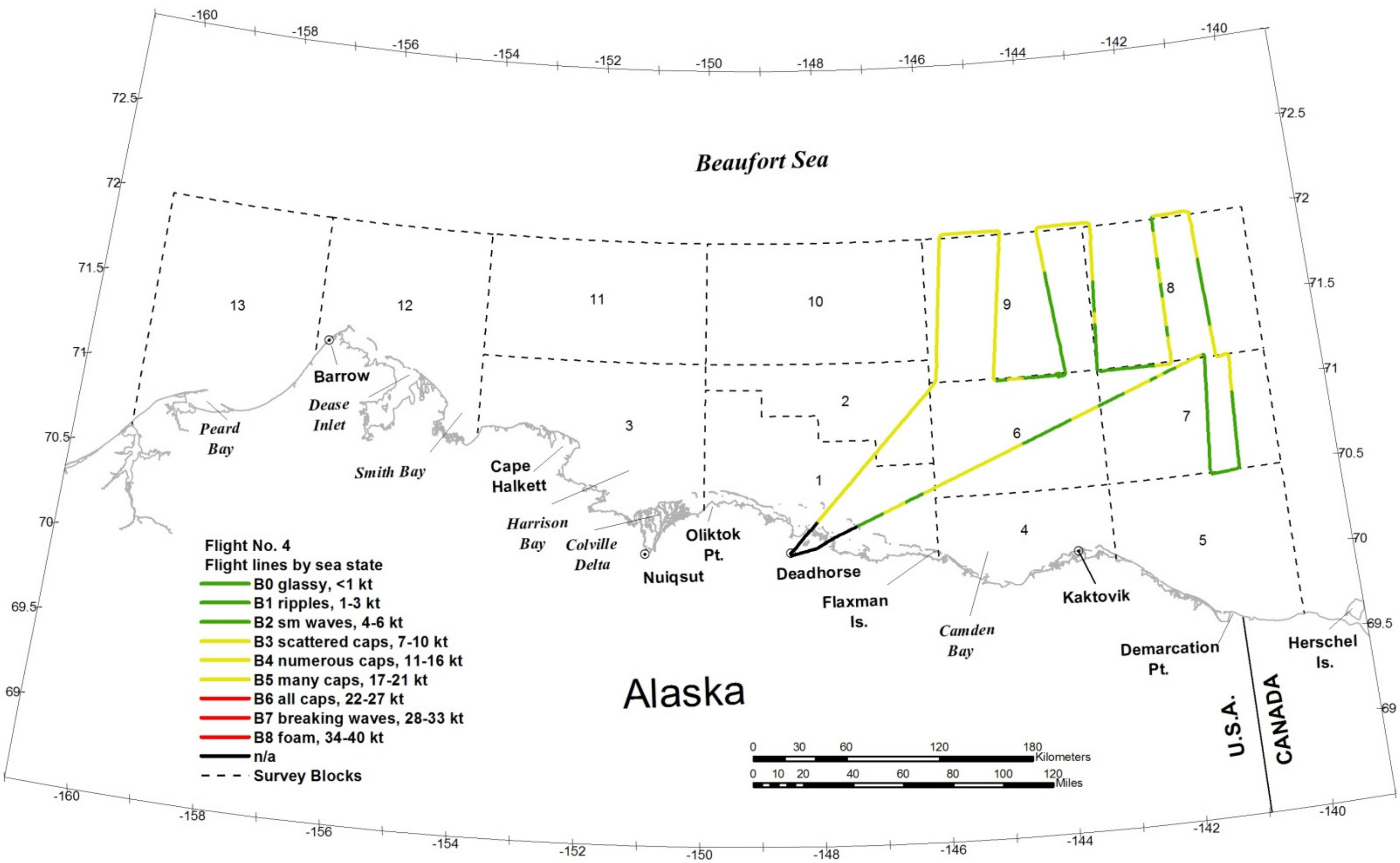

Figure C-4. -- Flight 4 survey track depicted by sea state, 5 September 2009.

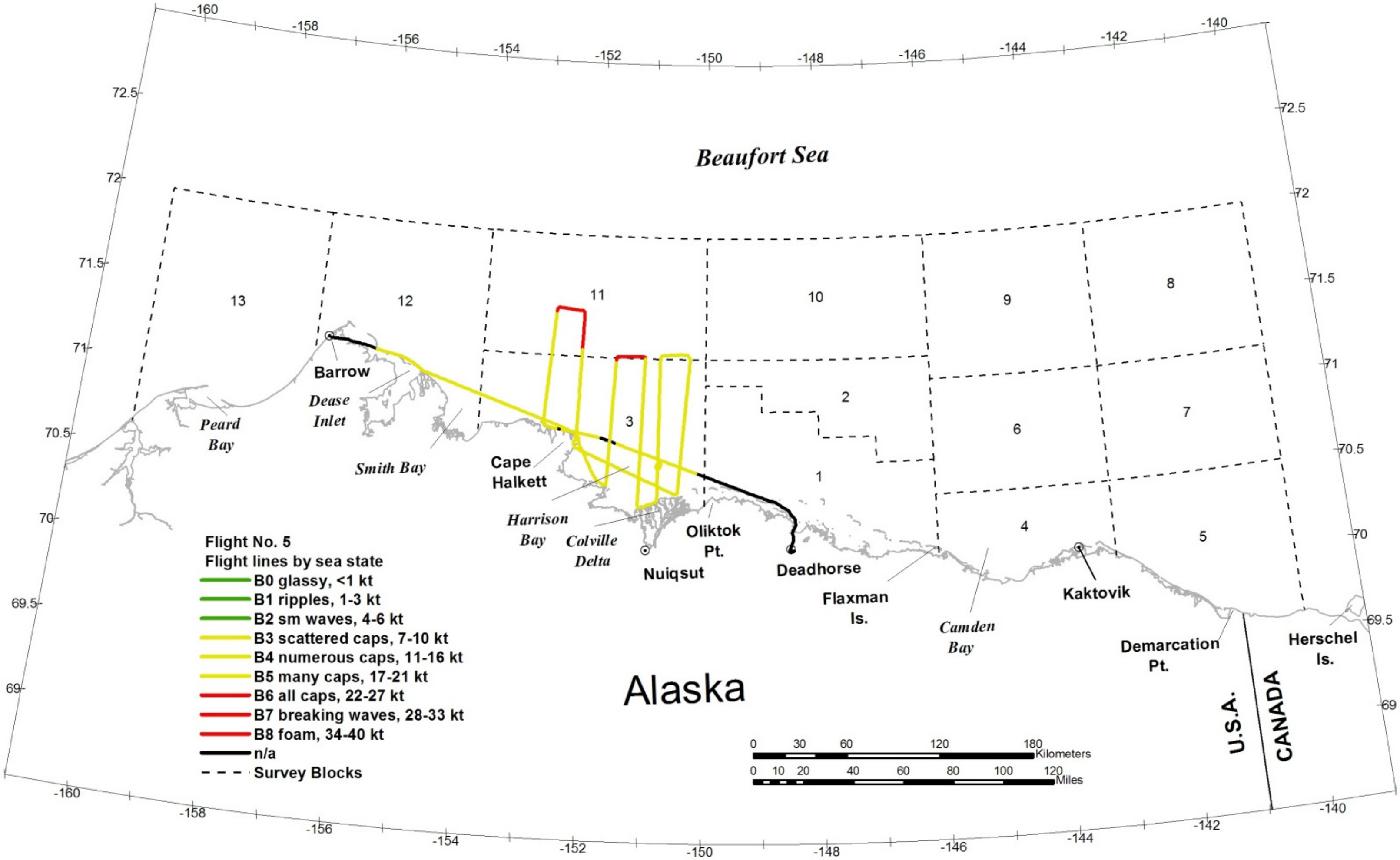

Figure C-5. -- Flight 5 survey track depicted by sea state, 6 September 2009.

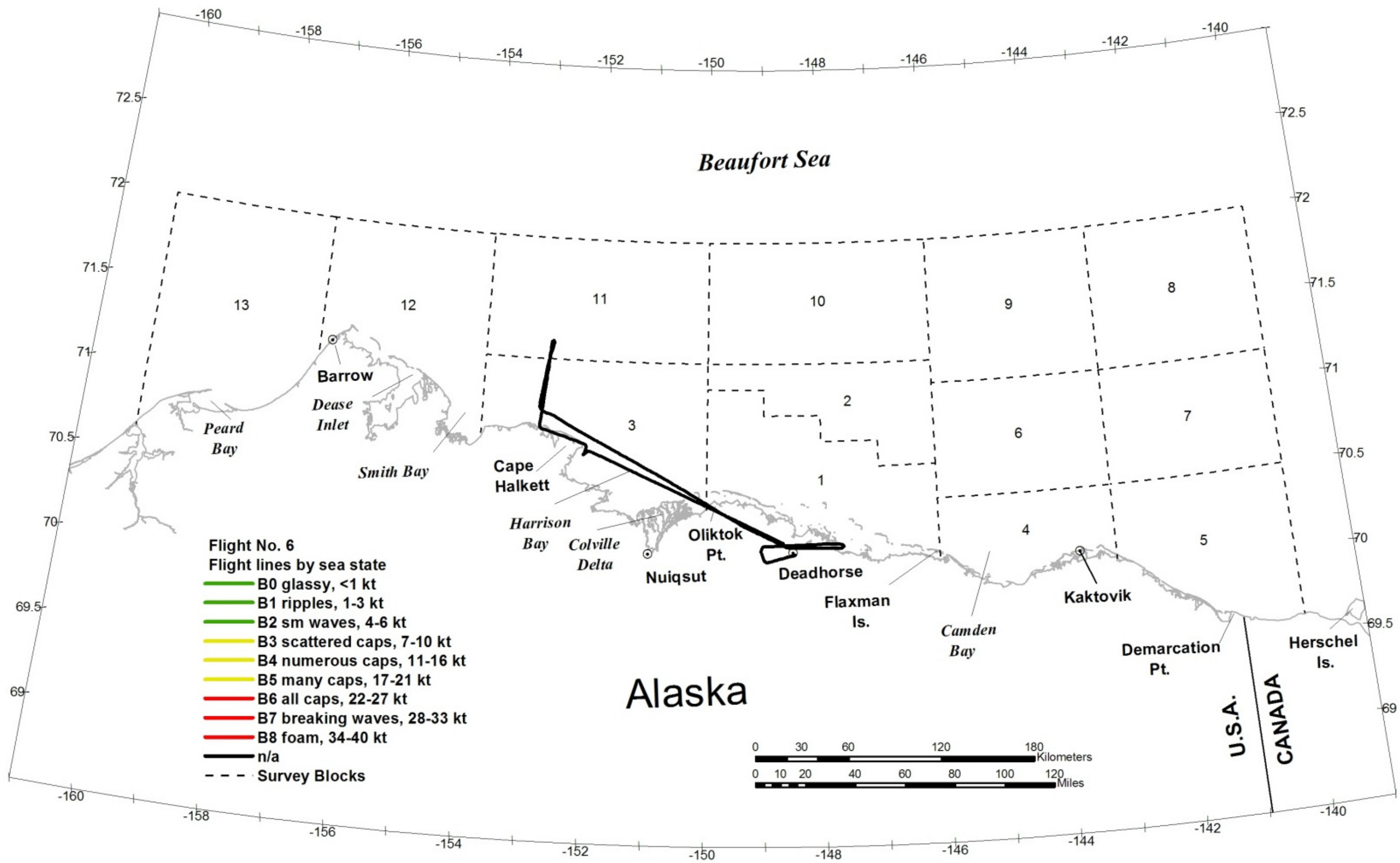

Figure C-6. -- Flight 6 survey track depicted by sea state, 14 September 2009.

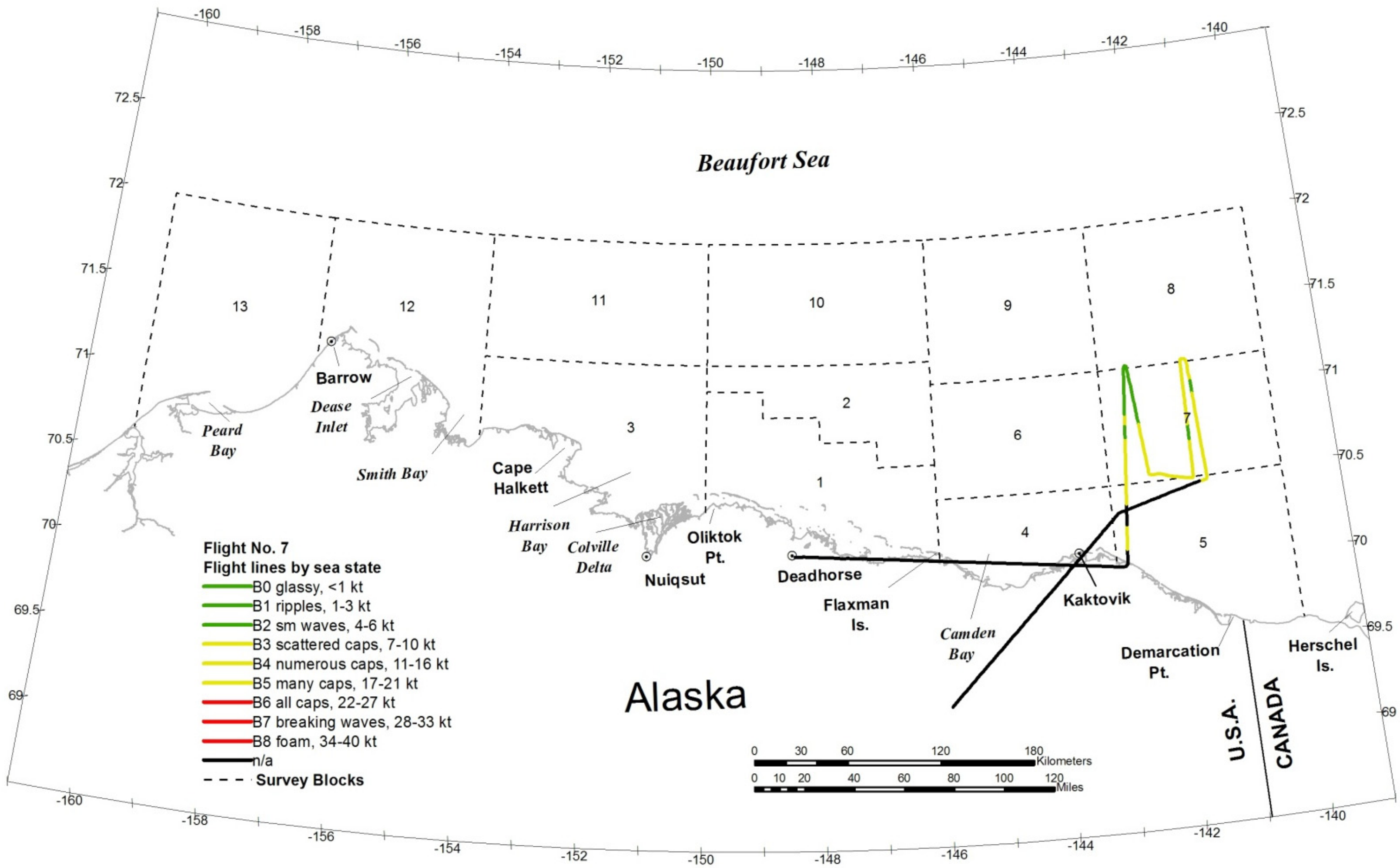

Figure C-7. -- Flight 7 survey track depicted by sea state, 16 September 2009.

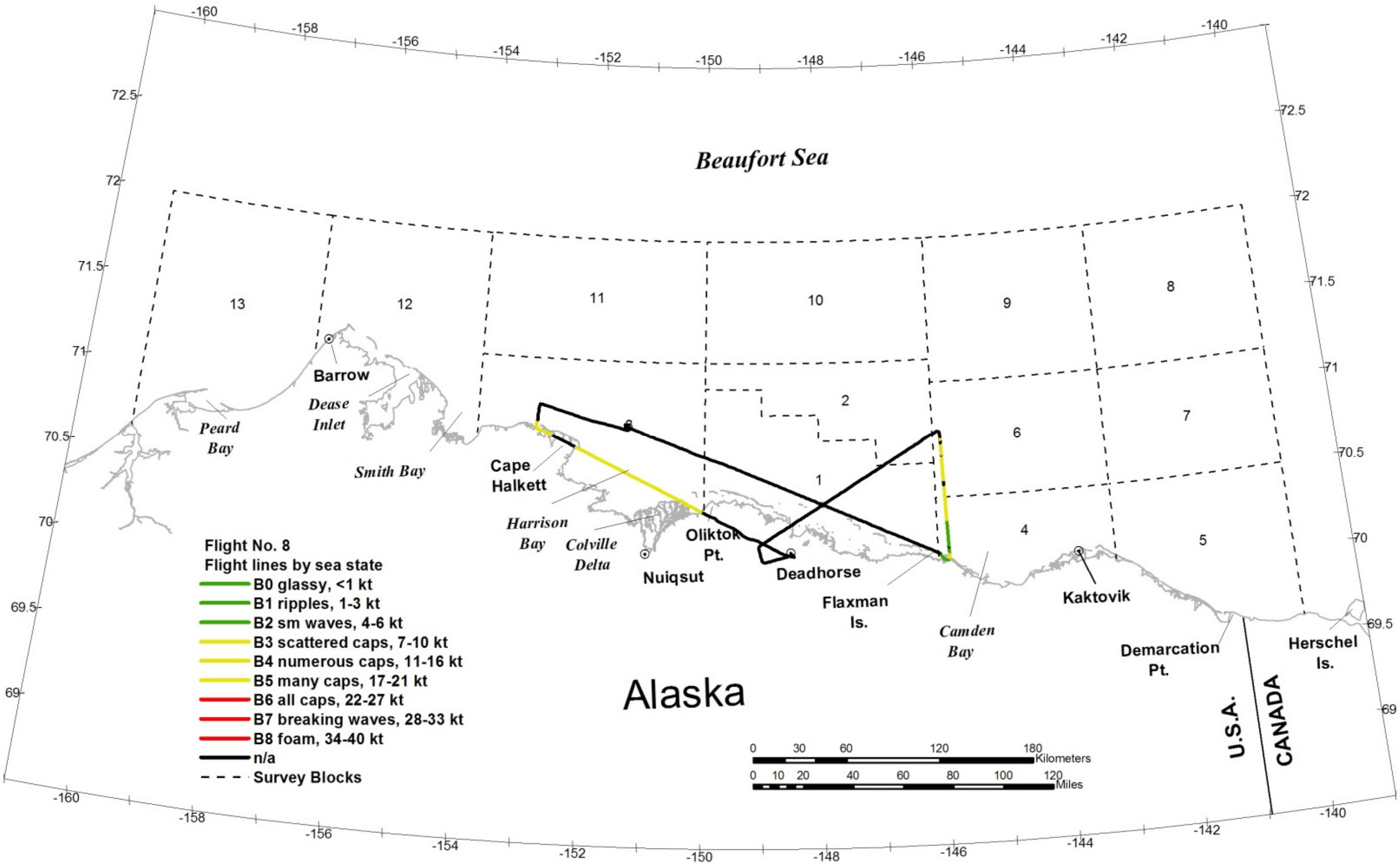

Figure C-8. -- Flight 8 survey track depicted by sea state, 19 September 2009.

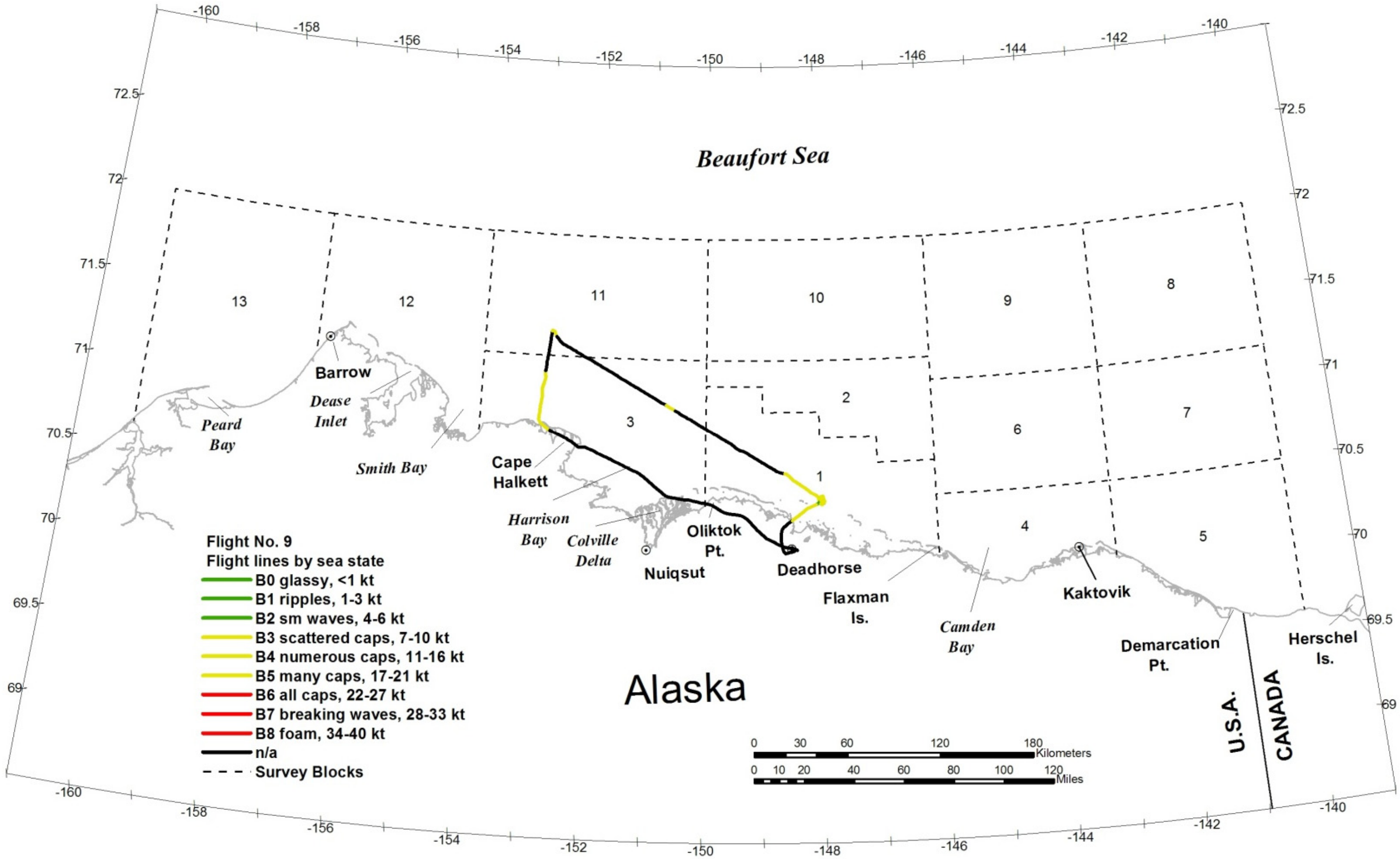

Figure C-9. -- Flight 9 survey track depicted by sea state, 25 September 2009.

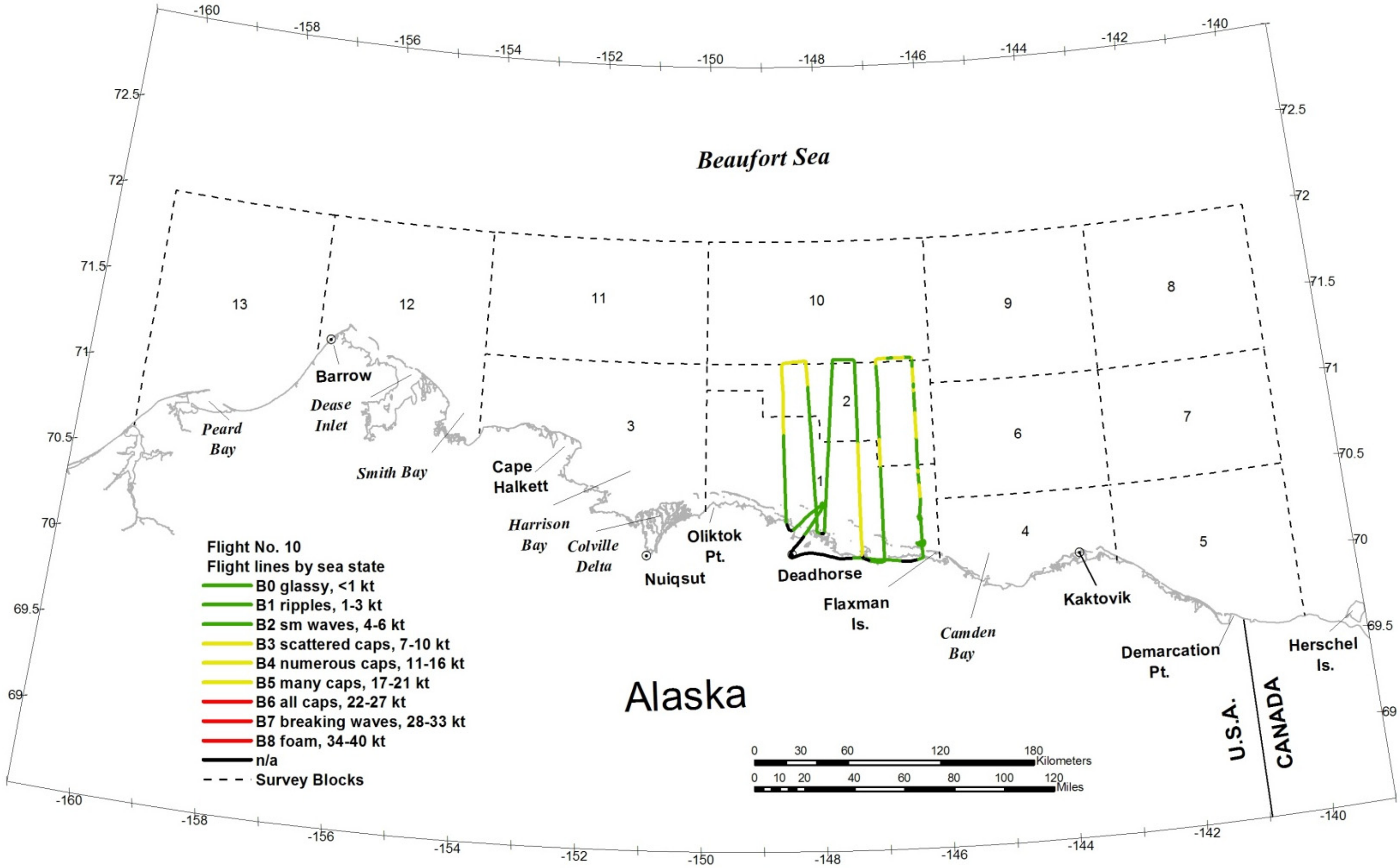

Figure C-10. -- Flight 10 survey track depicted by sea state, 28 September 2009.

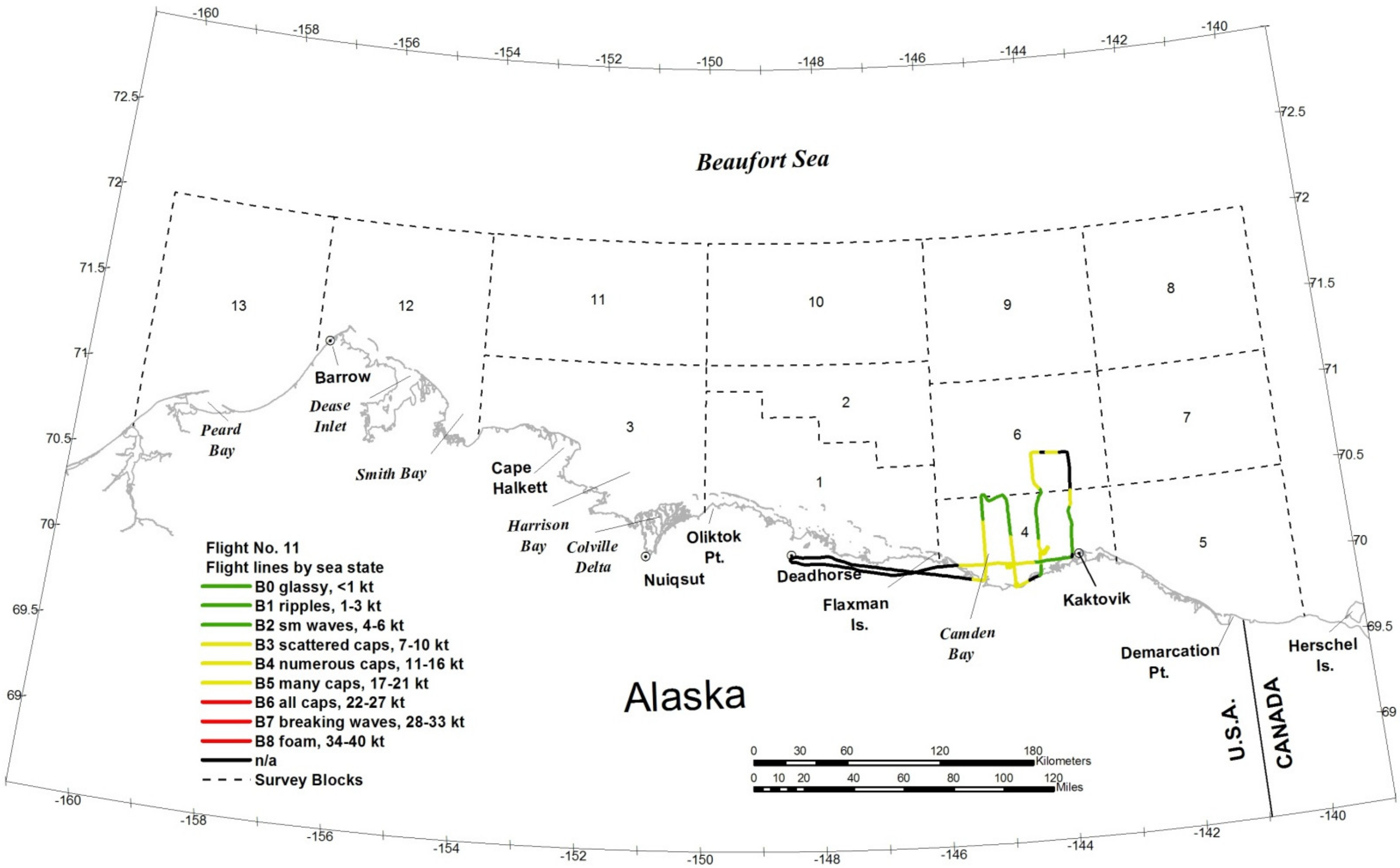

Figure C-11. -- Flight 11 survey track depicted by sea state, 29 September 2009.

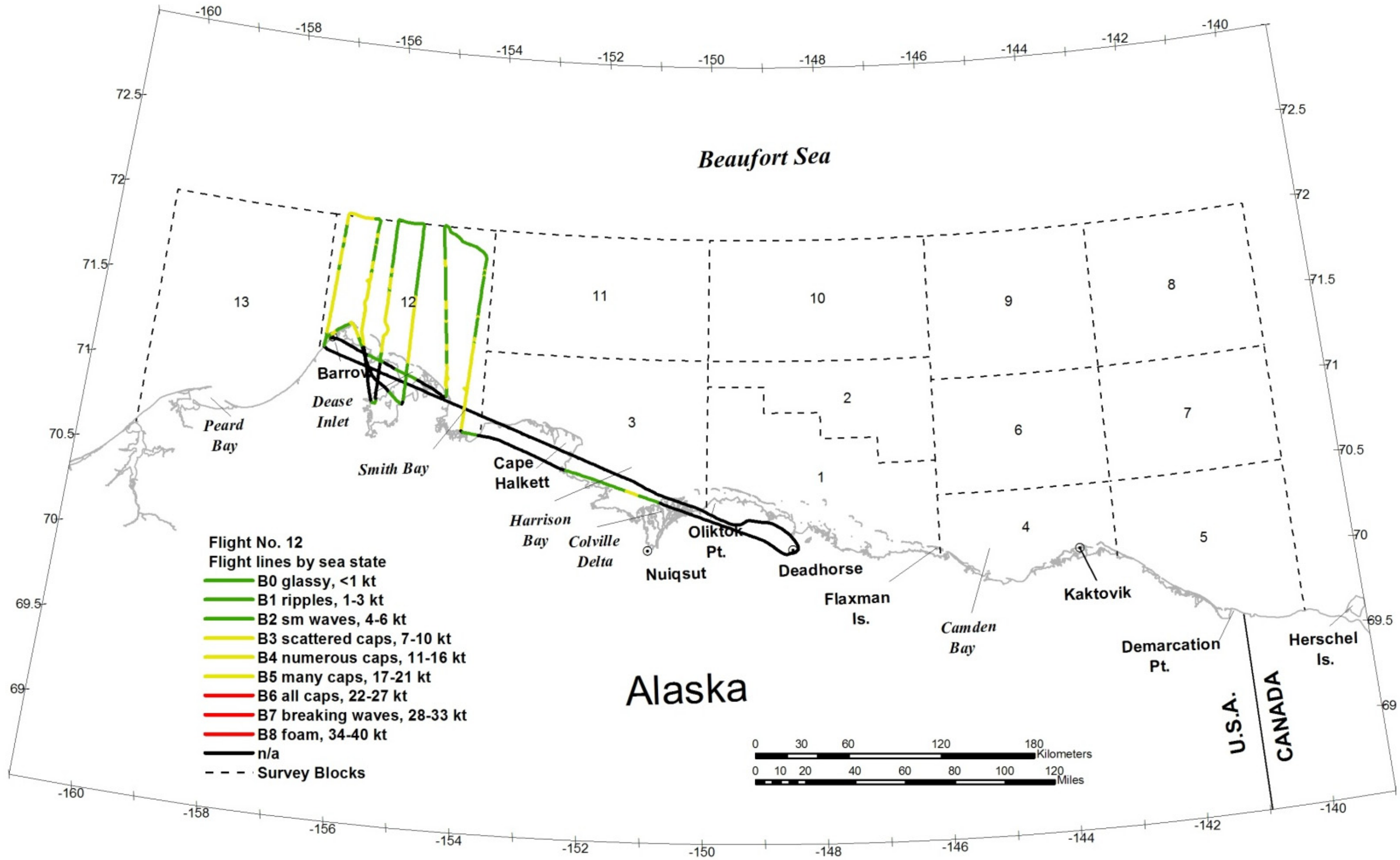

Figure C-12. -- Flight 12 survey track depicted by sea state, 1 October 2009.

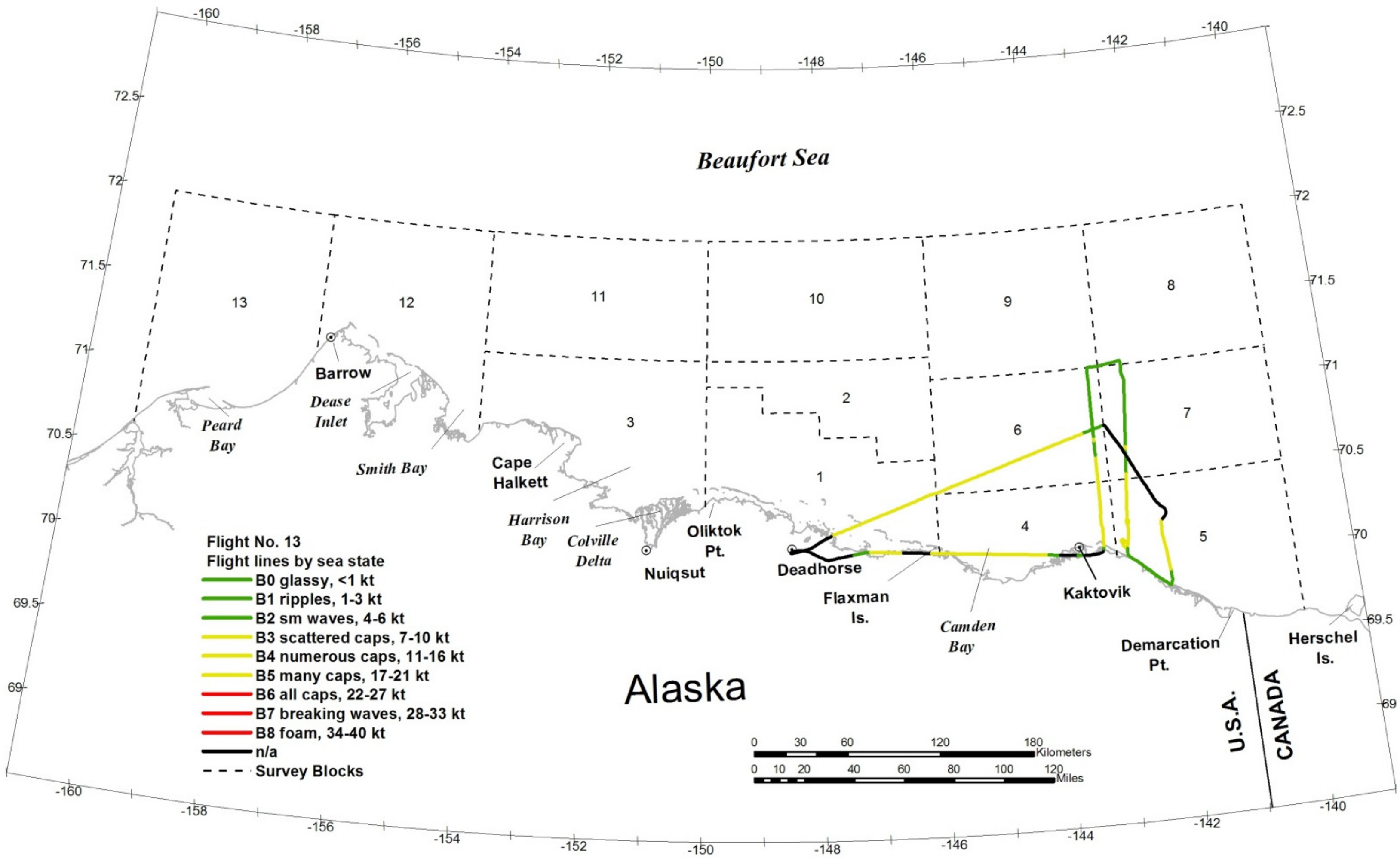

Figure C-13. -- Flight 13 survey track depicted by sea state, 2 October 2009.

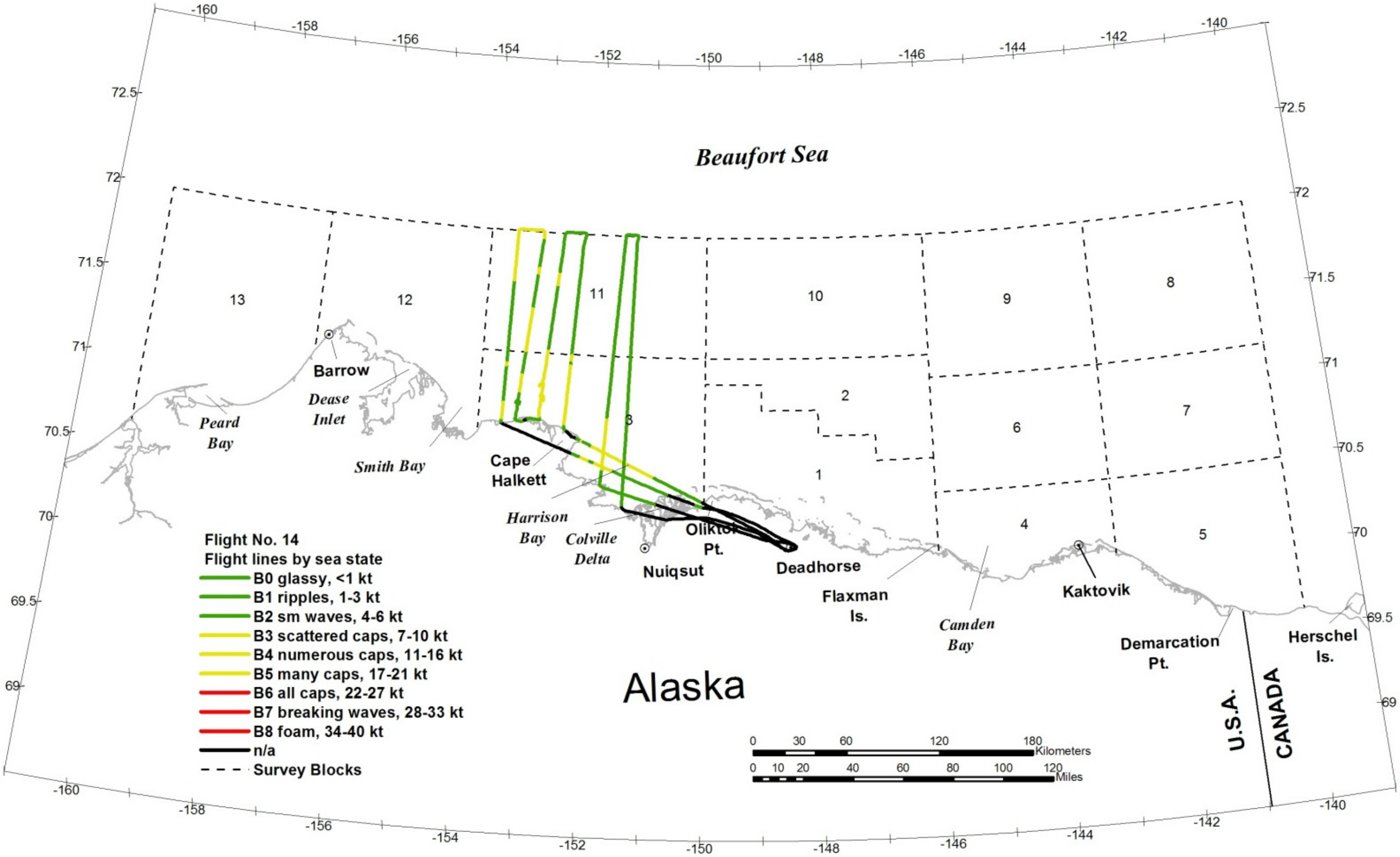

Figure C-14. -- Flight 14 survey track depicted by sea state, 6 October 2009.

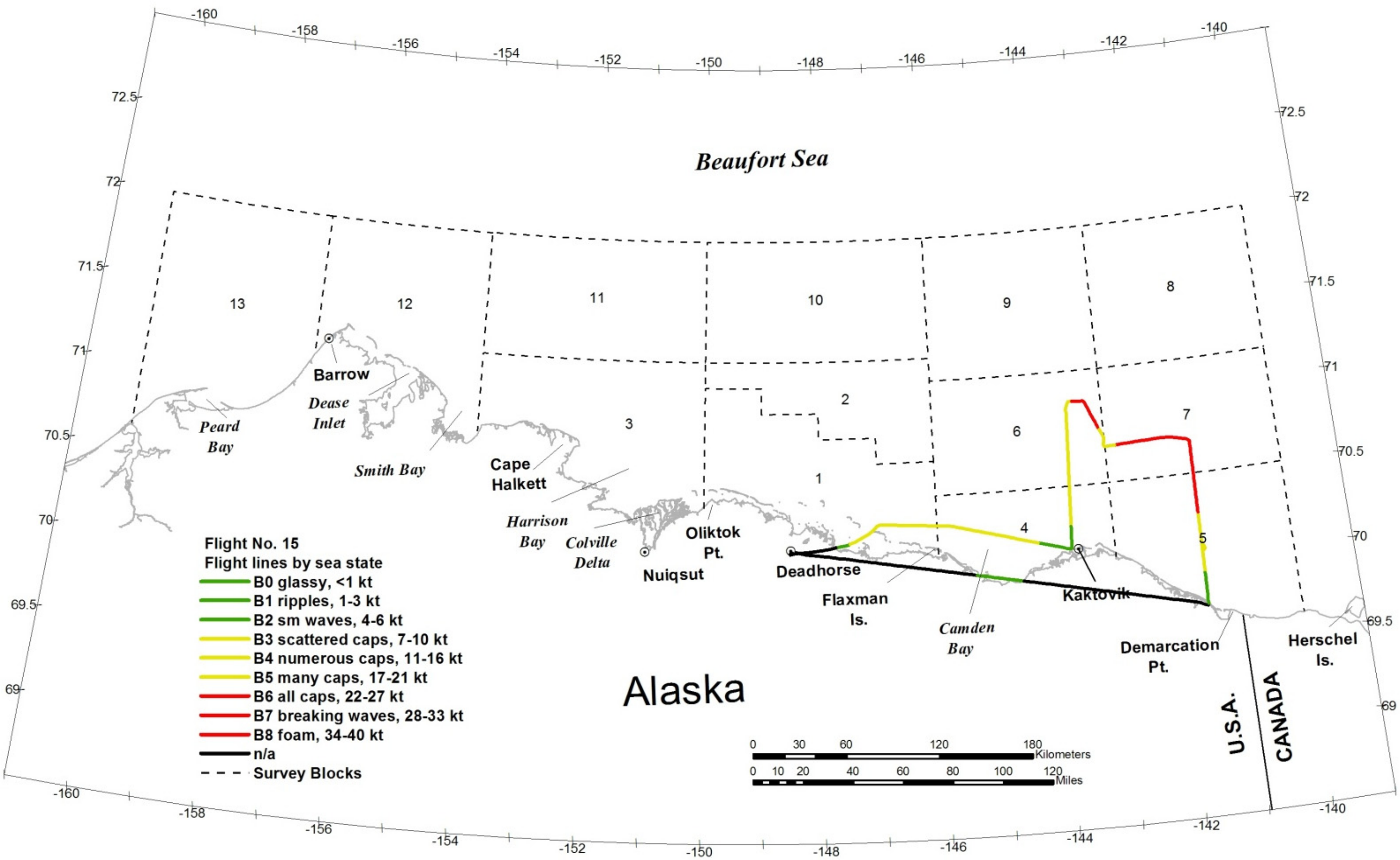

Figure C-15. -- Flight 15 survey track depicted by sea state, 10 October 2009.

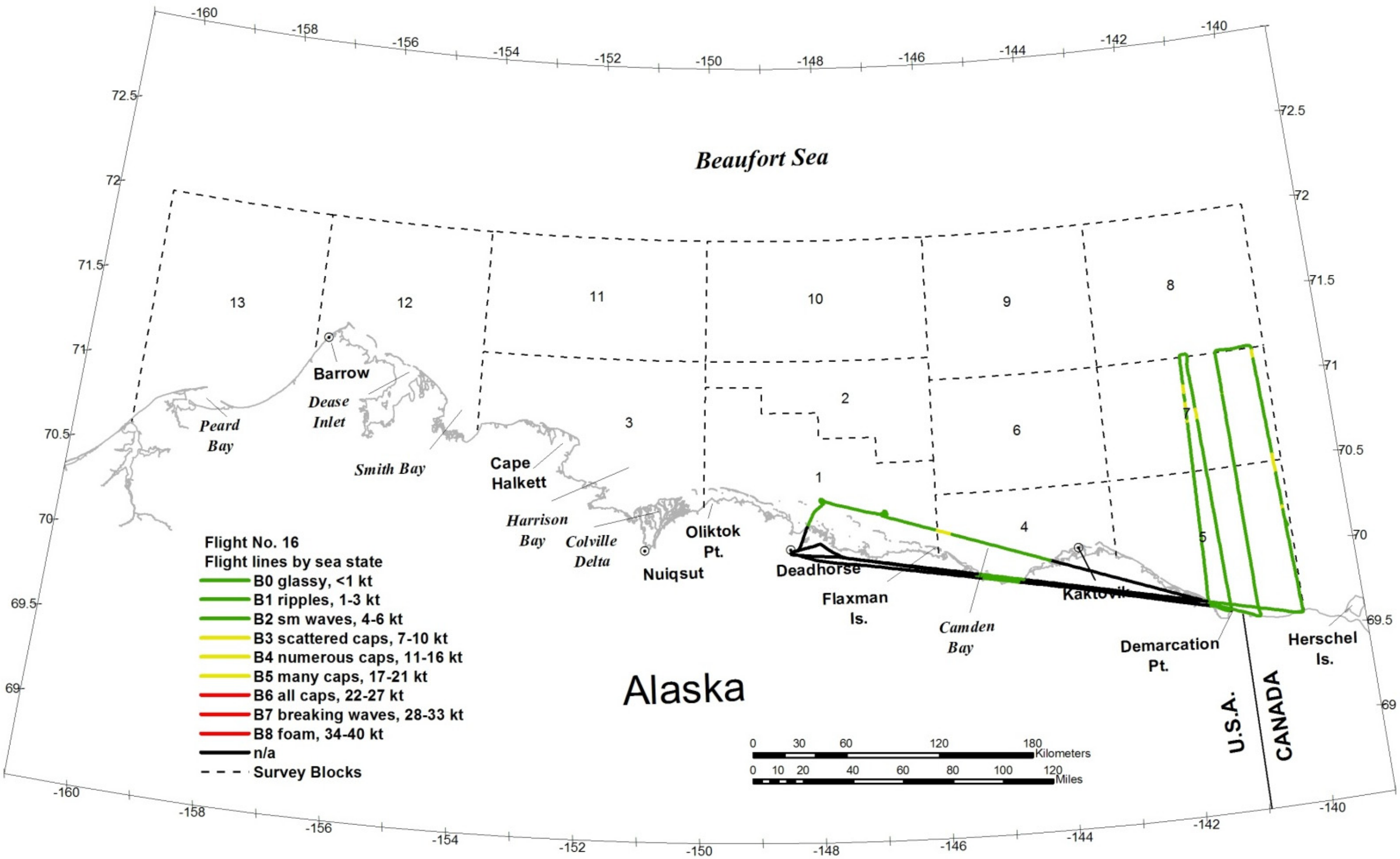

Figure C-16. -- Flight 16 survey track depicted by sea state, 12 October 2009.

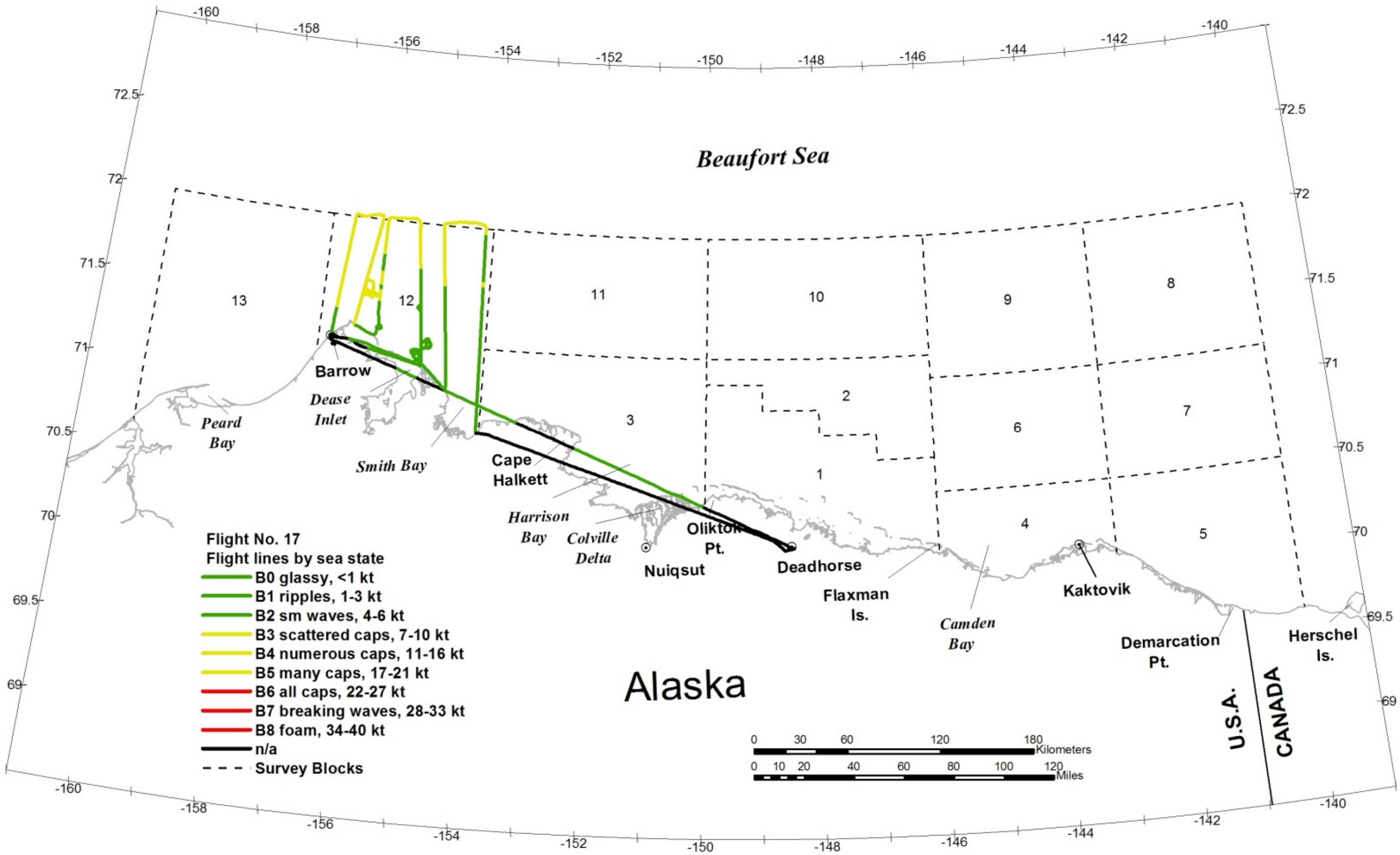

Figure C-17. -- Flight 17 survey track depicted by sea state, 13 October 2009.

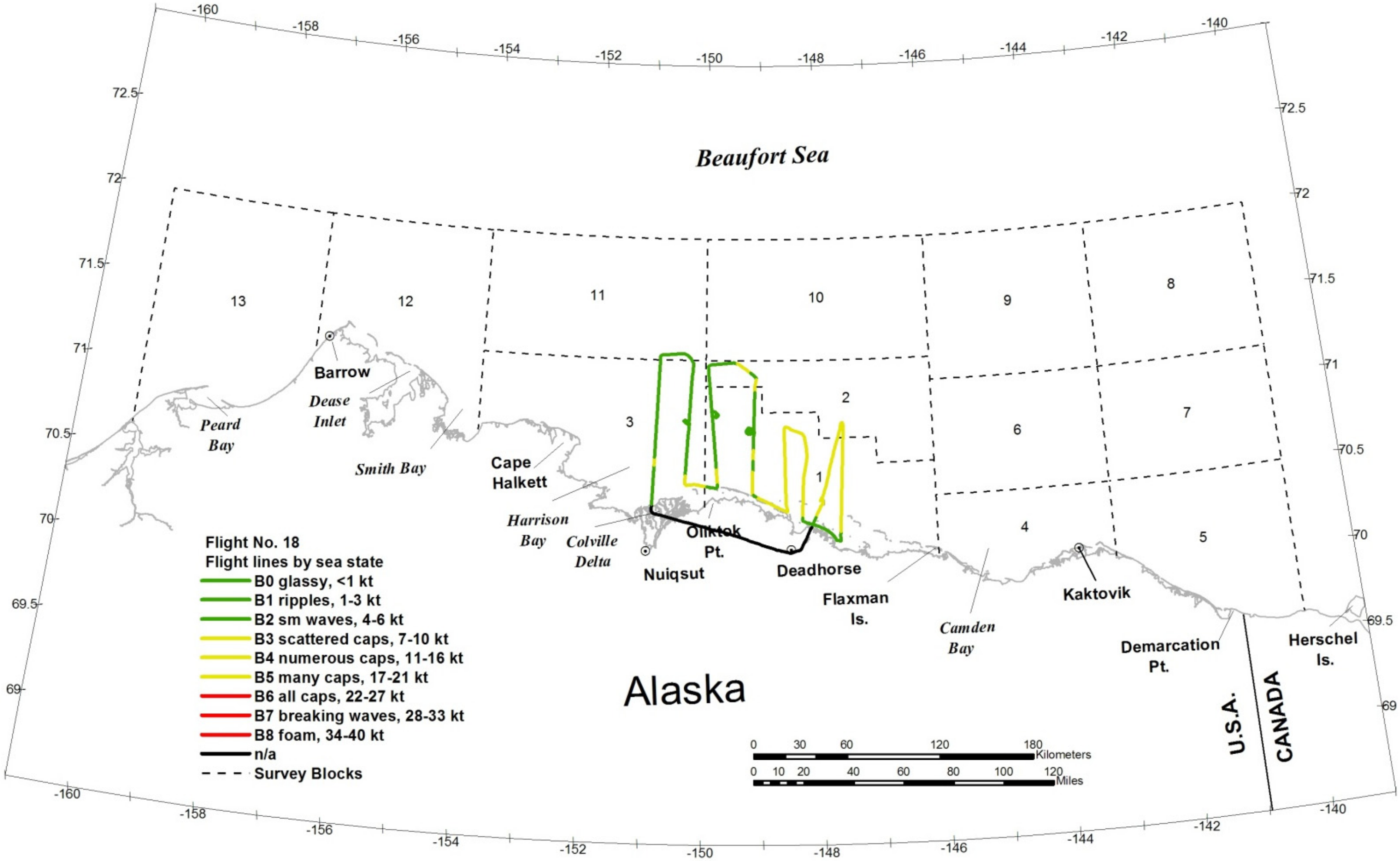

Figure C-18. -- Flight 18 survey track depicted by sea state, 18 October 2009.

APPENDIX D: GLOSSARY OF ABBREVIATIONS, ACRONYMS, AND INITIALISMS

AEWC	Alaska Eskimo Whaling Commission
AFSC	Alaska Fisheries Science Center
ANOVA	analysis of variance
BLM	Bureau of Land Management
BOEMRE	Bureau of Ocean Energy Management, Regulation and Enforcement
BWASP	Bowhead Whale Aerial Survey Project
CI	confidence interval
e.g.	for example
ESA	Endangered Species Act
FR	Federal Register
GPS	Global Positioning System
hr	hour
i.e.	that is
IBCAO	International Bathymetric Chart of the Arctic Ocean
km	kilometer
m	meter
Max	maximum
MMPA	Marine Mammal Protection Act
MMS	Minerals Management Service
Min	minimum
n	sample size
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
NOS	Notice of Sale
NMFS	National Marine Fisheries Service
nm	nautical mile
NSB	North Slope Borough
OAS	Office of Aircraft Services
OCS	Outer Continental Shelf
OCSLA	Outer Continental Shelf Lands Act
P	probability
RDI	Resource Data Incorporated
s	second
SAIC	Science Applications International Corporation
SD	standard deviation
SPUE	sightings per unit effort (sighting rate)
TrSi	transect sightings
USC	U.S. Code
USDOC	U.S. Department of Commerce
USDOD	U.S. Department of Defense
USDOI	U.S. Department of the Interior
WPUE	whales per unit effort (index of relative abundance or occurrence)

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The Department of the Interior Mission

Protecting America's Great Outdoors and Powering Our Future

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.