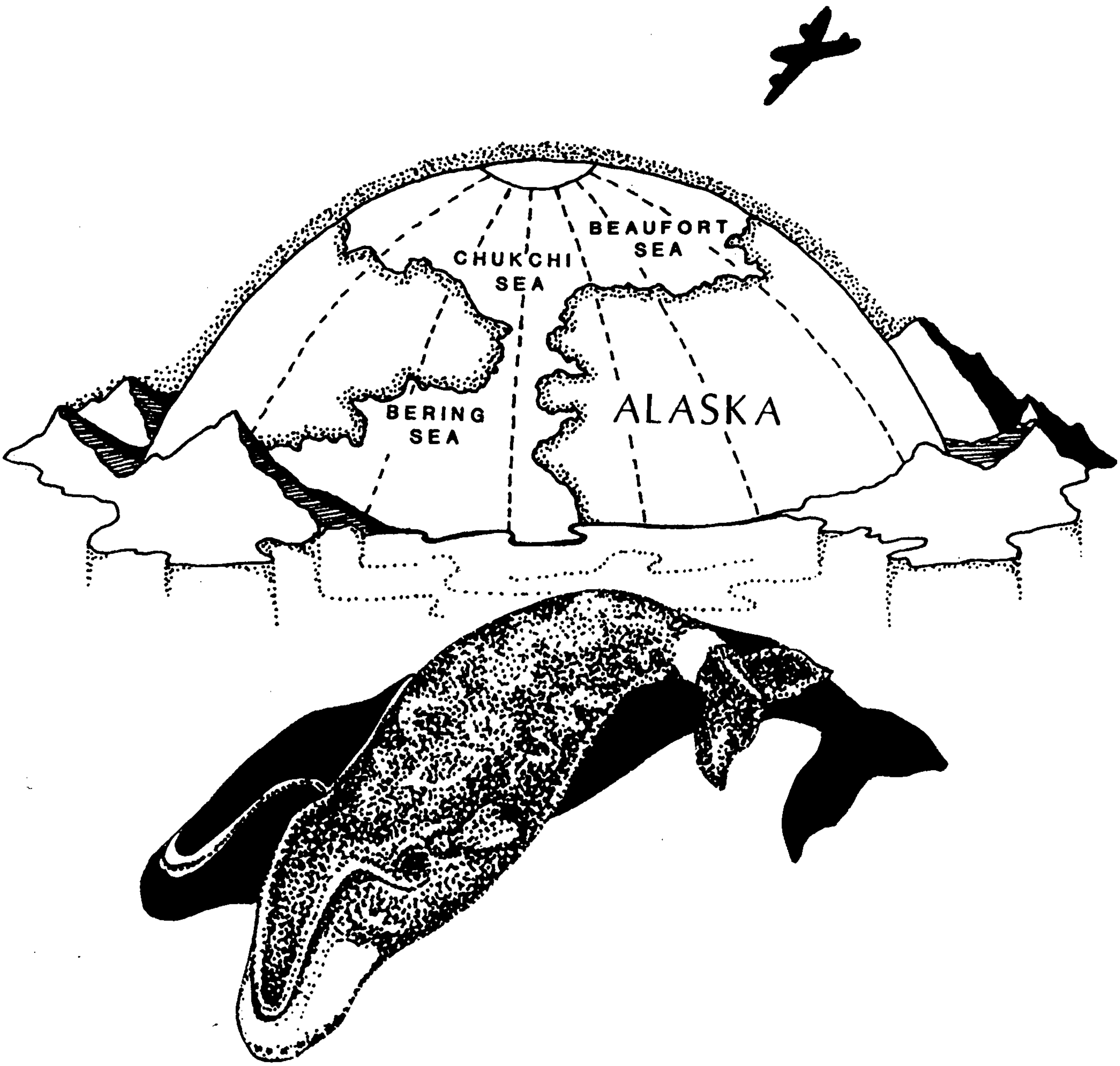
Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 1994

OCS Study
MMS 95-0033



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

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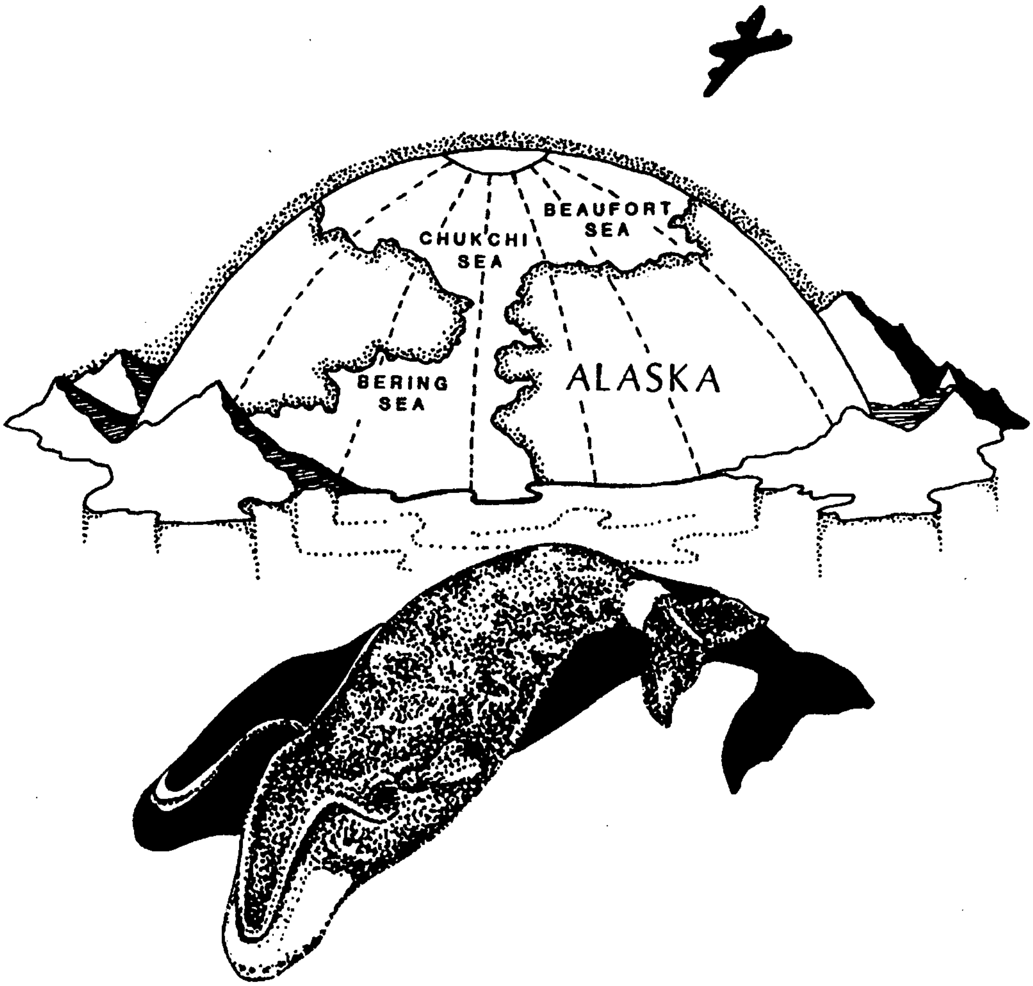
By Stephen D. Treacy, Project Manager
MMS Bowhead Whale Aerial Survey



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

Anchorage, Alaska

ABSTRACT

This report describes field activities and data analyses for aerial surveys of bowhead whales conducted between 31 August 1994 and 18 October 1994 in the Beaufort Sea, primarily between 140°W. and 157°W. longitudes south of 72°N. latitude. General ice cover during September and October 1994 was relatively light. The number of sightings of bowhead whales (n = 105) and the number of bowhead whales counted (n = 204) during Fall 1994 were lower than average totals for previous project surveys (1987-1993). The bowhead whales, 514 belukha whales, 81 bearded seals, 379 ringed seals, 19 unidentified pinnipeds, 15 polar bears, and 2 arctic foxes were observed in 1994 during 132.70 hours of survey effort that included 60.45 hours on randomized transects. The initial sighting of bowhead whales in Alaskan waters occurred on 31 August. Of all bowhead whales observed, half (median) had been counted by 9 September. The peak count (mode) of 65 whales also occurred on 9 September. These central tendencies occurred earlier in September than in previous surveys (1987-1993) and are being analyzed for statistical significance and for comparison with industry activity, sighting conditions, etc. The last sighting of a bowhead whale in the primary study area occurred in 90-percent ice in Block 12 on 13 October. Estimated median and mean ($\bar{x}$) water depths at the location of bowhead whales sighted on randomized line transects during September and October 1994, 40.0 meters and 58.7 meters, respectively, are consistent with a previously noted trend for whales to be located in shallower water during years of light ice cover.

ACKNOWLEDGMENTS

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I. INTRODUCTION

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

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

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

In June 1978, BLM entered into an ESA Section 7 consultation with 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 1994 to 18 October 1994, 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

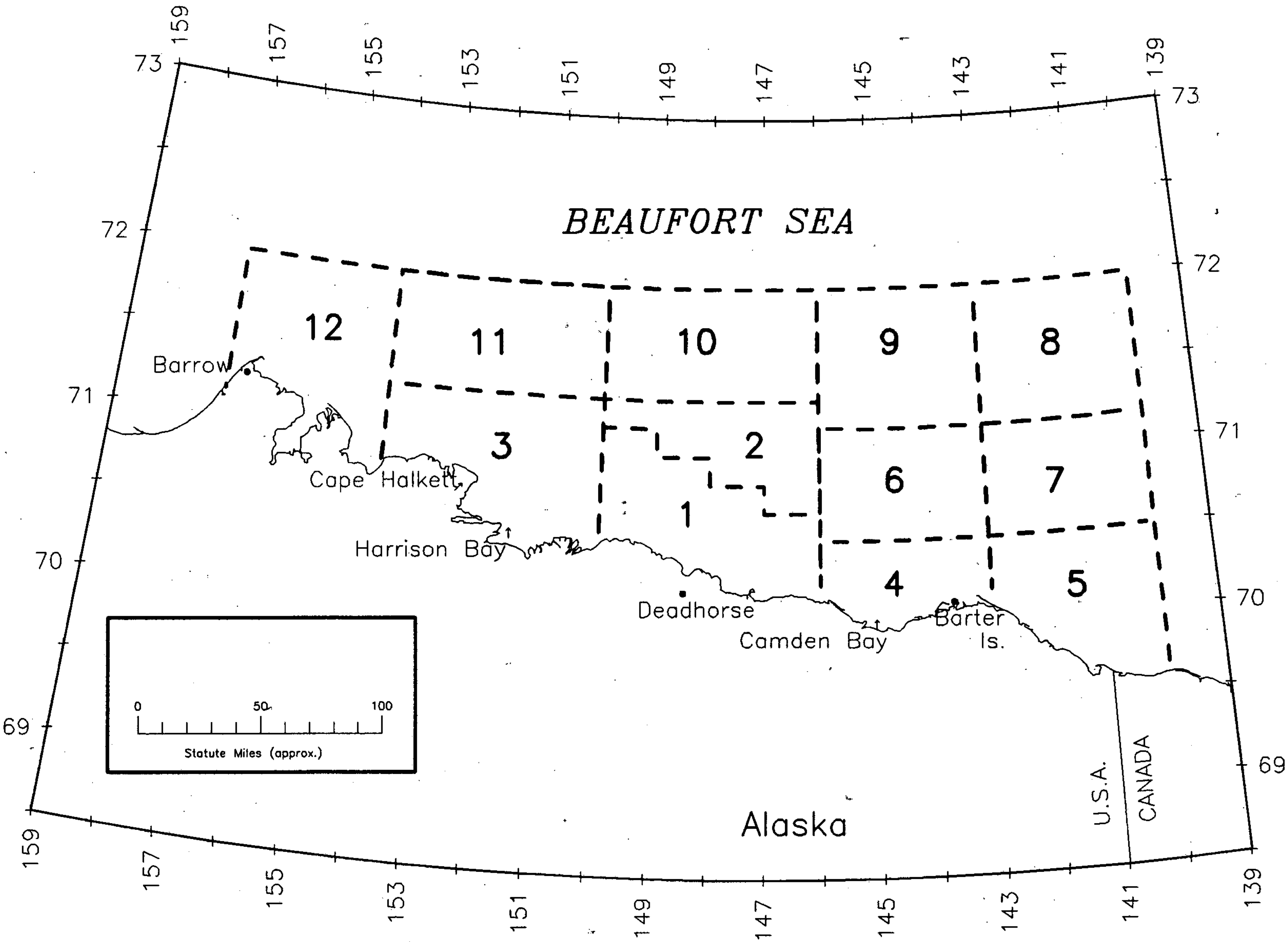

Figure 1. Fall 1994 Study Area Showing Survey Blocks

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. Electronic signals from the GPS were converted into an RS 232 serial stream; and data were polled every second for automatic input of time, latitude, longitude, and flight altitude. The GPS altitude (27-m precision) that was used exceeded the accuracy of the radar altimeter (32 m at the target altitude of 458 m). In the event of a system failure, the team leader could read directly from the aircraft instrument panel for manual entry of this information into the computer. System components required 115-volt alternating current (AC) power, which was supplied by a direct current→AC invertor connected to the aircraft electrical bus.

A portable 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 flight suits, and emergency crash helmets.

Flight-following equipment featured an experimental Radio Determination Satellite System (RDSS) under development by Mobile Datacom Corporation (MDC). Data on latitude, longitude, time, and other parameters were obtained from the aircraft's GPS and broadcast every minute to a satellite that was stationary over the equator at 87°W. longitude. The project helped to test a pair of toggled patch antennas used in tracking the project aircraft over the Alaskan Beaufort Sea during the 1994 field season. Real-time satellite signals were relayed to MDC in Clarksburg, Maryland, where OAS queried the RDSS every 15 minutes to obtain current flight-following information. The information was displayed as digital data on a computer screen and in the form of a map for visual tracking of the survey aircraft.

The RDSS was backed up by an onboard aircraft-band radio, used to transmit position data on very high frequency to Deadhorse Flight Service when entering a new survey block and, if possible, when ending southbound transect lines. An onboard high-frequency radio was also used to transmit 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 through 18 October 1994. The field schedule was designed to monitor the progress of the Fall 1994 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 and the level of offshore oil industry activity in various areas. Weather permitting, the project also uses a semimonthly flight-hour goal for each survey block allocated proportionately for survey blocks east of 154°W. longitude and semimonthly time periods based on relative abundance of bowhead whales as determined from earlier fall migrations (1979-1986). Such allocations, detailed in our Project Management Plan (USDOI, MMS, 1994), greatly favor survey coverage in inshore Survey Blocks 1 through 7 and 11 (Fig. 1), since bowheads were rarely sighted north of these blocks in previous surveys. The purpose of these survey-effort allocations was to increase the sample size (n) of whale sightings within the primary migration corridor, thus increasing the power of statistical analysis within these inshore blocks.

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

D. <u>Survey-Flight Procedures</u>

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 sighting of endangered whales when the initial sighting location was abeam of the aircraft.

When bowheads were encountered while surveying a transect line, the aircraft sometimes diverted from transect for brief (<10-minute) periods and circled the whales to observe behavior, obtain better estimates of their numbers, and determine whether calves were present. Only groups of bowheads seen before diverting from the transect line were included in density calculations.

E. <u>Data Entry</u>

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 (a pod is loosely defined here as either a singleton or a group of 2 or more whales within a few body lengths of each other and whose respiration patterns appear somewhat synchronous) were sighted within a short period of time. To avoid lumping of sightings in areas where whales were extremely concentrated, an even shorter rapid-sighting update was used. A position-update format including data on weather, visibility, ice cover, and sea state was entered at turning points, when changes in environmental conditions were observed, and otherwise within 10-minute intervals. All entries were coded to reflect the type of survey being conducted. Table 1 shows the data-entry sequence used in 1994 and the questions used to prompt entry of observational data. All data entered were simultaneously printed out in hard copy.

The behavior, swim speed, and swim direction for observed whales represent what the pod as a whole was doing at the time it was first sighted. Behaviors were entered into one of 14 categories as noted on previous

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

surveys. These categories--breaching, cow-calf association, diving, feeding, flipper-slapping, log playing, mating, milling, resting, rolling, spy-hopping, swimming, tail-slapping, and underwater blowing--are defined in Table 2. Swimming speed was subjectively estimated by observing the time it took a whale to swim one body length. An observed swimming rate of one body length per minute corresponded to an estimated speed of 1 km/hr; one body length per 30 seconds was estimated at 2 km/hr, and so on. Swimming speed and whale size were recorded by relative category (i.e., still, 0 km/hr; slow, 0-2 km/hr; medium, 2-4 km/hr; or fast, >4 km/hr; and calf [length less than half of accompanying adult], immature, adult, or large adult, respectively) rather than on an absolute scale. Swim direction was recorded in the field as a magnetic value, using the aircraft's compass.

Sea state was recorded according to the Beaufort scale outline in *Piloting, Seamanship, and Small Boat Handling* (Chapman, 1971). Ice type was identified using terminology presented in Naval Hydrographic Office Publication Number 609 (USDOD, Navy, 1956). Average ice cover within a few kilometers of the aircraft was estimated as a single percentage, regardless of ice type.

F. General Data Analyses

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

Application software (Grapher, Golden Software, Inc.) was used to plot daily maps of aircraft tracklines and positions of marine mammals observed. To function as a mapping package, coastlines were mapped using an Altec digitizer; and all points on the maps were based on number of meters north or to one side of a central meridian for Universal Transverse Mercator 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. Maps of ice concentrations were prepared with application software (ARC/INFO) using a Polar Stereographic Projection (central meridian = 150°W. longitude, latitude of true scale = 70°N., spheroid = Clark 1866, and North American Datum 1927).

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 1994 bowhead migration through the study area was analyzed as sightings per unit effort (SPUE = number of sightings counted/hr of survey effort) and WPUE per date. Because chance sightings of a few large groups of whales in a short period of time might produce artificially high WPUE values in certain blocks, values based on at least 4.00 hr of survey effort were distinguished when discussing relative abundance between areas.

Habitat preference was depicted as percentage of whales per ice class and percentage of whales per depth regime. Directionality of whale group headings was analyzed using Rayleigh's test (Batschelet, 1972) for all pods, excluding those that were resting, feeding, or milling. Directionality was analyzed as a True (T) heading, assuming a compass correction of -31° for the study area as a whole. Probabilities were interpolated from alpha values shown for calculated critical values of Rayleigh's z (Zar, 1984: Table B.32). 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 1982-1994 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

Table 2
Operational Definitions of Observed Whale Behaviors

Behavior	Definition
Breaching	Whale(s) launching upwards such that half to nearly all of the body is above the surface before falling back into the water, usually on its side, creating an obvious splash.
Cow-Calf	Calf nursing; calf swimming within 20 m of an adult.
Diving	Whale(s) changing swim direction or body orientation relative to the water surface, resulting in submergence; may or may not be accompanied by lifting the tail out of the water.
Feeding	Whale(s) diving repeatedly in a fixed general area, sometimes with mud streaming from the mouth and/or defecation observed upon surfacing. Feeding behavior is further defined as synchronous diving and surfacing or echelon-formations at the surface with swaths of clearer water behind the whale(s), or as surface swimming with mouth agape.
Flipper-Slapping	Whale(s) floating on side, striking the water surface with pectoral flipper one or many times; usually seen within groups or when the slapping whale is touching another whale.
Log Playing	Whale(s) milling or thrashing about in association with a floating log.
Mating	Ventral-ventral orienting of two whales, often with one or more other whales present to stabilize the mating pair. Mating is often seen within a group of milling whales. Pairs may appear to hold each other with their pectoral flippers and may entwine their tails.
Milling	Whale(s) swimming slowly at the surface in close proximity (within 100 m) to other whales, often with varying headings.
Resting	Whale(s) floating at the surface with head, or head and back exposed, showing no movement; more commonly observed in heavy-ice conditions than in open water.
Rolling	Whale(s) rotating on longitudinal axis, sometimes associated with mating.
Spy-Hopping	Whale(s) extending head vertically out of the water such that up to one-third of the body, including the eye, is above the surface.
Swimming	Whale(s) proceeding forward through the water propelled by tail pushes.
Tail-Slapping	Whale(s) floating horizontally or head-downward in the water, waving tail back and forth above the water and striking the water surface; usually seen in group situations.
Underwater Blowing	Whale(s) exhaling while submerged, thus creating a visible bubble.

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, 1993, 1994), repeat sightings or sightings of dead marine mammals were not included in summary analyses or maps. Where tables and figures exclude certain data, such exclusions are indicated in the captions.

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

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). If sample sizes were large ($n \geq 25$), a large-sample approximation (Zar, 1984: Page 113) was used to calculate the upper and lower limits.

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

The NEWSTAT program employed the Mann-Whitney U test to address the question of potential fine-scale shifts in the axis of the bowhead whale fall-migration route. The Mann-Whitney U test is a nonparametric procedure performed on ranked samples (Zar, 1984). The Normal Approximation to the Mann-Whitney Test

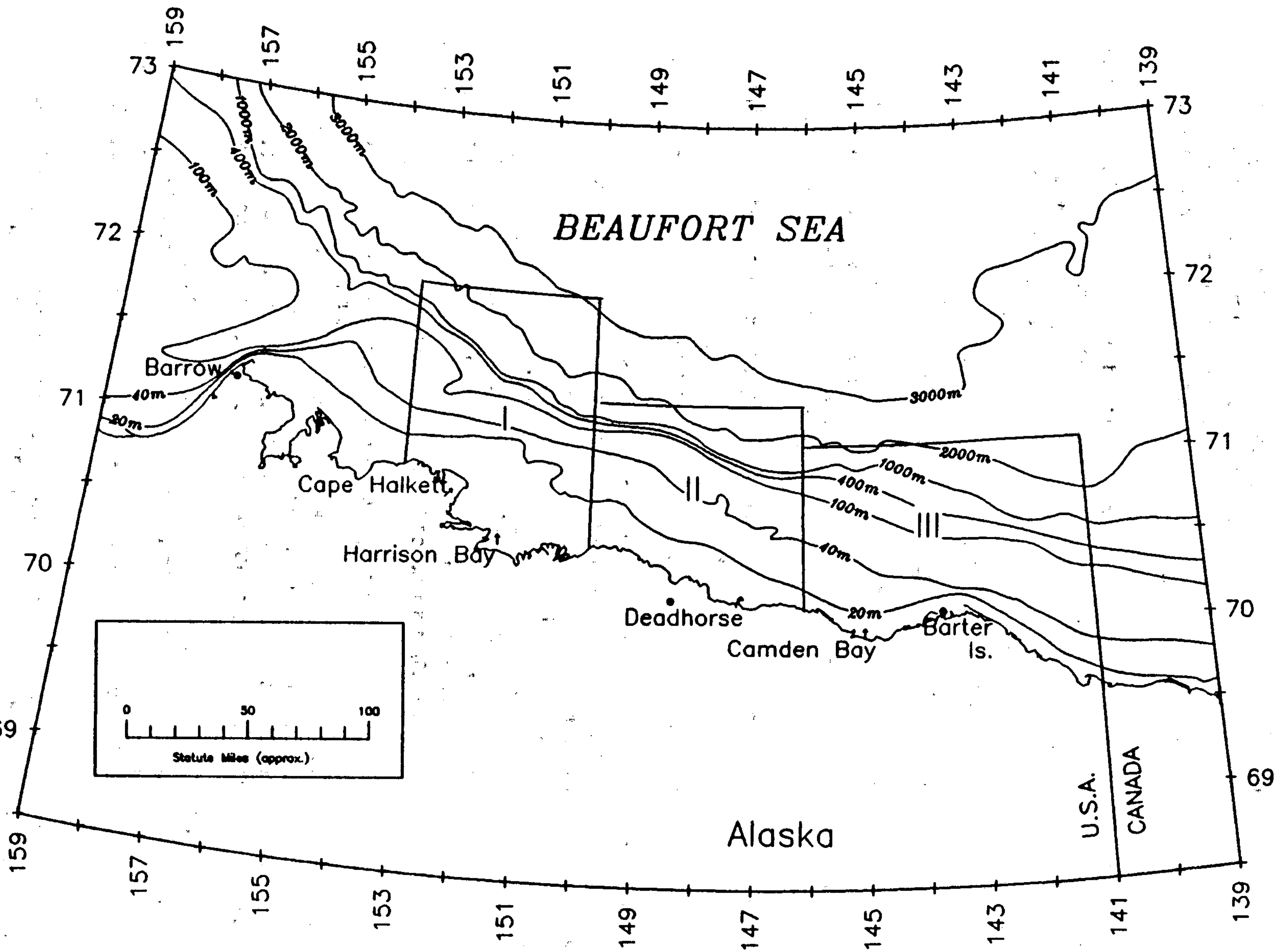

Figure 2. Regions I, II, and III (used in median-water-depth analyses) and Selected Isobaths

(Zar, 1984: Page 142) was used to hand-calculate the value of Z for larger sample sizes. A series of Mann-Whitney paired comparisons were made on annual depth values, with each year compared to all others such that annual and/or interannual shifts in migration route from 1982 to 1994 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).

III. RESULTS

A. Environmental Conditions

General ice coverage in the Alaskan Beaufort Sea was light during the Fall 1994 surveys (Figs. 3-12). During August (Figs. 3-4), there was a narrow strip of open water alongshore except for some light (>0-25%) ice concentrations contiguous with the shoreline between Barter Island, Alaska, and Herschel Island, Canada. During the first 3 weeks of September (Figs. 5-7), the nearshore ice concentrations generally diminished, widening the strip of open nearshore water across the Alaskan Beaufort Sea. By the end of September (Fig. 8), very heavy ice concentrations (>75%) were contiguous with the shoreline near Point Barrow, Alaska; and there was some very heavy shorefast ice in Camden Bay, just west of Barter Island. In early October (Fig. 9), the nearshore area was increasingly iced in. By mid-October (Figs. 10-11), very heavy ice concentrations (>75%) covered the Alaskan Arctic Ocean east of Icy Cape, Alaska, except for some moderate ice concentrations (51-75% and 26-50%) contiguous with the shoreline from Barter Island eastward into Canada. By the end of October (Fig.12), the Alaskan Arctic Ocean was essentially covered with very heavy ice (>75%) from Icy Cape to Banks Island, Canada.

The open-water conditions during Fall 1994 generally provided for good observation of subsurface whales, although associated high sea states sometimes reduced the ability of observers to spot whales near the surface or at great distances from the transect centerline. Cloud ceilings over portions of the study area were often lower than the target-survey altitude of 458 m. Overall, environmental conditions were considered favorable most of the time, permitting 33 flights in 48 days. Ice percent and sea state at each sighting of endangered whales are shown in Appendix B (Table B-1).

B. Survey Effort

Daily totals of kilometers and hours flown per survey flight are shown in Table 3. A total of 29,299 km of surveys were flown in 132.70 hours (Table 3) in the Beaufort Sea at an average speed of 220.8 km/hr. The average survey flight was 887.8 km, with flights ranging from 68 km to 1,539 km. Mean survey time per flight was 4.02 hr (SD = 1.92, n = 33). A total of 13,509 km of random-transect lines were flown in 60.45 hours (Table 3) at an average speed of 223.5 km/hr. These random transects constituted 46.1 percent of the total kilometers flown and 45.6 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, survey coverage was in the nearshore survey blocks east of Deadhorse (Fig. 13). There were 2.87 hours of random transects flown from a total of 5.63 flight hours during this period (Table 3), constituting 4.7 percent and 4.2 percent, respectively, of the total time spent in those effort categories.

During the first half of September, survey coverage was distributed between 140°W. and 154°W. longitudes, with most of the effort east of Harrison Bay within 60 nautical miles (nm) of shore (Fig. 14). There were 15.28 hours of random transects flown from a total of 34.35 flight hours during this period (Table 3), constituting 25.3 percent and 25.9 percent, respectively, of the total time spent in those effort categories.

During the second half of September, survey coverage was evenly distributed between 140°W. and 154°W. longitudes, mostly within 60 nautical miles (nm) of shore (Fig. 15). There were 15.62 hours of random transects flown from 33.37 total flight hours during this period (Table 3), constituting 25.8 percent and 25.1 percent, respectively, of the total time spent in those effort categories.

During the first half of October, survey coverage was distributed between 140°W. and 157°W. longitudes, with even coverage between 150°W. and 157°W. longitudes, south of 72°N. latitude (Fig. 16). There were

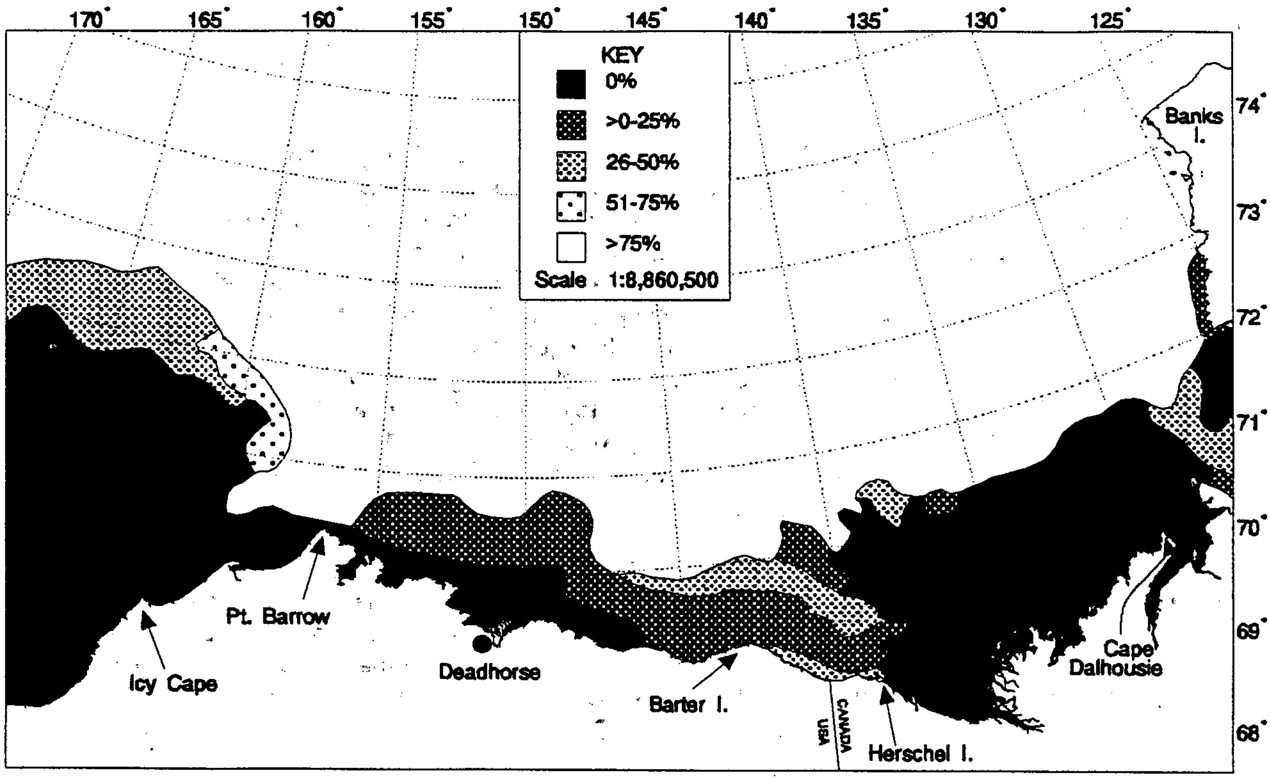

Figure 3. Map of Ice Concentrations in the Beaufort Sea, 23 August 1994.

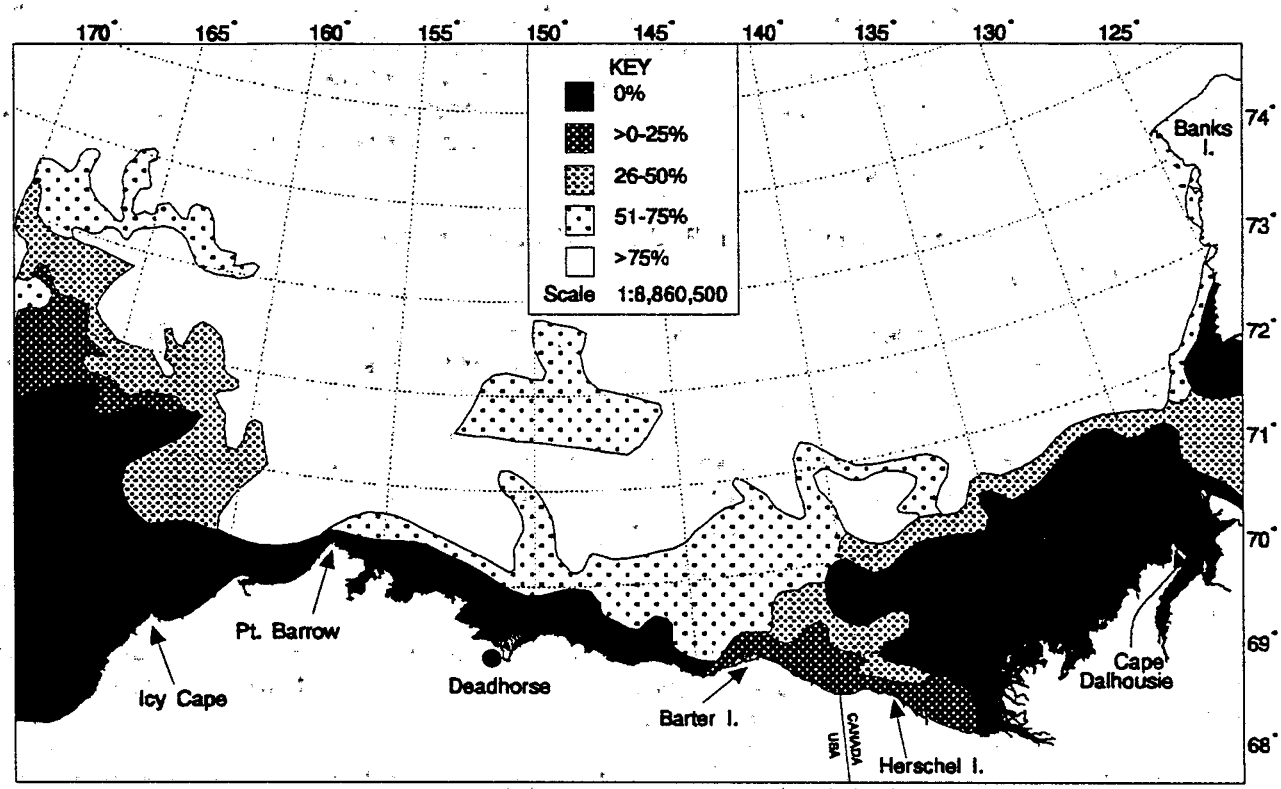

Figure 4. Map of Ice Concentrations in the Beaufort Sea, 30 August 1994

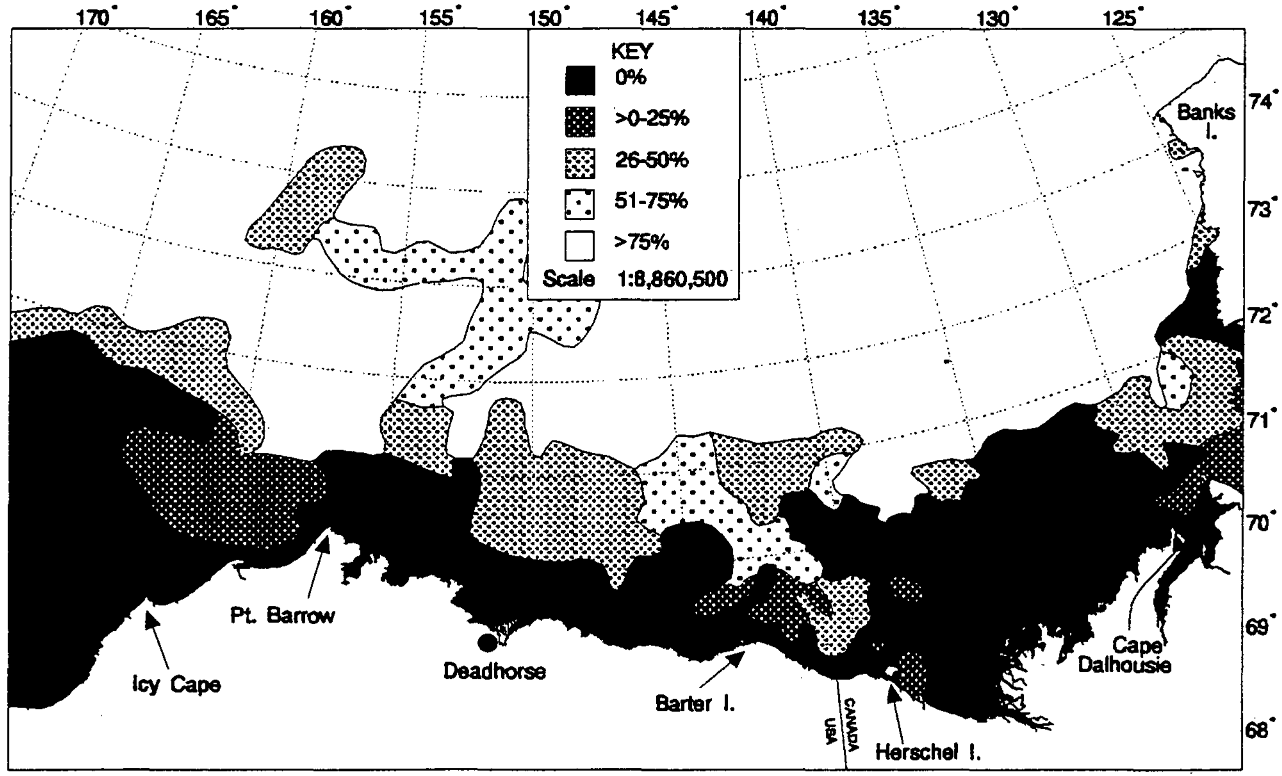

Figure 5. Map of Ice Concentrations in the Beaufort Sea, 6 September 1994.

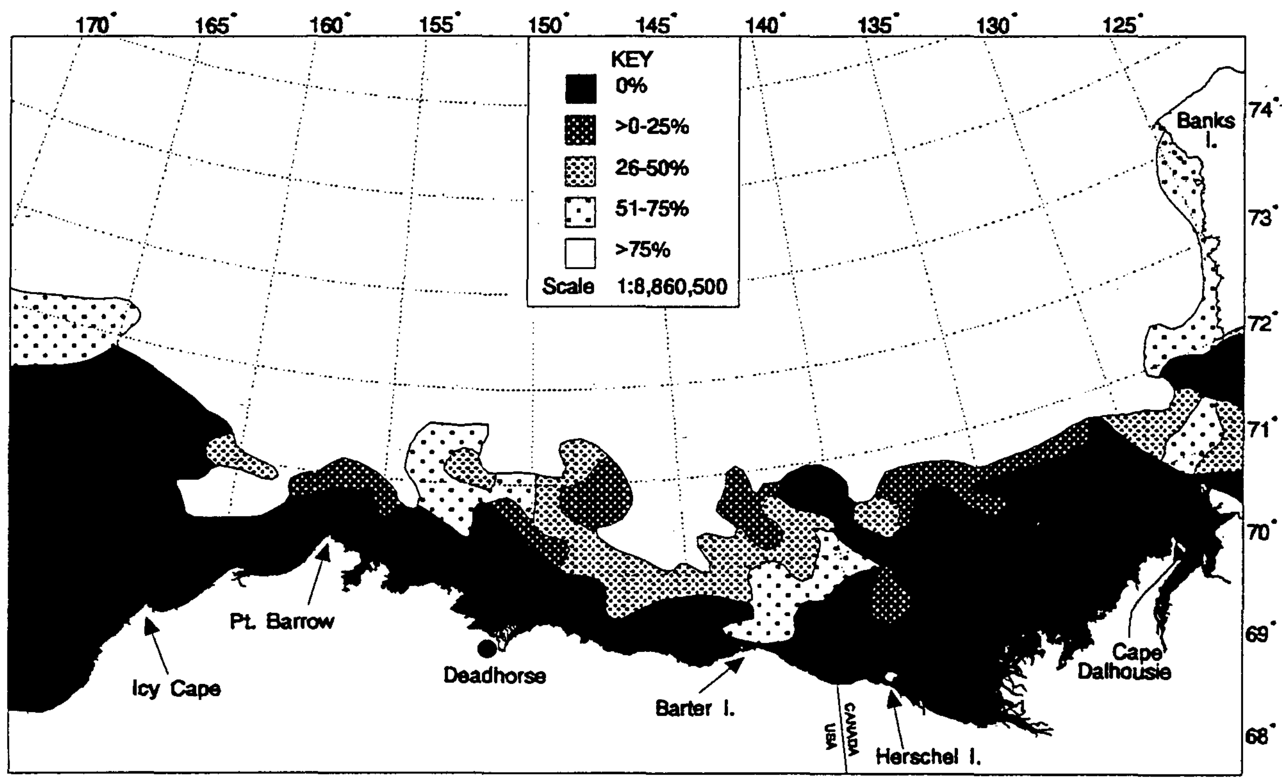

Figure 6. Map of Ice Concentrations in the Beaufort Sea, 13 September 1994

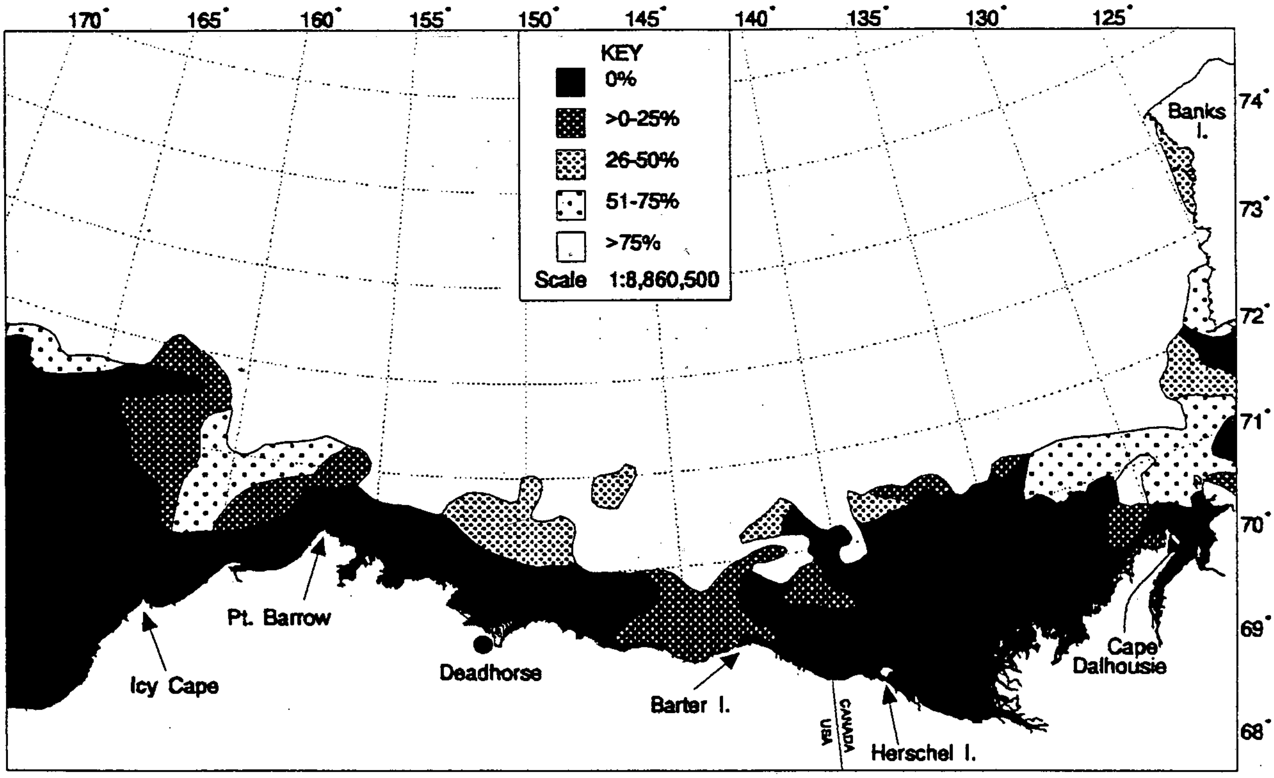

Figure 7. Map of Ice Concentrations in the Beaufort Sea, 20 September 1994

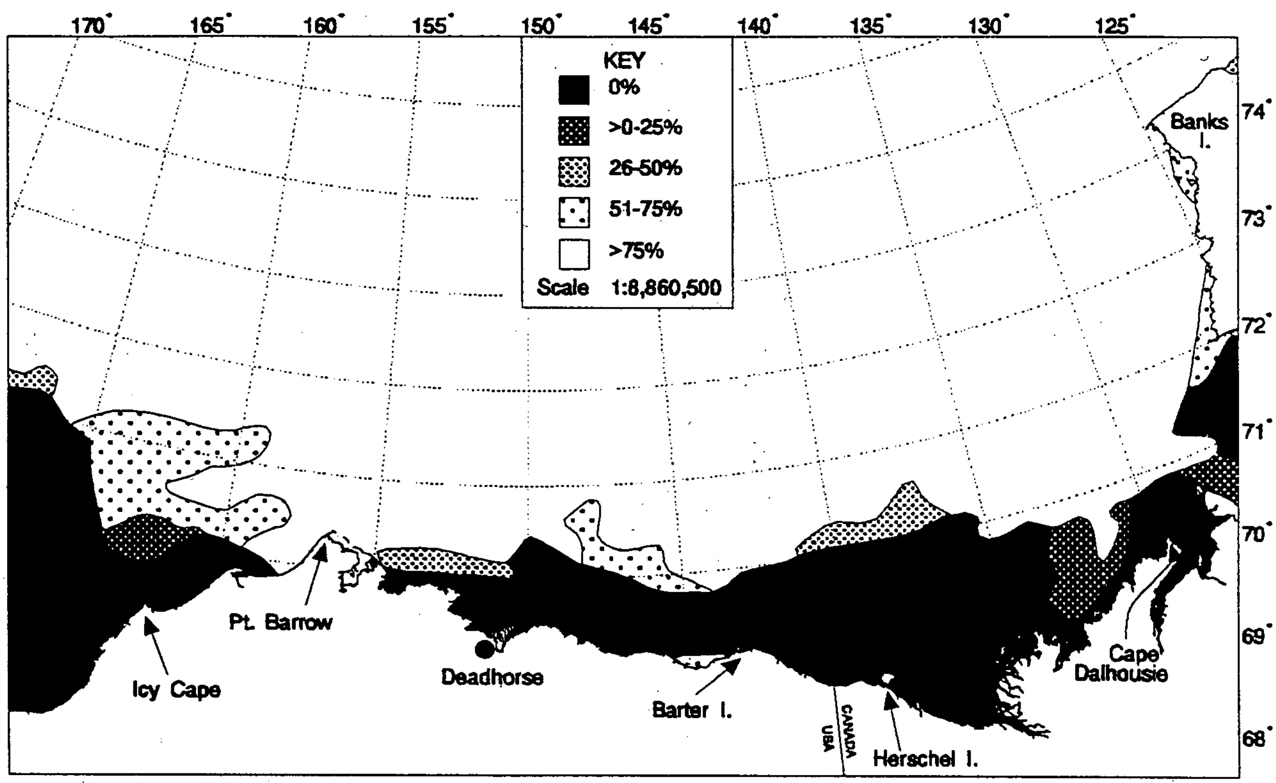

Figure 8. Map of Ice Concentrations in the Beaufort Sea, 27 September 1994

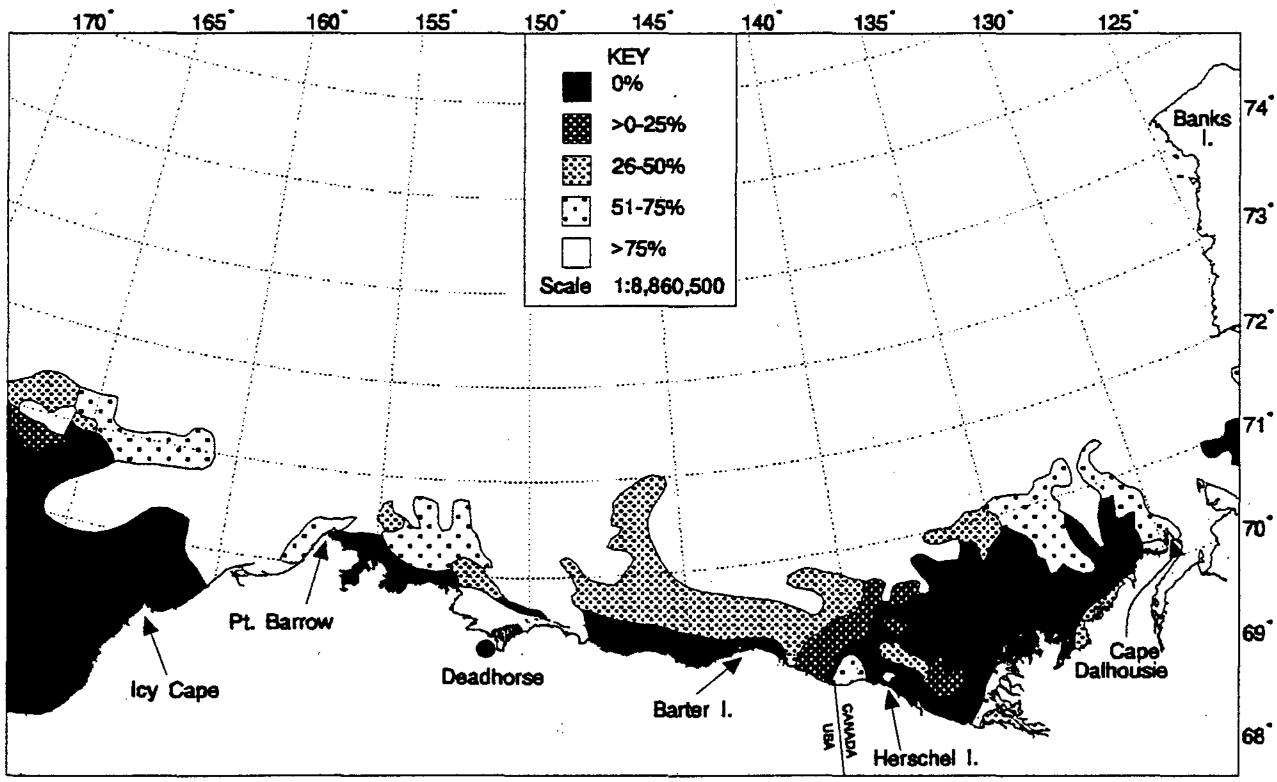

Figure 9. Map of Ice Concentrations in the Beaufort Sea, 4 October 1994

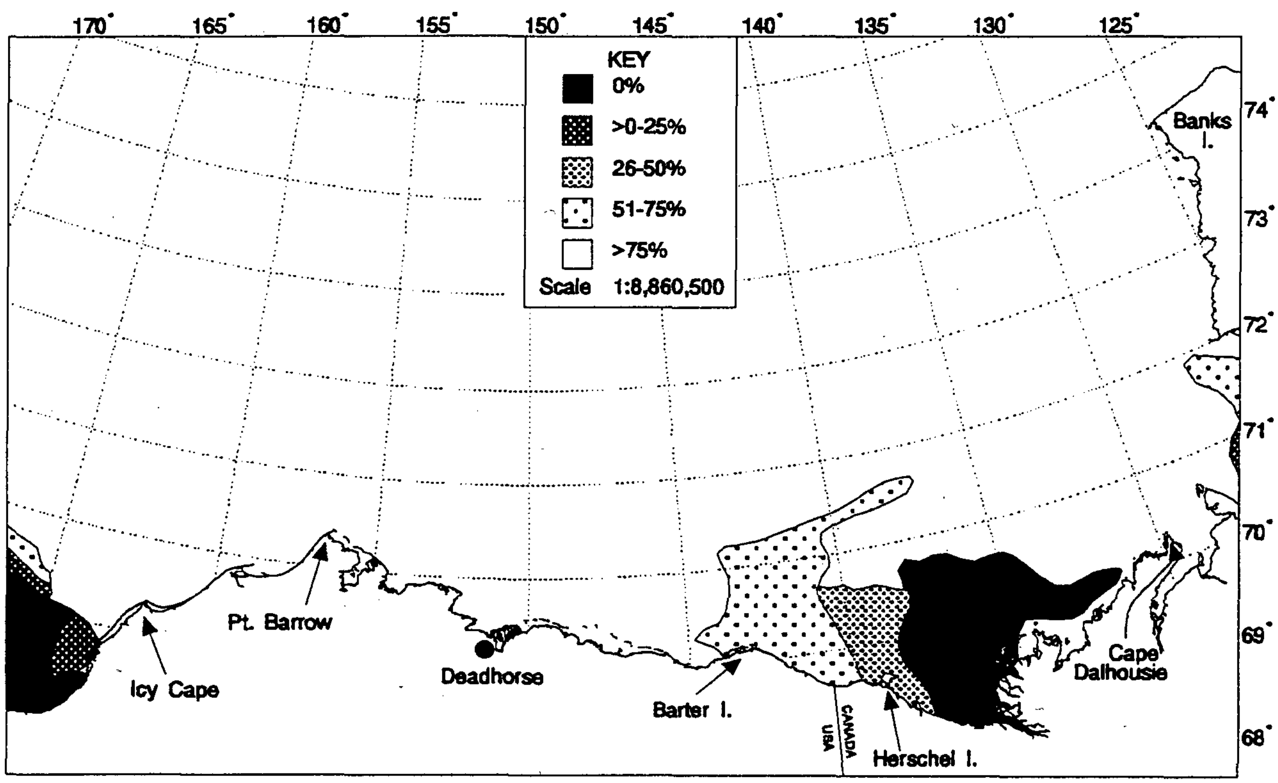

Figure 10. Map of Ice Concentrations in the Beaufort Sea, 11 October 1994

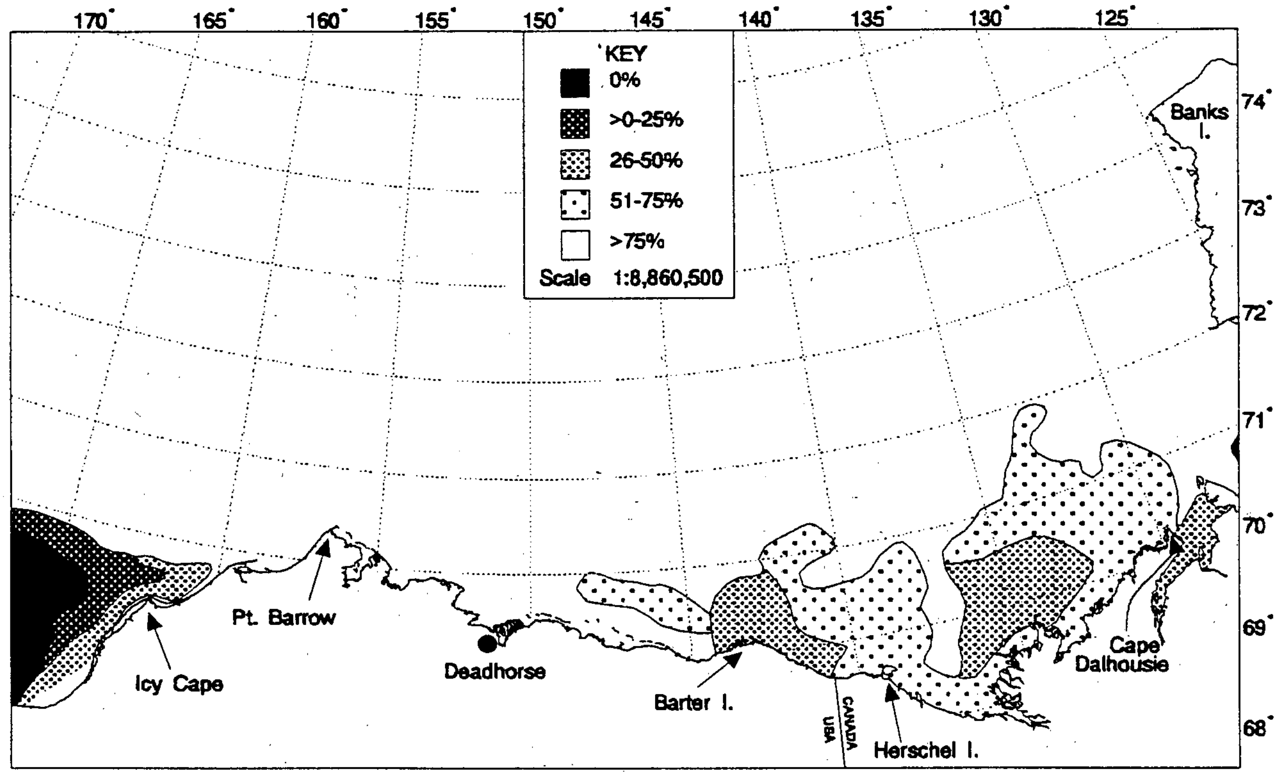

Figure 11. Map of Ice Concentrations in the Beaufort Sea, 18 October 1994

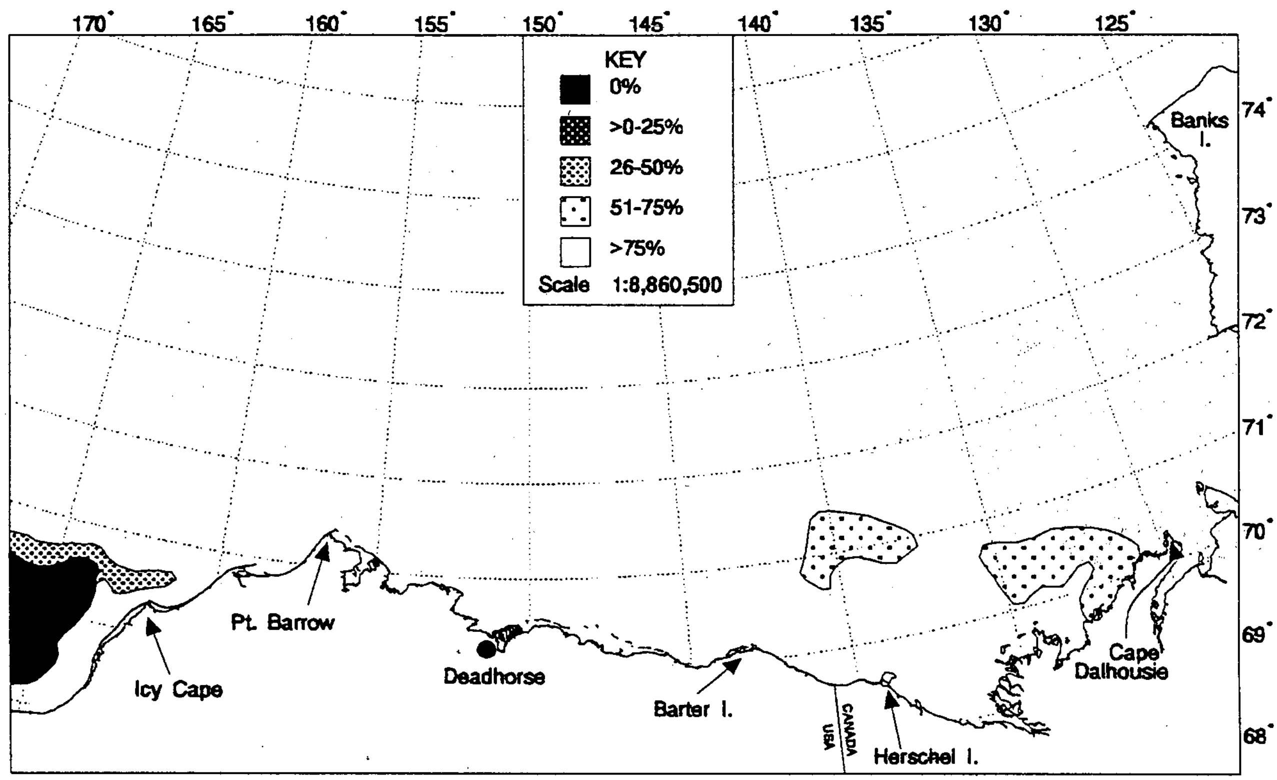

Figure 12. Map of Ice Concentrations in the Beaufort Sea, 25 October 1994

Table 3
Aerial-Survey Effort in the Beaufort Sea, 31 August-18 October 1994, by Survey Flight

Day	Flight No.	Transect (km)	Connect (km)	Search (km)	Total (km)	Transect Time (hr)	Total Survey Time (hr)
31 Aug	1	621	149	524	1,294	2.87	5.63
1 Sep	2	1090	205	237	1,532	4.77	6.77
2 Sep	3	201	74	591	866	0.88	3.97
4 Sep	4	165	16	417	598	0.75	2.98
5 Sep	5	0	0	68	68	0.00	0.28
5 Sep	6	119	0	497	616	0.53	2.77
7 Sep	7	318	95	404	817	1.38	3.65
8 Sep	8	614	97	171	882	2.73	4.28
9 Sep	9	460	111	553	1,124	2.15	5.25
12 Sep	10	0	0	141	141	0.00	0.68
13 Sep	11	451	81	296	828	2.08	3.72
16 Sep	12	0	0	337	337	0.00	1.42
17 Sep	13	815	117	252	1,184	3.72	5.57
20 Sep	14	0	0	204	204	0.00	0.93
22 Sep	15	415	73	601	1,089	1.77	4.77
23 Sep	16	635	63	454	1,152	2.72	5.03
24 Sep	17	718	54	382	1,154	3.28	5.70
25 Sep	18	149	20	224	393	0.63	1.70
27 Sep	19	377	98	185	660	1.82	3.20
28 Sep	20	110	0	385	495	0.47	2.10
29 Sep	21	274	108	258	640	1.22	2.95
1 Oct	22	670	87	266	1,023	2.98	4.62
7 Oct	23	150	0	417	567	0.67	2.65
8 Oct	24	548	51	588	1,187	2.47	5.05
10 Oct	25	979	189	348	1,516	4.25	6.62
11 Oct	26	1,000	121	269	1,390	4.73	6.60
12 Oct	27	39	0	613	652	0.15	2.87
13 Oct	28	544	62	629	1,235	2.52	6.02
14 Oct	29	1,120	124	295	1,539	4.92	7.02
15 Oct	30	0	0	398	398	0.00	1.68
16 Oct	31	405	22	636	1,063	1.78	4.92
17 Oct	32	522	56	553	1,131	2.22	4.82
18 Oct	33	0	0	1,524	1,524	0.00	6.50

Table 3
Aerial-Survey Effort in the Beaufort Sea, 31 August-18 October 1994, by Survey Flight
(Continued)

Semimonthly Period	Transect (km)	Connect (km)	Search (km)	Total (km)	Transect Time (hr)	Total Survey Time (hr)
31 Aug	621	149	524	1,294	2.87	5.63
1-15 Sep	3,418	679	3,375	7,472	15.28	34.35
16-30 Sep	3,493	533	3,282	7,308	15.62	33.37
1-15 Oct	5,050	634	3,823	9,507	22.68	43.12
16-18 Oct	927	78	2,713	3,718	4.00	16.23
TOTAL	13,509	2,073	13,717	29,299	60.45	132.70

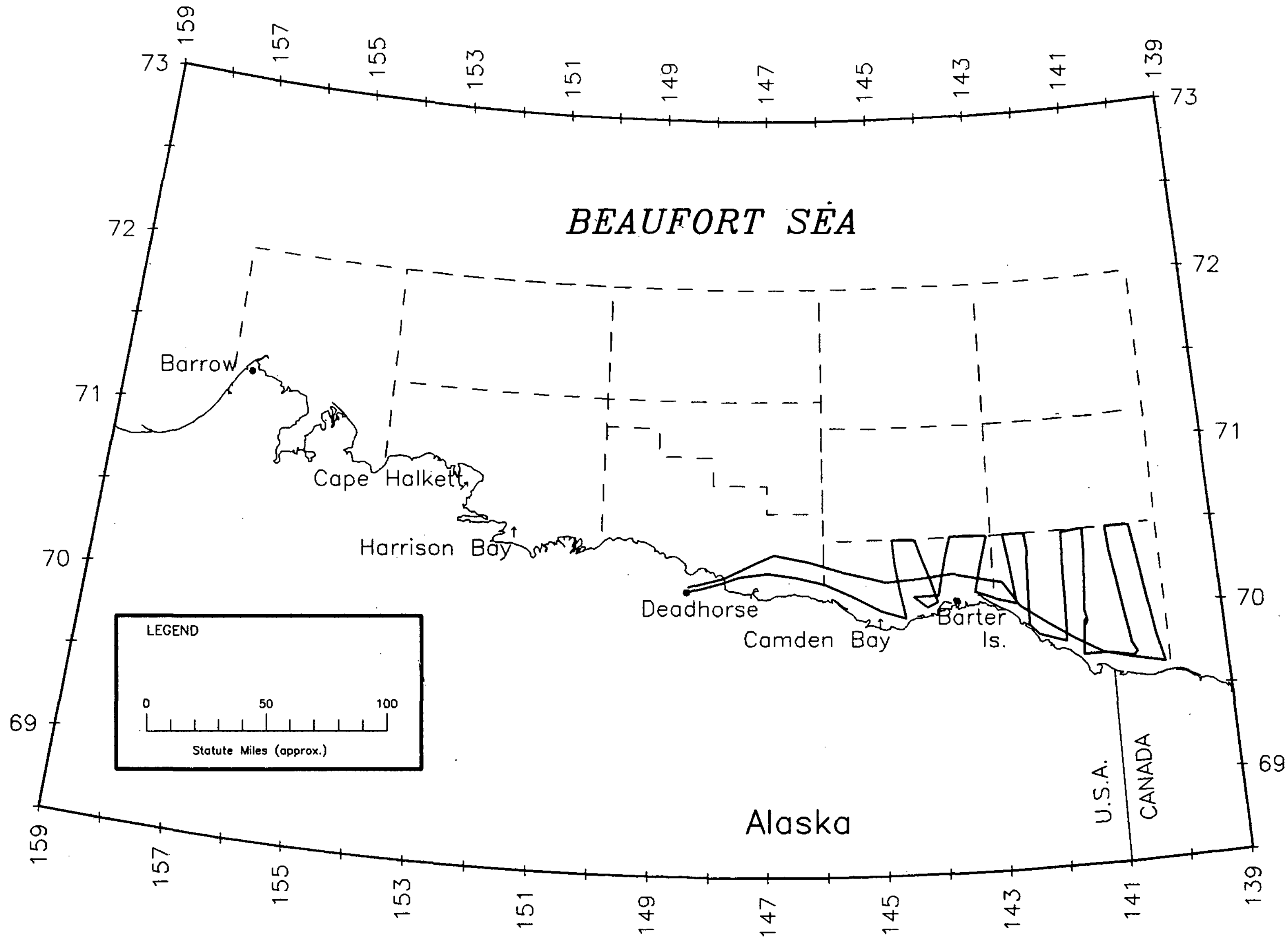

Figure 13. Flight Track, 31 August 1994

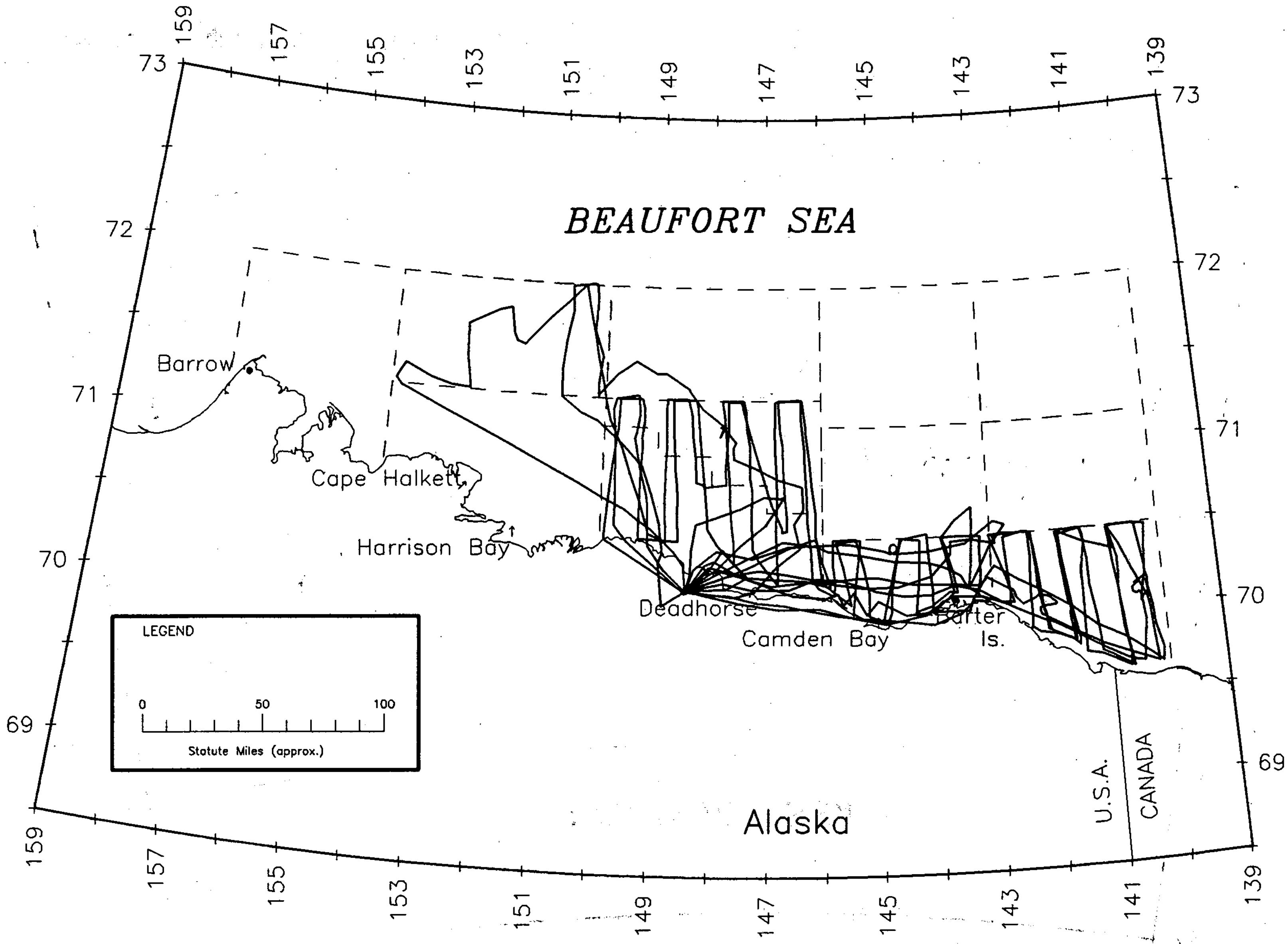

Figure 14. Combined Flight Tracks, 1–15 September 1994

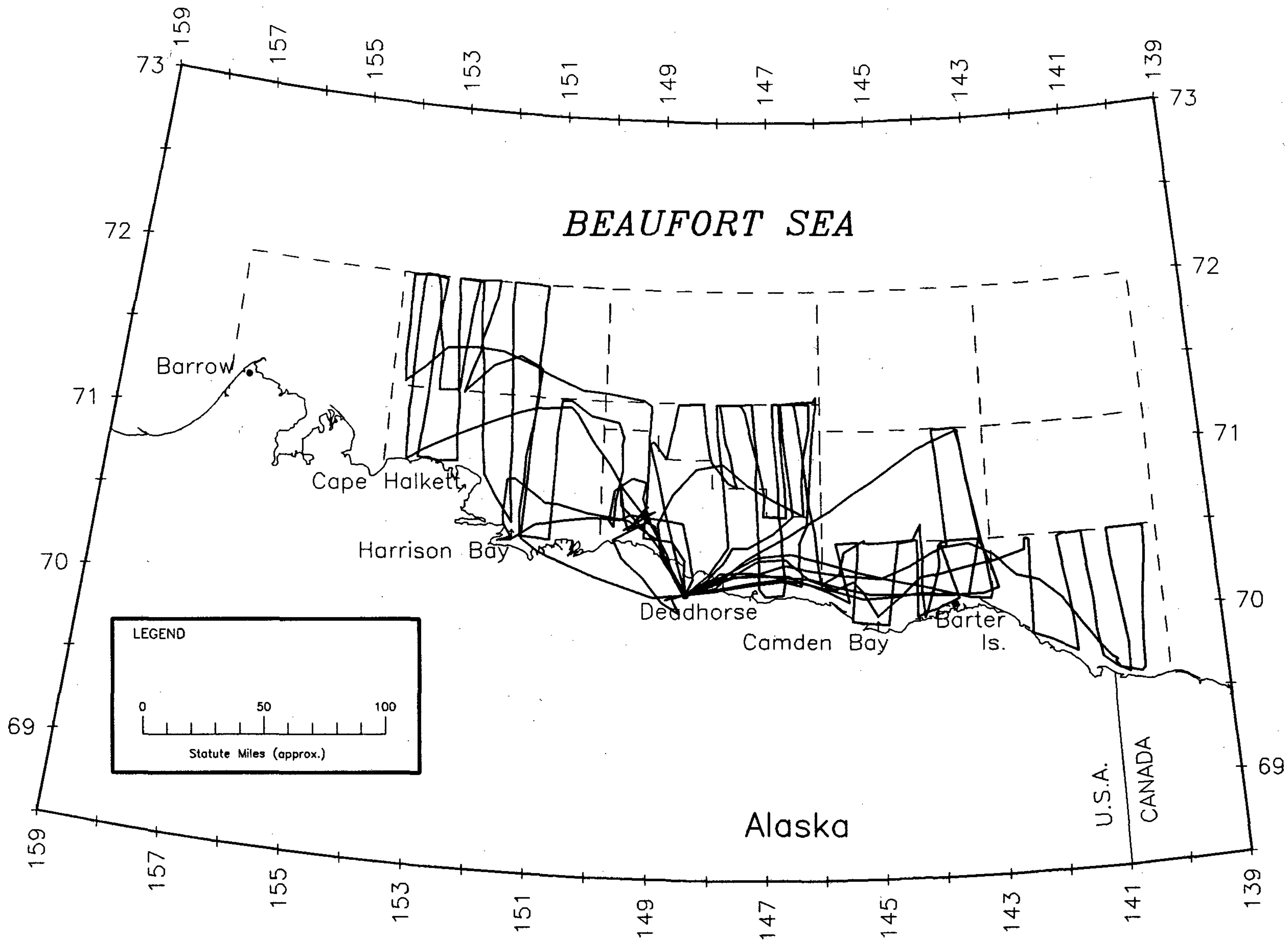

Figure 15. Combined Flight Tracks, 16–30 September 1994

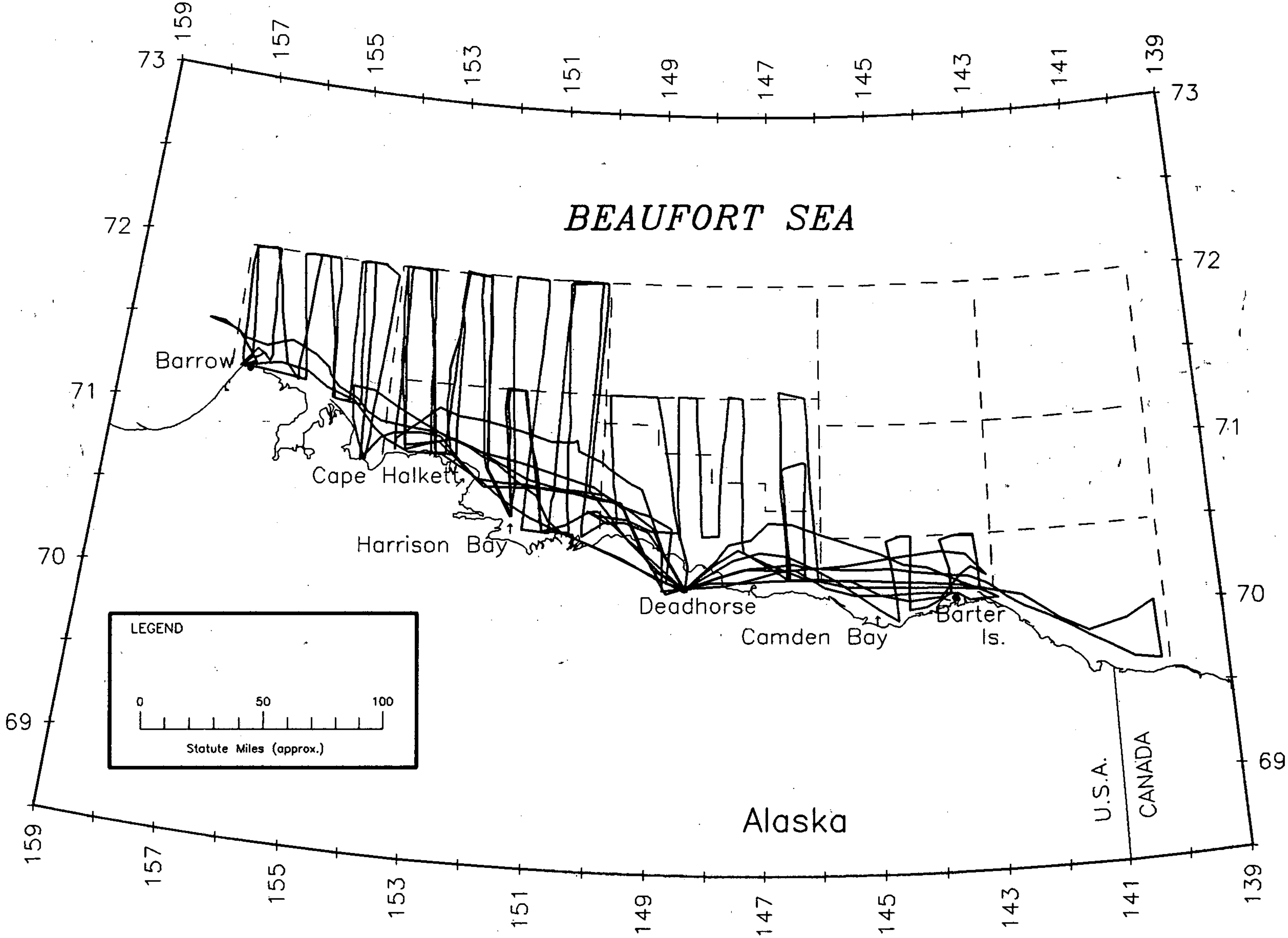

Figure 16. Combined Flight Tracks, 1–15 October 1994

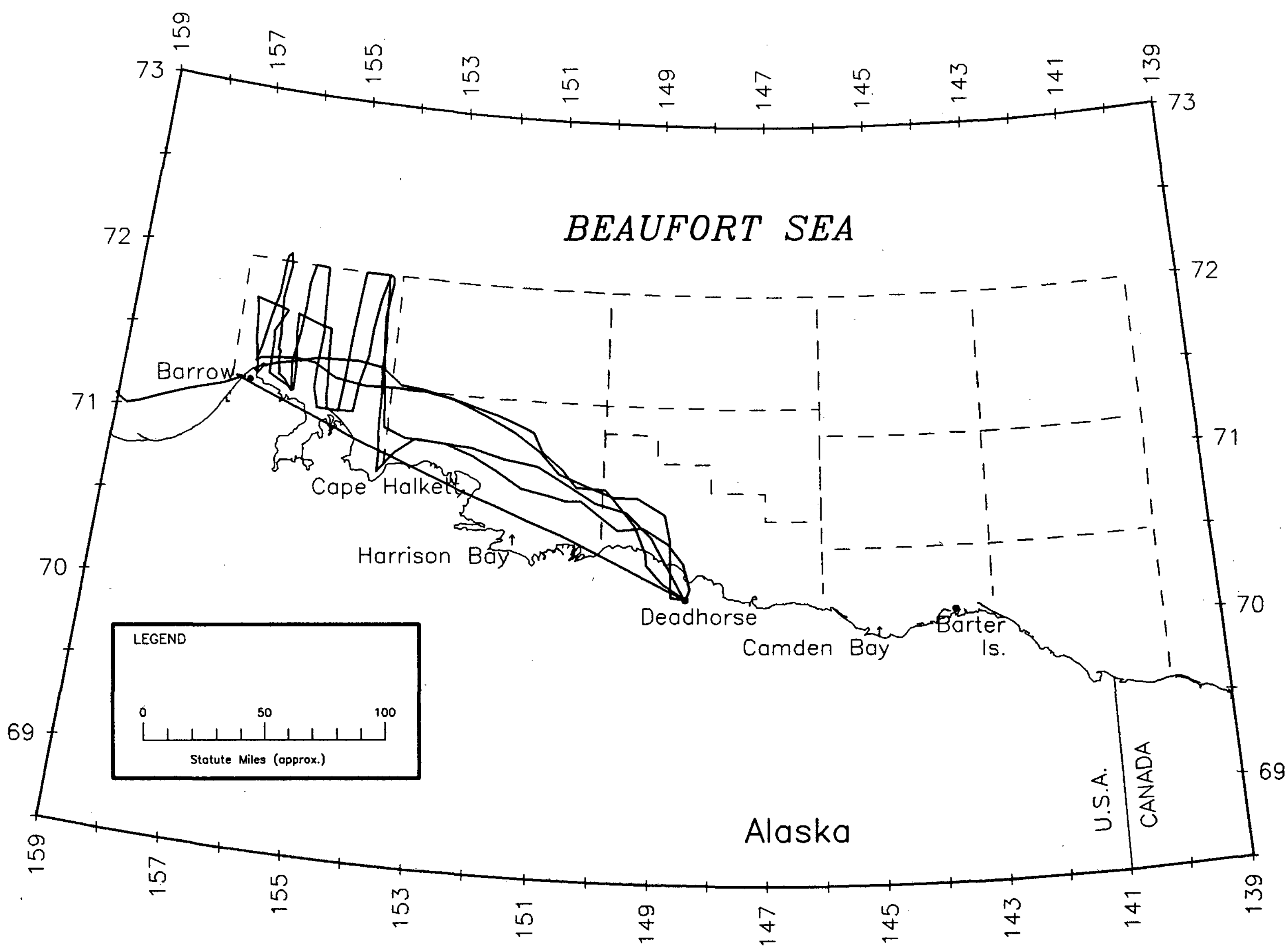

Figure 17. Combined Flight Tracks, 16–18 October 1994

22.68 hours of random transects flown from 43.12 total flight hours during this period (Table 3), constituting 37.5 percent and 32.5 percent, respectively, of the total time spent in those effort categories.

From 16 through 18 October, flight effort was distributed west of 148°W. longitude, with all transects conducted between 154°W. and 157°W. longitudes, south of 72°N. latitude (Fig. 17). During the return flight to Anchorage, one trackline extended southwest from Barrow, Alaska, along the Chukchi Sea coast. There were 4.00 hours of random transects flown from 16.23 total flight hours during this period (Table 3), constituting 6.6 percent and 12.2 percent, respectively, of the total time spent in those effort categories.

C. Bowhead Whale (*Balaena mysticetus*) Observations

1. Distribution: One hundred five sightings were made for a total of 204 bowhead whales observed during Fall-1994 surveys in the study area (Table 4 and Figs. 18-23), not counting repeat sightings. Three of these whales were identified as calves (Appendix B: Table B-1), resulting in a seasonal calf ratio (number calves/total whales) of 0.015. Daily sightings are shown on individual maps in Appendix B. A semi-monthly analysis follows.

On 31 August, 9 sightings were made for a total of 9 bowheads (Table 4), with sightings from 140°38.4'W. to 142°22.5'W. longitudes (Appendix B: Table B-1), based on survey coverage between 140°W. and 148°W. longitudes (Fig. 13). The whale pods were east of Barter Island, Alaska, within 30 nm north of the shoreline (Fig. 18). The first bowhead in the Alaskan Beaufort Sea was sighted on 31 August at 70°03.4'N. latitude, 141°24.3'W. longitude (Appendix B: Table B-1). Each pod contained only 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, 58 sightings were made for a total of 137 bowheads (Table 4), with sightings from 140°05.7'W. to 147°44.5'W. longitudes (Appendix B: Table B-1), based on survey coverage between 140°W. and 154°W. longitudes (Fig. 14). Most of the whale pods were east of Barter Island, Alaska, with only 1 pod west of 144°W.; all pods were within 60 nm north of the shoreline (Fig. 19). Pod sizes ranged from 1 to 14 whales (Appendix B: Table B-1), with a mean of 2.36 (SD = 2.24, n = 58).

An elongated aggregation of 29 bowhead whale pods (63 whales) was observed east of Barter Island between 141°39.0'W. and 143°15.0'W. longitudes, within 25 nm of shore on 2 September (Appendix B: Flight 3); a circular aggregation of 18 bowhead whale pods (63 whales) was observed just east of the Canadian border between 70°02.0'N. and 70°14.4'N. latitudes on 9 September (Appendix B: Flight 9). Two bowhead whale calves were observed during this period (2 September) at 70°06.2'N., 142°00.3'W. and 70°04.0'N., 141°41.2'W. (Appendix B: Table B-1).

During the second half of September, 30 sightings were made for a total of 46 bowheads (Table 4), with sightings from 140°23.5'W. to 152°40.6'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 40 nm north of the shoreline (Fig. 20). Pod sizes ranged from 1 to 6 whales (Appendix B: Table B-1), with a mean of 1.53 (SD = 1.20, n = 30). Only one bowhead whale calf was observed during this period (24 September) at 70°28.3'N., 143°53.4'W. (Appendix B: Table B-1).

During the first half of October, 7 sightings were made for a total of 11 bowheads (Table 4), with sightings from 146°37.0'W. to 157°32.6'W. longitudes (Appendix B: Table B-1), based on survey coverage between 143°W. and 158°W. longitudes (Fig. 16). The whale pods were fairly evenly distributed east-to-west over the area surveyed, within 50 nm north of the shoreline (Fig. 21). Pod sizes ranged from 1 to 3 whales (Appendix B: Table B-1), with a mean of 1.57 (SD = 0.79, n = 7). No bowhead whale calves were observed during this period (Appendix B: Table B-1).

From 16 through 18 October, no bowheads were seen in the primary study area. One sighting was made west of the study area (between 140°W. and 157°W. longitudes) for a total of 1 bowhead (Table 4) at 65°46.3'N. latitude, 167°57.6'W. longitude on 18 October (Appendix B: Table B-1), based on survey

Table 4
Summary of Marine Mammal Sightings, 31 August-18 October 1994, by Survey Flight
(number of sightings/number of animals)

Day	Flight No.	Bowhead Whale	Belukha Whale	Gray Whale	Bearded Seal	Ringed Seal	Pacific Walrus	Unidentified Pinniped	Polar Bear (PB)	PB Tracks (no bear)	Arctic Fox
31 Aug	1	9/9	4/27	0	2/2	2/3	0	0	0	0	0
1 Sep	2	2/2	11/101	0	1/2	33/239	0	1/1	0	0	0
2 Sep	3	29/63	0	0	0	3/22	0	1/2	0	0	0
4 Sep	4	0	8/33	0	1/1	1/8	0	0	1/2	0	0
5 Sep	5	0	0	0	0	0	0	0	0	0	0
5 Sep	6	0	0	0	0	0	0	0	0	0	0
7 Sep	7	2/2	0	0	3/4	1/1	0	0	0	0	0
8 Sep	8	0	6/18	0	2/2	2/4	0	0	2/9	2	0
9 Sep	9	20/65	3/4	0	2/3	6/12	0	1/1	2/4	0	0
12 Sep	10	0	0	0	0	1/2	0	0	0	0	0
13 Sep	11	5/5	3/3	0	7/8	10/18	0	1/1	0	0	0
16 Sep	12	0	0	0	0	2/10	0	0	0	0	0
17 Sep	13	3/8	24/141	0	3/4	7/12	0	0	0	3	0
20 Sep	14	0	0	0	0	0	0	0	0	0	0
22 Sep	15	11/16	7/37	0	0	0	0	0	0	0	0
23 Sep	16	0	9/45	0	0	0	0	0	0	0	0
24 Sep	17	13/18	1/42	0	1/1	1/1	0	0	0	0	0
25 Sep	18	0	1/2	0	0	0	0	0	0	0	0
27 Sep	19	0	2/2	0	1/2	3/5	0	0	0	4	0
28 Sep	20	0	0	0	0	0	0	0	0	0	0
29 Sep	21	3/4	0	0	0	0	0	0	0	0	0
1 Oct	22	2/2	8/35	0	5/18	1/1	0	0	0	0	0
7 Oct	23	2/4	0	0	0	0	0	1/1	1/1	0	0
8 Oct	24	1/2	3/7	0	7/22	3/9	0	2/2	0	10	0
10 Oct	25	0	0	0	2/4	6/10	0	1/1	0	14	0
11 Oct	26	0	2/17	0	5/6	8/18	0	1/1	0	3	0
12 Oct	27	0	0	0	0	0	0	0	0	3	0
13 Oct	28	2/3	0	0	1/1	1/1	0	1/1	1/1	15	0
14 Oct	29	0	0	0	0	3/4	0	1/1	3/6	19	2

Table 4
Summary of Marine Mammal Sightings, 31 August-18 October 1994, by Survey Flight
(number of sightings/number of animals)
(Continued)

Day	Flight No.	Bowhead Whale	Belukha Whale	Gray Whale	Bearded Seal	Ringed Seal	Pacific Walrus	Unidentified Pinniped	Polar Bear(PB)	PB Tracks (no bear)	Arctic Fox
15 Oct	30	0	0	0	0	0	0	0	0	7	0
16 Oct	31	0	0	0	1/1	0	0	0	2/4	10	0
17 Oct	32	0	0	0	0	1/1	0	0	3/5	16	0
18 Oct	33	1/1	0	0	0	0	0	1/7	0	1	0
Total Semimonthly Sightings											
31 Aug		9/9	4/27	0	2/2	2/3	0	0	0	0	0
1-15 Sep		58/137	31/159	0	16/20	57/304	0	4/5	5/15	2	0
16-30 Sep		30/46	44/269	0	5/7	13/28	0	0	0	7	0
1-15 Oct		7/11	13/59	0	20/51	22/43	0	7/7	5/8	71	2
16-18 Oct		1/1	0	0	1/1	1/1	0	1/7	5/9	27	0
TOTAL		105/204	92/514	0	44/81	95/379	0	12/19	15/32	107	2

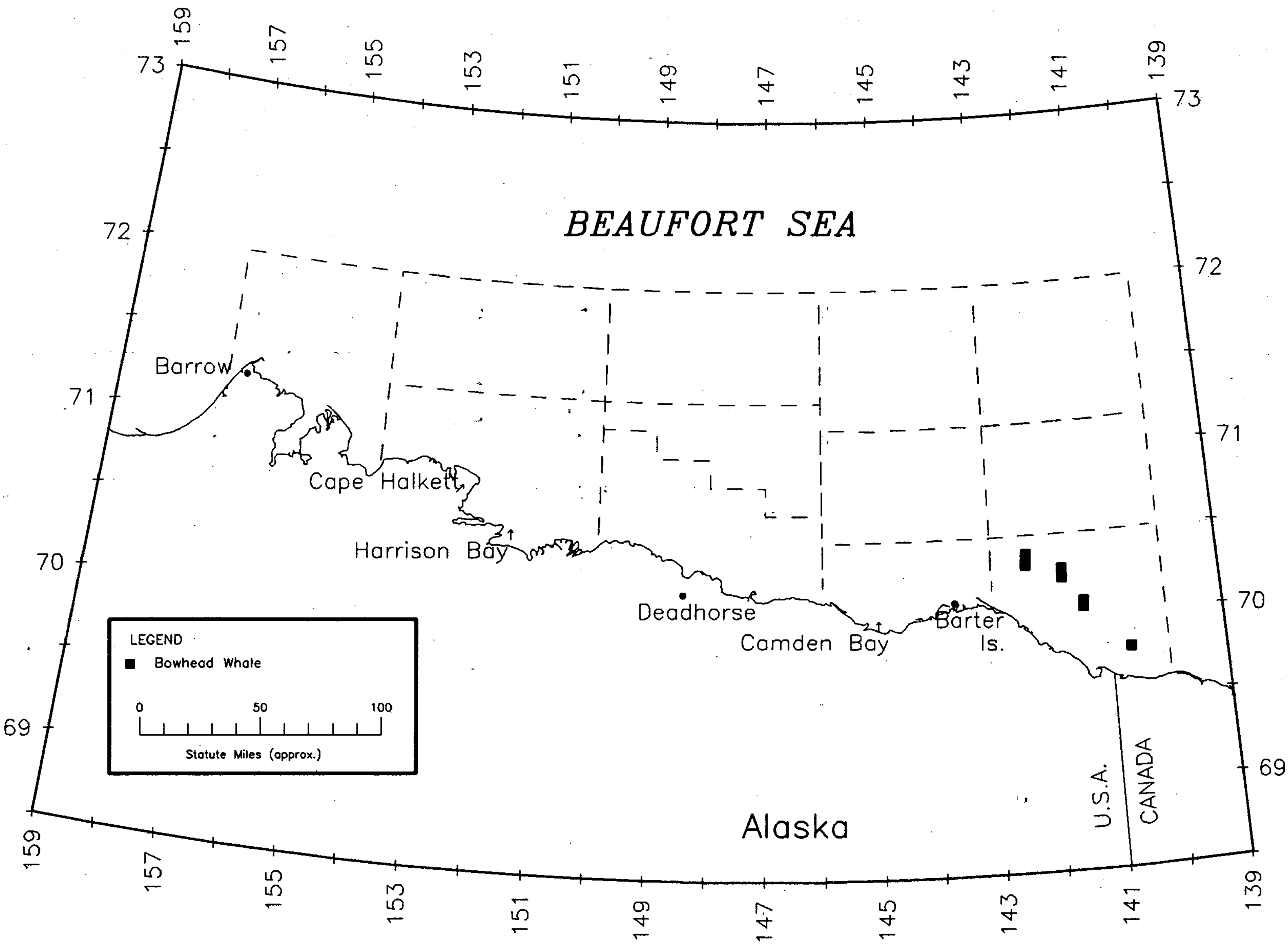

Figure 18. Map of Bowhead Whale Sightings, 31 August 1994

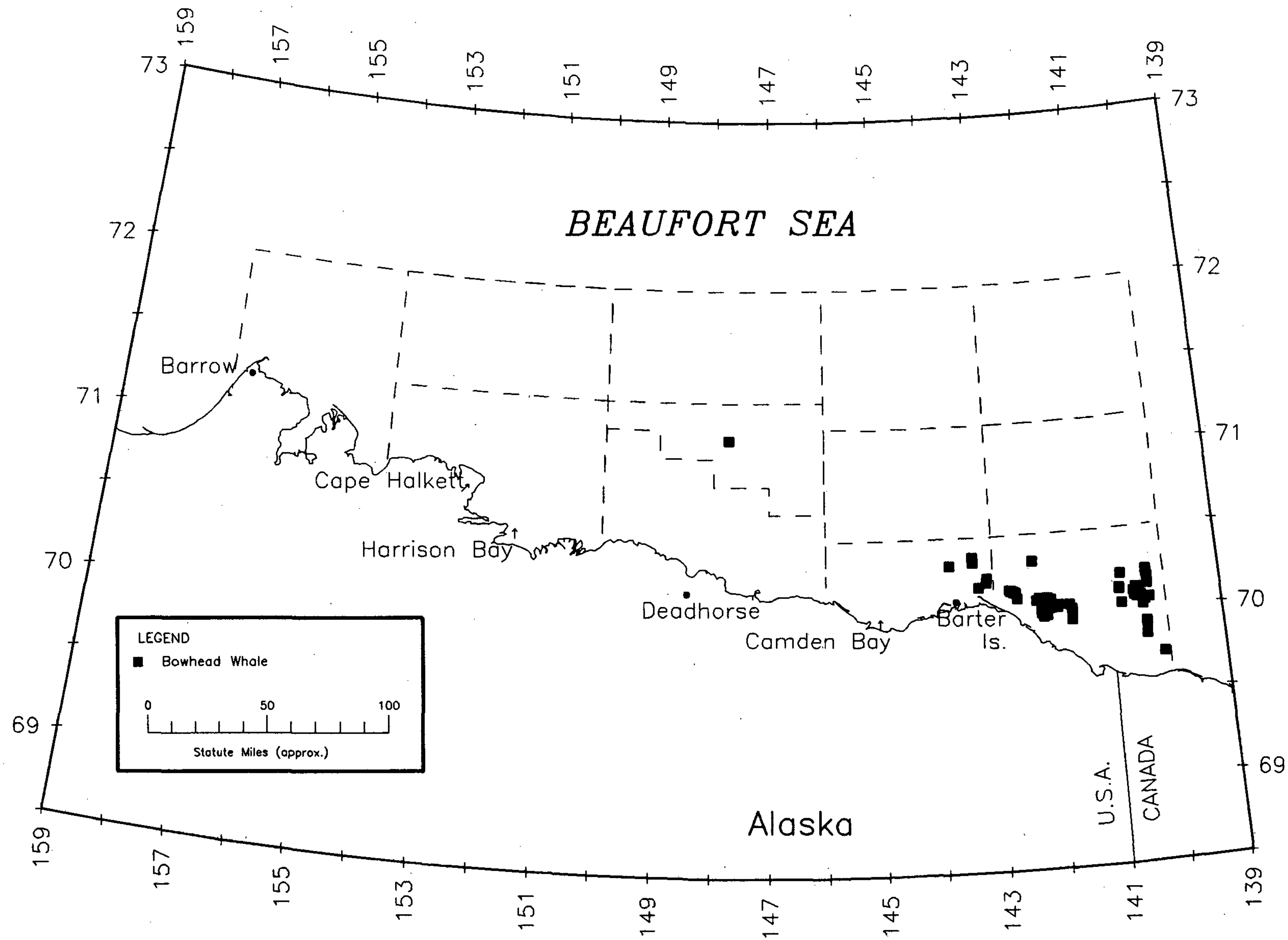

Figure 19. Map of Bowhead Whale Sightings, 1–15 September 1994

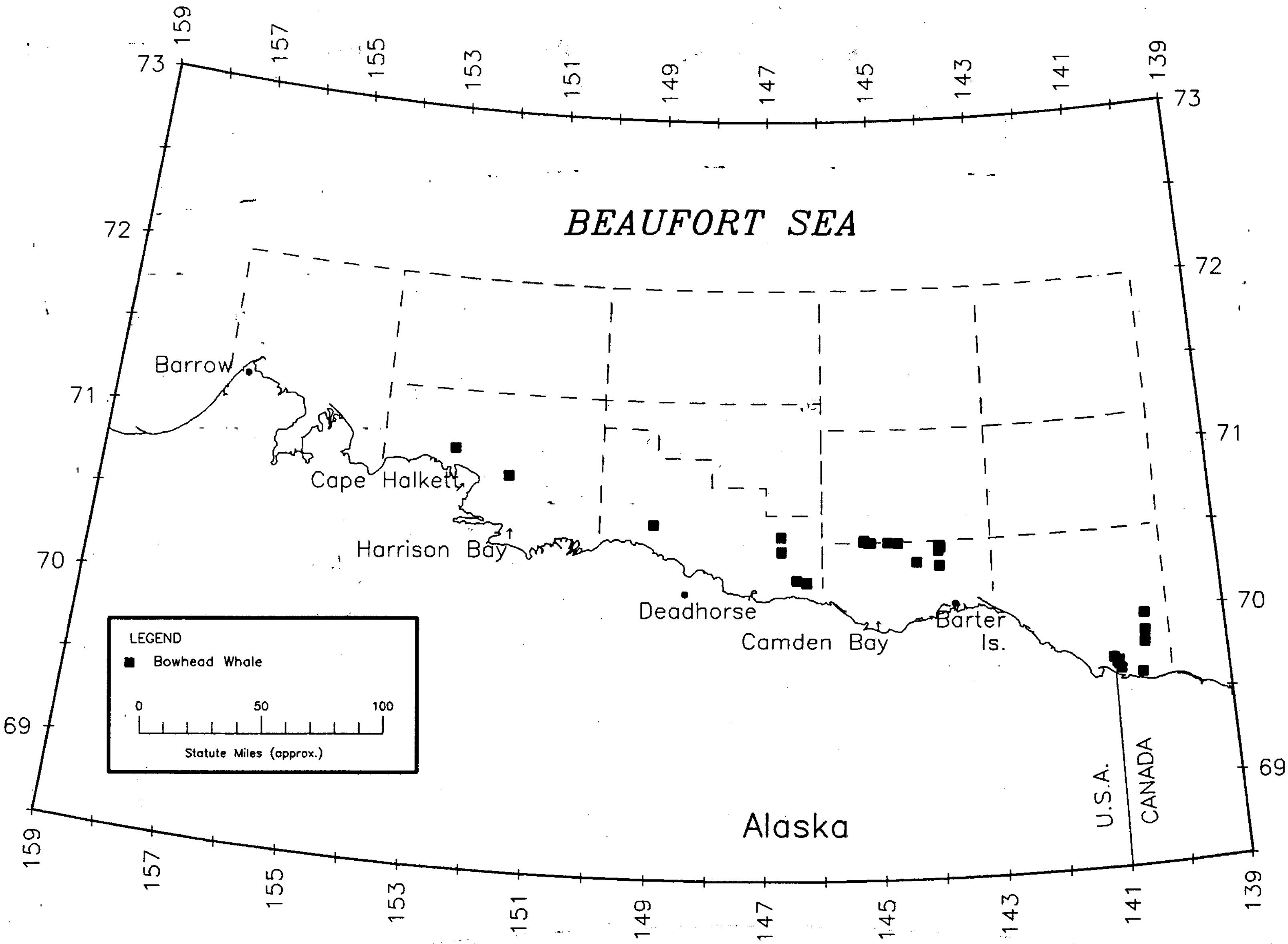

Figure 20. Map of Bowhead Whale Sightings, 16–30 September 1994

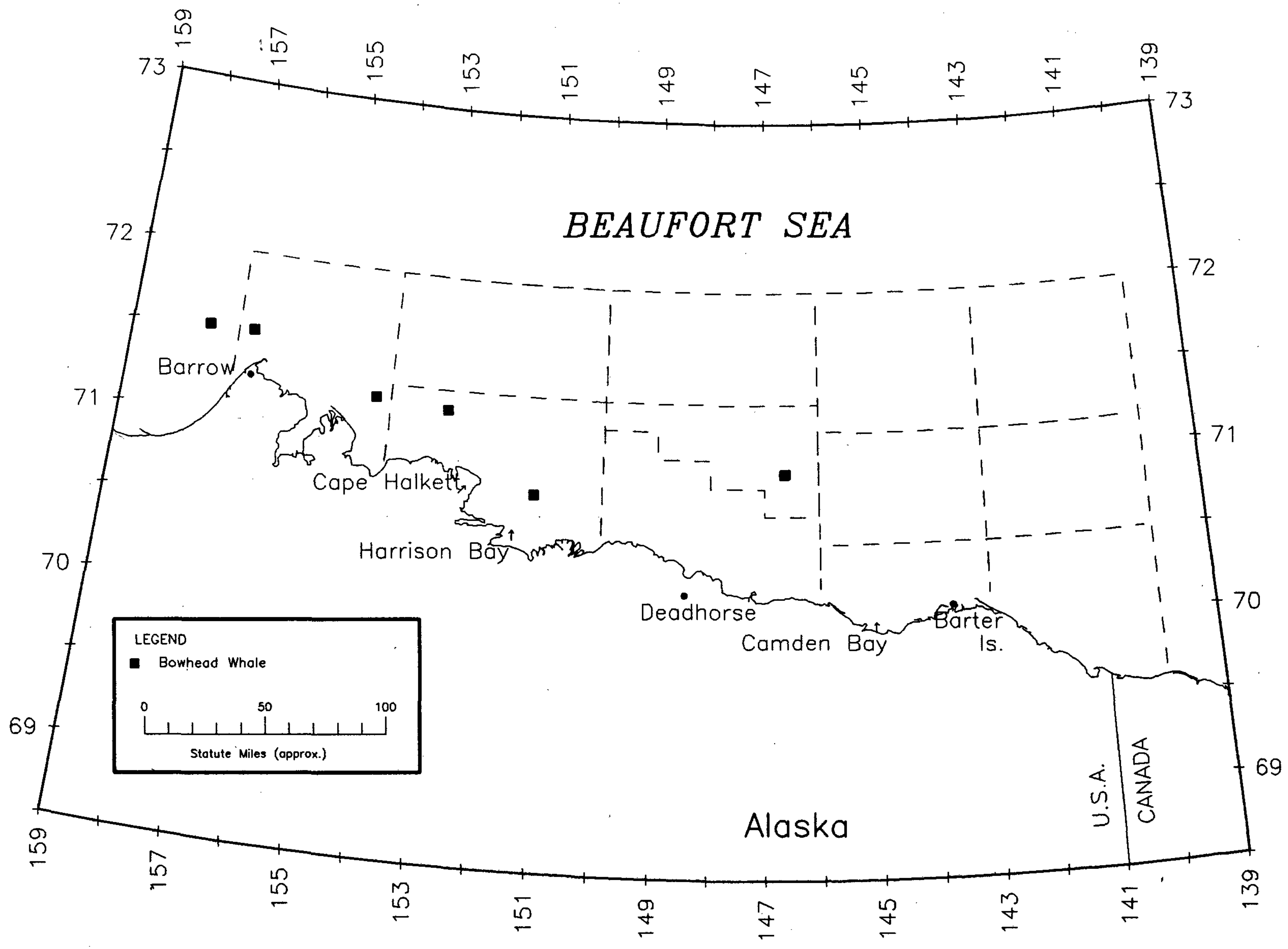

Figure 21. Map of Bowhead Whale Sightings, 1–15 October 1994

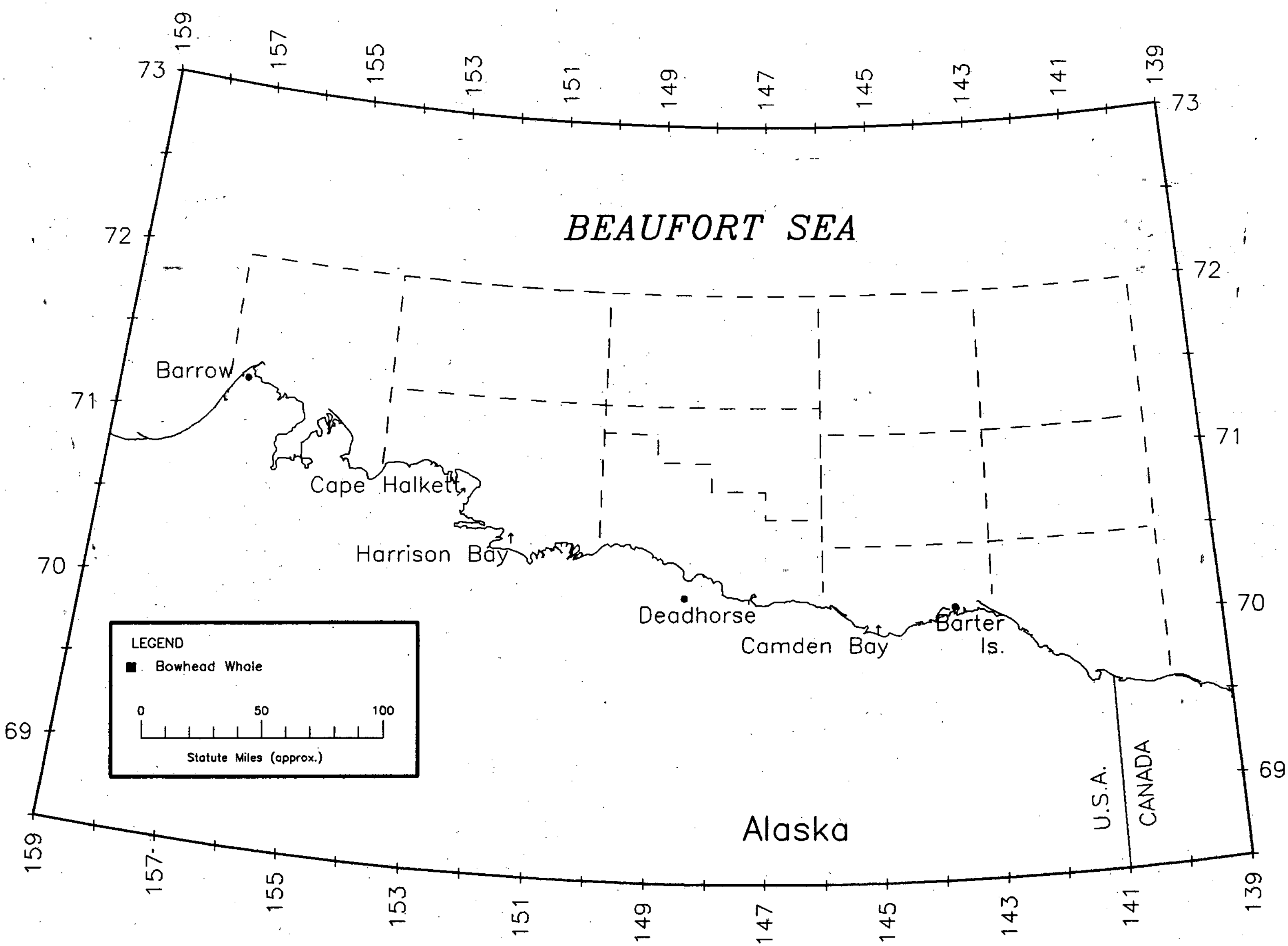

Figure 22. Map of Bowhead Whale Sightings, 16–18 October 1994

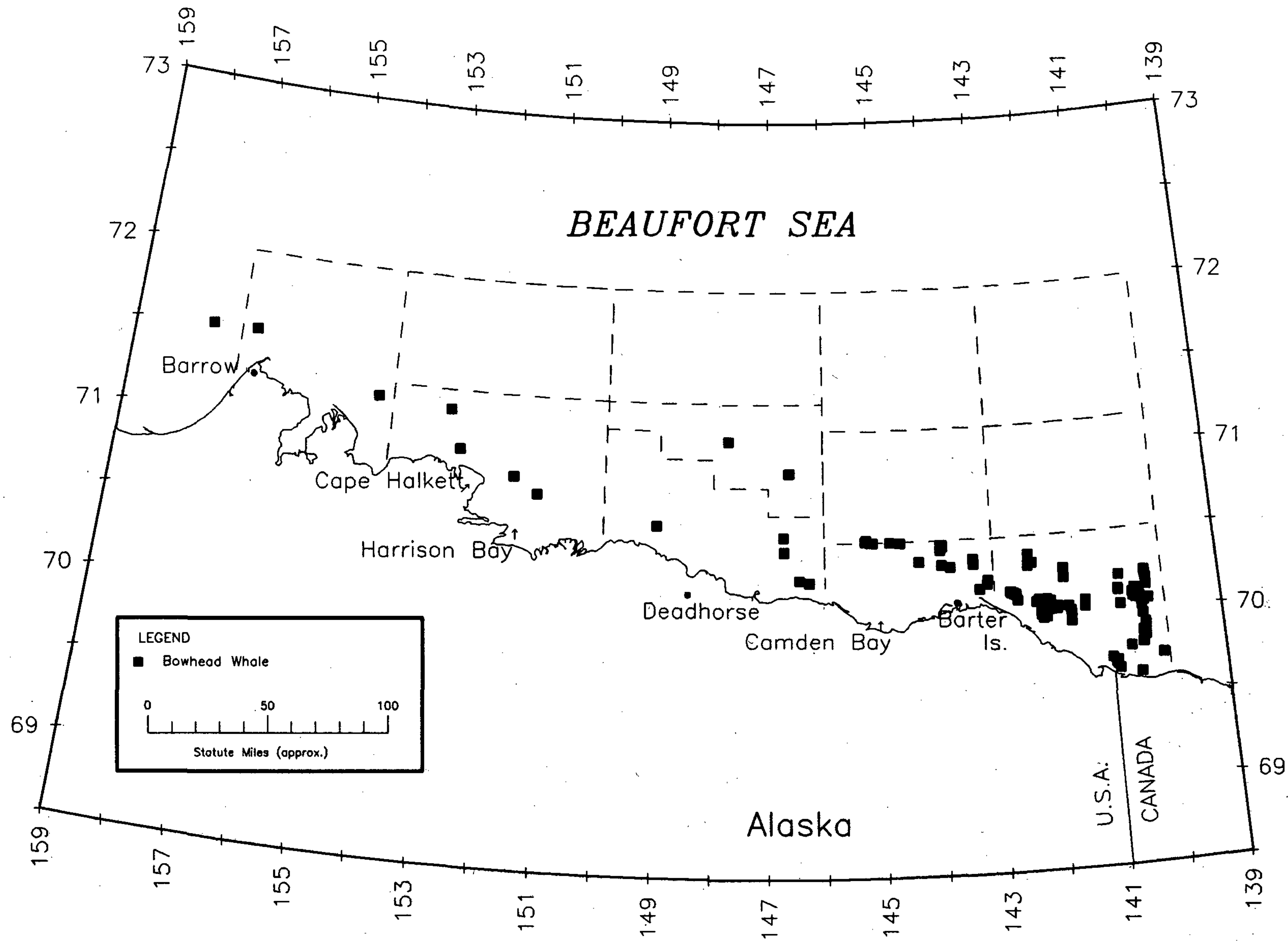

Figure 23. Map of Bowhead Whale Sightings, Fall 1994

coverage between 148°W. and 168°W. longitudes (Fig. 17). No bowhead whale calves were observed during this period (Appendix B: Table B-1).

2. Migration Timing: The day-to-day timing of the bowhead whale migration was calculated over the entire study area (Table 5 and Fig. 24) as a daily sighting rate, or sightings per unit effort (SPUE), and an index of relative abundance, or whales per unit effort (WPUE).

Of the 105 observed sightings of bowhead whales, Table 5 shows that the first bowhead whales were sighted on 31 August. The data for daily sighting rates show a peak of 7.30 SPUE on 2 September, followed by a second peak of 3.81 SPUE on 9 September.

A large aggregation of bowhead whale pods was observed in eastern Block 5 on 2 September (see Sec. III.C.1 above), representing the peak relative abundance for Fall 1994. The aggregation did not appear to be migratory. Of those whale pods exhibiting a deliberate swim direction on 2 September, only 36 percent appeared to be headed in a true (T) westerly direction (between 226°T and 315°T). A second large aggregation was observed in eastern Block 5 on 9 September, with 69 percent of swimming pods headed in a true westerly direction.

The last sighting of a bowhead was made west of the study area on 18 October, following 4 days in which no bowhead whales were sighted (Table 5 and Fig. 24).

Of the 204 bowhead whales counted during this period, the data for daily relative abundance (WPUE) show that the midpoint (median) of the bowhead migration in Blocks 1 through 12 (when 50% of all sighted whales had been recorded) occurred on 9 September (Table 5). The peak relative abundance (mode) of 15.87 WPUE occurred on 2 September (Table 5 and Fig. 24).

The most prominent differences in pattern between the graph for relative abundance and that for sighting rate occurred on 2 September and 9 September (Fig. 24), due to the several large pods of whales observed 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 west of 157°W. longitude, in Canadian waters east of 140°W. longitude, and in Alaskan waters outside of historically monitored survey blocks, was calculated in Table 6. Over the field season (31 August-18 October), there were 6 survey blocks in which ≥15.00 hr of survey effort were made. Of these coastal or offshore blocks (Blocks 1, 3, 4, 5, 11, and 12), coastal Block 5 (9.02 WPUE) had the greatest relative abundance, followed by Block 4 (0.99 WPUE), Block 3 (0.42 WPUE), and Block 1 (0.42 WPUE), Block 12 (0.22 WPUE), and Block 11 (0.00 WPUE) (Table 6).

On 31 August, there were no blocks in which ≥4.00 hr of survey effort were made. Although only 3.12 hr of survey effort were made in Block 5, it was notable that 9 whales were observed in this coastal block, for a high relative abundance (2.88 WPUE). No bowheads were observed during a total of 2.52 hr of survey effort in the remaining blocks (Blocks 1, 4, 6, and 7) of the primary study area or adjacent waters (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 or offshore blocks (Blocks 1, 2, 4, and 5), coastal Block 5 (14.18 WPUE) had the greatest relative abundance, followed by Block 1 (0.11 WPUE) and Blocks 2 and 3, for which no whales were observed. Although only 0.38 hr of survey effort were made in Block 6, it was notable that 6 whales were observed in this block, for a very high relative abundance (15.79 WPUE). No bowheads were observed during a total of 4.11 hr of survey effort in the remaining blocks (Blocks 3, 7, 10, and 11) of the primary study area or adjacent waters (Table 6).

During the second half of September, there were 5 blocks in which ≥4.00 hr of survey effort were made. Of these coastal or offshore blocks (Blocks 1, 2, 3, 4, and 11), coastal Block 4 (3.58 WPUE) had the greatest relative abundance, followed by Block 3 (1.49 WPUE), Block 1 (0.68 WPUE), and Blocks 1 and 11, for which

Table 5
Number of Sightings and Total Bowhead Whales Observed per Hour, 31 August-18 October 1994, by Flight Day

Day	No. of Sightings	No. of Whales	Total Survey Time (hr)	Sightings/ Hour (SPUE)	Whales/ Hour (WPUE)
31 Aug	9	9	5.63	1.60	1.60
1 Sep	2	2	6.77	0.30	0.30
2 Sep	29	63	3.97	7.30	15.87
4 Sep	0	0	2.98	0.00	0.00
5 Sep	0	0	3.05	0.00	0.00
7 Sep	2	2	3.65	0.55	0.55
8 Sep	0	0	4.28	0.00	0.00
9 Sep	20	65	5.25	3.81	12.38
12 Sep	0	0	0.68	0.00	0.00
13 Sep	5	5	3.72	1.34	1.34
16 Sep	0	0	1.42	0.00	0.00
17 Sep	3	8	5.57	0.54	1.44
20 Sep	0	0	0.93	0.00	0.00
22 Sep	11	16	4.77	2.31	3.35
23 Sep	0	0	5.03	0.00	0.00
24 Sep	13	18	5.70	2.28	3.16
25 Sep	0	0	1.70	0.00	0.00
27 Sep	0	0	3.20	0.00	0.00
28 Sep	0	0	2.10	0.00	0.00
29 Sep	3	4	2.95	1.02	1.36
1 Oct	2	2	4.62	0.43	0.43
7 Oct	2	4	2.65	0.75	1.51
8 Oct	1	2	5.05	0.20	0.40
10 Oct	0	0	6.62	0.00	0.00
11 Oct	0	0	6.60	0.00	0.00
12 Oct	0	0	2.87	0.00	0.00
13 Oct	2	3	6.02	0.33	0.50
14 Oct	0	0	7.02	0.00	0.00
15 Oct	0	0	1.68	0.00	0.00
16 Oct	0	0	4.92	0.00	0.00
17 Oct	0	0	4.82	0.00	0.00
18 Oct	1	1	6.50	0.15	0.15
TOTAL	105	204	132.70	0.79	1.54

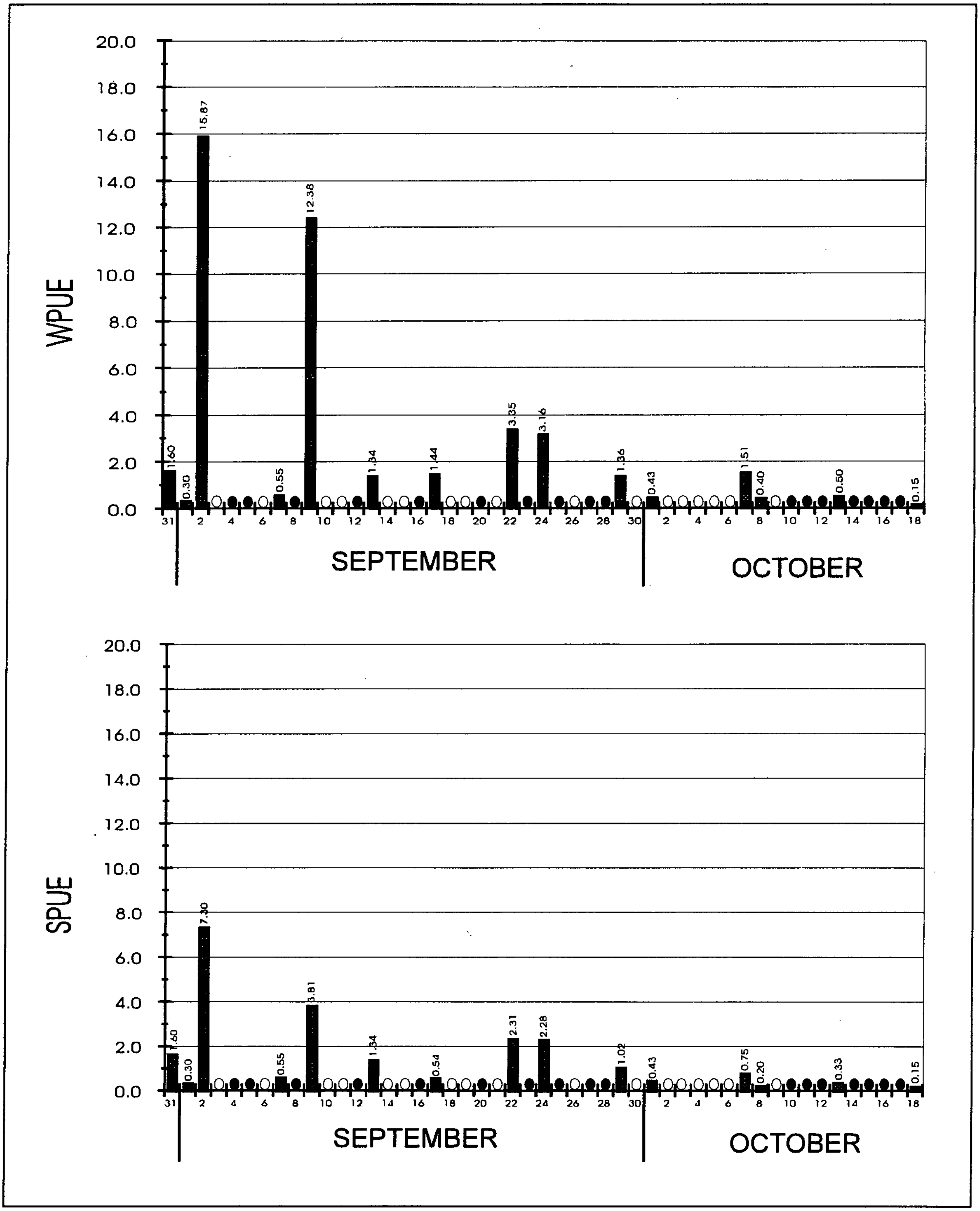

Figure 24. Daily Relative Abundance (WPUE) and Sighting Rate (SPUE) of Bowhead Whales, 31 August - 18 October 1994

(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 1994

	31 Aug			1-15 Sep			16-30 Sep			1-15 Oct			16-18 Oct			Total		
Block	Hr	BH	WPUE	Hr	BH	WPUE	Hr	BH	WPUE	Hr	BH	WPUE	Hr	BH	WPUE	Hr	BH	WPUE
1	0.55	0	0.00	8.81	1	0.11	8.85	6	0.68	6.91	4	0.58	1.22	0	0.00	26.33	11	0.42
2	[1]	[1]	[1]	4.65	0	0.00	4.10	0	0.00	2.05	0	0.00	[1]	[1]	[1]	10.79	0	0.00
3	[1]	[1]	[1]	0.83	0	0.00	4.69	7	1.49	12.85	2	0.16	3.07	0	0.00	21.44	9	0.42
4	1.78	0	0.00	7.23	0	0.00	5.30	19	3.58	4.90	0	0.00	[1]	[1]	[1]	19.21	19	0.99
5	3.12	9	2.88	9.17	130	14.18	3.04	11	3.62	1.30	0	0.00	[1]	[1]	[1]	16.63	150	9.02
6	0.11	0	0.00	0.38	6	15.79	2.18	3	1.38	0.03	0	0.00	[1]	[1]	[1]	2.70	9	3.33
7	0.08	0	0.00	0.27	0	0.00	0.12	0	0.00	[1]	[1]	[1]	[1]	[1]	[1]	0.46	0	0.00
10	[1]	[1]	[1]	0.90	0	0.00	0.32	0	0.00	0.28	0	0.00	[1]	[1]	[1]	1.51	0	0.00
11	[1]	[1]	[1]	2.06	0	0.00	4.65	0	0.00	6.68	0	0.00	0.25	0	0.00	13.63	0	0.00
12	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	7.58	3	0.40	6.12	0	0.00	13.69	3	0.22
13 [2]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	0.24	2	8.33	0.42	0	0.00	0.66	2	3.03
14 [2]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	0.22	0	0.00	0.22	0	0.00
17 [2]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	0.65	0	0.00	0.65	0	0.00
20 [2]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	0.82	0	0.00	0.82	0	0.00
22 [2]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	0.33	0	0.00	0.33	0	0.00
24 [2]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	0.22	0	0.00	0.22	0	0.00
25 [2]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	0.75	1	1.33	0.75	1	1.33
28 [2]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	0.29	0	0.00	0.29	0	0.00
30 [2]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	0.84	0	0.00	0.84	0	0.00
31 [2]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	0.76	0	0.00	0.76	0	0.00
12N [2]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	0.17	0	0.00	0.10	0	0.00	0.27	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]	0.05	0	0.00	0.13	0	0.00	0.14	0	0.00	0.18	0	0.00	0.50	0	0.00
TOTAL	5.63	9	1.60	34.35	137	3.99	33.37	46	1.38	43.12	11	0.26	16.23	1	0.06	132.70	204	1.54

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

no whales were observed. Although only 3.04 hr of survey effort were made in Block 5, it was notable that 11 whales were observed in this coastal block, for a high relative abundance (3.62 WPUE). Three bowheads were observed during a total of 2.75 hr of survey effort in the remaining blocks (Blocks 6, 7, and 10) of the primary study area or adjacent waters (Table 6).

During the first half of October, there were 5 blocks in which ≥4.00 hr of survey effort were made. Of these coastal or offshore blocks (Blocks 1, 3, 4, 11, and 12), coastal Block 1 (0.58 WPUE) had the greatest relative abundance, followed by Block 12 (0.40 WPUE), Block 3 (0.16 WPUE), and Blocks 4 and 11, for which no whales were observed. Although only 0.24 hr of survey effort were made in Chukchi Sea Block 13, it was notable that 2 whales were observed, for a very high relative abundance (8.33 WPUE). No bowheads were observed during a total of 3.97 hr of survey effort in the remaining blocks (Blocks 2, 5, 6, 10) of the primary study area, Block 12N, or adjacent waters (Table 6).

From 16 through 18 October, there was only 1 block in which ≥4.00 hr of survey effort were made. No whales were observed in this coastal block (Block 12). Only one bowhead was observed during a total of 10.11 hr of survey effort in the remaining blocks (Blocks 1, 3, 11, 12) of the primary study area, Block 12N, Chukchi Sea blocks (Blocks 13, 14, 17, 20, 22, 24, 25, 28, 30, 31), or adjacent waters (Table 6).

4. Habitat Associations: Of 204 bowhead whales sighted during Fall 1994, 160 (78%) were in shallow water (0-50 m deep), 42 (20%) were in waters of transitional depth (51-200 m), and 1 (1%) was sighted in deeper water (>200 m) (Table 7). A fuller description of depth associated with the bowhead migration appears in the discussion on median-water-depth analysis in Section IV.B.

In addition to general ice coverage for arctic waters (Figs. 3-12), 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-18 October), bowheads were sighted in each concentration of ice cover shown on Table 8. Of 204 bowheads, 110 (54%) were sighted in open water (0-% sea ice), 81 (39%) in 1- through 5-percent ice, 4 (2%) in 91- through 99-percent ice, 3 (1%) in 81- through 90-percent ice, 2 (1%) in 11- through 20-percent ice, 2 (1%) in 41- through 50-percent ice, 1 (1%) in 31- through 40-percent ice, and 1 (1%) in 61- through 70-percent ice (Table 8). From 31 August through 24 September, all but one whale were observed in association with open water or ≤5-percent sea ice (Appendix B: Table B-1).

5. Behavior, Swim Direction, and Speed: Of 204 bowhead whales observed during Fall 1994, 127 (62%) were swimming (Table 9), i.e., moving forward in an apparently deliberate manner, when first sighted. Over the fall season, the greatest proportion (0.24) of directional movement was between west and northwest, with a significant ($p < 0.02$) mean heading of 284.07°T (Fig. 25), consistent with a directed migration in rough parallel to Alaska's Beaufort Sea coastline. Of the 204 whales observed, 84 (41%) were judged to be swimming at medium speed, with 45 (22%) swimming slowly, 4 (2%) swimming fast, and 17 (8%) still. Swim speeds for 54 whales (27%) were not noted (Table 10). Of other behaviors noted for bowhead whales, 15 (7%) were milling, 9 (4%) were resting, 7 (3%) were in cow-calf associations, 6 (3%) were diving, 1 (1%) was playing with a log, and 1 (1%) was slapping its flukes on the surface of the water. Behaviors for 38 whales (19%) were not noted (Table 9). All behaviors noted are defined in Table 2.

On 31 August, 5 of 9 (56%) bowheads were initially observed swimming (Table 9). Whales were generally moving in southeasterly directions, with a significant ($p < 0.05$) mean heading of 120.48°T (Fig. 25). Five (56%) whales were judged to be swimming at medium speed, with 3 (33%) swimming slowly, and 1 (11%) still (Table 10). Of other behaviors noted for bowhead whales, 3 (33%) were resting and 1 (1%) was diving (Table 9).

During the first half of September, 78 of 137 (57%) bowheads were initially observed swimming (Table 9). Whales were generally moving in westerly directions, with a significant ($p < 0.02$) mean heading of 311.96°T (Fig. 25). Fifty-four (40%) whales were judged to be swimming at medium speed, with 20 (15%) swimming slowly, 10 (7%) still, and 2 (1%) swimming fast (Table 10). Of other behaviors noted for bowhead whales, 15 (11%) were milling, 5 (4%) were in cow-calf associations, 2 (1%) were resting, 1 (1%) was diving, and 1 (1%) was slapping its flukes on the surface of the water (Table 9).

Table 7
Semimonthly Summary of Bowhead Whales Observed, by Water Depth at Sighting Location, Fall 1994

Water Depth	31 Aug No. (%)	1-15 Sep No. (%)	16-30 Sep No. (%)	1-15 Oct No. (%)	16-18 Oct No. (%)	Total No. (%)
Shallow (0-50 m)	3 (33)	107 (78)	46 (100)	4 (36)	0	160 (78)
Transitional (51-200 m)	6 (67)	29 (21)	0	7 (64)	0	42 (20)
Deep (>200 m)	0	1 (1)	0	0	0	1 (1)
(not noted)	0	0	0	0	1 (100)	1 (1)
TOTAL	9 (100)	137 (100)	46 (100)	11 (100)	1 (100)	204 (100)

Table 8
Semimonthly Summary of Bowhead Whales Observed, by Percent Ice Cover Present at Sighting Location, Fall 1994

% Ice Cover	31 Aug No. (%)	1-15 Sep No. (%)	16-30 Sep No. (%)	1-15 Oct No. (%)	16-18 Oct No. (%)	Total No. (%)
0	1 (11)	65 (47)	44 (96)	0	0	110 (54)
1-5	8 (89)	71 (52)	1 (2)	0	1 (100)	81 (39)
6-10	0	0	0	0	0	0
11-20	0	0	0	2 (18)	0	2 (1)
21-30	0	0	0	0	0	0
31-40	0	0	0	1 (9)	0	1 (1)
41-50	0	1 (1)	1 (2)	0	0	2 (1)
51-60	0	0	0	0	0	0
61-70	0	0	0	1 (9)	0	1 (1)
71-80	0	0	0	0	0	0
81-90	0	0	0	3 (27)	0	3 (1)
91-99	0	0	0	4 (37)	0	4 (2)
TOTAL	9 (100)	137 (100)	46 (100)	11 (100)	1 (100)	204 (100)

Table 9
Semimonthly Summary of Bowhead Whales Observed, by Behavioral Category, Fall 1994

Behavior	31 Aug No. (%)	1-15 Sep No. (%)	16-30 Sep No. (%)	1-15 Oct No. (%)	16-18 Oct No. (%)	Total No. (%)
Cow-Calf	0	5 (4)	2 (4)	0	0	7 (3)
Diving	1 (11)	1 (1)	2 (4)	1 (9)	1 (100)	6 (3)
Log Playing	0	0	1 (2)	0	0	1 (1)
Milling	0	15 (11)	0	0	0	15 (7)
Resting	3 (33)	2 (1)	2 (4)	2 (18)	0	9 (4)
Swimming	5 (56)	78 (57)	36 (79)	8 (73)	0	127 (62)
Tail Slapping	0	1 (1)	0	0	0	1 (1)
(not noted)	0	35 (25)	3 (7)	0	0	38 (19)
TOTAL	9 (100)	137 (100)	46 (100)	11 (100)	1 (100)	204 (100)

Table 10
Semimonthly Summary of Bowhead Whales Observed, by Swimming Speed, Fall 1994

Swim Speed	31 Aug No. (%)	1-15 Sep No. (%)	16-30 Sep No. (%)	1-15 Oct No. (%)	16-18 Oct No. (%)	Total No. (%)
Still (0 km/hr)	3 (33)	10 (7)	2 (4)	2 (18)	0	17 (8)
Slow (<2 km/hr)	1 (11)	20 (15)	21 (46)	3 (27)	0	45 (22)
Medium (2-4 km/hr)	5 (56)	54 (40)	19 (41)	5 (46)	1 (100)	84 (41)
Fast (>4 km/hr)	0	2 (1)	1 (2)	1 (9)	0	4 (2)
(not noted)	0	51 (37)	3 (7)	0	0	54 (27)
TOTAL	9 (100)	137 (100)	46 (100)	11 (100)	1 (100)	204 (100)

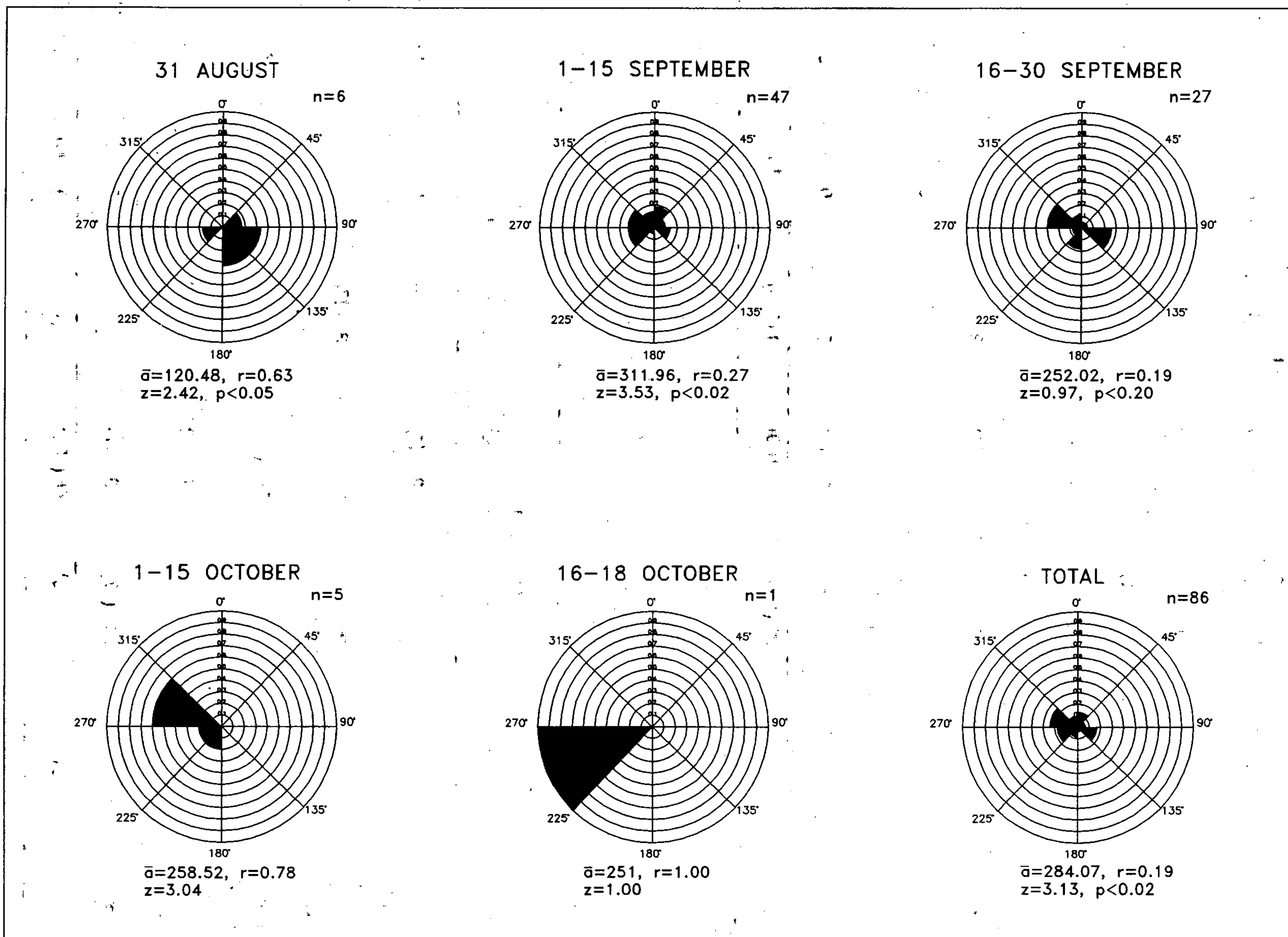

Figure 25. Semimonthly Summary of Swim Directions for Bowhead Whales, Fall 1994

On 2 September and 9 September, large aggregations of bowhead whale pods were observed (see Secs. III.C.1 and III.C.2 above). On 2 September, 8 of the whales were engaged in milling behavior and the aggregation as a whole was located in water depths ranging from 11 to 37 m. On 9 September, 7 of the whales were engaged in milling behavior and the aggregation was located in water 42 to 55 m deep. These were the only days during Fall 1995 when milling behavior was noted. No clear evidence of feeding behavior was observed on either day.

During the second half of September, 36 of 46 (79%) bowheads were initially observed swimming (Table 9). The greatest proportion (0.30) of directional movement was between west and northwest or between east and southeast (0.26), with a mean heading of 252.02°T (Fig. 25). Nineteen (41%) whales were judged to be swimming at medium speed, with 21 (46%) swimming slowly, 2 (4%) still, and 1 (2%) swimming fast (Table 10). Of other behaviors noted for bowhead whales, 2 (4%) were in cow-calf associations, 2 (4%) were diving, 2 (4%) were resting, and 1 (1%) was playing with a log (Table 9).

The bowhead whale playing with a log was observed on 24 September in choppy water at 70°30.3´N. latitude, 145°15.4´W. longitude (Appendix B: Table B-1). We circled this whale for at least 10 minutes, during which time it continued to play intently with the large log (approx. 5 m long by 1 m wide). Play behaviors included repeatedly pushing the log sideways through the water or pushing it under the water with its snout. This second behavior was soon punctuated by the splash of the log as it suddenly broke the surface.

During the first half of October, 8 of 11 (73%) bowheads were initially observed swimming (Table 9). The greatest proportion (0.60) of directional movement was between west and northwest, with a mean heading of 258.52°T (Fig. 25). Five (46%) whales were judged to be swimming at medium speed, with 3 (27%) swimming slowly, 2 (18%) still, and 1 (9%) swimming fast (Table 10). Of other behaviors noted for bowhead whales, 2 (18%) were resting and 1 (9%) was diving (Table 9).

From 16 through 18 October, only one bowhead was observed. This whale was diving (Table 9) and had a swim direction of 251°T (Fig. 25).

D. <u>Other Marine Mammal Observations</u>

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

2. <u>Belukha Whale (*Delphinapterus leucas*)</u>: Although the study area and survey altitude were designed to record the fall migration of bowhead whales, belukha whales, which undertake a somewhat parallel migration, were always counted and were considered suitable for selected analyses. Over the Fall 1994 field season, 92 sightings were made for a total of 514 belukha whales (Table 4) during 132.70 hr of survey effort (Table 3) for a seasonal relative abundance of 3.87 WPUE. Sightings of belukha whales were distributed between 140°W. and 156°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 42 whales, with a mean of 5.59 (SD = 7.25, n = 92). Seventy-three belukha calves were noted for a calf ratio of 0.142. Belukha whales were observed in association with 0- to 99-percent sea ice, with a mean of 36.15-percent ice (SD = 35.82, n = 92).

On 31 August, 4 sightings were made for a total of 27 belukha whales (Table 4) during 5.63 hr of survey effort (Table 3) and a relative abundance of 4.80 WPUE. The first belukha in the Alaskan Beaufort was sighted at 69°57.1´N. latitude, 141°25.4´W. longitude on 31 August. Sizes of pods (or close aggregations of pods) ranged from 1 to 14 whales, with a mean of 6.75 (SD = 5.44, n = 4). Five belukha calves were noted during this period. Belukha whales were observed in association with 1- to 3-percent sea ice, with a mean of 2.00-percent ice (SD = 1.15, n = 4).

During the first half of September, 31 sightings were made for a total of 159 belukha whales (Table 4) during 34.35 hr of survey effort (Table 3) and a relative abundance of 4.63 WPUE. Sizes of pods (or close

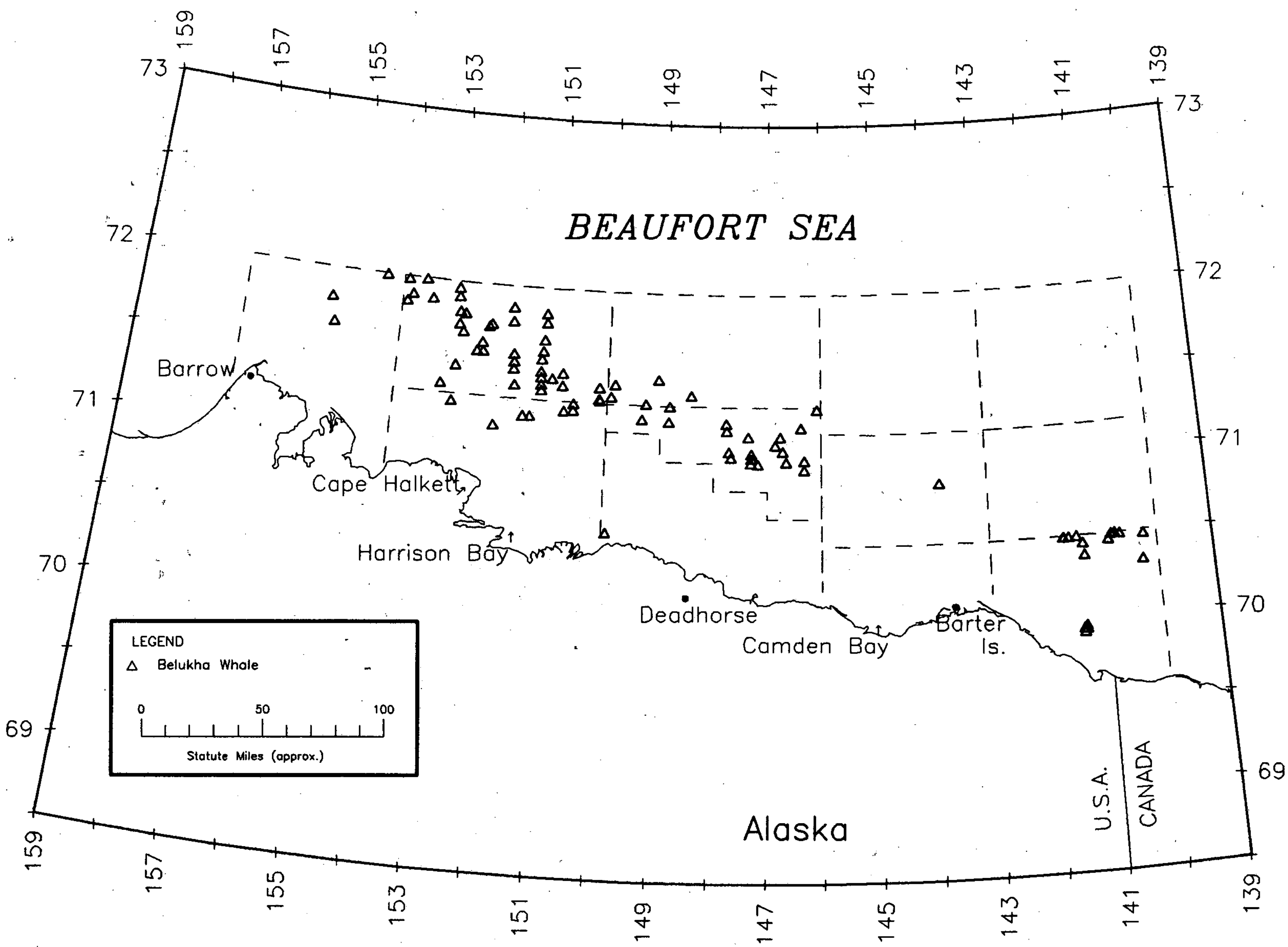

Figure 26. Map of Belukha Whale Sightings, Fall 1994

aggregations of pods) ranged from 1 to 38 whales, with a mean of 5.13 (SD = 7.89, n = 31). Thirty belukha calves were noted during this period. Belukha whales were observed in association with 0- to 85-percent sea ice, with a mean of 21.13-percent ice (SD = 25.01, n = 31).

On 8 September, a dead adult belukha whale was observed floating beside a large chunk of broken floe ice at 71°19.9′N. latitude, 148°50.1′W. longitude. Seven polar bears were on this ice chunk in association with an area of fresh blood, the obvious remains of a recent kill.

During the second half of September, 44 sightings were made for a total of 269 belukha whales (Table 4) during 33.37 hr of survey effort (Table 3) and a relative abundance of 8.06 WPUE. Sizes of pods (or close aggregations of pods) ranged from 1 to 42 whales, with a mean of 6.11 (SD = 7.60, n = 44). Twenty-nine belukha calves were noted during this period. Belukha whales were observed in association with 0- to 95-percent sea ice, with a mean of 34.30-percent ice (SD = 33.85, n = 44).

During the first half of October, 13 sightings were made for a total of 59 belukha whales (Table 4) during 43.12 hr of survey effort and a relative abundance of 1.37 WPUE. Sizes of pods (or close aggregations of pods) ranged from 1 to 16 whales, with a mean of 4.54 (SD = 4.99, n = 13). Nine belukha calves were noted during this period. Belukha whales were observed in association with 70- to 99-percent sea ice, with a mean of 88.77-percent ice (SD = 8.83, n = 13).

From 16 through 18 October, no sightings of belukha whales were made.

3. Bearded Seal (*Erignathus barbatus*): Over the field season, 44 incidental sightings were made for a total of 81 bearded seals (Table 4). Eight of these sightings were evenly distributed between 140°W. and 157°W. longitudes, south of the 400-m isobath (Figs. 2 and 27). Bearded seals were sighted on 16 of the 33 flights from 31 August through 16 October (Table 4). Thirty-eight (47%) of the bearded seals were on the ice when first sighted.

4. Ringed Seal (*Phoca hispida*): Over the field season, 95 incidental sightings were made for a total of 379 ringed seals (Table 4). Sightings were evenly distributed between 140°W. and 157°W. longitudes, mostly south of the 400-m isobath (Figs. 2 and 28). Ringed seals were sighted from 31 August through 17 October, with over 87 percent of these seals observed from 1 through 17 September (Table 4). Thirty-nine (10%) of the ringed seals were on the ice when first sighted.

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

6. Unidentified Pinnipeds: Over the field season, 12 incidental sightings were made for a total of 19 unidentified pinnipeds (Table 4). Sightings were distributed between 142°W. and 157°W. longitudes, south of 72°N. latitude (Fig. 29).

7. Polar Bear (*Ursus maritimus*): Over the field season, 15 incidental sightings were made for a total of 32 polar bears (Table 4). Sightings were distributed between 142°W. and 157°W. longitudes, within 60 nm of shore (Fig. 30). Polar bears were sighted from 4 September to 17 October (Table 4). Twenty-eight (88%) of the polar bears were on the ice when first sighted. Three of the 32 sightings were first identified by the presence of a kill site.

On 8 September, 7 polar bears were observed on a chunk of broken floe ice in association with a kill site and a dead belukha whale (see Sec. III.D.2 above).

In addition to the polar bear sightings, 107 sets of polar bear tracks were recorded for which no bear was present (Table 4). Sightings were distributed between 141°W. and 157°W. longitudes, with polar bear tracks fairly ubiquitous west of 146°W. longitude (Fig. 31). Of these sightings, seven were made during September and 100 were made from 8 through 18 October (Table 4), as heavy concentrations of sea ice covered the study area (Fig.10).

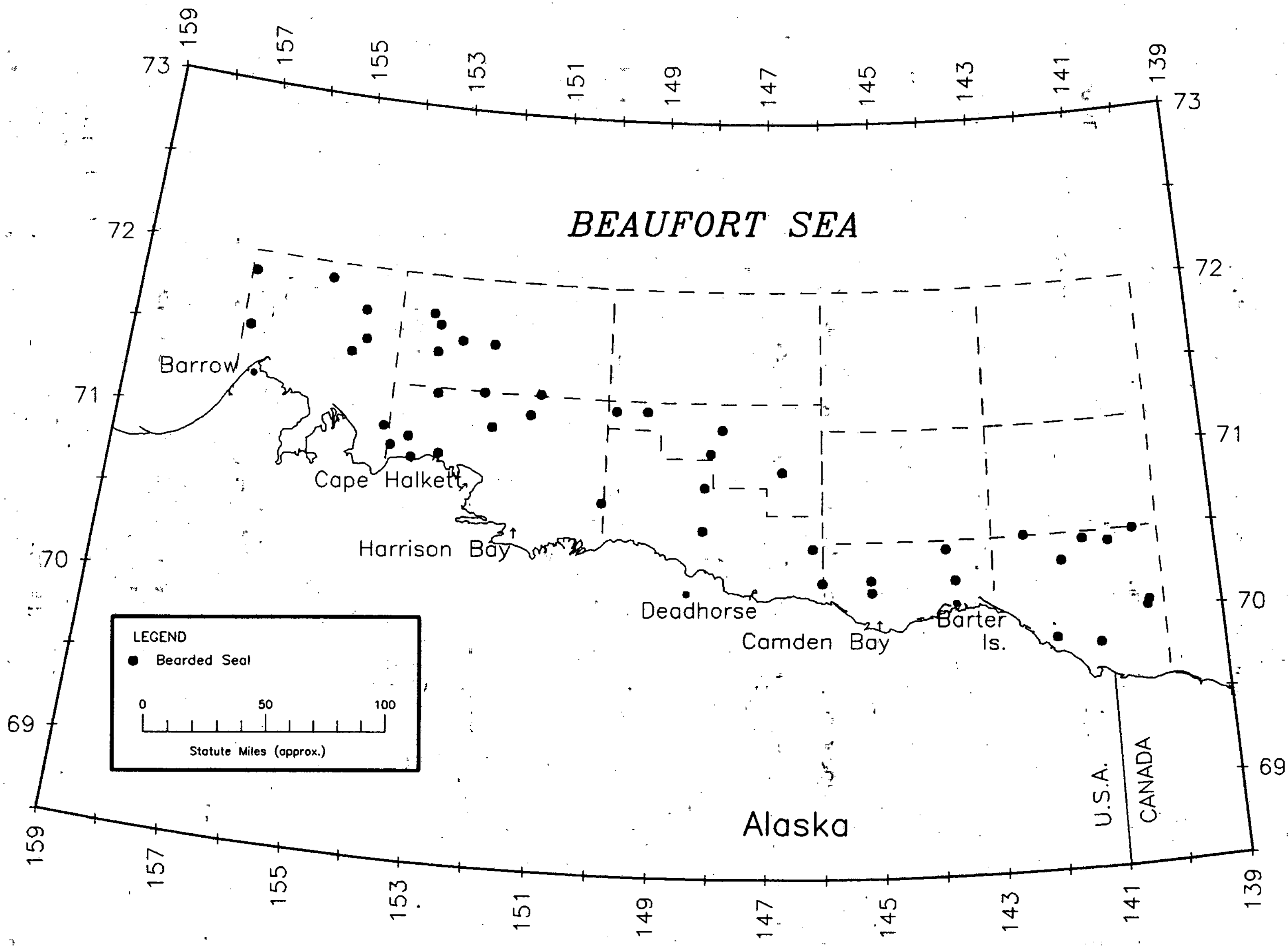

Figure 27. Map of Bearded Seal Sightings, Fall 1994

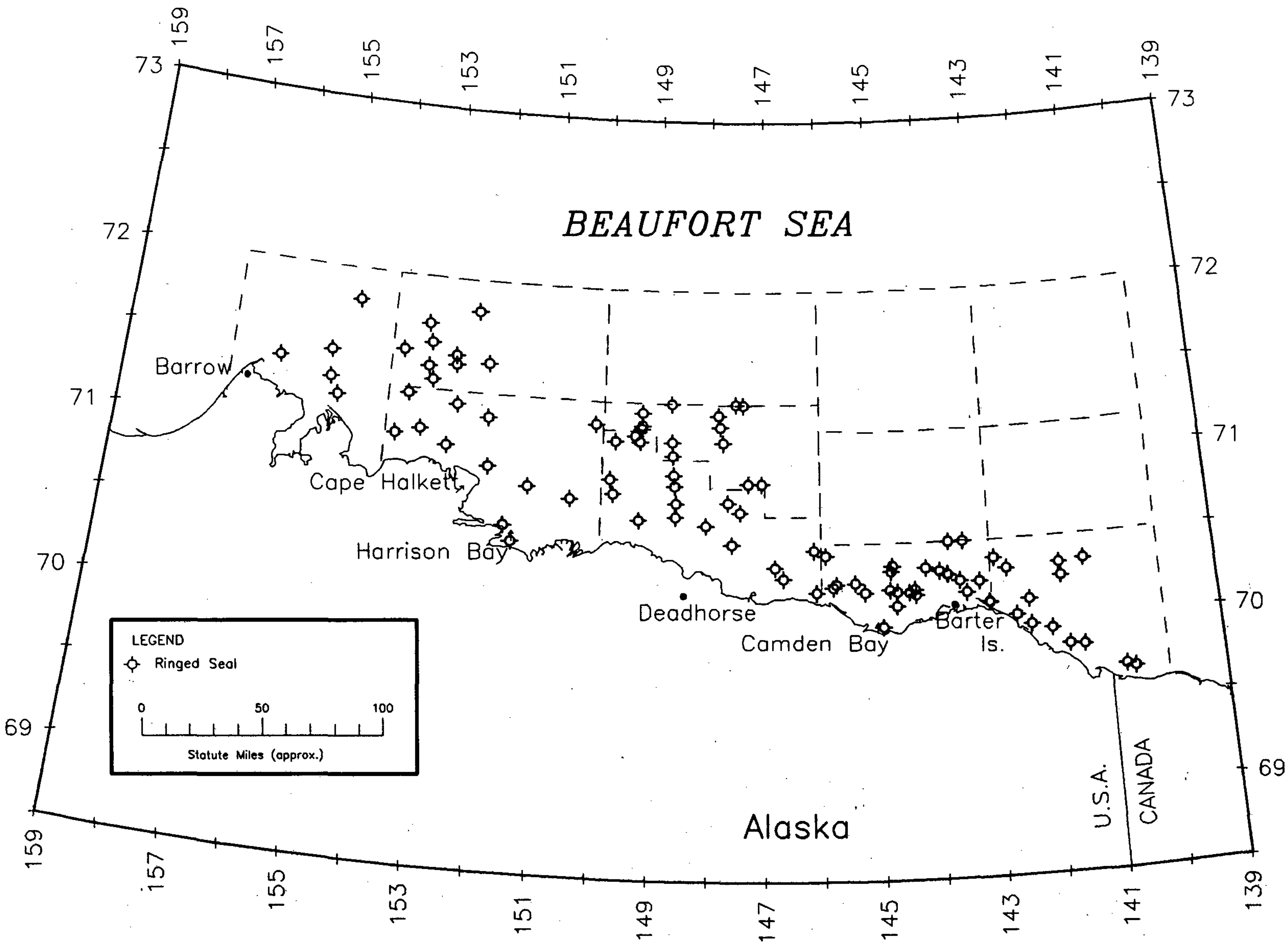

Figure 28. Map of Ringed Seal Sightings, Fall 1994

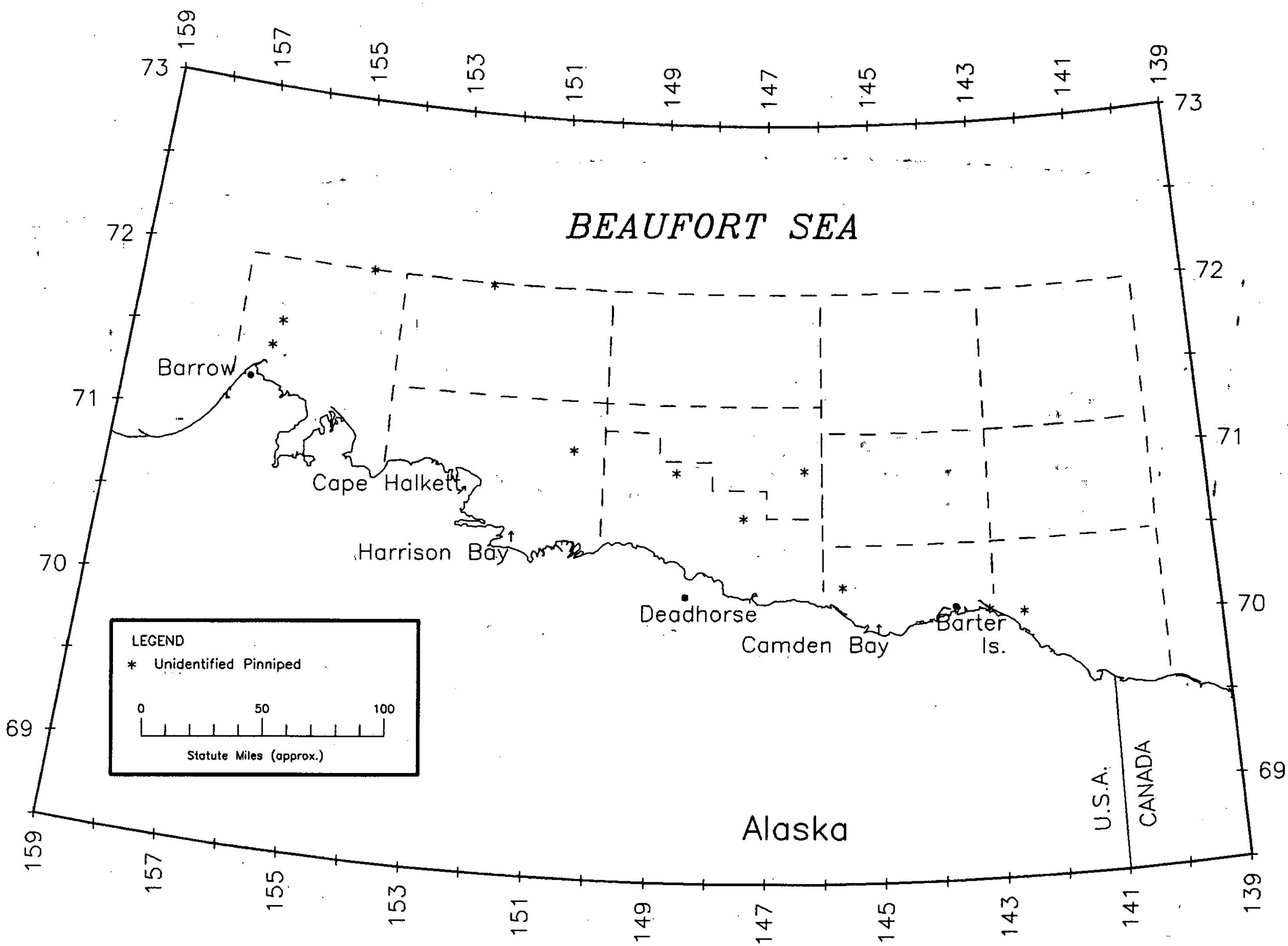

Figure 29. Map of Unidentified Pinniped Sightings, Fall 1994

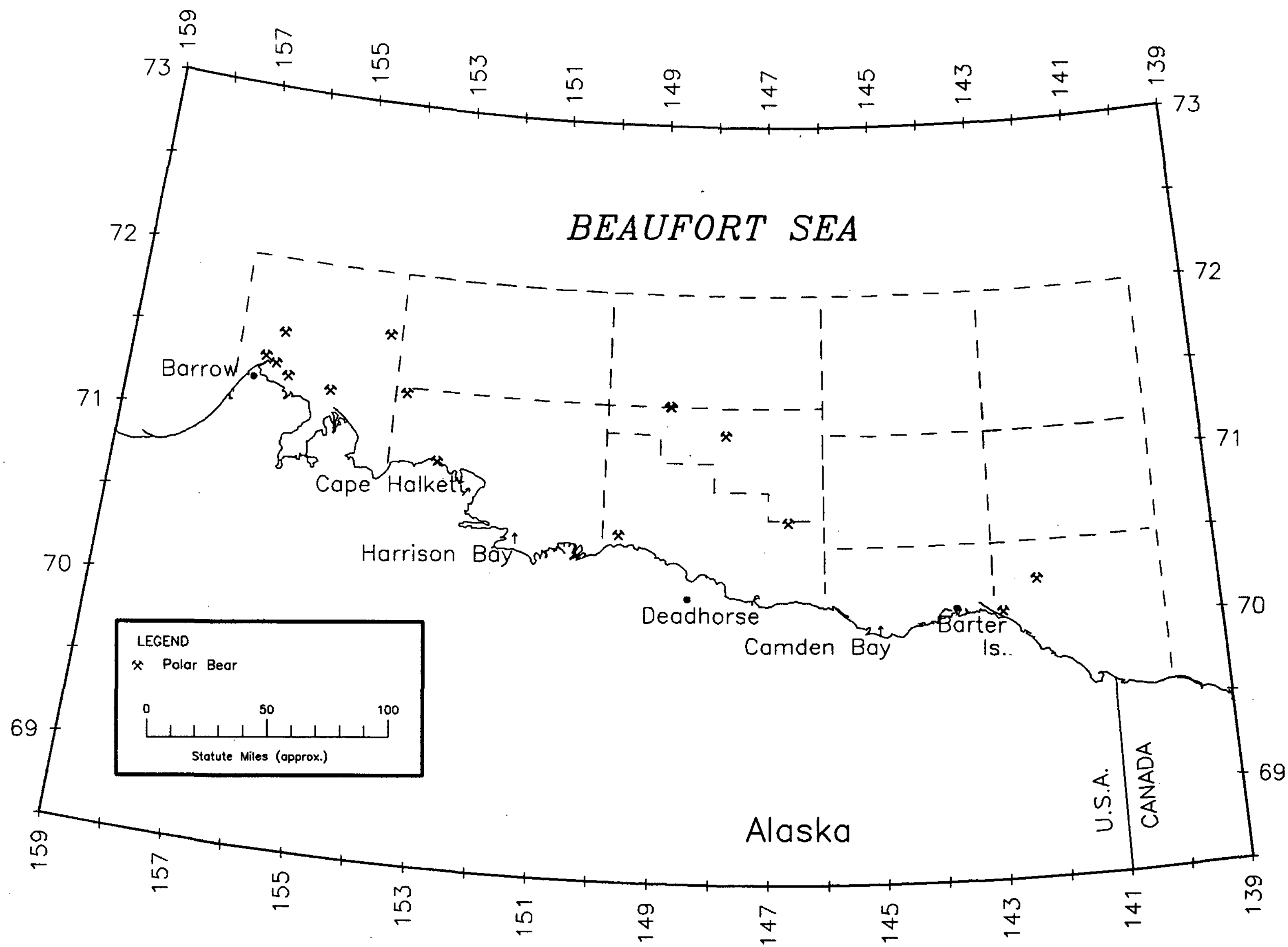

Figure 30. Map of Polar Bear Sightings, Fall 1994

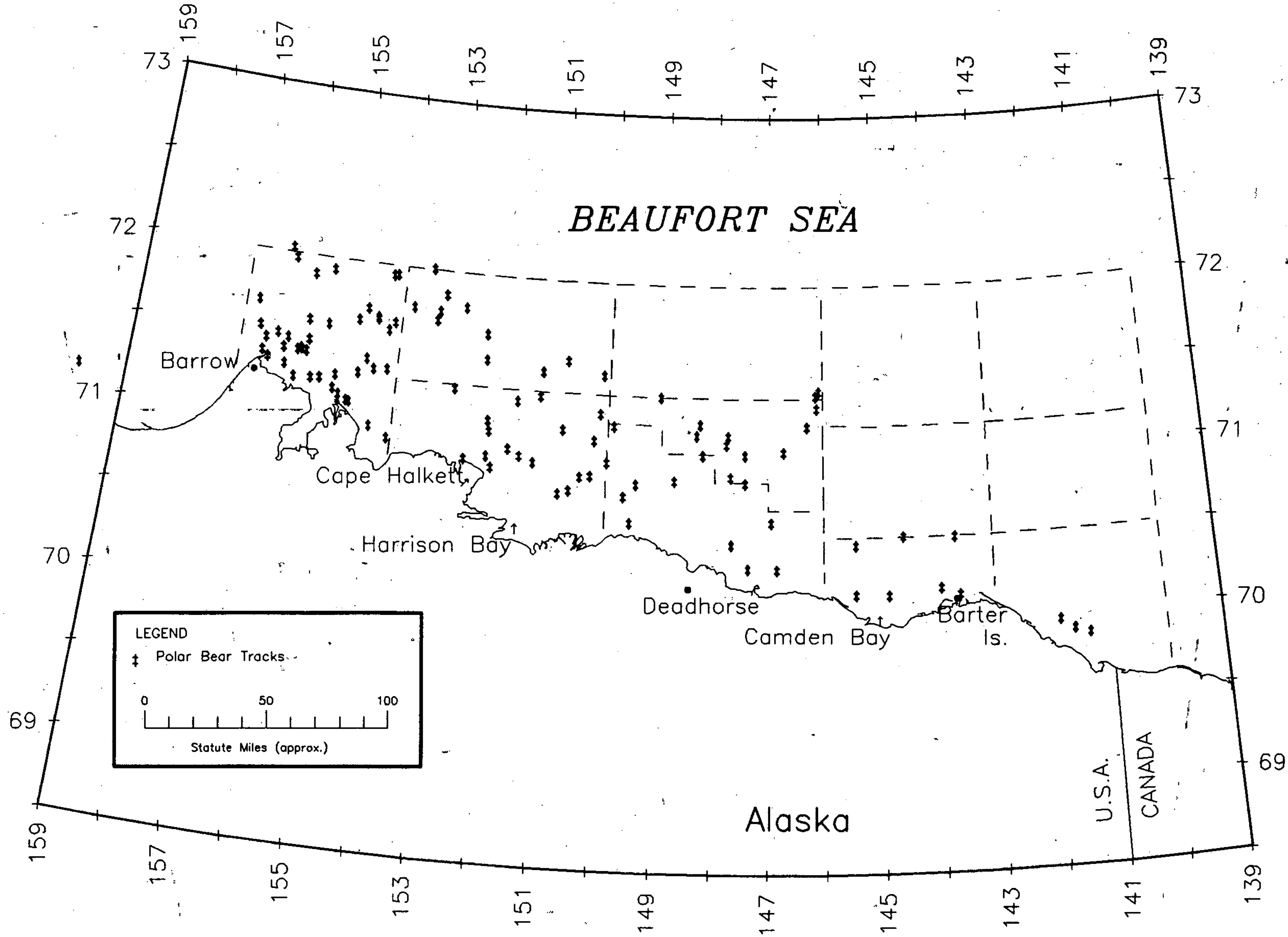

Figure 31. Map of Polar Bear Tracks (no bear or kill site present), Fall 1994

2 arctic foxes (Table 4). Both foxes were observed on shorefast ice west of Cape Halkett on 14 October. The foxes were in association with 4 polar bears that were feeding on a carcass at 70°55.3´N., 153°06.5´W. longitude (Fig. 32).

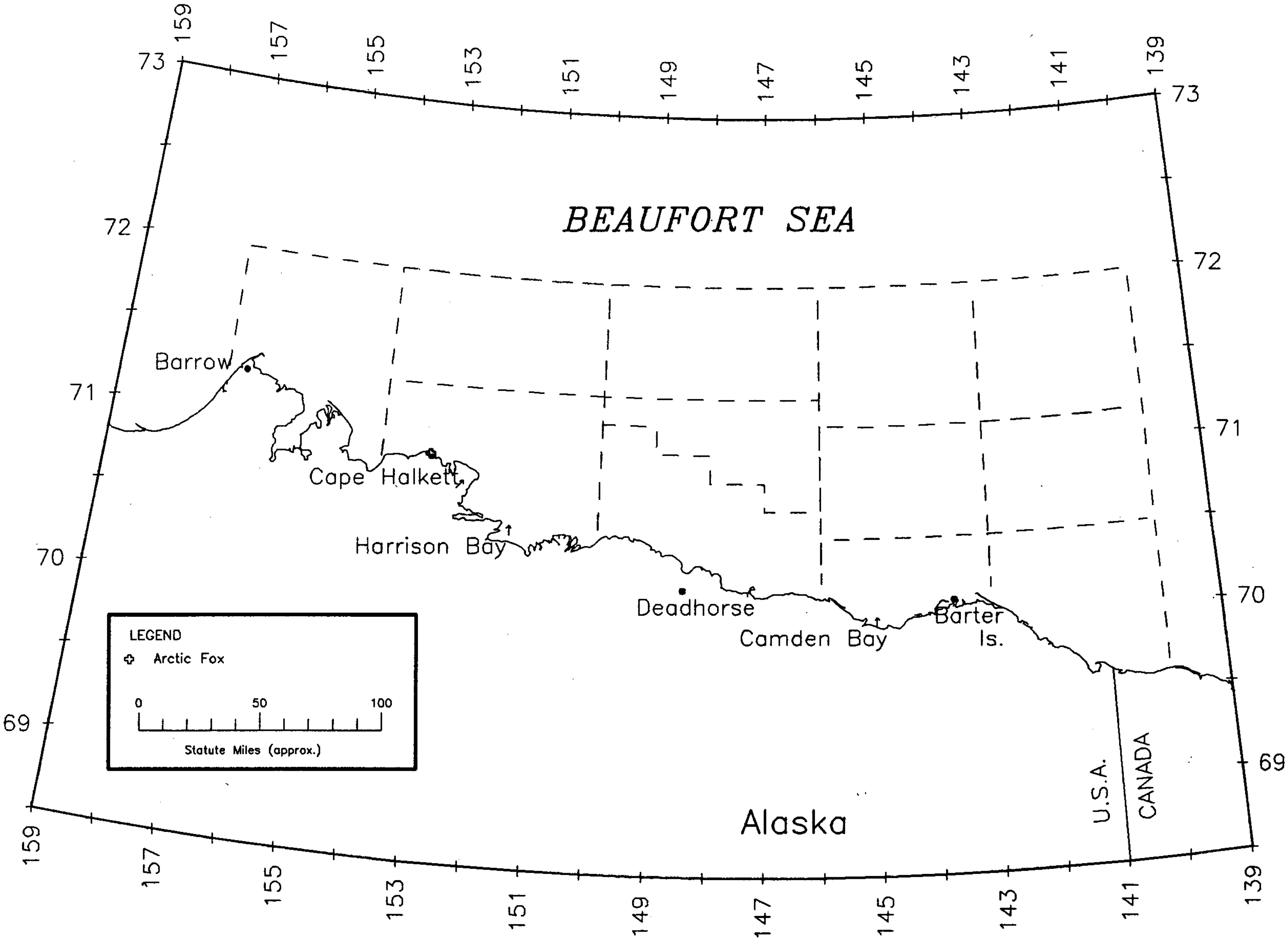

Figure 32. Map of Arctic Fox Sightings, Fall 1994

IV. DISCUSSION

A. General Comparisons with Previous Surveys (1979-1993)

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 (1979-1993) in the Beaufort Sea using similar survey methods (Ljungblad et al., 1987; Moore and Clarke, 1992; Treacy, 1988, 1989, 1990, 1991, 1992, 1993, 1994). Prior to Fall 1992, surveys in Block 12 were largely conducted from a modified Grumman Goose rather than a Twin Otter aircraft. Results for 1994 that were considered notable relative to previous values are described below.

The general ice coverage along the northern coast of Alaska during the 1994 navigation season was the 19th mildest in the Arctic Ocean for the 42 years from 1953 through 1994 (USDOD, Navy, Naval Polar Oceanography Center, 1995).

Cloud cover over most of the study area was considered favorable for surveying in 1994, without recurrent periods of "down-to-the-deck" fog as in many previous field seasons.

The 1994 total of 132.70 survey hours was higher than the mean of 129.79 hours (SD = 46.26, n = 7) of survey time for the years 1987 through 1993.

The number of sightings of bowhead whales (n = 105) and the number of bowhead whales counted (n = 204) during Fall 1994 were the fifth-highest totals for all project surveys (1987-1994).

For September 1994, the relative abundance of bowhead whales in Block 6 of 3.52 WPUE (Table 11) was slightly higher than for similar values in previous years (1990 value = 3.35 WPUE). Values for relative abundance in all other survey blocks during September or October 1994 were within the range of values shown for the years 1979 through 1993 (Table 11).

The central tendencies of bowhead whales counted and the SPUE and WPUE in 1994 show peaks that were earlier in September than for previous years (1987-1993). The difference in migration timing is being further analyzed for statistical significance and for comparison with the presence or absence of industry activity, sighting conditions, etc.

The log-playing behavior noted for one bowhead whale in 1994 has rarely been noted during our previous surveys (1987-1993).

The sighting of 7 polar bears on a chunk of broken floe ice in proximity to a dead adult belukha whale was considered unique. The recent kill site on this ice may well have been the remains of a second belukha whale.

The total number of belukha whales counted in Fall 1994 (n = 514) was the second-highest total number since the project began (1987-1994). The total number of bearded seals counted incidentally (n = 514) was higher than for previous values (1987-1993). Totals of other marine mammals sighted were within ranges established during previous project surveys in the Beaufort Sea (1987-1993).

B. Median and Mean Water Depth at Bowhead Sightings (1982-1994)

The median water depth at 27 sightings of bowhead whales made on randomized line transects in Regions I, II, and III (combined) (Fig. 2) during September and October 1994 was 40 m. This areawide median depth was slightly more than the cumulative median depth of 37 m for the years 1982 through 1994 (n = 443). It was within the range of median areawide depths for previous years (range = 18 to 347 m). The median water depth of 13 m for Region I was less than the cumulative median depth of 21 m for that region. The

IV

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

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

[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.

37 m for Region II during 1994 was identical to the cumulative median depth. The 40 m for Region III was less than the cumulative value (43 m). Bowhead whales were observed in shallower water in Region I for 1994 (13 m) than for any of the previous years, with 1993 (15 m) being the next-shallowest year (Table 12).

To determine whether any of the differences between the median water depth for 1994 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 1994 showed a highly significant difference ($p < 0.005$) when compared to medians for the years 1983, 1989, and 1991. Analysis by region showed no differences that were highly significant between 1994 and other years in Region I (between 150°W. and 153°30'W. longitudes) or Region II (between 146°W. and 150°W. longitudes). There was a highly significant difference ($p < 0.005$) between 1994 and the median depth for 1983 in Region III (between 141°W. and 146°W. longitudes) (Table 13).

The median water depth for the year 1987 (37 m) was considered typical in that it was identical to the cumulative median (all 3 regions combined) for the years 1982 through 1994 (Table 12). Of the years when bowheads tended to migrate in water that was deeper than in 1987, the years 1983, 1991, and 1992 showed highly significant ($p < 0.005$) differences from the 37-m median value. Likewise, of the years when whales tended to migrate in water that was shallower than in 1987, only the year 1989 showed a difference that was 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). The highly significant difference ($p < 0.005$) between 1983 and other years was shown, in some instances, 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 and 1993 (Table 13), because the 1989 median water depth of 18 m was clearly much shallower than the median depth for other years (Table 12). Such attained levels ($p < 0.005$) between 1989 and other years were shown, in some instances, in Region I (Table 13).

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

The mean water depth at 27 sightings of bowhead whales made on randomized line transects in Regions I, II, and III (combined) during September and October 1994 was 58.7 m (Table 12). The areawide mean depth for 1994 (58.7 m) was within the range of areawide mean depths for the years 1982 through 1993 (previous values ranged from 22.7 to 738.9 m). This areawide mean depth was also less than the cumulative mean depth of 84.5 m for the years 1982 through 1994 ($n = 443$). Mean water depths of 16.3 m for Region I and 41.0 m for Region III during 1994 were less than the cumulative mean depths of 85.1 m and 86.5 m, respectively, for these regions. The mean depth of 16.3 m in Region I for 1994 was nearly as shallow as in 1993 (16.1 m) and 1989 (16.0 m). The mean depth of 225.7 m in Region II for 1994 was very deep, exceeded only in 1983 (945.0 m) (Table 12).

Comparison of the means using ANOVA and the Tukey test (Zar, 1984) showed that 1983 was unique among other years in the spatial distribution of the fall bowhead migration. Differences between the mean for 1983 and all other years (including 1994) were considered very highly significant ($p < 0.001$) in all three regions combined and in Regions II and III, thus mirroring differences noted between the 1983 median and the medians for other years. Differences in mean water depths between all other years, including 1994, 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

Table 12
Central-Tendency Statistics for Water Depth (in meters) at Random Sightings of Bowhead Whales (September-October), by Year and Region, 1982-1994

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

Table 12
Central-Tendency Statistics for Water Depth (in meters) at Random Sightings of Bowhead Whales (September-October), by Year and Region, 1982-1994
(Continued)

Year	Region	SI[1]	Median	CI[2]	Mean	SD[3]	Range
1991	I	0	[4]	[4]	[4]	[4]	[4]
	II	7	66	[4]	126.7	100.04	27-274
	III	6	118	[4]	132.2	92.05	48-232
	All 3	13	66	48-238	129.2	92.42	27-274
1992	I	8	40	13-329	70.3	105.24	13-329
	II	3	46	[4]	119.0	126.44	46-265
	III	9	55	44-57	50.2	8.91	29-57
	All 3	20	46	37-55	68.6	79.75	13-329
1993	I	12	15	13-18	16.1	2.23	13-20
	II	24	29	22-38	30.0	9.58	15-53
	III	39	44	27-48	44.3	34.24	9-229
	All 3	75	29	24-38	35.2	27.25	9-229
1994	I	3	13	[4]	16.3	9.45	9-27
	II	3	37	[4]	225.7	335.48	27-613
	III	21	40	29-55	41.0	11.87	22-57
	All 3	27	40	26-55	58.7	111.58	9-613
Cumulative	I	88	21	18-31	85.1	261.25	9-2,323
(1982-1994)	II	133	37	29-37	80.6	239.50	7-2,021
	III	222	43	40-48	86.5	234.94	9-1,902
	All 3	443	37	37-38	84.5	241.18	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, 1982-1994
(Page 1 of 4)

REGION I

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
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		
1993	U = 66.0 p ≤ 0.20	U = 108.0 p < 0.001	U = 176.5 p < 0.001	U = 33.0 p < 0.05	U = 31.0 p > 0.20	U = 34.0 p > 0.20	U = 48.0 p ≤ 0.002	U = 96.0 p > 0.20	U = 28.5 p < 0.20	1	U = 84.5 p < 0.005	
1994	U = 18.0 p > 0.20	U = 26.0 p ≤ 0.02	U = 41.5 p < 0.05	U = 8.0 p ≤ 0.20	U = 8.5 p > 0.20	U = 7.5 p > 0.20	U = 12.0 p ≤ 0.10	U = 24.5 p > 0.20	U = 8.0 p ≤ 0.20	1	U = 21.5 p < 0.10	U = 23.0 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, 1982-1994
(Page 2 of 4)

REGION II

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
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]	$U' = 51.0$ $p \leq 0.002$	$U = 13.0$ $p > 0.20$		
1993	$U = 380.5$ $Z = 0.35$ $p > 0.20$	$U = 119.5$ $p < 0.001$	$U = 158.5$ $p < 0.05$	$U = 115.0$ $p > 0.20$	$U' = 196.5$ $p < 0.10$	$U' = 124.0$ $p > 0.20$	$U = 81.5$ $p < 0.05$	$U = 23.0$ $p \leq 0.20$	$U = 243.0$ $p > 0.20$	$U = 154.0$ $p < 0.001$	$U = 70.0$ $p < 0.005$	
1994	$U' = 63.0$ $p > 0.20$	$U = 13.0$ $p \leq 0.20$	$U' = 14.5$ $p > 0.20$	$U' = 19.0$ $p > 0.20$	$U' = 29.0$ $p < 0.20$	$U' = 21.0$ $p > 0.20$	$U = 7.0$ $p > 0.20$	$U = 2.0$ [1]	$U' = 28.5$ $p > 0.20$	$U = 12.5$ $p > 0.20$	$U = 6.0$ $p > 0.20$	$U' = 50.0$ $p > 0.20$

Table 13
Interyear Correlation (nonparametric) of the Median Water Depths at Random Bowhead Whale Sightings (September-October) Using the Mann-Whitney U Test, 1982-1994
(Page 3 of 4)

REGION III	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
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 ≤ 0.20	U = 195.5 p < 0.001	U = 216.0 p < 0.05	U = 22.0 p ≤ 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 ≤ 0.20	U′ = 284.0 p < 0.10							
1988	U = 13.0 p > 0.20	U = 43.0 p ≤ 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 ≤ 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 ≤ 0.10	U = 47.5 p < 0.02	U′ = 58.0 p > 0.20	U = 3.0 [1]	U′ 121.0 p ≤ 0.001	U′ = 100.0 p < 0.02	U′ = 24.0 p < 0.20	U′ = 13.0 p > 0.20	U′ = 354.0 Z = 2.96 p < 0.005			
1992	U′ = 31.0 p < 0.20	U = 74.5 p < 0.001	U′ = 74.0 p > 0.20	U = 9.0 [1]	U′ = 170.5 p < 0.001	U′ = 126.0 p ≤ 0.02	U′ = 31.0 p < 0.20	U′ = 14.5 p > 0.20	U′ = 477.5 Z = 3.47 p < 0.001	U = 34.5 p > 0.20		
1993	U = 114.5 p > 0.20	U = 341.5 p < 0.001	U = 338.5 p < 0.20	U = 37.0 p < 0.20	U′ = 520.0 Z = 1.36 p < 0.20	U = 425.5 Z = 0.56 p > 0.20	U = 104.0 p > 0.20	U = 84.5 p > 0.20	U = 1,384.0 Z = 0.37 p > 0.20	U = 201.5 p < 0.005	U = 271.5 p < 0.001	
1994	U = 58.0 p > 0.20	U = 182.5 p < 0.001	U = 171.0 p > 0.20	U = 21.0 p ≤ 0.10	U′ = 298.5 Z = 1.63 p < 0.05	U = 217.5 p > 0.20	U = 56.0 p > 0.20	U = 44.5 p > 0.20	U′ = 747.5 Z = 0.32 p > 0.20	U = 106.5 p < 0.02	U = 139.00 p < 0.01	U′ = 437.5 Z = 0.43 p > 0.20

Table 13
Interyear Correlation (nonparametric) of the Median Water Depths at Random Bowhead Whale Sightings (September-October) Using the Mann-Whitney U Test, 1982-1994
(Page 4 of 4)

ALL THREE REGIONS (COMBINED)

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1983	U′ = 882.0 Z = 5.21 p < 0.001											
1984	U′ = 1,138.5 Z = 3.04 p < 0.005	U = 717.5 Z = 4.17 p < 0.001										
1985	U′ = 316.5 Z = 0.71 p > 0.20	U = 249.5 p < 0.001	U = 297.5 p > 0.20									
1986	U = 898.0 Z = 0.76 p > 0.20	U = 786.0 Z = 5.19 p < 0.001	U = 1,043.0 Z = 3.33 p < 0.001	U = 314.0 p < 0.20								
1987	U′ = 798.5 Z = 0.93 p > 0.20	U = 666.5 Z = 4.77 p < 0.001	U = 809.5 Z = 2.10 p < 0.05	U = 223.0 p > 0.20	U′ = 760.5 Z = 1.53 p < 0.20							
1988	U′ = 414.0 Z = 2.60 p < 0.01	U = 245.5 p < 0.002	U′ = 248.0 p > 0.20	U′ = 104.5 p > 0.20	U′ = 356.5 p < 0.02	U′ = 291.0 p < 0.10						
1989	U = 598.0 Z = 2.89 p < 0.005	U = 417.5 p < 0.001	U = 617.0 p < 0.001	U = 198.5 p < 0.005	U = 457.0 p < 0.20	U = 480.5 p < 0.002	U = 214.0 p < 0.001					
1990	U′ = 2,473.5 Z = 2.85 p < 0.005	U = 1,729.5 Z = 8.10 p < 0.001	U = 1,949.5 Z = 1.47 p < 0.20	U′ = 682.5 Z = 1.12 p > 0.20	U′ = 2,227.5 Z = 2.95 p < 0.005	U′ = 1,717.5 Z = 1.54 p < 0.20	U = 674.5 Z = 1.03 p > 0.20	U′ = 1,353.0 Z = 4.21 p < 0.001				
1991	U′ = 503.0 Z = 4.33 p < 0.001	U = 213.0 p < 0.05	U′ = 373.5 p < 0.01	U′ = 134.5 p < 0.02	U′ = 446.0 p < 0.001	U′ = 377.0 p < 0.001	U′ = 135.0 p ≤ 0.01	U′ = 236.0 p < 0.001	U′ = 999.0 Z = 4.33 p < 0.001			
1992	U′ = 663.0 Z = 3.88 p < 0.001	U = 368.5 p < 0.001	U′ = 410.0 p > 0.20	U′ = 170.5 p < 0.10	U′ = 578.0 p < 0.001	U′ = 470.5 p < 0.005	U′ = 150.5 p > 0.20	U′ = 325.5 p < 0.001	U′ = 1,185.5 Z = 2.85 p < 0.005	U = 193.5 p < 0.01		
1993	U′ = 1,614.5 Z = 0.01 p > 0.20	U = 1,545.5 Z = 5.72 p < 0.001	U = 1,981.0 Z = 3.38 p < 0.001	U = 568.0 Z = 0.94 p > 0.20	U′ = 1,580.5 Z = 0.95 p > 0.20	U = 1,381.5 Z = 0.96 p > 0.20	U = 679.5 Z = 2.25 p < 0.05	U′ = 1,007.0 Z = [1]2.77 p < 0.01	U = 4,200.5 Z = 3.00 p < 0.005	U = 886.5 Z = 4.69 p < 0.001	U = 1,111.0 Z = 3.75 p < 0.001	
1994	U′ = 754.0 Z = 2.09 p < 0.05	U = 523.0 Z = 4.13 p < 0.001	U = 594.5 Z = 1.08 p > 0.20	U′ = 190.0 p > 0.20	U′ = 682.0 Z = 2.24 p < 0.05	U′ = 510.5 Z = 0.96 p > 0.20	U = 205.5 p > 0.20	U′ = 410.0 p < 0.001	U′ = 1,190.0 Z = 0.01 p > 0.20	U = 293.5 p < 0.001	U = 347.0 p < 0.05	U′ = 1,267.5 Z = 1.93 p < 0.10

[1] Insufficient sample size.

Table 14
Interyear Correlation (parametric) of the Mean Water Depths at Random Bowhead Whale Sightings (September-October) Using Analysis of Variants (ANOVA) and the Tukey Test, 1982-1994

REGION I[1]
ANOVA F = 1.600, $p > 0.20$

Tukey Test:

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

REGION II
ANOVA F = 11.586, $p << 0.001$

Tukey Test:

(1987)	(1993)	(1985)	(1982)	(1990)	(1984)	(1989)	(1988)	(1986)	(1992)	(1991)	(1994)	(1983)
27.3	30.0	30.4	30.6	33.6	43.7	44.0[2]	44.8	60.8	119.0	126.7	225.7	945.0
							└──	──	($p < 0.001$)	──	──	──┘

REGION III
ANOVA F = 26.902, $p << 0.001$

Tukey Test:

(1986)	(1990)	(1994)	(1982)	(1993)	(1989)	(1987)	(1992)	(1985)	(1984)	(1988)	(1991)	(1983)
34.1	40.5	41.0	43.4	44.3	49.3	49.9	50.2	64.0[2]	90.4	90.4	132.2	969.8
							└──	──	($p < 0.001$)	──	──	──┘

ALL THREE REGIONS (COMBINED)
ANOVA F = 24.925, $p << 0.001$

Tukey Test:

(1989)	(1993)	(1990)	(1987)	(1986)	(1982)	(1994)	(1988)	(1984)	(1992)	(1985)	(1991)	(1983)
22.7	35.2	38.8	40.0	44.3	47.5	58.7	61.0	64.7	68.6	76.6	129.2	739.0
							└──	──	($p << 0.001$)	──	──	──┘

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

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, 1995), the bowhead migration was observed in water almost an order of magnitude deeper than for other years (Table 12).

In general, mean water depths at sightings of bowhead whales were skewed to the deeper (north) side of the migration axis (median), with cumulative mean values for each region (1982-1994) approximately twice as great (as deep) as the cumulative medians (Table 12). The reason for the differences between the median and mean values is unknown but may simply reflect the increasing gradient of the sea floor farther offshore.

C. Potential Responses of Bowheads to Survey Aircraft

During the 1994 field season, there were no sightings of bowhead whales for which definite responses to the survey aircraft were apparent. Although it was not possible to determine if any responses would have been a direct result of overflight by survey aircraft, sudden overt changes 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 (1979-1994)

During September and October (combined) 1994, there were 192 bowhead whales observed during 120.79 hr for a relative abundance of 1.59 WPUE in Survey Blocks 1 through 12. The relative abundance in this primary study area was 2.71 WPUE during September and 0.17 WPUE during October. The combined September and October relative abundance of 1.59 WPUE for 1994 was considered representative of the cumulative relative abundance (1.55 WPUE) found during moderate ice years (Table 15), even though the following independent criteria dictate that 1994 should be lumped with light ice years.

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 1994 and show distances between Point Barrow and the five-tenths ice concentration on 15 September ranging from 10 to 25 nm (USDOD, Navy, Naval Polar Oceanography Center, 1995).

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 1994 and show distances between Point Barrow and the five-tenths ice concentration on 15 September ranging from 50 to 75 nm (USDOD, Navy, Naval Polar Oceanography Center, 1995).

The years 1979, 1981, 1982, 1986, 1987, 1989, 1990, 1993, and 1994, 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 1994 and show distances between Point Barrow and the five-tenths ice concentration on 15 September ranging from 60 to 185 nm (USDOD, Navy, Naval Polar Oceanography Center, 1995).

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

Although cumulative values for the three ice-year categories (Table 15) and the Kruskal-Wallis test 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 ($\bar{x} = 2.17$, SD = 1.30, n = 9)

Table 15
Relative Abundance (WPUE) of Bowhead Whales within the Primary Study Area (Survey Blocks 1-12) during September and October[1], by Year and General Ice Coverage, 1979-1994

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

Table 15
Relative Abundance (WPUE) of Bowhead Whales within the Primary Study Area (Survey Blocks 1-12) during September and October[1], by Year and General Ice Coverage, 1979-1994
(Continued)

Ice Coverage	September			October			Total (Sep-Oct)		
	Hours	BH	WPUE	Hours	BH	WPUE	Hours	BH	WPUE
Heavy Ice Years[2](Σ)	281.46	132	0.47	198.82	88	0.44	480.28	220	0.46
Moderate Ice Years[3](Σ)	245.31	331	1.35	212.23	376	1.77	457.54	707	1.55
Light Ice Years (Σ)	669.84	1,642	2.45	501.32	695	1.39	1,171.16	2,337	2.00

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

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).

Even though the study should not be used to estimate total whale population, the relative abundance of bowhead whales was compared between years to obtain a rough indication of any gross temporal trends. In order to control one particular bias against extreme variation in ice severity between years, the WPUE was compared during September, October, and both months combined (Table 15) for only those years of light ice (1979, 1981, 1982, 1986, 1987, 1989, 1990, 1993, and 1994). The data showed weak tendencies for bowhead relative abundance to increase from 1979 through 1994, 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 airguns; vessel geological-geophysical permits for shallow seismic exploration using an airgun; on-ice geophysical permits using VIBROSEIS technology; both vessel and on-ice geological permits for obtaining core samples; and permits to drill for gas and oil.

During 1994, MMS issued a single over-ice geophysical (VIBROSEIS) permit to industry for seismic exploration in the central to eastern 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. No open-water geophysical permits were issued in the same general area, and there were no preliminary activities for site clearance in 1994.

In general, to prevent potential operational effects on subsistence whaling, any geophysical vessel explorations permitted during the fall follow stringent restrictions--including a provision to stop seismic operations when whales were visible from the vessel--as the bowhead whale migration progresses through the area of operations. For any explorations that occur during the fall, daily summaries of survey information are transferred from the field to Anchorage for use by MMS Resource Evaluation and by NMFS in implementing areawide permit restrictions on high-energy seismic operations during periods of limited visibility.

There were no drilling operations in the Beaufort Sea in 1994. In general, during any fall drilling operations, daily summaries of field information from this survey, and other arctic surveys being conducted concurrently, are transferred by the MMS Team Leader to MMS Field Operations in Anchorage. The MMS and NMFS review daily reports to determine the distributional patterns of bowheads in the vicinity of oil and gas industry activities and the timing of the bowhead whale migration, especially the "end of the migration" past any drill sites.

Project ice data were transmitted daily to the U.S. Navy-NOAA Joint Ice Center for their use in ground-truthing satellite imagery. In general, sighting data are used by several management groups to monitor the progress of the overall fall migration of bowhead whales across the Alaskan Beaufort Sea and to determine the position of their overall migratory corridor relative to shore. Data from previous surveys continue to be used by MMS in writing Environmental Impact Statements and Environmental Assessments and in interpreting the results of site-specific studies.

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., and the Alaska Eskimo Whaling Commission, Barrow, Alaska. We also coordinated with NMFS, Anchorage, Alaska, and with Craig George of the North Slope Borough, Barrow, Alaska, who accompanied our survey flight on 13 October 1994.

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APPENDIX A

BOWHEAD WHALE DENSITIES

BOWHEAD WHALE DENSITIES

This appendix presents estimated bowhead whale densities in the Beaufort Sea for the period 31 August through 18 October 1994. 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-1994 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, there were no survey blocks for which more than 10 percent of the area was surveyed. Six bowheads were observed within 1 km of the randomly generated transect line in Block 5, where only 9.38 percent of the block was surveyed, for an estimated density of 0.67. No bowhead whales were observed within 1 km of the transect line in other Beaufort Sea blocks during this period (Table A-1).

During the first half of September, over 10 percent of the area was surveyed for Blocks 1, 2, 4, and 5. Of these blocks, no bowheads were observed in Blocks 1 and 2 within 1 km of the randomly generated transect line, for estimated densities of 0.00 whales per 100 km^2. Nine bowheads were observed in Block 5, for an estimated density of 0.41. Three bowheads were observed in Block 4, for an estimated density of 0.27. No bowhead whales were observed within 1 km of the transect line in other Beaufort Sea blocks during this period (Table A-1).

During the second half of September, over 10 percent of the area was surveyed for Blocks 2, 4, and 11. Of these blocks, no bowheads were observed in Blocks 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 4, for an estimated density of 0.13. An additional six bowheads were observed in Block 5, where only 9.68 percent of the block was surveyed, for an estimated density of 0.54. Three bowhead whales were observed within 1 km of the transect line in other Beaufort Sea blocks during this period (Table A-1).

During the first half of October, over 10 percent of the area was surveyed for Blocks 1, 2, 3, 11, and 12. Of these blocks, no bowheads were observed in Blocks 1, 2, and 11 within 1 km of the randomly generated transect line, for an estimated density of 0.00 whales per 100 km^2. One bowhead was observed in Block 3 and also in Block 12, for estimated densities of 0.03 and 0.05, respectively. No bowhead whales were observed within 1 km of the transect line in other Beaufort Sea blocks during this period.

Table A-1
Semimonthly Estimates of Bowhead Whale Densities, by Survey Block, Fall 1994
(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								
4	5,714	174	6.09	0.78	27.29	4	0	0.00
5	9,481	445	9.38	2.08	72.58	7	6	0.67
6	8,109	0	0.00	0.00	0.04	1	0	0.00
7	8,109	1	0.01	0.00	0.09	3	0	0.00
1-15 Sep								
1	10,222	765	14.97	3.31	21.53	17	0	0.00
2	6,672	666	19.97	3.02	19.65	17	0	0.00
3	11,475	0	0.00	0.00	0.01	1	0	0.00
4	5,714	556	19.47	2.47	16.10	14	3	0.27
5	9,481	1,106	23.33	5.10	33.22	18	9	0.41
6	8,109	21	0.53	0.08	0.52	3	0	0.00
7	8,109	1	0.02	0.00	0.03	3	0	0.00
10	10,358	43	0.82	0.18	1.15	8	0	0.00
11	10,358	266	5.14	1.19	7.75	4	0	0.00
16-30 Sep								
1	10,222	443	8.68	1.99	12.74	13	1	0.11
2	6,672	705	21.14	3.23	20.71	13	0	0.00
3	11,475	555	9.68	2.50	16.00	11	6	0.54
4	5,714	381	13.35	1.71	10.97	10	1	0.13
5	9,481	414	8.74	1.77	11.34	6	2	0.24
6	8,109	235	5.79	1.06	6.81	7	0	0.00
7	8,109	0	0.01	0.00	0.01	1	0	0.00
10	10,358	5	0.09	0.03	0.17	2	0	0.00
11	10,358	741	14.30	3.31	21.19	12	0	0.00

Table A-1
Semimonthly Estimates of Bowhead Whale Densities, by Survey Block, Fall 1994
(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	533	10.43	2.31	10.17	10	0	0.00
2	6,672	411	12.32	1.85	8.16	10	0	0.00
3	11,475	1,449	25.26	6.56	28.93	22	1	0.03
4	5,714	175	6.13	0.73	3.23	4	0	0.00
5	9,481	39	0.82	0.15	0.66	1	0	0.00
10	10,358	6	0.11	0.02	0.11	4	0	0.00
11	10,358	1,329	25.66	6.06	26.74	19	0	0.00
12	11,163	1,088	19.49	4.98	21.95	14	1	0.05
12N	11,453	1	0.02	0.00	0.02	3	0	0.00
16-28 Oct								
12	11,163	917	16.43	3.97	99.32	14	0	0.00
12N	11,453	7	0.12	0.03	0.68	4	0	0.00

From 16 through 18 October, no blocks were surveyed over 10 percent of their area and no whales were observed within 1 km of the transect line in other Beaufort Sea blocks during this period.

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APPENDIX B

DAILY FLIGHT SUMMARIES

DAILY FLIGHT SUMMARIES

This appendix consists of maps for Flights 1 through 33 that depict aerial surveys flown over the study area from 31 August through 18 October 1994 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 1994
(Page 1 of 3)

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	69°47.9′	140°38.4′	body	rest	50°	0	1	31
1	31 Aug	1	0	70°03.4′	141°24.3′	body	rest	180°	3	1	40
1	31 Aug	1	0	70°05.5′	141°23.8′	body	swim	50°	2	1	40
1	31 Aug	1	0	70°17.7′	141°44.6′	body	swim	110°	1	1	57
1	31 Aug	1	0	70°14.4′	141°44.9′	blow	dive	220°	1	1	55
1	31 Aug	1	0	70°19.4′	142°22.5′	body	swim	110°	1	1	53
1	31 Aug	1	0	70°21.0′	142°22.2′	body	swim	60°	1	1	55
1	31 Aug	1	0	70°21.6′	142°22.0′	body	rest	60°	1	1	55
1	31 Aug	1	0	70°23.5′	142°21.5′	splash	swim	70°	1	1	55
2	1 Sep	1	0	70°20.2′	143°45.8′	splash	swim	50°	1	1	40
2	1 Sep	1	0	71°06.7′	147°44.5′	splash	swim	320°	50	0	613
3	2 Sep	1	0	70°11.9′	143°15.0′	body	swim	240°	1	1	11
3	2 Sep	1	0	70°13.7′	143°07.0′	body	swim	330°	1	1	29
3	2 Sep	1	0	70°15.1′	143°06.1′	body	swim	310°	1	1	37
3	2 Sep	3	0	70°10.1′	142°41.7′	slick	swim	60°	1	1	33
3	2 Sep	1	0	70°09.6′	142°39.2′	body	slap	320°	1	1	29
3	2 Sep	1	0	70°10.4′	142°43.1′	body	swim	240°	1	1	33
3	2 Sep	1	0	70°09.6′	142°37.4′	[1]	[1]	290°	1	1	29
3	2 Sep	2	0	70°09.8′	142°39.3′	[1]	[1]	240°	1	1	29
3	2 Sep	3	0	70°10.3′	142°41.7′	body	swim	250°	1	1	33
3	2 Sep	3	0	70°09.1′	142°36.8′	slick	swim	260°	1	1	29
3	2 Sep	1	0	70°07.3′	142°35.5′	body	swim	310°	1	1	27
3	2 Sep	1	0	70°06.3′	142°15.4′	[1]	[1]	210°	1	1	33
3	2 Sep	1	0	70°07.0′	142°12.8′	splash	swim	230°	1	1	33
3	2 Sep	3	0	70°06.9′	142°03.8′	body	[1]	[1]	1	1	38
3	2 Sep	3	1	70°06.2′	142°00.3′	[1]	cow-calf	350°	1	1	38
3	2 Sep	1	0	70°04.2′	141°52.9′	[1]	[1]	10°	1	1	29
3	2 Sep	3	0	70°03.4′	141°53.5′	body	swim	[1]	1	0	29
3	2 Sep	2	0	70°03.3′	141°59.1′	body	[1]	360°	1	0	29
3	2 Sep	8	0	70°03.3′	142°01.1′	body	mill	[1]	1	0	26
3	2 Sep	2	0	70°02.6′	142°10.8′	body	swim	[1]	1	0	18
3	2 Sep	1	0	70°01.4′	142°10.7′	body	rest	260°	1	0	18
3	2 Sep	1	0	70°00.2′	142°09.0′	body	swim	210°	1	0	22
3	2 Sep	2	1	70°04.0′	141°41.2′	blow	cow-calf	10°	0	1	29
3	2 Sep	2	0	70°02.4′	141°39.1′	body	swim	[1]	0	1	31
3	2 Sep	6	0	70°01.0′	141°39.0′	slick	swim	350°	0	1	31

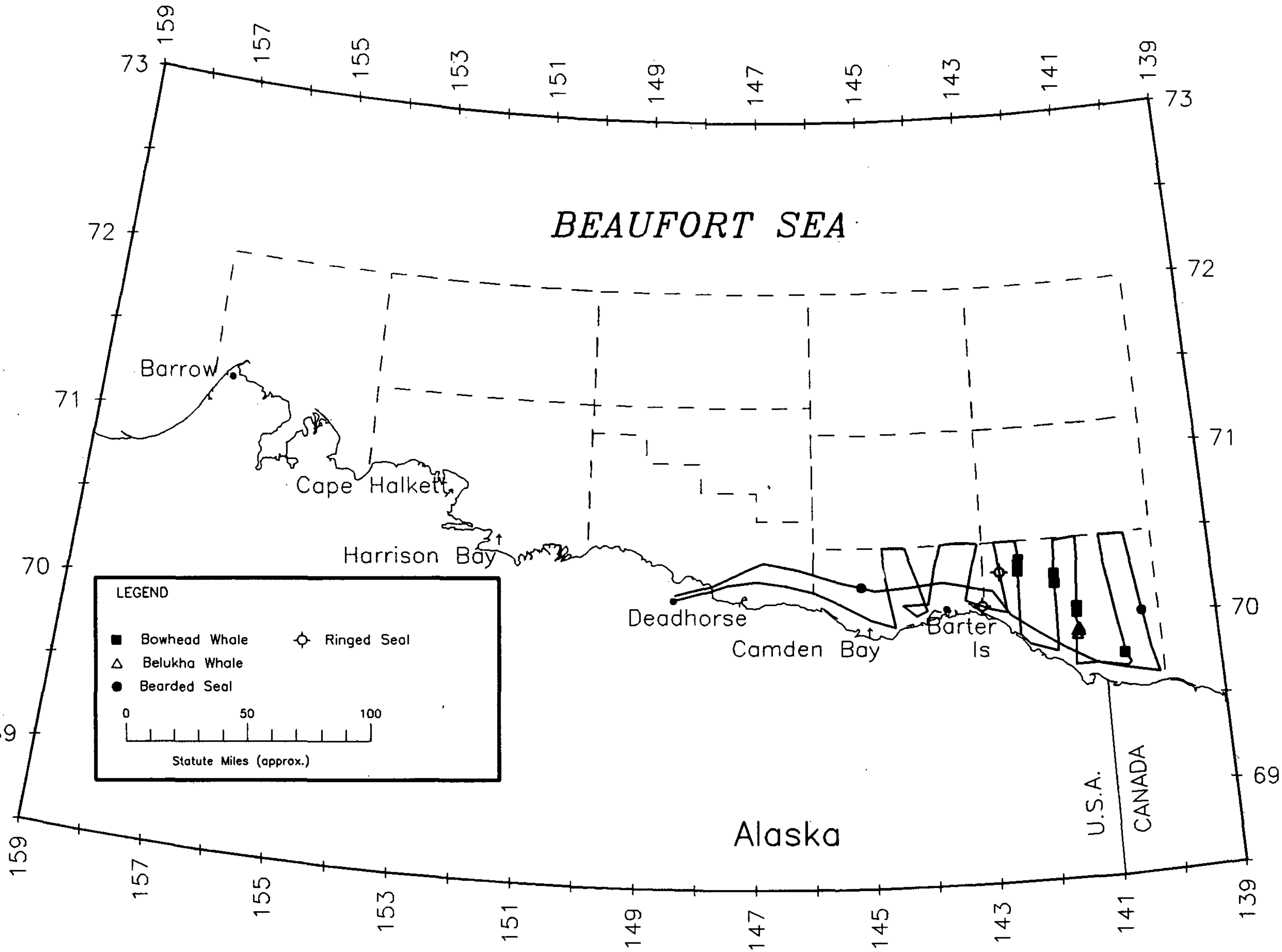
Table B-1
Selected Sighting Data for Bowhead Whales Observed, Fall 1994
(Page 2 of 3)

Flight No.	Day	Total Whales	No. of Calves	Latitude (North)	Longitude (West)	Sighting Cue	Behavior	Compass Heading	Ice (%)	Sea State	Dept (m)
3	2 Sep	4	0	69°58.6′	141°39.5′	slick	swim	340°	0	1	40
3	2 Sep	1	0	70°00.7′	142°04.9′	body	rest	130°	0	1	22
3	2 Sep	1	0	70°02.4′	142°06.2′	body	swim	30°	0	1	22
3	2 Sep	3	0	70°04.5′	142°07.7′	body	swim	90°	0	1	26
7	7 Sep	1	0	70°21.2′	143°20.9′	blow	swim	40°	0	2	46
7	7 Sep	1	0	70°22.9′	143°21.2′	body	swim	40°	0	2	46
9	9 Sep	1	0	69°44.5′	140°05.7′	splash	swim	220°	0	4	26
9	9 Sep	4	0	70°09.1′	140°18.1′	body	swim	330°	0	2	55
9	9 Sep	3	0	70°08.5′	140°30.3′	[1]	[1]	320°	0	2	42
9	9 Sep	2	0	70°08.3′	140°27.3′	[1]	[1]	330°	0	2	42
9	9 Sep	6	0	70°07.0′	140°33.2′	body	[1]	[1]	1	2	42
9	9 Sep	1	0	70°05.5′	140°32.5′	[1]	[1]	210°	1	2	46
9	9 Sep	4	0	70°04.8′	140°29.9′	[1]	[1]	210°	1	2	44
9	9 Sep	3	0	70°04.9′	140°27.4′	[1]	mill	60°	1	2	44
9	9 Sep	1	0	70°05.4′	140°25.7′	body	swim	200°	1	2	44
9	9 Sep	4	0	70°04.1′	140°23.7′	[1]	mill	[1]	1	2	44
9	9 Sep	3	0	70°02.0′	140°23.9′	[1]	[1]	[1]	0	2	48
9	9 Sep	1	0	70°03.6′	140°21.4′	body	[1]	270°	0	2	44
9	9 Sep	1	0	70°04.4′	140°16.8′	slick	swim	200°	0	2	49
9	9 Sep	6	0	70°11.8′	140°17.7′	[1]	swim	210°	0	2	55
9	9 Sep	5	0	70°13.2′	140°18.2′	slick	[1]	190°	0	2	55
9	9 Sep	14	0	70°14.4′	140°18.3′	body	swim	210°	0	2	55
9	9 Sep	2	0	70°13.5′	140°46.0′	body	swim	190°	1	2	48
9	9 Sep	1	0	70°08.0′	140°47.3′	body	swim	270°	1	2	48
9	9 Sep	2	0	70°03.0′	140°46.5′	blow	swim	250°	1	2	46
9	9 Sep	1	0	70°03.8′	142°08.4′	body	swim	250°	1	2	20
11	13 Sep	1	0	69°51.4′	140°22.7′	slick	swim	90°	0	4	31
11	13 Sep	1	0	69°54.9′	140°21.3′	slick	swim	90°	0	4	40
11	13 Sep	1	0	69°55.9′	140°21.5′	splash	swim	100°	0	4	40
11	13 Sep	1	0	70°08.6′	140°47.8′	blow	swim	250°	0	4	48
11	13 Sep	1	0	70°20.4′	142°17.9′	body	dive	80°	5	5	49
13	17 Sep	1	0	70°36.1′	149°01.8′	body	swim	180°	1	5	13
13	17 Sep	6	0	70°59.4′	152°40.6′	blow	swim	100°	0	4	9
13	17 Sep	1	0	70°51.1′	151°40.5′	body	dive	90°	0	4	13
15	22 Sep	5	0	70°22.6′	144°18.9′	body	swim	360°	0	2	42
15	22 Sep	2	0	69°44.4′	140°59.6′	body	swim	280°	0	1	24

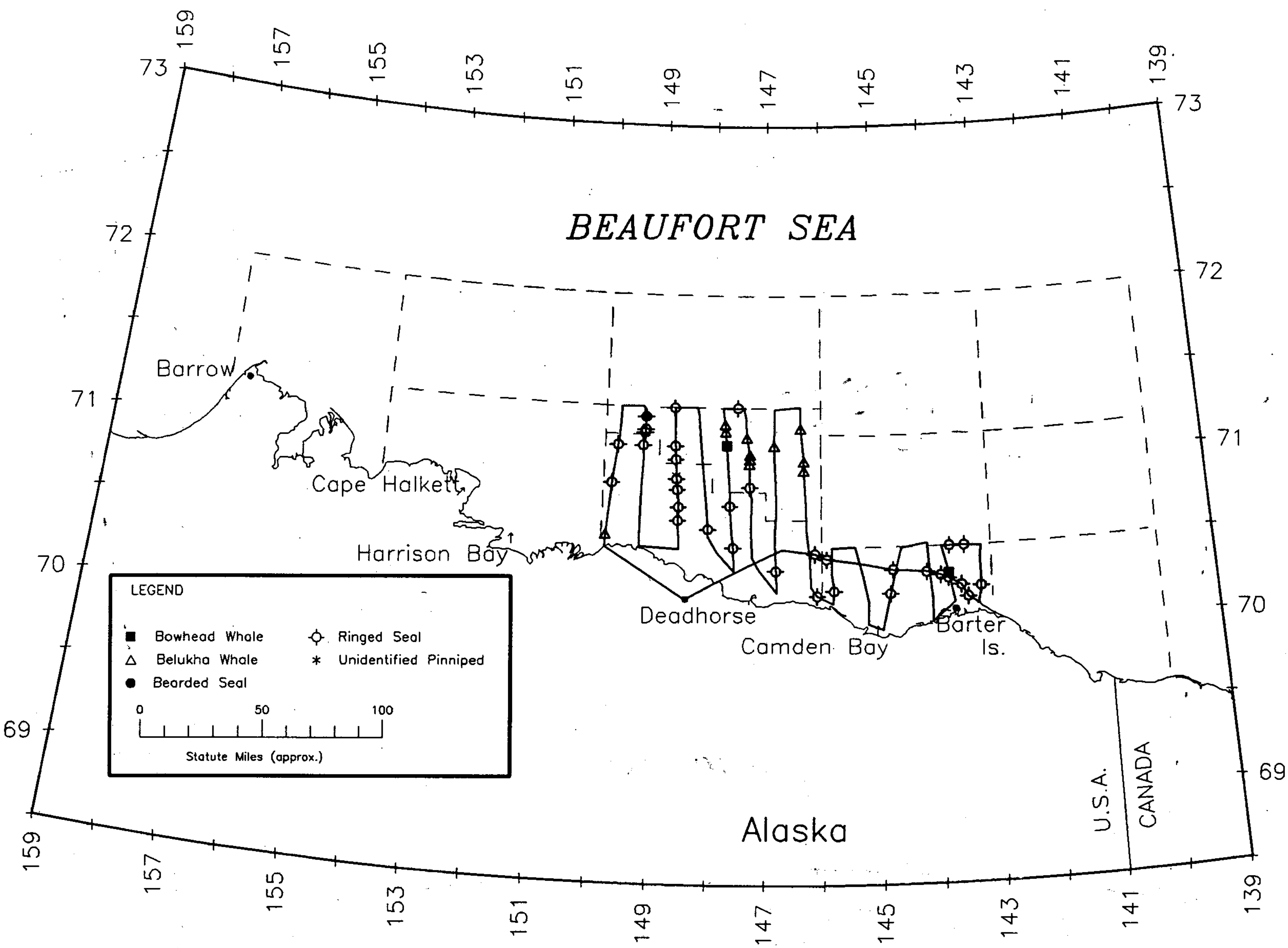
Table B-1
Selected Sighting Data for Bowhead Whales Observed, Fall 1994
(Page 3 of 3)

Flight No.	Day	Total Whales	No. of Calves	Latitude (North)	Longitude (West)	Sighting Cue	Behavior	Compass Heading	Ice (%)	Sea State	Depth (m)
15	22 Sep	1	0	69°43.3′	140°54.1′	body	[1]	300°	0	1	24
15	22 Sep	1	0	69°42.7′	140°56.4′	body	[1]	280°	0	1	24
15	22 Sep	1	0	69°41.9′	140°54.5′	body	[1]	290°	0	1	18
15	22 Sep	1	0	69°40.3′	140°52.4′	body	dive	280°	0	1	18
15	22 Sep	1	0	69°38.3′	140°30.1′	slick	swim	240°	0	1	13
15	22 Sep	1	0	69°48.9′	140°25.7′	body	rest	210°	0	1	29
15	22 Sep	1	0	69°52.2′	140°24.5′	body	rest	220°	0	1	31
15	22 Sep	1	0	69°53.1′	140°24.3′	slick	swim	240°	0	1	31
15	22 Sep	1	0	69°59.1′	140°23.5′	body	swim	230°	0	1	49
17	24 Sep	1	0	70°27.8′	143°53.2′	body	swim	170°	0	4	37
17	24 Sep	2	0	70°28.0′	143°55.3′	body	swim	30°	0	4	37
17	24 Sep	2	1	70°28.3′	143°53.4′	body	cow-calf	150°	0	4	37
17	24 Sep	3	0	70°28.4′	143°55.2′	body	swim	60°	0	4	37
17	24 Sep	1	0	70°26.5′	143°55.7′	blow	swim	60°	0	4	37
17	24 Sep	1	0	70°21.2′	143°54.7′	splash	swim	100°	0	4	35
17	24 Sep	1	0	70°29.9′	144°49.3′	body	swim	150°	0	4	42
17	24 Sep	1	0	70°29.8′	145°07.3′	splash	swim	100°	0	4	42
17	24 Sep	1	0	70°29.9′	145°09.8′	body	swim	100°	0	4	42
17	24 Sep	1	0	70°30.3′	145°15.4′	splash	log play	[1]	0	4	42
17	24 Sep	2	0	70°30.9′	145°14.3′	body	swim	190°	0	4	42
17	24 Sep	1	0	70°32.3′	146°43.6′	splash	swim	210°	0	3	37
17	24 Sep	1	0	70°27.1′	146°43.4′	splash	swim	260°	0	3	27
21	29 Sep	1	0	70°29.5′	144°38.1′	body	swim	300°	50	2	42
21	29 Sep	1	0	70°16.0′	146°16.5′	body	swim	250°	0	2	15
21	29 Sep	2	0	70°16.9′	146°27.4′	splash	swim	260°	0	2	15
22	1 Oct	1	0	70°45.4′	151°14.0′	body	swim	220°	40	1	16
22	1 Oct	1	0	71°13.1′	152°54.3′	body	swim	240°	70	2	27
23	7 Oct	1	0	70°55.2′	146°38.1′	body	dive	150°	95	2	181
23	7 Oct	3	0	70°55.4′	146°37.0′	body	swim	[1]	95	2	181
24	8 Oct	2	0	71°15.0′	154°16.3′	body	rest	210°	90	1	20
28	13 Oct	1	0	71°32.6′	156°42.4′	blow	swim	270°	90	1	144
28	13 Oct	2	0	71°32.2′	157°32.6′	blow	swim	240°	20	5	73
33	18 Oct	1	0	65°46.3′	167°57.6′	body	dive	220°	2	2	[1]

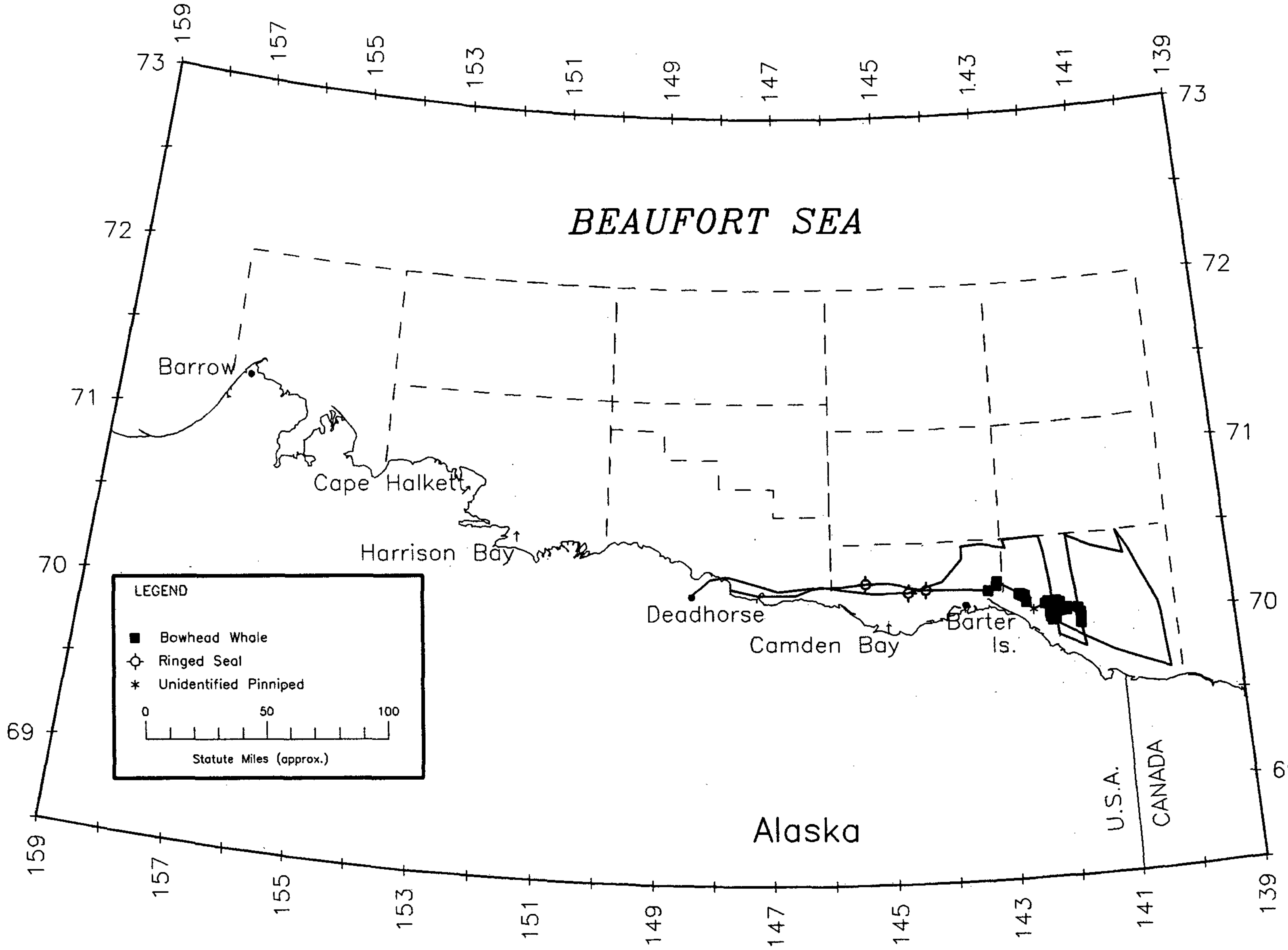
[1] Not recorded



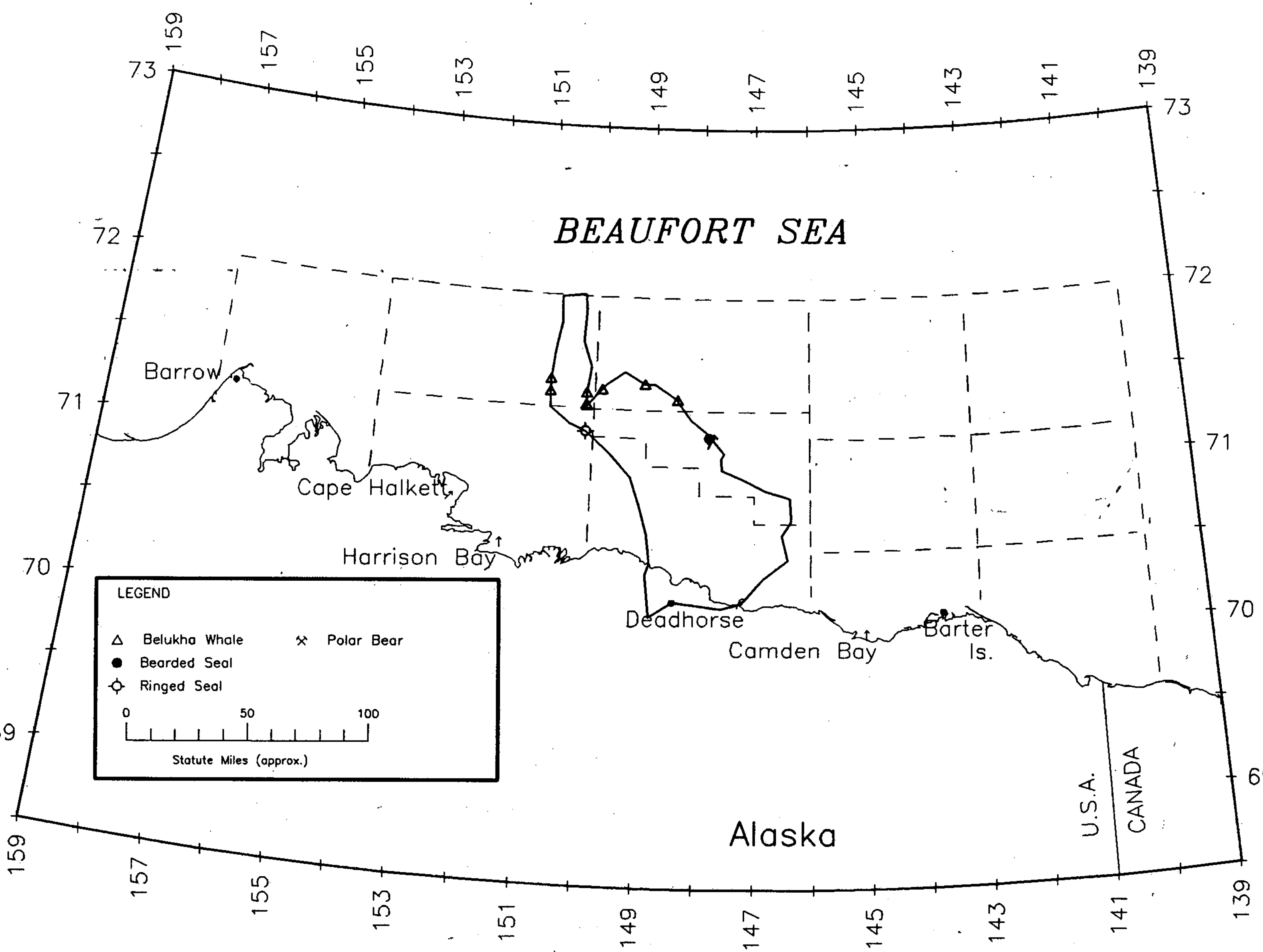
FLIGHT 1 31 August 1994
Survey Track and Sightings



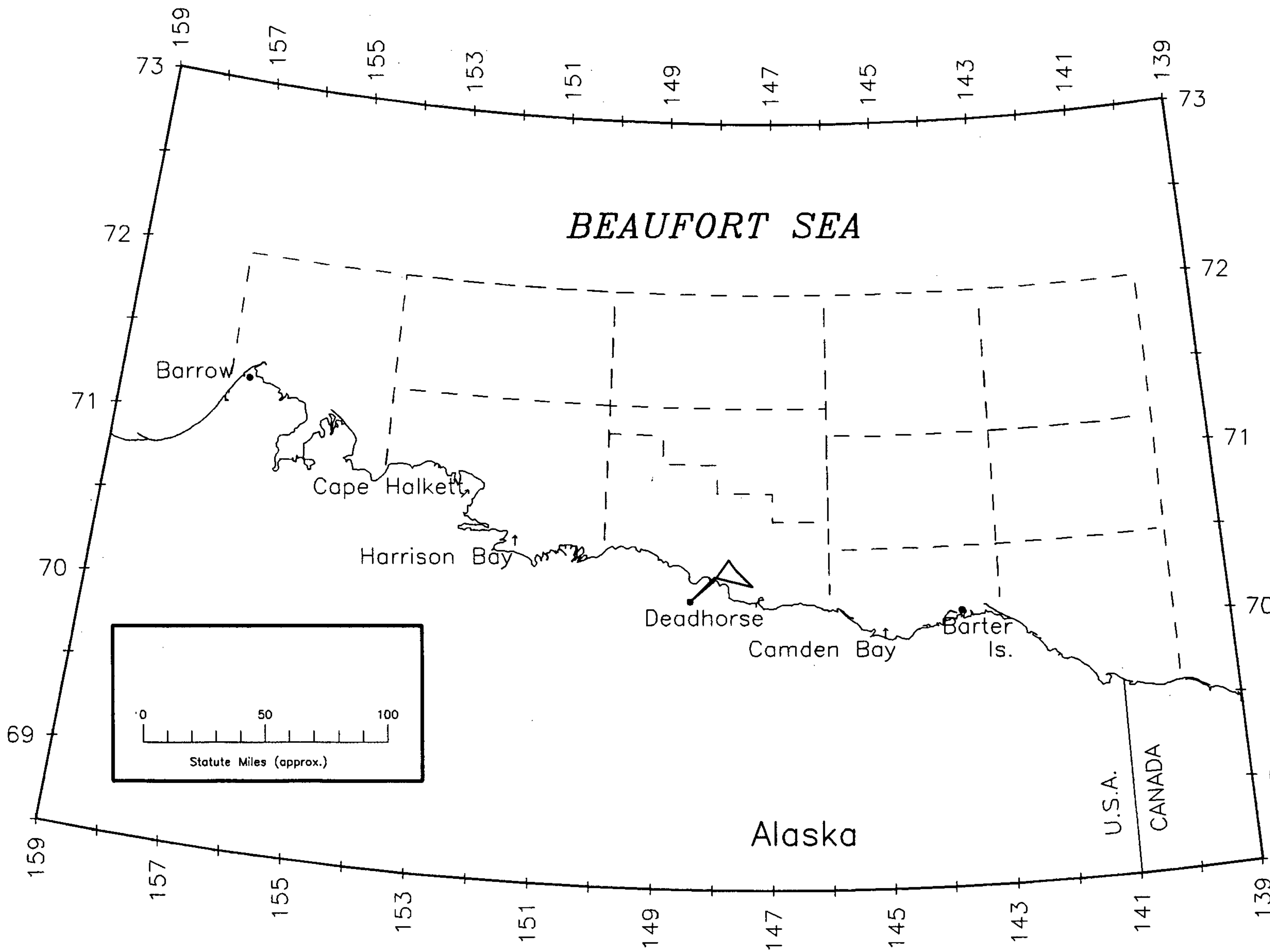
FLIGHT 2 1 September 1994
Survey Track and Sightings



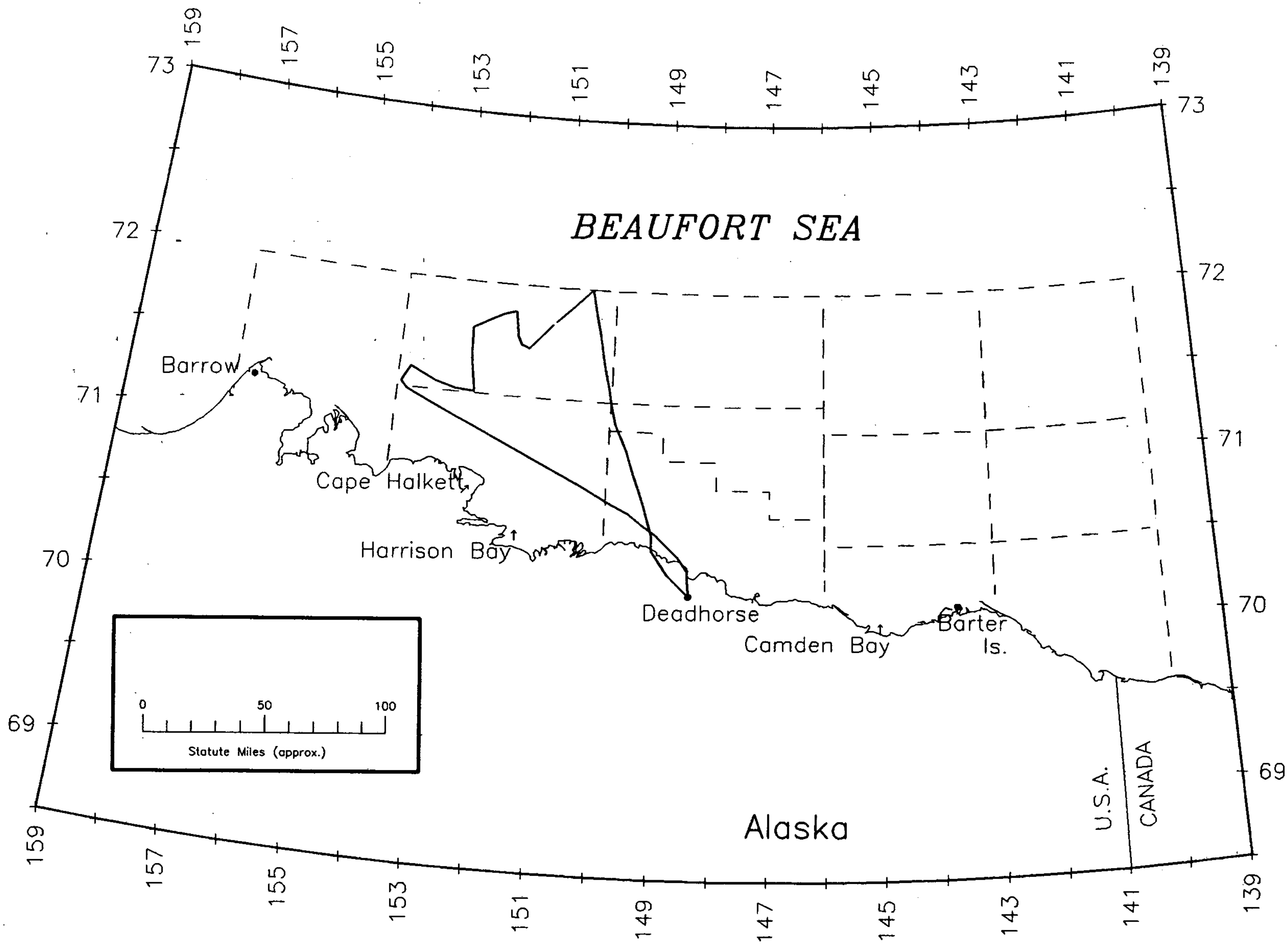
FLIGHT 3 2 September 1994
Survey Track and Sightings



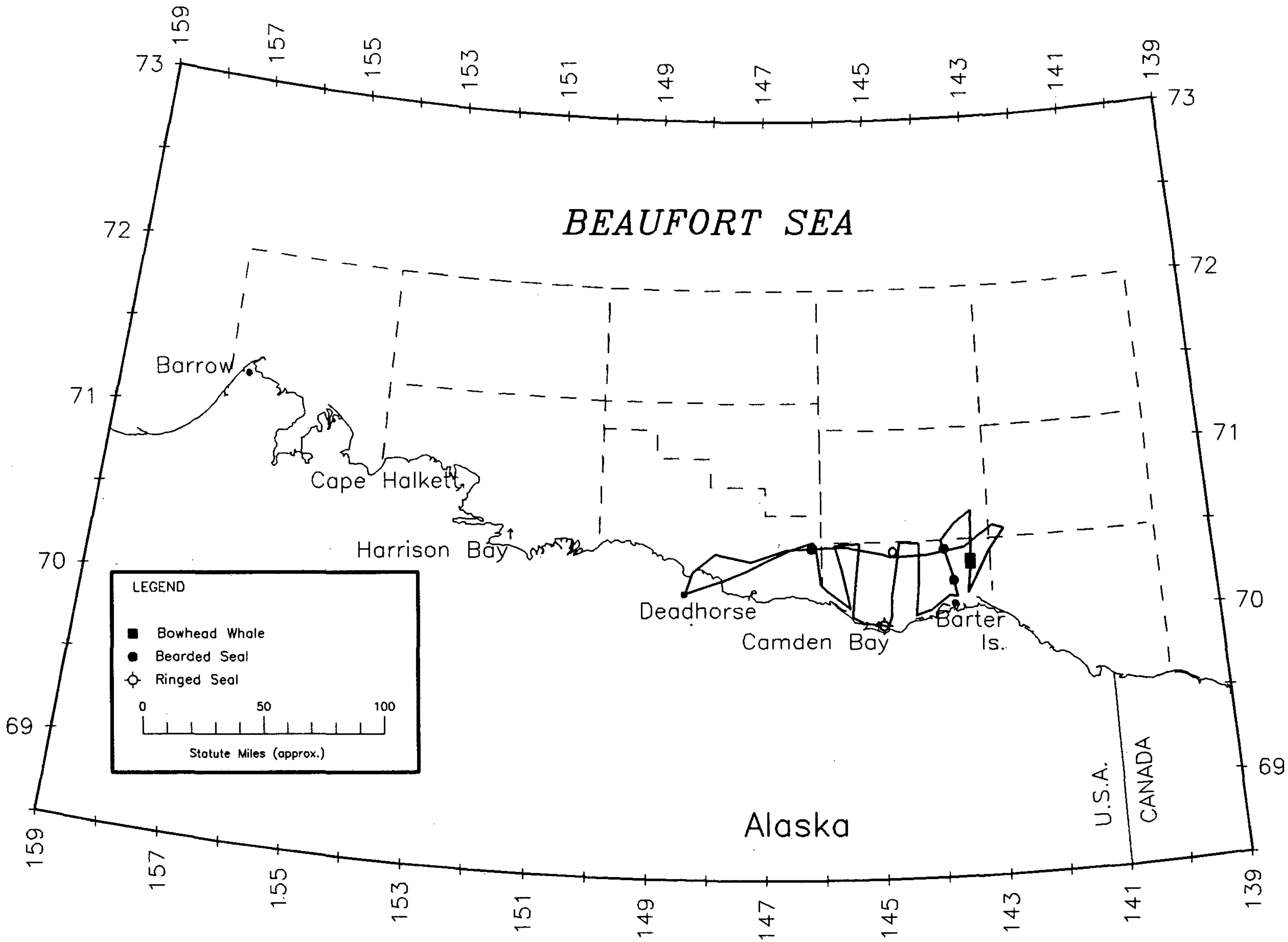
FLIGHT 4 4 September 1994
Survey Track and Sightings



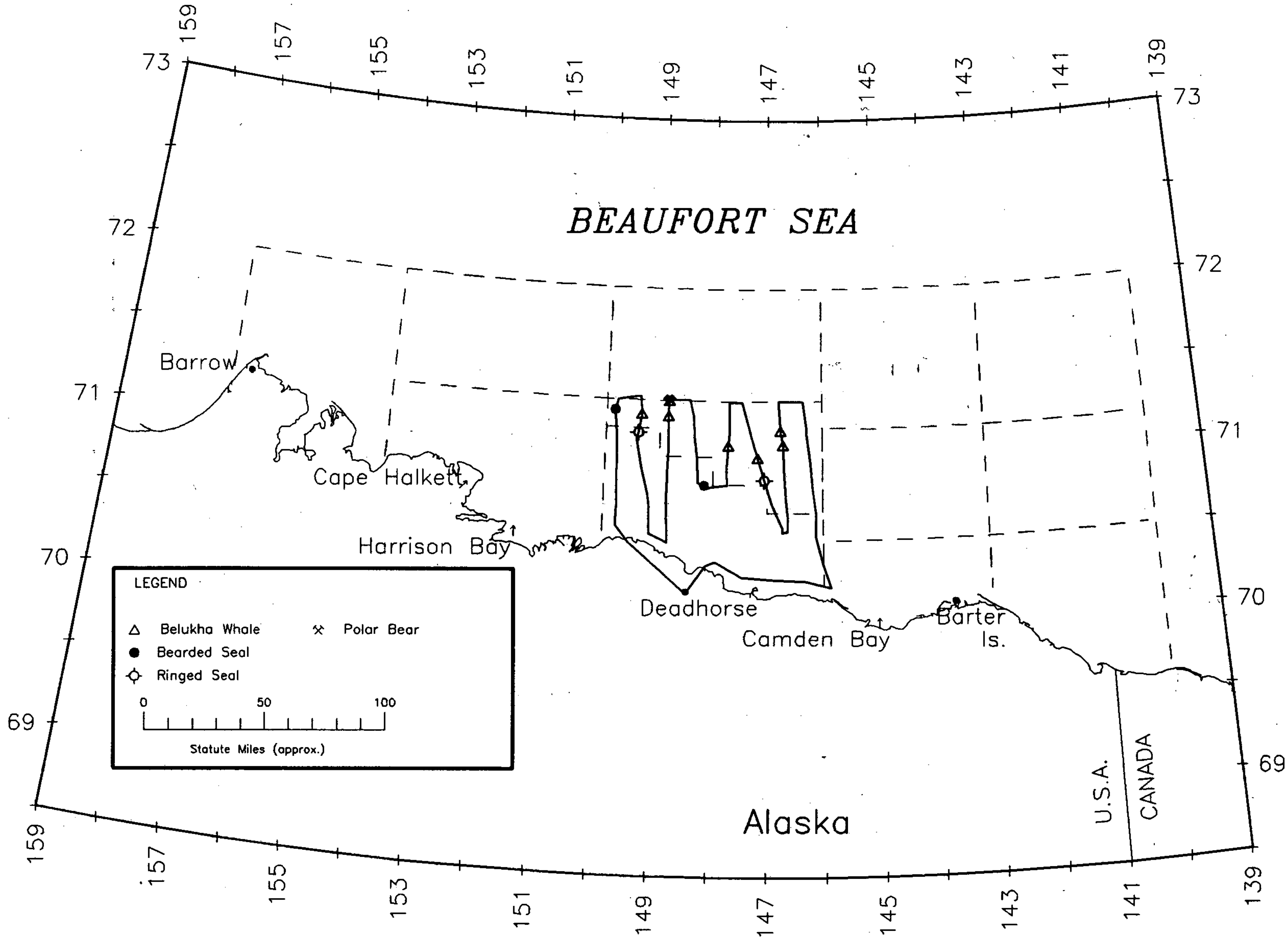
FLIGHT 5 5 September 1994
Survey Track and Sightings



FLIGHT 6 5 September 1994
Survey Track and Sightings



FLIGHT 7 7 September 1994
Survey Track and Sightings



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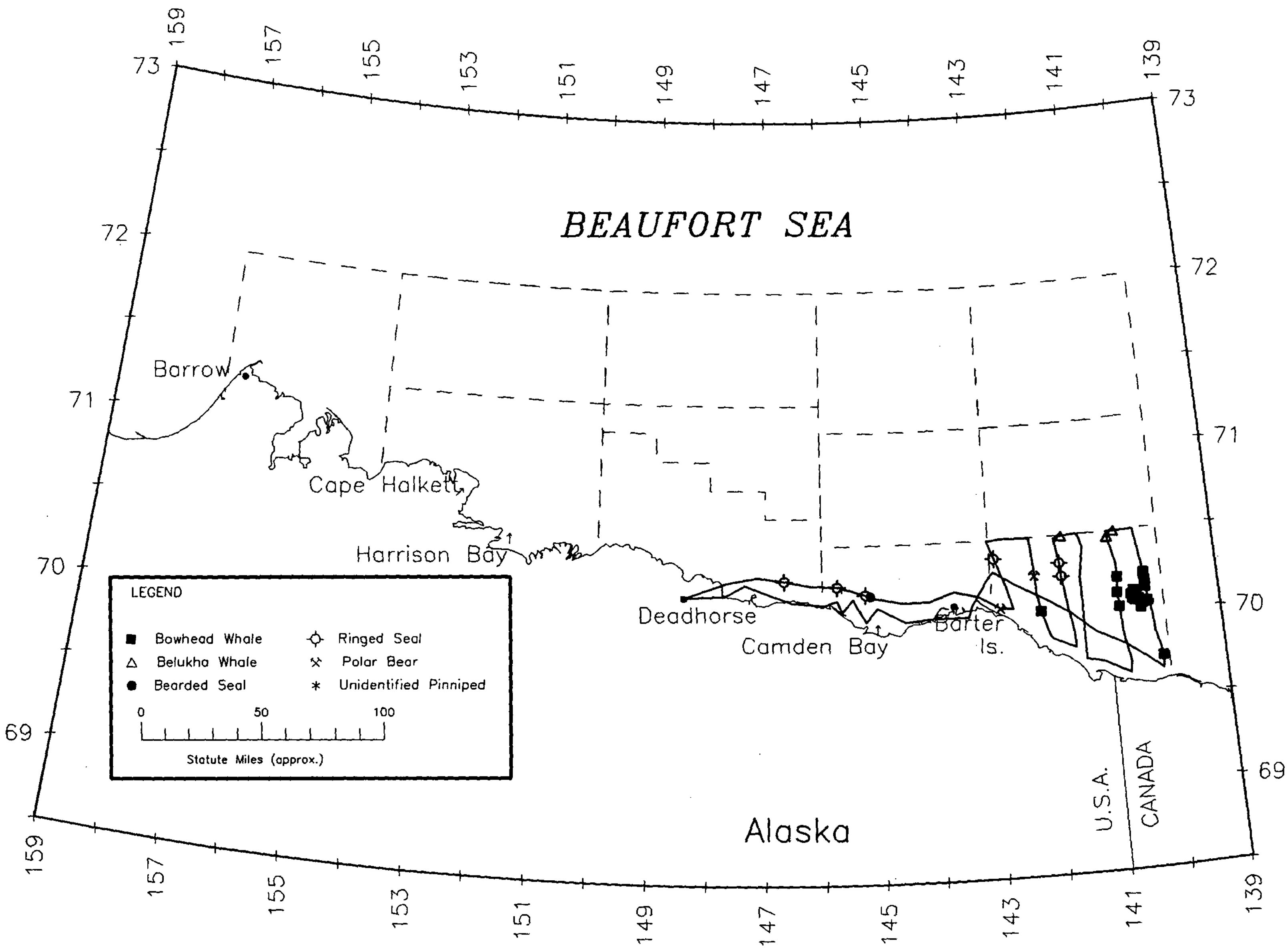
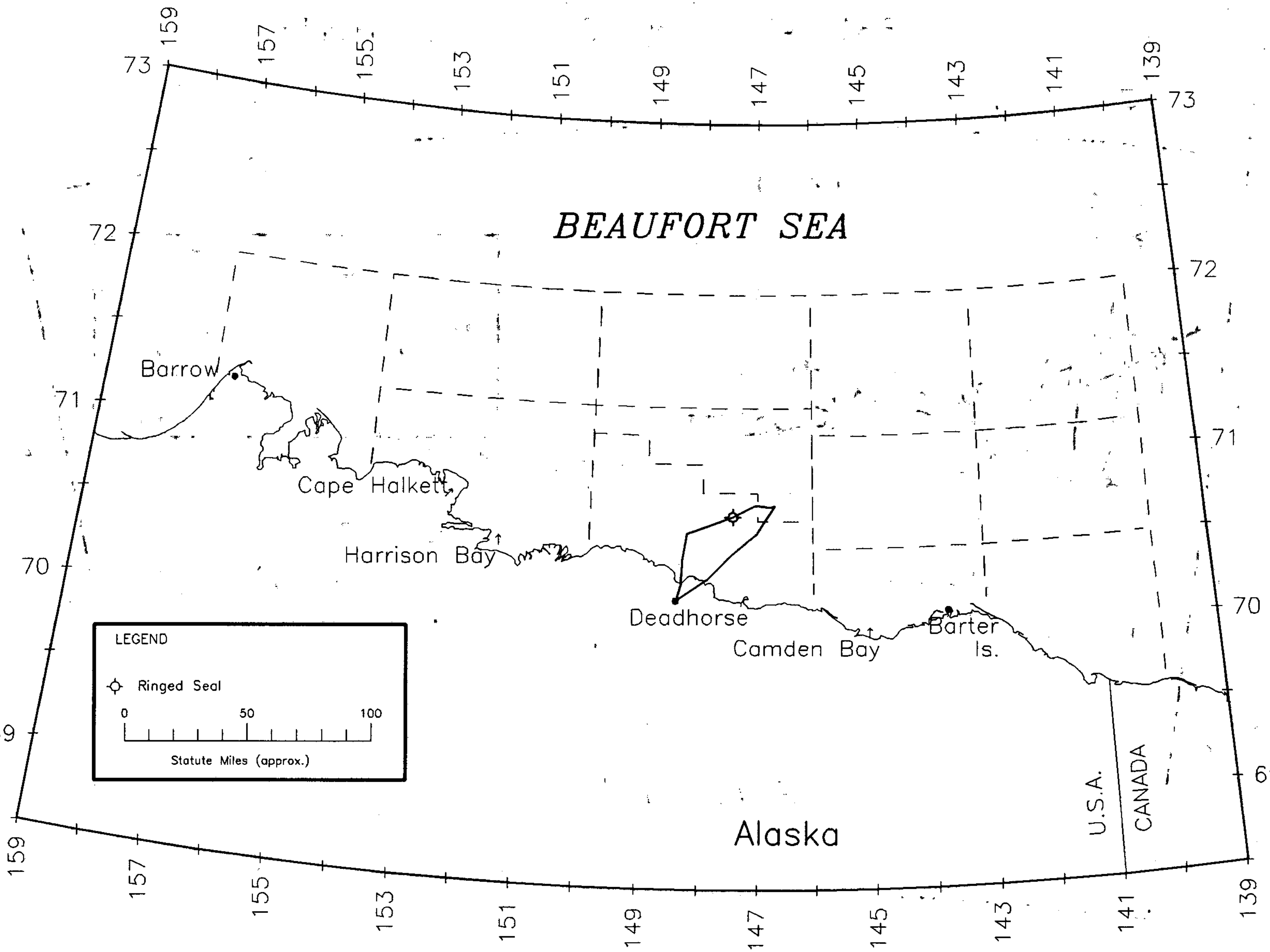
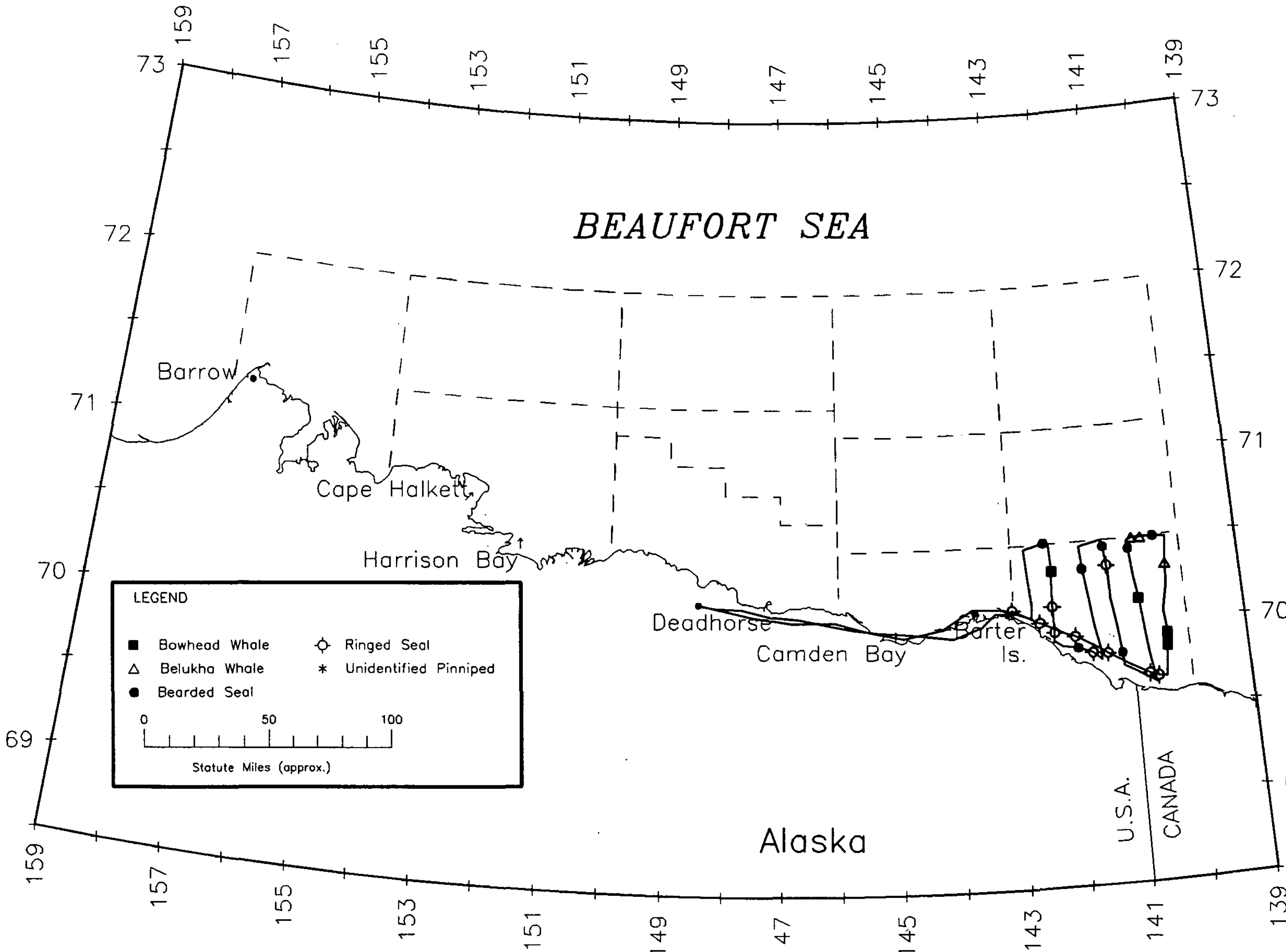


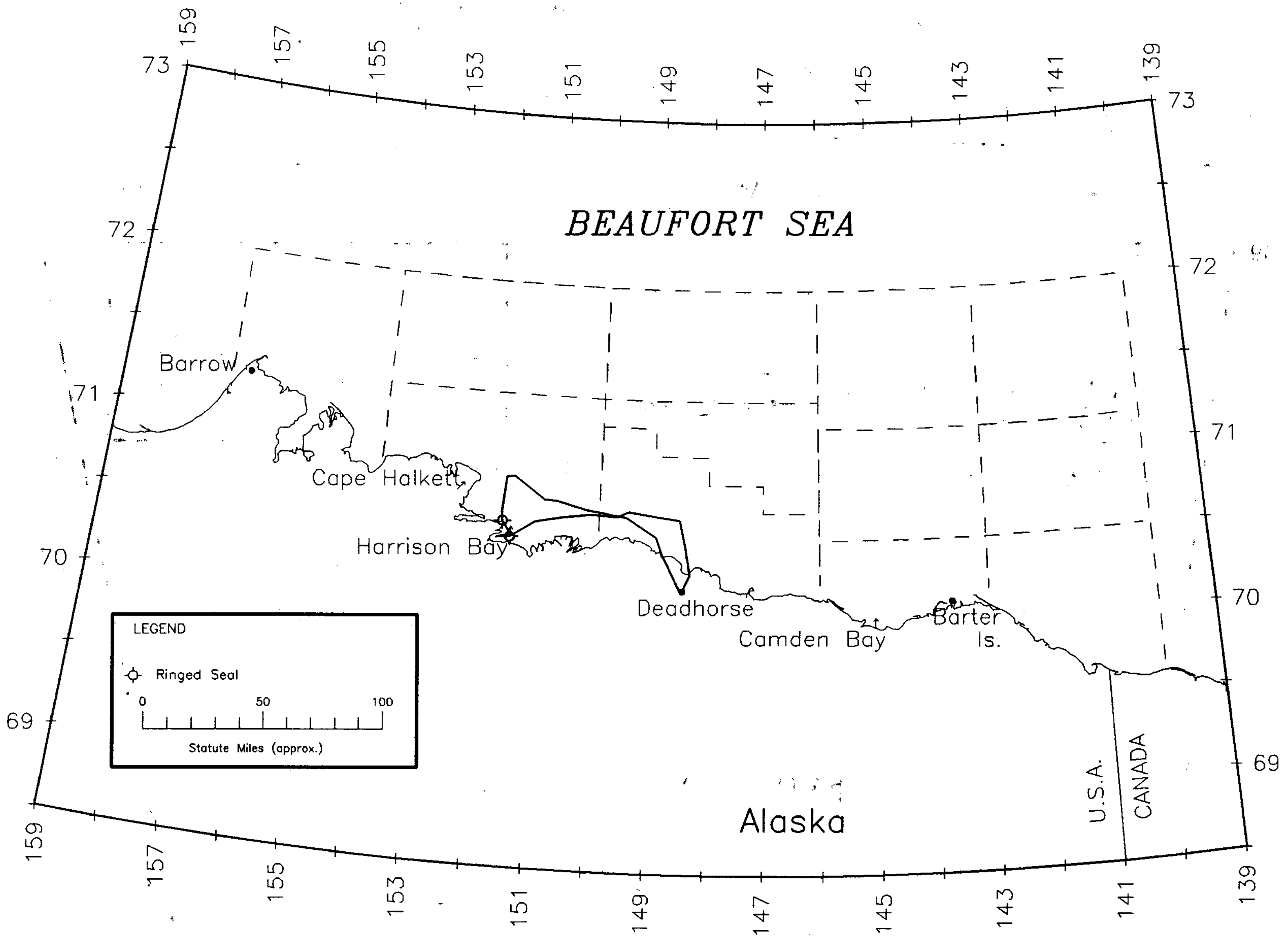
FLIGHT 9 9 September 1994
Survey Track and Sightings



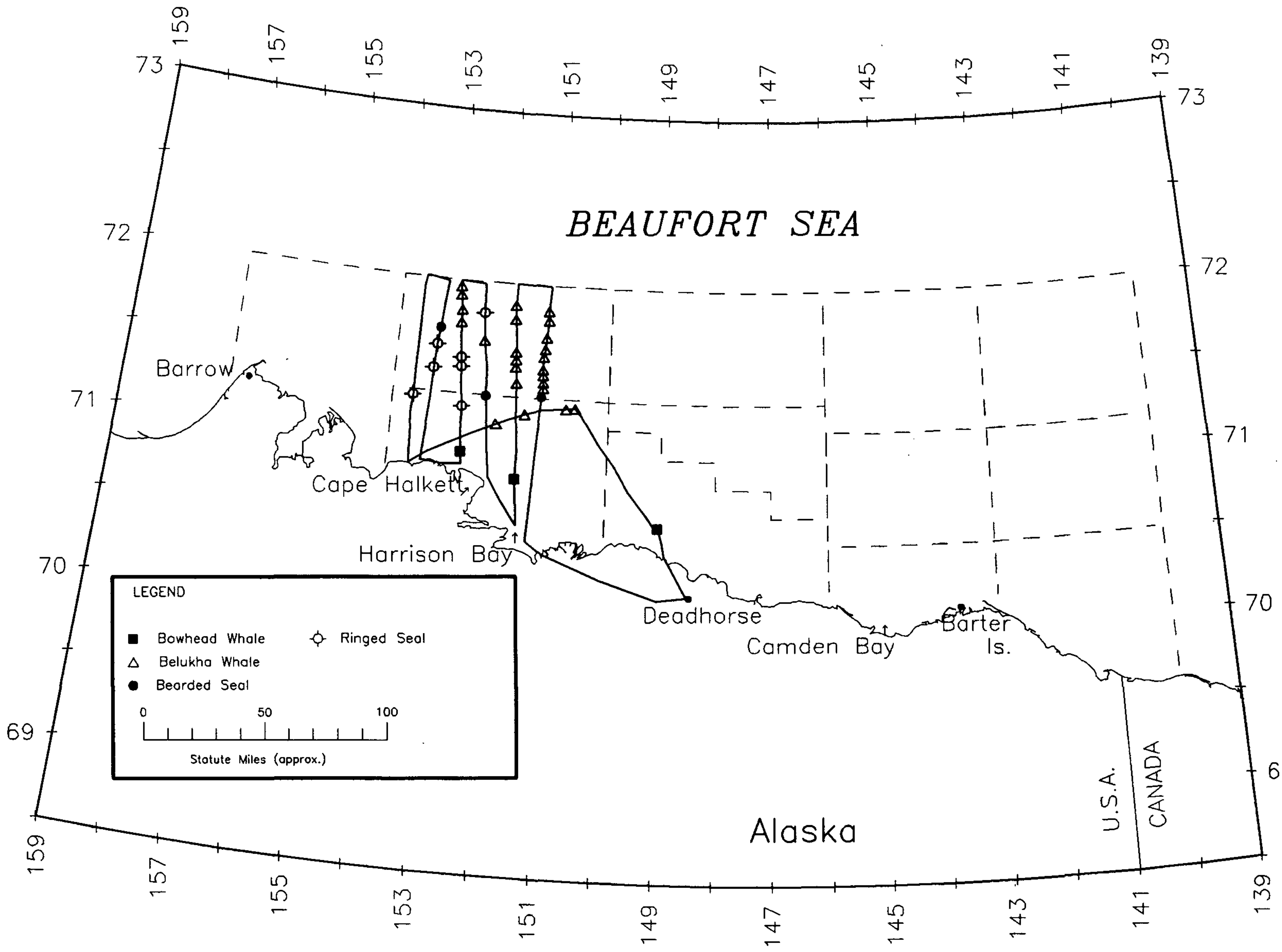
FLIGHT 10 12 September 1994
Survey Track and Sightings



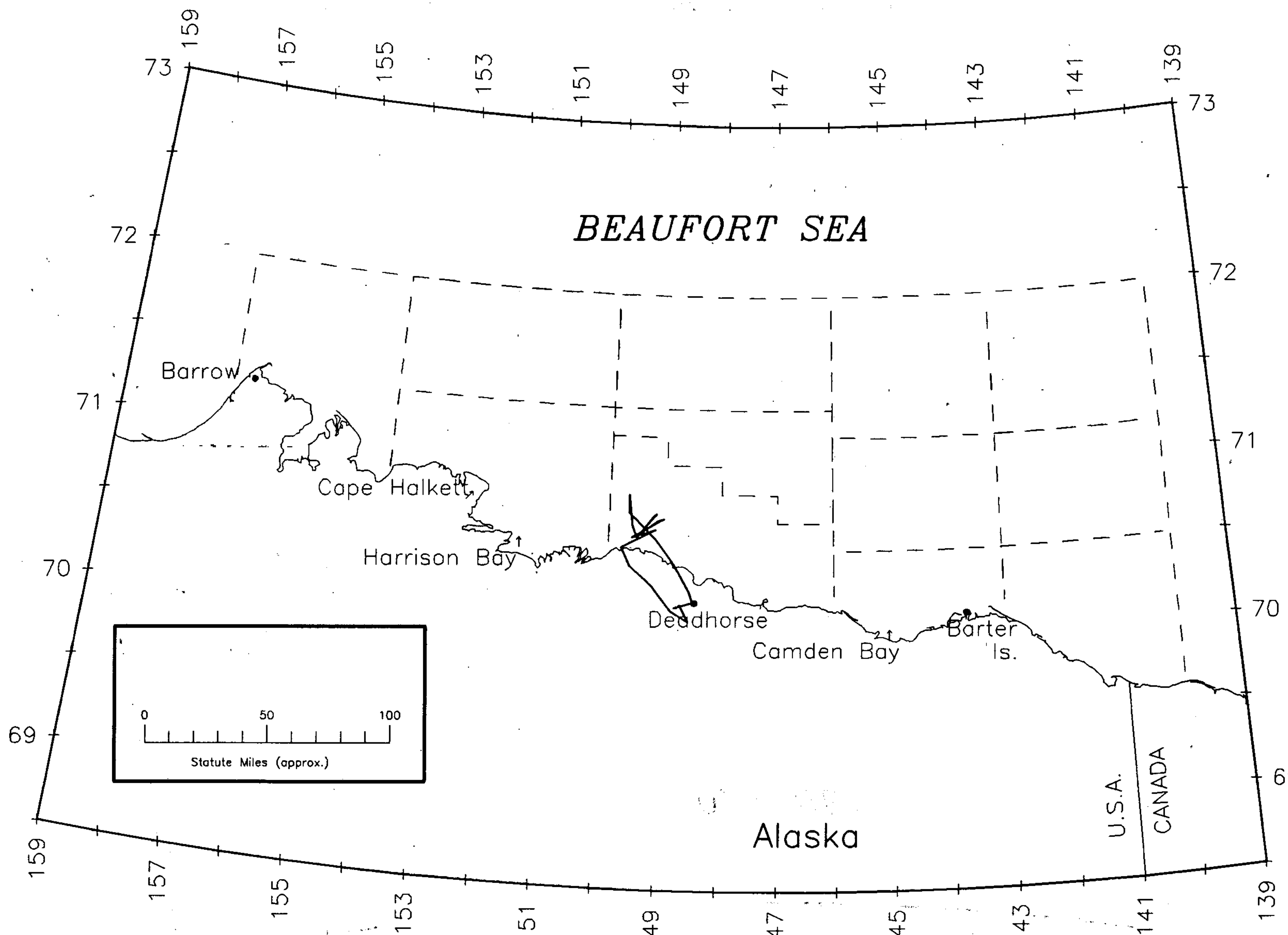
FLIGHT 11 13 September 1994
Survey Track and Sightings



FLIGHT 12 16 September 1994
Survey Track and Sightings



FLIGHT 13 17 September 1994
Survey Track and Sightings



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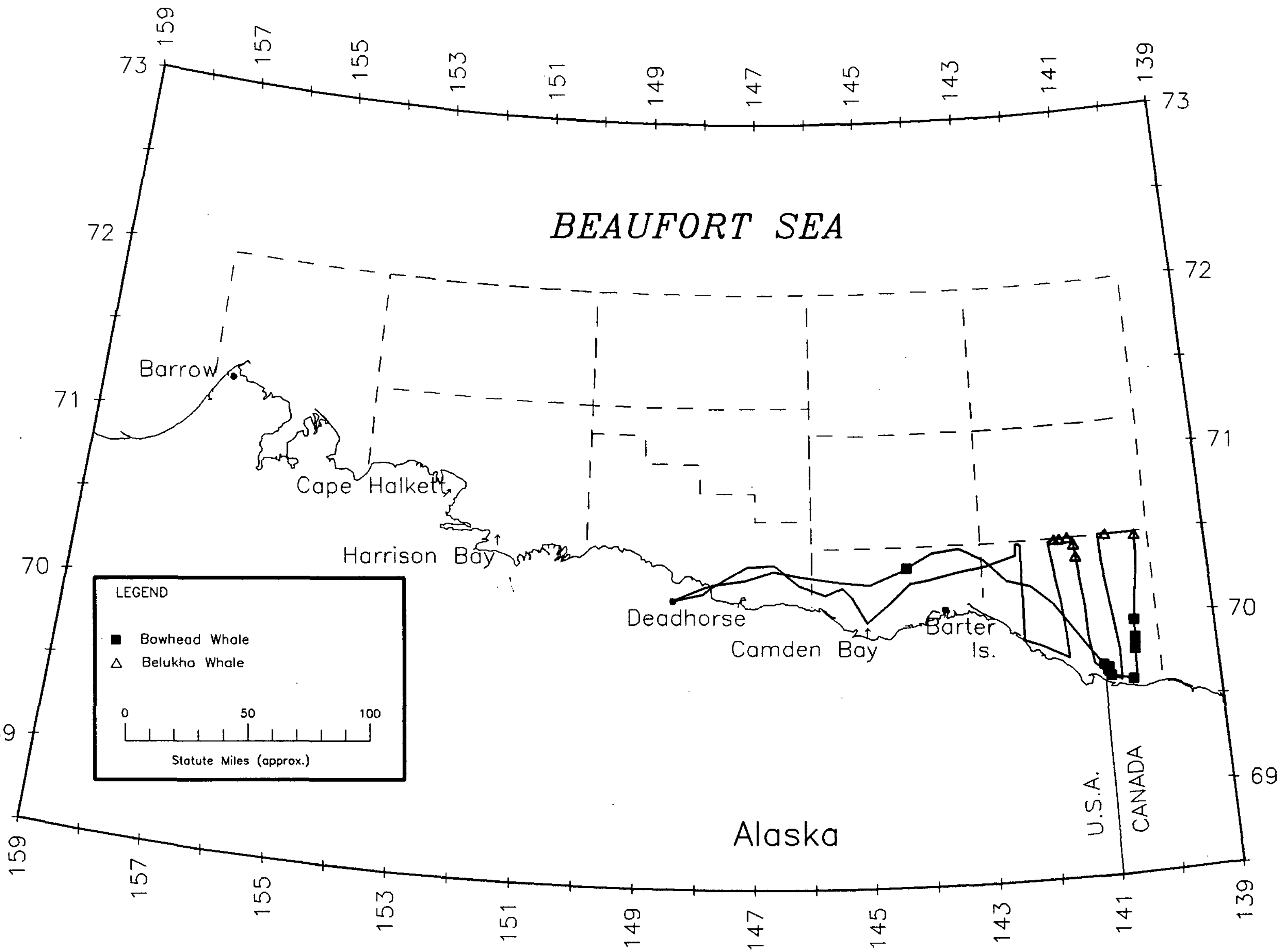
Survey Track and Sightings



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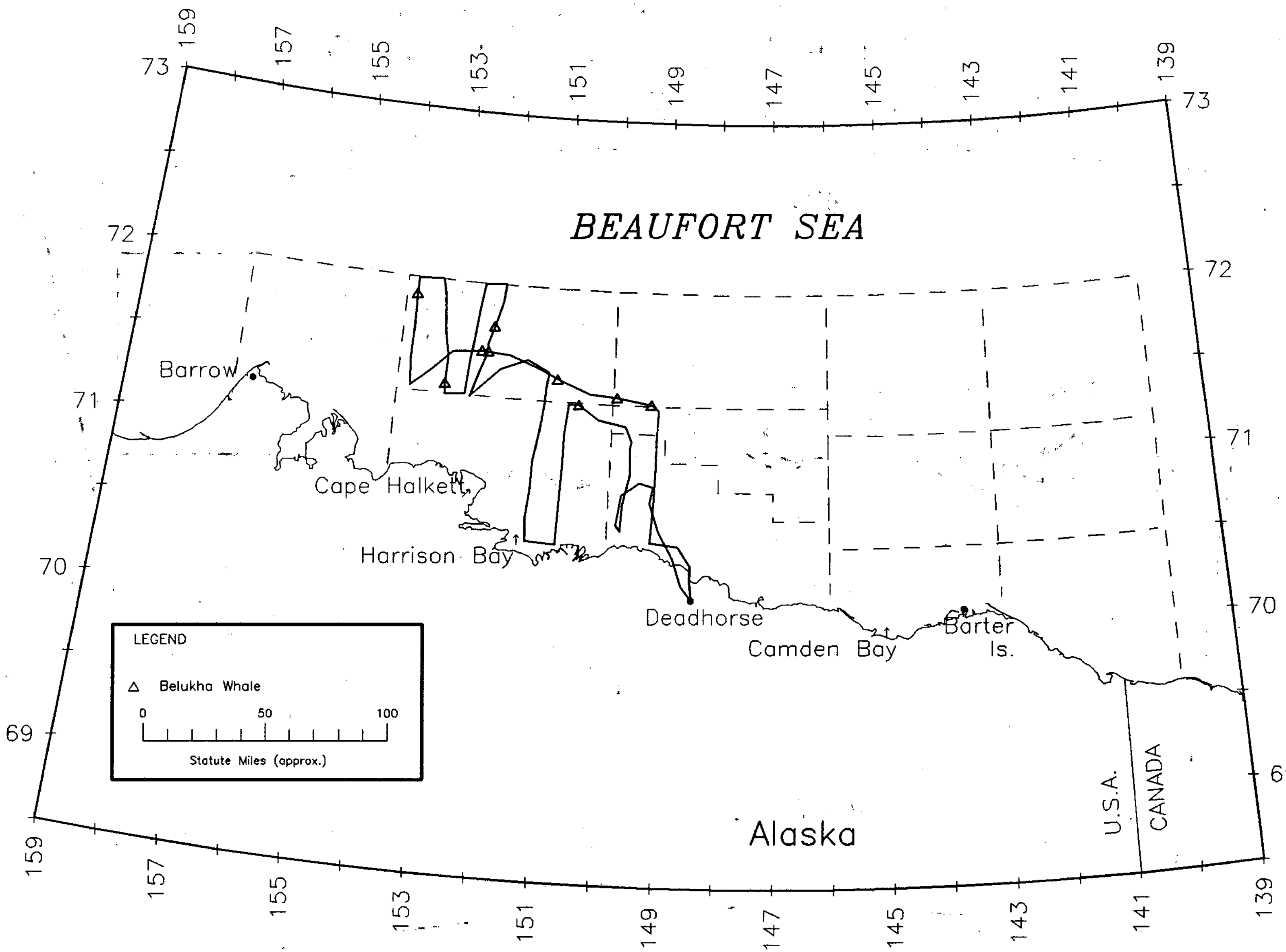
Survey Track and Sightings



FLIGHT 16 23 September 1994
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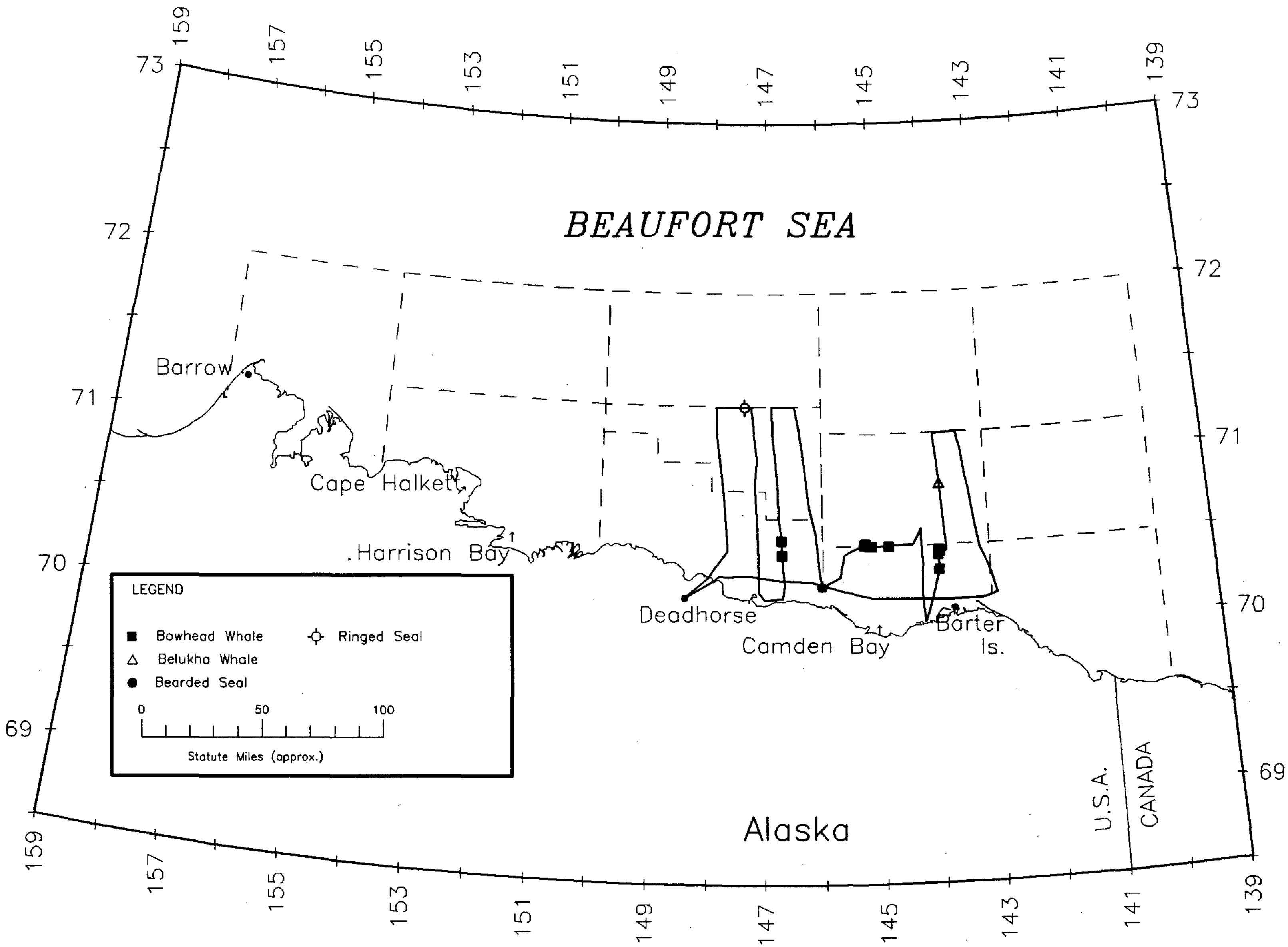
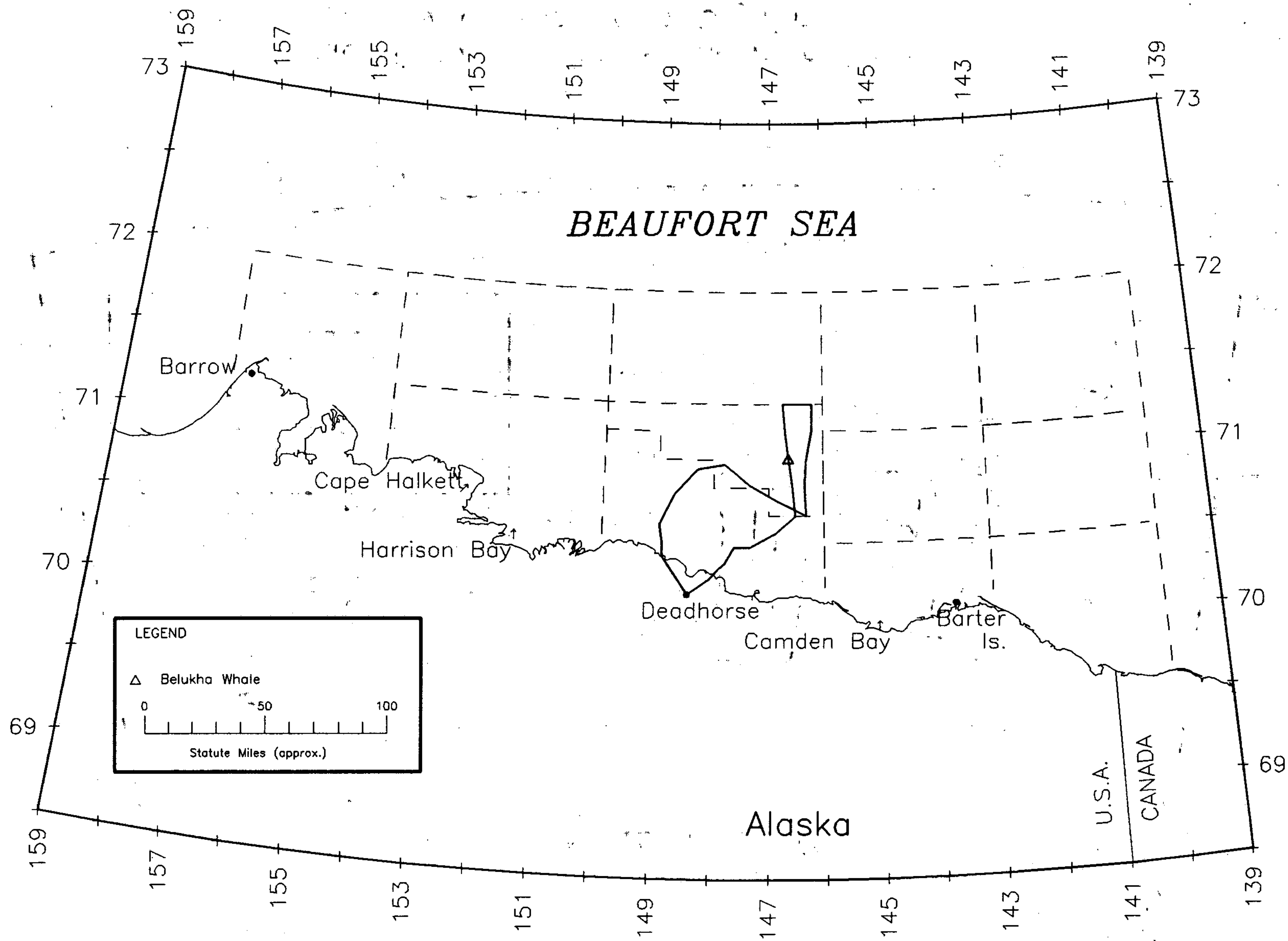
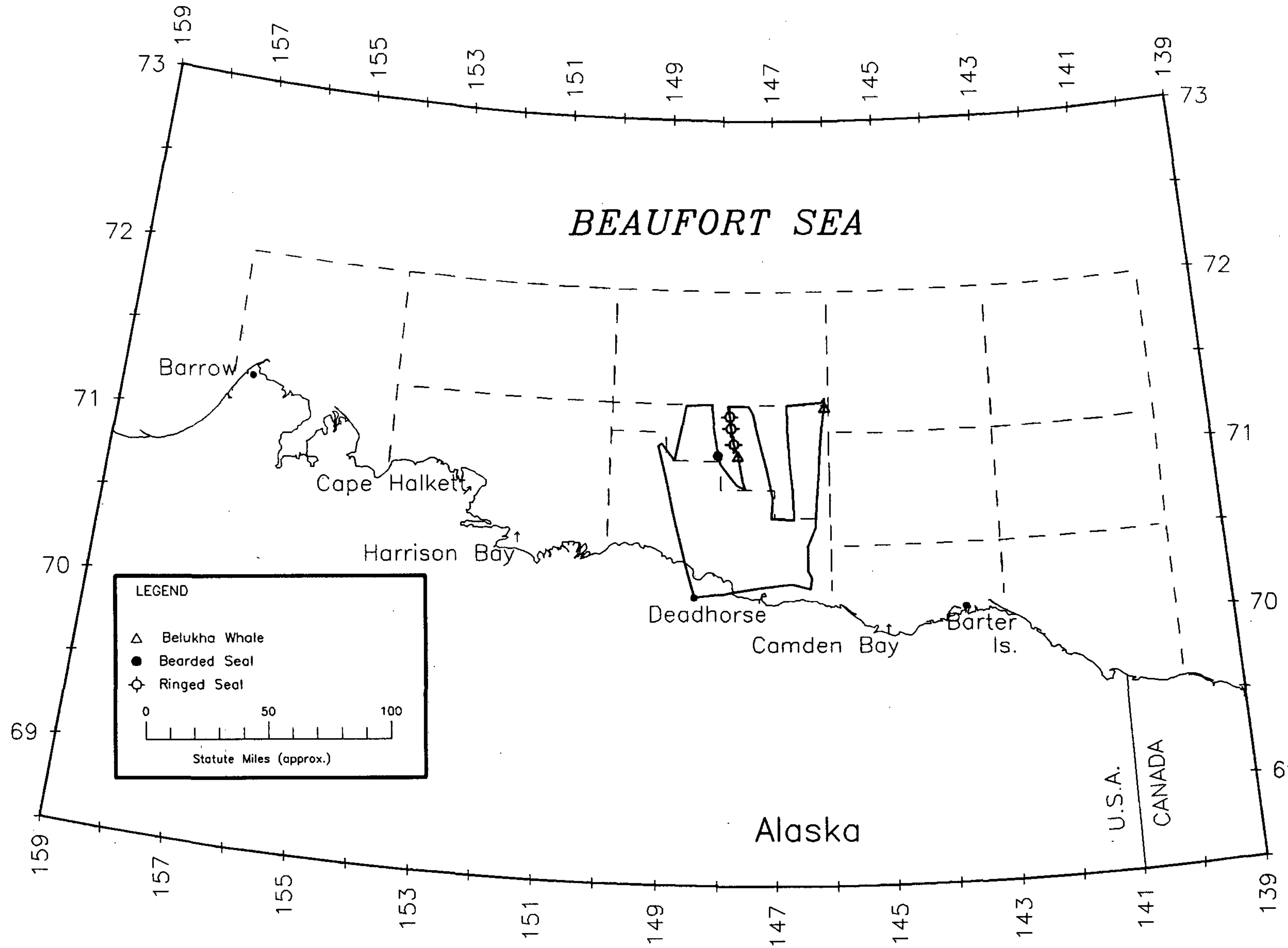


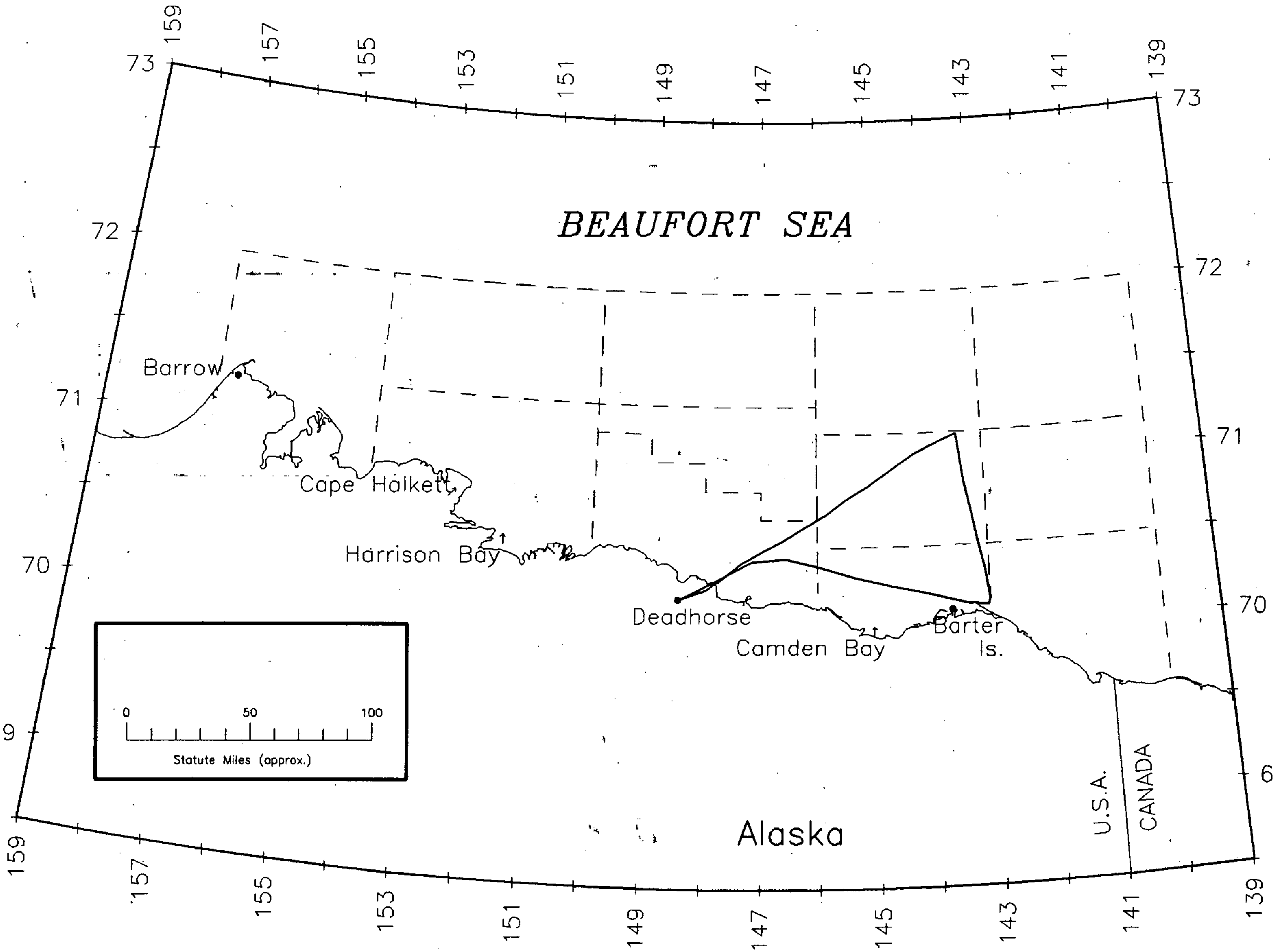
FLIGHT 17 24 September 1994
Survey Track and Sightings



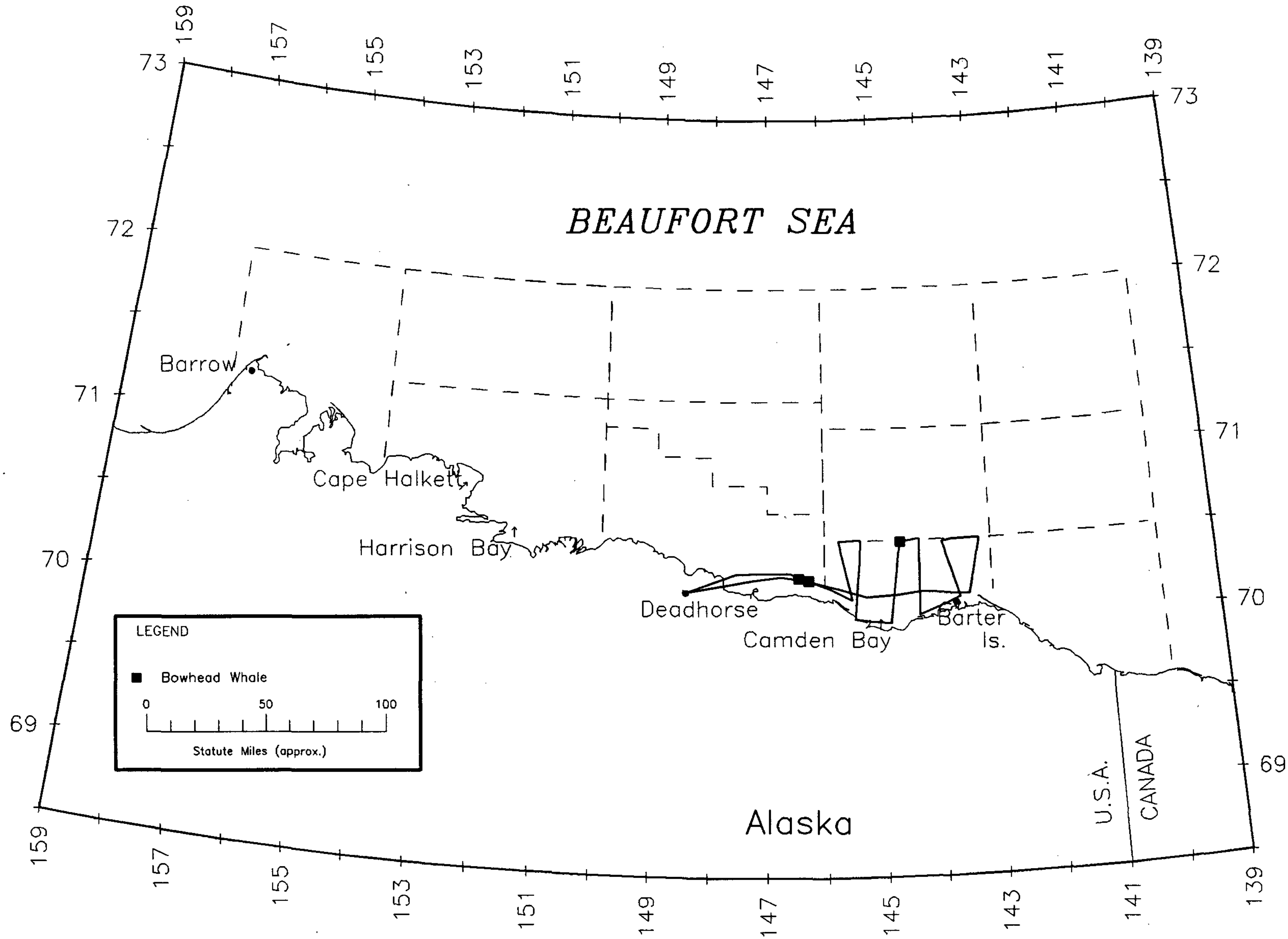
FLIGHT 18 25 September 1994
Survey Track and Sightings



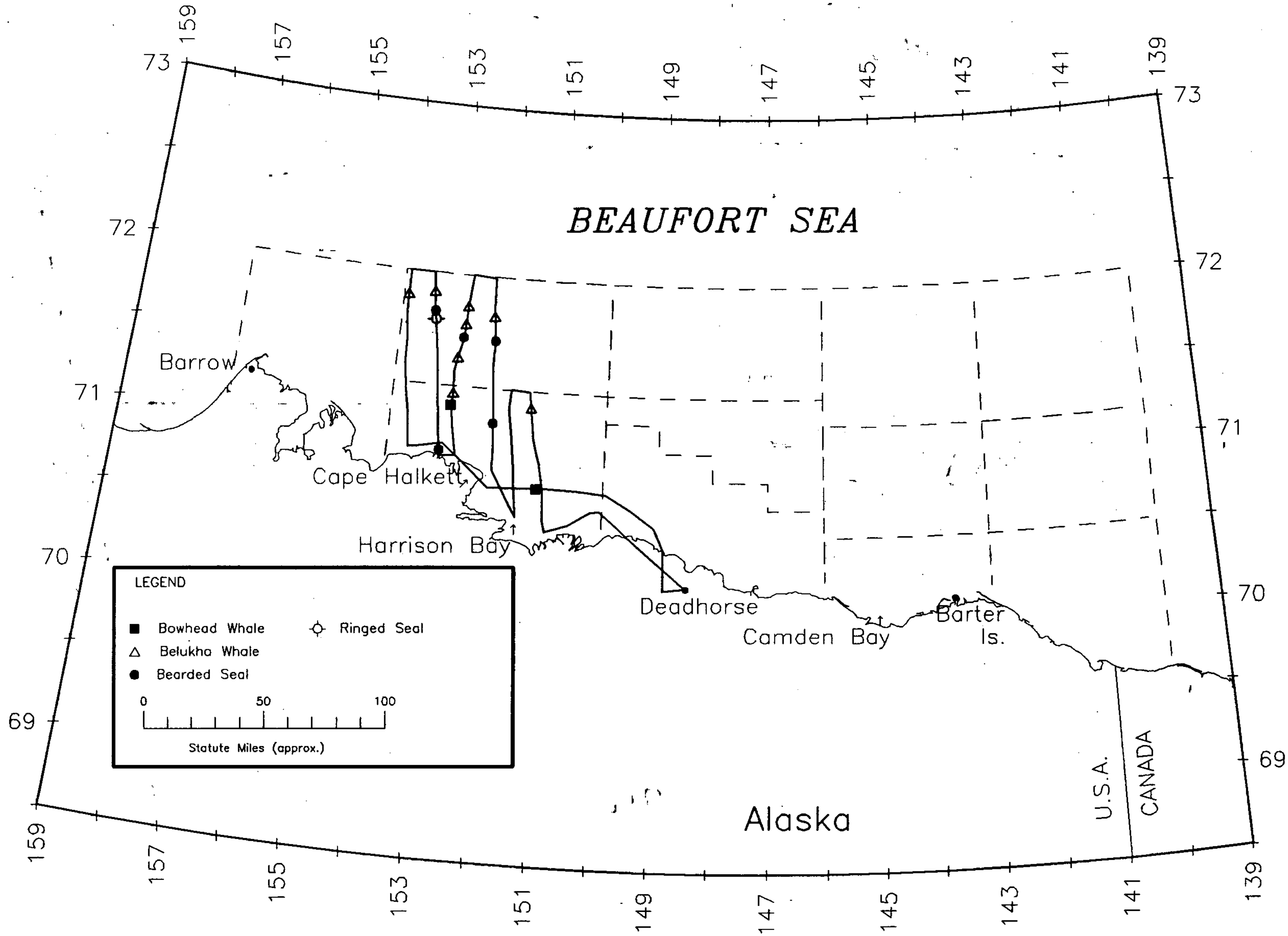
FLIGHT 19 27 September 1994
Survey Track and Sightings



FLIGHT 20 28 September 1994
Survey Track and Sightings



FLIGHT 21 29 September 1994
Survey Track and Sightings



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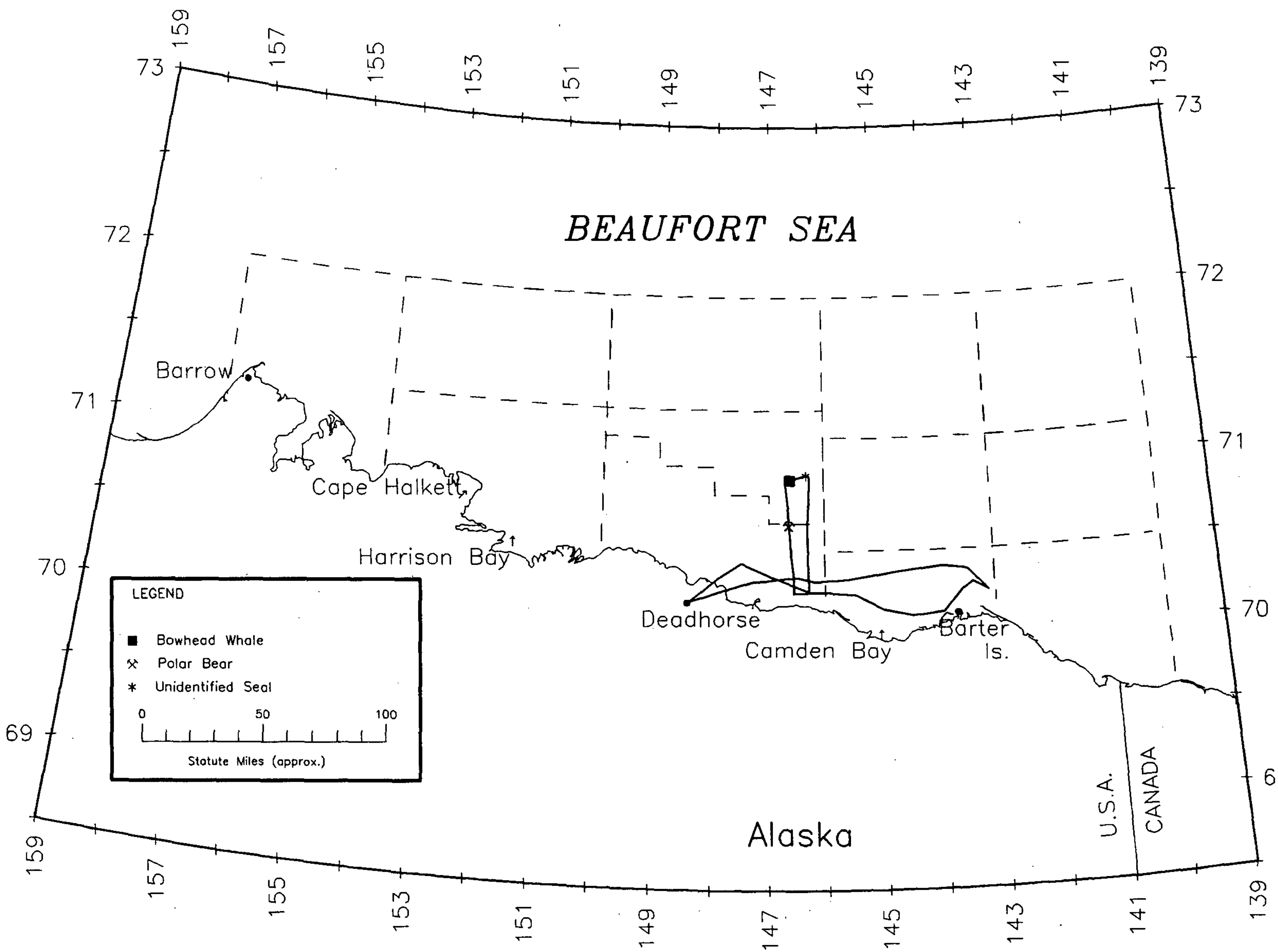
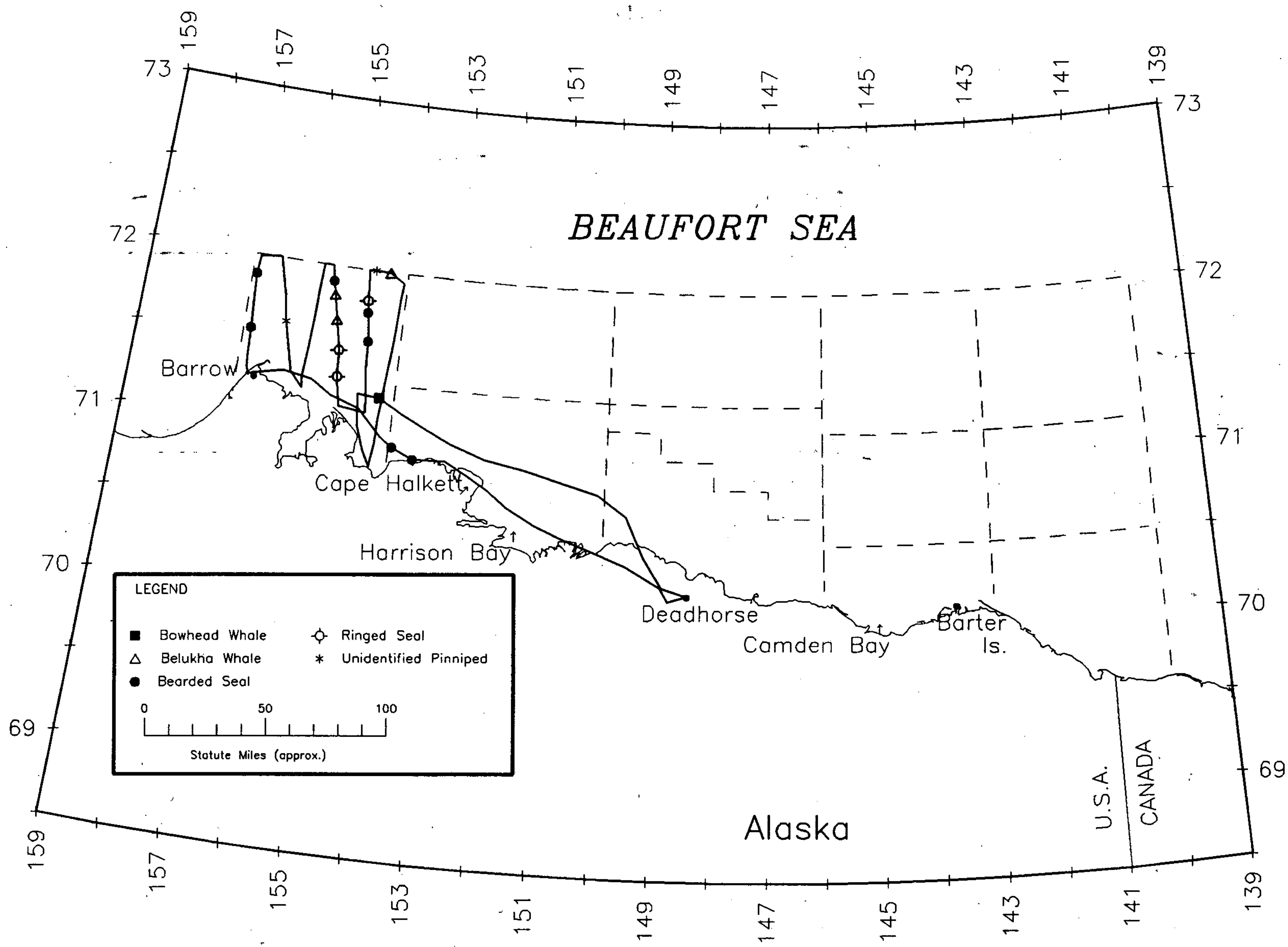
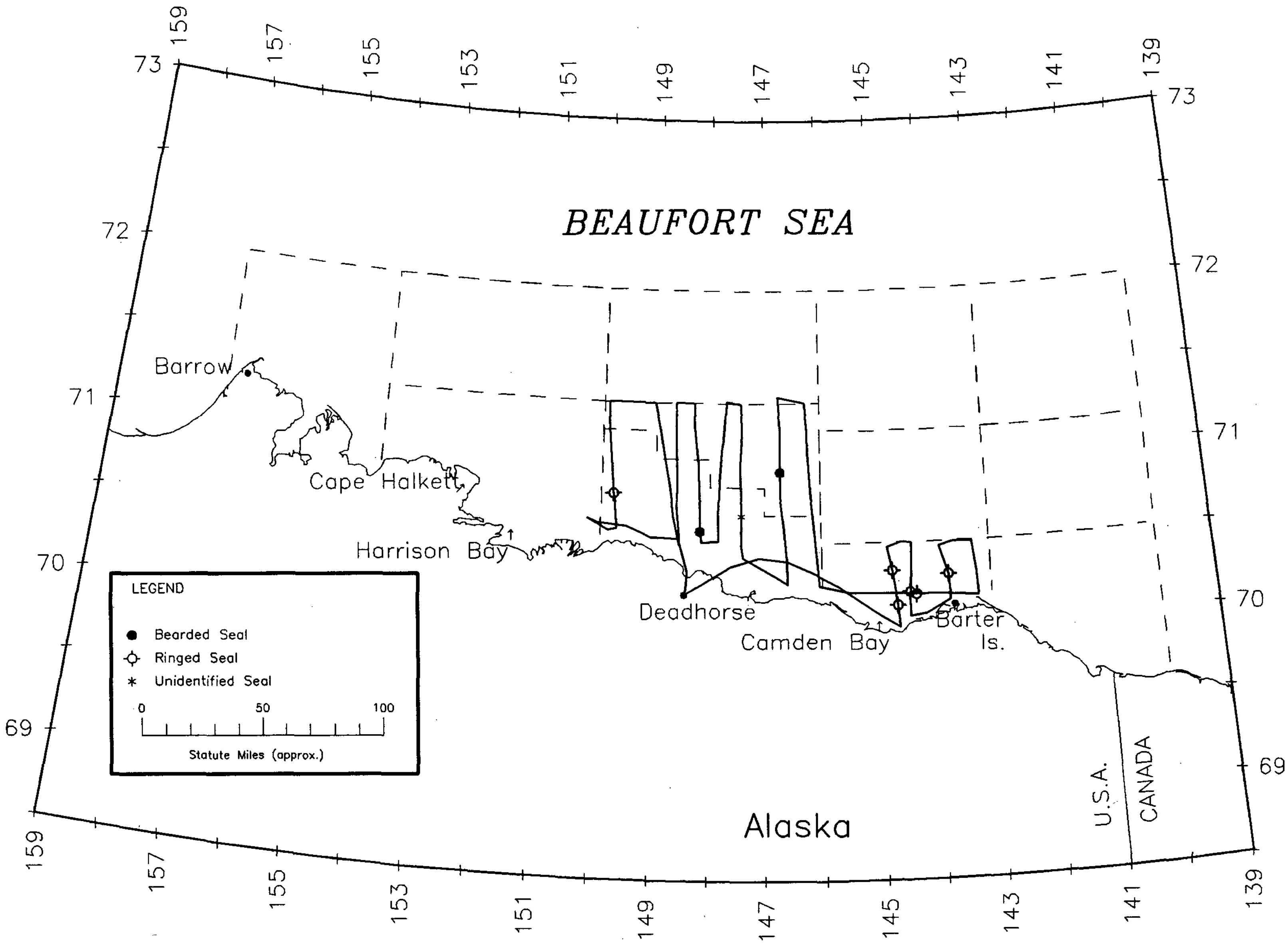
Survey Track and Sightings



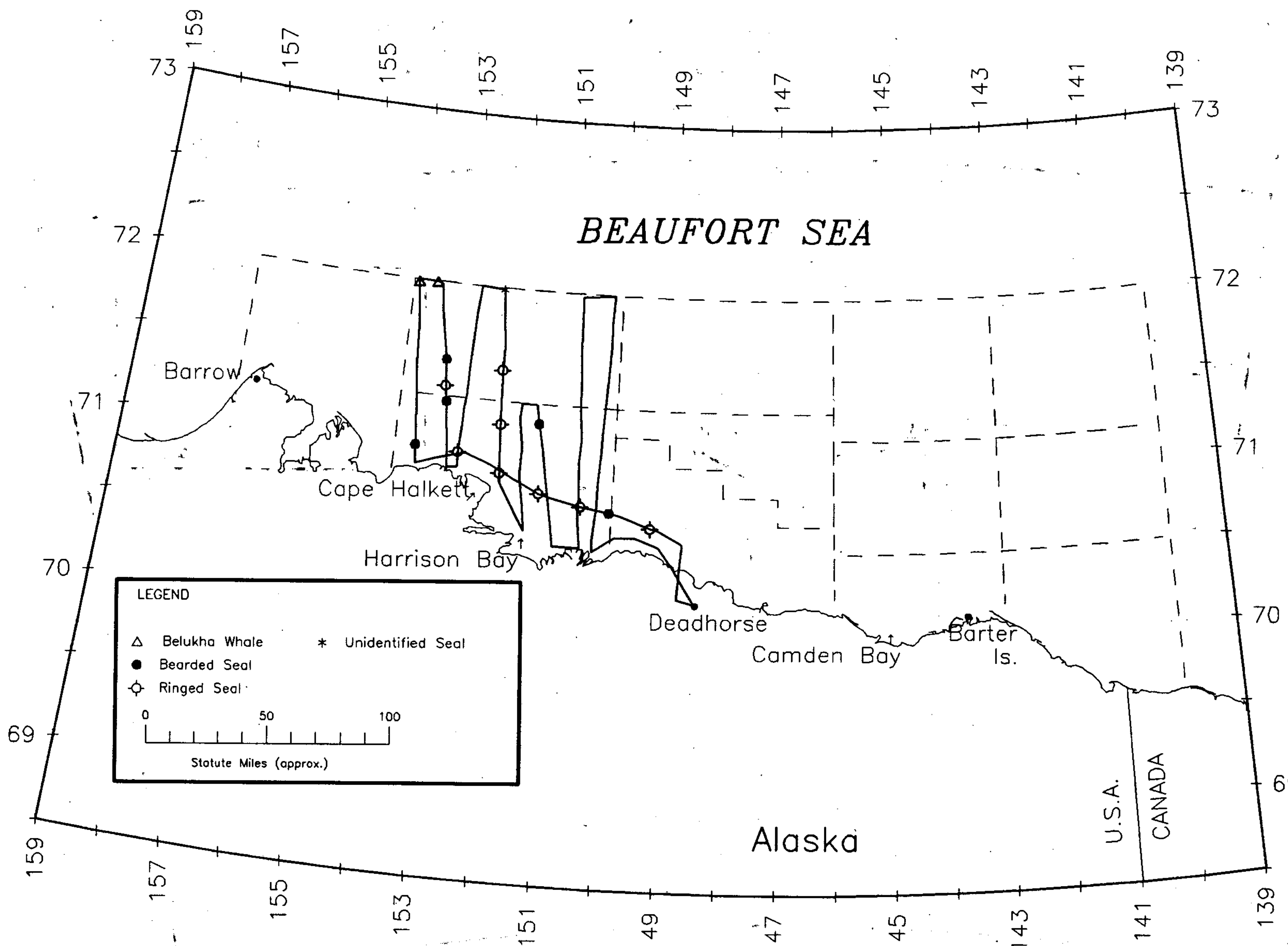
FLIGHT 23 7 October 1994
Survey Track and Sightings



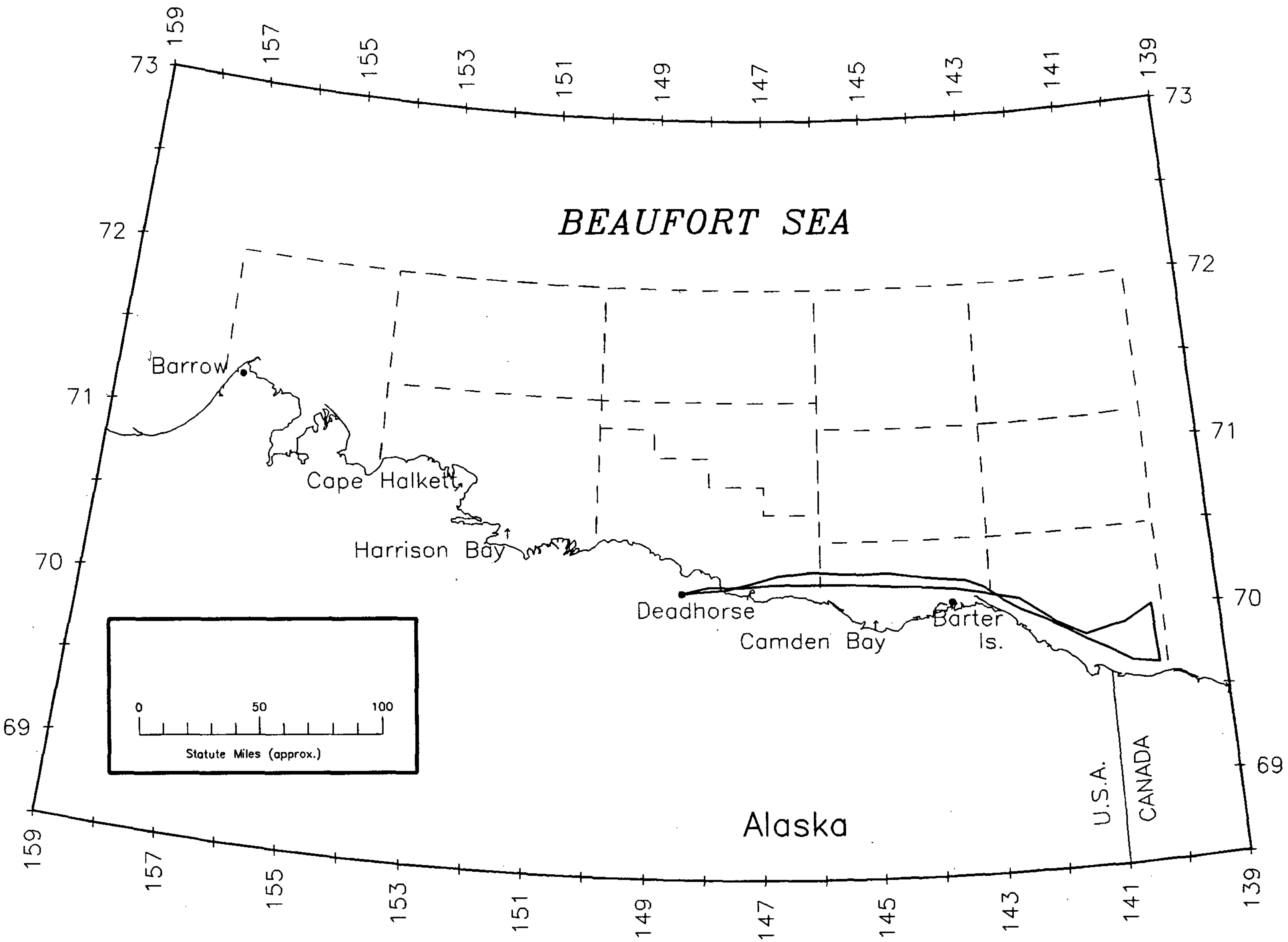
FLIGHT 24 8 October 1994
Survey Track and Sightings



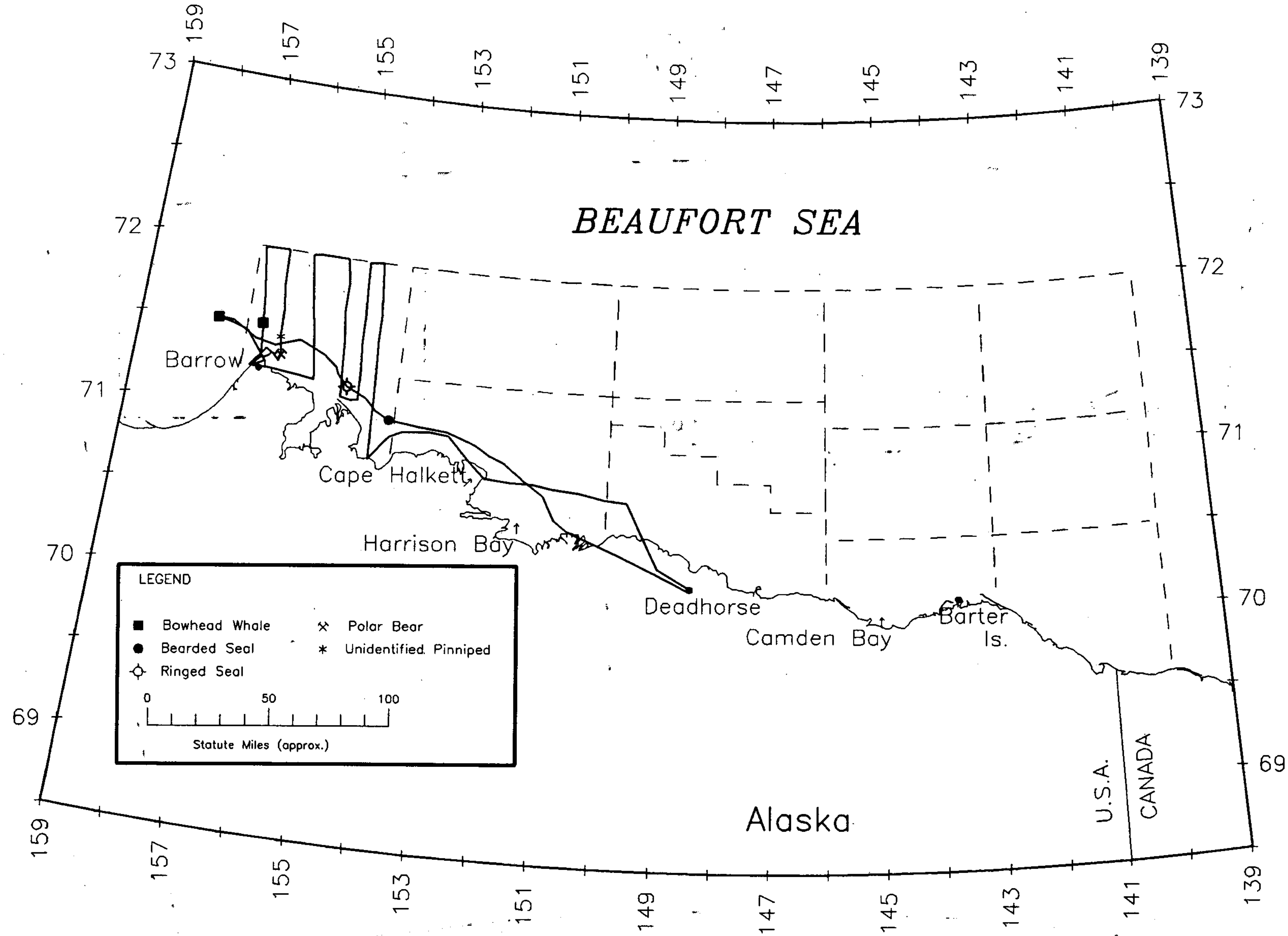
FLIGHT 25 10 October 1994
Survey Track and Sightings



FLIGHT 26 11 October 1994
Survey Track and Sightings



FLIGHT 27 12 October 1994
Survey Track and Sightings



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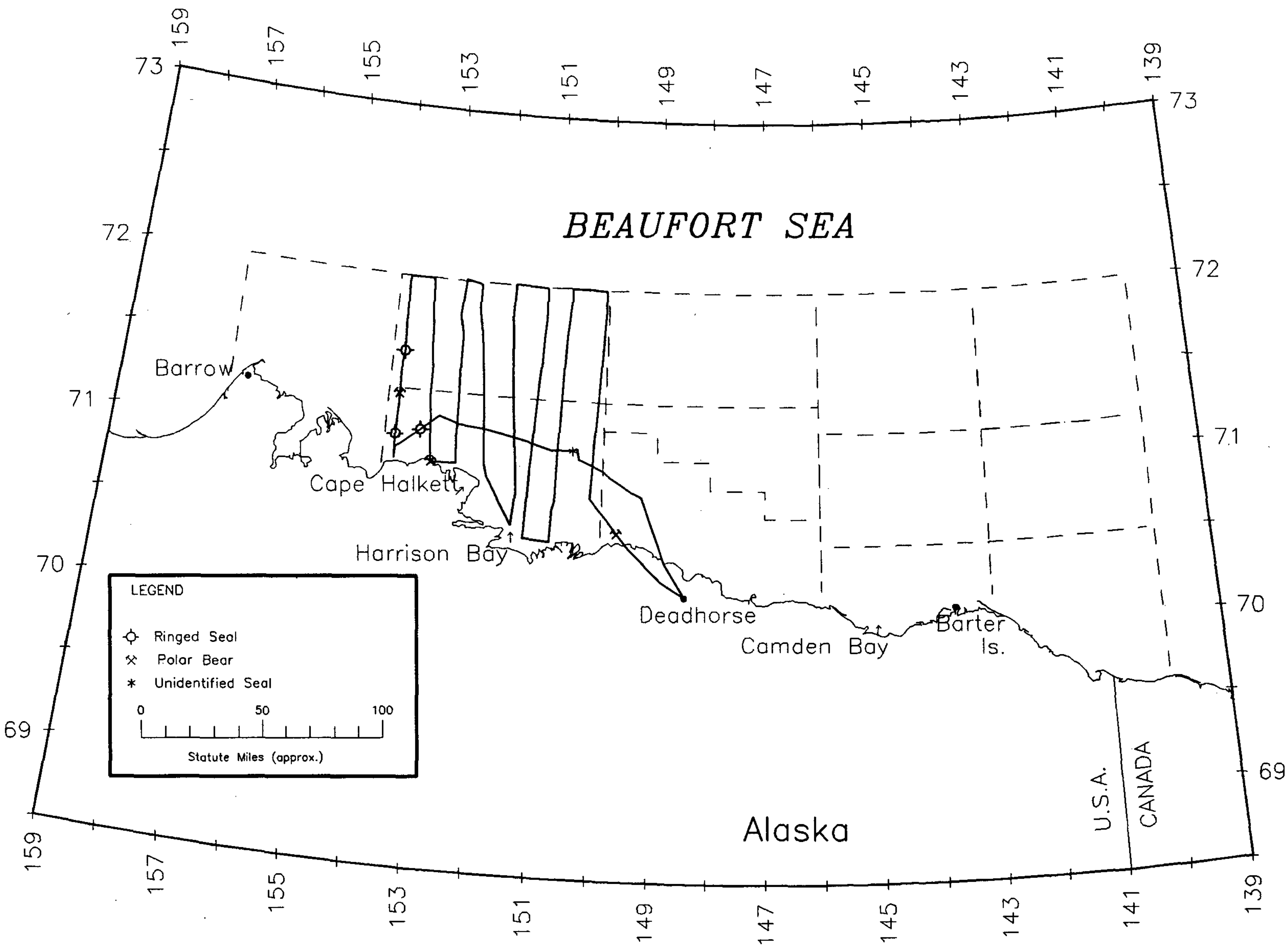
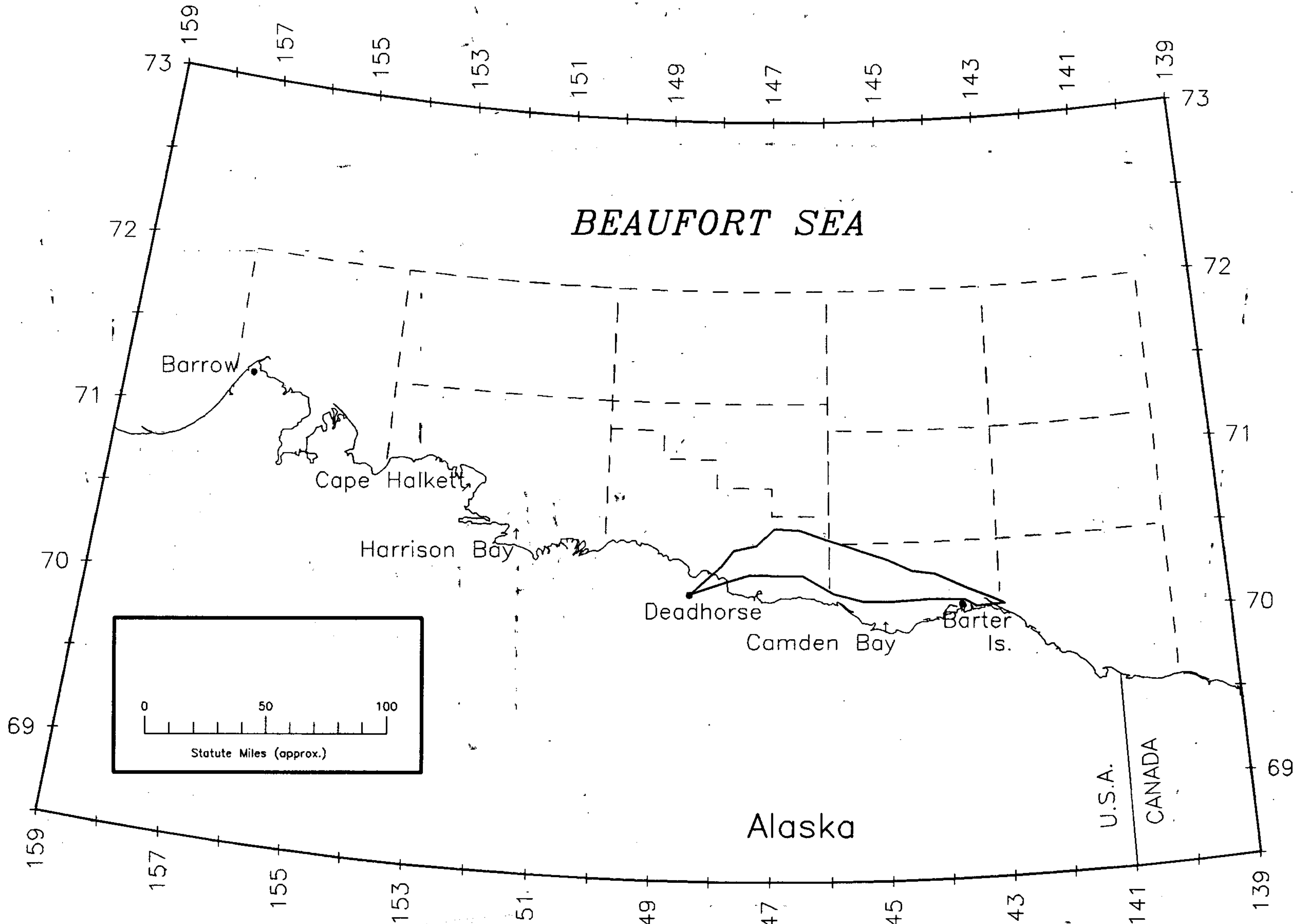
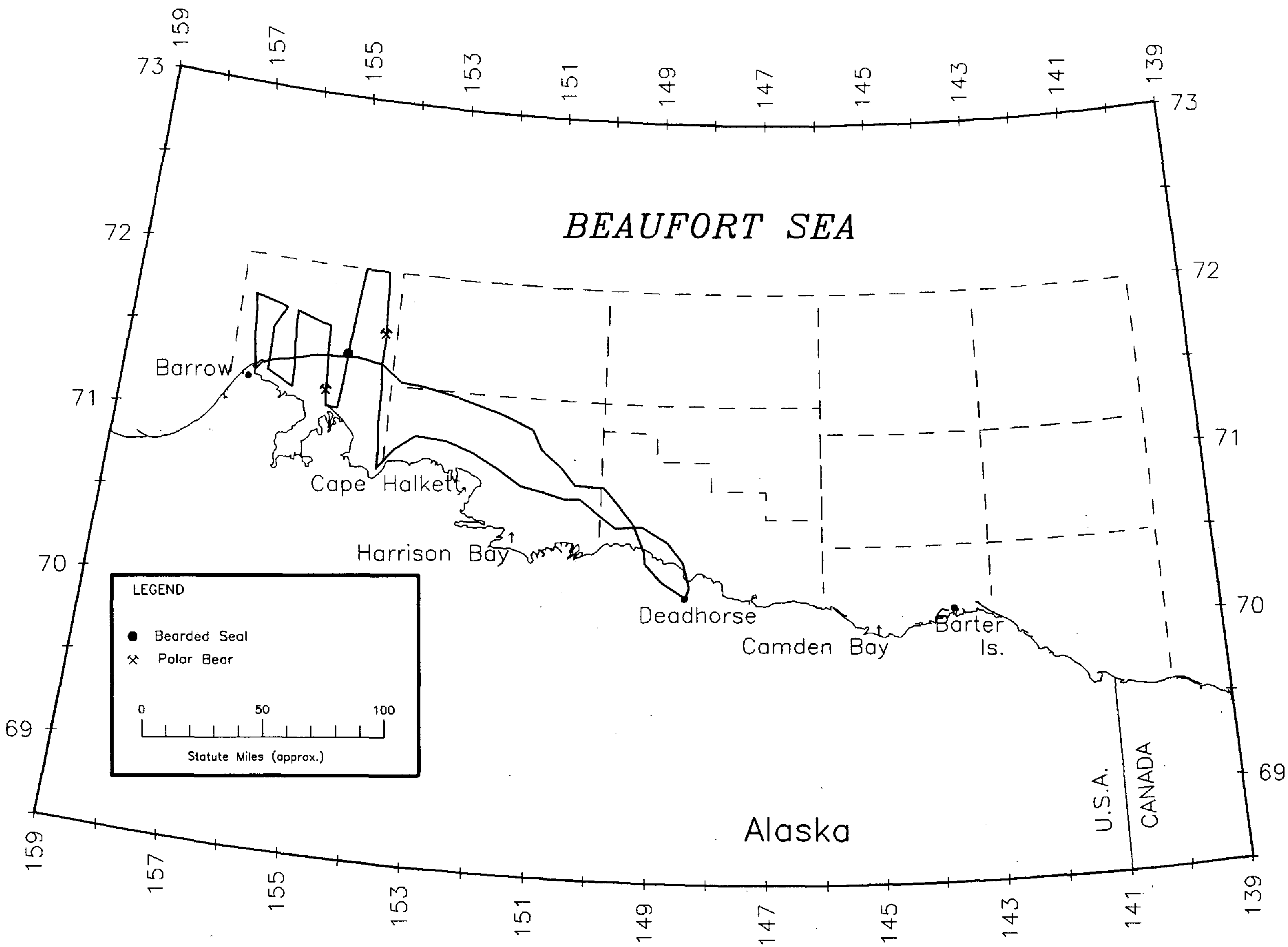
Survey Track and Sightings



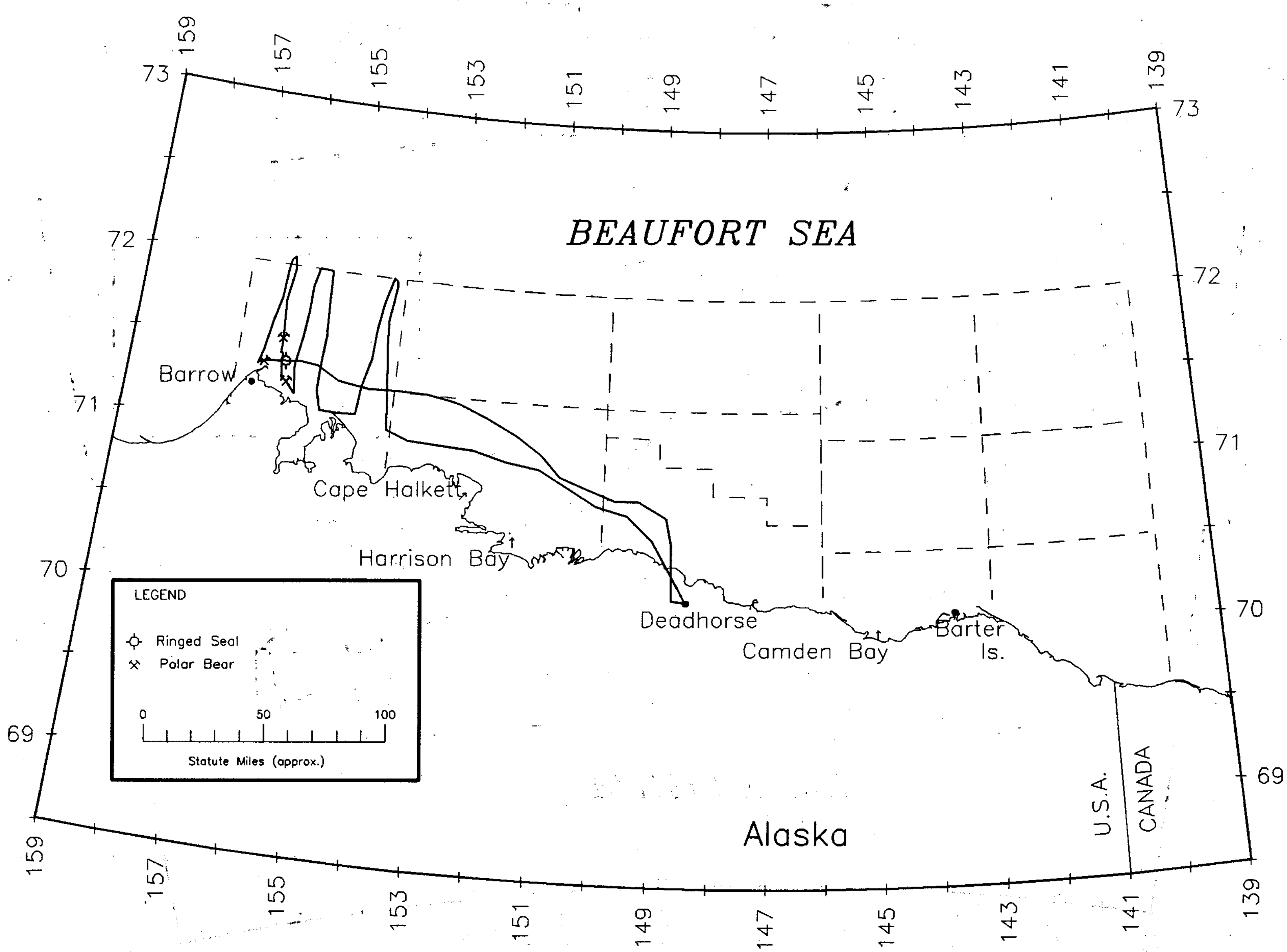
FLIGHT 29 14 October 1994
Survey Track and Sightings



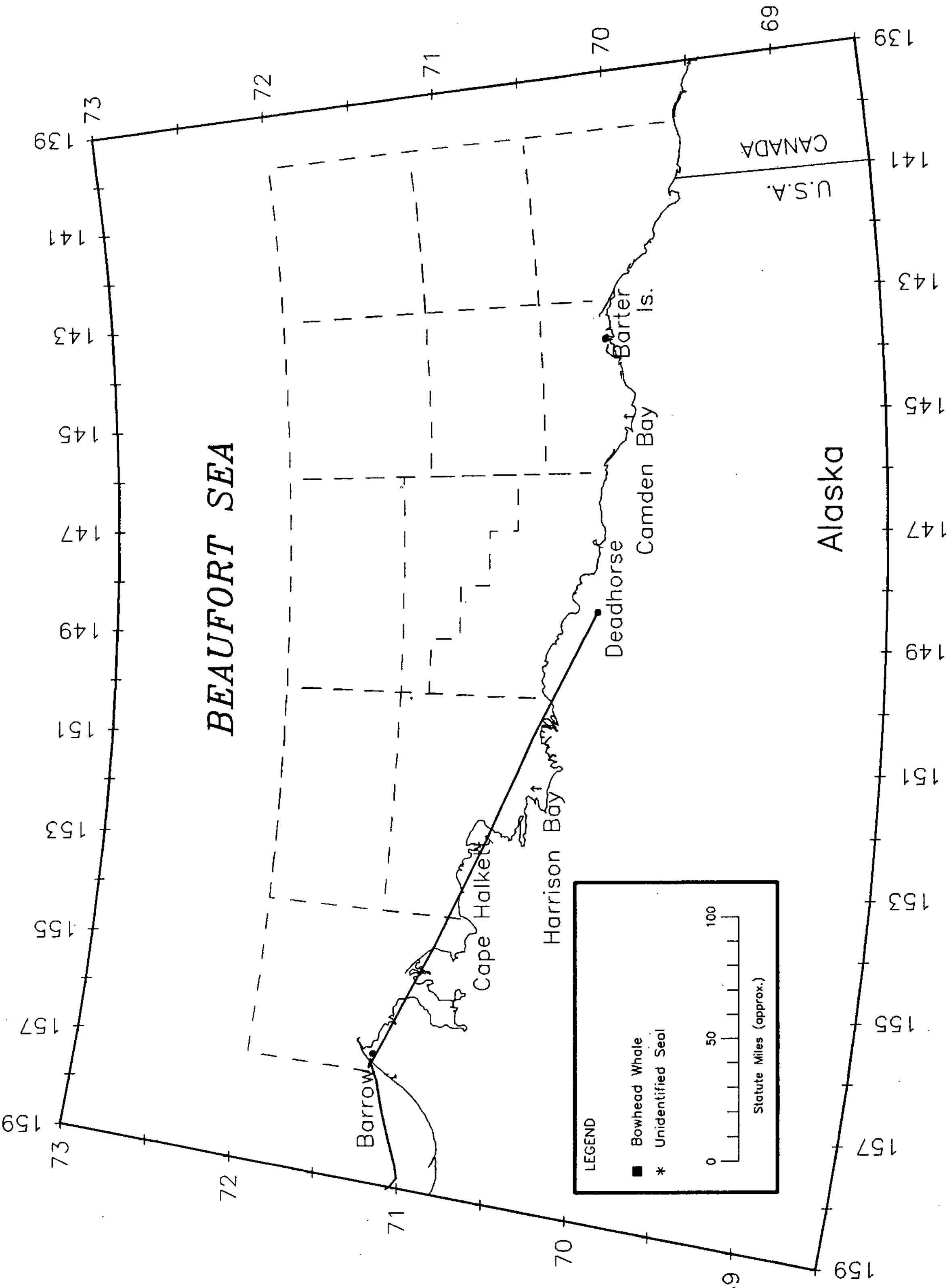
FLIGHT 30 15 October 1994
Survey Track and Sightings



FLIGHT 31 16 October 1994
Survey Track and Sightings



FLIGHT 32 17 October 1994
Survey Track and Sightings



FLIGHT 33 18 October 1994
Survey Track and Sightings

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GLOSSARY OF ACRONYMS 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
MDC	Mobile Datacom Corporation
MMS	Minerals Management Service
n	sample size
NOAA	National Oceanic and Atmospheric Administration
NOS	Notice of Sale
NOSC	Naval Ocean Systems Center
NMFS	National Marine Fisheries Service
nm	nautical mile
OAS	Office of Aircraft Services
OCS	Outer Continental Shelf
OCSLA	Outer Continental Shelf Lands Act
p	probability
RDSS	Radio Determination Satellite System
SD	standard deviation
SPUE	sightings per unit effort (number of whale sightings counted per hour)
T	true heading
USC	U.S. Code
USDOC	U.S. Department of Commerce
USDOD	U.S. Department of Defense
USDOI	U.S. Department of the Interior
WPUE	whales per unit effort (number of whales counted per hour); relative abundance

The Department of the Interior Mission

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

The Minerals Management Service Mission

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

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

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