OCS Study
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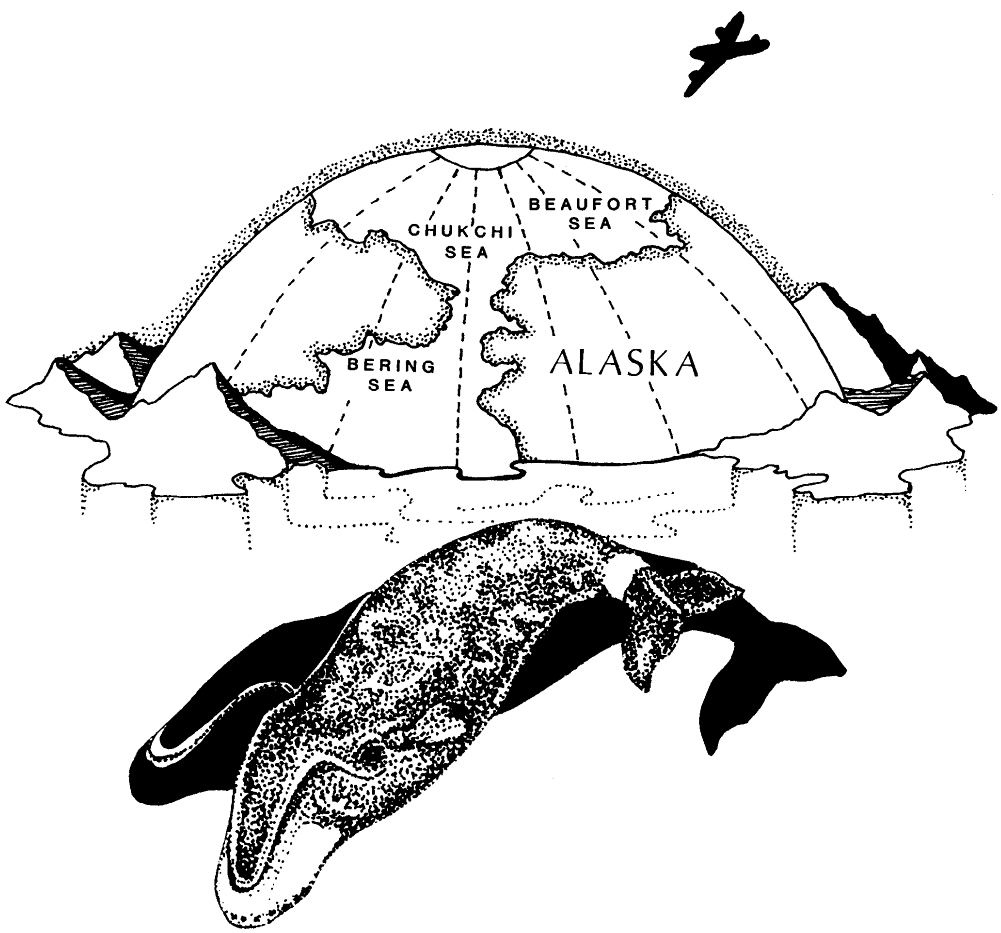
Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 2000

By Stephen D. Treacy, Research Manager
MMS Bowhead Whale Aerial Survey



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ABSTRACT

This report describes field activities and data analyses for aerial surveys of bowhead whales conducted during Fall 2000 (1 September-19 October) in the Beaufort Sea, primarily between 140°W. and 157°W. longitudes south of 72°N. latitude.

During Fall 2000, general ice cover during September and October was the 28th-mildest open-water season (1953-2000). There were 89 sightings for a total of 193 bowhead whales counted during Fall 2000. Additionally, 4 gray whales, 266 beluga whales, 35 bearded seals, 243 ringed seals, 23 polar bears, and 28 sets of polar bear tracks were observed during 89.89 hours of survey effort that included 46.54 hours on randomized transects. The initial sighting of bowhead whales in Alaskan waters occurred on 1 September, when 3 bowheads were observed swimming in an easterly direction northeast of Deadhorse. Of the 193 bowheads observed, half (median) had been counted by 12 September. The peak count (mode) of 88 bowheads also occurred on 12 September, when 77 of these whales were observed feeding next to shore between Dease Inlet and Smith Bay, Alaska. The last sighting of bowhead whales was made on 11 October when 5 whales were observed swimming in a westerly direction near Cape Halkett, Alaska.

The axis of bowhead whale sightings in the West Region was much nearer to shore during Fall 2000 (11.0 km median distance) than for any single year, 1982-2000, and much less than the cumulative median (32.5 km). Likewise, the mean distance from shore for West-Region bowheads in 2000 (17.7 km) was less than for any single year and much less than the cumulative mean (35.4 km). The Tukey test showed that West-Region bowheads in 2000 migrated significantly ($p<0.05$) nearer to shore than for most (>9) other years.

Analysis of sighting rates showed that bowhead whales occur farther offshore in heavy-ice years during fall migrations across the Central Alaskan Beaufort Sea (142°W. to 155°W. longitudes). Bowheads generally occupy nearshore waters in years of light sea-ice severity, somewhat more offshore waters in moderate ice years, and are even farther offshore in heavy ice years. While factors other than sea ice may have localized effects on site-specific distributions, broad-area distributions of bowhead whale sightings in the central Alaskan Beaufort Sea are related to overall sea-ice severity. This relationship is more geographically restricted than previously noted.

An ANOVA of cumulative distances of bowhead whale sightings from a normalized shoreline in heavy, moderate, and light sea-ice categories over a 19-year period (1982-2000) showed significant differences ($F=143.8_{(2, 1294)}$; $p<0.0001$). Post-hoc testing using both the Scheffe Test and Tukey HSD test for unequal sample sizes indicated significant differences ($p<0.0001$) between the distances of bowhead whale sightings from a normalized shoreline under each pair of sea-ice conditions.

ACKNOWLEDGMENTS

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I. INTRODUCTION

In 1953, the Outer Continental Shelf Lands Act (OCSLA) (43 USC 1331-1356) charged the Secretary of the Interior with the responsibility for administering minerals exploration and development of the 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 Minerals Management Service (MMS) assumed these responsibilities.

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

In June 1978, BLM entered into an ESA Section 7 consultation with 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 (*Eschrichtius robustus*) whales. The 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 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, 1988) and monitoring of bowhead whale presence during periods when geophysical exploration and drilling are occurring. The current ARBO, issued by NMFS in 2001 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), a variable 2-month seasonal-drilling restriction on fall exploratory activity in the joint Federal/State Beaufort Sea sale area was implemented. The period of restriction would vary depending on bowhead whale presence, and "this determination would require development of a monitoring program. . .." (USDOI, MMS, 1982). Subsequently, 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, and 170) did not include a seasonal drilling restriction but the NOS for each contained an Information to Lessees clause that "MMS intends to continue its areawide endangered whale monitoring program in the Beaufort Sea during exploration activities" (USDOI, MMS, 1988, 1991, 1996, 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. On 15 April 1987, a proposal for MMS scientists to conduct aerial surveys of endangered whales was approved by the Associate Director for Offshore Minerals Management. The MMS uses agency personnel to perform fieldwork and reporting activities for the Beaufort Sea on an annual basis. Previous survey reports are available for inspection at the Minerals Management Service, Alaska OCS Region, Resource Center, 949 East 36th Avenue, Anchorage, Alaska 99508-4363.

The goals of the ongoing program for monitoring endangered whales are to:

1. Provide real-time data to MMS and NMFS on the general progress of the fall migration of bowhead whales across the Alaskan Beaufort Sea, for use in implementing overall limitations on seasonal drilling and geological/geophysical exploration;

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

3. Define the axis of the fall bowhead migration and analyze for significant interyear differences and long-term trends in the distance from shore and water depth at which whales migrate;

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 whale distribution and incidental sightings of other marine mammals; and

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

II. METHODS AND MATERIALS

A. Study Area

The annual survey program has been based on a design of random field transects within established geographic blocks overlapping or near Chukchi and Beaufort Sea sale areas offshore of Alaska. The present study, which was focused on the fall bowhead whale migrations during 2000, included Beaufort Sea Survey Blocks 1 through 12 (Fig. 1) between 140°W. and 157°W. longitude south of 72°N. latitude.

A large-scale Beaufort Gyre moves waters clockwise from the Canadian Basin westward in the deeper offshore regions. Nearshore surface currents tend to follow local wind patterns and bathymetry, moving from the east in winter, with an onshore component, and to the west in summer, with an offshore component (Brower et al., 1988). There is recent evidence for the existence of two regimes or climate states for arctic atmospheric-ice-ocean circulation. 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 for 5-7 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 kilometers (km) offshore by the end of winter (Norton and Weller, 1984). The pack ice, which includes multiyear ice averaging 4 meters (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 totally covered by ice considered too thick for whales to penetrate. In mid-May, a recurring flaw 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.

Local weather patterns affect the frequency and effectiveness of all marine aerial surveys. The present study area is in the arctic climate zone, with mean temperatures at the Alaskan Beaufort Sea coast communities of Barrow, Lonely, Oliktok, and Barter Island from -0.9°C to -0.1°C during September and from -9.7°C to -8.5°C during October. Precipitation in these communities occurred an average of 10 to 34 percent of the time during September (snow with some rain) and 13 to 43 percent during October (almost all snow), with the heaviest precipitation at Barrow and Barter Island during both months. Fog (without precipitation) reduces visibility approximately 11 to 19 percent of the time during September and 6 to 8 percent of the time during October. Mean windspeed in the same communities is from 5 to 6 m per second during September and 5 to 7 m per second during October (Brower et al., 1988).

Sea state is another environmental factor affecting 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, during which time the ice pack continues to limit fetch. Because of the pack ice, significant wave heights are reduced by a factor of 4 from heights that would otherwise be expected during the open-water season. Wave heights greater than 0.5 m occurred in 23.9 to 38.9 percent of observations during September and 14.1 to 37.4 percent during October, with the greater percentage of larger waves (>0.5 m) reported for the eastern third of the study area during both months. Wave heights greater than 3.5 m are not reported within the study area during September or October (Brower, 1988).

The study area contains sufficient zooplankton to support some feeding by bowhead whales. The availability of zooplankton during the fall would be expected to vary between years, geographic locations, and water depths in response to ambient oceanographic conditions. In September 1985 and 1986, average zooplankton biomass in the Alaskan Beaufort Sea east of 144°W. longitude was highest south of the 50-m isobath in subsurface water (LGL Ecological Research Associates, Inc., 1987).

B. Equipment

The survey aircraft was a de Havilland Twin Otter Series 300 (call sign: N321EA). The aircraft was equipped with two medium-size bubble windows behind the cabin bulkhead and one on the aft starboard side that afforded complete trackline viewing. The pilot and copilot seats provided good forward and side viewing.

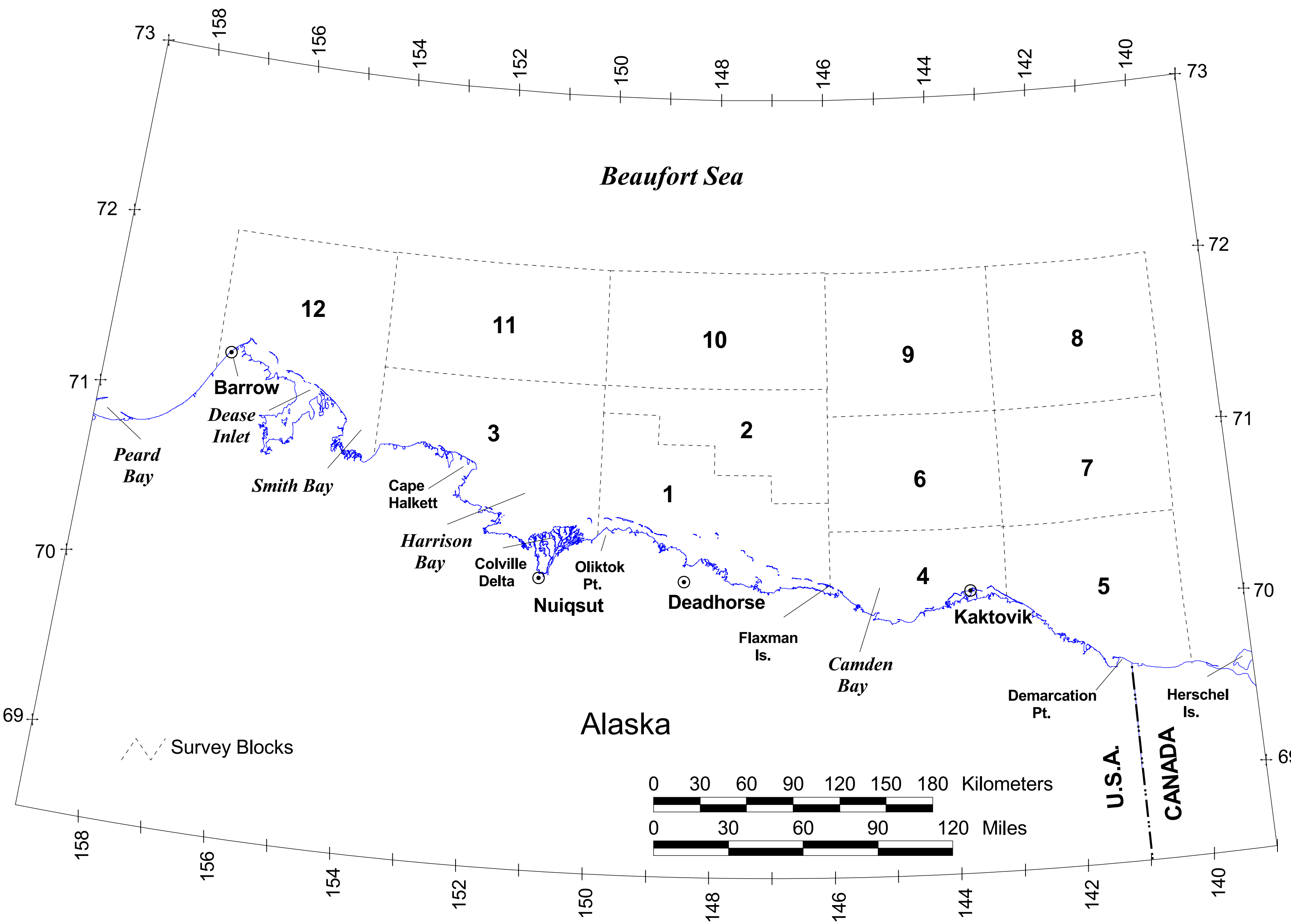


Figure 1. Study Area Showing Survey Blocks

Each observer was issued a hand-held clinometer (Suunto) for measuring the angle of inclination to the sighting location of endangered whales. Observers and pilots were linked to common communication systems, and commentary could be recorded. The aircraft's maximum time aloft under normal survey load was extended to approximately 8 hours (hr) through the use of a supplemental onboard fuel tank.

A portable Gateway Solo 5100 SE laptop computing system was used aboard the aircraft to store and analyze flight and observational data. From 30 August through 15 September, the computer system was connected to a local Garmin III Global Positioning System (GPS) with external aircraft antenna. When the data connection to this GPS failed on 16 September, the project switched to inputting latitude, longitude, and flight altitude into the computer through a standard serial connection from the aircraft's Flight Management System 5000, Model GPS-505. A custom moving-map program developed by MMS project personnel in Visual Basic permitted surveyors to view the aircraft's trackline in real time.

Onboard safety equipment included an impact-triggered emergency locator transmitter installed in the aircraft, a 6-person Switlik Search and Rescue Life Raft equipped with a portable Personal Locator Beacon and desalination pump, a portable ICOM A3 Sport aircraft-band transceiver, an emergency Magellan 3000 GPS, White dry suits, and emergency flight helmets.

In 2000, we used both SkyCell and Windstream satellite flight-following systems for tracking the project aircraft over the Alaskan Beaufort Sea. The OAS obtained current flight information in the form of maps for visual tracking of the survey aircraft. In addition to satellite flight following, the onboard transponder was set at a discrete identification code for radar tracking by air-traffic-control personnel.

C. Aerial-Survey Design

Aerial surveys were based out of Deadhorse, Alaska, from 1 September through 17 October during 2000. Field schedules were designed to monitor the progress of fall bowhead migrations across the Alaskan Beaufort Sea. All bowhead (and beluga) whales observed were recorded, along with incidental sightings of other marine mammals. Particular emphasis was placed on regional surveys to assess large-area shifts in the migration pathway of bowhead whales and on the coordination of effort and management of data necessary to support seasonal offshore-drilling and seismic-exploration regulations.

Daily flight patterns were based on sets of unique transect grids computer-generated for each survey block. 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 then connected by a straight line to a similarly selected endpoint along the southern edge of that same section. This procedure was followed for all sections of that 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 use of random-transect grids is a requirement for subsequent analyses of the bowhead migration corridor based on line-transect theory (Cochran, 1963).

The selection of the survey blocks to be flown on a given day was nonrandom, based primarily on criteria such as reported or observed weather conditions over the study area and the level of offshore oil industry activity in various areas. Weather permitting, the project attempted to distribute effort fairly evenly east-to-west across the entire study area. It also used a semimonthly flight-hour goal for each survey block allocated proportionately for survey blocks east of 154°W. longitude and semimonthly time periods based on relative abundance of bowhead whales as determined from earlier fall migrations (1979-1986). Such allocations, detailed in our Project Management Plan (USDOI, MMS, 2000), greatly favor survey coverage in inshore Survey Blocks 1 through 7 and 11 (Fig. 1), since bowheads 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 random-transect legs were used to analyze the migration axis, using a line-transect model.

D. Survey-Flight Procedures

During a typical flight, a "search" leg was flown to the target survey block, beginning a series of random-"transect" legs (above) joined together by "connect" legs, followed by a search leg back to Deadhorse. Surveys generally were flown at a target altitude of 458 m. Weather permitting, this altitude was maintained in order to maximize visibility and to minimize potential disturbance to marine mammals. Flights were normally aborted when cloud ceilings were consistently less than 305 m or the wind force was consistently above Beaufort 4.

Port observers included a Primary Observer, whose field of vision through a bubble window included the trackline directly below the aircraft to the horizon, the Pilot, and an occasional secondary observer-visitor, stationed aft at a flat window. Starboard observers included a Data Recorder-Observer, whose field of vision through a bubble window was particularly focused on guarding the trackline, as well as a Team Leader and a second Pilot, who were alternately stationed at an aft bubble window and the copilot's seat. A clinometer was used to measure the angle of inclination to each sighting of endangered whales when the initial sighting location was abeam of the aircraft.

When bowheads were encountered while surveying a transect line, the aircraft sometimes diverted from transect for brief (<10-minute) periods and circled the whales to observe behavior, obtain better estimates of their numbers, and determine whether calves were present. Any new sightings of whales made while circling were not counted as "on transect." Likewise, sightings made while en route to transect grids were counted as "on search".

E. Data Entry

A customized computer data-entry form developed by MMS project personnel was used to record all data in database format (Access 97). A multi-columnar data table permitted several entries of sighting and position-update data to be logged and edited simultaneously. The data-entry form is menu-driven, facilitating entry of a complete data sequence for sightings of whales. These data included date, time, latitude, longitude, altitude, aircraft heading, reason for entry, species, total number, observer, swim direction (magnetic), clinometer angle, calf number, behavior, sighting cue, predominant size, habitat, swim speed, repeat sighting, and response to aircraft. Reduced data sequences were used when recording other marine mammals. Position-update data on sky conditions, visual impediments, visibility left and right, percent ice coverage, ice type, and wind force were entered at sightings, turning points, when changes in environmental conditions were observed, and otherwise within 10-minute intervals. Entries were simultaneously printed out in hard copy.

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 one of 15 categories as noted on previous surveys. These categories—breaching, cow-calf association, diving, feeding, flipper-slapping, log playing, mating, milling, resting, rolling, spy-hopping, swimming, tail-slapping, thrashing, and underwater blowing—are defined in Table 1. 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). Likewise, whale size was estimated relatively as calf (length less than half of accompanying adult), immature, adult, or large adult. Swim direction was initially recorded in magnetic degrees, using the aircraft's compass.

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.

F. General Data Analyses

Preliminary field data analysis was performed by a computer program—developed by MMS project personnel—that provided daily summations of marine mammals observed, plus calculation of time and

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 general 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 about in association with a floating log.
Mating	Ventral-ventral orienting 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	Whale(s) swimming slowly at the surface in close proximity (within 100 m) to other whales, often with varying headings.
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 pushes.
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.

distance on transect legs, connect legs, and general search portions of the flight. This analysis program provided options for editing the data file, calculating summary values, and printing various flight synopses.

Tables showing the number of survey hours flown for individual days, half-months, months, or survey blocks were subject to decimal-rounding errors and may or may not add up to the grand total shown for the entire field season. For greatest accuracy and consistency, the total survey hours shown in tables was calculated separately from the cumulative total minutes flown over the entire field season.

An index of relative abundance was derived as whales per unit effort (WPUE = number of whales counted per hour of survey effort on transect, connect, and search). Sighting rates used in report tables were derived as total sightings per unit effort (SPUE = whale pods sighted per hour of survey effort on transect, connect, and search). Sighting rates were depicted on a gridded map representing pods sighted per kilometer of survey effort while on northerly-southerly transects within each grid cell (5' latitude by 15' longitude).

The water depth at each bowhead sighting in the 1982-2000 database was derived from the International Bathymetric Chart of the Arctic Ocean (IBCAO) containing grid cells 2.5 km square (website http://www.ngdc.noaa.gov/mgg/bathymetry/arctic/arctic.html. 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), also derived from IBCAO data, were included in Figure 2 for visual reference.

The maps in this report were prepared with application software (ArcView 3.2A) based on Universal Transverse Mercator Zone 6 (central meridian =147°W. longitude, reference latitude 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.

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, including sea-ice observations made by the project. Polygons of ice concentrations in the Beaufort Sea bracketing the field seasons were downloaded from the National Ice Center Internet web site for the western Arctic (http://www.natice. noaa.gov) and imported into ArcView. Total sea-ice concentrations, regardless of ice type, were edited from these polygons and specially coded to distinguish 0-percent, 1- to 19-percent, 20- to 39-percent, 40- to 59-percent, 60- to 79-percent, 80- to 94-percent, or 95- to 100-percent ice cover.

Survey effort and observed bowhead distribution were plotted semimonthly over the Beaufort Sea study area. Overall fall sightings of beluga whales, 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).

Overall, whale sightings were shown on distribution maps and entered into relative-abundance analyses, regardless of the type of survey leg (transect, search, or connect) being conducted or the prevailing environmental conditions (sea state, ice cover, etc.) when the sightings were made. As with previous reports in this series (Treacy, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, and 2000), 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.

G. Analysis of the Bowhead Whale Migration Corridor

The corridor used by bowhead whales during their fall migration was analyzed both by the mean distance from shore to whales sighted on randomized transects as well as mean water depth at random whale sightings. The analyses presented here were completed using *Statistica*™ StatSoft, Version 5.1 and ArcView 3.2A. The mean distance from shore at bowhead sightings between years were compared employing parametric analysis of variance (ANOVA) and Tukey "honestly significant difference" (HSD) tests. The ANOVA tests the hypothesis that distances from shore are the same among years. The Tukey HSD test is a multiple comparison procedure that provides statistical comparison of means for any pair of years (Zar, 1984).

Distance from shore is of particular interest to North Slope residents who rely on a successful harvest of whales for subsistence purposes. Subsistence whalers generally agree that the farther offshore whales migrate, the riskier whales are to hunt and the more likely carcasses will spoil before reaching the villages (USDOI, MMS, 1997).

An analysis protocol specifying the use of median water depth to detect interannual shifts in the bowhead migration route was initially described in Chapters 4.2.3 and 5.3.3 of "Beaufort Sea Monitoring Program Workshop Synthesis and Sampling Design Recommendations" (Houghton, Segar, and Zeh, 1984). Because of the bathymetry of the Alaskan Beaufort Sea, a seaward displacement of the fall-migration route would be represented, via this analysis, as a shift to deeper water and a greater median depth.

The present analyses provide biological information needed to test the following null hypotheses recommended by the above workshop:

Ho_1: The axis of the fall migration of bowhead whales will not be altered during periods of increased OCS oil and gas development activities in the Alaskan Beaufort Sea.

Ho_2: Changes in bowhead migration patterns are not related to OCS oil and gas development activity.

To determine the usefulness of these analyses for detecting differences in distance from shore between years, a preliminary power analysis was performed (Treacy, 1998).

H. Oceanographic Regions

To define the migration axis, a separate file was created for bowhead whale sightings made while on random transects, regardless of distance from the transect line. Distance from shore and water depth at bowhead whale sightings made during random transect aerial surveys in the Alaskan Beaufort Sea were analyzed for two regions (Fig. 2), the boundaries of which correspond roughly to oceanographic patterns and the offshore-extent of sampling.

Oceanographic patterns common to waters offshore 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 West-East regions for this analysis occurs at 148°W., based upon association with general patterns for these water masses.

The northern extent of each region is based upon survey effort. For example, the East Region extends from 140°W. to 148°W. and from the shore north 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 6, 7 and 2 (Fig. 1): blocks with sufficient survey effort to support analyses (Treacy, 1997: Table 11). The West Region extends from 148°W. to 156°W. and from the shore north 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 eastern boundary (140°W.) is simply the easternmost longitude of the survey blocks. The western cutoff at 156°W. limits the analysis to bowheads seen in the Alaskan Beaufort Sea and avoids the influence of Barrow Canyon on bowhead depth distribution.

The shoreline used for this 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 derived by connecting, with straight lines, eleven points at various shoreline or barrier islands locations across Alaska's North Slope between 156°W. and 140°W.

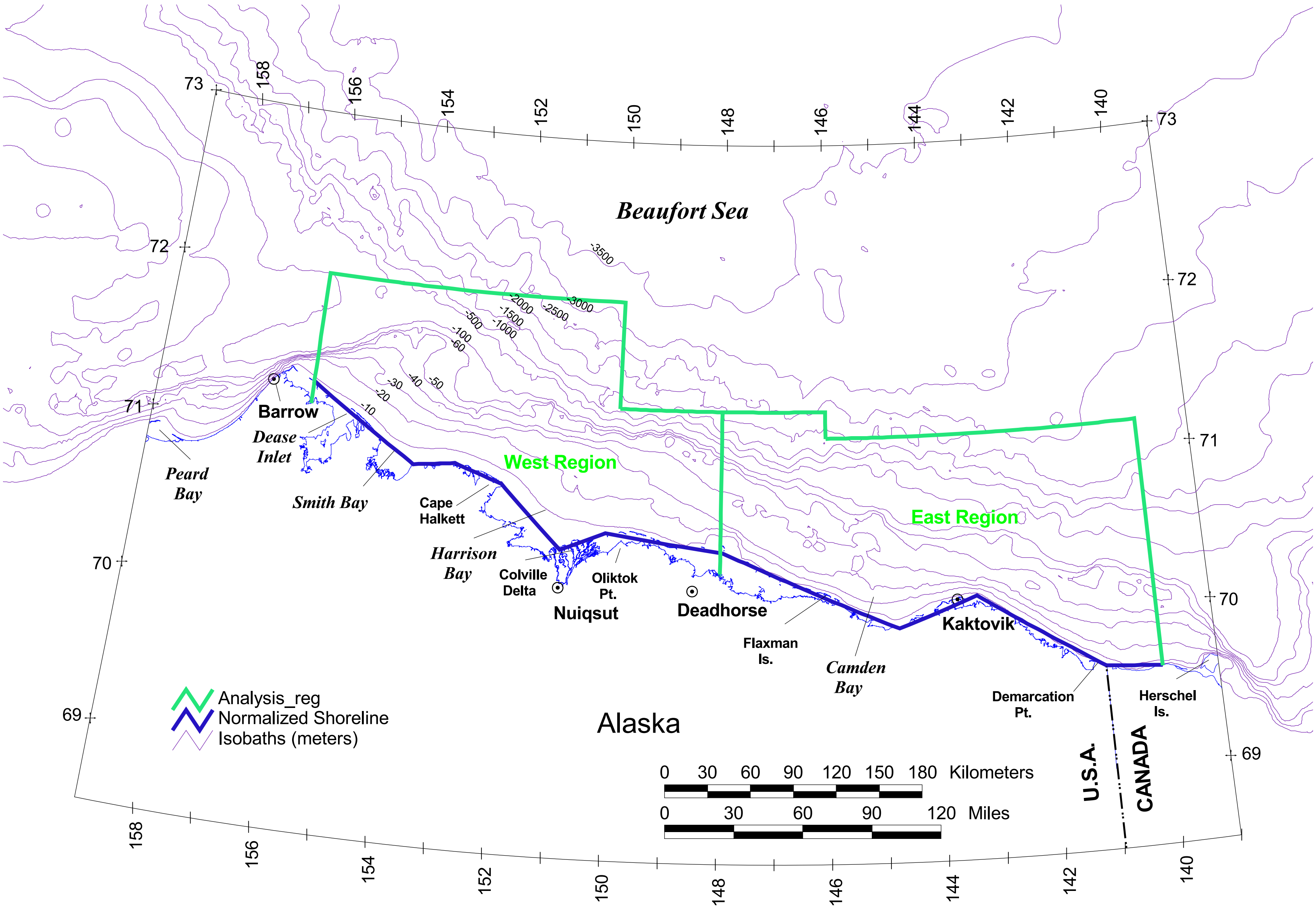


Figure 2. East and West Regions, Showing a Normalized Shoreline and Selected IBCAO Isobaths

(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.

III. FALL 2000 RESULTS

A. Environmental Conditions

General ice coverage in the Alaskan Beaufort Sea (Appendix A) was fairly light during most of the Fall 2000. Ice coverage began to open up after 28 August. During the first half of September, the western half of the study area was relatively ice-free, whereas the eastern half had 1-19% inshore concentrations, with heavier offshore concentrations. During the latter half of September, sea ice across the study area was either ice-free or nearly so (1-9%), except for a narrow strip of shore-fast ice at the end of the month. By 6 October, a small area between Deadhorse and Dease Inlet, Alaska was still ice-free, with fairly low concentrations of ice elsewhere in the study area. By mid-October, heavy ice concentrations prevailed along shore and offshore, with an area of light ice (1-9%) remaining in the western half of the study areas. Ice percentages and sea states at each sighting of endangered whales are shown in Appendix B (Table B-1).

Environmental conditions permitted 28 flights during Fall 2000. Of these, only 8 flights were made during October, primarily due to high sea states and/or low cloud ceilings (Table 2).

B. Survey Effort

The fall field season was from 1 September 2000 through 19 October 2000. Daily totals of kilometers and hours flown per survey flight during this period are shown in Table 2. A total of 21,053 km of surveys were flown in 89.89 hours in the study area at an average speed of 234.21 km/hr. The average survey flight was 751.89 km, with over-ocean flight distances ranging from 48 km to 1,394 km. A total of 10,579 km of random-transect lines were flown in 46.54 hours at an average transect speed of 227.31 km/hr. These random transects constituted 50.25 percent of the total kilometers flown and 51.77 percent of the total flight hours. Survey-flight lines are shown by semimonthly period in Figures 3 through 6.

During the first half of September, survey coverage ranged from 140°W. to 157°W. longitudes, with most of the effort within 70 nautical miles (nm) of shore (Fig. 3). There were 19.78 hours of random transects flown out of 37.72 total flight hours during this period (Table 2), constituting 42.50 percent and 41.96 percent, respectively, of the total time spent in those effort categories over the fall season.

During the second half of September, most survey coverage ranged from 140°W. to 150°W. longitudes, within 80 nm of shore (Fig. 4). There were 9.55 hours of random transects flown out of 21.02 total flight hours during this period (Table 2), constituting 20.52 percent and 23.38 percent, respectively, of the total time spent in those effort categories.

During the first half of October, survey coverage ranged from 140°W. to 154°W. longitudes, mostly within 100 nm of shore (Fig. 5). There were 17.01 hours of random transects flown out of 29.03 total flight hours during this period (Table 2), constituting 36.55 percent and 32.30 percent, respectively, of the total time spent in those effort categories.

From 16 through 19 October, survey coverage was limited to one flight ranging from 148°W. to 154°W. longitudes, within 30 nm of shore (Fig. 6). There were 0.20 hours of random transects flown out of 2.12 total flight hours during this period (Table 2), constituting 0.43 percent and 2.36 percent, respectively, of the total time spent in those effort categories.

C. Bowhead Whale (*Balaena mysticetus*) Observations

1. Sighting Summary: Eighty-nine sightings were made for a total of 193 bowhead whales observed during Fall-2000 surveys in the study area (Table 3 and Figs. 7-10), not counting definite repeat sightings or dead whales. Relatively widespread survey coverage between 140°W. and 157°W. longitudes (Figs. 3-6), resulted in distribution of bowhead whales all across the study area within 70 nm north of the shoreline unadjusted for effort (Fig. 10). One of the 193 whales was identified as a calf (Appendix B: Table B-1), resulting in a seasonal calf ratio (number calves/total whales) of 0.005. A semi-monthly analysis follows.

Table 2
Aerial-Survey Effort in the Beaufort Sea, 1 September–19 October 2000, by Survey Flight

Day	Flight No.	Transect (km)	Connect (km)	Search (km)	Total (km)	Transect (hr)	Total (hr)
1 Sep	1	767	170	457	1,394	3.27	6.02
2 Sep	2	856	106	430	1,391	3.80	6.23
3 Sep	3	722	116	430	1,268	3.13	5.53
6 Sep	4	0	0	166	166	0.00	0.68
7 Sep	5	0	0	254	254	0.00	0.93
9 Sep	6	0	0	231	231	0.00	1.07
12 Sep	7	574	100	533	1,207	2.63	5.38
13 Sep	8	900	214	170	1,284	3.92	5.68
14 Sep	9	0	0	313	313	0.00	1.15
15 Sep	10	0	0	96	96	0.00	0.38
15 Sep	11	689	203	180	1,073	3.03	4.67
16 Sep	12	0	0	48	48	0.00	0.22
17 Sep	13	514	160	341	1,016	2.35	4.42
18 Sep	14	52	0	228	280	0.22	1.05
20 Sep	15	751	148	435	1,335	3.32	5.72
21 Sep	16	0	0	99	99	0.00	0.37
23 Sep	17	24	0	456	479	0.08	1.82
25 Sep	18	809	221	193	1,224	3.58	5.37
28 Sep	19	0	0	169	169	0.00	0.63
29 Sep	20	0	0	341	341	0.00	1.42
2 Oct	21	76	3	294	373	0.33	1.65
5 Oct	22	134	33	616	782	0.60	3.15
9 Oct	23	741	138	172	1,051	3.25	4.53
10 Oct	24	723	167	280	1,170	3.17	4.95
11 Oct	25	965	85	316	1,365	4.23	5.82
12 Oct	26	698	195	431	1,323	3.05	5.58
13 Oct	27	543	92	138	773	2.38	3.35
17 Oct	28	41	0	506	548	0.20	2.12
Semimonthly Effort Summary							
1-15 Sep		4,508	909	3,260	8,677	19.78	37.72
16-30 Sep		2,150	529	2,310	4,991	9.55	21.02
1-15 Oct		3,880	713	2,247	6,837	17.01	29.03
16-19 Oct		41	0	506	548	0.20	2.12
TOTAL		10,579	2,151	8,323	21,053	46.54	89.89

Table 3
Summary of Marine Mammal Sightings, 1 September-19 October 2000, by Survey Flight
(number of sightings/number of animals)

Day	Flight No.	Bowhead Whale	Gray Whale	Beluga Whale	Unidentified Cetacean	Bearded Seal	Ringed Seal	Pacific Walrus	Unidentified Pinniped	Polar Bear (PB)	PB Tracks (no bear)
1 Sep	1	10/12	0	0	0	6/6	4/4	0	0	0	0
2 Sep	2	8/15	1/4	4/8	1/1	0	4/6	0	0	0	0
3 Sep	3	11/19	0	5/20	0	5/7	7/10	0	0	0	0
6 Sep	4	0	0	0	0	0	0	0	0	0	0
7 Sep	5	0	0	0	0	0	0	0	0	0	0
9 Sep	6	1/1	0	0	0	0	0	0	0	0	0
12 Sep	7	13/88	0	4/44	0	0	0	0	0	0	0
13 Sep	8	1/1	0	1/9	0	2/2	8/77	0	0	0	0
14 Sep	9	0	0	0	0	0	0	0	0	0	0
15 Sep	10	0	0	0	0	0	0	0	0	0	0
15 Sep	11	6/6	0	4/104	0	1/1	30/83	0	0	0	0
16 Sep	12	0	0	0	0	0	0	0	0	0	0
17 Sep	13	4/4	0	0	0	0	1/1	0	0	0	3
18 Sep	14	0	0	0	0	0	0	0	0	0	0
20 Sep	15	1/1	0	0	0	10/14	38/57	0	1/6	1/3	0
21 Sep	16	0	0	0	0	0	0	0	0	0	0
23 Sep	17	6/6	0	0	0	0	0	0	0	0	0
25 Sep	18	5/5	0	2/2	0	1/2	0	0	0	0	0
28 Sep	19	0	0	0	0	0	0	0	0	0	0
29 Sep	20	0	0	0	0	0	0	0	0	1/2	0
2 Oct	21	0	0	0	0	0	0	0	0	0	0
5 Oct	22	1/2	0	0	0	1/1	0	0	0	2/4	3
9 Oct	23	0	0	4/5	0	0	0	0	0	0	1
10 Oct	24	12/13	0	10/27	0	0	4/5	0	0	1/1	0
11 Oct	25	10/20	0	4/46	0	0	0	0	0	0	1
12 Oct	26	0	0	1/1	0	2/2	0	0	0	4/13	19
13 Oct	27	0	0	0	0	0	0	0	0	0	1
17 Oct	28	0	0	0	0	0	0	0	0	0	0

Table 3
Summary of Marine Mammal Sightings, 1 September-19 October 2000, by Survey Flight
(number of sightings/number of animals)

Day	Flight No.	Bowhead Whale	Gray Whale	Beluga Whale	Unidentified Cetacean	Bearded Seal	Ringed Seal	Pacific Walrus	Unidentified Pinniped	Polar Bear (PB)	PB Tracks (no bear)
Total Semimonthly Sightings											
1-15 Sep		50/142	1/4	18/185	1/1	14/16	53/180	0	0	0	0
16-30 Sep		16/16	0	2/2	0	11/16	39/58	0	1/6	2/5	3
1-15 Oct		23/35	0	19/79	0	3/3	4/5	0	0	7/18	25
16-19 Oct		0	0	0	0	0	0	0	0	0	0
TOTAL		89/193	1/4	39/266	1/1	28/35	96/243	0	1/6	9/23	28

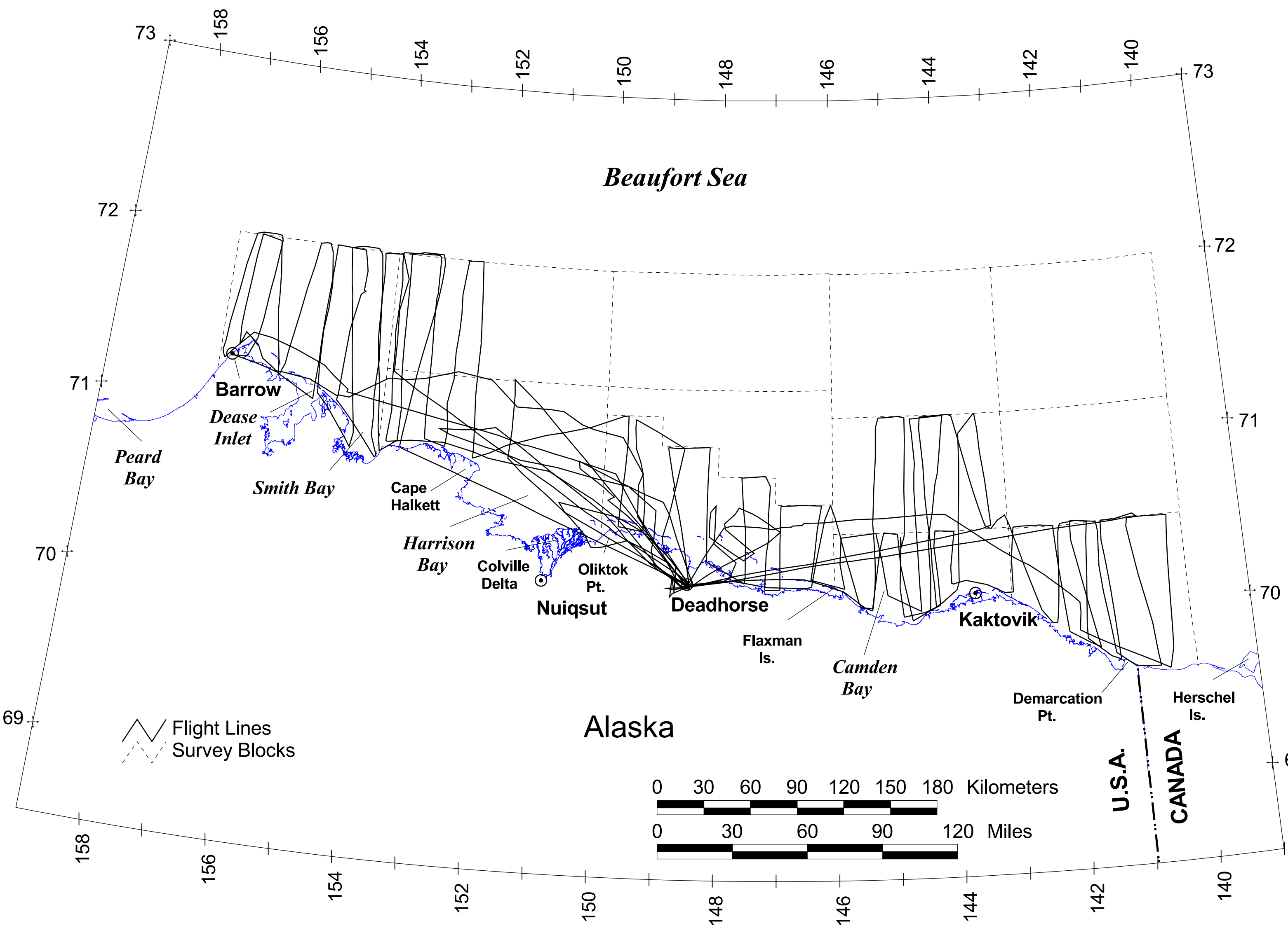


Figure 3. Combined Flight Tracks, 1-15 September 2000

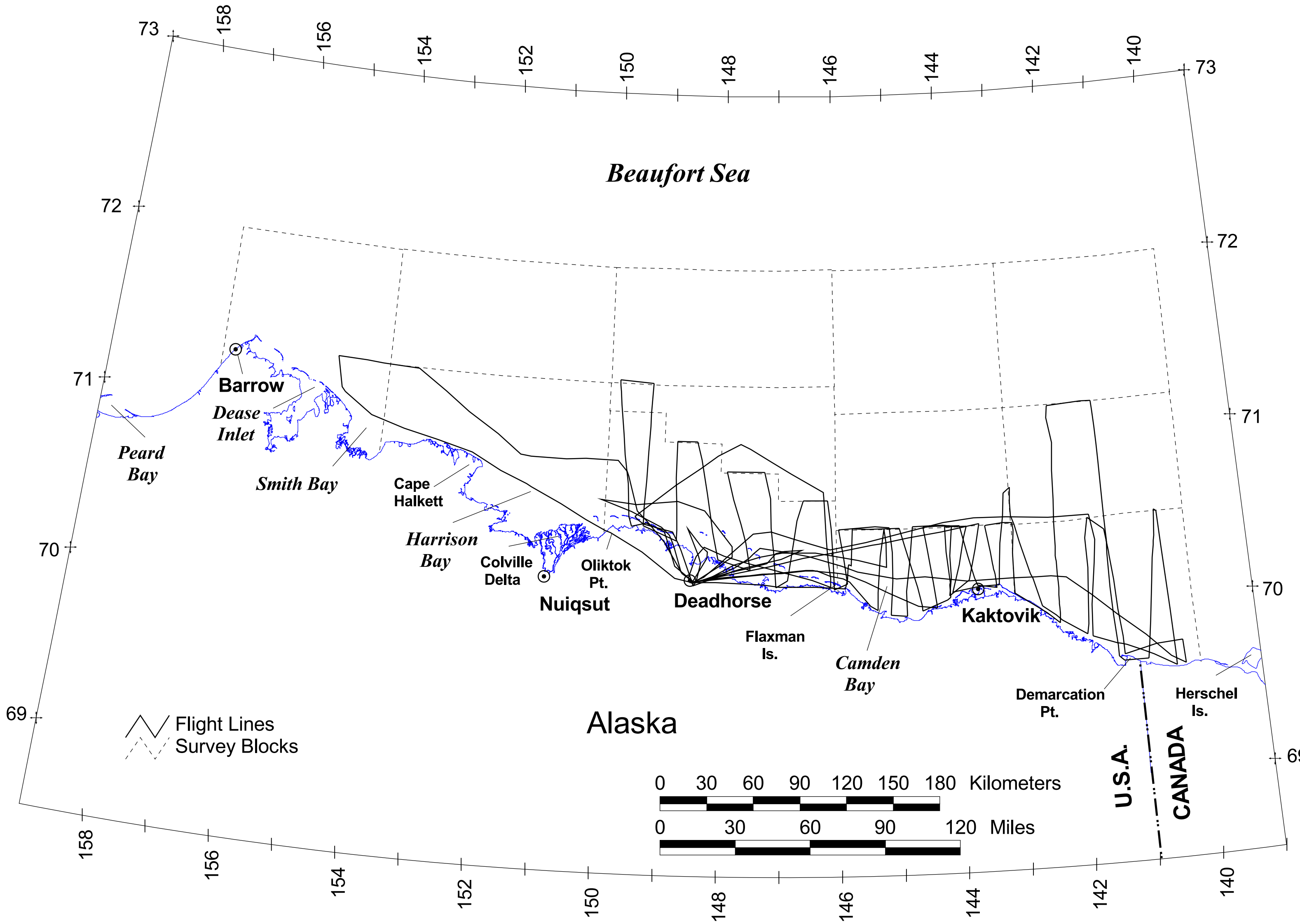


Figure 4. Combined Flight Tracks, 16-30 September 2000

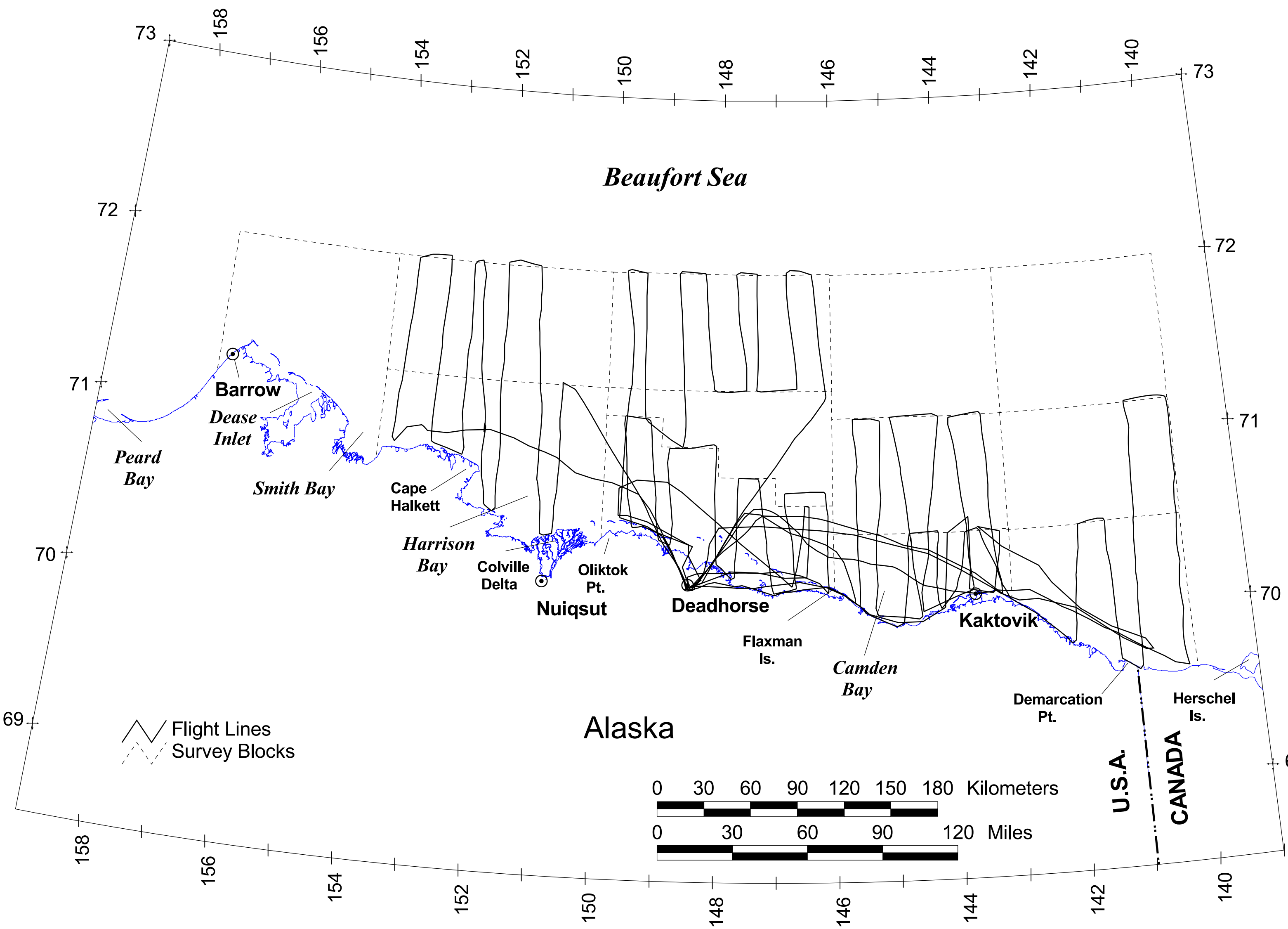


Figure 5. Combined Flight Tracks, 1-15 October 2000

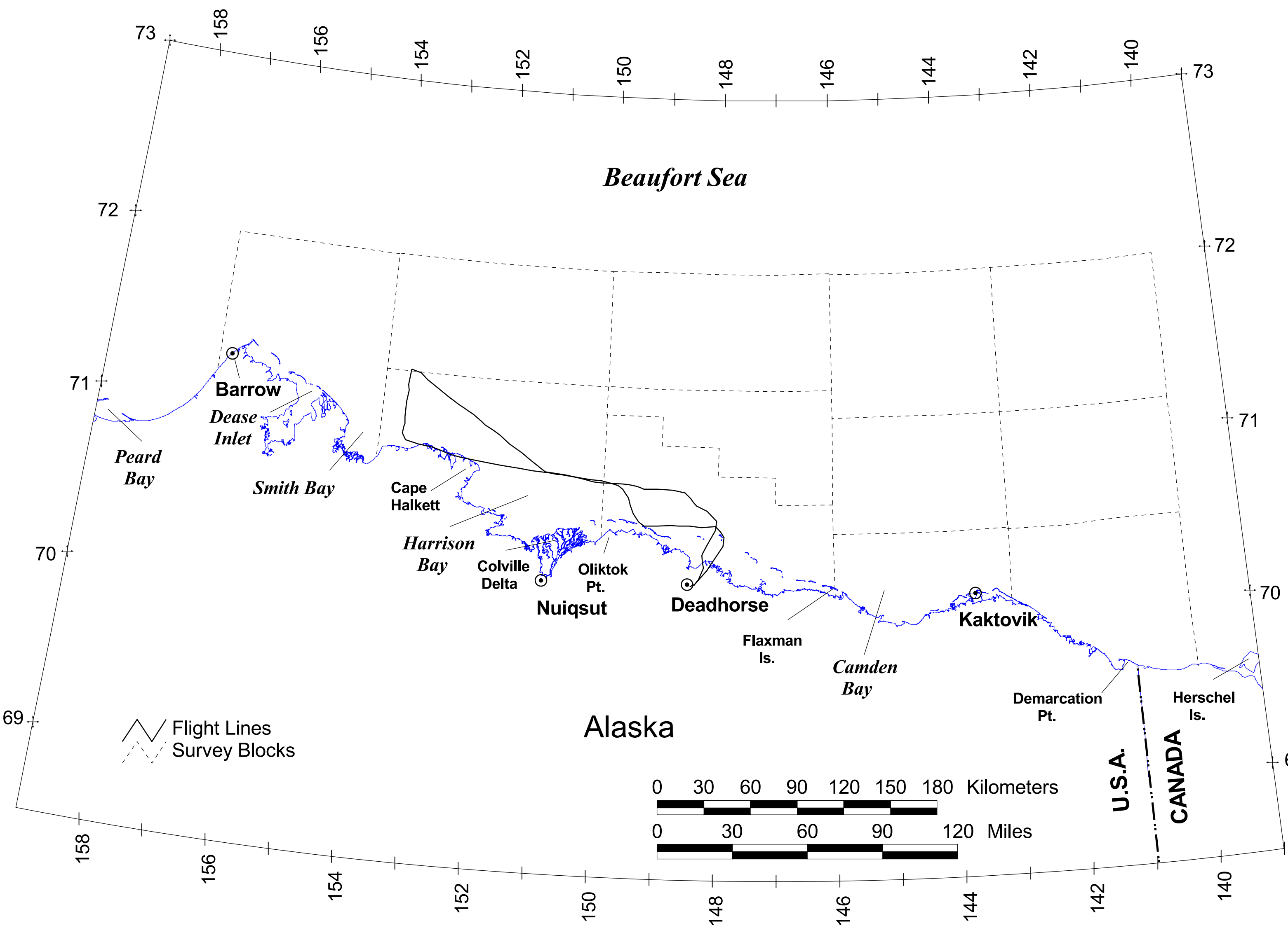


Figure 6. Combined Flight Tracks, 16-19 October 2000

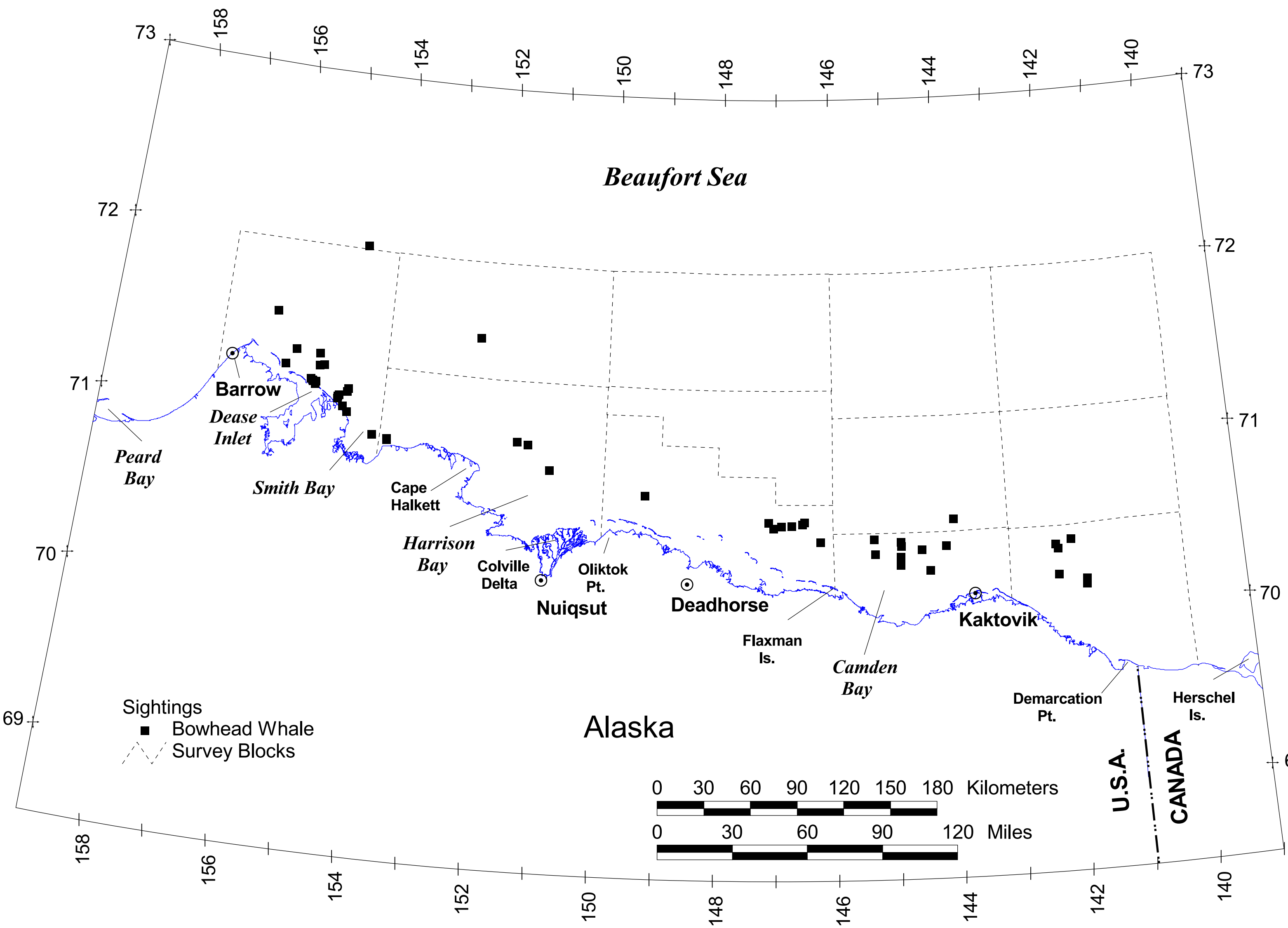


Figure 7. Map of Bowhead Whale Sightings, 1-15 September 2000

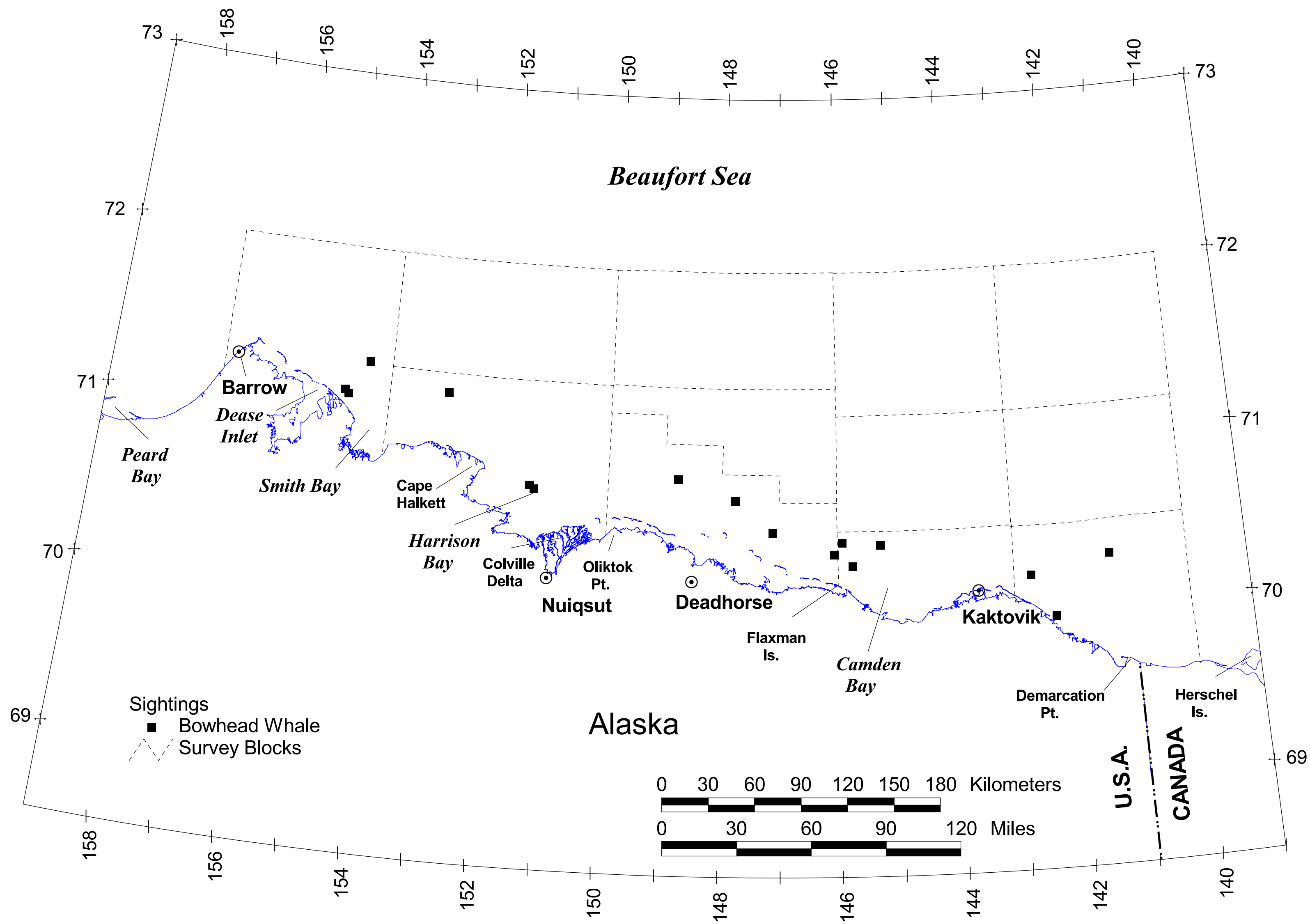


Figure 8. Map of Bowhead Whale Sightings, 16-30 September 2000

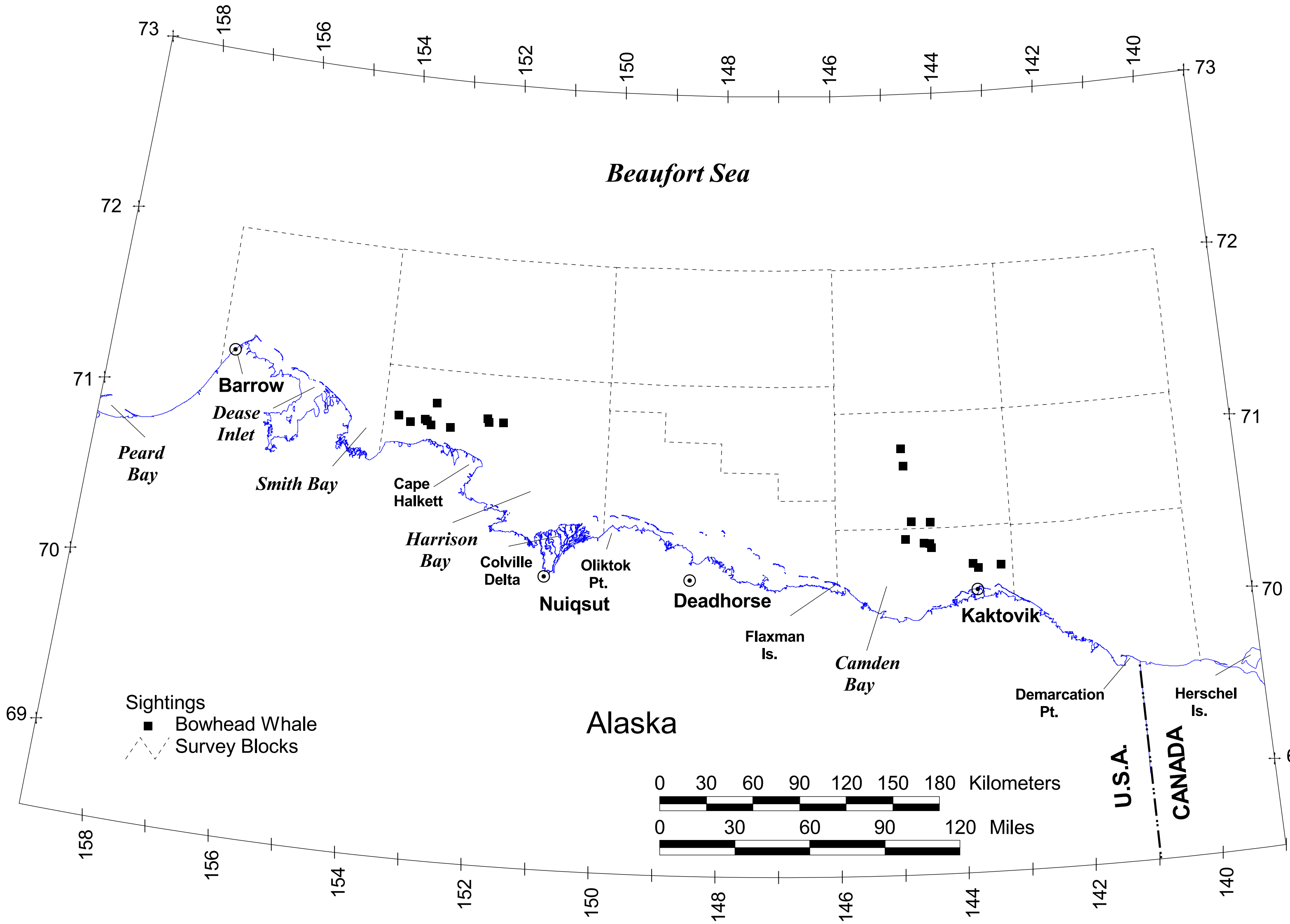


Figure 9. Map of Bowhead Whale Sightings, 1-15 October 2000

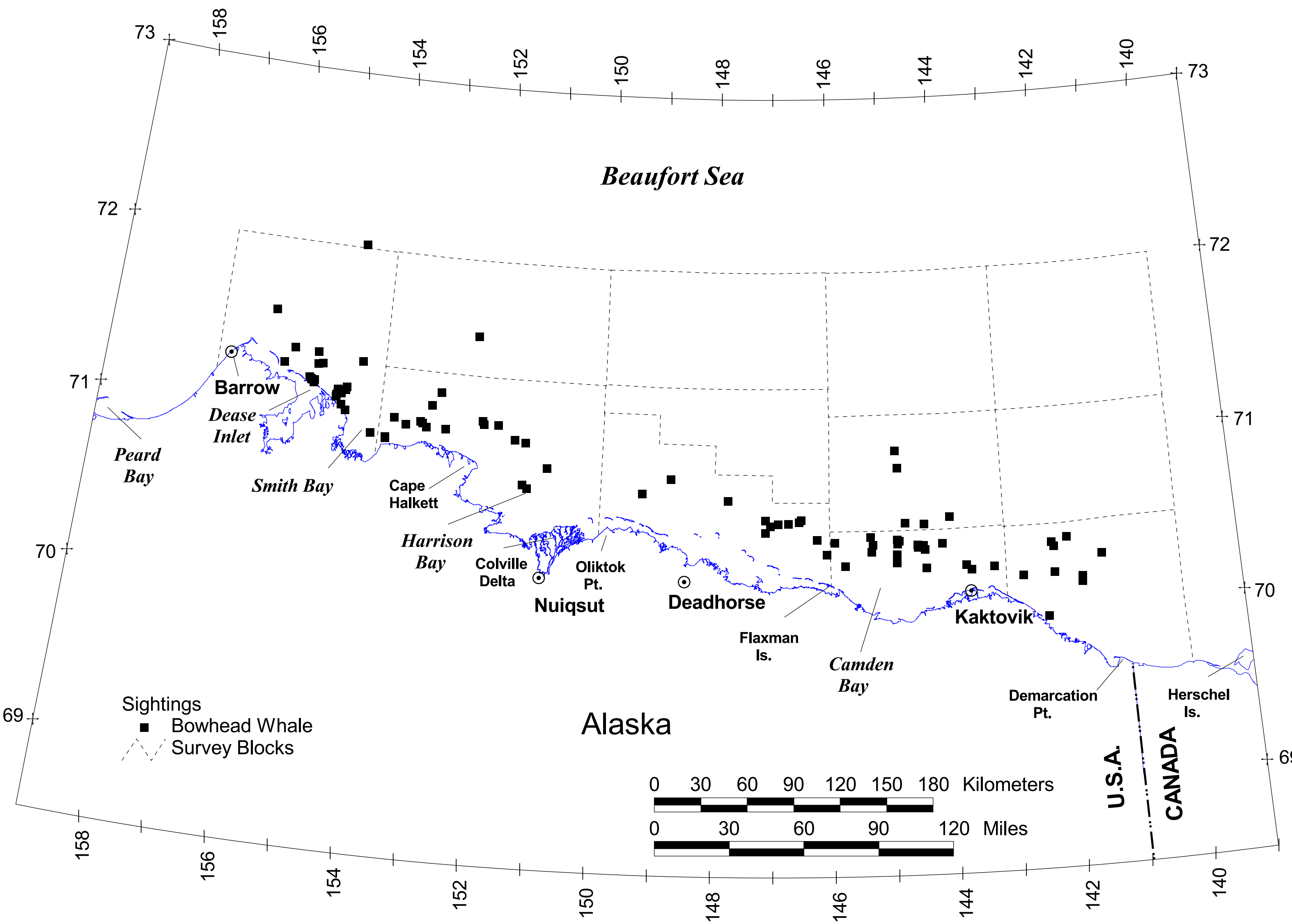


Figure 10. Map of Bowhead Whale Sightings, Fall 2000

During the first half of September, 50 sightings were made for a total of 142 bowheads (Table 3), with sightings ranging between 141°W. and 157°W. longitudes, based on survey coverage across the study area (Fig. 3). The first bowheads observed in the Alaskan Beaufort Sea were sighted on 1 September at 70°31.8´N. latitude, 147°03.1´W. longitude. Whale pods were evenly distributed east to west, mostly within 60 nm north of the shoreline (Fig. 7). Pod or aggregation sizes ranged from 1 to 47 whales, with a mean of 2.84 (SD=6.78, n=50). No bowhead whale calves were observed during this period (Appendix B: Table B-1).

During the second half of September, 16 sightings were made for a total of 16 bowheads (Table 3), with sightings between 141°W. and 155°W. longitudes, based on similar geographic survey coverage (Fig. 4). Whale pods were distributed evenly east to west, mostly within 30 nm north of the shoreline (Fig. 8). All pods were of single whales. No bowhead whale calves were observed during this period (Appendix B: Table B-1).

During the first half of October, 23 sightings were made for a total of 35 bowheads (Table 3), with sightings clustered between 141°W. and 145°´W. longitudes within 60 nm north of the shoreline as well as between 151°W. and 154°´W. longitudes within 30 nm north of the shoreline (Fig. 9), based on widespread survey coverage (Fig. 5). Pod sizes ranged from 1 to 5 whales, with a mean of 1.52 (SD=1.04, n=23). One bowhead whale calf was observed during this period (Appendix B: Table B-1). The last bowhead whales in the Alaskan Beaufort Sea were sighted on 11 October at 71°03.2´N. latitude, 151°53.3´W. longitude.

From 16 through 19 October, no bowhead whales were sighted (Table 3) during one survey flight (Fig. 6).

2. Sighting Rates and Distance from Shore: Maps of raw sighting points like Figure 10 can give a misleading visual impression when survey effort is unequal. Because survey effort was unequal across our study area, due primarily to environmental conditions, a graphic method that adjusts for discontinuities in effort was desired. First, a grid matrix was superimposed across the study area using a Geographic Information System (*ArcView,* Version 3.2A). The matrix, consisting of approximately equilateral grid cells sized 5' latitude by 15' longitude, was considered appropriate to the data, simple to query, and visually easy to interpret. Bowhead sighting rates were calculated as the number of sightings per kilometer while on northerly-southerly transect (trSI/km) per individual grid cell. Fall-2000 results, color-coded by calculated sighting rate, are shown in Figure 11.

In Fall 2000, bowhead sighting rates between Demarcation Point and Flaxman Island, Alaska, were highest in a horizontal east-west band 15-40 nm from shore (Fig. 11). Other whales between Dease Inlet and Smith Bay, Alaska, were concentrated very near to the shoreline (see Behaviors section below).

Distances of each bowhead whale sighting from shore in Fall-2000 were measured by ArcView 3.2 as the distance due north of a normalized shoreline. The mean distance from shore and Standard Deviations for an East and West Region were calculated (Table 7). West Region bowheads in Fall 2000 (mean = 17.7 km) were extremely close to shore, such that the southernmost Standard Deviation line was essentially identical to the normalized shoreline (Fig. 12).

3. Migration Timing: Temporal SPUE was calculated over the entire study area as the number of sightings made per hour while on search, connect, and transect. These hourly sighting rates (regardless of survey-effort type), were calculated by survey day during the Fall-2000 bowhead whale migration to identify any obvious temporal patterns. Of the 89 sightings of bowhead whale pods, the first whale observed was on 1 September. Daily sighting rates were fairly level over the field season, ranging from 0.00 SPUE on 13 separate days up to 3.30 WPUE on 23 September. The last sighting of a bowhead whale was made on 11 October (Table 4).

The WPUE was calculated over the entire study area as the number of individual animals counted per hour while on search, connect, and transect. This index of relative abundance by survey day was also used to identify any obvious temporal patterns. Of the 193 individual bowhead whales counted, the data for daily relative abundance show that the midpoint (median) of the bowhead migration in Blocks 1 through 12 (when 50% of all sighted whales had been recorded) occurred on 12 September. The peak relative abundance (mode) of 16.36 WPUE also occurred on 12 September (Table 4).

Table 4
Number of Sightings and Total Bowhead Whales Observed per Hour,
1 September-19 October 2000, by Flight Day

Day	No. of Sightings	No. of Whales	Survey Time (hr)	Sightings/hr (SPUE)	Whales/hr (WPUE)
1 Sep	10	12	6.02	1.66	1.99
2 Sep	8	15	6.23	1.28	2.41
3 Sep	11	19	5.53	1.99	3.44
6 Sep	0	0	0.68	0.00	0.00
7 Sep	0	0	0.93	0.00	0.00
9 Sep	1	1	1.07	0.93	0.93
12 Sep	13	88	5.38	2.42	16.36
13 Sep	1	1	5.68	0.18	0.18
14 Sep	0	0	1.15	0.00	0.00
15 Sep	6	6	5.05	1.19	1.19
16 Sep	0	0	0.22	0.00	0.00
17 Sep	4	4	4.42	0.90	0.90
18 Sep	0	0	1.05	0.00	0.00
20 Sep	1	1	5.72	0.17	0.17
21 Sep	0	0	0.37	0.00	0.00
23 Sep	6	6	1.82	3.30	3.30
25 Sep	5	5	5.37	0.93	0.93
28 Sep	0	0	0.63	0.00	0.00
29 Sep	0	0	1.42	0.00	0.00
2 Oct	0	0	1.65	0.00	0.00
5 Oct	1	2	3.15	0.32	0.63
9 Oct	0	0	4.53	0.00	0.00
10 Oct	12	13	4.95	2.42	2.63
11 Oct	10	20	5.82	1.72	3.44
12 Oct	0	0	5.58	0.00	0.00
13 Oct	0	0	3.35	0.00	0.00
17 Oct	0	0	2.12	0.00	0.00

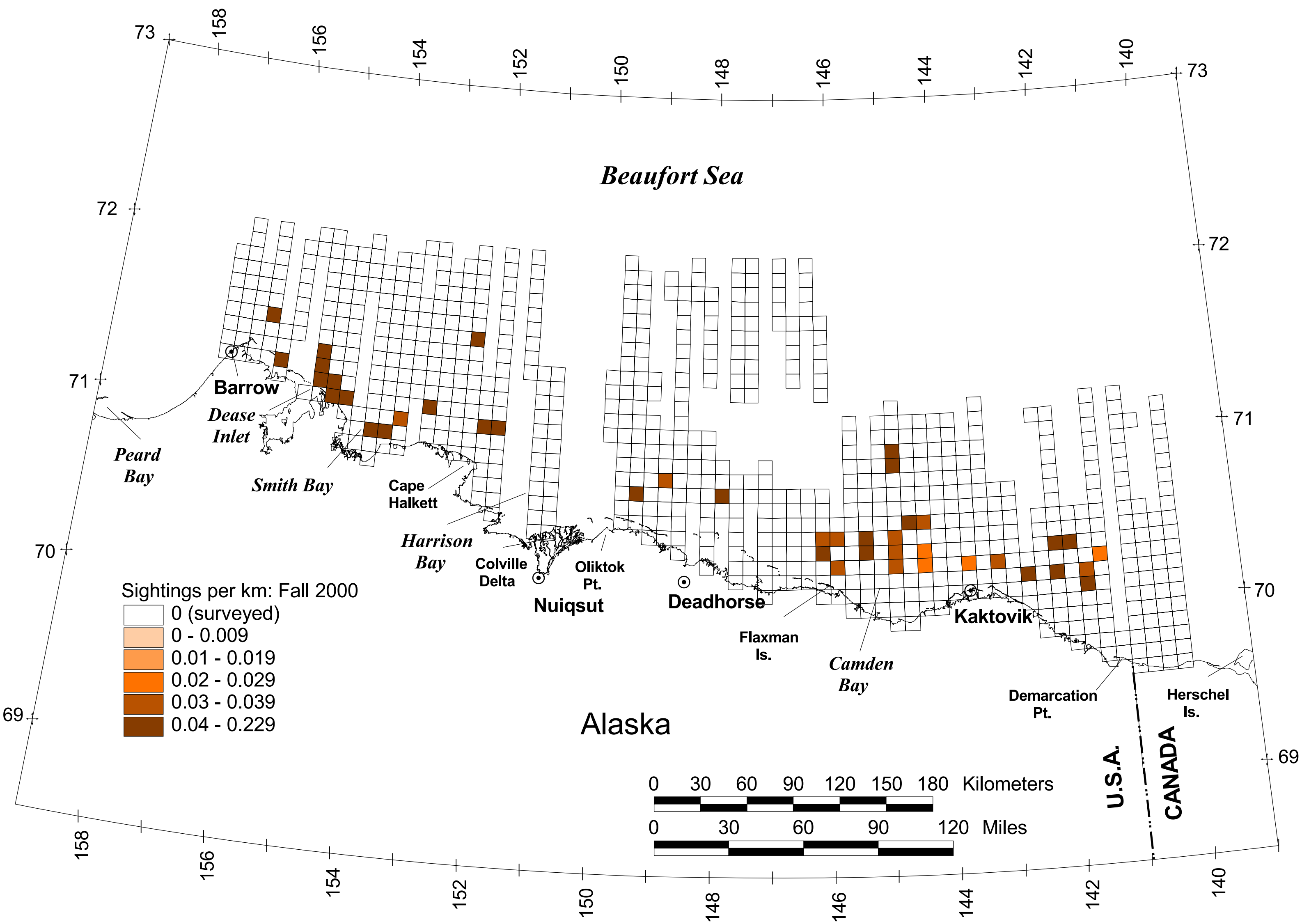


Figure 11. Sighting Rates of Bowhead Whales on Transect, Fall 2000

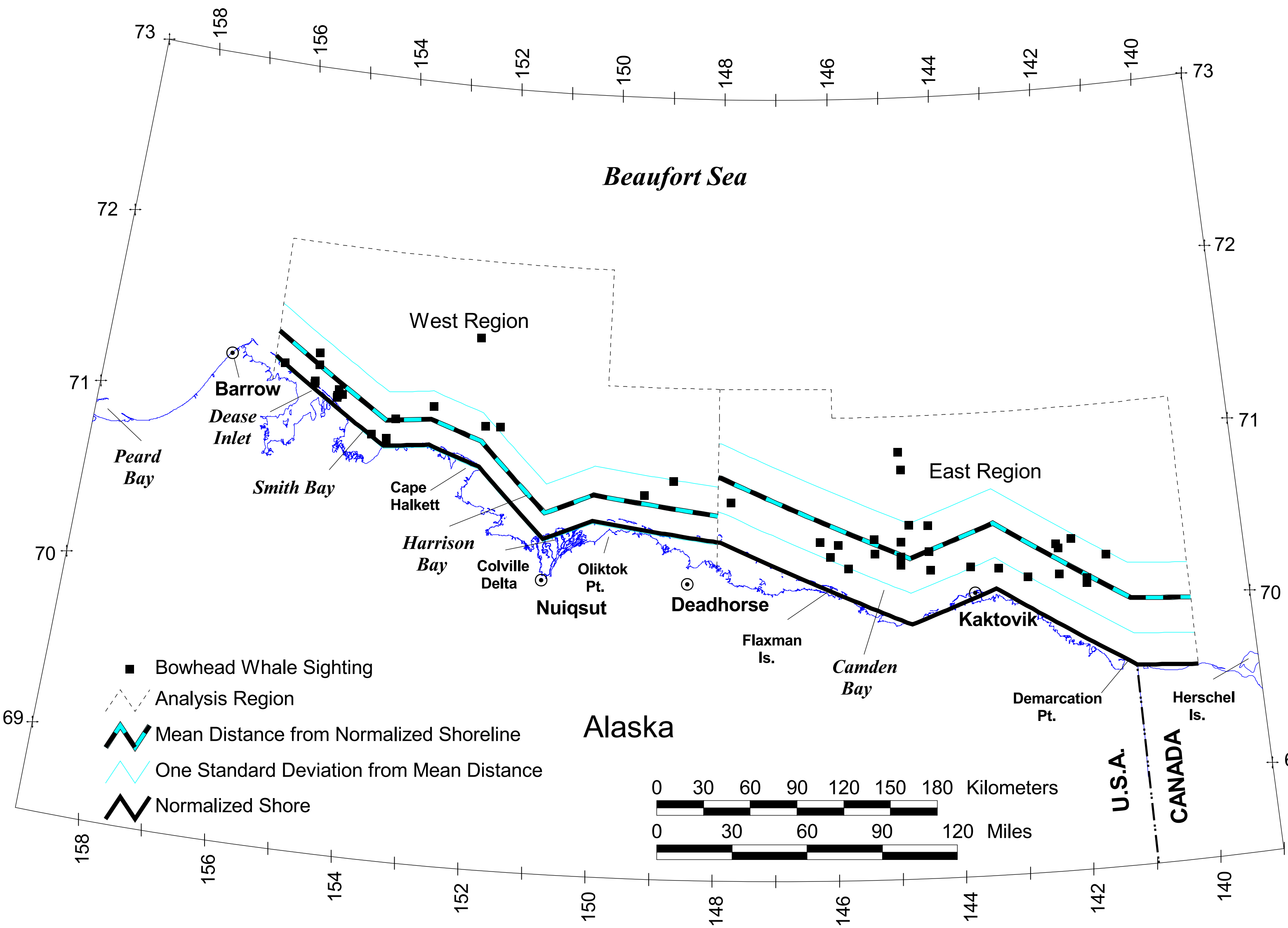


Figure 12. Fall Bowhead Whale Sightings on Transect during Fall 2000, Showing Mean Distance from a Normalized Shoreline

The most prominent difference in pattern between SPUE and WPUE occurred on 12 September (Table 4), due to several large pods or aggregations of feeding whales observed on that day (Appendix B: Table B-1).

4. Habitat Associations: In addition to general ice coverage for arctic waters during Fall 2000 (Appendix A), the percentage of ambient ice cover visible from the aircraft at each bowhead sighting (Appendix B: Table B-1) was summarized. Of the 193 bowheads counted over the field season, 142 whales (74%) were sighted in open water and 22 (11%) were observed in 1-5% sea ice. When ice cover increased during October, only small numbers of whales were observed in these higher ice concentrations (Table 5). Observing fewer whales in heavy ice concentrations is expected given the reduced counts of bowheads per unit effort noted for those years of increased general sea-ice severity (Treacy, 1998: Table 13).

5. Behaviors: Of 193 bowhead whales observed during Fall 2000, 80 (41%) were feeding, 78 (40%) traveling (swimming forward in an apparently deliberate manner), 19 (10%) resting, and 10 (5%) milling when first sighted. Less frequent behaviors included 3 (2%) that were tail-slapping, 2 (1%) spy-hopping, and 1 (1%) diving (Table 6). All behaviors noted are defined in Table 1.

Of the 80 feeding bowhead whales observed, 77 were observed on 12 September next to shore between Dease Inlet and Smith Bay, Alaska, with whales feeding between 154°38.5'W. and 154°49.7'W. longitudes. The high percentage of feeding behaviors in Fall 2000 was likely associated with greater availability of prey species in this region. Such activity further confirms the importance of the nearshore area east of Barrow as an occasional feeding area (Landino et al., 1994; Ljungblad et al., 1986). On 11 October, 3 bowhead whales were observed feeding near 71°10.0' N., between 154°31.0' W. and 155°21.8' W., (Appendix B: Table B-1).

Sudden overt changes (e.g., an abrupt dive, course diversion, or cessation of behavior ongoing) in whale behavior were looked for. On 10 October 2000, one swimming bowhead was observed from 1490 ft ASL and a sighting of 2 spy-hopping bowheads was made from 1513 ft ASL for which responses to the survey aircraft were noted.

D. Other Marine Mammal Observations

1. Gray Whale (*Eschrichtius robustus*): Over the 2000 season, there was one sighting of 4 gray whales. These whales were sighted on 2 September just west of Barrow, Alaska (Table 3 and Fig. 13).

2. Beluga Whale (*Delphinapterus leucas*): Although the study area and survey altitude were designed to record the fall migration of bowhead whales, beluga whales, which undertake a somewhat parallel migration farther offshore, were always counted. Over the Fall-2000 field season, 39 sightings were made for a total of 266 beluga whales (Table 3) during 89.89 hr of overall survey effort (Table 2), for a seasonal index of relative abundance of 2.96 WPUE. Beluga whales were observed beginning 2 September through 12 October, between 140°W. and 155°W. longitudes, mostly between 30 and 70 nm from shore (Fig. 14). Twenty-nine beluga calves were noted for a calf ratio of 0.109. Forty-six (17%) belugas were in 25% or greater concentration of ambient sea ice.

3. Bearded Seal (*Erignathus barbatus nauticus*): Over the 2000 season, 28 incidental sightings were made for a total of 35 bearded seals (Table 3). All but one bearded seal sighting was made east of 147°W. longitude within 40 nm of shore (Fig. 15).

4. Ringed Seal (*Pusa hispida hispida*): Over the 2000 season, 96 incidental sightings were made for a total of 243 ringed seals (Table 3). Sightings were made across the study area, mostly within 60 nm of shore (Fig. 16).

5. Walrus (*Odobenus rosmarus divergens*): Over the 2000 season, no incidental sightings were made (Table 3).

6. Unidentified Cetaceans and Pinnipeds: Over the 2000 season, there was 1 incidental sighting for a total of 6 unidentified pinnipeds and 1 incidental sighting of an unidentified cetacean (Table 3).

Table 5
Semimonthly Summary of Bowhead Whales Observed,
by Percent Ice Cover Present at Sighting Location, Fall 2000

% Ice Cover	1-15 Sep		16-30 Sep		1-15 Oct		16-19 Oct		Total	
0	123	(87%)	9	(56%)	10	(29%)	0		142	(74%)
1-5	16	(11%)	6	(38%)	0		0		22	(11%)
6-10	2	(1%)	1	(6%)	2	(6%)	0		5	(3%)
11-20	0		0		3	(9%)	0		3	(2%)
21-30	1	(1%)	0		4	(11%)	0		5	(2%)
31-40	0		0		0		0		0	
41-50	0		0		5	(14%)	0		5	(2%)
51-60	0		0		0		0		0	
61-70	0		0		1	(3%)	0		1	(1%)
71-80	0		0		4	(11%)	0		4	(2%)
81-90	0		0		6	(17%)	0		6	(3%)
91-99	0		0		0		0		0	
TOTAL	142	(100%)	16	(100%)	35	(100%)	0	(100%)	193	(100%)

Table 6
Semimonthly Summary of Bowhead Whales Observed, by Behavioral Category, Fall 2000

Behavior	1-15 Sep		16-30 Sep		1-15 Oct		16-19 Oct		Total	
Diving	1	(1%)	0		0		0		1	(1%)
Feeding	77	(54%)	0		3	(9%)	0		80	(41%)
Milling	9	(7%)	1	(6%)	0		0		10	(5%)
Resting	15	(10%)	2	(13%)	2	(6%)	0		19	(10%)
Spy Hopping	0		0		2	(6%)	0		2	(1%)
Swimming	40	(28%)	13	(81%)	25	(71%)	0		78	(40%)
Tail Slapping	0		0		3	(8%)	0		3	(2%)
(not noted)	0		0		0		0		0	
TOTAL	142	(100%)	16	(100%)	35	(100%)	0	(100%)	193	(100%)

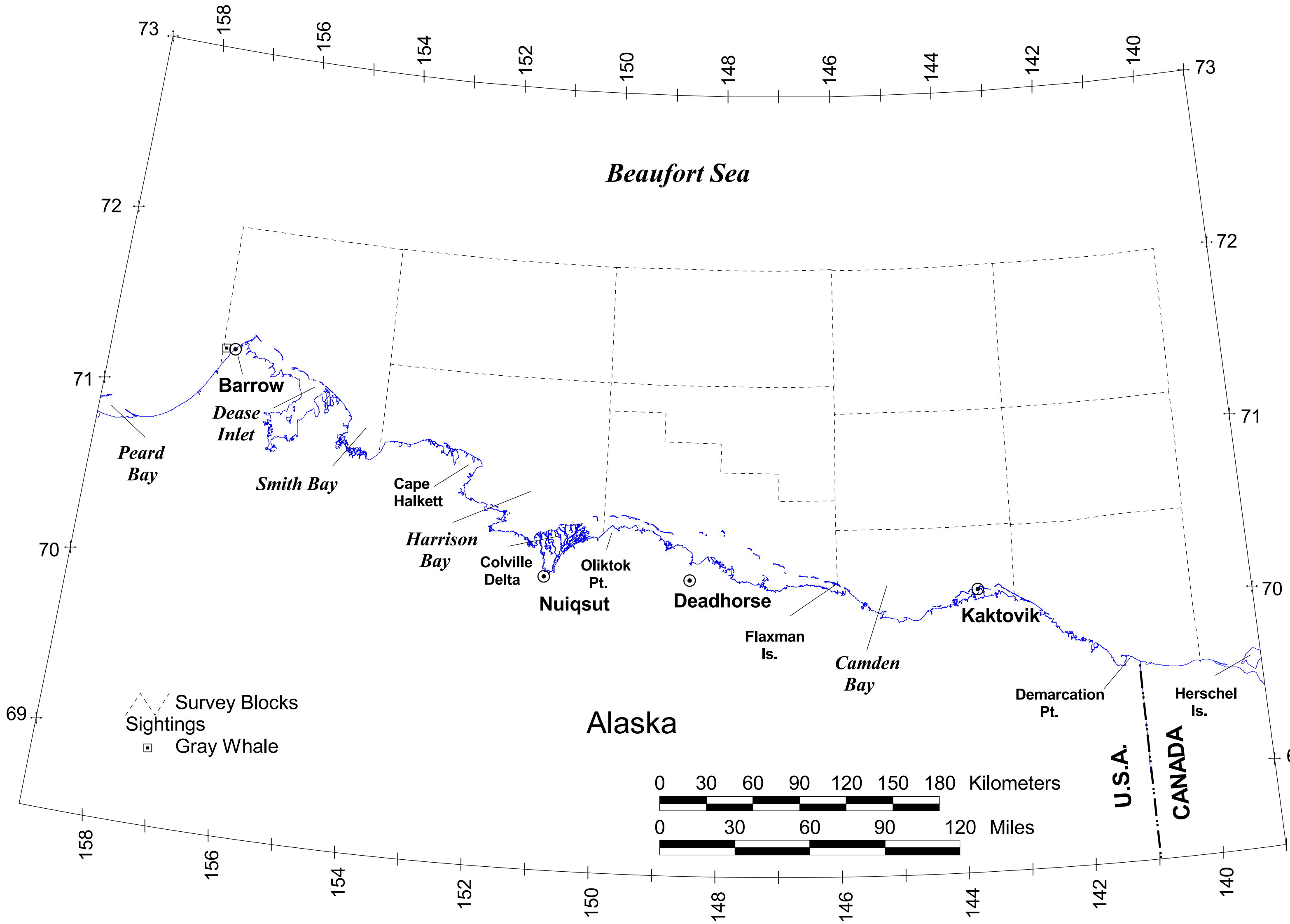


Figure 13. Map of Gray Whale Sightings, Fall 2000

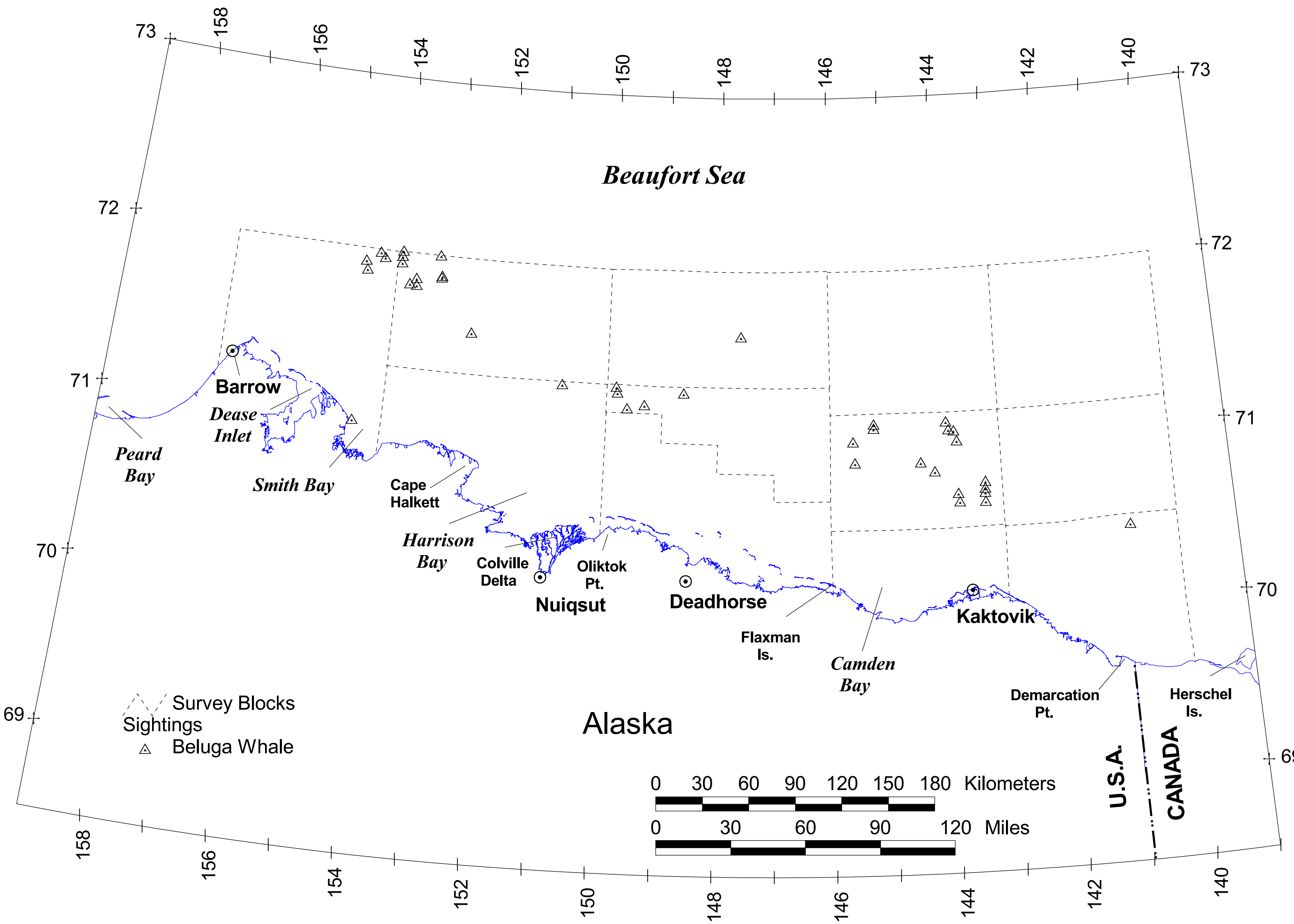


Figure 14. Map of Beluga Whale Sightings, Fall 2000

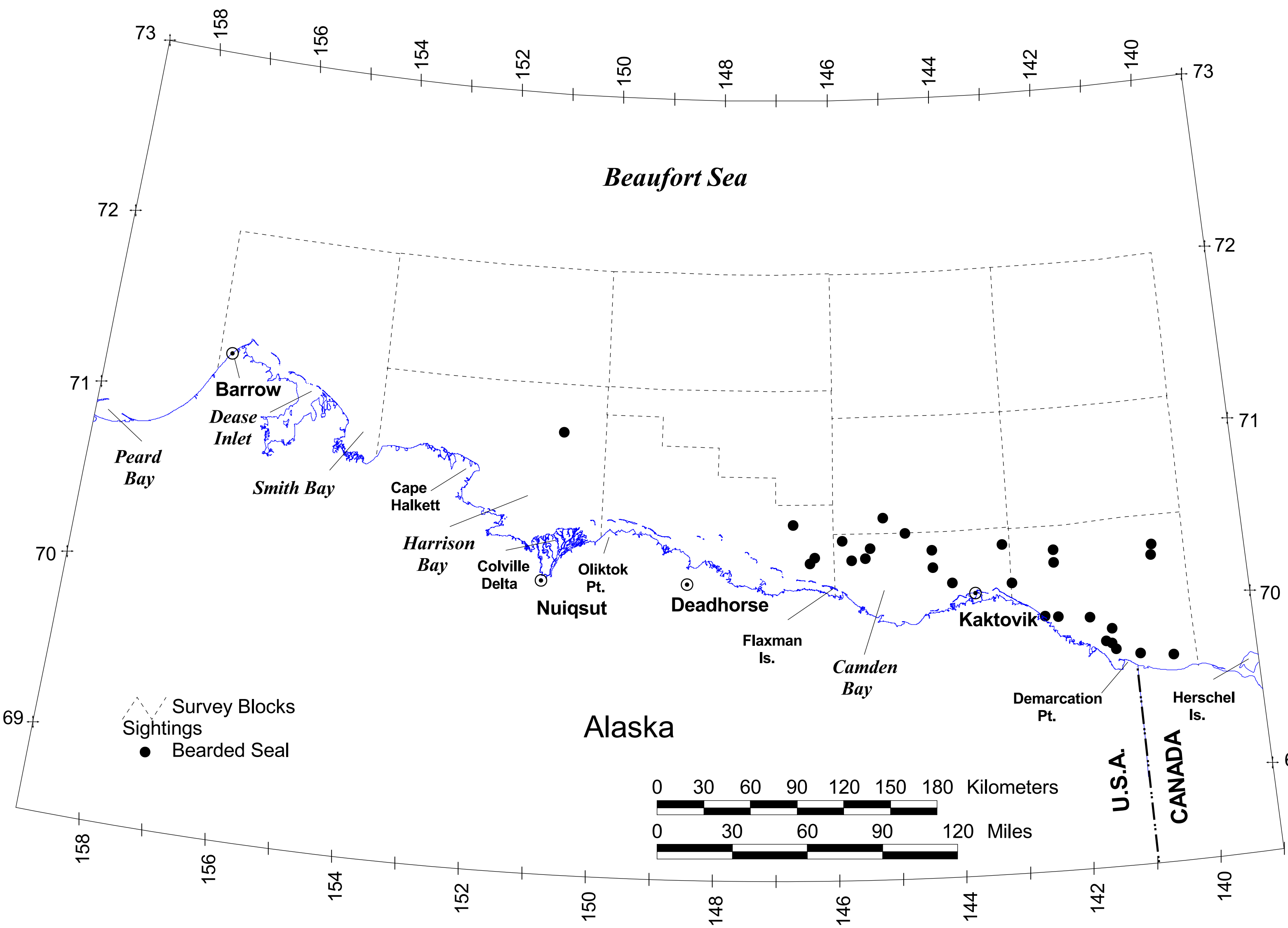


Figure 15. Map of Bearded Seal Sightings, Fall 2000

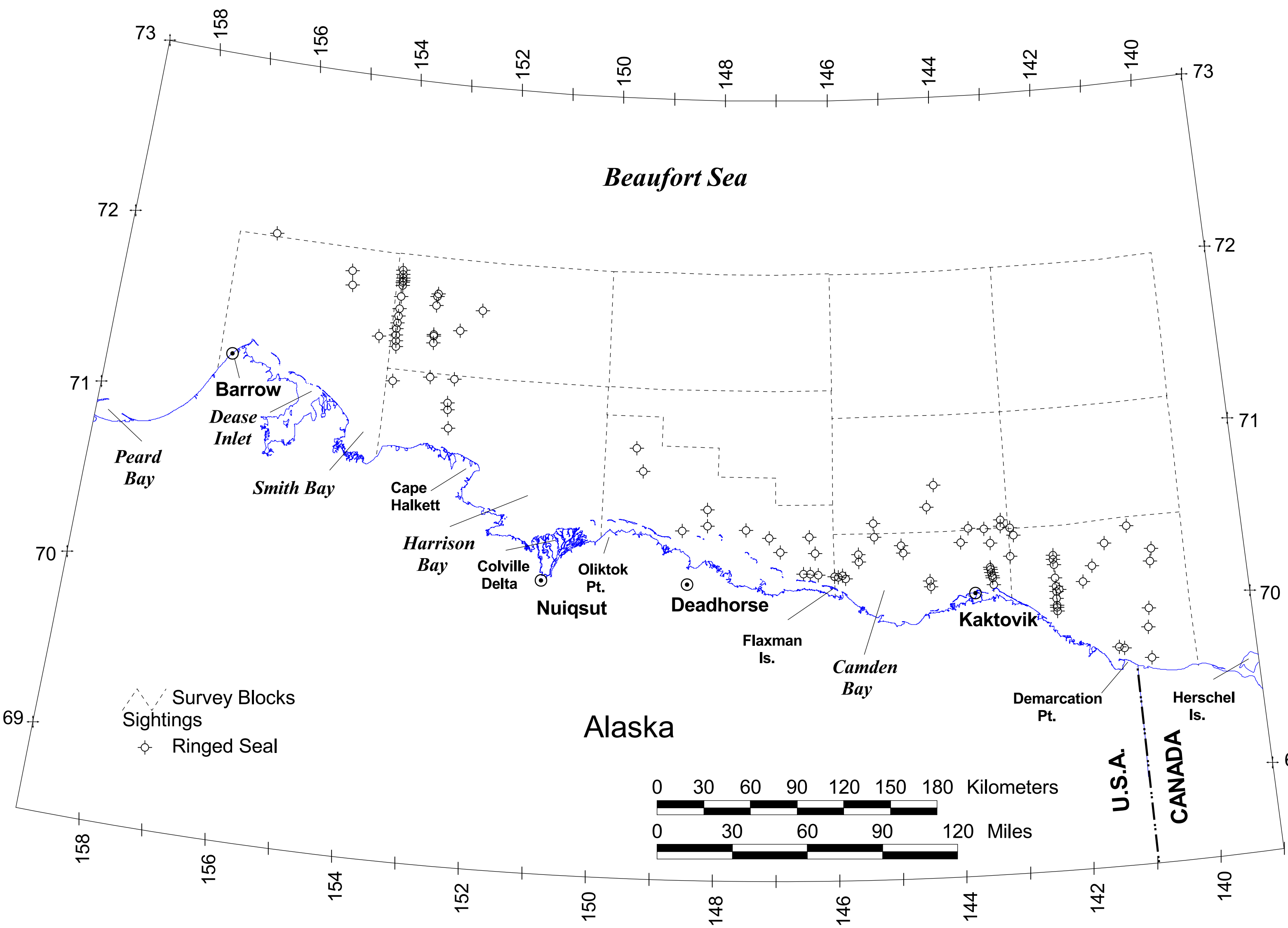


Figure 16. Map of Ringed Seal Sightings, Fall 2000

7. **Polar Bear (*Ursus maritimus marinus*):** Over the 2000 season, 9 incidental sightings were made for a total of 23 polar bears (Table 3). Most of the bears were on barrier islands between 141°W. and 150°W. longitudes (Fig. 17). An unknown proportion of these bears appeared to remain on the islands waiting for the sea ice and may have been recounted on subsequent days. In addition to sightings of polar bears, 28 sets of polar bear tracks were noted for which no bear was present (Table 3 and Fig. 18).

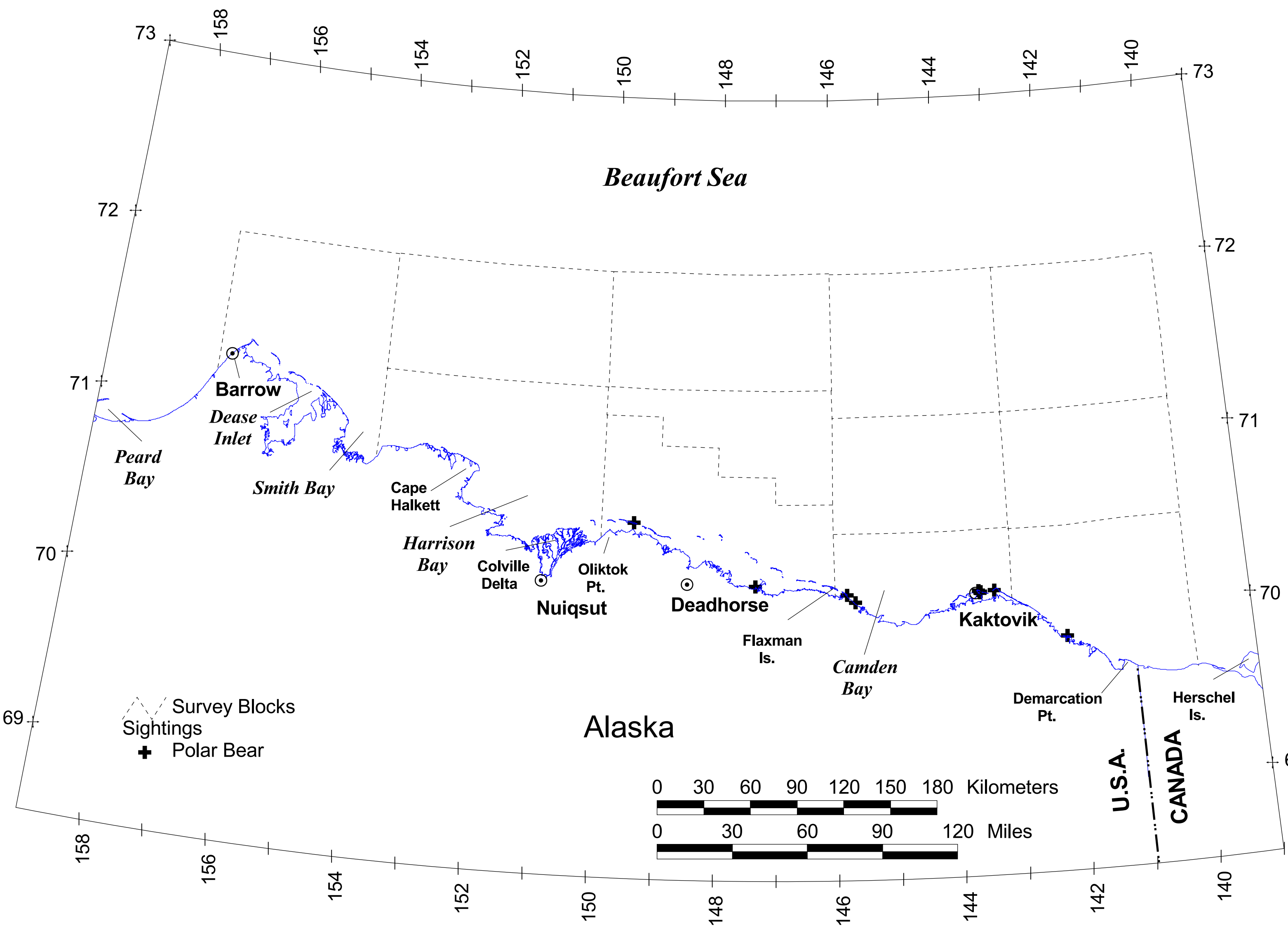


Figure 17. Map of Polar Bear Sightings, Fall 2000

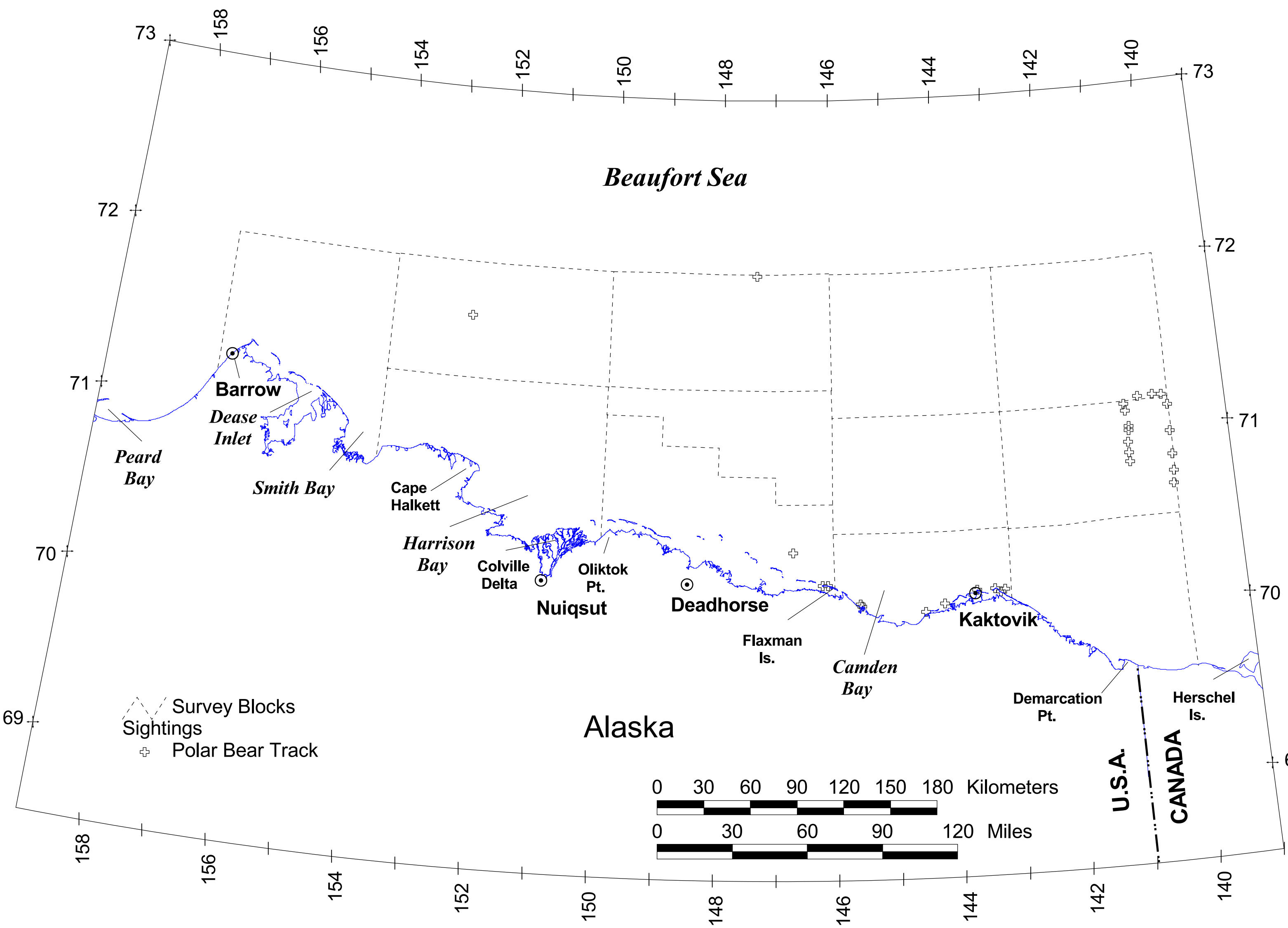


Figure 18. Map of Polar Bear Tracks, Fall 2000

IV. INTERANNUAL RESULTS

A. Statistical Analyses of Bowhead Whale Sighting Distribution (1982-2000)

1. Central Tendency Statistics - Distance from Shore: Transect data were analyzed over a 19-year period (1982-2000) in two regions of the Alaskan Beaufort Sea (Fig. 2). Annual central-tendency statistics for distance of bowhead whales from shore were summarized by year and region (Table 7). The mean distance of whale sightings from shore in each region was also depicted visually for Fall 2000 (Fig. 12).

East Region

The combined data (1982-2000) included 691 transect sightings (trSI) in the East Region. Mean measures of distance from shore among years ranged from 15.1 km (in 1997) to 89.7 km (in 1983). The Confidence Interval (CI) about the mean was widest (>30 km) in 1988 and 1989, each of which had a small sample size (<10 trSI) (Table 7).

West Region

The combined data (1982-2000) included 603 transect sightings in the West Region. Mean measures of distance from shore ranged from 17.7 km (in 2000) to 65.9 km (in 1988). The Confidence Interval (CI) about the mean was widest (>30 km) in 1985, 1987, 1990, 1991, and 1994, each of which had a small sample size (<10 trSI). The axis of the bowhead migration in the West Region was much nearer to shore (median = 11.0 km) during Fall 2000 than for any other year (1982-2000) and much less than the cumulative median for those years (32.5 km). Likewise, the mean distance from shore for West Region bowheads in 2000 (17.7 km) was less than for any other year and much less than the cumulative mean for those years (35.4 km) (Table 7).

2. Central Tendency Statistics - Water Depth: The transect data were analyzed over a 19-year period (1982-2000) in two regions of the Alaskan Beaufort Sea (Fig. 2). Annual central-tendency statistics for water depth at bowhead whale sightings were summarized by year and region (Table 8).

East Region

The combined data (1982-2000) included 691 transect sightings in the East Region. Annual mean depths ranged from 23.9 m (in 1997) to 915.5 m (in 1983). The CI about the mean was widest (>100 m) in 1983, 1988, 1989, 1991 and 1994, four of which had a small sample size (<20 trSI). The 25^{th} - 75^{th} quartiles about the median were widest apart (>35 m) in 1983, 1989, and 1991 (Table 8).

West Region

The combined data (1982-2000) included 603 transect sightings in the West Region. Annual mean depths ranged from 18.7 m (in 1989) to 312.7 m (in 1983). The CI about the mean was widest (>100 m) in 1982, 1983, 1985, 1986, 1991, 1992, and 1995, four of which had a small sample size (<20 trSI). The 25^{th}-75^{th} quartiles about the median were widest apart (>35 m) in 1983, 1985, 1986, and 1991. The axis of the bowhead migration in the West Region was in shallower water (median = 11.3 m) during Fall 2000 than for any previous year (1982-1999) (Table 8).

3. ANOVA - Distance from Shore: A parametric ANOVA of distances from shore over a 19-year period (1982-2000) indicated strongly significant differences among years for the East Region ($F=19.7_{(18, 691)}$; $p<0.0001$) and for the West Region ($F=10.6_{(18, 603)}$; $p<0.0001$). A preliminary power analysis of the ANOVA ($\alpha=0.05$, $\beta\leq0.01$), comparing only those years from 1982 through1997 having a larger sample size ($n\geq20$ trSI), showed minimum detectable differences of 7.8 km in the East Region and 9.7 km in the West (Treacy, 1998).

4. Tukey HSD Test - Distance from Shore: Since the ANOVA showed significant differences among years, the Tukey HSD test was applied to all transect sightings of bowhead whales over a 19-year period (1982-2000) without exclusions to determine which years were significantly different from each other.

East Region

The Tukey test showed that bowheads in 1983 migrated significantly ($p<0.05$) farther offshore than in any other year except 1989. The data also showed that whales in 1989 were significantly farther offshore, and in 1997, and 1998 were significantly nearer to shore, than for most (>9) other years.

Table 7
Central-Tendency Statistics for Distance from Shore (in kilometers) to Random Sightings of Bowhead Whales (September-October), by Year and Region, 1982-2000

Year	Region	trSI [1]	Median	25^{th}-75^{th} Quartile Range	Mean	SD [2]	CI [3]	Range
1982	East	28	36.9	31.5-43.2	38.2	8.5	34.9-41.5	26.0-56.6
	West	26	41.7	37.7-48.9	43.7	16.7	36.9-50.4	14.6-86.3
1983	East	14	89.5	82.0-98.9	89.7	15.7	80.7-98.8	59.6-121.2
	West	15	53.3	42.3-86.6	62.2	26.3	47.6-76.7	27.5-125.3
1984	East	23	36.6	25.6-56.5	39.7	23.9	29.3-50.0	1.9-103.4
	West	36	46.2	36.8-60.3	45.7	19.2	39.2-52.2	8.9-85.2
1985	East	10	29.5	23.7-40.5	31.8	16.0	20.4-43.3	1.9-61.4
	West	7	50.3	25.9-86.3	53.8	29.2	26.8-80.8	15.4-88.9
1986	East	30	27.5	16.7-39.8	27.8	16.7	21.5-34.0	1.0-58.1
	West	19	38.8	24.7-52.4	39.9	22.8	28.9-50.9	3.7-81.7
1987	East	30	33.5	18.5-50.1	37.0	20.7	29.3-44.7	6.9-86.1
	West	8	29.2	16.7-51.2	32.7	20.2	15.9-49.6	7.4-60.3
1988	East	6	29.5	24.4-33.9	33.4	23.5	8.8-58.0	6.4-76.8
	West	8	64.5	59.1-71.4	65.9	11.2	56.6-75.3	50.7-86.8
1989	East	6	55.8	49.3-89.4	63.4	23.4	38.8-87.9	36.1-94.0
	West	17	35.4	15.6-45.8	32.8	19.4	22.8-42.8	7.5-74.5
1990	East	93	33.8	25.4-43.0	34.5	13.8	31.7-37.4	8.1-78.6
	West	6	35.8	32.3-48.2	42.5	18.5	23.1-61.9	25.9-77.3
1991	East	14	62.4	39.4-76.7	59.2	20.5	47.4-71.1	34.5-85.6
	West	6	46.0	34.1-72.3	51.5	18.8	31.7-71.2	33.6-76.8
1992	East	12	38.2	34.3-51.6	42.5	10.9	35.6-49.4	28.5-60.5
	West	13	61.1	45.1-74.3	59.3	17.2	48.9-69.7	29.9-82.2
1993	East	55	30.3	21.2-40.4	31.9	17.0	27.3-36.5	6.4-88.4
	West	35	25.1	20.4-38.6	29.9	12.7	25.6-34.3	11.8-62.7
1994	East	32	29.4	22.4-56.2	37.2	18.7	30.4-44.0	13.9-77.7
	West	3	23.3	[4]	24.8	11.5	[4]	14.1-36.9

Table 7
Central-Tendency Statistics for Distance from Shore (in kilometers) to Random Sightings of Bowhead Whales (September-October), by Year and Region, 1982-2000

Year	Region	trSI[1]	Median	25th-75th Quartile Range	Mean	SD[2]	CI[3]	Range
1995	East	94	30.2	23.6-41.6	33.1	16.4	29.7-36.5	3.7-99.5
	West	44	36.5	25.3-51.7	42.9	26.5	34.8-50.9	7.6-118.7
1996	East	13	29.4	21.0-34.6	29.1	11.4	22.2-36.0	15.3-57.6
	West	15	40.6	23.6-55.1	40.8	14.8	32.6-49.1	21.4-64.1
1997	East	35	10.2	5.9-20.4	15.1	11.9	11.0-19.1	3.4-44.9
	West	145	27.4	20.0-36.3	29.2	13.0	27.1-31.3	1.0-66.0
1998	East	103	22.2	13.6-31.3	23.8	13.0	21.3-26.3	4.0-73.8
	West	113	20.9	14.7-32.5	26.3	18.6	22.8-29.8	1.1-124.0
1999	East	68	40.2	28.5-49.7	39.5	13.5	36.3-42.8	-0.1[5]-65.8
	West	68	36.1	27.0-52.1	39.3	17.5	35.1-43.6	9.2-75.6
2000	East	26	39.3	28.7-52.1	43.5	22.7	34.3-52.7	13.9-108.8
	West	19	11.0	4.7-25.3	17.7	19.2	8.5-27.0	0.02-80.8
Cumulative	East	691	32.0	20.9-43.6	34.5	19.4	33.0-35.9	-0.1[5]-121.2
(1982-2000)	West	603	32.5	20.2-47.1	35.4	20.5	33.8-37.1	0.02-125.3

1 trSI = number of transect sightings.
2 SD = standard deviation.
3 CI ≥ 95-percent confidence interval (positive values).
4 Insufficient sample size.
5 Negative value is for one transect sighting between the actual and normalized coastline.

Table 8
Central-Tendency Statistics for Water Depth (in meters) at Random Sightings of Bowhead Whales (September-October), by Year and Region, 1982-2000

Year	Region	trSI [1]	Median	25^{th}-75^{th} Quartile Range	Mean	SD [2]	CI [3]	Range
1982	East	28	42.1	38.6-49.0	43.5	6.4	41.0-46.0	34.9-57.3
	West	26	30.3	22.8-37.4	94.0	210.9	8.9-179.2	14.3-1041.5
1983	East	14	804.0	263-1779	915.5	718.8	501-1331	64.6-1952.8
	West	15	68.3	33.7-209.1	312.7	597.9	18.4-643.9	20.7-2165.7
1984	East	23	43.9	35.2-54.3	77.0	104.8	31.7-122.3	17.8-507.9
	West	36	40.3	31.7-55.6	47.7	33.2	36.5-59.0	12.8-189.2
1985	East	10	38.3	34.8-40.8	37.5	7.4	32.3-42.8	22.8-51.0
	West	7	35.7	23.9-148.1	193.3	348.5	129-515.6	16.1-974.7
1986	East	30	41.1	24.0-50.2	38.1	18.2	31.4-44.9	6.8-91.5
	West	19	28.3	18.9-75.1	77.9	117.4	21.3-134.6	9.6-489.7
1987	East	30	39.7	32.7-54.3	56.3	47.9	38.4-74.2	14.9-223.3
	West	8	25.2	13.1-31.6	22.6	10.0	14.2-30.9	8.3-32.4
1988	East	6	48.8	39.1-50.3	92.2	123.5	37.3-221.8	22.9-343.4
	West	8	49.4	46.9-52.7	50.3	6.8	44.6-55.9	40.5-63.5
1989	East	6	60.5	51.1-448.4	196.1	219.7	34.5-426.7	47.3-508.8
	West	17	20.1	11.3-24.1	18.7	8.1	14.5-22.8	5.8-33.8
1990	East	93	42.0	35.9-50.1	47.7	33.0	40.9-54.5	19.6-284.6
	West	6	31.5	22.8-39.2	32.6	11.4	20.6-44.6	20.0-50.6
1991	East	14	68.7	50.5-190.7	128.3	109.6	65.0-191.6	46.3-387.0
	West	6	41.5	35.5-204.8	96.6	94.2	2.2-195.5	26.3-230.2
1992	East	12	53.5	47.1-56.0	51.5	6.0	47.7-55.3	40.5-58.9
	West	13	50.8	43.9-53.6	54.1	27.8	37.3-70.8	14.3-121.3
1993	East	55	40.5	33.5-50.2	58.4	96.5	32.3-84.5	11.4-716.6
	West	35	20.1	16.4-25.4	22.8	9.4	19.6-26.0	10.7-49.3
1994	East	32	46.8	39.0-53.3	79.8	175.6	16.5-143.1	30.7-1037.8
	West	3	12.0	[4]	21.4	16.6	[4]	11.6-40.5

Table 8
Central-Tendency Statistics for Water Depth (in meters) at Random Sightings of Bowhead Whales (September-October), by Year and Region, 1982-2000

Year	Region	trSI [1]	Median	25^{th}-75^{th} Quartile Range	Mean	SD [2]	CI [3]	Range
1995	East	94	41.4	35.7-49.9	52.5	68.7	38.4-66.6	14.9-628.0
	West	44	30.8	25.8-38.8	107.4	259.7	28.4-186.4	6.5-1232.8
1996	East	13	39.4	33.4-45.6	37.7	9.3	32.1-43.3	15.0-48.5
	West	15	34.8	23.6-44.3	37.0	17.1	27.5-46.5	18.6-82.5
1997	East	35	22.1	13.0-32.0	23.9	11.9	19.8-28.0	10.5-50.0
	West	145	20.0	15.7-26.5	25.0	21.4	21.5-28.5	4.7-189.2
1998	East	103	32.4	26.1-40.3	34.2	12.0	31.9-36.6	6.6-82.6
	West	113	15.2	11.6-21.5	37.7	170.8	5.9-69.6	5.4-1814.7
1999	East	68	50.2	39.5-54.6	51.2	20.9	46.2-56.3	7.9-171.3
	West	68	30.7	21.1-41.9	42.6	42.9	32.2-53.0	10.9-210.3
2000	East	26	40.6	36.3-56.9	81.6	122.0	32.3-130.9	28.4-108.8
	West	19	11.3	6.8-19.6	31.5	81.5	7.8-70.8	4.0-366.8
Cumulative	East	691	40.7	33.5-50.6	70.5	172.3	57.6-83.4	6.6-1952.8
(1982-2000)	West	603	23.9	15.8-36.0	52.4	159.1	39.7-65.1	4.0-2165.7

[1] trSI = number of transect sightings.
[2] SD = standard deviation.
[3] CI ≥ 95-percent confidence interval (positive values).
[4] Insufficient sample size.

West Region

The Tukey test showed that bowheads in 2000 migrated significantly ($p<0.05$) nearer to shore than for most (>9) other years.

B. General Sea Ice Severity (1979-2000)

General ice coverage along the northern coast of Alaska during the 2000 navigation season was the 28th-mildest for the 48 years from 1953 through 2000 and showed a distance of 75 nm from Point Barrow northward to the boundary of 5-tenths ice concentration on 15 September (USDOC, NOAA, National Ice Center/USDOD, Navy, Naval Ice Center, 2001).

The years 1980, 1983, 1988, and 1991 were categorized as having "heavy" ice cover during the navigation season. These 4 years are ranked as having the severest seasonal ice for the years 1979 through 2000 and showed distances ranging from 10 to 25 nm between Point Barrow and the five-tenths ice concentration on 15 September (USDOC, NOAA, National Ice Center/USDOD, Navy, Naval Ice Center, 2001).

The years 1984, 1985, and 1992, categorized as having "moderate" ice cover during the open-water season, are ranked next in seasonal ice severity for the years 1979 through 2000 and showed distances ranging from 50 to 75 nm between Point Barrow and the five-tenths ice concentration on 15 September (USDOC, NOAA, National Ice Center/USDOD, Navy, Naval Ice Center, 2001).

The years 1979, 1981, 1982, 1986, 1987, 1989, 1990, and 1993-2000, categorized as having "light" ice cover during the open-water season, are ranked as having the least-severe seasonal ice for the years 1979 through 2000 and showed distances ranging from 50 to 240 nm between Point Barrow and the five-tenths ice concentration on 15 September (USDOC, NOAA, National Ice Center/USDOD, Navy, Naval Ice Center, 2001). The recent eight years of unbroken light ice coverage (1993-2000) based on these criteria were not inconsistent with recently hypothesized global and/or cyclical warming.

C. General Sea Ice Severity and Bowhead Whale Sighting Rates (1982-2000)

The Geographic Information System (*ArcView,* Version 3.2A) was used to depict bowhead whales sighting rates during their fall migration across the Alaskan Beaufort Sea relative to overall sea-ice severity. Cumulative sightings made on northerly-southerly transects for September-October MMS surveys over a 19-year period (1982-2000) were calculated as sighting rates then mapped per individual grid cell as was done for Figure 11 (see Section III.C.2). Selected ETOPO-5 isobaths were also included for visual reference (Treacy, 2001).

Sighting location data were pooled over years with light ice (1982, 1986-87, 1989-90, 1993-2000), moderate ice (1984-85, 1992), and heavy ice (1983, 1988, 1991) as defined in MMS survey reports (Treacy, 2000), based on a severity index for the North Coast of Alaska (USDOC, NOAA, National Ice Center/USDOD, Navy, Naval Ice Center, 2001). Thirteen of the 19 years (1982-2000) were in light ice years. The total number of bowhead whales observable per hour of survey flight (1979-1997) was much higher for light ice years (2.96 WPUE) than for moderate ice years (1.55 WPUE) or heavy ice years (0.46 WPUE) (Treacy, 1998).

Visual inspection of a gridded map of sighting rates of bowhead whales by previously described ice severity (Figs. 19-22) showed substantial overlap east of Kaktovik, Alaska, and west of Dease Inlet, Alaska, with more distinct differences for the central Alaskan Beaufort Sea (142°W. to 155°W. longitudes). During light-ice years, the highest sighting rates of central-area bowhead whales were generally in shallower, near-shore waters reflecting coastal contours. During moderate-ice years, area whales occurred in mid-range waters, albeit with some overlap of both light- and heavy-ice categories. During heavy-ice years, area whales occupied deeper, offshore waters, with little overlap of whale sighting rates for light-ice years. The relationship between distance from shore and sea-ice severity appears to be more geographically restricted than previously noted (Moore, 2000; Treacy, 2000).

A preliminary analysis using the parametric ANOVA of cumulative distances of bowhead sightings from a

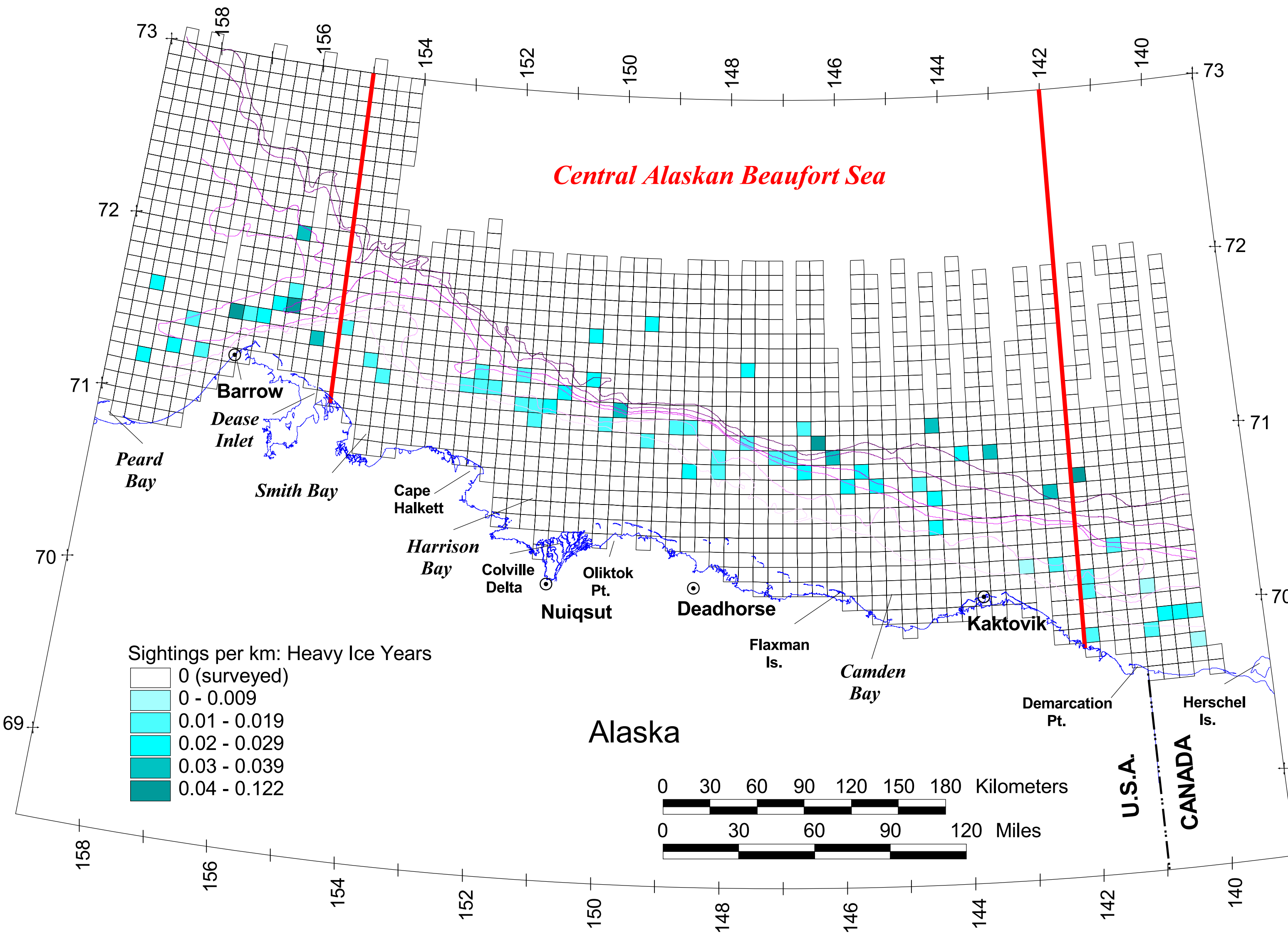


Figure 19. Fall Sighting Rates of Bowhead Whales on Transect, Showing Years of Heavy Sea Ice Severity

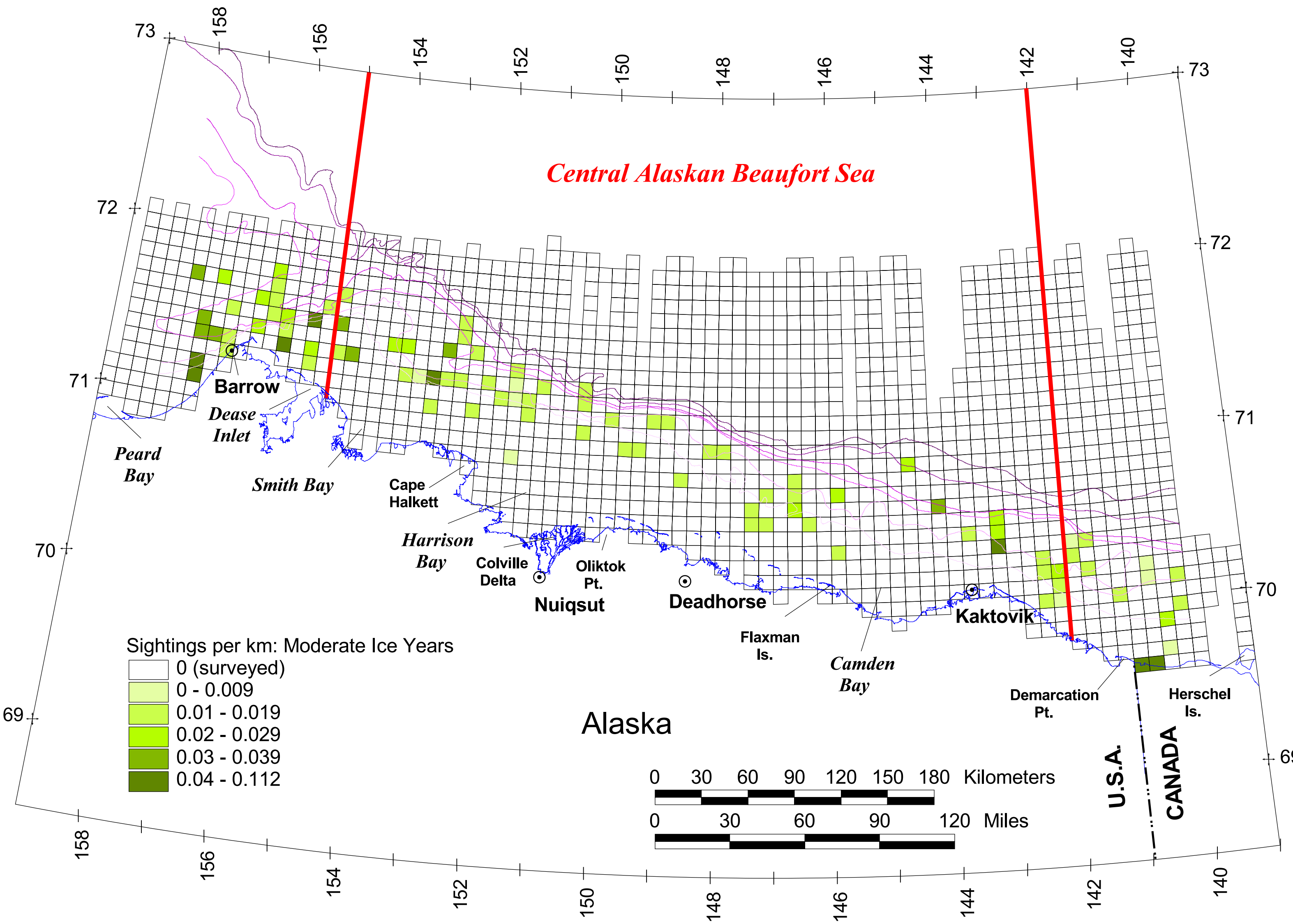


Figure 20. Fall Sighting Rates of Bowhead Whales on Transect, Showing Years of Moderate Sea Ice Severity

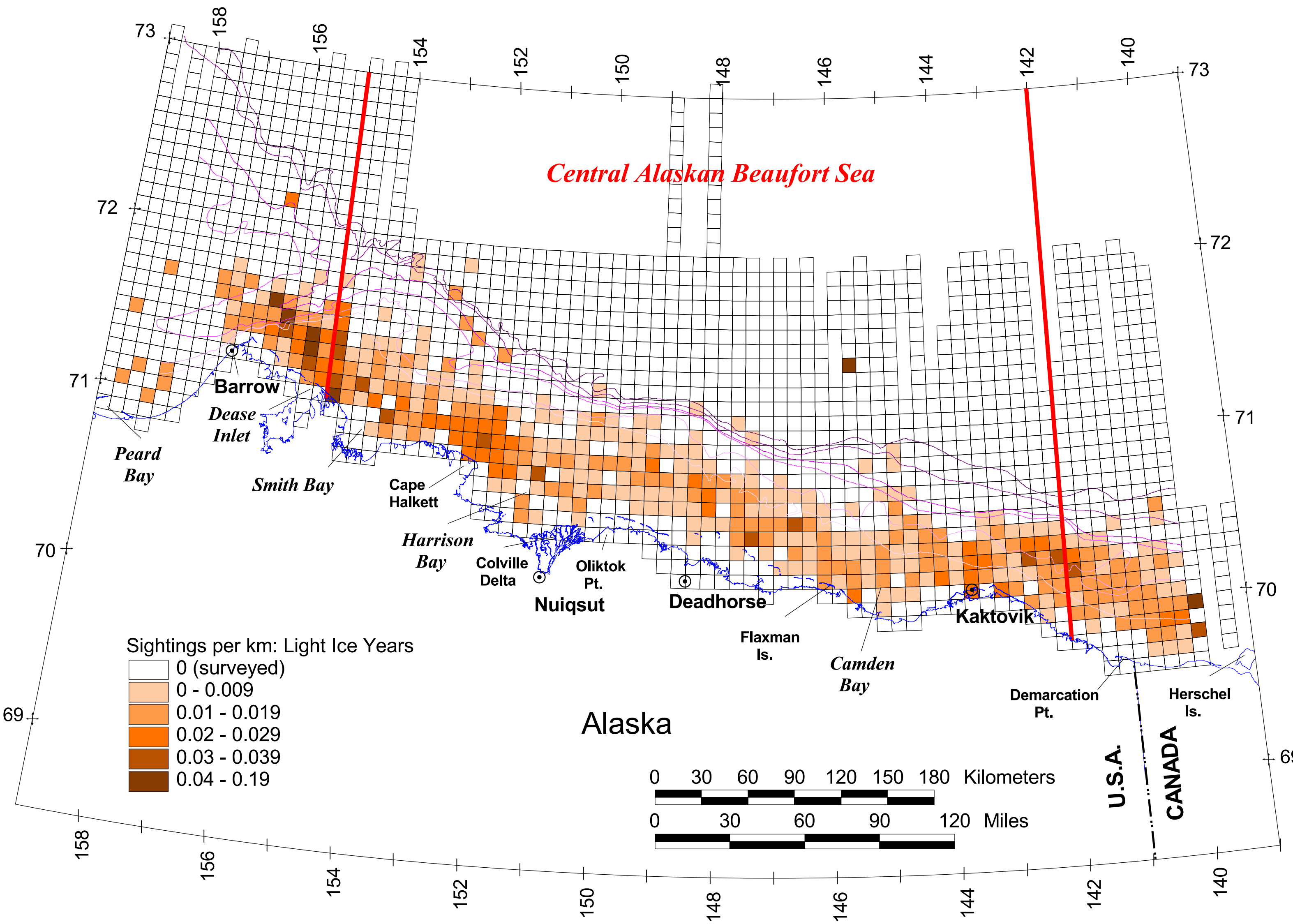


Figure 21. Fall Sighting Rates of Bowhead Whales on Transect, Showing Years of Light Sea Ice Severity

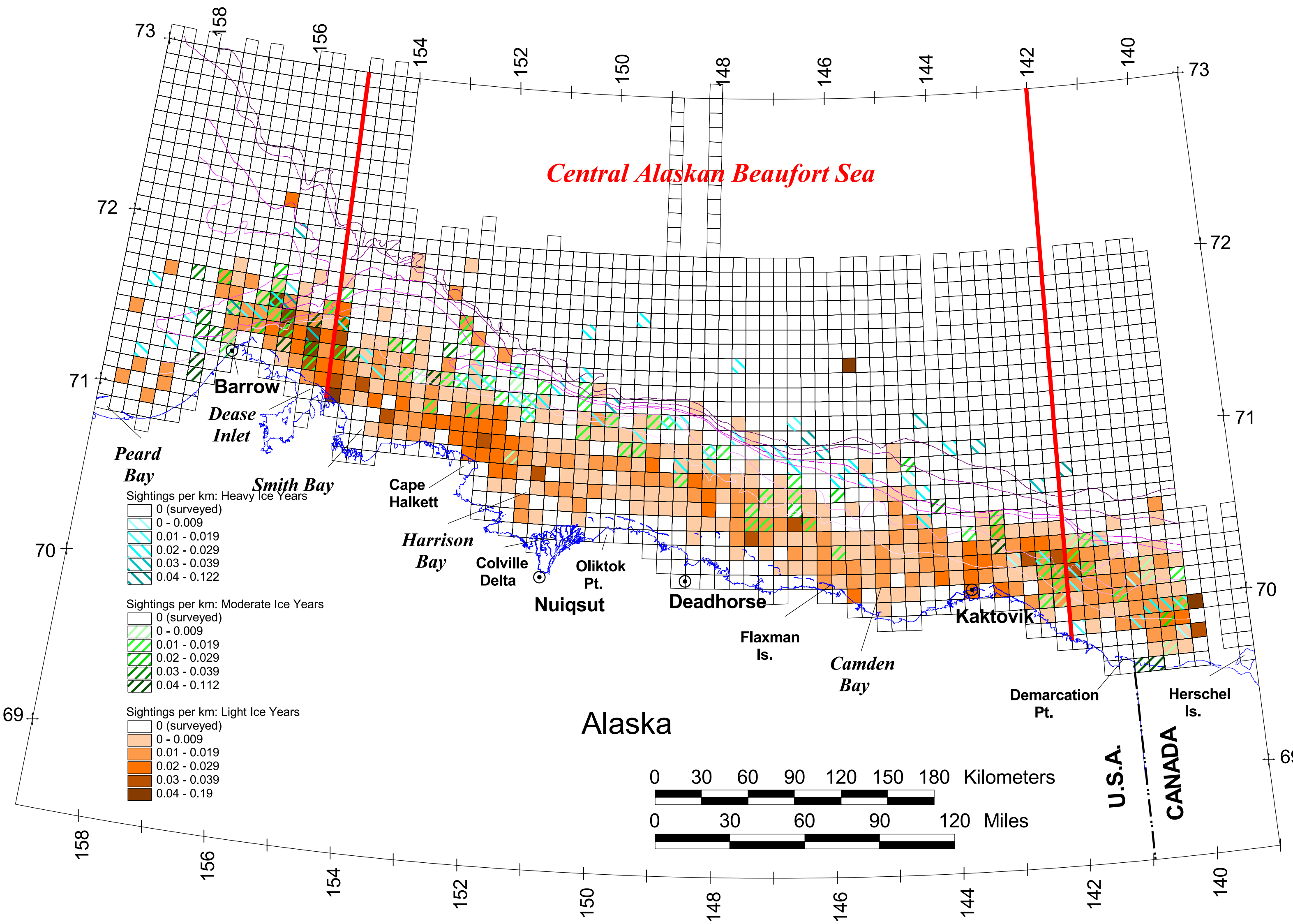


Figure 22. Fall Sighting Rates of Bowhead Whales on Transect, Showing Years of Heavy, Moderate, and Light Sea Ice Severity

normalized shoreline in heavy, moderate, and light sea-ice categories over a 19-year period (1982-2000) indicated significant differences ($F=143.8_{(2, 1294)}$; $p<0.0001$). Post-hoc testing using both the Scheffe Test and Tukey HSD test for unequal sample sizes (*Statistica*™ StatSoft, Version 5.1) indicated significant differences ($p<0.0001$) between the distances of bowhead whale sightings from a normalized shoreline under each pair of sea-ice conditions.

These ice-severity categories were reflected in the mean distances of bowhead whales from the normalized shoreline in the central Alaskan Beaufort Sea. Mean distances for the heavy ice years (1983, 1988, 1991) ranged from 61.5 km to 80.1 km. Mean distances for the moderate ice years (1984, 1985, 1992) ranged from 46.3 km to 51.4 km. Mean distances for the light ice years (1982, 1986, 19897, 1989, 1990, 1993-2000) ranged from 23.9 km to 42.1 km.

D. Key Results Summary (1979-2000)

- General sea ice severity north of Alaska during the 2000 navigation season was the 28th mildest for the 48-year period from 1953 through 2000 (USDOC, NOAA, National Ice Center/USDOD, Navy, Naval Ice Center, 2001). Sea ice was heavier in the east bathymetric region.

- Environmental conditions permitted 28 flights during Fall 2000. Of these, only 8 flights were made during October, primarily due to high sea states and/or low cloud ceilings.

- Due to adverse environmental conditions, the annual total of 89.89 survey hours for 2000 was the third lowest for the MMS surveys (1987-2000), considerably lower than the mean of 130.63 hours (SD=36.47, n=13) for previous years (1987-1999).

- Also due to adverse environmental conditions, the 89 sightings for a total of 193 individual bowhead whales in Fall 2000 ranked 10th for the 14 MMS project surveys (1987-2000), lower than the 417 annual mean for whales in previous MMS surveys (1987-1999) (SD=455, n=13).

- A high percentage of bowheads were feeding (41%) when observed in Fall 2000. Of these, 77 (96%) of the total 80 feeding bowheads were only observed on 12 September very near shore between Dease Inlet and Smith Bay, Alaska (between 154°38.5' W. and 154°49.3' W.), further confirming the importance of this area as an occasional feeding area.

- In 2000, the first bowheads observed were on 1 September. Sighting rates were highest on 12 September (2.42 SPUE), 23 September (3.30 SPUE), and 10 October (2.42 SPUE). The data on daily relative abundance (WPUE) showed that the peak (mode) of the bowhead migration occurred on 12 September (16.36 WPUE), corresponding with the large feeding aggregations noted on that day. The midpoint (median) of the total whales observed (n=193) also occurred on 12 September. The last sighting of a bowhead in 2000 was made on 11 October.

- The axis of bowhead whale sightings in the West Region was much nearer to shore (median = 11.0 km) during Fall 2000 than for any other year (1982-2000) as well as much less than the cumulative median for those years (32.5 km). Likewise, the mean distance from shore for West Region bowheads in 2000 (17.7 km) was less than for any other year as well as much less than the cumulative mean for those years (35.4 km). The Tukey test confirmed that bowheads in 2000 migrated significantly ($p<0.05$) nearer to shore than for most (>9) other years.

- Bowhead whales occur farther offshore in heavy-ice years during fall migrations across the Central Alaskan Beaufort Sea (142°W. to 155°W. longitudes). Bowheads generally occupy nearshore waters in years of light sea-ice severity, somewhat more offshore waters in moderate ice years, and are even farther offshore in heavy ice years. While factors other than sea ice may have localized effects on site-specific distributions, broad-area distributions of bowhead whale sightings in the central Alaskan Beaufort Sea are related to overall sea-ice severity.

- An ANOVA of cumulative distances of bowhead whale sightings from a normalized shoreline in heavy, moderate, and light sea-ice categories over a 19-year period (1982-2000) indicated significant differences ($F=143.8_{(2, 1294)}$; $p<0.0001$). Post-hoc testing using both the Scheffe Test and Tukey HSD test for unequal sample sizes indicated significant differences ($p<0.0001$) between the distances of bowhead whale sightings from a normalized shoreline under each pair of sea-ice conditions.

- Other results of the present study were generally within the range of result values from previous MMS-funded endangered-whale monitoring conducted during September and October (1979-1999) in the Beaufort Sea using similar survey methods (Ljungblad et al., 1987; Moore and Clarke, 1992; Treacy, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, and 2000).

V. DISCUSSION

A. 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.

During winter-spring of 1999-2000, two over-ice seismic programs proposed for the offshore Beaufort Sea area were canceled because of thick ice conditions and difficulties in implementing regulatory restrictions relative to ringed seals. During the open-water season, Western Geophysical conducted seismic-vessel exploration from 28 July to 31 August, with no seismic exploration during September and October. In general, to prevent potential operational effects on subsistence whaling, any geophysical-vessel explorations permitted during the fall follow stringent restrictions—including a provision to stop seismic operations when whales are visible from the vessel—as the bowhead whale migration progresses through the area of operations. For any explorations that occur during the fall, daily summaries of survey information are transferred from the field to Anchorage for use by MMS Resource Evaluation and by NMFS in implementing area-wide permit restrictions on high-energy seismic operations during the whale migration.

During Spring 2000, the gravel island and pipeline associated with the Northstar Unit were completed. During the open-water season, pre-fabricated facilities and a drill-rig were transported and installed at Northstar. There were no drilling operations, with associated helicopter and vessel support, in the Beaufort Sea in Fall 2000. In general, during any fall drilling operations, daily summaries of field information from this survey, and other arctic surveys being conducted concurrently, are transferred by the MMS Team Leader to MMS Field Operations in Anchorage. The MMS and NMFS review daily reports to determine the distributional patterns of bowheads in the vicinity of oil-and-gas-industry activities and the timing of the bowhead whale migration, especially the “end of the migration” past any drill sites.

The sighting data are typically used by management groups to monitor the progress of the overall fall migration of bowhead whales across the Alaskan Beaufort Sea and to determine the position of their overall migratory corridor relative to shore. Project ice and weather data were also transmitted daily to the National/Naval Ice Center and National Weather Service for use in ground-truthing satellite imagery.

B. Management Use of Interannual Monitoring

The MMS bowhead whale monitoring began in 1979 and has continued every year up to the present. While some aspects of this study have been updated from time to time, the data recorded have remained remarkably parallel (especially data from 1982-2000), thus permitting many one-to-one comparisons between years. Such continuous, long-term, wide-area, aerial monitoring of a large whale migration is indeed unique.

In addition to the use of real-time information by both MMS and NMFS when documenting the progress of endangered bowhead whales past offshore drilling and seismic exploration operations (see Section VI.A. above), the project has been helpful to managers in other ways. Some notable examples are:

- providing raw data to all parties (MMS, Western Geophysical, NMFS, ARCO Alaska, Inc., and Alaska Eskimo Whaling Commission (AEWC) at an Oil/Whalers Agreement Post Season Meeting on 18 December 1990 to determine whether the Fall 1990 bowhead migration had been temporarily blocked due to seismic exploration activities;
- providing all parties with annual reports from which data were subsequently cited in a declaration to a lawsuit in 1993 (AEWC et al. vs. Dr. Nancy Foster et al., Civil Action No. 93-1629 HHG) on the effects of Kuvlum drilling and seismic exploration operations on the bowhead migration corridor;
- providing upstream, offshore, and downstream sighting-and-effort data in order to enhance sample sizes of many site-specific studies looking at the potential effects of oil-industry activity on bowhead whale migrations;

- documenting geographic areas, especially migration corridors and feeding areas, used annually by bowhead whales. Such data from previous surveys continue to be used by MMS in writing Environmental Impact Statements and Environmental Assessments and in interpreting the results of site-specific studies.
- performing an analysis of the distances from shore to bowhead sightings relative to general sea ice severity.

The BWASP was cited in the MMS Annual Report 1999, "What does it take to best manage America's mineral resources?", as an example of how our agency manages the OCS in the Beaufort Sea;

The NMFS Administrator, Alaska Region, (letter dated 22 December 1998) commended MMS information support to NMFS: "The BWASP has provided a critical element in our ability to evaluate the effects of development in the Beaufort Sea on the bowhead whale. Additionally, the Minerals Management Service has demonstrated the flexibility and willingness to allow this program to compliment and extend project-specific monitoring required for authorizations under the Marine Mammal Protection Act (Incidental Harassment Authorizations). The combined information of these efforts has greatly extended our knowledge and facilitated conflict avoidance agreements. These agreements have allowed oil and gas activities to go forward while minimizing interference with traditional Native subsistence hunting. We have found BWASP statistical analysis and data presentation to be very useful in assessing potential impacts within the Beaufort Sea."

C. Conclusions

We saw no indications that the migration was "stopped" in Fall 2000, including areas near the Northstar production site.

Oil-industry studies, pooling our data with their own site-specific data, have detected localized deflections on the order of 10 to 20 km by bowhead whales in the immediate vicinity of certain types of active seismic exploration (USDOI, MMS, 1997b). Since preliminary power analysis of the ANOVA for distance of bowhead whales from shore (α=0.05, $\beta \leq$0.01) showed minimum detectable differences of 7.8 km in the East Region and 9.7 km in the West (Treacy, 1998), we should be able to detect any region-wide 10- to 20-km shifts between years that may have derived from localized deflections.

Bowhead whales occur farther offshore in heavy-ice years during fall migrations across the Central Alaskan Beaufort Sea (142°W. to 155°W. longitudes). Bowheads generally occupy nearshore waters in years of light sea-ice severity, somewhat more offshore waters in moderate ice years, and are even farther offshore in heavy ice years. While other factors (other than sea ice) may have localized effects on site-specific distributions, broad-area distributions of bowhead whale sightings in the central Alaskan Beaufort Sea are related to overall sea-ice severity. Both Kaktovik and Nuiqsut communities conduct subsistence whale hunts each year in the central Alaskan Beaufort Sea, where the distance offshore to conduct this important subsistence activity can be crucial to their safety and hunting success. To the extent villagers from Barrow utilize the area east of 155°W. longitude to hunt whales, distances from shore to the main migration corridor would likewise be negatively affected in heavier ice years.

D. Field Coordination and Other Information Support

During the field season, we coordinated with AEWC, Barrow, Alaska; Whalers Communication Center, Deadhorse, Alaska; NMFS, Anchorage, Alaska; and NSB, Department of Wildlife Management, Barrow, Alaska.

Selected BWASP information-support activities during calendar year 2000 included:

- providing whale distribution data in support of site-specific/acoustic monitoring of marine mammals near the Northstar pre-production facility;
- presenting a paper, "Fall 1997 Migration of Bowhead Whales Across the Alaskan Beaufort Sea as Noted by the MMS Bowhead Whale Aerial Survey Project with Preliminary Fall 1998-99 Survey Results" (*In* MMS Alaska Region Beaufort Sea Information Update Meeting, OCS Study MMS 2000-023), in Barrow, Alaska, on 28 March 2000 (http://www.mms.gov/omm/alaska/ess);

- participating in annual interagency evaluations (with NMFS, NSB, AEWC) on BP Exploration (Alaska)'s and WesternGeco's site-specific planned and reported monitoring of marine mammals near seismic and Northstar pre-production operations on 23-24 May 2000 at the National Marine Mammal Laboratory (NMML);
- presenting project information at a Workshop on the Design of Studies Needed for the Evaluation of Cumulative Impacts of Oil and Gas Exploration and Production on Fall Migrating Bowhead Whales and the Fall Bowhead Whale Subsistence Hunt" , held 6-7 November 2000 at NMML;
- providing data to and coordinating with scientists and subsistence whalers in support of the MMS study "Bowhead Whale Feeding in the Eastern Alaskan Beaufort Sea: Update of Scientific and Traditional Information";
- providing maps of bowhead whale distribution to the MMS Regional Director in support of a Briefing Book for Lease Sale 176;
- providing BWASP maps Mr. Michael Baffrey, USDOI;
- providing a set of previous BWASP reports to Ms. Jan Philips, North Slope Borough, and to Dr. Stephen R. Braund and Associates, Anchorage, Alaska.

VI. LITERATURE CITED

Aagaard, K. 1984. The Beaufort Undercurrent. *In:* The Alaskan Beaufort Sea: Ecosystems and Environment. P.W. Barnes, D.M. Schell, and E. Reimnitz (eds.). Academic Press., pp. 47-71.

Brower, W.A., R.G. Baldwin, C.N. Williams, J.L. Wise, and L.D. Leslie. 1988. Climatic Atlas of the Outer Continental Shelf Waters and Coastal Regions of Alaska, Volume III. OCS Study MMS 87-0013. USDOI, MMS, Alaska OCS Region, 524 pp.

Chapman, C.F. 1971. *Piloting, Seamanship and Small Boat Handling*. New York, NY: Hearst Books, 640 pp.

Cochran, W.G. 1963. Sampling Techniques. New York, NY: J. Wiley, 413 pp.

Endangered Species Act of 1973, as amended. 16 USC 1531-1543.

Houghton, J.P., D.A. Segar, and J.E. Zeh. 1984. Beaufort Sea Monitoring Program. *In:* Proceedings of a Workshop (September 1983) and Sampling Design Recommendations. Prepared by Dames and Moore, Seattle, WA, for the OCS Environmental Assessment Program, Juneau, AK, 111 pp.

Johnson, M.A., A.Y. Proshutinsky, and I.V. Polakov. 1999. Atmospheric Patterns Forcing Two Regimes of Arctic Circulation: A Return to Anticyclonic Conditions? Geophys. Res. Lett 26: 1621-1624.

LaBelle, J.C., J.L. Wise, R.P. Voelker, R.H. Schulze, and G.M. Wohl. 1983. Alaska Marine Ice Atlas. Arctic Environmental Information and Data Center, University of Alaska, Anchorage, AK, 302 pp.

Landino, S.W., S.D. Treacy, S.A. Zerwick, and J.B. Dunlap. 1994. A Large Aggregation of Bowhead Whales (*Balaena mysticetus*) Feeding near Point Barrow, Alaska, in Late October 1992. Arctic 47 (3): 232-235.

LGL Ecological Research Associates, Inc. 1987. Importance of the Eastern Alaskan Beaufort Sea to Feeding Bowhead Whales, 1985-86, W.J. Richardson, ed. OCS Study MMS 87-0037. Prepared for USDOI, MMS, Alaska OCS Region.

Ljungblad, D.K., S.E. Moore, and J.T. Clarke. 1986. Assessment of Bowhead Whale (*Balaena mysticetus*) Feeding Patterns in the Alaskan Beaufort and Northeastern Chukchi Seas via Aerial Surveys, Fall 1979-84. Rep. Int. Whal. Commn. 36 (SC/37/PS1): 265-272.

Ljungblad, D.K., S.E. Moore, J.T. Clarke, and J.C. Bennett. 1987. Distribution, Abundance, Behavior and Bioacoustics of Endangered Whales in the Alaskan Beaufort and Eastern Chukchi Seas, 1979-86. OCS Study MMS 87-0039. Anchorage, AK: USDOI, MMS, Alaska OCS Region, 391 pp.

Marine Mammal Protection Act of 1972. 16 USC 1361-1407.

Moore, S.E. 2000. Variability of Cetacean Distribution and Habitat Selection in the Alaskan Arctic, Autumn 1982-91. Arctic 53 (4): 448-460.

Moore, S.E. and J.T. Clarke. 1992. Distribution, Abundance and Behavior of Endangered Whales in the Alaskan Chukchi and Western Beaufort Seas, 1991: With a Review 1982-91. OCS Study MMS 92-0029. Anchorage, AK: USDOI, MMS, Alaska OCS Region, 211 pp.

Moore, S.E. and D.P. DeMaster. 1997. Cetacean Habitats in the Alaskan Arctic. J. NW Atlantic Fish. Sci. 22: 55-69.

National Environmental Policy Act of 1969. 42 USC 4321-4347.

Norton, D. and G. Weller. 1984. The Beaufort Sea: Background, History, and Perspective. *In:* The Alaskan Beaufort Sea, P. Barnes, D. Schell, and E. Reimnitz, eds. Orlando, FL: Academic Press, Inc., 466 pp.

Outer Continental Shelf Lands Act of 1953, as amended in 1978. 43 USC 1331-1356 and 1801-1866.

Proshutinsky and Johnson. 1997. Two Circulation Regimes of the Wind-driven Arctic Ocean. Journal of Geophysical Research 102(C6):12493-12514.

Rice, D.W. 1998. Marine Mammals of the World: Systematics and Distribution. Special Publication Number 4. The Society for Marine Mammalogy. 231 pp.

Treacy, S.D. 1988. Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 1987. OCS Study MMS 88-0030. Anchorage, AK: USDOI, MMS, Alaska OCS Region, 141 pp.

Treacy, S.D. 1989. Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 1988. OCS Study MMS 89-0033. Anchorage, AK: USDOI, MMS, Alaska OCS Region, 101 pp.

Treacy, S.D. 1990. Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 1989. OCS Study MMS 90-0047. Anchorage, AK: USDOI, MMS, Alaska OCS Region, 104 pp.

Treacy, S.D. 1991. Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 1990. OCS Study MMS 91-0055. Anchorage, AK: USDOI, MMS, Alaska OCS Region, 107 pp.

Treacy, S.D. 1992. Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 1991. OCS Study MMS 92-0017. Anchorage, AK: USDOI, MMS, Alaska OCS Region, 92 pp.

Treacy, S.D. 1993. Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 1992. OCS Study MMS 93-0023. Anchorage, AK: USDOI, MMS, Alaska OCS Region, 135 pp.

Treacy, S.D. 1994. Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 1993. OCS Study MMS 94-0032. Anchorage, AK: USDOI, MMS, Alaska OCS Region, 132 pp.

Treacy, S.D. 1995. Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 1994. OCS Study MMS 95-0033. Anchorage, AK: USDOI, MMS, Alaska OCS Region, 116 pp.

Treacy, S.D. 1996. Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 1995. OCS Study MMS 96-0006. Anchorage, AK: USDOI, MMS, Alaska OCS Region, 120 pp.

Treacy, S.D. 1997. Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 1996. OCS Study MMS 97-0016. Anchorage, AK: USDOI, MMS, Alaska OCS Region, 115 pp.

Treacy, S.D. 1998. Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 1997. OCS Study MMS 98-0059. Anchorage, AK: USDOI, MMS, Alaska OCS Region, 143 pp.

Treacy, S.D. 2000. Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 1998-1999. OCS Study MMS 2000-066. Anchorage, AK: USDOI, MMS, Alaska OCS Region, 135 pp.

Treacy, S.D. 2001. Bowhead Whales (*Balaena mysticetus*) Occur Farther Offshore in Heavy-Ice Years during Fall Migrations across the Central Alaskan Beaufort Sea. Abstract *In*: 14th Biennial Conference on the Biology of Marine Mammals, Abstracts (28 Nov. – 3 Dec 2001; Vancouver B.C. Canada). p. 217.

USDOC, NOAA, NMFS. 1982. Endangered Species Act, Section 7 Consultation - Biological Opinion, Oil and Gas Lease Sale 71 (Diapir Field). 19 May 1982. Washington, D.C.

USDOC, NOAA, NMFS. 1983. Endangered Species Act, Section 7 Consultation - Biological Opinion, Oil and Gas Leasing and Exploration-Diapir Field Lease Offering (Sale 87). 19 December 1983. Washington, D.C.

USDOC, NOAA, NMFS. 1987. Endangered Species Act, Section 7 Consultation - Biological Opinion, Oil and Gas Leasing and Exploration - Beaufort Sea Sale 97. 20 May 1987. Washington, D.C.

USDOC, NOAA, NMFS. 1988. Endangered Species Act, Section 7 Consultation - Biological Opinion, Oil and Gas Leasing and Exploration - Arctic Region. 23 November 1988. Washington, D.C.

USDOC, NOAA, National Ice Center/USDOD, Navy, Naval Ice Center. 2001. Seasonal Outlook, Sea Ice Conditions for the Alaskan North Coast, Summer 2001. Washington, D.C., 5 pp.

USDOD, Navy, Naval Hydrographic Office. 1956. Aerial Ice Reconnaissance and Functional Glossary of Ice Terminology. Hydrographic Office Publication No. 609, 14 pp.

USDOI, MMS. 1979. State of Alaska, Department of Natural Resources; Federal/State Joint Beaufort Sea Oil and Gas Lease Sale BF, November 7, 1979 (44 FR 64752).

USDOI, MMS. 1982. Memorandum from Director, BLM, to Secretary of the Interior, dated 30 April 1982; subject: Decision on the Modification of the Seasonal Drilling Restriction.

USDOI, MMS. 1984. Outer Continental Shelf, Diapir Field, Oil and Gas Lease Sale 87, July 23, 1984 (49 FR 29726).

USDOI, MMS. 1988. Outer Continental Shelf, Beaufort Sea, Oil and Gas Lease Sale 97, February 12, 1988 (53 FR 4356).

USDOI, MMS. 1991. Outer Continental Shelf Beaufort Sea Oil and Gas Lease Sale 124, May 24, 1991 (56 FR 23966).

USDOI, MMS. 1996. Outer Continental Shelf Beaufort Sea Oil and Gas Lease Sale 144, August 16, 1996 (61 FR 42682).

USDOI, MMS. 1997. Arctic Seismic Synthesis and Mitigating measures Workshop. OCS Study MMS 97-0014. Anchorage, AK: USDOI, MMS, Alaska OCS Region, 71 pp. plus appendices.

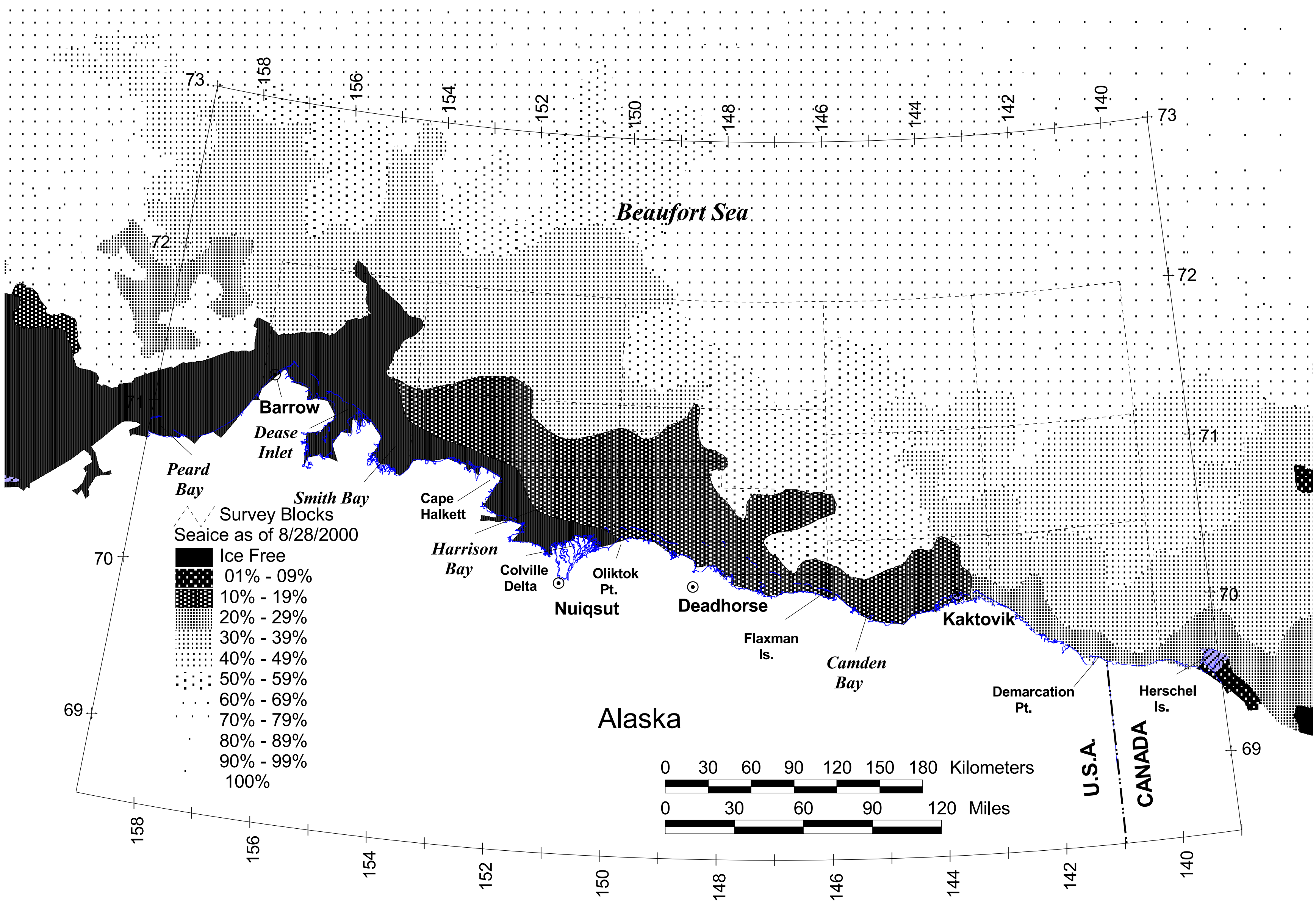
USDOI, MMS. 1998. Alaska Outer Continental Shelf, Beaufort Sea Planning Area Oil and Gas Lease Sale 170 OCS EIS/EA MMS 98-0007.

USDOI, MMS. 2000. Project Management Plan, MMS Fall 2000 Bowhead Whale Aerial Survey Project, August 1998. Anchorage, AK: USDOI, MMS, Alaska OCS Region, 14 pp.

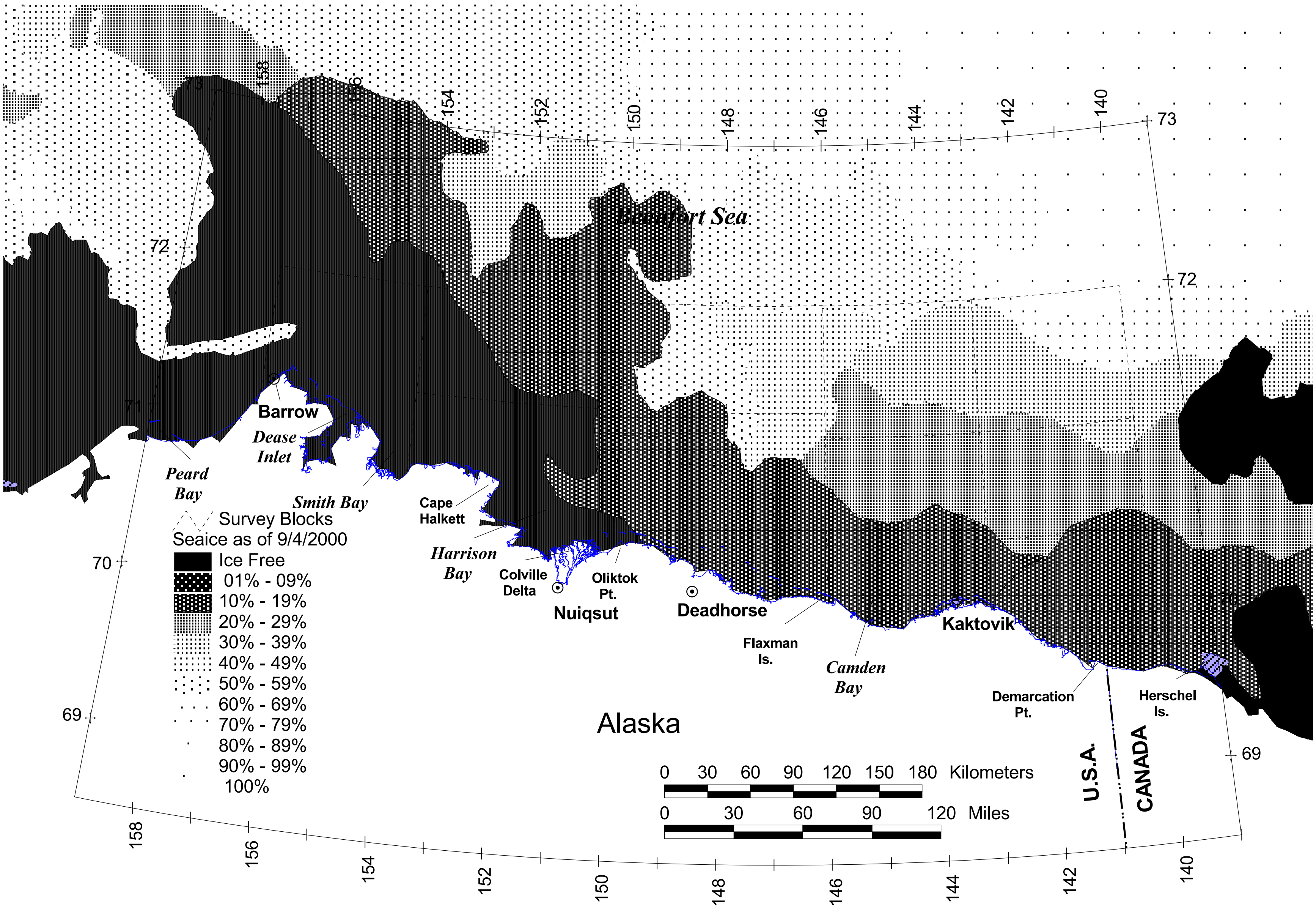
Zar, S.H. 1984. Biostatistical Analysis. Englewood Cliffs, NJ: Prentice Hall, Inc., 620 pp.

APPENDIX A

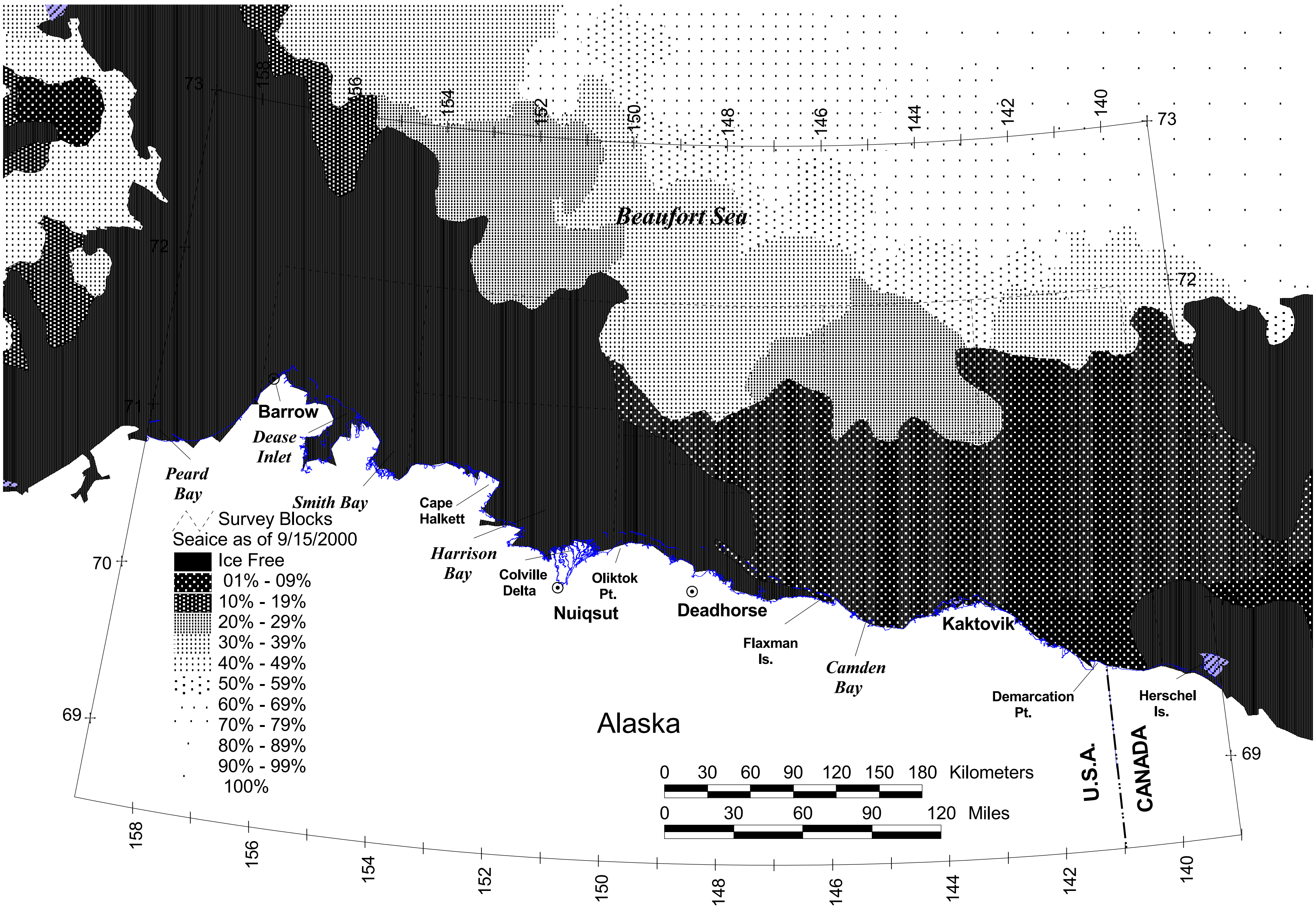
FALL 2000 ICE CONCENTRATION MAPS FOR THE BEAUFORT SEA



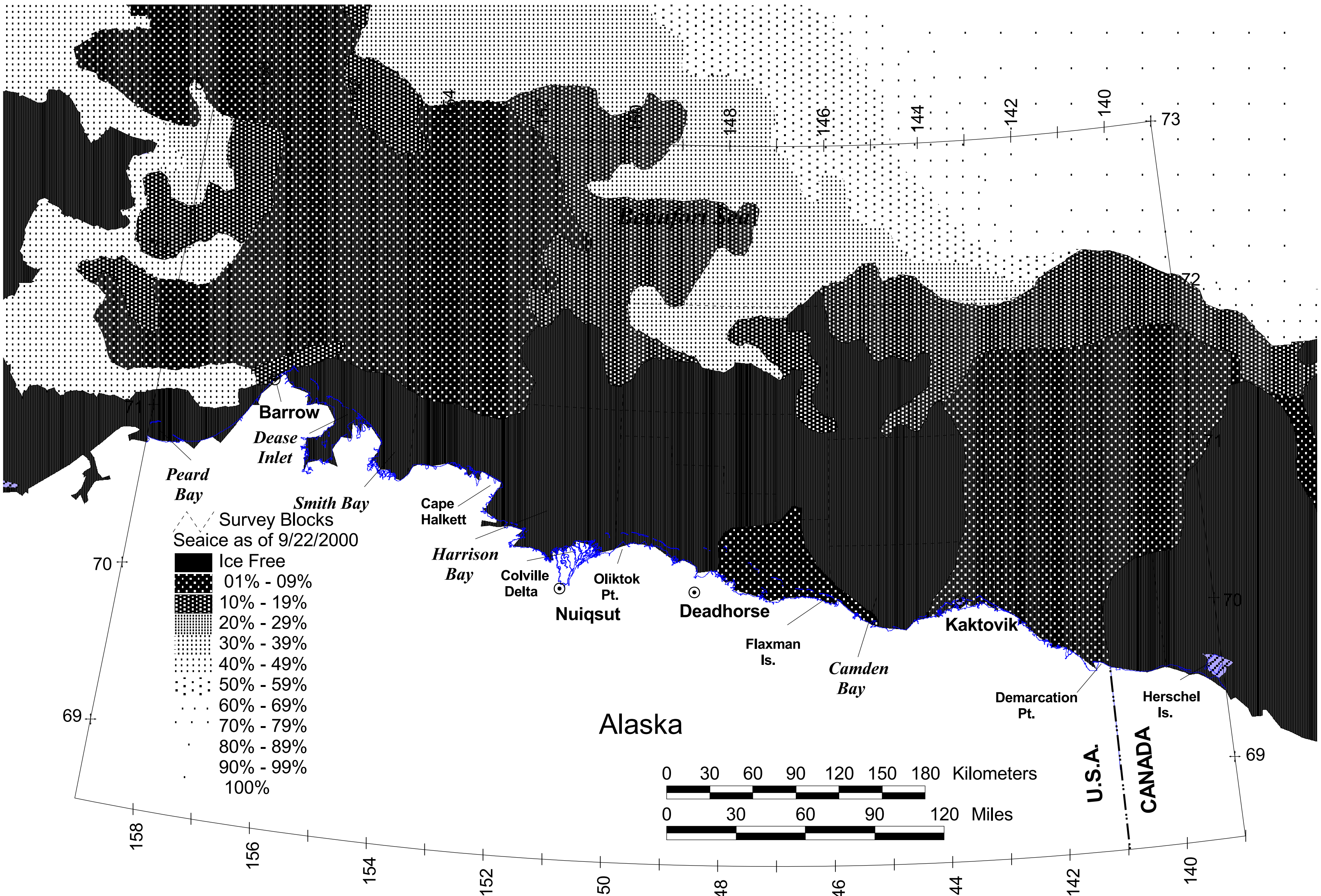
Map of Ice Concentrations in the Beaufort Sea, 28 August 2000



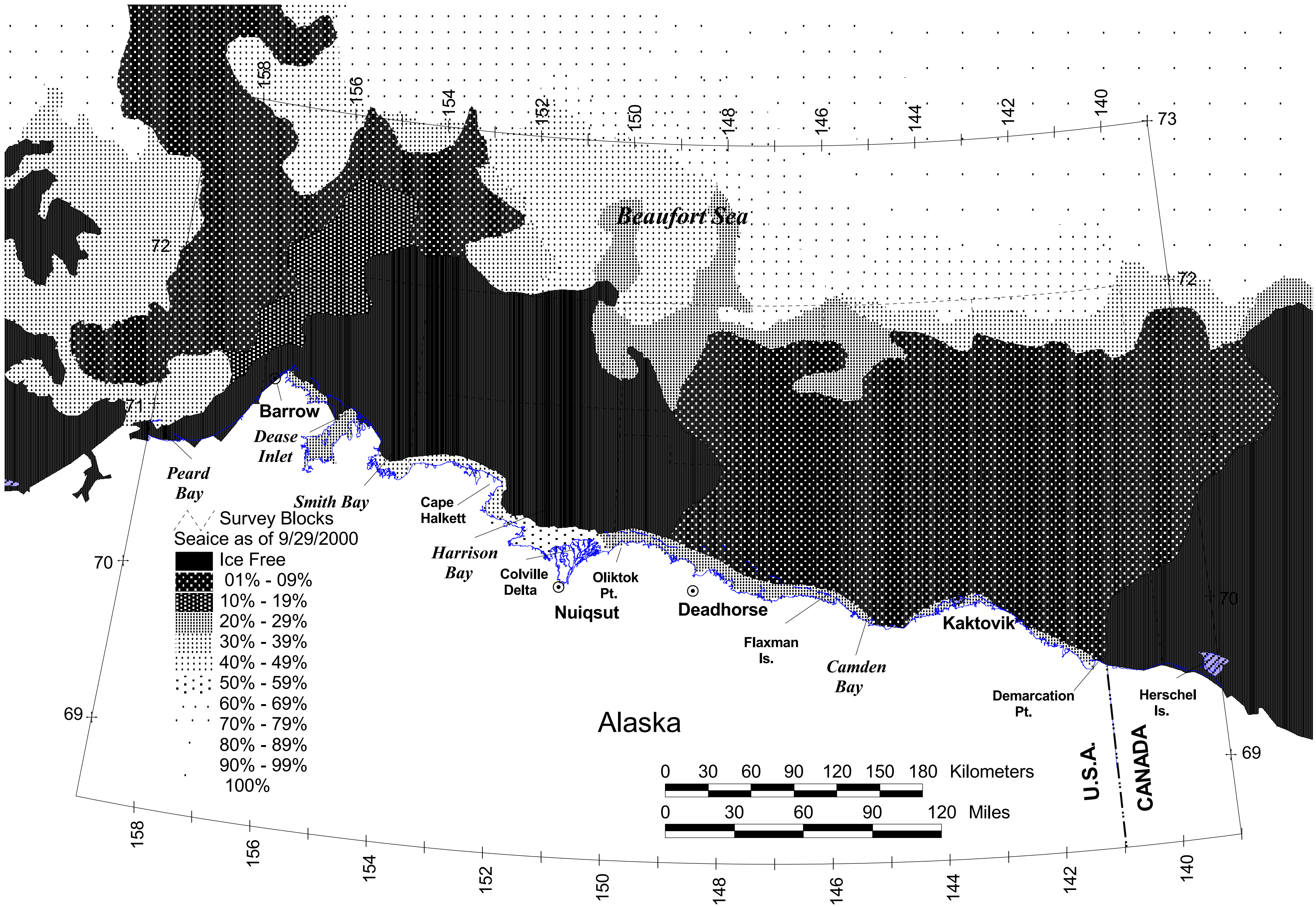
Map of Ice Concentrations in the Beaufort Sea, 4 September 2000



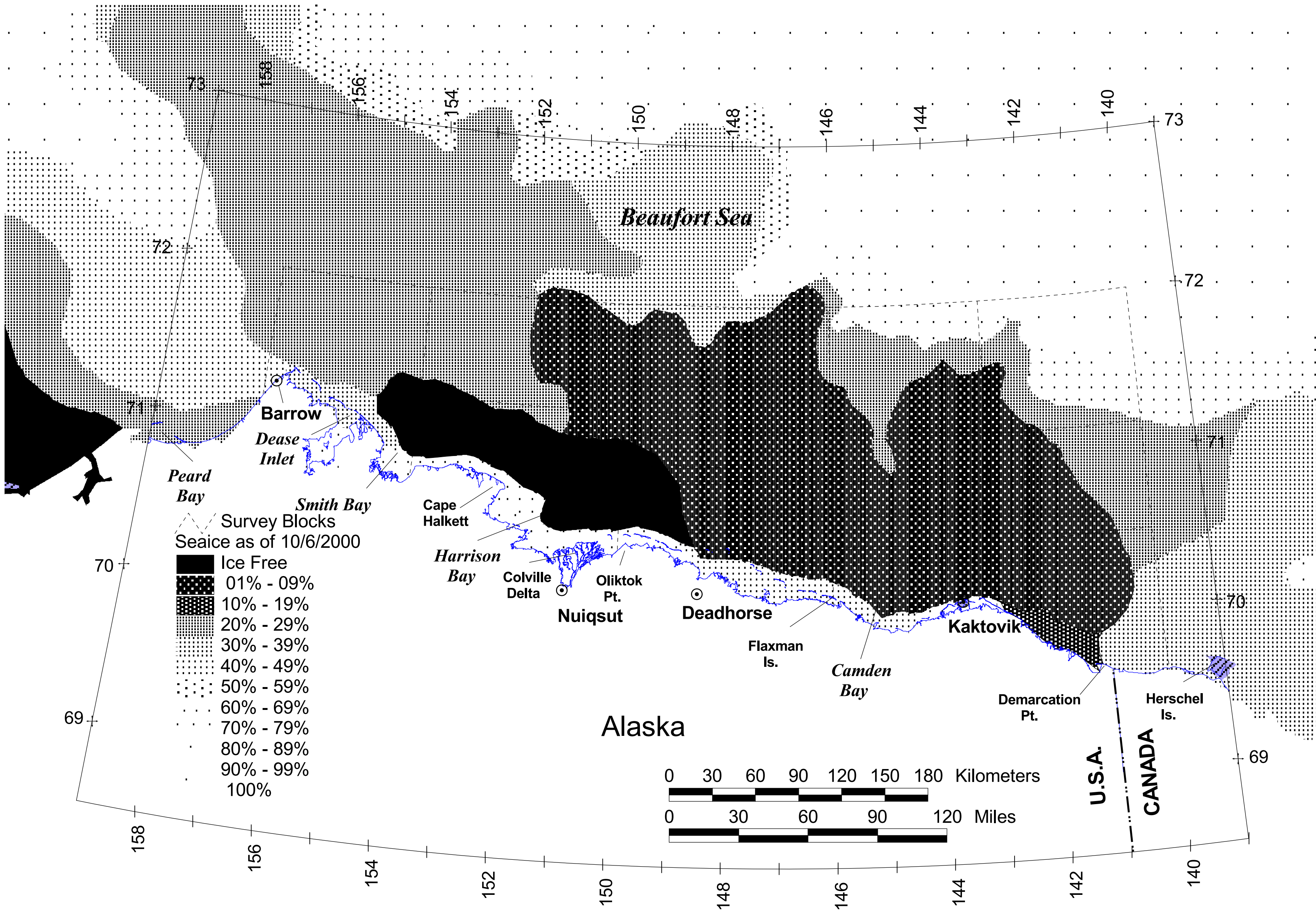
Map of Ice Concentrations in the Beaufort Sea, 15 September 2000



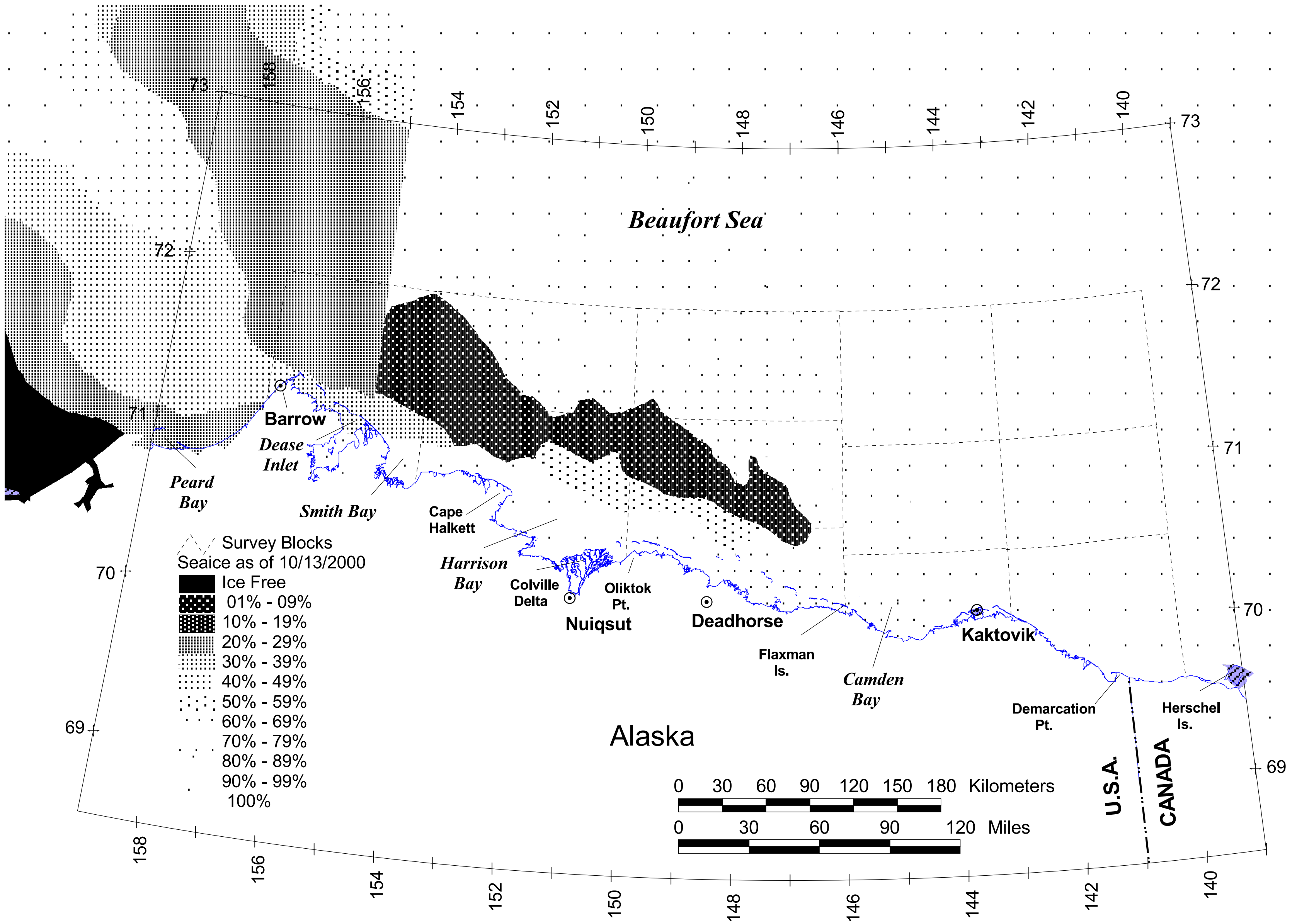
Map of Ice Concentrations in the Beaufort Sea, 22 September 2000



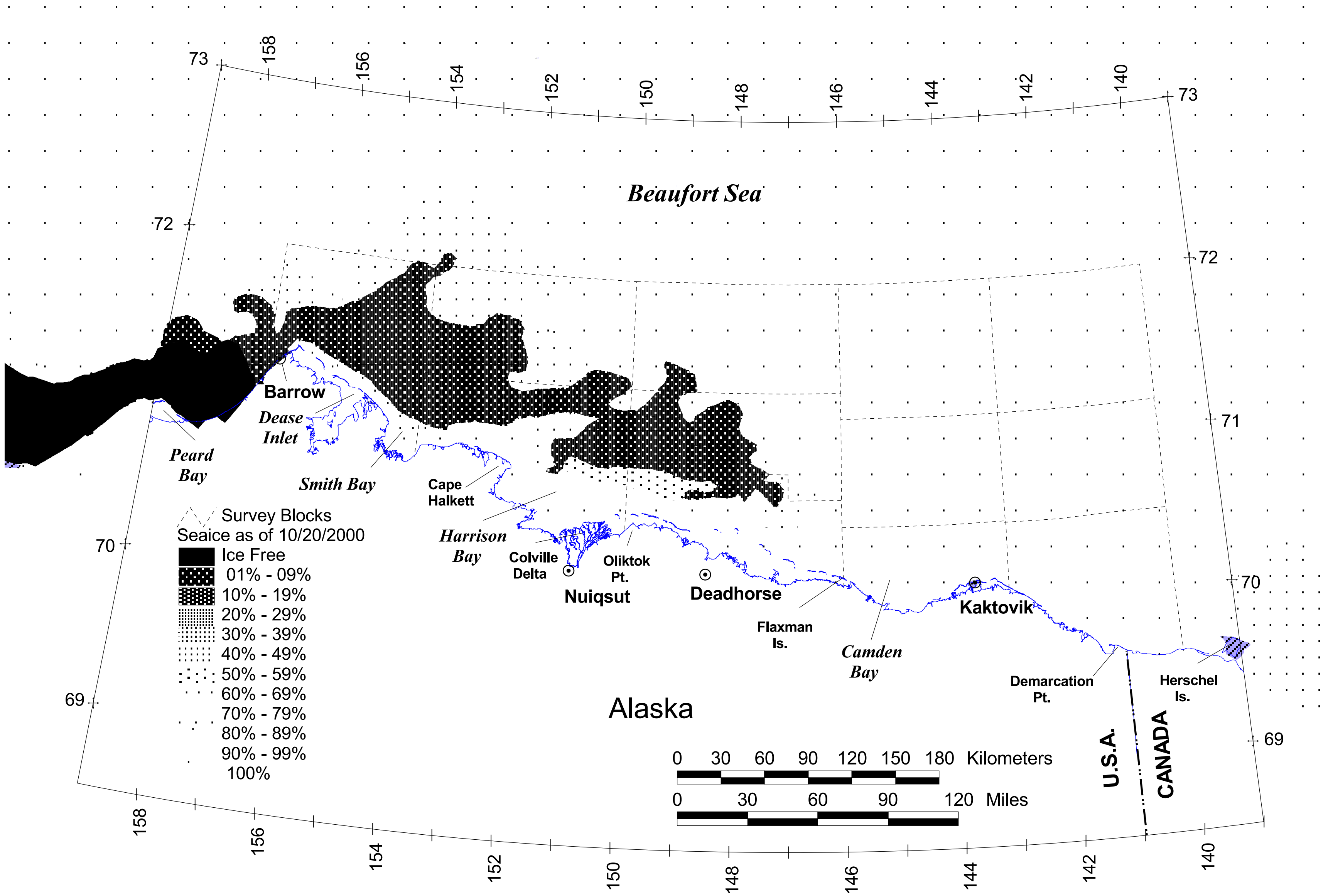
Map of Ice Concentrations in the Beaufort Sea, 29 September 2000



Map of Ice Concentrations in the Beaufort Sea, 6 October 2000



Map of Ice Concentrations in the Beaufort Sea, 13 October 2000



Map of Ice Concentrations in the Beaufort Sea, 20 October 2000

APPENDIX B

FALL 2000 BOWHEAD WHALE SIGHTING DATA

Table B-1
Selected Sighting Data for Bowhead Whales Observed, Fall 2000

Flight No.	Day	Total Whales	No. of Calves	Latitude	Longitude	Behavior	Compass Heading	Ice (%)	Wind Force
1	1 Sep	3	0	70°31.8'	147°03.1'	swim	130°	1	3
1	1 Sep	1	0	70°32.5'	146°54.5'	swim	330°	1	3
1	1 Sep	1	0	70°32.7'	146°43.8'	swim	230°	1	3
1	1 Sep	1	0	70°33.1'	146°32.7'	rest	250°	1	3
1	1 Sep	1	0	70°34.0'	146°30.7'	swim	120°	1	3
1	1 Sep	1	0	70°33.8'	143°56.1'	rest	180°	0	O
1	1 Sep	1	0	70°24.2'	141°56.1'	rest	160°	0	1
1	1 Sep	1	0	70°22.9'	142°12.3'	rest	90°	30	1
1	1 Sep	1	0	70°18.5'	144°52.1'	swim	50°	0	1
1	1 Sep	1	0	70°27.0'	146°14.4'	dive	250°	1	2
2	2 Sep	2	0	70°57.9'	151°23.1'	swim	70°	1	4
2	2 Sep	7	0	71°10.0'	154°39.8'	mill	[1]	0	3
2	2 Sep	1	0	71°11.1'	154°39.0'	swim	180°	0	3
2	2 Sep	1	0	71°18.2'	155°07.7'	swim	170°	0	3
2	2 Sep	1	0	71°22.4'	155°40.2'	swim	80°	0	3
2	2 Sep	1	0	71°16.9'	155°49.5'	rest	130°	0	4
2	2 Sep	1	0	71°17.8'	155°12.6'	swim	290°	0	2
2	2 Sep	1	0	72°00.7'	154°35.9'	swim	340°	0	2
3	3 Sep	1	0	70°23.6'	144°30.0'	swim	240°	0	1
3	3 Sep	1	0	70°24.7'	144°04.6'	swim	240°	0	1
3	3 Sep	2	0	70°08.6'	141°43.3'	swim	60°	1	1
3	3 Sep	1	0	70°10.3'	141°42.7'	swim	30°	1	1
3	3 Sep	2	0	70°21.4'	142°10.0'	mill	[1]	10	1
3	3 Sep	2	0	70°12.3'	142°11.1'	rest	180°	0	1
3	3 Sep	2	0	70°21.3'	144°51.9'	rest	250°	0	1
3	3 Sep	4	0	70°26.5'	144°51.2'	rest	50°	0	1
3	3 Sep	2	0	70°25.0'	144°50.8'	swim	250°	0	1
3	3 Sep	1	0	70°27.7'	145°18.8'	swim	60°	1	1
3	3 Sep	1	0	70°22.5'	145°18.2'	rest	240°	1	1
6	9 Sep	1	0	70°33.7'	147°07.6'	swim	270°	0	2
7	12 Sep	9	0	71°08.6'	154°48.2'	feed	[1]	0	4
7	12 Sep	1	0	71°12.3'	155°17.9'	swim	240°	0	4
7	12 Sep	3	0	71°12.3'	155°18.4'	swim	340°	0	4
7	12 Sep	1	0	71°12.7'	155°20.4'	swim	[1]	0	4
7	12 Sep	1	0	71°34.5'	156°05.5'	swim	240°	0	4
7	12 Sep	1	0	71°11.2'	155°14.9'	swim	190°	0	4
7	12 Sep	1	0	71°12.2'	155°14.9'	swim	220°	0	4
7	12 Sep	1	0	71°21.8'	155°13.7'	swim	10°	0	4
7	12 Sep	1	0	71°45.4'	154°33.4'	dead[4]	[1]	0	6
7	12 Sep	1	0	71°08.1'	154°49.3'	swim	230°	0	4
7	12 Sep	11	0	71°07.4'	154°49.7'	feed	[1]	0	4
7	12 Sep	47	0	71°04.8'	154°43.4'	feed	[1]	0	4

Table B-1
Selected Sighting Data for Bowhead Whales Observed, Fall 2000

Flight No.	Day	Total Whales	No. of Calves	Latitude	Longitude	Behavior	Compass Heading	Ice (%)	Wind Force
7	12 Sep	10	0	71°03.0'	154°38.5'	feed	[1]	0	4
7	12 Sep	1	0	70°56.2'	154°08.7'	swim	180°	0	2
8	13 Sep	1	0	70°16.4'	144°21.7'	swim	300°	0	2
11	15 Sep	1	0	70°49.4'	150°58.6'	swim	290°	0	4
11	15 Sep	1	0	70°55.1'	153°52.7'	rest	290°	0	2
11	15 Sep	1	0	70°55.5'	153°52.9'	swim	150°	0	2
11	15 Sep	1	0	71°33.2'	152°21.6'	swim	40°	0	3
11	15 Sep	1	0	70°58.4'	151°34.7'	swim	240°	0	6
11	15 Sep	1	0	70°42.4'	149°17.4'	swim	240°	1	3
13	17 Sep	1	0	70°17.7'	141°21.8'	swim	220°	1	4
13	17 Sep	1	0	69°57.3'	142°19.8'	swim	90°	10	3
13	17 Sep	1	0	70°12.0'	142°42.9'	swim	290°	1	5
13	17 Sep	1	0	70°17.7'	145°45.7'	swim	210°	1	4
15	20 Sep	1	0	70°29.6'	147°07.7'	swim	290°	1	5
17	23 Sep	1	0	71°12.8'	152°56.7'	swim	220°	0	5
17	23 Sep	1	0	71°20.4'	154°25.2'	mill	[1]	0	5
17	23 Sep	1	0	71°10.0'	154°48.5'	rest	310°	0	6
17	23 Sep	1	0	71°08.6'	154°44.6'	swim	310°	0	6
17	23 Sep	1	0	70°43.2'	151°24.2'	swim	180°	0	5
17	23 Sep	1	0	70°42.1'	151°18.8'	swim	300°	0	5
18	25 Sep	1	0	70°47.6'	148°47.3'	swim	270°	0	3
18	25 Sep	1	0	70°40.6'	147°46.8'	swim	270°	0	2
18	25 Sep	1	0	70°21.7'	146°04.1'	rest	[1]	0	3
18	25 Sep	1	0	70°25.9'	145°56.0'	swim	160°	1	2
18	25 Sep	1	0	70°24.8'	145°16.4'	swim	230°	1	3
22	5 Oct	2	0	70°16.8'	143°40.7'	rest	150°	0	3
24	10 Oct	1	0	70°26.0'	144°48.9'	swim	260°	30	2
24	10 Oct	1	0	70°26.0'	144°48.9'	swim	260°	30	2
24	10 Oct	1	0	70°26.0'	144°48.9'	swim	360°	30	2
24	10 Oct	1	0	70°24.5'	144°30.2'	swim	260°	0	2
24	10 Oct	1	0	70°24.3'	144°24.2'	swim	260°	0	2
24	10 Oct	1	0	70°15.2'	143°35.9'	swim	250°	30	2
24	10 Oct	1	0	70°15.8'	143°12.4'	swim	270°	65	2
24	10 Oct	1	0	70°22.8'	144°22.8'	swim	245°	50	2
24	10 Oct	1	0	70°31.7'	144°22.7'	swim	60°	85	2
24	10 Oct	1	0	70°57.4'	144°51.2'	swim	180°	10	4
24	10 Oct	1	0	70°51.3'	144°48.8'	swim	180°	10	5
24	10 Oct	2	0	70°32.1'	144°42.3'	spy hop	270°	90	2
25	11 Oct	1	0	71°00.1'	152°48.9'	swim	270°	50	2
25	11 Oct	1	0	71°00.3'	153°09.8'	swim	270°	50	2
25	11 Oct	1	0	71°01.5'	153°14.5'	swim	210°	50	2
25	11 Oct	1	0	71°02.0'	153°16.7'	swim	200°	50	2

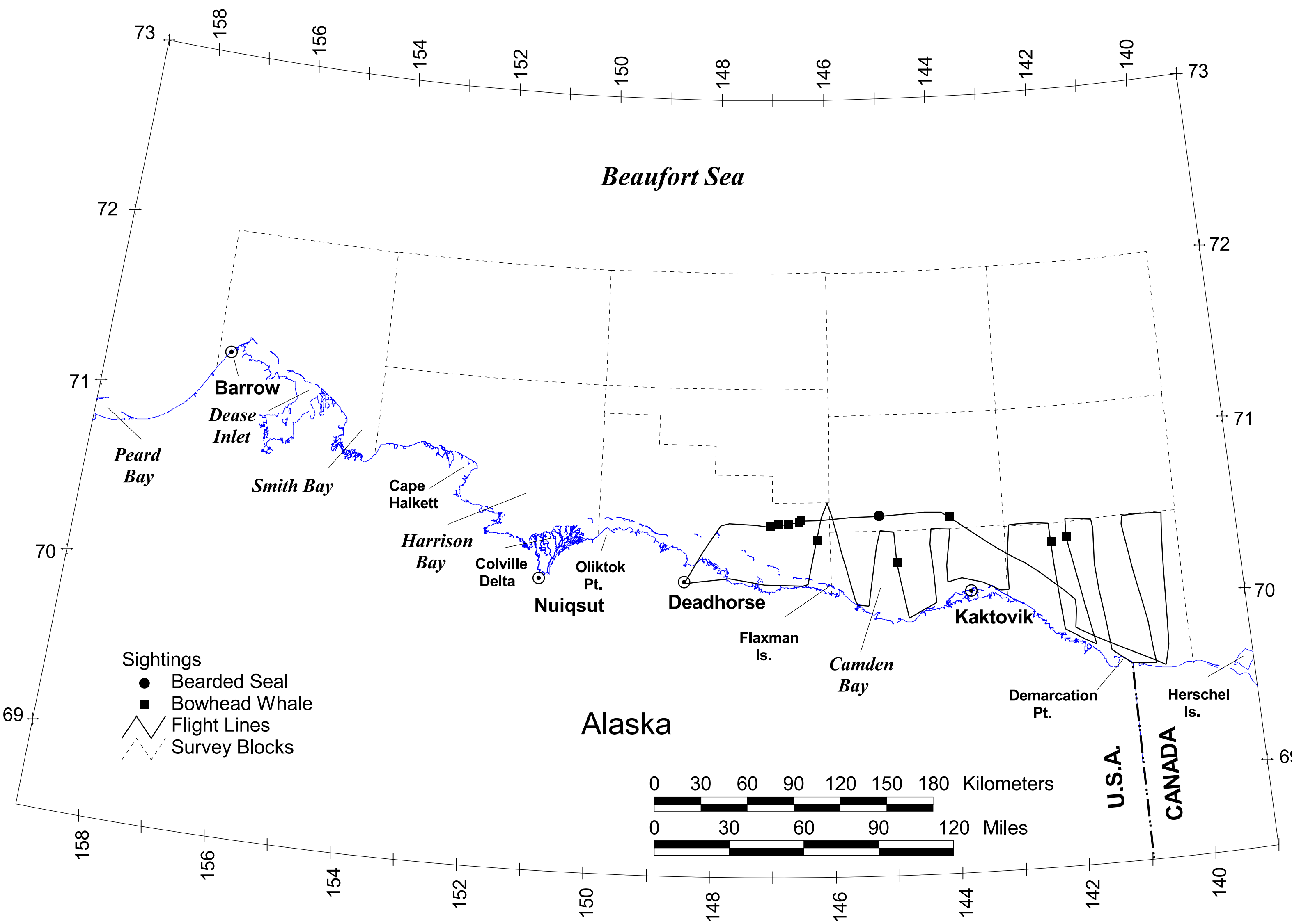
Table B-1
Selected Sighting Data for Bowhead Whales Observed, Fall 2000

Flight No.	Day	Total Whales	No. of Calves	Latitude	Longitude	Behavior	Compass Heading	Ice (%)	Wind Force
25	11 Oct	3	0	71°00.7'	153°32.0'	swim	190°	90	2
25	11 Oct	1	0	71°02.5'	153°44.8'	swim	200°	80	2
25	11 Oct	1	0	71°08.1'	153°05.6'	swim	285°	0	4
25	11 Oct	3	0	71°04.2'	152°10.1'	feed	210°	80	2
25	11 Oct	3	0	71°03.0'	152°09.0'	tail slap	360°	20	2
25	11 Oct	5	1	71°03.2'	151°53.3'	swim	230°	0	4

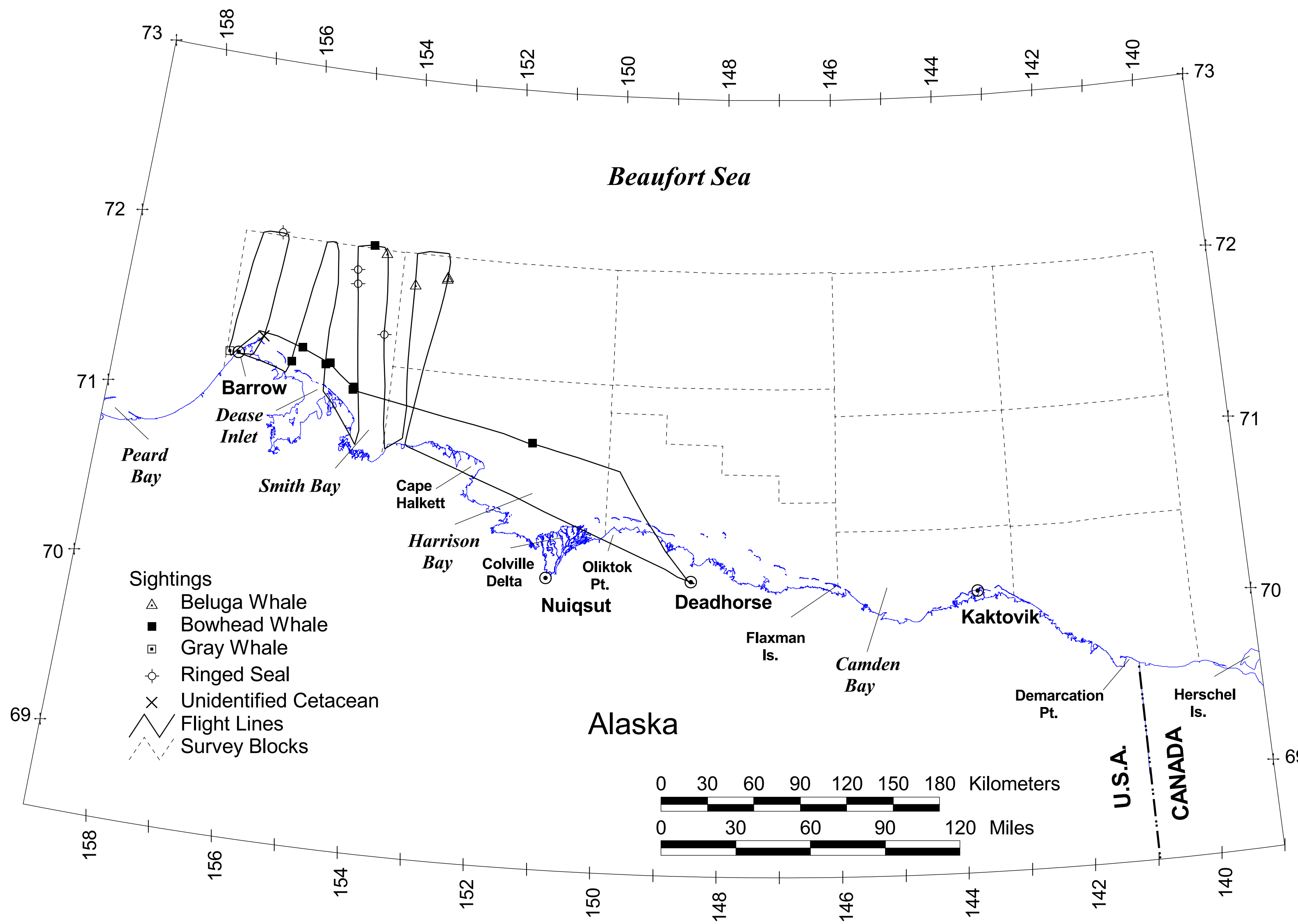
[1] Not recorded.
[2] Possible repeat sighting.
[3] Definite repeat sighting (excluded from analyses).
[4] Dead whale (excluded from analyses).

APPENDIX C

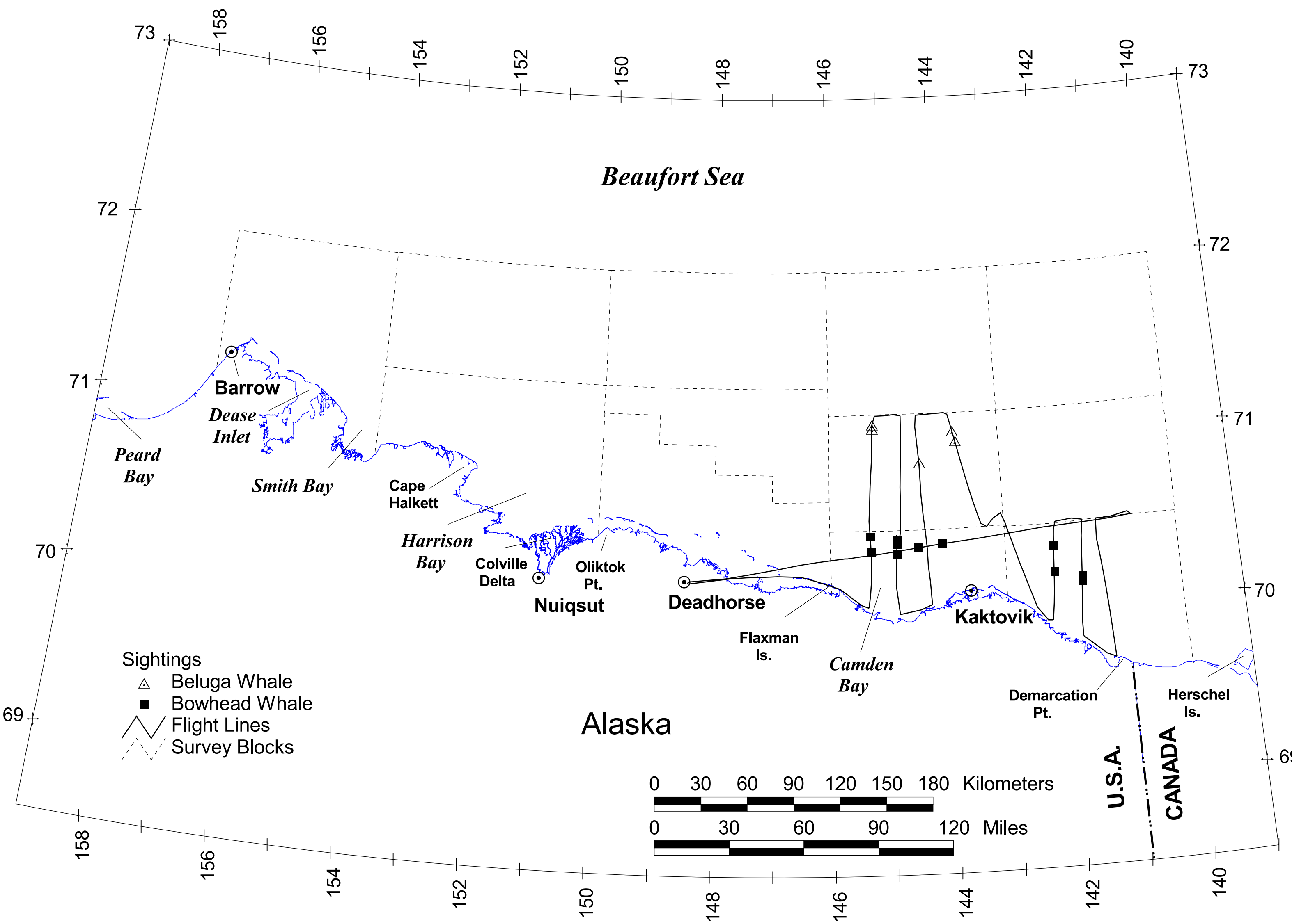
FALL 2000 DAILY FLIGHT SUMMARIES



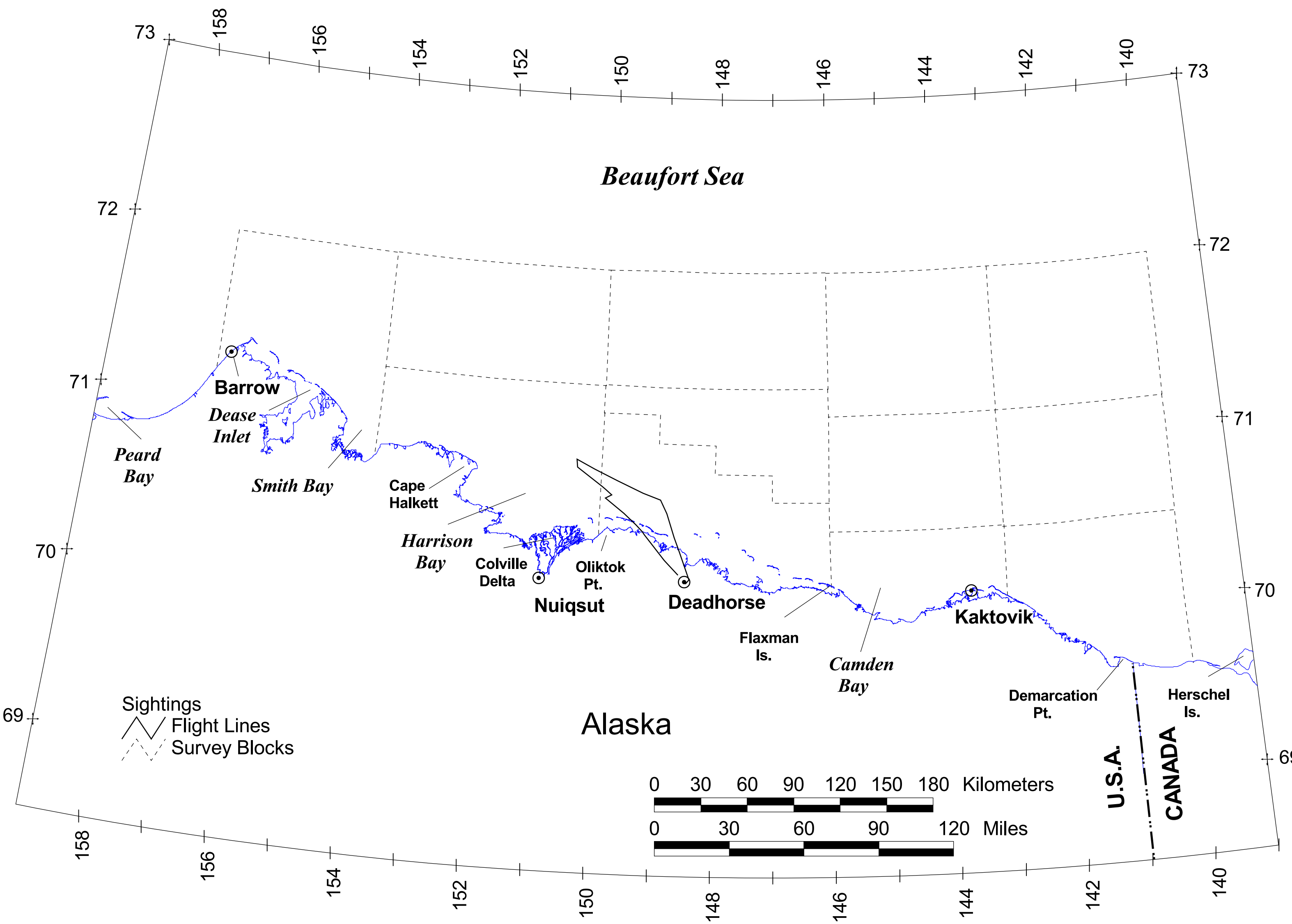
Flight 1: 1 September 2000 Survey Track and Sightings



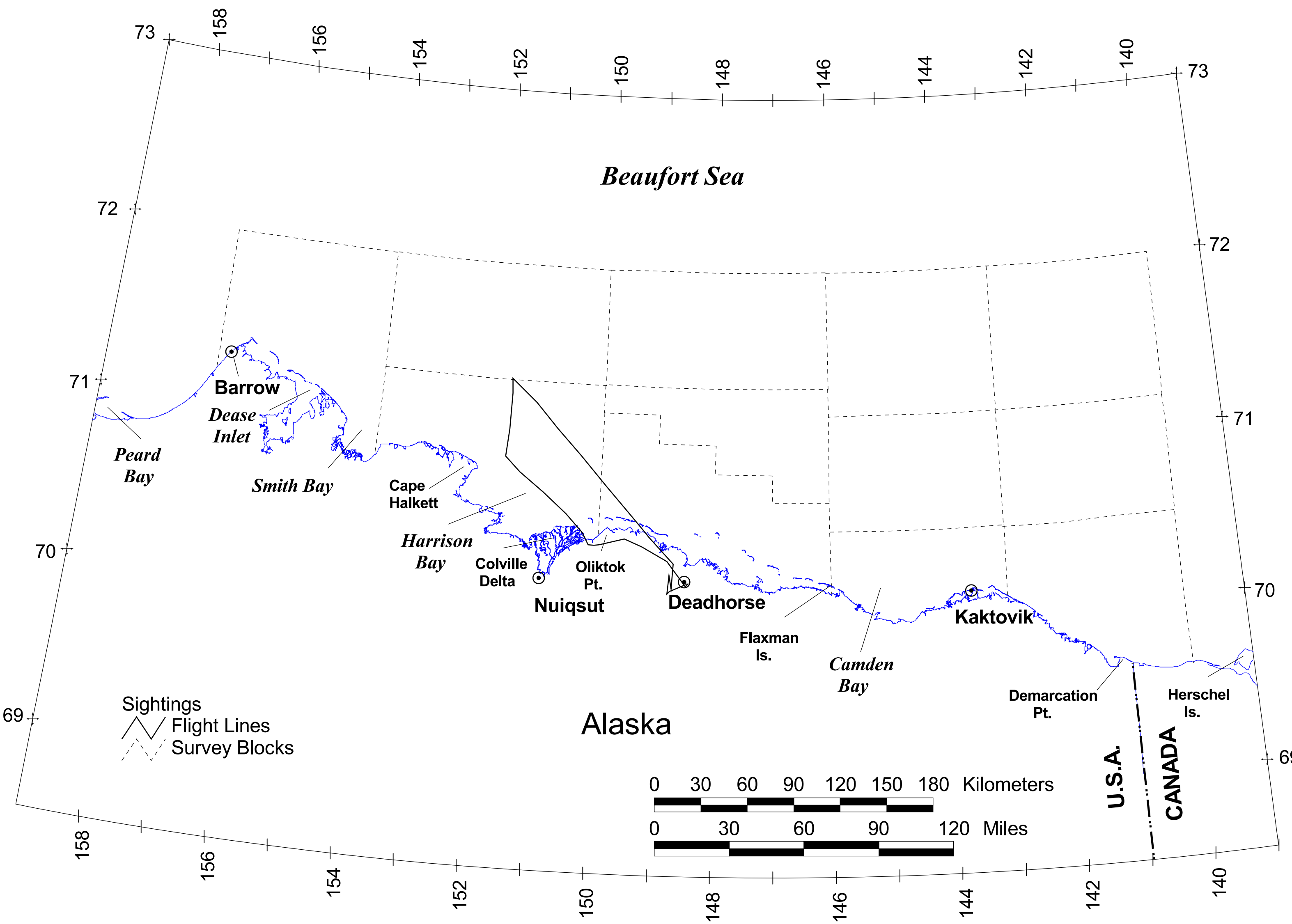
Flight 2: 2 September 2000 Survey Track and Sightings



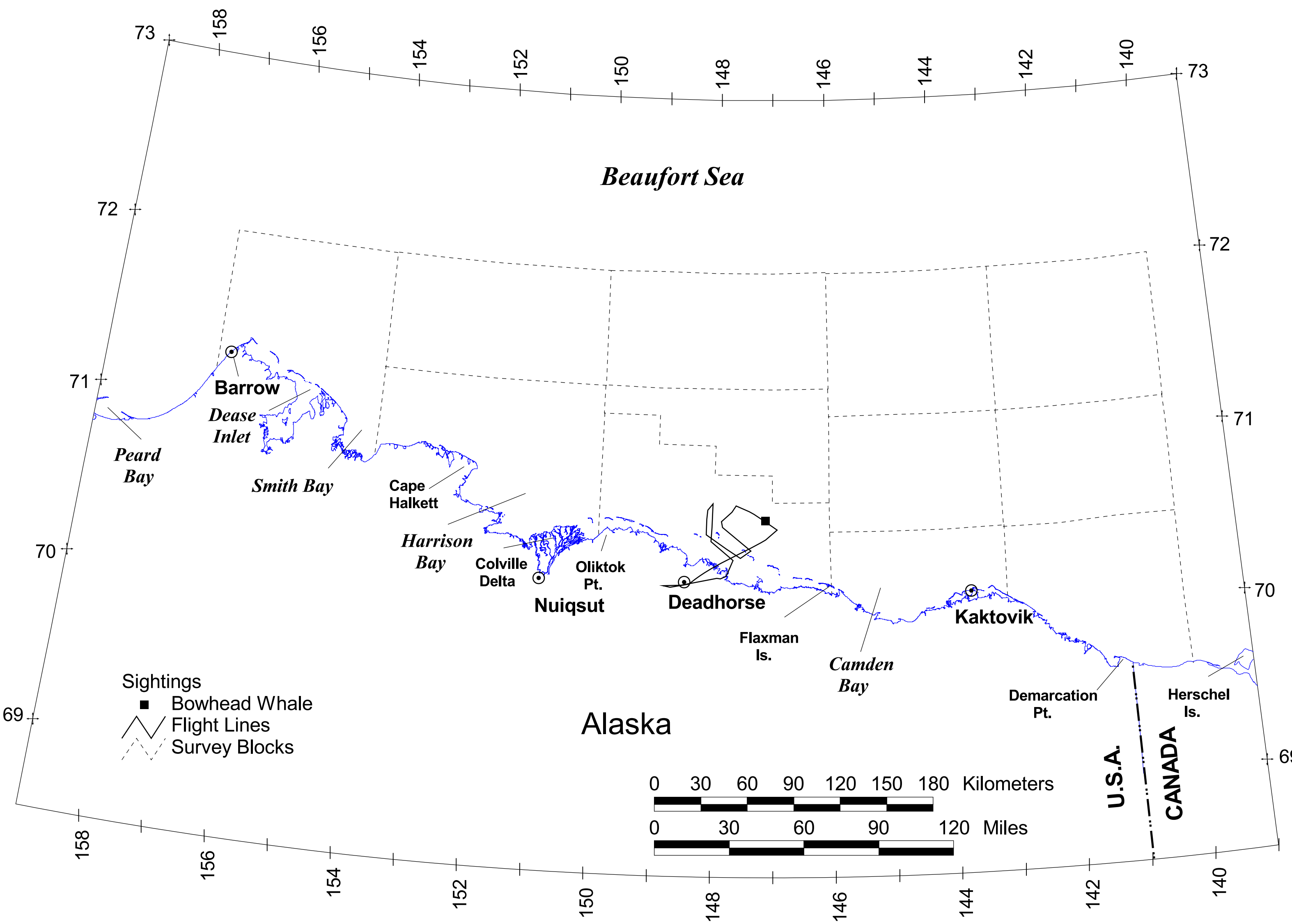
Flight 3: 3 September 2000 Survey Track and Sightings



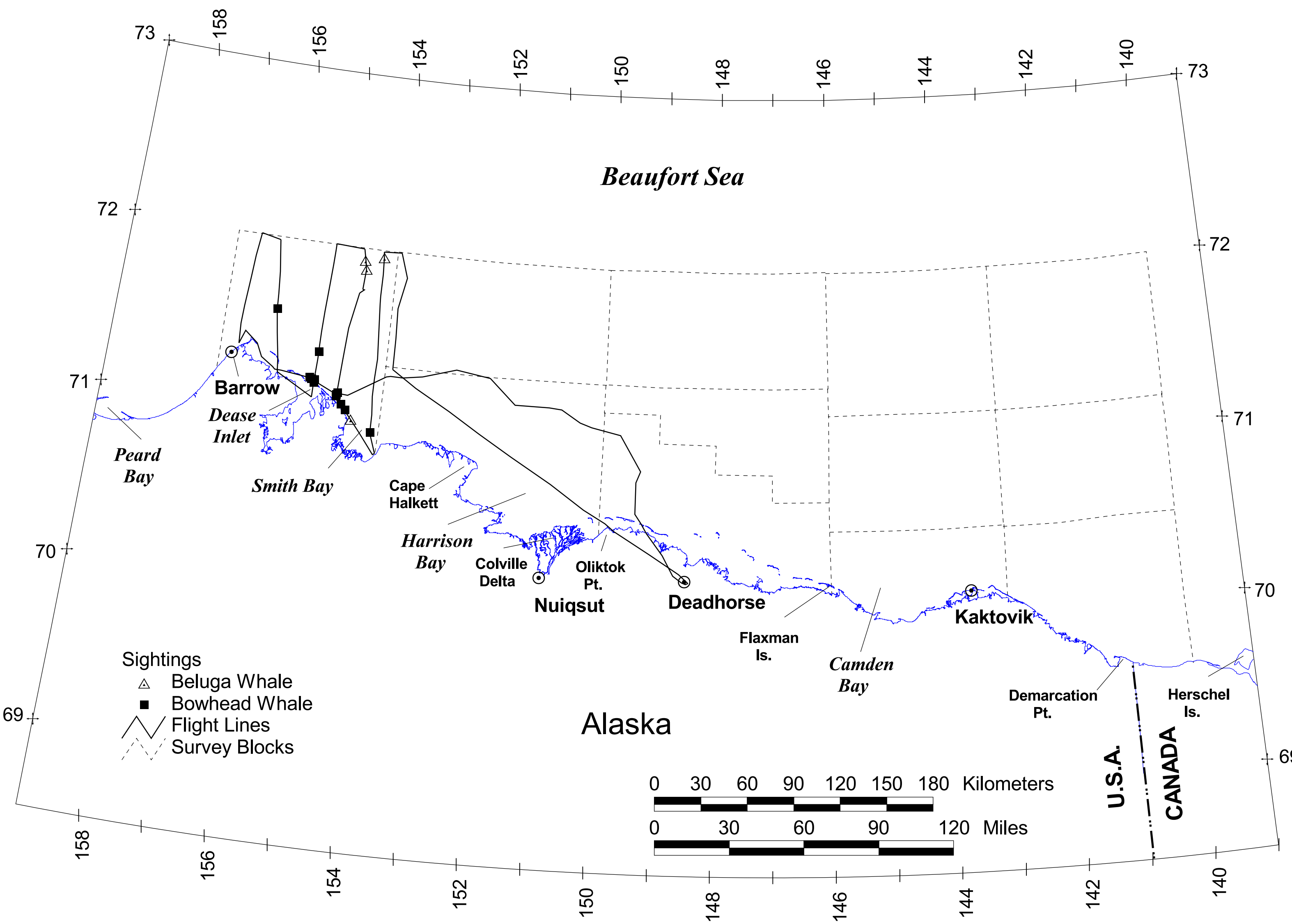
Flight 4: 6 September 2000 Survey Track and Sightings



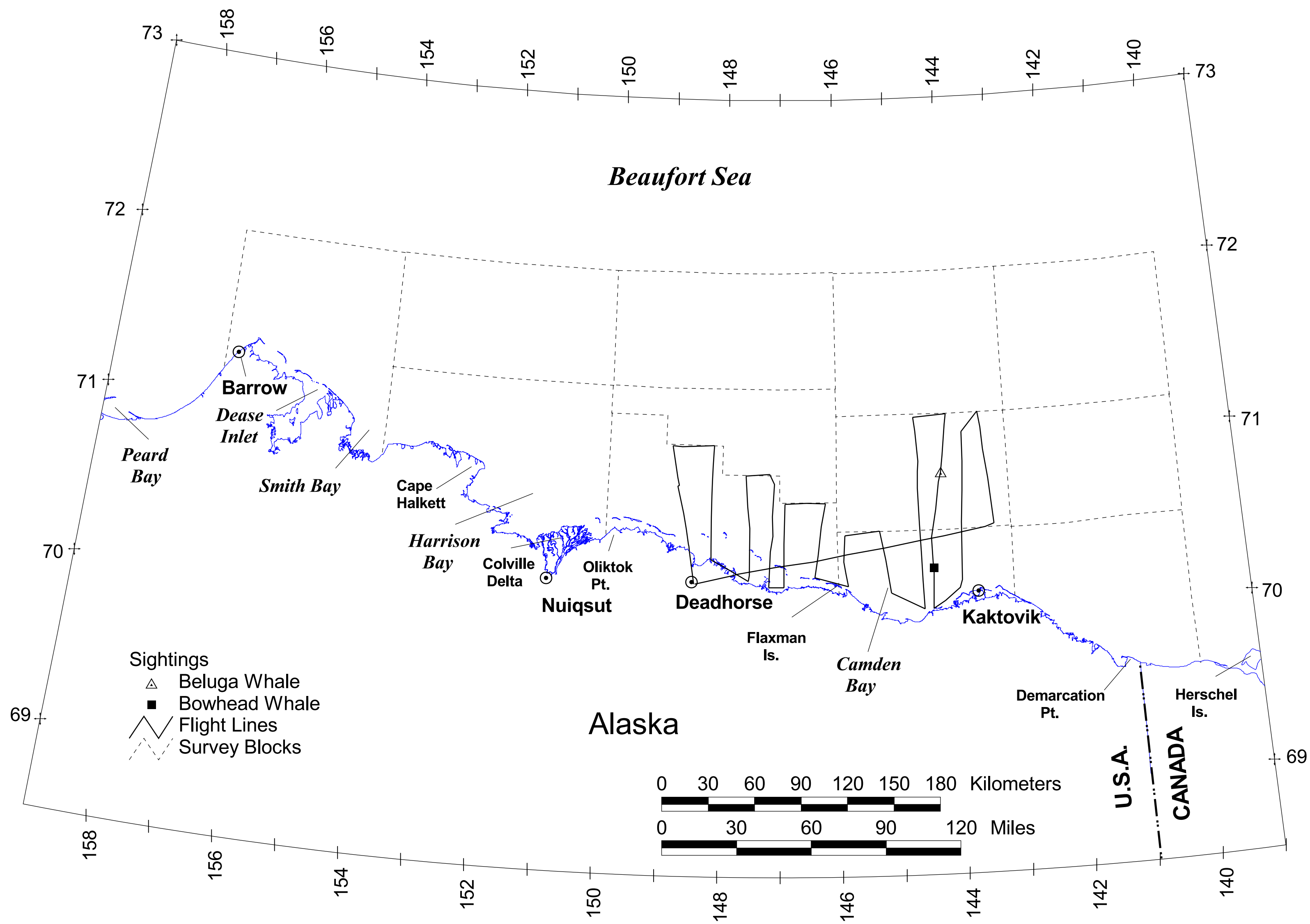
Flight 5: 7 September 2000 Survey Track and Sightings



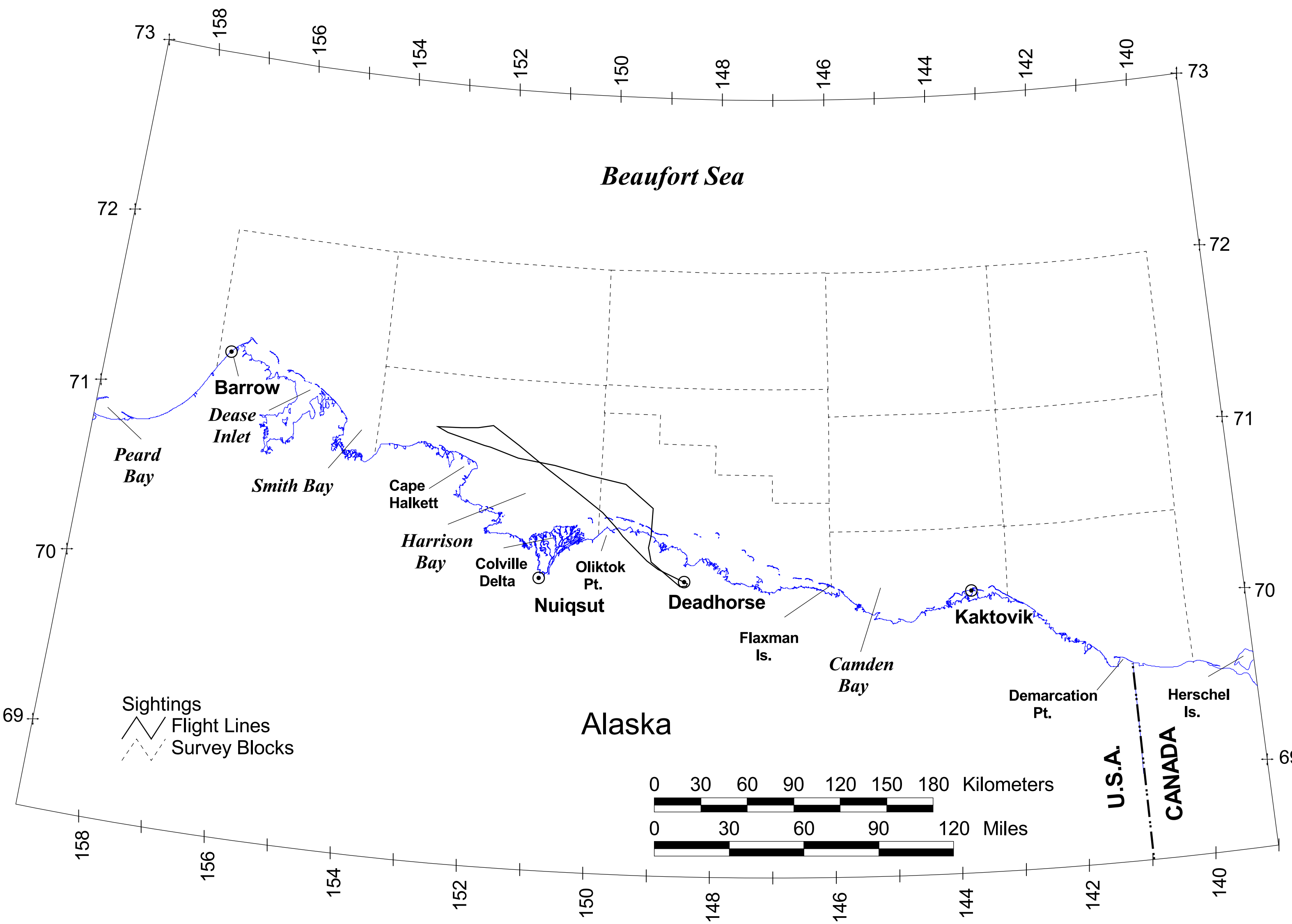
Flight 6: 9 September 2000 Survey Track and Sightings



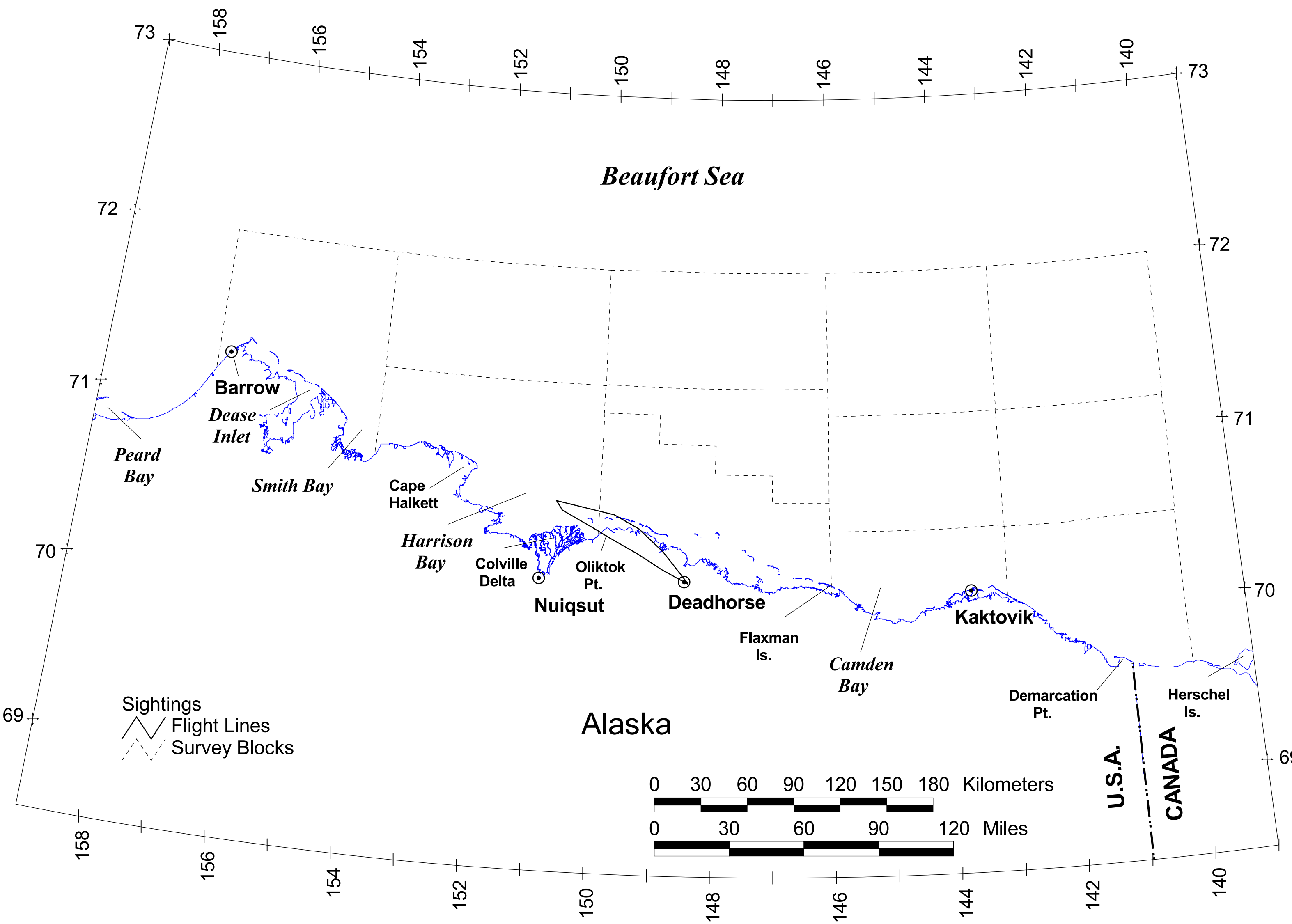
Flight 7: 12 September 2000 Survey Track and Sightings



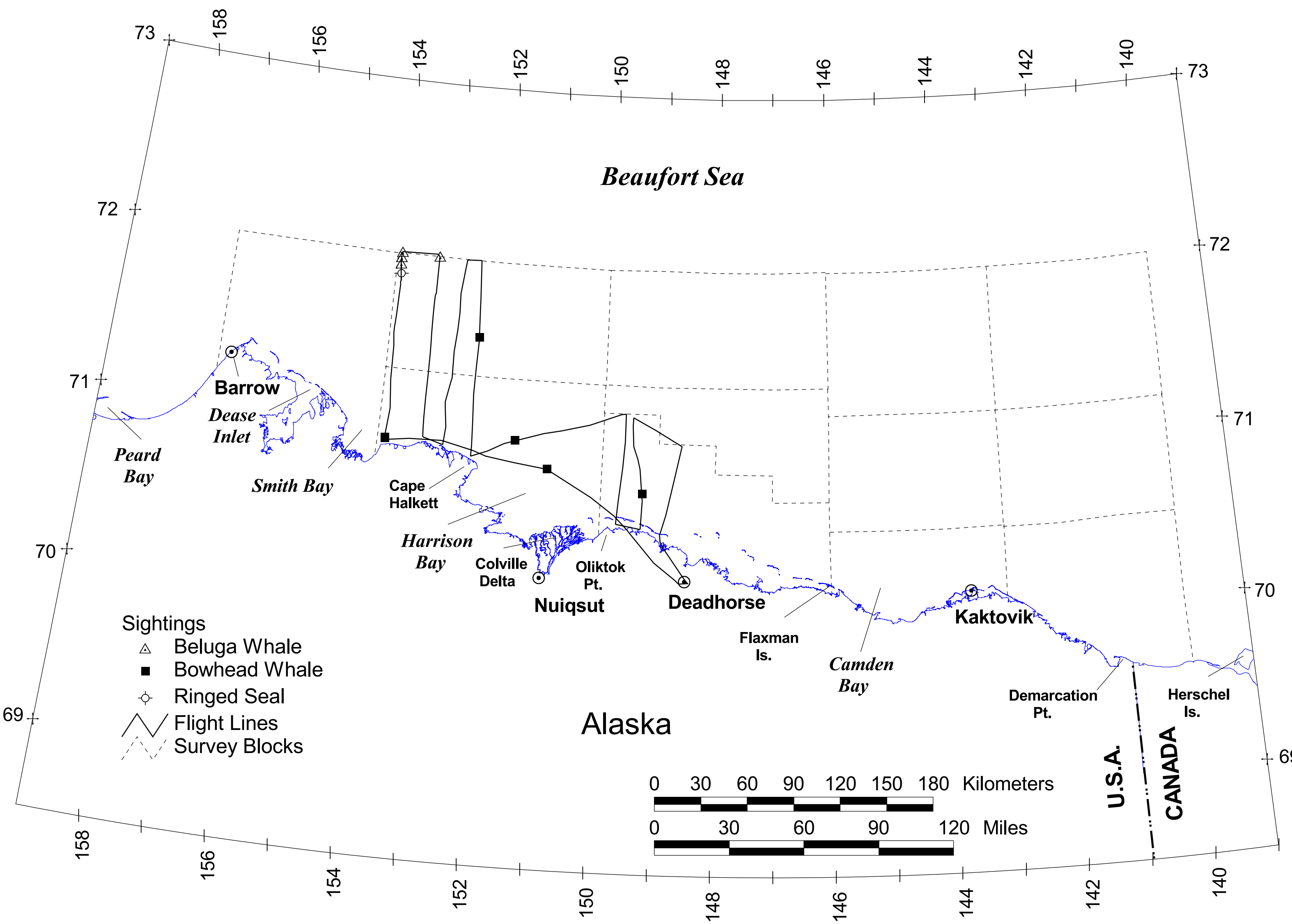
Flight 8: 13 September 2000 Survey Track and Sightings



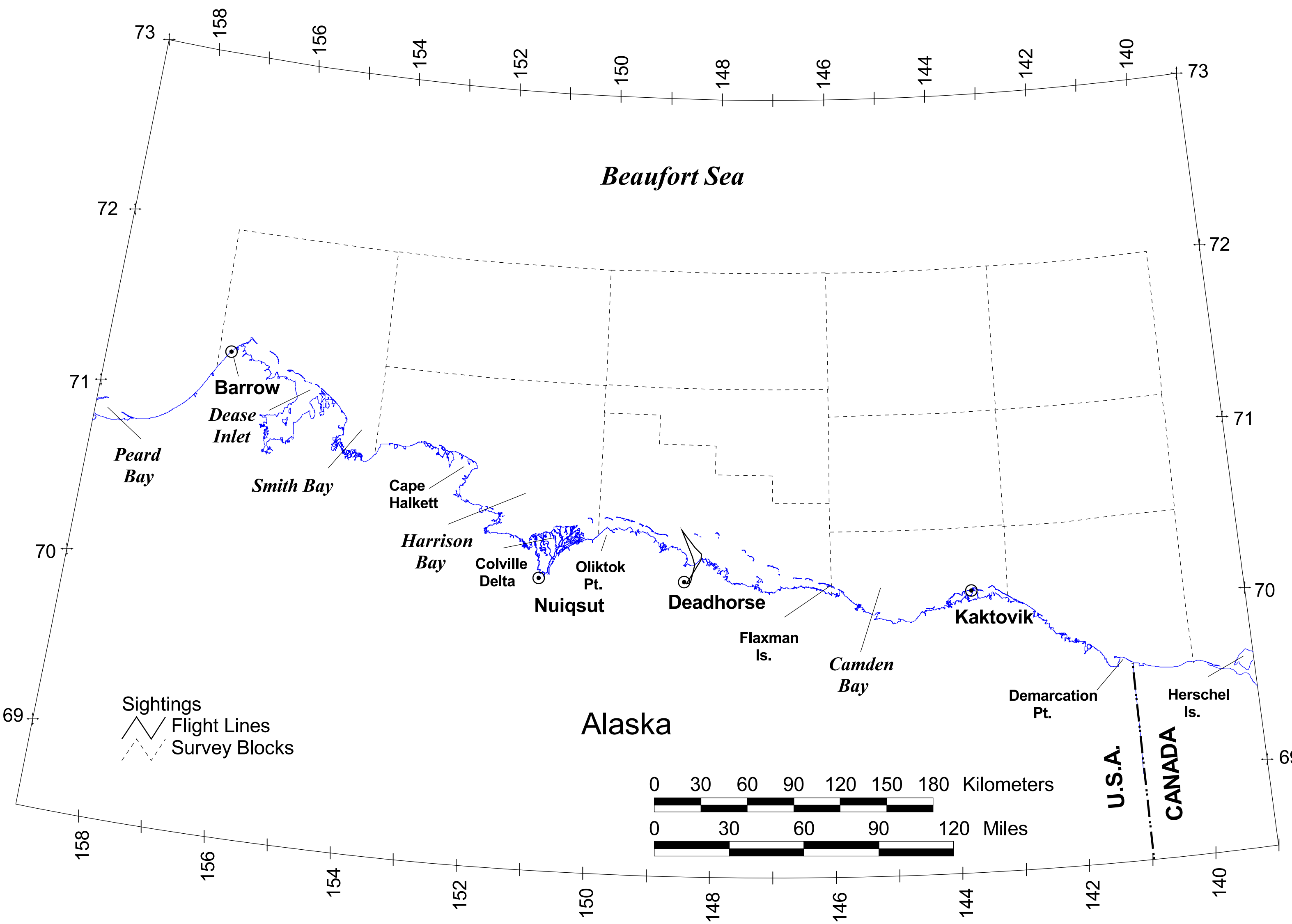
Flight 9: 14 September 2000 Survey Track and Sightings



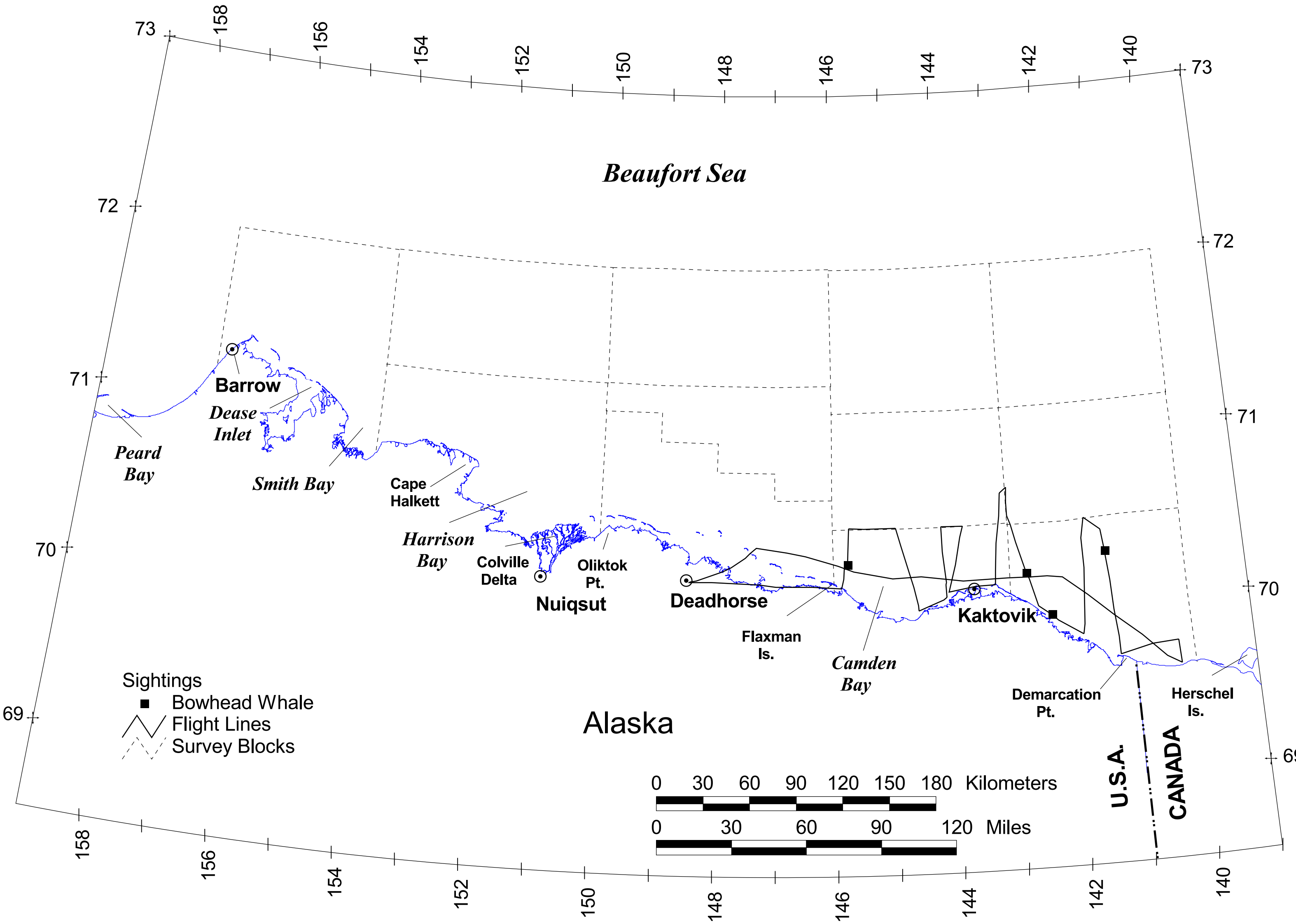
Flight 10: 15 September 2000 Survey Track and Sightings



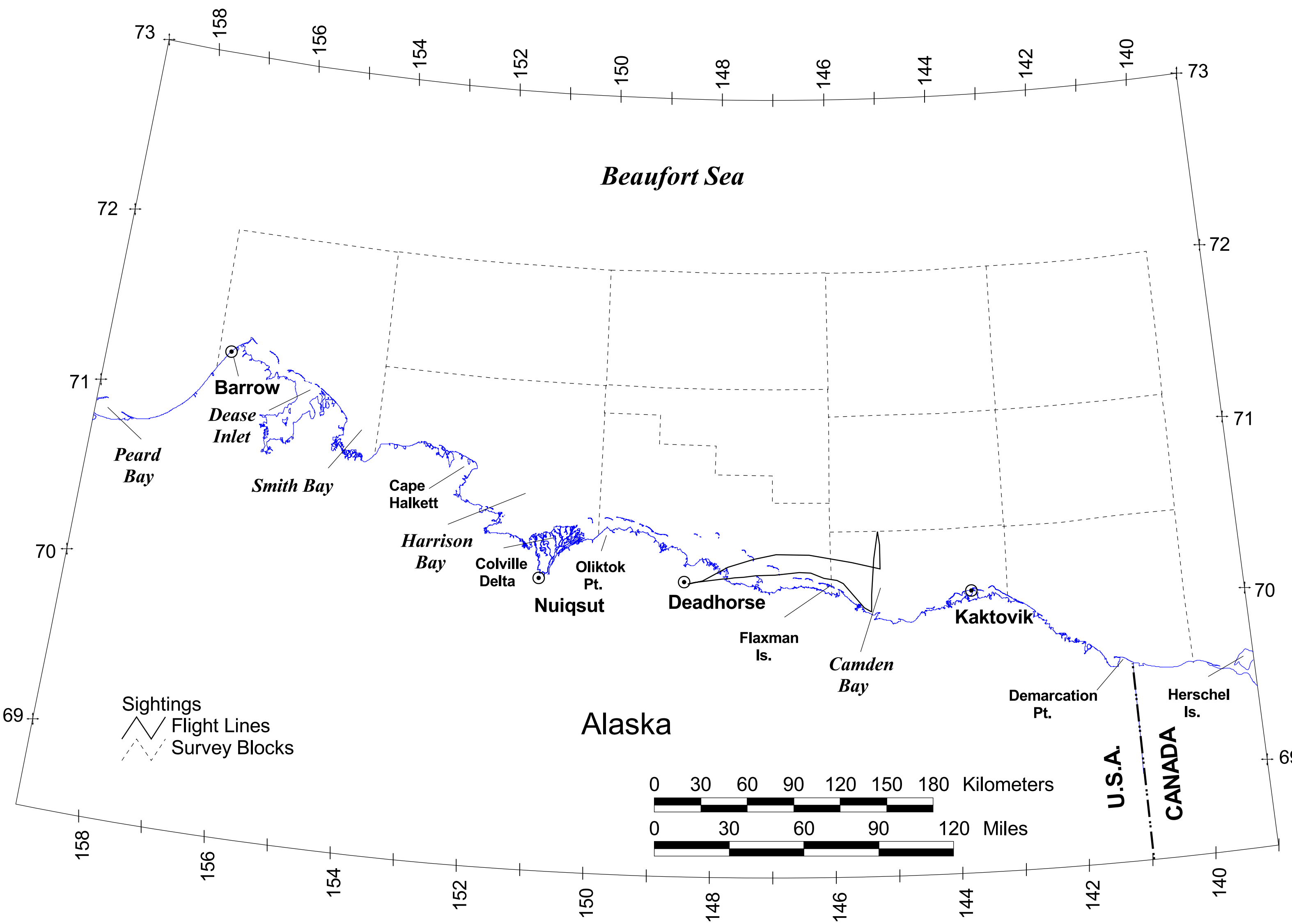
Flight 11: 15 September 2000 Survey Track and Sightings



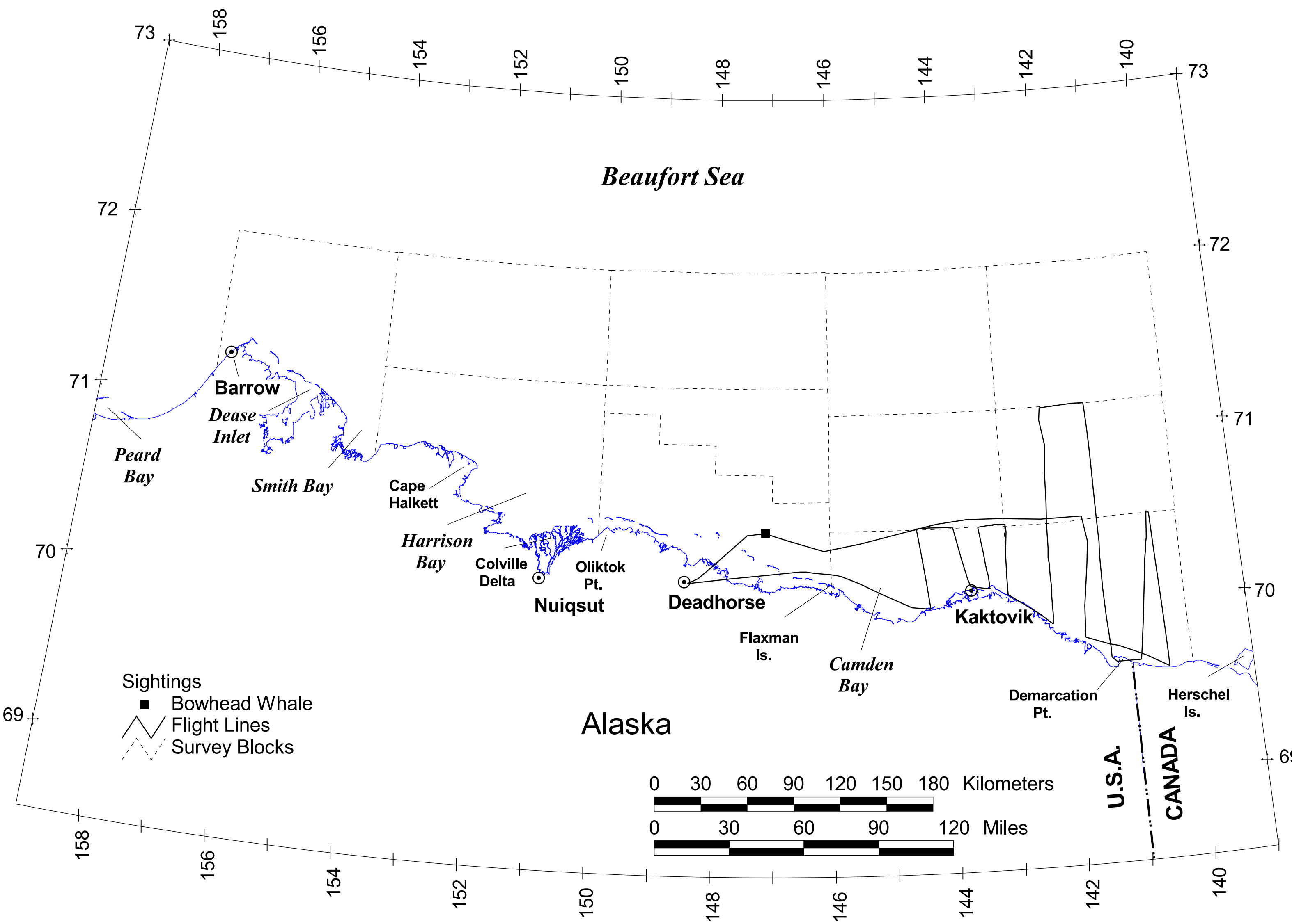
Flight 12: 16 September 2000 Survey Track and Sightings



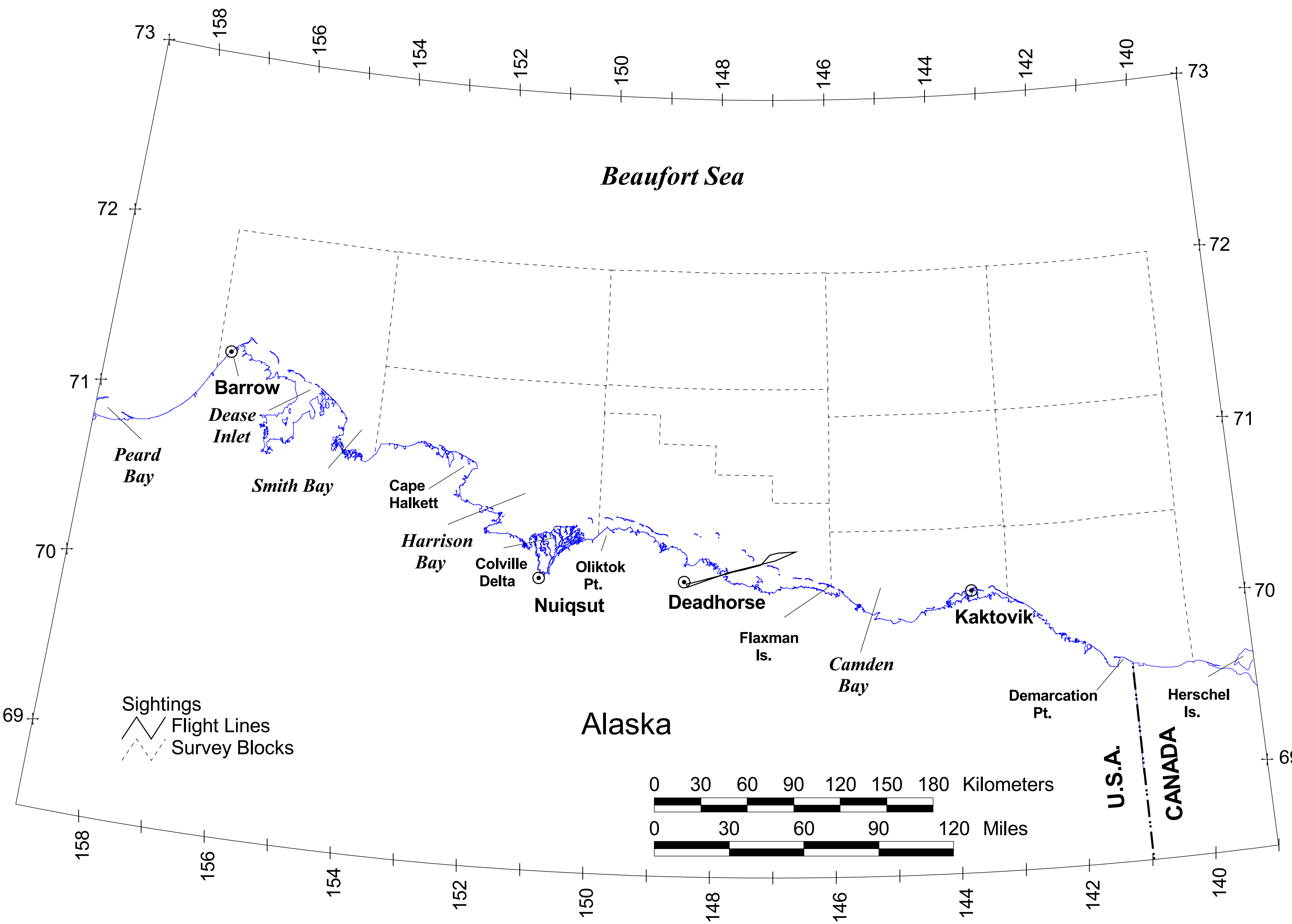
Flight 13: 17 September 2000 Survey Track and Sightings



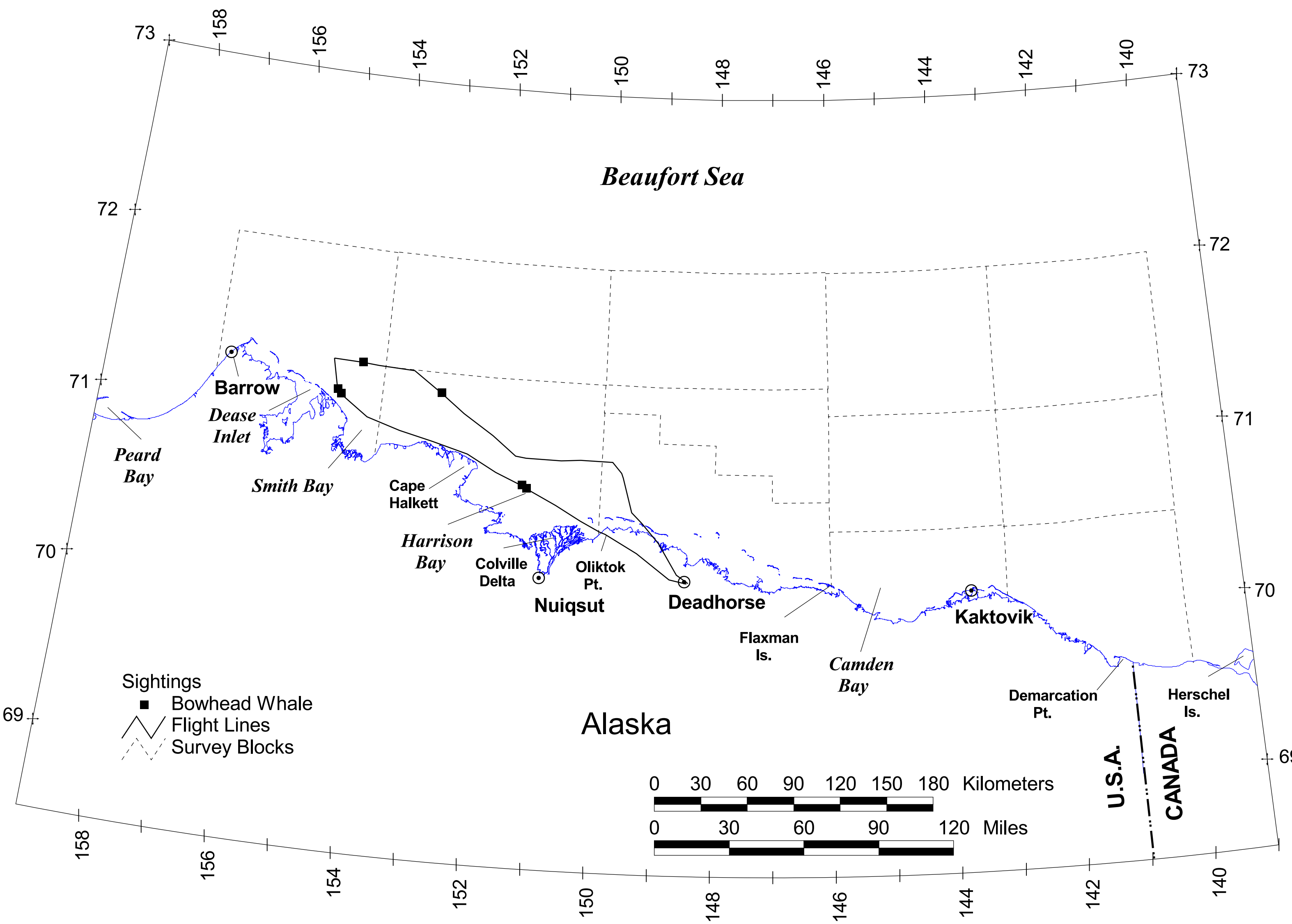
Flight 14: 18 September 2000 Survey Track and Sightings



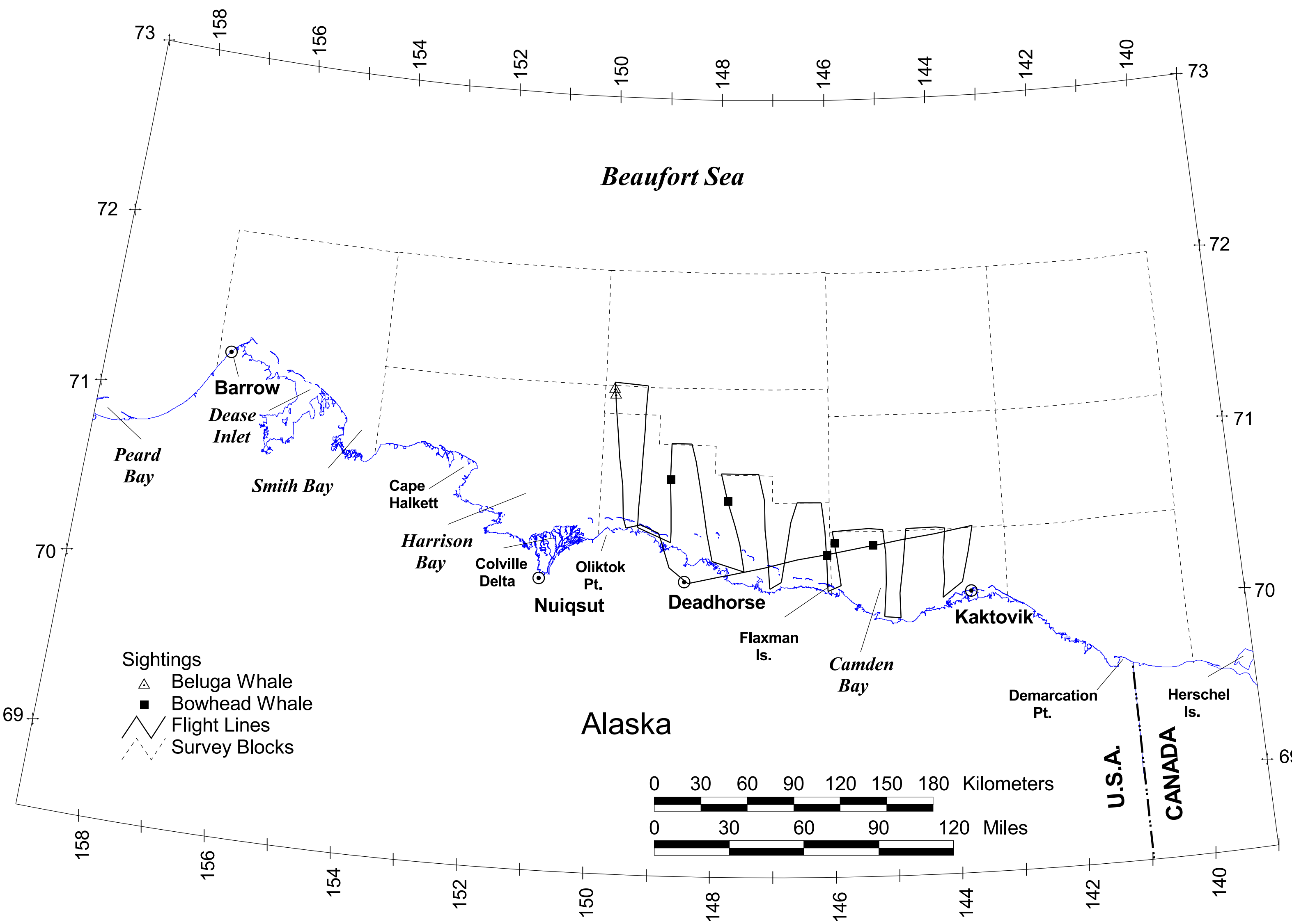
Flight 15: 20 September 2000 Survey Track and Sightings



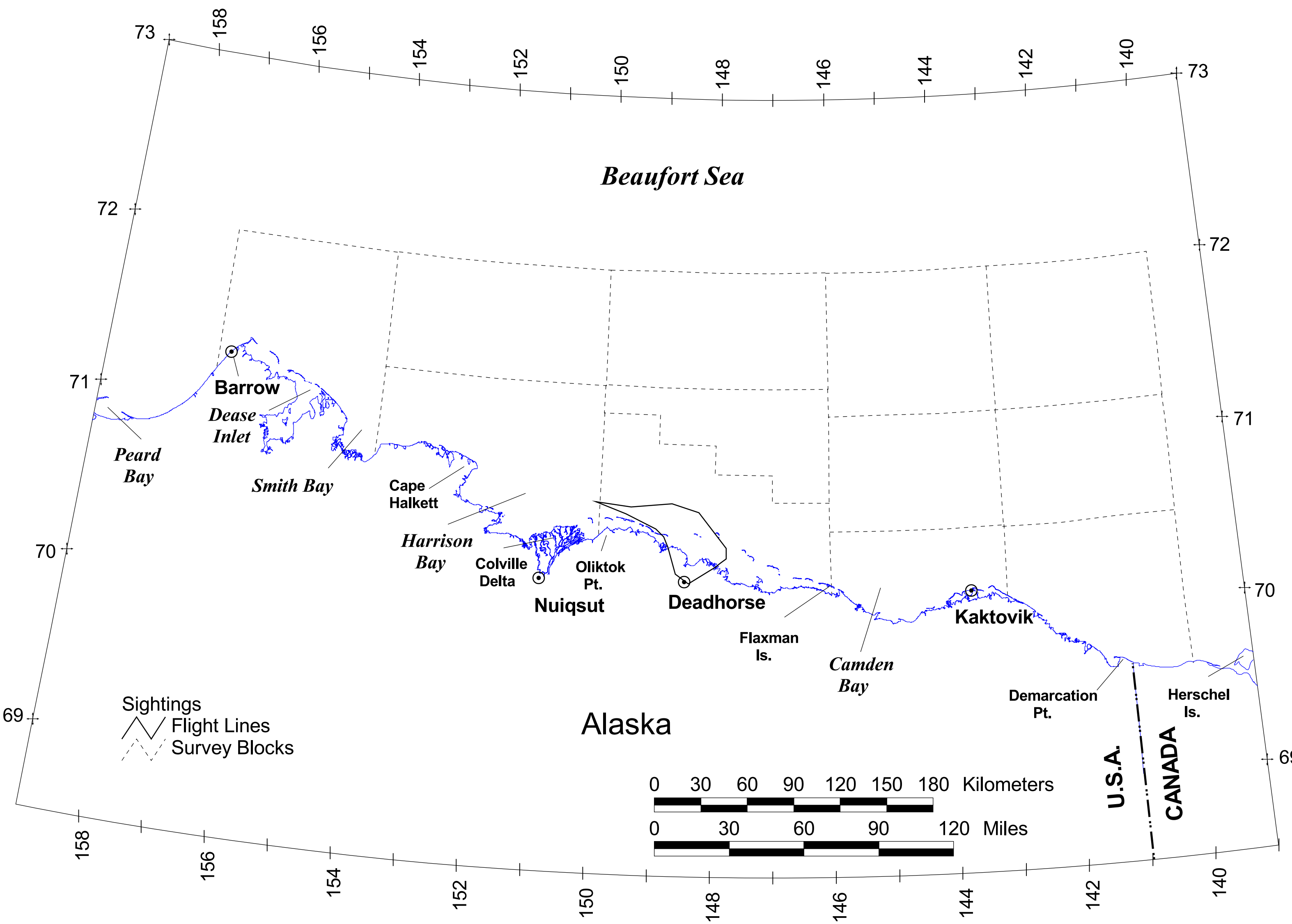
Flight 16: 21 September 2000 Survey Track and Sightings



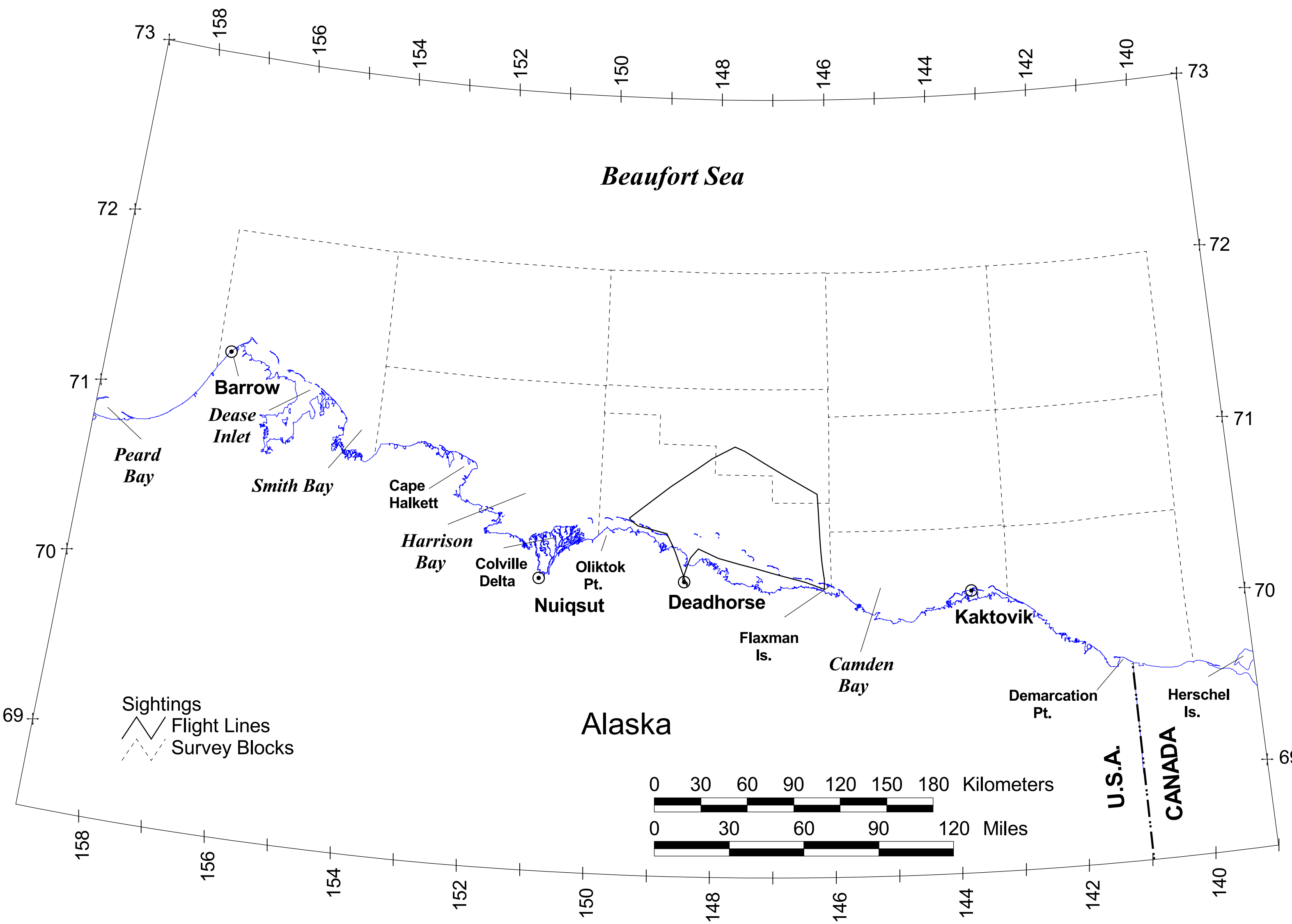
Flight 17: 23 September 2000 Survey Track and Sightings



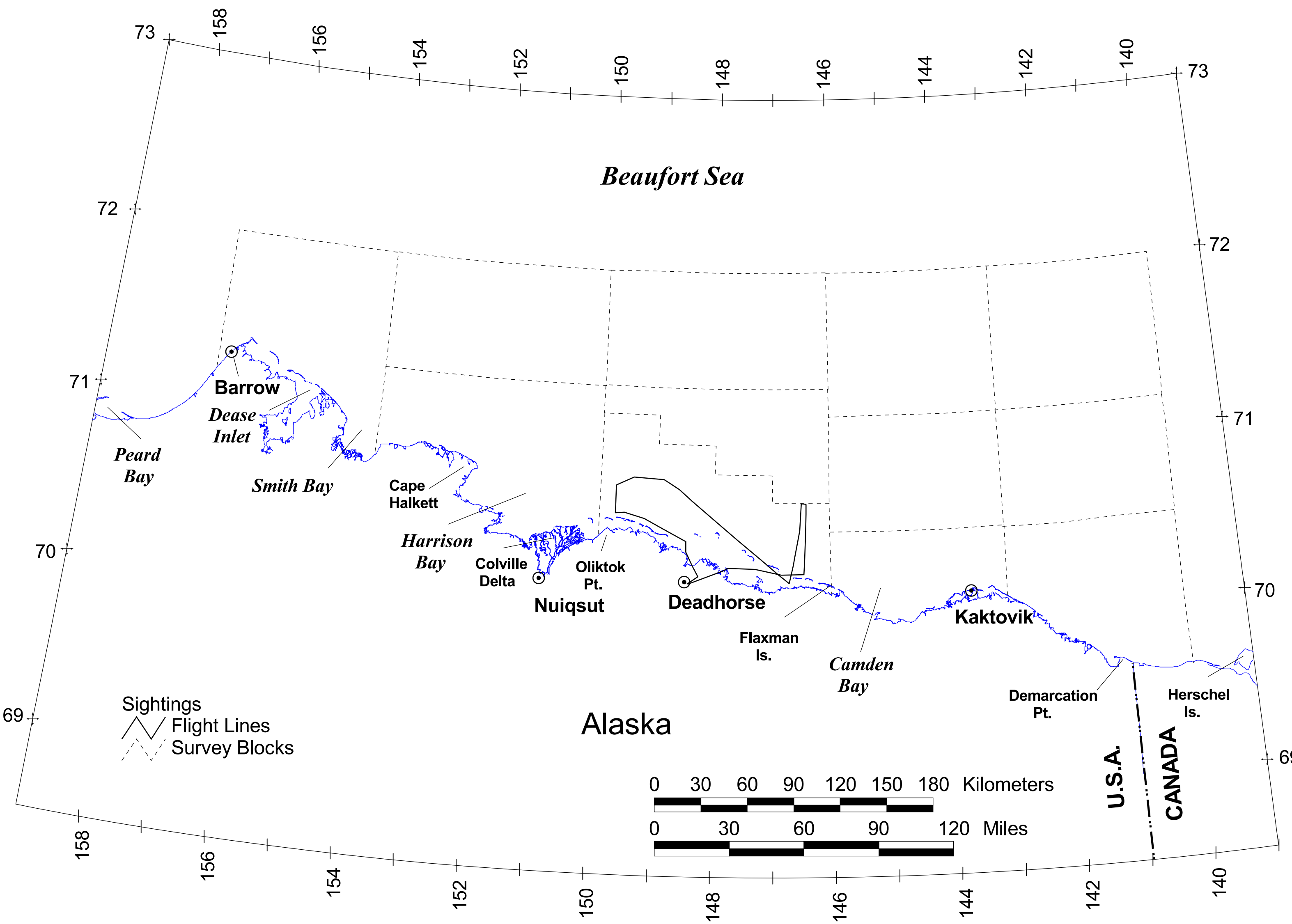
Flight 18: 25 September 2000 Survey Track and Sightings



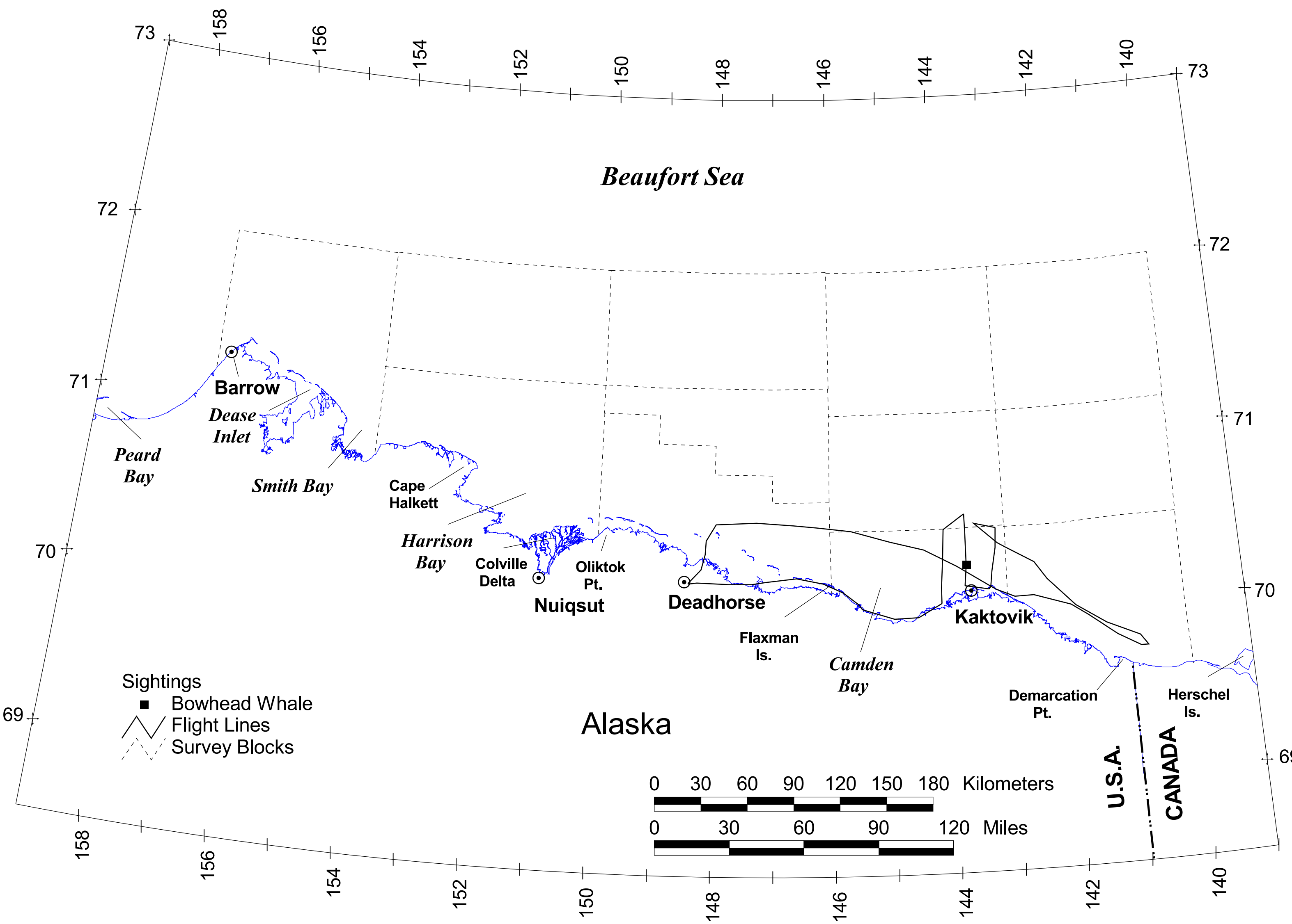
Flight 19: 28 September 2000 Survey Track and Sightings



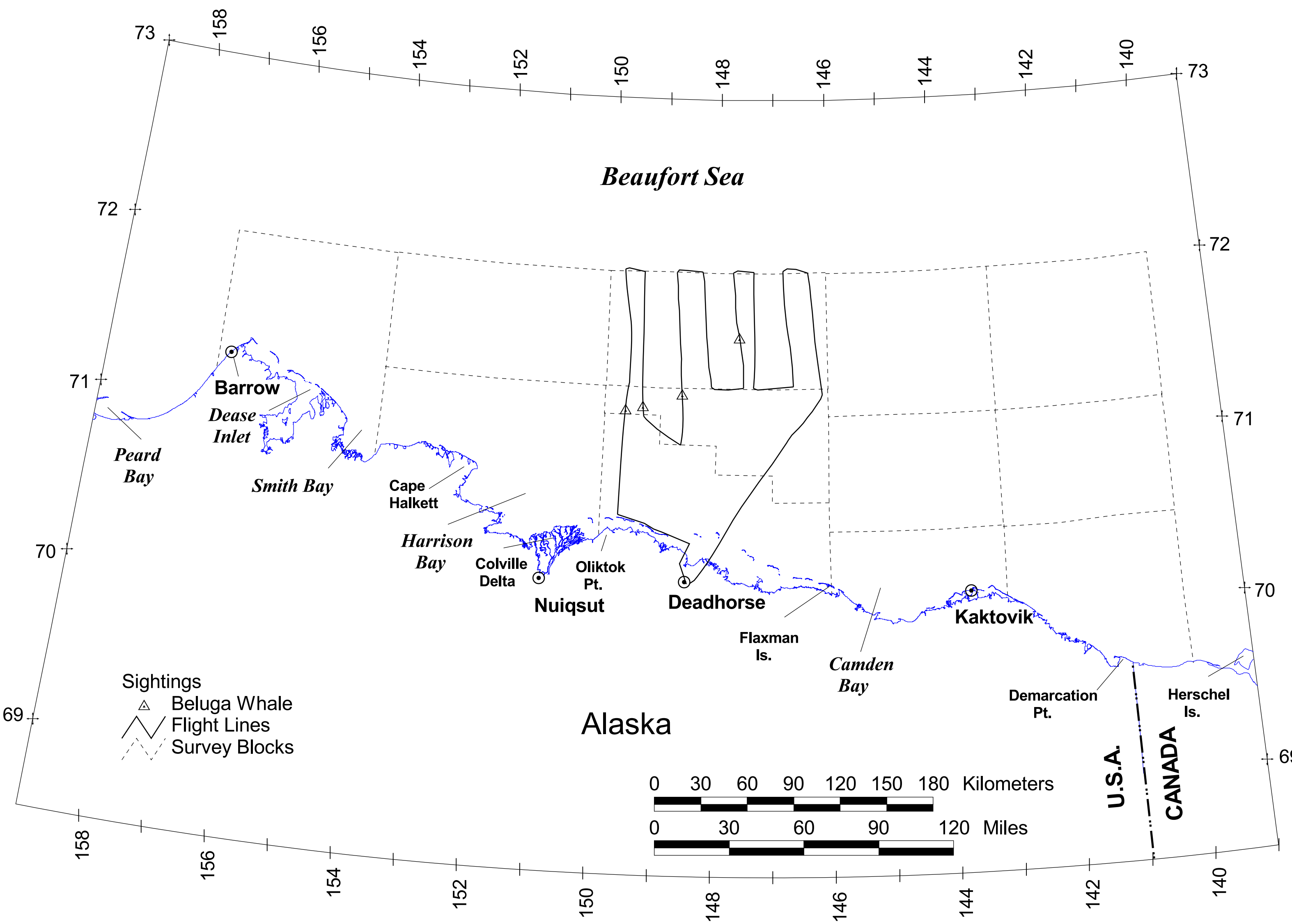
Flight 20: 29 September 2000 Survey Track and Sightings



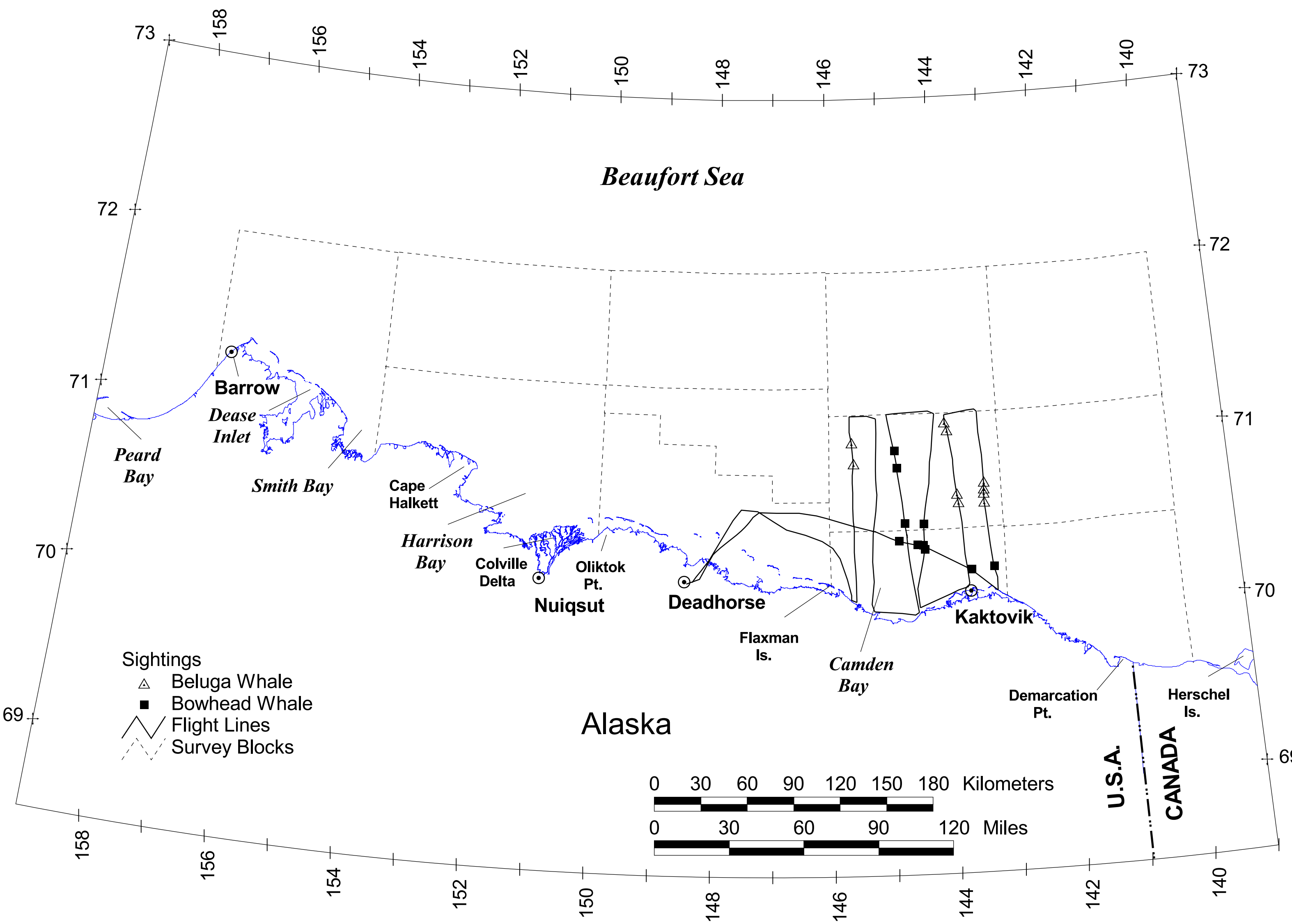
Flight 21: 2 October 2000 Survey Track and Sightings



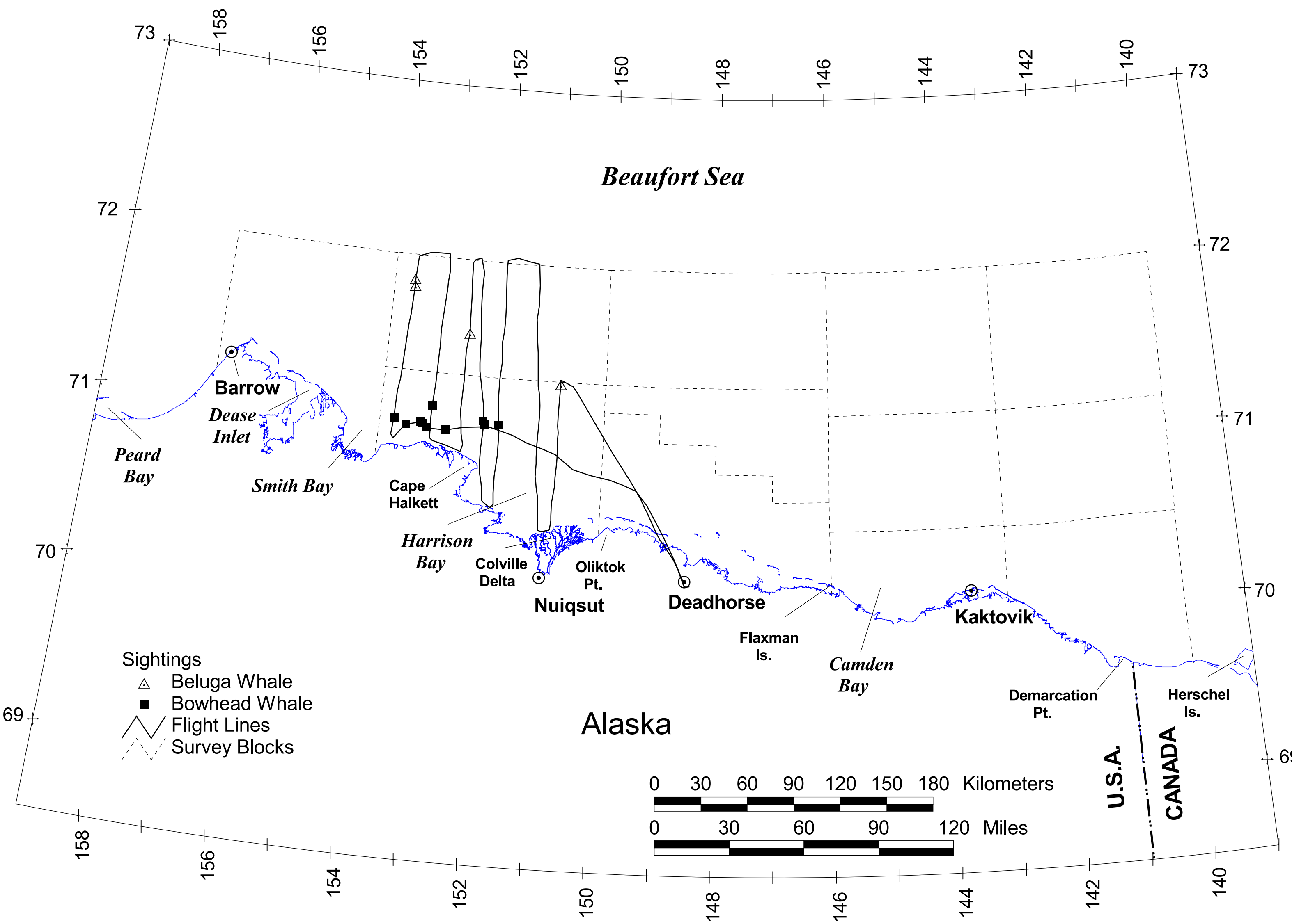
Flight 22: 5 October 2000 Survey Track and Sightings



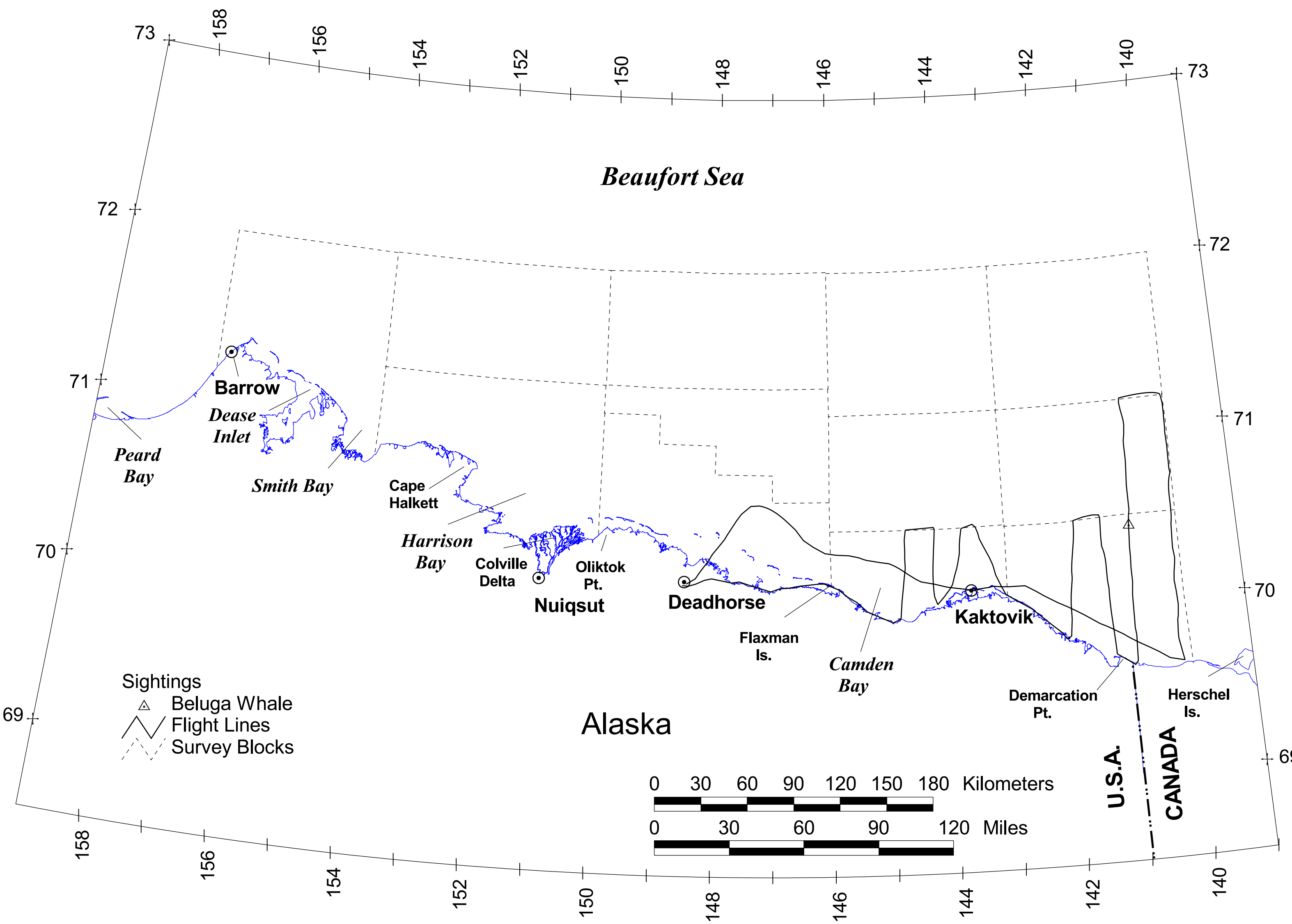
Flight 23: 9 October 2000 Survey Track and Sightings



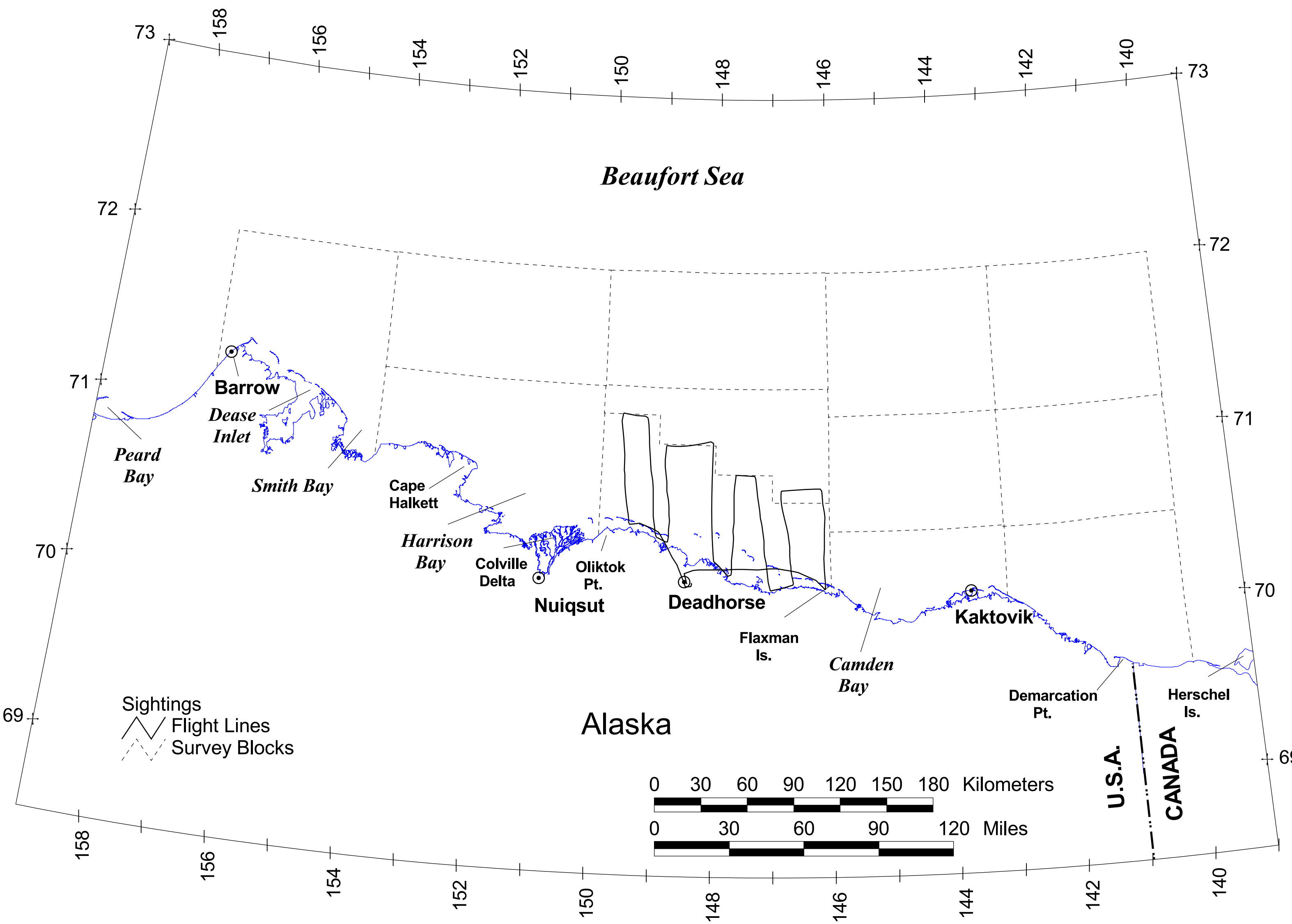
Flight 24: 10 October 2000 Survey Track and Sightings



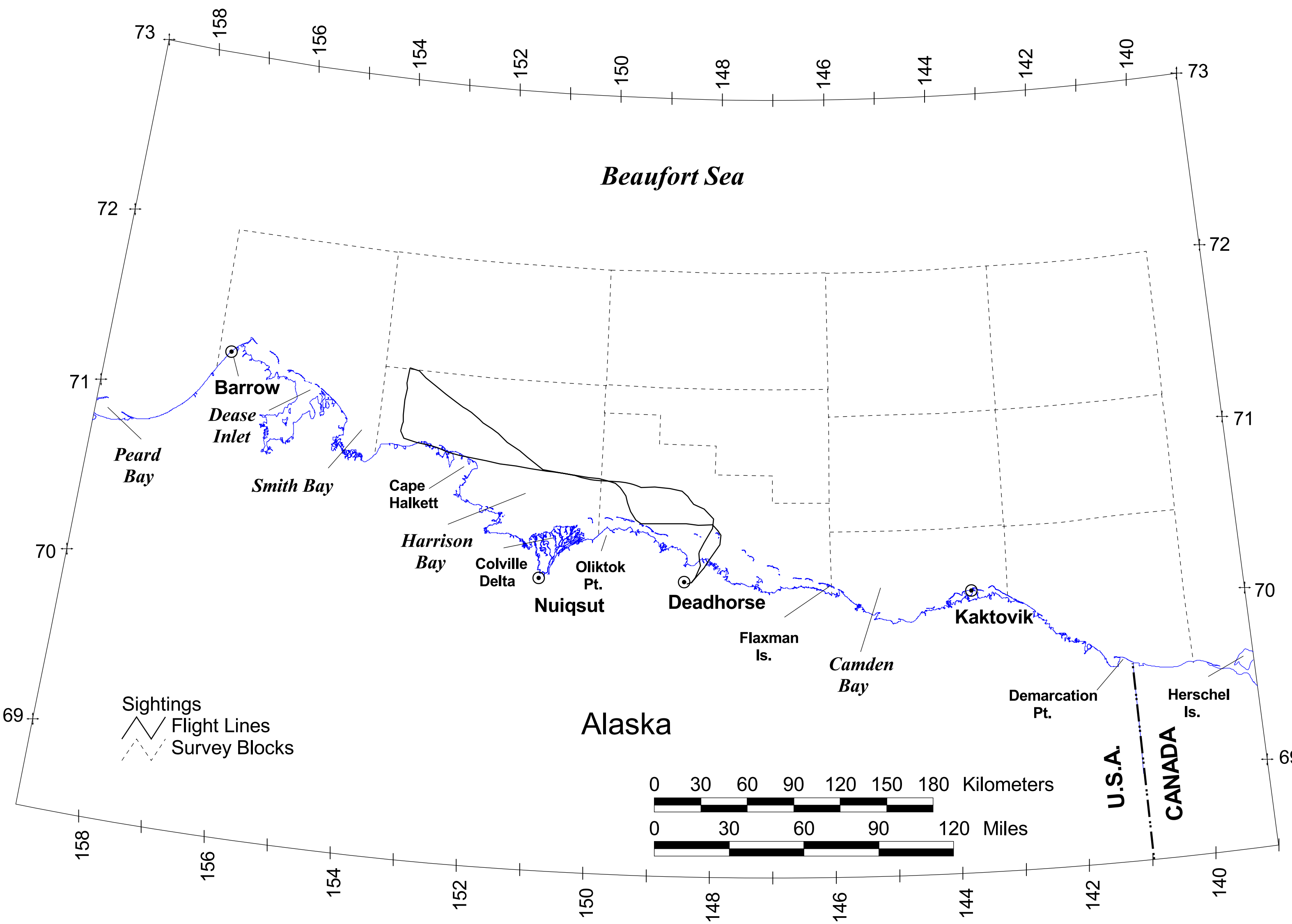
Flight 25: 11 October 2000 Survey Track and Sightings



Flight 26: 12 October 2000 Survey Track and Sightings



Flight 27: 13 October 2000 Survey Track and Sightings



Flight 28: 17 October 2000 Survey Track and Sightings

APPENDIX D

GLOSSARY OF ABBREVIATIONS, ACRONYMS, AND INITIALISMS

GLOSSARY OF ABBREVIATIONS, ACRONYMS, AND INITIALISMS

AEWC	Alaska Eskimo Whaling Commission
ANOVA	analysis of variance
BLM	Bureau of Land Management
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
HSD	“honestly significant difference” (Tukey statistical test)
i.e.	that is
k	number of samples
km	kilometer
m	meter
MMS	Minerals Management Service
n	sample size
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
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; relative abundance

The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Royalty Management Program** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.