Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 1992

OCS Study
MMS 93-0023

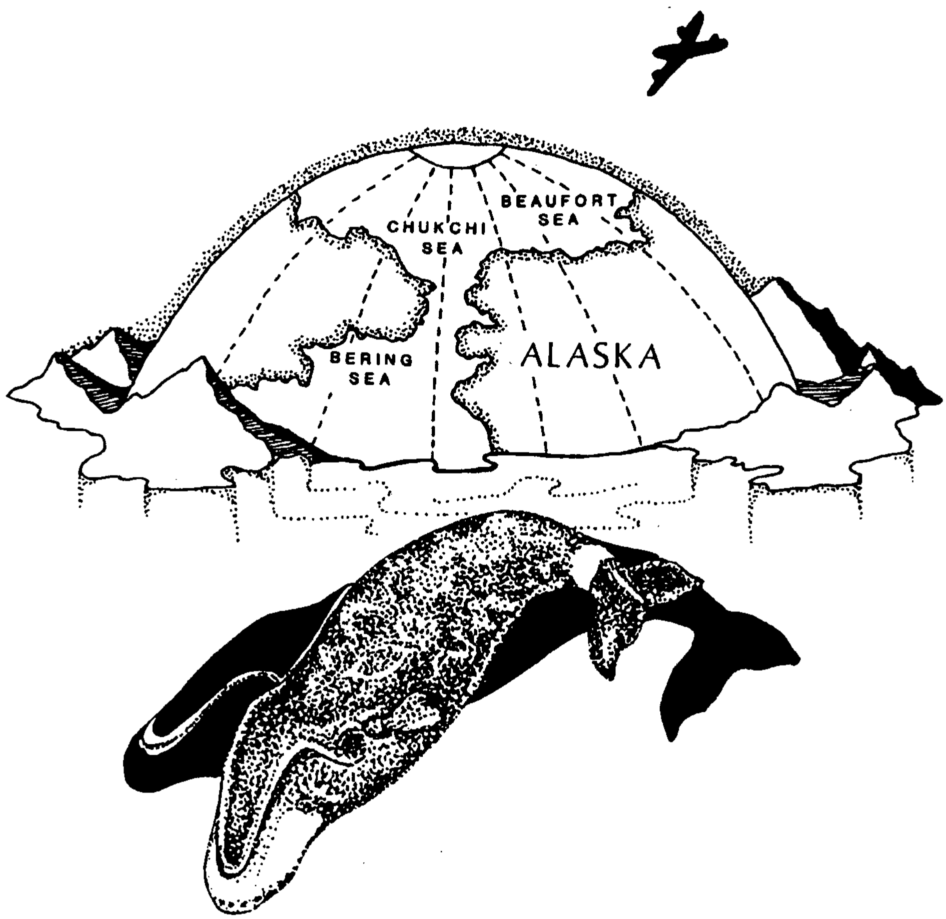
MMS
U.S. Department of the Interior
Minerals Management Service
Alaska OCS Region

Any use of trade names is for description purposes only and
does not constitute endorsement of these products
by the Minerals Management Service.

Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 1992

OCS Study
MMS 93-0023

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



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

Anchorage, Alaska
1993

ABSTRACT

This report describes field activities and data analyses for aerial surveys of bowhead whales conducted between 31 August 1992 and 23 October 1992 in the Beaufort Sea, primarily between 140°W. and 154°W. longitudes south of 72°N. latitude. This report also describes surveys west of 154°W. longitude flown during the latter part of the field season. General ice cover during September and October 1992 was moderately heavy, limiting the counts of subsurface marine mammals. A total of 315 bowhead whales, 635 belukha whales, 45 bearded seals, 606 ringed seals, 203 polar bears, 1 Pacific walrus, 5 unidentified cetaceans, and 163 unidentified pinnipeds were observed in 1992 during 205.78 hours of survey effort that included 99.02 hours on randomized transects. Also, 636 sets of polar bear tracks and 27 polar bear kill sites were observed when no bears were present. The initial sighting of bowhead whales in Alaskan waters occurred on 31 August. Of the 102 bowhead whales observed east of 154°W. longitude, half (median) had been counted by 20 September. Of these 102 whales, the peak count (mode) of 7 whales was observed on 1 October; and the last sighting occurred in 95-percent ice on 6 October. A large aggregation of bowhead whale pods, many of which were feeding, was subsequently observed west of 154°W. longitude (just northeast of Barrow, Alaska) on 17 October. By 21 October, the aggregation had begun to disperse farther west. Estimated median and mean ($\bar{x}$) water depths at the location of bowhead whales sighted on randomized line transects during September and October 1992, 46.0 meters and 70.6 meters, respectively, are consistent with a previously noted trend for whales to be located in deeper water during years of moderately heavy ice cover.

ACKNOWLEDGMENTS

Project Management

Cleveland J. Cowles, Ph.D., Supervisor
Stephen D. Treacy, Project Manager

Minerals Management Service (MMS) Project Field Scientists

Stephen D. Treacy, Team Leader (Flights 1-22 and 43-45)
Donald Hansen, Team Leader (Flights 23-34)
John Dunlap, Team Leader (Flights 35-42)
Kristopher Nuttall, Data Recorder-Observer (Flights 1-19)
Susan Zerwick, Data Recorder-Observer (Flights 20-45)
Richard Pomeroy, Primary Observer (Flights 1-4)
Peter Johnson, Primary Observer (Flights 5-14)
Donald Hansen, Primary Observer (Flights 15-22)
Stephen D. Treacy, Primary Observer (Flight 23)
Steve Landino, Primary Observer (Flights 24-45)

Technical Support Personnel

John Dunlap, Computer Systems Developer
Kristopher Nuttall, Field Equipment Coordinator

Contracting Officer's Administrative Representative - Aircraft Support

Stephen D. Treacy - MMS/Office of Aircraft Services (OAS) IA 14-35-0001-12493

National Marine Fisheries Service (NMFS) Liaison

Ron Morris, NMFS, Anchorage, Alaska

The project management acknowledges Joanne Groves and Birgit Njastad, respectively, of the University of Alaska-Fairbanks Geophysical Institute for analysis and initial graphic portrayal of ice concentrations.

We acknowledge the Department of the Interior, OAS, for making all aircraft arrangements; Anders Ahren, Rod Elg, Pete Hassinger, Tony Oney, and Jeff Sharp (ERA Aviation) for piloting the Twin Otter; and the Deadhorse Flight Service for providing us with daily telefaxes of local weather.

We appreciate review comments on this and/or previous project reports by the NMFS, the State of Alaska, the North Slope Borough, and Dr. Steven Swartz of the Marine Mammal Commission.

Ruth Poff, Alaska OCS Region, provided administrative and financial-management support for the field work. Alaska OCS Region personnel who supported production of this study were Colleen Ryan, who edited the manuscript; Bill Chambers, who drafted Beaufort Sea isobaths (Fig. 2), Figures 24 and 25, and the final ice maps using application software (AutoCAD, Autodesk, Inc.); and Jean Thomas, who photographed the ice maps and helped with pagination. Ann Treacy contributed the cover illustration.

CONTENTS

LIST OF FIGURES

LIST OF FIGURES
(Continued)

LIST OF TABLES

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). 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). The Beaufort Sea Sale 97 NOS (1988) and Beaufort Sea Sale 124 NOS (1991) do not contain a seasonal offshore-drilling restriction but state that "MMS intends to continue its areawide endangered whale monitoring program in the Beaufort Sea during exploration activities. The program will gather information on whale distribution and abundance patterns and will provide additional assistance to determine the extent, if any, of adverse effects to the species" (USDOI, MMS, 1988, 1991).

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, Library/Public Information Room, 949 East 36th Avenue, Anchorage, Alaska 99508-4302.

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 seasonal drilling restrictions and limitations on 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 31 August 1992 to 23 October 1992, 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 -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

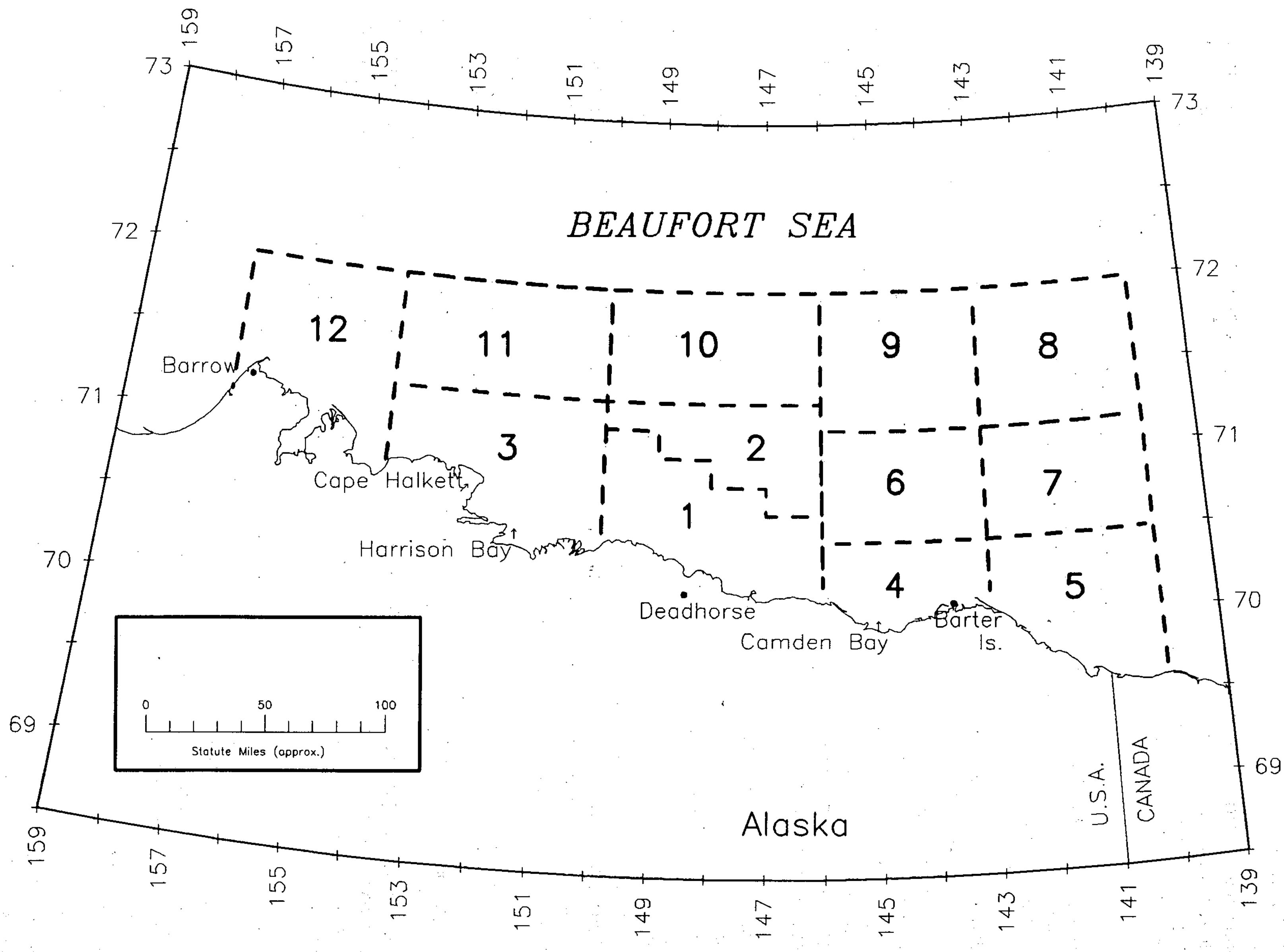


Figure 1. Fall 1992 Study Area Showing Survey Blocks

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

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. Electric 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 Mitsubishi MP 286L 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 location transmitter (ELT) installed in the aircraft, a portable ELT in a 6-person Switlik Search and Rescue Life Raft, a portable aircraft-band transceiver, flotation suits, Nomex flightsuits, and emergency crash helmets.

Flight-following equipment included the onboard very high-frequency aircraft-band radio, which was used to transmit position data to Deadhorse Flight Service when entering a new survey block and, if possible, when ending southbound transect lines. The onboard high-frequency radio was used to transmit hourly position data to OAS Flight Operations, Anchorage. 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 31 August to 20 October 1992 and out of Barrow, Alaska, from 21 October to 23 October 1992. The field schedule was designed to monitor the progress of the Fall 1992 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 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, the level of offshore oil industry activity in various areas, and a semimonthly flight-hour goal for each survey block. Flight-hour goals were 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 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. In 1993, survey effort was reduced in the area of the drill site to avoid simultaneous sampling in the same area where a site-specific monitoring, funded by ARCO Alaska Inc., was being conducted. Additional survey effort in Block 12 (Fig. 1) was used to document the end of the fall migration of bowhead whales in the Beaufort Sea.

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.

A clinometer was used to measure the angle of inclination to each initial sighting of endangered whales when the sighting location (or whale-dive site) 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. Only groups of bowheads seen before diverting from the transect line were included in density calculations.

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 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 sequence used in 1992 and the questions used to prompt entry of observational data. All data entered were simultaneously printed out in hard copy.

For the purpose of discussion, behaviors were entered into one of 13 categories noted on previous surveys. These categories--swimming, diving, milling, feeding, mating, cow/calf association, resting, rolling, flipper-slapping, tail-slapping, spy-hopping, breaching, 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, immature, adult, or large adult, respectively) rather than on an absolute scale.

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

Table 2
Operational Definitions of Observed Whale Behaviors

Behavior	Definition
Swimming	Whale(s) proceeding forward through the water propelled by tail pushes.
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.
Milling	Whale(s) swimming slowly at the surface in close proximity (within 100 m) to other whales, often with varying headings.
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.
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.
Cow-Calf	Calf nursing; calf swimming within 20 m of an adult.
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.
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.
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.
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.
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.
Underwater Blowing	Whale(s) exhaling while submerged, thus creating a visible bubble.

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 Zone 6. Observed bowhead distribution was plotted semimonthly over the Beaufort Sea study area. September-October sightings of belukha whales, ringed and bearded seals, and other marine mammals were depicted on separate maps. Maps in this report were plotted on a Hewlett-Packard (HP) Laser Jet II printer equipped with an HP 7475A plotter emulator cartridge.

Ice concentrations in the Beaufort Sea were digitized or hand-drafted as either 0-percent, 0- to 25-percent, 26- to 50-percent, 51- to 75-percent, or 76- to 100-percent ice cover from U.S. Navy-NOAA Joint Ice Center Southern Ice Limit charts. All but one of these charts were available for every seventh day from 25 August through 27 October 1992. The chart for 7 October 1992 was provided by National Weather Service, Anchorage, Alaska.

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 1992 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, and assuming a compass correction of 31°. Probabilities were interpolated from alpha values shown for calculated critical values of Rayleigh's z (Zar, 1984: Table B.32). A generalized bathymetry map was adapted from U.S. Geological Survey Open-file Maps 76-821, 76-822, and 76-823. Additional statistical comparisons, correlations, and regressions (Zar, 1984) were performed as appropriate.

The water depth at each bowhead sighting in the 1982-1992 database was derived using a computer program--DEPTH--that assigned a metric depth value averaged over gridded areas (each 5.6 km^2) in the Beaufort Sea west of 139°W. longitude and south of 72°N. 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 within 1 km of random-transect legs. Density estimates were derived by survey block and are presented, with a description of density-estimate methodologies, in Appendix A.

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), repeat sightings or sightings of dead marine mammals, listed in Appendix B: Table B-1, were not included in summary analyses or maps. When tables and figures exclude certain data, such exclusions were indicated in the captions.

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

The 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 null hypotheses tested via median-depth analysis were prescribed in Houghton, Segar, and Zeh (1984) as:

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.

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 a deeper median depth. Selected isobaths (20 m, 40 m, 100 m, 400 m, 1,000 m, 2,000 m, and 3,000 m), after a Beaufort Sea Planning Area Map (USDOI, MMS, 1985), are included for general reference (Fig. 2).

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). When sample sizes were large ($n \geq 25$), a large-sample approximation (Zar, 1984) 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). 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 1992 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).

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).

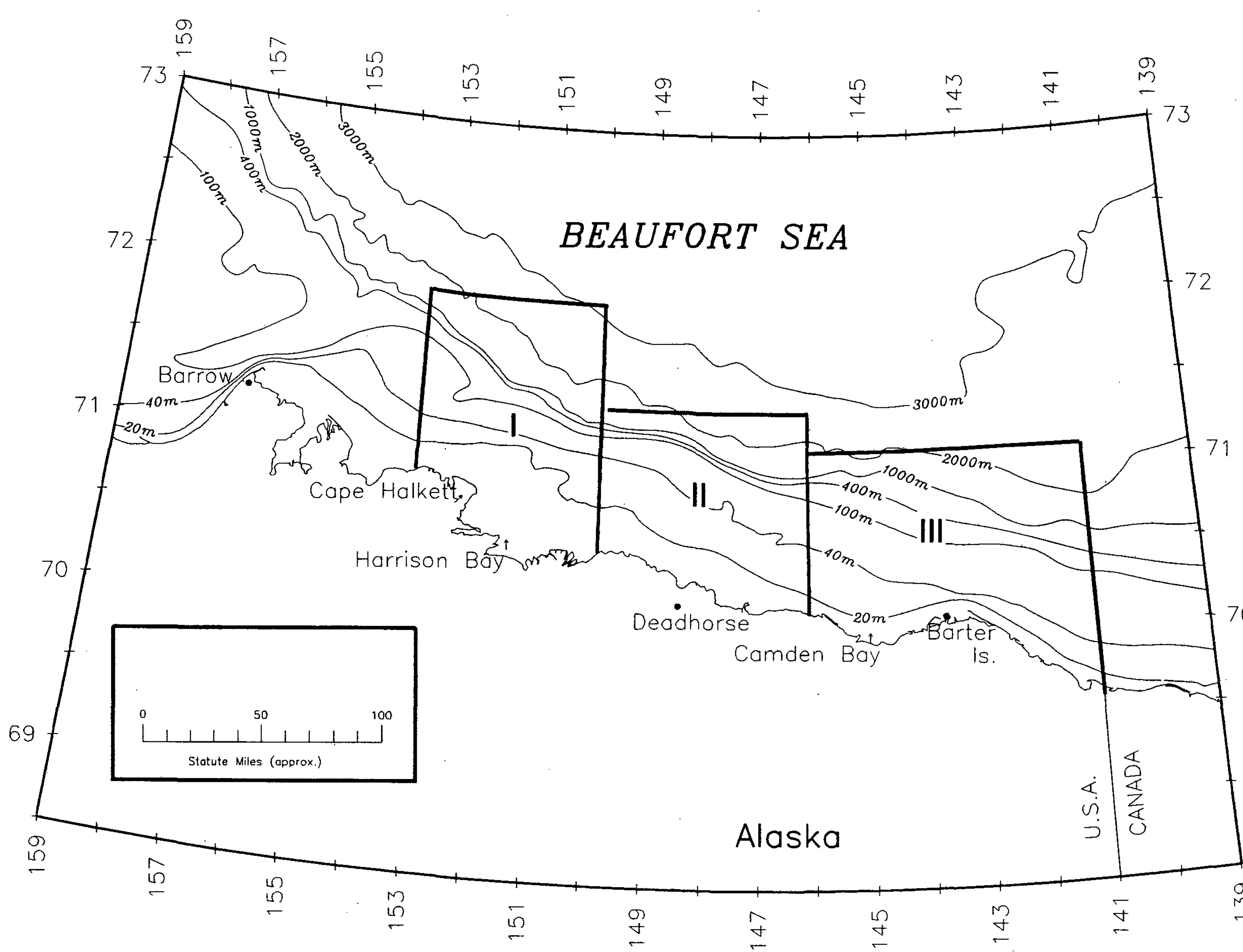


Figure 2. Regions I, II, and III (used in median-water-depth analyses) and Selected Isobaths

III. RESULTS

A. Environmental Conditions

General ice coverage in the Alaskan Beaufort Sea was moderately heavy during the Fall 1992 surveys (Figs. 3-12). The nearshore area remained open from 25 August through 8 September (Figs. 3-5). By 15 September, an arm of moderately light ice (25-50%) reached the shoreline (Fig. 6) of Camden Bay in the vicinity of the Kuvlum drill site. The general ice cover became more and more concentrated by 22 September (Fig. 7). By 29 September, heavy ice (75%) extended over the Alaskan Beaufort Sea, with only a narrow band of lighter ice concentrations (26-50%) near shore (Figs. 8-11). By 7 October, heavy sea ice (>75%) replaced lighter nearshore ice in the Canadian Beaufort Sea as far east as Cape Dalhousie. By 27 October, heavy ice cover (>75%) extended throughout the Beaufort Sea, at least as far east as Banks Island (Fig. 12). The general ice severity during Fall 1992, especially broken floe ice, may have reduced the ability of observers to spot whales near the surface or at great distances from the transect centerline. Ice percent and sea state 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; but flying conditions were considered favorable most of the time, permitting 45 flights in 54 days.

III

B. Survey Effort

Daily totals of kilometers and hours flown per survey flight are shown in Table 3. A total of 44,815 km of surveys were flown in 205.78 hours (Table 3) in the Beaufort Sea at an average speed of 217.8 km/hr. A total of 22,662 km of random-transect lines were flown in 99.02 hours (Table 3) at an average speed of 228.9 km/hr. These random transects constituted 50.6 percent of the total kilometers flown and 48.1 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 13 through 17.

On 31 August, one flight was made between Deadhorse and 143°W. longitude, south of 70°40′N. latitude (Fig. 13), to record part of the initial westward migration of the bowhead whales. There were 1.57 hours of random transects flown from 4.10 total flight hours on this day (Table 3), constituting 1.6 percent and 2.0 percent, respectively, of the total time spent in those effort categories.

During the first half of September, survey coverage was widely distributed between 140°W. and 154°W. longitudes, within 100 nautical miles of shore (Fig. 14). There were 20.17 hours of random transects flown from a total of 42.78 flight hours during this period (Table 3), constituting 20.4 percent and 20.8 percent, respectively, of the total time spent in those effort categories.

During the second half of September, survey coverage was widely distributed between 140°W. and 154°W. longitudes, within 100 nautical miles of shore (Fig. 15). There were 28.00 hours of random transects flown from 61.63 total flight hours during this period (Table 3), constituting 28.3 percent and 29.9 percent, respectively, of the total time spent in those effort categories.

During the first half of October, survey coverage was widely distributed across the study area, with some effort in each survey block (Fig. 16). There were 44.98 hours of random transects flown from 77.00 total flight hours during this period (Table 3), constituting 45.4 percent and 37.4 percent, respectively, of the total time spent in those effort categories.

From 16 through 23 October, flight effort included a few randomized transects west of 150°W. longitude but mostly consisted of search surveys west of 143°W. longitude (Figure 17). The effort also included some high-resolution surveys just east of Barrow. The final flight on 23 October 1993 departed from Barrow and proceeded southwest (Appendix B: Flight 45), generally followed the coastline to Point Hope, Alaska, and

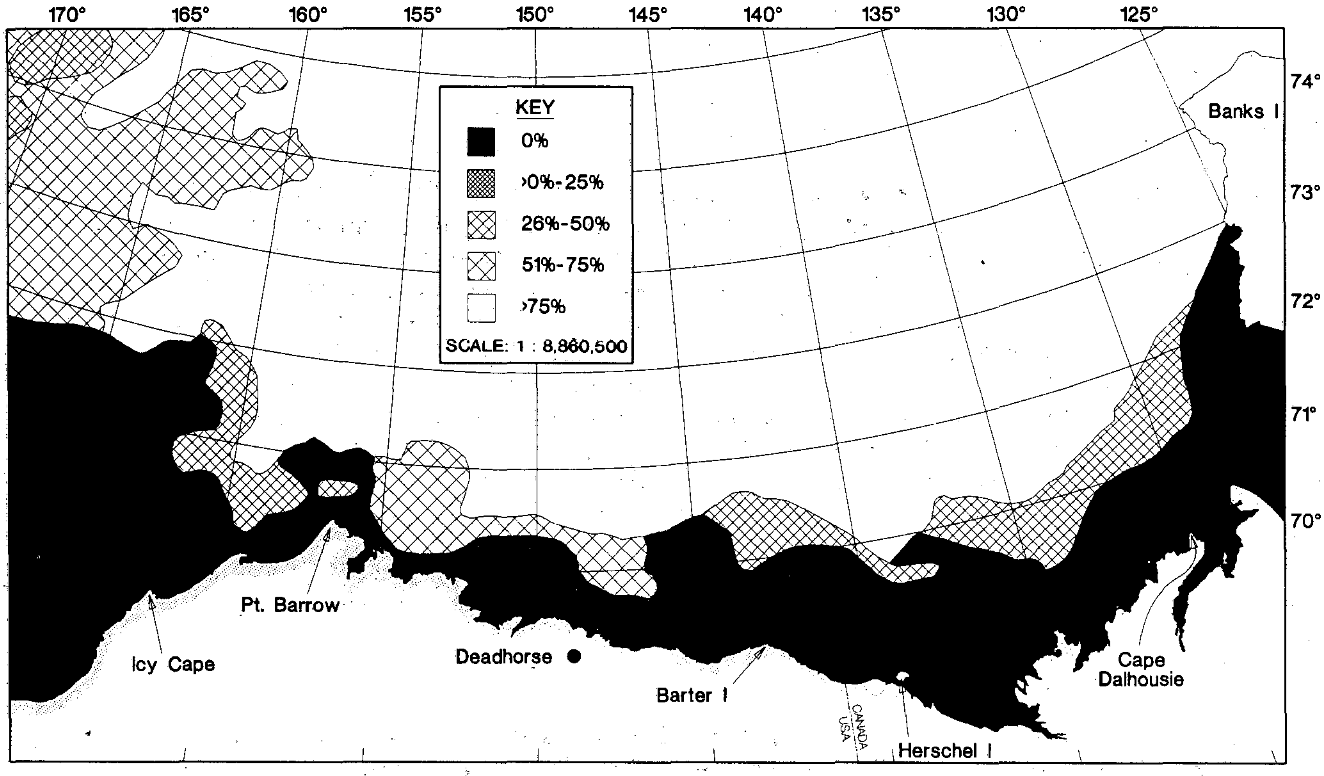


Figure 3. Map of Ice Concentrations in the Beaufort Sea, 25 August 1992

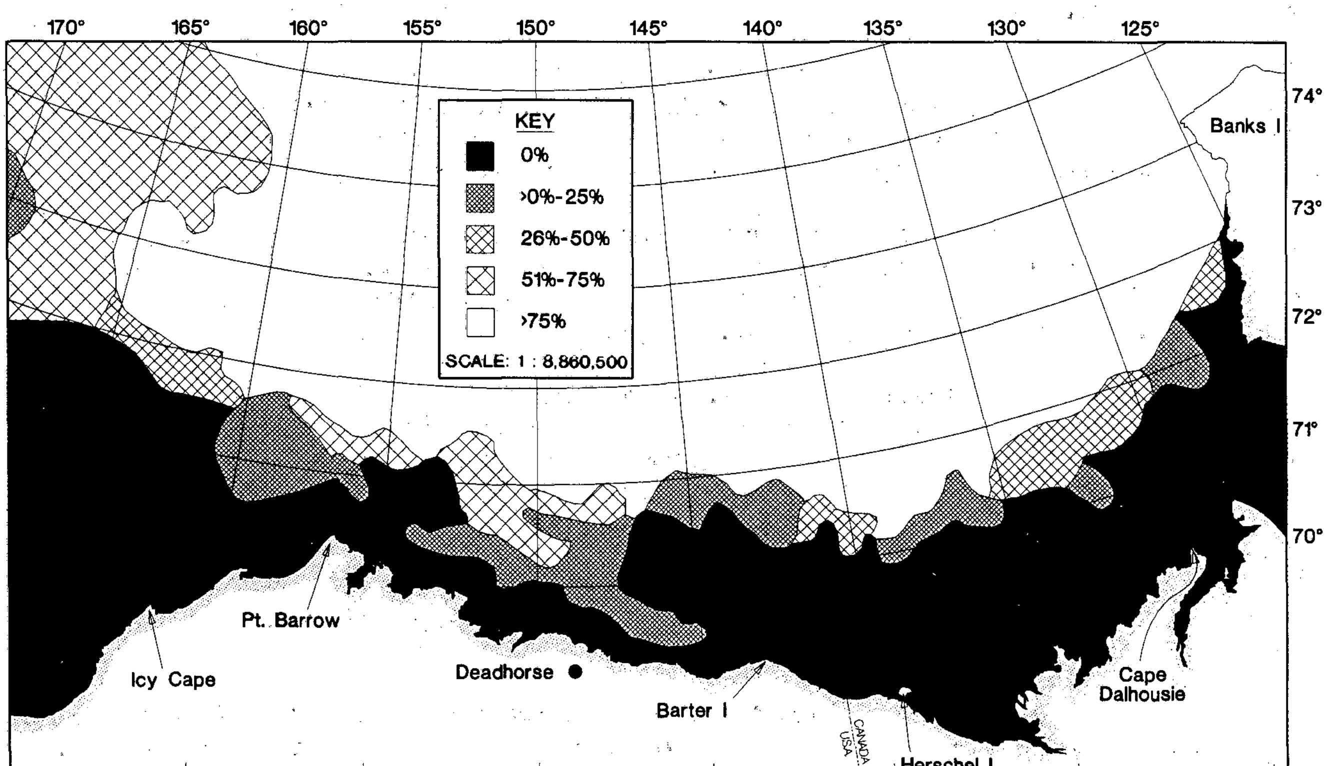


Figure 4. Map of Ice Concentrations in the Beaufort Sea, 1 September 1992

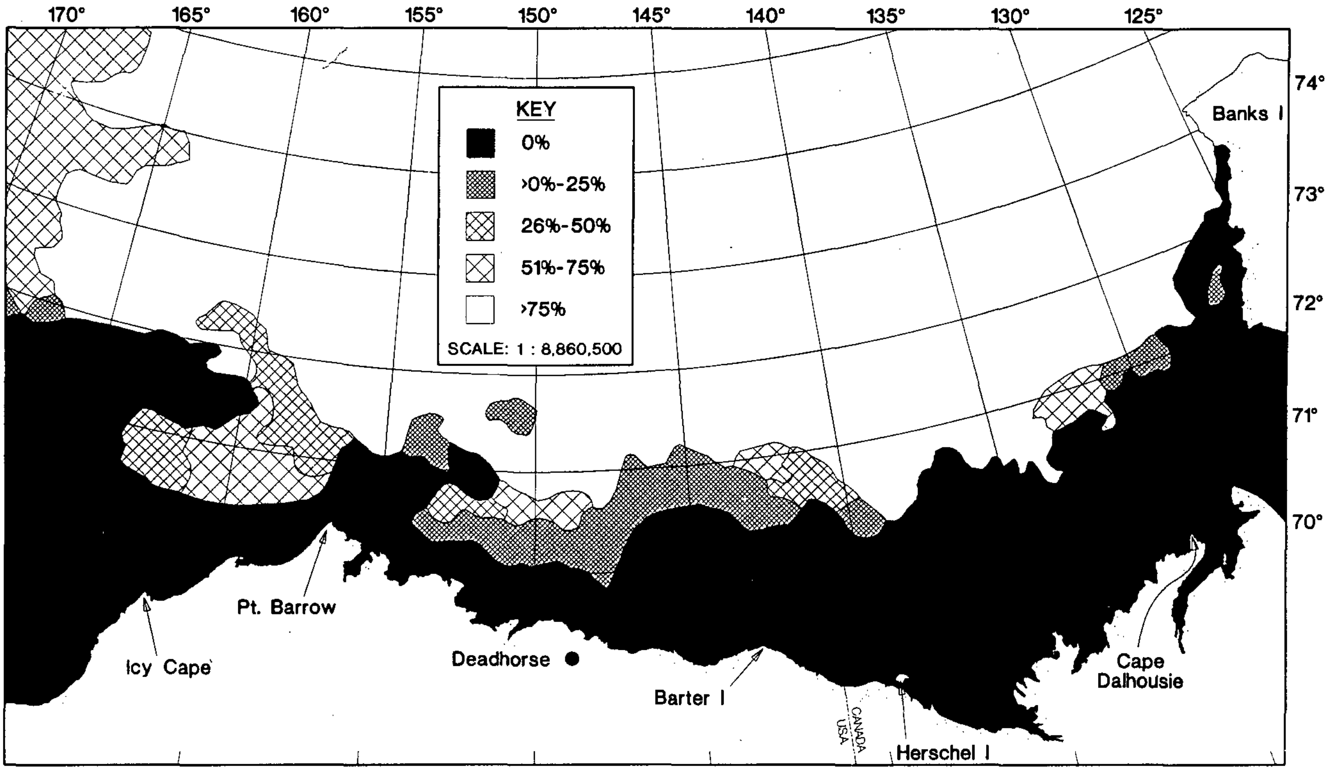


Figure 5. Map of Ice Concentrations in the Beaufort Sea, 8 September 1992

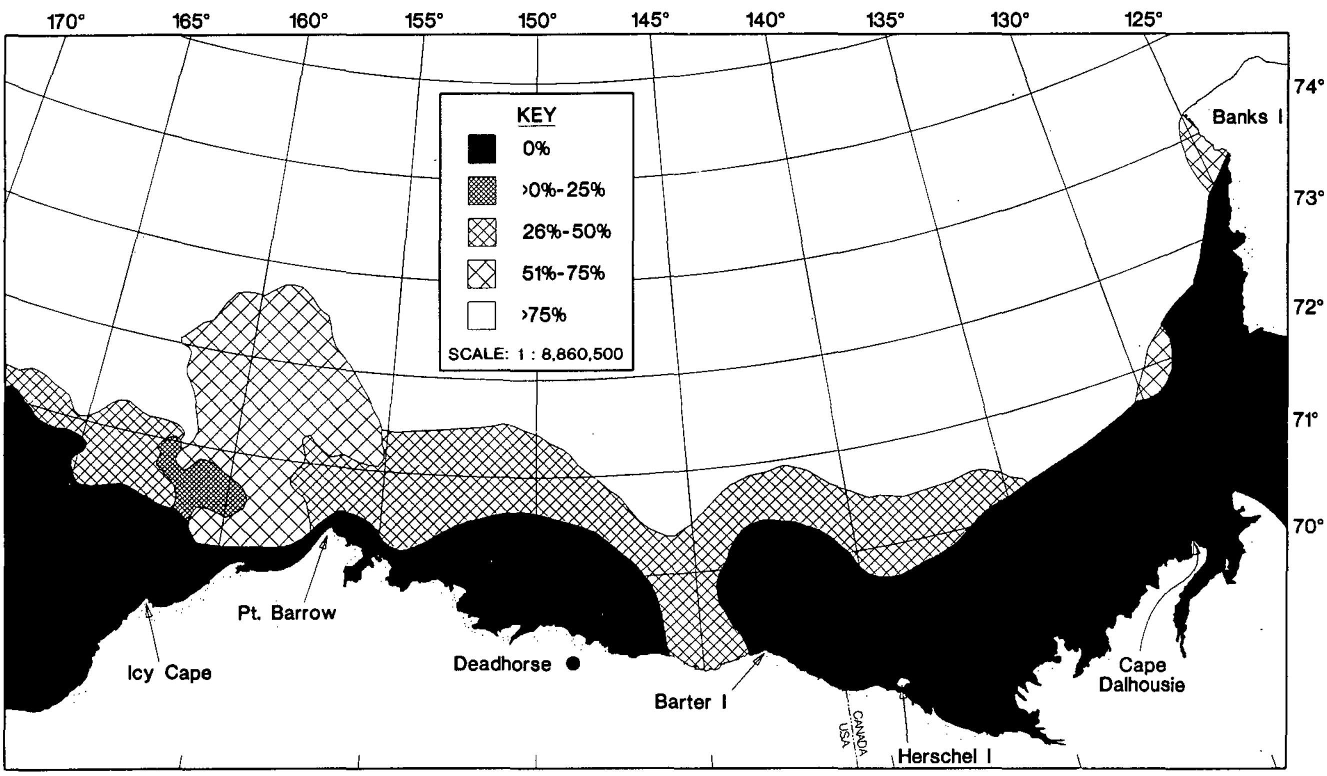


Figure 6. Map of Ice Concentrations in the Beaufort Sea, 15 September 1992

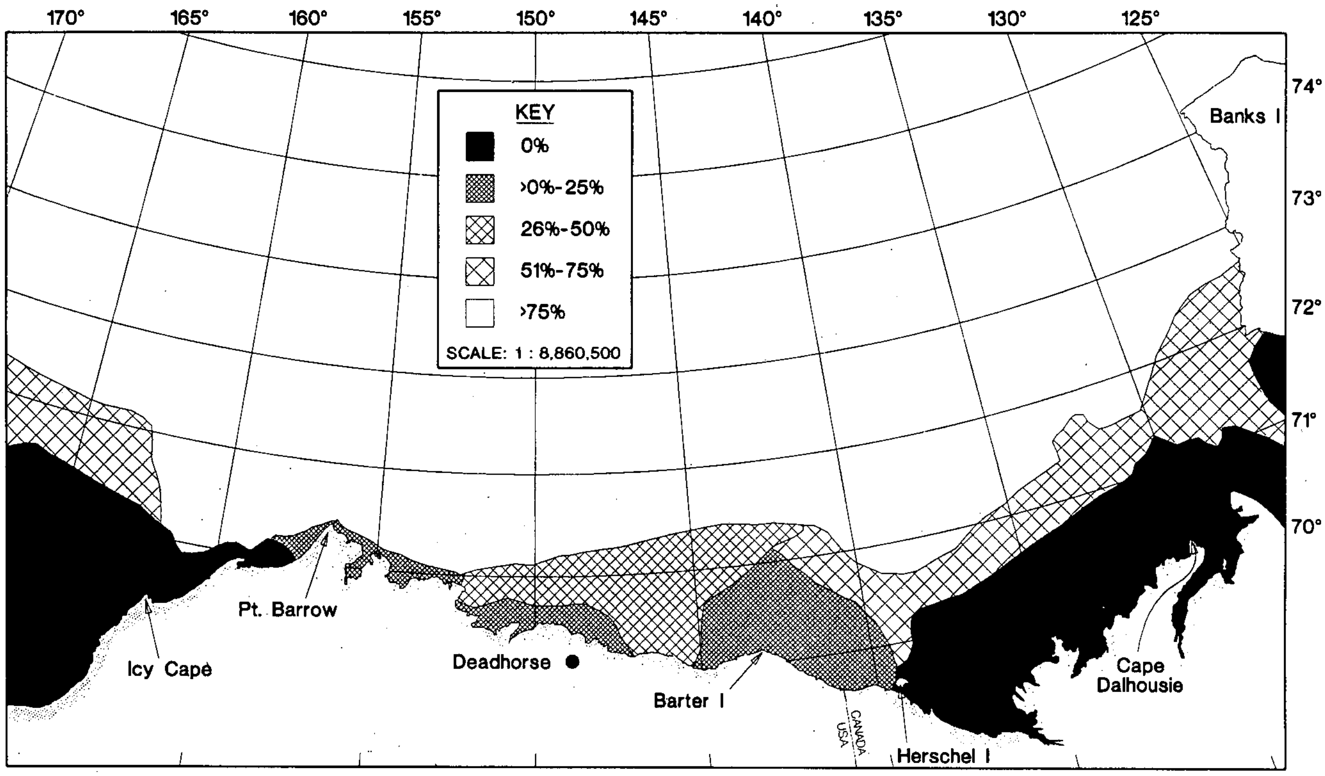


Figure 7. Map of Ice Concentrations in the Beaufort Sea, 22 September 1992

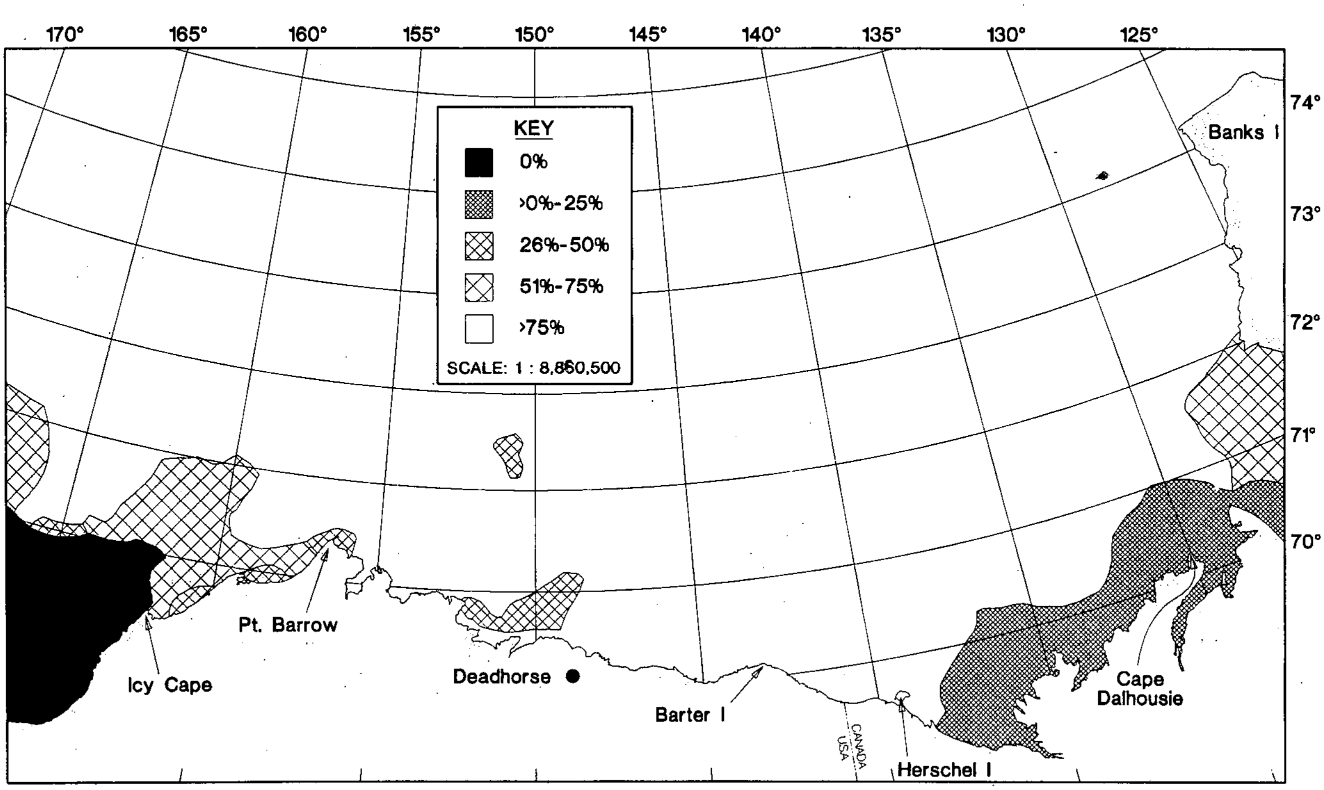


Figure 8. Map of Ice Concentrations in the Beaufort Sea, 29 September 1992

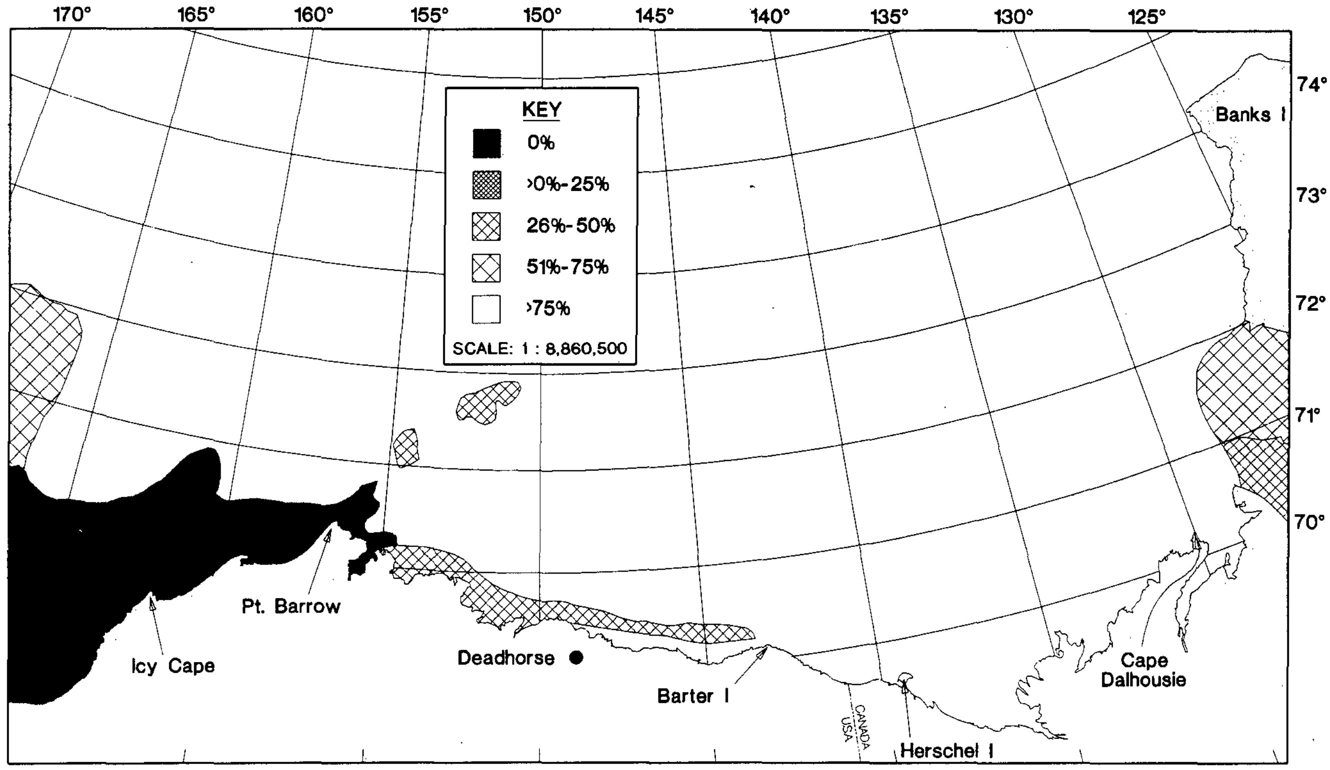


Figure 9. Map of Ice Concentrations in the Beaufort Sea, 7 October 1992

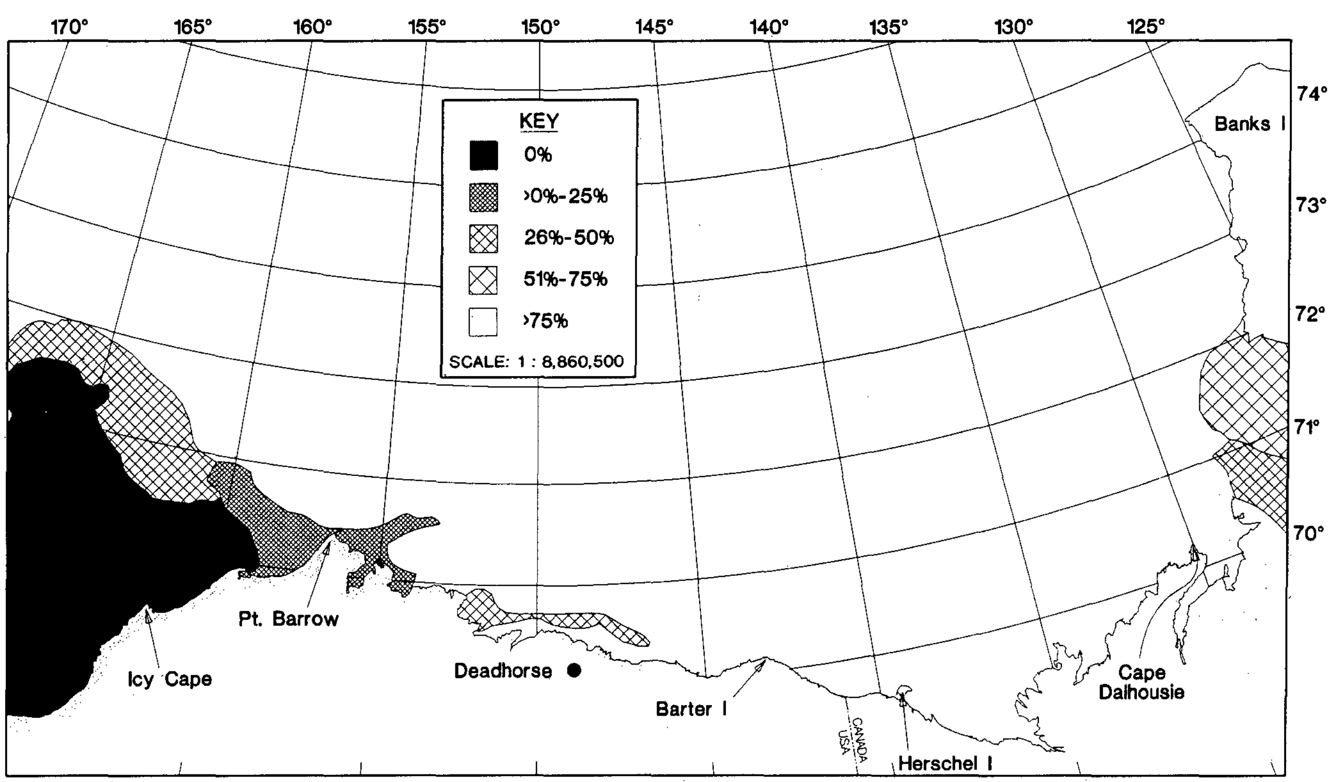


Figure 10. Map of Ice Concentrations in the Beaufort Sea, 13 October 1992

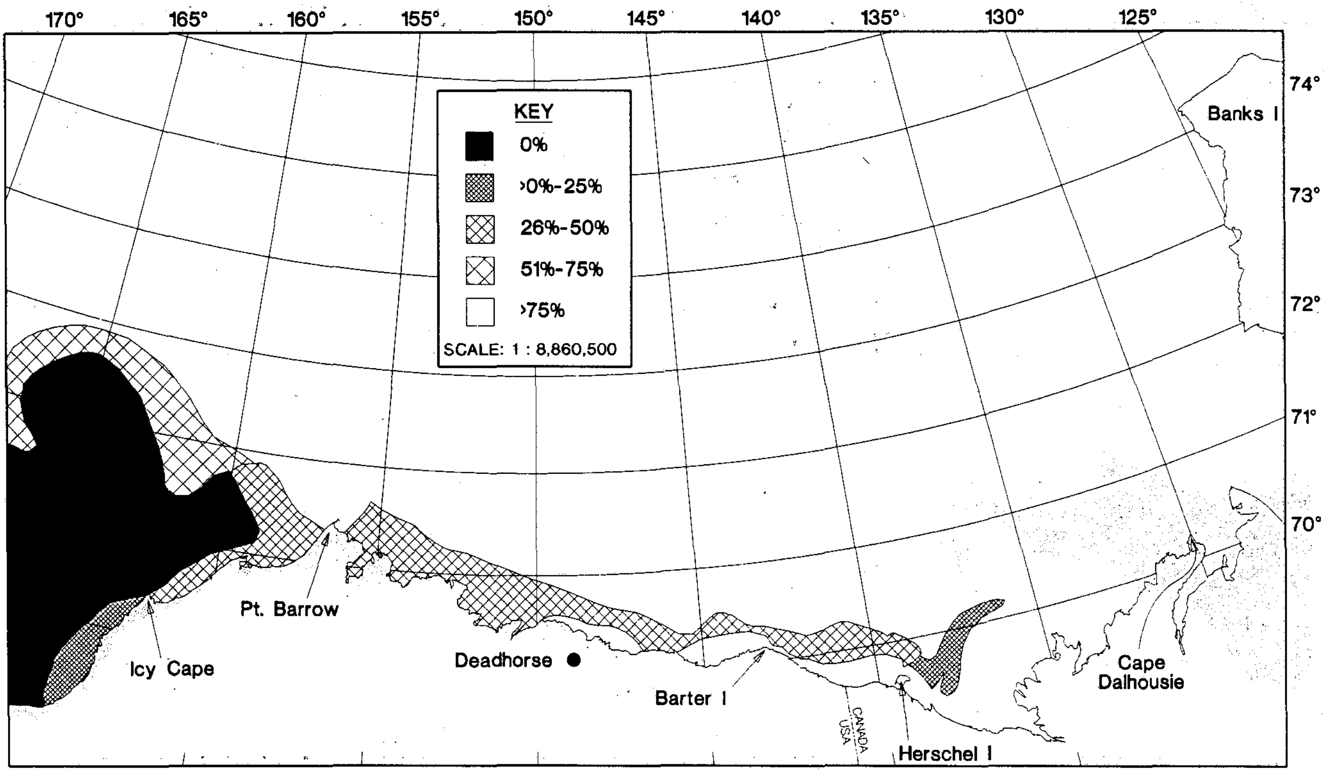


Figure 11. Map of Ice Concentrations in the Beaufort Sea, 20 October 1992

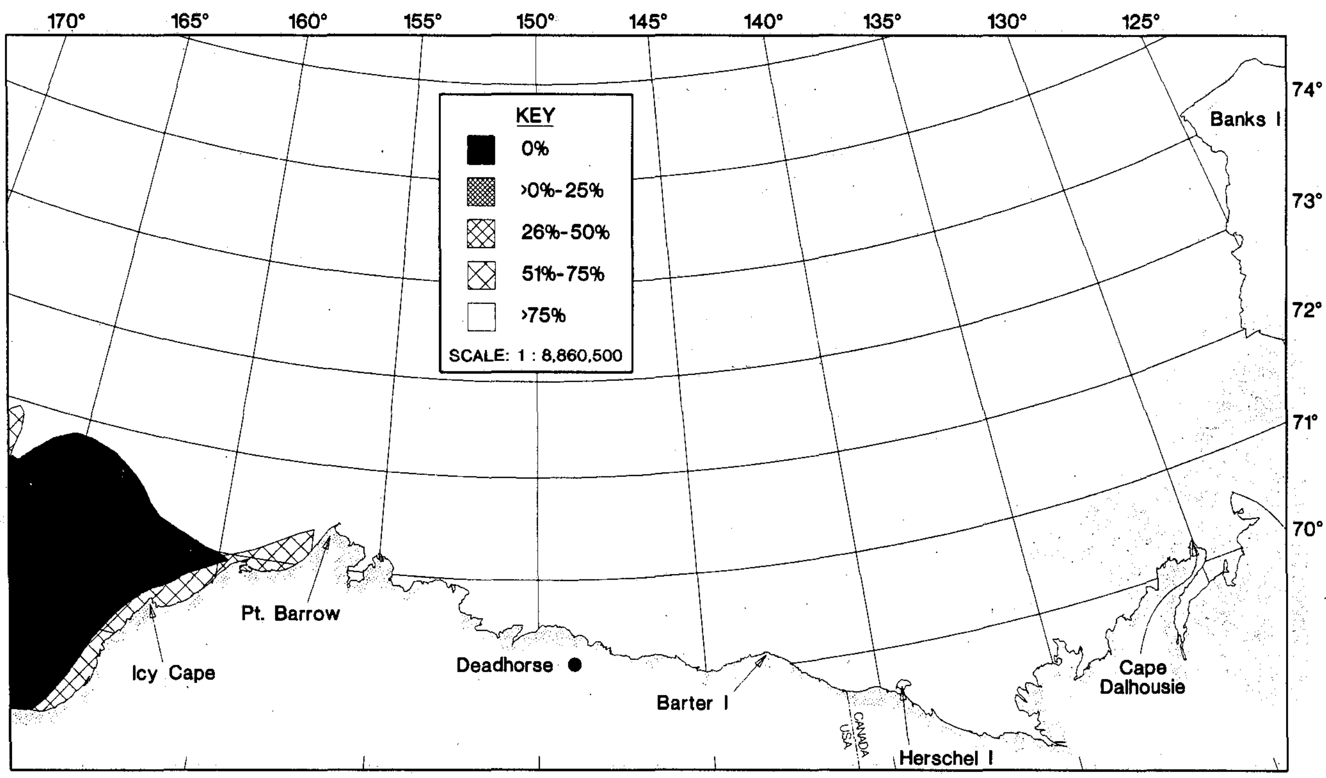


Figure 12. Map of Ice Concentrations in the Beaufort Sea, 27 October 1992

Table 3
Aerial-Survey Effort in the Beaufort Sea, 31 August-23 October 1992, by Survey Flight

Day	Flight No.	Transect (km)	Connect (km)	Search (km)	Total (km)	Transect Time (hr)	Total Survey Time (hr)
31 Aug	1	349	151	294	794	1.57	4.10
1 Sep	2	164	17	550	731	0.72	3.17
3 Sep	3	441	86	396	923	1.83	3.98
7 Sep	4	457	114	333	904	2.08	4.30
8 Sep	5	546	143	508	1,197	2.38	6.17
9 Sep	6	204	6	139	349	0.93	1.57
10 Sep	7	399	74	541	1,014	1.87	4.90
11 Sep	8	1,068	76	112	1,256	4.43	5.32
12 Sep	9	415	31	810	1,256	1.85	5.77
13 Sep	10	418	79	405	902	1.72	3.82
14 Sep	11	648	100	197	945	2.35	3.80
16 Sep	12	0	0	548	548	0.00	2.58
17 Sep	13	456	102	647	1,205	1.90	5.08
19 Sep	14	808	69	346	1,223	3.60	5.83
20 Sep	15	399	57	554	1,010	1.83	4.82
21 Sep	16	893	117	263	1,273	4.05	5.87
23 Sep	17	339	108	273	720	1.58	3.55
24 Sep	18	616	99	604	1,319	2.70	6.62
25 Sep	19	213	55	525	793	1.00	3.85
26 Sep	20	669	112	563	1,344	3.02	6.40
27 Sep	21	331	61	617	1,009	1.43	4.45
28 Sep	22	612	99	134	845	2.78	4.65
29 Sep	23	572	87	368	1,027	2.42	4.52
30 Sep	24	391	68	286	745	1.68	3.42
1 Oct	25	935	136	294	1,365	4.27	6.52
2 Oct	26	987	124	211	1,322	4.63	6.37
3 Oct	27	0	0	96	96	0.00	0.40
4 Oct	28	806	103	645	1,554	3.62	7.07
5 Oct	29	882	154	376	1,412	3.93	6.30
6 Oct	30	794	117	119	1,030	3.53	4.73
7 Oct	31	889	79	561	1,529	4.00	6.75
8 Oct	32	792	152	189	1,133	3.52	5.07
10 Oct	33	675	122	513	1,310	2.92	5.73
11 Oct	34	994	165	228	1,387	4.40	6.35
12 Oct	35	540	103	105	748	2.33	3.27
13 Oct	36	1,064	169	265	1,498	4.43	6.38
14 Oct	37	868	146	328	1,342	3.40	5.40
15 Oct	38	0	0	1,293	1,293	0.00	6.67
16 Oct	39	707	146	508	1,361	2.82	5.48
17 Oct	40	0	0	657	657	0.00	3.03
18 Oct	41	0	0	464	464	0.00	1.98
19 Oct	42	0	0	101	101	0.00	1.07
21 Oct	43	321	41	262	624	1.48	3.00
22 Oct	44	0	0	444	444	0.00	2.43
23 Oct	45	0	0	813	813	0.00	3.27

Table 3
Aerial-Survey Effort in the Beaufort Sea, 31 August-23 October 1992, by Survey Flight
(Continued)

Semimonthly Period	Transect (km)	Connect (km)	Search (km)	Total (km)	Transect Time (hr)	Total Survey Time (hr)
31 Aug	349	151	294	794	1.57	4.10
1-15 Sep	4,760	726	3,991	9,477	20.17	42.78
16-30 Sep	6,299	1,034	5,728	13,061	28.00	61.63
1-15 Oct	10,226	1,570	5,223	17,019	44.98	77.00
16-20 Oct	1,028	187	3,249	4,464	4.30	20.27
TOTAL	22,662	3,668	18,485	44,815	99.02	205.78

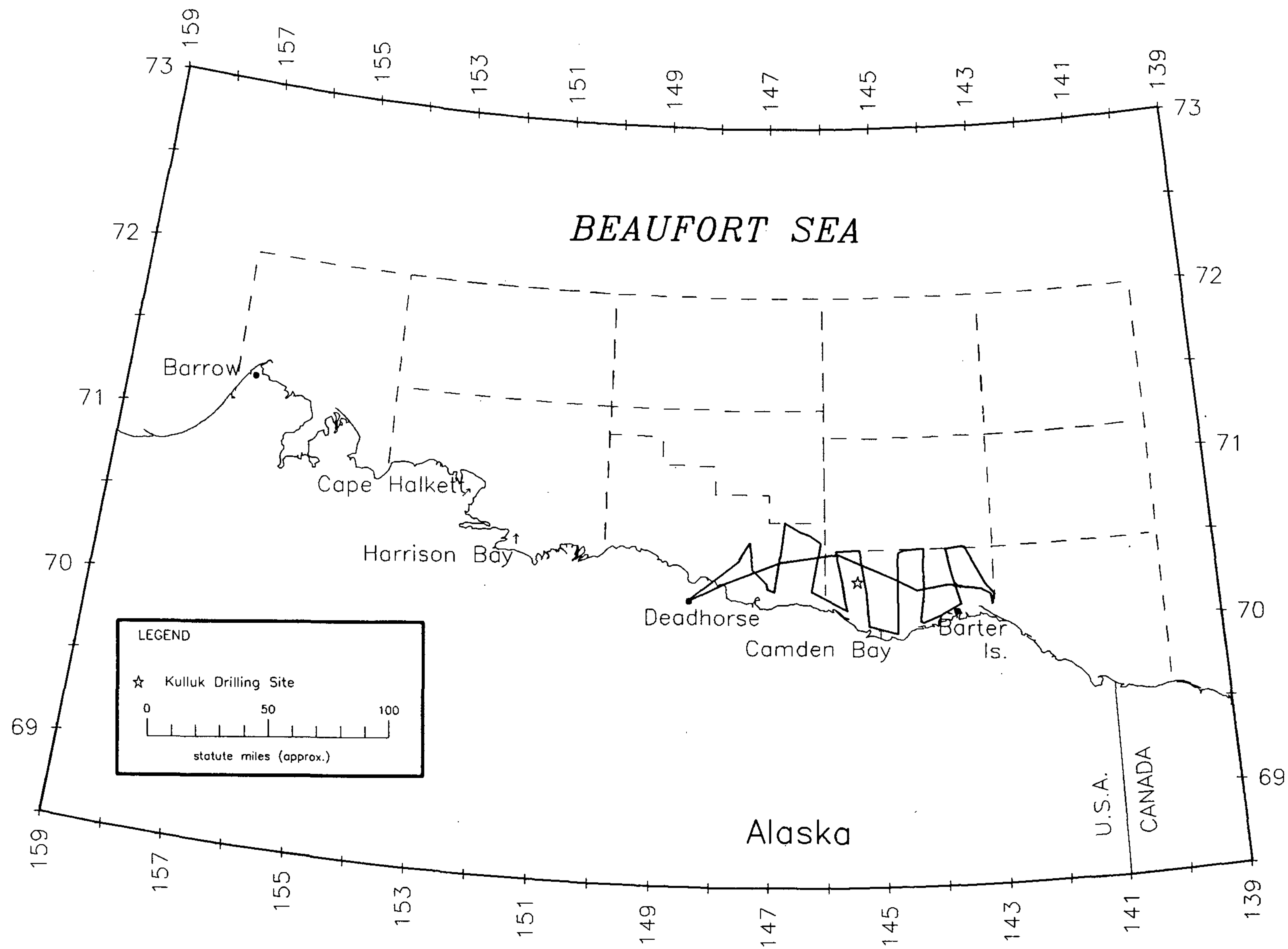


Figure 13. Combined Flight Tracks, 31 August 1992

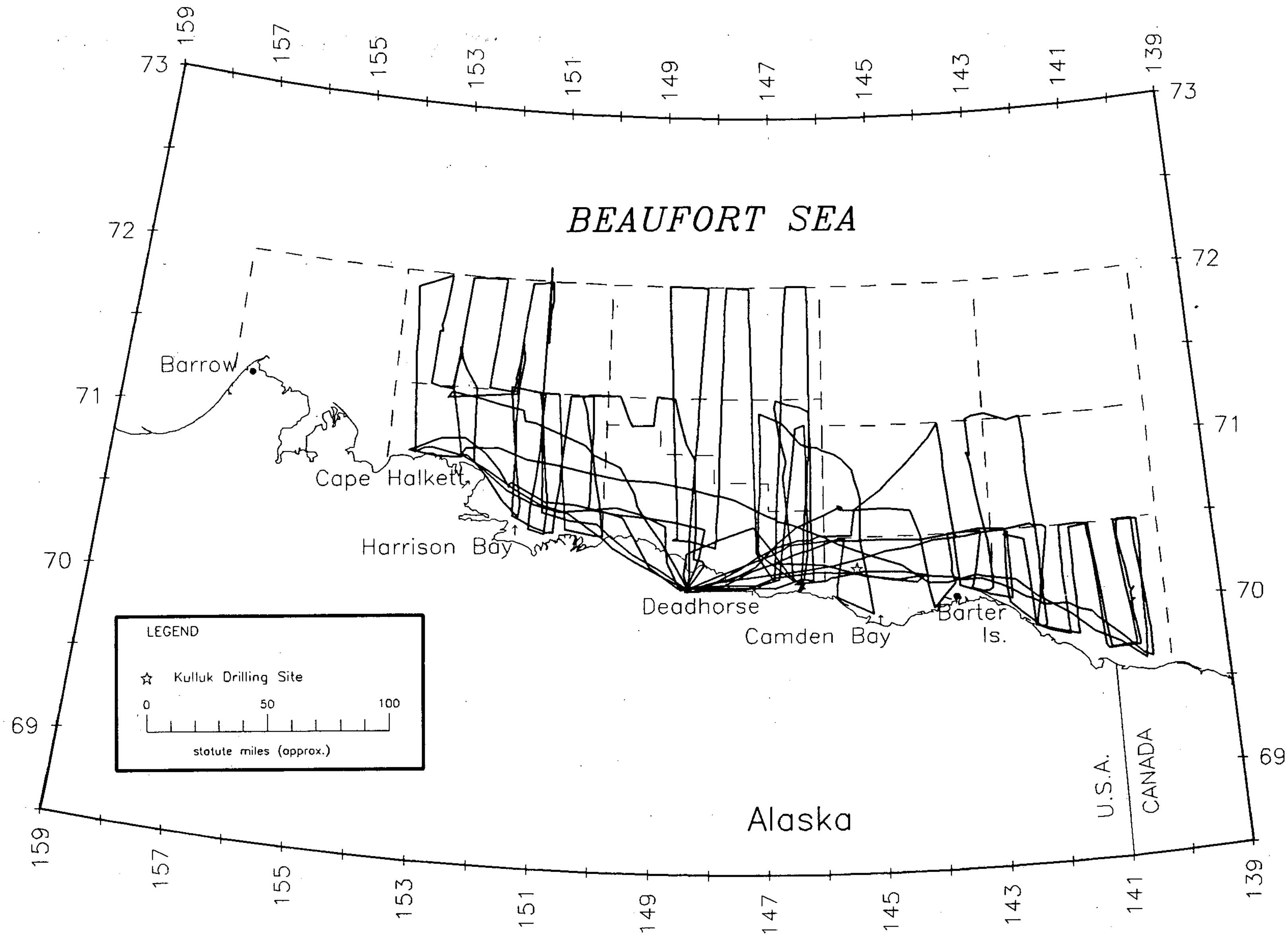


Figure 14. Combined Flight Tracks, 1-15 September 1992

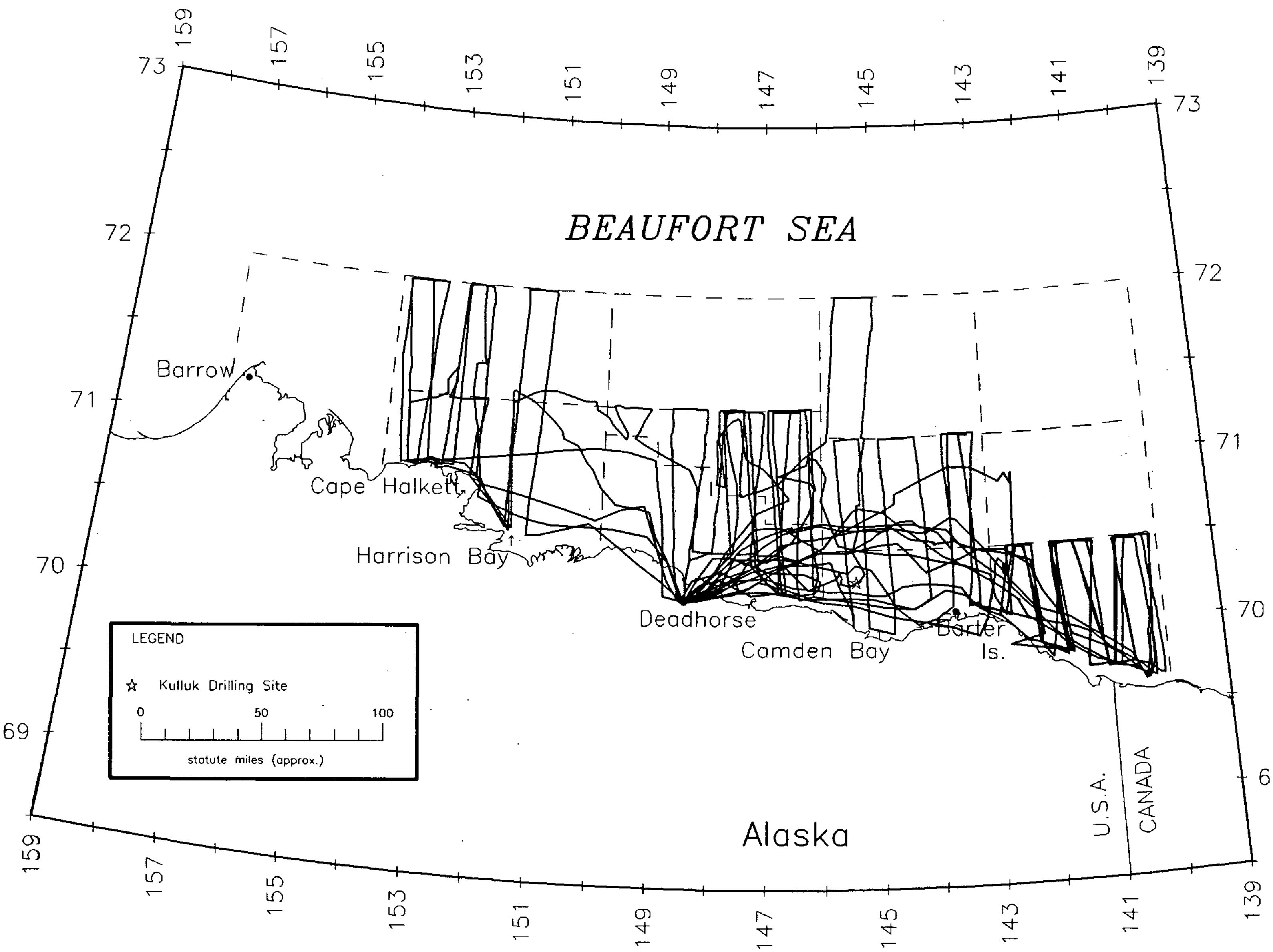


Figure 15. Combined Flight Tracks, 16-30 September 1992

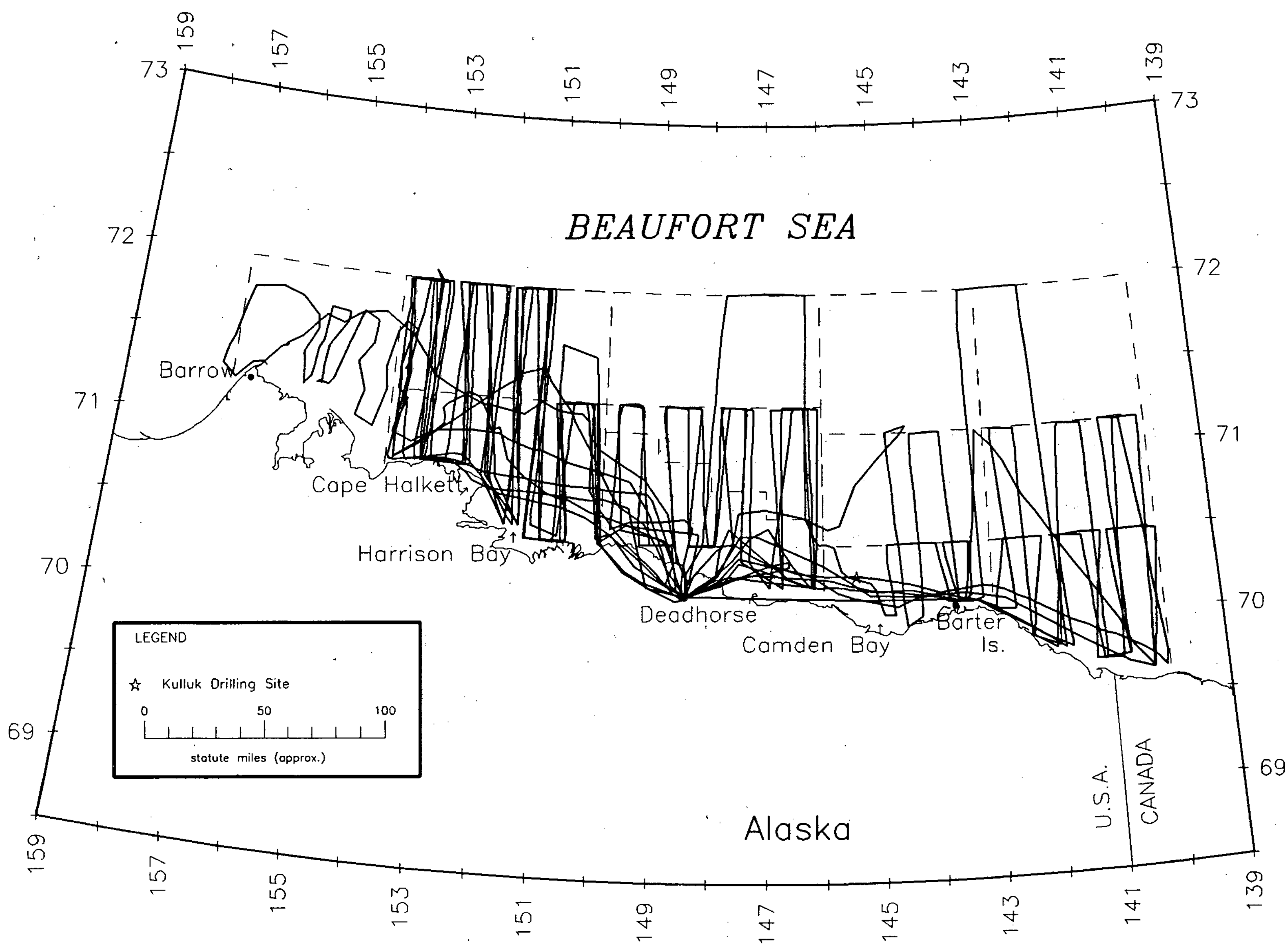


Figure 16. Combined Flight Tracks, 1-15 October 1992

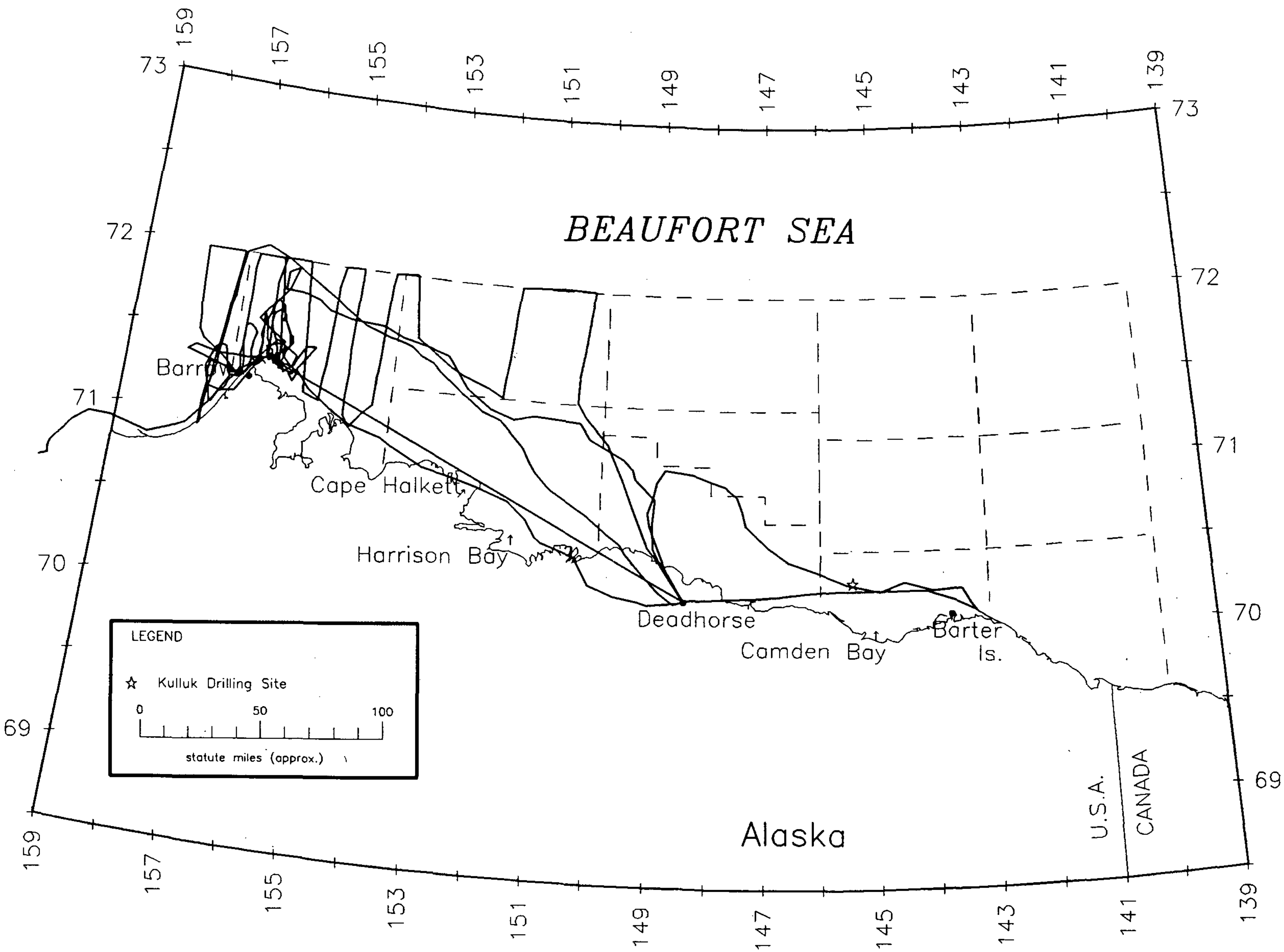


Figure 17. Combined Flight Tracks, 16-23 October 1992

then surveyed along the northern shore of Kotzebue Sound. There were 4.30 hours of random transects flown from 20.27 total flight hours during this period (Table 3), constituting 4.3 percent and 9.9 percent, respectively, of the total time spent in those effort categories.

C. Bowhead Whale (*Balaena mysticetus*) Observations

1. Distribution: One hundred fifty-three sightings were made for a total of 315 bowhead whales observed during Fall-1992 surveys in the study area (Table 4 and Figs. 18-23), not counting repeat sightings. Six of these whales were identified as calves (Appendix B: Table B-1), resulting in a seasonal calf ratio (number calves/total whales) of 0.02. Daily sightings are shown on individual maps in Appendix B. A semi-monthly analysis and a description of a large aggregation of bowhead whales near Barrow, Alaska, follow.

On 31 August, 5 sightings were made for a total of 5 bowhead whales (Table 4), with sightings from 143°00.9′W. to 147°32.7′W. longitudes (Appendix B: Table B-1), based on survey coverage between 143°W. and 148°W. longitudes, south of 70°40′N. latitude (Fig. 13). All but one of the whale pods were near Barter Island, and all were within 20 statute miles north of the shoreline (Fig. 18). The first bowheads in the Alaskan Beaufort were sighted on this day at 70°15.2′N. latitude, 143°13.4′W. longitude (Appendix B: Flight 1). Each of the 5 pods consisted of one whale (Appendix B: Table B-1). No bowhead whale calves were observed during this period (Appendix B: Table B-1).

During the first half of September, 32 sightings were made for a total of 42 bowheads (Table 4), with sightings from 140°32.2′W. to 151°39.1′W. longitudes (Appendix B: Table B-1), based on survey coverage between 140°W. and 154°W. longitudes (Fig. 14). All but one of the whale pods were east of Deadhorse, Alaska; and all were within 50 statute miles north of the shoreline (Fig. 19). Pod sizes ranged from 1 to 3 whales (Appendix B: Table B-1), with a mean of 1.31 (SD = 0.59, n = 32). In addition, a dead bowhead whale was observed on 12 September at 70°08.5′N. latitude, 143°13.6′W. longitude (Appendix B: Table B-1), just east of Barter Island. No bowhead whale calves were observed during this period (Appendix B: Table B-1).

During the second half of September, 16 sightings were made for a total of 21 bowheads (Table 4), with sightings from 140°10.5′W. to 153°41.7′W. longitudes (Appendix B; Table B-1), based on survey coverage between 140°W. and 154°W. longitudes (Fig. 15). The whale pods were fairly evenly distributed east to west over the area surveyed, within 50 statute miles north of the shoreline (Fig. 20). Pod sizes ranged from 1 to 3 whales (Appendix B: Table B-1), with a mean of 1.31 (SD = 0.70, n = 16). No bowhead whale calves were observed during this period (Appendix B: Table B-1).

During the first half of October, 30 sightings were made for a total of 56 bowheads (Table 4), with sightings from 148°50.5′W. to 156°09.2′W. longitudes (Appendix B: Table B-1), based on wide survey coverage over the study area (Fig. 16). All but two of the whale pods were west of 151°W., and all were within 60 statute miles north of the shoreline (Fig. 21). Pod sizes ranged from 1 to 7 whales (Appendix B: Table B-1), with a mean of 1.87 (SD = 1.48, n = 30). Four bowhead whale calves were observed during this period at the following latitudes and longitudes: 71°27.2′N., 153°48.6′W.; 71°30.8′N., 155°26.8′W.; 71°18.8′N., 155°13.8′W.; and 71°18.4′N., 155°11.3′W. (Appendix B: Table B-1). Beginning on 15 October, survey coverage was extended west into Block 12, and the season's first bowhead whales west of 154°W. longitude were observed (Appendix B: Flight 38).

From 16 through 23 October, 70 sightings were made for a total of 191 bowheads (Table 4), with sightings from 155°49.9′W. to 157°30.2′W. longitudes (Appendix B: Table B-1), based on survey coverage between 143°W. and 158°W. longitudes (Fig. 17), and a single flight extending well west of the study area. All of the whale pods were near Barrow, Alaska, within 30 statute miles north of the shoreline (Fig. 22). Pod sizes ranged from 1 to 30 whales (Appendix B: Table B-1), with a mean of 2.73 (SD = 4.17, n = 70). Two bowhead whale calves were observed during this period at the following latitudes and longitudes: 71°30.4′N., 156°07.3′W. and 71°28.6′N., 156°04.7′W. (Appendix B: Table B-1). The last pod of bowheads

Table 4
Summary of Marine Mammal Sightings, 31 August-23 October 1992, by Survey Flight
(number of sightings/number of animals)

Day	Flight No.	Bowhead Whale	Belukha Whale	Unident. Cetacean	Bearded Seal	Ringed Seal	Unident. Pinniped	Polar Bear	Pacific Walrus
31 Aug	1	5/5	1/1	1/2	1/1	0	2/2	0	0
1 Sep	2	1/1	0	0	3/3	0	3/6	0	0
3 Sep	3	0	0	0	0	1/2	7/26	0	0
7 Sep	4	0	2/5	0	0	0	0	0	0
8 Sep	5	11/16	0	1/1	1/1	3/5	7/8	0	0
9 Sep	6	0	0	0	0	0	0	0	0
10 Sep	7	13/16	2/22	0	4/5	28/61	5/8	0	0
11 Sep	8	0	9/56	0	0	5/11	2/2	0	0
12 Sep	9	7/9	5/14	0	2/2	9/18	5/12	2/4	0
13 Sep	10	0	4/36	1/1	1/1	29/87	1/1	0	0
14 Sep	11	0	5/9	0	0	0	3/5	4/7	0
16 Sep	12	0	0	0	1/1	0	1/8	0	0
17 Sep	13	0	6/7	0	1/1	14/85	2/28	2/3	0
19 Sep	14	0	11/30	0	1/2	4/7	3/5	2/2	0
20 Sep	15	3/6	3/8	0	3/4	9/23	0	0	0
21 Sep	16	0	11/27	0	3/3	5/14	1/2	0	0
23 Sep	17	0	4/8	0	3/5	4/33	1/1	0	0
24 Sep	18	4/6	2/4	0	2/2	3/3	0	2/10	0
25 Sep	19	1/1	7/22	0	0	5/18	3/8	0	0
26 Sep	20	1/1	1/4	0	1/1	4/8	0	6/20	0
27 Sep	21	0	0	0	1/1	2/2	0	1/9	0
28 Sep	22	5/5	3/59	0	0	4/7	1/1	0	0
29 Sep	23	1/1	4/70	0	1/1	5/16	1/1	2/2	0
30 Sep	24	1/1	0	0	0	9/15	0	0	0
1 Oct	25	9/24	13/27	1/1	2/3	10/14	1/1	1/1	1/1
2 Oct	26	3/6	3/34	0	4/4	24/36	0	4/4	0
3 Oct	27	0	0	0	1/1	0	0	1/1	0
4 Oct	28	0	1/47	0	0	9/19	0	4/37	0
5 Oct	29	0	1/26	0	1/1	25/40	3/3	2/2	0
6 Oct	30	2/4	1/2	0	0	20/30	1/2	2/4	0
7 Oct	31	0	1/3	0	0	12/15	3/10	1/20	0
8 Oct	32	0	1/22	0	1/1	11/12	3/3	1/1	0
10 Oct	33	0	0	0	0	6/9	2/2	2/26	0
11 Oct	34	0	0	0	1/1	4/4	3/3	2/3	0
12 Oct	35	0	1/6	0	0	6/7	0	0	0
13 Oct	36	0	0	0	0	3/3	1/2	0	0
14 Oct	37	0	0	0	0	1/1	2/3	3/27	0
15 Oct	38	16/22	1/20	0	0	1/1	3/6	0	0
16 Oct	39	0	2/18	0	0	0	2/2	0	0
17 Oct	40	19/56	0	0	0	0	0	0	0
18 Oct	41	0	0	0	0	0	2/2	3/19	0
19 Oct	42	27/104	0	0	0	0	0	0	0
21 Oct	43	24/31	0	0	0	0	0	1/1	0
22 Oct	44	0	5/47	0	0	0	0	0	0
23 Oct	45	0	1/1	0	0	0	0	0	0

Table 4
Summary of Marine Mammal Sightings, 31 August-23 October 1992, by Survey Flight
(number of sightings/number of animals)
(Continued)

Day	Bowhead Whale	Belukha Whale	Unident. Cetacean	Bearded Seal	Ringed Seal	Unident. Pinniped	Polar Bear	Pacific Walrus
Total Semimonthly Sightings								
31 Aug	5/5	1/1	1/2	1/1	0	2/2	0	0
1-15 Sep	32/42	27/142	2/2	11/12	75/184	33/68	6/11	0
16-30 Sep	16/21	52/239	0	17/21	68/231	12/54	15/46	0
1-15 Oct	30/56	23/187	1/1	10/11	132/191	22/35	23/126	1/1
16-20 Oct	70/191	8/66	0	0	0	4/4	4/20	0
TOTAL	153/315	111/635	4/5	39/45	275/606	73/163	48/203	1/1

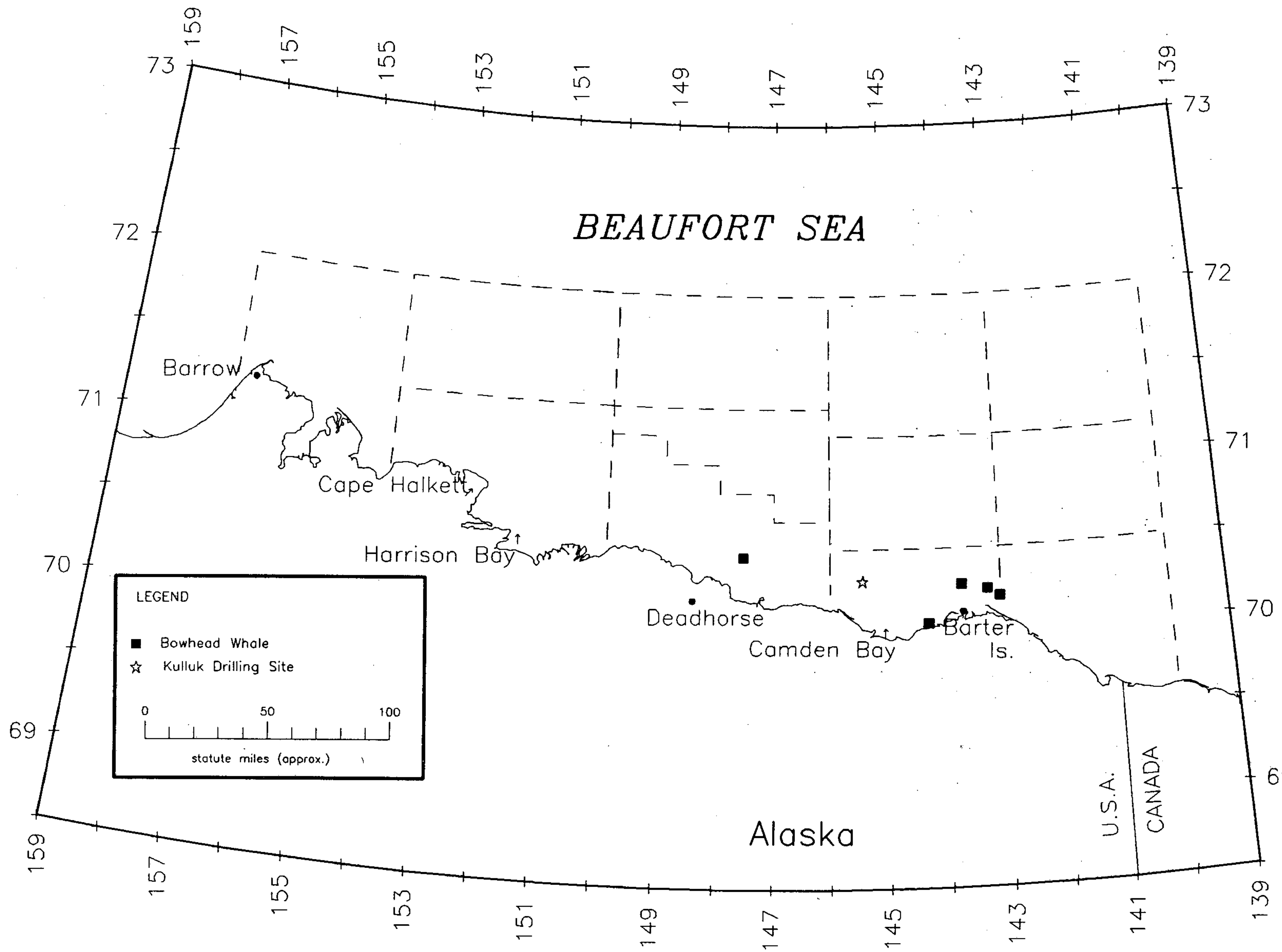


Figure 18. Map of Bowhead Whale Sightings, 31 August 1992

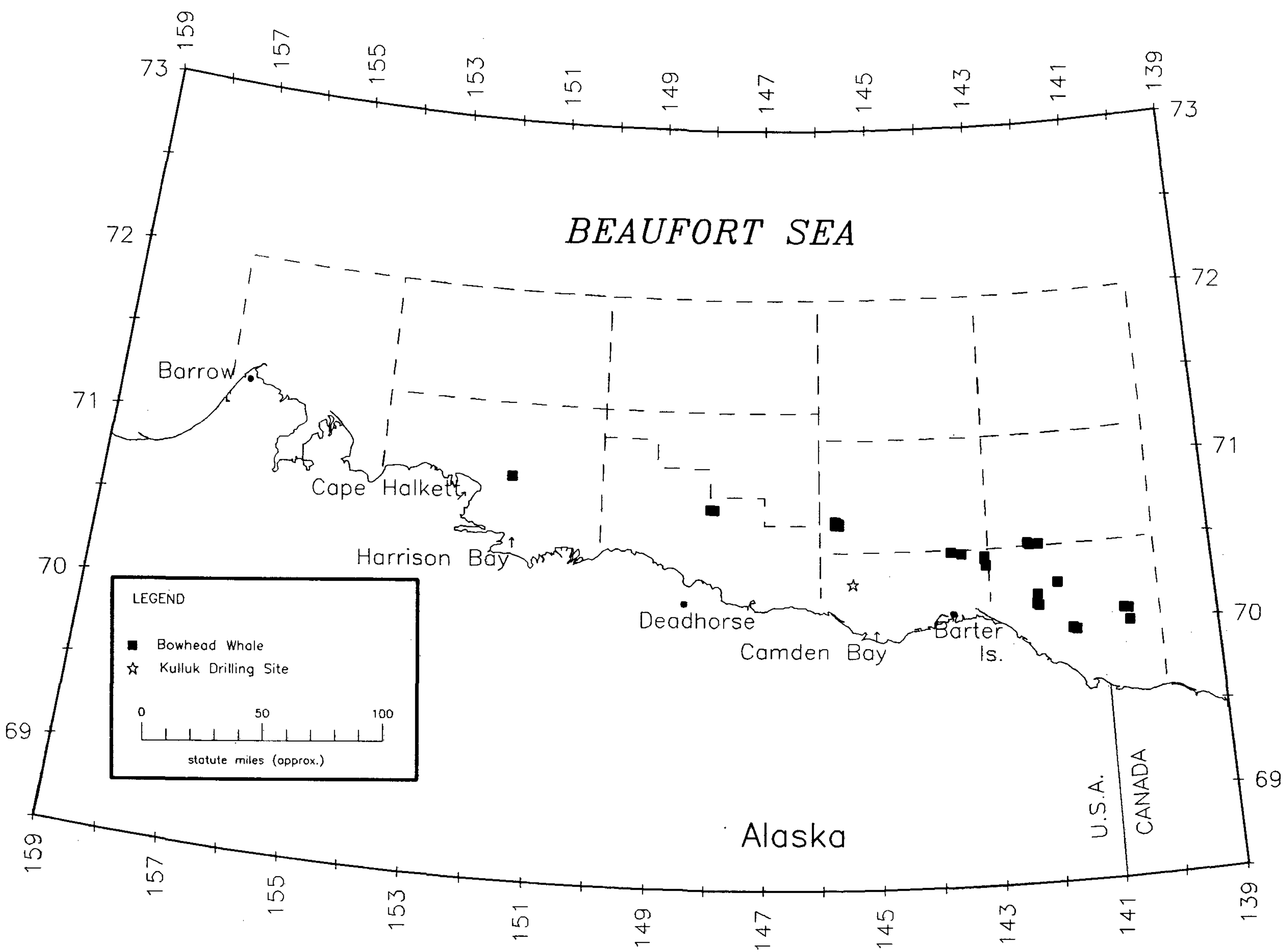


Figure 19. Map of Bowhead Whale Sightings, 1-15 September 1992

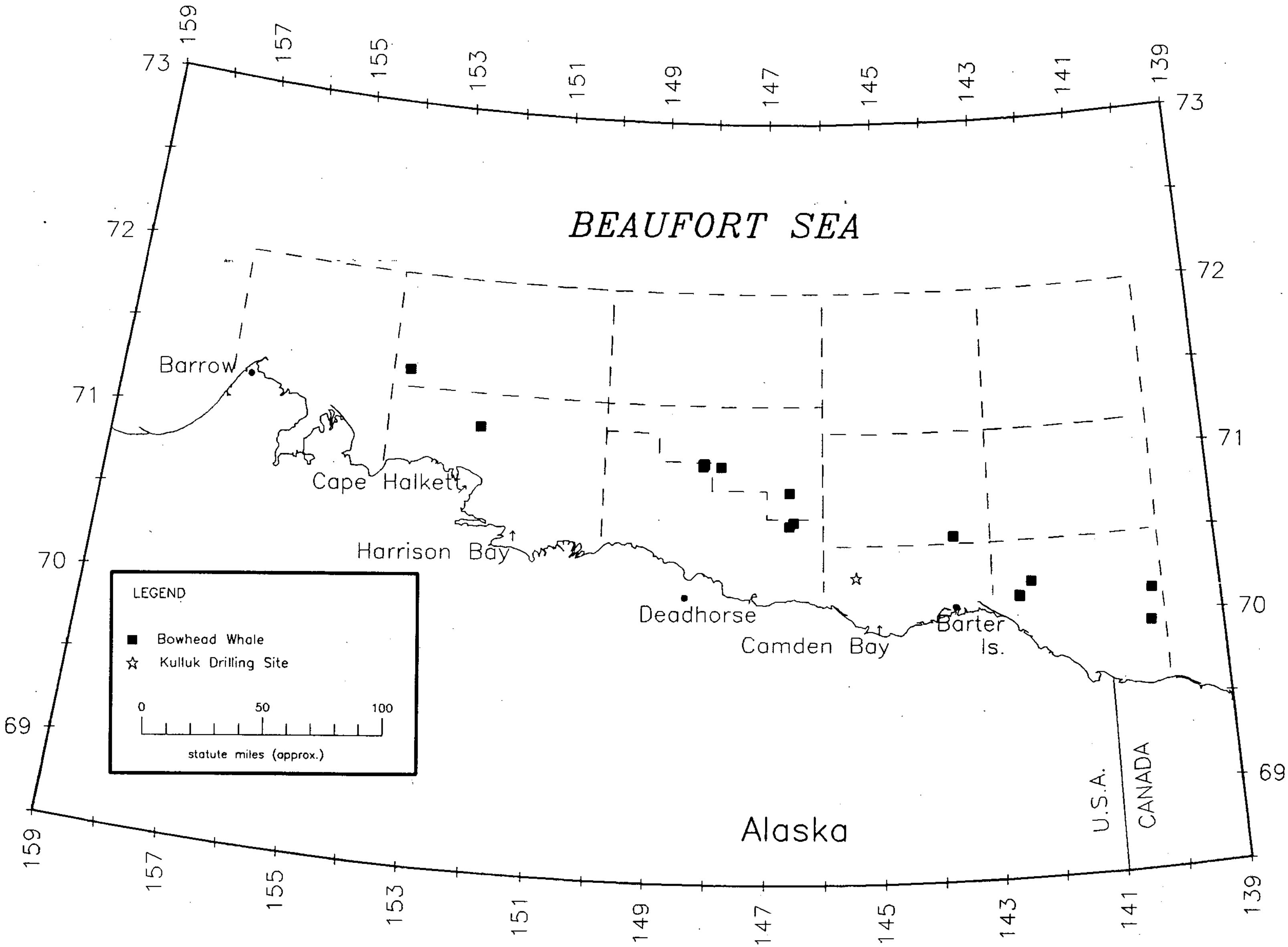


Figure 20. Map of Bowhead Whale Sightings, 16-30 September 1992

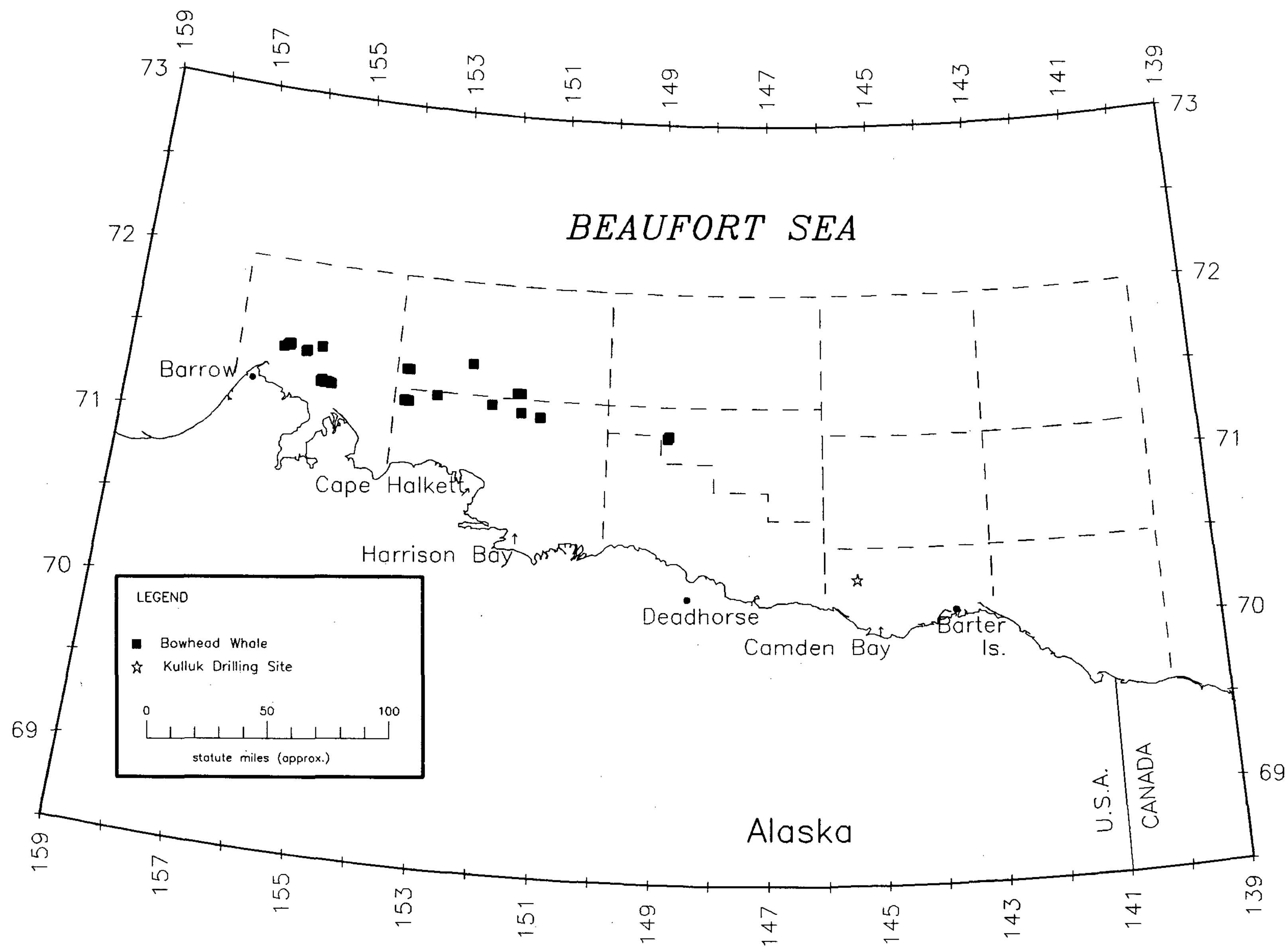


Figure 21. Map of Bowhead Whale Sightings, 1-15 October 1992

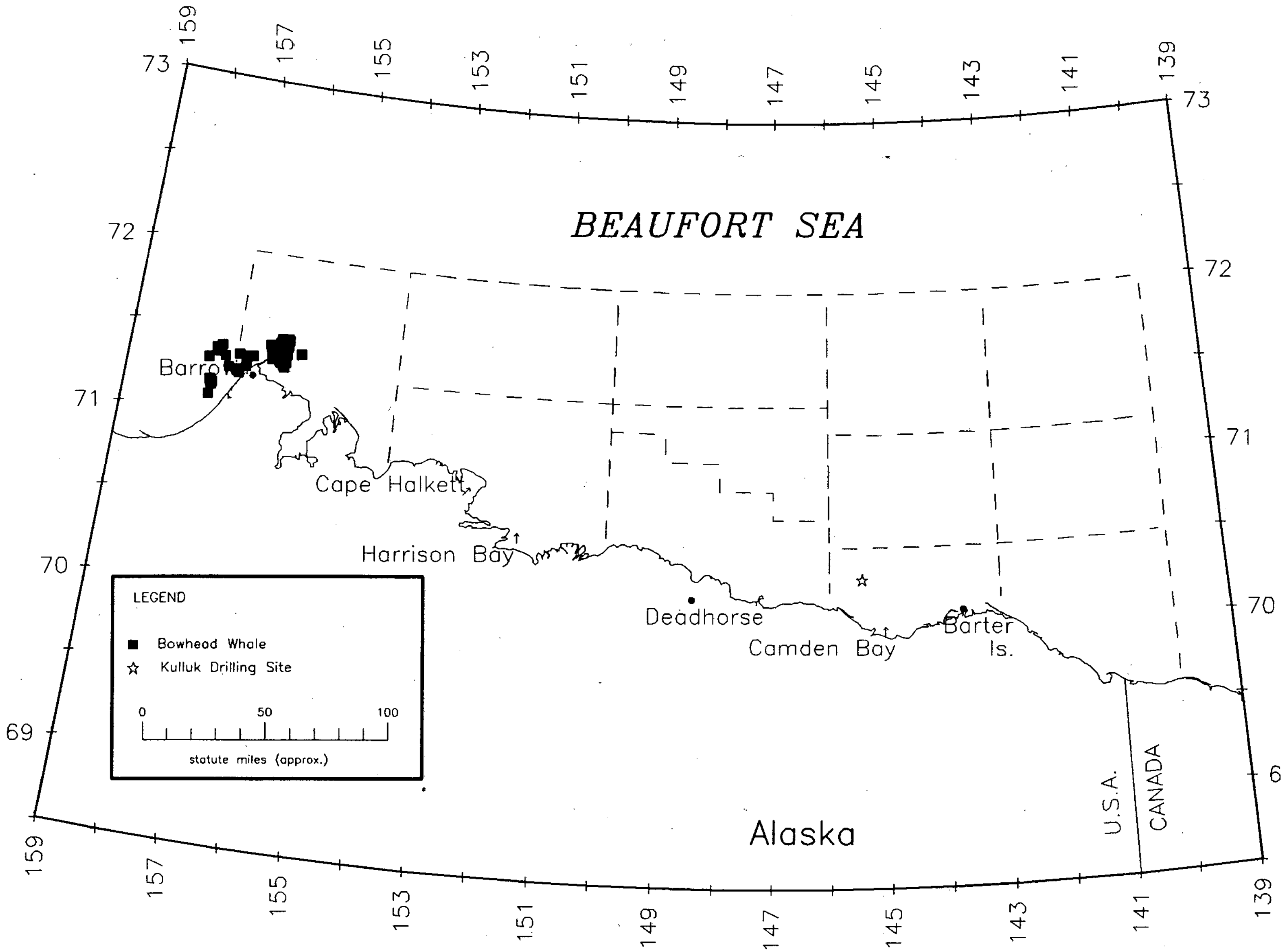


Figure 22. Map of Bowhead Whale Sightings, 16-23 October 1992

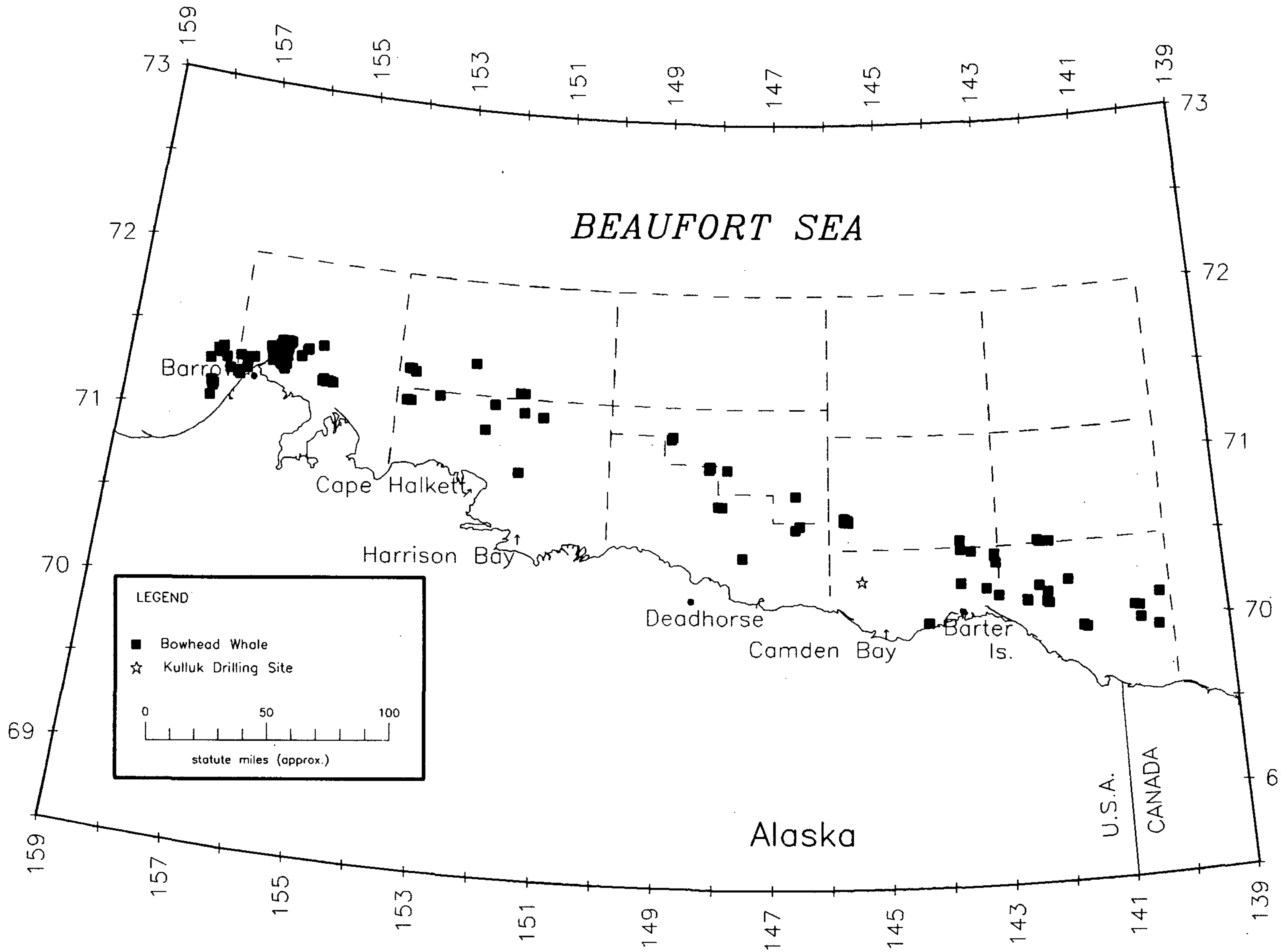


Figure 23. Map of Bowhead Whale Sightings, Fall 1992

seen in the primary study area (east of 157°W. longitude) occurred on 21 October at 71°17.4'N. latitude, 156°55.8'W. longitude (Appendix B: Table B-1).

On 15 October, when survey coverage began to extend into Block 12, 5 bowhead whale pods (5 whales) were recorded between 156°02'W. and 156°25'W. longitudes, between 71°20'N. and 71°31'N. latitudes (Appendix B: Table B-1 and Flight 38). On 17 October, a close aggregation of 19 bowhead whale pods (56 whales) was observed in the same location (Appendix B: Table B-1 and Flight 40). On 19 October, 26 pods (103 whales) also were observed there (Appendix B: Table B-1 and Flight 42). The close aggregations included many milling and feeding whales (Appendix B: Table B-1), without a significant mean heading, making discrete pods difficult to distinguish. In particular, one pod of 30 whales reported on 19 October (Appendix B: Table B-1) may well have represented a cumulative count of several nearby pods. The aggregation appeared to have spread out farther west by 21 October, with only 2 of 24 pods (2 whales) still between 156°02'W. and 156°25'W. longitudes (Appendix B: Flight 43). Dispersal of the aggregation into the Chukchi Sea may have been associated with rapidly increasing concentrations of sea ice from 20 to 27 October (Figs. 11 and 12).

2. Migration Timing: The day-to-day timing of the bowhead whale migration was calculated over the entire study area (Table 5 and Fig. 24) as a daily sighting rate, or sightings per unit effort (SPUE), and an index of relative abundance, or whales per unit effort (WPUE). Because 1992 survey effort from 31 August through 14 October was only in Blocks 1 through 11 and all bowhead whales observed after 14 October were west of these blocks, day-to-day comparisons of bowhead sighting rates and relative abundance for these two periods are discussed separately (Table 5 and Fig. 24).

31 August through 14 October 1992

Of the 67 sightings of bowhead whales observed during this period, Table 5 shows that the first bowhead whales were sighted on 31 August. The data for daily sighting rates show a peak of 2.65 SPUE on 10 September. The last sighting of a bowhead was made on 6 October, followed by 7 flights in which no bowhead whales were sighted (Table 5 and Fig. 24).

Of the 102 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 11 (when 50% of all sighted whales had been recorded) occurred on 20 September (Table 5). The peak relative abundance (mode) of 3.68 WPUE occurred on 1 October (Table 5 and Fig. 24).

15 October through 23 October 1992

Of the 86 sightings of bowhead whales observed during this period, the data for daily sighting rates (Table 5) show a peak of 25.31 SPUE on 19 October. The last sighting of a bowhead was made on 21 October, followed by 2 flights in which no bowhead whales were sighted (Table 5 and Fig. 24).

Of the 213 bowhead whales counted during this period, the data for daily relative abundance (WPUE) show that the peak relative abundance (mode) of 97.50 WPUE occurred on 19 October (Table 5 and Fig. 24).

The most prominent difference in pattern between the graph for relative abundance and that for sighting rate occurred on 17 and 19 October (Fig. 24), due to particularly large pods of whales on those days (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, 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 (31 August-23 October), there were 5 survey blocks in which $\geq$20.00 hr of survey effort were made. Of these coastal blocks (Blocks 1,

Table 5
Number of Sightings and Total Bowhead Whales Observed per Hour,
31 August-23 October 1992, by Flight Day

Day	No. of Sightings	No. of Whales	Total Survey Time (hr)	Sightings/ Hour (SPUE)	Whales/ Hour (WPUE)
31 Aug	5	5	4.10	1.22	1.22
1 Sep	1	1	3.17	0.32	0.32
3 Sep	0	0	3.98	0.00	0.00
7 Sep	0	0	4.30	0.00	0.00
8 Sep	11	16	6.17	1.78	2.59
9 Sep	0	0	1.57	0.00	0.00
10 Sep	13	16	4.90	2.65	3.27
11 Sep	0	0	5.32	0.00	0.00
12 Sep	7	9	5.77	1.21	1.56
13 Sep	0	0	3.82	0.00	0.00
14 Sep	0	0	3.80	0.00	0.00
16 Sep	0	0	2.58	0.00	0.00
17 Sep	0	0	5.08	0.00	0.00
19 Sep	0	0	5.83	0.00	0.00
20 Sep	3	6	4.82	0.62	1.25
21 Sep	0	0	5.87	0.00	0.00
23 Sep	0	0	3.55	0.00	0.00
24 Sep	4	6	6.62	0.60	0.91
25 Sep	1	1	3.85	0.26	0.26
26 Sep	1	1	6.40	0.16	0.16
27 Sep	0	0	4.45	0.00	0.00
28 Sep	5	5	4.65	1.08	1.08
29 Sep	1	1	4.52	0.22	0.22
30 Sep	1	1	3.42	0.29	0.29
1 Oct	9	24	6.52	1.38	3.68
2 Oct	3	6	6.37	0.47	0.94
3 Oct	0	0	0.40	0.00	0.00
4 Oct	0	0	7.07	0.00	0.00
5 Oct	0	0	6.30	0.00	0.00
6 Oct	2	4	4.73	0.42	0.85
7 Oct	0	0	6.75	0.00	0.00
8 Oct	0	0	5.07	0.00	0.00
10 Oct	0	0	5.73	0.00	0.00
11 Oct	0	0	6.35	0.00	0.00
12 Oct	0	0	3.27	0.00	0.00
13 Oct	0	0	6.38	0.00	0.00
14 Oct	0	0	5.40	0.00	0.00
15 Oct	16	22	6.67	2.40	3.30
16 Oct	0	0	5.48	0.00	0.00
17 Oct	19	56	3.03	6.26	18.46
18 Oct	0	0	1.98	0.00	0.00
19 Oct	27	104	1.07	25.31	97.50
21 Oct	24	31	3.00	8.00	10.33
22 Oct	0	0	2.43	0.00	0.00
23 Oct	0	0	3.27	0.00	0.00
TOTAL	153	315	205.78	0.74	1.53

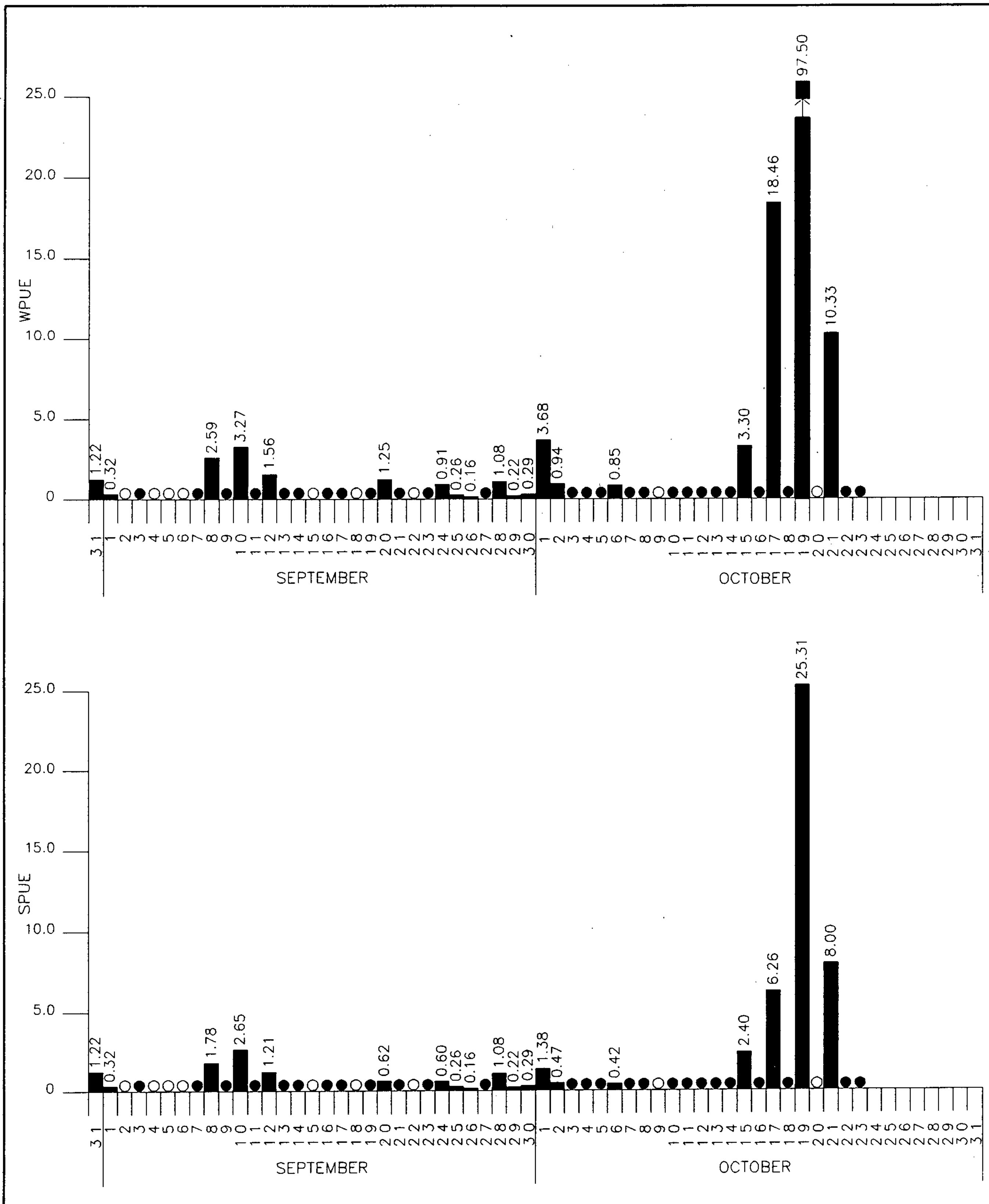


Figure 24. Daily Relative Abundance (WPUE) and Sighting Rate (SPUE) of Bowhead Whales, 31 August-23 October 1992

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

Table 6
Semimonthly Relative Abundance (WPUE) of Bowhead Whales (BH), by Survey Block, Fall 1992

Block	31 Aug			1-15 Sep			16-30 Sep			1-15 Oct			16-23 Oct			Total		
	Hr	BH	WPUE	Hr	BH	WPUE	Hr	BH	WPUE	Hr	BH	WPUE	Hr	BH	WPUE	Hr	BH	WPUE
1	1.33	1	0.75	9.48	2	0.21	12.56	8	0.64	13.22	0	0.00	1.49	0	0.00	38.08	11	0.29
2	[1]	[1]	[1]	3.26	0	0.00	6.62	2	0.30	5.78	4	0.69	0.08	0	0.00	15.73	6	0.38
3	[1]	[1]	[1]	9.70	1	0.10	7.23	1	0.14	19.57	17	0.87	1.29	0	0.00	37.79	19	0.50
4	2.62	4	1.53	4.60	8	1.74	6.41	0	0.00	5.36	0	0.00	1.05	0	0.00	20.04	12	0.60
5	0.02	0	0.00	6.55	12	1.83	15.34	8	0.52	8.57	0	0.00	[1]	[1]	[1]	30.48	20	0.66
6	0.12	0	0.00	2.94	16	5.44	6.78	1	0.15	2.30	0	0.00	[1]	[1]	[1]	12.14	17	1.40
7	[1]	[1]	[1]	0.74	3	4.05	0.47	0	0.00	3.82	0	0.00	[1]	[1]	[1]	5.02	3	0.60
8	[1]	[1]	[1]	0.08	0	0.00	[1]	[1]	[1]	0.43	0	0.00	[1]	[1]	[1]	0.51	0	0.00
9	[1]	[1]	[1]	0.05	0	0.00	1.14	0	0.00	0.47	0	0.00	[1]	[1]	[1]	1.66	0	0.00
10	[1]	[1]	[1]	2.04	0	0.00	0.42	0	0.00	0.67	0	0.00	[1]	[1]	[1]	3.13	0	0.00
11	[1]	[1]	[1]	3.24	0	0.00	4.63	1	0.22	12.64	13	1.03	1.55	0	0.00	22.06	14	0.63
12	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	3.62	22	6.08	8.61	178	20.68	12.24	200	16.34
13 [2]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	0.17	0	0.00	3.07	13	4.23	3.24	13	4.01
17 [2]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	0.54	0	0.00	0.54	0	0.00
20 [2]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	0.76	0	0.00	0.76	0	0.00
22 [2]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	0.55	0	0.00	0.55	0	0.00
30 [2]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	0.65	0	0.00	0.65	0	0.00
31 [2]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	0.20	0	0.00	0.20	0	0.00
12N [2]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	0.23	0	0.00	0.23	0	0.00
13N [2]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	0.01	0	0.00	0.01	0	0.00
Other Canadian Areas	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
Other Alaskan Areas	[1]	[1]	[1]	0.10	0	0.00	0.04	0	0.00	0.39	0	0.00	0.20	0	0.00	0.73	0	0.00
TOTAL	4.10	5	1.22	42.78	42	0.98	61.63	21	0.34	77.00	56	0.73	20.27	191	9.42	205.78	315	1.53

[1] No survey effort.
[2] Chukchi Sea survey blocks.

3, 4, 5, and 11), Block 5 (0.66 WPUE) had the greatest relative abundance, followed by Block 11 (0.63 WPUE), Block 4 (0.60 WPUE), Block 3 (0.50 WPUE), and Block 1 (0.29 WPUE).

On 31 August, there were no survey blocks or areas in which ≥4.00 hr of survey effort were made. Five bowhead whales were observed during a total of 4.10 hr of survey effort (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 5 (1.83 WPUE) had the greatest relative abundance, followed by Block 4 (1.74 WPUE), Block 1 (0.21 WPUE), and Block 3 (0.10 WPUE). Although only 2.94 hr and 0.74 hr of survey effort were made in offshore Blocks 6 and 7, respectively, it was notable that 16 whales were observed in offshore Block 6 for a high relative abundance (5.44 WPUE) and 3 whales were observed in offshore Block 7 for a high relative abundance (4.05 WPUE). No bowheads were observed during a total of 8.77 hr of survey effort in the remaining blocks (Blocks 2, 8, 9, 10, and 11) or in other Alaskan areas (Table 6).

During the second half of September, there were 7 blocks in which ≥4.00 hr of survey effort were made. Of these coastal and offshore blocks (Blocks 1, 2, 3, 4, 5, 6, and 11), coastal Block 1 (0.64 WPUE) had the greatest relative abundance, followed by Block 5 (0.52 WPUE), Block 2 (0.30 WPUE), Block 11 (0.22 WPUE), Block 6 (0.15 WPUE), Block 3 (0.14 WPUE), and Block 4, for which no whales were observed. No bowheads were observed during a total of 2.07 hr of survey effort in the remaining blocks (Blocks 7, 9, and 10) or in other Alaskan areas (Table 6).

During the first half of October, there were 6 blocks in which ≥4.00 hr of survey effort were made. Of these coastal and offshore blocks (Blocks 1, 2, 3, 4, 5, and 11), offshore Block 11 (1.03 WPUE) had the greatest relative abundance, followed by Block 3 (0.87 WPUE), Block 2 (0.69 WPUE), and Blocks 1, 4, and 5, for which no whales were observed. Although only 3.62 hr of survey effort were made in coastal Block 12, it was notable that 22 whales were observed for a high relative abundance (6.08 WPUE). No bowheads were observed during a total of 8.25 hr of survey effort in the remaining blocks (Blocks 6, 7, 8, 9, 10, and 13) or in other Alaskan areas (Table 6).

From 16 through 23 October, there was only 1 block in which ≥4.00 hr of survey effort were made; coastal Block 12 (20.68 WPUE) had a very high relative abundance due to the presence of the large aggregation of bowhead whales described above. Although only 3.07 hr of survey effort were made in coastal Block 13 (Chukchi Sea block), it was notable that 13 whales were observed for a high relative abundance (4.23 WPUE). No bowhead whales were observed during 8.60 hr of survey effort in the remaining blocks (Blocks 1, 2, 3, 4, 11 and Chukchi Sea Blocks 17, 20, 22, 30, 31, 12N, 13N) or in other Alaskan areas (Table 6).

4. Habitat Associations: Of 315 bowhead whales sighted during Fall 1992, 227 (72%) were in shallow water (0-50 m deep), 84 (27%) were in waters of transitional depth (51-200 m), and 4 (1%) were 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. 3-12), 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 (31 August-23 October), bowheads were sighted in each concentration of ice cover shown on Table 8. Of 315 bowheads, 66 (21%) were sighted in association with 61- through 70-percent sea ice, 58 (18%) in 11- through 20-percent ice, 40 (12%) in 41- through 50-percent ice, and 34 (11%) in 81- through 90-percent ice (Table 8). From 31 August through 15 September, all bowheads sighted were associated with ≤20-percent sea ice (Table 8). This was followed by a period, from 16 September through 15 October, during which all bowheads were sighted in association with ≥40-percent sea ice (Appendix B: Table B-1). After 15 October, bowheads were sighted in diverse concentrations of sea ice.

Table 7
Semimonthly Summary of Bowhead Whales Observed, by Water Depth at Sighting Location, Fall 1992

Water Depth	31 Aug No. (%)	1-15 Sep No. (%)	16-30 Sep No. (%)	1-15 Oct No. (%)	16-23 Oct No. (%)	Total No. (%)
Shallow (0-50 m)	5 (100)	13 (31)	16 (76)	38 (68)	155 (81)	227 (72)
Transitional (51-200 m)	0	29 (69)	5 (24)	14 (25)	36 (19)	84 (27)
Deep (>200 m)	0	0	0	4 (7)	0	4 (1)
TOTAL	5 (100)	42 (100)	21 (100)	56 (100)	191 (100)	315 (100)

Table 8
Semimonthly Summary of Bowhead Whales Observed, by Percent Ice Cover Present at Sighting Location, Fall 1992

% Ice Cover	31 Aug No. (%)	1-15 Sep No. (%)	16-30 Sep No. (%)	1-15 Oct No. (%)	16-23 Oct No. (%)	Total No. (%)
0	0	9 (22)	0	0	4 (2)	13 (4)
1-5	4 (80)	24 (57)	0	0	0	28 (9)
6-10	1 (20)	3 (7)	0	0	2 (1)	6 (2)
11-20	0	6 (14)	0	0	52 (27)	58 (18)
21-30	0	0	0	0	2 (1)	2 (1)
31-40	0	0	0	3 (5)	6 (3)	9 (3)
41-50	0	0	9 (43)	13 (23)	18 (10)	40 (12)
51-60	0	0	0	4 (7)	8 (4)	12 (4)
61-70	0	0	2 (10)	10 (18)	54 (28)	66 (21)
71-80	0	0	1 (4)	5 (9)	22 (12)	28 (9)
81-90	0	0	7 (33)	4 (7)	23 (12)	34 (11)
91-99	0	0	2 (10)	17 (31)	0	19 (6)
TOTAL	5 (100)	42 (100)	21 (100)	56 (100)	191 (100)	315 (100)

5. Behavior, Swim Direction, and Speed: Of 315 bowhead whales observed during Fall 1992, 137 (44%) were swimming (Table 9), i.e., moving forward in an apparently deliberate manner, when first sighted. Over the fall season, the greatest proportion (.45) of directional movement was between west and northwest, with a significant ($p < 0.001$) mean heading of 275.49° True (T) (Fig. 25), consistent with a directed migration in rough parallel to Alaska's Beaufort Sea coastline. Of whales for which swim speeds were noted, most were judged to be moving at either medium or slow speeds (Table 10). Other behaviors noted for bowhead whales were feeding (25%), milling (4%), resting (4%), cow-calf association (3%), diving (3%), breaching (1%), and rolling (1%) (Table 9). All behaviors noted are defined in Table 2.

On 31 August, 4 of 5 (80%) bowheads were observed swimming (Table 9). Whales were generally moving in westerly directions, with a mean heading of 274.55° True (T) (Fig. 25). Bowheads were mostly moving at a slow speed (60%), with 1 whale still and another moving at a fast speed (Table 10). The other behavior noted was resting (20%) (Table 9).

During the first half of September, 40 of 42 (96%) bowheads were observed swimming (Table 9). The greatest proportion by far (.80) of directional movement was between west and northwest, with a significant ($p<0.001$) mean heading of 291.07°T (Fig. 25). Of whales for which swim speeds were noted, all were moving at medium speed (Table 10). Other behaviors noted were diving (2%) or feeding (2%) (Table 9).

During the second half of September, 17 of 21 (81%) bowheads were observed swimming (Table 9). The greatest proportion (.46) of directional movement was between west and southwest, with a significant ($p<0.005$) mean heading of 273.16°T (Fig. 25). Bowheads were mostly moving at medium (67%) or slow (19%) speeds (Table 10). Other behaviors noted were resting (14%) or breaching (5%) (Table 9).

During the first half of October, 38 of 56 (68%) bowheads were observed swimming (Table 9). Whales were generally moving in westerly directions, with a significant ($p<0.001$) mean heading of 232.46°T (Fig. 25). Bowheads were mostly moving at medium (36%) or slow (27%) speeds, with others either still (11%) or moving at fast (3%) speeds (Table 10). Other behaviors noted were cow-calf association (11%), resting (9%), diving (7%), or milling (5%) (Table 9).

From 16 through 23 October, 79 of 191 (41%) bowheads were observed feeding and 38 (20%) were observed swimming (Table 9). Whales were moving in many directions, with a mean heading of 293.25°T (Fig. 25). Of whales for which swim speeds were noted, most were moving mostly at medium or slow speeds (Table 10). Other behaviors noted were milling (5%), diving (3%), cow-calf association (2%), rolling (2%), breaching (2%), or resting (1%) (Table 9). A separate description of bowhead whale aggregations northeast of Barrow, Alaska, during this period appears in Section III.C.1.

A few bowhead whales were followed long enough to record blow intervals during a sequence of near-surface breathing. One whale, swimming on a 240° compass heading in 1-percent ice on 8 September and recorded at 70°44.5'N. latitude, 145°42.0'W. longitude, had a mean blow interval of 11.60 seconds ($SD = 3.78$, $n = 5$). A second whale, swimming on a 240° compass heading in 90-percent ice on 28 September, had a mean blow interval of 11.40 seconds ($SD = 1.34$, $n = 5$), before elevating its flukes in a dive 9 seconds later at 70°59.6'N. latitude, 148°10.1'W. longitude. A third whale, swimming on a 240° compass heading in 90-percent ice on 28 September, had a mean blow interval of 11.60 seconds ($SD = 1.14$, $n = 5$), before elevating its flukes in a dive 10 seconds later at 70°59.5'N. latitude, 148°11.7'W. longitude.

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 considered suitable for selected analyses. Over the field

Table 9
Semimonthly Summary of Bowhead Whales Observed, by Behavioral Category, Fall 1992

Behavior	31 Aug No. (%)	1-15 Sep No. (%)	16-30 Sep No. (%)	1-15 Oct No. (%)	16-23 Oct No. (%)	Total No. (%)
Breaching	0	0	1 (5)	0	3 (2)	4 (1)
Cow-Calf	0	0	0	6 (11)	4 (2)	10 (3)
Diving	0	1 (2)	0	4 (7)	5 (3)	10 (3)
Feeding	0	1 (2)	0	0	79 (41)	80 (25)
Milling	0	0	0	3 (5)	10 (5)	13 (4)
Resting	1 (20)	0	3 (14)	5 (9)	2 (1)	11 (4)
Rolling	0	0	0	0	4 (2)	4 (1)
Swimming	4 (80)	40 (96)	17 (81)	38 (68)	38 (20)	137 (44)
(not noted)	0	0	0	0	46 (24)	46 (15)
TOTAL	5 (100)	42 (100)	21 (100)	56 (100)	191 (100)	315 (100)

Table 10
Semimonthly Summary of Bowhead Whales Observed, by Swimming Speed, Fall 1992

Swim Speed	31 Aug No. (%)	1-15 Sep No. (%)	16-30 Sep No. (%)	1-15 Oct No. (%)	16-23 Oct No. (%)	Total No. (%)
Still (0 km/hr)	1 (20)	0	2 (9)	6 (11)	1 (1)	10 (3)
Slow (<2 km/hr)	3 (60)	0	4 (19)	15 (27)	17 (9)	39 (12)
Medium (2-4 km/hr)	1 (20)	35 (83)	14 (67)	20 (36)	10 (5)	80 (26)
Fast (>4 km/hr)	0	0	0	2 (3)	4 (2)	6 (2)
(not noted)	0	7 (17)	1 (5)	13 (23)	159 (83)	180 (57)
TOTAL	5 (100)	42 (100)	21 (100)	56 (100)	191 (100)	315 (100)

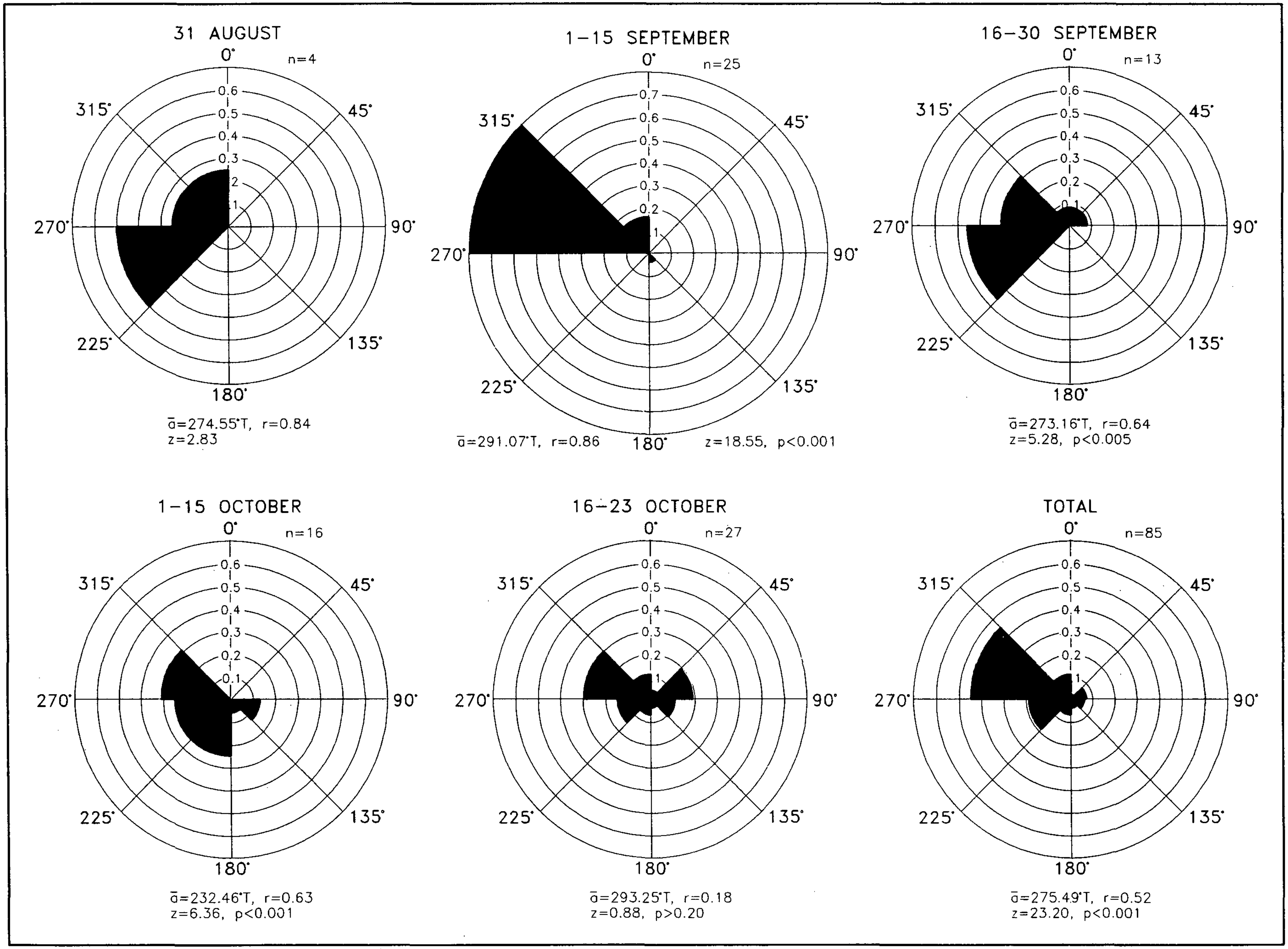


Figure 25. Semimonthly Summary of Swim Directions for Bowhead Whales, Fall 1992

season, 111 sightings were made for a total of 635 belukha whales (Table 4) during 205.78 hr of survey effort (Table 3) for a seasonal relative abundance of 3.09 WPUE. Whales were distributed between 140°W. and 157°W. longitudes, south of 72°N. latitude (Fig. 26). The positions of most belukha sightings were between the 100 m- and 2,000 m-isobaths (Figs. 2 and 26). Sizes of pods (or close aggregations of pods) ranged from 1 to 57 whales, with a mean of 5.72 (SD = 10.21, n = 111).

On 31 August, 1 sighting was made for a total of 1 belukha whale (Table 4) during 4.10 hr of survey effort (Table 3) and a relative abundance of 0.24 WPUE. This first belukha in the Alaskan Beaufort was sighted at 70°35.4´N. latitude, 146°16.4´ longitude. No calves were noted during this period. The whale was observed in association with 35-percent sea ice.

During the first half of September, 27 sightings were made for a total of 142 belukha whales (Table 4) during 42.78 hr of survey effort (Table 3) and a relative abundance of 3.32 WPUE. Sizes of pods (or close aggregations of pods) ranged from 1 to 38 whales, with a mean of 5.26 (SD = 8.50, n = 27). Eleven belukha calves were noted during this period. Belukha whales were observed in association with 0- to 99-percent sea ice, with a mean of 50.74 percent ice (SD = 37.87, n = 27).

During the second half of September, 52 sightings were made for a total of 239 belukha whales (Table 4) during 61.63 hr of survey effort (Table 3) and a relative abundance of 3.88 WPUE. Sizes of pods (or close aggregations of pods) ranged from 1 to 57 whales, with a mean of 4.60 (SD = 10.49, n = 52). Fourteen belukha calves were noted during this period. Belukha whales were observed in association with 1- to 99-percent sea ice, with a mean of 75.56 percent ice (SD = 24.17, n = 52).

During the first half of October, 23 sightings were made for a total of 187 belukha whales (Table 4) during 77.00 hr of survey effort and a relative abundance of 2.43 WPUE. Sizes of pods (or close aggregations of pods) ranged from 1 to 47 whales, with a mean of 8.13 (SD = 11.48, n = 23). Two belukha calves were noted during this period. Belukha whales were observed in association with 40- to 99-percent sea ice, with a mean of 90.78 percent ice (SD = 12.55, n = 23).

From 16 through 23 October, 8 sightings were made for a total of 66 belukha whales (Table 4) during 20.27 hr of survey effort and a relative abundance of 3.26 WPUE. One belukha, sighted on 23 October 1992 at 69°09.3´N. latitude, 164°51.2´W. longitude, was too far west of the study area to appear on any of the maps in this report. Sizes of pods (or close aggregations of pods) ranged from 1 to 30 whales, with a mean of 8.25 (SD = 10.69, n = 8). Belukha whales were observed in association with 40- to 95-percent sea ice, with a mean of 64.38 percent (SD = 19.54, n = 8).

3. Bearded Seal (*Erignathus barbatus*): Over the field season, 39 incidental sightings were made for a total of 45 bearded seals (Table 4). Sightings were distributed between 140°W. and 154°W. longitudes, generally south of the 1,000-m isobath (Figs. 2 and 27). Bearded seals were sighted on most of the flights from 31 August through 11 October (Table 4). Ninety-six percent of bearded seals were in the water when first sighted; the other 4 percent were on the ice.

4. Ringed Seal (*Phoca hispida*): Over the field season, 275 incidental sightings were made for a total of 606 ringed seals (Table 4). Sightings were distributed between 140°W. and 156°W. longitudes, mostly south of the 2,000-m isobath (Figs. 2 and 28). Ringed seals were sighted from 3 September through 15 October, with over 95 percent of these seals observed from 10 September through 10 October (Table 4). Ninety-four percent of ringed seals were in the water when first sighted; the other 6 percent were on the ice.

5. Polar Bear (*Ursus maritimus*): Over the field season, 48 incidental sightings were made for a total of 203 polar bears (Table 4). Sightings were distributed between 141°W. and 158°W. longitudes, south of 72°N. latitude (Fig. 29). Polar bears were sighted from 12 September through 21 October (Table 4). Sixty-five percent of polar bears were on sea ice when first sighted, 34 percent were on land, and 1 percent was in the water.

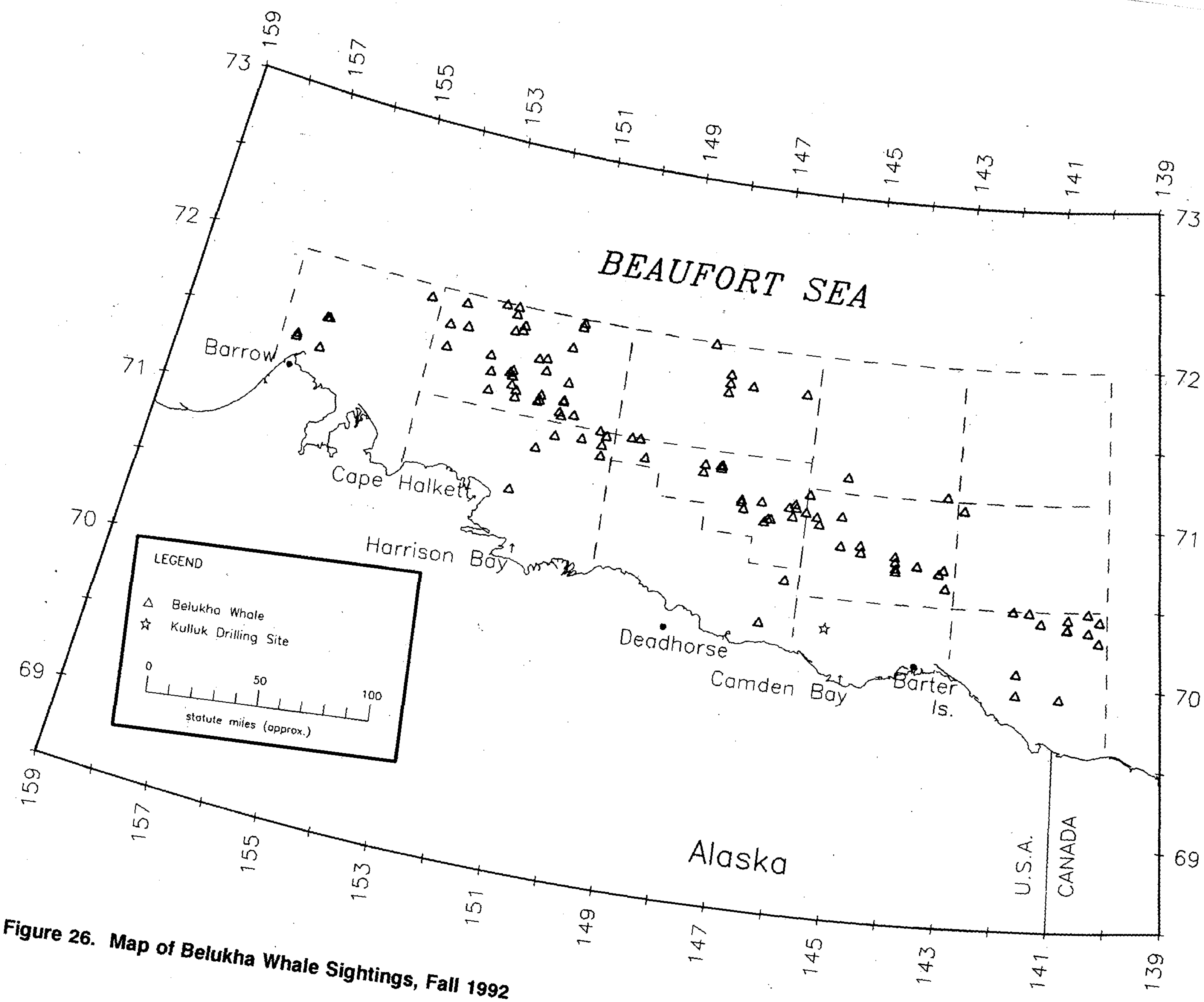


Figure 26. Map of Belukha Whale Sightings, Fall 1992

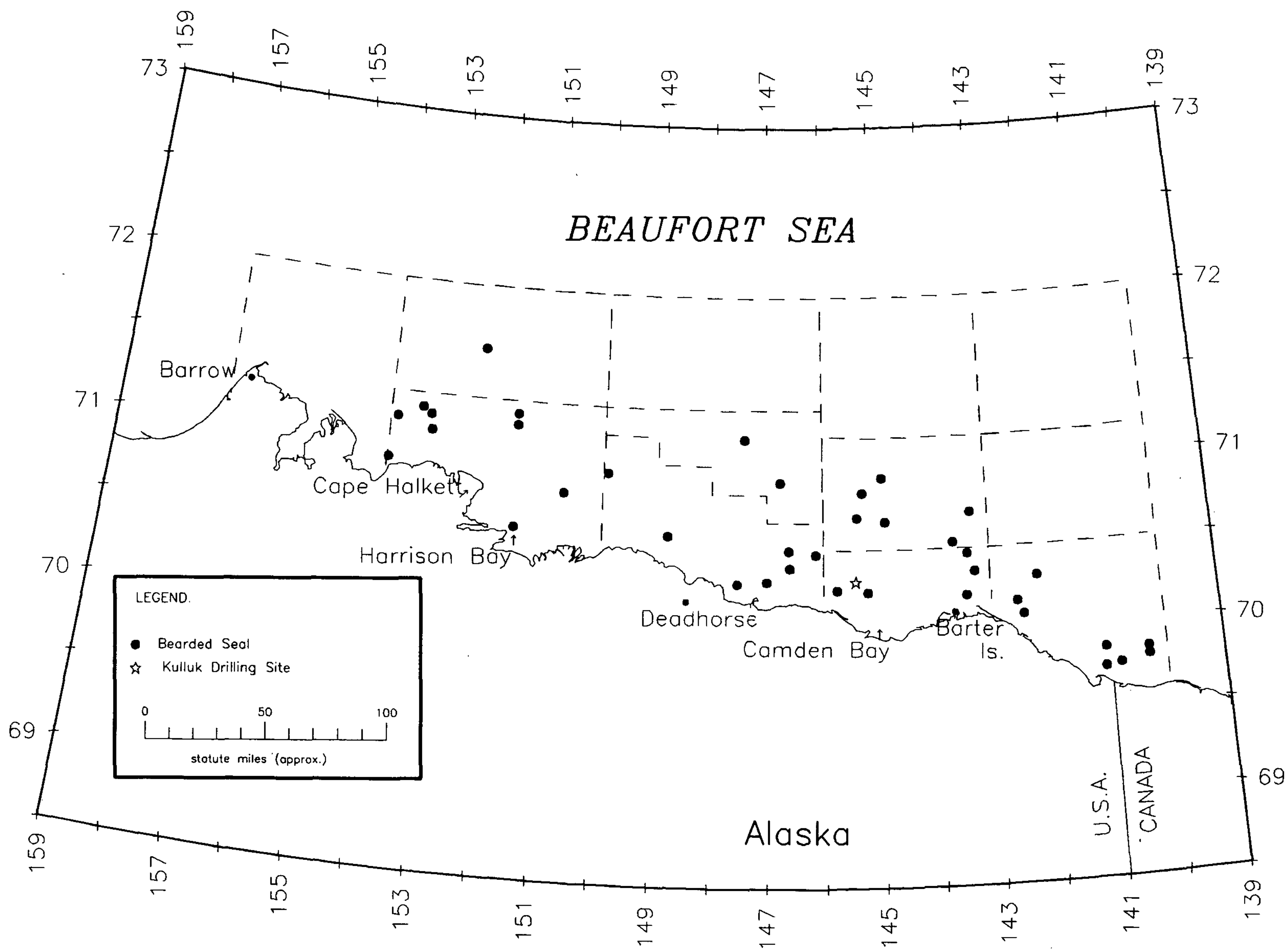


Figure 27. Map of Bearded Seal Sightings, Fall 1992

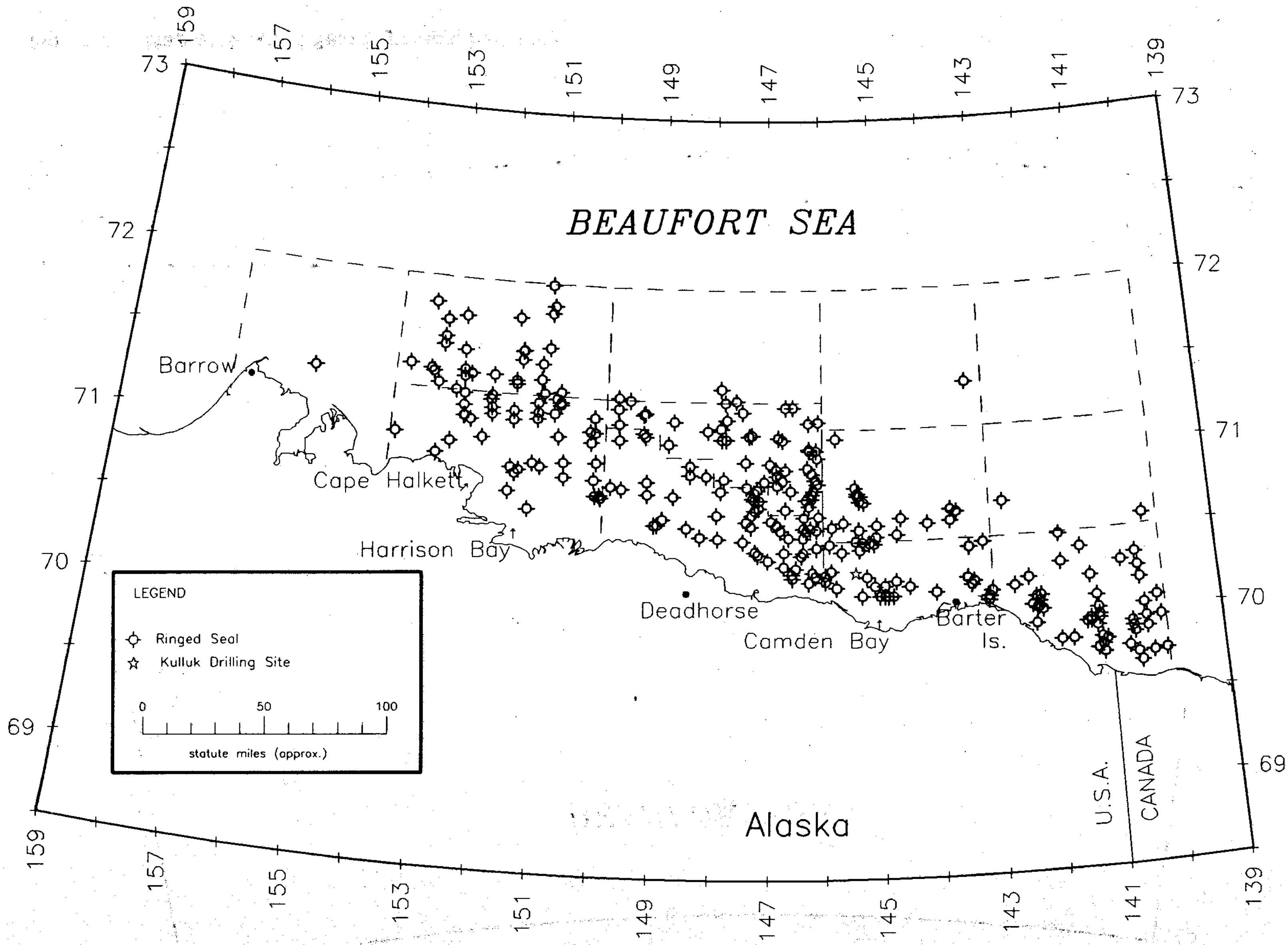


Figure 28. Map of Ringed Seal Sightings, Fall 1992

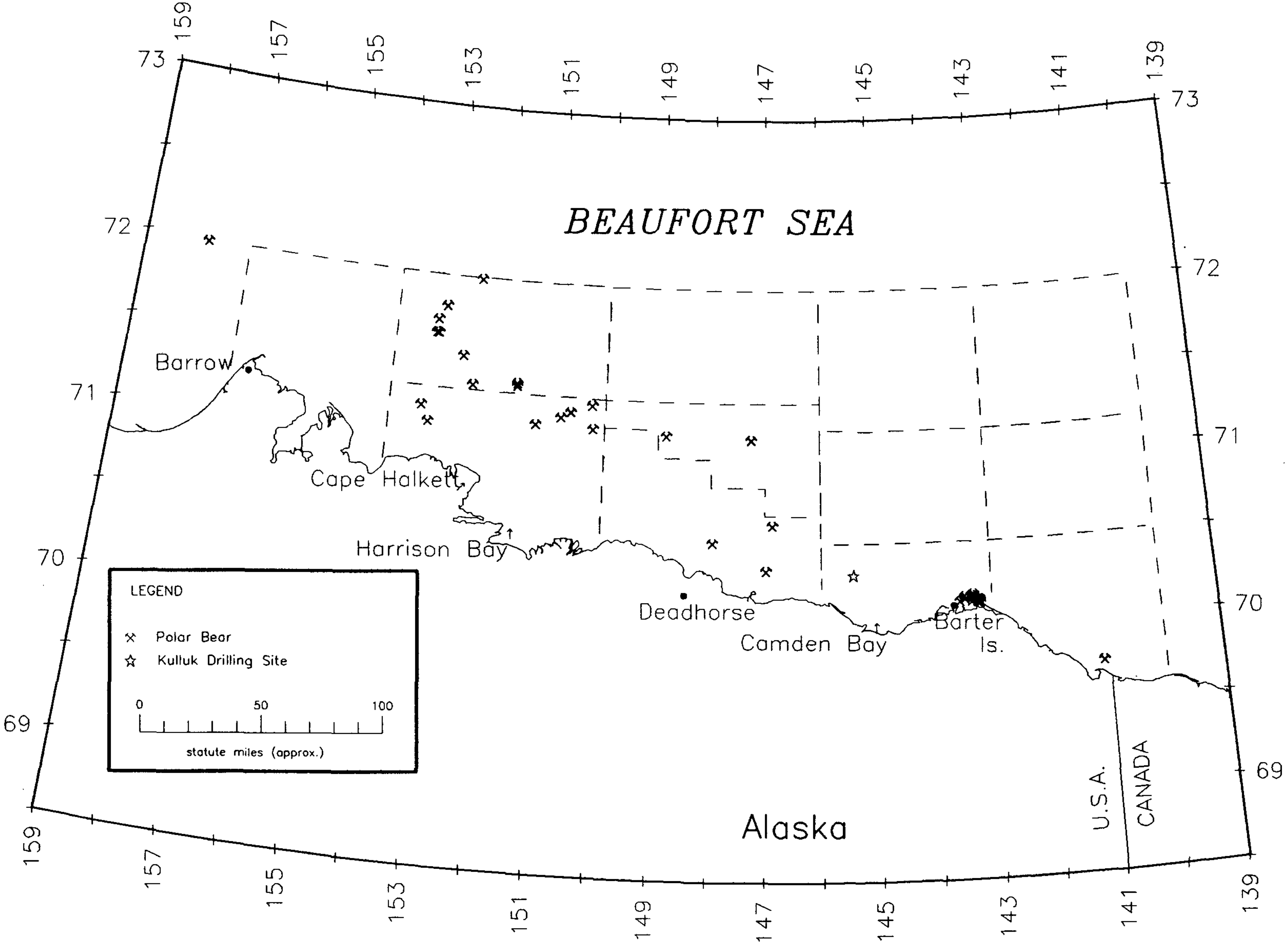


Figure 29. Map of Polar Bear Sightings, Fall 1992

East of 146°W. longitude, bears were sighted very nearshore, mostly clumped around the site of a dead bowhead whale carcass just east of Barter Island. Polar bears were first observed in association with the whale carcass on 12 September. On 4 October, as many as 30 bears were counted in the immediate vicinity. Bears continued to be observed on all subsequent flights over the whale carcass until 18 October, after which flight effort was abandoned in that area. Polar bear kill sites and polar bear tracks also were recorded and are further discussed in Appendix C.

6. Pacific Walrus (*Odobenus rosmarus*): Over the field season, 1 incidental sighting was made for a total of 1 Pacific walrus (Table 4). The walrus was sighted in water on 1 October at 71°17.5′N. latitude, 153°45.7′W. longitude (Fig. 30).

7. Unidentified Cetaceans: Over the field season, 4 incidental sightings were made for a total of 5 unidentified cetaceans (Table 4). Sightings were distributed between 143°W. and 154°W. longitudes, south of the 40-m isobath (Figs. 2 and 31).

8. Unidentified Pinnipeds: Over the field season, 73 incidental sightings were made for a total of 163 unidentified pinnipeds (Table 4). Sightings were distributed between 140°W. and 156°W. longitudes, mostly south of the 2,000-m isobath (Figs. 2 and 32). These sightings were made from 31 August through 18 October (Table 4).

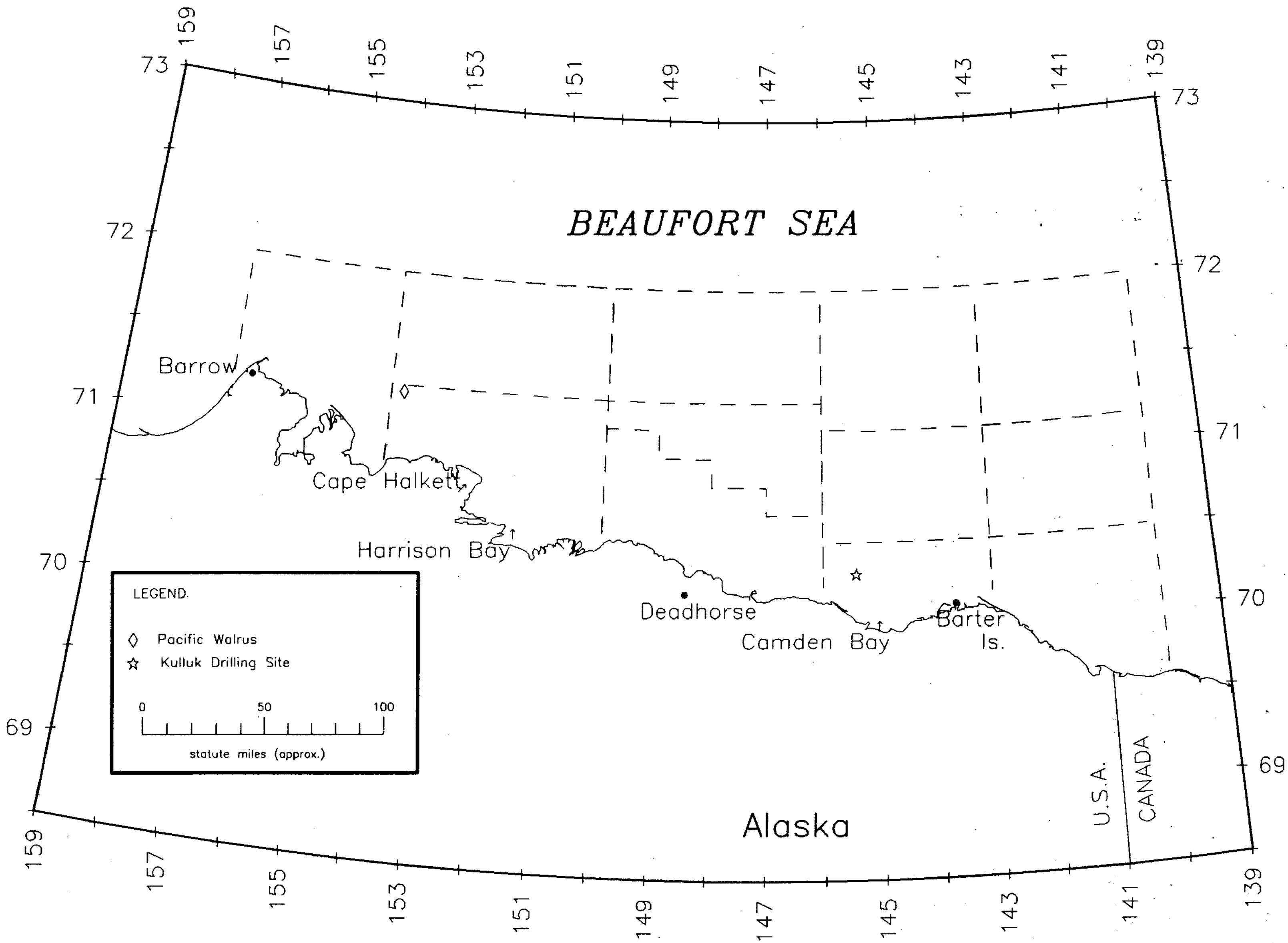


Figure 30. Map of Pacific Walrus Sightings, Fall 1992

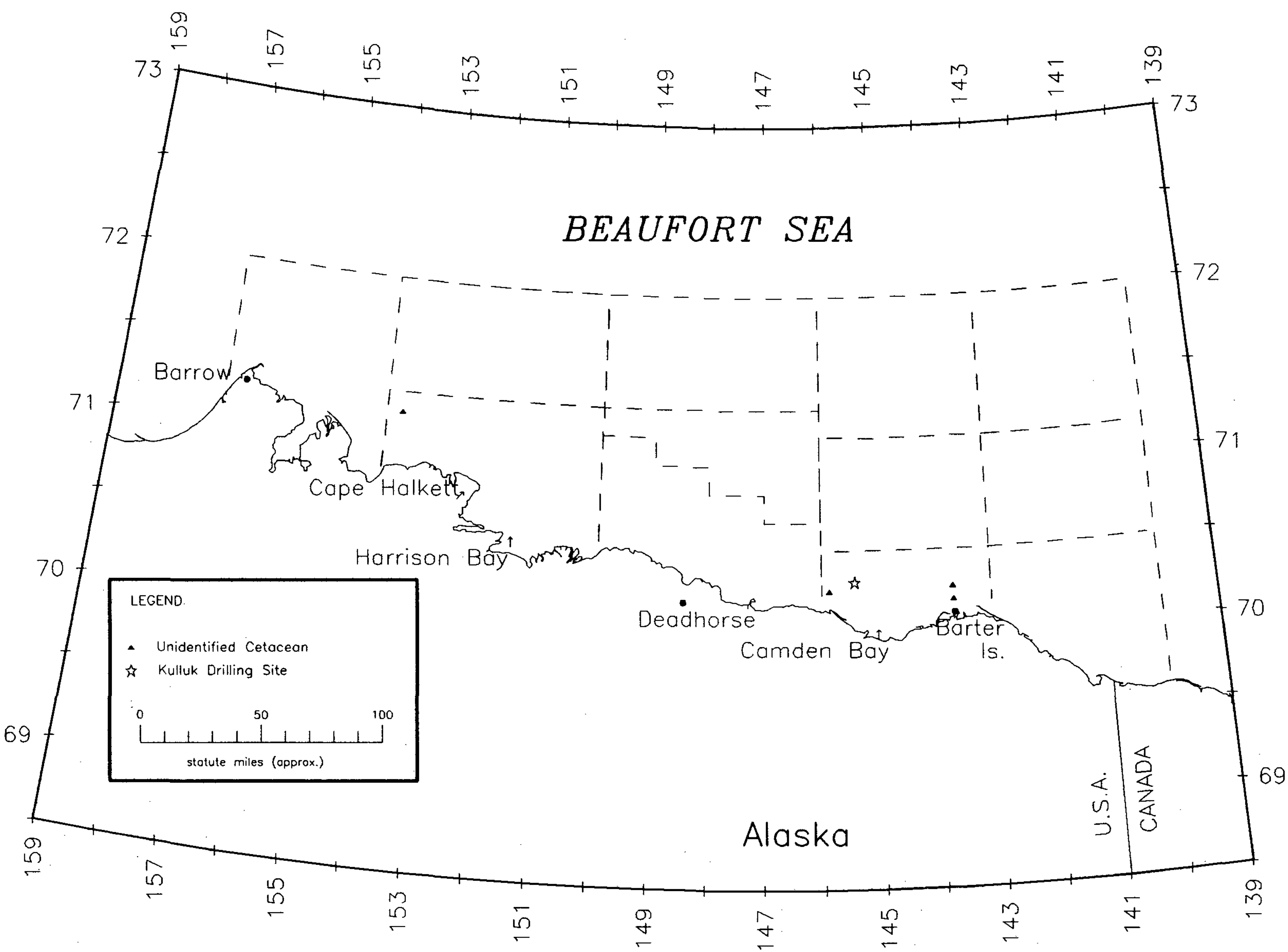


Figure 31. Map of Unidentified Cetacean Sightings, Fall 1992

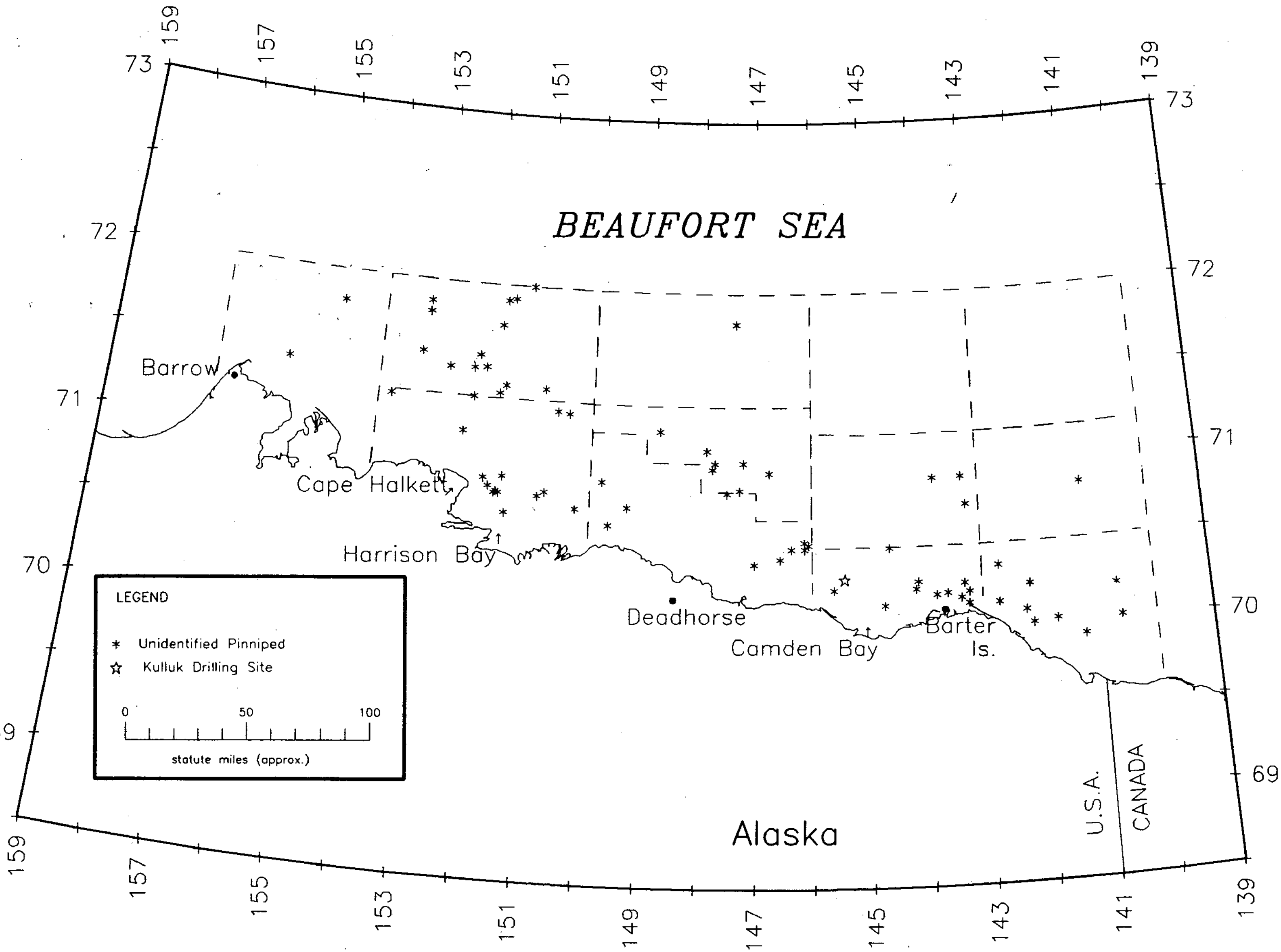


Figure 32. Map of Unidentified Pinniped Sightings, Fall 1992

IV. DISCUSSION

A. General Comparisons with Previous Surveys (1979-1991)

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 (1979-1991) in the Beaufort Sea using similar survey methods (Ljungblad et al., 1987; Moore and Clarke, 1992; Treacy, 1988, 1989, 1990, 1991, 1992). Prior to Fall 1992, surveys in Block 12 were largely conducted from a modified Grumman Goose rather than a Twin Otter aircraft. Results for 1992 that varied greatly from previous values are described below.

The general ice coverage along the northern coast of Alaska during the 1992 navigation season was the fifth most severe since MMS began bowhead whale monitoring in 1979 (USDOD, Navy, Naval Polar Oceanography Center, 1993).

Cloud cover over most of the study area was considered favorable for surveying in 1992, without recurrent periods of "down-to-the-deck" fog as in many previous field seasons.

During the Fall 1992 season, the project surveyed enough distance to circumnavigate the globe. The number of kilometers surveyed (44,645 km), mostly over the Alaskan Beaufort Sea, was the highest since in-house monitoring began in 1987 and does not include miles flown over land en route to and from arctic waters. The average survey flight was almost 1,000 km, with some flights up to 7 hours in duration. The longer flights resulted from improved flying conditions and an improved fuel capacity in the Twin Otter aircraft used by the project. The 1992 total of 205.78 survey hours was much higher than the mean of 107.22 survey hours (SD = 28.28, n = 5) for the years 1987 through 1991.

For September 1992, the relative abundance of bowhead whales in Block 7 of 2.48 WPUE (Table 11) was much higher than the mean September value in Block 7 (1979-1991) of 0.40 WPUE (SD = 0.75, n = 13). For October 1992, the relative abundance in Block 1 of 0.00 WPUE was the same as for October 1983 and lower than for all other October values in Block 1. The relative abundance during October 1992 for Block 12 of 16.35 WPUE was higher than for previous Octobers (Table 11). The high value for October 1992 was the result of a large aggregation of bowhead whale pods feeding just northeast of Barrow during expanded survey effort west of 154°W. longitude. The relative abundances in Block 12 shown for September 1984 and October 1989 were likewise high due to large aggregations of feeding whales. Values for relative abundance in all other survey blocks during September or October 1992 were within the range of values shown for the years 1979 through 1991 (Table 11).

The large aggregation of bowhead whale pods (up to 103 whales) just northeast of Barrow, Alaska, between 156°02'W. and 156°25'W. longitudes, on 17 and 19 October 1992 (Appendix B: Table B-1) was considered very similar to another large aggregation of bowheads (up to 50 whales) northeast of Barrow, between 155°15'W. and 156°25'W. longitudes, on 22, 24, and 28 September 1984 (Ljungblad et al., 1985). In both years, the aggregations included many feeding whales that appeared to remain in the same area over a period of days.

The total numbers of polar bears (n = 203) and ringed seals (n = 606) observed in 1992 were the highest since 1982 (Ljungblad et al., 1987; Treacy, 1988, 1989, 1990, 1991, 1992). The total numbers of belukha whales and bearded seals also were the highest noted since in-house monitoring, using a single aircraft, began in 1987. Higher counts were most likely due to the substantial increase in total survey hours. The seasonal relative abundance of belukha whales in 1992 (3.09 WPUE) was much higher than the mean of 0.95 WPUE (SD = 0.38, n = 5) for the years 1987 through 1991. The large aggregation of polar bears (up to 30 bears) recorded in 1992 near a dead bowhead whale (just east of Barter Island) was considered unique in comparison with our polar bear sightings for previous years.

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

	Survey Block												Other Canadian Areas[2]	Other Alaskan Areas[3]
Year	1	2	3	4	5	6	7	8	9	10	11	12		
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
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

[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.

B. Median and Mean Water Depth at Bowhead Sightings (1982-1992)

The median water depth at 19 sightings of bowhead whales made on randomized line transects in Regions I, II, and III (combined) (Fig. 2) during September and October 1992 was 46 m. This areawide median depth was greater than the cumulative median depth of 38 m for the years 1982 through 1992 (n = 340). It was within the range of median areawide depths for previous years (range = 18 to 347 m) and was greater than for other single years, except for 1983 and 1991. Median water depths of 40 m for Region I, 46 m for Region II, and 55 m for Region III during 1992 were slightly greater than the cumulative median depths of 27 m, 37 m, and 44 m for these respective regions. Values for Region II and Region III also were greater in 1992 than in other single years, except for 1983 and 1991 (Table 12).

To determine whether any of the differences between the median water depth for 1992 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 1992 showed a highly significant difference ($p < 0.005$) when compared to medians for the years 1982, 1983, 1986, and 1989. Analysis by region showed a high degree of statistical significance ($p < 0.005$) between the median depth for 1992 and that for 1989 in Region I (between 150°W. and 153°30′W. longitudes), between 1992 and the median depths for 1982 and 1990 in Region II (between 146°W. and 150°W. longitudes), and between 1992 and the median depths for 1983, 1986, and 1990 in Region III (between 141°W. and 146°W. longitudes) (Table 13).

The median water depth for the year 1990 (38 m) was identical to the cumulative median for the years 1982-1992 (Table 12). Of the years when bowheads tended to migrate in water that was deeper than 1990, only 1983 and 1991 showed differences that were considered highly significant ($p < 0.005$). Likewise, of the years when whales tended to migrate in water that was shallower than 1990, only 1982, 1986, and 1989 showed differences that were considered highly significant (Table 13).

A high level of significance ($p < 0.005$) was noted between the 1983 median value (all 3 regions combined) and the median values for other years except 1991 (Table 13), due to the fact that the 1983 median water depth of 347 m was greater by far than the median for other years (Table 12). A high degree of significance ($p < 0.005$) between 1983 and other years was shown, to a lesser extent, 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) and the median values for other years, except 1986 (Table 13), because the 1989 median water depth of 18 m was clearly shallower than the median depth for other years (Table 12). Such attained levels ($p < 0.005$) between 1989 and other years were shown, to a lesser extent, in Region I (Table 13).

Mean water depths also were 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 19 sightings of bowhead whales made on randomized line transects in Regions I, II, and III (combined) during September and October 1992 was 70.6 m (Table 12). The areawide mean depth for 1992 (70.6 m) was within the range of areawide mean depths for the years 1982 through 1991 (previous values ranged from 22.7 to 738.9 m). This areawide mean depth was less than the cumulative mean depth of 97.5 m for the years 1982 through 1992 (n = 340). It was within the range of mean areawide depths for previous years (range = 22.7 to 738.9 m) and was greater than for other single years, except for 1983 and 1991. Mean water depths of 70.3 m for Region I and 52.9 m for Region III during 1992 were less than the cumulative mean depths of 99.2 m and 103.0 m for these respective regions. The mean depth of 119.0 m for Region II was greater than the cumulative mean depth of 88.0 m for this region and greater than for previous years, except for 1983 and 1991 (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

Table 12
Central-Tendency Statistics for Water Depth (in meters) at Random Sightings of Bowhead Whales (September-October), by Year and Region, 1982-1992

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	740.24	49-1,902
	All 3	23	347	49-1,737	738.9	782.96	22-2,323
1984	I	15	42	27-69	53.3	41.43	18-177
	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	84.09	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]	51.0	69.37	13-155
	II	12	17	9-40	60.8	144.79	7-519
	III	22	34	22-48	34.0	13.91	11-57
	All 3	38	26	18-44	44.3	82.99	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	49.8	41.38	18-219
	All 3	33	37	24-44	40.0	34.54	13-219
1988	I	4	36	[4]	40.5	15.11	29-62
	II	4	44	[4]	44.8	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, 1982-1992
(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	8	55	44-57	52.9	4.29	44-57
	All 3	19	46	37-55	70.6	81.37	13-329
Cumulative	I	73	27	18-42	99.2	285.09	9-2,323
(1982-1992)	II	106	37	29-38	88.0	262.11	7-2,021
	III	161	44	40-48	103.0	273.75	11-1,902
	All 3	340	38	37-40	97.5	271.95	7-2,323

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

Table 13
Interyear Correlation (nonparametric) of the Median Water Depths at Random Bowhead Whale Sightings (September-October) Using the Mann-Whitney U Test, 1982-1992
(Page 1 of 4)

REGION I

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
1983	U′ = 54.0 p ≤ 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 ≤ 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]

Table 13
Interyear Correlation (nonparametric) of the Median Water Depths at Random Bowhead Whale Sightings (September-October) Using the Mann-Whitney U Test, 1982-1992
(Page 2 of 4)

REGION II	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
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' 21.0 $p > 0.20$	$U' = 27.0$ $p \leq 0.01$	$U' = 33.0$ $p < 0.05$	$U' = 27.0$ $p \leq 0.01$	$U' = 9.0$ $p > 0.20$	$U' = 3.0$ [1]	$U' = 51.0$ $p \leq 0.002$	$U = 13.0$ $p > 0.20$

Table 13
Interyear Correlation (nonparametric) of the Median Water Depths at Random Bowhead Whale Sightings (September-October) Using the Mann-Whitney U Test, 1982-1992
(Page 3 of 4)

REGION III

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
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	$U' = 30.5$ $p < 0.20$	$U = 65.5$ $p < 0.005$	$U' = 71.0$ $p > 0.20$	$U = 8.0$ [1]	$U' = 160.5$ $p < 0.001$	$U' = 122.5$ $p < 0.05$	$U' = 30.0$ $p \leq 0.20$	$U' = 14.5$ $p > 0.20$	$U' = 466.0$ $Z = 3.28$ $p < 0.001$	$U = 28.5$ $p > 0.20$

Table 13
Interyear Correlation (nonparametric) of the Median Water Depths at Random Bowhead Whale Sightings (September-October) Using the Mann-Whitney U Test, 1982-1992
(Page 4 of 4)

ALL THREE REGIONS (COMBINED)

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
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	$U = 898.0$ $Z = 0.76$ $p > 0.20$	$U = 786.0$ $Z = 5.19$ $p < 0.001$	$U = 1043.0$ $Z = 3.33$ $p < 0.001$	$U = 314.0$ $p < 0.20$						
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	$U' = 503.0$ $Z = 4.33$ $p < 0.001$	$U = 213.0$ $p < 0.05$	$U' = 373.5$ $p < 0.01$	$U' = 134.5$ $p < 0.02$	$U' = 446.0$ $p < 0.001$	$U' = 377.0$ $p < 0.001$	$U' = 135.0$ $p \leq 0.01$	$U' = 236.0$ $p < 0.001$	$U' = 999.0$ $Z = 4.33$ $p < 0.001$	
1992	$U' = 641.5$ $Z = 3.55$ $p < 0.001$	$U = 347.5$ $p < 0.001$	$U' = 399.5$ $p > 0.20$	$U' = 167.5$ $p < 0.10$	$U' = 556.5$ $p < 0.001$	$U' = 457.0$ $p < 0.01$	$U' = 148.5$ $p > 0.20$	$U' = 310.5$ $p < 0.001$	$U' = 1,170.0$ $Z = 2.72$ $p < 0.01$	$U = 181.5$ $p < 0.05$

[1] Insufficient sample size.

for 1983 and all other years (including 1992) were considered highly significant ($p < 0.005$) 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 1992, 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 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). During 1983, the most severe ice year since 1975 (USDOD, Navy, Naval Polar Oceanography Center, 1993), the bowhead migration was observed in water almost an order of magnitude deeper than for other years (Table 12).

During 1992, the fifth-most severe ice year since the beginning of the surveys in 1979 (USDOD, Navy, Naval Polar Oceanography Center, 1993), the bowhead migration was observed at a greater-than-average areawide median depth in all three regions, a greater-than-average mean water depth in Region II, and a less-than-average mean water depth in Regions I and III (Table 12).

In general, mean water depths at sightings of bowhead whales were skewed to the deeper (north) side of the migration axis (median), with cumulative mean values for each region (1982-1992) over twice as great (as deep) as cumulative medians (Table 12). The differences between the median and mean values are unknown but may simply reflect the increasing gradient of the seafloor farther offshore.

C. Potential Responses of Bowheads to Survey Aircraft

During the 1992 field season, there were no sightings of bowhead whales for which 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 in whale behavior were sought. Such changes included an abrupt dive, course diversion, or cessation of behavior ongoing at first sighting.

D. Potential Effect of General Ice Cover on WPUE (1979-1992)

There were 297 bowhead whales observed during 194.80 hr for a relative abundance of 1.52 WPUE for the combined months of September and October 1992 in Survey Blocks 1 through 12 (note that similar comparisons in previous reports in this series compared only Blocks 1-11). The number of hours spent in these blocks in 1992 was greater than for all previous years since the survey began in 1979 (see Sec. IV.A). The record survey effort in the primary study area during the fall comprised separate monthly records for both September (90.52 hr) and October (104.28 hr). The combined September and October relative abundance of 1.52 WPUE for 1992 was representative of the middle-range values found during moderate ice years. The relative abundance of bowheads for October 1992 in these blocks (2.59 WPUE) was exceeded only in 1989 (Table 15).

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 1992 and show distances between Point Barrow and the five-tenths ice concentration on 15 September ranging from 10 nautical miles (nm) to 25 nm (USDOD, Navy, Naval Polar Oceanography Center, 1993).

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 1992 and show distances between Point Barrow and the five-tenths ice concentration on 15 September ranging from 50 nm to 75 nm (USDOD, Navy, Naval Polar Oceanography Center, 1993).

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, 1982-1992

REGION I [1]
ANOVA F = 1.496, $p < 0.50$

Tukey Test:

(1989)	(1987)	(1990)	(1988)	(1986)	(1984)	(1992)	(1982)	(1985)	(1983)
16.0	19.3	29.3	40.5	51.3	53.4	70.3	113.4	219.3	393.7

REGION II
ANOVA F = 11.392, $p << 0.001$

Tukey Test:

(1987)	(1985)	(1982)	(1990)	(1984)	(1989)	(1988)	(1986)	(1992)	(1991)	(1983)
27.3	30.4	30.6	33.6	43.7	44.0[2]	44.8	60.8	119.0	126.7	945.0

(1984) through (1983): ($p < 0.005$)

REGION III
ANOVA F = 22.897, $p << 0.001$

Tukey Test:

(1986)	(1990)	(1982)	(1989)	(1987)	(1992)	(1985)	(1984)	(1988)	(1991)	(1983)
34.1	40.5	43.4	49.3	49.9	52.9	64.0[2]	90.4	90.4	132.2	969.8

(1987) through (1983): ($p < 0.001$)

ALL THREE REGIONS (COMBINED)
ANOVA F = 22.896, $p << 0.001$

Tukey Test:

(1989)	(1990)	(1987)	(1986)	(1982)	(1988)	(1984)	(1992)	(1985)	(1991)	(1983)
22.7	38.8	40.0	44.3	47.5	61.0	64.7	70.63	76.6	129.2	739.0

(1982) through (1983): ($p << 0.001$)

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

Table 15
Relative Abundance (WPUE) of Bowhead Whales within the Primary Study Area
(Survey Blocks 1-12) during September and October,
by Year and General Ice Coverage, 1979-1992
(after Ljungblad et al. [1987], Moore and Clarke [1992], and Treacy [1988, 1989, 1990, 1991, 1992])

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[1]	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[1]	101.73	72	0.71	41.48	17	0.41	143.21	89	0.62
1984[2]	73.64	216	2.93	63.49	85	1.34	137.13	301	2.19
1985[2]	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[1]	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[1]	38.36	9	0.23	51.13	40	0.78	89.49	49	0.55
1992[2]	104.28	63	0.60	90.52	234	2.59	194.80	297	1.52
Ice Coverage									
Heavy Ice Years[1] (Σ)	281.46	132	0.47	198.82	88	0.44	480.28	220	0.46
Moderate Ice Years[2] (Σ)	245.31	331	1.35	212.23	376	1.77	457.54	707	1.55
Light Ice Years (Σ)	514.96	1,242	2.41	370.19	550	1.49	885.15	1,792	2.02

[1] 1980, 1983, 1988, and 1991 were considered years of heavy ice coverage.
[2] 1984, 1985, and 1992 were considered years of moderate ice coverage.

The years 1979, 1981, 1982, 1986, 1987, 1989, and 1990, 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 1992 and show distances between Point Barrow and the five-tenths ice concentration on 15 September ranging from 85 nm to 125 nm (USDOD, Navy, Naval Polar Oceanography Center, 1993).

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 (2.02 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 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 ($\bar{x}$ = 2.25, SD = 1.48, n = 7) 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 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).

The relative abundance of bowhead whales was compared between years to obtain a rough indication of any temporal trends. In order to control 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, and 1990). The data showed weak tendencies for bowhead relative abundance to increase from 1979 through 1990, but the correlations were not statistically significant.

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 air guns; vessel geological-geophysical permits for shallow seismic exploration using an airgun; on-ice geophysical permits using VIBROSEIS technology; both vessel and on-ice geological permits for obtaining core samples; and permits to drill for gas and oil.

During 1992, MMS issued three on-ice geophysical (VIBROSEIS) permits to industry for seismic exploration in the central to western portions of the Alaskan Beaufort Sea. These explorations were permitted from the first part of January through the end of May, prior to the fall migration of bowhead whales.

In order 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 were visible from the vessel--as the bowhead whale migration progressed through the area of operations. For explorations that occurred during the fall, daily summaries of survey information were 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 periods of limited visibility.

ARCO Alaska Inc. conducted drilling operations at its Kuvlum Prospect north of Camden Bay (70°19.0'N. latitude, 145°25.2'W. longitude) using the semi-submersible drilling barge *Kulluk*, supported by four ice-management vessels. The maximum hull diameter of this circular floating structure is 80.8 m and the maximum hull depth is 18.5 m. The *Kulluk* has a 12-point mooring system employing anchor wires that are 8.9 centimeters in diameter. Drilling operations began on 22 August 1992, the well was plugged on 14 October, and the site was abandoned on 15 October.

Sightings of bowhead whales in the general study area, including those in the vicinity of drill sites, are shown for each bimonthly period of the Fall-1992 survey in Figures 18 through 22. The closest sighting of a bowhead whale to a drill site was noted on 8 September 1992 (Appendix B: Flight 5) at a distance of 39.8 km north of the operational *Kulluk* drilling barge. This adult whale was swimming at a 240° compass heading in 1-percent ice when observed.

Daily summaries of field information from this survey, and other arctic surveys being conducted concurrently, were transferred by the MMS Team Leader to MMS Field Operations in Anchorage. The MMS and NMFS reviewed 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 the Kuvlum drill site.

F. Field Coordinations

Information summaries were provided to various requesting agencies and private-sector organizations, including the USDOD Naval Polar Oceanography Center, Washington, D.C.; Alaska Eskimo Whaling Commission, Barrow, Alaska; and an ARCO Alaska Inc.-funded study, conducted by Coastal & Offshore Pacific Corporation, that was monitoring marine mammals in the vicinity of the Kuvlum drill site.

Aircraft safety was coordinated with the ARCO Alaska Inc.-funded study to avoid simultaneous sampling in the same area. We also coordinated with NMFS, Anchorage, Alaska; North Slope Borough, Barrow, Alaska; an oil industry/whalers' conflict-avoidance group, Deadhorse, Alaska; and a concurrent MMS-funded study, conducted by Oregon State University, in which satellite tags were applied to bowhead whales.

V. LITERATURE CITED

Batschelet, E. 1972. Recent Statistical Methods for Orientation Data. In: Animal Orientation and Navigation, S.R. Galler, K. Schmidt-Koenig, G.J. Jacobs, and R.E. Bellevue, eds. Washington, D.C.: National Aeronautics and Space Administration, pp. 41-61.

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

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

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

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

Estes, J.A. and J.R. Gilbert. 1978. Evaluation of an Aerial Survey of Pacific Walruses (*Odobenus rosmarus divergens*). Journal of the Fisheries Research Board of Canada 35:1,130-1,140.

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

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

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

Ljungblad, D.K., S.E. Moore, J.T. Clarke, and J.C. Bennett. 1985. Aerial Surveys of Endangered Whales in the Northern Bering, Eastern Chukchi, and Alaskan Beaufort Seas, 1984: With a Six Year Review, 1979-1984. OCS Study MMS 85-0018. NOSC Technical Report 1046 prepared for USDOI, MMS, Alaska OCS Region, 302 pp.

Ljungblad, D.K., S.E. Moore, J.T. Clarke, and J.C. Bennett. 1987. Distribution, Abundance, Behavior and Bioacoustics of Endangered Whales in the Alaskan Beaufort and Eastern Chukchi Seas, 1979-86. OCS Study MMS 87-0039. NOSC Technical Report 1177 prepared for USDOI, MMS, Alaska OCS Region, 391 pp.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

USDOD, Navy, Naval Polar Oceanography Center. 1993. U.S. Navy-NOAA Joint Ice Center, Seasonal Outlook, Western Arctic Ice, 1993. Washington, D.C., 5 pp.

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

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

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

USDOI, MMS. 1985. Beaufort Sea Planning Area Map (June 1985). Anchorage, AK: USDOI, MMS, Alaska OCS Region.

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

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

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

APPENDIX A

BOWHEAD WHALE DENSITIES

BOWHEAD WHALE DENSITIES

This appendix presents estimated bowhead whale densities in the Beaufort Sea for the period 31 August through 23 October 1992. 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-1992 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).

On 31 August, no block received more than 10-percent survey coverage. One bowhead was observed within 1 km of the randomly generated transect lines in Block 4, where only 9.32 percent of the block was surveyed, for an estimated density of 0.19 whales per 100 km^2. No bowheads were observed within 1 km of the transect line in other blocks on this day.

During the first half of September, over 10 percent of the area was surveyed for Blocks 1, 2, 3, 5, and 11. Of these blocks, no bowheads were observed in Blocks 1, 2, and 11 within 1 km of the randomly generated transect line, for estimated densities of 0.00 whales per 100 km^2. One bowhead was observed in Block 3, for an estimated density of 0.05. One bowhead was observed in Block 5, for an estimated density of 0.05. Also, five bowheads were observed in Block 4, where only 9.55 percent of the block was surveyed, for an estimated density of 0.92. No bowhead whales were observed within 1 km of the transect line in other blocks during this period.

During the second half of September, over 10 percent of the area was surveyed for Blocks 1, 2, 3, 5, 6, and 11. Of these blocks, no bowheads were observed in Blocks 1 and 6 within 1 km of the randomly generated transect line, for estimated densities of 0.00 whales per 100 km^2. One bowhead was observed in Block 2, for an estimated density of 0.05. One bowhead was observed in Block 3, for an estimated density of 0.06. Three bowheads were observed in Block 5, for an estimated density of 0.07. One bowhead was observed in Block 11, for an estimated density of 0.07. No bowhead whales were observed within 1 km of the transect line in other blocks during this period.

During the first half of October, over 10 percent of the area was surveyed for Blocks 1, 2, 3, 4, 5, 7, and 11. Of these blocks, no bowheads were observed in Blocks 1, 4, 5, and 7 within 1 km of the randomly generated transect line, for estimated densities of 0.00 whales per 100 km^2. Three bowheads were observed in Block 2, for an estimated density of 0.14. Ten bowheads were observed in Block 3, for an estimated density of

Table A-1
Semimonthly Estimates of Bowhead Whale Densities, by Survey Block, Fall 1992
(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)
31 Aug								
1	10,222	79	1.54	0.33	21.28	2	0	0.00
4	5,714	266	9.32	1.20	76.86	8	1	0.19
5	9,481	0	0.01	0.02	1.31	1	0	0.00
6	8,109	2	0.05	0.01	0.55	3	0	0.00
1-15 Sep								
1	10,222	575	11.26	2.46	12.25	12	0	0.00
2	6,672	639	19.15	2.72	13.54	14	0	0.00
3	11,475	1,054	18.36	4.55	22.67	19	1	0.05
4	5,714	273	9.55	1.27	6.34	9	5	0.92
5	9,481	942	19.86	4.19	20.86	17	1	0.05
6	8,109	153	3.76	0.66	3.27	4	0	0.00
7	8,109	76	1.87	0.33	1.64	4	0	0.00
8	9,753	1	0.01	0.00	0.01	1	0	0.00
9	9,753	1	0.02	0.00	0.02	1	0	0.00
10	10,358	444	8.58	1.85	9.24	8	0	0.00
11	10,358	564	10.88	2.03	10.13	12	0	0.00
16-30 Sep								
1	10,222	706	13.81	3.21	11.49	17	0	0.00
2	6,672	926	27.76	4.17	14.95	21	1	0.05
3	11,475	796	13.88	3.53	12.65	15	1	0.06
4	5,714	270	9.47	1.20	4.30	8	0	0.00
5	9,481	2,052	43.29	9.00	32.23	31	3	0.07
6	8,109	594	14.64	2.65	9.51	10	0	0.00
7	8,109	0	0.01	0.00	0.01	1	0	0.00
9	9,753	189	3.88	0.89	3.20	6	0	0.00
10	10,358	4	0.08	0.02	0.07	7	0	0.00
11	10,358	742	14.32	3.23	11.59	14	1	0.07

Table A-1
Semimonthly Estimates of Bowhead Whale Densities, by Survey Block, Fall 1992
(strip width = 2 km)
(Continued)

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 Oct								
1	10,222	1,210	23.68	5.32	11.87	24	0	0.00
2	6,672	1,084	32.50	4.75	10.58	25	3	0.14
3	11,475	2,616	45.60	11.75	26.20	44	10	0.19
4	5,714	395	13.82	1.70	3.79	10	0	0.00
5	9,481	1,296	27.35	5.75	12.81	17	0	0.00
6	8,109	370	9.12	1.60	3.56	7	0	0.00
7	8,109	665	16.39	2.95	6.57	10	0	0.00
8	9,753	93	1.91	0.41	0.91	3	0	0.00
9	9,753	93	1.90	0.32	0.71	2	0	0.00
10	10,358	148	2.86	0.56	1.26	2	0	0.00
11	10,358	2,191	42.31	9.76	21.76	36	1	0.02
16-23 Oct								
11	10,358	187	3.61	0.71	16.59	3	0	0.00
12	11,163	574	10.29	2.41	56.16	7	1	0.09
13	13,673	261	3.82	1.17	27.13	3	5	0.96
12N	11,453	1	0.01	0.00	0.04	2	0	0.00

0.19. One bowhead was observed in Block 11, for an estimated density of 0.02. No bowhead whales were observed within 1 km of the transect line in other blocks during this period.

From 16 through 23 October, over 10 percent of the area was surveyed for Block 12. One bowhead was observed in Block 12 within 1 km of the randomly generated transect line, for an estimated density of 0.09 whales per 100 km^2. Also, five bowheads were observed in Block 13, where only 3.82 percent of the block was surveyed, for an estimated density of 0.14. No bowhead whales were observed within 1 km of the transect line in other blocks during this period.

LITERATURE CITED

Estes, J.A. and J.R. Gilbert. 1978. Evaluation of an Aerial Survey of Pacific Walruses (*Odobenus rosmarus divergens*). Journal of the Fisheries Research Board of Canada 35:1,130-1,140.

Hayne, D.W. 1949. An Examination of the Strip Census Method for Estimating Animal Populations. Journal of Wildlife Management 13:145-157.

Ljungblad, D.K., S.E. Moore, J.T. Clarke, and J.C. Bennett. 1987. Distribution, Abundance, Behavior and Bioacoustics of Endangered Whales in the Alaskan Beaufort and Eastern Chukchi Seas, 1979-86. OCS Study MMS 87-0039. NOSC Technical Report 1177 prepared for USDOI, MMS, Alaska OCS Region, 391 pp.

APPENDIX B

DAILY FLIGHT SUMMARIES

DAILY FLIGHT SUMMARIES

This appendix consists of maps for Flights 1 through 45, depicting aerial surveys flown over the study area from 31 August through 23 October 1992 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 1992
(Page 1 of 5)

Flight No.	Day	Total Whales	No. of Calves	Latitude (North)	Longitude (West)	Sighting Cue	Behavior	Compass Heading	Ice (%)	Sea State	Depth (m)
1	31 Aug	1	0	70°15.2′	143°13.4′	body	swim	255	2	2	37
1	31 Aug	1	0	70°12.6′	143°00.9′	splash	swim	230	5	2	29
1	31 Aug	1	0	70°17.2′	143°40.8′	blow	swim	200	1	2	37
1	31 Aug	1	0	70°03.6′	144°16.0′	body	rest	[1]	1	1	9
1	31 Aug	1	0	70°27.3′	147°32.7′	body	swim	290	10	1	13
2	1 Sep	1	0	70°54.1′	151°39.1′	blow	swim	240	0	2	13
5	8 Sep	1	0	70°39.9′	145°38.7′	body	swim	240	1	3	66
5	8 Sep	3	0	70°40.2′	145°38.9′	body	swim	240	1	3	66
5	8 Sep	1	0	70°40.3′	145°39.7′	body	swim	[1]	1	3	66
5	8 Sep	1	0	70°40.3′	145°41.1′	[1]	swim	[1]	1	3	64
5	8 Sep	1	0	70°40.6′	145°41.9′	[1]	swim	[1]	1	3	64
5[2]	8 Sep	1	0	70°40.3′	145°41.1′	[1]	swim	235	1	3	[2]
5	8 Sep	2	0	70°40.1′	145°40.7′	[1]	swim	[1]	1	3	64
5	8 Sep	1	0	70°41.2′	145°42.0′	[1]	swim	[1]	1	3	64
5[2]	8 Sep	1	0	70°40.8′	145°43.4′	[1]	swim	240	1	3	[2]
5[2]	8 Sep	1	0	70°40.9′	145°43.0′	[1]	swim	235	1	3	[2]
5	8 Sep	2	0	70°40.1′	145°42.0′	body	swim	240	1	3	64
5[2]	8 Sep	1	0	70°41.1′	145°43.2′	[1]	swim	240	1	3	[2]
5[2]	8 Sep	1	0	70°41.1′	145°44.5′	[1]	swim	240	1	3	[2]
5[2]	8 Sep	2	0	70°40.7′	145°43.6′	[1]	swim	240	1	3	[2]
5	8 Sep	1	0	70°41.4′	145°43.3′	[1]	swim	240	1	3	64
5[2]	8 Sep	2	0	70°40.7′	145°43.0′	[1]	swim	240	1	3	[2]
5[2]	8 Sep	1	0	70°41.7′	145°44.8′	[1]	swim	250	1	3	[2]
5[2]	8 Sep	2	0	70°40.9′	145°42.7′	[1]	swim	240	1	3	[2]
5[2]	8 Sep	1	0	70°41.3′	145°45.3′	[1]	swim	260	1	3	[2]
5[2]	8 Sep	1	0	70°41.3′	145°44.8′	[1]	swim	260	1	3	[2]
5	8 Sep	2	0	70°40.2′	145°43.4′	body	swim	280	1	3	64
5[2]	8 Sep	2	0	70°41.1′	145°44.4′	body	swim	260	1	3	[2]
5	8 Sep	1	0	70°40.7′	145°39.4′	body	swim	240	1	3	66
5[2]	8 Sep	2	0	70°40.8′	145°44.0′	body	swim	300	1	3	[2]
7	10 Sep	2	0	70°00.1′	141°33.4′	body	swim	300	5	2	31
7	10 Sep	1	0	69°59.5′	141°29.4′	blow	swim	300	1	2	40
7	10 Sep	2	0	70°05.7′	140°37.5′	body	swim	260	0	2	46
7	10 Sep	1	0	70°05.4′	140°32.5′	splash	swim	250	0	2	46
7	10 Sep	1	0	70°01.1′	140°32.2′	splash	swim	260	0	2	49
7	10 Sep	1	0	70°16.6′	141°46.3′	body	swim	120	1	3	57
7	10 Sep	1	0	70°09.6′	142°09.9′	body	swim	310	10	1	44
7	10 Sep	1	0	70°08.9′	142°07.6′	body	swim	250	5	1	38
7	10 Sep	2	0	70°12.8′	142°08.3′	body	swim	280	5	1	53
7	10 Sep	1	0	70°30.7′	142°04.5′	blow	swim	240	0	4	69
7	10 Sep	1	0	70°30.9′	142°14.4′	splash	swim	290	0	4	75

Table B-1
Selected Sighting Data for Bowhead Whales Observed, Fall 1992
(Page 2 of 5)

Flight No.	Day	Total Whales	No. of Calves	Latitude (North)	Longitude (West)	Sighting Cue	Behavior	Compass Heading	Ice (%)	Sea State	Depth (m)
7	10 Sep	1	0	70°31.4′	142°16.3′	body	swim	[1]	0	4	75
7	10 Sep	1	0	70°28.6′	143°28.1′	body	swim	280	0	6	48
9	12 Sep	1	0	70°45.5′	147°59.5′	body	feed	270	10	4	42
9	12 Sep	1	0	70°45.4′	147°55.2′	body	swim	270	10	4	42
9	12 Sep	1	0	70°29.3′	143°39.7′	body	swim	270	1	2	55
9	12 Sep	1	0	70°08.5′	143°13.6′	body	dead	[1]	25	0	7
9	12 Sep	1	0	70°24.2′	143°02.5′	body	dive	260	20	1	55
9	12 Sep	1	0	70°24.2′	143°02.5′	body	swim	260	20	1	55
9	12 Sep	3	0	70°26.7′	143°03.7′	body	swim	240	20	1	55
9	12 Sep	1	0	70°27.4′	143°03.4′	body	swim	250	20	1	51
13[2]	17 Sep	1	0	70°08.8′	143°13.6′	body	dead	[1]	95	0	[2]
15	20 Sep	3	0	70°10.0′	142°30.4′	splash	swim	310	50	4	29
15[2]	20 Sep	3	0	70°10.6′	142°30.6′	blow	swim	310	50	4	[2]
15	20 Sep	2	0	70°10.4′	142°31.0′	body	swim	220	50	4	29
15[2]	20 Sep	1	0	70°10.4′	142°32.3′	body	swim	240	50	4	[2]
15	20 Sep	1	0	70°32.6′	143°39.9′	body	swim	210	70	1	29
18	24 Sep	1	0	69°58.0′	140°14.4′	splash	swim	230	90	1	59
18	24 Sep	1	0	70°15.2′	142°17.1′	body	swim	210	95	1	49
18	24 Sep	1	0	70°37.5′	146°36.0′	splash	swim	50	50	2	33
18	24 Sep	3	0	70°38.7′	146°31.5′	body	swim	270	50	2	33
19	25 Sep	1	0	71°08.3′	152°18.9′	splash	swim	330	90	1	20
20	26 Sep	1	0	70°09.5′	140°10.5′	blow	swim	270	90	2	55
20[2]	26 Sep	1	0	70°09.5′	140°12.0′	splash	swim	290	90	2	[2]
22	28 Sep	1	0	70°58.4′	147°50.3′	body	rest	300	80	1	46
22	28 Sep	1	0	70°58.6′	148°10.0′	body	breach	200	90	1	46
22	28 Sep	1	0	70°59.6′	148°09.0′	blow	swim	200	90	1	46
22	28 Sep	1	0	70°59.2′	148°08.4′	splash	swim	240	90	1	46
22	28 Sep	1	0	70°59.3′	148°10.1′	body	swim	240	90	1	37
22[2]	28 Sep	1	0	70°59.6′	148°10.1′	body	swim	[1]	90	1	[2]
22[2]	28 Sep	1	0	70°59.5′	148°09.9′	[1]	swim	[1]	90	1	[2]
22[2]	28 Sep	1	0	70°59.6′	148°11.8′	blow	swim	[1]	90	1	[2]
22[2]	28 Sep	1	0	70°59.5′	148°11.7′	body	swim	[1]	90	1	[2]
22[2]	28 Sep	1	0	70°59.8′	148°10.9′	body	swim	[1]	90	1	[2]
23	29 Sep	1	0	71°26.1′	153°41.7′	body	rest	150	70	2	51
24	30 Sep	1	0	70°49.4′	146°36.0′	splash	rest	[1]	95	2	82
25	1 Oct	3	0	71°15.8′	153°43.5′	body	swim	250	70	3	22
25	1 Oct	6	0	71°16.1′	153°47.9′	blow	swim	[1]	70	3	22
25	1 Oct	1	0	71°15.9′	153°48.1′	body	swim	[1]	70	3	22
25	1 Oct	3	0	71°27.1′	153°46.0′	body	swim	180	95	2	51
25	1 Oct	7	1	71°27.2′	153°48.6′	body	swim	[1]	95	2	51
25	1 Oct	1	0	71°31.1′	152°34.9′	splash	swim	200	90	2	46

Table B-1
Selected Sighting Data for Bowhead Whales Observed, Fall 1992
(Page 3 of 5)

Flight No.	Day	Total Whales	No. of Calves	Latitude (North)	Longitude (West)	Sighting Cue	Behavior	Compass Heading	Ice (%)	Sea State	Depth (m)
25	1 Oct	1	0	71°15.2′	151°37.7′	body	rest	[1]	80	2	37
25	1 Oct	1	0	71°22.1′	151°38.6′	blow	swim	240	80	2	329
25[2]	1 Oct	1	0	71°21.7′	151°41.3′	blow	swim	220	80	2	[2]
25	1 Oct	1	0	71°22.1′	151°43.4′	body	swim	[1]	80	2	55
26	2 Oct	3	0	71°18.8′	153°12.6′	body	swim	250	85	2	42
26	2 Oct	2	0	71°17.4′	152°10.5′	body	swim	90	95	1	29
26	2 Oct	1	0	71°14.2′	151°16.5′	splash	rest	180	98	1	46
30	6 Oct	3	0	71°09.5′	148°50.5′	body	swim	230	95	3	265
30	6 Oct	1	0	71°08.7′	148°52.2′	body	dive	[1]	95	3	49
38	15 Oct	1	0	71°30.7′	156°03.8′	body	swim	200	50	4	165
38	15 Oct	1	0	71°29.9′	156°03.4′	body	dive	[1]	50	4	13
38	15 Oct	1	0	71°30.5′	156°02.2′	body	rest	[1]	50	4	165
38	15 Oct	1	0	71°30.0′	156°05.0′	body	dive	[1]	50	4	165
38	15 Oct	1	0	71°29.4′	156°09.2′	body	dive	190	50	4	13
38	15 Oct	3	0	71°29.1′	155°43.0′	body	mill	270	60	3	16
38	15 Oct	1	0	71°28.6′	155°43.5′	body	swim	250	60	3	16
38	15 Oct	2	1	71°30.8′	155°26.8′	blow	cow with calf	160	80	3	20
38	15 Oct	1	0	71°18.9′	155°18.7′	splash	rest	250	50	4	16
38	15 Oct	1	0	71°19.4′	155°22.1′	body	swim	[1]	50	3	13
38	15 Oct	1	0	71°18.6′	155°19.0′	body	swim	160	50	4	16
38	15 Oct	1	0	71°18.9′	155°16.6′	body	swim	140	40	4	16
38	15 Oct	2	0	71°18.8′	155°15.3′	blow	swim	225	50	4	16
38	15 Oct	1	0	71°18.7′	155°23.9′	body	rest	90	50	4	13
38	15 Oct	2	1	71°18.8′	155°13.8′	body	cow with calf	90	40	5	16
38	15 Oct	2	1	71°18.4′	155°11.3′	body	cow with calf	270	50	4	16
40	17 Oct	2	0	71°30.8′	156°07.5′	body	swim	240	30	4	165
40	17 Oct	1	0	71°30.7′	156°05.7′	body	swim	240	20	3	165
40	17 Oct	1	0	71°30.8′	156°08.7′	body	swim	[1]	20	3	165
40	17 Oct	1	0	71°30.9′	156°07.6′	body	swim	[1]	20	3	165
40	17 Oct	1	0	71°30.9′	156°06.3′	body	swim	110	20	3	165
40	17 Oct	1	0	71°30.4′	156°04.9′	body	swim	[1]	20	3	165
40	17 Oct	2	0	71°25.9′	156°09.2′	body	dive	280	20	3	15
40	17 Oct	1	0	71°25.5′	156°10.5′	body	swim	360	20	3	9
40	17 Oct	1	0	71°25.9′	156°08.4′	body	swim	300	20	3	15
40	17 Oct	1	0	71°26.1′	156°11.3′	body	swim	300	20	4	9
40	17 Oct	2	0	71°25.2′	156°11.7′	body	feed	[1]	20	4	9
40	17 Oct	10	0	71°24.6′	156°11.1′	body	feed	[1]	20	4	9
40	17 Oct	8	0	71°23.8′	156°10.8′	body	feed	[1]	20	4	5
40	17 Oct	2	0	71°22.7′	156°12.2′	body	feed	[1]	20	4	5
40	17 Oct	9	0	71°22.3′	156°11.2′	mud plumes	feed	[1]	20	5	5
40	17 Oct	10	0	71°21.5′	156°08.7′	mud plumes	feed	[1]	20	5	9

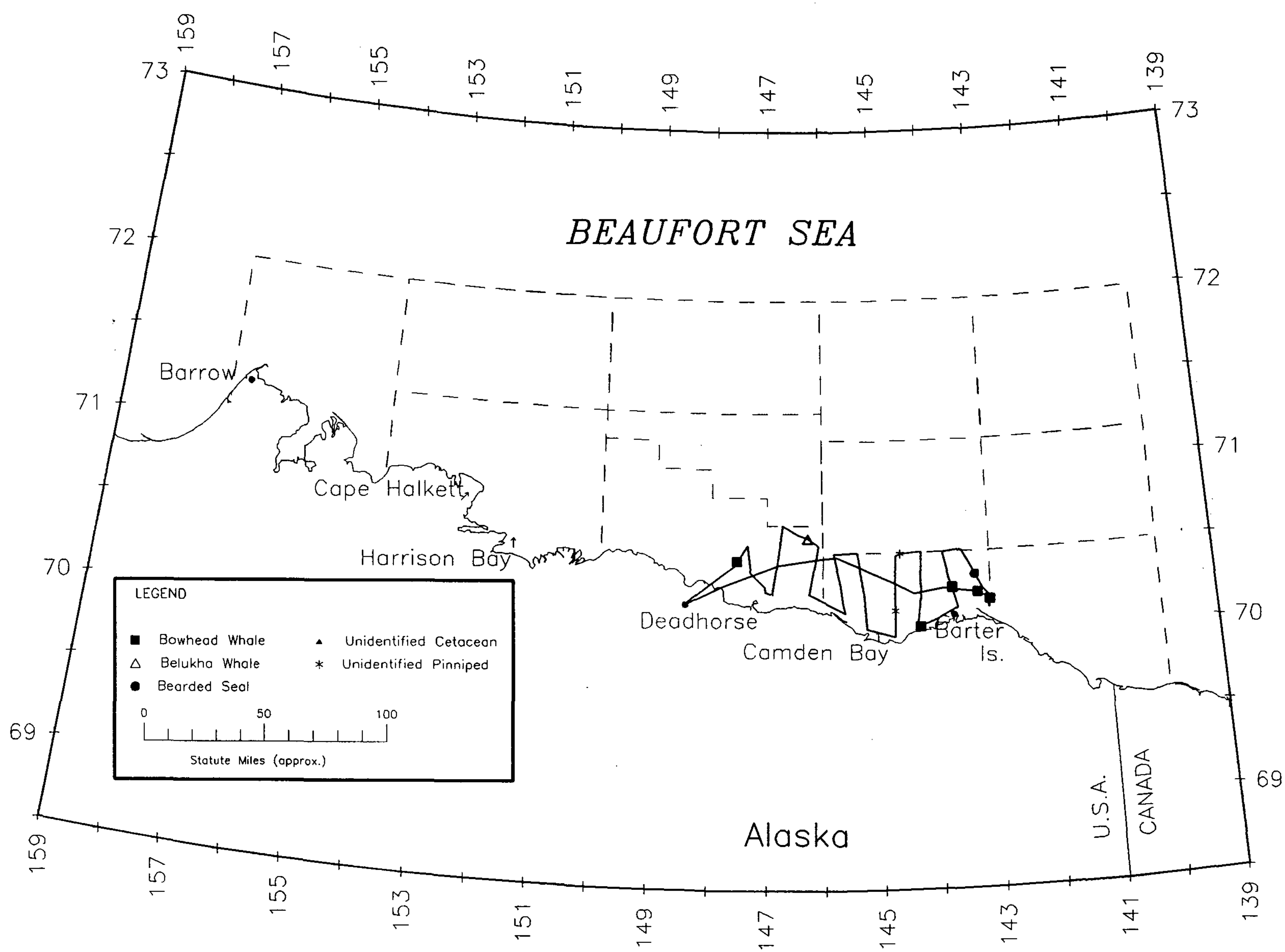
Table B-1
Selected Sighting Data for Bowhead Whales Observed, Fall 1992
(Page 4 of 5)

Flight No.	Day	Total Whales	No. of Calves	Latitude (North)	Longitude (West)	Sighting Cue	Behavior	Compass Heading	Ice (%)	Sea State	Depth (m)
40	17 Oct	1	0	71°20.9′	156°07.0′	body	feed	[1]	40	4	7
40	17 Oct	1	0	71°21.8′	156°07.4′	body	swim	100	40	2	9
40	17 Oct	1	0	71°22.7′	156°05.8′	body	swim	100	40	2	9
42	19 Oct	3	0	71°24.3′	156°21.7′	body	mill	[1]	70	2	7
42	19 Oct	1	0	71°23.2′	156°21.1′	body	[1]	[1]	70	2	2
42	19 Oct	1	0	71°23.3′	156°20.7′	no cue	[1]	[1]	70	2	2
42	19 Oct	30	0	71°24.3′	156°13.4′	body	feed	[1]	70	3	9
42	19 Oct	9	0	71°23.9′	156°17.9′	body	[1]	[1]	70	2	5
42	19 Oct	3	0	71°24.2′	156°21.0′	body	[1]	[1]	70	2	7
42	19 Oct	4	0	71°25.5′	156°20.5′	body	[1]	[1]	70	2	7
42	19 Oct	2	0	71°25.6′	156°17.7′	body	[1]	[1]	70	2	9
42	19 Oct	5	0	71°25.5′	156°16.9′	body	swim	[1]	85	2	9
42	19 Oct	1	0	71°27.2′	156°18.7′	body	[1]	[1]	85	2	9
42	19 Oct	2	0	71°27.3′	156°19.9′	body	[1]	[1]	85	2	9
42	19 Oct	12	0	71°27.2′	156°21.2′	body	[1]	[1]	85	2	126
42	19 Oct	1	0	71°27.4′	156°23.6′	body	[1]	[1]	85	2	126
42	19 Oct	1	0	71°27.8′	156°23.8′	body	breach	[1]	85	2	126
42	19 Oct	1	0	71°28.2′	156°24.7′	body	swim	20	85	2	126
42	19 Oct	1	0	71°27.8′	156°24.0′	body	mill	180	0	4	126
42	19 Oct	1	0	71°29.5′	156°14.0′	body	rest	[1]	80	2	9
42	19 Oct	1	0	71°29.4′	156°11.2′	body	mill	260	80	2	9
42	19 Oct	2	1	71°30.4′	156°07.3′	body	cow with calf	[1]	80	2	165
42	19 Oct	2	1	71°28.6′	156°04.7′	body	cow with calf	210	80	2	13
42	19 Oct	3	0	71°28.1′	156°05.6′	body	[1]	30	80	2	13
42	19 Oct	5	0	71°27.0′	156°06.2′	body	[1]	[1]	80	2	13
42	19 Oct	7	0	71°26.7′	156°07.4′	body	feed	[1]	80	2	15
42	19 Oct	2	0	71°27.4′	156°07.2′	body	[1]	[1]	60	2	13
42	19 Oct	1	0	71°25.4′	156°04.9′	body	dive	[1]	60	2	15
42	19 Oct	1	0	71°26.3′	155°49.9′	body	swim	210	60	3	15
42	19 Oct	2	0	71°30.8′	156°13.1′	body	swim	20	60	3	108
43	21 Oct	1	0	71°16.8′	156°54.8′	body	swim	[1]	20	2	24
43	21 Oct	3	0	71°16.8′	156°54.8′	body	mill	80	50	3	24
43	21 Oct	1	0	71°18.4′	157°07.2′	body	swim	[1]	50	3	46
43	21 Oct	1	0	71°20.7′	157°30.2′	body	swim	270	50	4	90
43	21 Oct	2	0	71°23.3′	156°57.0′	body	mill	[1]	50	2	113
43	21 Oct	1	0	71°23.2′	156°44.9′	body	swim	[1]	50	2	44
43	21 Oct	2	0	71°23.3′	156°42.2′	body	swim	[1]	50	2	44
43	21 Oct	1	0	71°24.3′	156°11.3′	body	swim	40	80	3	9
43	21 Oct	1	0	71°25.3′	156°15.3′	body	dive	[1]	70	3	9
43	21 Oct	1	0	71°21.4′	156°48.5′	body	rest	[1]	40	2	44
43	21 Oct	1	0	71°19.3′	156°48.4′	body	swim	320	40	2	33

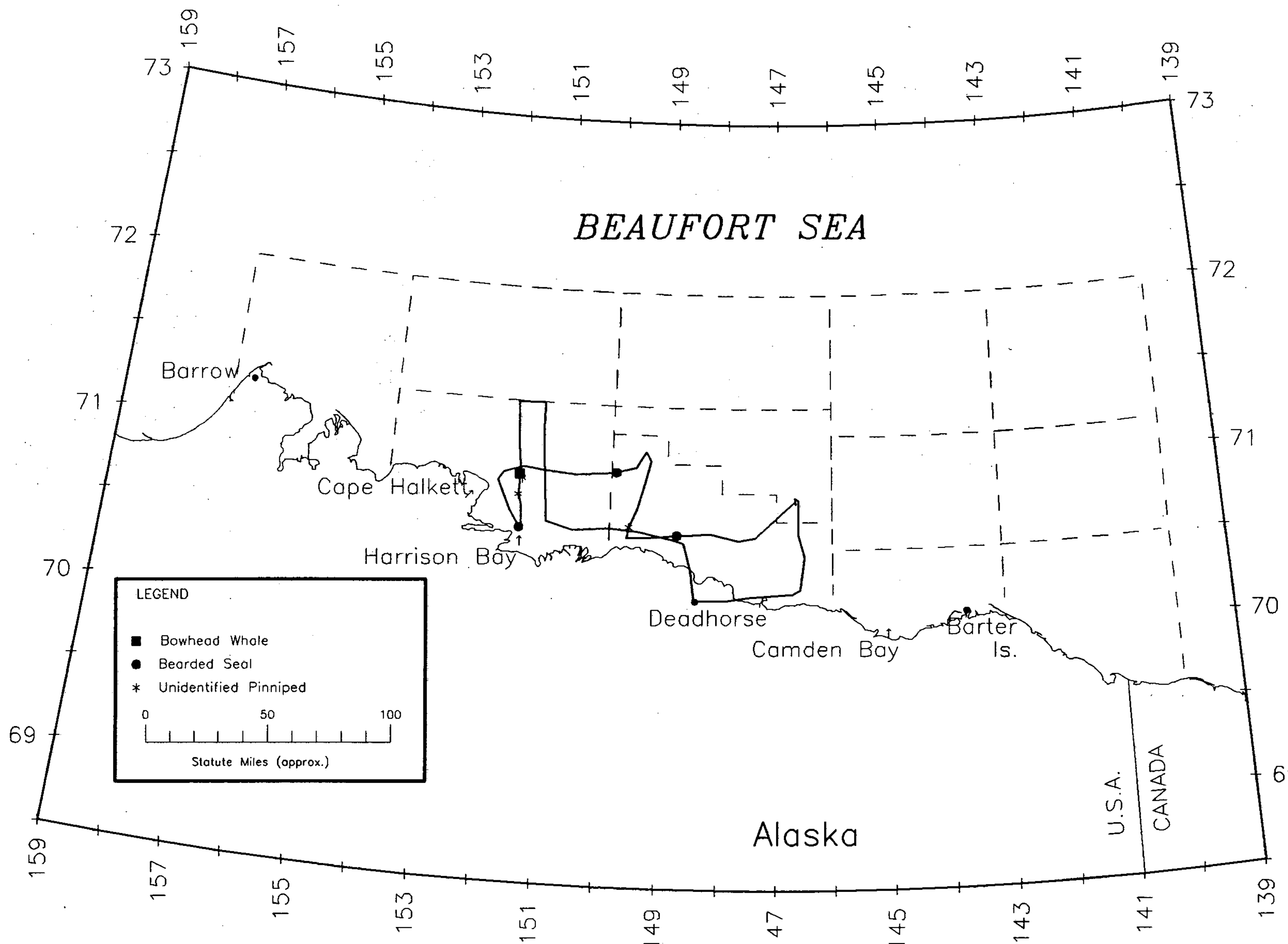
Table B-1
Selected Sighting Data for Bowhead Whales Observed, Fall 1992
(Page 5 of 5)

Flight No.	Day	Total Whales	No. of Calves	Latitude (North)	Longitude (West)	Sighting Cue	Behavior	Compass Heading	Ice (%)	Sea State	Depth (m)
43	21 Oct	1	0	71°17.6′	156°55.4′	body	swim	30	50	2	24
43	21 Oct	1	0	71°17.9′	156°57.2′	body	swim	210	50	2	24
43	21 Oct	1	0	71°13.0′	157°25.8′	splash	breach	[1]	10	4	38
43	21 Oct	1	0	71°12.3′	157°25.2′	body	swim	270	10	4	38
43	21 Oct	1	0	71°07.8′	157°25.0′	body	swim	250	0	5	33
43	21 Oct	1	0	71°11.1′	157°23.5′	body	roll	270	0	5	37
43	21 Oct	1	0	71°12.2′	157°22.6′	body	swim	240	0	5	38
43	21 Oct	1	0	71°23.2′	157°19.6′	body	swim	160	60	4	91
43	21 Oct	1	0	71°25.6′	157°18.0′	blow	swim	210	60	3	115
43	21 Oct	1	0	71°24.6′	157°23.1′	splash	dive	[1]	50	3	117
43	21 Oct	1	0	71°23.6′	157°20.6′	splash	breach	100	40	3	97
43	21 Oct	2	0	71°22.0′	157°12.3′	body	swim	150	50	3	91
43	21 Oct	3	0	71°17.4′	156°55.8′	splash	roll	[1]	50	3	24

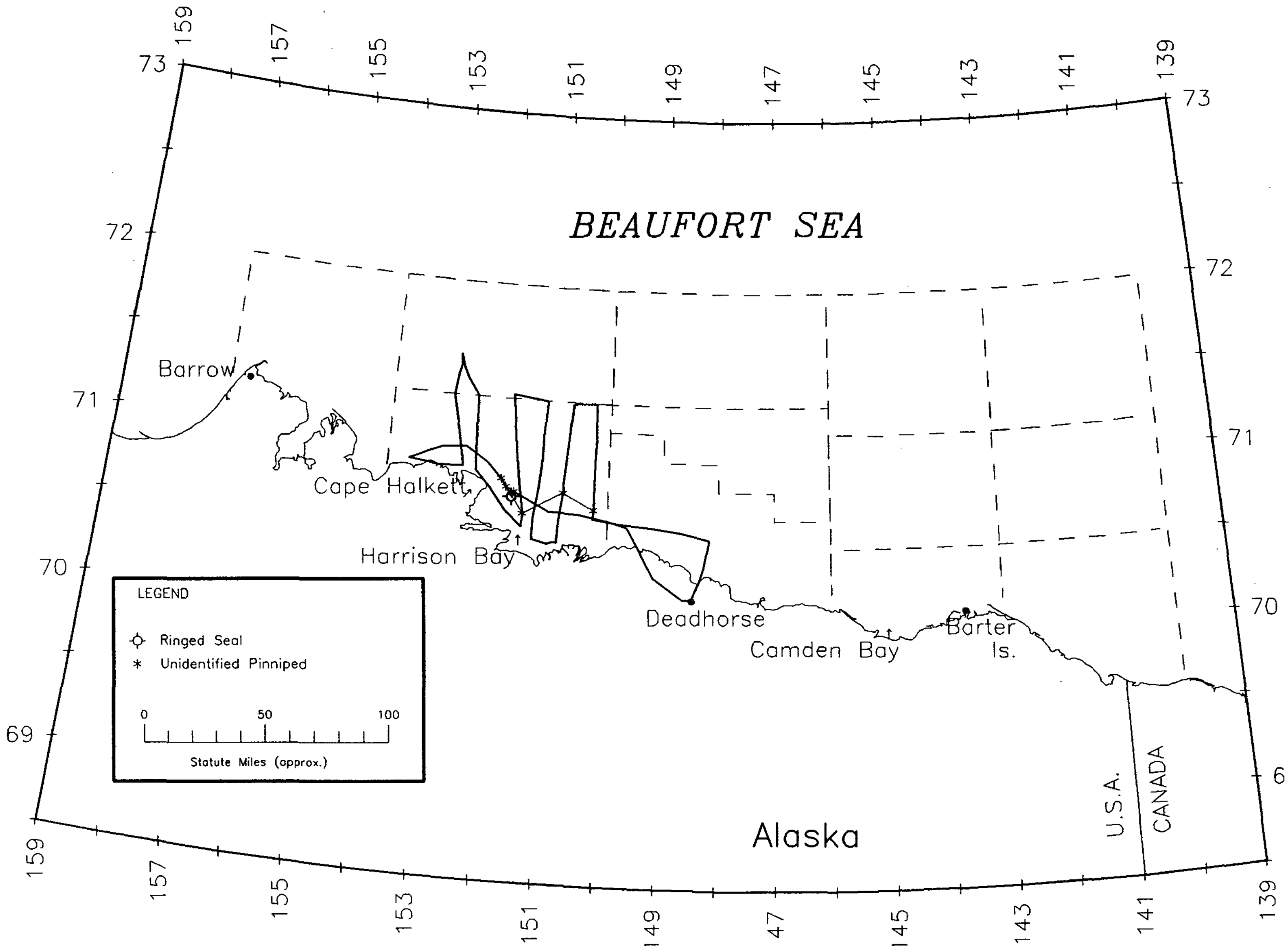
[1] Not recorded.
[2] Repeat sighting.



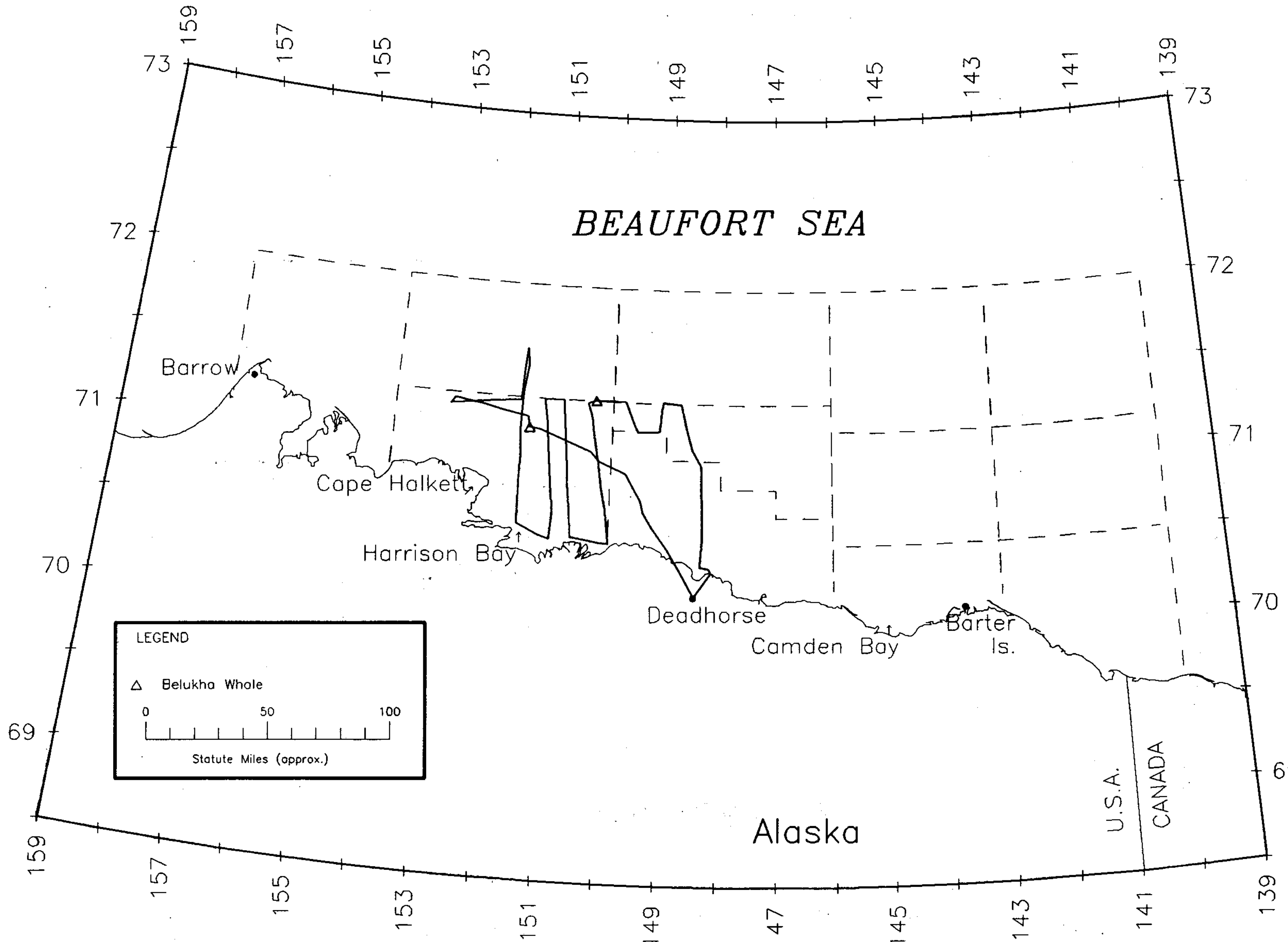
FLIGHT 1 31 August 1992
Survey Track and Sightings



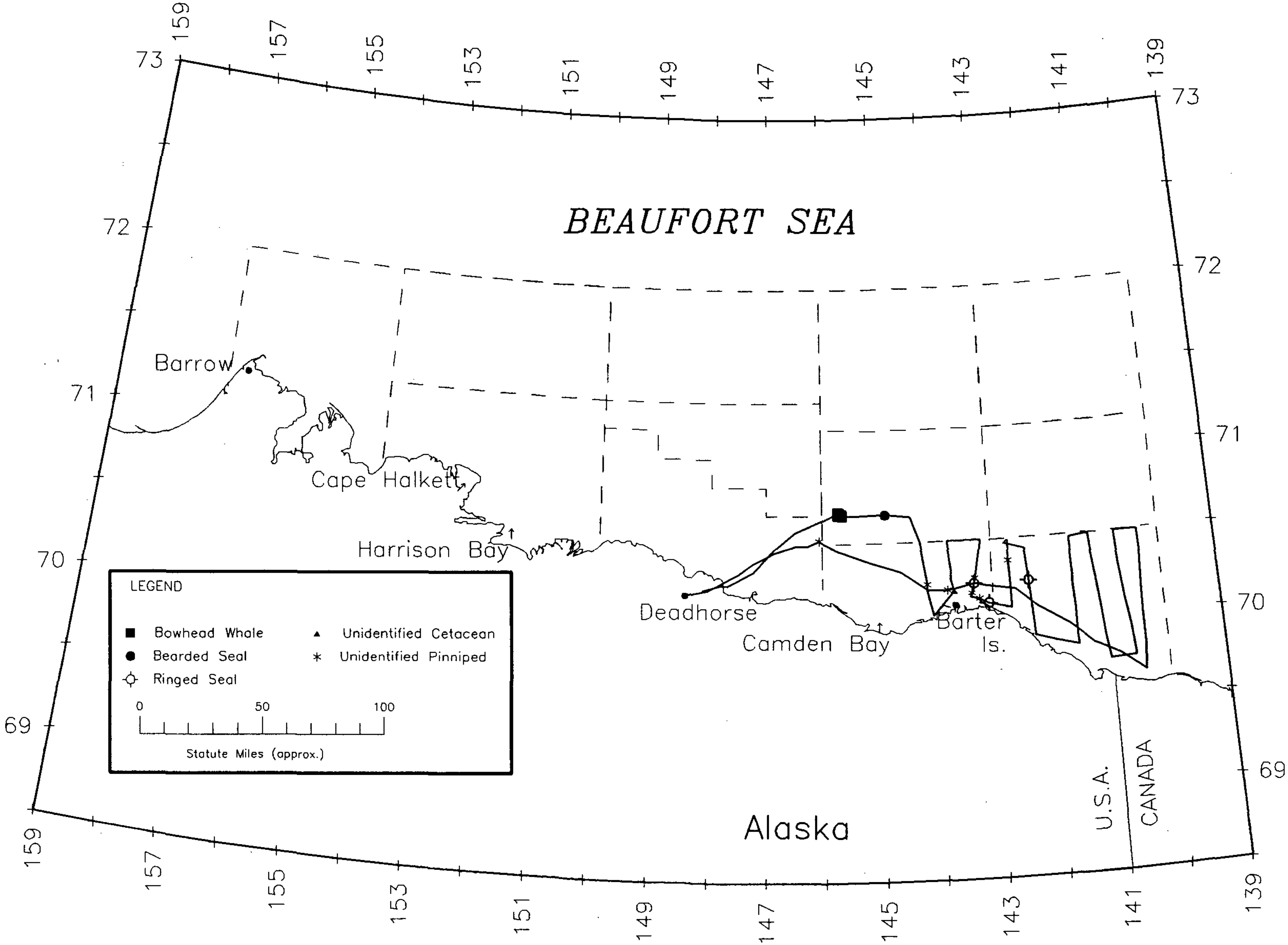
FLIGHT 2 1 September 1992
Survey Track and Sightings



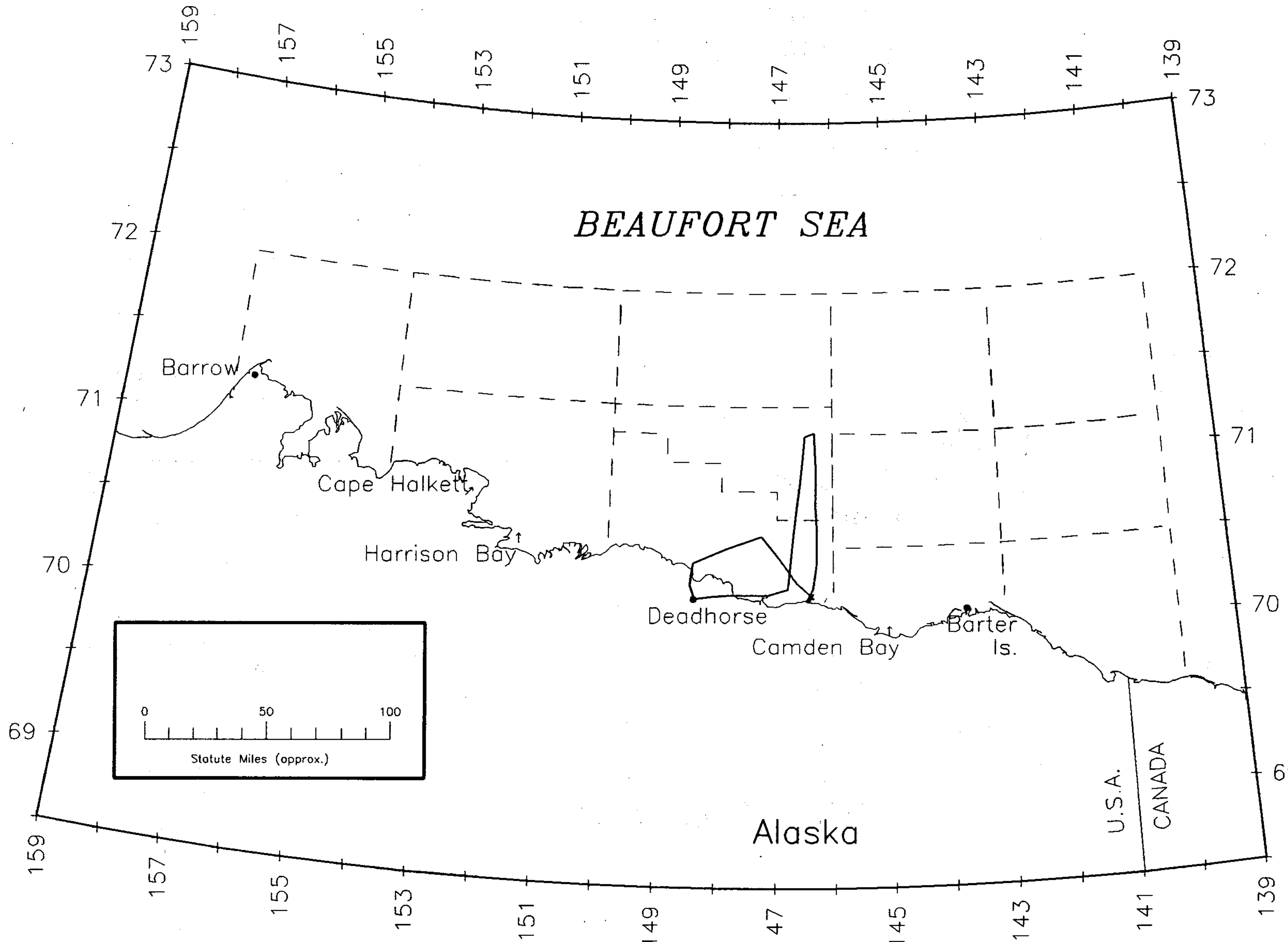
FLIGHT 3 3 September 1992
Survey Track and Sightings



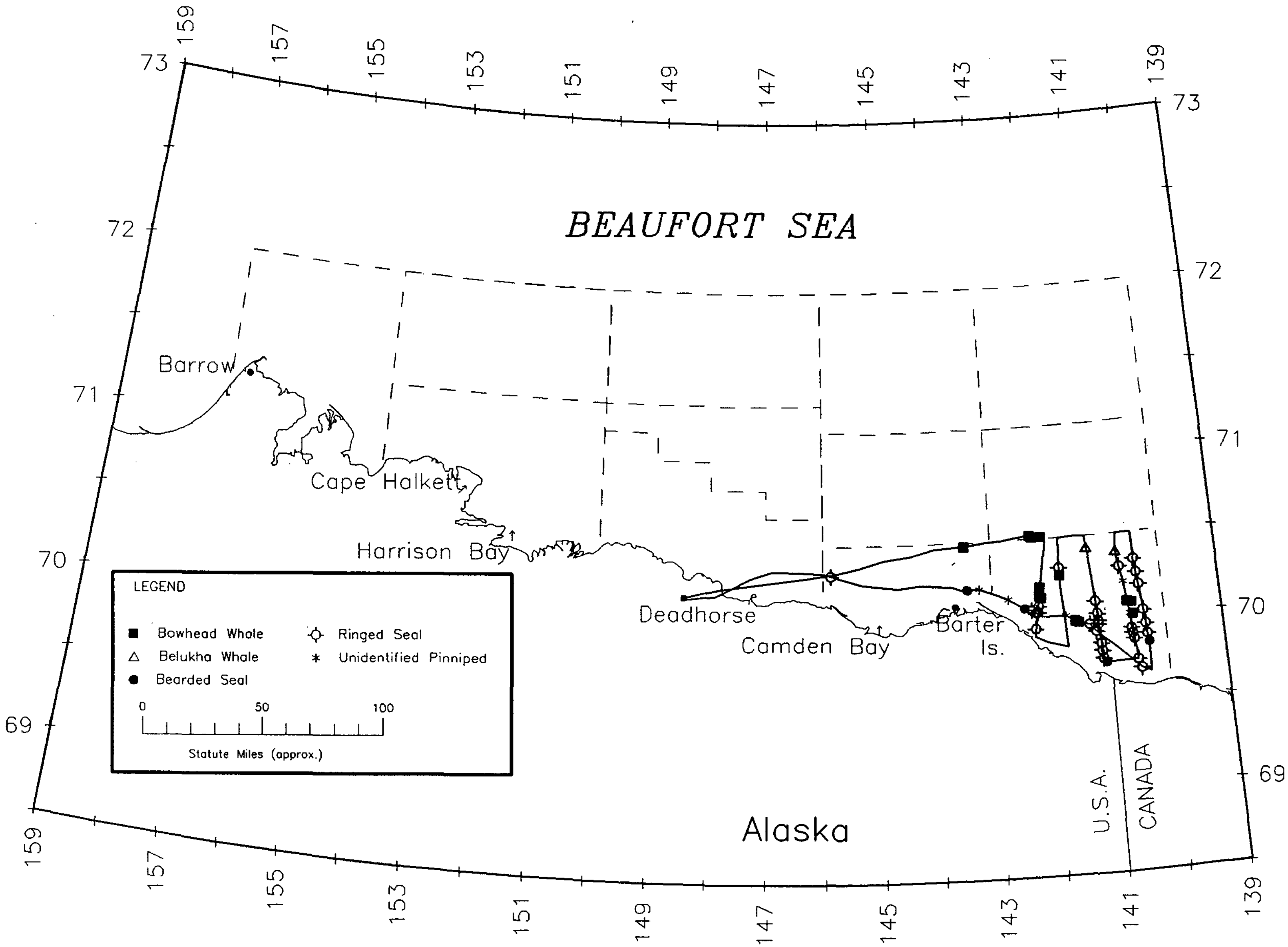
FLIGHT 4 7 September 1992
Survey Track and Sightings



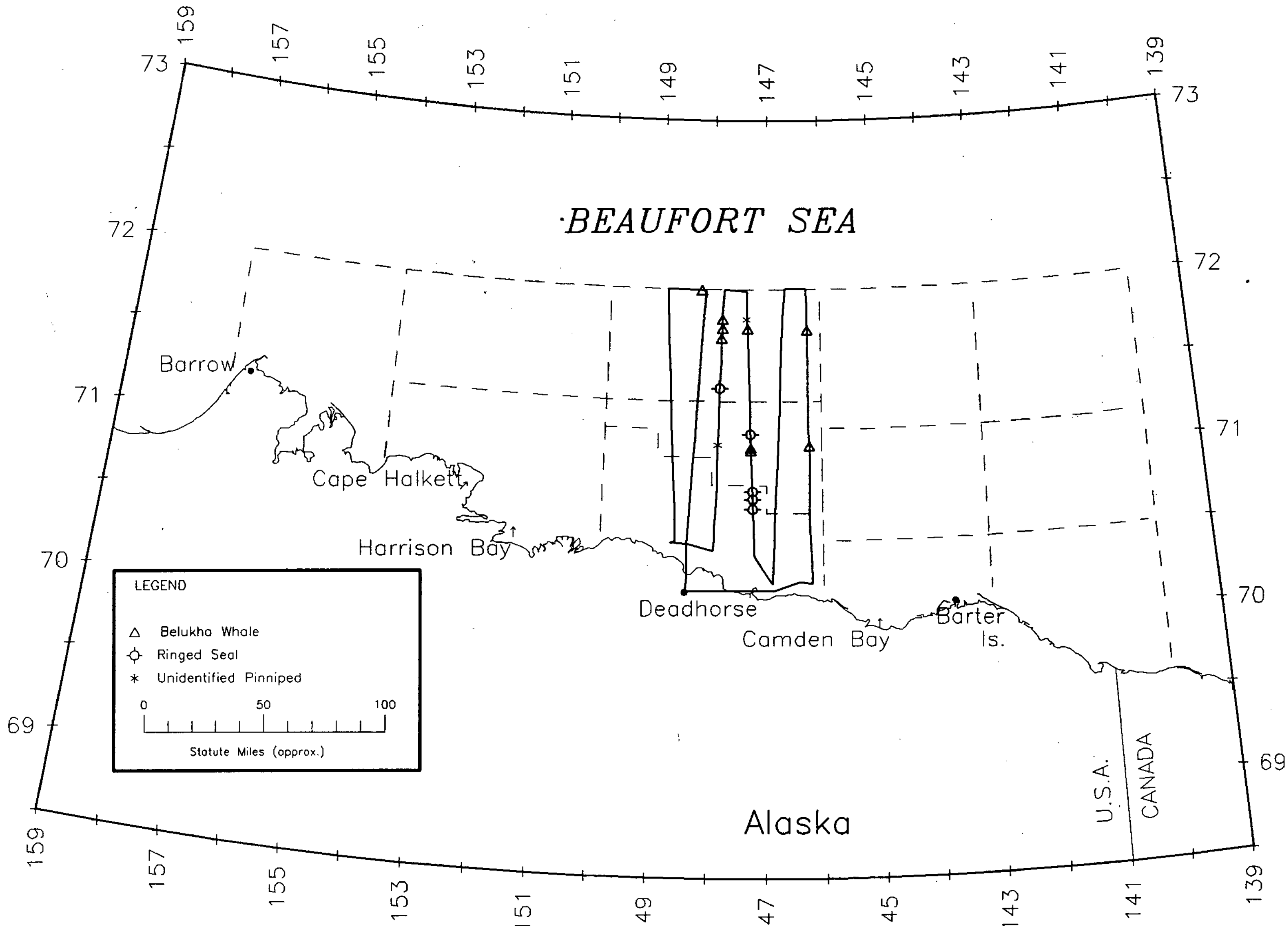
FLIGHT 5 8 September 1992
Survey Track and Sightings



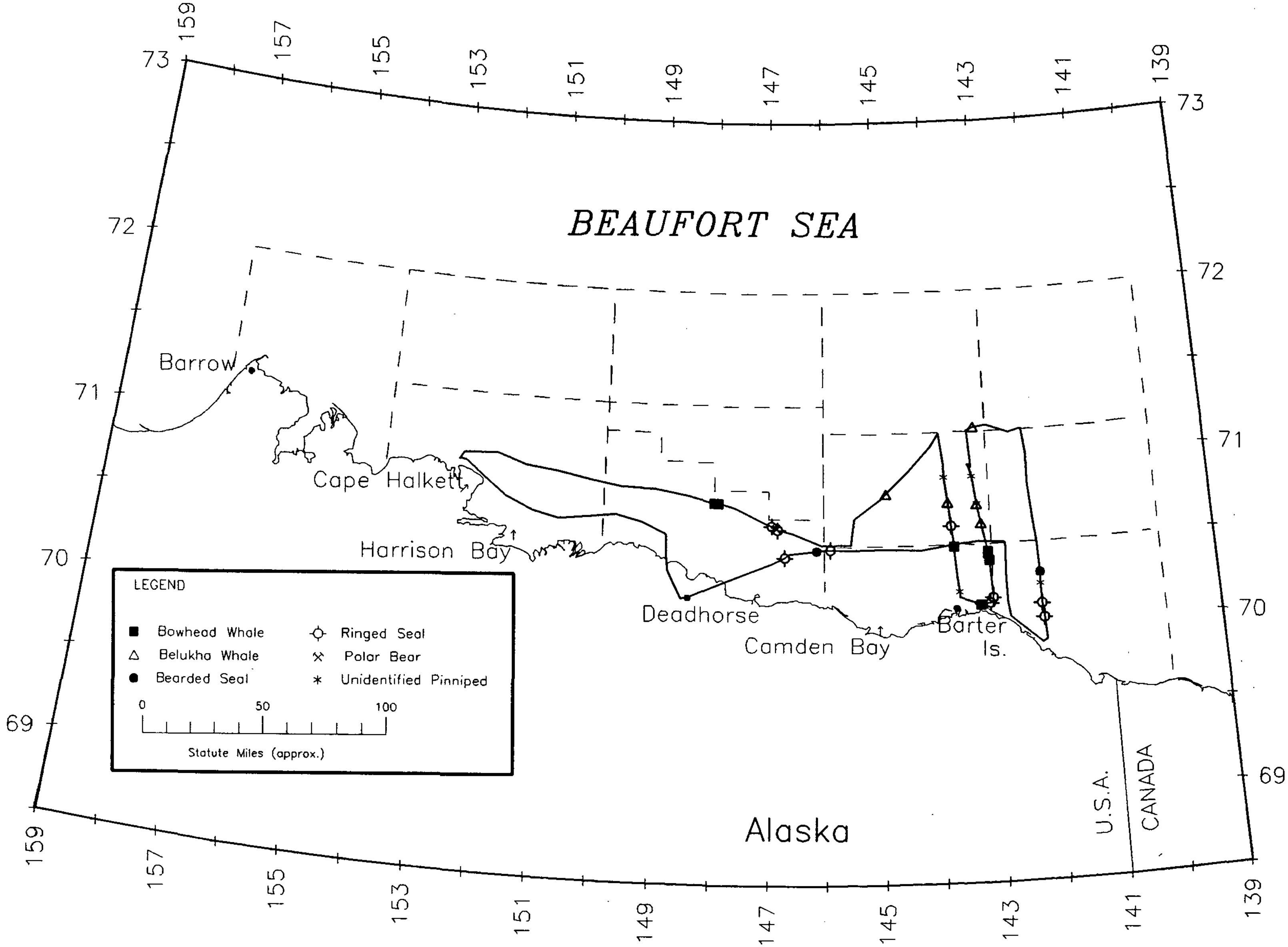
FLIGHT 6 9 September 1992
Survey Track and Sightings



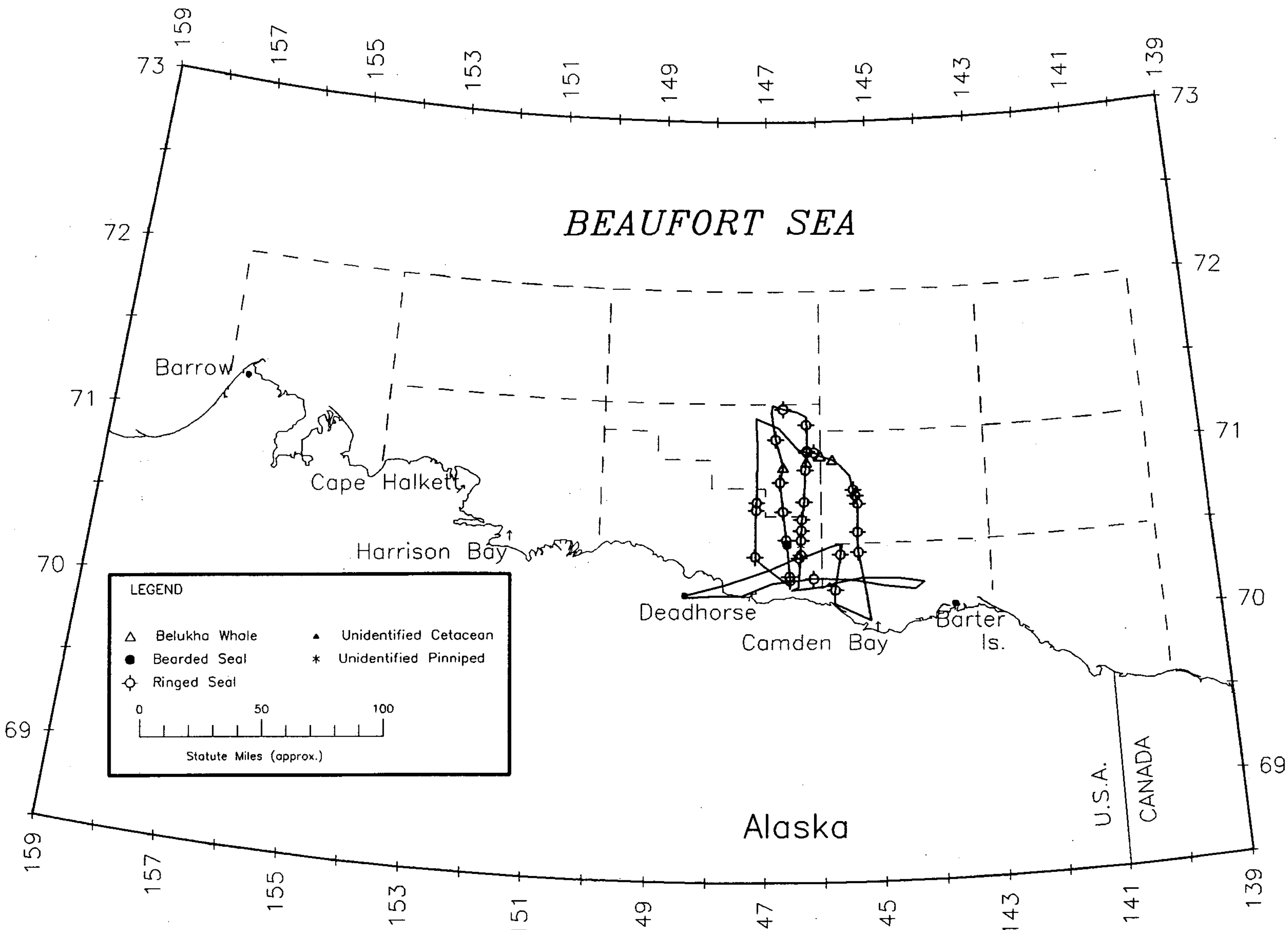
FLIGHT 7 10 September 1992
Survey Track and Sightings



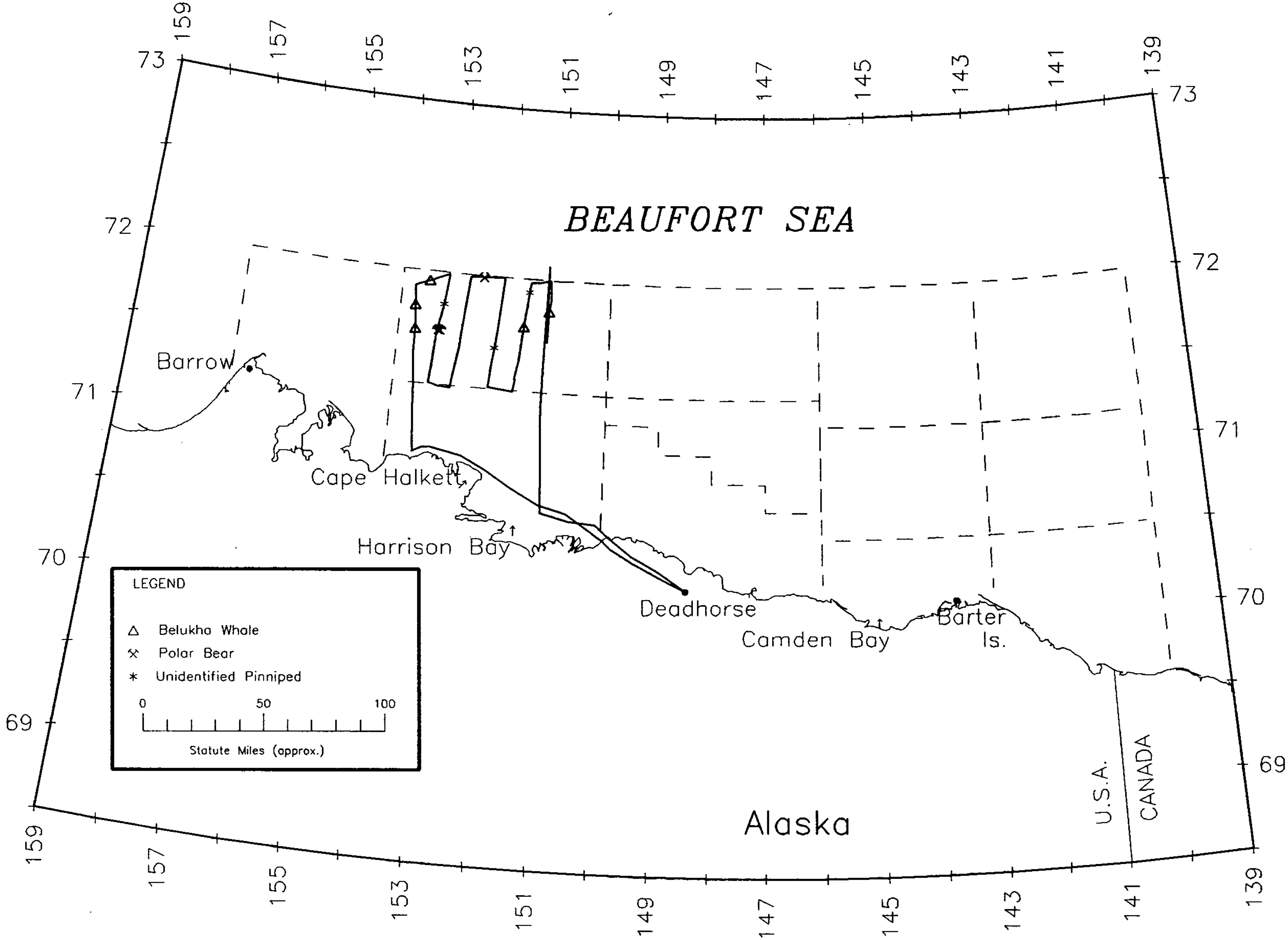
FLIGHT 8 11 September 1992
Survey Track and Sightings



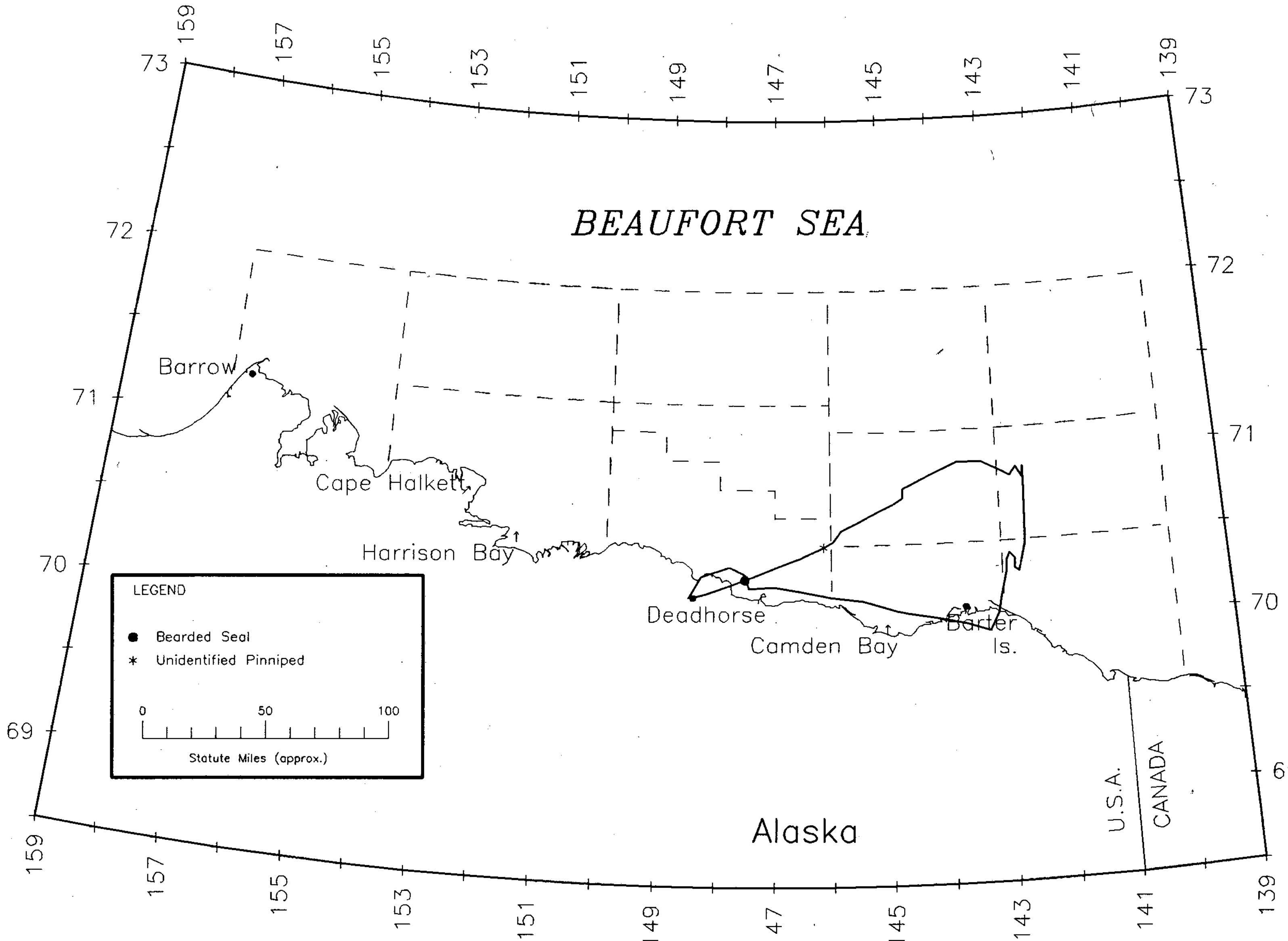
FLIGHT 9 12 September 1992
Survey Track and Sightings



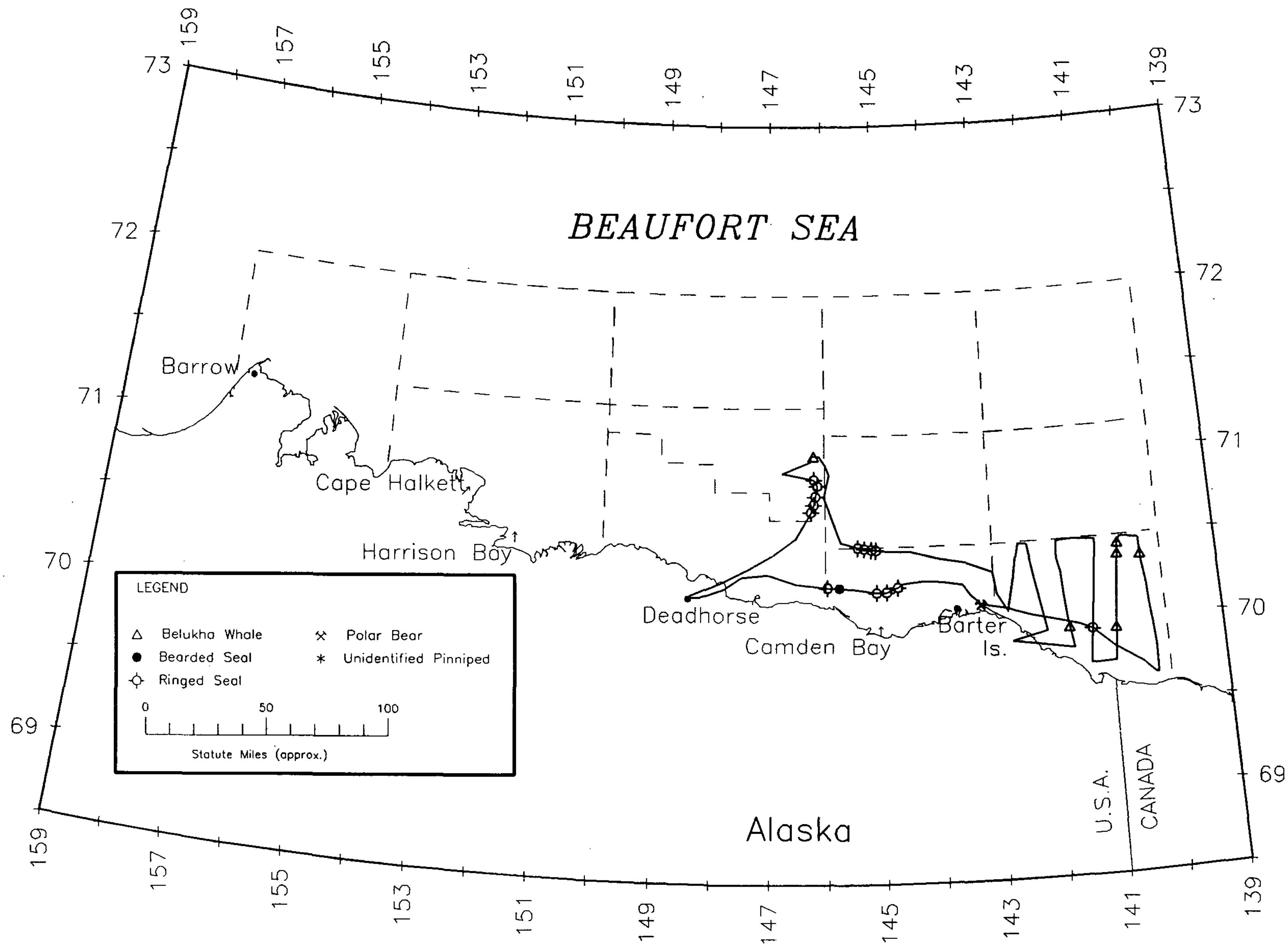
FLIGHT 10 13 September 1992
Survey Track and Sightings



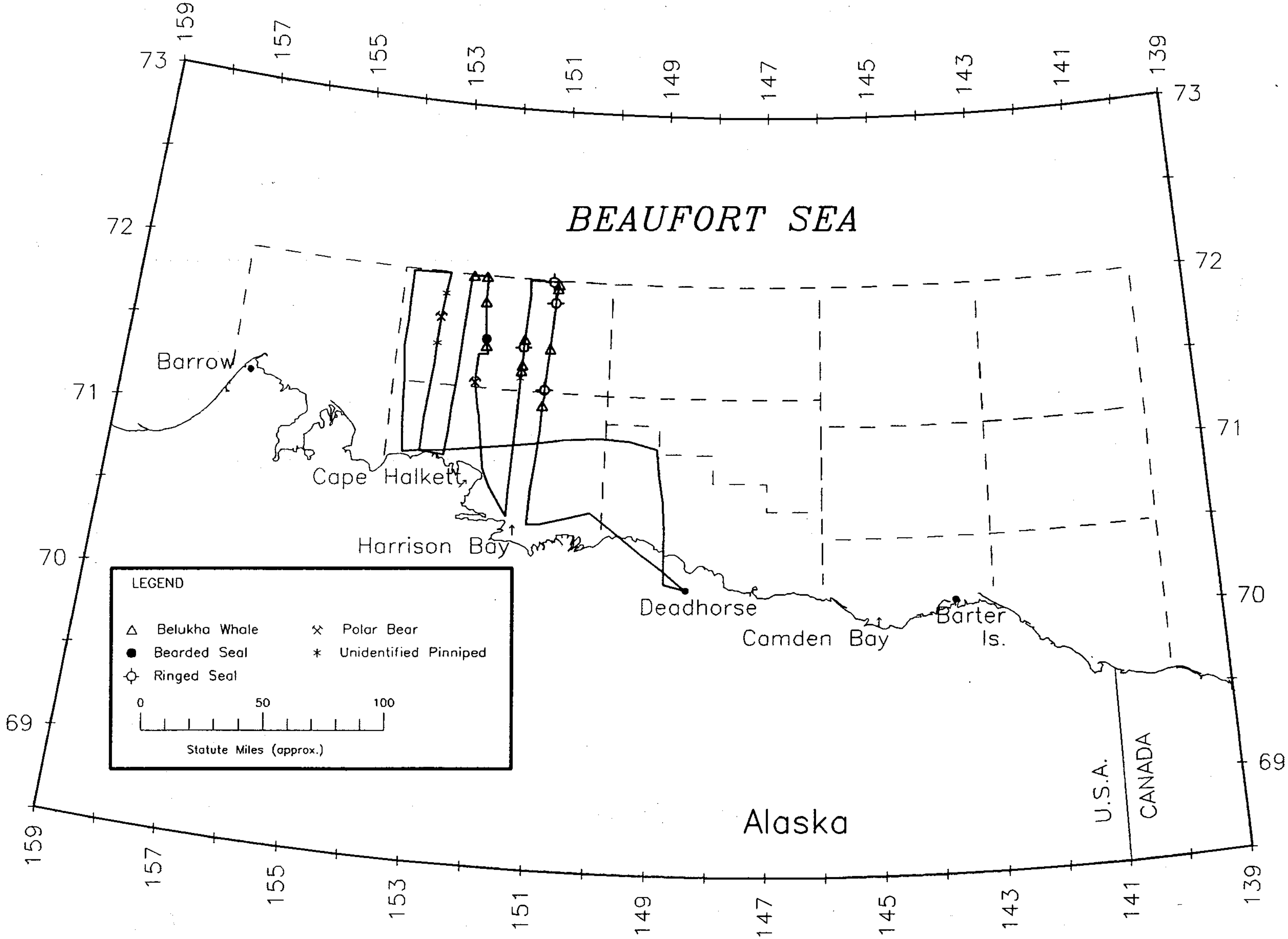
FLIGHT 11 14 September 1992
Survey Track and Sightings



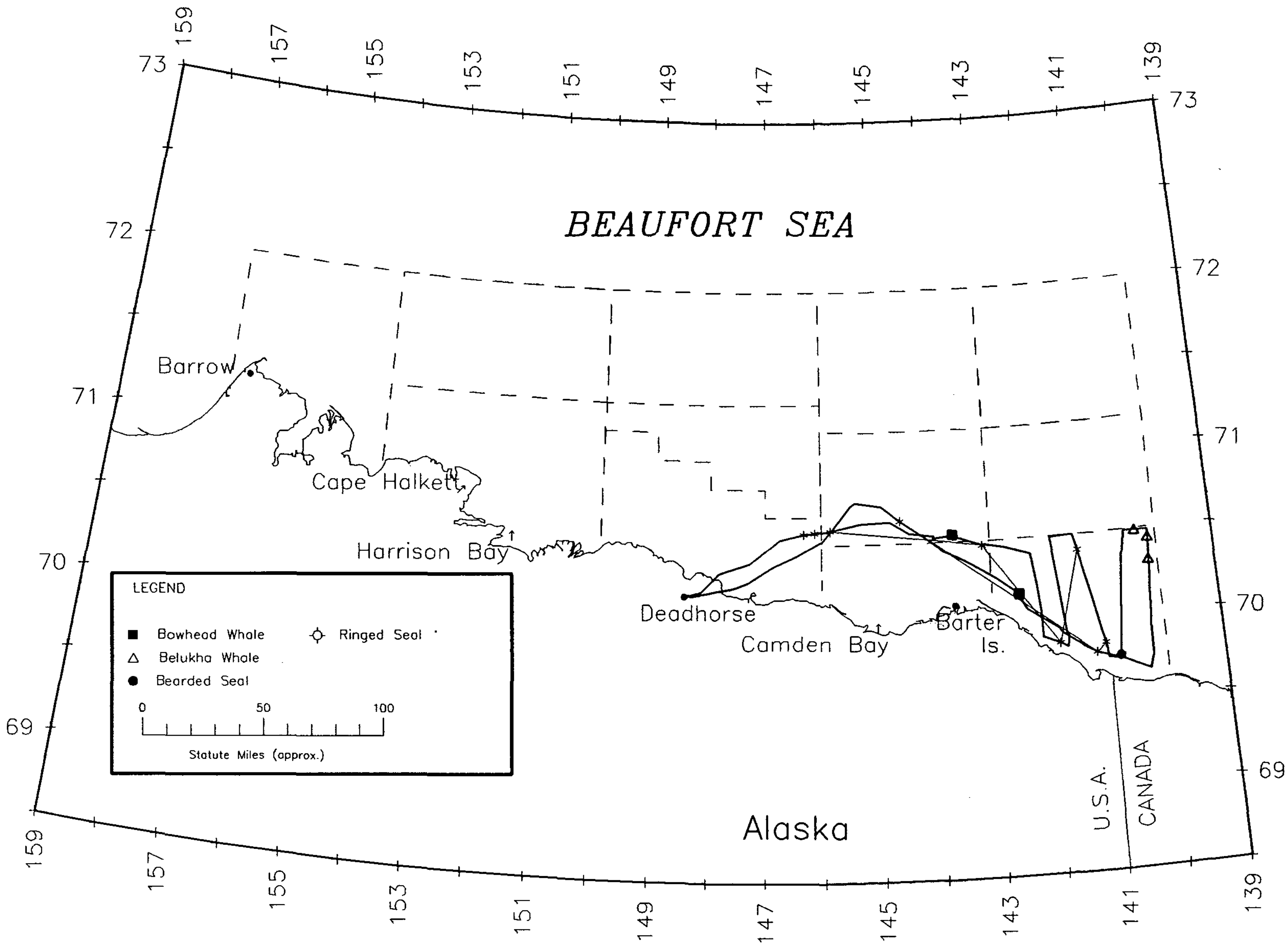
FLIGHT 12 16 September 1992
Survey Track and Sightings



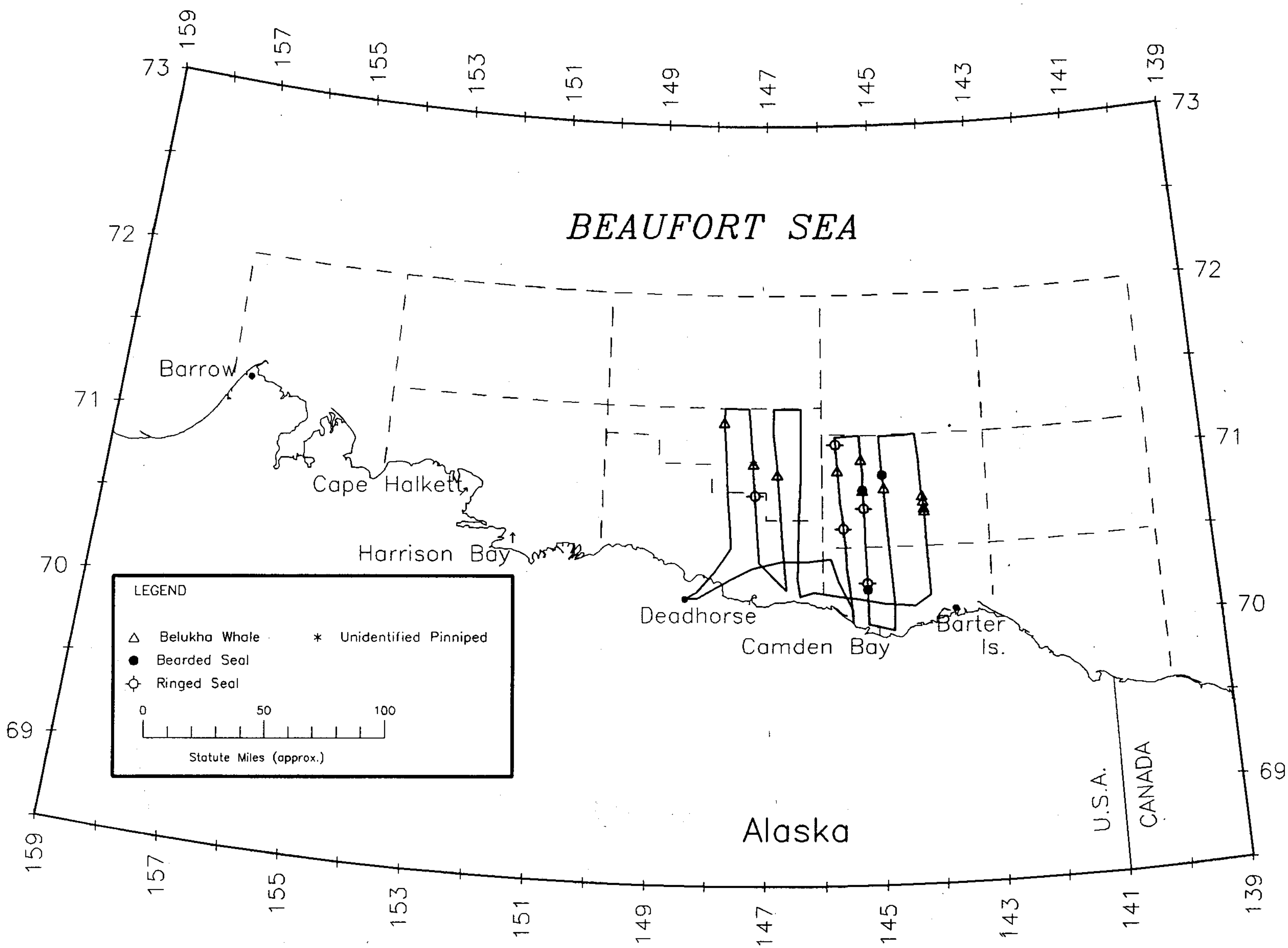
FLIGHT 13 17 September 1992
Survey Track and Sightings



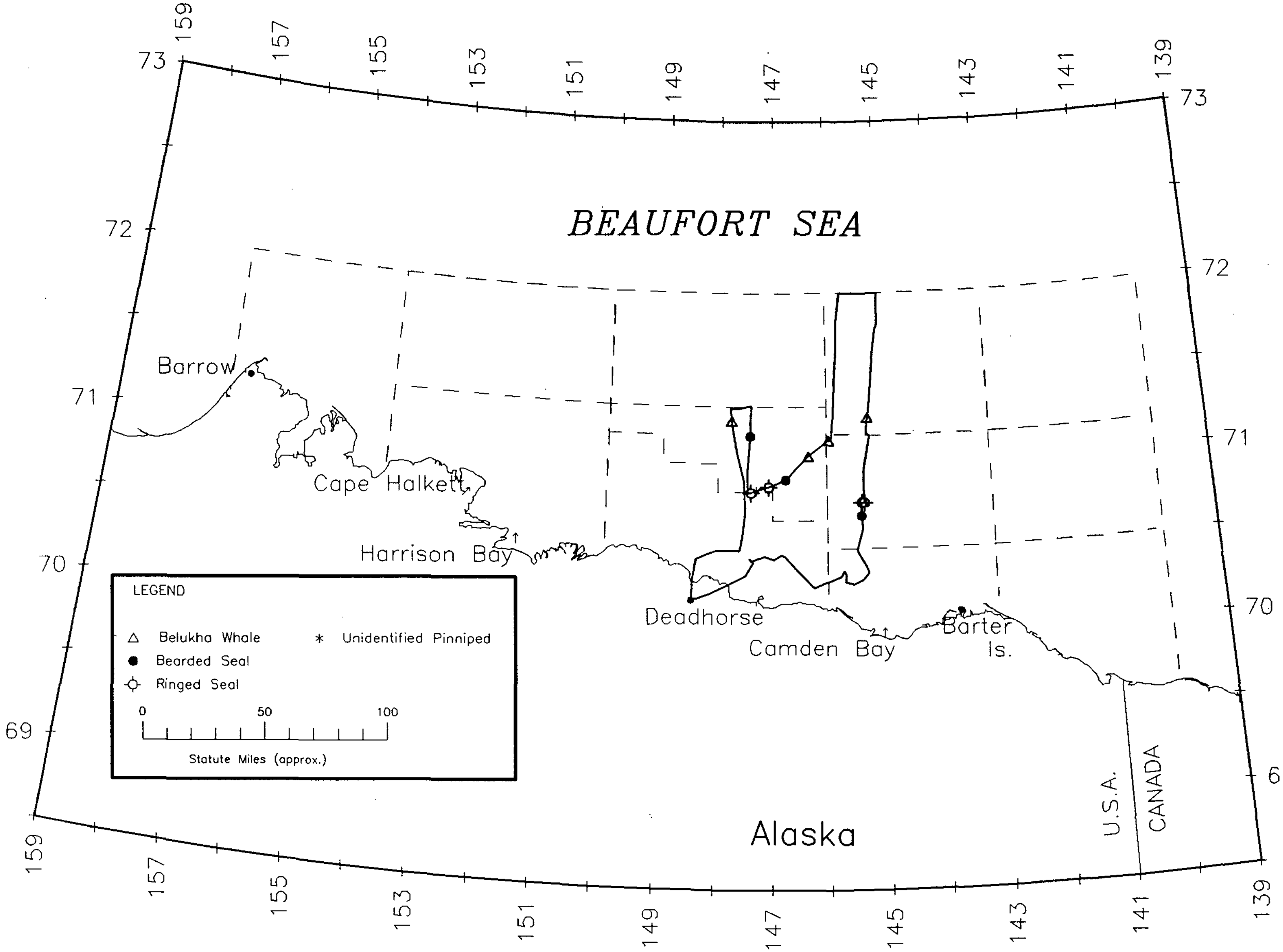
FLIGHT 14 19 September 1992
Survey Track and Sightings



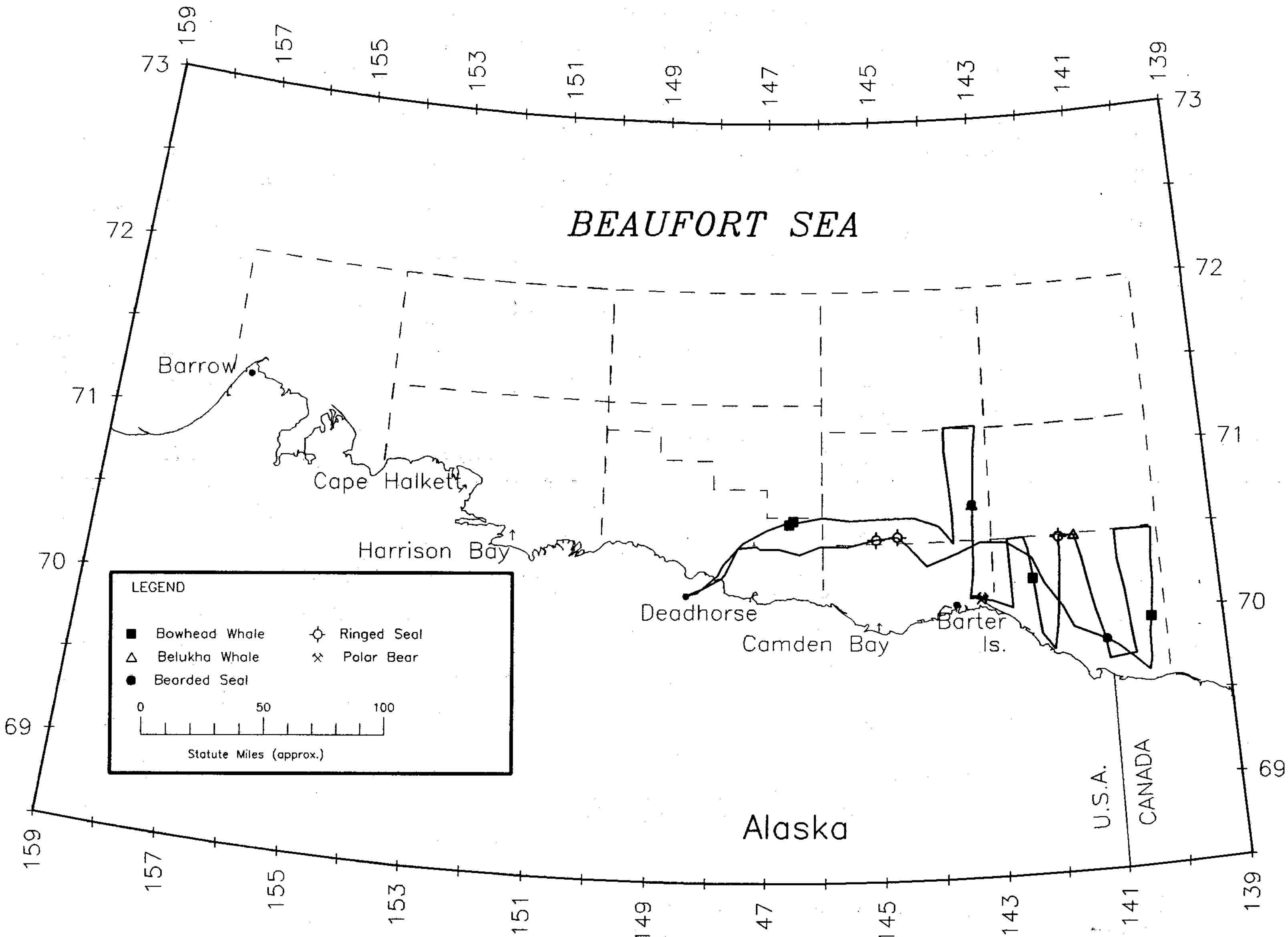
FLIGHT 15 20 September 1992
Survey Track and Sightings



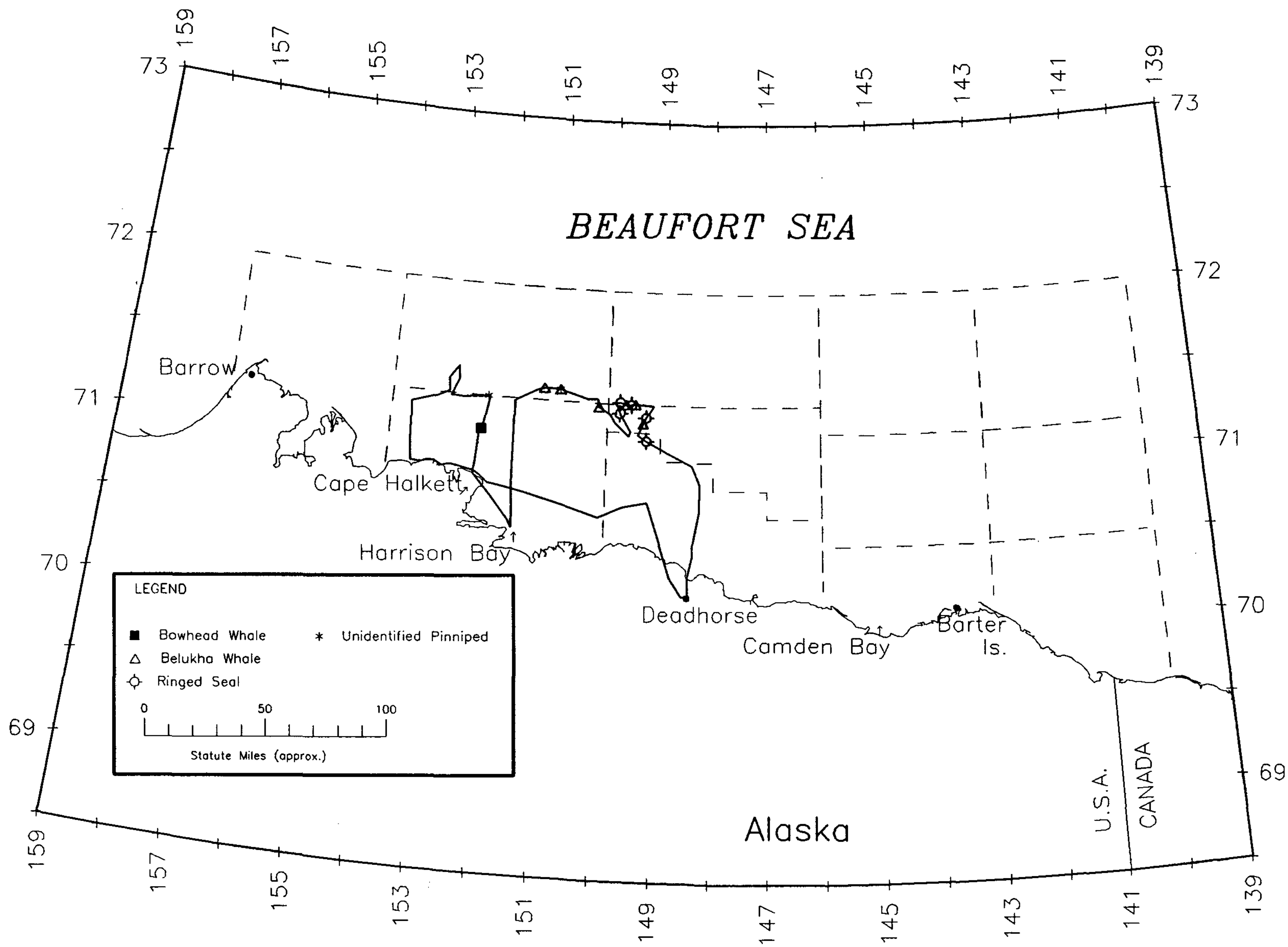
FLIGHT 16 21 September 1992
Survey Track and Sightings



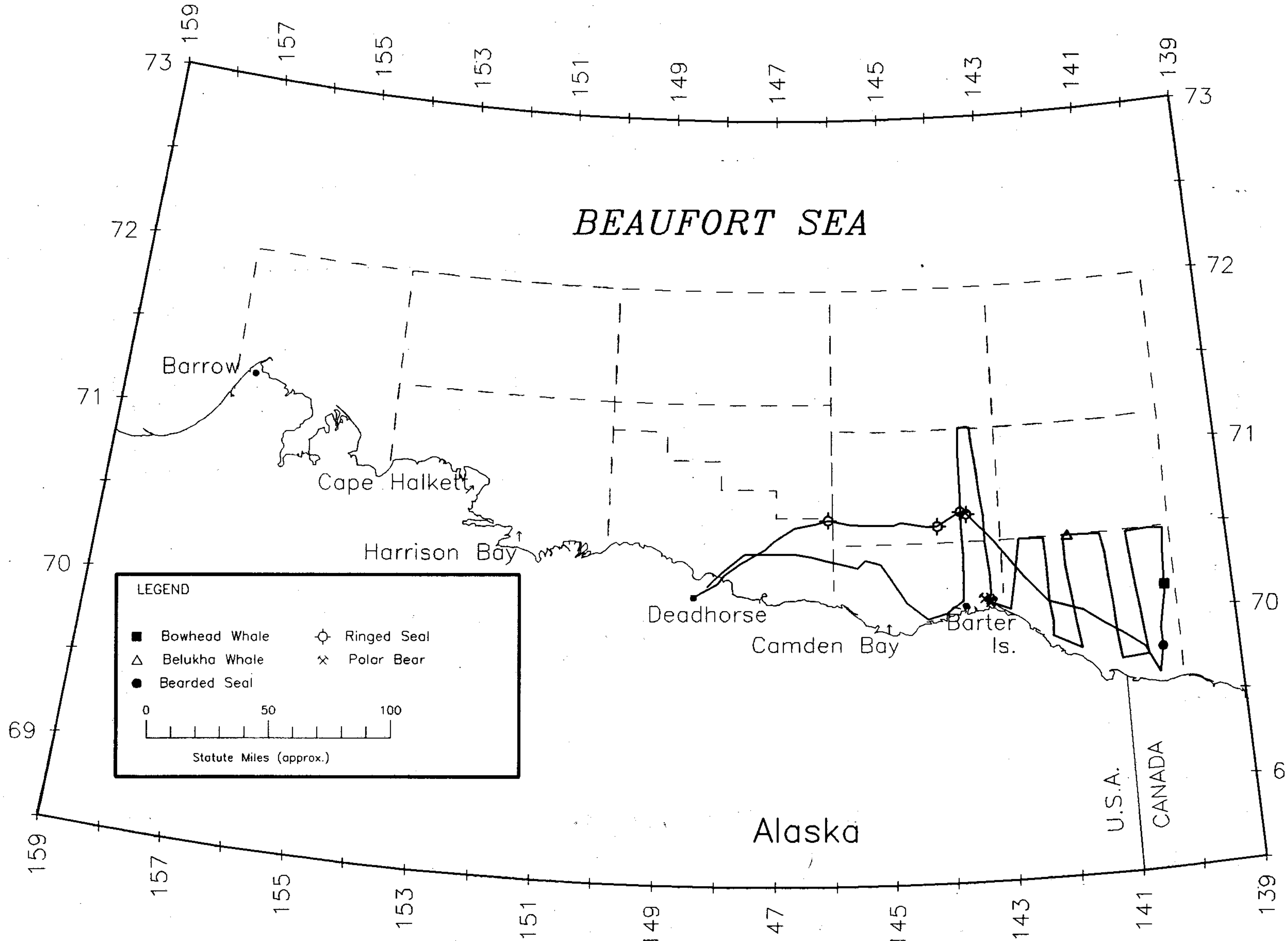
FLIGHT 17 23 September 1992
Survey Track and Sightings



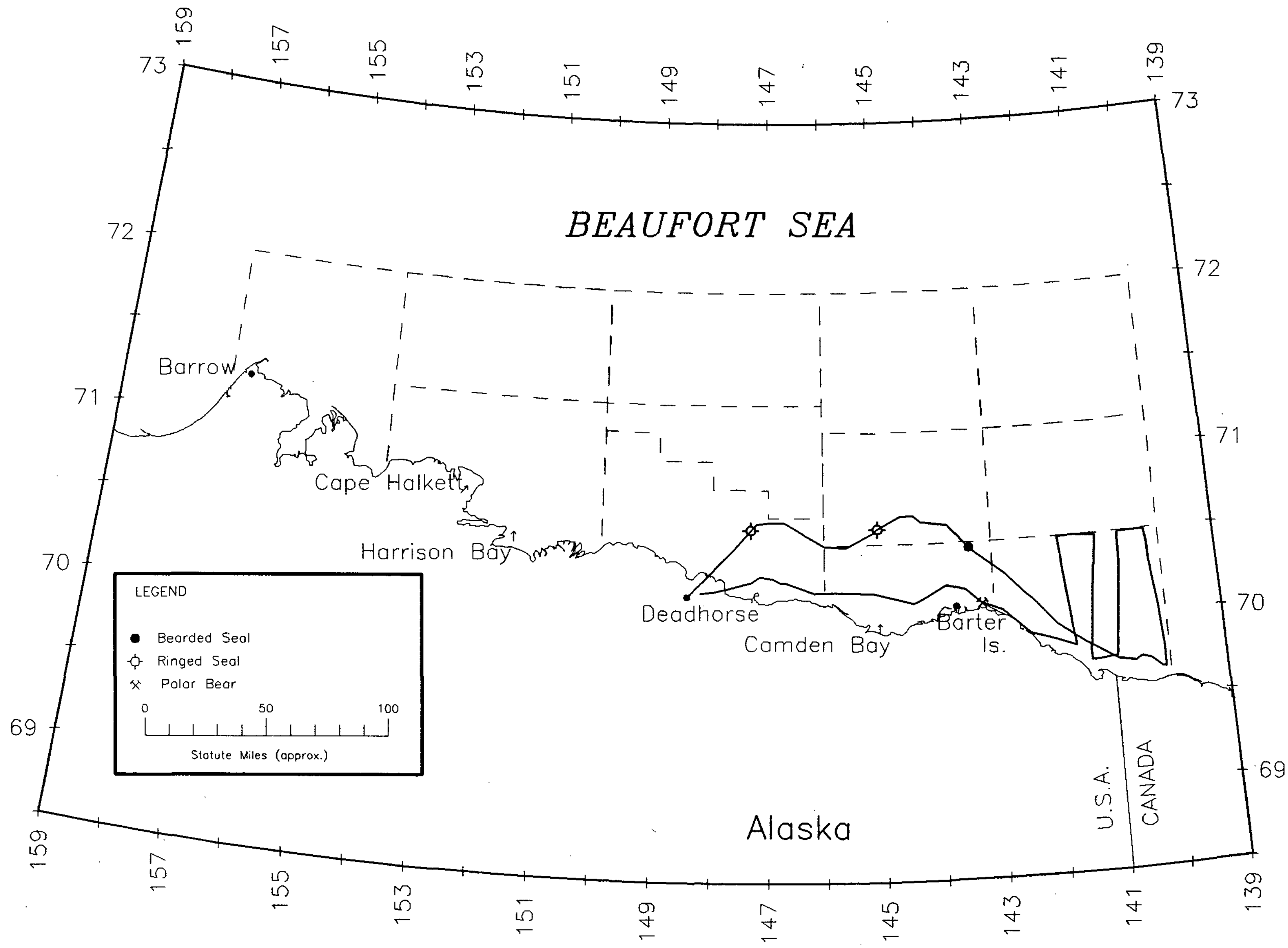
FLIGHT 18 24 September 1992
Survey Track and Sightings



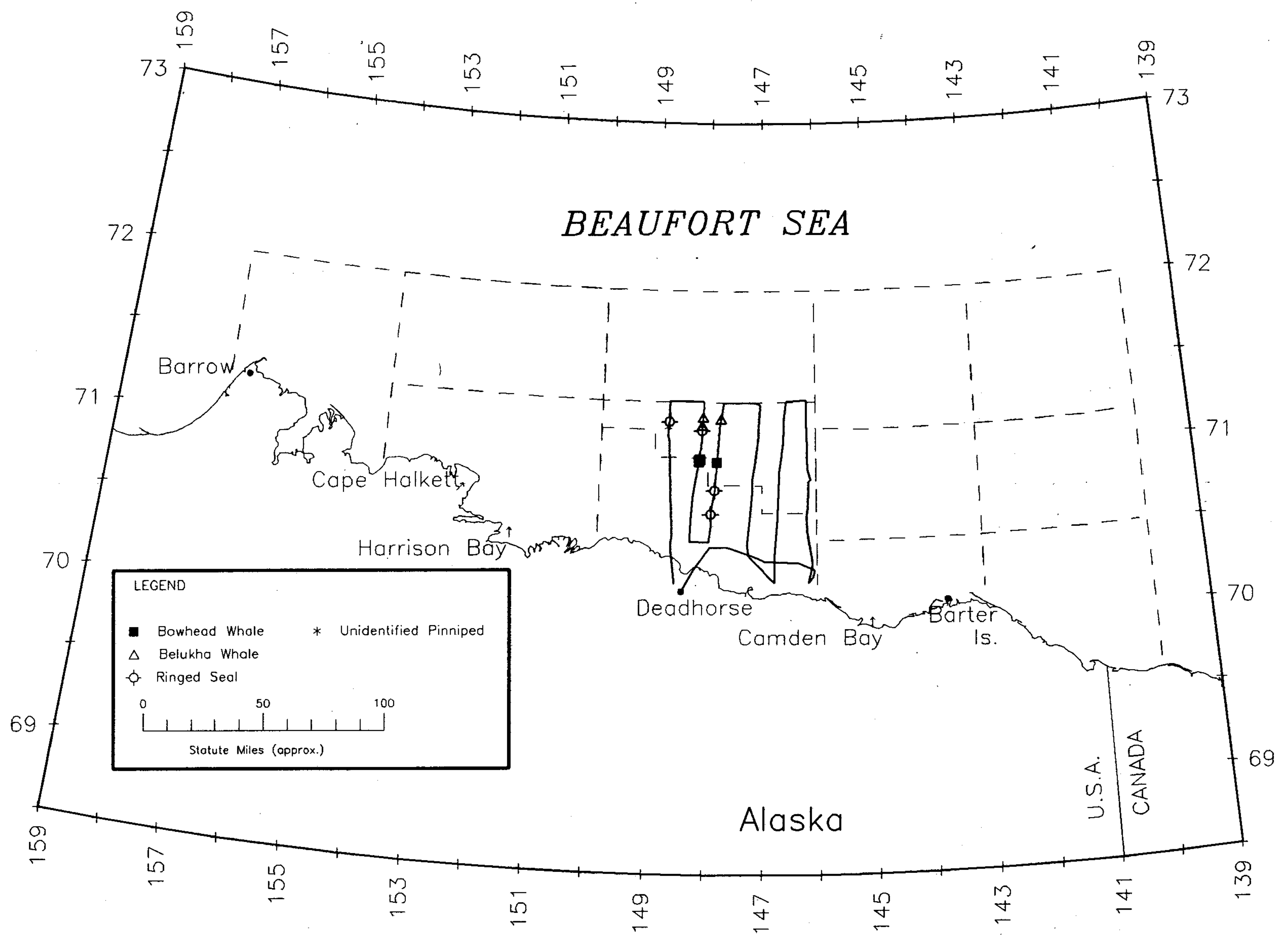
FLIGHT 19 25 September 1992
Survey Track and Sightings



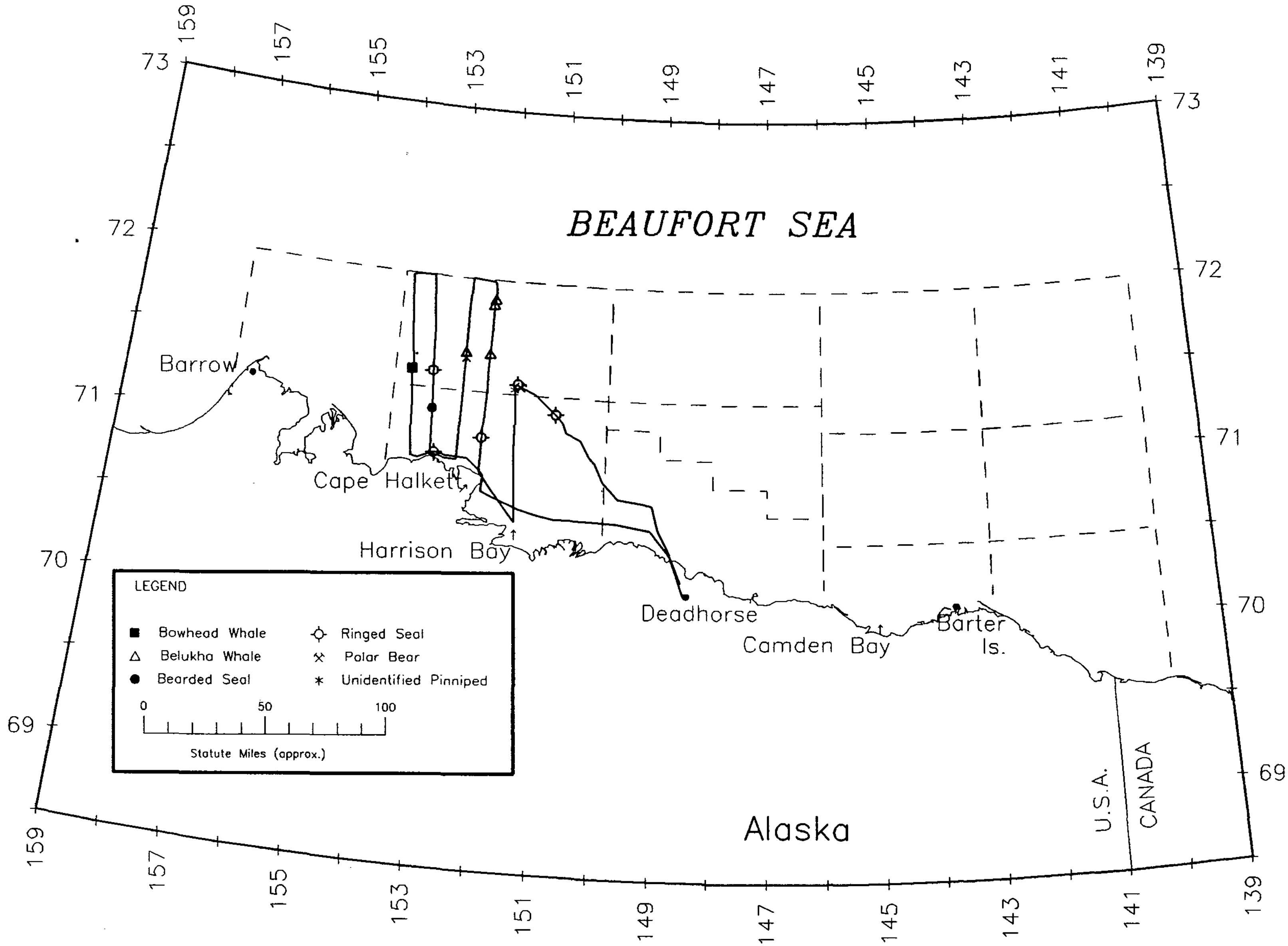
FLIGHT 20 26 September 1992
Survey Track and Sightings



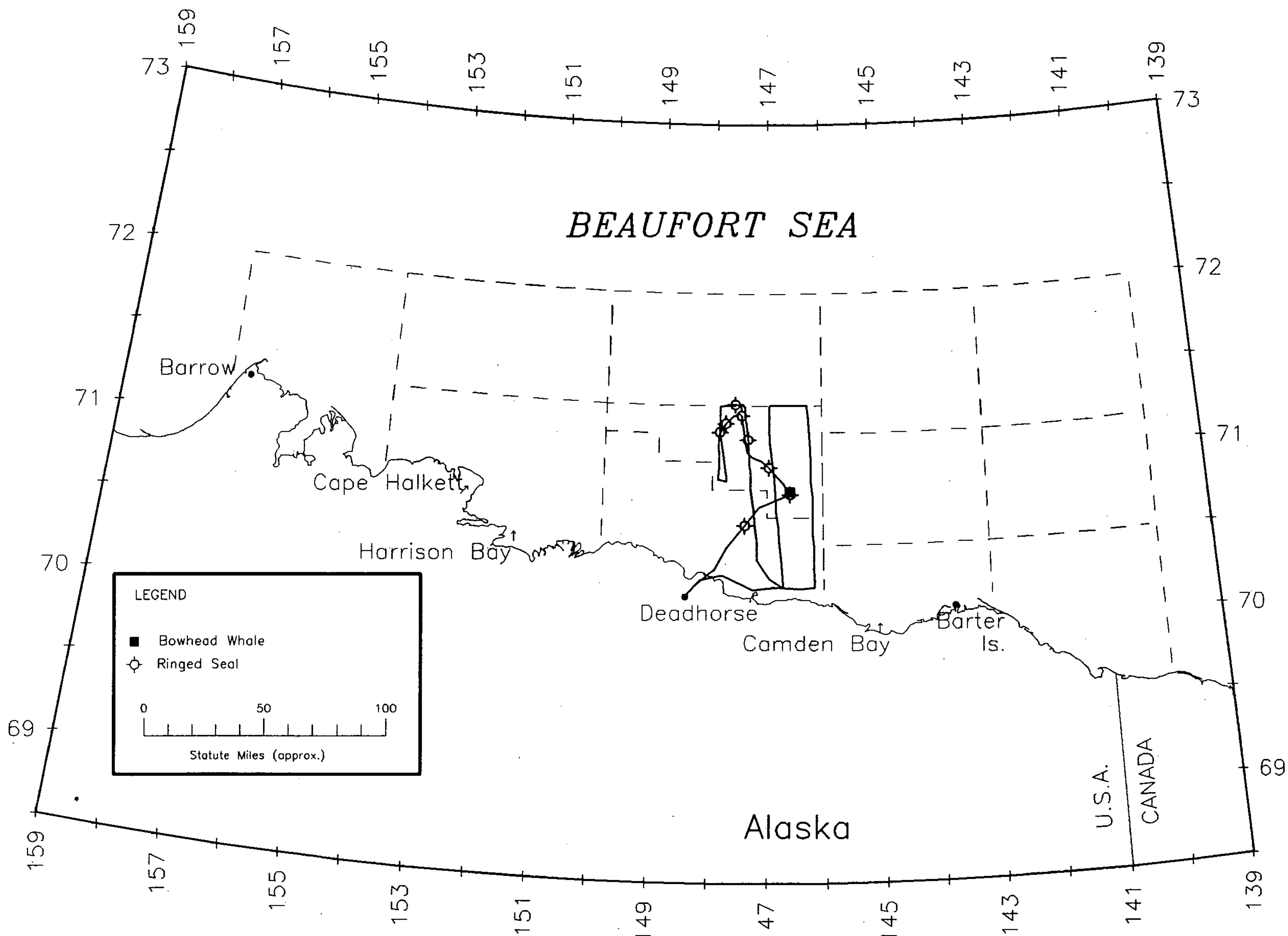
FLIGHT 21 27 September 1992
Survey Track and Sightings



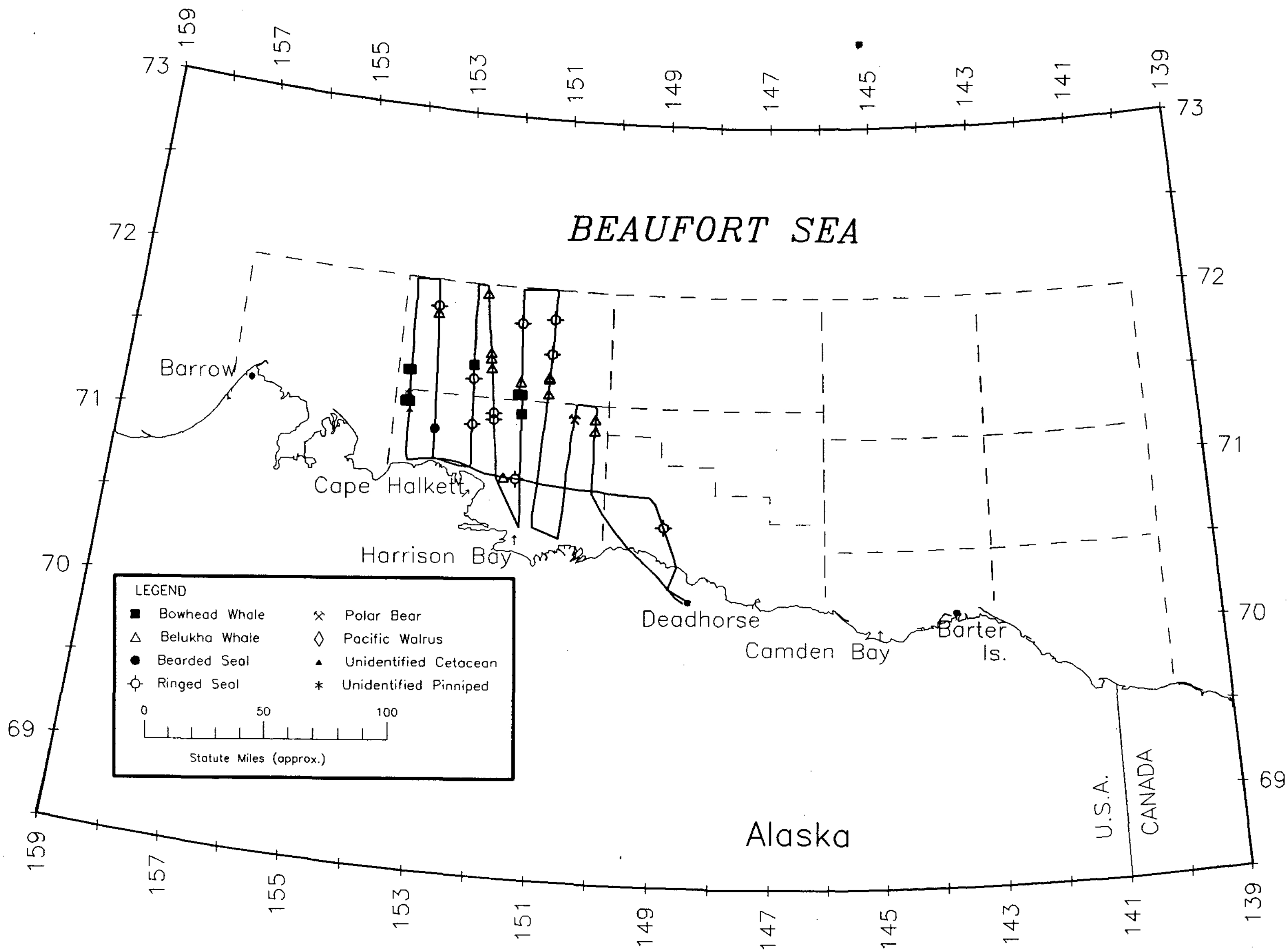
FLIGHT 22 28 September 1992
Survey Track and Sightings



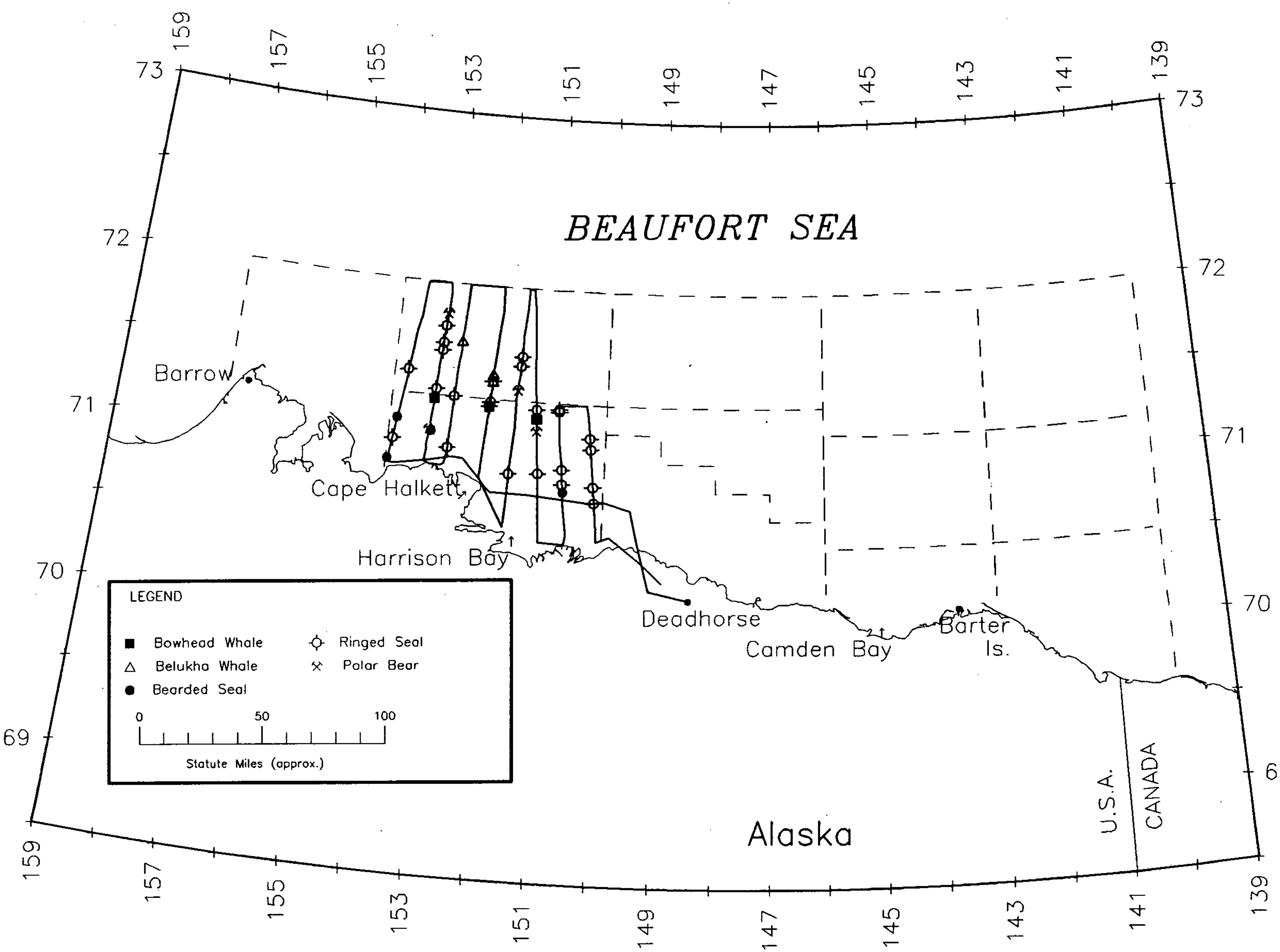
FLIGHT 23 29 September 1992
Survey Track and Sightings



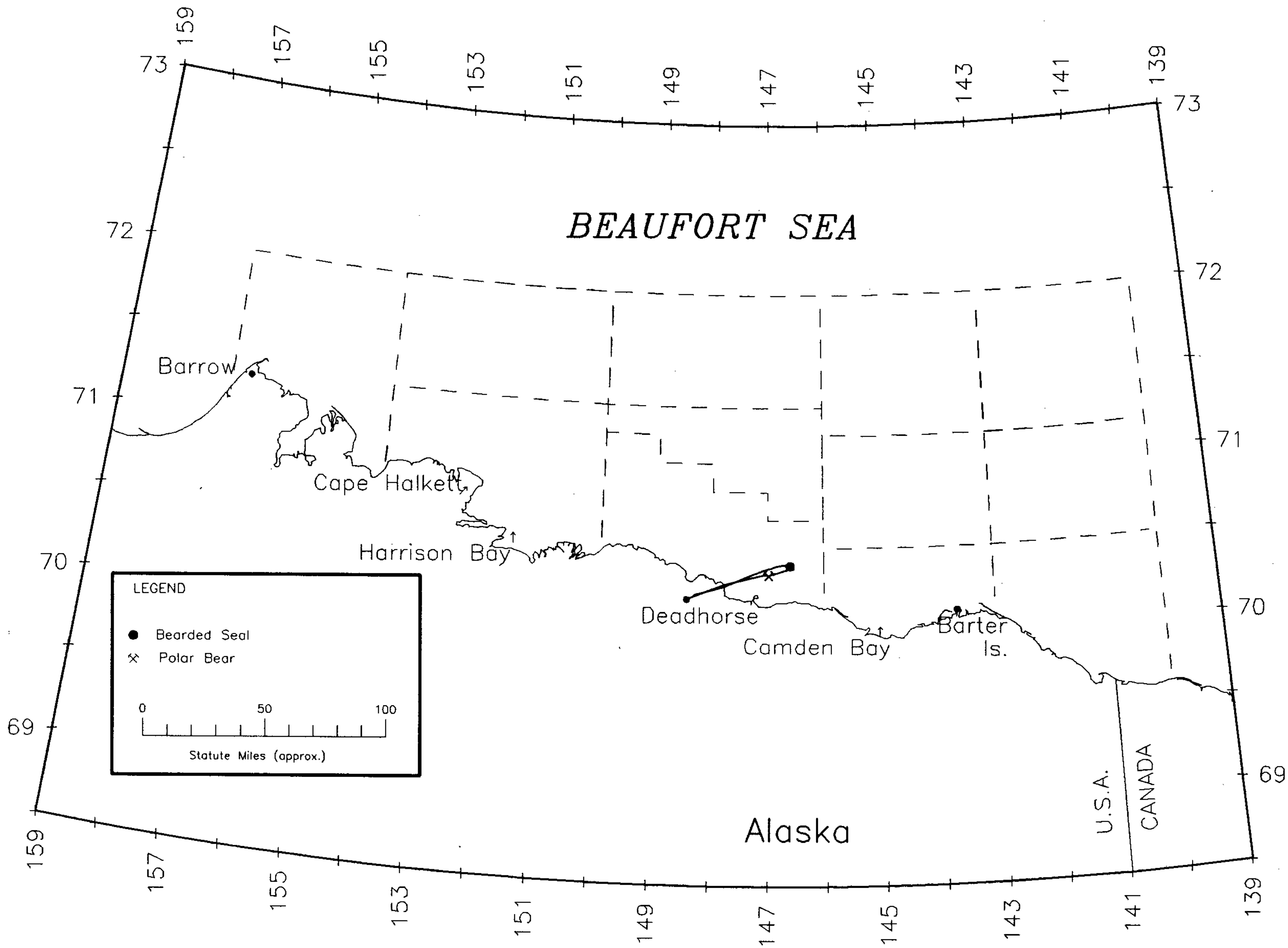
FLIGHT 24 30 September 1992
Survey Track and Sightings



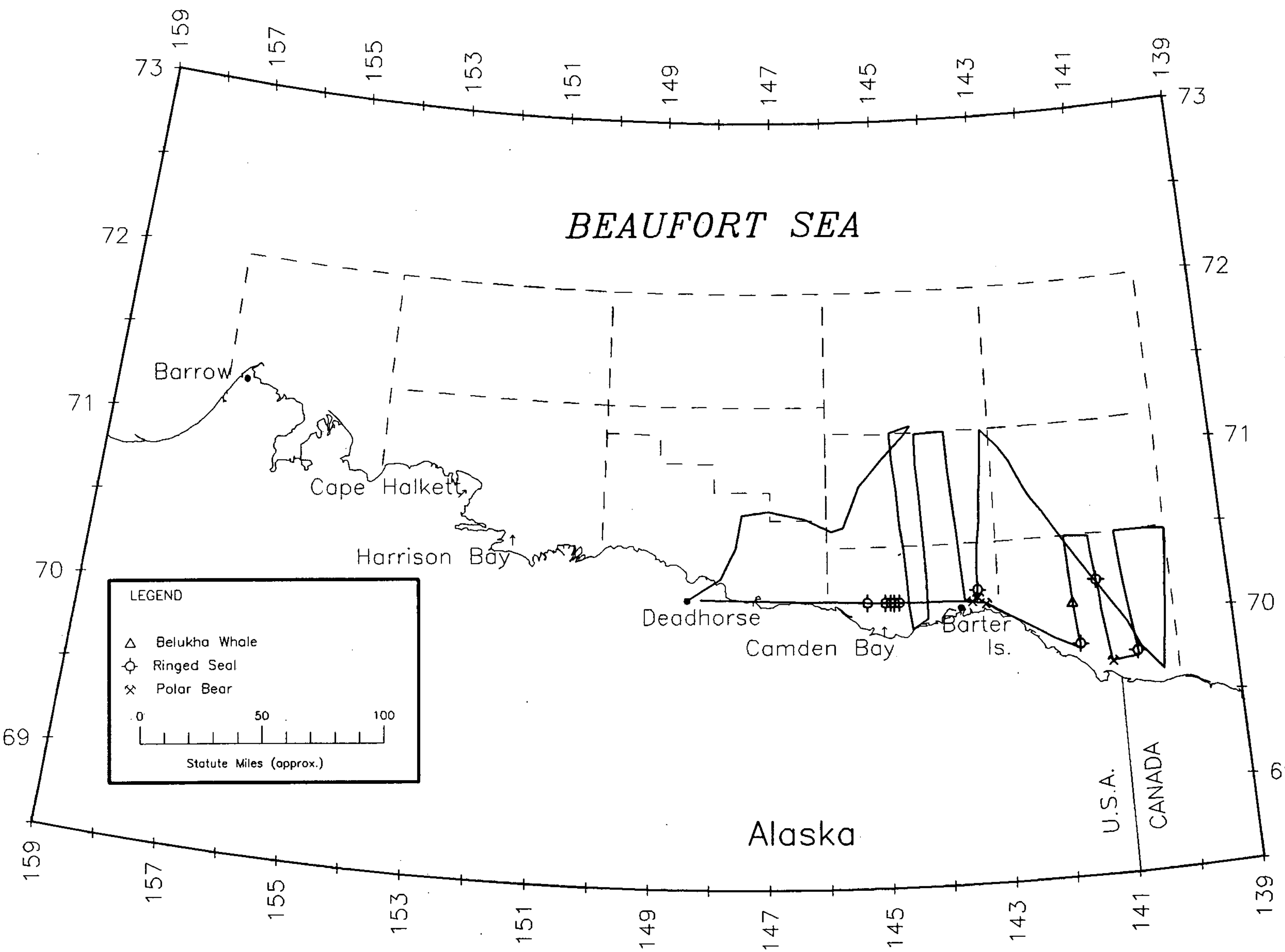
FLIGHT 25 1 October 1992
Survey Track and Sightings



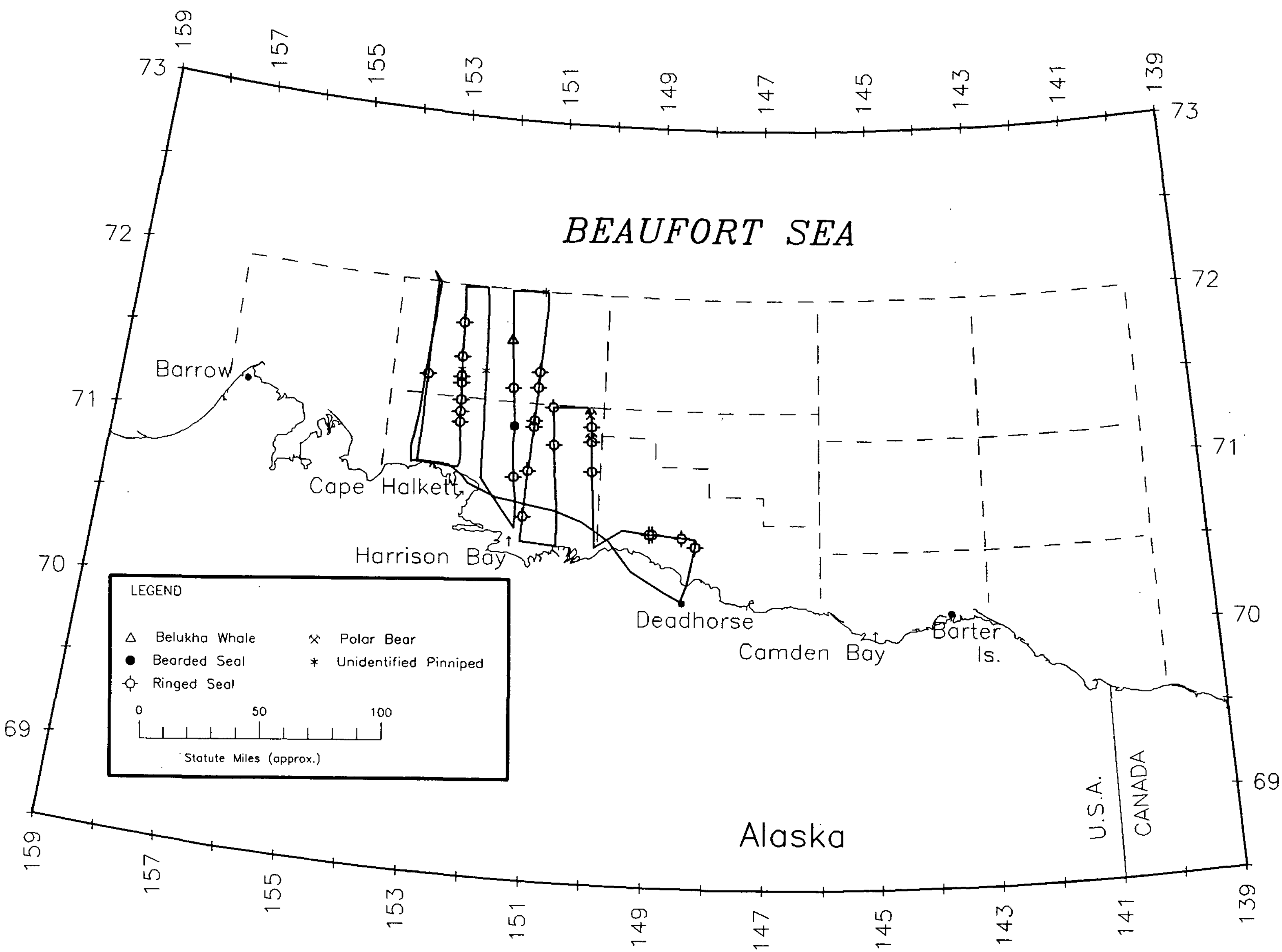
FLIGHT 26 2 October 1992
Survey Track and Sightings



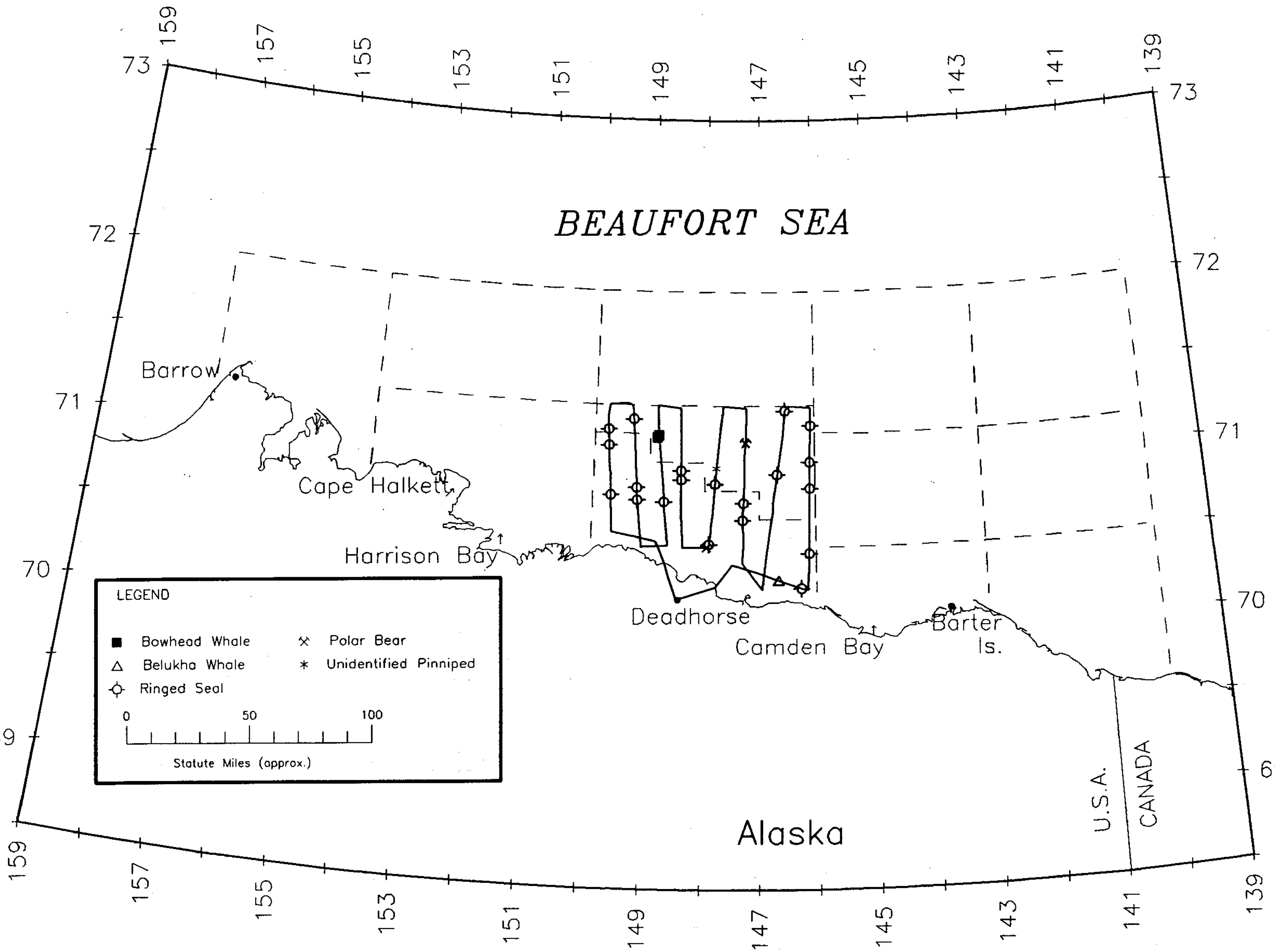
FLIGHT 27 3 October 1992
Survey Track and Sightings



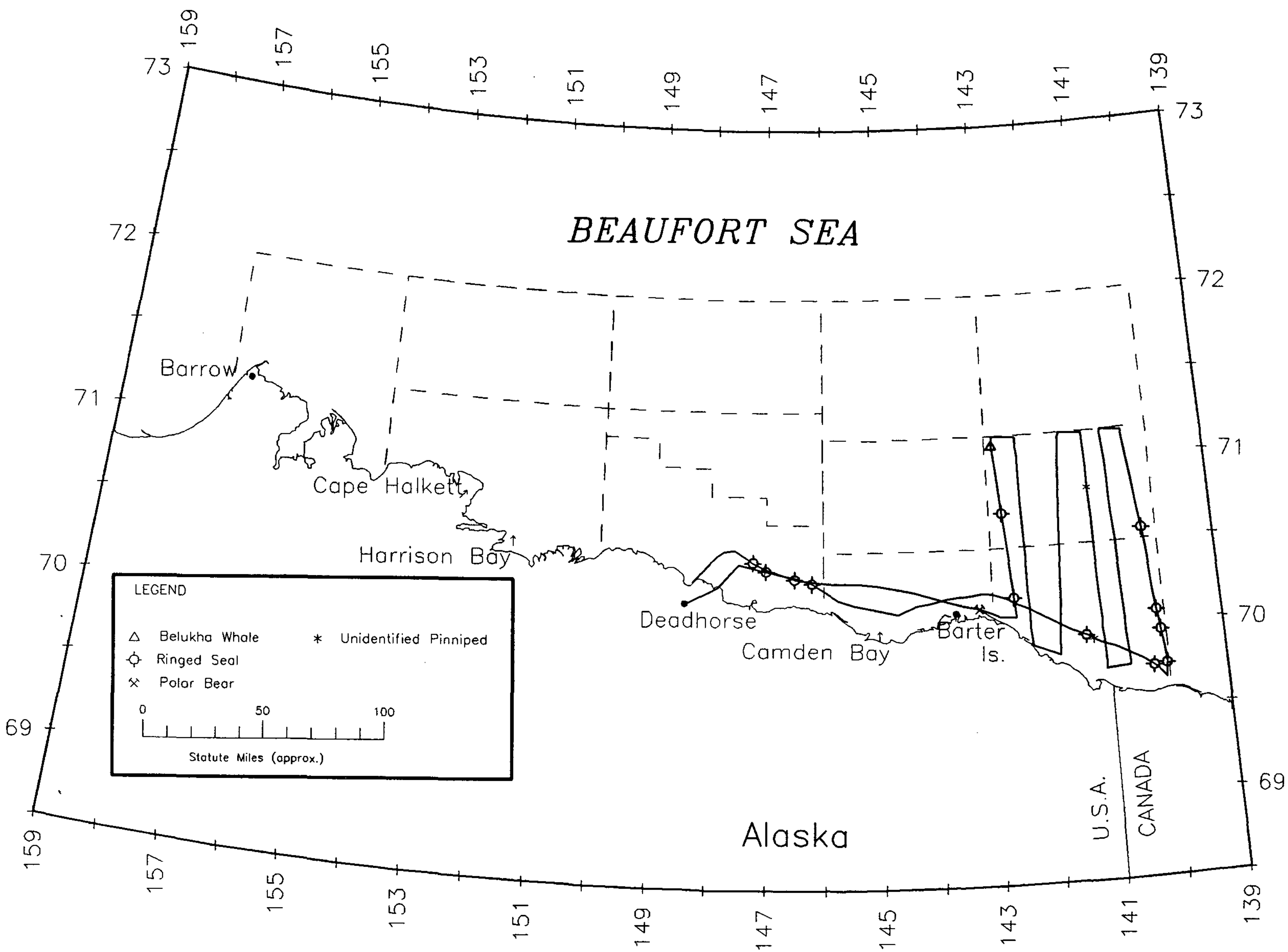
FLIGHT 28 4 October 1992
Survey Track and Sightings



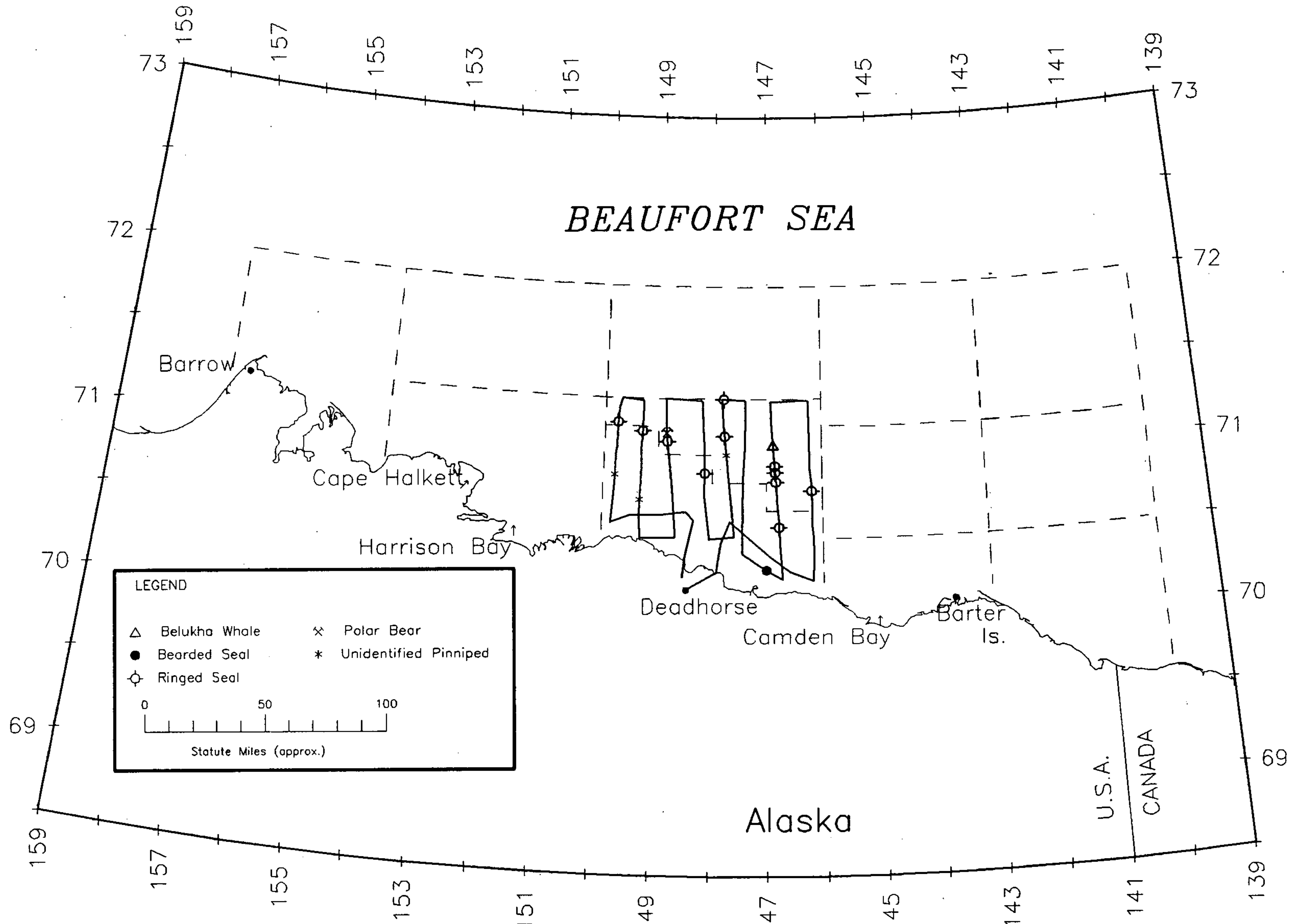
FLIGHT 29 5 October 1992
Survey Track and Sightings



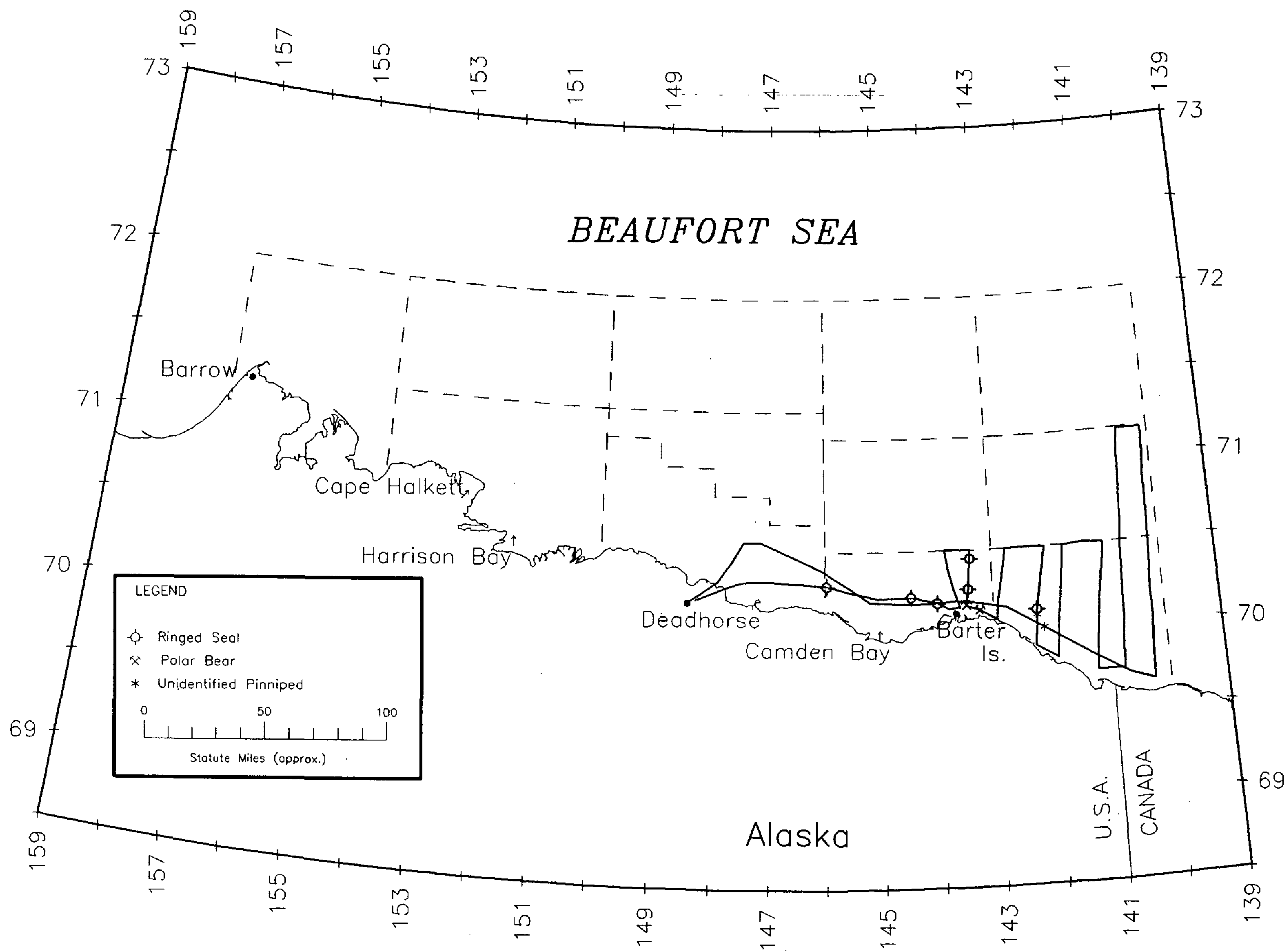
FLIGHT 30 6 October 1992
Survey Track and Sightings



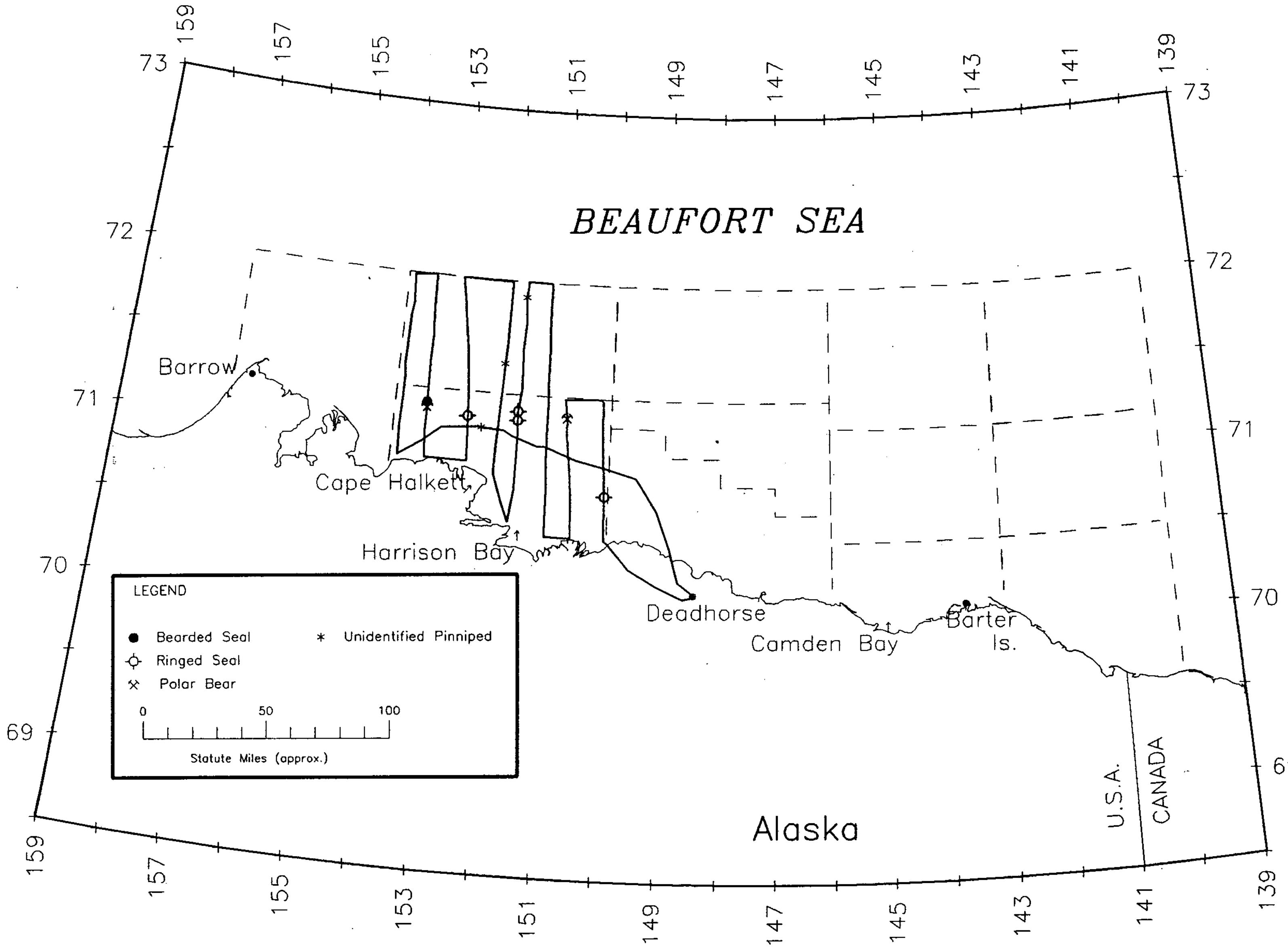
FLIGHT 31 7 October 1992
Survey Track and Sightings



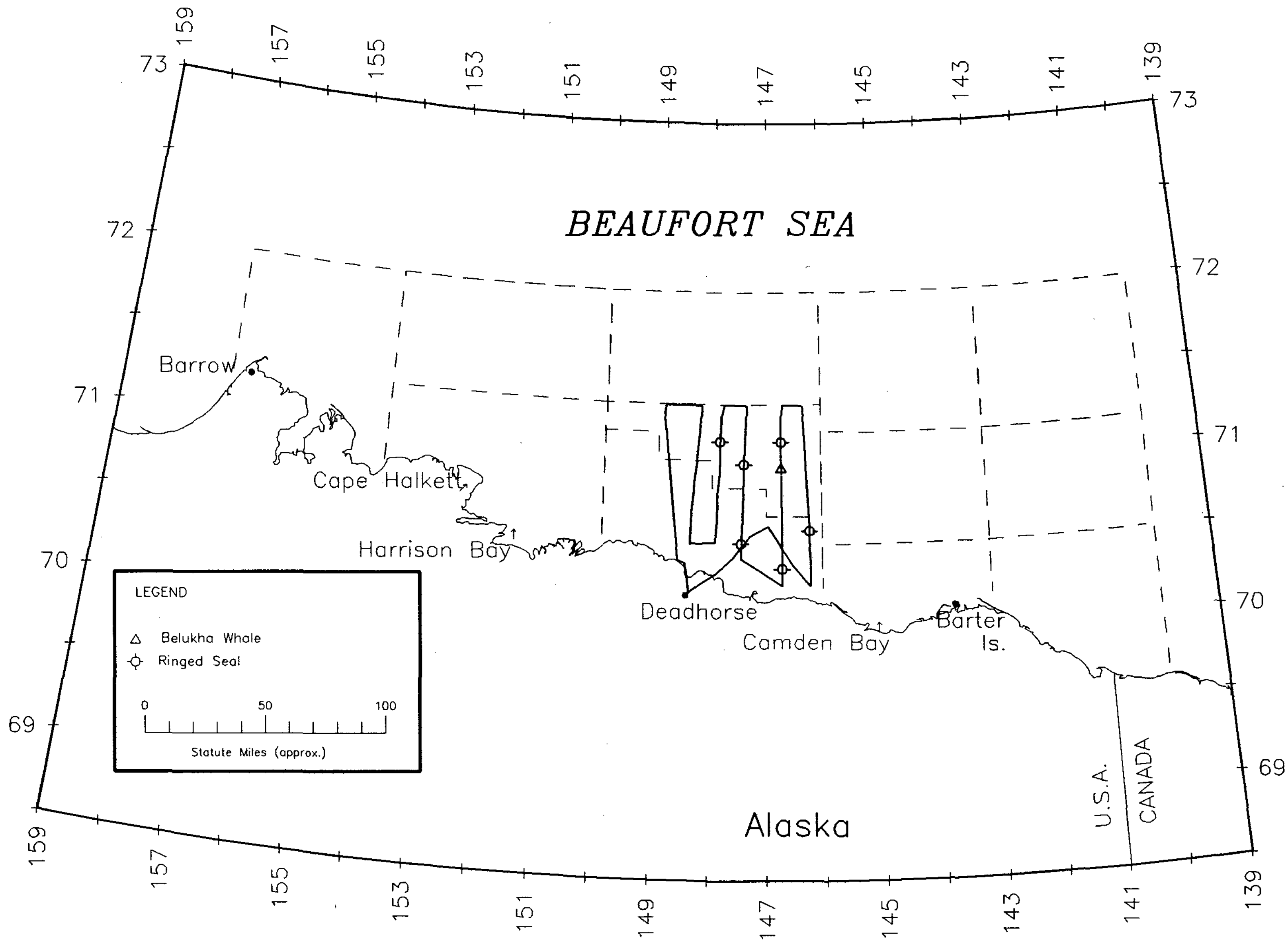
FLIGHT 32 8 October 1992
Survey Track and Sightings



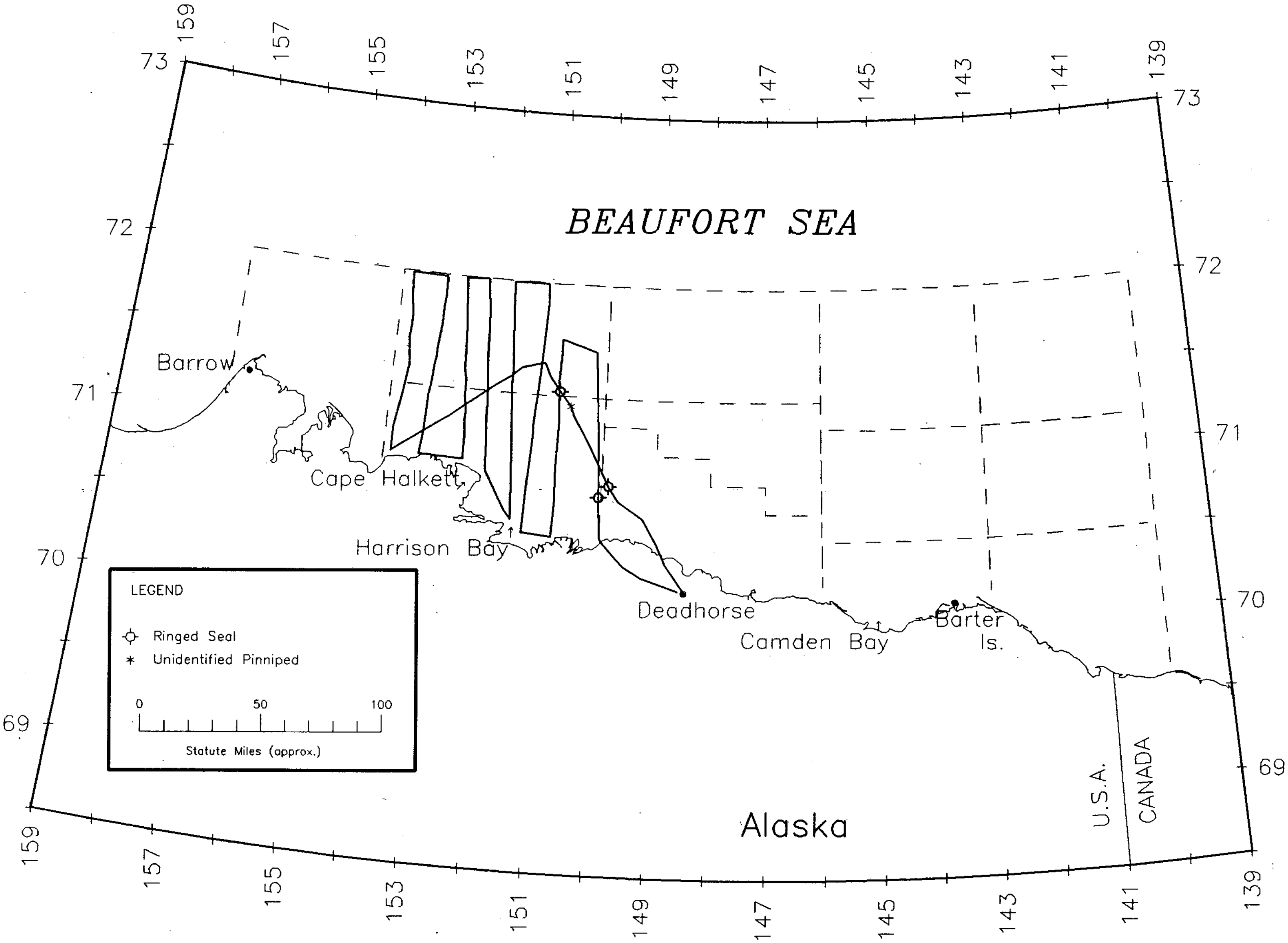
FLIGHT 33 10 October 1992
Survey Track and Sightings



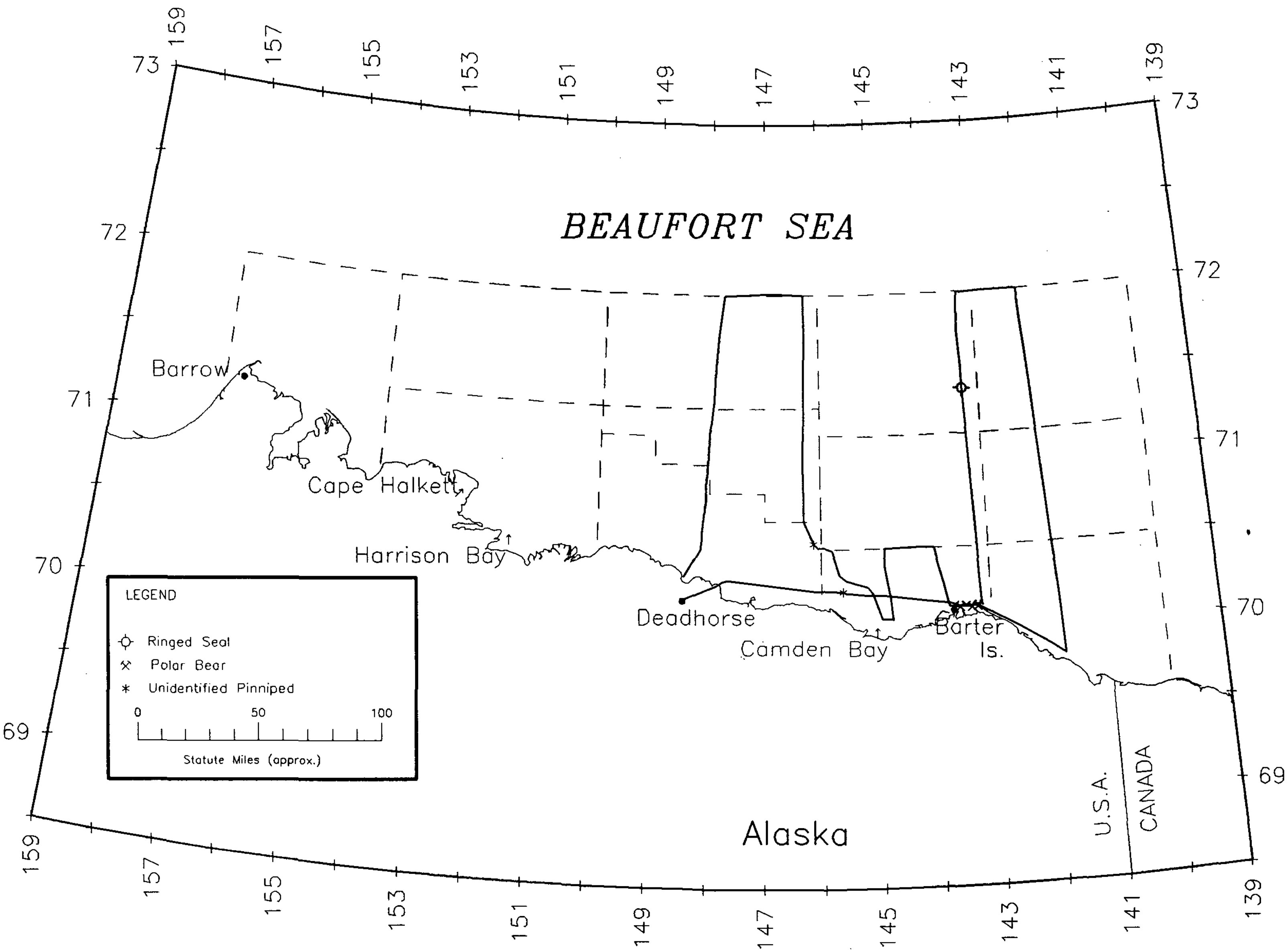
FLIGHT 34 11 October 1992
Survey Track and Sightings



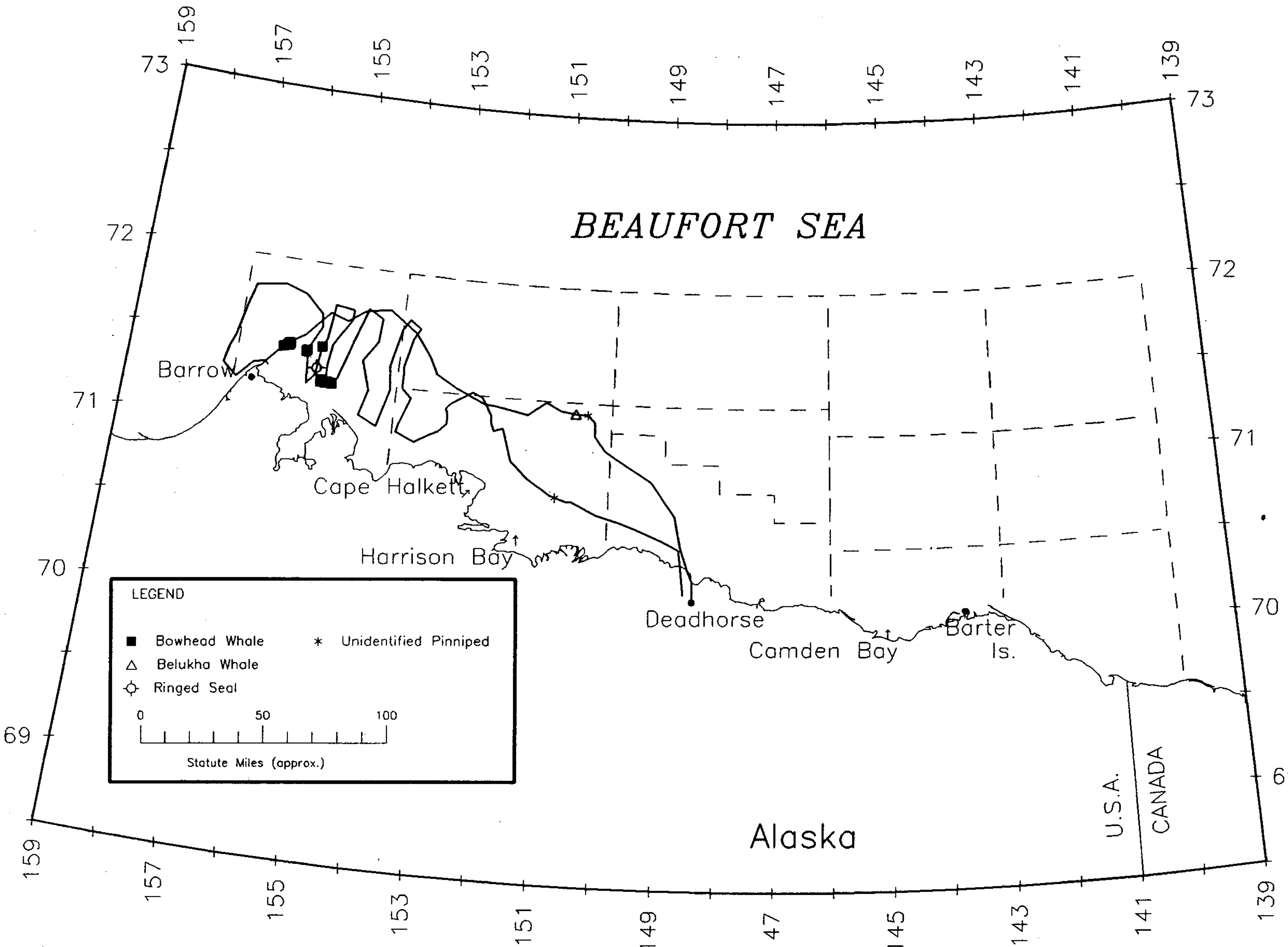
FLIGHT 35 12 October 1992
Survey Track and Sightings



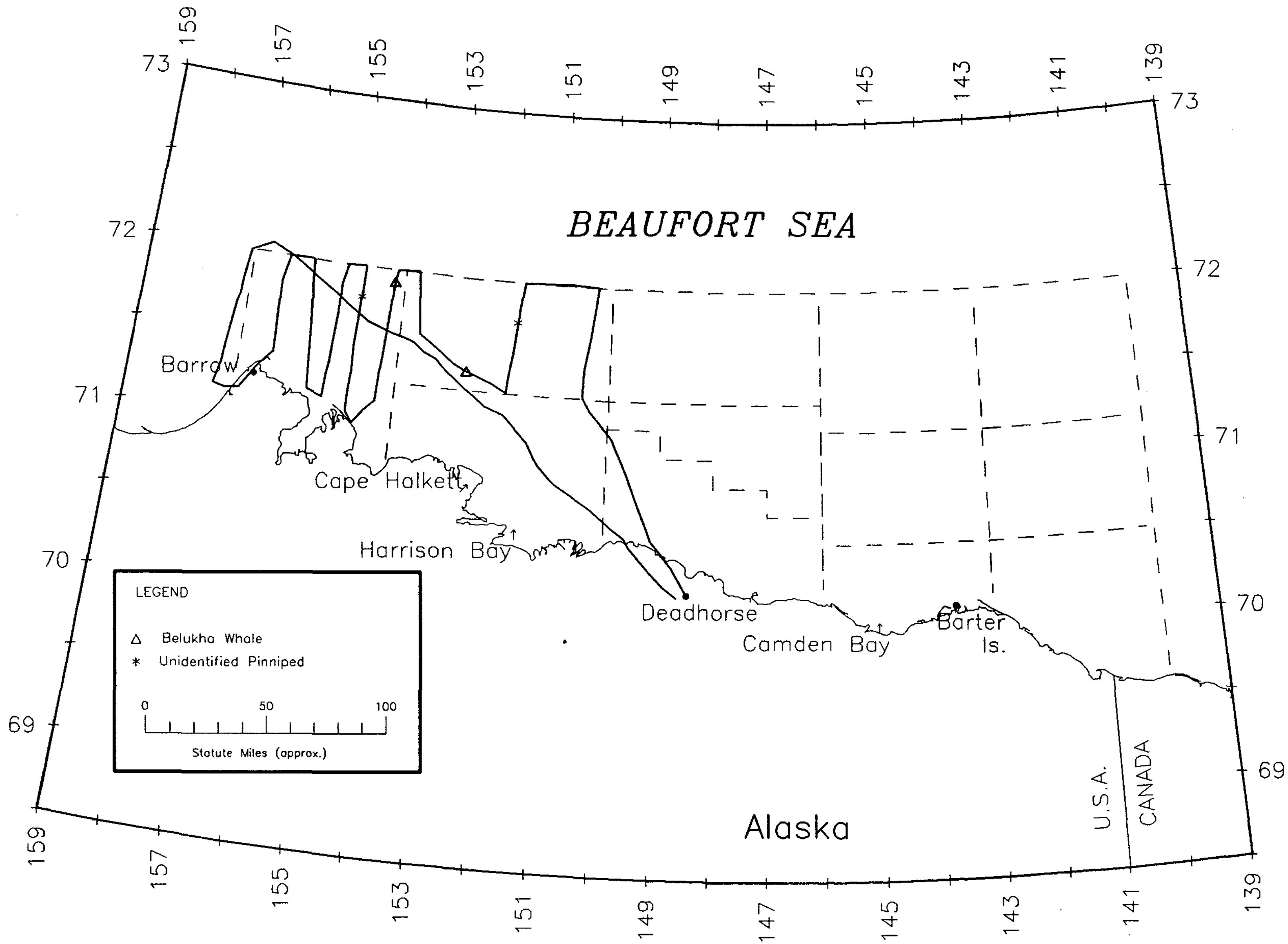
FLIGHT 36 13 October 1992
Survey Track and Sightings



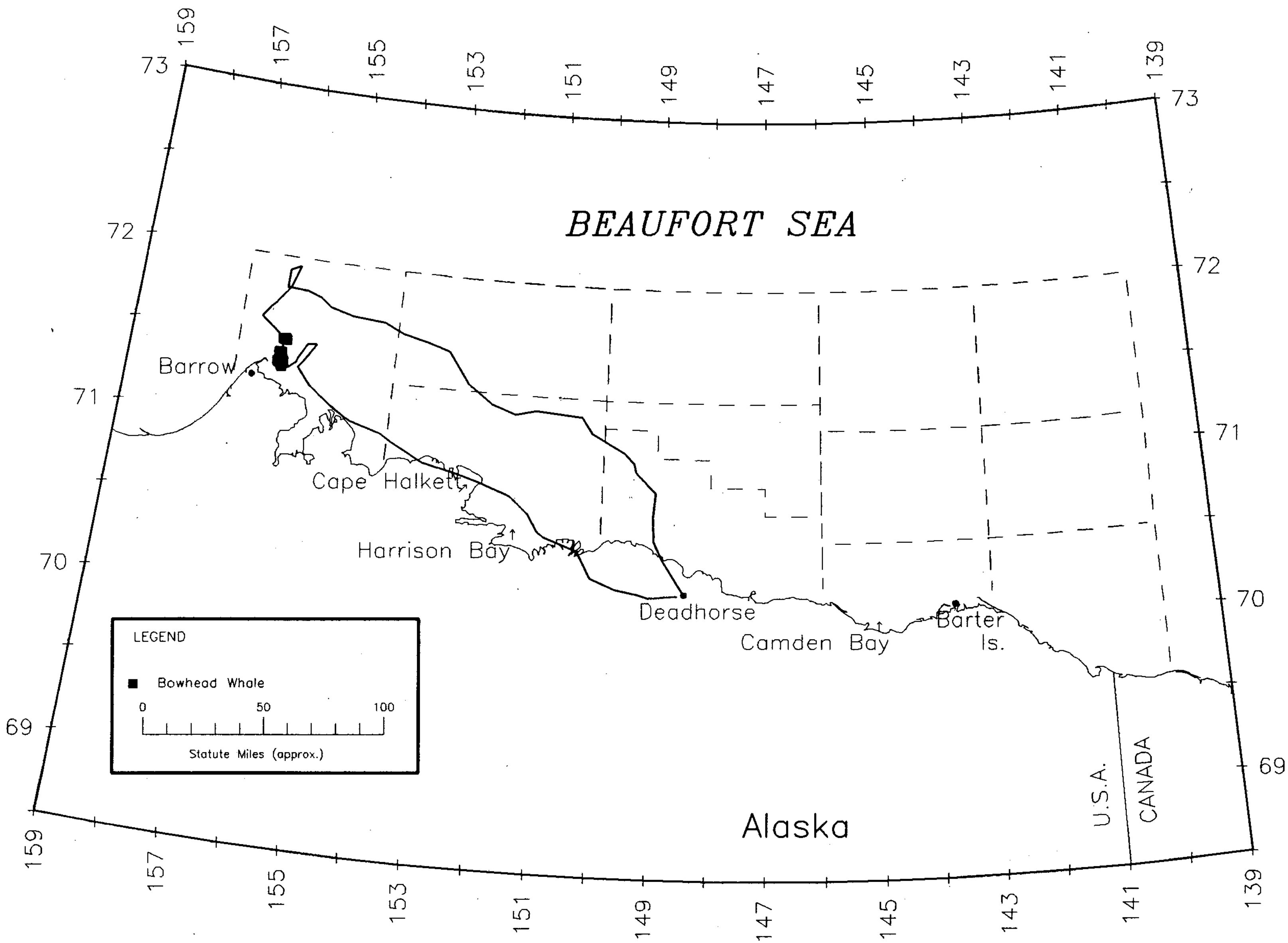
FLIGHT 37 14 October 1992
Survey Track and Sightings



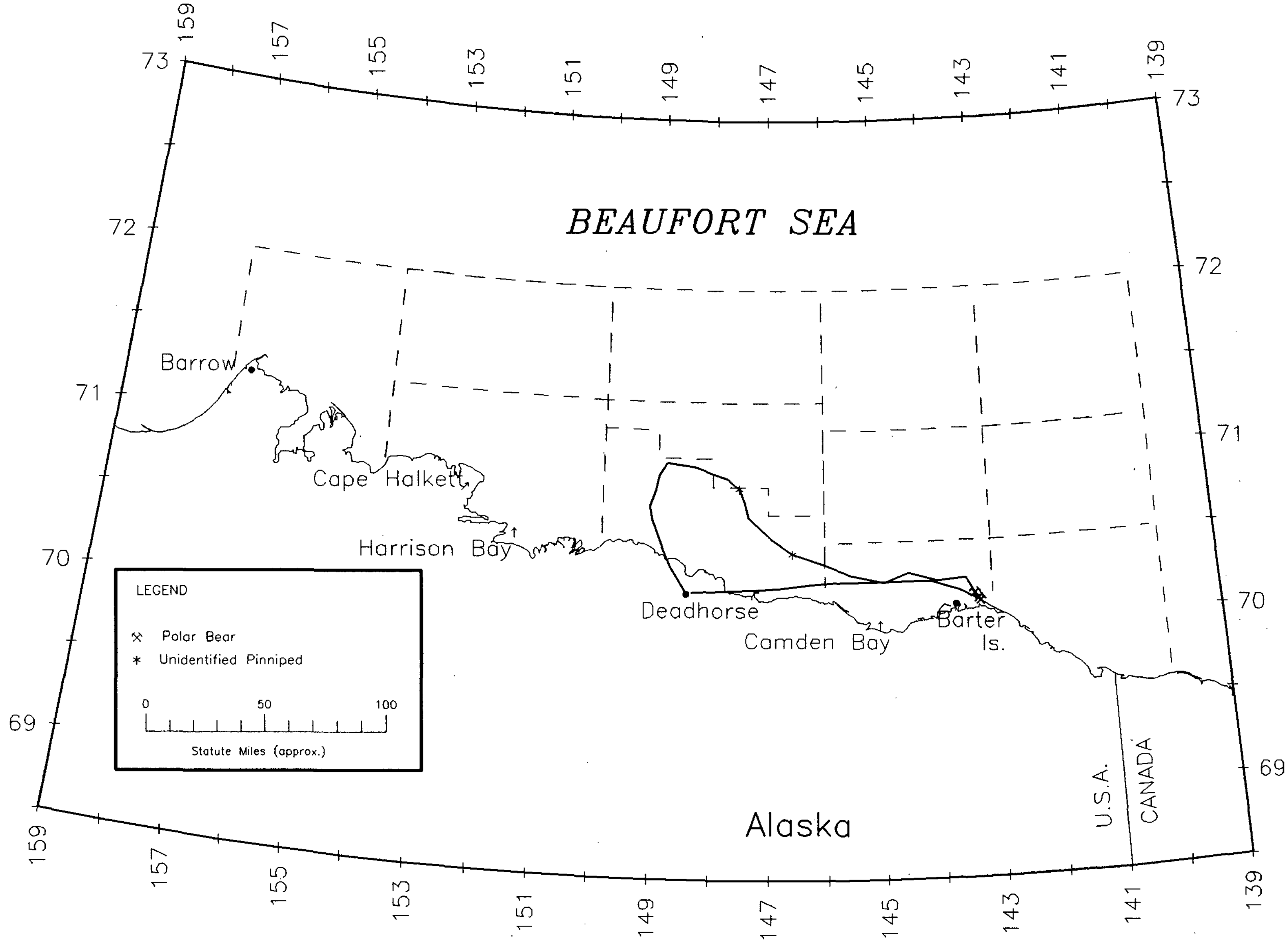
FLIGHT 38 15 October 1992
Survey Track and Sightings



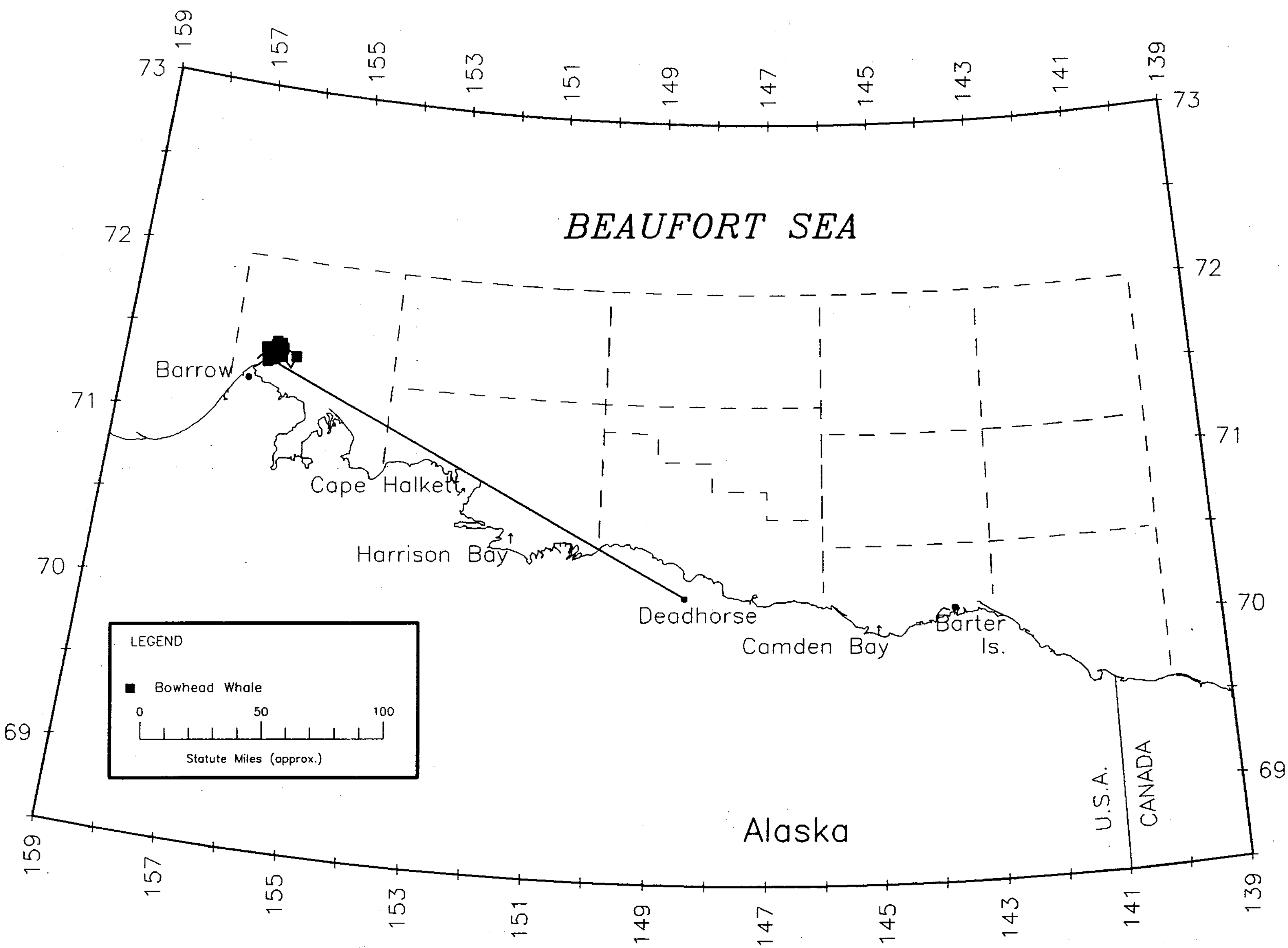
FLIGHT 39 16 October 1992
Survey Track and Sightings



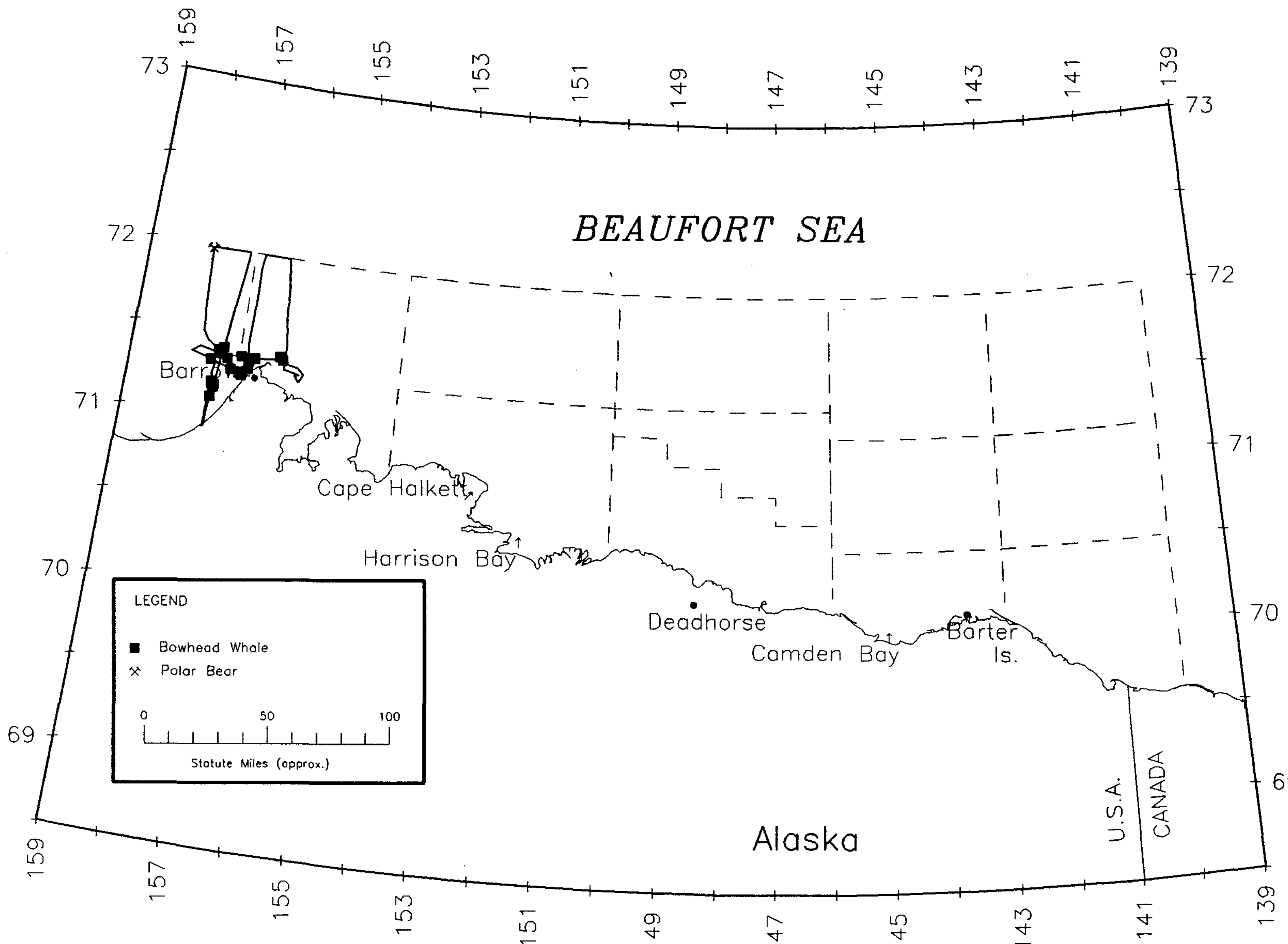
FLIGHT 40 17 October 1992
Survey Track and Sightings



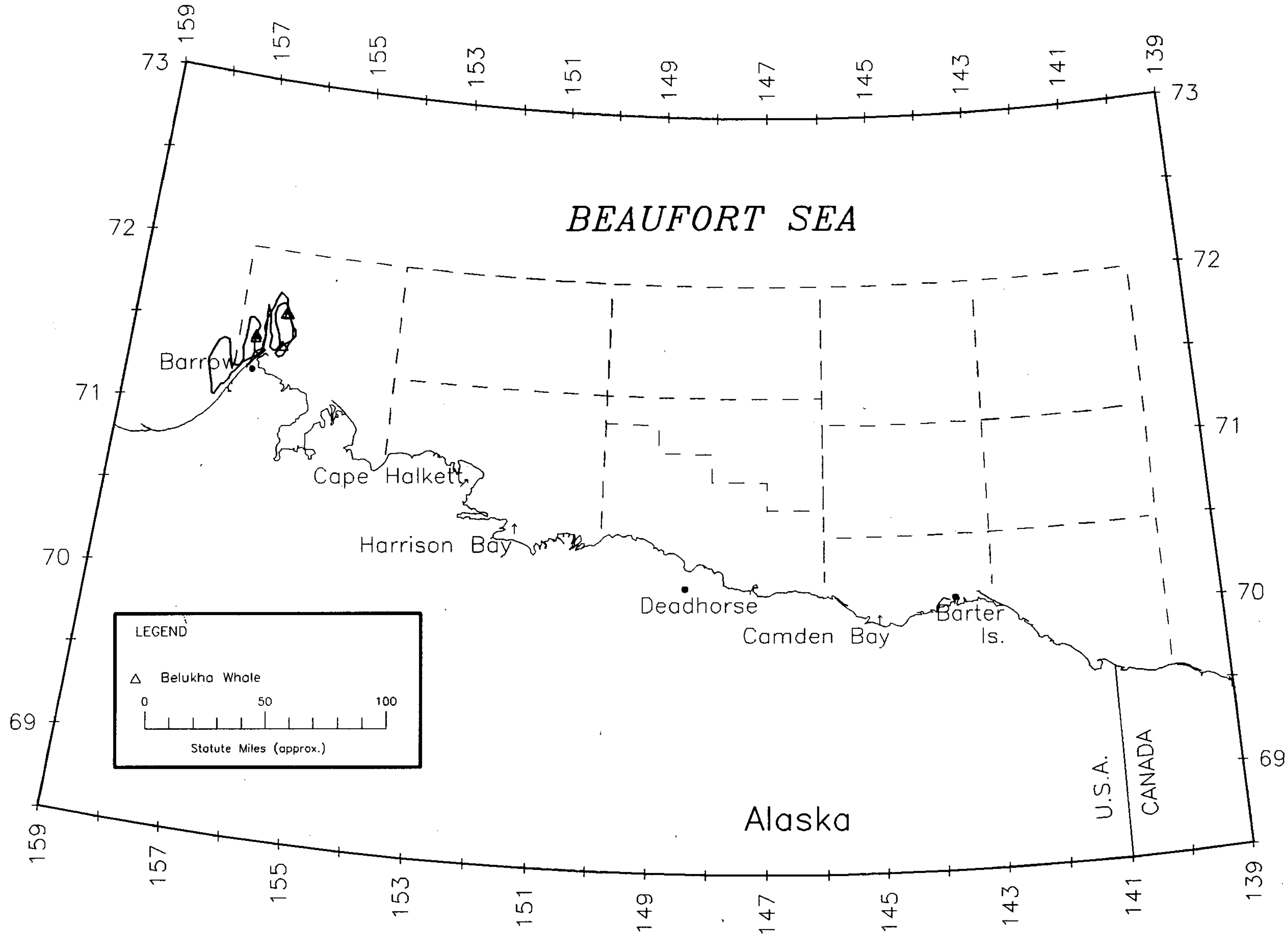
FLIGHT 41 18 October 1992
Survey Track and Sightings



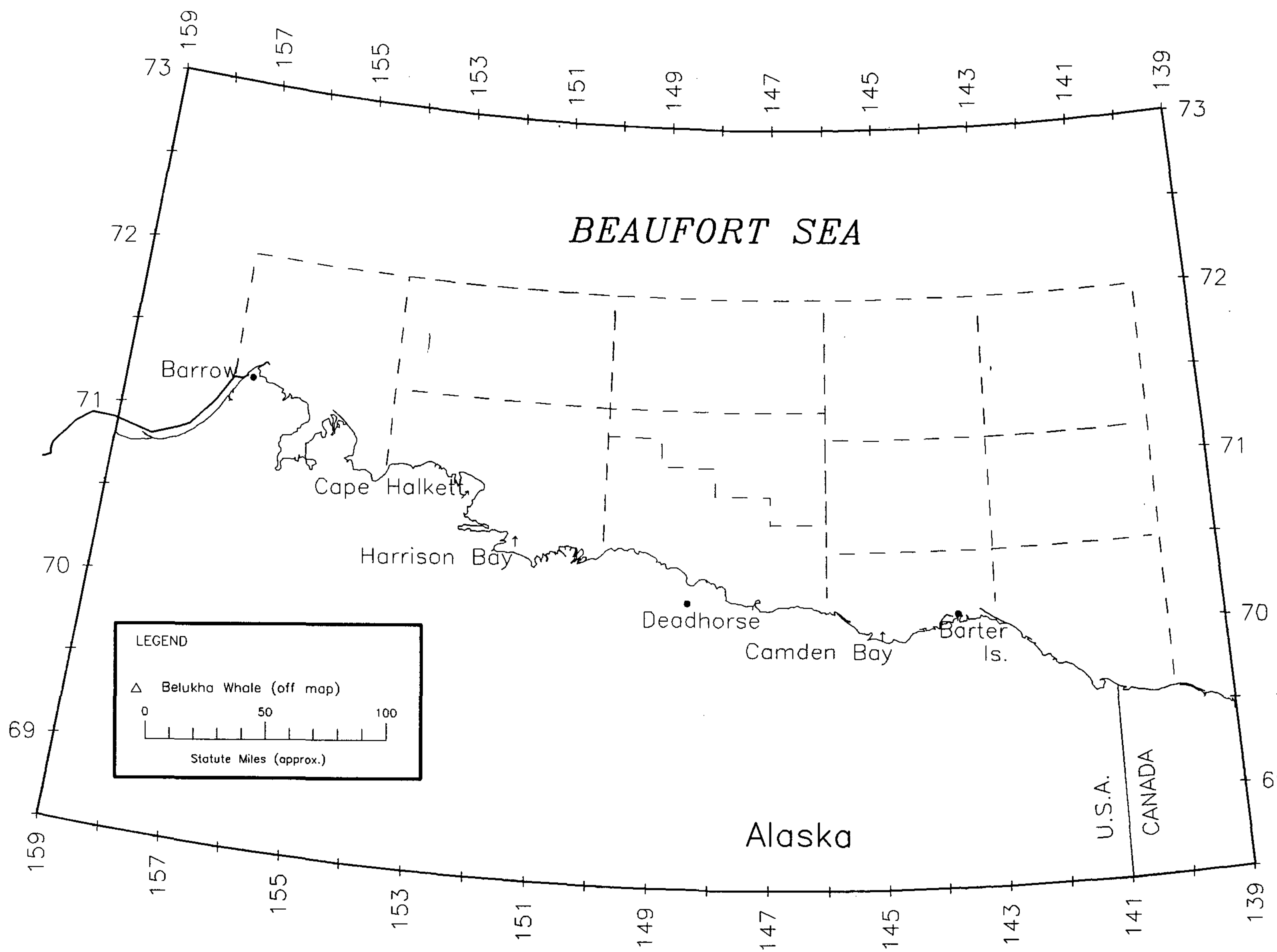
FLIGHT 42 19 October 1992
Survey Track and Sightings



FLIGHT 43 21 October 1992
Survey Track and Sightings



FLIGHT 44 22 October 1992
Survey Track and Sightings



FLIGHT 45 23 October 1992
Survey Track and Sightings

APPENDIX C

POLAR BEAR TRACKS AND KILL SITES

POLAR BEAR TRACKS AND KILL SITES

In addition to sightings of 203 polar bears in Fall 1992 (see Sec. III.D.6), 636 sightings of polar bear tracks and 27 sightings of polar bear kill sites were recorded (Table C-1). Positions of tracks and kill sites shown in Figures C-1 and C-2 do not duplicate positions shown in Figure 29, where all polar bears observed were recorded. All large blood-red smears on the ice were assumed to be polar bear kill sites but were recorded only when live polar bears were not present (Fig. C-2). Sets of polar bear tracks were visible as a double line of individual footprints in the snow and were recorded only when no bears or no kill sites were present.

It was difficult to interpret data on polar bear tracks and kill sites due to potential inherent biases. One problem is that large floes of sea ice, upon which the tracks and kill sites were visible, move about. Fresh tracks would have been more representative of actual geographic positions of the bears that made them. However, both fresh and old tracks were recorded together because they were difficult to distinguish at target altitudes. Also, it was hoped that the region's ubiquitous snow squalls would tend to obscure tracks before they became very old.

Because the interpretation of data on polar bear tracks and kill sites was considered equivocal, they were not analyzed statistically but were presented as maps showing geographic distribution. Each track or kill site is marked with a designated symbol that can be keyed out using the map legend.

Taken together, maps of the study area showing polar bears (Fig. 29), polar bear tracks (Fig. C-1), and polar bear kill sites (Fig. C-2) showed a wide, evenly spaced distribution of sightings between 146°W. and 154°W. longitudes within those survey blocks (Blocks 1, 2, 3, and 11) receiving more than 5.00 hr of survey effort. Distribution west of 154°W. longitude appeared light, based on 12.24 hr of survey effort in Block 12. Distribution of bears, kill sites, and tracks east of 146°W. longitude appeared to be fairly close to shore, based on those survey blocks (Blocks 4, 5, 6, and 7) receiving more than 5.00 hr of survey effort (Table 6 and Fig. 1).

A visual comparison of the map showing polar bear tracks (Fig. C-1) with the map showing ringed seal distribution (Fig. 28) suggests that polar bears, a known major predator of ringed seals, may tend to distribute themselves wherever ringed seals are found.

Table C-1
Summary of Sightings of Polar Bears (PB), Polar Bear Tracks, and Polar Bear Kill Sites, 31 August-23 October 1992, by Survey Flight

Day	Flight No.	PB Sightings	PB Count	PB Tracks (no bear)	PB Kills (no bear)
31 Aug	1	0	0	0	0
1 Sep	2	0	0	0	0
3 Sep	3	0	0	0	0
7 Sep	4	0	0	0	0
8 Sep	5	0	0	0	0
9 Sep	6	0	0	0	0
10 Sep	7	0	0	0	0
11 Sep	8	0	0	0	2
12 Sep	9	2	4	0	0
13 Sep	10	0	0	4	0
14 Sep	11	4	7	9	1
16 Sep	12	0	0	0	0
17 Sep	13	2	3	6	1
19 Sep	14	2	2	15	2
20 Sep	15	0	0	0	3
21 Sep	16	0	0	7	0
23 Sep	17	0	0	6	0
24 Sep	18	2	10	1	0
25 Sep	19	0	0	6	0
26 Sep	20	6	20	2	0
27 Sep	21	1	9	15	0
28 Sep	22	0	0	38	2
29 Sep	23	2	2	26	0
30 Sep	24	0	0	27	1
1 Oct	25	1	1	83	0
2 Oct	26	4	4	79	5
3 Oct	27	1	1	6	0
4 Oct	28	4	37	3	0
5 Oct	29	2	2	18	2
6 Oct	30	2	4	36	3
7 Oct	31	1	20	45	2
8 Oct	32	1	1	33	1
10 Oct	33	2	26	21	1
11 Oct	34	2	3	21	0
12 Oct	35	0	0	12	0
13 Oct	36	0	0	43	1
14 Oct	37	3	27	16	0
15 Oct	38	0	0	19	0
16 Oct	39	0	0	24	0
17 Oct	40	0	0	7	0
18 Oct	41	3	19	3	0
19 Oct	42	0	0	0	0
21 Oct	43	1	1	0	0
22 Oct	44	0	0	5	0
23 Oct	45	0	0	0	0

Table C-1
Summary of Sightings of Polar Bears (PB), Polar Bear Tracks, and Polar Bear Kill Sites, 31 August-23 October 1992, by Survey Flight
(Continued)

Day	PB Sightings	PB Count	PB Tracks (no bear)	PB Kills (no bear)
Total Semimonthly Sightings				
31 Aug	0	0	0	0
1-15 Sep	6	11	13	3
16-30 Sep	15	46	149	9
1-15 Oct	23	126	435	15
16-20 Oct	4	20	39	0
TOTAL	48	203	636	27

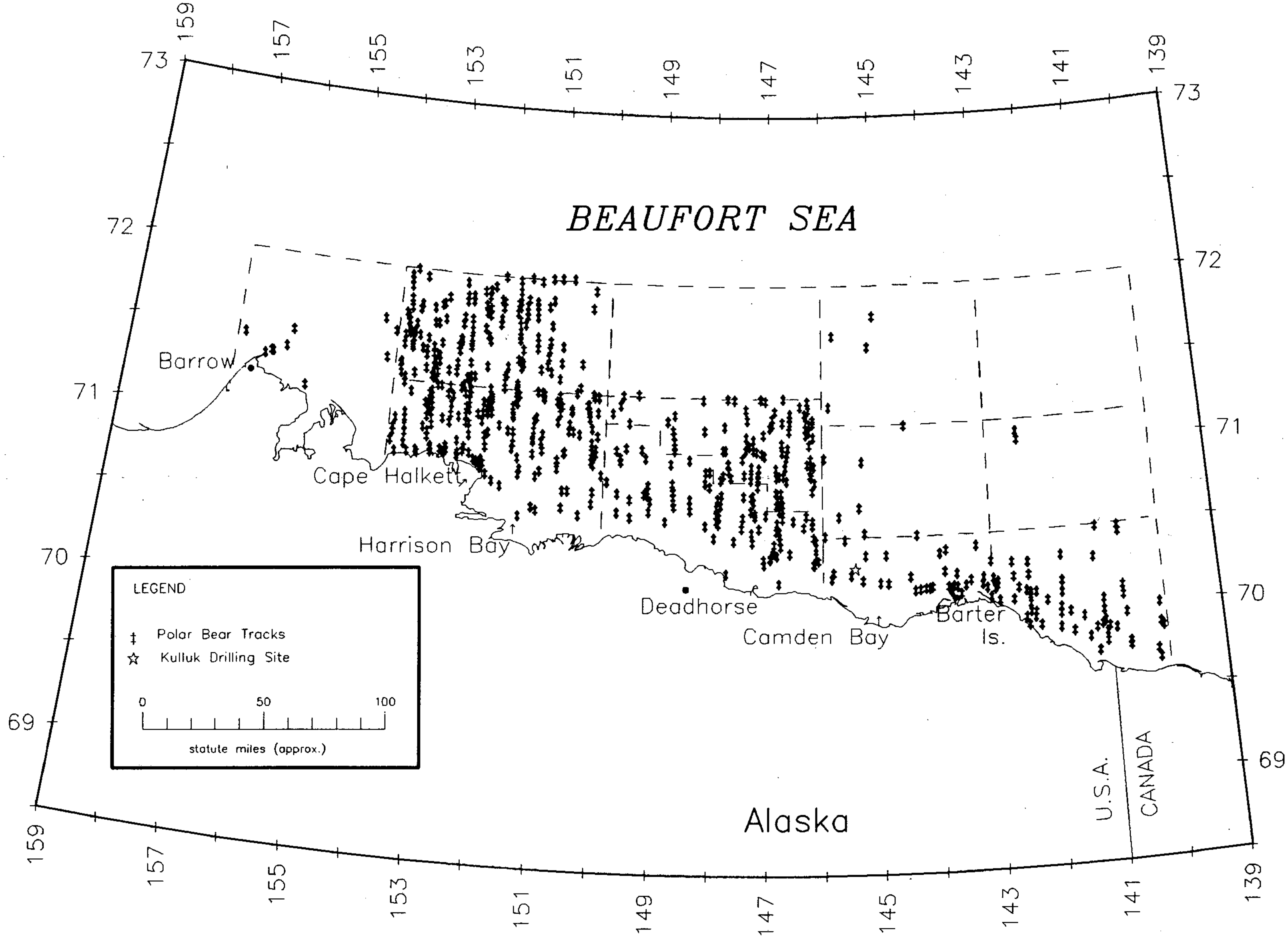


Figure C-1. Map of Polar Bear Tracks (no bear or kill site present), Fall 1992

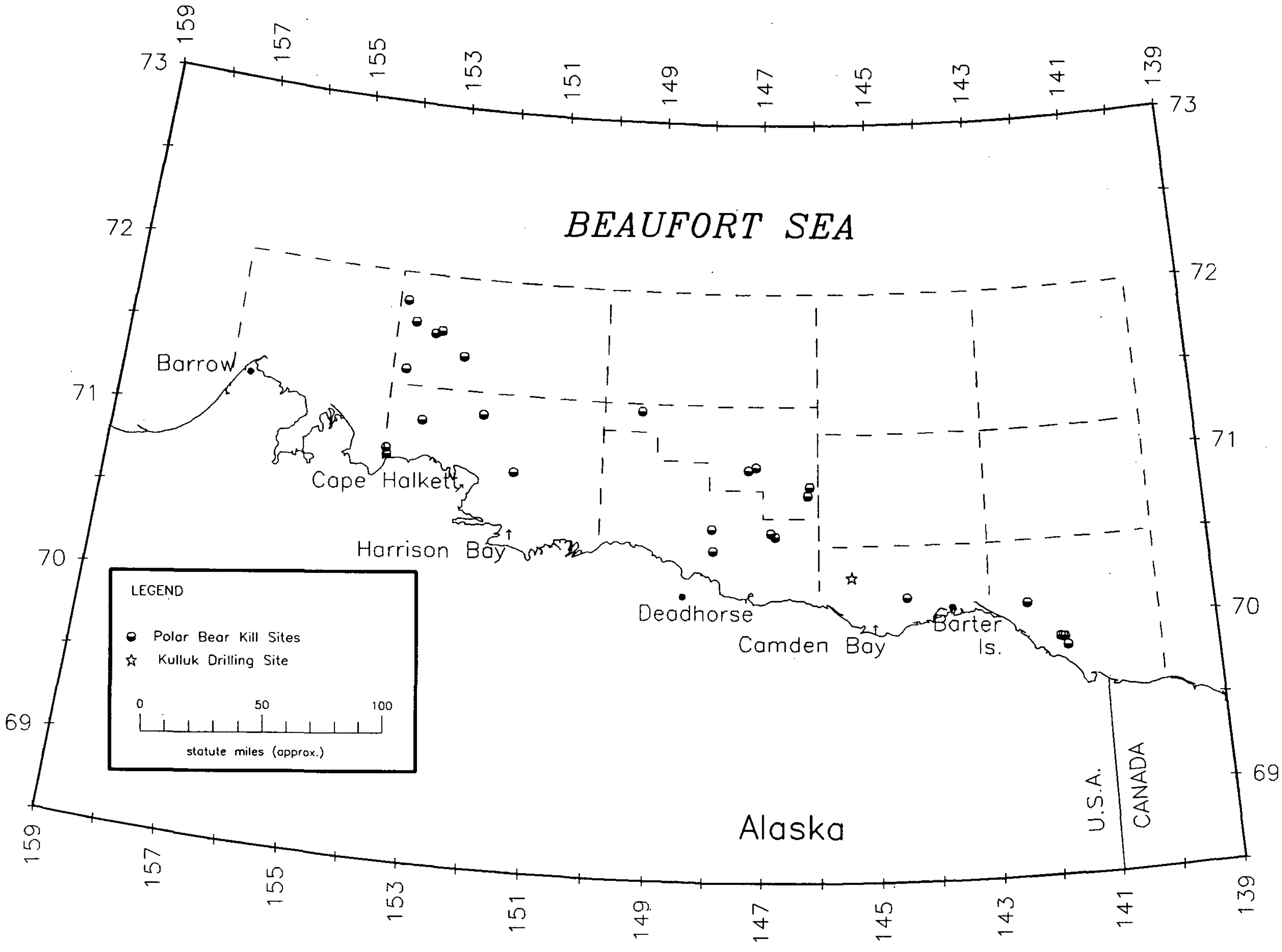


Figure C-2. Map of Polar Bear Kill Sites (no bear present), Fall 1992

GLOSSARY OF ACRONYMS, INITIALISMS, AND ABBREVIATIONS

AC	alternating current
ANOVA	analysis of variance
BLM	Bureau of Land Management
C	Celsius
CI	confidence interval
ELT	emergency location transmitter
ESA	Endangered Species Act
FMS	Flight Management System
FR	Federal Register
GPS	Global Positioning System
hr	hour
HP	Hewlett-Packard
km	kilometer
m	meter
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 miles
OAS	Office of Aircraft Services
OCS	Outer Continental Shelf
OCSLA	Outer Continental Shelf Lands Act
p	probability
SD	standard deviation
SPUE	sightings per unit effort (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
WPUE	whales per unit effort (number of whales counted per hour); relative abundance

☆ U.S. GOVERNMENT PRINTING OFFICE: 1993—790-124 / 81801 REGION NO. 10

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.