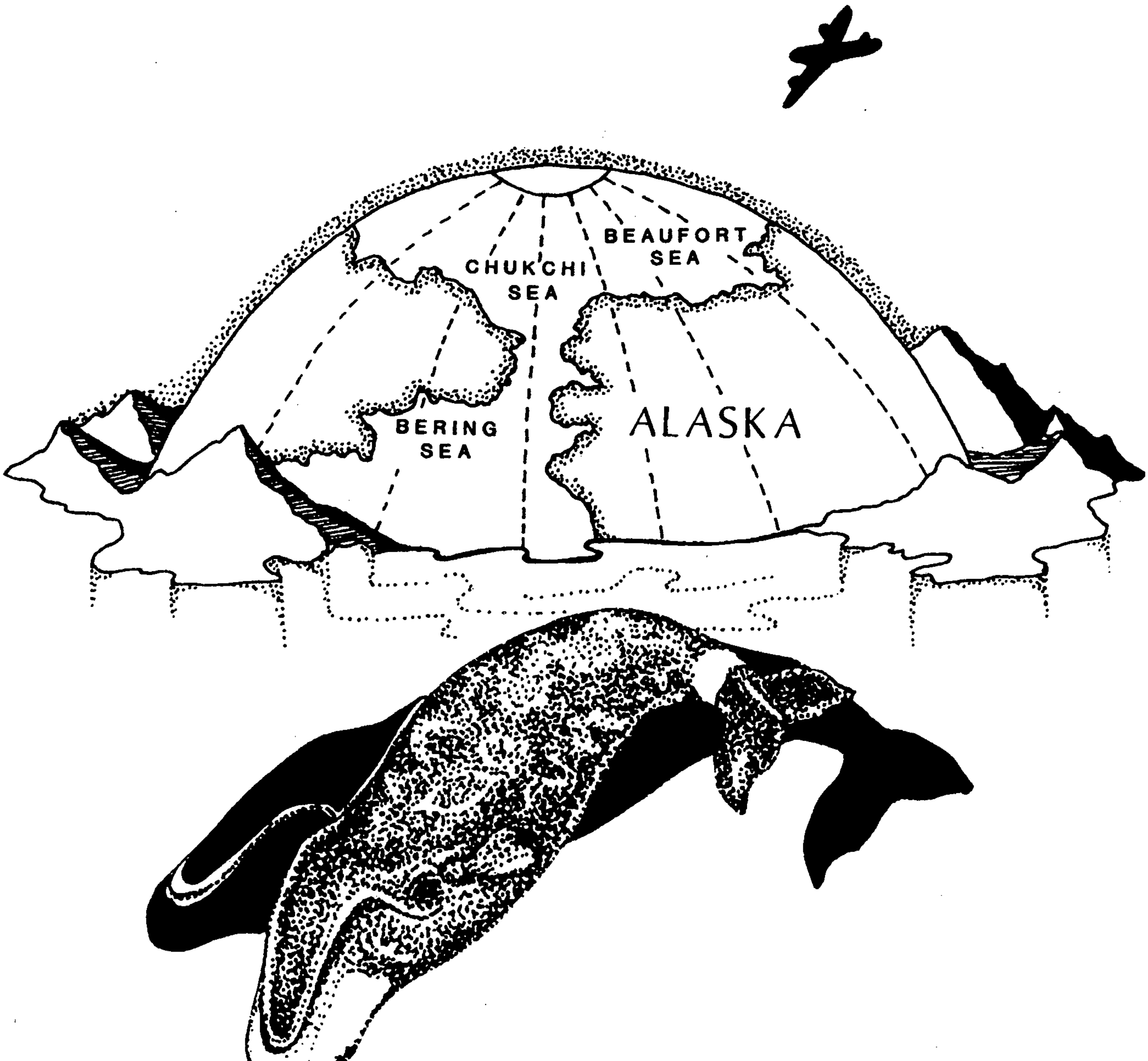
Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 1996

OCS Study
MMS 97-0016



MMS
U.S. Department of the Interior
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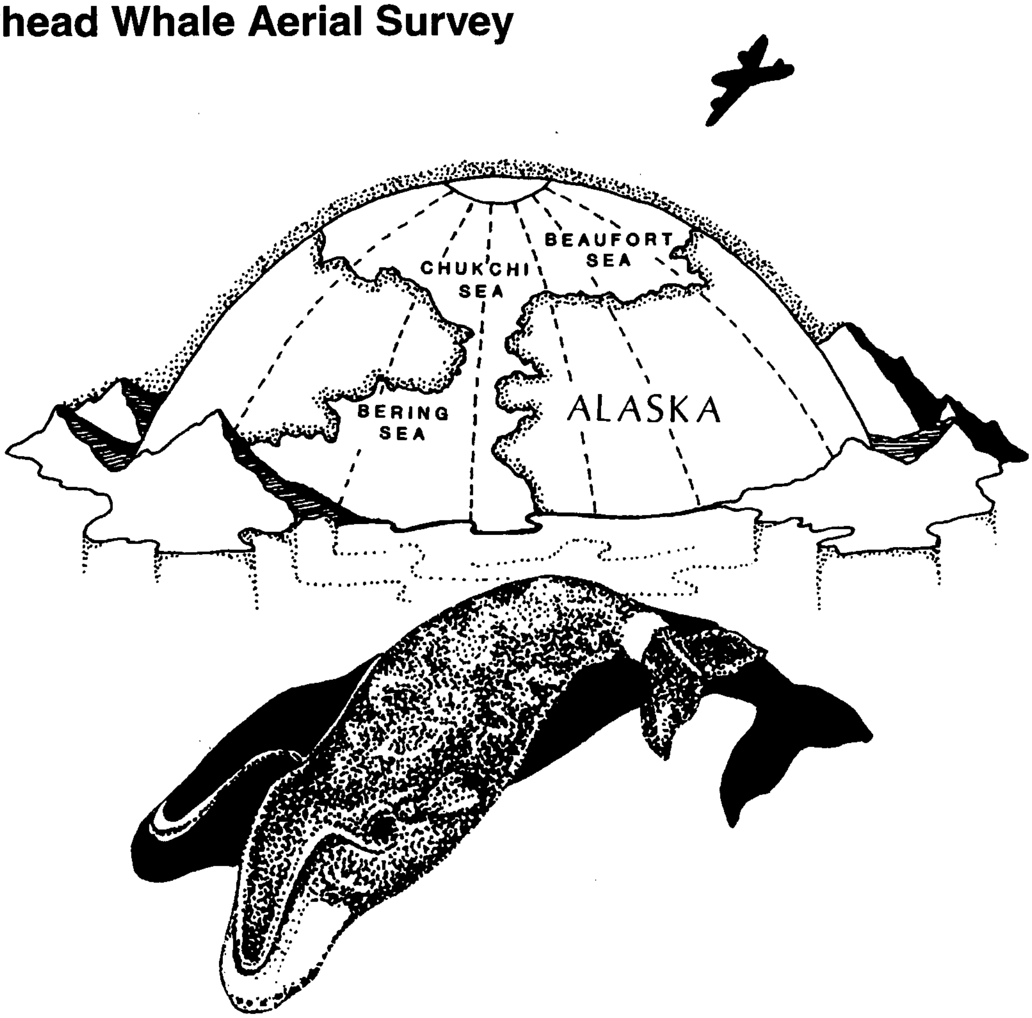
By Stephen D. Treacy, Research Manager
MMS Bowhead Whale Aerial Survey



U.S. Department of the Interior
Minerals Management Service
Alaska OCS Region

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ABSTRACT

This report describes field activities and data analyses for aerial surveys of bowhead whales conducted between 1 September 1996 and 10 October 1996 in the Beaufort Sea, primarily between 140°W. and 157°W. longitudes south of 72°N. latitude. General ice cover during September and October 1996 was relatively light, although after mid-September higher sea-ice concentrations often prevailed in areas where whales were observed. The number of sightings of bowhead whales (n = 69) and the number of bowhead whales counted (n = 114) during Fall 1996 were somewhat limited by local ice concentrations. The bowhead whales, 617 belukha whales, 6 unidentified cetaceans, 3 bearded seals, 137 ringed seals, 10 polar bears, and 90 sets of polar bear tracks were observed in 1996 during 123.00 hours of survey effort that included 59.53 hours on randomized transects. The initial sighting of bowhead whales in Alaskan waters occurred on 2 September. Of all bowhead whales observed, half (median) had been counted by 20 September. The peak count (mode) of 34 whales occurred on 26 September. The last sighting of a bowhead whale in the primary study area occurred in 80-percent ice in Block 11 on 5 October. Estimated median and mean ($\bar{x}$) water depths at the location of bowhead whales sighted on randomized line transects during September and October 1996, 35.0 meters and 35.3 meters, respectively, are consistent with a previously noted trend for whales to be located in shallower water during years of light ice cover.

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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 the National Marine Fisheries Service (NMFS). The purpose of the consultation was to determine the likely effects of the proposed Beaufort Sea Oil and Gas Lease Sale on endangered bowhead (*Balaena mysticetus*) and gray (*Eschrichtius robustus*) whales. After reviewing available information on the two species, 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 Arctic Region sales—including a regional biological opinion; a revised opinion relative to the joint Federal/State lease area; and opinions on Sales 71 (issued in 1982), 87 (issued in 1983), 97 (issued in 1987), and Arctic Region sales (issued in 1988)—recommended continuing studies of whale distribution and OCS-industry effects on bowhead whales (USDOC, NOAA, NMFS, 1982, 1983, 1987, 1988). The Arctic Region Biological Opinion was used by NMFS for subsequent sales in the Beaufort Sea (Sale 124 in 1991 and Sale 144 in 1996). These opinions also requested monitoring of bowhead whale presence during periods when geophysical exploration and drilling are occurring.

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). Three subsequent lease sales in the Beaufort Sea, Sale 97 (1988), Sale 124 (1991), and Sale 144 (1996), have not included a seasonal drilling restriction. The NOS for each of these sales contains 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). The information gathered will provide additional assistance to 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 (NOSC) 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 field work 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 present 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. Provide annual analyses of long-term interyear trends in the median depth (or north-south positioning) of the migration axis of bowhead whales;

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

5. Monitor behaviors, swim directions, dive times, surfacing patterns, and tracklines of selected bowhead whales;

6. Record and map belukha whale distribution and incidental sightings of other marine mammals; and

7. 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 is based on a design of random field transects within established geographic blocks in and adjacent to Chukchi and Beaufort Sea sale areas offshore of Alaska. The present study, which was focused on the bowhead whale migration from 1 September 1996 to 9 October 1996, 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).

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: N302EH). The aircraft was equipped with medium-size bubble windows aft that afforded complete trackline viewing for a port observer and a starboard data recorder-observer. A third observer-navigator occupied the copilot seat, which provided good forward and side viewing. 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

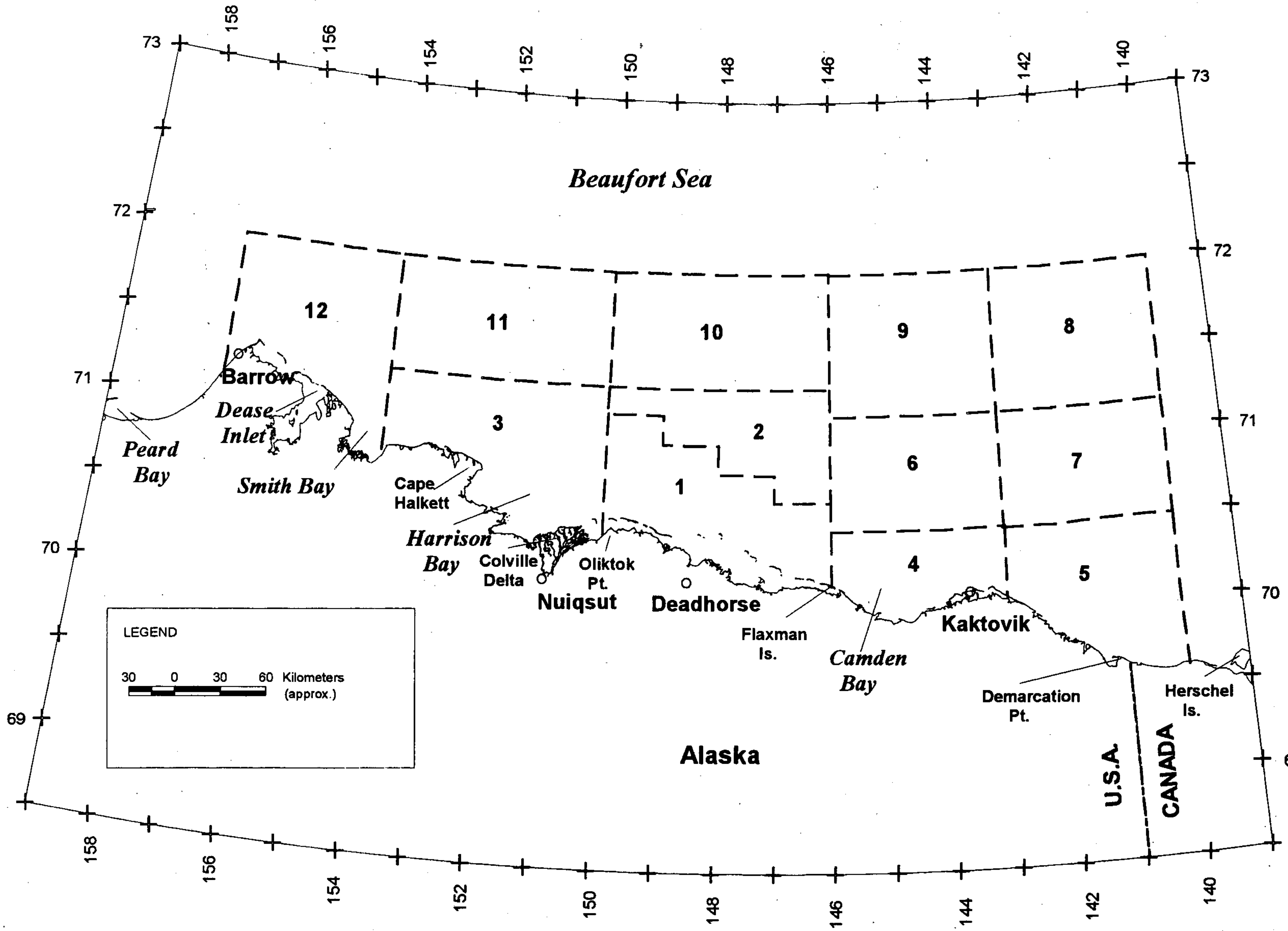

Figure 1. Fall 1996 Study Area Showing Survey Blocks

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.

Avionics included a Flight Management System (FMS) by ARNAV Systems, Inc., part of which was a Global Positioning System (GPS). The FMS 5000, Model GPS-505, is a worldwide satellite-based system that provides continuous position updating (15-m precision) and survey navigation through preprogramming of transect start and end points. Electronic signals from the GPS were converted into an RS 232 serial stream; and data were polled every second for automatic input of time, latitude, longitude, and flight altitude. The GPS altitude (27-m precision) that was used exceeded the accuracy of the radar altimeter (32 m at the target altitude of 458 m). In the event of a system failure, the team leader could read directly from the aircraft instrument panel for manual entry of this information into the computer. System components required 115-volt alternating current (AC) power, which was supplied by a direct current-AC invertor connected to the aircraft electrical bus.

A portable AST Premium Exec 386SX/20 computing system was used aboard the aircraft to store and analyze flight and observational data. A small, portable Kodak Diconix 150 Plus inkjet printer was used to produce tractor-fed hard copy and to plot onboard flight maps.

Onboard safety equipment included an impact-triggered emergency locator transmitter (ELT) installed in the aircraft, a portable ELT in a 6-person Switlik Search and Rescue Life Raft, a portable aircraft-band transceiver, a portable GPS, cold-water immersion suits, Nomex flight suits, and emergency crash helmets.

Flight-following equipment used during the 1996 field season featured an experimental Radio Determination Satellite System (RDSS), developed by Mobile Datacom Corporation (MDC), that tracked the project aircraft over the Alaskan Beaufort Sea. The project tested the use of three toggled patch antennas, two of which were mounted externally on the aft section of the fuselage and one which was installed in the nose of the aircraft for greater radial coverage. Data on latitude, longitude, time, and other parameters were obtained from the aircraft's GPS and broadcast every minute through the patch antennas to a satellite that was stationary over the equator at 87°W. longitude. Real-time satellite signals were relayed to MDC in Clarksburg, Maryland, where OAS queried the RDSS every 15 minutes to obtain current flight-following information. The information was displayed as digital data on a computer screen and in the form of a map for visual tracking of the survey aircraft. When west of the satellite coverage area, an aircraft-band very-high-frequency radio was used to transmit periodic position data to Barrow Flight Service. During Fall 1996, a 3-way antenna system for tracking the survey aircraft—regardless of its heading—was tested for the first time in Alaska. In addition to RDSS 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 9 October 1996. The field schedule was designed to monitor the progress of the Fall 1996 bowhead migration across the Alaskan Beaufort Sea. All bowhead (and belukha) whales observed were recorded, along with incidental sightings of other marine mammals. Particular emphasis was placed on regional surveys to assess fine-scale shifts in the migration pathway of bowhead whales in this area 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 produced 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 to designate one end of a transect leg. The other endpoint of the transect leg was determined similarly using a separate randomly generated number along the southern edge of the same section. A straight line, representing one transect leg, was drawn between the two points. The same procedure was followed for all sections of the survey block. 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 later analyses of median water depths at bowhead sightings based on line-transect theory (Cochran, 1963) and analyses of absolute densities based on strip-transect theory (Estes and Gilbert, 1978).

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 also uses 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, 1996), 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.

Random-transect legs were used for obtaining data to analyze the migration axis, using a line-transect model, and to estimate whale density, using a strip-transect model. Nonrandom surveys were flown to further identify whales and their behaviors when sighted adjacent to a transect line or when in transit to a transect block.

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. This altitude was maintained—when weather permitted—in order to maximize visibility and minimize potential disturbance to marine mammals. Flights were normally aborted when cloud ceilings were consistently less than 305 m or sea states were 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."

E. Data Entry

A computer program developed by project personnel was used to record all data. Time of day was maintained by the computer and recorded at each entry. Greenwich Mean Time, local time, latitude, longitude, and altitude as well as a question list and the main menu selections were shown continuously on the computer monitor. The program is menu-driven, facilitating entry of a complete data sequence for sightings of endangered whales. An abbreviated data-entry format was available whenever several whale pods (the use of the term pod includes sightings of any single animal or group of nearby animals whose respiration patterns appear to be synchronous) were sighted within a short period of time. To avoid lumping of sightings in areas where whales were extremely concentrated, an even shorter rapid-sighting update was used. A position-update format including data on weather, visibility, ice cover, and sea state was entered at turning points, when changes in environmental conditions were observed, and otherwise within 10-minute intervals. All entries were coded to reflect the type of survey being conducted. Table 1 shows the data-entry

Table 1
Data-Entry Sequence on the Portable Flight Computer

Sequence	Position Update	Large Whale Sightings	Polar Bear/ Belukha Whale Sightings	Other Species
1. Entry number	X	X	X	X
2. Time	X	X	X	X
3. Latitude	X	X	X	X
4. Longitude	X	X	X	X
5. Altitude	X	X	X	X
6. Reason for entry	X	X	X	X
7. Search type	X	X	X	X
8. Species		X	X	X
9. Sighting cue		X		
10. Habitat		X	X	X
11. Behavior		X	X	X
12. Size		X		
13. Total number		X	X	X
14. Calf number		X	X	X
15. Clinometer angle		X		
16. Side of plane		X		
17. Swim direction		X	X	
18. Swim speed		X		
19. Aircraft response		X	X	X
20. Repeat sighting		X		
21. Observer		X	X	
22. Weather	X	X	X	X
23. Visibility right	X	X	X	X
24. Visibility left	X	X	X	X
25. Ice coverage	X	X	X	X
26. Ice type	X	X	X	X
27. Sea state	X	X	X	X
28. Water color	X	X	X	X

sequence used in 1996 and the questions used to prompt entry of observational data. All data entered 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 14 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, and underwater blowing—are defined in Table 2. 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 and whale size were 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; and calf [length less than half of accompanying adult], immature, adult, or large adult, respectively) rather than on an absolute scale. Swim direction was recorded in the field as a magnetic value, using the aircraft's compass.

Sea state was recorded according to the Beaufort scale outline 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 within a few kilometers of the aircraft was estimated as a single percentage, regardless of ice type.

F. General Data Analyses

Preliminary data analysis was performed by a computer program—developed by project personnel—that provided daily summations of marine mammals observed, plus calculation of time and distance on transect legs, connect legs, and general search portions of the flight. The analysis program provided options for editing the data file, calculating summary values, and printing various flight synopses.

Application software (Grapher, Golden Software, Inc.) was used to plot daily maps of aircraft tracklines and positions of marine mammals observed. To function as a mapping package, coastlines were mapped using an Altec digitizer; and all points on the maps were based on number of meters north or to one side of a central meridian for Universal Transverse Mercator (UTM) Zone 6.

Tables showing the number of survey hours flown for individual days, half-months, or months 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/hr of survey effort) per survey block for bowheads and belukhas. The timing of the 1996 bowhead migration through the study area was analyzed as sightings per unit effort (SPUE = number of sightings counted/hr of survey effort) and WPUE per date. Because chance sightings of a few large groups of whales in a short period of time might produce artificially high WPUE values in certain blocks, values based on at least 4.00 hr of survey effort were distinguished when discussing relative abundance between areas.

Habitat preference was depicted as percentage of whales per ice class and percentage of whales per depth regime. Directionality of whale group headings was analyzed using Rayleigh's test (Batschelet, 1972) for all pods, excluding those that were resting, feeding, or milling. Directionality was analyzed as a True (T) heading, assuming a compass correction of -31° for the study area as a whole. Probabilities were interpolated from alpha values shown for calculated critical values of Rayleigh's z (Zar, 1984: Table B.32). Additional statistical comparisons, correlations, and regressions (Zar, 1984) were performed as appropriate.

The water depth at each bowhead sighting in the 1982-1996 database was derived using a computer program—DEPTH—that assigned a metric depth value averaged over gridded areas (each 3 minutes of latitude by 10 minutes of longitude) in the Beaufort Sea west of 139°W. longitude and south of 72°N.

Table 2
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; calf swimming within 20 m of an adult.
Diving	Whale(s) changing swim direction or body orientation relative to the water surface, resulting in submergence; may or may not be accompanied by 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 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.
Underwater Blowing	Whale(s) exhaling while submerged, thus creating a visible bubble.

latitude. Values assigned to each grid block were initially subjective and were averaged from depths read from NOAA Provisional Chart 16004.

Raw density estimates were calculated using a computer program—DENSITY—and are presented only for relative comparison with similar values from previous survey reports. The program was based on strip-transect-analyses methods using only sightings made while on random transect within 1 km of the trackline. Density estimates were derived by survey block and are presented, with a description of density-estimate methodologies, in Appendix A.

All maps in this report were prepared with application software (ArcView 3.0) based on UTM 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).

Selected isobaths (60 m, 100 m, 500 m, 1,000 m, 2,000 m, 2,500 m, 3,000 m, and 3,500 m) were included in Figure 2 for visual reference only and were not used in data analyses. A point file of ETOPO5 5-minute gridded elevation data (USDOC, NOAA, National Geophysical Data Center, 1988) was downloaded from the National Geophysical Data Center Internet web site (http://www.ngdc.noaa.gov/mgg/global/etopo5.html). ArcView Spatial Analyst was used with these data to generate isobaths.

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 for the period 23 August through 11 October 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 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 belukha whales, as well as incidental sightings of other marine mammals, were depicted on separate maps. Both effort and marine mammal sightings were included on daily flight maps.

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), 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. Median and Mean Water Depth at Bowhead Sightings (Analysis Protocol)

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). The present water-depth analyses provide biological information needed to test the following null hypotheses recommended by the workshop:

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

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

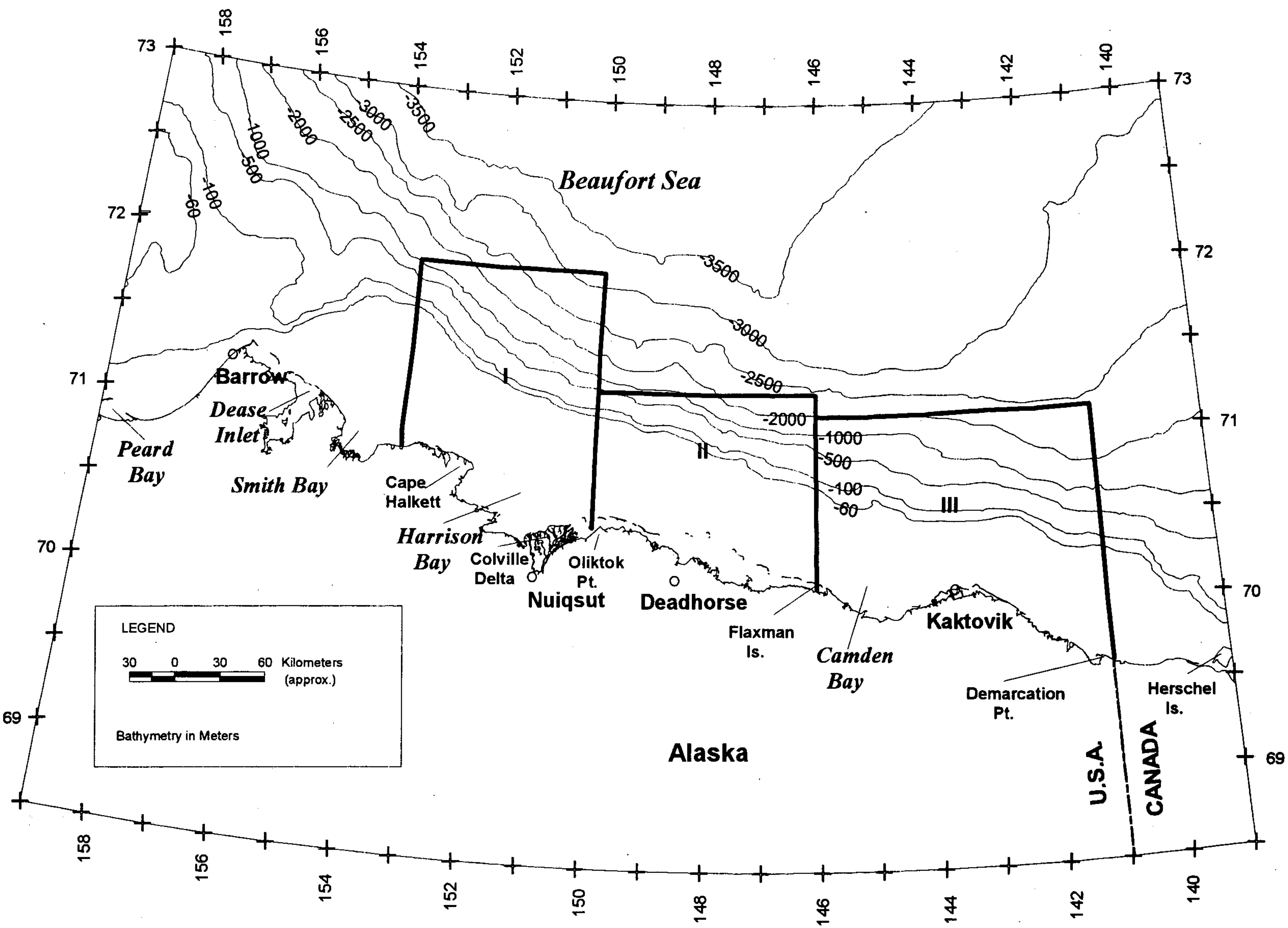

Figure 2. Regions I, II, and III (used in medium-water-depth analyses) and Selected Isobaths

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. The Beaufort Sea was divided into three regions in order to analyze east-west components of the known fall-migration corridor. Region I was delimited by 150°W. and 153°30′W. longitudes, south of 72°N. latitude. Region II was between 146°W. and 150°W. longitudes, south of 71°20′N. latitude. Region III was between 141°W. and 146°W. longitudes, south of 71°10′N. latitude (Fig. 2). 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.

A computer program—NEWSTAT—was used to analyze the file and describe central tendencies of water depths at bowhead whale sightings. The program was used to calculate median depth, mean depth, Standard Deviation (SD) about the mean, and overall depth range for Regions I, II, and III. NEWSTAT also was used to rank median depths from lowest to highest values. Upper and lower confidence limits for population medians were calculated by hand (Zar, 1984: Table B.26). If sample sizes were large ($n \geq 25$), a large-sample approximation (Zar, 1984: Page 113) was used to calculate the upper and lower limits.

Confidence Intervals (CI) were calculated at the 1-percent level to reduce the probability of incorrectly postulating a change in migration route when no change from other years had occurred. For example, the probability of incorrectly determining that a change had occurred is approximately 23 percent if tested at the 5-percent level, but only about 5 percent if tested at the 1-percent level (Houghton, Segar, and Zeh, 1984).

The NEWSTAT program employed the Mann-Whitney U test to address the question of potential fine-scale shifts in the axis of the bowhead whale fall-migration route. The Mann-Whitney U test is a nonparametric procedure performed on ranked samples (Zar, 1984). The Normal Approximation to the Mann-Whitney Test (Zar, 1984: Page 142) was used to hand-calculate the value of Z for larger sample sizes. A series of Mann-Whitney paired comparisons were made on annual depth values, with each year compared to all others such that annual and/or interannual shifts in migration route from 1982 to 1996 could be evaluated. Similar paired comparisons were made by region (I, II, and III) such that annual variations or potential shifts in median depth could be assessed for these smaller areas. Probabilities were interpolated from alpha values shown for calculated critical values of the Mann-Whitney U distribution (Zar, 1984: Table B.10). Application software (Systat 5.0) was used for graphing between-year median depths.

The NEWSTAT program compared mean water depths at bowhead sightings between years employing an analysis of variance (ANOVA) and the Tukey test (Zar, 1984). Probabilities were estimated as alpha values shown for calculated critical values of the F and q distributions (Zar, 1984: Tables B.4 and B.5).

III. RESULTS

A. Environmental Conditions

General ice coverage in the Alaskan Beaufort Sea (Figs. 3-10) was light during the Fall 1996 surveys. During the last week of August (Figs. 3 and 4), the very heavy sea ice (>79%) was generally confined to the eastern third of the study area, with lighter ice concentrations (<40%) inshore and open water west of Barrow. By early September (Figs. 5 and 6), when surveys began, the very heavy sea ice (>79%) had receded to the northeast corner of the study area, with a broad area of very light ice (< 20%) throughout the western half of the study area. By 20 September, very heavy sea ice (>79%) occupied the eastern half of the study area with some moderate (40-59%) or heavy (60-79%) sea ice near shore and increasing concentrations of sea ice west of Deadhorse (Figs. 7 and 8). By 4 October (Fig. 9), near-solid sea ice (95-100%) covered the eastern half of the study area. By 11 October (Fig. 10), the entire study area was locked in near-solid sea ice, except for a small area of moderate (40-59%) sea ice just north of Barrow. Ice percent at each sighting of endangered whales is shown in Appendix B (Table B-1).

Other environmental conditions during Fall 1996 were considered good for observing whales at or near the surface, permitting 34 flights during that time period. Sea states sometimes reduced the ability of observers to spot whales near the surface or at great distances from the transect centerline. Sea states at each sighting of endangered whales are shown in Appendix B (Table B-1). Cloud ceilings over portions of the study area were often lower than the target-survey altitude of 458 m, most notably during the first week in September.

B. Survey Effort

Daily totals of kilometers and hours flown per survey flight are shown in Table 3. A total of 26,008 km of surveys were flown in 123.00 hours (Table 3) in the study area at an average speed of 211.45 km/hr. The average survey flight was 764.94 km, with flights ranging from 0 km to 1,514 km of over-water survey. Mean survey time per flight was 3.62 hr (SD = 1.83, n = 34). A total of 13,056 km of random-transect lines were flown in 59.53 hours (Table 3) at an average speed of 219.32 km/hr. These random transects constituted 50.2 percent of the total kilometers flown and 48.40 percent of the total flight hours. The number of flight hours over each survey block is shown in subsequent analyses.

Day-to-day flight tracks are shown in Appendix B. Survey-flight lines are summarized by semimonthly period in Figures 11 through 13.

During the first half of September, survey coverage ranged from 140°W. to 157°W. longitudes, with most of the effort within 50 nautical miles (nm) of shore (Fig. 11). There were 19.23 hours of random transects flown from a total of 42.63 flight hours during this period (Table 3), constituting 32.3 percent and 34.7 percent, respectively, of the total time spent in those effort categories.

During the second half of September, survey coverage ranged from 141°W. to 156°W. longitudes, mostly within 75 nm of shore (Fig. 12). There were 25.10 hours of random transects flown from 49.38 total flight hours during this period (Table 3), constituting 42.2 percent and 40.1 percent, respectively, of the total time spent in those effort categories.

From 1 through 9 October, survey coverage ranged from 143°W. to 157°W. longitudes, mostly within 75 nm of shore (Fig. 13). There were 15.20 hours of random transects flown from 30.98 total flight hours during this period (Table 3), constituting 25.5 percent and 25.2 percent, respectively, of the total time spent in those effort categories.

C. Bowhead Whale (*Balaena mysticetus*) Observations

1. Distribution: Sixty-nine sightings were made for a total of 114 bowhead whales observed during Fall-1996 surveys in the study area (Table 4 and Figs. 14-17), not counting repeat sightings. Relatively even

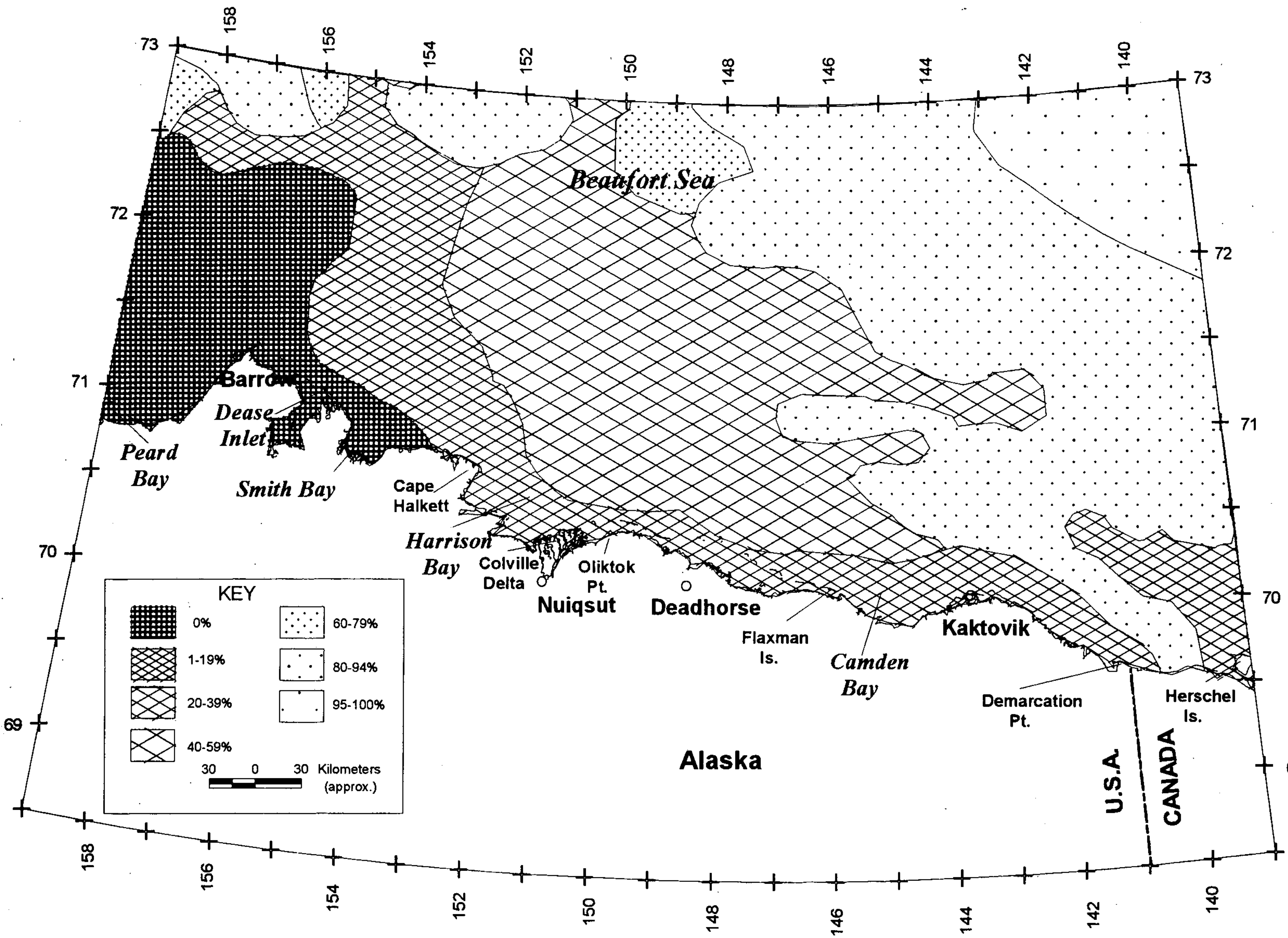

Figure 3. Map of Ice Concentrations in the Beaufort Sea, 23 August 1996

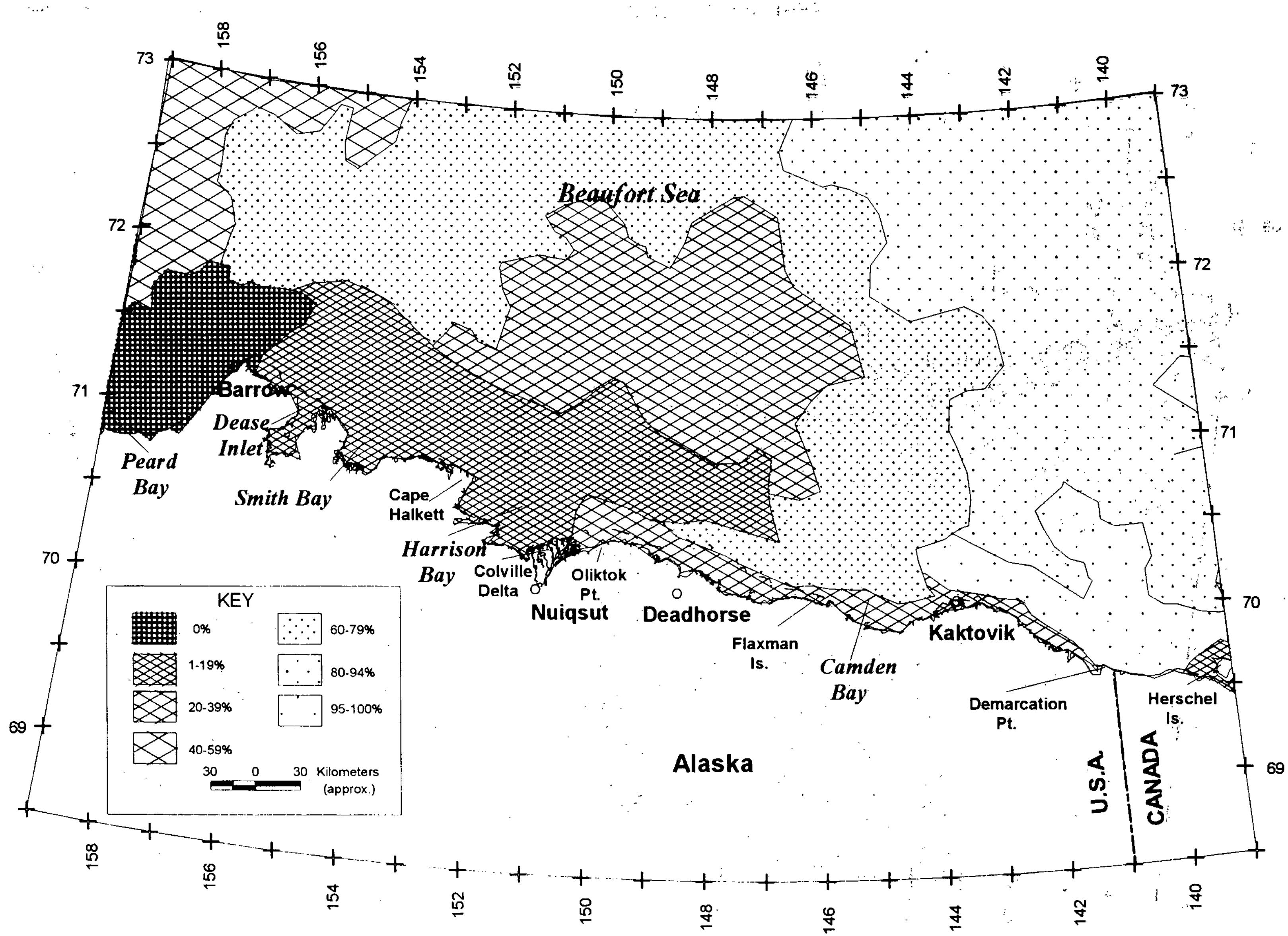

Figure 4. Map of Ice Concentrations in the Beaufort Sea, 30 August 1996

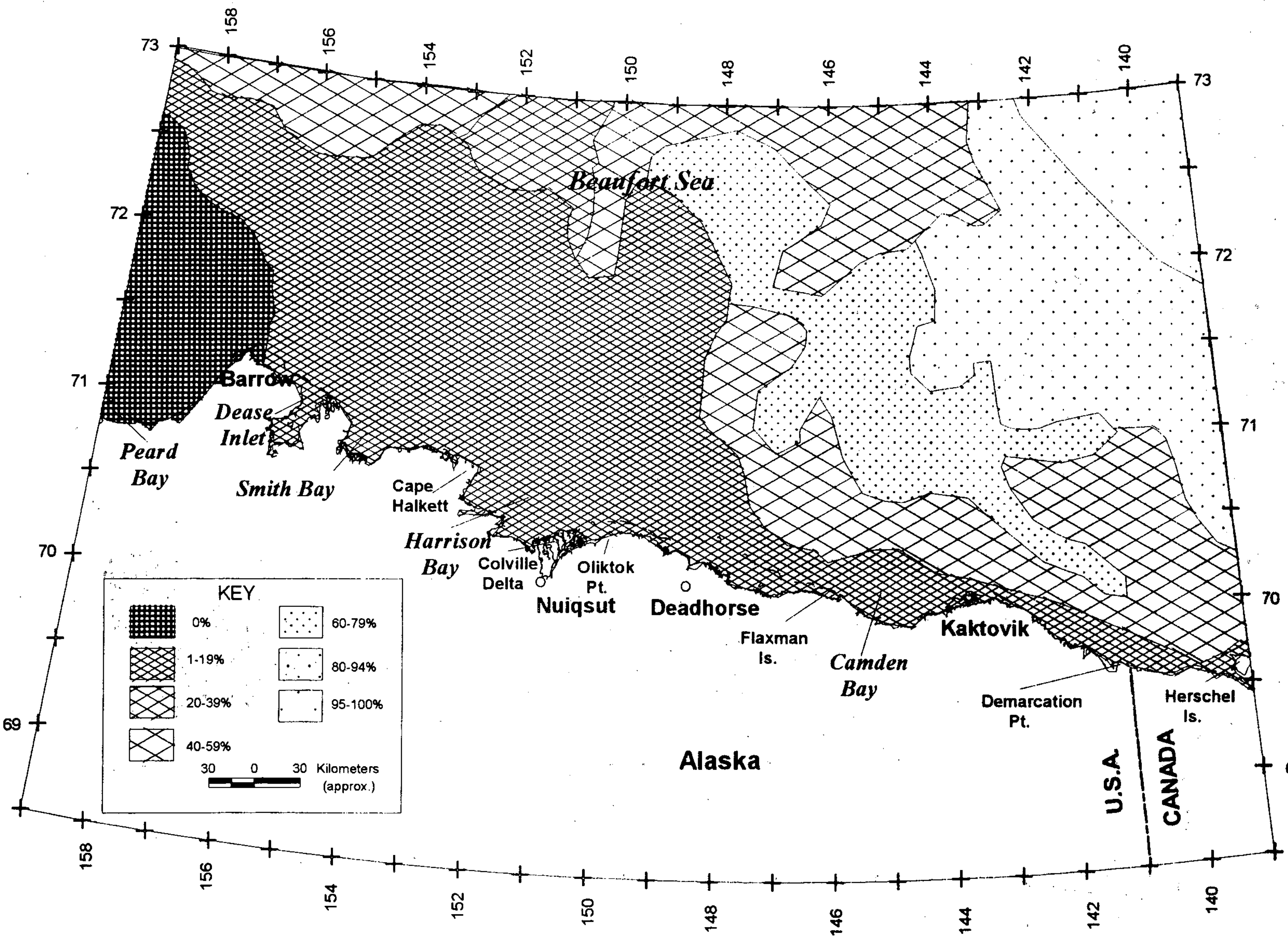

Figure 5. Map of Ice Concentrations in the Beaufort Sea, 6 September 1996

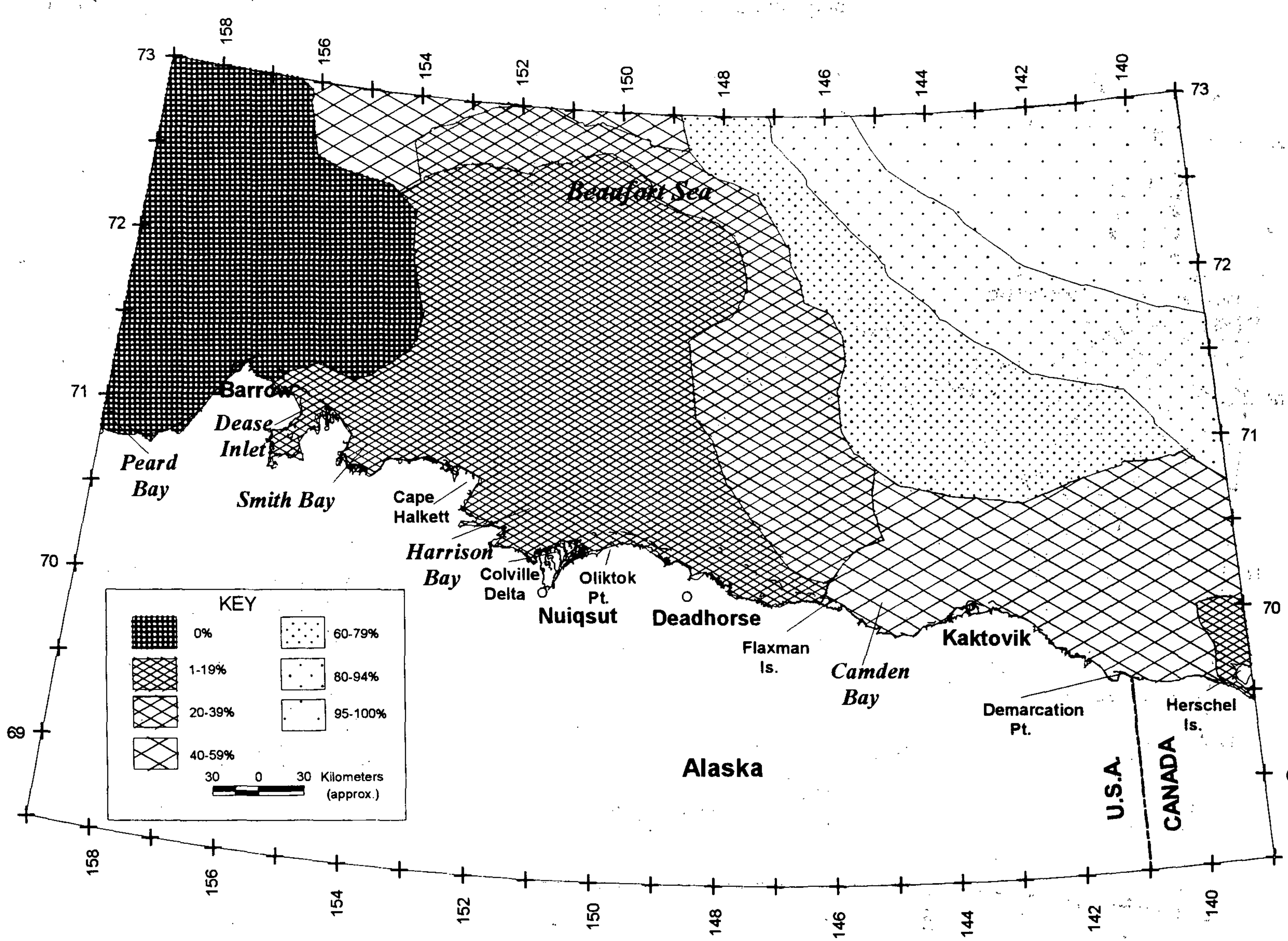

Figure 6. Map of Ice Concentrations in the Beaufort Sea, 13 September 1996

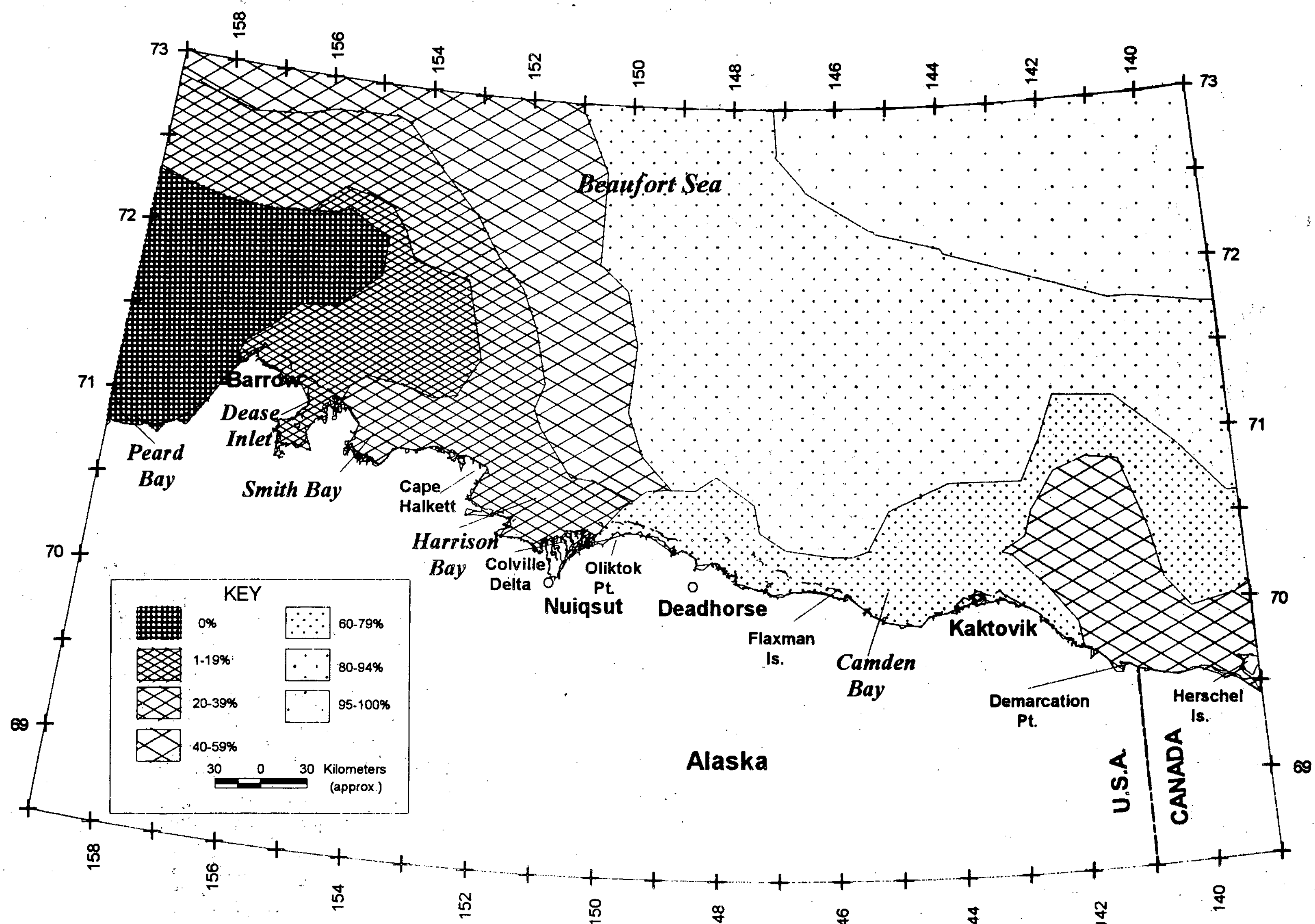

Figure 7. Map of Ice Concentrations in the Beaufort Sea, 20 September 1996

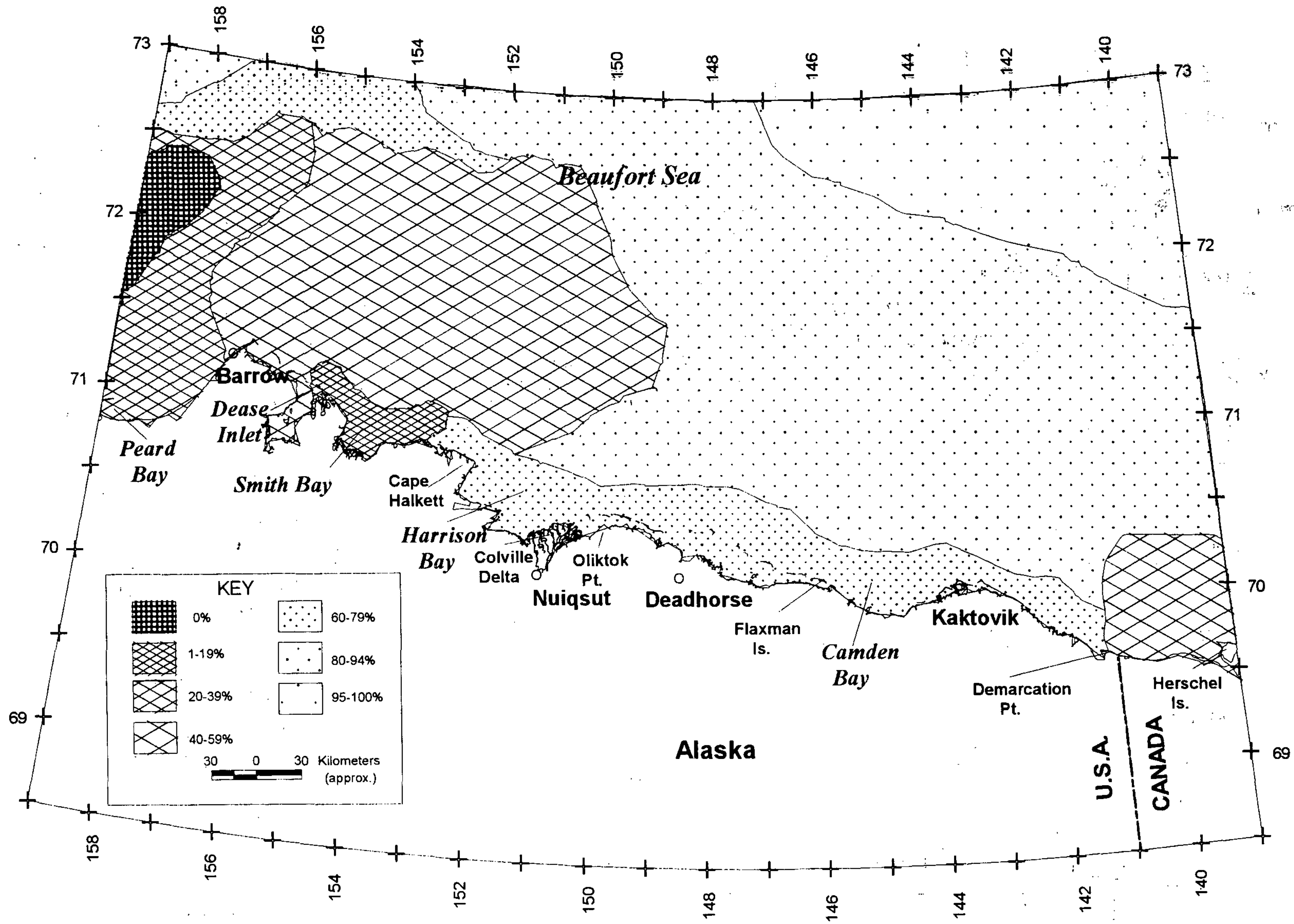

Figure 8. Map of Ice Concentrations in the Beaufort Sea, 27 September 1996

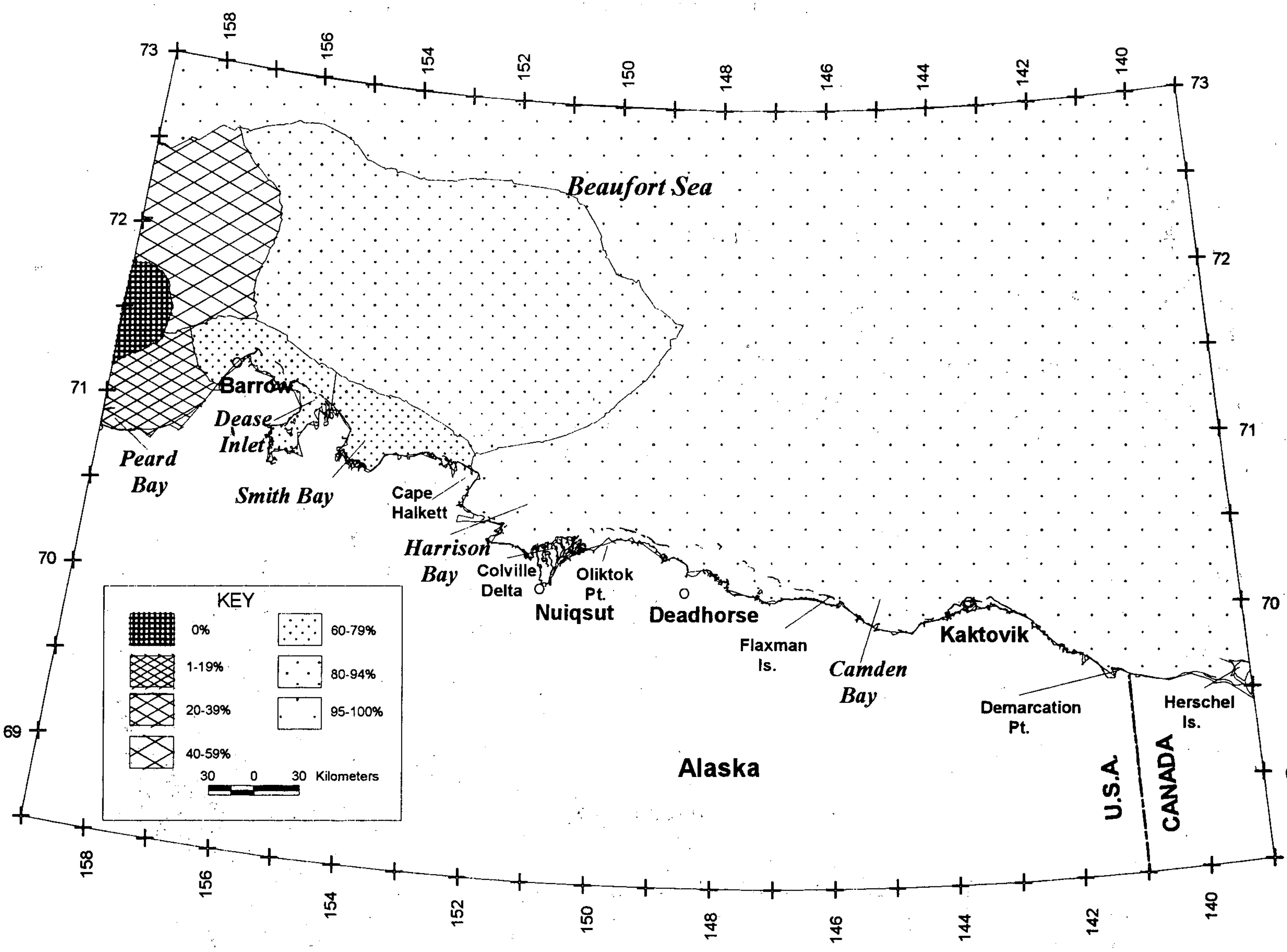

Figure 9. Map of Ice Concentrations in the Beaufort Sea, 4 October 1996

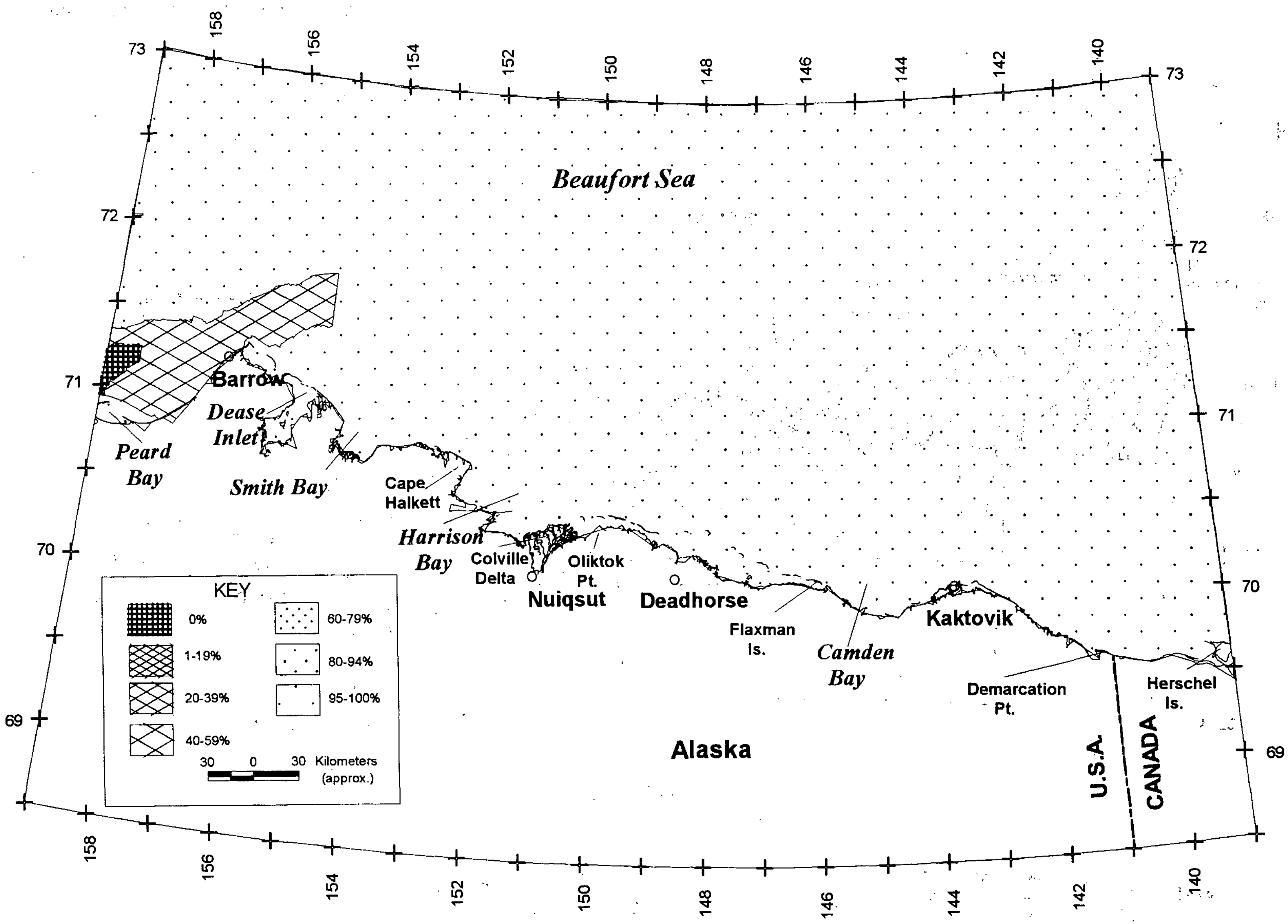

Figure 10. Map of Ice Concentrations in the Beaufort Sea, 11 October 1996

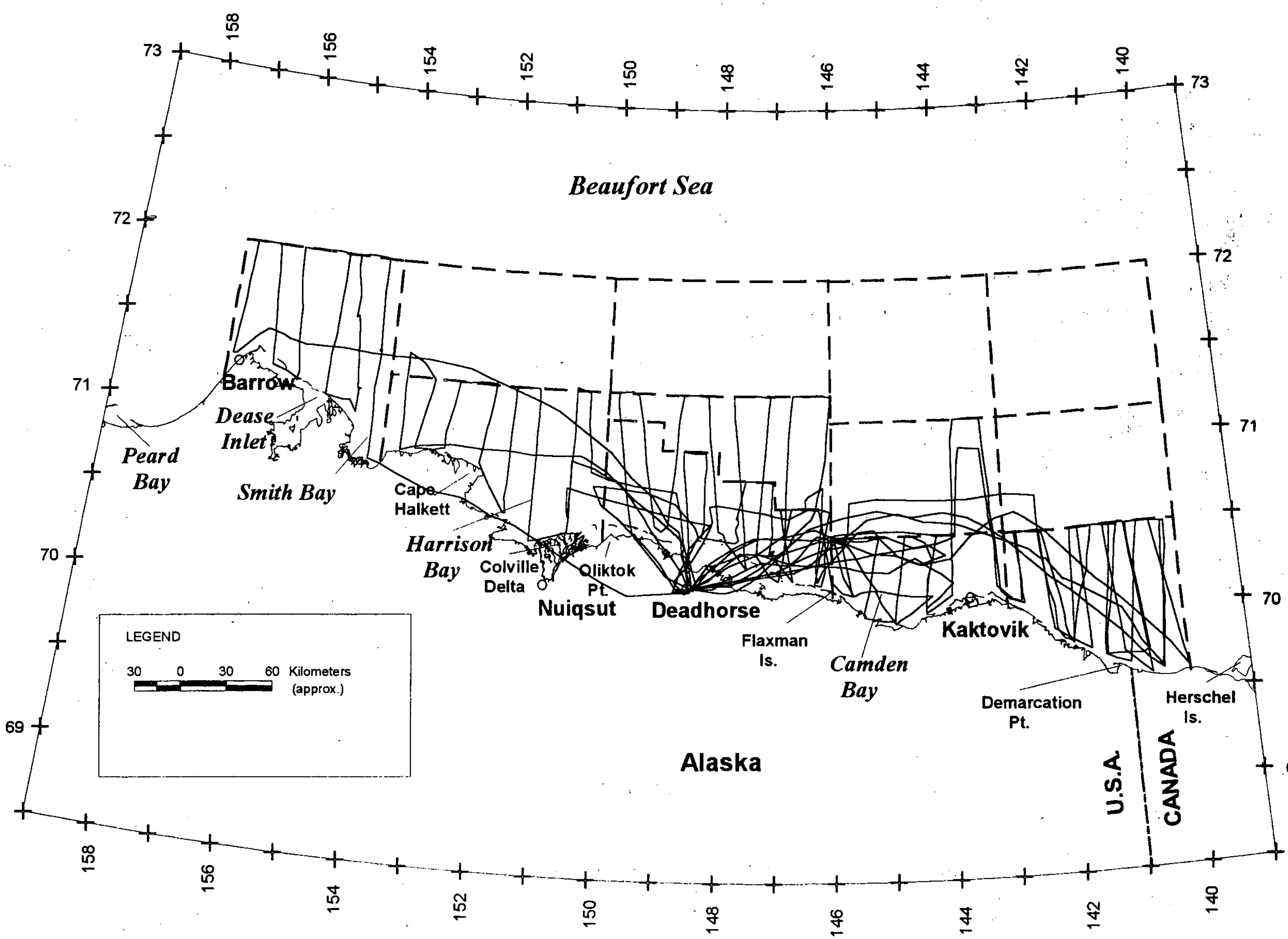

Figure 11. Combined Flight Tracks, 1-15 September 1996

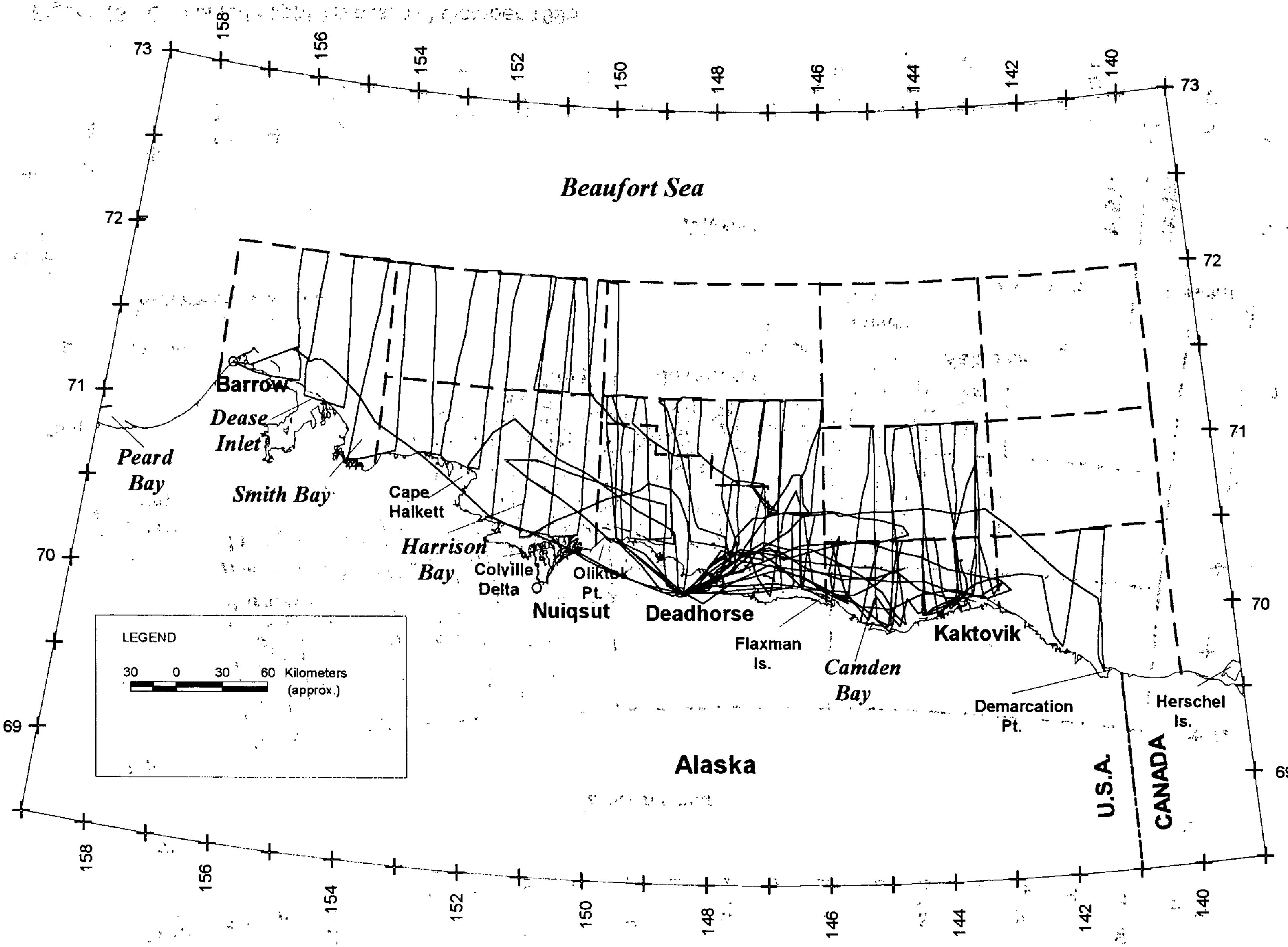

Figure 12. Combined Flight Tracks, 16-30 September 1996

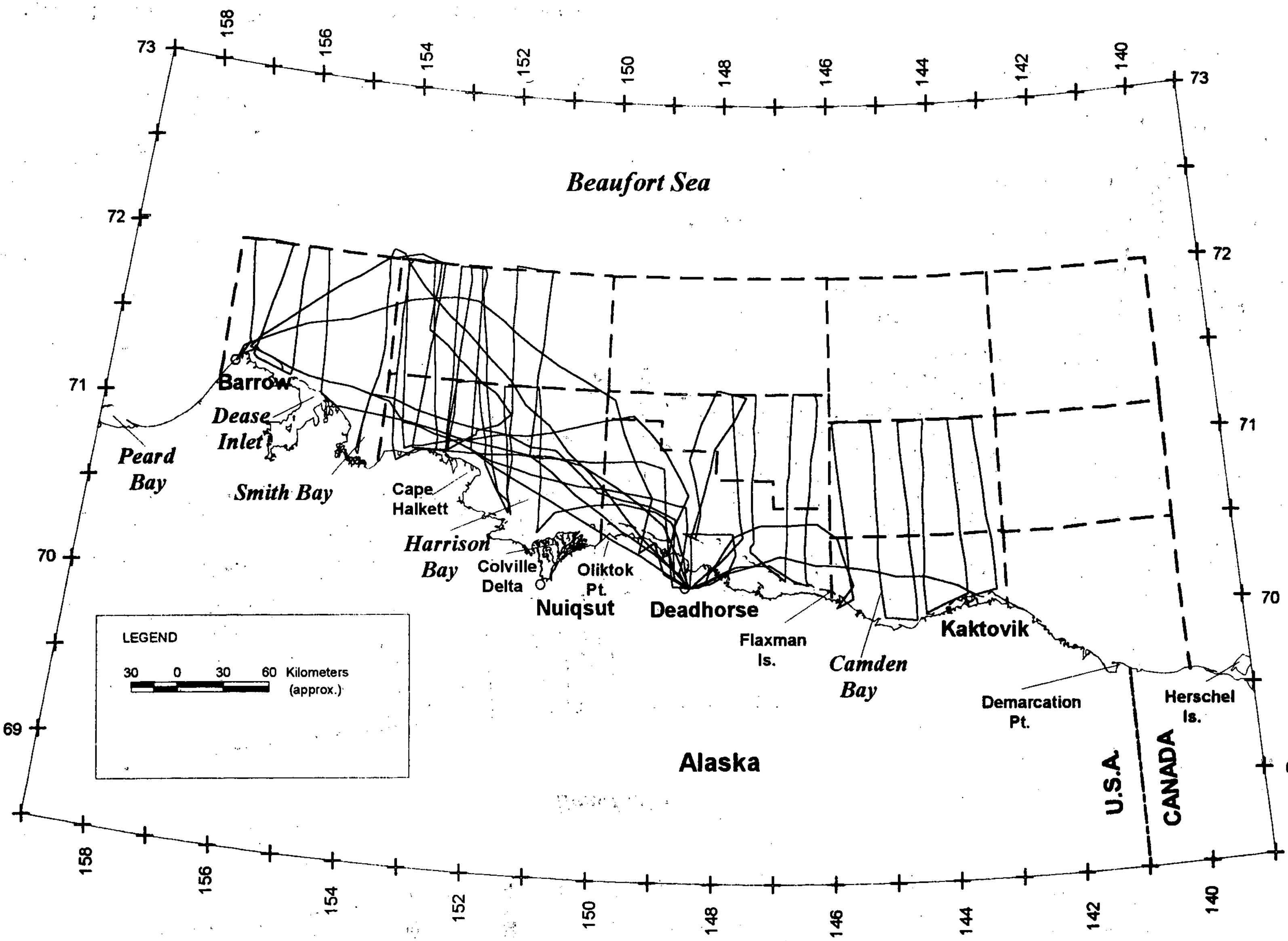

Figure 13. Combined Flight Tracks, 1-9 October 1996

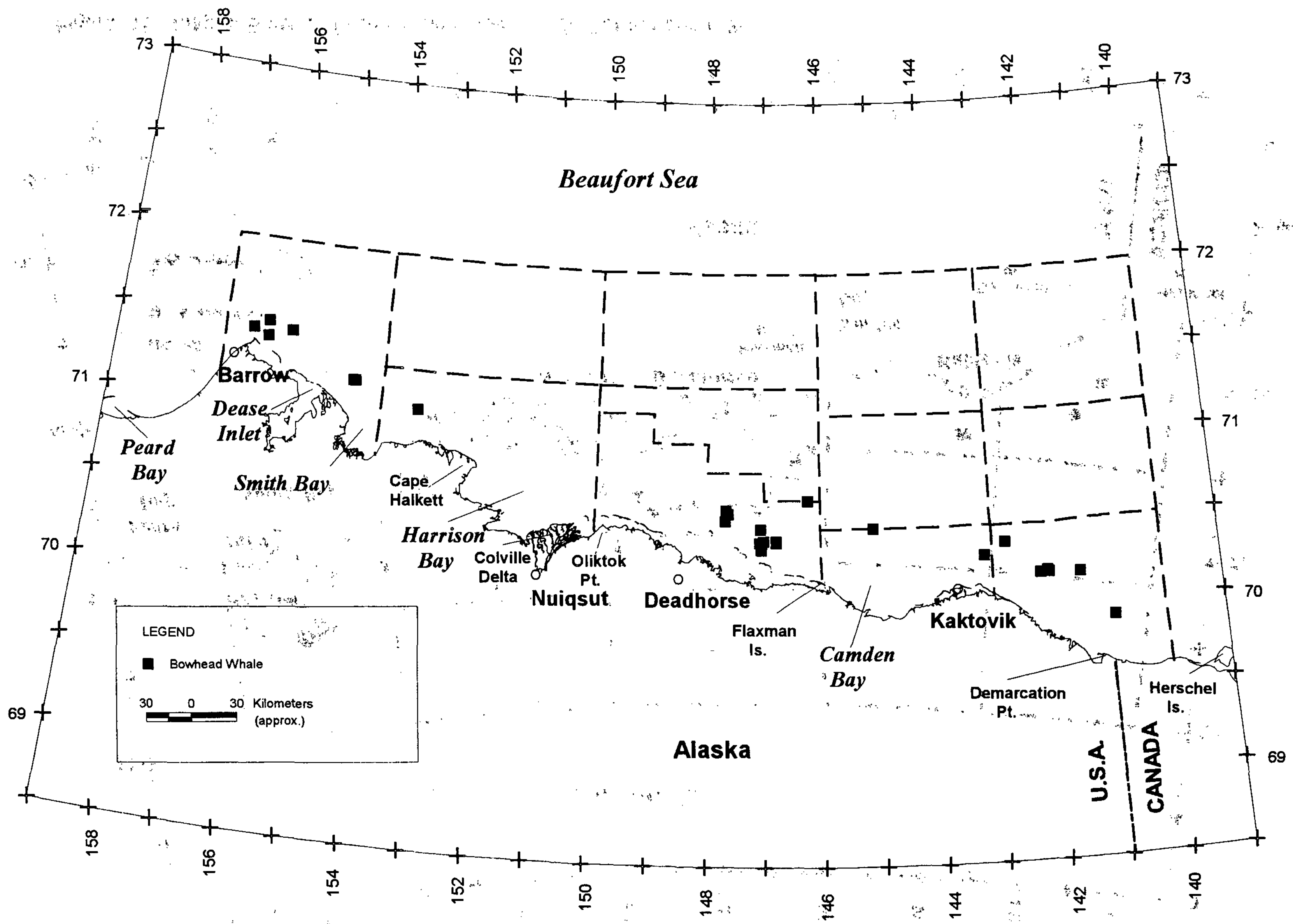

Figure 14. Map of Bowhead Whale Sightings, 1-15 September 1996

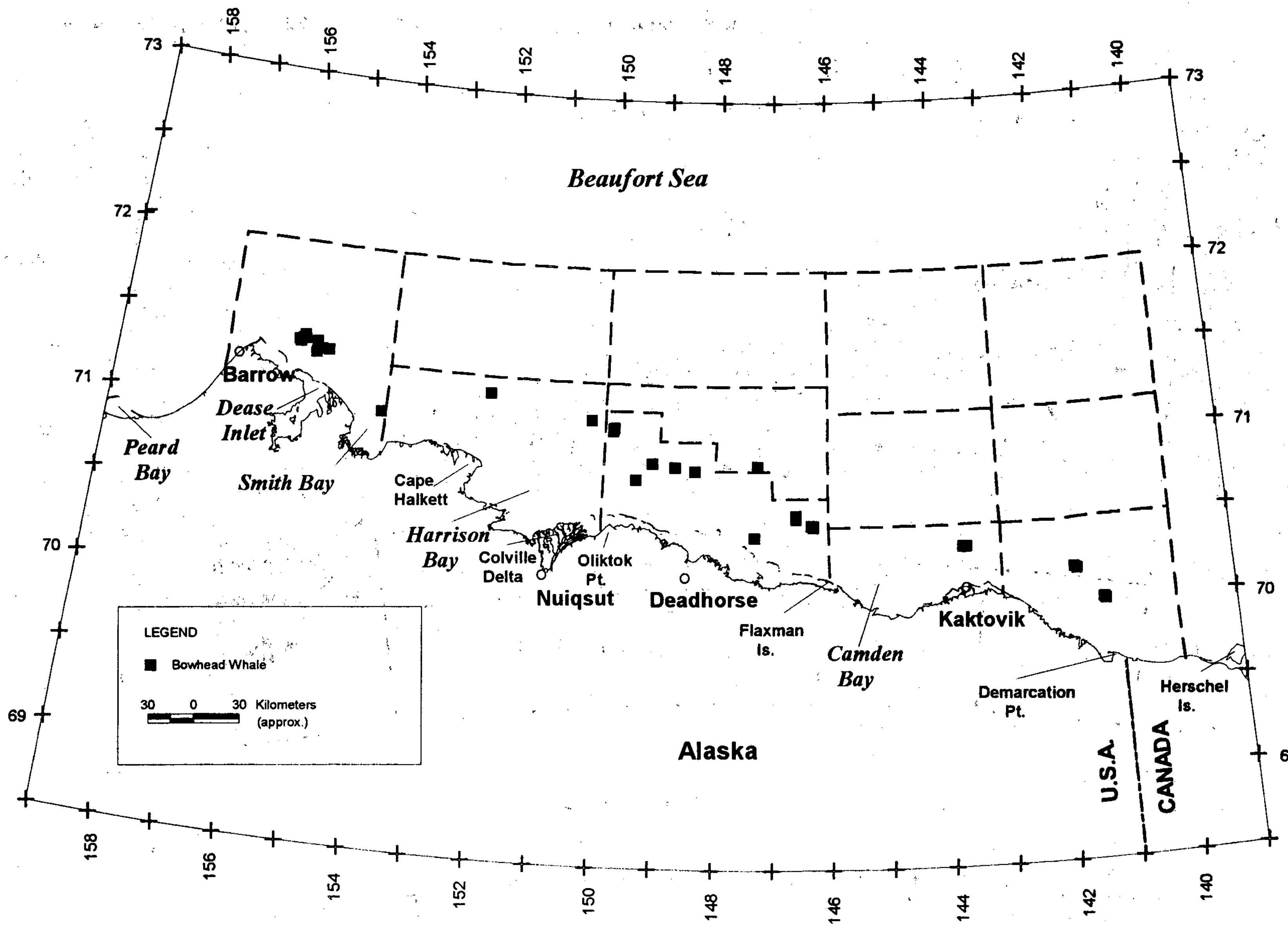

Figure 15. Map of Bowhead Whale Sightings, 16-30 September 1996

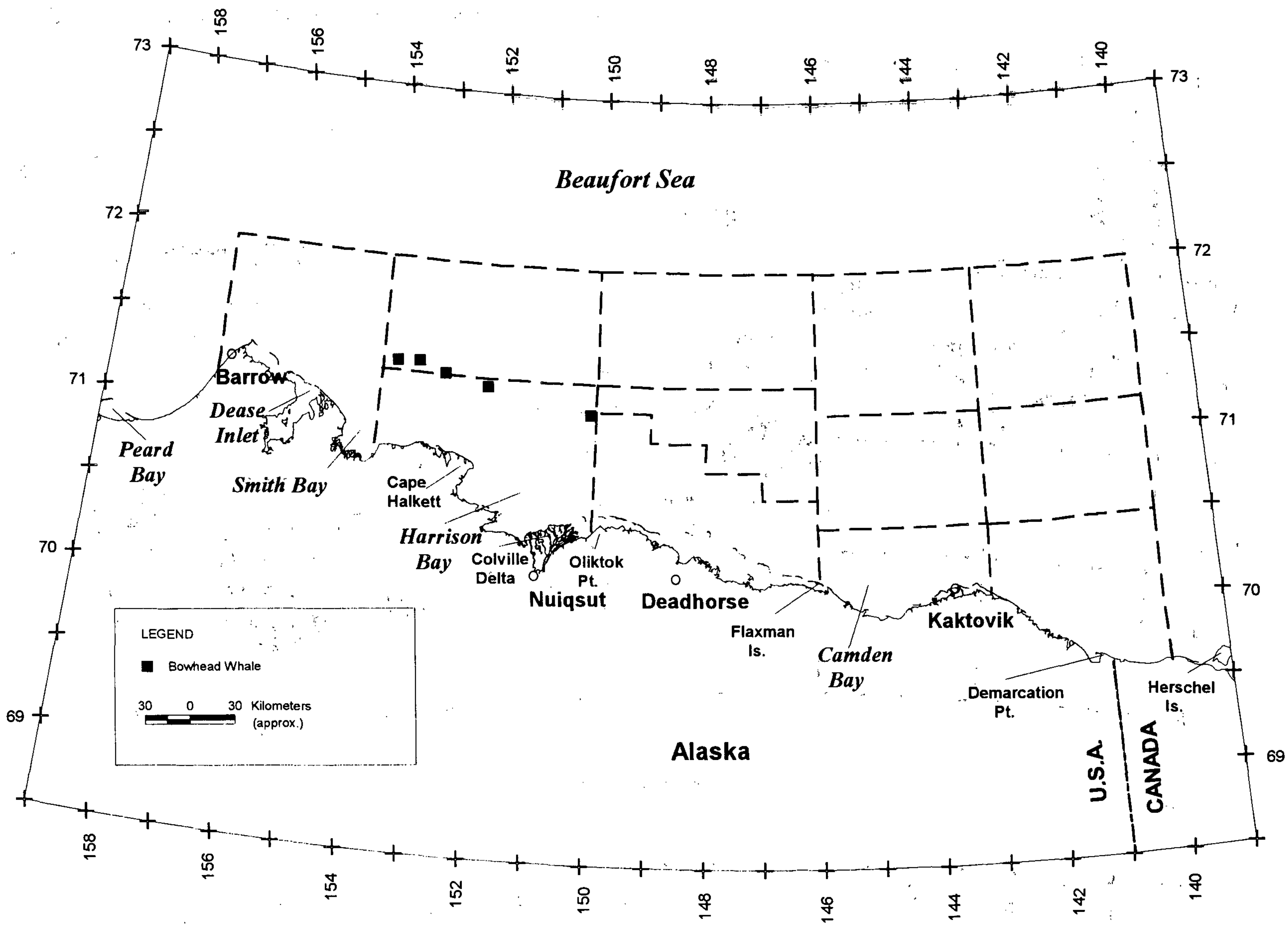

Figure 16. Map of Bowhead Whale Sightings, 2-9 October 1996

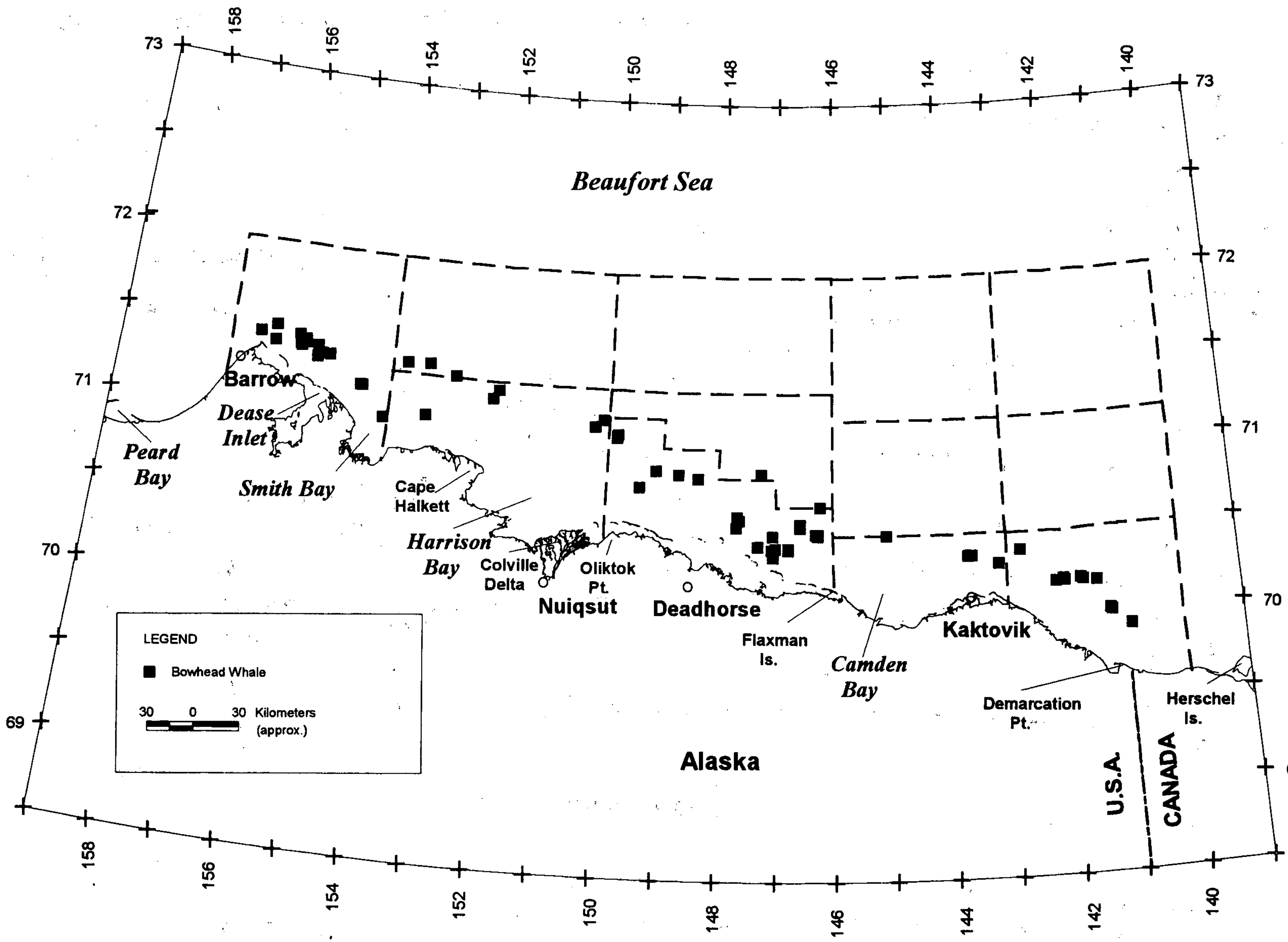

Figure 17. Map of Bowhead Whale Sightings, Fall 1996

Table 3
Aerial-Survey Effort in the Beaufort Sea, 1 September-9 October 1996, by Survey Flight

Day	Flight No.	Transect (km)	Connect (km)	Search (km)	Total (km)	Transect Time (hr)	Total Survey Time (hr)
2 Sep	1	476	166	237	879	2.15	4.77
5 Sep	2	674	106	350	1,130	3.08	5.47
6 Sep	3	0	0	0	0	0.00	0.00
7 Sep	4	144	25	119	288	0.65	1.40
8 Sep	5	62	0	344	406	0.27	2.20
9 Sep	6	598	121	482	1,201	2.75	5.62
10 Sep	7	726	156	483	1,365	3.12	6.22
11 Sep	8	437	145	315	897	1.97	4.18
12 Sep	9	567	82	453	1,102	2.55	5.12
13 Sep	10	444	83	603	1,130	2.07	5.12
14 Sep	11	0	0	147	147	0.00	0.70
15 Sep	12	136	9	242	387	0.63	1.85
16 Sep	13	214	25	640	879	1.05	4.38
18 Sep	14	0	0	234	234	0.00	0.92
19 Sep	15	435	149	335	919	2.05	4.55
20 Sep	16	141	35	264	440	0.63	2.23
20 Sep	17	355	67	82	504	1.65	2.33
22 Sep	18	759	257	150	1,166	3.47	5.28
23 Sep	19	0	0	286	286	0.00	1.42
24 Sep	20	366	150	253	769	1.68	3.52
26 Sep	21	882	129	503	1,514	3.88	7.12
27 Sep	22	277	40	149	466	1.27	2.32
27 Sep	23	666	48	122	836	2.90	3.75
28 Sep	24	476	46	346	868	2.23	4.27
29 Sep	25	719	104	258	1,081	3.35	5.10
30 Sep	26	220	41	204	465	0.93	2.20
1 Oct	27	768	91	321	1,180	3.52	5.53
2 Oct	28	317	36	749	1,102	1.58	5.48
4 Oct	29	433	60	106	599	1.98	2.82
5 Oct	30	479	59	363	901	2.17	4.13
6 Oct	31	720	108	344	1,172	3.27	5.37
7 Oct	32	200	20	90	310	0.93	1.47
7 Oct	33	36	0	295	331	0.17	1.73
9 Oct	34	329	66	659	1,054	1.58	4.45
Total Semimonthly Effort							
1-15 Sep		4,264	893	3,775	8,932	19.23	42.63
16-30 Sep		5,510	1,091	3,826	10,427	25.10	49.38
1-9 Oct		3,282	440	2,927	6,649	15.20	30.98
TOTAL		13,056	2,424	10,528	26,008	59.53	123.00

Table 4
Summary of Marine Mammal Sightings, 1 September-9 October 1996, by Survey Flight
(number of sightings/number of animals)

Day	Flight No.	Bowhead Whale	Gray Whale	Belukha Whale	Unidentified Cetacean	Bearded Seal	Ringed Seal	Pacific Walrus	Unidentified Pinniped	Polar Bear (PB)	PB Tracks (no bear)
2 Sep	1	10/12	0	0	0	0	0	0	0	0	0
5 Sep	2	1/1	0	2/11	0	0	0	0	0	0	0
6 Sep	3	0	0	0	0	0	0	0	0	0	0
7 Sep	4	0	0	0	0	0	0	0	0	0	0
8 Sep	5	2/6	0	2/6	0	0	0	0	0	0	0
9 Sep	6	2/2	0	2/9	0	0	0	0	0	0	0
10 Sep	7	4/5	0	6/23	0	0	1/3	0	0	1/1	1
11 Sep	8	1/1	0	0	1/1	0	2/2	0	0	0	0
12 Sep	9	7/11	0	4/132	1/1	1/1	3/26	0	0	0	0
13 Sep	10	1/2	0	4/20	0	0	1/50	0	0	0	0
14 Sep	11	0	0	0	0	0	0	0	0	0	0
15 Sep	12	0	0	0	0	0	0	0	0	0	0
16 Sep	13	5/5	0	0	0	0	1/25	0	0	0	0
18 Sep	14	0	0	0	0	0	0	0	0	0	0
19 Sep	15	4/10	0	2/24	1/1	0	1/1	0	0	0	3
20 Sep	16	5/7	0	0	0	0	1/5	0	0	0	3
20 Sep	17	2/2	0	0	0	0	1/2	0	0	0	6
22 Sep	18	0	0	22/100	0	0	0	0	0	0	6
23 Sep	19	0	0	0	0	0	0	0	0	0	1
24 Sep	20	0	0	0	1/1	0	0	0	0	0	2
26 Sep	21	12/34	0	16/74	0	0	1/4	0	0	0	5
27 Sep	22	5/7	0	5/91	0	0	0	0	0	0	0
27 Sep	23	2/2	0	6/19	0	0	2/2	0	0	0	8
28 Sep	24	0	0	0	0	1/1	4/6	0	0	0	6
29 Sep	25	0	0	1/4	0	0	1/1	0	0	0	6
30 Sep	26	1/1	0	0	0	0	0	0	0	0	4
1 Oct	27	0	0	6/20	1/2	0	3/4	0	0	0	7
2 Oct	28	1/2	0	2/5	0	0	1/2	0	0	1/3	7
4 Oct	29	0	0	0	0	0	1/2	0	0	0	5

Table 4
Summary of Marine Mammal Sightings, 1 September-9 October 1996, by Survey Flight
(number of sightings/number of animals)
(Continued)

Day	Flight No.	Bowhead Whale	Gray Whale	Belukha Whale	Unidentified Cetacean	Bearded Seal	Ringed Seal	Pacific Walrus	Unidentified Pinniped	Polar Bear (PB)	PB Tracks (no bear)
5 Oct	30	4/4	0	4/17	0	0	0	0	0	0	3
6 Oct	31	0	0	1/1	0	0	0	0	0	2/2	2
7 Oct	32	0	0	0	0	0	0	0	0	0	3
7 Oct	33	0	0	8/45	0	1/1	2/2	0	0	0	3
9 Oct	34	0	0	1/3	0	0	0	0	0	4/4	9
Total Semimonthly Sightings											
1-15 Sep		28/40	0	30/201	2/2	1/1	7/81	0	0	1/1	1
16-30 Sep		36/68	0	52/325	2/2	1/1	12/46	0	0	0	50
1-9 Oct		5/6	0	22/91	1/2	1/1	7/10	0	0	7/9	39
TOTAL		69/114	0	104/617	5/6	3/3	26/137	0	0	8/10	90

survey coverage between 140°W. and 157°W. longitudes (Figs. 11-13), resulted in relatively even distribution of bowhead whales across the study area, within 45 nm north of the shoreline (Fig. 17). Three of the 114 whales were identified as calves (Appendix B: Table B-1), resulting in a seasonal calf ratio (number calves/total whales) of 0.026. Daily sightings are shown on individual maps in Appendix B. A semi-monthly analysis follows.

During the first half of September, 28 sightings were made for a total of 40 bowheads (Table 4), with sightings from 141°27.9'W. to 156°30.1'W. longitudes (Appendix B: Table B-1), based on survey coverage between 140°W. and 157°W. longitudes (Fig. 11). The first bowheads in the Alaskan Beaufort Sea were sighted on 2 September at 70°25.5'N. latitude, 146°47.3'W. longitude (Appendix B: Table B-1). Whale pods were concentrated either east of Deadhorse or west of Cape Halkett, within 30 nm north of the shoreline (Fig. 14). Pod sizes ranged from 1 to 4 whales (Appendix B: Table B-1), with a mean of 1.43 (SD = 0.84, n = 28). One bowhead whale calf was observed during this period (Appendix B: Table B-1).

During the second half of September, 36 sightings were made for a total of 68 bowheads (Table 4), with sightings from 141°15.0'W. to 155°44.1'W. longitudes (Appendix B: Table B-1), based on survey coverage between 141°W. and 156°W. longitudes (Fig. 12). Whale pods were distributed fairly evenly east to west across the study area, within 45 nm north of the shoreline (Fig. 15). Pod sizes ranged from 1 to 7 whales (Appendix B: Table B-1), with a mean of 1.89 (SD = 1.69, n = 36). Two bowhead whale calves were observed during this period (Appendix B: Table B-1).

From 1 through 9 October, 5 sightings were made for a total of 6 bowheads (Table 4), with sightings from 150°07.4'W. to 153°44.1'W. longitudes (Appendix B: Table B-1), based on survey coverage between 143°W. and 157°W. longitudes (Fig. 13). Whale pods were located in a narrow band between Oliktok Point and Smith Bay, approximately 25 to 45 nm north of the shoreline (Fig.16). Pod sizes ranged from 1 to 2 whales (Appendix B: Table B-1), with a mean of 1.20 (SD = 0.45, n = 5). The last bowhead in the Alaskan Beaufort Sea was sighted on 5 October at 71°20.2'N. latitude, 152°50.6'W. longitude (Appendix B: Table B-1). No bowhead whale calves were observed during this period (Appendix B: Table B-1).

2. Migration Timing: The day-to-day timing of the bowhead whale migration was calculated over the entire study area (Table 5 and Fig. 18) as a daily sighting rate, or sightings per unit effort (SPUE), and an index of relative abundance, or whales per unit effort (WPUE).

Of the 69 sightings of bowhead whales, the first bowhead whales were observed on 2 September. The data for daily sighting rates showed a fairly level distribution over the field season, with a minor peak (mode) of 2.10 SPUE on 2 September. The last sighting of a bowhead was made west of the study area on 5 October (Table 5 and Fig. 18).

Of the 114 bowhead whales counted during this period, the data for daily relative abundance (WPUE) 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 20 September (Table 5). The peak relative abundance (mode) of 4.78 WPUE occurred on 26 September (Table 5 and Fig. 18).

The most prominent differences in pattern between the graph for relative abundance and that for sighting rate occurred on 26 September (Fig. 18), due to several large pods of whales observed on that day (Appendix B: Table B-1).

3. Relative Abundance by Survey Blocks: The relative abundance of bowhead whales in each Beaufort Sea survey block (Fig. 1), in Chukchi Sea survey blocks west of 157°W. longitude, in Canadian waters east of 140°W. longitude, and in Alaskan waters outside of historically monitored survey blocks, was calculated in Table 6. Over the field season (1 September-9 October), there were 3 survey blocks in which ≥15.00 hr of survey effort were made. Of these coastal blocks (Blocks 1, 3, and 4), coastal Block 1 (1.12 WPUE) had the greatest relative abundance, followed by Block 4 (0.50 WPUE) and Block 3 (0.31 WPUE). Although less than 15.00 hr of survey effort were made in coastal Blocks 5 and 12, it was notable that 44

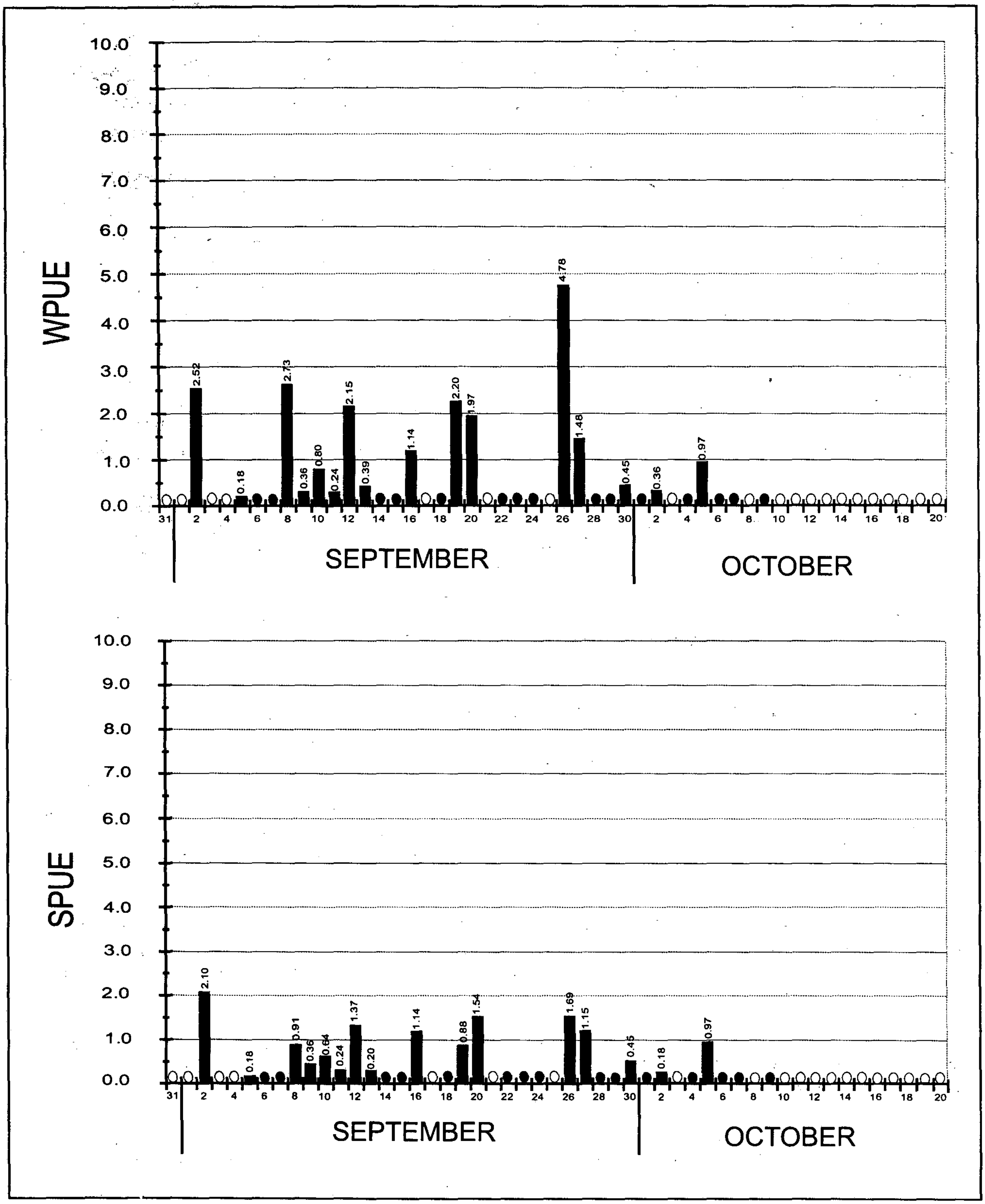

Figure 18. Daily Relative Abundance (WPUE) and Sighting Rate (SPUE) of Bowhead Whales, 1 September - 9 October 1996

(Solid circles indicate days when flights were made during which no bowheads were observed. Open circles indicate days when no flight was made.)

Table 5
Number of Sightings and Total Bowhead Whales Observed per Hour, 1 September-9 October 1996, by Flight Day

Day	No. of Sightings	No. of Whales	Total Survey Time (hr)	Sightings/ Hour (SPUE)	Whales/ Hour (WPUE)
2 Sep	10	12	4.77	2.10	2.52
5 Sep	1	1	5.47	0.18	0.18
6 Sep	0	0	0.00	[1]	[1]
7 Sep	0	0	1.40	0.00	0.00
8 Sep	2	6	2.20	0.91	2.73
9 Sep	2	2	5.62	0.36	0.36
10 Sep	4	5	6.22	0.64	0.80
11 Sep	1	1	4.18	0.24	0.24
12 Sep	7	11	5.12	1.37	2.15
13 Sep	1	2	5.12	0.20	0.39
14 Sep	0	0	0.70	0.00	0.00
15 Sep	0	0	1.85	0.00	0.00
16 Sep	5	5	4.38	1.14	1.14
18 Sep	0	0	0.92	0.00	0.00
19 Sep	4	10	4.55	0.88	2.20
20 Sep	7	9	4.56	1.54	1.97
22 Sep	0	0	5.28	0.00	0.00
23 Sep	0	0	1.42	0.00	0.00
24 Sep	0	0	3.52	0.00	0.00
26 Sep	12	34	7.12	1.69	4.78
27 Sep	7	9	6.07	1.15	1.48
28 Sep	0	0	4.27	0.00	0.00
29 Sep	0	0	5.10	0.00	0.00
30 Sep	1	1	2.20	0.45	0.45
1 Oct	0	0	5.53	0.00	0.00
2 Oct	1	2	5.48	0.18	0.36
4 Oct	0	0	2.82	0.00	0.00
5 Oct	4	4	4.13	0.97	0.97
6 Oct	0	0	5.37	0.00	0.00
7 Oct	0	0	3.20	0.00	0.00
9 Oct	0	0	4.45	0.00	0.00
TOTAL	69	114	123.00	0.56	0.93

[1] Flight aborted due to weather: did not include over-water survey.

Table 6
Semimonthly Relative Abundance (WPUE) of Bowhead Whales (BH), by Survey Block, Fall 1996

	1-15 Sep			16-30 Sep			1-9 Oct			10-31 Oct			Total		
Block	Hr	BH	WPUE	Hr	BH	WPUE	Hr	BH	WPUE	Hr	BH	WPUE	Hr	BH	WPUE
1	12.70	17	1.34	14.12	20	1.42	6.14	0	0.00	[1]	[1]	[1]	32.95	37	1.12
2	2.03	0	0.00	4.50	0	0.00	1.84	0	0.00	[1]	[1]	[1]	8.37	0	0.00
3	4.91	1	0.20	4.93	2	0.41	9.76	3	0.31	[1]	[1]	[1]	19.59	6	0.31
4	5.56	1	0.18	10.15	8	0.79	2.37	0	0.00	[1]	[1]	[1]	18.07	9	0.50
5	9.25	8	0.86	2.09	5	2.39	[1]	[1]	[1]	[1]	[1]	[1]	11.34	13	1.15
6	3.12	2	0.64	5.34	0	0.00	2.22	0	0.00	[1]	[1]	[1]	10.68	2	0.19
7	0.53	0	0.00	0.08	0	0.00	[1]	[1]	[1]	[1]	[1]	[1]	0.62	0	0.00
8	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
9	0.08	0	0.00	0.32	0	0.00	0.07	0	0.00	[1]	[1]	[1]	0.47	0	0.00
10	0.02	0	0.00	0.57	0	0.00	0.05	0	0.00	[1]	[1]	[1]	0.63	0	0.00
11	0.60	0	0.00	3.95	0	0.00	5.17	3	0.58	[1]	[1]	[1]	9.72	3	0.31
12	3.62	11	3.04	3.02	33	10.93	4.43	0	0.00	[1]	[1]	[1]	11.07	44	3.97
12N[2]	0.22	0	0.00	0.14	0	0.00	0.19	0	0.00	[1]	[1]	[1]	0.55	0	0.00
Other Canadian Areas	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
Other Alaskan Areas	[1]	[1]	[1]	0.19	0	0.00	0.30	0	0.00	[1]	[1]	[1]	0.49	0	0.00
TOTAL	42.63	40	0.94	49.38	68	1.38	32.53	6	0.18	[1]	[1]	[1]	123.00	114	0.93

[1] No survey effort.
[2] Block 12N is between Block 12 and 73°N. latitude.

whales were observed in Block 12 and 13 were observed in Block 5, for a greater relative abundance of 3.97 WPUE and 1.15 WPUE, respectively (Table 6).

During the first half of September, there were 4 blocks in which ≥4.00 hr of survey effort were made. Of these coastal blocks (Blocks 1, 3, 4, and 5), Block 1 (1.34 WPUE) had the greatest relative abundance, followed by Block 5 (0.86 WPUE), Block 3 (0.20 WPUE), and Block 4 (0.18 WPUE). Although less than 4.00 hr of survey effort were made in coastal Block 12, it was notable that 11 whales were observed in this block, for a higher relative abundance of 3.04 WPUE. Two bowheads were observed during a total of 6.60 hr of survey effort in the remaining blocks (Blocks 2, 6, 7, 9, 10, and 11) of the primary study area or adjacent waters (Table 6).

During the second half of September, there were 5 blocks in which ≥4.00 hr of survey effort were made. Of these coastal or offshore blocks (Blocks 1, 2, 3, 4, and 6), coastal Block 1 (1.42 WPUE) had the greatest relative abundance, followed by Block 4 (0.79 WPUE), Block 3 (0.41 WPUE), and Blocks 2 and 6, for which no whales were observed. Although less than 4.00 hr of survey effort were made in Blocks 5 and 12, it was notable that 33 whales were observed in coastal Block 12 and 5 whales in coastal Block 5, for a higher relative abundance of 10.93 WPUE and 2.39 WPUE, respectively. No bowheads were observed during a total of 5.25 hr of survey effort in the remaining blocks (Blocks 7, 9, 10, and 11) of the primary study area or adjacent waters (Table 6).

From 1 through 9 October, there were 4 blocks in which ≥4.00 hr of survey effort were made. Of these coastal or offshore blocks (Blocks 1, 3, 11, and 12), coastal Block 11 (0.58 WPUE) had the greatest relative abundance, followed by Block 3 (0.31 WPUE) and Blocks 1 and 12, for which no whales were observed. No bowheads were observed during a total of 7.04 hr of survey effort in the remaining blocks (Blocks 2, 4, 6, 9, and 10) of the primary study area or adjacent waters (Table 6).

4. Habitat Associations: Of 114 bowhead whales sighted over the field season (1 September-9 October), 99 (87%) were in shallow water (0-50 m deep), 15 (13%) were in waters of transitional depth (51-200 m), and none was sighted in deeper water (>200 m) (Table 7). A fuller description of depth associated with the bowhead migration appears in the discussion on median-water-depth analysis in Section IV.B.

In addition to general ice coverage for arctic waters (Figs. 3-10), the percentage of ice cover visible from the aircraft at each bowhead sighting (Appendix B: Table B-1) was summarized (Table 8). Over the field season, whales were sighted in a wide range of sea-ice concentrations, with 17 (15% sea-ice) sighted in 11- through 20-percent sea ice, 16 (14%) in 6- through 10-percent ice, 16 (14%) in 81- through 90-percent ice, 15 (13%) in 31- through 40-percent ice, 12 (11%) in open water (0% sea ice), 12 (11%) 61- through 70-percent ice, 9 (8%) in 41- through 50-percent ice, 6 (5%) in 1- through 5-percent ice, 6 (5%) in 21- through 30-percent ice, 4 (3%) in 71- through 80-percent ice, and 1 (1%) in 51- through 60-percent ice. Lighter concentrations (0- through 20- percent ice) predominated during the first half of September, while heavier ice concentrations prevailed during the remainder of the field season (Table 8).

5. Behavior, Swim Direction, and Speed: Of 114 bowhead whales observed during Fall 1996, 55 (48%) were swimming (Table 9), i.e., moving forward in an apparently deliberate manner, when first sighted. Over the fall season, whale headings were generally toward the western quadrant (proportion = 0.46). Their significant ($p < 0.02$) mean heading was 300.39°T (Fig. 19), consistent with a directed migration in rough parallel to Alaska's Beaufort Sea coastline. Over the field season, 43 (38%) were judged to be swimming at medium speed, with 34 (30%) still, 32 (28%) swimming slowly, and 5 (4%) swimming fast. Other behaviors noted for bowhead whales included 20 (17%) that were milling, 12 (11%) resting, 9 (8%) diving, 9 (8%) tail slapping, 7 (6%) feeding, and 2 (2%) in cow-calf associations (Table 9). All behaviors noted are defined in Table 2.

During the first half of September, 23 of 40 (58%) bowheads were initially observed swimming (Table 9). Whale headings were generally toward the western quadrant (proportion = 0.37), with the octant of strongest directionality (0.31) between west and northwest. Their mean heading was 338.70°T (Fig. 19). Thirteen (33%) whales were judged to be still, with 11 (27%) swimming slowly, 11 (27%) swimming at medium speed,

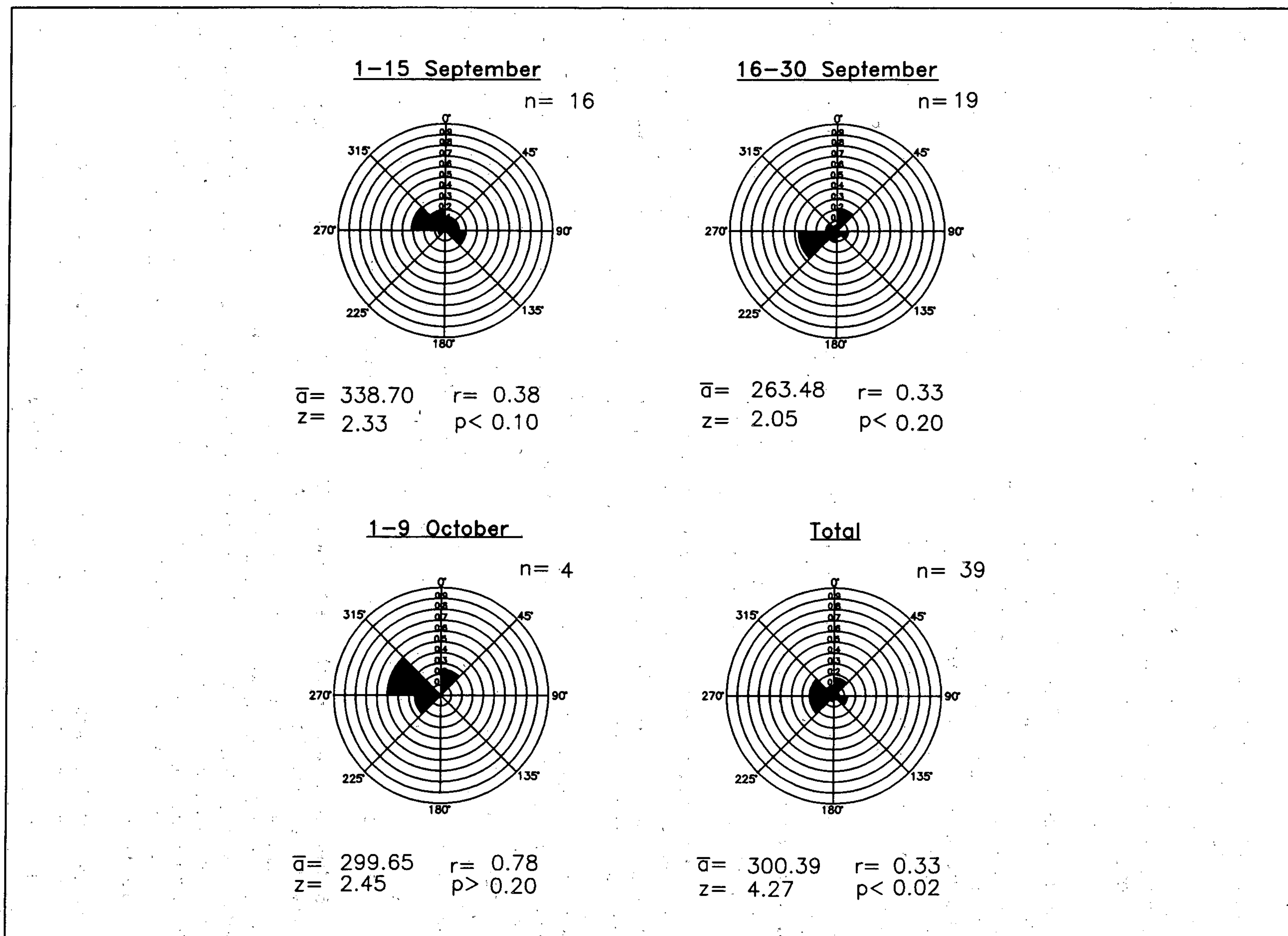

Figure 19. Semimonthly Summary of Swim Directions for Bowhead Whales, Fall 1996

Table 7
Semimonthly Summary of Bowhead Whales Observed, by Water Depth at Sighting Location, Fall 1996

Water Depth	1-15 Sep No. (%)	16-30 Sep No. (%)	1-9 Oct No. (%)	10-31 Oct No. (%)	Total No. (%)
Shallow (0-50 m)	29 (72)	66 (97)	4 (67)	[1]	99 (87)
Transitional (51-200 m)	11 (28)	2 (3)	2 (33)	[1]	15 (13)
Deep (>200 m)	0	0	0	[1]	0
TOTAL	40 (100)	68 (100)	6 (100)	[1]	114 (100)

Table 8
Semimonthly Summary of Bowhead Whales Observed, by Percent Ice Cover Present at Sighting Location, Fall 1996

% Ice Cover	1-15 Sep No. (%)	16-30 Sep No. (%)	1-9 Oct No. (%)	10-31 Oct No. (%)	Total No. (%)
0	12 (30)	0	0	[1]	12 (11)
1-5	4 (10)	2 (3)	0	[1]	6 (5)
6-10	16 (39)	0	0	[1]	16 (14)
11-20	3 (7)	14 (21)	0	[1]	17 (15)
21-30	1 (3)	5 (7)	0	[1]	6 (5)
31-40	1 (3)	14 (21)	0	[1]	15 (13)
41-50	2 (5)	6 (9)	1 (17)	[1]	9 (8)
51-60	0	1 (1)	0	[1]	1 (1)
61-70	0	12 (18)	0	[1]	12 (11)
71-80	0	3 (4)	1 (17)	[1]	4 (3)
81-90	1 (3)	11 (16)	4 (66)	[1]	16 (14)
91-99	0	0	0	[1]	0
TOTAL	40 (100)	68 (100)	6 (100)	[1]	114 (100)

[1] No survey effort.

Table 9
Semimonthly Summary of Bowhead Whales Observed, by Behavioral Category, Fall 1996

Behavior	1-15 Sep No. (%)	16-30 Sep No. (%)	1-9 Oct No. (%)	10-31 Oct No. (%)	Total No. (%)
Cow-Calf	2 (5)	0	0	[1]	2 (2)
Diving	3 (7)	5 (7)	1 (17)	[1]	9 (8)
Feeding	1 (3)	6 (9)	0	[1]	7 (6)
Milling	6 (15)	14 (21)	0	[1]	20 (17)
Resting	3 (7)	8 (12)	1 (17)	[1]	12 (11)
Swimming	23 (58)	28 (41)	4 (66)	[1]	55 (48)
Tail Slapping	2 (5)	7 (10)	0	[1]	9 (8)
(not noted)	0	0	0	[1]	0
TOTAL	40 (100)	68 (100)	6 (100)	[1]	114 (100)

Table 10
Semimonthly Summary of Bowhead Whales Observed, by Swimming Speed, Fall 1996

Swim Speed	1-15 Sep No. (%)	16-30 Sep No. (%)	1-9 Oct No. (%)	10-31 Oct No. (%)	Total No. (%)
Still (0 km/hr)	13 (33)	20 (29)	1 (17)	[1]	34 (30)
Slow (<2 km/hr)	11 (27)	19 (28)	2 (33)	[1]	32 (28)
Medium (2-4 km/hr)	11 (27)	29 (43)	3 (50)	[1]	43 (38)
Fast (>4 km/hr)	5 (13)	0	0	[1]	5 (4)
(not noted)	0	0	0	[1]	0
TOTAL	40 (100)	68 (100)	6 (100)	[1]	114 (100)

[1] No survey effort.

and 5 (13%) swimming fast (Table 10). Other behaviors noted for bowhead whales included 6 (15%) that were milling, 3 (7%) diving, 3 (7%) resting, 2 (5%) in cow-calf associations, 2 (5%) tail slapping, and 1 (3%) feeding (Table 9).

During the second half of September, 28 of 68 (41%) bowheads were initially observed swimming (Table 9). Whale headings were generally toward the western quadrant (proportion = 0.48), with the octant of strongest directionality (0.37) between west and southwest. Their mean heading was 263.48°T (Fig. 19). Twenty-nine (43%) whales were judged to be swimming at medium speed, with 20 (29%) still, and 19 (28%) swimming slowly (Table 10). Other behaviors noted for bowhead whales included 14 (21%) that were milling, 8 (12%) resting, 7 (10%) tail slapping, 6 (9%) feeding, and 5 (7%) diving (Table 9).

From 1 through 9 October, 4 of 6 (66%) bowheads were initially observed swimming (Table 9). Whale headings were generally toward the western quadrant (proportion = 0.75), with the octant of strongest directionality (0.50) between west and northwest. Their mean heading was 299.65°T (Fig. 19). Three (50%) whales were judged to be swimming at medium speed, with 2 (33%) swimming slowly and 1 (17%) still. Other behaviors noted for bowhead whales included 1 (17%) that was diving and 1 (17%) resting (Table 9).

D. Other Marine Mammal Observations

1. **Gray Whale (*Eschrichtius robustus*):** No gray whales were sighted during the study.

2. **Belukha Whale (*Delphinapterus leucas*):** Although the study area and survey altitude were designed to record the fall migration of bowhead whales, belukha whales, which undertake a somewhat parallel migration, were always counted and were considered suitable for selected analyses. Over the Fall 1996 field season, 104 sightings were made for a total of 617 belukha whales (Table 4) during 123.00 hr of survey effort (Table 3) and a seasonal relative abundance of 5.02 WPUE. Sightings of belukha whales were distributed between 140°W. and 157°W. longitudes, mostly between 30 and 70 nm from shore south of 72°N. latitude (Fig. 20). Sizes of pods (or close aggregations of pods) ranged from 1 to 63 whales, with a mean of 5.93 (SD =9.00, n = 104). Fifty belukha calves were noted for a calf ratio of 0.08. Belukha whales were observed in association with 0- to 98-percent sea ice, with a mean of 58.32-percent ice (SD = 31.76, n = 104).

During the first half of September, 30 sightings were made for a total of 201 belukha whales (Table 4) during 42.63 hr of survey effort (Table 3) and a relative abundance of 4.71 WPUE. The first belukha in the Alaskan Beaufort was sighted at 71°15.1'N. latitude, 148°41.6'W. longitude on 2 September. Sizes of pods (or close aggregations of pods) ranged from 1 to 38 whales, with a mean of 6.70 (SD = 9.12, n = 30). Nineteen belukha calves were noted during this period. Belukha whales were observed in association with 0- to 80-percent sea ice, with a mean of 21.67-percent ice (SD = 24.68, n = 30).

During the second half of September, 52 sightings were made for a total of 325 belukha whales (Table 4) during 49.38 hr of survey effort (Table 3) and a relative abundance of 6.58 WPUE. Sizes of pods (or close aggregations of pods) ranged from 1 to 63 whales, with a mean of 6.25 (SD = 10.47, n = 52). Twenty belukha calves were noted during this period. Belukha whales were observed in association with 0- to 98-percent sea ice, with a mean of 71.12-percent ice (SD = 20.54, n = 52).

From 1 through 9 October, 22 sightings were made for a total of 91 belukha whales (Table 4) during 30.98 hr of survey effort and a relative abundance of 2.94 WPUE. Sizes of pods (or close aggregations of pods) ranged from 1 to 15 whales, with a mean of 4.14 (SD = 3.45, n = 22). Eleven belukha calves were noted during this period. Belukha whales were observed in association with 0- to 97-percent sea ice, with a mean of 78.05-percent ice (SD = 18.65, n = 22).

3. **Unidentified Cetaceans:** Over the field season, 5 incidental sightings were made for a total of 6 unidentified cetaceans (Table 4). Sightings were distributed between 144°W. and 155°W. longitudes, south of 72°N. latitude (Fig. 21).

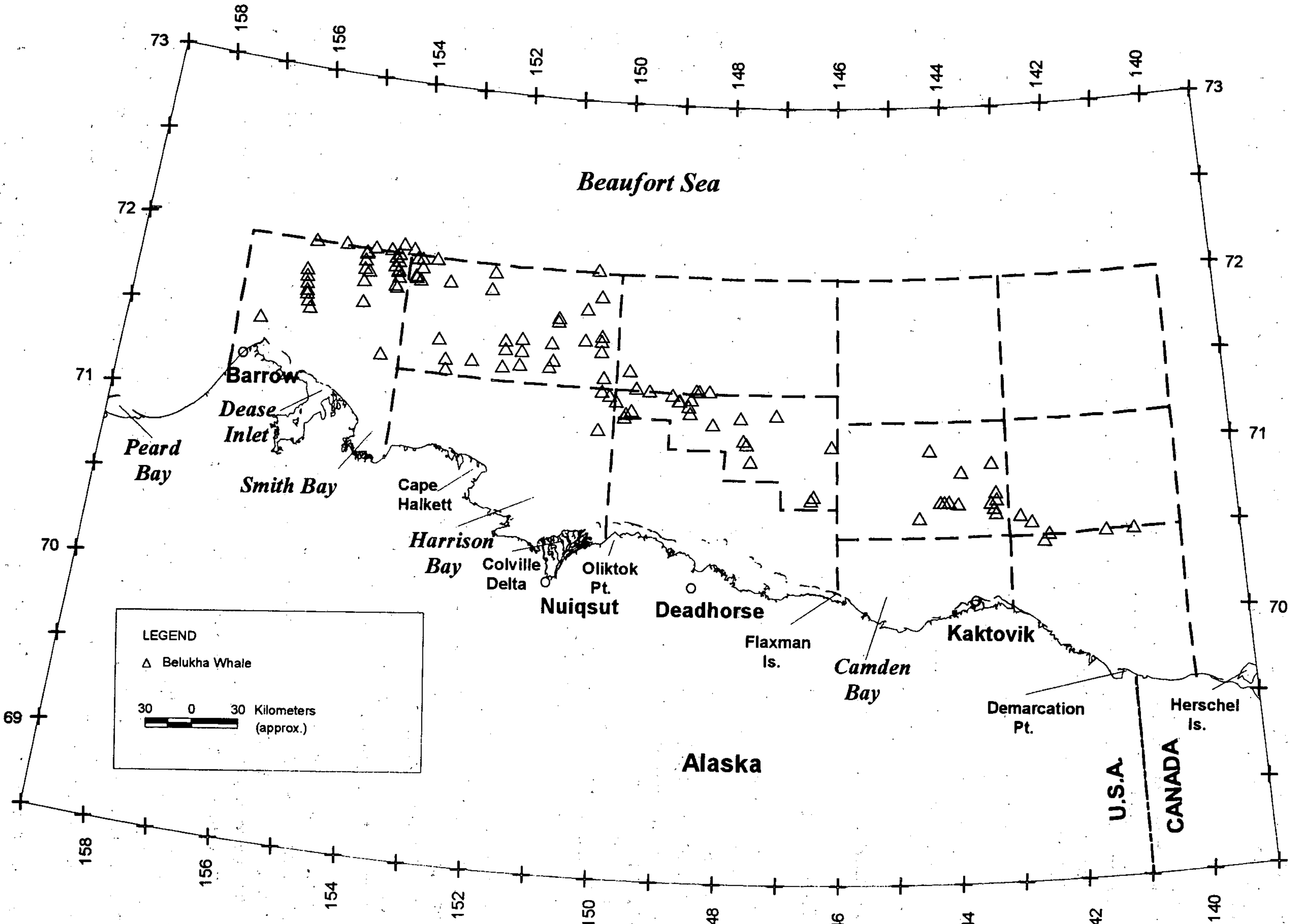

Figure 20. Map of Belukha Whale Sightings, Fall 1996

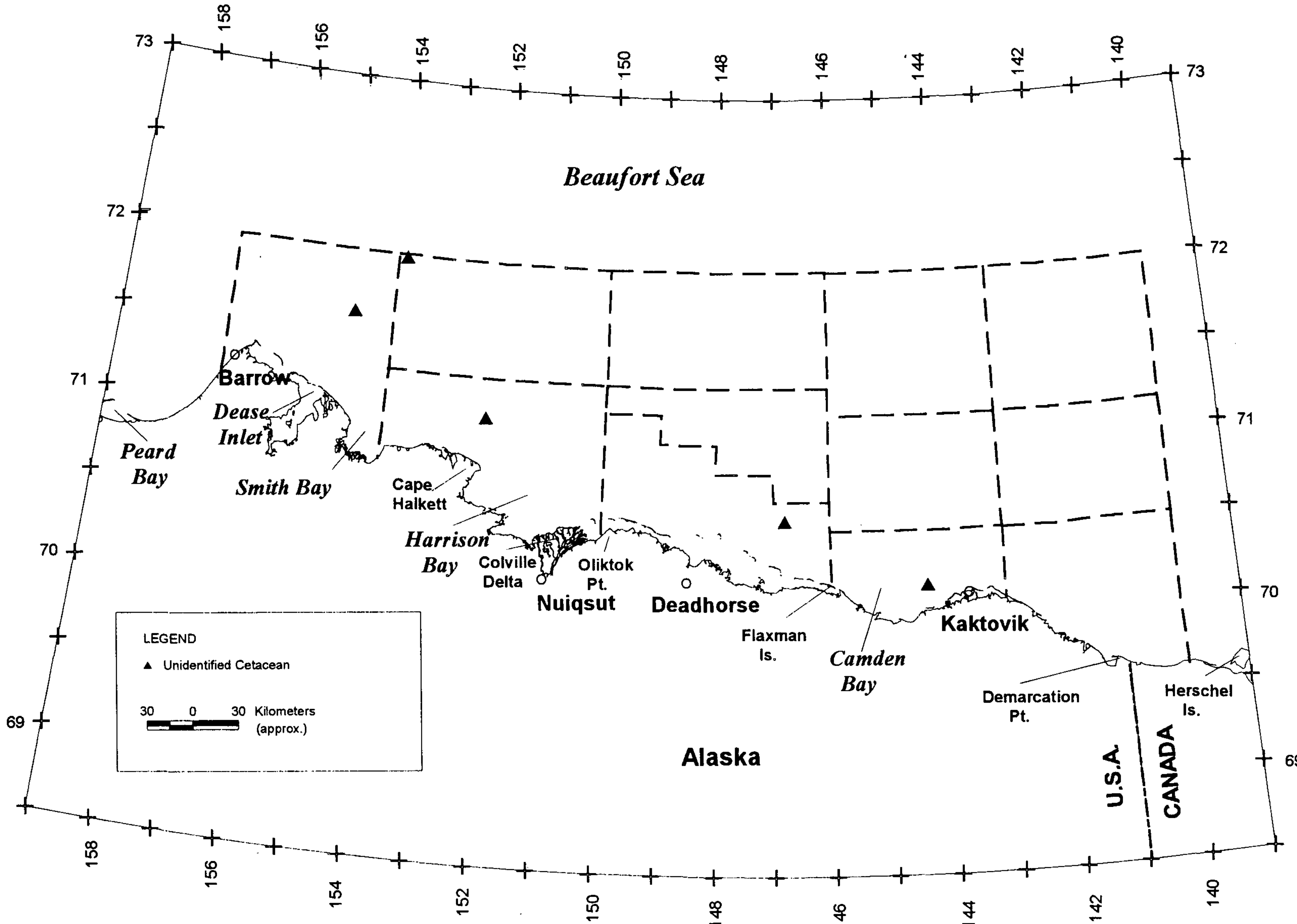

Figure 21. Map of Unidentified Cetacean Sightings, Fall 1996

4. Bearded Seal (*Erignathus barbatus*): Over the field season, 3 incidental sightings were made for a total of 3 bearded seals (Table 4) (Fig. 22). Bearded seals were sighted on 12 September, 28 September, and 7 October (Table 4) within 60 nm north of the shoreline. Two (67%) of the bearded seals were in open water and one (33%) was on the sea ice when first sighted.

5. Ringed Seal (*Phoca hispida*): Over the field season, 26 incidental sightings were made for a total of 137 ringed seals (Table 4). Sightings were evenly distributed between 143°W. and 155°W. longitudes, within 50 nm north of the shoreline (Fig.23). Ringed seals were sighted from 10 September through 7 October (Table 4). One hundred twenty-nine (94%) of the ringed seals were in open water and 8 (6%) were on the sea ice when first sighted.

6. Pacific Walrus (*Odobenus rosmarus*): No walruses were sighted during the study.

7. Unidentified Pinnipeds: No unidentified pinnipeds were sighted during the study.

8. Polar Bear (*Ursus maritimus*): Over the field season, 8 incidental sightings were made for a total of 10 polar bears (Table 4). Three sightings were made within 20 nm northeast of Flaxman Island, 2 between Cape Halkett and Smith Bay within 15 nm north of the shoreline, and 3 between Dease Inlet and Barrow within 50 nm north of the shoreline (Fig. 24). One polar bear was sighted on 10 September and 9 were sighted from 2 through 9 October (Table 4), after heavy ice concentrations had covered the study area. All 10 (100%) of the bears were on the sea ice when first sighted.

In addition to the polar bear sightings, 90 sets of polar bear tracks were recorded for which no bear was present (Table 4). Sightings were distributed between 142°W. and 157°W. longitudes within 80 nm north of the shoreline (Fig. 25). All but one of the polar bear tracks were sighted from 19 September through 9 October (Table 4), as heavy concentrations of sea ice covered the study area (Figs. 7-10).

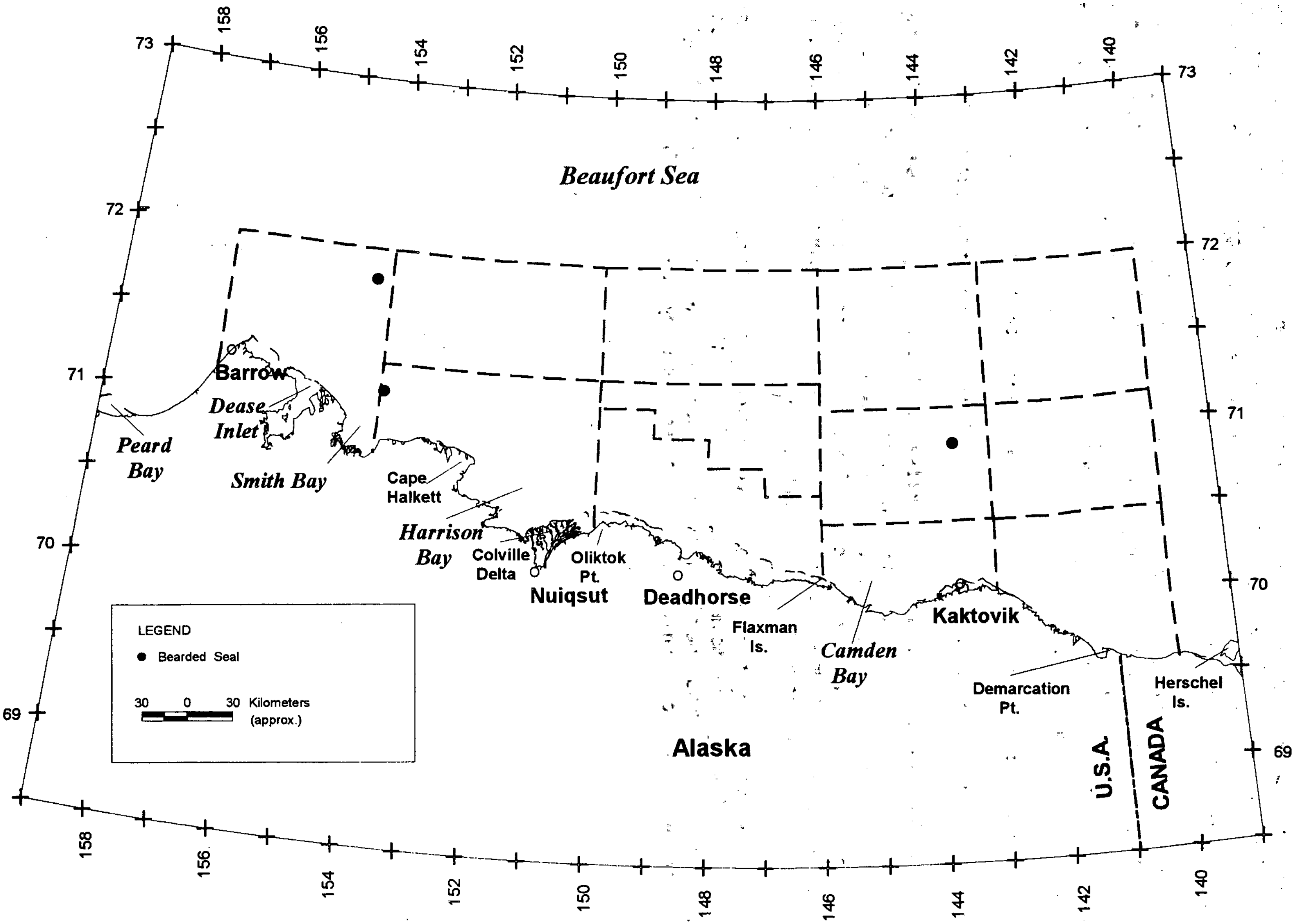

Figure 22. Map of Bearded Seal Sightings, Fall 1996

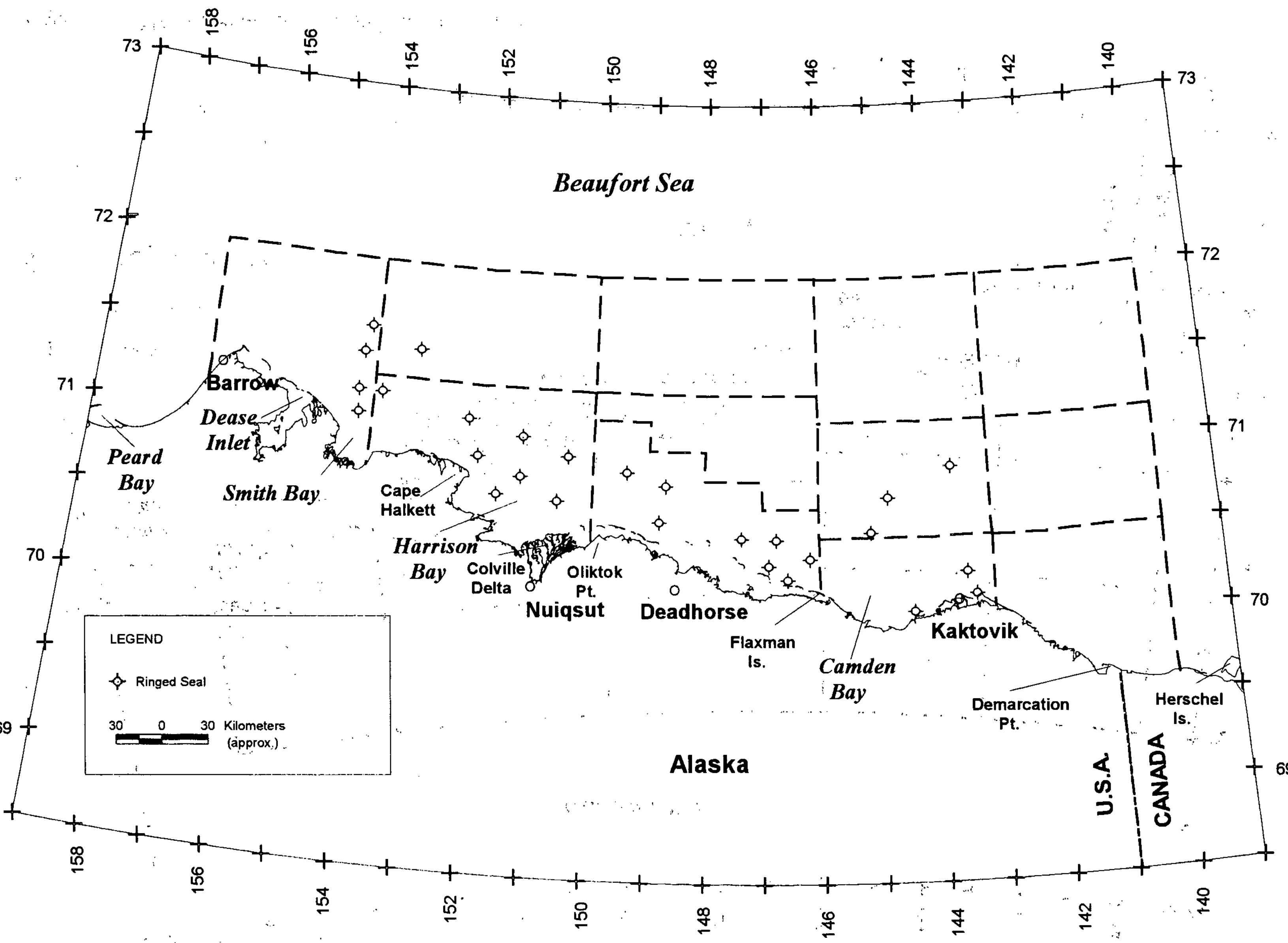

Figure 23. Map of Ringed Seal Sightings, Fall 1996

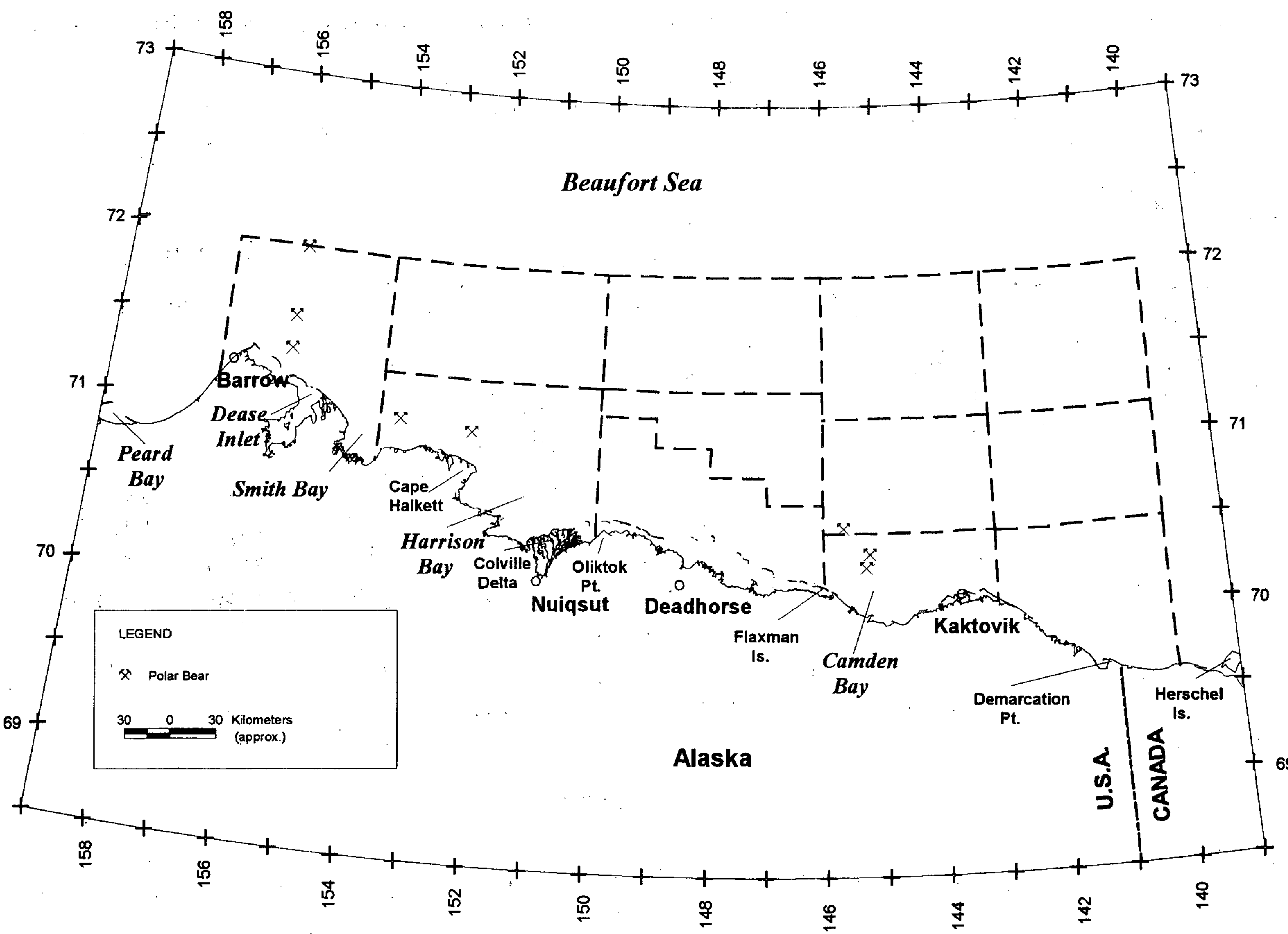

Figure 24. Map of Polar Bear Sightings, Fall 1996

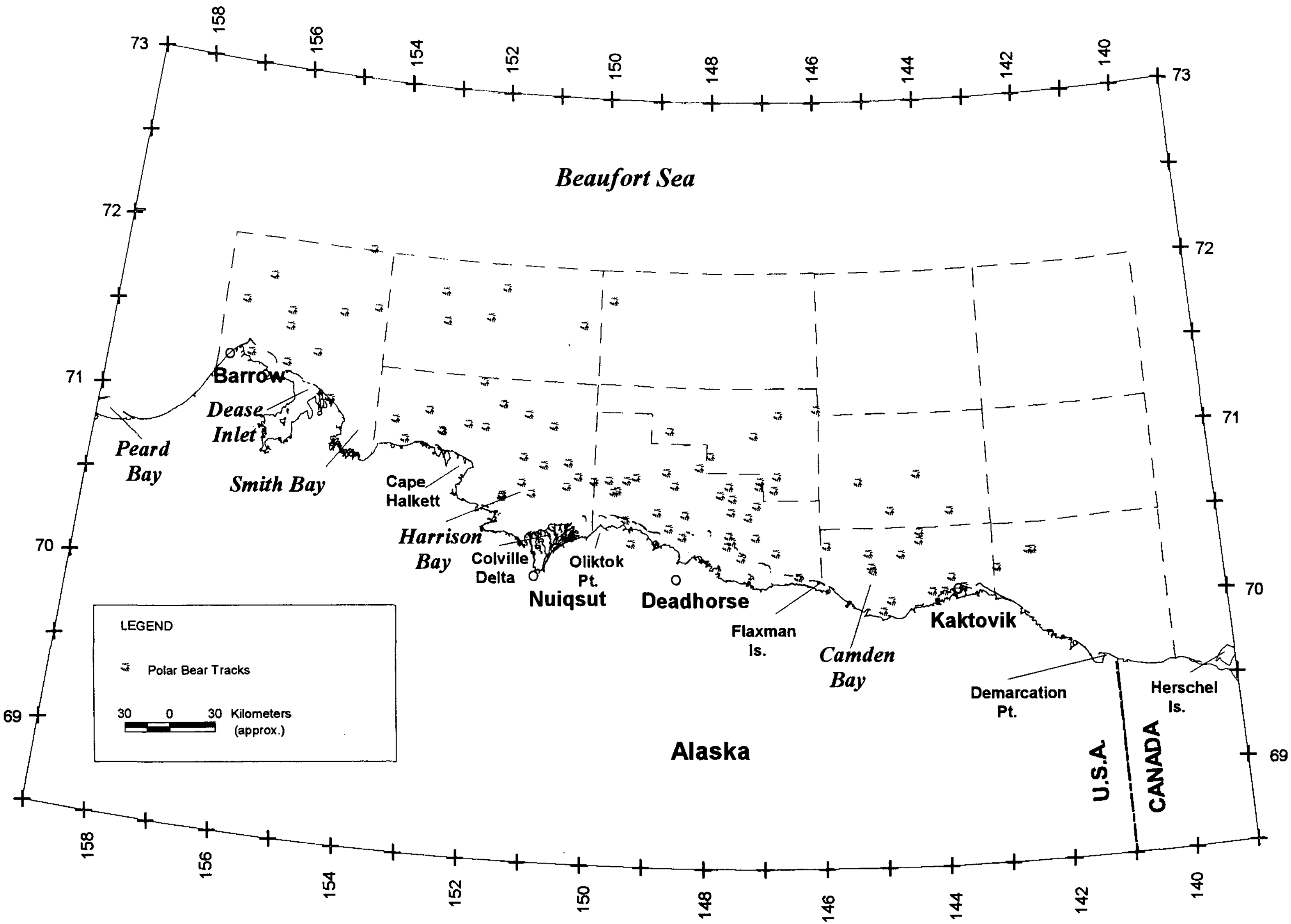

Figure 25. Map of Polar Bear Tracks, Fall 1996

IV. DISCUSSION

A. General Comparisons with Previous Surveys (1979-1995)

Most results of the present study are generally within the range of result values from previous MMS-funded endangered whale monitoring conducted during September and October (1979-1995) 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). Prior to Fall 1992, surveys in Block 12 were largely conducted from a modified Grumman Goose rather than a Twin Otter aircraft. Results for 1996 that were considered notable relative to previous values are described below.

The general ice coverage along the northern coast of Alaska during the 1996 navigation season was the tenth-mildest in the Arctic Ocean for the 44 years from 1953 through 1996 (USDOC, NOAA, National Ice Center/USDOD, Navy, Naval Ice Center, 1997).

Cloud cover over most of the study area was considered favorable for surveying in 1996, without recurrent periods of "down-to-the-deck" fog or sustained high winds and associated high sea states as in many previous field seasons.

The 1996 total of 123.00 survey hours was close to the mean of 128.53 hours (SD = 40.37, n = 9) for previous MMS surveys (1987-1995).

The number of bowhead whales counted (n = 114) during Fall 1996 was the seventh-highest out of the 10 MMS project surveys (1987-1996) and was within one SD of the mean for previous years ($\bar{x}$ = 245.44, SD = 157.87, n = 9).

For September 1996, the relative abundance of bowhead whales in Block 12 (6.63 WPUE) was the second-highest for the years 1979 through 1996. Values for relative abundance in all other survey blocks during September or October 1996 were within the range of values shown for the years 1979 through 1995 (Table 11).

The total number of belukha whales counted in Fall 1996 (n = 617) was the third-highest total number since the project began (1987-1996). The overall relative abundance of belukhas for Fall 1996 (5.12 WPUE) was more than 1 SD higher than the mean of 2.32 WPUE (SD = 2.51, n = 9) for previous project surveys (1987-1995). The number of bearded seals sighted in Fall 1996 (n=3) was lower than for previous surveys (1987-1995). Totals of other marine mammals sighted were within ranges established during previous project surveys in the Beaufort Sea (1987-1995).

B. Median and Mean Water Depth at Bowhead Sightings (1982-1995)

The median water depth at 23 sightings of bowhead whales made on randomized line transects in Regions I, II, and III (combined) (Fig. 2) during September and October 1996 was 35 m. This areawide median depth appears to be closely related to median areawide depths for most other years (Fig. 26) and falls within the range of values for previous years (range = 18 to 347 m). It is slightly less than the cumulative median depth of 37 m for the years 1982 through 1996 (n = 591). During Fall 1996, the median water depths noted for each of the 3 bathymetric regions were within the range of values for previous years. The 1996 value for Region I (42 m) was higher than the cumulative value (24 m) for previous years (1982-1995). The Fall 1996 median water depths for Regions II (28 m) and III (44 m) were very close to the cumulative values (31 m and 42 m, respectively) for previous years (1982-1995) (Table 12).

To determine whether any of the differences between the median water depth for 1996 and previous years (Table 12) were statistically significant, these values were tested using the Mann Whitney U test (Zar, 1984). The median water depth (all 3 regions combined) for the year 1996 showed a highly significant difference ($p < 0.005$) when compared to medians for the years 1983, 1989, and 1991. Analysis by region showed no differences that were highly significant between 1996 and other years in Region I (between 150°W. and

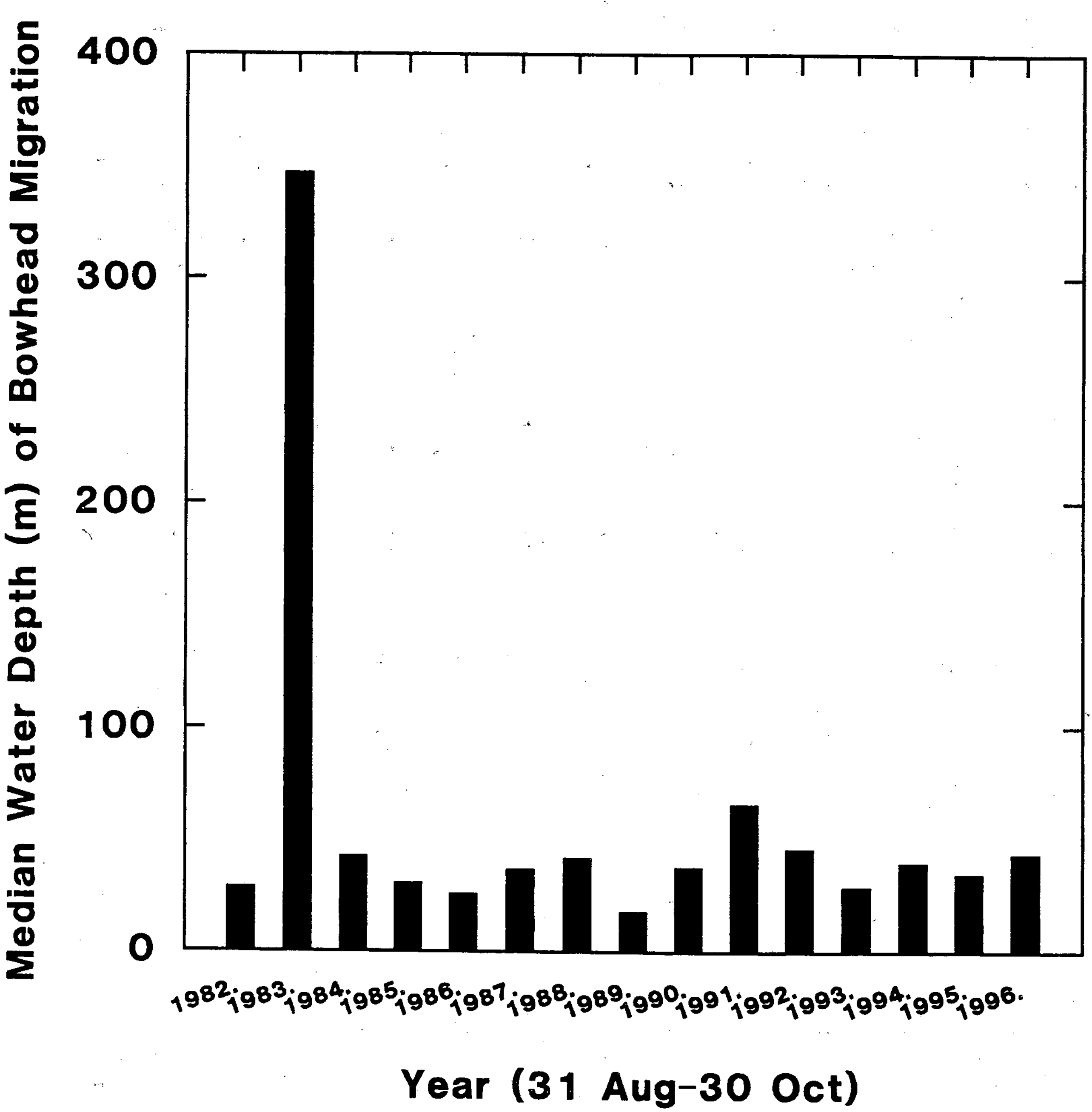

Figure 26. Median Water Depth (in meters) at Random Sightings of Bowhead Whales, by Year, 1982-1996

Table 11
Bowhead Whale Relative Abundance (WPUE) by Beaufort Sea Survey Block
during September and October, 1979-1996
(after Ljungblad et al. [1987], Moore and Clarke [1992],
and Treacy [1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996])

	Survey Block												Other	Other
Year	1	2	3	4	5	6	7	8	9	10	11	12	Canadian Areas[2]	Alaskan Areas[3]
SEPTEMBER														
1979	0.08	0.00	0.00	0.09	10.08	0.73	0.00	[1]	[1]	[1]	[1]	0.00	[1]	[1]
1980	0.38	0.00	0.00	0.47	0.99	0.00	0.00	0.00	0.00	0.00	0.00	[1]	0.47	[1]
1981	0.22	0.00	0.00	6.13	6.20	0.00	0.00	0.00	0.00	[1]	0.00	[1]	0.32	0.00
1982	6.83	1.35	0.80	0.93	11.30	0.00	0.00	0.00	1.28	[1]	0.00	0.44	48.65	0.00
1983	0.11	0.87	0.61	0.00	0.00	1.51	1.90	0.00	0.36	0.21	0.53	2.28	[1]	0.00
1984	0.59	1.05	0.18	2.69	3.19	1.94	0.00	0.00	0.00	0.00	0.00	26.24	17.00	0.00
1985	0.54	0.00	0.00	2.21	1.74	0.39	0.00	0.00	0.00	0.00	0.00	0.00	6.52	0.00
1986	0.10	0.00	0.00	0.94	2.36	0.29	0.10	0.00	0.00	0.00	0.45	0.00	7.98	0.00
1987	0.74	0.00	0.00	1.32	0.72	0.31	0.00	[1]	0.00	[1]	0.00	0.26	0.66	0.33
1988	0.14	0.00	[1]	0.35	0.48	0.45	0.00	0.00	[1]	[1]	[1]	[1]	0.00	[1]
1989	2.37	0.33	0.00	6.23	0.71	0.33	1.52	[1]	0.00	0.00	[1]	0.73	[1]	0.00
1990	5.54	0.00	0.72	7.61	18.51	3.35	1.72	[1]	0.00	0.00	0.00	[1]	63.64	0.00
1991	0.00	0.00	0.00	0.30	0.20	1.88	0.00	0.00	0.00	0.00	0.00	0.00	20.50	0.00
1992	0.45	0.20	0.12	0.73	0.91	1.75	2.48	0.00	0.00	0.00	0.13	[1]	[1]	0.00
1993	4.39	0.00	3.03	4.07	2.11	0.00	0.00	0.00	0.00	0.00	0.00	1.93	[1]	0.00
1994	0.40	0.00	1.27	1.52	11.55	3.52	0.00	[1]	[1]	0.00	0.00	[1]	[1]	0.00
1995	7.77	0.00	0.27	10.37	7.40	4.73	1.18	[1]	0.00	0.00	0.52	0.15	0.00	0.00
1996	1.38	0.00	0.30	0.57	1.15	0.24	0.00	[1]	0.00	0.00	0.00	6.63	[1]	0.00
OCTOBER														
1979	1.58	0.00	3.67	2.35	[1]	0.00	[1]	[1]	[1]	[1]	0.00	0.70	[1]	0.00
1980	0.10	1.18	0.35	0.29	0.00	0.00	[1]	[1]	[1]	0.00	0.00	0.00	0.00	0.00
1981	0.89	0.00	0.52	4.22	0.00	0.00	0.00	[1]	[1]	[1]	0.00	0.00	[1]	[1]
1982	0.19	0.00	2.48	0.00	0.70	0.00	[1]	0.00	0.00	0.00	0.19	1.87	0.46	0.00
1983	0.00	0.00	0.49	0.00	0.00	0.27	2.17	[1]	[1]	0.00	0.00	0.75	[1]	0.00
1984	0.29	0.26	1.24	0.00	1.37	0.00	[1]	[1]	[1]	0.00	3.05	2.37	3.70	0.00
1985	2.26	0.00	0.40	0.00	0.00	0.00	0.00	0.00	[1]	0.00	9.00	0.53	0.00	0.00
1986	1.00	0.38	0.47	0.71	[1]	0.00	[1]	[1]	0.00	0.00	0.00	0.91	[1]	0.00
1987	0.19	0.00	2.94	0.62	0.32	0.00	0.00	0.00	0.00	0.00	0.00	1.71	0.00	0.00
1988	0.18	0.26	1.12	0.12	0.14	0.00	0.00	[1]	0.00	[1]	0.19	1.01	0.00	0.00
1989	1.32	0.00	5.58	0.00	0.00	0.00	0.00	[1]	[1]	0.00	0.00	12.98	[1]	0.00
1990	3.00	0.00	2.14	2.17	[1]	2.86	[1]	[1]	[1]	0.00	0.97	0.74	[1]	0.00
1991	0.07	2.23	0.27	1.48	4.36	0.00	1.39	0.00	0.00	0.00	0.00	1.04	0.49	0.55
1992	0.00	0.68	0.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.92	16.35	[1]	0.00
1993	0.88	0.00	1.78	2.32	2.19	1.24	0.00	0.00	0.00	0.00	0.00	4.40	0.00	0.00
1994	0.49	0.00	0.13	0.00	0.00	0.00	[1]	[1]	[1]	0.00	0.00	0.22	[1]	0.00
1995	0.00	0.00	0.00	1.55	[1]	0.00	[1]	[1]	0.00	[1]	1.05	0.00	133.33	0.36
1996	0.00	0.00	0.31	0.00	[1]	0.00	[1]	[1]	0.00	0.00	0.58	0.00	[1]	0.00

[1] No survey effort.
[2] Between 140°W. and 141°W. longitudes north of 72°N. latitude or east of 140°W. longitude.
[3] Between 141°W. and 157°W. longitudes north of 72°N. latitude.

Table 12
Central-Tendency Statistics for Water Depth (in meters) at Random Sightings of Bowhead Whales (September-October), by Year and Region, 1982-1996

Year	Region	SI[1]	Median	CI[2]	Mean	SD[3]	Range
1982	I	8	17	11-457	113.4	176.23	11-457
	II	30	27	22-38	30.6	9.03	16-51
	III	5	40	[4]	43.4	11.24	29-59
	All 3	43	29	22-38	47.5	79.22	11-457
1983	I	9	69	22-2,323	393.7	740.61	22-2,323
	II	5	1,289	[4]	945.0	858.85	53-2,021
	III	9	797	49-1,902	969.7	740.33	49-1,902
	All 3	23	347	49-1,737	739.0	783.00	22-2,323
1984	I	15	42	27-69	53.4	41.44	18-178
	II	9	38	22-82	43.7	18.73	22-82
	III	14	48	22-274	90.4	130.05	18-485
	All 3	38	43	27-59	64.7	84.12	18-485
1985	I	3	183	[4]	219.3	221.74	18-457
	II	9	31	20-38	30.4	5.00	20-38
	III	1	[4]	[4]	[4]	[4]	64[5]
	All 3	13	31	20-183	76.6	122.13	18-457
1986	I	4	18	[4]	51.3	69.87	13-156
	II	12	17	9-40	60.7	144.79	7-519
	III	22	33	22-48	34.0	13.91	11-57
	All 3	38	26	18-44	44.3	83.03	7-519
1987	I	4	20	[4]	19.2	4.86	13-24
	II	9	27	15-38	27.3	7.60	15-38
	III	20	41	29-55	49.9	41.38	18-219
	All 3	33	37	24-44	40.0	34.54	13-219
1988	I	4	35	[4]	40.5	15.11	29-62
	II	4	44	[4]	44.7	13.60	29-62
	III	5	46	[4]	90.4	116.40	24-298
	All 3	13	42	29-62	61.0	72.17	24-298
1989	I	15	18	9-20	16.0	4.58	9-24
	II	1	[4]	[4]	[4]	[4]	44[5]
	III	3	49	[4]	49.3	9.50	40-59
	All 3	19	18	13-40	22.7	14.39	9-59
1990	I	3	31	[4]	29.3	13.58	15-42
	II	17	37	29-38	33.6	7.05	15-38
	III	68	40	37-48	40.5	10.49	16-60
	All 3	88	38	37-38	38.8	10.43	15-60

Table 12
Central-Tendency Statistics for Water Depth (in meters) at Random Sightings of Bowhead Whales (September-October), by Year and Region, 1982-1996
(Continued)

Year	Region	SI[1]	Median	CI[2]	Mean	SD[3]	Range
1991	I	0	[4]	[4]	[4]	[4]	[4]
	II	7	66	[4]	126.7	100.04	27-274
	III	6	118	[4]	132.2	92.05	48-232
	All 3	13	66	48-238	129.2	92.42	27-274
1992	I	8	40	13-329	70.3	105.24	13-329
	II	3	46	[4]	119.0	126.44	46-265
	III	9	55	44-57	50.2	8.91	29-57
	All 3	20	46	37-55	68.6	79.75	13-329
1993	I	12	15	13-18	16.1	2.23	13-20
	II	24	29	22-38	30.0	9.58	15-53
	III	39	44	27-48	44.3	34.24	9-229
	All 3	75	29	24-38	35.2	27.25	9-229
1994	I	3	13	[4]	16.3	9.45	9-27
	II	3	37	[4]	225.7	335.48	27-613
	III	21	40	29-55	41.0	11.87	22-57
	All 3	27	40	26-55	58.7	111.58	9-613
1995	I	6	131	[4]	389.2	499.21	7-1,024
	II	53	26	24-33	27.4	7.40	16-40
	III	66	39	26-48	42.0	18.39	9-143
	All 3	125	35	29-37	52.5	126.73	7-1,024
1996	I	5	42	[4]	44.2	21.41	13-68
	II	14	28	24-38	29.8	8.71	13-49
	III	4	44	[4]	43.8	7.54	35-51
	All 3	23	35	24-49	35.3	13.65	13-68
Cumulative (1982-1996)	I	99	24	18-37	101.4	280.72	7-2,323
	II	200	31	24-38	62.9	196.70	7-2,021
	III	292	42	40-46	75.9	205.81	9-1,902
	All 3	591	37	37-38	75.8	217.25	7-2,323

[1] SI = random sightings.
[2] CI ≥ 99-percent confidence interval.
[3] SD = standard deviation.
[4] Insufficient sample size.
[5] One datum.

153°30'W. longitudes) or in Region III (between 141°W. and 146°W. longitudes). There was a highly significant difference (<0.005) between the median depth for 1996 and for 1983 and 1991 in Region II (between 146°W. and 150°W. longitudes) (Table 13).

The median water depth for the year 1987 (37 m) was considered typical in that it was identical to the cumulative median (all 3 regions combined) for the years 1982 through 1996 (Table 12). Of the years when bowheads tended to migrate in water that was deeper than in 1987, the years 1983, 1991, and 1992 showed highly significant (p <0.005) differences from the 1987 depth. Conversely, the median depth for the year 1989 was very significantly (p <0.005) shallower than for 1987 (Table 13).

A high level of significance (p <0.005) was noted between the 1983 median value (all 3 regions combined = 347 m) and the median value for each other year except 1991 (p <0.05). The highly significant difference (p <0.005) between 1983 and other years was generally reflected in bathymetric Regions II and III (Table 13).

A high level of significance (p <0.005) was noted between the 1989 median value (all 3 regions combined = 18 m) and the median values for other years, except 1986 (p <0.20) and 1993 (p <0.01). In Region I, this level of difference (p <0.005) between 1989 and other years was noted for 1983, 1984, 1988, and 1993 (Table 13).

Mean water depths were also calculated for Regions I, II, and III. Mean values, although less descriptive of the apparent "axis" of the migration, were considered more robust for demonstrating significant differences between years.

The mean water depth at 23 sightings of bowhead whales made on randomized line transects in Regions I, II, and III (combined) during September and October 1996 was 35.3 m. This was within the range of areawide mean depths for the years 1982 through 1995 (previous values ranged from 22.7 to 738.9 m) and was less than the cumulative mean depth of 75.8 m for the years 1982 through 1996 (n = 591). Likewise, Fall-1996 mean water depths for Regions I (44.2 m), II (29.8 m), and III (43.8 m) were less than the cumulative values for these Regions (101.4 m, 62.9 m, and 75.9 m, respectively) (Table 12).

Comparison of the means using ANOVA and the Tukey test (Zar, 1984) showed that 1983 was unique among other years in the spatial distribution of the fall bowhead migration. Differences between the mean for 1983 and all other years (including 1996) were considered very highly significant (p <0.001) in all three regions combined and in Regions II and III, thus mirroring differences noted between the 1983 median and the medians for other years. Differences in mean water depths between all other years, including 1996, were not considered statistically significant (Table 14).

The reasons for the offshore (deep-water) migratory route of 1983 and the comparatively shallower route followed in other years (Fig. 26) may be attributable to general ice cover (see Sec. IV.D). Differences in human activity levels, oceanographic conditions, and the possible indirect effect of heavy ice cover on prey availability are additional potential factors. Ice cover probably has the greatest potential for interacting with environmental conditions that, in turn, may have biological significance to migrating bowhead whales (e.g., net primary production, availability of leads, water temperature). Median-water-depth data show that the fall migration of bowhead whales occurs in deeper water when general ice cover is more severe. Conversely, bowheads tend to migrate in shallower water during years of lighter ice cover. During 1983, the most severe ice year since 1975 (USDOC, NOAA, National Ice Center/USDOD, Navy, Naval Ice Center, 1997), the bowhead migration (all 3 regions combined) was observed in water almost an order of magnitude deeper than for other years (Table 12).

In general, mean water depths at sightings of bowhead whales were skewed to the deeper (northern) side of the migration axis (median), with cumulative mean values for each region (1982-1996) approximately twice as great (as deep) as the cumulative medians (Table 12). The reason for the differences between the mean and median values is unknown but may simply reflect the increasing gradient of the seafloor farther offshore.

Table 13
Interyear Correlation (nonparametric) of the Median Water Depths at Random Bowhead Whale Sightings (September-October) Using the Mann-Whitney U Test, 1982-1996
(Page 1 of 4)

REGION I	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
1983	$U' = 54.0$ $p \le 0.10$													
1984	$U' = 81.5$ $p < 0.20$	$U = 92.5$ $p < 0.20$												
1985	$U' = 18.0$ $p > 0.20$	$U = 14.5$ $p > 0.20$	$U' = 30.5$ $p > 0.20$											
1986	$U = 16.0$ $p > 0.20$	$U = 31.0$ $p < 0.10$	$U = 45.0$ $p < 0.20$	$U = 10.0$ $p > 0.20$										
1987	$U = 16.5$ $p > 0.20$	$U = 34.5$ $p < 0.02$	$U = 55.5$ $p < 0.01$	$U = 9.5$ $p > 0.20$	$U' = 8.5$ $p > 0.20$									
1988	$U' = 21.0$ $p > 0.20$	$U = 23.0$ $p > 0.20$	$U' = 30.5$ $p > 0.20$	$U = 8.0$ $p > 0.20$	$U' = 12.0$ $p > 0.20$	$U' = 16.0$ $p < 0.05$								
1989	$U = 76.5$ $p > 0.20$	$U = 134.0$ $p < 0.001$	$U = 216.5$ $p < 0.001$	$U = 39.0$ $p < 0.10$	$U = 37.0$ $p > 0.20$	$U = 41.5$ $p > 0.20$	$U = 60.0$ $p \le 0.001$							
1990	$U = 13.0$ $p > 0.20$	$U = 20.0$ $p > 0.20$	$U = 31.5$ $p > 0.20$	$U = 7.0$ $p > 0.20$	$U' = 7.0$ $p > 0.20$	$U' = 9.0$ $p > 0.20$	$U = 7.5$ $p > 0.20$	$U' = 35.5$ $p < 0.20$						
1991	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]					
1992	$U' = 39.5$ $p > 0.20$	$U = 48.5$ $p > 0.20$	$U = 68.0$ $p > 0.20$	$U = 16.0$ $p > 0.20$	$U' = 22.5$ $p > 0.20$	$U' = 26.5$ $p < 0.20$	$U = 16.5$ $p > 0.20$	$U' = 106.5$ $p < 0.002$	$U' = 15.5$ $p > 0.20$	[1]				
1993	$U = 66.0$ $p \le 0.20$	$U = 108.0$ $p < 0.001$	$U = 176.5$ $p < 0.001$	$U = 33.0$ $p < 0.05$	$U = 31.0$ $p > 0.20$	$U = 34.0$ $p > 0.20$	$U = 48.0$ $p \le 0.002$	$U = 96.0$ $p > 0.20$	$U = 28.5$ $p < 0.20$	[1]	$U = 84.5$ $p < 0.005$			
1994	$U = 18.0$ $p > 0.20$	$U = 26.0$ $p \le 0.02$	$U = 41.5$ $p < 0.05$	$U = 8.0$ $p \le 0.20$	$U = 8.5$ $p > 0.20$	$U = 7.5$ $p > 0.20$	$U = 12.0$ $p \le 0.10$	$U = 24.5$ $p > 0.20$	$U = 8.0$ $p \le 0.20$	[1]	$U = 21.5$ $p < 0.10$	$U = 23.0$ $p > 0.20$		
1995	$U' = 31.5$ $p > 0.20$	$U = 32.0$ $p > 0.20$	$U' = 47.5$ $p > 0.20$	$U' = 9.5$ $p > 0.20$	$U' = 17.0$ $p > 0.20$	$U' = 17.0$ $p > 0.20$	$U = 12.0$ $p > 0.20$	$U' = 68.5$ $p < 0.10$	$U' = 11.0$ $p > 0.20$	[1]	$U' = 26.0$ $p > 0.20$	$U' = 57.0$ $p < 0.10$	$U' = 13.0$ $p > 0.20$	
1996	$U' = 23.0$ $p > 0.20$	$U = 29.5$ $p > 0.20$	$U' = 38.0$ $p > 0.20$	$U = 11.0$ $p > 0.20$	$U' = 12.5$ $p > 0.20$	$U' = 16.5$ $p < 0.20$	$U' = 12.0$ $p > 0.20$	$U' = 64.0$ $p \le 0.02$	$U' = 10.5$ $p > 0.20$	[1]	$U' = 23.0$ $p > 0.20$	$U' = 49.0$ $p \le 0.05$	$U' = 13.5$ $p < 0.20$	$U = 17.0$ $p > 0.20$

Table 13
Interyear Correlation (nonparametric) of the Median Water Depths at Random Bowhead Whale Sightings (September-October) Using the Mann-Whitney U Test, 1982-1996
(Page 2 of 4)

REGION II	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
1983	$U' = 150.0$ $p < 0.001$													
1984	$U' = 193.0$ $p < 0.10$	$U = 42.0$ $p \leq 0.01$												
1985	$U = 136.0$ $p > 0.20$	$U = 45.0$ $p \leq 0.001$	$U = 62.0$ $p < 0.10$											
1986	$U = 254.0$ $p < 0.05$	$U = 58.0$ $p \leq 0.002$	$U = 86.5$ $p < 0.05$	$U = 76.5$ $p < 0.20$										
1987	$U = 155.0$ $p > 0.20$	$U = 45.0$ $p \leq 0.001$	$U = 63.5$ $p < 0.10$	$U = 53.0$ $p > 0.20$	$U' = 70.5$ $p > 0.20$									
1988	$U' = 103.0$ $p \leq 0.02$	$U = 19.0$ $p \leq 0.05$	$U' = 20.5$ $p > 0.20$	$U' = 29.0$ $p < 0.20$	$U' = 41.0$ $p \leq 0.05$	$U' = 33.0$ $p \leq 0.02$								
1989	$U' = 29.0$ $p < 0.20$	$U = 5.0$ [1]	$U' = 5.5$ $p > 0.20$	$U' = 9.0$ $p \leq 0.20$	$U' = 11.0$ $p > 0.20$	$U' = 9.0$ $p \leq 0.20$	$U = 2.0$ [1]							
1990	$U' = 280.5$ $p > 0.20$	$U = 85.0$ $p < 0.001$	$U = 101.5$ $p < 0.20$	$U' = 108.5$ $p < 0.10$	$U' = 146.0$ $p < 0.10$	$U' = 114.0$ $p \leq 0.05$	$U = 54.0$ $p < 0.10$	$U = 17.0$ $p \leq 0.20$						
1991	$U' = 195.0$ $p < 0.001$	$U = 26.00$ $p < 0.20$	$U' = 51.0$ $p \leq 0.05$	$U' = 56.0$ $p \leq 0.01$	$U' = 74.0$ $p < 0.01$	$U' = 58.5$ $p < 0.005$	$U' = 22.0$ $p < 0.20$	$U' = 6.0$ [1]	$U' = 104.0$ $p < 0.005$					
1992	$U' = 88.0$ $p \leq 0.002$	$U = 13.0$ $p \leq 0.20$	U' $p > 0.20$	21.0 $p \leq 0.01$	$U' = 27.0$ $p < 0.05$	$U' = 33.0$ $p \leq 0.01$	$U' = 27.0$ $p > 0.20$	$U' = 9.0$ [1]	$U' = 3.0$ $p \leq 0.002$	$U' = 51.0$ $p > 0.20$	$U = 13.0$			
1993	$U = 380.5$ $Z = 0.35$ $p > 0.20$	$U = 119.5$ $p < 0.001$	$U = 158.5$ $p < 0.05$	$U = 115.0$ $p > 0.20$	$U' = 196.5$ $p < 0.10$	$U' = 124.0$ $p > 0.20$	$U = 81.5$ $p < 0.05$	$U = 23.0$ $p \leq 0.20$	$U = 243.0$ $p > 0.20$	$U = 154.0$ $p < 0.001$	$U = 70.0$ $p < 0.005$			
1994	$U' = 63.0$ $p > 0.20$	$U = 13.0$ $p \leq 0.20$	$U' = 14.5$ $p > 0.20$	$U' = 19.0$ $p > 0.20$	$U' = 29.0$ $p < 0.20$	$U' = 21.0$ $p > 0.20$	$U = 7.0$ $p > 0.20$	$U = 2.0$ [1]	$U' = 28.5$ $p > 0.20$	$U = 12.5$ $p > 0.20$	$U = 6.0$ $p > 0.20$	$U' = 50.0$ $p > 0.20$		
1995	$U = 977.0$ $Z < 1.72$ $p < 0.10$	$U = 265.0$ $Z = 3.66$ $p < 0.001$	$U = 382.0$ $Z = 2.86$ $p < 0.005$	$U = 301.0$ $Z = 1.24$ $p > 0.20$	$U' = 419.5$ $Z = 1.71$ $p < 0.10$	$U = 251.5$ $Z = 0.25$ $p > 0.20$	$U = 193.5$ $Z = 2.72$ $p < 0.01$	$U = 53.0$ $Z = 1.67$ $p < 0.10$	$U = 663.5$ $Z = 2.91$ $p < 0.005$	$U = 348.5$ $Z = 3.74$ $p < 0.001$	$U = 159.0$ $Z = 2.87$ $p < 0.005$	$U = 744.0$ $Z = 1.18$ $p > 0.20$	$U = 128.0$ $Z = 1.75$ $p < 0.10$	
1996	$U = 215.5$ $p > 0.20$	$U = 70.0$ $p < 0.001$	$U = 92.5$ $p < 0.10$	$U = 73.0$ $p > 0.20$	$U' = 115.5$ $p < 0.20$	$U' = 68.0$ $p > 0.20$	$U = 48.0$ $p < 0.05$	$U = 13.0$ $p > 0.20$	$U = 158.0$ $p < 0.20$	$U = 90.5$ $p < 0.002$	$U = 40.0$ $p \leq 0.02$	$U = 168.0$ $p > 0.20$	$U = 31.0$ $p > 0.20$	$U' = 435.5$ $Z = 0.99$ $P > 0.20$

Table 13
Interyear Correlation (nonparametric) of the Median Water Depths at Random Bowhead Whale Sightings (September-October) Using the Mann-Whitney U Test, 1982-1996

REGION III	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
1983	$U' = 43.5$ $p < 0.005$													
1984	$U' = 36.5$ $p > 0.20$	$U = 117.0$ $p < 0.001$												
1985	$U' = 5.0$ [1]	$U = 8.0$ $p > 0.20$	$U' = 11.0$ $p > 0.20$											
1986	$U = 77.0$ $p \leq 0.20$	$U = 195.5$ $p < 0.001$	$U = 216.0$ $p < 0.05$	$U = 22.0$ $p \leq 0.10$										
1987	$U = 54.5$ $p > 0.20$	$U = 173.0$ $p < 0.001$	$U = 159.0$ $p > 0.20$	$U = 19.0$ $p \leq 0.20$	$U' = 284.0$ $p < 0.10$									
1988	$U = 13.0$ $p > 0.20$	$U = 43.0$ $p \leq 0.005$	$U = 38.0$ $p > 0.20$	$U = 4.0$ [1]	$U' = 70.5$ $p > 0.20$	$U' = 56.0$ $p > 0.20$								
1989	$U' = 10.0$ $p > 0.20$	$U = 25.5$ $p < 0.02$	$U' = 24.5$ $p > 0.20$	$U = 3.0$ [1]	$U' = 54.0$ $p \leq 0.10$	$U' = 41.5$ $p > 0.20$	$U' = 10.0$ $p > 0.20$							
1990	$U = 200.5$ $Z = 0.66$ $p > 0.20$	$U = 596.5$ $Z = 4.60$ $p < 0.001$	$U = 572.5$ $Z = 1.18$ $p > 0.20$	$U = 68.0$ $Z = 1.68$ $p < 0.10$	$U' = 946.0$ $Z = 1.85$ $p < 0.10$	$U = 732.0$ $Z = 0.51$ $p > 0.20$	$U = 189.0$ $Z = 0.40$ $p > 0.20$	$U = 154.0$ $Z = 1.47$ $p < 0.20$						
1991	$U' = 25.0$ $p \leq 0.10$	$U = 47.5$ $p < 0.02$	$U' = 58.0$ $p > 0.20$	$U = 3.0$ [1]	$U' = 121.0$ $p \leq 0.001$	$U' = 100.0$ $p < 0.02$	$U' = 24.0$ $p < 0.20$	$U' = 13.0$ $p > 0.20$	$U' = 354.0$ $Z = 2.96$ $p < 0.005$					
1992	$U' = 31.0$ $p < 0.20$	$U = 74.5$ $p < 0.001$	$U' = 74.0$ $p > 0.20$	$U = 9.0$ [1]	$U' = 170.5$ $p < 0.001$	$U' = 126.0$ $p \leq 0.02$	$U' = 31.0$ $p < 0.20$	$U' = 14.5$ $p > 0.20$	$U' = 477.5$ $Z = 3.47$ $p < 0.001$	$U = 34.5$ $p > 0.20$				
1993	$U = 114.5$ $p > 0.20$	$U = 341.5$ $p < 0.001$	$U = 338.5$ $p < 0.20$	$U = 37.0$ $p < 0.20$	$U' = 520.0$ $Z = 1.36$ $p < 0.20$	$U = 425.5$ $Z = 0.56$ $p > 0.20$	$U = 104.0$ $p > 0.20$	$U = 84.5$ $p > 0.20$	$U = 1,384.0$ $Z = 0.37$ $p > 0.20$	$U = 201.5$ $p < 0.005$	$U = 271.5$ $p < 0.001$			
1994	$U = 58.0$ $p > 0.20$	$U = 182.5$ $p < 0.001$	$U = 171.0$ $p > 0.20$	$U = 21.0$ $p \leq 0.10$	$U' = 298.5$ $Z = 1.63$ $p < 0.05$	$U = 217.5$ $p > 0.20$	$U = 56.0$ $p > 0.20$	$U = 44.5$ $p > 0.20$	$U' = 747.5$ $Z = 0.32$ $p > 0.20$	$U = 106.5$ $p < 0.02$	$U = 139.00$ $p < 0.01$	$U' = 437.5$ $Z = 0.43$ $p > 0.20$		
1995	$U = 189.5$ $Z = 0.54$ $p > 0.20$	$U = 577.5$ $Z = 4.56$ $p < 0.001$	$U = 555.5$ $Z = 1.18$ $p > 0.20$	$U = 63.0$ $Z = 1.53$ $p < 0.20$	$U' = 898.5$ $Z = 1.29$ $p < 0.20$	$U = 708.5$ $Z = 0.49$ $p > 0.20$	$U = 189.5$ $Z = 0.54$ $p > 0.20$	$U = 144.5$ $Z = 1.32$ $p < 0.20$	$U' = 2,249.5$ $Z = 0.02$ $p > 0.20$	$U = 343.0$ $Z = 2.94$ $p < 0.005$	$U = 436.5$ $Z = 2.27$ $p < 0.05$	$U' = 1,322.5$ $Z = 0.23$ $p > 0.20$	$U = 710.5$ $Z = 0.17$ $p > 0.20$	
1996	$U' = 10.5$ $p > 0.20$	$U = 34.5$ $p < 0.02$	$U = 29.5$ $p > 0.20$	$U = 4.0$ [1]	$U' = 64.0$ $p < 0.20$	$U' = 42.5$ $p > 0.20$	$U' = 11.0$ $p > 0.20$	$U = 8.0$ $p > 0.20$	$U' = 161.0$ $Z = 0.60$ $p > 0.20$	$U = 20.0$ $p < 0.20$	$U = 28.5$ $p < 0.20$	$U' = 95.0$ $p > 0.20$	$U' = 45.5$ $p > 0.20$	$U' = 155.5$ $Z = 0.58$ $p > 0.20$

Table 13
Interyear Correlation (nonparametric) of the Median Water Depths at Random Bowhead Whale Sightings (September-October) Using the Mann-Whitney U Test, 1982-1996

ALL THREE REGIONS (COMBINED)

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
1983	U′ = 882.0 Z = 5.21 p < 0.001													
1984	U′ = 1,138.5 Z = 3.04 p < 0.005	U = 717.5 Z = 4.17 p < 0.001												
1985	U′ = 316.5 Z = 0.71 p > 0.20	U = 249.5 p < 0.001	U = 297.5 p > 0.20											
1986	U = 898.0 Z = 0.76 p > 0.20	U = 786.0 Z = 5.19 p < 0.001	U = 1,043.0 Z = 3.33 p < 0.001	U = 314.0 p < 0.20										
1987	U′ = 798.5 Z = 0.93 p > 0.20	U = 666.5 Z = 4.77 p < 0.001	U = 809.5 Z = 2.10 p < 0.05	U = 223.0 p > 0.20	U′ = 760.5 Z = 1.53 p < 0.20									
1988	U′ = 414.0 Z = 2.60 p < 0.01	U = 245.5 p < 0.002	U′ = 248.0 p > 0.20	U′ = 104.5 p > 0.20	U′ = 356.5 p < 0.02	U′ = 291.0 p < 0.10								
1989	U = 598.0 Z = 2.89 p < 0.005	U = 417.5 p < 0.001	U = 617.0 p < 0.001	U = 198.5 p < 0.005	U = 457.0 p < 0.20	U = 480.5 p < 0.002	U = 214.0 p < 0.001							
1990	U′ = 2,473.5 Z = 2.85 p < 0.005	U = 1,729.5 Z = 8.10 p < 0.001	U = 1,949.5 Z = 1.47 p < 0.20	U′ = 682.5 Z = 1.12 p > 0.20	U′ = 2,227.5 Z = 2.95 p < 0.005	U′ = 1,717.5 Z = 1.54 p < 0.20	U = 674.5 Z = 1.03 p > 0.20	U′ = 1,353.0 Z = 4.21 p < 0.001						
1991	U′ = 503.0 Z = 4.33 p < 0.001	U = 213.0 p < 0.05	U′ = 373.5 p < 0.01	U′ = 134.5 p < 0.02	U′ = 446.0 p < 0.001	U′ = 377.0 p < 0.001	U′ = 135.0 p ≤ 0.01	U′ = 236.0 p < 0.001	U′ = 999.0 Z = 4.33 p < 0.001					
1992	U′ = 663.0 Z = 3.88 p < 0.001	U = 368.5 p < 0.001	U′ = 410.0 p > 0.20	U′ = 170.5 p < 0.10	U′ = 578.0 p < 0.001	U′ = 470.5 p < 0.005	U′ = 150.5 p > 0.20	U′ = 325.5 p < 0.001	U′ = 1,185.5 Z = 2.85 p < 0.005	U = 193.5 p < 0.01				
1993	U′ = 1,614.5 Z = 0.01 p > 0.20	U = 1,545.5 Z = 5.72 p < 0.001	U = 1,981.0 Z = 3.38 p < 0.001	U = 568.0 Z = 0.94 p > 0.20	U′ = 1,580.5 Z = 0.95 p > 0.20	U = 1,381.5 Z = 0.96 p > 0.20	U = 679.5 Z = 2.25 p < 0.05	U′ = 1,007.0 Z = 2.77 p < 0.01	U = 4,200.5 Z = 3.00 p < 0.005	U = 886.5 Z = 4.69 p < 0.001	U = 1,111.0 Z = 3.75 p < 0.001			
1994	U′ = 754.0 Z = 2.09 p < 0.05	U = 523.0 Z = 4.13 p < 0.001	U = 594.5 Z = 1.08 p > 0.20	U′ = 190.0 p > 0.20	U′ = 682.0 Z = 2.24 p < 0.05	U′ = 510.5 Z = 0.96 p > 0.20	U = 205.5 p > 0.20	U′ = 410.0 p < 0.001	U′ = 1,190.0 Z = 0.01 p > 0.20	U = 293.5 p < 0.001	U = 347.0 p < 0.05	U′ = 1,267.5 Z = 1.93 p < 0.10		
1995	U′ = 2,945.5 Z = 0.94 p > 0.20	U = 2,516.5 Z = 5.71 p < 0.001	U = 3,109.0 Z = 2.88 p < 0.005	U = 830.5 Z = 0.13 p > 0.20	U′ = 2,837.0 Z = 1.81 p < 0.10	U = 2,117.0 Z = 0.23 p > 0.20	U = 1,101.0 Z = 2.10 p < 0.05	U′ = 1,814.5 Z = 3.70 p < 0.001	U = 6,708.0 Z = 2.73 p < 0.01	U = 1,432.0 Z = 4.51 p < 0.001	U = 1,801.0 Z = 3.16 p < 0.002	U′ = 5,144.5 Z = 1.15 p > 0.20	U = 1,979.5 Z = 1.41 p < 0.20	
1996	U′ = 561.5 Z = 0.89 p > 0.20	U = 465.5 Z = 4.40 p < 0.001	U = 564.5 Z = 1.89 p < 0.10	U = 153.5 p > 0.20	U′ = 535.5 Z = 1.46 p < 0.20	U′ = 380.0 [1]	U = 201.0 p ≤ 0.10	U′ = 339.0 p ≤ 0.002	U = 1,213.0 Z = 1.46 p < 0.20	U = 266.5 p < 0.001	U = 332.0 p < 0.02	U′ = 962.0 Z = 0.83 p > 0.20	U = 361.0 Z = 0.97 p > 0.20	U′ = 1,479.5 Z = 0.22 p > 0.20

[1] Insufficient sample size.

Table 14
Interyear Correlation (parametric) of the Mean Water Depths at Random Bowhead Whale Sightings (September-October) Using Analysis of Variants (ANOVA) and the Tukey Test, 1982-1996

REGION I[1]
ANOVA F = 1.781, $p < 0.20$

Tukey Test:

(1989)	(1993)	(1994)	(1987)	(1990)	(1988)	(1996)	(1986)	(1984)	(1992)	(1982)	(1985)	(1995)	(1983)
16.0	16.1	16.3	19.3	29.3	40.5	44.2	51.3	53.4	70.3	113.4	219.3	389.2	393.7

REGION II
ANOVA F = 15.760, $p << 0.001$

Tukey Test:

(1987)	(1995)	(1996)	(1993)	(1985)	(1982)	(1990)	(1984)	(1989)	(1988)	(1986)	(1992)	(1991)	(1994)	(1983)
27.3	27.4	29.8	30.0	30.4	30.6	33.6	43.7	44.0[2]	44.8	60.8	119.0	126.7	225.7	945.0

(p < 0.001)

REGION III
ANOVA F = 30.853, $p << 0.001$

Tukey Test:

(1986)	(1990)	(1994)	(1995)	(1982)	(1996)	(1993)	(1989)	(1987)	(1992)	(1985)	(1984)	(1988)	(1991)	(1983)
34.1	40.5	41.0	42.0	43.4	43.8	44.3	49.3	49.9	50.2	64.0[2]	90.4	90.4	132.2	969.8

(p < 0.001)

ALL THREE REGIONS (COMBINED)
ANOVA F = 25.623, $p << 0.001$

Tukey Test:

(1989)	(1993)	(1996)	(1990)	(1987)	(1986)	(1982)	(1995)	(1994)	(1988)	(1984)	(1992)	(1985)	(1991)	(1983)
22.7	35.2	35.4	38.8	40.0	44.3	47.5	52.5	58.7	61.0	64.7	68.6	76.6	129.2	739.0

(p << 0.001)

[1] No data for Region I during 1991.
[2] One datum.

C. Potential Responses of Bowheads to Survey Aircraft

During the 1996 field season, there were no sightings of bowhead whales for which definite responses to the survey aircraft were apparent. Although it was not possible to determine if any responses would have been a direct result of overflight by survey aircraft, sudden overt changes (e.g., an abrupt dive, course diversion, or cessation of behavior ongoing) in whale behavior were looked for.

D. Potential Effect of General Ice Cover on WPUE (1979-1996)

During September and October (combined) 1996, there were 114 bowhead whales observed during 123.54 hr for a relative abundance of 0.93 WPUE in Survey Blocks 1 through 12, with 1.18 WPUE during September and 0.19 WPUE during October (Table 15). Bowhead relative abundance in 1996 was considered representative of that for more severe ice years, possibly due to a higher proportion of survey effort over sea-ice concentrations that were heavier than for the study area as a whole.

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 1995 and show 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, 1997).

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 1995 and show 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, 1997).

The years 1979, 1981, 1982, 1986, 1987, 1989, 1990, 1993, 1994, 1995, and 1996, 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 1996 and show distances ranging from 50 to 185 nm between Point Barrow and the five-tenths ice concentration on 15 September (USDOC, NOAA, National Ice Center/USDOD, Navy, Naval Ice Center, 1997).

Table 15 shows a low relative abundance of bowhead whales in the primary study area (Survey Blocks 1-12) during September and October (combined) for years of heavy ice cover (0.46 WPUE), a middle-range value for moderate ice years (1.55 WPUE), and a high value for light ice years (2.04 WPUE). A Kruskal-Wallis single-factor analysis of variance by ranks (Zar, 1984) showed that ice-year categories were significantly related ($p < 0.05$) to annual relative abundance.

Although cumulative values for the three ice-year categories (Table 15) and the Kruskal-Wallis test ($p \leq 0.010$) suggest a relationship to annual relative abundance, it is clear that WPUE value is not totally dependent on general ice coverage. While the mean WPUE for heavy ice years ($\bar{x} = 0.46$, SD = 0.15, n = 4) appears separable from other ice-year categories, the SD of the mean WPUE for light ice years ($\bar{x} = 2.20$, SD = 1.33, n = 11) overlaps that for moderate ice years ($\bar{x} = 1.53$, SD = 0.66, n = 3). Likewise, a nonparametric Tukey-type test (Zar, 1984) for comparing unequal sample sizes showed that while relative abundance of bowheads in light ice years was significantly different ($p < 0.05$) from that in heavy ice years, neither of these two categories was significantly different from relative abundance in moderate ice years. A separate comparison of ice concentrations at the location of bowhead sightings (1981-1986) with the observability of whales showed that sighting distance was significantly affected by local ice cover only in 1982 and 1983 (Ljungblad et al., 1987).

Even though the study should not be used to estimate total whale population, the relative abundance of bowhead whales was compared between years to obtain a rough indication of any gross temporal trends. In order to control one particular bias against extreme variation in ice severity between years, the WPUE was compared during September, October, and both months combined (Table 15) for only those years of light ice (1979, 1981, 1982, 1986, 1987, 1989, 1990, 1993, 1994, 1995, and 1996). The data showed weak tendencies for bowhead relative abundance to increase from 1979 through 1995, but the correlations were

Table 15
Relative Abundance (WPUE) of Bowhead Whales within the Primary Study Area (Survey Blocks 1-12) during September and October[1], by Year and General Ice Coverage, 1979-1996

Year	September			October			Total (Sep-Oct)		
	Hours	BH	WPUE	Hours	BH	WPUE	Hours	BH	WPUE
1979	51.80	60	1.16	79.99	130	1.63	131.79	190	1.44
1980[2]	76.41	30	0.39	50.72	12	0.24	127.13	42	0.33
1981	70.28	231	3.29	46.00	54	1.17	116.28	285	2.45
1982	77.91	283	3.63	35.19	29	0.82	113.10	312	2.76
1983[2]	101.73	72	0.71	41.48	17	0.41	143.21	89	0.62
1984[3]	73.64	216	2.93	63.49	85	1.34	137.13	301	2.19
1985[3]	67.39	52	0.77	58.22	57	0.98	125.61	109	0.87
1986	100.21	65	0.65	51.96	35	0.67	152.17	100	0.66
1987	90.07	61	0.68	77.07	76	0.99	167.14	137	0.82
1988[2]	64.96	21	0.32	55.49	19	0.34	120.45	40	0.33
1989	69.84	141	2.02	38.61	149	3.86	108.45	290	2.67
1990	54.85	401	7.31	41.37	77	1.86	96.22	478	4.97
1991[2]	38.36	9	0.23	51.13	40	0.78	89.49	49	0.55
1992[3]	104.28	63	0.60	90.52	234	2.59	194.80	297	1.52
1993	87.33	217	2.48	77.89	136	1.75	165.22	353	2.14
1994	67.55	183	2.71	53.24	9	0.17	120.79	192	1.59
1995	91.72	413	4.50	19.33	7	0.36	111.05	420	3.78
1996	91.49	108	1.18	32.05	6	0.19	121.96	114	0.93

Table 15
Relative Abundance (WPUE) of Bowhead Whales within the Primary Study Area (Survey Blocks 1-12) during September and October[1], by Year and General Ice Coverage, 1979-1996
(Continued)

Ice Coverage	September			October			Total (Sep-Oct)		
	Hours	BH	WPUE	Hours	BH	WPUE	Hours	BH	WPUE
Heavy Ice Years[2](∑)	281.46	132	0.47	198.82	88	0.44	480.28	220	0.46
Moderate Ice Years[3](∑)	245.31	331	1.35	212.23	376	1.77	457.54	707	1.55
Light Ice Years (∑)	853.05	2,163	2.54	552.70	708	1.28	1,404.17	2,871	2.04

[1] After Ljungblad et al. (1987), Moore and Clarke (1992), and Treacy (1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996).
[2] 1980, 1983, 1988, and 1991 were considered years of heavy ice coverage.
[3] 1984, 1985, and 1992 were considered years of moderate ice coverage.

not statistically significant. This result is likely influenced by between-year variations in migration timing, the large size of the study area, as well as day-to-day variations in ice cover and other environmental conditions affecting observer visibility.

E. 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.

In Winter and Spring 1996, there was one over-ice seismic program in the Beaufort Sea in Federal waters. The program took place east of Prudhoe Bay (24 March-17 April) and used vibrators as an energy source. There was also one shallow-coring program in Federal waters in the eastern Beaufort Sea in April. There was one marine-seismic program northwest of Prudhoe Bay during the summer of 1996 (24 July-19 September).

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 areawide permit restrictions on high-energy seismic operations during the whale migration.

There were no drilling operations, with associated helicopter and vessel support, in the Beaufort Sea in 1996. 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.

Project ice data were transmitted daily to the U.S. Navy, Naval Ice Center, for their use in ground-truthing satellite imagery. In general, sighting data are used by several 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. Data from previous surveys continue to be used by MMS in writing Environmental Impact Statements (EIS) and Environmental Assessments and in interpreting the results of site-specific studies.

F. Field Coordinations and Information Support

During the field season, we coordinated with the Alaska Eskimo Whaling Commission (AEWC), Barrow, Alaska; the BP Exploration (Alaska) Inc. (BPXA) Northstar site-specific aerial survey team; Whalers Communication Center, Deadhorse, Alaska; NMFS, Anchorage, Alaska; and North Slope Borough (NSB), Department of Wildlife Management, Barrow, Alaska. Accompanying the project this year and actively participating in selected survey flights were John Goll, MMS Acting Alaska Region Director (Flights 22 and 23); Mary Catherine Ishee, USDOI Solicitor (Flight 16); and George Valiulis, MMS Environmental Specialist (Flight 32).

Selected BWASP information-support activities during the year included (1) providing data summaries to various requesting agencies and private-sector organizations, including AEWC, BPXA, and Northstar EIS Development Project; (2) providing our Fall-1995 report, along with project descriptions, on the Alaska OCS Region MMS Internet web site (http://www.mms.gov/omm/alaska); (3) photographing Dinkum Sands (near Deadhorse, Alaska) for use by the MMS Leasing Activities Section and the U.S. Department of Justice; (4) providing an interview about project activities for a radio station (KBRW) in Barrow, Alaska; (5) authoring an article entitled "MMS Alaska Arctic Environmental Studies: Melding Science and Traditional Ecological Knowledge for Future Offshore Oil and Gas Development Decisions" submitted to the *Arctic Science Journal*; (6) providing the text for an article entitled "Global Positioning Technology Helps Track People, Aircraft, and Whales" in *USDOI, People, Land, & Water* (Vol. 4, No. 1); (7) providing a set of previous project reports to the Seal Conservation Society, Aberdeenshire, United Kingdom, for use in their society's Seal Reference Database; (8) providing digital data and technical support to a re-analysis by Mr. Jeremy Davies of the Fall-1993 bowhead whale distribution in the vicinity of the Kuvlum drill site; and (9) serving as Co-Chair (with Dr. Tom Albert, NSB) at an Arctic Seismic Synthesis and Mitigating Measures Workshop, Barrow, Alaska, and presenting a talk there entitled "The Beaufort Sea Bowhead Whale Migration."

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APPENDIX A

BOWHEAD WHALE DENSITIES

BOWHEAD WHALE DENSITIES

This appendix presents estimated bowhead whale densities in the Beaufort Sea for the period 1 September through 9 October 1996. Present survey goals do not include estimation of absolute population abundance; therefore, raw density values found in this report were not adjusted to account for submergence of whales, sighting variability, etc., and are presented only for relative visual comparison with similarly calculated values from previous survey reports. Also, sample sizes for determining density in individual survey blocks were considered too small to stratify by category (sea state, ice cover, etc.) or to make statistical correlations having real biological significance.

METHODS

A computer program—DENSITY—was used to calculate raw density estimates for survey blocks previously shown for the Beaufort Sea (Fig. 1). The program was based on strip-transect methodologies that use only sightings made on random-transect legs (Estes and Gilbert, 1978) and that were within a predetermined distance from the aircraft (Hayne, 1949). Distance from the transect line was calculated trigonometrically from the altitude of the survey plane at the time of sighting and the clinometer angle recorded for each initial sighting location. Only endangered whale sightings within 1 km of random-transect legs were used to derive density estimates. The number of sightings made from project aircraft decreased markedly much beyond that distance, with 69 percent of sightings from the Twin Otter made within 1 km of the trackline. The basic assumptions for use of this formula, and the degree to which these assumptions were met in the Fall-1996 and previous MMS-funded arctic whale surveys, are incorporated by reference (Ljungblad et al., 1987: Appendix B).

RESULTS

Densities by survey block were estimated as the number of bowhead whales per 100 km^2 (Table A-1).

During the first half of September, there were no Beaufort Sea blocks for which more than 10 percent of the area was surveyed, and no bowheads were observed within 1 km of the randomly generated transect line (Table A-1).

During the second half of September, over 10 percent of the area was surveyed for Blocks 1, 2, 4, 6, and 11. Of these particular blocks, 8 bowhead whales were observed in Block 1 within 1 km of the randomly generated transect line, for an estimated density of 0.36 per 100 km^2; 2 whales were observed in Block 4, for an estimated density of 0.10; 1 whale was observed in Block 2, for an estimated density of 0.08; and no whales were observed in Blocks 6 and 11, for estimated densities of 0.00. Eleven bowhead whales were observed within 1 km of the transect line in other Beaufort Sea blocks during this period (Table A-1).

From 1 through 9 October, over 10 percent of the area was surveyed for Blocks 3, 6, and 11. Of these particular blocks, 3 bowhead whales were observed in Block 11 within 1 km of the randomly generated transect line, for an estimated density of 0.19 per 100 km^2; and no whales were observed in Blocks 3 and 6, for estimated densities of 0.00. No bowhead whales were observed within 1 km of the transect line in other Beaufort Sea blocks during this period (Table A-1).

Table A-1
Semimonthly Estimates of Bowhead Whale Densities, by Survey Block, Fall 1996
(strip width = 2 km)

Block No. (by Semi-monthly Period)	Block Area (km^2)	Transect Distance (km)	Percent of Area Surveyed	Transect Time (hr)	Percent of Total Time	No. of Transects Flown	No. of Whales Observed	Density (Whales/ 100 km^2)
1-15 Sep								
3	11,475	134	2.34	0.63	23.19	2	0	0.00
5	9,481	421	8.88	1.96	72.45	5	0	0.00
7	8,109	22	0.54	0.11	4.09	1	0	0.00
11	10,358	1	0.03	0.01	0.27	1	0	0.00
16-30 Sep								
1	10,222	1,099	21.50	5.04	20.06	32	8	0.36
2	6,672	617	18.50	2.78	11.06	19	1	0.08
3	11,475	559	9.74	2.45	9.78	10	2	0.18
4	5,714	958	33.53	4.50	17.94	24	2	0.10
5	9,481	197	4.16	0.97	3.85	4	1	0.25
6	8,109	789	19.46	3.69	14.71	15	0	0.00
9	9,753	1	0.02	0.00	0.02	3	0	0.00
10	10,358	72	1.39	0.32	1.28	2	0	0.00
11	10,358	809	15.61	3.64	14.49	12	0	0.00
12	11,163	388	6.95	1.70	6.76	6	8	1.03
12N	11,453	1	0.01	0.00	0.01	1	0	0.00
1-9 Oct								
1	10,222	309	6.04	1.42	9.03	7	0	0.00
2	6,672	319	9.57	1.49	9.47	6	0	0.00
3	11,475	776	13.53	3.66	23.31	14	0	0.00
4	5,714	274	9.60	1.26	8.01	6	0	0.00
6	8,109	443	10.93	2.01	12.78	6	0	0.00
9	9,753	0	0.01	0.00	0.01	1	0	0.00
10	10,358	2	0.05	0.01	0.07	1	0	0.00
11	10,358	780	15.06	3.60	22.92	14	3	0.19
12	11,163	457	8.19	2.23	14.18	6	0	0.00
12N	11,453	4	0.08	0.02	0.15	1	0	0.00

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APPENDIX B

DAILY FLIGHT SUMMARIES

DAILY FLIGHT SUMMARIES

This appendix consists of maps for Flights 1 through 34 that depict aerial surveys flown over the study area from 1 September through 9 October 1996 aboard the Twin Otter aircraft. Daily maps show survey tracks and the initial position of marine mammal sightings.

A comparison of daily flight maps can be made on a visual basis over the period of the field season to evaluate ongoing patterns of marine mammal distribution and aircraft coverage. Each map shows the flight track as a line drawn through position updates recorded on the aircraft computer system. Each animal sighting is marked with a species symbol on the flight-track plot. The symbols used can be keyed out using the species legend found on each map. Positional and other data for each sighting of bowhead whales are summarized in Table B-1.

Table B-1
Selected Sighting Data for Bowhead Whales Observed, Fall 1996
(Page 1 of 3)

Flight No.	Day	Total Whales	No. of Calves	Latitude	Longitude	Sighting Cue	Behavior	Compass Heading	Ice (%)	Sea State	Depth (m)
1	2 Sep	2	0	70°25.5	146°47.3	body	slap	[1]	10	3	27
1	2 Sep	1	0	70°22.8	147°03.2	body	rest	240°	10	3	15
1	2 Sep	1	0	70°22.8	147°03.2	body	swim	27°	1	3	15
1	2 Sep	1	0	70°24.5	147°02.4	body	feed	340°	1	3	18
1	2 Sep	1	0	70°25.4	147°04.9	body	rest	[1]	10	3	18
1	2 Sep	1	0	70°25.9	147°00.4	body	swim	50°	10	3	18
1	2 Sep	2	0	70°30.2	147°03.5	body	mill	[1]	5	3	33
1	2 Sep	1	0	70°36.6	147°40.5	body	dive	240°	10	2	29
1	2 Sep	1	0	70°35.1	147°39.2	body	swim	300°	10	2	29
1	2 Sep	1	0	70°32.9	147°41.9	body	swim	[1]	10	4	13
2	5 Sep	1	0	70°40.0	146°13.9	body	swim	70°	15	4	40
5	8 Sep	4	0	70°24.9	146°47.3	body	mill	[1]	10	4	27
5	8 Sep	2	1	70°30.2	145°04.4	body	cow with calf	[1]	15	3	42
6	9 Sep	1	0	70°23.1	142°45.4	body	swim	[1]	40	4	59
6	9 Sep	1	0	70°12.1	142°10.4	body	swim	210°	30	3	49
7	10 Sep	2	0	70°12.1	142°01.3	body	swim	270°	10	1	53
7	10 Sep	1	0	70°12.8	142°02.4	body	swim	270°	10	1	53
7	10 Sep	1	0	69°54.9	140°55.5	body	swim	300°	10	2	31
7	10 Sep	1	0	70°19.3	143°08.0	body	swim	260°	85	1	51
8	11 Sep	1	0	71°05.8	153°19.9	body	swim	260°	0	4	13
9	12 Sep	4	0	71°27.7	156°30.1	blow	swim	[1]	0	1	73
9	12 Sep	1	0	71°27.7	156°30.1	body	swim	300°	0	1	73
9	12 Sep	1	0	71°30.5	156°13.0	body	swim	330°	0	3	108
9	12 Sep	1	0	71°25.4	156°11.7	body	rest	[1]	0	3	9
9	12 Sep	1	0	71°28.1	155°46.0	body	swim	70°	0	2	16
9	12 Sep	1	0	71°13.7	154°33.5	splash	swim	90°	0	3	16
9	12 Sep	2	0	71°13.9	154°31.0	body	swim	330°	0	2	16

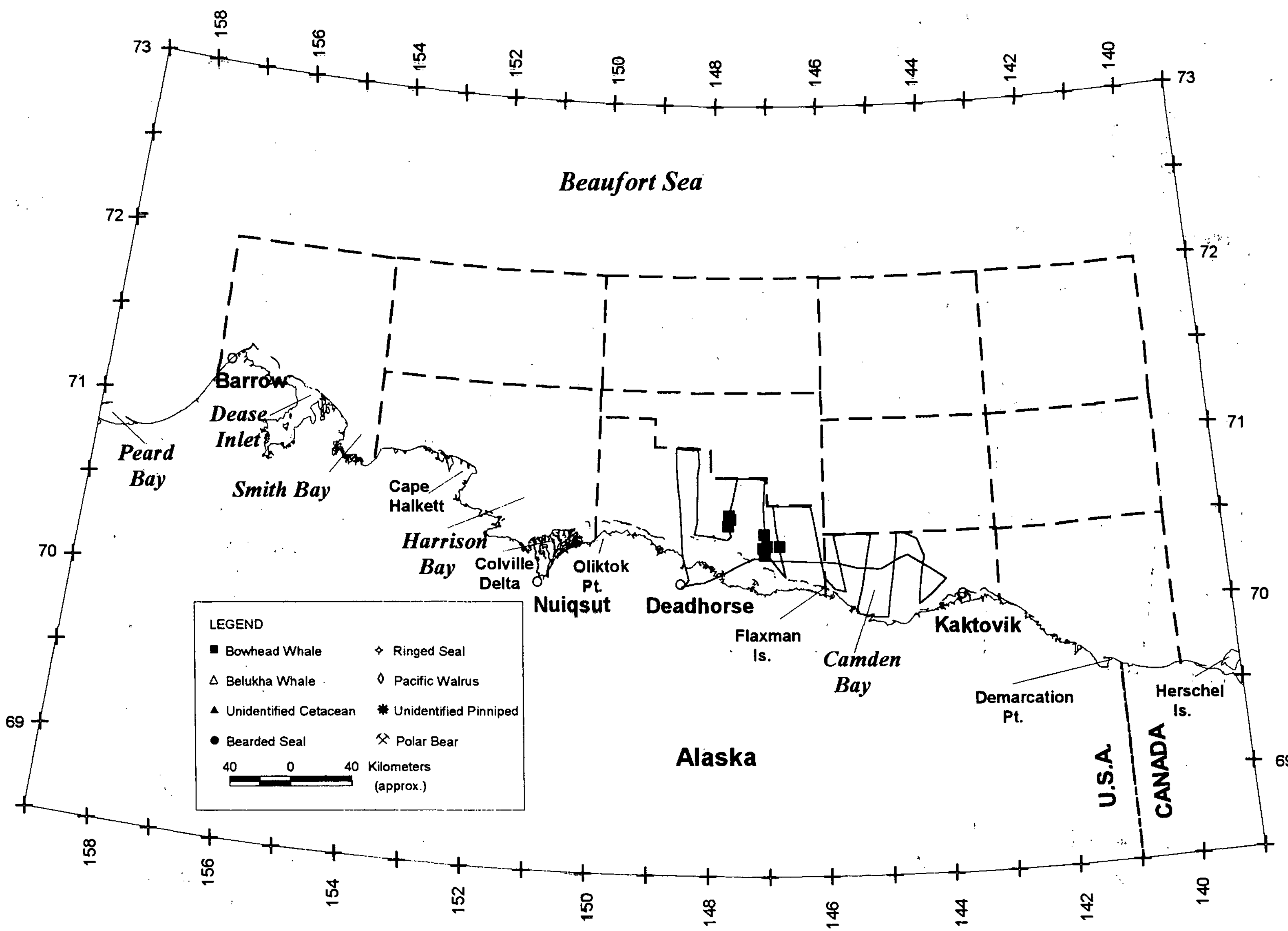
Table B-1
Selected Sighting Data for Bowhead Whales Observed, Fall 1996
(Page 2 of 3)

Flight No.	Day	Total Whales	No. of Calves	Latitude	Longitude	Sighting Cue	Behavior	Compass Heading	Ice (%)	Sea State	Depth (m)
10	13 Sep	2	0	70°11.6	141°27.9	body	dive	[1]	50	1	49
13	16 Sep	1	0	70°12.3	141°44.4	blow	swim	[1]	50	2	55
13	16 Sep	1	0	70°12.4	141°44.6	blow	swim	240°	50	2	55
13	16 Sep	1	0	70°11.7	141°41.8	body	swim	190°	50	2	48
13	16 Sep	1	0	70°00.9	141°16.3	splash	swim	330°	40	3	40
13	16 Sep	1	0	70°00.8	141°15.0	body	dive	80°	40	3	40
15	19 Sep	2	0	70°26.4	147°19.3	body	mill	[1]	90	1	15
15	19 Sep	2	0	70°21.9	143°39.8	body	rest	330°	50	1	35
15	19 Sep	1	0	70°21.9	143°36.2	body	rest	[1]	70	1	35
15	19 Sep	5	0	70°21.9	143°37.9	body	mill	[1]	70	1	35
16	20 Sep	1	0	70°30.5	146°15.9	blow	swim	60°	50	0	37
16	20 Sep	3	0	70°30.8	146°18.5	blow	swim	340°	70	0	37
16	20 Sep	1	0	70°29.9	146°15.9	slick	swim	290°	70	0	37
16	20 Sep	1	0	70°34.2	146°34.9	body	rest	330°	60	0	38
16	20 Sep	1	0	70°33.2	146°34.6	body	swim	160°	80	0	38
17	20 Sep	1	0	70°49.9	148°23.0	blow	swim	220°	80	1	24
17	20 Sep	1	0	70°49.9	148°23.0	blow	swim	280°	80	1	24
21	26 Sep	1	0	71°13.6	152°08.0	blow	swim	210°	70	1	42
21	26 Sep	1	0	71°25.2	155°24.8	blow	rest	40°	5	1	18
21	26 Sep	7	1	71°26.8	155°39.0	splash	slap	120°	20	0	18
21	26 Sep	6	1	71°25.9	155°37.9	body	feed	[1]	20	0	18
21	26 Sep	1	0	71°25.7	155°39.3	body	swim	200°	15	0	18
21	26 Sep	2	0	71°25.6	155°40.5	body	swim	[1]	30	0	15
21 [2]	26 Sep	14	0	71°25.1	155°44.1	blow	feed	[1]	30	0	[2]
21	26 Sep	2	0	71°24.8	155°42.5	splash	swim	[1]	30	0	15
21	26 Sep	1	0	71°25.1	155°42.9	body	swim	[1]	30	0	15
21	26 Sep	7	0	71°21.8	155°24.0	body	mill	[1]	40	0	9

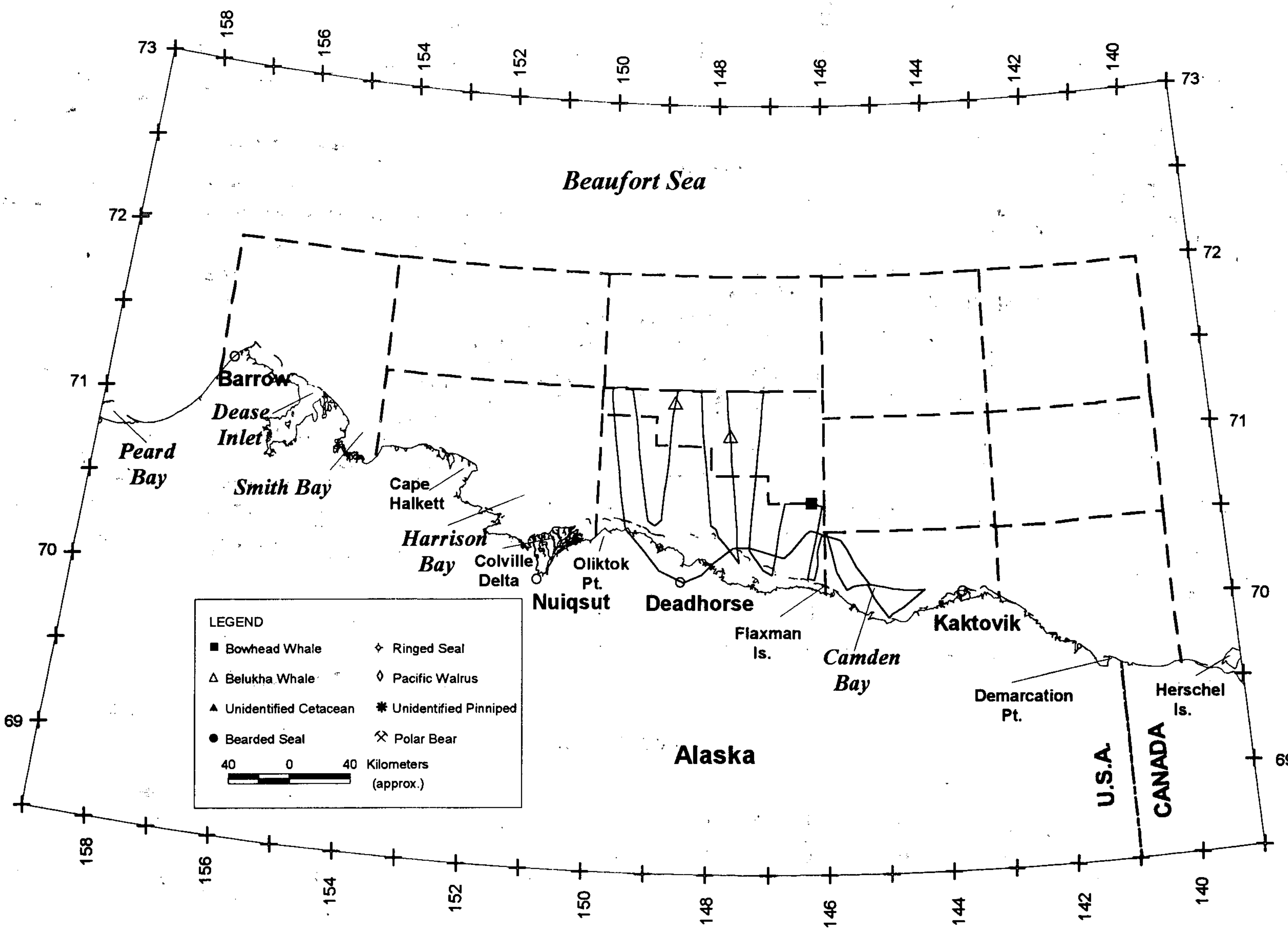
Table B-1
Selected Sighting Data for Bowhead Whales Observed, Fall 1996
(Page 3 of 3)

Flight No.	Day	Total Whales	No. of Calves	Latitude	Longitude	Sighting Cue	Behavior	Compass Heading	Ice (%)	Sea State	Depth (m)
21	26 Sep	3	0	71°22.8	155°18.6	body	swim	[1]	40	0	11
21	26 Sep	2	0	71°22.5	155°10.9	body	swim	[1]	40	0	11
21	26 Sep	1	0	71°03.8	154°05.6	body	rest	270°	1	0	15
22	27 Sep	1	0	70°50.7	148°44.3	splash	rest	60°	85	1	26
22	27 Sep	2	0	70°52.1	149°08.4	slick	dive	330°	85	1	24
22	27 Sep	1	0	71°03.8	149°52.0	body	rest	[1]	90	1	26
22	27 Sep	2	0	71°04.4	149°50.7	body	swim	360°	90	1	26
22	27 Sep	1	0	71°03.0	149°51.3	body	swim	230°	90	1	26
23	27 Sep	1	0	70°46.4	149°25.7	body	swim	230°	85	1	18
23	27 Sep	1	0	71°06.7	150°16.2	body	dive	200°	90	1	38
26	30 Sep	1	0	70°51.7	147°16.2	body	dive	200°	70	3	49
28	2 Oct	2	0	71°16.7	152°02.2	body	swim	270°	90	2	29
30	5 Oct	1	0	71°08.7	150°07.4	body	rest	60°	85	2	44
30	5 Oct	1	0	71°23.5	153°44.1	body	swim	330°	50	4	40
30	5 Oct	1	0	71°23.8	153°19.9	body	dive	260°	85	3	68
30	5 Oct	1	0	71°20.2	152°50.6	body	swim	220°	80	2	60

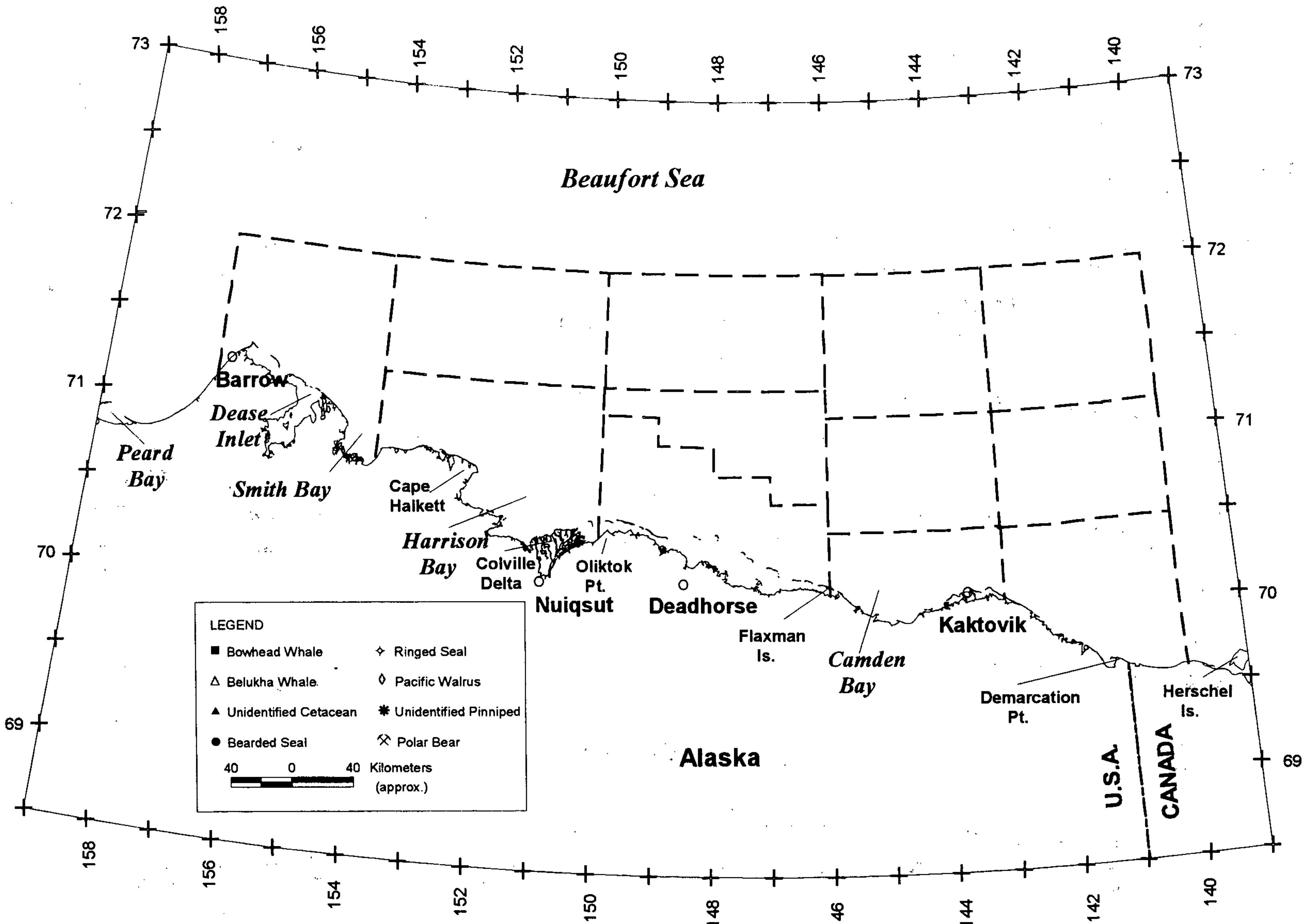
[1] Not recorded.
[2] Repeat sighting.



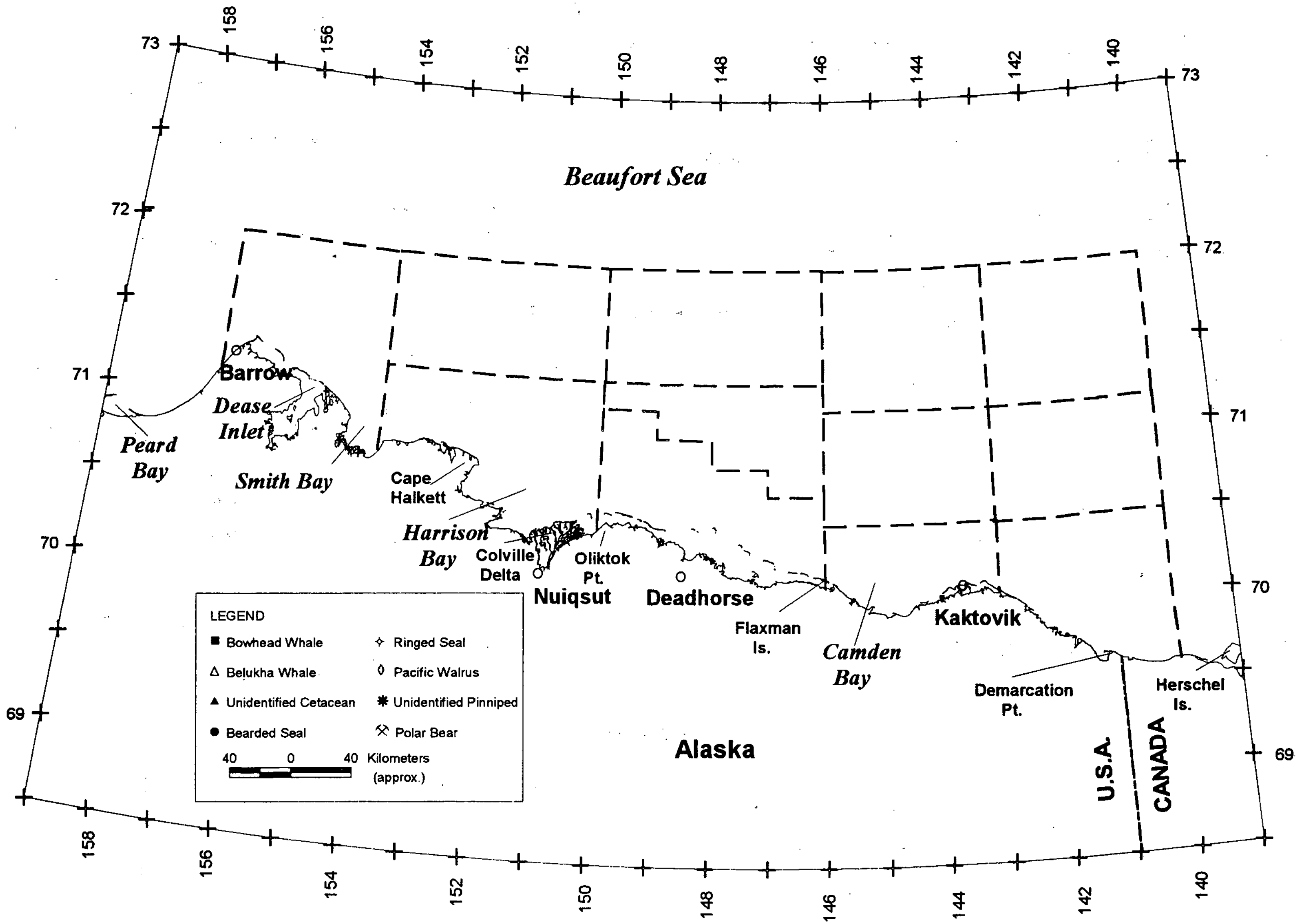
Flight 1: 2 September 1996 Survey Track and Sightings



Flight 2: 5 September 1996 Survey Track and Sightings



Flight 3: 6 September 1996 Survey Track and Sightings



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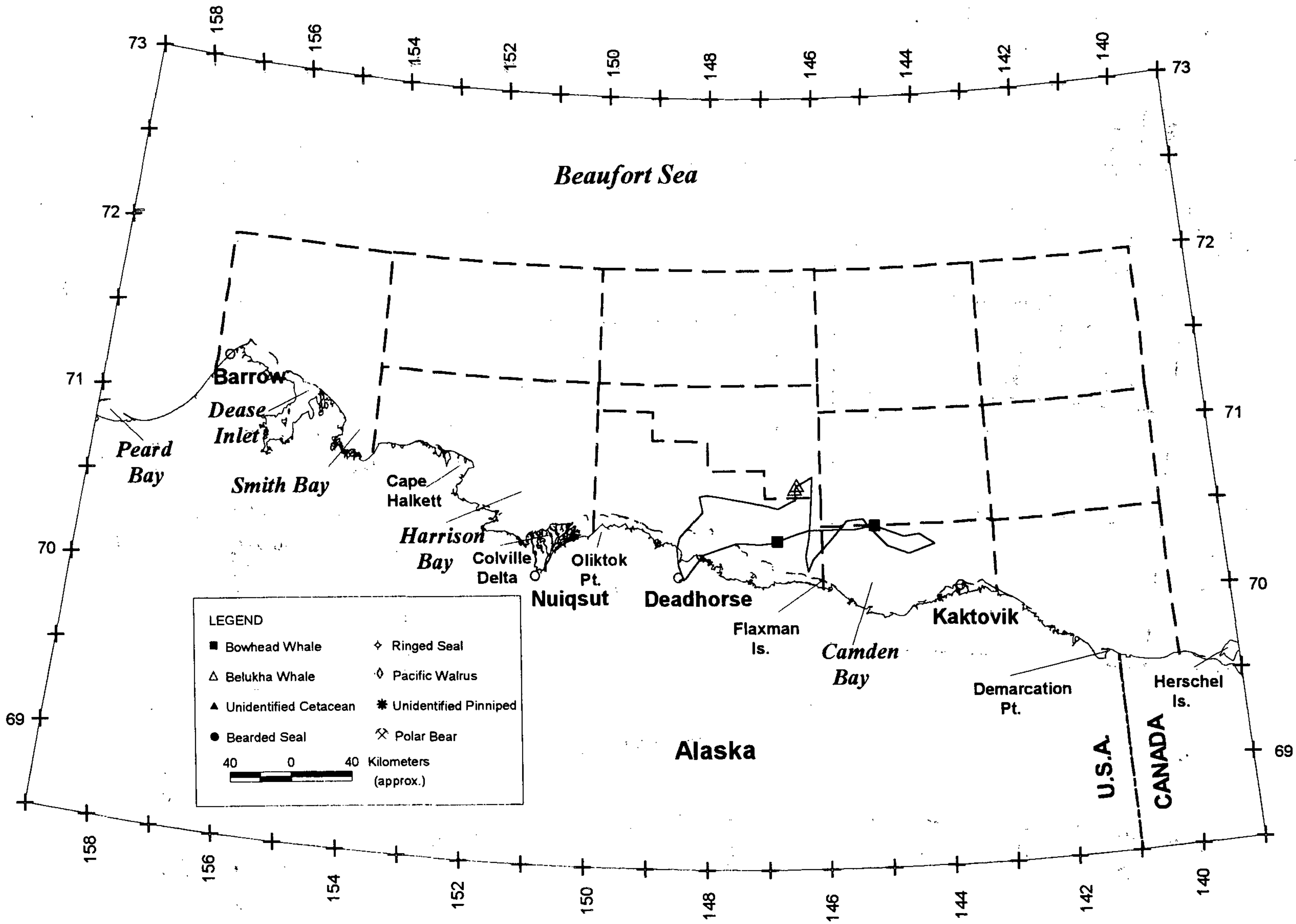
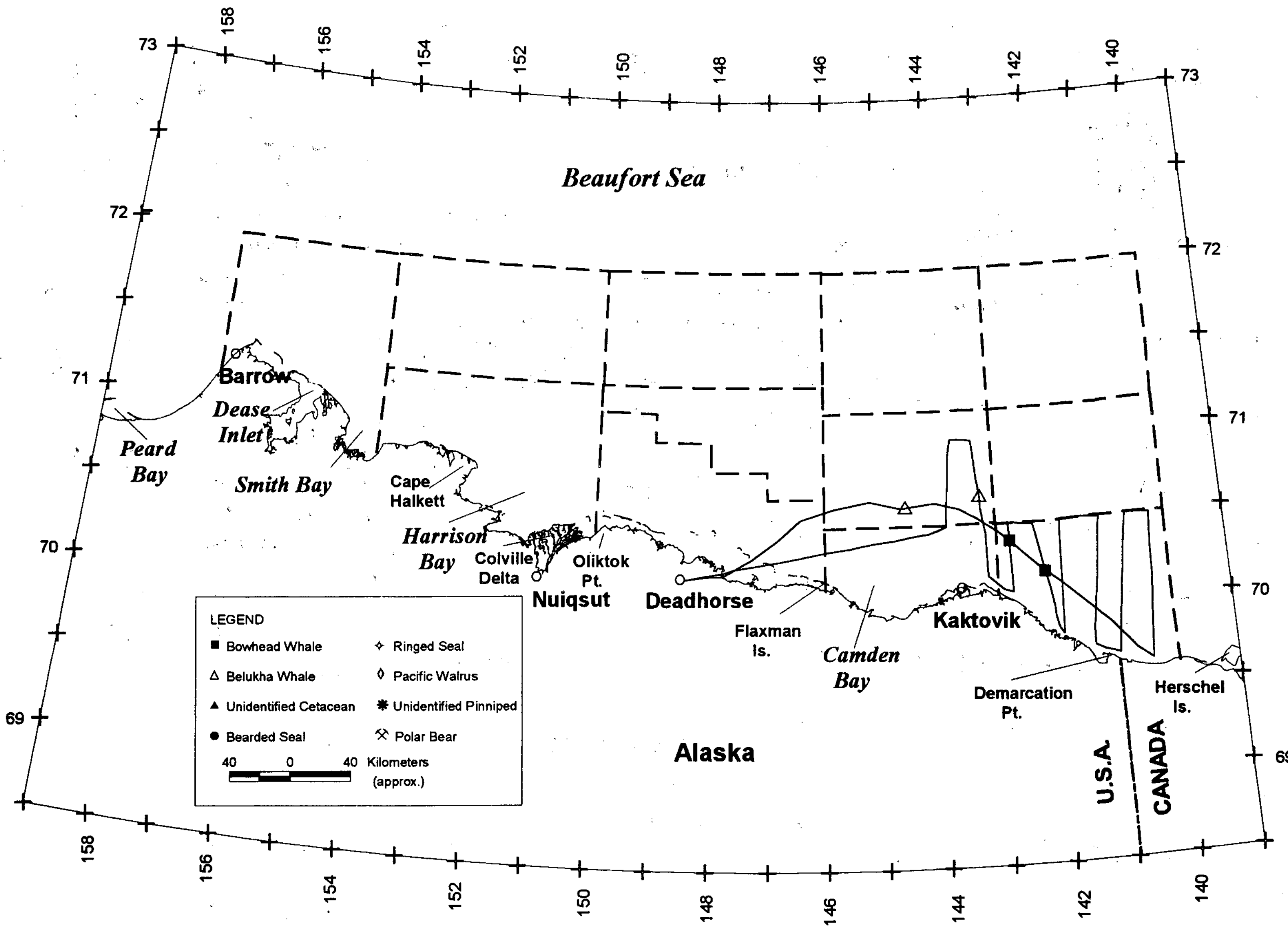
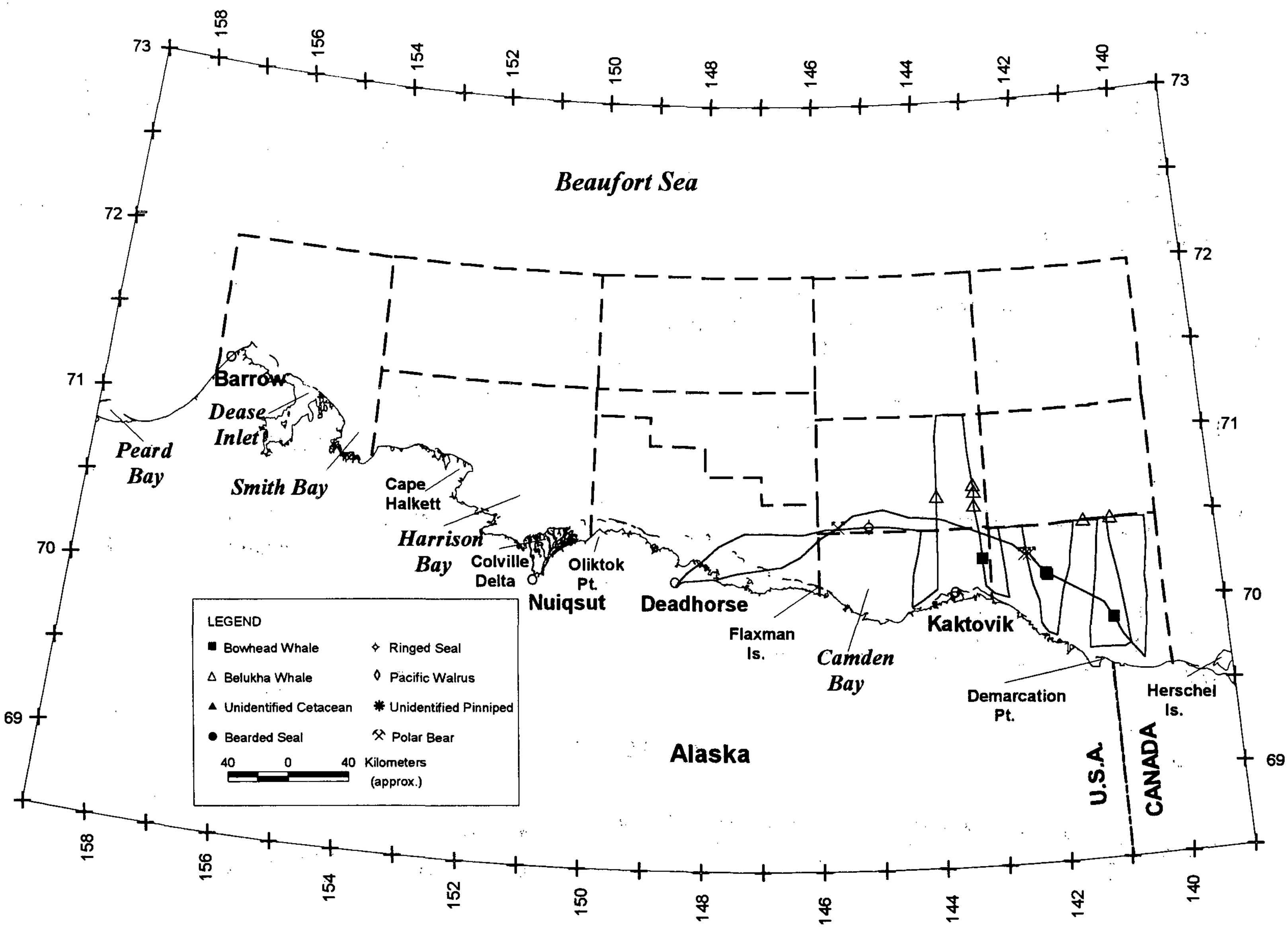


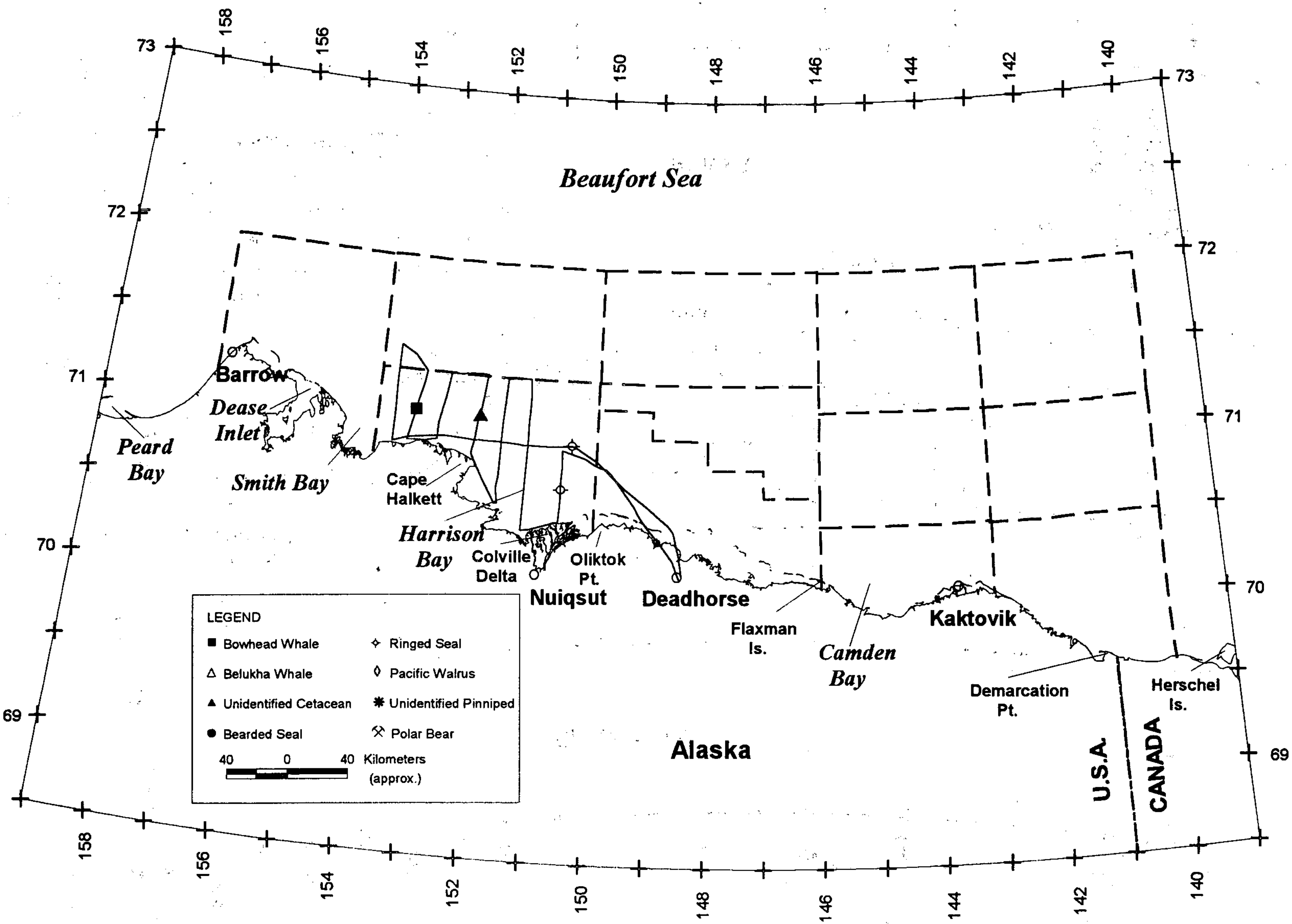
Flight 5: 8 September 1996 Survey Track and Sightings



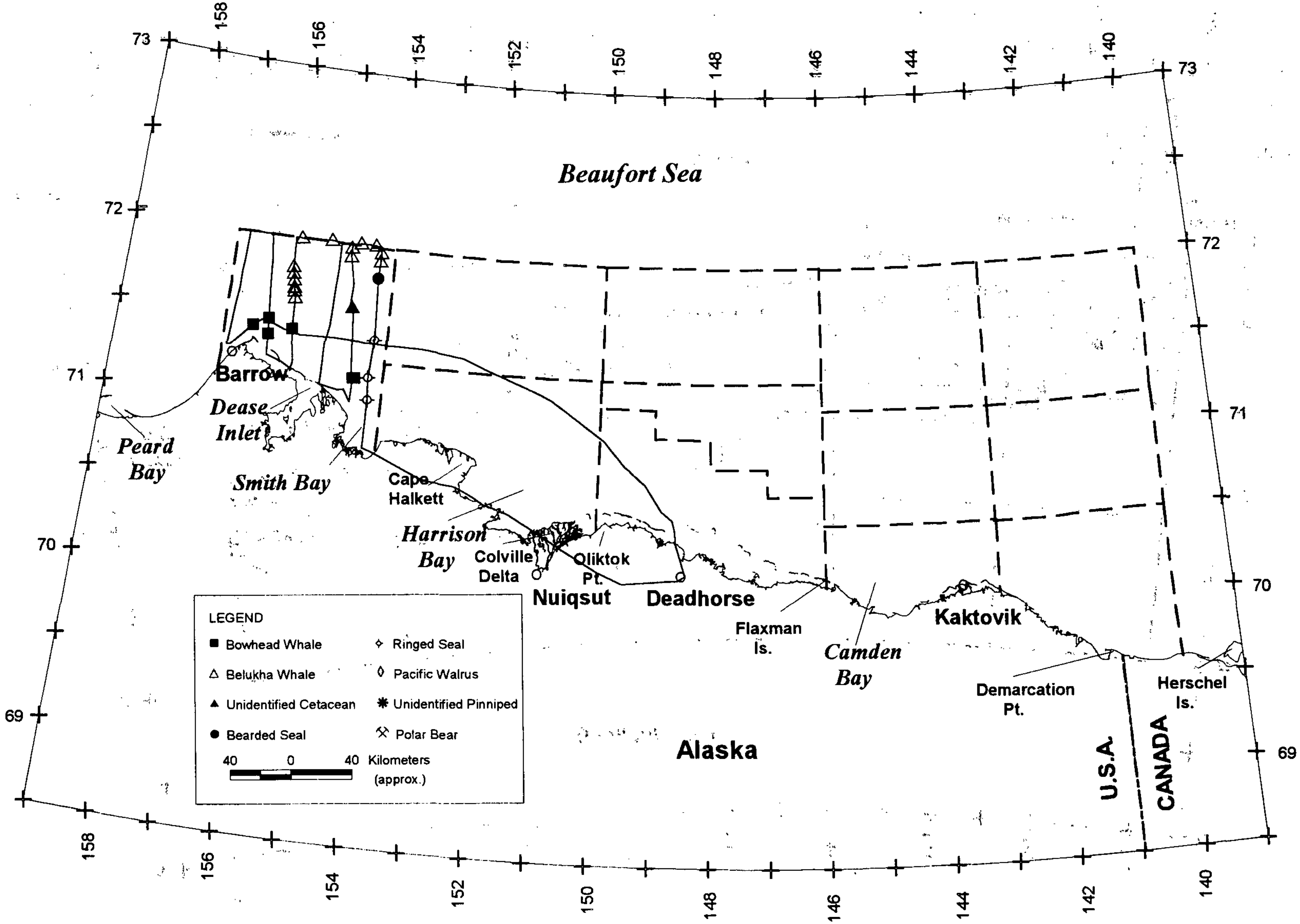
Flight 6: 9 September 1996 Survey Track and Sightings



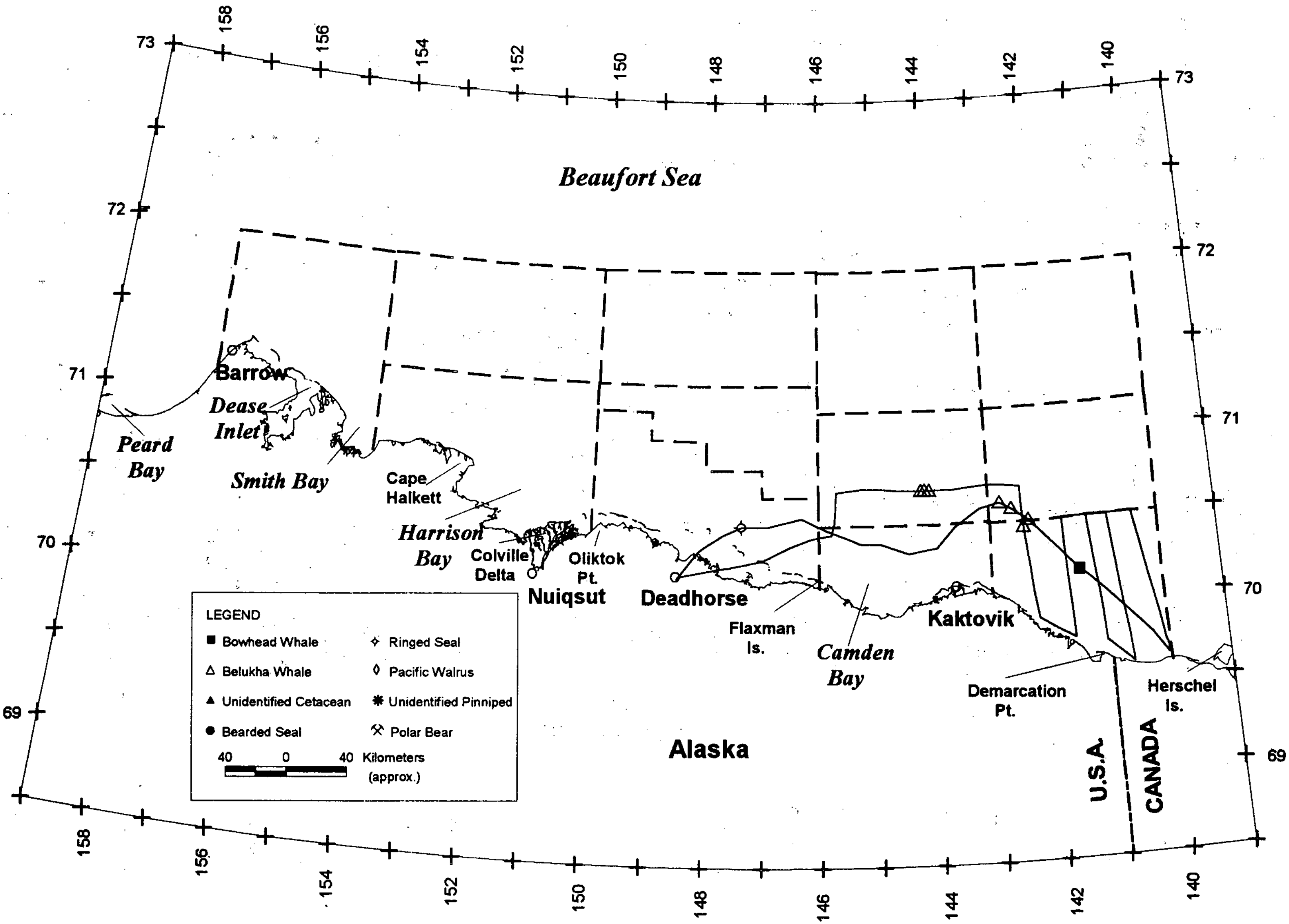
Flight 7: 10 September 1996 Survey Track and Sightings



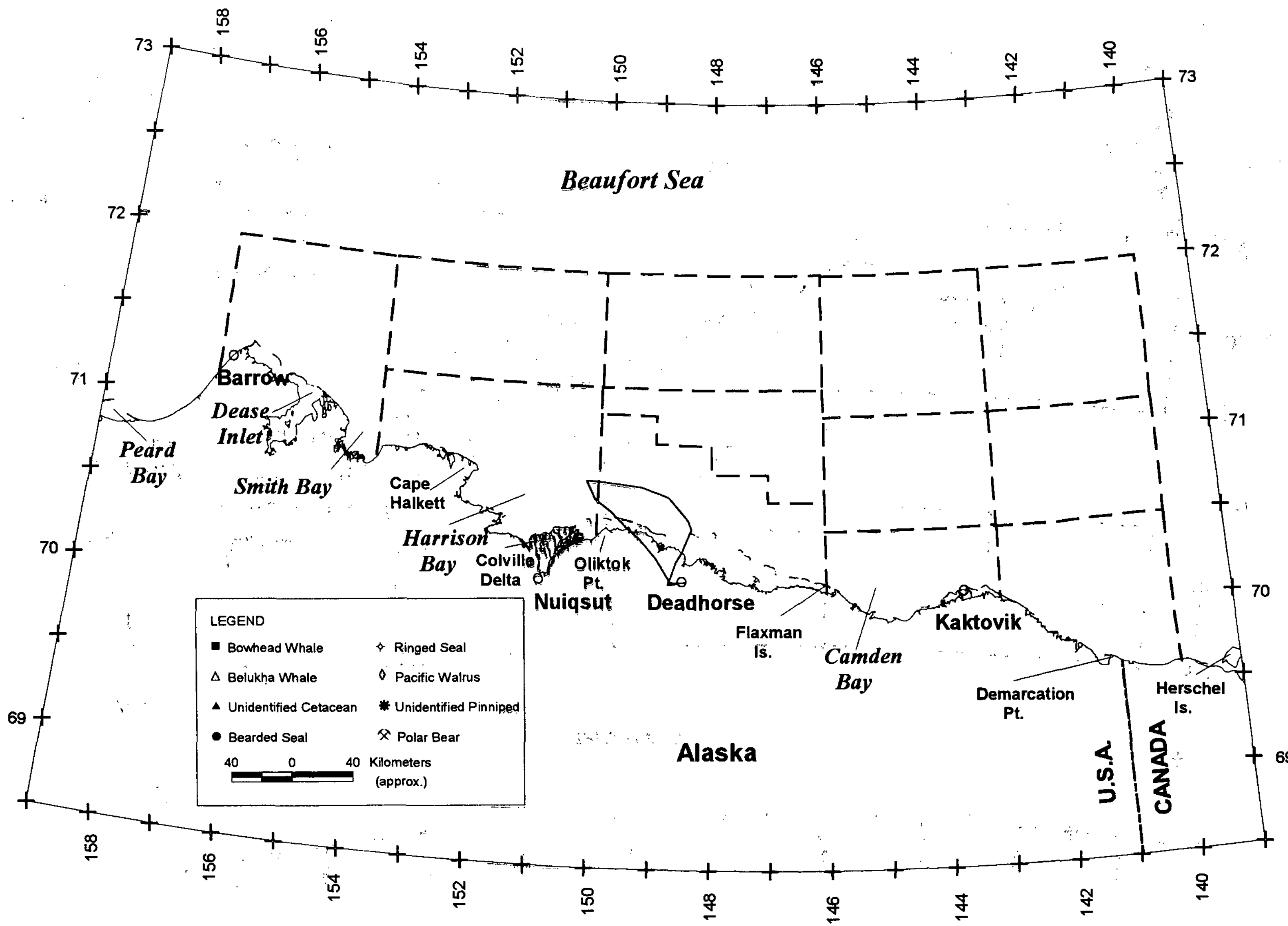
Flight 8: 11 September 1996 Survey Track and Sightings



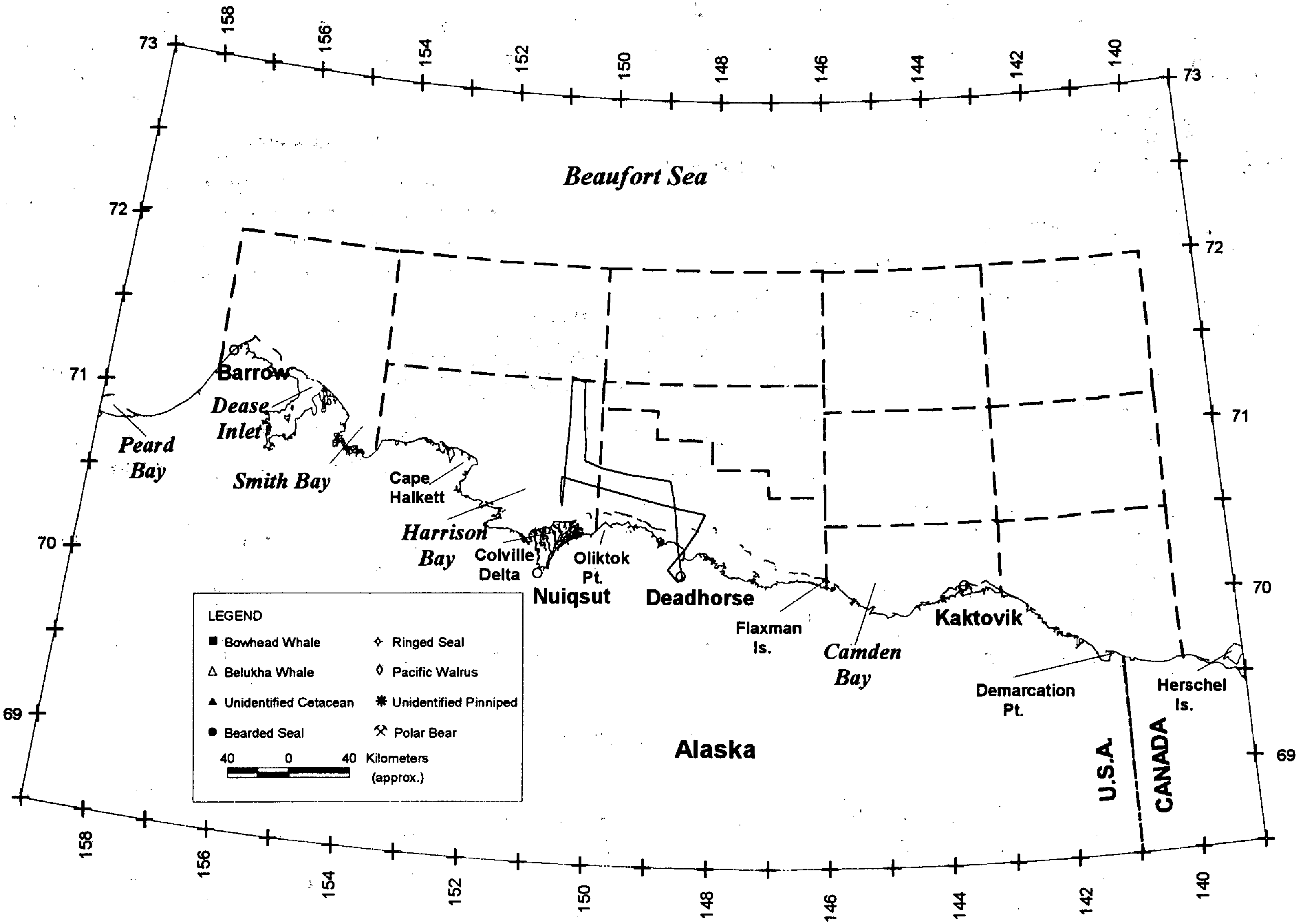
Flight 9: 12 September 1996 Survey Track and Sightings



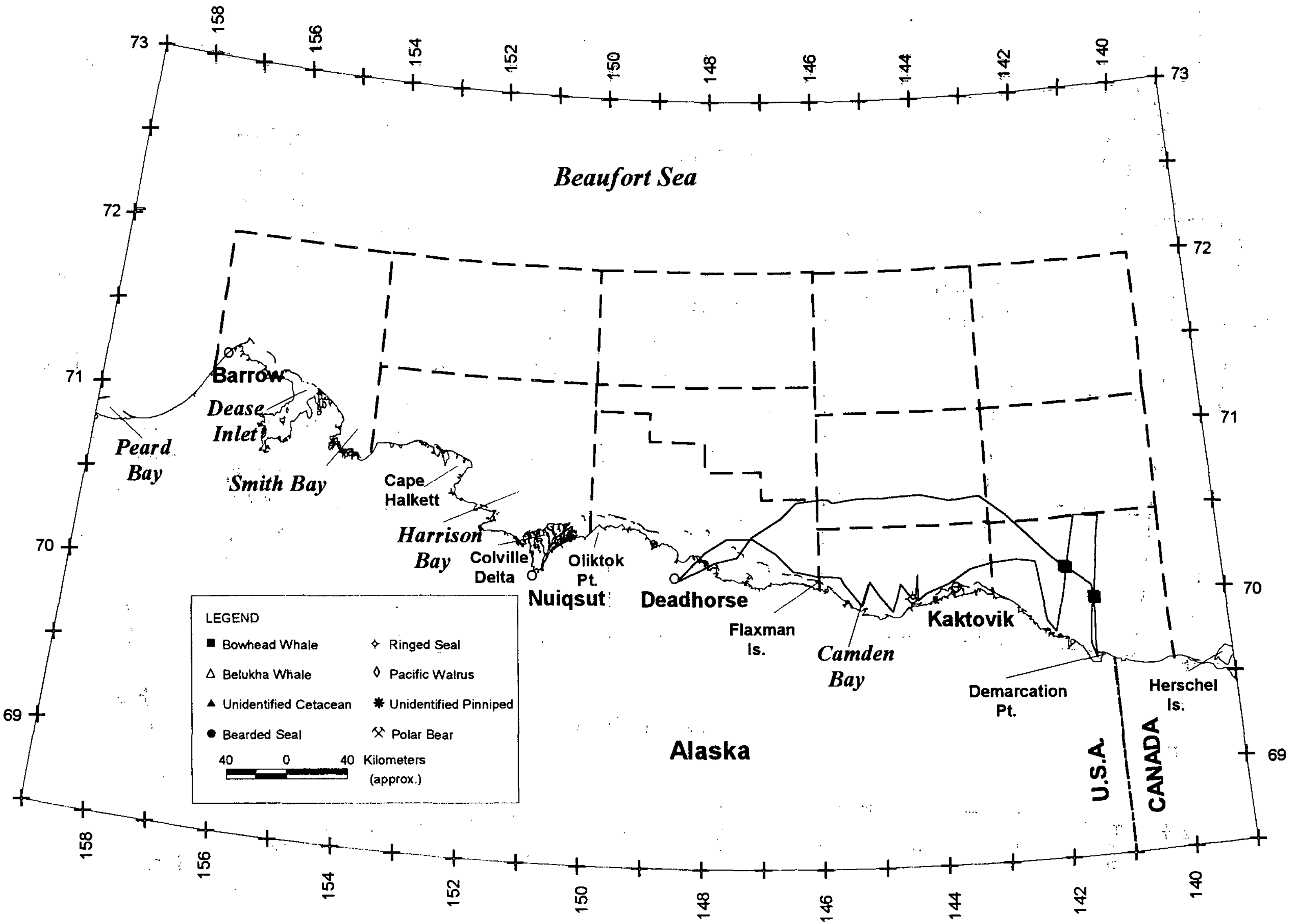
Flight 10: 13 September 1996 Survey Track and Sightings



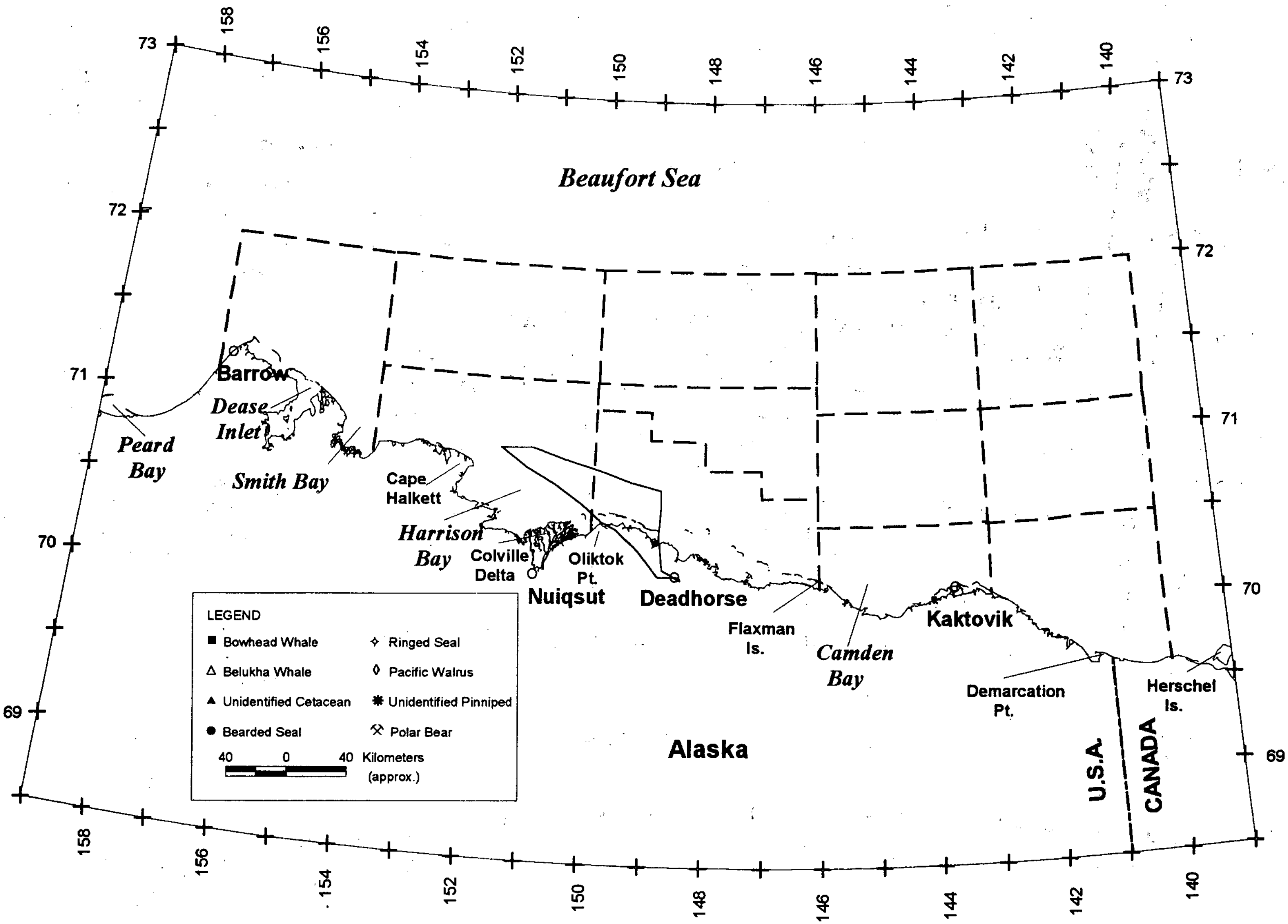
Flight 11: 14 September 1996 Survey Track and Sightings



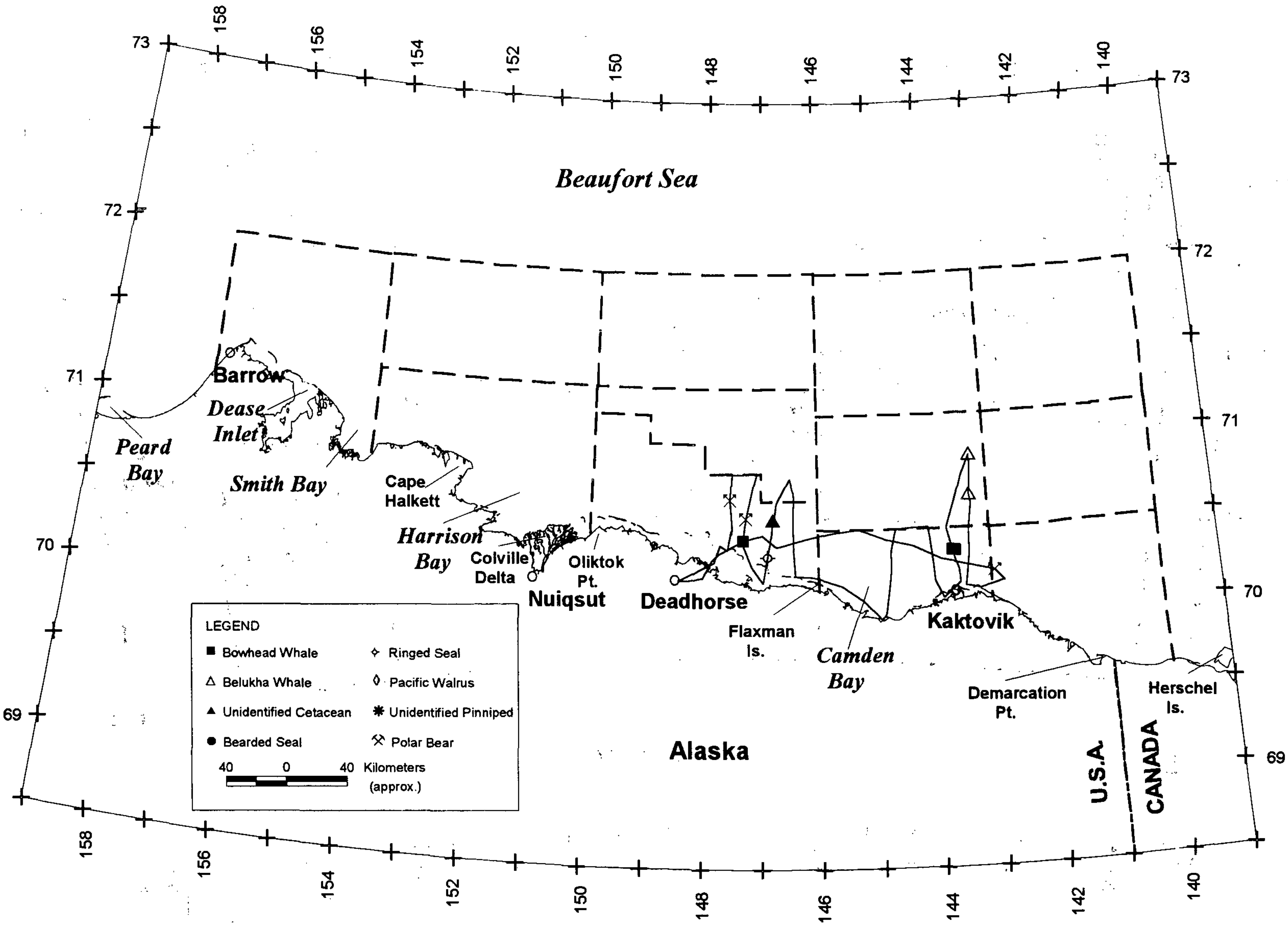
Flight 12: 15 September 1996 Survey Track and Sightings



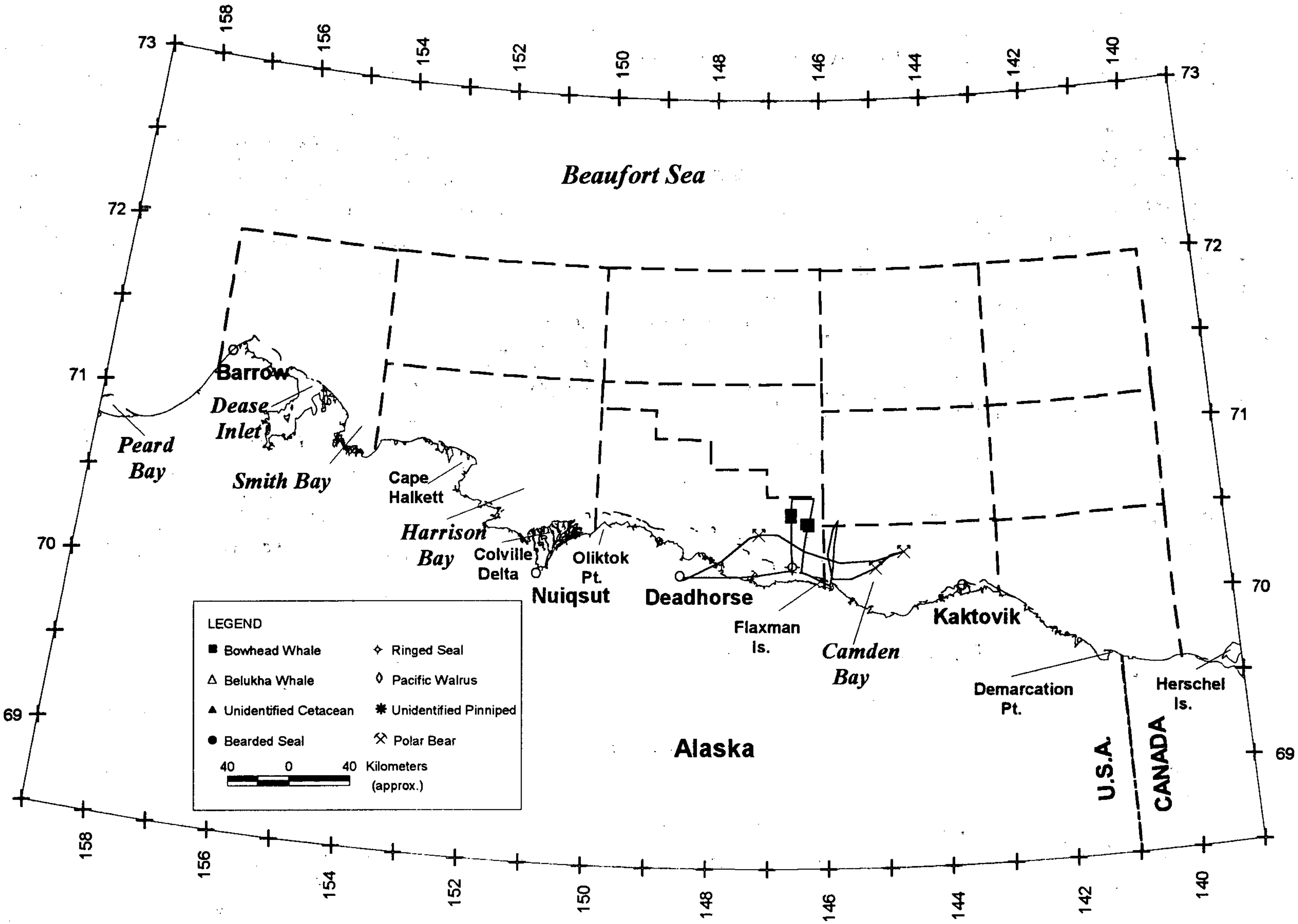
Flight 13: 16 September 1996 Survey Track and Sightings



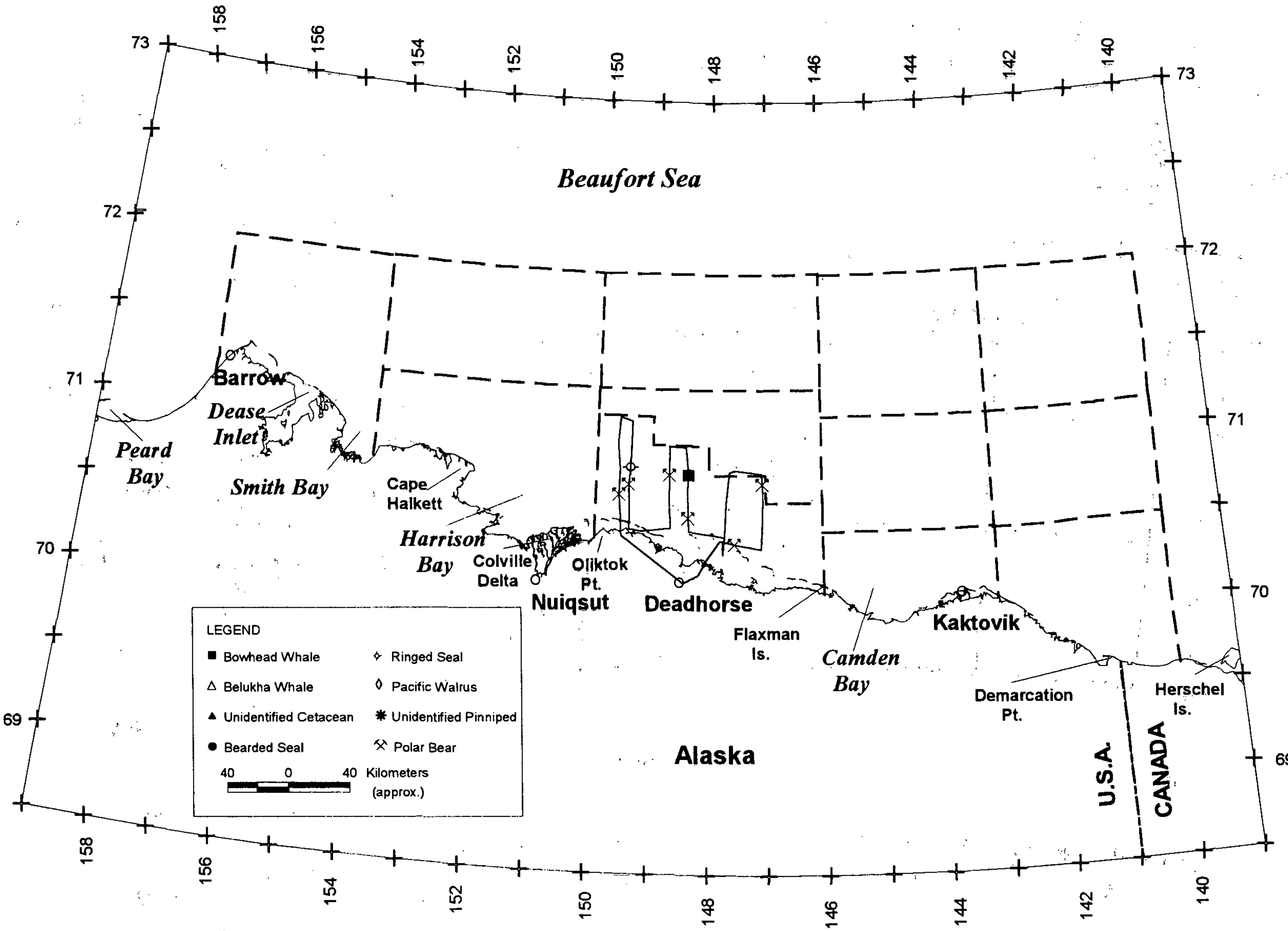
Flight 14: 18 September 1996 Survey Track and Sightings



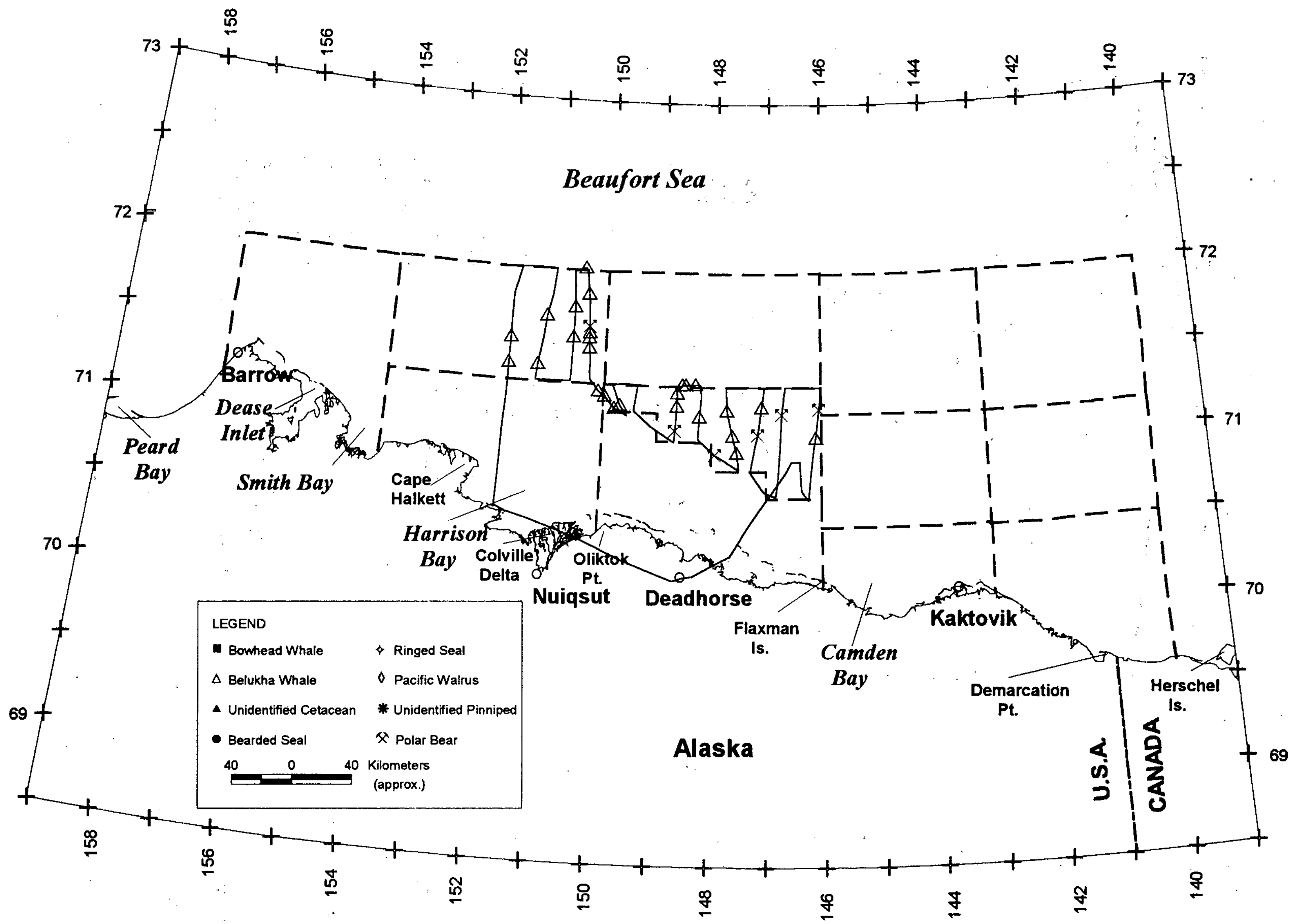
Flight 15: 19 September 1996 Survey Track and Sightings



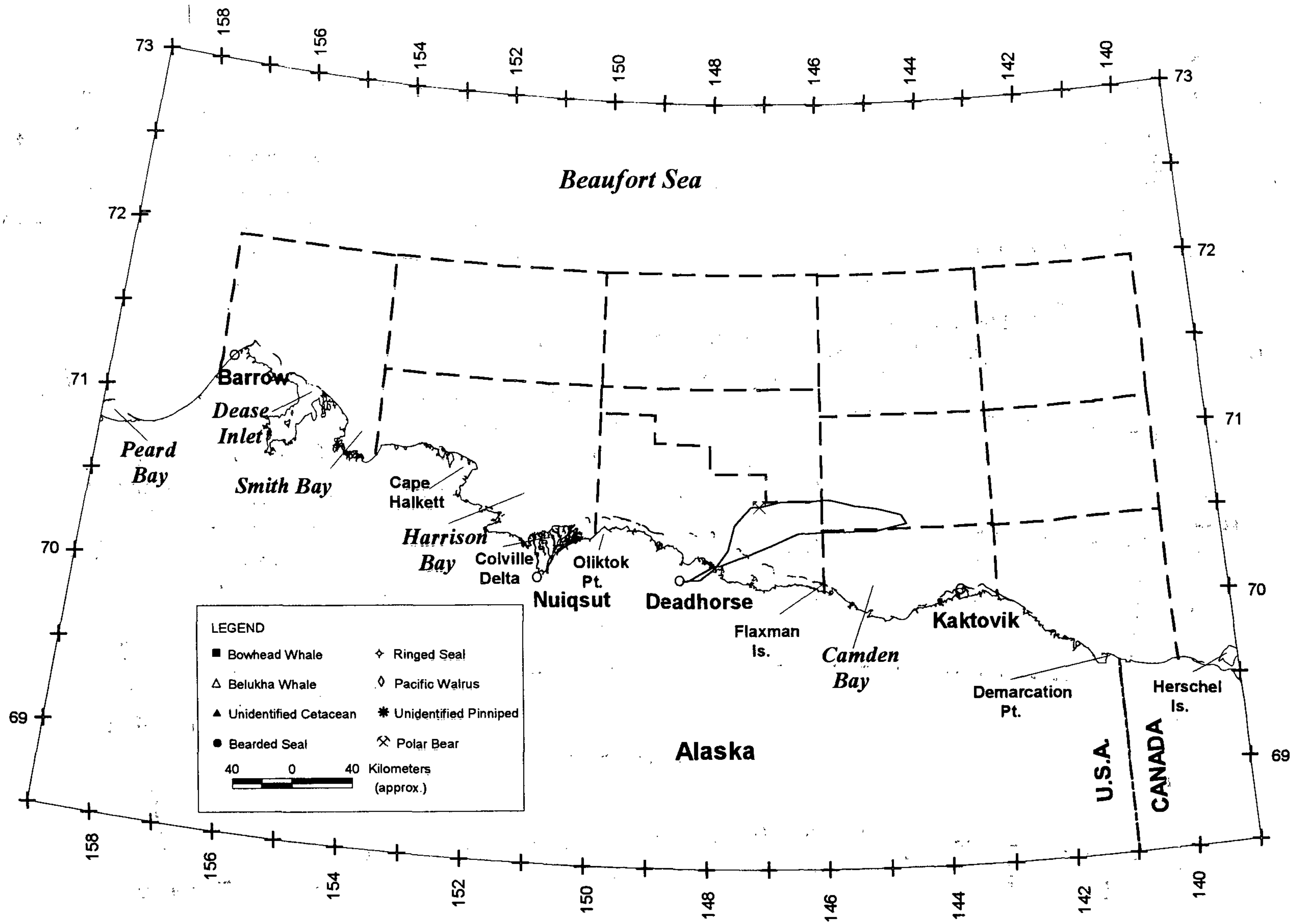
Flight 16: 20 September 1996 Survey Track and Sightings



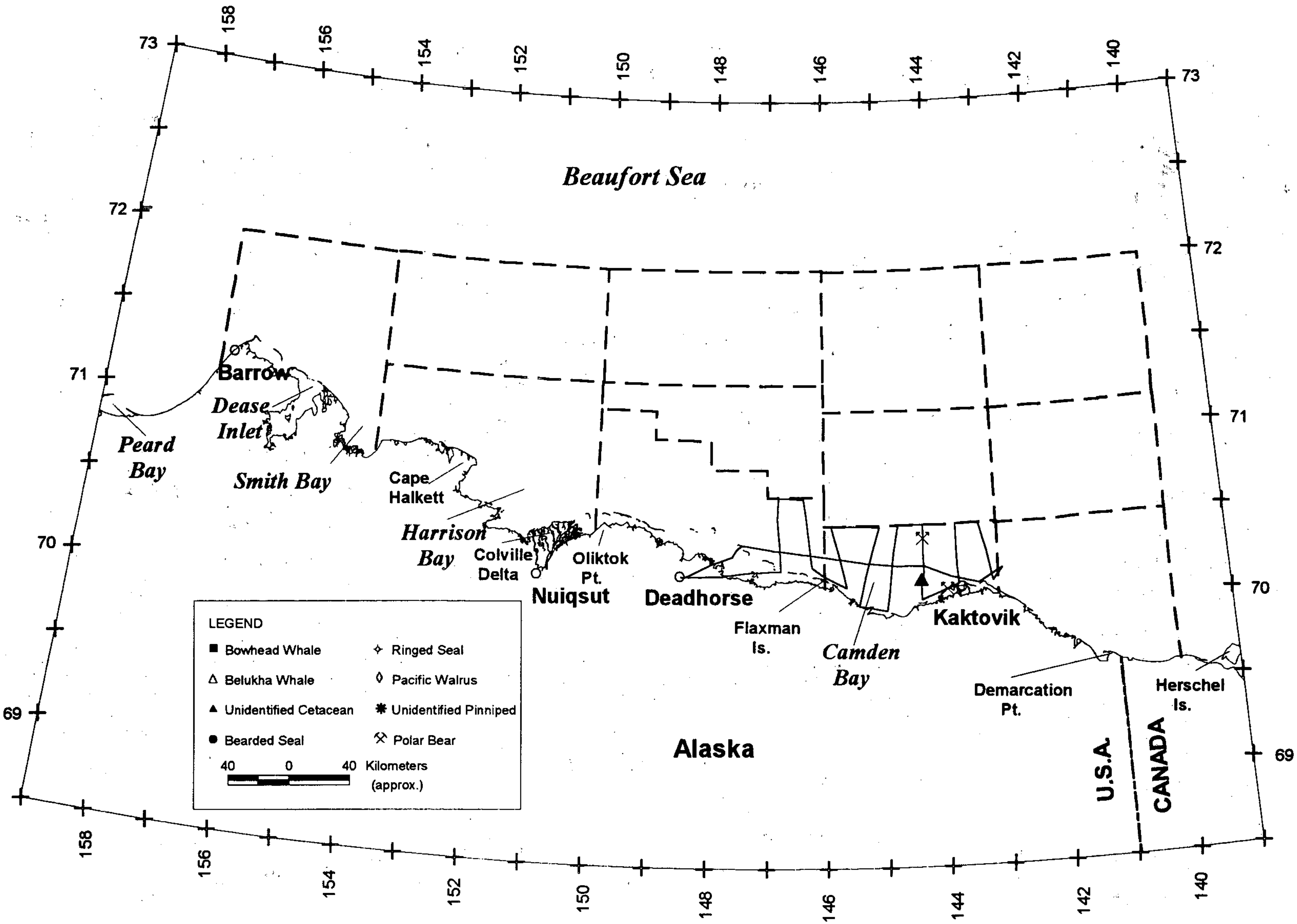
Flight 17: 20 September 1996 Survey Track and Sightings



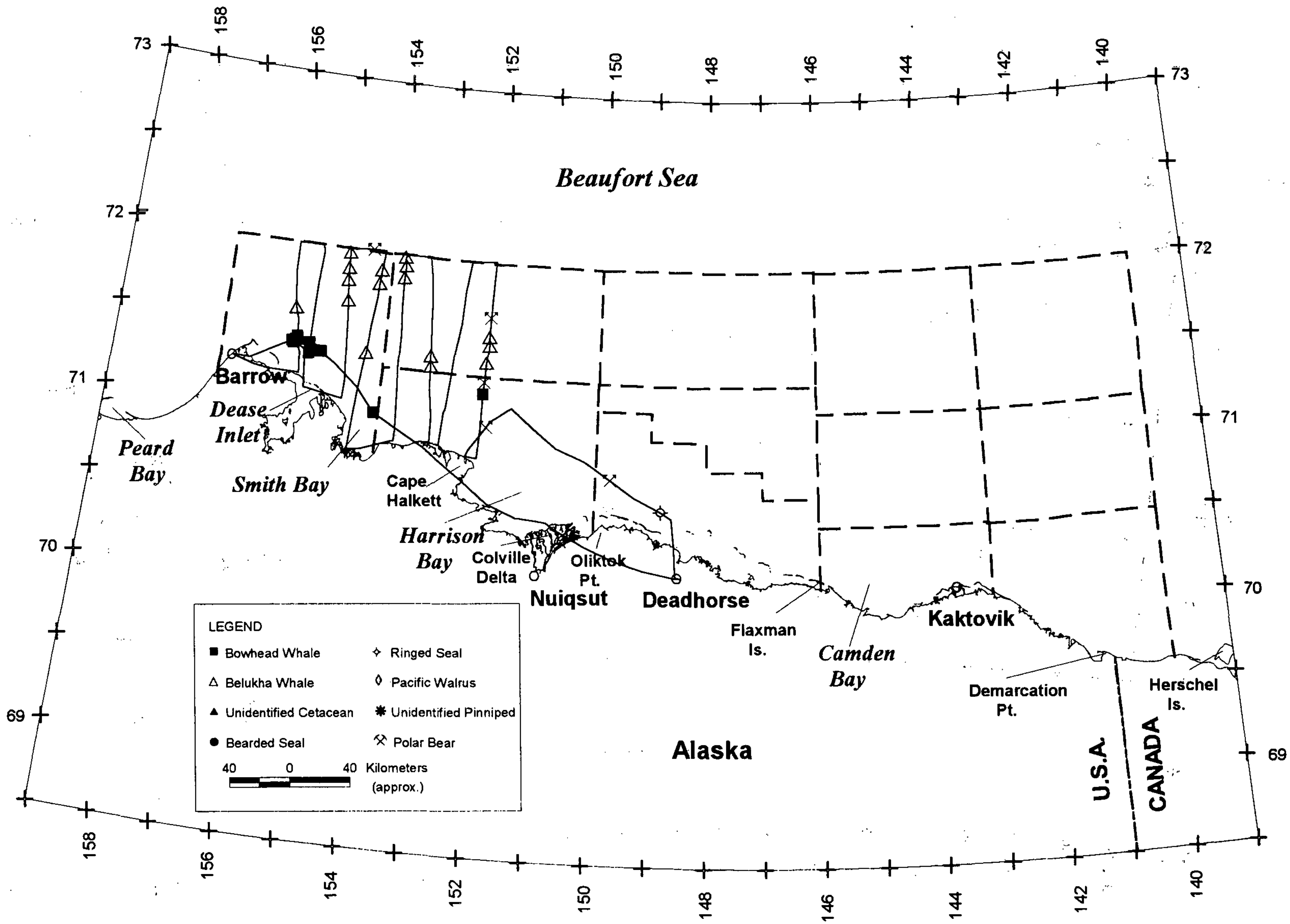
Flight 18: 22 September 1996 Survey Track and Sightings



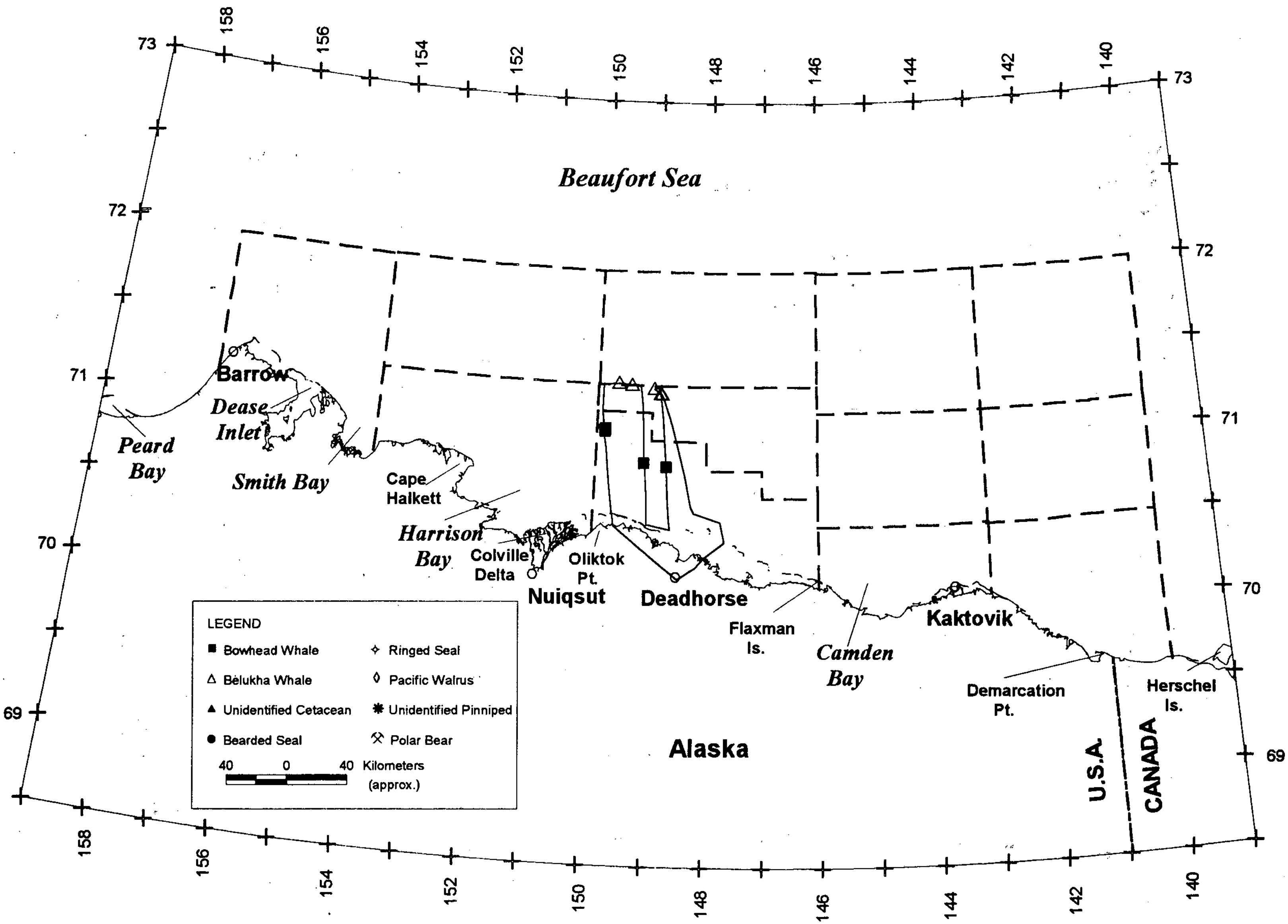
Flight 19: 23 September 1996 Survey Track and Sightings



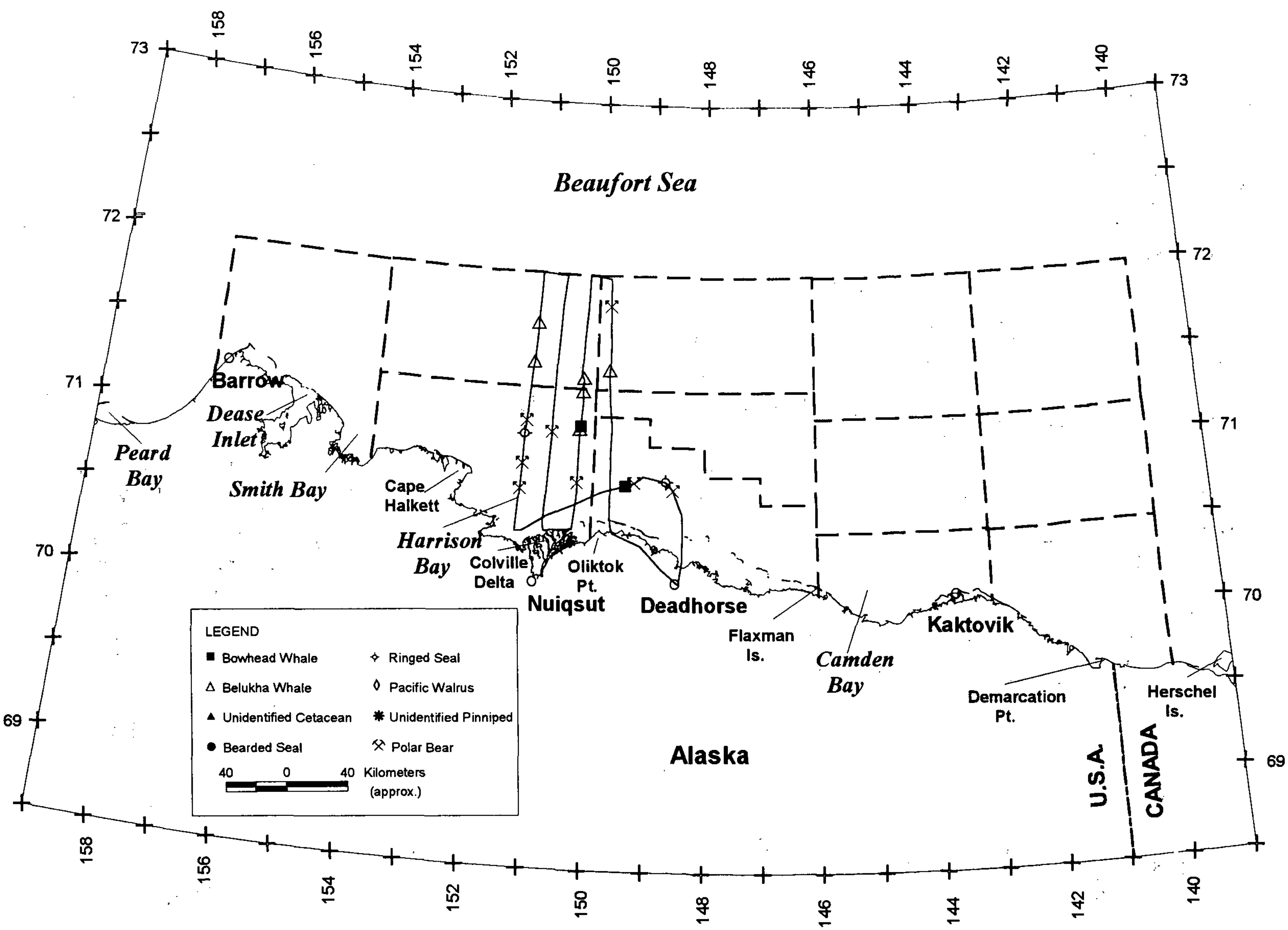
Flight 20: 24 September 1996 Survey Track and Sightings



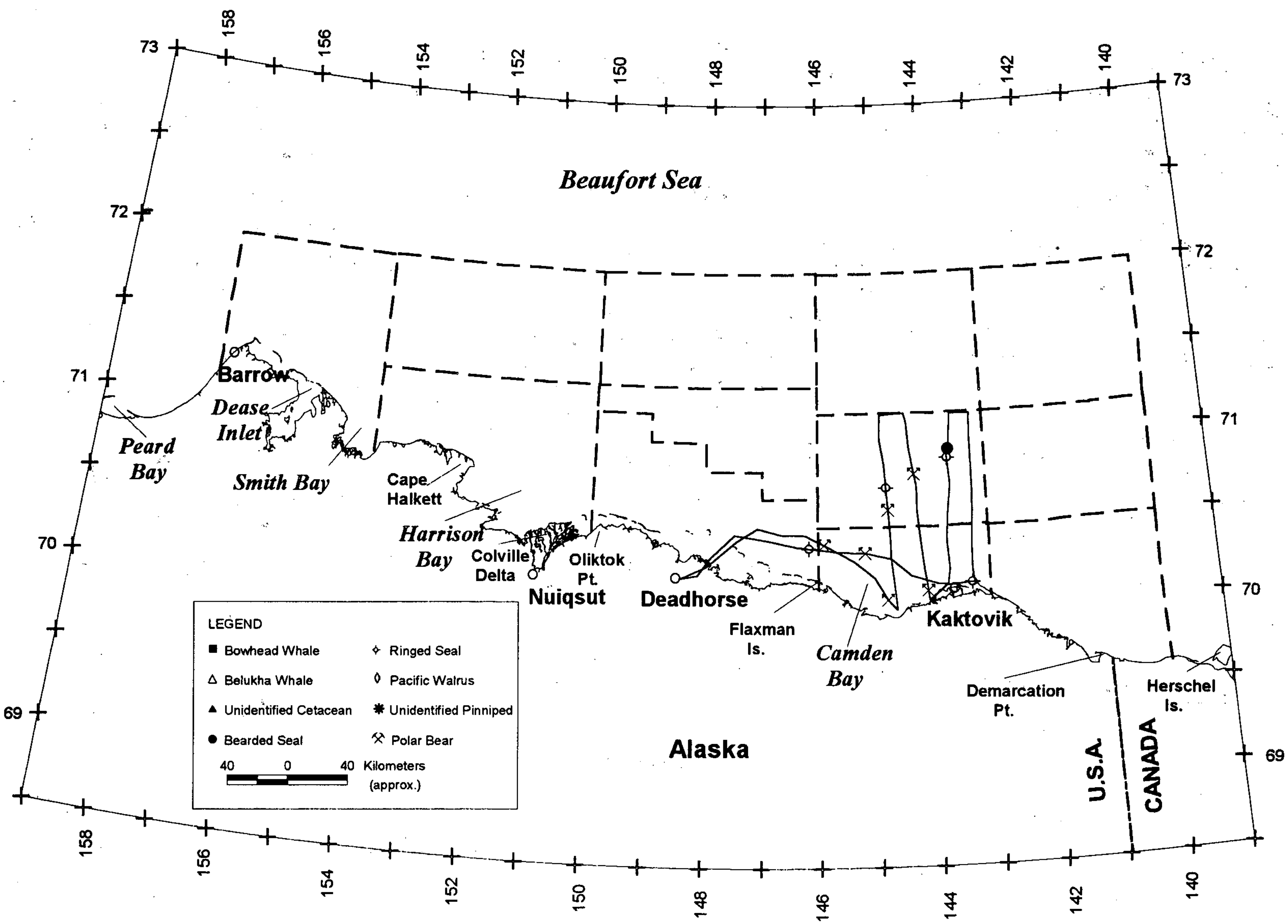
Flight 21: 26 September 1996 Survey Track and Sightings



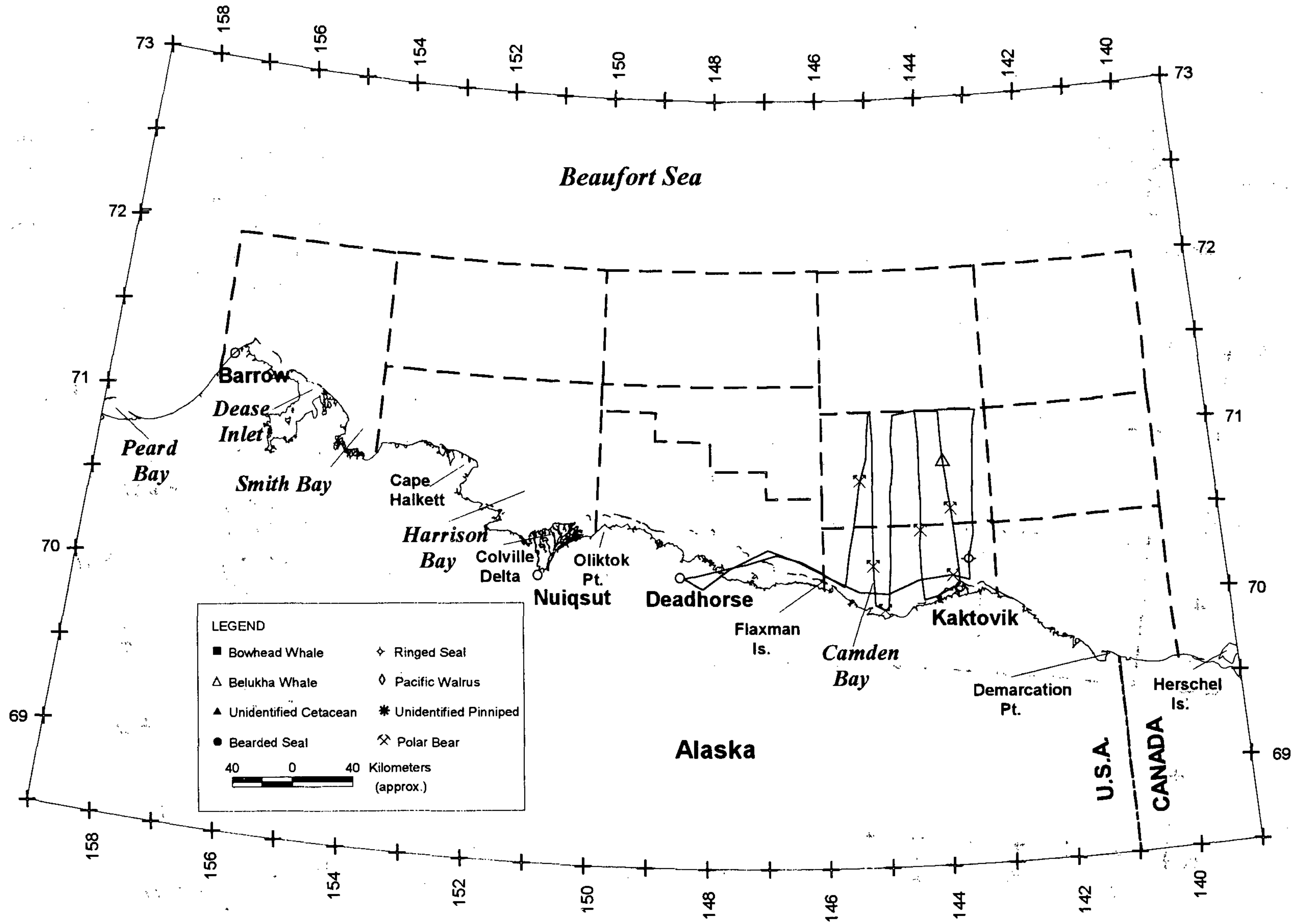
Flight 22: 27 September 1996 Survey Track and Sightings



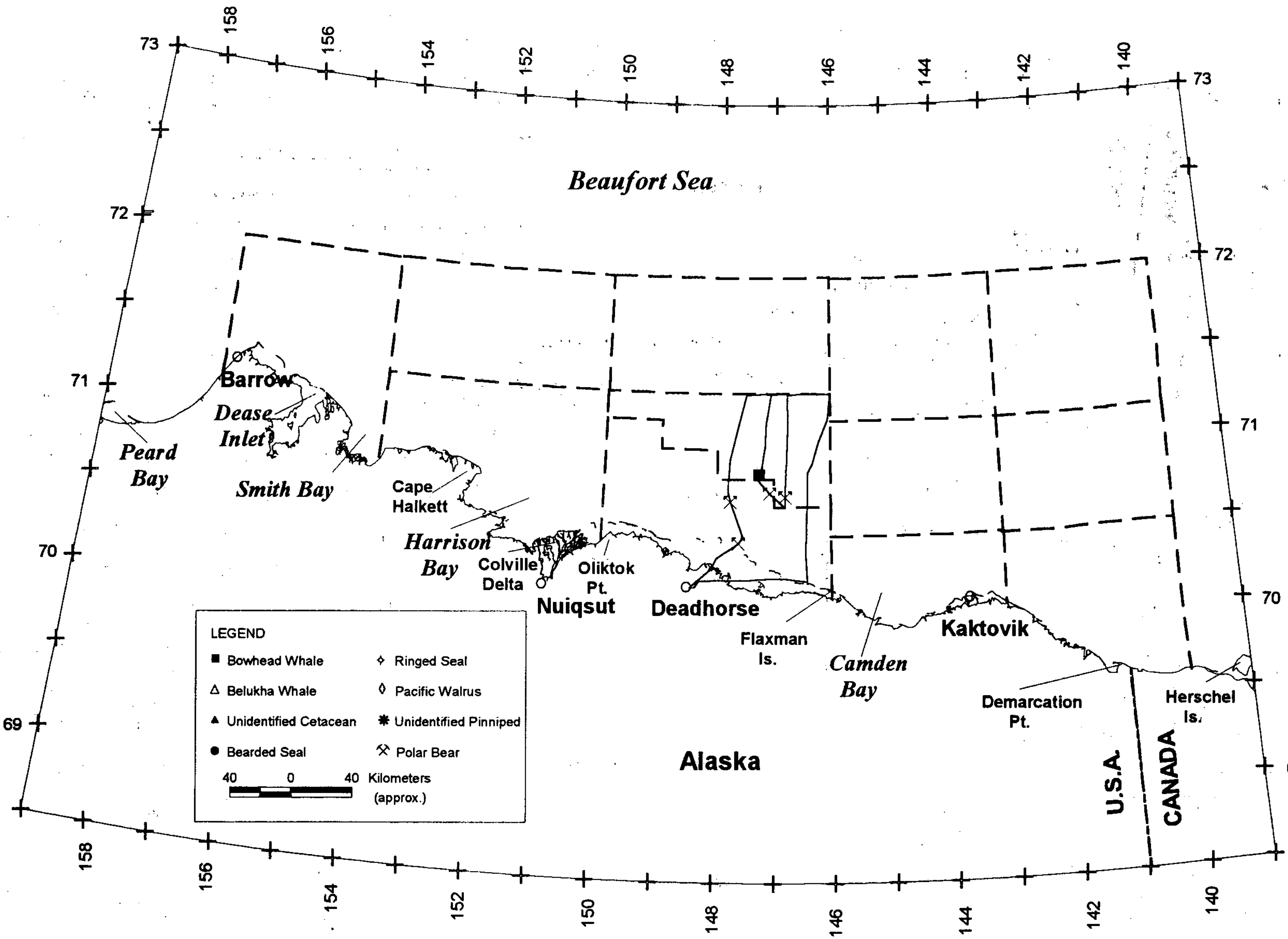
Flight 23: 27 September 1996 Survey Track and Sightings



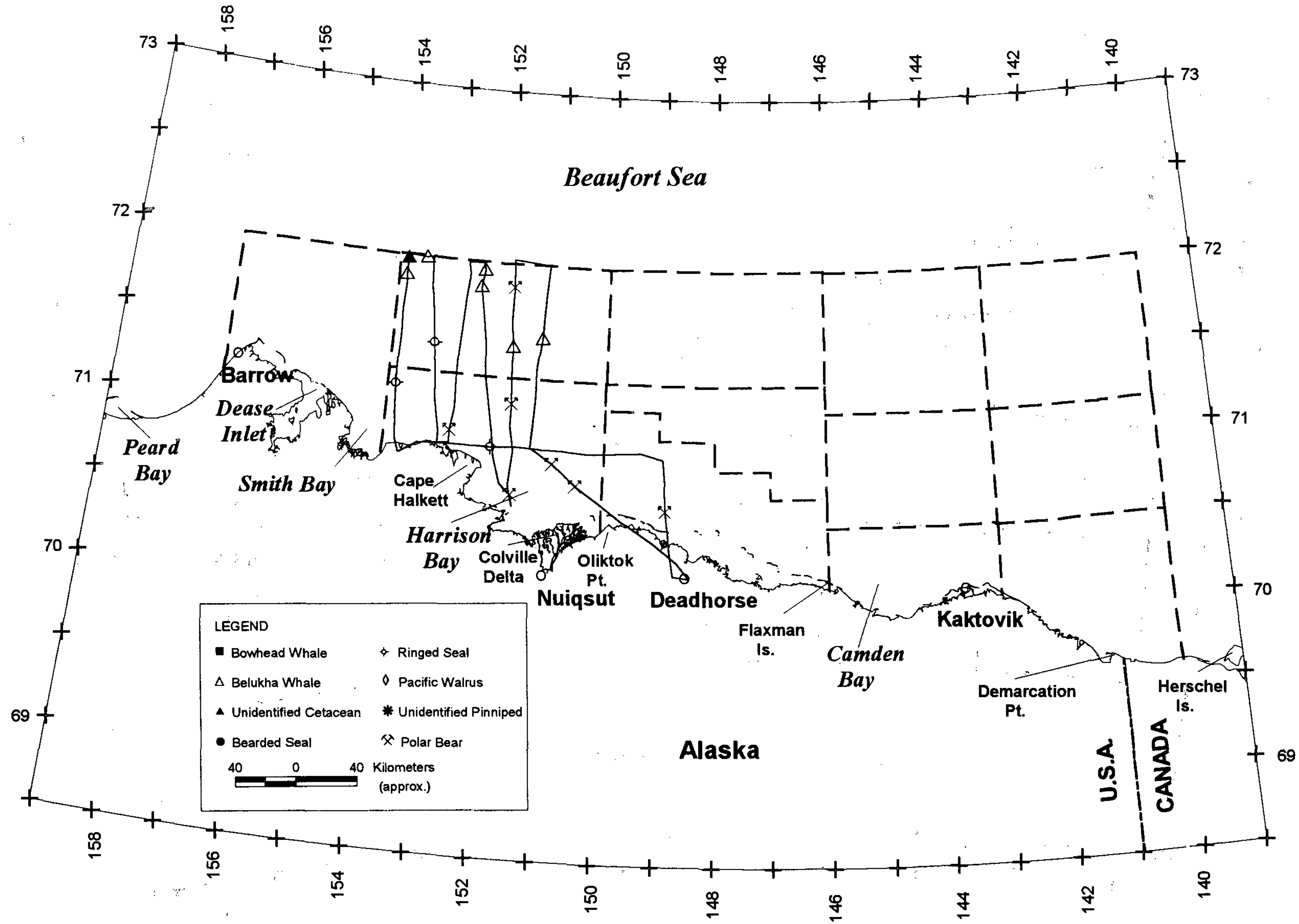
Flight 24: 28 September 1996 Survey Track and Sightings



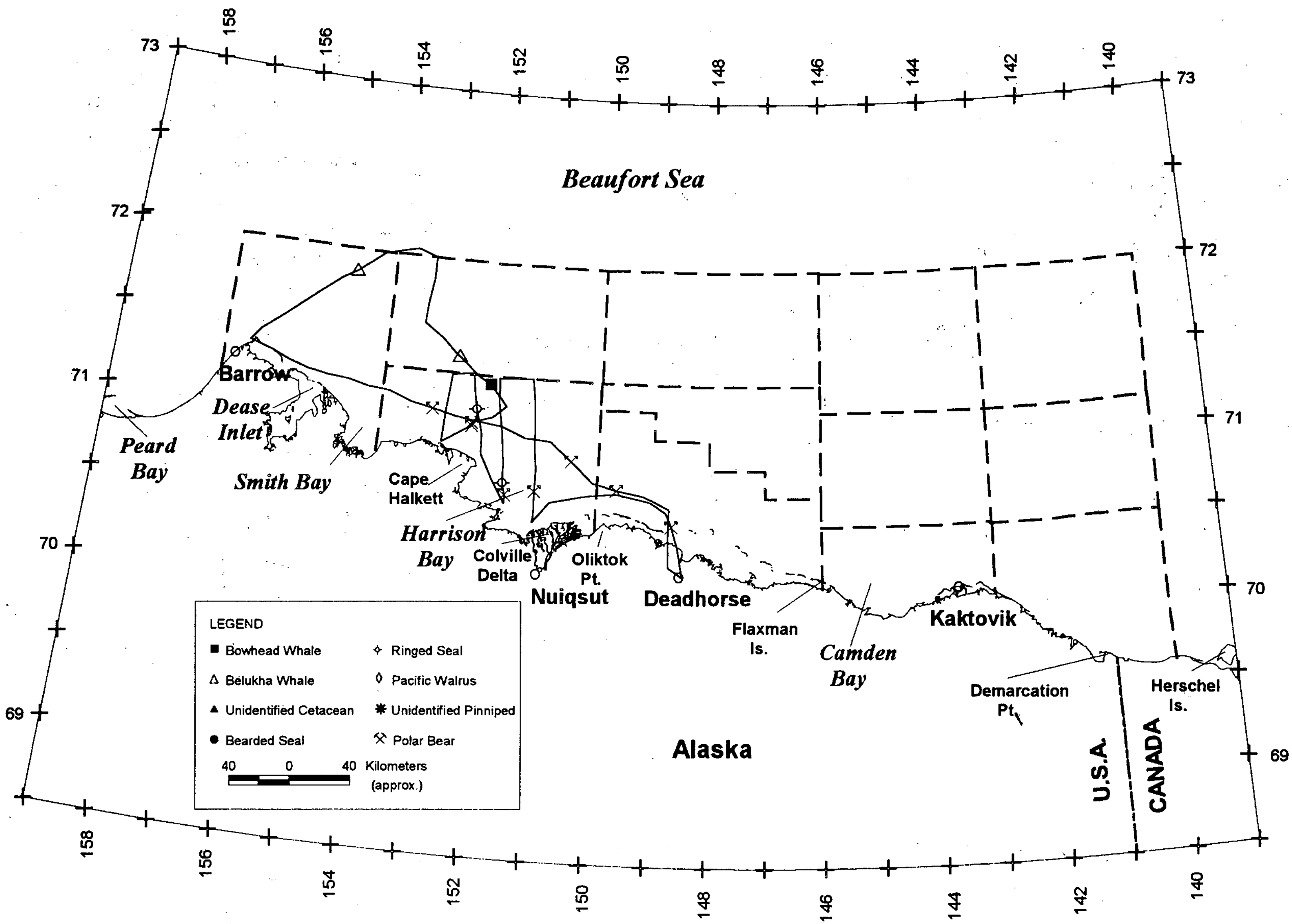
Flight 25: 29 September 1996 Survey Track and Sightings



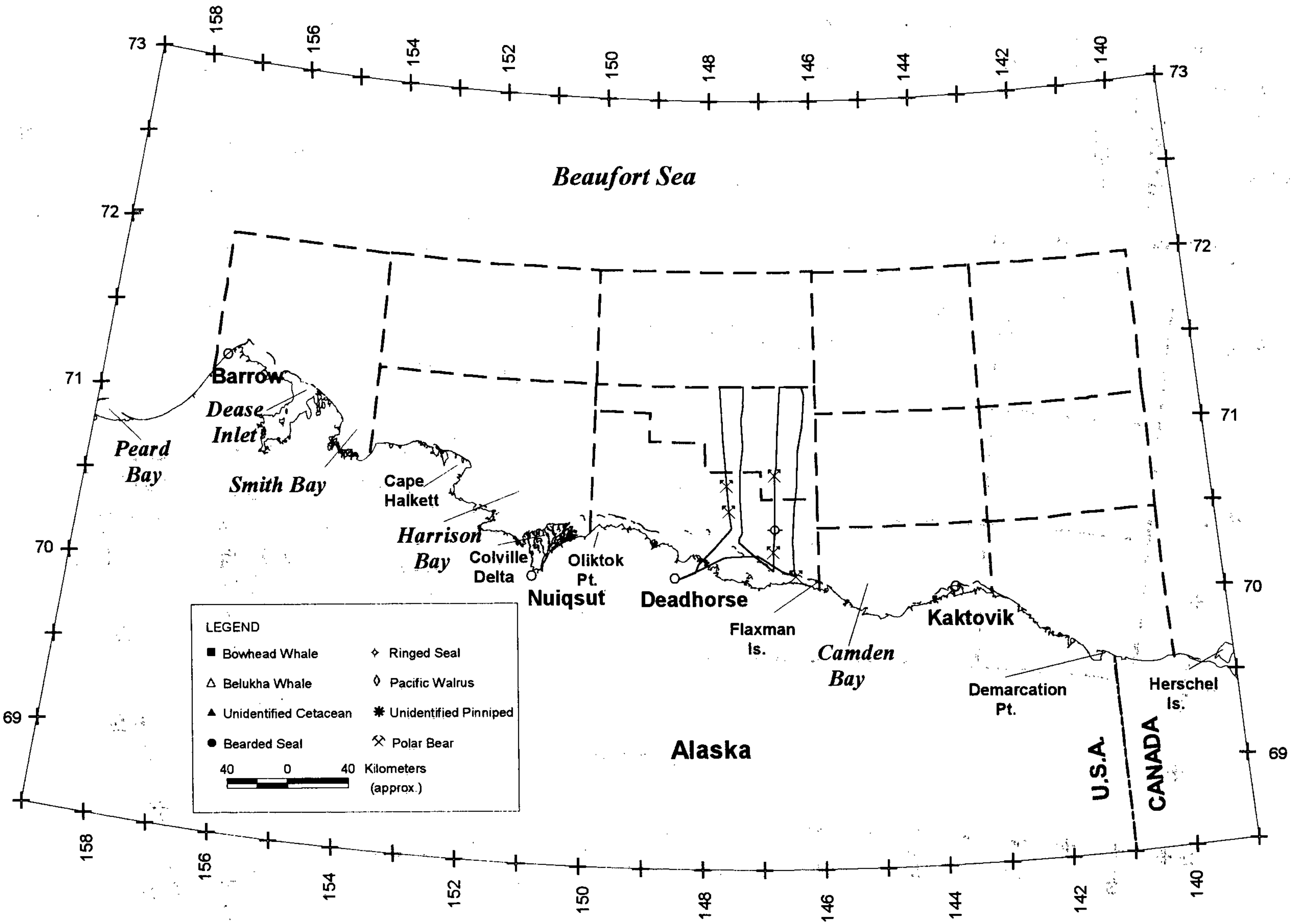
Flight 26: 30 September 1996 Survey Track and Sightings



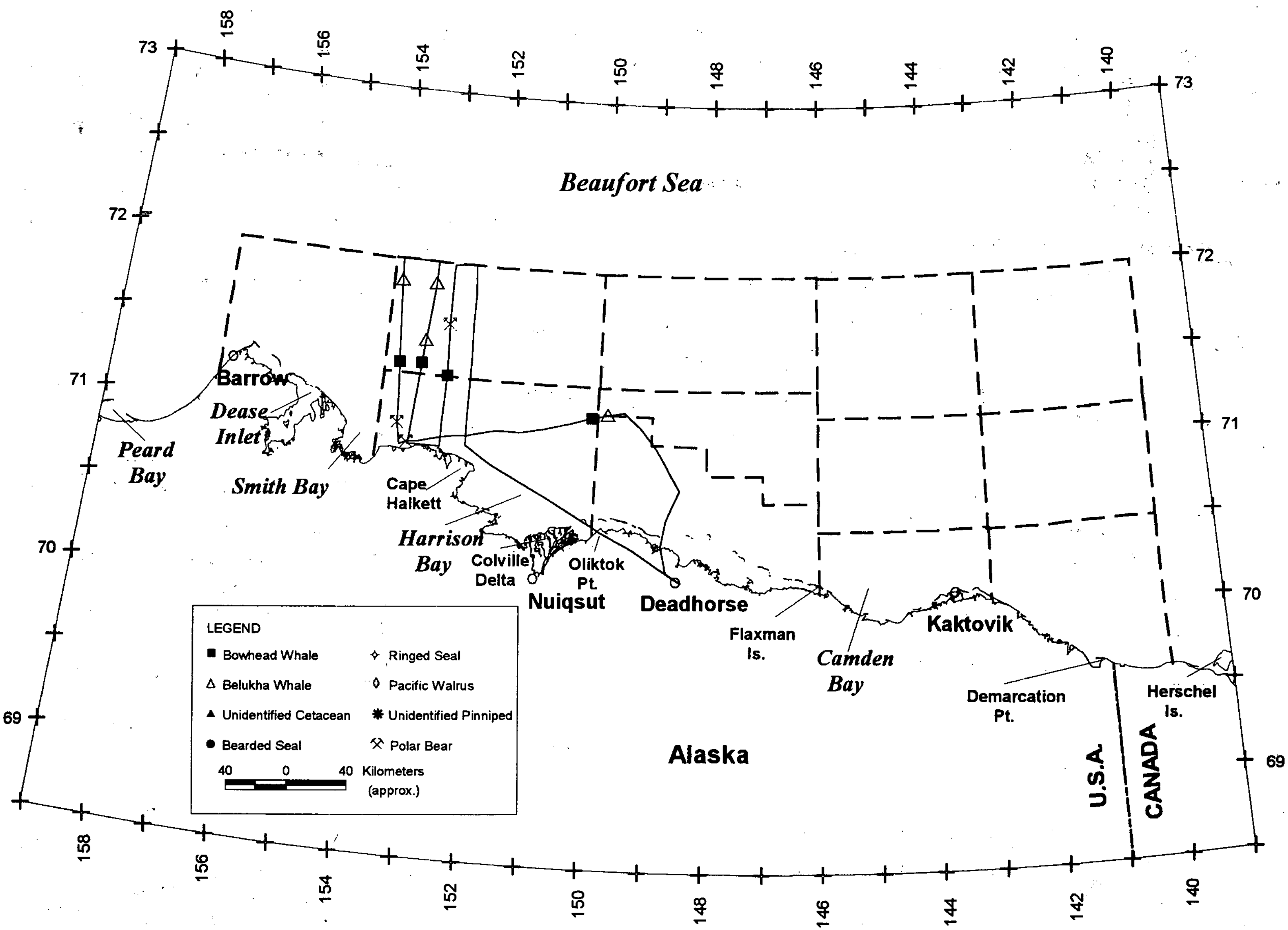
Flight 27: 1 October 1996 Survey Track and Sightings



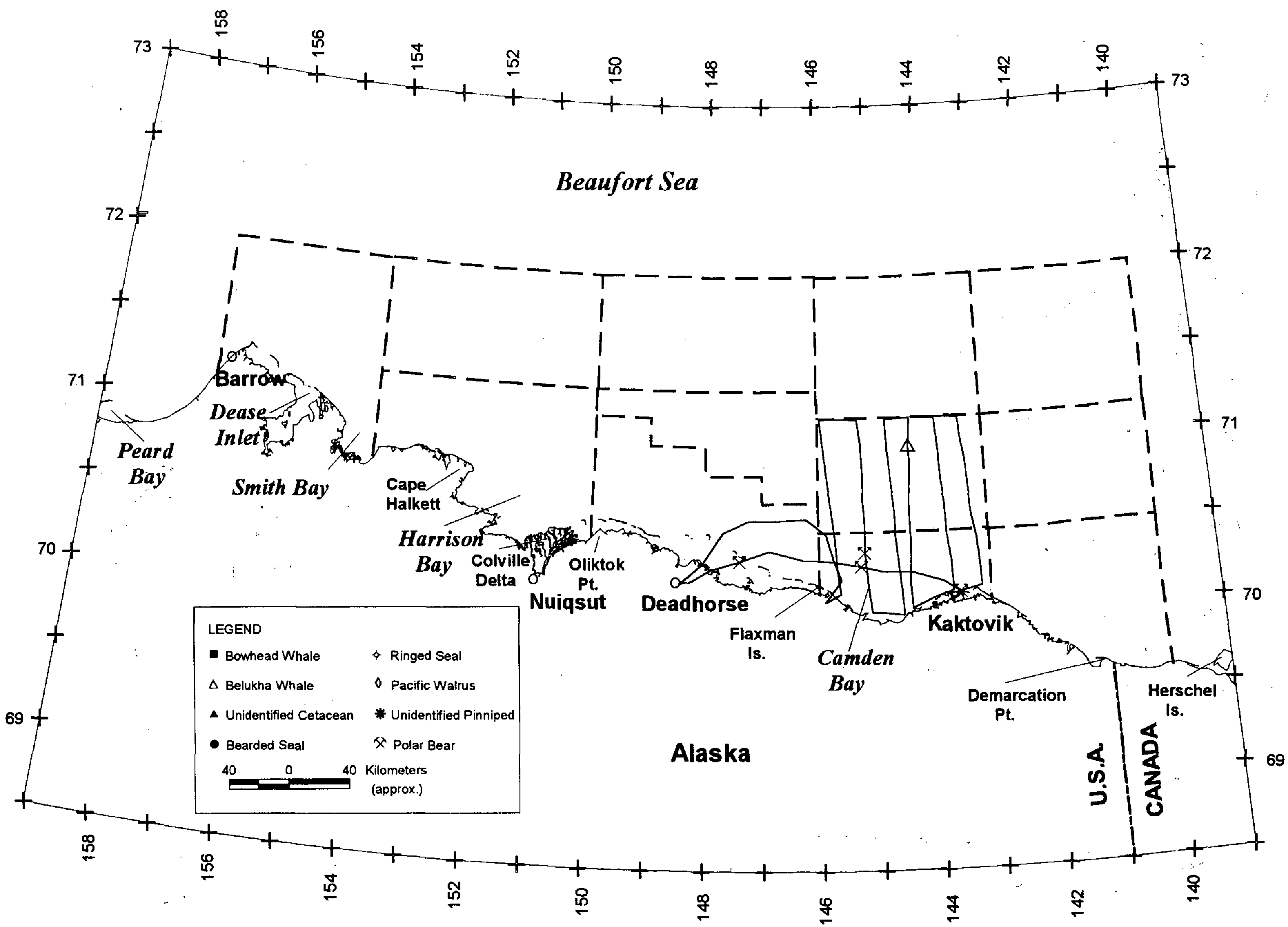
Flight 28: 2 October 1996 Survey Track and Sightings



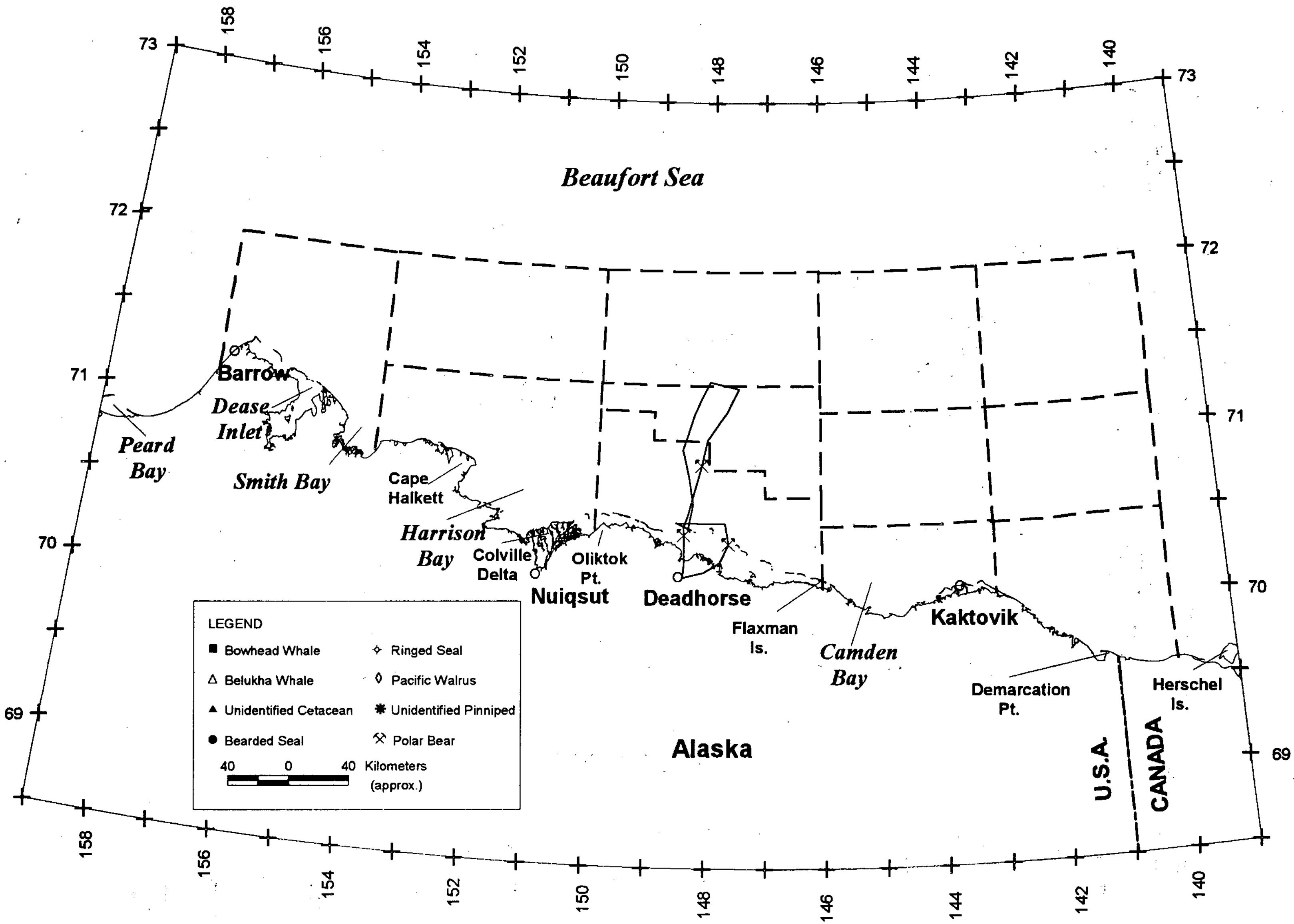
Flight 29: 4 October 1996 Survey Track and Sightings



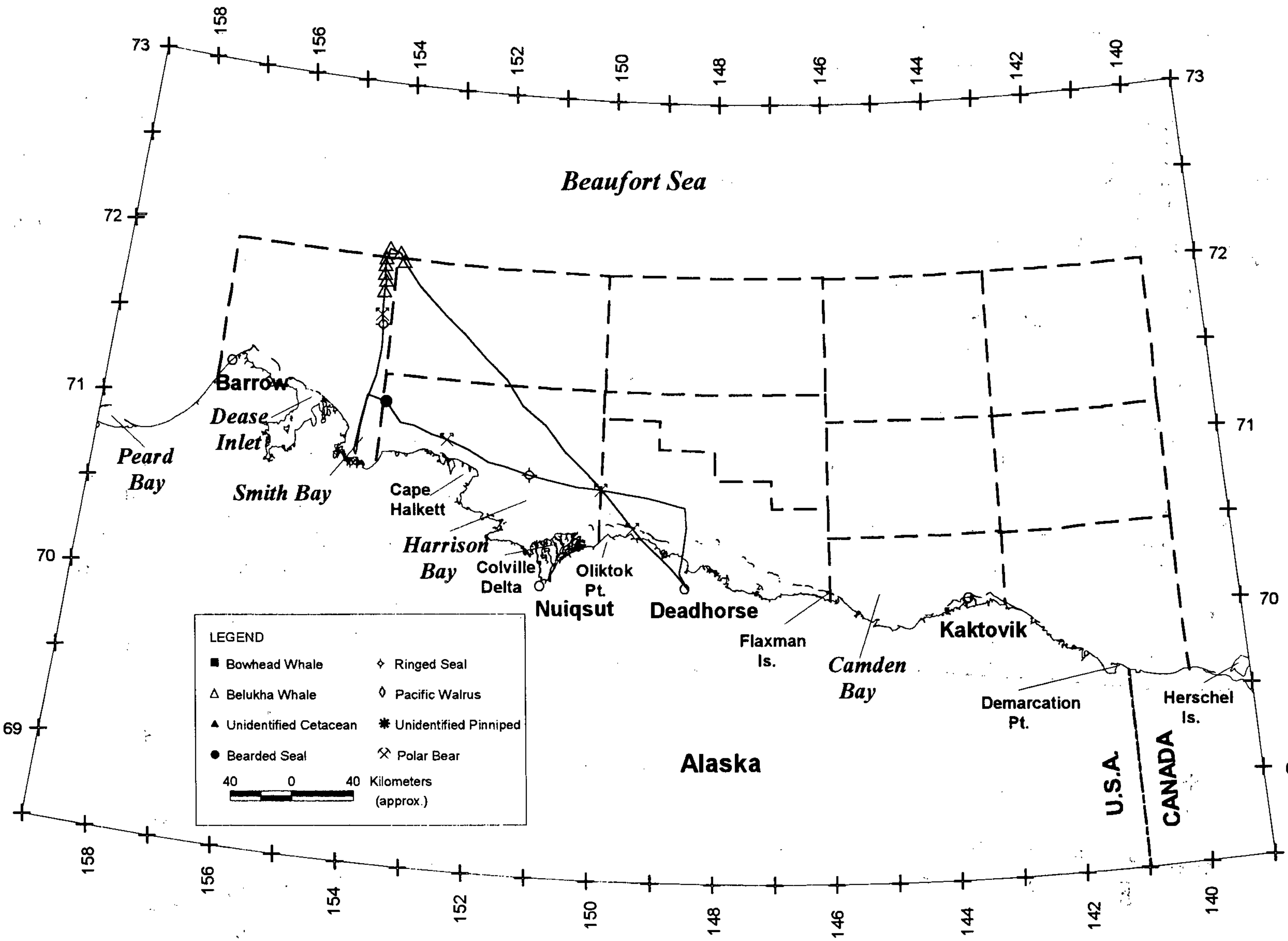
Flight 30: 5 October 1996 Survey Track and Sightings



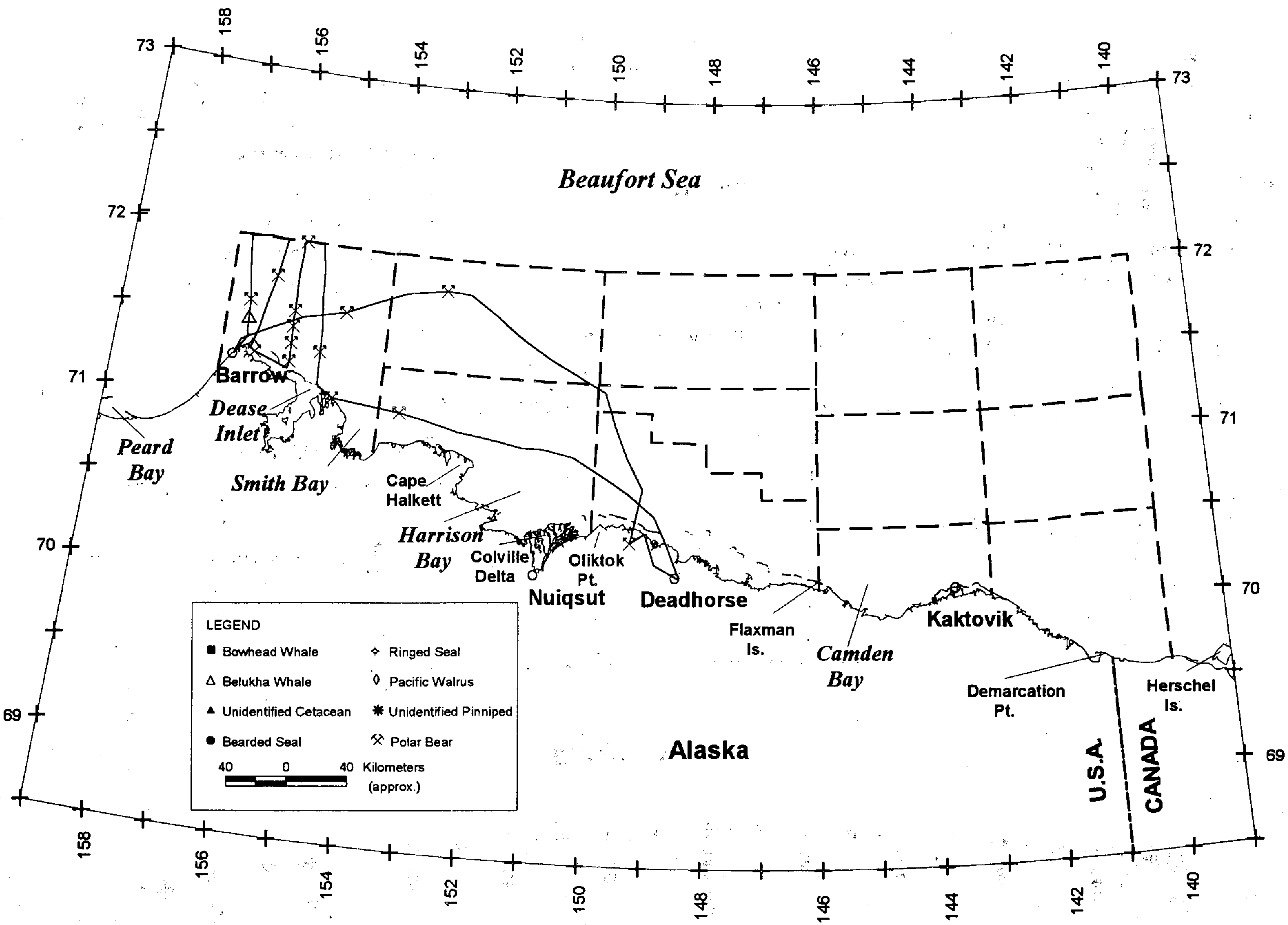
Flight 31: 6 October 1996 Survey Track and Sightings



Flight 32: 7 October 1996 Survey Track and Sightings



Flight 33: 7 October 1996 Survey Track and Sightings



Flight 34: 9 October 1996 Survey Track and Sightings

GLOSSARY OF ABBREVIATIONS, ACRONYMS, AND INITIALISMS

AC	alternating current
AEWC	Alaska Eskimo Whaling Commission
ANOVA	analysis of variance
BLM	Bureau of Land Management
BPXA	BP Exploration (Alaska) Inc.
C	Celsius
CI	confidence interval
e.g.	for example
EIS	Environmental Impact Statement
ELT	emergency locator transmitter
ESA	Endangered Species Act
FMS	Flight Management System
FR	Federal Register
GPS	Global Positioning System
hr	hour
i.e.	that is
km	kilometer
m	meter
MDC	Mobile Datacom Corporation
MMS	Minerals Management Service
n	sample size
NOAA	National Oceanic and Atmospheric Administration
NOS	Notice of Sale
NOSC	Naval Ocean Systems Center
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
RDSS	Radio Determination Satellite System
SD	standard deviation
SPUE	sightings per unit effort (number of whale sightings counted per hour)
T	true heading
USC	U.S. Code
USDOC	U.S. Department of Commerce
USDOD	U.S. Department of Defense
USDOI	U.S. Department of the Interior
UTM	Universal Transverse Mercator
WPUE	whales per unit effort (number of whales counted per hour); 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.