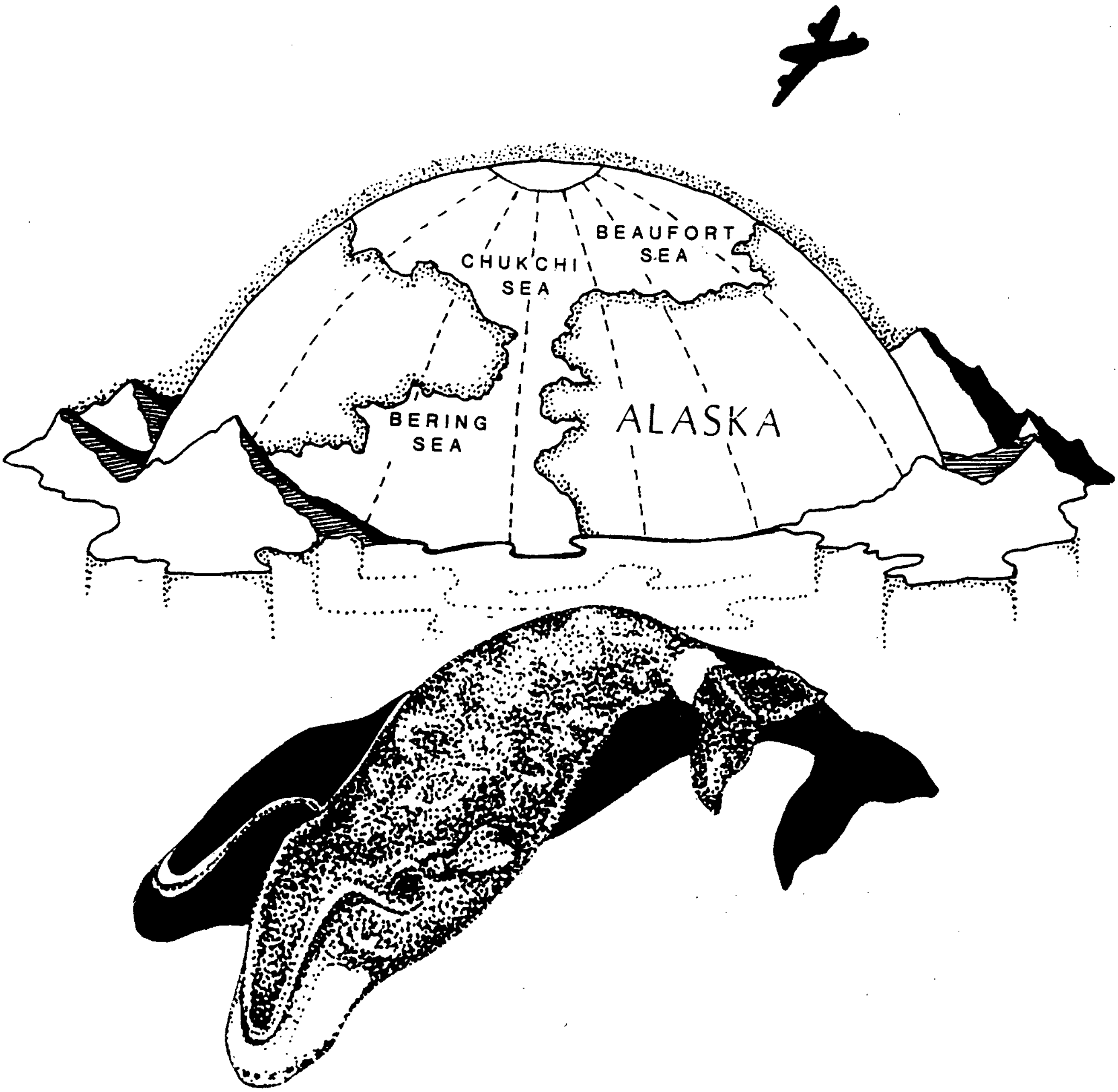
Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 1989

OCS Study
MMS 90-0047



MMS
U.S. Department of the Interior
Minerals Management Service
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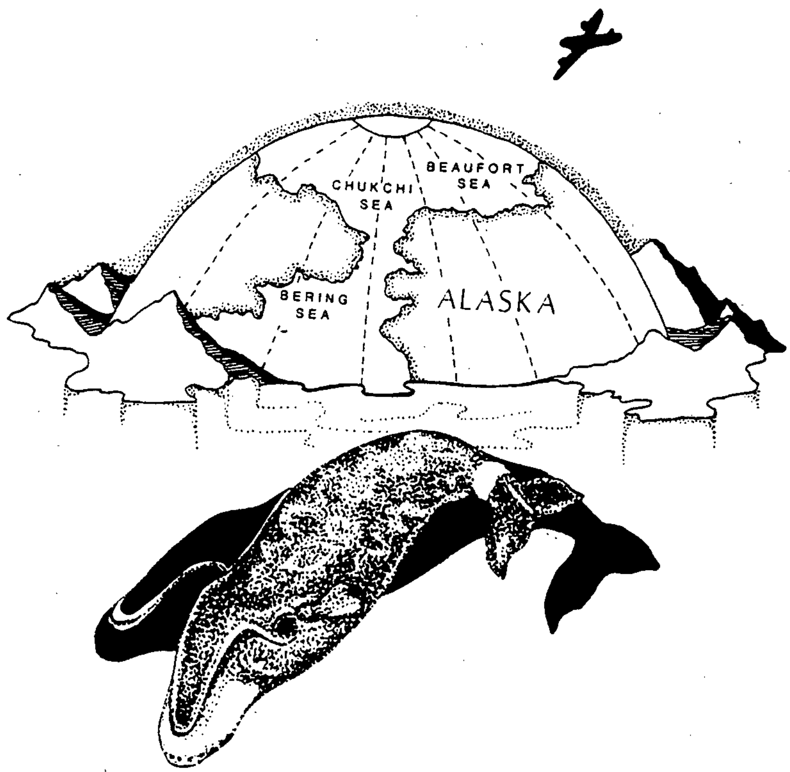
By Stephen D. Treacy, Project Manager
MMS Bowhead Whale Aerial Survey



U.S. Department of the Interior
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Anchorage, Alaska
1990

ABSTRACT

This report describes field activities and data analyses for aerial surveys of bowhead whales conducted between 1 September 1989 and 20 October 1989 in the Beaufort Sea, primarily between 140°W. and 154°W. longitudes south of 72°N. latitude. Ice cover during September and October 1989 was exceptionally light. A total of 215 bowhead whales, 104 belukha whales, 9 bearded seals, 84 ringed seals, and 32 unidentified pinnipeds were observed in 1989 during 98.70 hours of survey effort that included 38.10 hours on randomized transects. The initial sighting of bowhead whales in Alaskan waters occurred on 8 September 1989. Half (median) of the 215 bowheads observed had been counted by 29 September, while the peak count (mode) of 53 bowhead whales occurred on 28 September 1989. The last sighting of a bowhead whale made during this survey occurred in open water on 19 October 1989. No whales were sighted during a subsequent flight on 20 October 1989. Estimated median and mean water depths at the location of bowhead whales sighted on line transects in 1989, 18 meters and 22.7 meters respectively, were shallower than for previous surveys (1982-1989). This is consistent with a trend for whales to be located in shallower water during years of generally light ice cover.

ACKNOWLEDGMENTS

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The project management gratefully acknowledges team personnel who volunteered computer-related support during conversion to an improved computer system. John Dunlap (Computer Systems Developer for the project) programmed all data-collection and preliminary-analysis software and coordinated all hardware linkages (see Appendix C). Mary Werner wrote a program for post-season entry of field data into a permanent database and (with technical assistance from Bruce Herman, MMS) adapted a commercial software package so that it generates high-resolution coastline and flight-track maps in the field. Lydia Lourbacos produced a preliminary user's manual for the field programs.

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I. INTRODUCTION

In 1953, the Outer Continental Shelf Lands Act (OCSLA) (43 U.S.C. 1331-1356) established Federal jurisdiction over the submerged lands of the continental shelf seaward of State boundaries. The Act charged the Secretary of the Interior with the responsibility for administering minerals exploration and development of the OCS. It also empowered the Secretary to formulate regulations so that the provisions of the Act might be met. The OCSLA Amendments of 1978 (43 U.S.C. 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 authorizes the Secretary of the Interior to 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 U.S.C. 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 (USGS) for classification and evaluation of submerged Federal lands and regulation of exploration and production. In 1982, the Minerals Management Service (MMS) assumed these responsibilities.

In response to information needed for environmental impact statements (EIS's) and environmental assessments under the National Environmental Policy Act of 1969, and to assure protection of marine mammals under the Marine Mammal Protection Act of 1972 (16 U.S.C. 1361-1407) and the Endangered Species Act (ESA) of 1973, 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), and 97 (issued in 1987)--recommended continuing studies of whale distribution and OCS-industry effects on bowhead whales (USDOC, NOAA, NMFS, 1982, 1983, 1987). These opinions also requested monitoring of bowhead whale presence during periods when geophysical exploration and drilling may be occurring.

On 14 May 1982, the Secretary of the Interior imposed an approximately 2-month seasonal-drilling restriction on exploratory activity in the joint Federal/State Beaufort Sea sale area. 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 a monitoring plan for endangered whales that required aerial surveys. The Diapir Field Sale 87 Notice of Sale (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 Notice of Sale (1988) does not contain a seasonal-drilling restriction but states 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).

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 fieldwork and reporting activities for the Beaufort Sea on an annual basis. A concurrent study conducted by SEACO, a division of SAIC, under contract to MMS employs identical aerial-survey and data-analysis methodologies to monitor whales in the Chukchi Sea. These reports, as well as 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 endangered whale-survey program are to:

1. Provide real-time data to MMS and NMFS on the fall migration of bowhead whales for use in implementing overall seasonal-drilling restrictions and seasonal limitations on geological/geophysical exploration;

2. Provide real-time, site-specific data on endangered whales for use by MMS in day-to-day regulation of seismic-exploration operations;

3. Continue monitoring temporal and spatial trends in the distribution, relative abundance, habitat, and behaviors of endangered whales in arctic waters;

4. Continue data collection and between-year trend analysis of the median depth (or north-south positioning) of the migration axis for bowhead whales;

5. Record and map belukha whales and incidental sightings of other marine mammals; and

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

II. METHODS AND MATERIALS

A. Study Area

The overall annual survey program is based on a design of random field transects within established geographic blocks in and adjacent to Chukchi and Beaufort Sea sale areas offshore of Alaska. The present study, which was focused on the bowhead whale migration from 1 September 1989 to 20 October 1989, included Beaufort Sea Survey Blocks 1 through 11 (Fig. 1) between 140°W. and 154°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 4 meters (m) thick, on average, 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, where mean annual temperature is about -12°C (Brower et al., 1977). Total precipitation (rain and snow) ranges from 12 centimeters (cm) at Barrow to 16 cm at Barter Island and occurs mostly as summer rain (Brower et al., 1988). Fog frequently reduces visibility along the coast during the open-water season. The prevailing wind direction at Barrow and Barter Island is from the east. Mean annual windspeed is 6 m per second at Barrow and 7 m per second at Barter Island (Brower et al., 1988). Sea breezes occur during about 25 percent of the summer and extend to at least 20 km offshore (Brower et al., 1977).

Sea state is another environmental factor affecting visibility during aerial surveys. Ocean waves, which are generally from the northeast and east, are limited to the open-water season, during which 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 in summer. Wave heights greater than 0.5 m occurred in only 22 percent of the observations summarized by Brower et al. (1977). Wave heights greater than 5.5 m are not reported within this Beaufort Sea database of 2,570 observations.

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 with call sign 301EH. The aircraft was equipped with a Global Navigation System (GNS) 500 that provided continuous position updating (0.6-km/survey-hour [hr] precision) and transect-turning-point programming. The aircraft's maximum time aloft under normal survey load was extended to approximately 6.5 hr through the use of a supplemental onboard fuel tank.

The Twin Otter 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, having good forward and side viewing from that position. Each observer was issued a hand-held clinometer (Suunto) for measuring the angle of inclination to the sighting location of endangered whales.

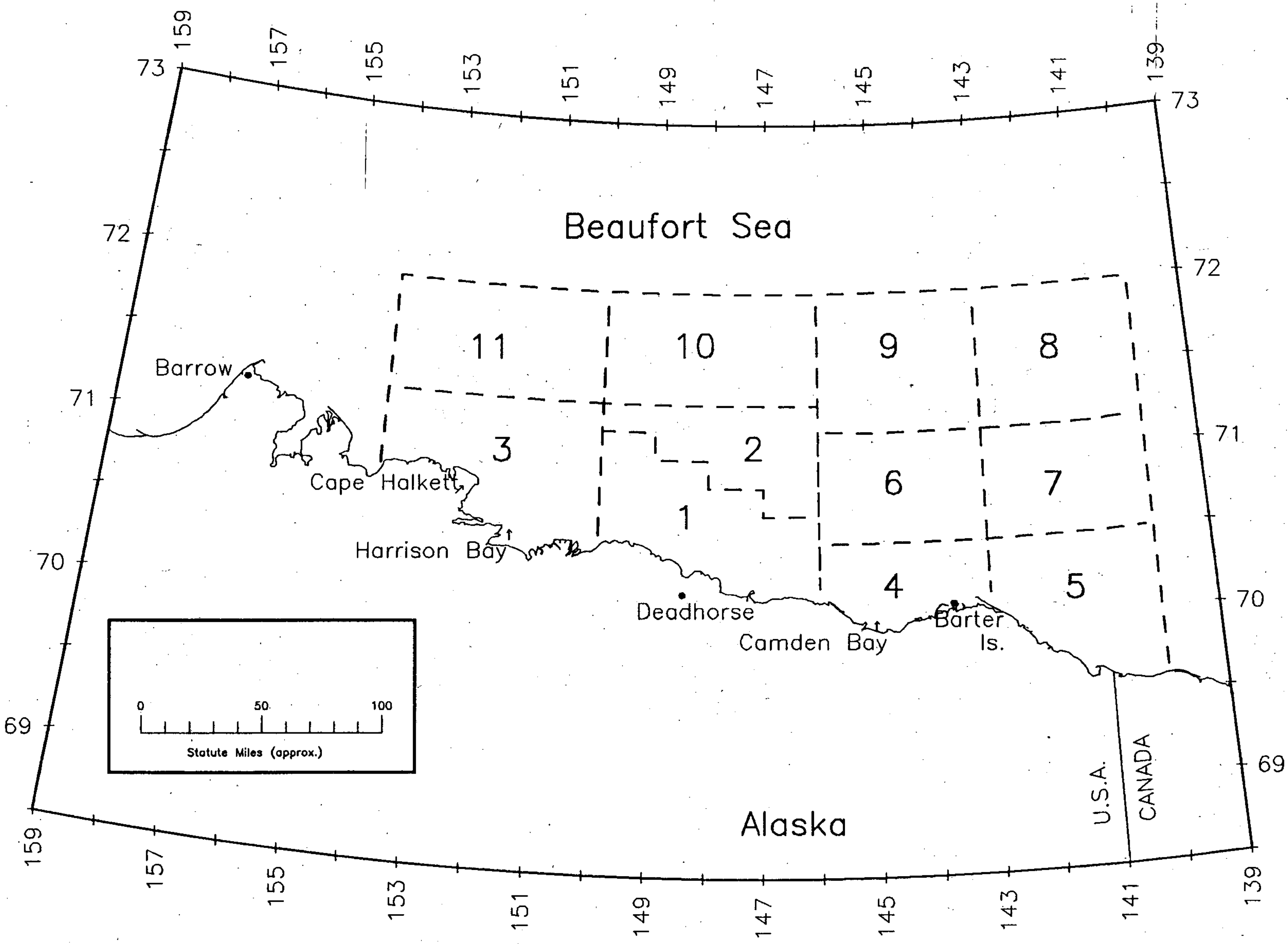

Figure 1. Fall 1989 Study Area Showing Survey Blocks

Observers and pilots were linked to common communication systems, and commentary could be recorded.

A portable (Mitsubishi MP 286L) computing system was used aboard the aircraft to store and analyze flight data. The computer was linked by a hardware interface (Arinc 429 to RS232) to the GNS for automatic input of time, latitude, and longitude and to the radar altimeter for precise input of altitude.

C. Aerial-Survey Design

Aerial surveys were based out of Deadhorse, Alaska, from 1 September to 20 October 1989. The field schedule was designed to monitor the progress of the Fall 1989 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 effort coordination and data management necessary to support implementation of 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 which survey block to fly on a given day was nonrandom, based primarily on criteria such as reported weather conditions over the study area, the level of oil drilling activity in various areas, and a semimonthly flight-hour goal for each survey block. Flight-hour goals were allocated proportionately for survey blocks and semimonthly time periods based on relative abundance of bowhead whales as determined from earlier fall migrations (1979-1986). Such allocations greatly favor survey coverage in inshore Survey Blocks 1 through 7 and 11 (Fig. 1), since bowheads were rarely sighted north of these blocks in previous surveys. The purpose of these survey-effort allocations was to increase the sample size of whale sightings within the primary migration corridor, thus increasing the power of statistical analysis within these inshore blocks.

Random transect legs were used to obtain data for use in migration axis (line-transect) and density (strip-transect) analyses. Nonrandom surveys were flown to further identify whales and their behaviors adjacent to a transect line or when in transit to a transect block. Data from nonrandom surveys were considered combinable with random-transect data to obtain overall behaviors and distribution patterns of marine mammals and to obtain an index of relative whale abundance (whales per unit effort).

D. Survey-Flight Procedures

During a typical flight, a "search" leg was flown to the target survey block, beginning a series of random-transect legs (above) joined together by "connect" legs, followed by a search leg back to Deadhorse. Surveys generally were flown at a target altitude of 458 m. This altitude was maintained, when weather permitted, in order to maximize visibility and minimize potential disturbance to marine mammals.

A hand-held Suunto clinometer was used to measure the angle of inclination to each initial sighting of endangered whales when the sighting location (or whale-dive site) was abeam of the aircraft.

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

E. Data Entry

An improved computer program, developed by John Dunlap (MMS, Alaska OCS Region), was used to collect all survey data. The new program processes the same data as on previous surveys but is much faster and easier to use (Appendix C).

The new program is menu-driven, allowing for a full data-entry sequence for sightings of endangered whales whenever possible. An abbreviated sighting-update format was used when several whales were sighted within a short period of time. An even shorter rapid-sighting update was used in areas of extremely high animal concentrations to avoid any lumping of sightings. 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.

For the purpose of discussion, behaviors were entered into one of 13 categories noted on previous surveys. These categories--including swimming, diving, milling, feeding, mating, cow/calf association, resting, breaching, spy-hopping, tail- and flipper-slapping, rolling, and underwater blowing--are defined in Table 1. Swimming speed was subjectively estimated by observing the time it took a whale to swim one body length. An observed swimming rate of one body length per minute corresponded to an estimated speed of 1 km/hr; one body length per 30 seconds was estimated at 2 km/hr, and so on. Swimming speed and whale size were recorded by relative category (i.e., still, 0 km/hr; slow, 0-2 km/hr; medium, 2-4 km/hr; or fast, >4 km/hr; and calf, immature, adult, or large adult, respectively) rather than on an absolute scale.

In compliance with Condition B.4-6 of NMFS Permit No. 459, to "take" endangered marine mammals, any sudden overt change in whale behavior observed coincidentally with the arrival of the survey aircraft was recorded (and later reported) as "response to aircraft," although it was impossible to determine the specific stimulus for the behavioral change. Such changes included abrupt dives, sudden course diversion, or cessation of behavior ongoing at first sighting.

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), and ice cover was estimated in percent.

F. General Data Analyses

Ice concentrations in the Beaufort Sea were digitized as either zero 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. These charts were available for every seventh day from 29 August through 24 October 1989.

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.

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 1989 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.

All whale sightings were entered into the distribution and relative-abundance analyses, regardless of the type of survey leg being conducted when the sighting was made. Therefore, distribution scattergrams and WPUE represent the total sighting database in relation to the total survey effort.

Habitat preference was depicted as percentage of whales per ice class and percentage of whales per depth regime. Directionality of whale headings was analyzed using Rayleigh's test (Batschelet, 1972). Additional statistical comparisons, correlations, and regressions were performed as appropriate (Zar, 1984).

Density estimates were calculated here only for relative comparison with similar values from previous survey

Table 1
Operational Definitions of Observed Bowhead Whale Behaviors

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

reports. Calculations were based on strip-transect-analyses methods using only sightings made on random-transect legs (Estes and Gilbert, 1978). 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 1,000 m of the trackline. If no sightings were made on random transects within a survey area, that density was not calculated. Density estimates were derived by survey block and are presented, with a description of density-estimate methodologies, in Appendix A. 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.

The general water depth at each bowhead sighting in the 1982-1989 database was initially derived using the computer program DPTH, which assigned a metric depth value averaged over an area 5 minutes (′) of latitude by 20′ of longitude in the Beaufort Sea west of 139°W. longitude and south of 72°N. latitude. This scaling assigns depth to sighting locations with an accuracy of approximately ±3.5 m over most of the study area. At the shelf break between 100 m and 1,000 m in Regions I and II, the accuracy was approximately ±20 m. Values assigned to each segment were subjectively averaged from depths read from NOAA Provisional Chart 16004 when the DPTH software was written.

A supplemental program "NEW DEPTH" was used to assign more accurate depth values. These "new depths" were generated using a finer grid; the dimensions of this grid were 3′ of latitude by 10′ of longitude, making each grid box less than one-third the size of the original grid boxes used for "old depths." In offshore areas where depth soundings were far fewer, "new depths" were entered only if there was a depth sounding in, or within the vicinity of (adjacent to), the grid box. Sightings that occur in offshore areas where no "new depth" value has been assigned retain the "old depth" value.

G. Median 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 is 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) and is incorporated by reference from Ljungblad et al. (1987).

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.

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.

To assess possible fine-scale shifts in the 1989 migration axis over the known fall-migration corridor, the median depth, 99-percent confidence interval (CI), and overall depth range were calculated for Regions I, II, and III of the study area (Fig. 2). All bowhead sightings made while on random line transects were included in the median-water-depth analyses. Region I is delimited by 150°W. and 153°30′W. longitudes, south of 72°N. latitude. Region II is between 146°W. and 150°W. longitudes south of 71°20′N. latitude. Region III is between 141°W. and 146°W. longitudes, south of 71°10′N. latitude.

The bowhead-sighting database was sorted such that only sightings made on random-transect lines were stored onto a separate data file (MEDEPTH1). The MEDEPTH1 data file was sorted such that only bowhead sightings made on random transects in September and October were stored (MEDEPTH2).

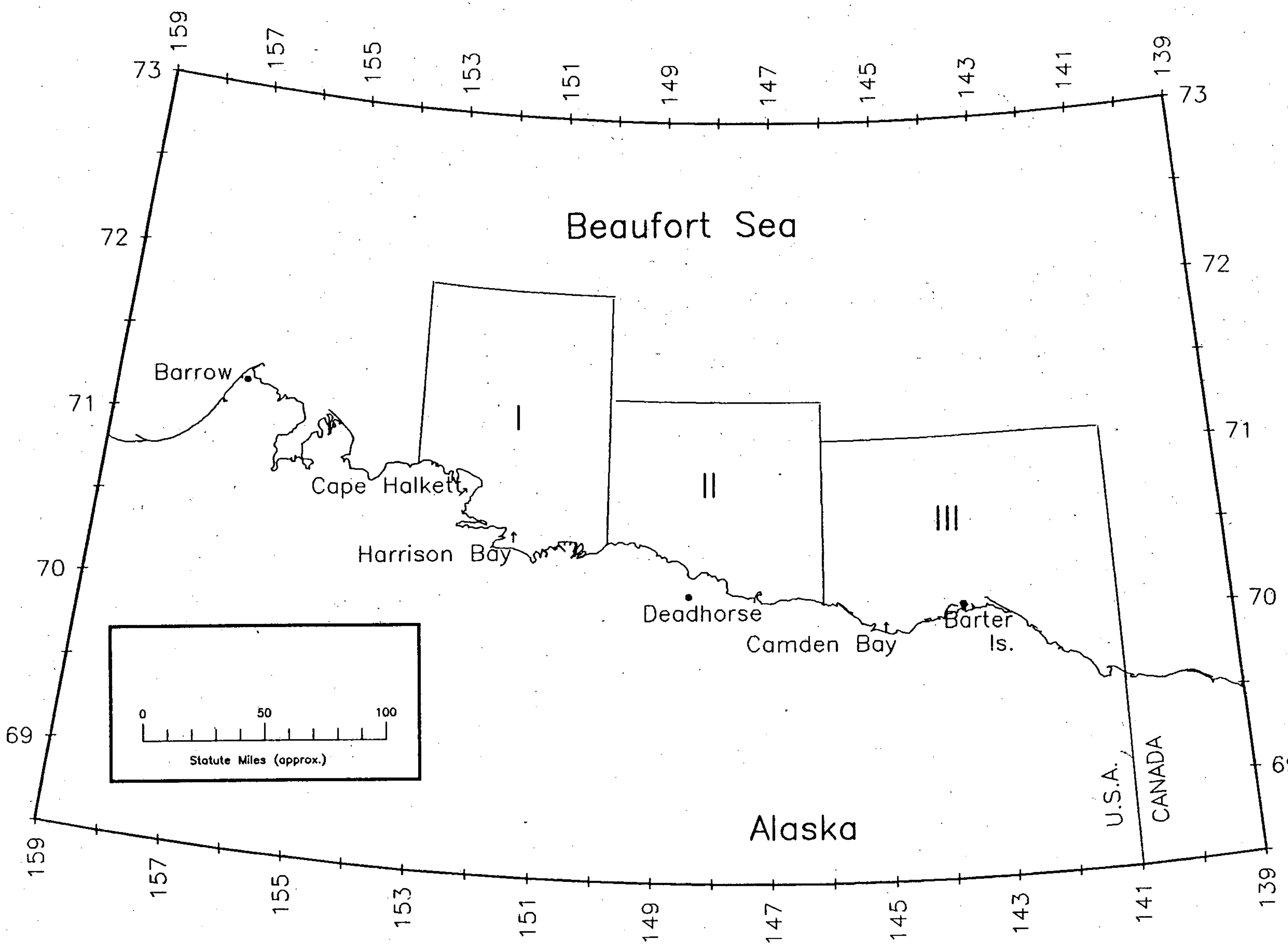

Figure 2. Regions I, II, and III (used in median-water-depth analyses)

The MEDEPTH2 depth values were then ranked from lowest to highest values; and a sample median, 99-percent CI, and overall sample range were tabulated. The 99-percent CI was defined as

$$L_1 = X_{C+1} : \text{ lower limit}$$
$$L_2 = X_{n-C} : \text{ upper limit}$$

where $\alpha(2) = 0.01$, C is determined from a table of critical values (Zar, 1984: Table B-26) when sample size $n \geq 8$. The CI's were calculated at the 1-percent level to reduce the probability of incorrectly asserting that a change in migration route had occurred based on comparing any one year to six others. For example, the probability of incorrectly determining a change occurred based on one of five tests 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 Mann-Whitney U test was then used to address the question of potential shifts in the axis of the bowhead whale fall migration route. The Mann-Whitney test is a nonparametric procedure performed on ranked samples (Zar, 1984). A series of Mann-Whitney paired comparisons were made on annual depth values derived from the MEDEPTH2 data file, with each year compared to all others such that annual and/or overall shifts in migration route over the 1979-1989 study period 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.

In addition, mean water depths at bowhead sightings were compared between years using an analysis of variance (ANOVA) and the Tukey test (Zar, 1984).

III. RESULTS

A. Environmental Conditions

Ice coverage was extremely light during September and October 1989 in the Alaskan Beaufort Sea (Figs. 3-11), permitting good observation of whales. 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 2. A total of 23,175 km of surveys were flown in 98.70 hours (Table 2) in the Beaufort Sea at an overall average speed of 234.8 km/hr. A total of 9,354 km of random-transect lines were flown in 38.10 hours (Table 2) at an average speed of 245.5 km/hr. These random transects constituted 40.4 percent of the total kilometers flown and 38.6 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 for the Twin Otter aircraft are shown in Appendix B. Survey flight lines are summarized by semimonthly period in Figures 12 through 15.

During the first half of September, flight effort was concentrated east of Harrison Bay (Fig. 12) in order to record the initial part of the westward migration of the bowhead whale. There were 10.67 hours of random transects flown from a total of 30.05 flight hours during this period (Table 2), constituting 28.0 percent and 30.4 percent, respectively, of the Fall-1989 study effort.

During the second half of September, flight effort continued to be concentrated east of Harrison Bay (Fig. 13). There were 11.63 hours of random transects flown from 34.43 total flight hours during this period (Table 2), constituting 30.5 percent and 34.9 percent, respectively, of the overall fall effort.

During the first half of October, survey coverage was equally balanced east and west of Deadhorse (Fig. 14). There were 14.20 hours of random transects flown from 28.70 total flight hours during this period (Table 2), constituting 37.3 percent and 29.1 percent, respectively, of the overall fall effort.

From 16 through 20 October, 3 flights were made between Barter Island and the western edge of the study area (Fig.15). There were 1.60 hours of random transects flown from 5.52 total flight hours during this period (Table 2), constituting 4.2 percent and 5.6 percent, respectively, of the overall fall effort.

C. Bowhead Whale (*Balaena mysticetus*) Observations

1. Distribution: One hundred and three sightings were made for a total of 215 bowhead whales observed during Fall-1989 surveys in the study area (Table 3 and Figs. 16-20). Two of these whales were identified as calves (Appendix B: Table B-1), resulting in an overall calf ratio (number calves/total whales) of 0.01. Daily sightings are shown on individual maps in Appendix B.

During the first half of September, 17 sightings were made for a total of 43 bowhead whales with sightings north and east of Camden Bay (Fig. 16). The first bowheads in the Alaskan Beaufort were sighted on 8 September east of Barter Island (Appendix B: Flight 6). The westernmost sighting during this period was made between Deadhorse and Barter Island, on 15 September (Appendix B: Flight 9). Group sizes ranged between 1 and 6 whales (Appendix B: Table B-1), with a mean of 2.53 (Standard Deviation [SD] = 1.87, n = 17).

During the second half of September, 56 sightings were made for a total of 94 bowheads, with sightings somewhat evenly distributed in the eastern half of the study area (Fig. 17). The westernmost bowhead sighted in blocks surveyed during this period (Fig. 13) was northeast of Deadhorse (Appendix B: Flight 17). Group sizes were generally small, ranging between 1 and 7 whales (Appendix B: Table B-1), with a mean of 1.68 (SD = 1.11, n = 56). Two bowhead whale calves were observed on 28 September (Appendix B: Table B-1).

Table 2
Aerial-Survey Effort in the Beaufort Sea, September-October 1989, by Survey Flight

Day	Flight No.	Transect (km)	Connect (km)	Search (km)	Total (km)	Transect Time (hr)	Total Survey Time (hr)
3 Sep	1	0	0	175	175	0.00	0.72
4 Sep	2	487	176	399	1,062	2.10	4.50
5 Sep	3	357	151	334	842	1.40	3.37
6 Sep	4	104	62	537	703	0.42	2.93
7 Sep	5	490	147	455	1,092	1.92	4.35
8 Sep	6	539	99	523	1,158	2.05	4.58
9 Sep	7	554	68	494	1,116	2.12	4.58
10 Sep	8	174	0	607	781	0.67	3.68
15 Sep	9	0	0	286	286	0.00	1.33
17 Sep	10	435	94	496	1,025	1.90	4.23
18 Sep	11	0	0	429	429	0.00	1.73
19 Sep	12	183	54	368	605	0.78	2.53
20 Sep	13	450	109	537	1,096	1.85	4.47
21 Sep	14	304	26	442	772	1.15	3.13
22 Sep	15	74	0	360	434	0.30	1.73
27 Sep	16	98	0	272	370	0.45	1.77
28 Sep	17	442	72	439	953	1.73	5.05
29 Sep	18	443	84	562	1,089	1.95	5.05
30 Sep	19	393	82	596	1,071	1.52	4.73
1 Oct	20	654	130	270	1,054	2.88	5.05
5 Oct	21	520	166	465	1,151	2.05	4.68
6 Oct	22	882	53	120	1,055	3.38	4.30
9 Oct	23	0	0	381	381	0.00	1.55
10 Oct	24	447	155	236	838	1.80	3.42
11 Oct	25	328	155	253	736	1.32	3.00
12 Oct	26	0	0	108	108	0.00	0.43
13 Oct	27	243	61	292	596	1.13	2.60
15 Oct	28	375	116	350	841	1.63	3.67
17 Oct	29	0	0	211	211	0.00	0.85
18 Oct	30	0	0	367	367	0.00	1.48
19 Oct	31	381	96	301	778	1.60	3.18
Total Semimonthly Survey Effort							
1-15 Sep		2,702	703	3,810	7,215	10.67	30.05
16-30 Sep		2,822	521	4,501	7,844	11.63	34.43
1-15 Oct		3,449	836	2,475	6,760	14.20	28.70
16-20 Oct		381	96	879	1,356	1.60	5.52
TOTAL	1-31	9,354	2,156	11,665	23,175	38.10	98.70

Table 3
Summary of Marine Mammal Sightings, September-October 1989, by Survey Flight
(number of sightings/number of animals)

Day	Flight No.	Bowhead Whale	Gray Whale	Belukha Whale	Bearded Seal	Ringed Seal	Unidentified Pinniped	Polar Bear
3 Sep	1	0	0	0	0	0	0	0
4 Sep	2	0	0	0	1/1	3/6	5/6	0
5 Sep	3	0	0	0	0	0	0	0
6 Sep	4	0	0	0	0	0	0	0
7 Sep	5	0	0	0	0	0	0	0
8 Sep	6	2/3	0	0	1/1	1/1	4/4	0
9 Sep	7	6/18	0	0	1/1	3/11	1/2	0
10 Sep	8	8/20	0	0	1/1	7/53	2/4	0
15 Sep	9	1/2	0	0	0	0	0	0
17 Sep	10	1/1	0	0	1/1	0	1/1	0
18 Sep	11	0	0	0	0	0	0	0
19 Sep	12	0	0	0	1/4	2/3	0	0
20 Sep	13	1/1	0	0	0	1/1	0	0
21 Sep	14	0	0	1/1	0	0	0	0
22 Sep	15	0	0	0	0	0	0	0
27 Sep	16	0	0	3/4	0	0	1/1	0
28 Sep	17	26/52	0	1/34	0	0	0	0
29 Sep	18	11/14	0	1/2	0	1/1	0	0
30 Sep	19	17/26	0	9/35	0	0	0	0
1 Oct	20	15/36	0	1/22	0	0	1/1	0
5 Oct	21	0	0	1/1	0	0	0	0
6 Oct	22	5/12	0	2/5	0	2/8	2/13	0
9 Oct	23	0	0	0	0	0	0	0
10 Oct	24	0	0	1/1	0	0	0	0
11 Oct	25	0	0	0	0	0	0	0
12 Oct	26	0	0	0	0	0	0	0
13 Oct	27	4/21	0	0	0	0	0	0
15 Oct	28	4/7	0	0	0	0	0	0
17 Oct	29	0	0	0	0	0	0	0
18 Oct	30	0	0	0	0	0	0	0
19 Oct	31	2/2	0	0	0	0	0	0

Total Semimonthly Sightings

Period		Bowhead Whale	Gray Whale	Belukha Whale	Bearded Seal	Ringed Seal	Unidentified Pinniped	Polar Bear
1-15 Sep		17/43	0	0	4/4	14/71	12/16	0
16-30 Sep		56/94	0	15/76	2/5	4/5	2/2	0
1-15 Oct		28/76	0	5/29	0	2/8	3/14	0
16-20 Oct		2/2	0	0	0	0	0	0
TOTAL	1-31	103/215	0	20/105	6/9	20/84	17/32	0

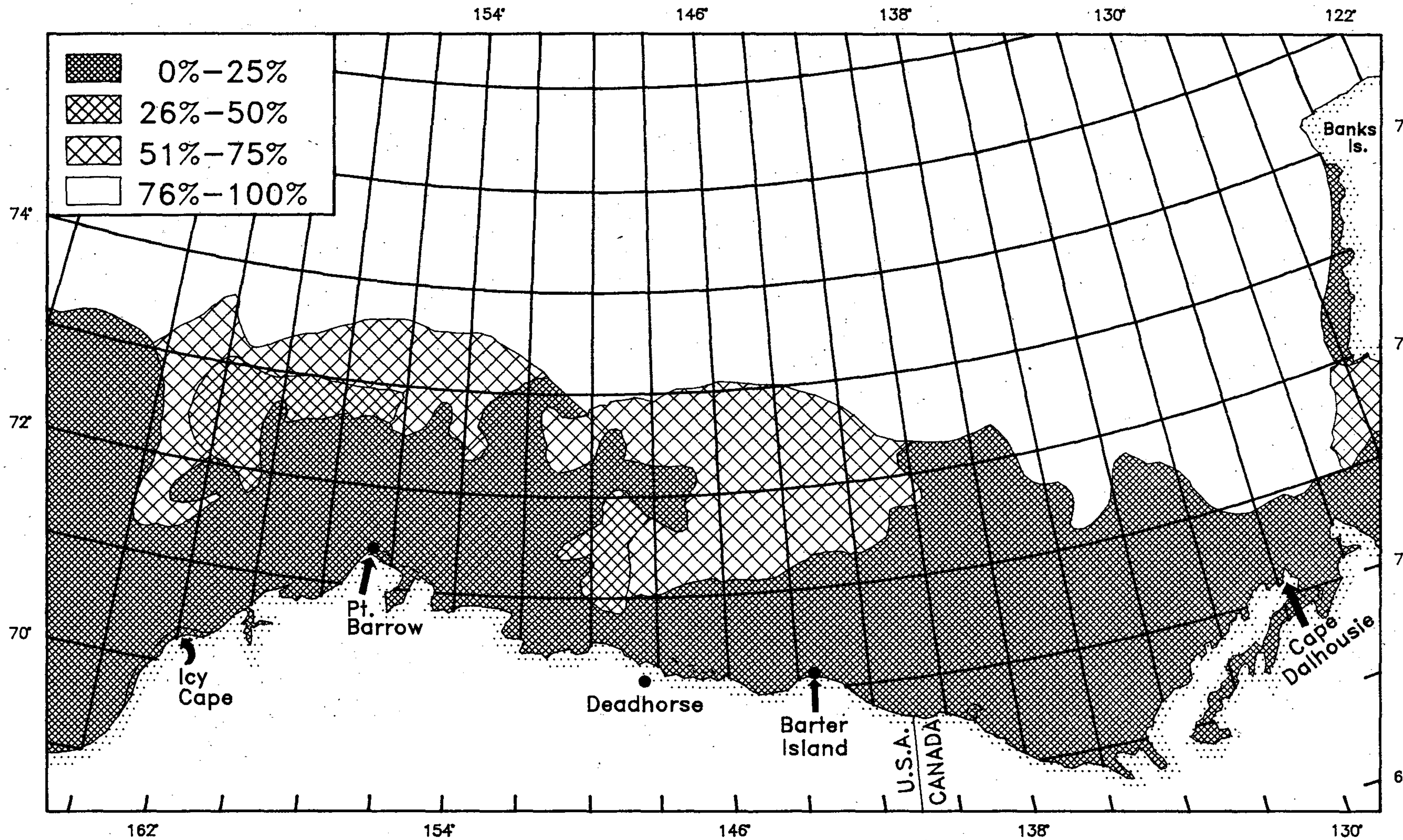

Figure 3. Map of Ice Concentrations in the Beaufort Sea, 29 August 1989

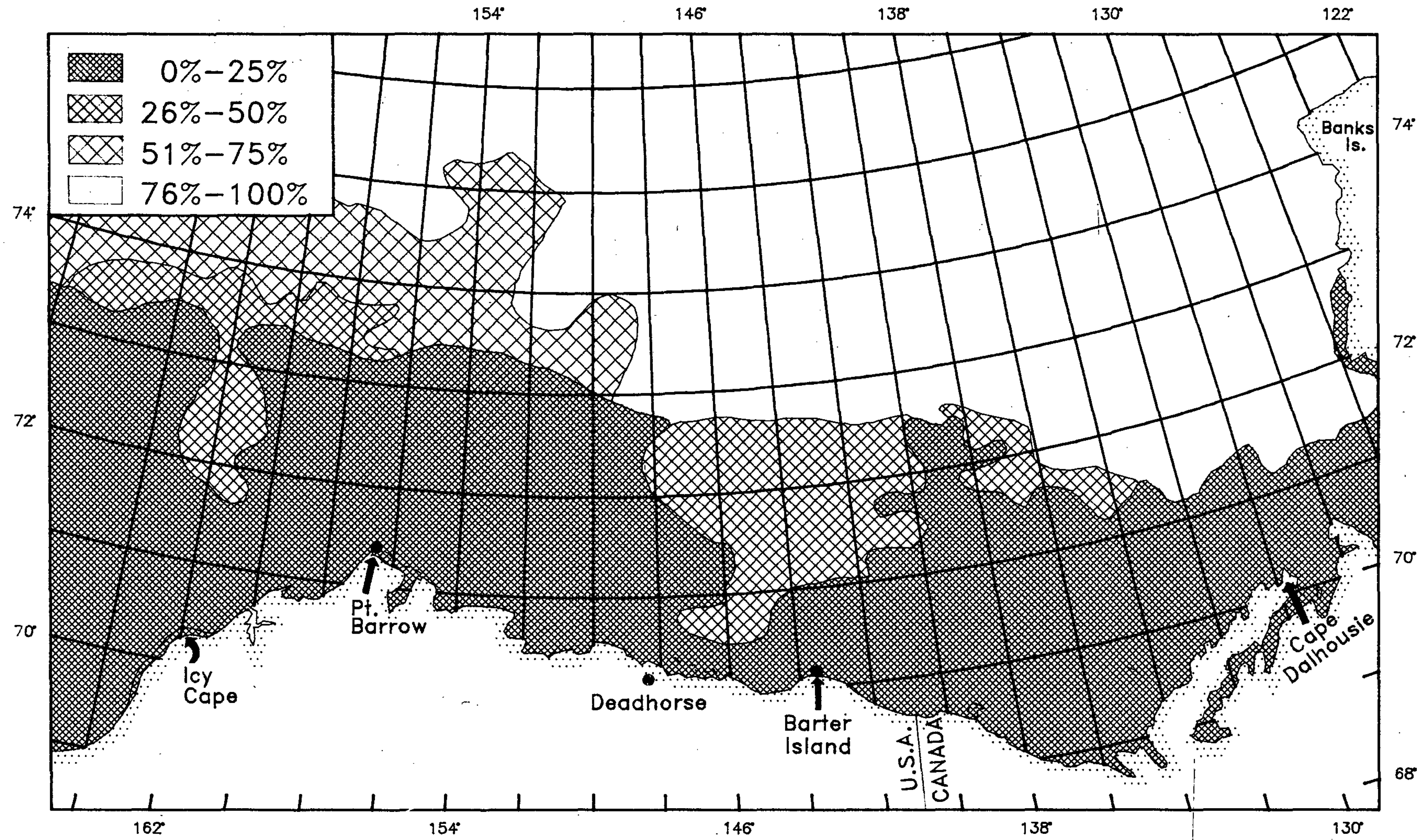

Figure 4. Map of Ice Concentrations in the Beaufort Sea, 5 September 1989

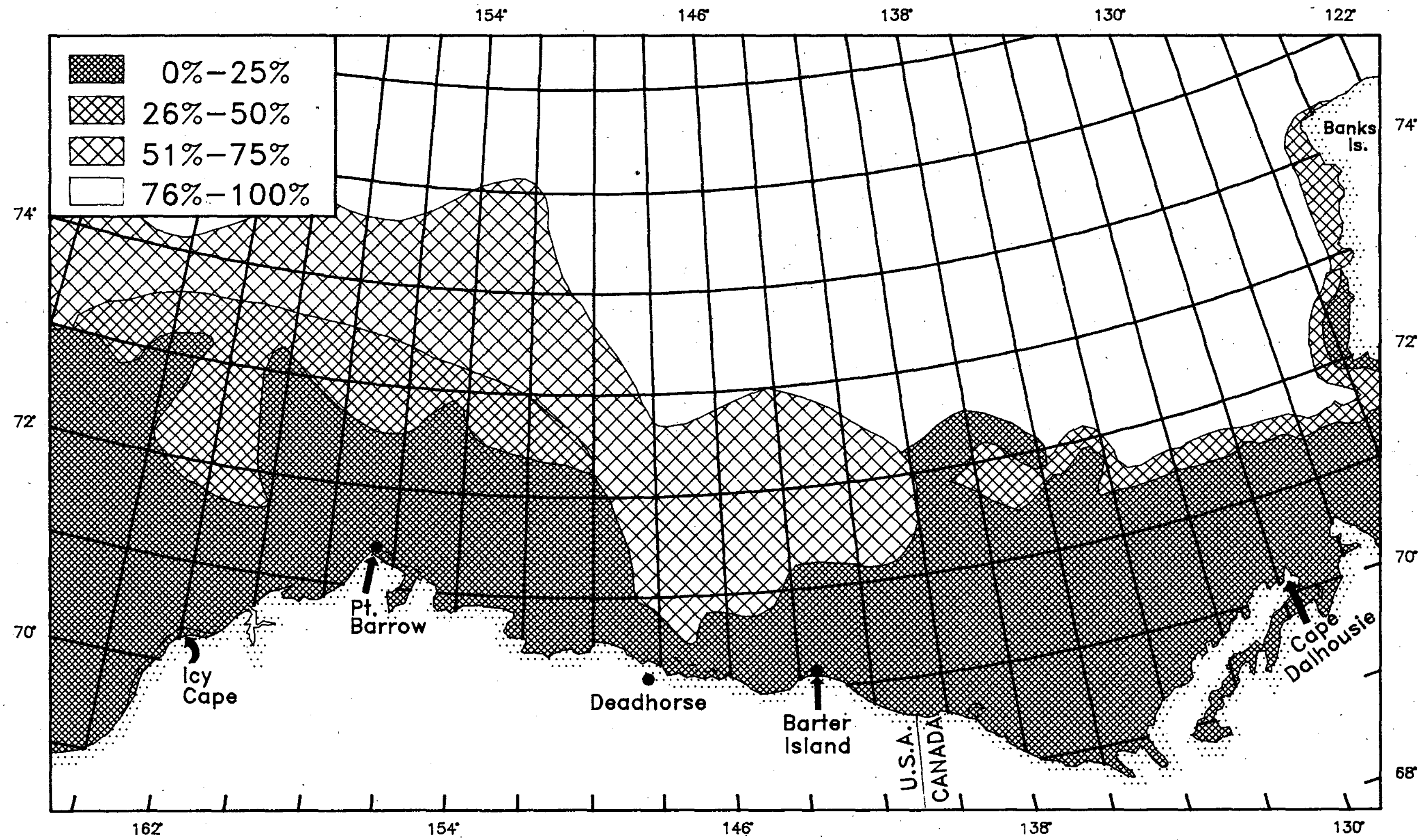

Figure 5. Map of Ice Concentrations in the Beaufort Sea, 12 September 1989

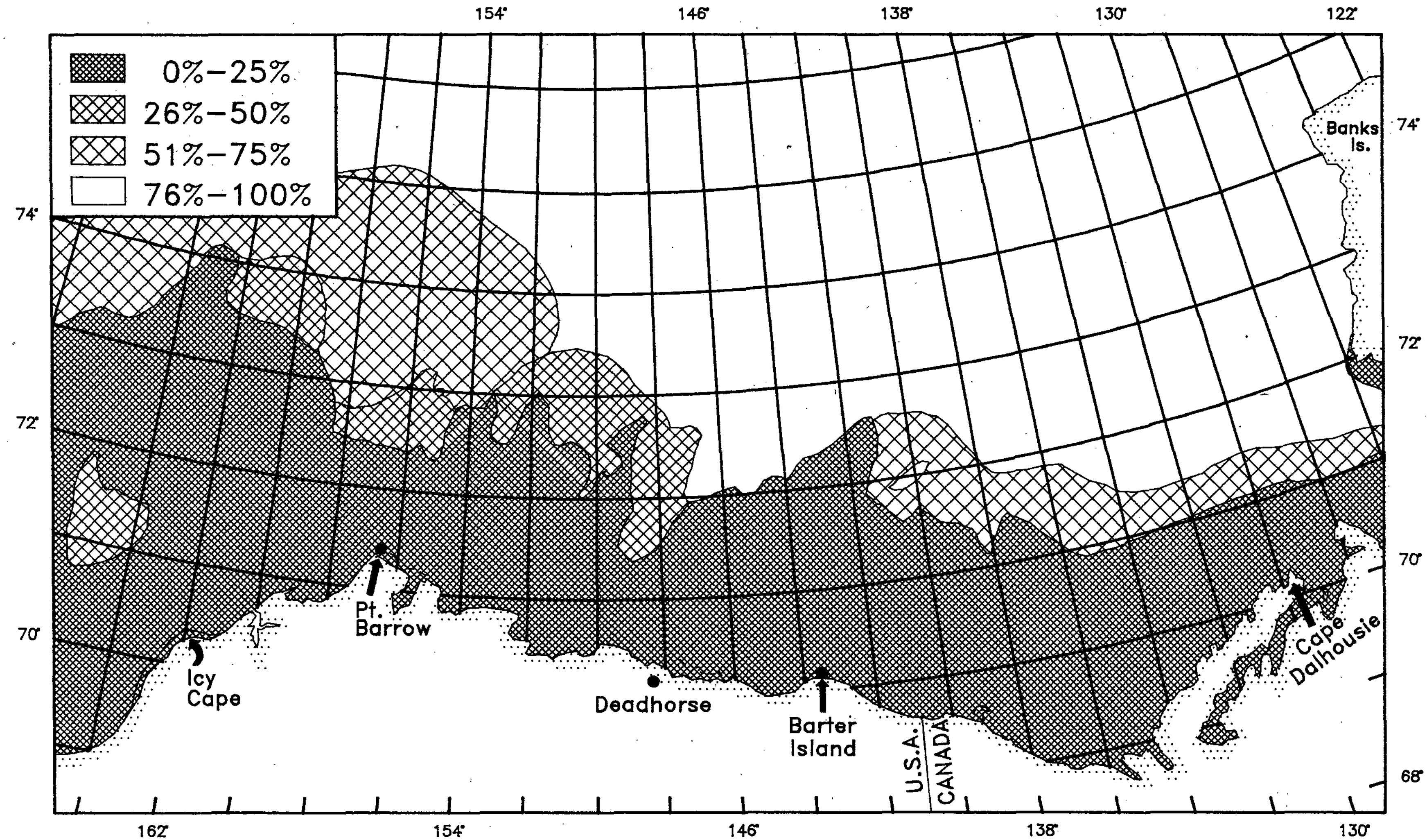

Figure 6. Map of Ice Concentrations in the Beaufort Sea, 19 September 1989

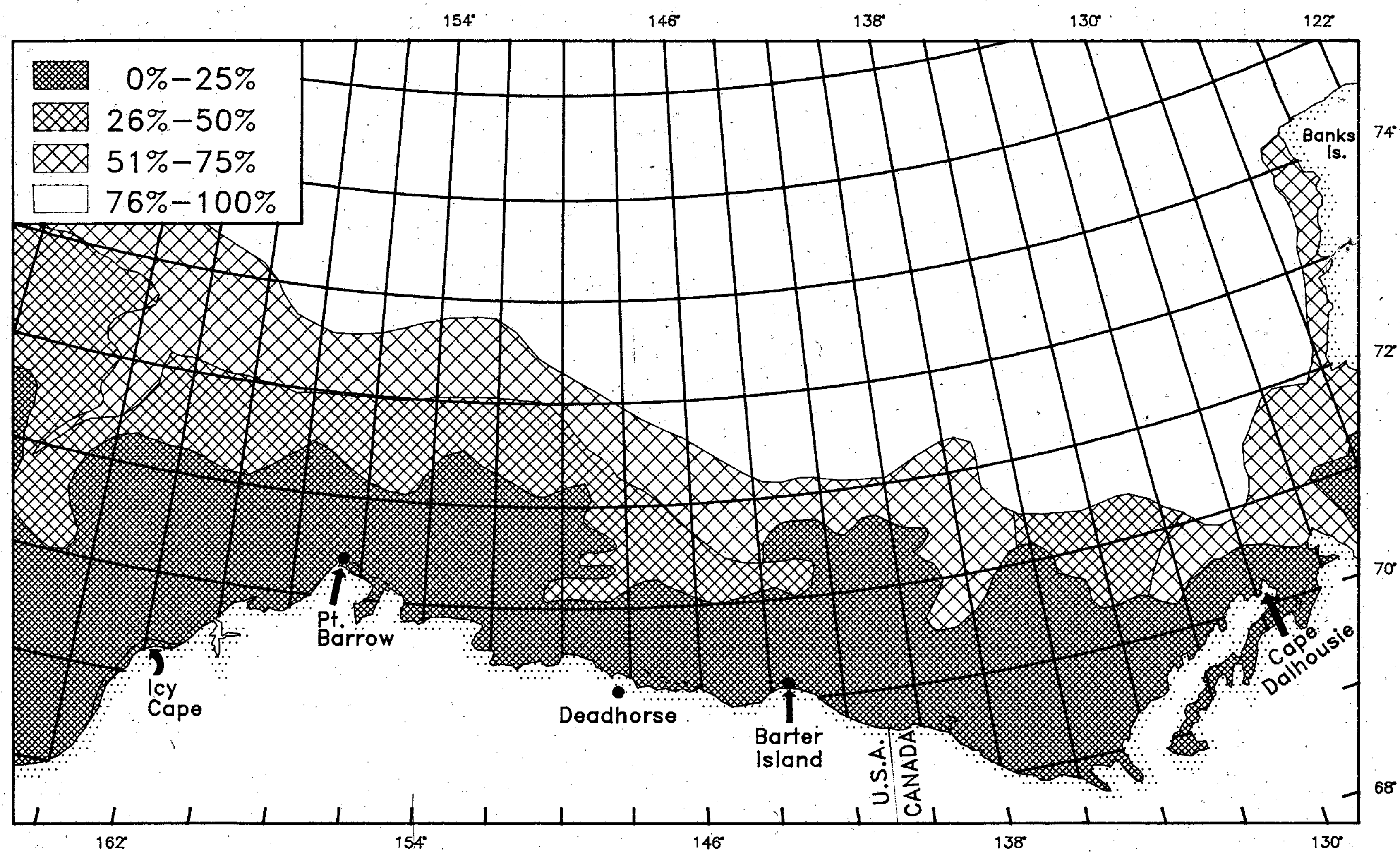

Figure 7. Map of Ice Concentrations in the Beaufort Sea, 26 September 1989

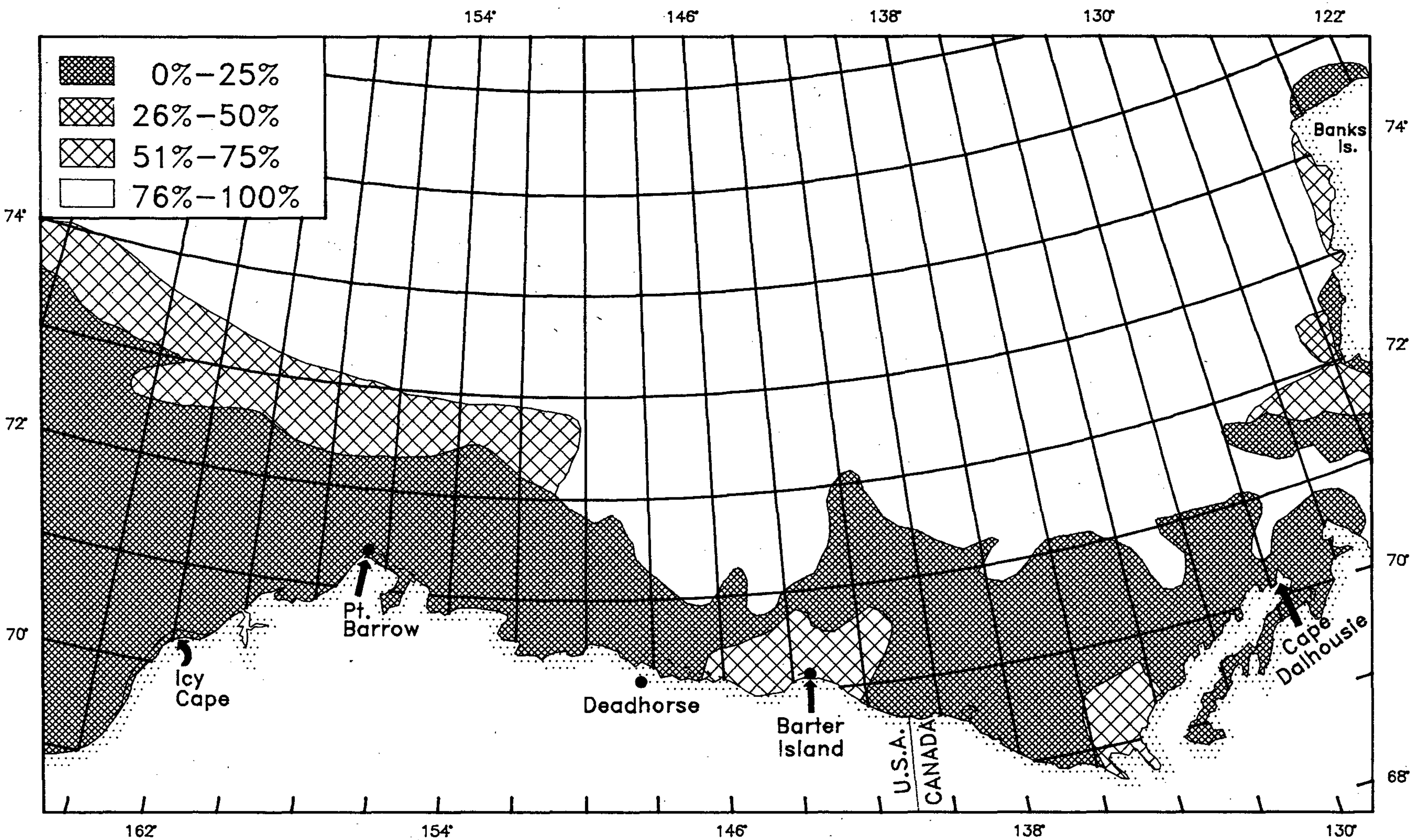

Figure 8. Map of Ice Concentrations in the Beaufort Sea, 3 October 1989

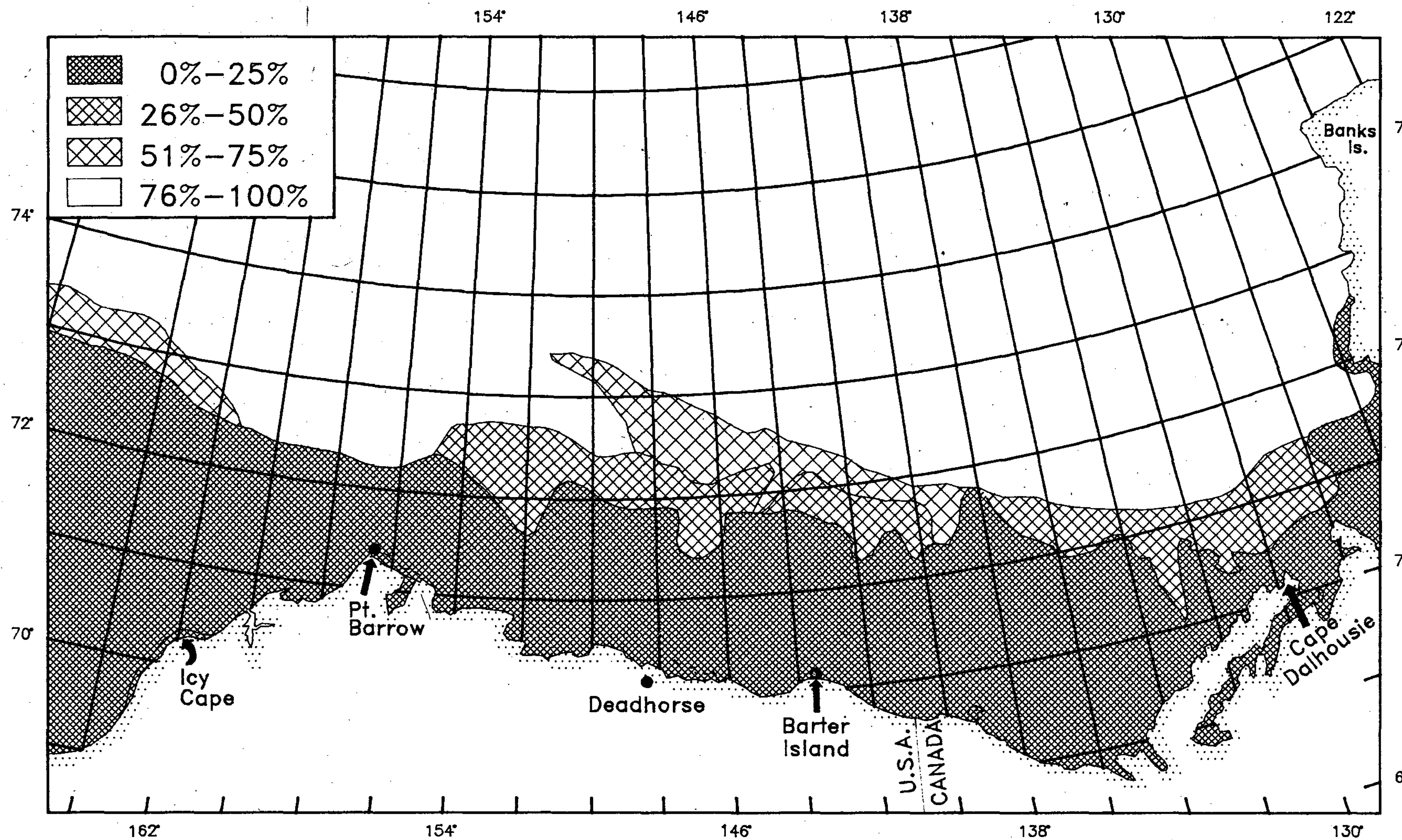

Figure 9. Map of Ice Concentrations in the Beaufort Sea, 10 October 1989

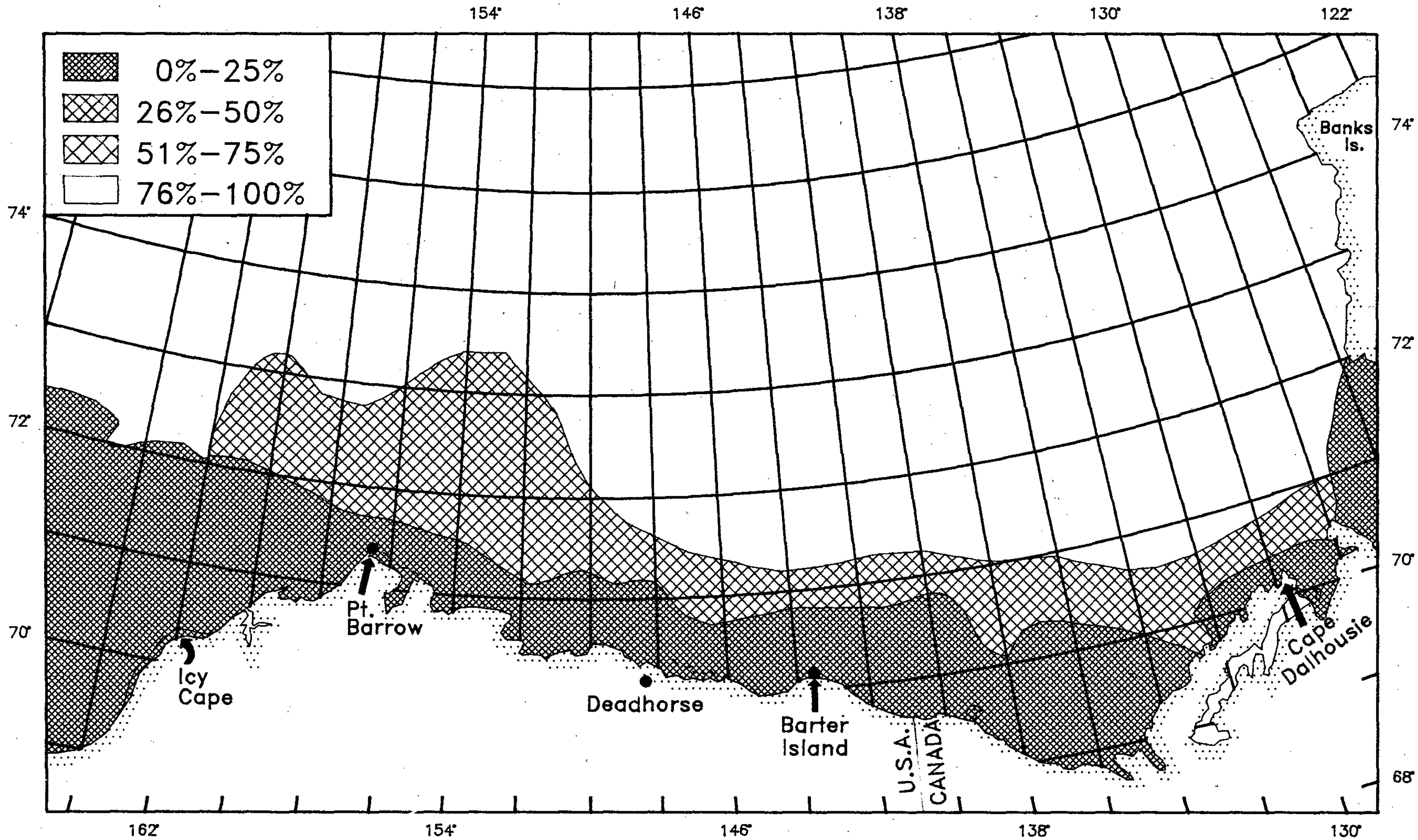

Figure 10. Map of Ice Concentrations in the Beaufort Sea, 17 October 1989

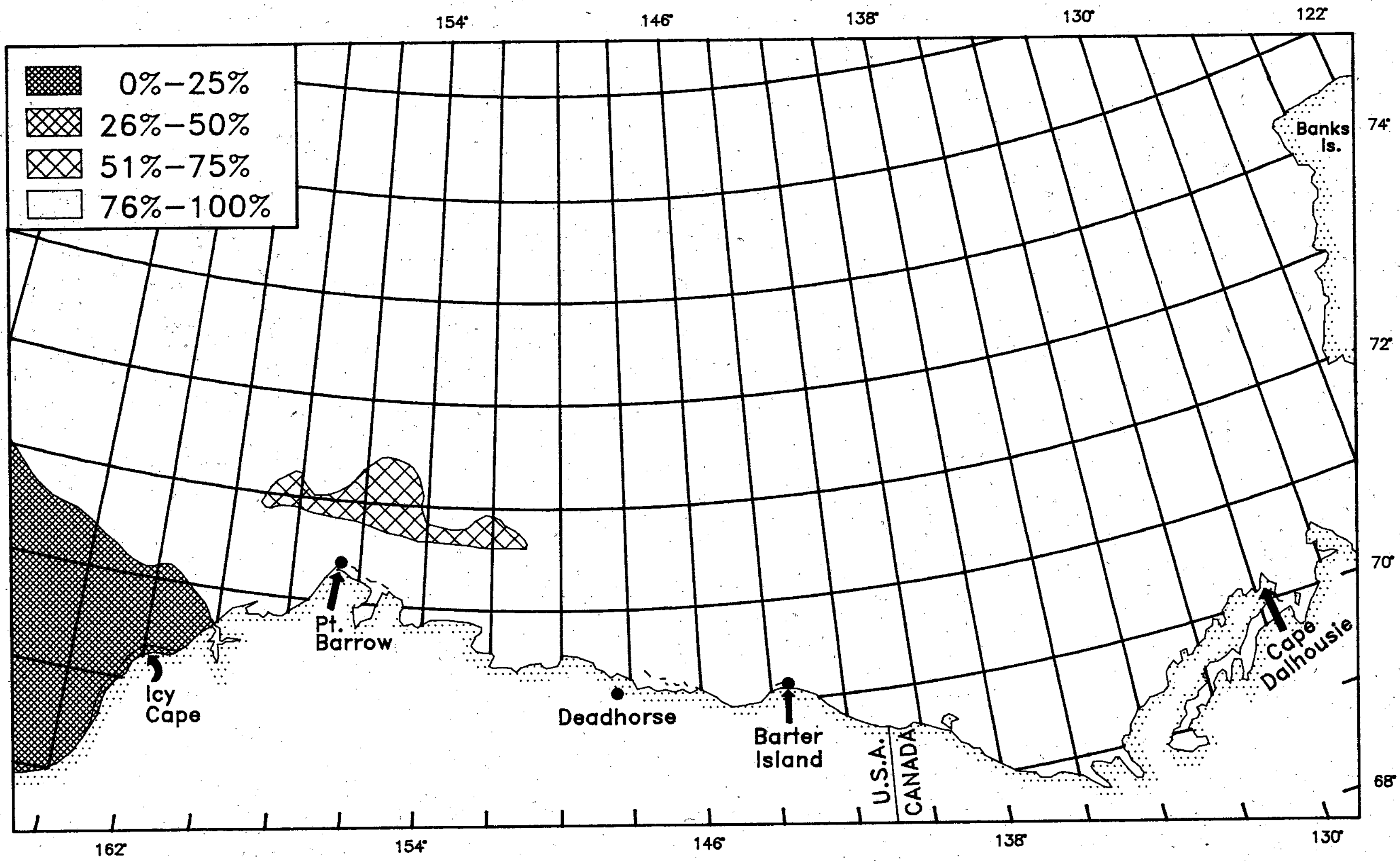

Figure 11. Map of Ice Concentrations in the Beaufort Sea, 24 October 1989

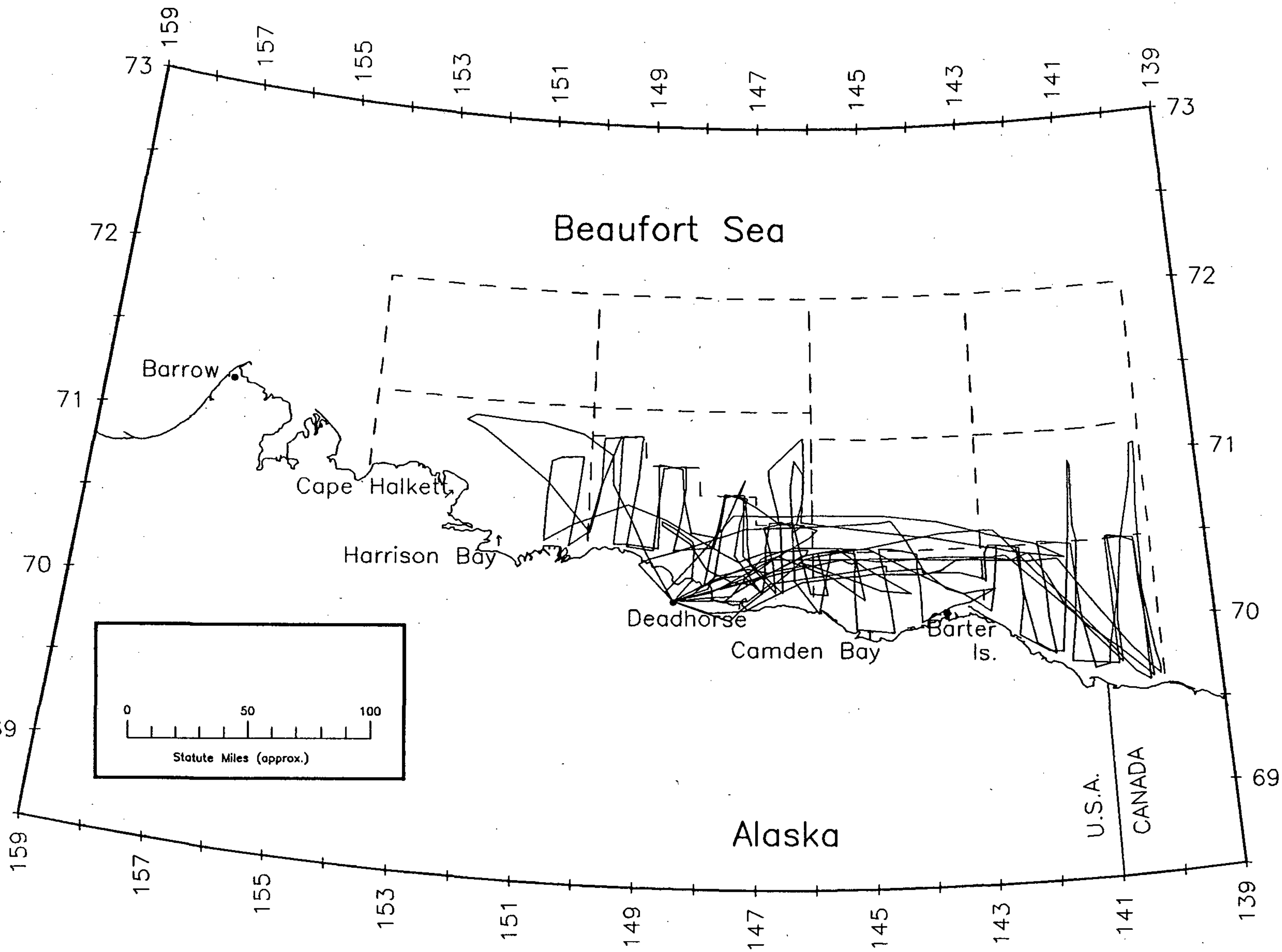

Figure 12. Combined Flight Tracks, 1–15 September 1989

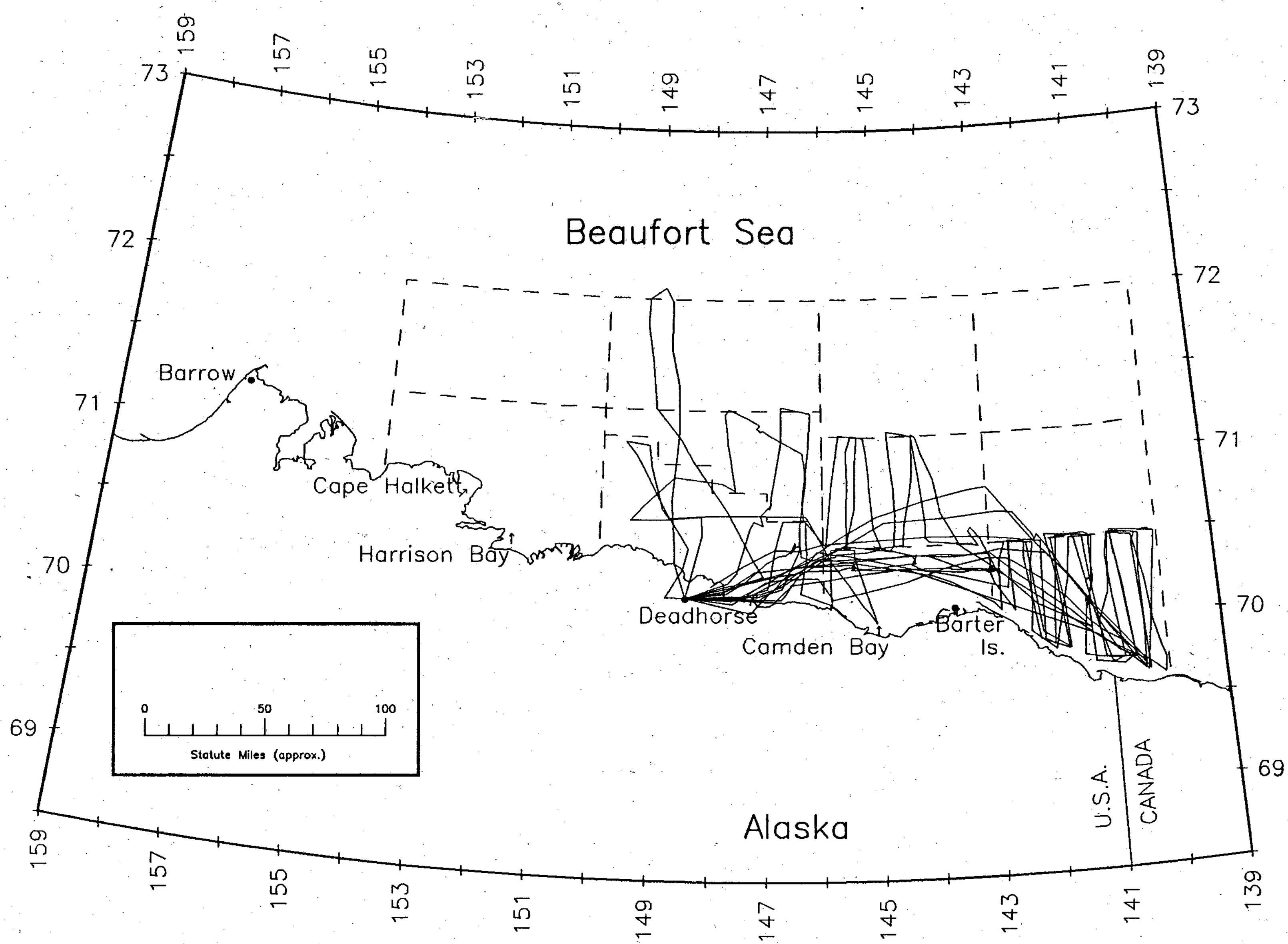

Figure 13. Combined Flight Tracks, 16–30 September 1989

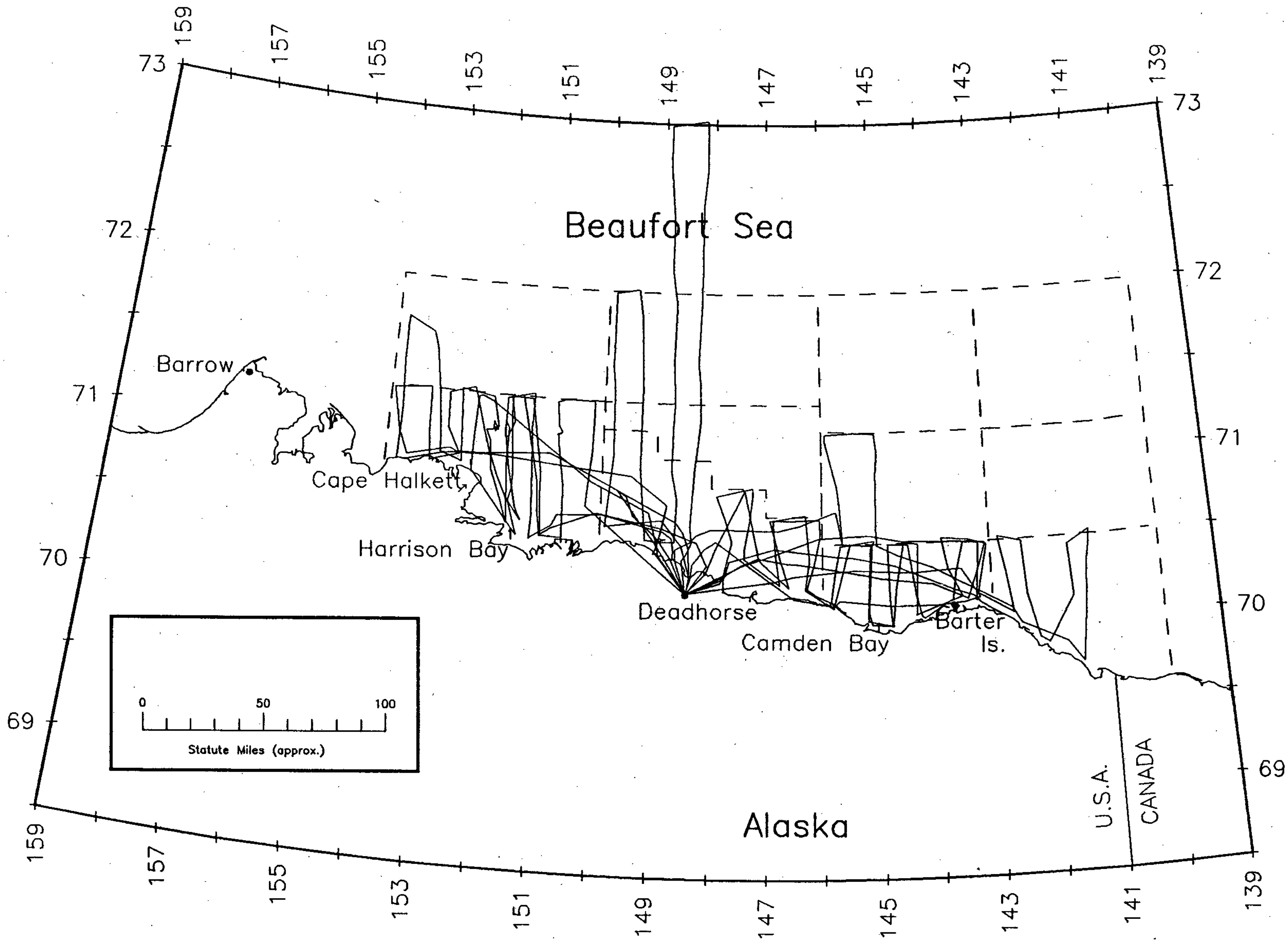

Figure 14. Combined Flight Tracks, 1–15 October 1989

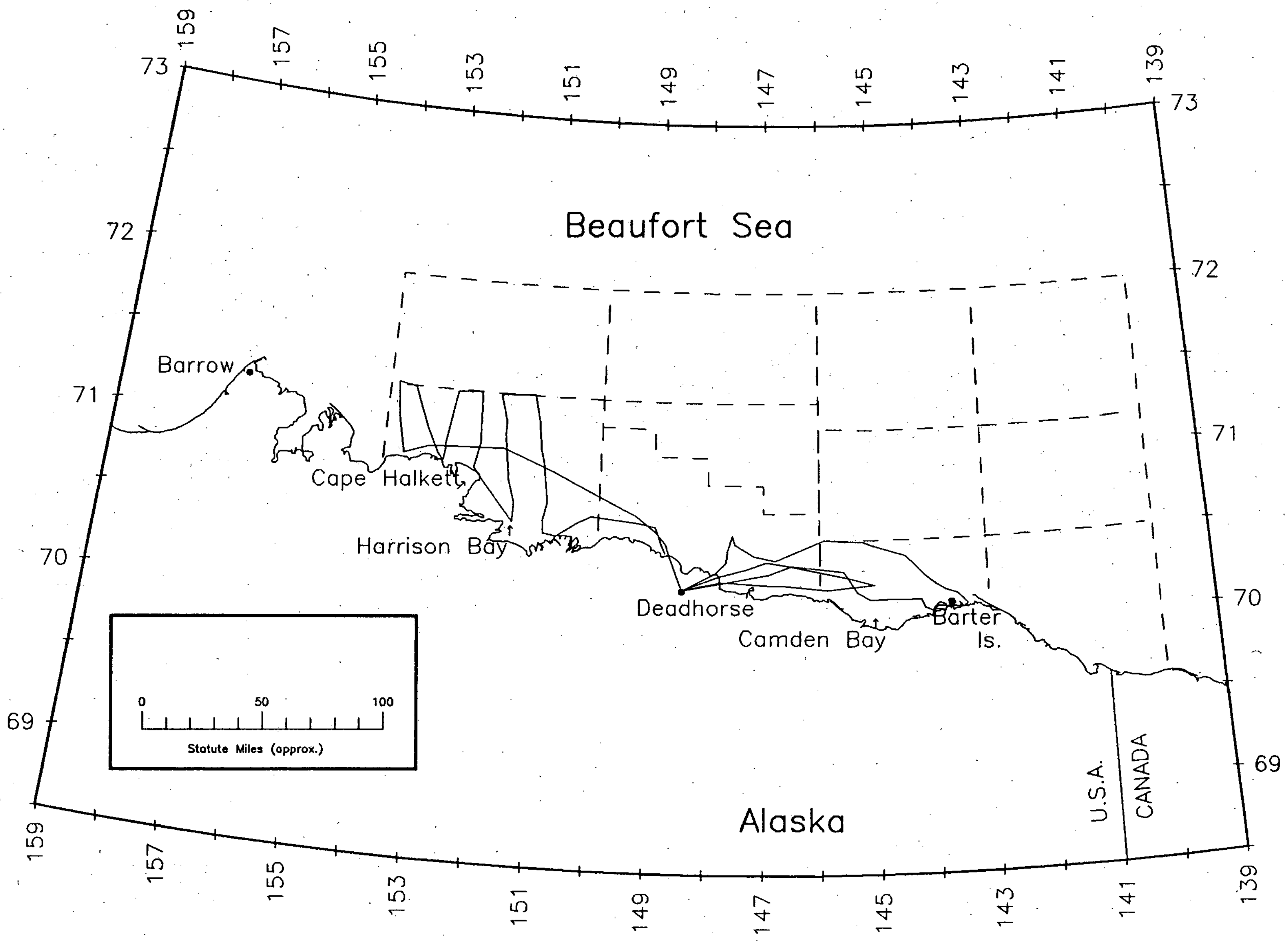

Figure 15. Combined Flight Tracks, 16–20 October 1989

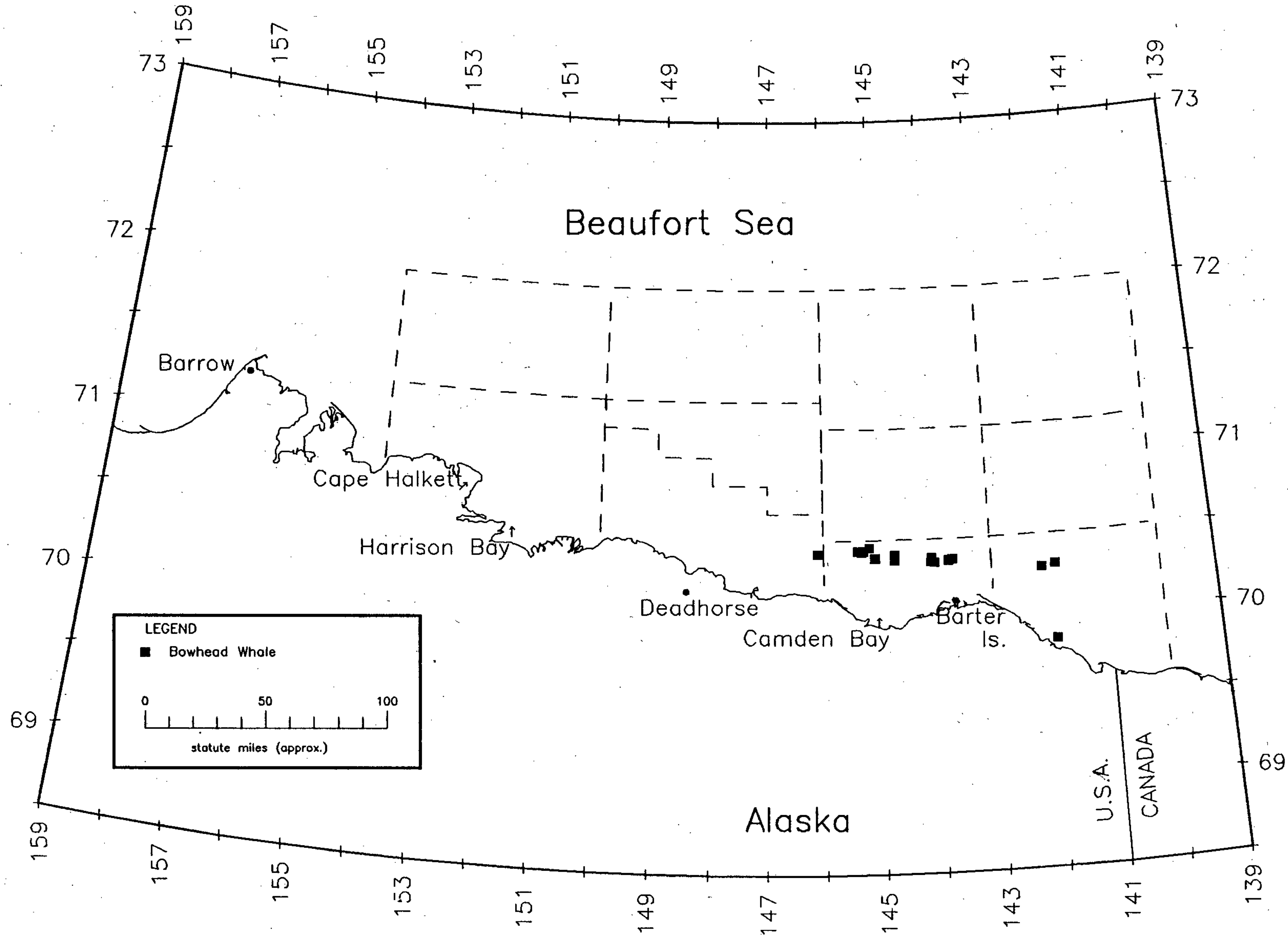

Figure 16. Map of Bowhead Whale Sightings, 1–15 September 1989

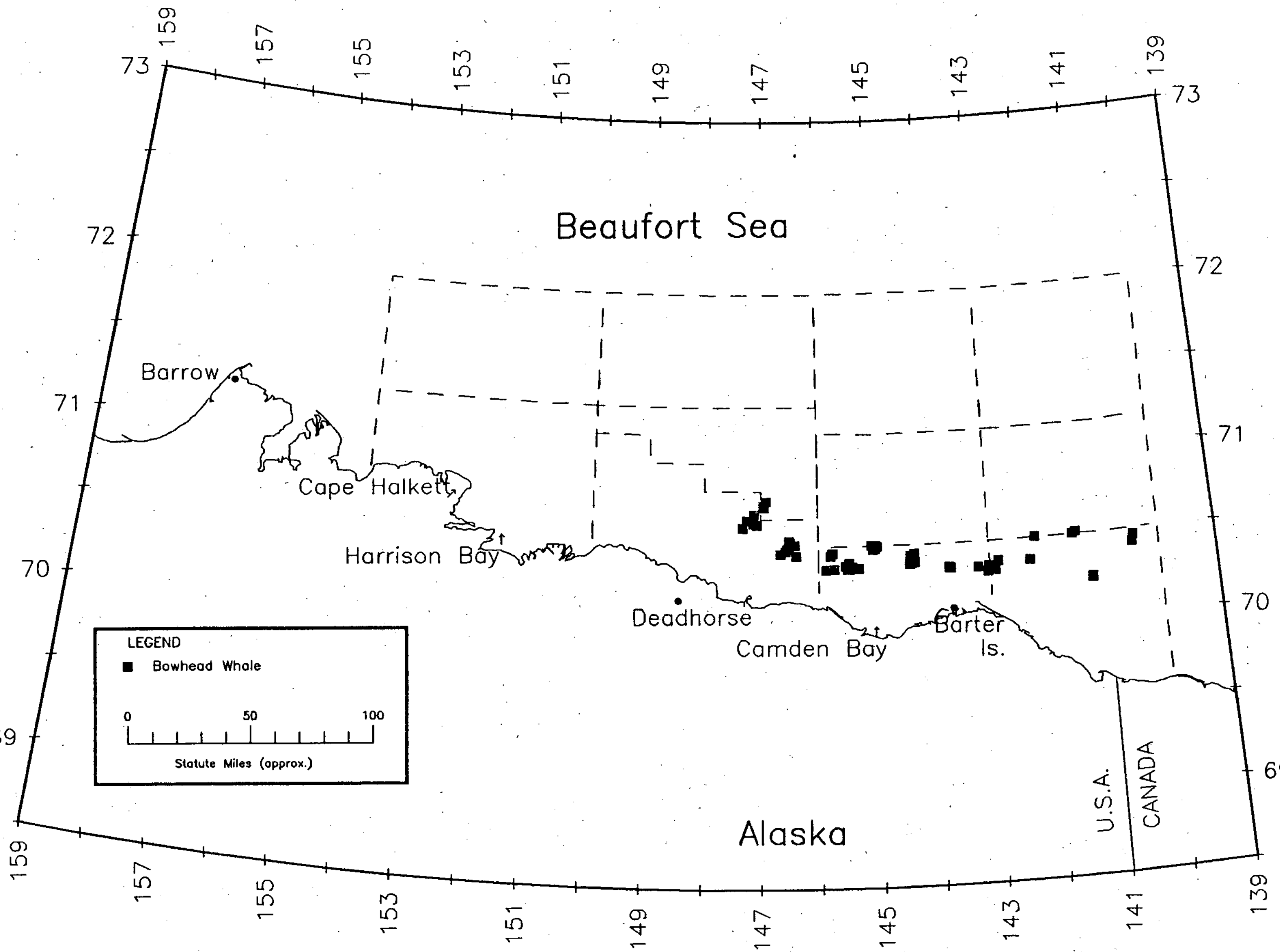

Figure 17. Map of Bowhead Whale Sightings, 16–30 September 1989

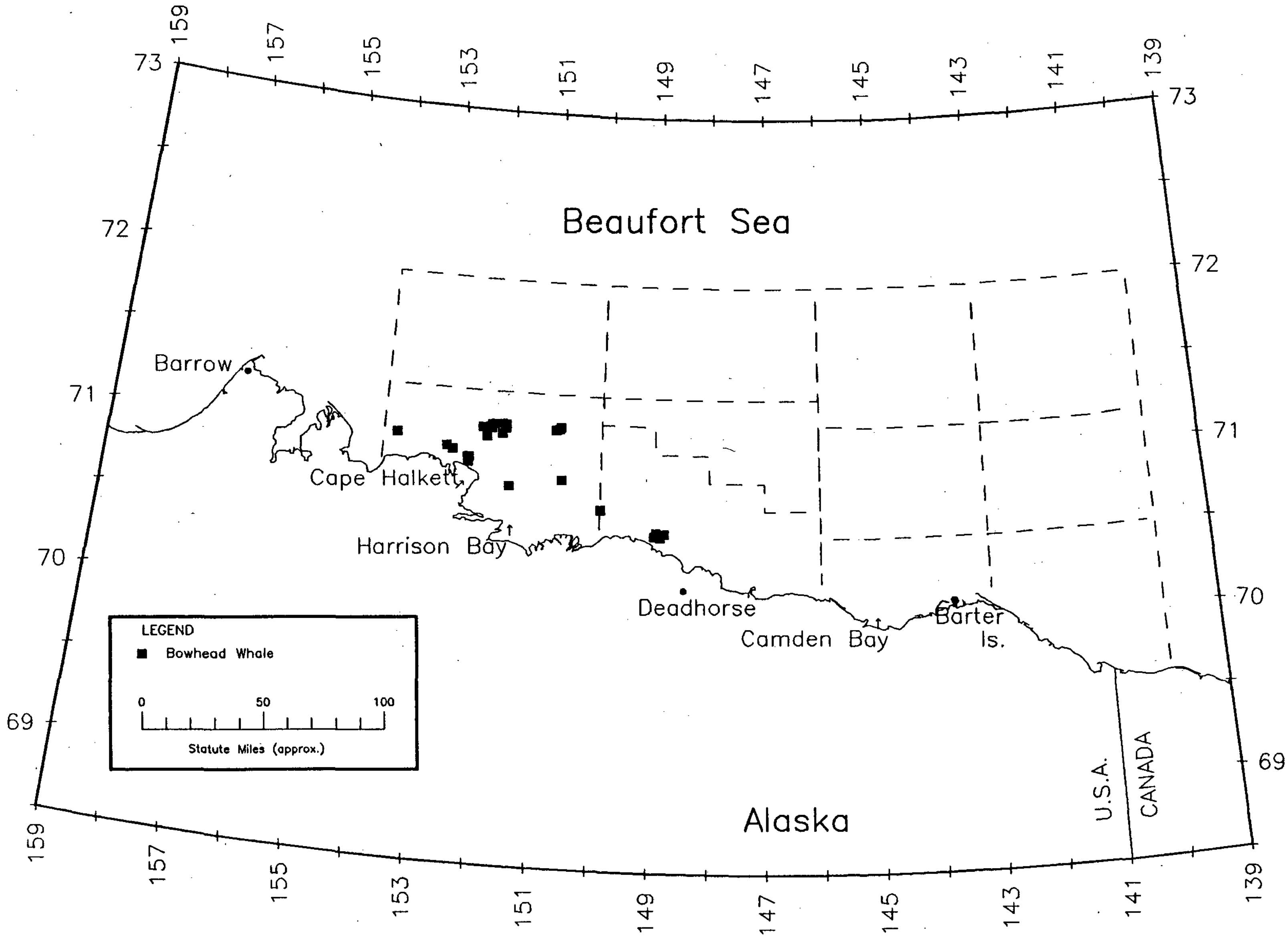

Figure 18. Map of Bowhead Whale Sightings, 1–15 October 1989

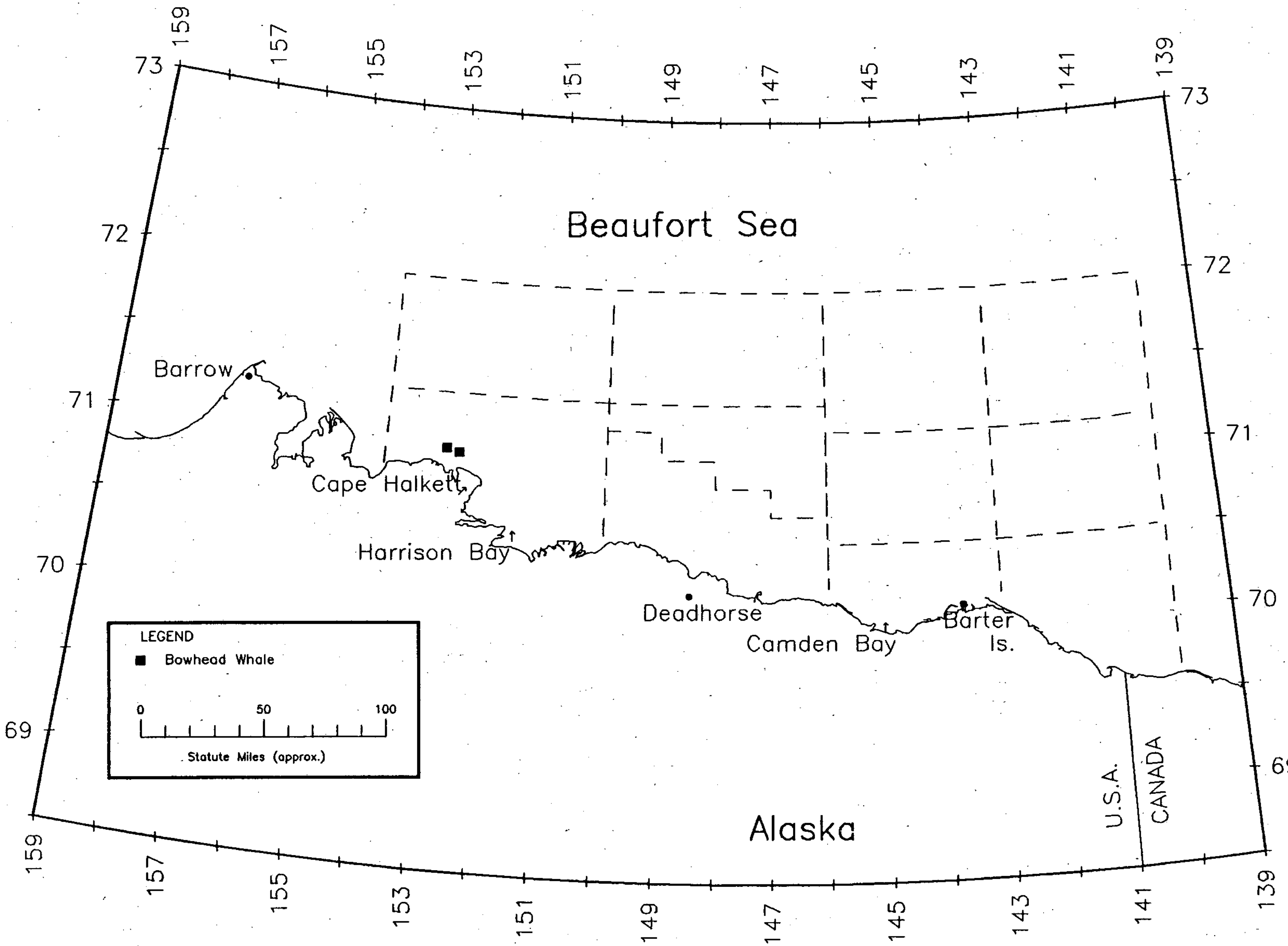

Figure 19. Map of Bowhead Whale Sightings, 16–20 October 1989

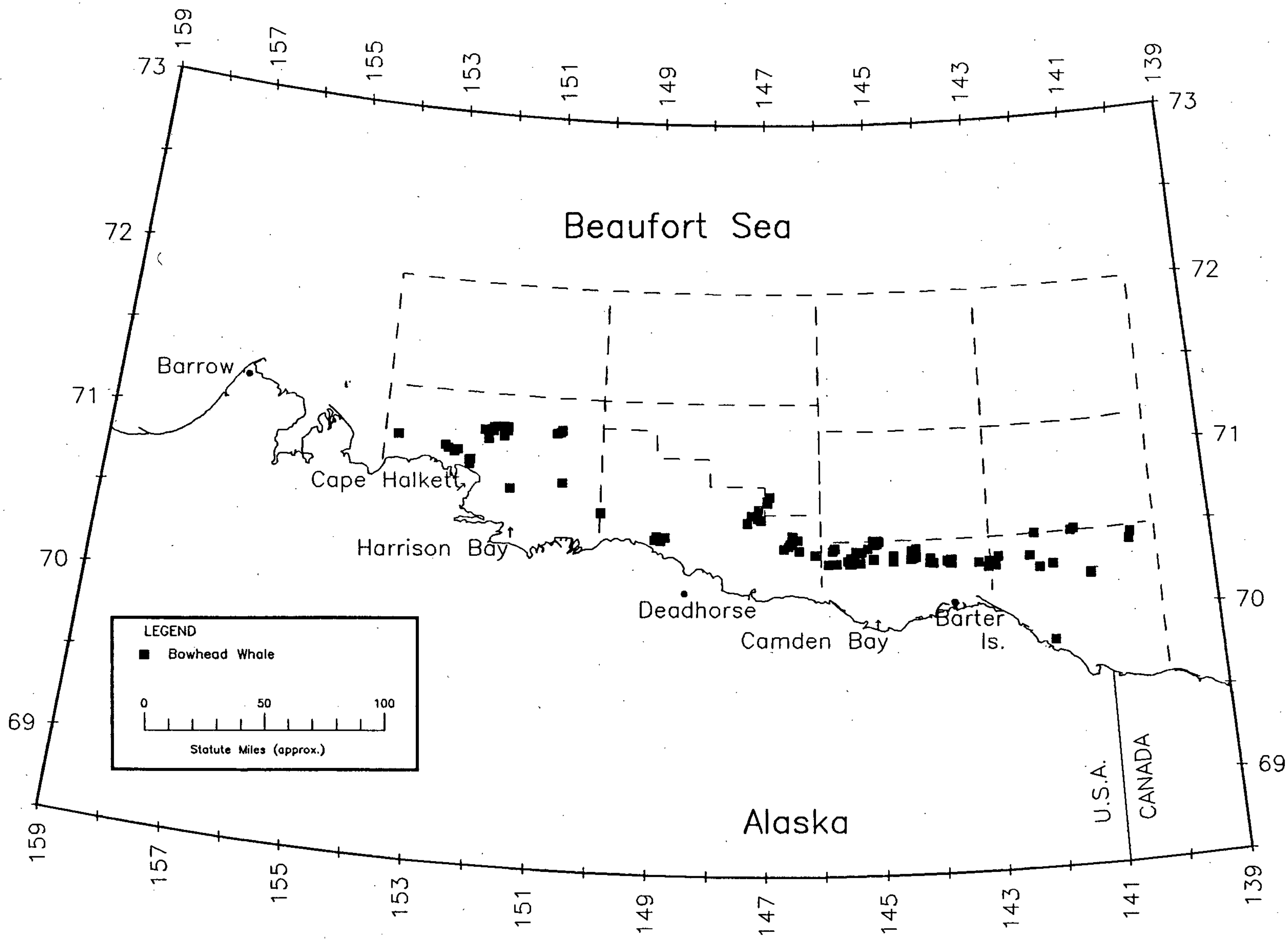

Figure 20. Map of Bowhead Whale Sightings, 1 September–20 October 1989

During the first half of October, 28 sightings were made for a total of 76 bowheads, with all sightings west of Deadhorse (Fig. 18). Group sizes ranged from 1 to 15 whales (Appendix B: Table B-1), with a mean of 2.71 (SD = 3.10, n = 28).

From 16 through 20 October, only 2 sightings were made for a total of 2 bowheads (Fig. 19). The last bowhead seen in the Beaufort Sea during the study occurred on 19 October at 71°00.3′N. latitude, 152°52.9′W. longitude (Appendix B: Table B-1).

2. Relative Temporal and Spatial Abundance: The day-to-day timing of the bowhead whale migration was calculated over the entire study area in Table 4 and graphically depicted in Figure 21. A daily sighting rate, or sightings per unit effort (SPUE), and an index of relative abundance, or whales per unit effort (WPUE), were determined.

The sighting-rate data show that an initial sighting was made on 8 September. The daily sighting rate peaked at 5.15 SPUE on 28 September. The last sighting of a bowhead in the study area was made on 19 October.

The data for relative daily abundance show that the midpoint (median) of the bowhead migration over the entire study area (when 50% of all sighted whales had been recorded) occurred on 29 September (Table 4). The peak relative abundance (mode) of 10.30 occurred on 28 October (Table 4 and Fig. 21).

The greatest difference between the relative abundance and the sighting rate for all areas surveyed occurs on 13 October (Fig. 21), when four sightings of 21 bowheads within only 2.60 hr of survey effort resulted in a relative abundance of 8.08 WPUE, compared to 1.54 SPUE (Table 4). This disparity was primarily due to a single large pod of 15 whales recorded on that day.

The relative abundance of bowhead whales in each survey block, in Canadian waters east of 140°W. longitude, and in Alaskan waters outside of study-area blocks, was calculated in Table 5.

During the first half of September, there were three survey blocks in which ≥ 4 hr of survey effort were made (Table 5). Of these (Blocks 1, 4, and 5), coastal Block 4 had the greatest relative abundance (6.98 WPUE), with coastal Block 5 also having a relative abundance (0.54 WPUE) >0.50. No whales were observed during a total of 6.17 hr of survey effort in Blocks 2, 3, 6, and 7.

During the second half of September, there were four blocks in which ≥ 4 hr of survey effort were made (Table 5). Of these (Blocks 1, 4, 5, and 6), coastal Blocks 1 and 4 shared the greatest relative abundance (5.56 WPUE), with coastal Block 5 also having a relative abundance (0.81 WPUE) >0.50. Five whales were observed during a total of 4.18 hr of survey effort in the remaining blocks (Blocks 2, 7, 9, and 10) or in other Alaskan areas.

During the first half of October, there were three blocks in which ≥ 4 hr of survey effort were made (Table 5). Of these coastal blocks (Blocks 1, 3, and 4), Block 3 had the greatest relative abundance (6.95 WPUE), with Block 1 also having a relative abundance (1.71 WPUE) >0.50. No whales were observed during a total of 6.36 hr of survey effort in the remaining blocks (Blocks 2, 5, 6, 7, 10, and 11) or in other Alaskan areas.

From 16 through 20 October, there were no blocks in which ≥ 4 hr of survey effort were made (Table 5). Two whales were observed during a total of 5.52 hr of survey effort in the study area.

3. Habitat Relationships: Almost all the bowheads (94%) were sighted in shallow water (0-50 m deep). The remainder (6%) were sighted in water ranging from 51 m (Table 6) to a maximum depth of 525 m. All but one of the whales at water depths greater than 50 m were observed during the last half of September. A fuller description of depth associated with the bowhead migration, based on more accurate depth values, appears in the discussion on median-water-depth analysis in Section IV.B.

In addition to overall ice coverage (Figs. 3-11), the percentage of ice cover visible from the aircraft at each bowhead sighting was summarized (Appendix B: Table B-1). All bowheads sighted during the study were in 0- to 20-percent sea ice (Table 7).

Table 4
Number of Sightings and Total Bowhead Whales Observed per Hour, September-October 1989, by Flight Day

Day	No. of Sightings	No. of Whales	Total Survey Time (hr)	Sightings/ Hour (SPUE)	Whales/ Hour (WPUE)
3 Sep	0	0	0.72	0.00	0.00
4 Sep	0	0	4.50	0.00	0.00
5 Sep	0	0	3.37	0.00	0.00
6 Sep	0	0	2.93	0.00	0.00
7 Sep	0	0	4.35	0.00	0.00
8 Sep	2	3	4.58	0.44	0.66
9 Sep	6	18	4.58	1.31	3.93
10 Sep	8	20	3.68	2.17	5.43
15 Sep	1	2	1.33	0.75	1.50
17 Sep	1	1	4.23	0.24	0.24
18 Sep	0	0	1.73	0.00	0.00
19 Sep	0	0	2.53	0.00	0.00
20 Sep	1	1	4.47	0.22	0.22
21 Sep	0	0	3.13	0.00	0.00
22 Sep	0	0	1.73	0.00	0.00
27 Sep	0	0	1.77	0.00	0.00
28 Sep	26	52	5.05	5.15	10.30
29 Sep	11	14	5.05	2.18	2.77
30 Sep	17	26	4.73	3.59	5.50
1 Oct	15	36	5.05	2.97	7.13
5 Oct	0	0	4.68	0.00	0.00
6 Oct	5	12	4.30	1.16	2.79
9 Oct	0	0	1.55	0.00	0.00
10 Oct	0	0	3.42	0.00	0.00
11 Oct	0	0	3.00	0.00	0.00
12 Oct	0	0	0.43	0.00	0.00
13 Oct	4	21	2.60	1.54	8.08
15 Oct	4	7	3.67	1.09	1.91
17 Oct	0	0	0.85	0.00	0.00
18 Oct	0	0	1.48	0.00	0.00
19 Oct	2	2	3.18	0.63	0.63
TOTAL	103	215	98.70	1.04	2.18

Table 5
Semimonthly Relative Abundance (WPUE) of Bowhead Whales (BH), by Survey Block (Fall 1989)

	1-15 Sep			16-30 Sep			1-15 Oct			16-20 Oct			Total		
Block	Hr	BH	WPUE	Hr	BH	WPUE	Hr	BH	WPUE	Hr	BH	WPUE	Hr	BH	WPUE
1	11.20	2	0.18	7.80	43	5.56	8.14	13	1.60	1.71	0	0.00	28.85	58	2.01
2	1.12	0	0.00	1.94	1	0.55	0.44	0	0.00	0.00	*	*	3.50	1	0.29
3	1.61	0	0.00	0.00	*	*	9.06	63	6.95	2.59	2	0.77	13.26	65	4.90
4	5.30	37	6.98	6.10	34	5.56	5.16	0	0.00	1.08	0	0.00	17.64	71	4.02
5	7.38	4	0.54	12.27	10	0.81	1.57	0	0.00	0.00	*	*	21.22	14	0.70
6	2.06	0	0.00	4.08	2	0.49	1.47	0	0.00	0.03	0	0.00	7.64	2	0.26
7	1.38	0	0.00	1.25	4	3.17	0.10	0	0.00	0.00	*	*	2.73	4	1.47
8	0.00	*	*	0.00	*	*	0.00	*	*	0.00	*	*	0.00	*	*
9	0.00	*	*	0.19	0	0.00	0.00	*	*	0.00	*	*	0.19	0	0.00
10	0.00	*	*	0.69	0	0.00	1.17	0	0.00	0.00	*	*	1.86	0	0.00
11	0.00	*	*	0.00	*	*	0.61	0	0.00	0.11	0	0.00	0.72	0	0.00
Other Canadian Areas	0.00	*	*	0.00	*	*	0.00	*	*	0.00	*	*	0.00	*	*
Other Alaskan Areas	0.00	*	*	0.11	0	0.00	1.00	0	0.00	0.00	*	*	1.11	0	0.00
TOTAL	30.05	43	1.43	34.43	94	2.73	28.72	76	2.65	5.52	2	0.36	98.72	215	2.18

* No survey effort.

Table 6
Semimonthly Summary of Bowhead Whales Observed, by Water Depth at Sighting Location (Fall 1989)

Water Depth	1-15 Sep No. (%)	16-30 Sep No. (%)	1-15 Oct No. (%)	16-20 Oct No. (%)	Total No. (%)
Shallow (0-50 m)	42 (98)	83 (88)	76 (100)	2 (100)	203 (94)
Transitional (51-200 m)	1 (2)	5 (5)	0	0	6 (3)
Deep (>200 m)	0	6 (7)	0	0	6 (3)
TOTAL	43 (100)	94 (100)	76 (100)	2 (100)	215 (100)

Table 7
Semimonthly Summary of Bowhead Whales Observed,
by Percent Ice Cover Present at Sighting Location (Fall 1989)

% Ice Cover	1-15 Sep No. (%)	16-30 Sep No. (%)	1-15 Oct No. (%)	16-20 Oct No. (%)	Total No. (%)
0-20	43 (100)	94 (100)	76 (100)	2 (100)	215 (100)
21-30	0	0	0	0	0
31-40	0	0	0	0	0
41-50	0	0	0	0	0
51-60	0	0	0	0	0
61-70	0	0	0	0	0
71-80	0	0	0	0	0
81-90	0	0	0	0	0
91-99	0	0	0	0	0
TOTAL	43 (100)	94 (100)	76 (100)	2 (100)	215 (100)

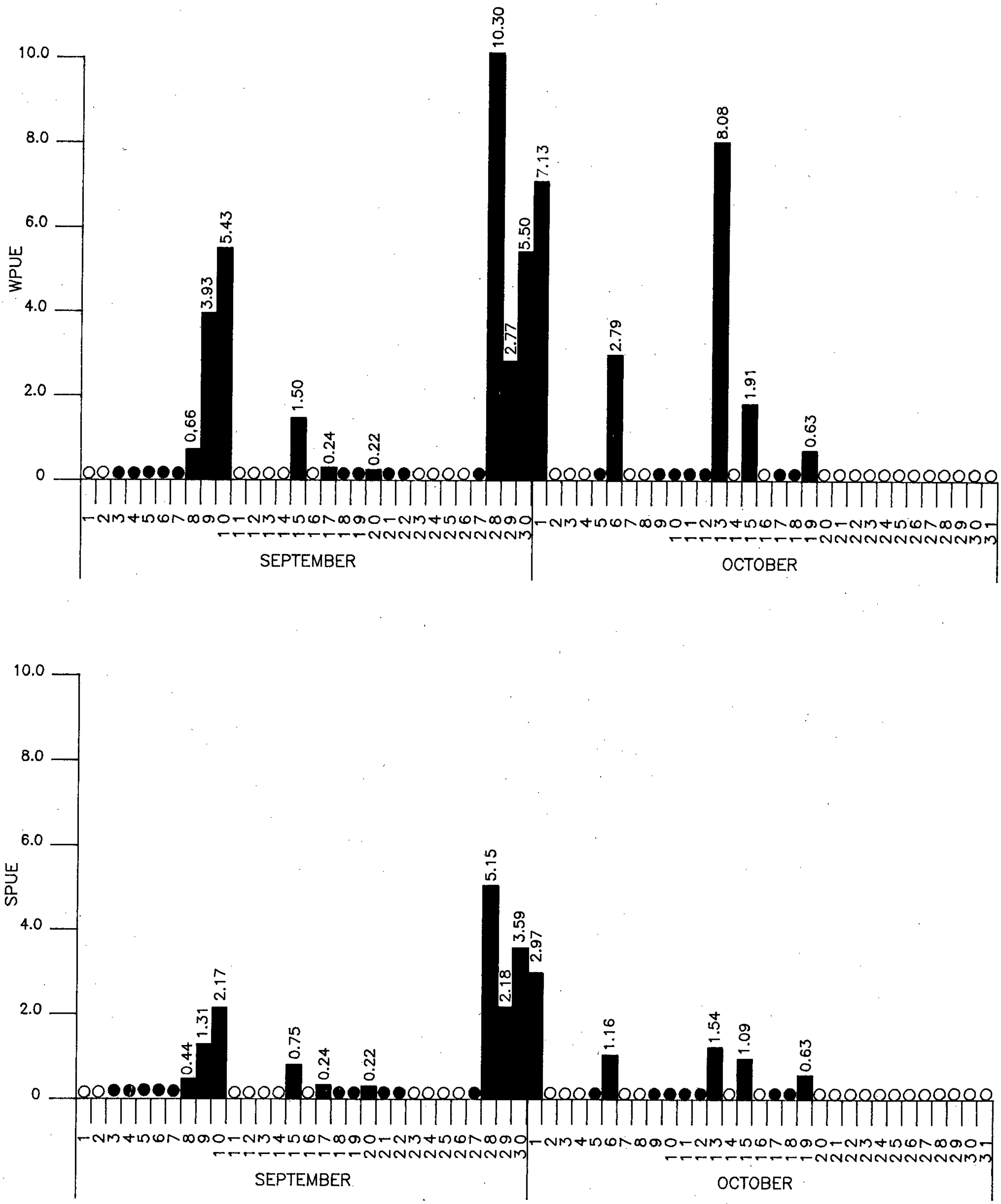

Figure 21. Daily Relative Abundance (WPUE) and Sighting Rate (SPUE) of Bowhead Whales (Fall 1989)

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

4. Behavior, Swim Direction, and Speed: Overall, 196 of the bowheads observed during Fall 1989 were either swimming (71%), i.e., moving forward in an apparently deliberate manner (Table 8), or milling (21%) when first sighted. Swim direction over the fall season was significantly west-northwest (Fig. 22), consistent with a directed migration in rough parallel to Alaska's Beaufort Sea coastline. Bowheads were judged to be moving at either slow (22%), medium (57%), or fast (1%) speeds or were still (9%) (Table 9). Others were milling (21%), diving (3%), resting (3%), rolling (3%), or breaching (2%) (Table 8).

During the first half of September, 33 of 43 (76%) bowheads were observed swimming (Table 8) predominantly west-northwest or otherwise westerly, with a small proportion (approx. 0.2) headed east-southeast towards Canada (Fig. 22). Bowheads were mostly moving at medium (65%) or slow (26%) speed (Table 9). Others were either diving (12%) or milling (12%) (Table 8).

During the second half of September, 72 of 94 (77%) bowheads were observed swimming (Table 8) significantly west-northwest (Fig. 22). Bowheads were mostly moving at medium (61%) speed or were still (20%) (Table 9). Others were milling (12%), resting (6%), rolling (3%), or breaching (2%).

During the first half of October, 45 of 76 (60%) bowheads were observed swimming (Table 8), primarily west-northwest with substantial proportions (approx. 0.4) swimming in easterly directions (Fig. 22). Bowheads were moving at either medium (50%) or slow (42%) speeds (Table 9).

From 16 through 20 October, only two whales were observed. One was swimming and the other was diving (Table 8).

D. Other Marine Mammal Observations

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

2. Belukha Whale (*Delphinapterus leucas*): Twenty sightings for a total of 105 belukha whales were made east of 151°W. longitude, predominantly between 45 and 60 statute miles from shore (Fig. 23). Pod sizes ranged from 1 to 34 whales (Table 3).

All sightings of belukhas in September occurred during the second half of the month (21-30 September), when 15 sightings were made for a total of 76 whales (Table 3). During the last half of September, the overall relative abundance of belukha whales was 2.21 WPUE.

All sightings of belukhas in October occurred during the first half of the month (1-10 October), when 5 sightings were made for a total of 29 whales (Table 3). During the first half of October, the overall relative abundance of belukha whales was 1.01 WPUE.

3. Ringed Seal (*Phoca hispida*): Twenty incidental sightings for a total of 84 ringed seals were made east of 151°W. longitude, within 60 statute miles of shore (Fig. 24). Most of these (18 sightings of 76 seals) were observed in September (Table 3).

4. Bearded Seal (*Erignathus barbatus*): Six incidental sightings for a total of 9 bearded seals were made east of 148°W. longitude, within 35 statute miles of shore (Fig. 25). All of these were observed from 4 through 19 September.

5. Unidentified Pinnipeds: Seventeen incidental sightings for a total of 34 unidentified pinnipeds were made east of 152°W. longitude, within 55 statute miles of shore (Fig. 26). All of these were observed from 4 September through 6 October (Table 3).

6. Polar Bear (*Ursus maritimus*): No polar bears were sighted during the study.

Table 8
Semimonthly Summary of Bowhead Whales Observed, by Behavioral Category (Fall 1989)

Behavior	1-15 Sep No.	(%)	16-30 Sep No.	(%)	1-15 Oct No.	(%)	16-20 Oct No.	(%)	Total No.	(%)
Breaching	0		2	(2)	0		0		2	(1)
Diving	5	(12)	0		1	(1)	1	(50)	7	(3)
Milling	5	(12)	11	(12)	29	(38)	0		45	(21)
Resting	0		6	(6)	0		0		6	(3)
Rolling	0		3	(3)	0		0		3	(1)
Swimming	33	(76)	72	(77)	45	(60)	1	(50)	151	(71)
(not noted)	0		0		1	(1)	0		1	(-)
TOTAL	43	(100)	94	(100)	76	(100)	2	(100)	215	(100)

Table 9
Semimonthly Summary of Bowhead Whales Observed, by Swimming Speed (Fall 1989)

Swim Speed	1-15 Sep No.	(%)	16-30 Sep No.	(%)	1-15 Oct No.	(%)	16-20 Oct No.	(%)	Total No.	(%)
Still (0 km/hr)	0		19	(20)	0		0		19	(9)
Slow (<2 km/hr)	11	(26)	4	(4)	32	(42)	0		47	(22)
Medium (2-4 km/hr)	28	(65)	57	(61)	38	(50)	0		123	(57)
Fast (>4 km/hr)	0		1	(1)	0		0		1	(-)
(not noted)	4	(9)	13	(14)	6	(8)	2	(100)	25	(12)
TOTAL	43	(100)	94	(100)	76	(100)	2	(100)	215	(100)

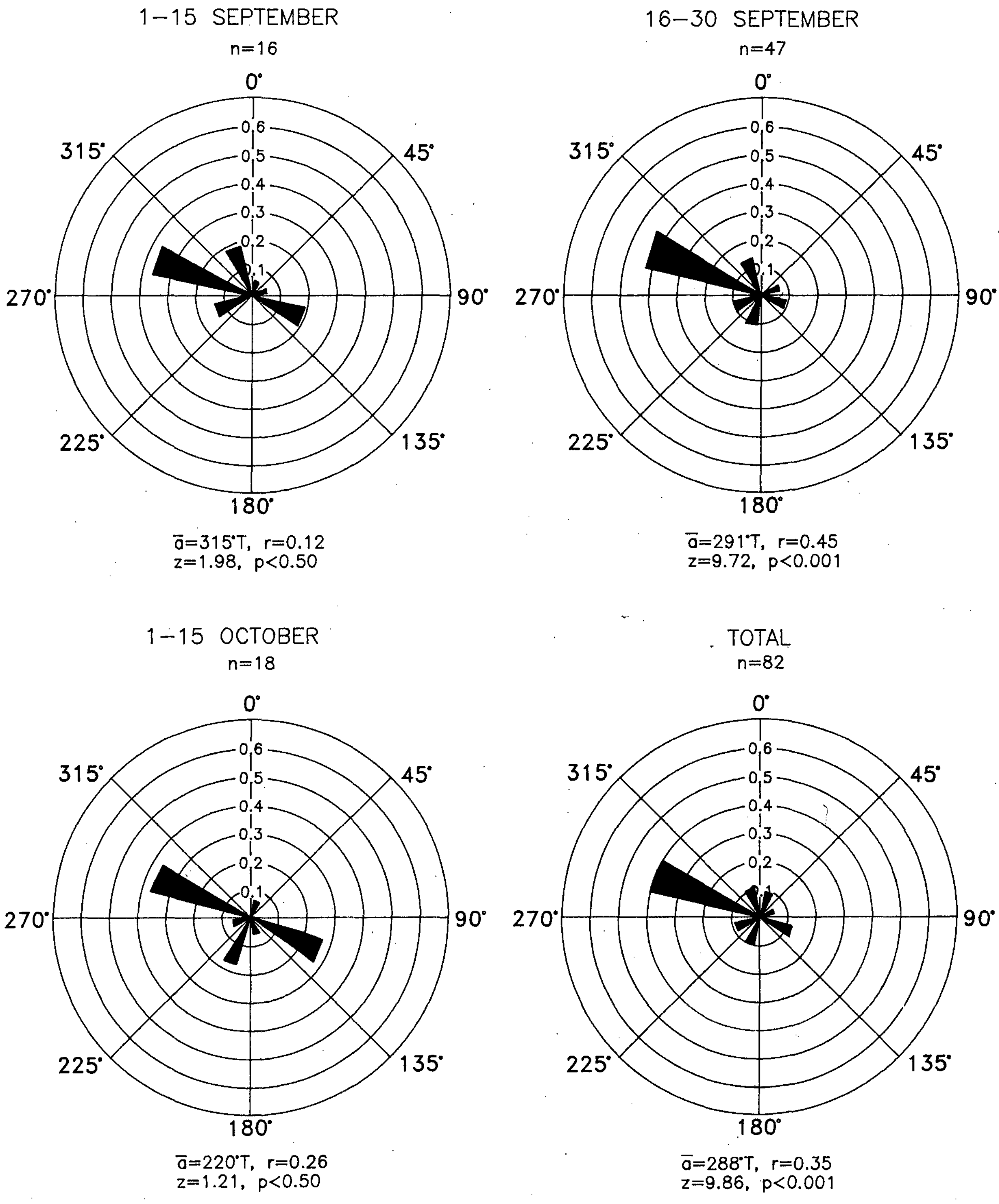

Figure 22. Semimonthly Summary of Swim Directions for Bowhead Whales (Fall 1989)

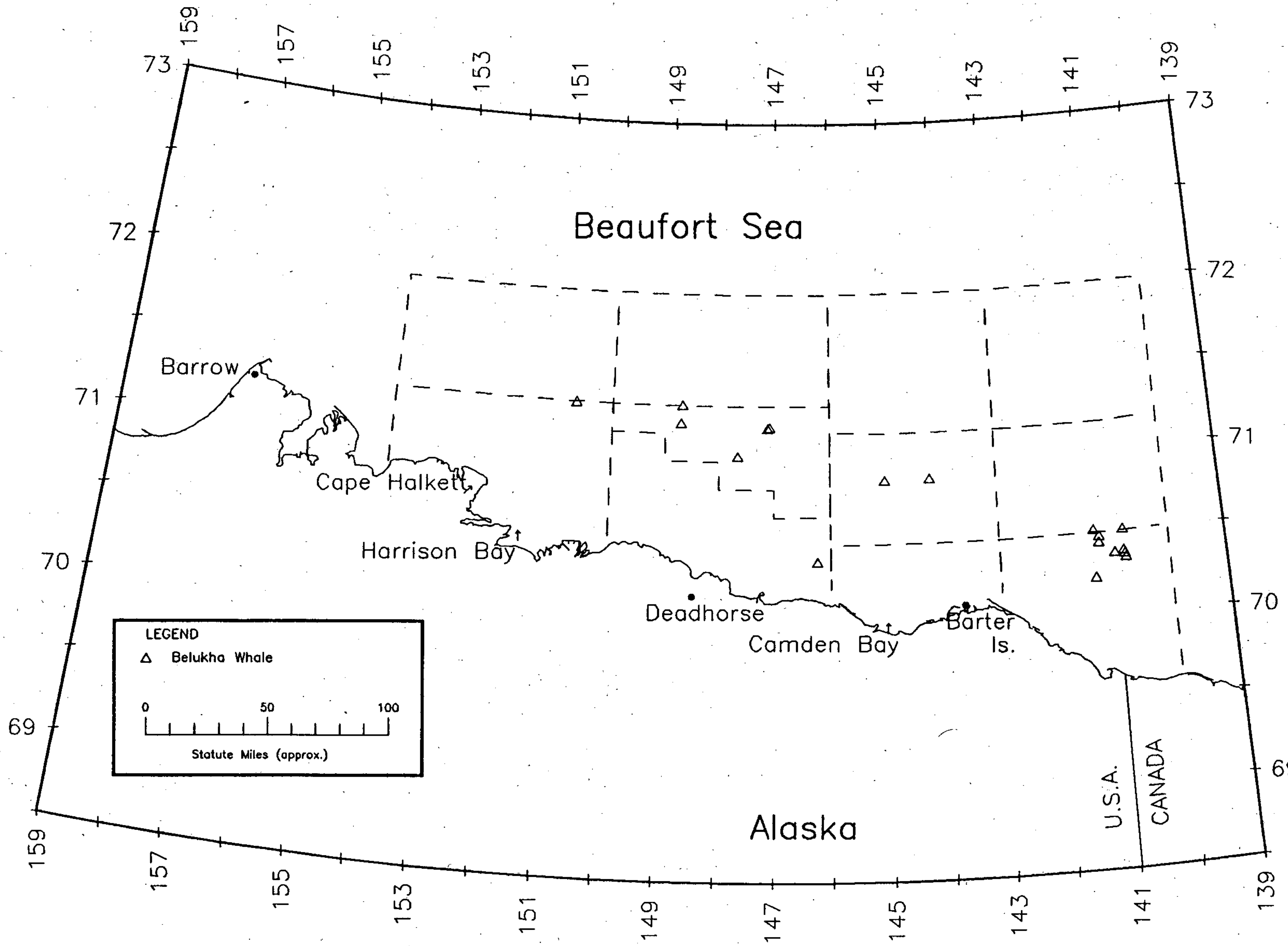

Figure 23. Map of Belukha Whale Sightings, 1 September–20 October 1989

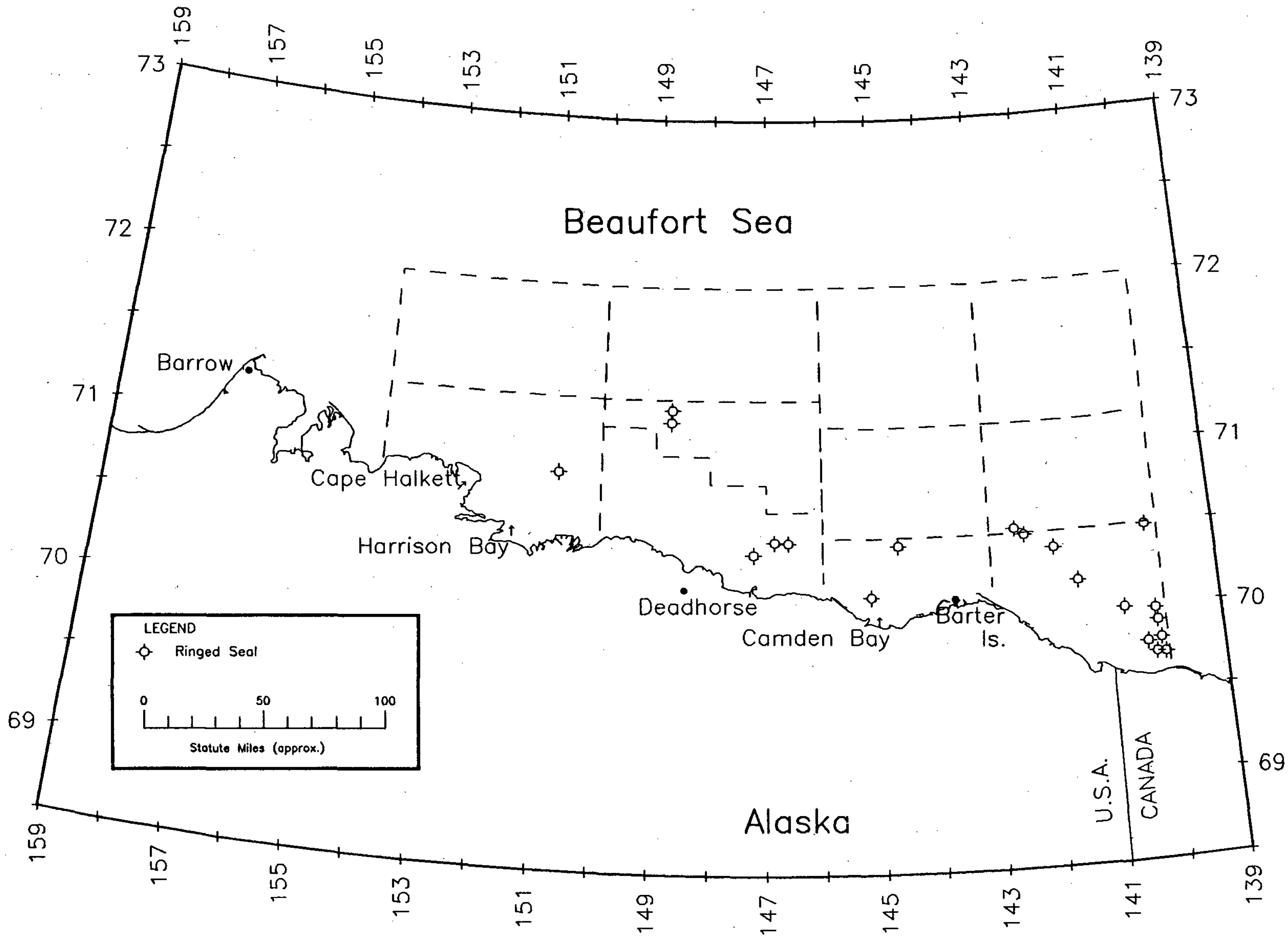

Figure 24. Map of Ringed Seal Sightings, 1 September–20 October 1989

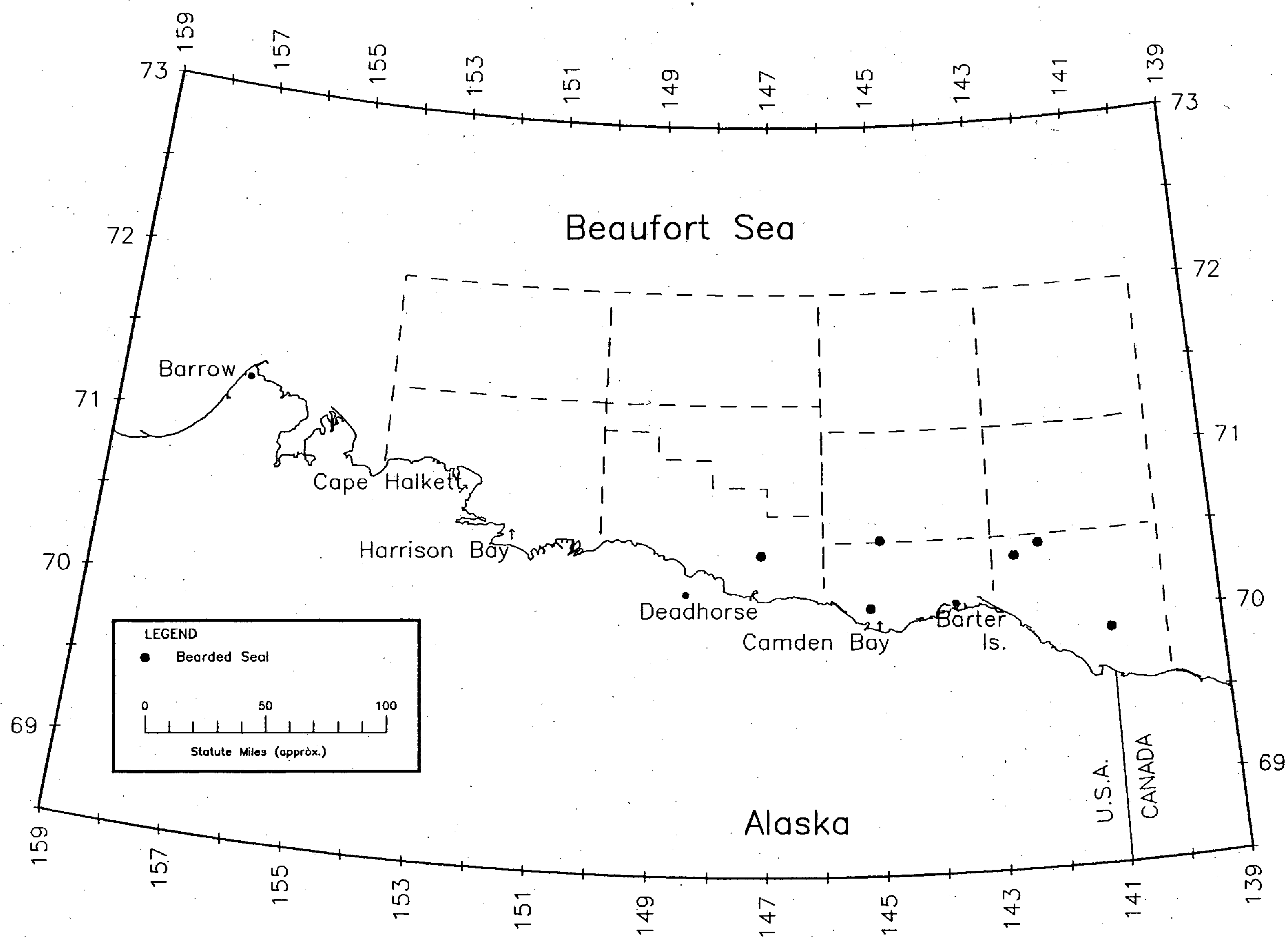

Figure 25. Map of Bearded Seal Sightings, 1 September–20 October 1989

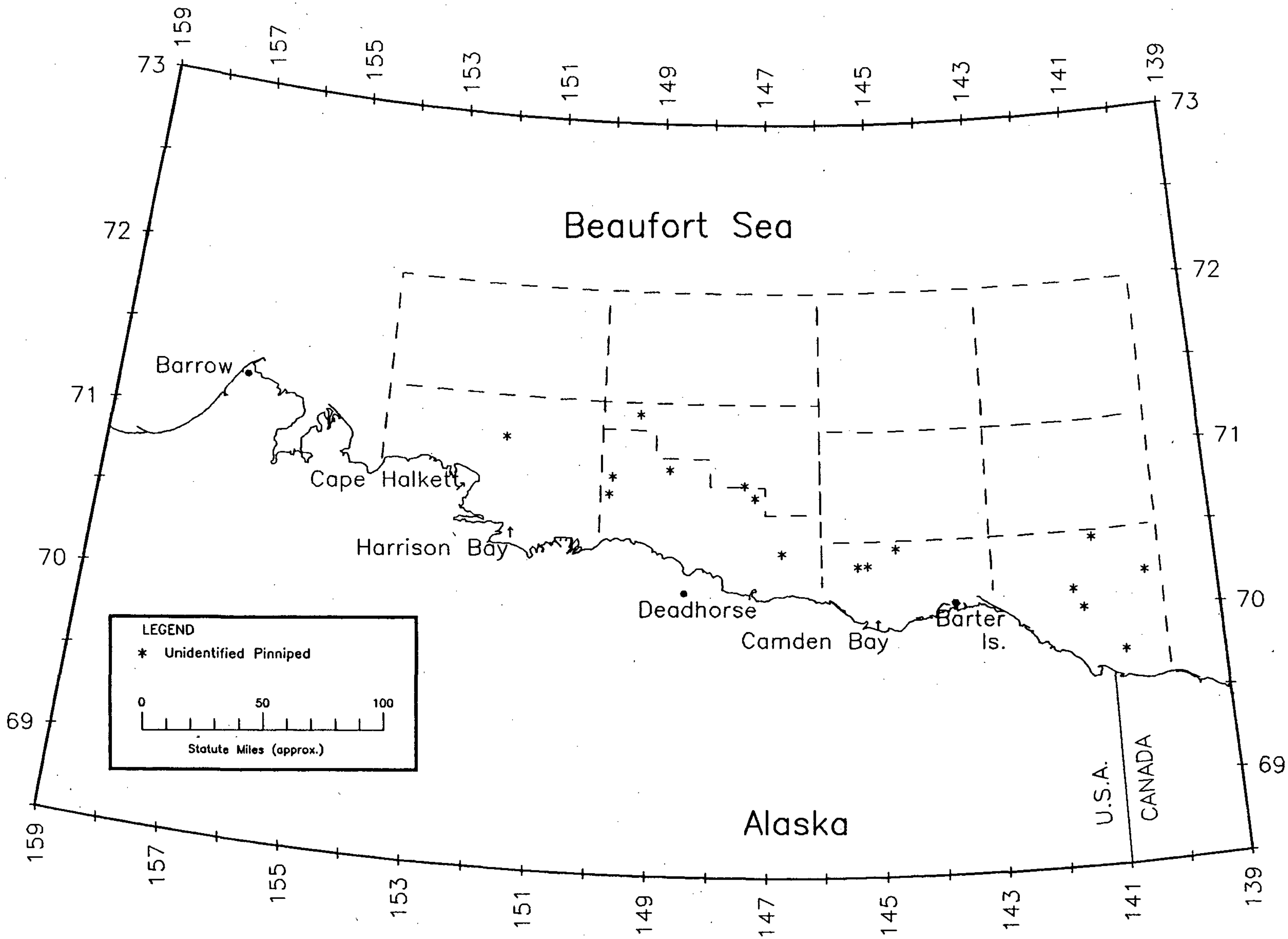

Figure 26. Map of Unidentified–Pinniped Sightings, 1 September–20 October 1989

IV. DISCUSSION

A. General Comparisons with Previous Surveys (1979-1988)

Results of the present study are generally within the range of result values from previous MMS-funded endangered whale surveys conducted during September and October (1979-1988) in the Beaufort Sea (Ljungblad et al., 1987; Treacy, 1988, 1989).

The general ice coverage in 1989 during the navigation season was the ninth mildest in the Arctic Ocean for the years 1953 through 1989 and was the second mildest (after 1979) since the MMS surveys began in 1979 (USDOD, Navy, Naval Polar Oceanographic Center, 1990).

The relative abundance of bowhead whales during September 1989 in Block 4 (6.23 WPUE) was higher than in previous years (next highest value = 6.13 WPUE for September 1981). The relative abundance of bowhead whales during October 1989 in Block 3 was also higher than previous values (next highest = 3.67 WPUE for October 1979 [Table 10]). The relative abundance in all other survey blocks during September and October 1989 was within the range of values observed for the years 1979 through 1988 (Table 10).

The percentage of bowhead whales engaged in "milling" behavior in 1989 (21%) was higher than for previous Beaufort Sea surveys (previous high = 17% in 1982).

The ratio of bowhead calves for 1989 (0.01) was relatively low, although identical to the 1981, 1984, and 1987 ratios (0.01).

No polar bears were observed during September through October 1989, probably due to generally ice-free conditions prevalent in the study area during 1989 compared with previous years (USDOD, Navy, Naval Polar Oceanographic Center, 1990).

B. Median Water Depth at Bowhead Sightings (1982-1989)

The median water depth at 19 sightings of bowhead whales made on line transects in Regions I, II, and III (combined) during September and October 1989 was 18 m (Table 11). This was shallower than the median September-October value (all three regions combined) for any previous year from 1982 through 1988 (previous median values ranged from 26-347 m) and was less than half the cumulative median depth (37 m) of all sightings (n = 220) made on line transect during the same timeframe.

Differences between the median water depth for 1989 and previous years were tested using the Mann Whitney U test (Zar, 1984). Differences with a high degree of statistical significance ($p < 0.005$) occurred (all three regions combined) between the value for 1989 and the values for all years from 1982 through 1988 except for 1986 (Table 12). Analysis by region showed that this degree of difference was found for the years 1983, 1984, and 1988 in Region I (between 150°W. and 153°30′W. longitudes [Table 12]).

Differences with a high degree of statistical significance ($p < 0.002$) were also noted (all 3 regions combined) between the median for 1984 and the medians for 1982, 1983, and 1986 (Table 12). Such differences ($p < 0.002$) were also noted between the 1983 median value (all three regions combined) and medians for all other years tested using this nonparametric test. The most significant differences between 1983 and other years occur primarily in Regions II and III (between 141°W. and 150°W. longitudes). The 1983 median (347 m) is by far the highest value (Table 11).

Mean water depths also were calculated for Regions I, II, and III (Table 11). Mean values, although less descriptive of the migration "axis," were considered more robust for demonstrating significant differences between years. 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 mean values for 1983 and some of the other years (including 1989) were considered highly significant ($p < 0.001$) in all three regions combined and in Regions II and III (Table 13), thus mirroring differences noted between median values in those regions. A visual comparison of mean values (Table 11) showed that the mean water depth at random sightings (all three regions combined) during 1989 (22.7 m) was less than in all previous years and well below the cumulative mean for all years combined (121.5 m).

Table 10
Bowhead Whale Relative Abundance (WPUE) by Beaufort Sea Survey Block
during September and October, 1979-1989
(after Ljungblad et al. [1987] and Treacy [1988, 1989])

Year	Survey Block 1	2	3	4	5	6	7	8	9	10	11	Other Canadian Areas	Other Alaskan Areas
SEPTEMBER													
1979	0.08	0.00	0.00	0.09	10.08	0.73	0.00	*	*	*	*	*	*
1980	0.38	0.00	0.00	0.47	0.99	0.00	0.00	0.00	0.00	0.00	0.00	0.47	*
1981	0.22	0.00	0.00	6.13	6.20	0.00	0.00	0.00	0.00	*	0.00	0.32	0.00
1982	6.83	1.35	0.80	0.93	11.30	0.00	0.00	0.00	1.28	*	0.00	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	*	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	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	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	7.98	0.00
1987	0.74	0.00	0.00	1.32	0.72	0.31	0.00	*	0.00	*	0.00	0.66	0.00
1988	0.14	0.00	*	0.35	0.48	0.45	0.00	0.00	*	*	*	0.00	*
1989	2.37	0.33	0.00	6.23	0.71	0.33	1.52	*	0.00	0.00	*	*	0.00
OCTOBER													
1979	1.58	0.00	3.67	2.35	*	0.00	*	*	*	*	0.00	*	0.00
1980	0.10	1.18	0.35	0.29	0.00	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	*	*	*	0.00	*	*
1982	0.19	0.00	2.48	0.00	0.70	0.00	*	0.00	0.00	0.00	0.19	0.46	0.00
1983	0.00	0.00	0.49	0.00	0.00	0.27	2.17	*	*	0.00	0.00	*	0.00
1984	0.29	0.26	1.24	0.00	1.37	0.00	*	*	*	0.00	3.05	3.70	0.00
1985	2.26	0.00	0.40	0.00	0.00	0.00	0.00	0.00	*	0.00	9.00	0.00	0.00
1986	1.00	0.38	0.47	0.71	*	0.00	*	*	0.00	0.00	0.00	*	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	0.00	0.00
1988	0.18	0.26	1.12	0.12	0.14	0.00	0.00	*	0.00	*	0.19	0.00	0.00
1989	1.32	0.00	5.58	0.00	0.00	0.00	0.00	*	*	0.00	0.00	*	0.00

* No survey effort.

Table 11
Central-Tendency Statistics for Water Depth (in meters) at Random Sightings of Bowhead Whales (September-October), by Year and Region

Year	Region	SI[1]	Median	CI[2]	Mean	SD[3]	Range
1982	I	8	17	11-457	113.4	176.23	11-457
	II	30	27	22-38	30.6	9.03	16-51
	III	5	40	[4]	43.4	11.24	29-59
	All 3	43	29	22-38	47.5	79.22	11-457
1983	I	9	69	22-2,323	393.7	740.61	22-2,323
	II	5	1,289	[4]	945.0	858.85	53-2,021
	III	9	797	49-1,902	969.7	740.24	49-1,902
	All 3	23	347	49-1,737	738.9	782.96	22-2,323
1984	I	15	42	27-69	53.3	41.43	18-177
	II	9	38	22-82	43.7	18.73	22-82
	III	14	48	22-274	90.4	130.05	18-485
	All 3	38	43	27-59	64.7	84.09	18-485
1985	I	3	183	[4]	219.3	221.74	18-457
	II	9	31	20-38	30.4	5.00	20-38
	III	1	[4]	[4]	[4]	[4]	64[5]
	All 3	13	31	20-183	76.6	122.13	18-457
1986	I	4	18	[4]	51.0	69.37	13-155
	II	12	17	9-40	60.8	144.79	7-519
	III	22	34	22-48	34.0	13.91	11-57
	All 3	38	26	18-44	44.3	82.99	7-519
1987	I	4	20	[4]	19.2	4.86	13-24
	II	9	27	15-38	27.3	7.60	15-38
	III	20	41	29-55	49.8	41.38	18-219
	All 3	33	37	24-44	40.0	34.54	13-219
1988	I	4	36	[4]	40.5	15.11	29-62
	II	4	44	[4]	44.8	13.60	29-62
	III	5	46	[4]	90.4	116.40	24-298
	All 3	13	42	29-62	61.0	72.17	24-298
1989	I	15	18	9-20	16.0	4.58	9-24
	II	1	[4]	[4]	[4]	[4]	44[5]
	III	3	49	[4]	49.3	9.50	40-59
	All 3	19	18	13-40	22.7	14.39	9-59
Cumulative (1982-1989)	I	62	26	18-42	106.3	307.00	9-2,323
	II	79	31	26-38	95.1	300.71	7-2,021
	III	79	44	37-49	159.7	382.18	11-1,902
	All 3	220	37	29-38	121.5	333.66	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 12
Interyear Correlation (nonparametric) of the Median Water Depths at Random Bowhead Whale Sightings (September-October), Using the Mann-Whitney U Test

REGION I	1982	1983	1984	1985	1986	1987	1988
1983	U′ = 54 $p < 0.10$						
1984	U′ = 82 $p < 0.20$	U = 92 $p < 0.20$					
1985	U = 18 $p \leq 0.50$	U′ = 14 $p \leq 0.50$	U = 30 $p \leq 0.50$				
1986	U = 16 $p \leq 0.50$	U′ = 31 $p \leq 0.10$	U′ = 45 $p \leq 0.20$	U = 10 $p \leq 0.50$			
1987	U′ = 16 $p < 0.50$	U′ = 34 $p < 0.02$	U′ = 56 $p < 0.01$	U = 10 $p < 0.50$	U′ = 8 $p < 0.50$		
1988	U = 21 $p < 0.50$	U′ = 23 $p < 0.50$	U = 30 $p < 0.50$	U = 8 $p < 0.50$	U′ = 12 $p < 0.50$	U′ = 16 $p < 0.05$	
1989	U = 76 $p \leq 0.50$	U = 134 $p < 0.001$	U = 216 $p < 0.001$	U = 39 $p < 0.10$	U = 37 $p \leq 0.50$	U = 42 $p \leq 0.50$	U = 60 $p < 0.001$

REGION II	1982	1983	1984	1985	1986	1987	1988
1983	U = 150 $p < 0.001$						
1984	U = 193 $p < 0.10$	U = 42 $p \leq 0.01$					
1985	U′ = 136 $p < 0.50$	U = 45 $p \leq 0.001$	U = 62 $p < 0.10$				
1986	U′ = 254 $p < 0.05$	U = 58 $p \leq 0.002$	U = 86 $p = 0.05$	U = 76 $p < 0.20$			
1987	U′ = 155 $p < 0.50$	U = 45 $p \leq 0.001$	U = 64 $p < 0.05$	U = 53 $p < 0.50$	U = 70 $p < 0.50$		
1988	U = 103 $p < 0.02$	U′ = 19 $p < 0.05$	U = 20 $p < 0.50$	U = 29 $p < 0.20$	U = 41 $p < 0.05$	U = 33 $p < 0.02$	
1989	U = 29 $p < 0.20$	U′ = 5 *	U = 6 $p \leq 0.50$	U = 9 $p < 0.20$	U = 11 $p \leq 0.50$	U = 9 $p < 0.20$	U = 2 *

Table 12
Interyear Correlation (nonparametric) of the Median Water Depths at Random Bowhead Whale Sightings (September-October), Using the Mann-Whitney U Test (Continued)

REGION III

	1982	1983	1984	1985	1986	1987	1988
1983	U′ = 44 $p \leq 0.002$						
1984	U′ = 36 $p < 0.50$	U = 117 $p < 0.001$					
1985	U = 5 *	U′ = 8 $p < 0.50$	U = 11 $p < 0.50$				
1986	U = 77 $p < 0.20$	U = 196 $p < 0.001$	U = 216 $p < 0.05$	U = 22 $p \leq 0.10$			
1987	U = 55 $p < 0.50$	U = 173 $p < 0.001$	U = 159 $p < 0.50$	U = 19 $p \leq 0.20$	U′ = 284 $p < 0.10$		
1988	U = 13 $p < 0.50$	U′ = 43 $p < 0.005$	U′ = 38 $p < 0.50$	U = 4 *	U = 70 $p < 0.50$	U = 56 $p < 0.50$	
1989	U = 10 $p \leq 0.50$	U′ = 26 $p < 0.02$	U = 24 $p \leq 0.50$	U = 3 *	U = 54 $p \leq 0.10$	U = 42 $p < 0.50$	U = 10 $p \leq 0.50$

ALL THREE REGIONS (COMBINED)

	1982	1983	1984	1985	1986	1987	1988
1983	U = 882 Z = 5.22 $p < 0.001$						
1984	U = 1,138 Z = 3.03 $p < 0.002$	U = 718 Z = 4.19 $p < 0.001$					
1985	U = 316 $p < 0.50$	U′ = 250 $p < 0.002$	U = 298 $p < 0.50$				
1986	U′ = 898 Z = 0.76 $p < 0.50$	U = 786 Z = 5.20 $p < 0.001$	U = 1,043 Z = 3.34 $p < 0.001$	U = 314 $p < 0.20$			
1987	U = 798 Z = 0.93 $p < 0.50$	U = 666 Z = 4.78 $p < 0.001$	U = 810 Z = 2.10 $p < 0.05$	U = 223 $p < 0.50$	U = 760 Z = 1.53 $p < 0.20$		
1988	U = 414 Z = 2.57 $p < 0.02$	U′ = 246 $p < 0.002$	U = 248 $p < 0.50$	U = 104 $p < 0.50$	U = 356 $p < 0.02$	U = 291 $p < 0.10$	
1989	U′ = 598 Z = 2.89 $p < 0.005$	U′ = 418 $p < 0.001$	U′ =617 Z = 4.33 $p < 0.001$	U = 198 $p < 0.005$	U′ = 457 Z = 1.62 $p < 0.20$	U′ = 480 $p < 0.002$	U = 214 $p < 0.001$

Table 14
Relative Abundance (WPUE) of Bowhead Whales within the Primary Study Area (Survey Blocks 1-11) during September and October, by Year and General Ice Coverage (after Ljungblad et al. [1987] and Treacy [1988, 1989])

Year	September			October			Total (Sep-Oct)		
	Hours	BH	WPUE	Hours	BH	WPUE	Hours	BH	WPUE
1979	51.38	60	1.17	72.85	125	1.72	124.23	185	1.49
1980[1]	76.41	30	0.39	48.78	12	0.25	125.19	42	0.34
1981	70.28	231	3.29	45.63	54	1.18	115.91	285	2.46
1982	73.33	281	3.83	27.16	14	0.52	100.49	295	2.94
1983[1]	93.84	54	0.58	30.80	9	0.29	124.64	63	0.51
1984[2]	68.00	68	1.00	47.89	48	1.00	115.89	116	1.00
1985[2]	64.30	52	0.81	44.96	50	1.11	109.26	102	0.93
1986	96.88	65	0.67	39.84	24	0.60	136.72	89	0.65
1987	82.35	59	0.72	61.85	50	0.81	144.20	109	0.76
1988[1]	64.96	21	0.32	52.51	16	0.30	117.47	37	0.31
1989	64.37	137	2.13	33.14	78	2.35	97.61	215	2.20
Ice Coverage									
Heavy Ice Years[1](Σ)	235.21	105	0.45	132.09	37	0.28	367.30	142	0.30
Moderate Ice Years[2](Σ)	132.30	120	0.91	92.85	98	1.06	225.15	218	0.97
Light Ice Years(Σ)	438.59	833	1.90	280.47	345	1.23	719.06	1,178	1.64

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

potential operational effects on subsistence whaling, the permittees followed stringent restrictions--including a provision to stop seismic operations when whales were visible from the vessel--as the bowhead whale migration progressed through the area of operations. Daily summaries of survey information were transferred from the field to Anchorage for use by MMS Resource Evaluation and by NMFS in implementing areawide permit restrictions on high-energy seismic operations during periods of limited visibility.

Prior to the Fall-1989 survey, Amoco Production Company operated the Kulluk, a semisubmersible drilling barge at 70°16.6′N. latitude, 141°28.5′W. longitude--east-northeast of Barter Island at the Belcher drilling site. The maximum hull diameter of this circular floating structure is 80.8 m and the maximum hull depth is 18.5 m. The Kulluk has a 12-point mooring system employing anchor wire lines that are 8.9 cm in diameter. The exploratory well was plugged and abandoned on 30 August 1989, and the Kulluk was relocated to the Canadian Beaufort Sea on 31 August 1989. No other exploratory drilling occurred in the Alaska OCS during this survey. ARCO Alaska, Inc., operated Global Marine Drilling Co. Beaufort Sea I, a Concrete Island Drilling Structure, during the study in Alaska state waters at approximately 70°10′N. by 145°42′W.

Daily summaries of field information from this and other arctic surveys were transferred to MMS Field Operations in Anchorage. The MMS and NMFS reviewed daily reports to determine the beginning and end of the bowhead whale migration in relation to the Belcher location. Although the drilling operations were completed prior to the beginning of the migration, the beginning and end of the migration were determined for consideration in further statistical analyses. Based largely on daily summaries of survey information provided by the present study, NMFS determined the official starting date (10 September) of the Fall-1989 bowhead whale migration and the area-specific ending date (11 October) for the Alaskan Beaufort Sea between Prudhoe Bay and Demarcation Point.

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APPENDIX A

APPENDIX A

BOWHEAD WHALE DENSITIES

BOWHEAD WHALE DENSITIES

This appendix presents an analysis of bowhead whale densities in the Beaufort Sea for the period 1 September through 20 October 1989. Density estimates were calculated here only for relative comparison with similar values from previous survey reports. 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.

METHODS

Density estimates were calculated for survey blocks previously shown for the Beaufort Sea (Fig. 1) based on strip-transect methodologies using only sightings made on random-transect legs (Estes and Gilbert, 1978) 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 1,000 m of the trackline. If no sightings were made on random transects within a survey area, that density was not calculated. The basic formula for strip-transect estimators (Hayne, 1949) is:

$$N = \frac{nA}{2\,LH}$$

where N is the estimated animal population, n is the number of individuals counted, A is the size of the larger area for which the estimate is made, L is the transect length, and H is the mean sighting distance. The basic assumptions for use of this formula, and the degree to which these assumptions were met in the Fall-1989 and previous MMS-funded arctic whale surveys, are incorporated by reference (Ljungblad et al., 1987: Appendix B).

A computer program (SPEED) developed for previous surveys was utilized to screen for unlikely data values and to check the chronological order of time. Aerial-survey-data files were screened for obvious errors in geographic position by separately plotting the course of each daily aerial survey. A computer program was used to evaluate flight speeds and distances on a point-to-point basis, and listings of these values were scanned for suspiciously slow or fast speeds. The listings and maps were compared, errors were flagged and edited, and the process was repeated until data files were error-free with respect to these conditions.

RESULTS

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

During the first half of September, over 10 percent of the area was surveyed for Block 5. No bowheads were observed in Block 5 within 1 km of the randomly generated transect line, for an estimated density of 0.00. No bowhead whales were observed within 1 km of the transect line in other blocks during this period.

During the second half of September, over 10 percent of the area was surveyed for Block 5. Five bowheads were observed in Block 5 within 1 km of the transect line, for an estimated density of 0.15 whales per 100 km^2. Two bowhead whales were observed within 1 km of the transect line in Block 1 during this period.

During the first half of October, over 10 percent of the area was surveyed for Block 3. Thirty-two bowheads were observed in Block 3 within 1 km of the transect line, for an estimated density of 1.36 whales per 100 km^2. No bowhead whales were observed within 1 km of the transect line in other blocks during this period.

From 16 through 20 October, no block received more than 10-percent random-survey coverage. One bowhead whale was observed within 1 km of the transect line in Block 3 during this period.

Table A-1
Semimonthly Estimates of Bowhead Whale Densities, by Survey Block (Fall 1989)
(strip width = 2 km)

Block No. (by Semi-monthly Period)	Block Area (km^2)	Transect Distance (km)	Percent of Area Surveyed	Transect Time (hr)	Percent of Total Time	No. of Transects Flown	No. of Whales Observed	Density (Whales/ 100 km^2)
1-15 Sep								
1	10,222	953	18.64	3.93	36.84	23	0	0.00
2	6,672	109	3.26	0.42	3.94	11	0	0.00
3	11,475	113	1.96	0.45	4.22	2	0	0.00
4	5,714	254	8.90	1.01	9.49	6	0	0.00
5	9,481	1,022	21.56	3.92	36.71	14	0	0.00
6	8,109	5	0.13	0.02	0.19	3	0	0.00
7	8,109	238	5.86	0.92	8.60	9	0	0.00
16-30 Sep								
1	10,222	114	2.24	0.49	4.17	5	2	0.87
2	6,672	216	6.46	0.91	7.83	5	0	0.00
4	5,714	89	3.13	0.39	3.33	4	0	0.00
5	9,481	1,702	35.91	7.16	61.59	24	5	0.15
6	8,109	593	14.62	2.28	19.62	8	0	0.00
7	8,109	12	0.30	0.05	0.45	10	0	0.00
9	9,753	7	0.15	0.03	0.27	4	0	0.00
10	10,358	78	1.50	0.32	2.75	3	0	0.00
1-15 Oct								
1	10,222	559	10.93	2.26	15.94	11	0	0.00
2	6,672	112	3.35	0.43	3.00	5	0	0.00
3	11,475	1,173	20.45	5.30	37.30	19	32	1.36
4	5,714	560	19.59	2.19	15.44	14	0	0.00
5	9,481	249	5.25	0.99	6.97	4	0	0.00
6	8,109	168	4.15	0.67	4.75	5	0	0.00
7	8,109	2	0.06	0.01	0.07	1	0	0.00
10	10,358	296	5.71	1.14	8.00	4	0	0.00
11	10,358	95	1.83	0.35	2.49	7	0	0.00
16-20 Oct								
3	11,475	377	6.57	1.59	99.45	6	1	0.13
11	10,358	3	0.05	0.01	0.55	2	0	0.00

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APPENDIX B

DAILY FLIGHT SUMMARIES

APPENDIX B

DAILY FLIGHT SUMMARIES

This appendix consists of Flight Tracks 1 through 31, depicting aerial surveys flown over the study area from 3 September through 20 October 1989, by MMS personnel aboard a Twin Otter aircraft. Maps were prepared using a computer program written in Turbo Pascal for the collection of field data and an application program (Grapher) that was adapted for generating daily maps on a Hewlett-Packard (HP) Laser Jet II printer equipped with an HP 7475A plotter emulator cartridge. Daily maps show survey tracks and position of all marine mammal sightings. Coastlines were mapped using an Altec digitizer. All points on the maps are based on the number of meters north or to one side of a central meridian for Universal Transverse Mercator Zone 6.

A comparison of flight tracks can be made on a visual basis over the period of the field season to evaluate ongoing patterns of the animal 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 is summarized in Table B-1.

Table B-1
Selected Sighting Data for Bowhead Whales Observed, September-October 1989
(Page 1 of 3)

Flight No.	Date	Total Whales	No. Calves	Latitude (North)	Longitude (West)	Sighting Cue	Behavior	Heading	Ice (%)	Sea State
6	8 Sep	1	0	70°18.1'	142°06.6'	blow	swim	98	0	2
6	8 Sep	2	0	69°51.8'	141°55.4'	body	swim	250	0	2
7	9 Sep	1	0	70°21.7'	143°59.9'	body	swim	300	0	4
7	9 Sep	6	0	70°22.0'	144°03.6'	body	swim	60	0	4
7	9 Sep	2	0	70°23.3'	144°03.1'	body	swim	240	0	4
7	9 Sep	6	0	70°22.7'	144°42.4'	body	swim	270	0	4
7	9 Sep	2	0	70°24.7'	144°42.6'	body	swim	270	0	4
7	9 Sep	1	0	70°23.6'	145°03.7'	body	swim	50	0	4
8	10 Sep	1	0	70°22.7'	143°40.8'	splash	swim	210	0	2
8	10 Sep	1	0	70°22.2'	143°45.0'	blow	swim	10	0	2
8	10 Sep	1	0	70°19.0'	141°52.0'	splash	swim	60	0	3
8	10 Sep	2	0	70°27.3'	145°09.9'	body	swim	210	0	2
8	10 Sep	5	0	70°26.3'	145°15.6'	body	mill	[1]	0	2
8	10 Sep	1	0	70°25.8'	145°18.3'	body	swim	300	0	2
8	10 Sep	5	0	70°26.4'	145°22.6'	body	dive	240	0	2
8	10 Sep	4	0	70°26.2'	145°22.4'	body	swim	310	0	2
9	15 Sep	2	0	70°25.5'	146°06.2'	splash	swim	280	0	[1]
10	17 Sep	1	0	70°22.4'	142°16.8'	body	swim	150	10	3
13	20 Sep	1	0	70°22.8'	142°50.6'	splash	swim	250	5	2
17	28 Sep	2	0	70°27.7'	146°39.6'	[1]	swim	20	0	2
17	28 Sep	1	0	70°32.2'	146°30.4'	blow	swim	300	0	2
17	28 Sep	1	0	70°30.2'	146°30.5'	[1]	mill	60	0	2
17	28 Sep	3	0	70°28.6'	146°34.1'	body	swim	330	0	2
17	28 Sep	1	0	70°29.4'	146°31.8'	body	swim	300	0	2
17	28 Sep	3	0	70°32.0'	146°29.1'	body	swim	270	0	2
17	28 Sep	3	0	70°29.5'	146°32.6'	[1]	swim	10	0	2
17	28 Sep	2	0	70°30.7'	146°29.2'	[1]	swim	200	0	2
17	28 Sep	2	0	70°30.9'	146°24.4'	[1]	swim	180	0	2
17	28 Sep	2	0	70°27.0'	146°23.1'	[1]	swim	250	0	2
17	28 Sep	1	0	70°26.8'	145°47.0'	splash	swim	230	0	2
17	28 Sep	1	0	70°27.7'	145°45.1'	body	swim	240	0	2
17	28 Sep	1	0	70°28.9'	145°02.5'	blow	swim	20	0	3
17	28 Sep	1	0	70°30.3'	144°59.5'	body	swim	20	0	3
17	28 Sep[2]	1	0	70°29.1'	145°00.2'	body	swim	360	0	3
17	28 Sep	3	0	70°29.9'	144°58.0'	blow	swim	300	0	3
17	28 Sep	1	0	70°30.2'	145°03.8'	[1]	swim	30	0	3
17	28 Sep	2	0	70°44.9'	146°56.8'	body	swim	240	0	2
17	28 Sep	1	0	70°46.4'	146°54.8'	blow	swim	270	0	2
17	28 Sep	2	0	70°44.9'	146°57.4'	[1]	swim	300	0	2
17	28 Sep	1	0	70°44.2'	146°57.1'	[1]	swim	240	0	2
17	28 Sep	2	1	70°44.3'	146°57.1'	body	swim	230	0	2

Table B-1
Selected Sighting Data for Bowhead Whales Observed, September-October 1989
(Page 2 of 3)

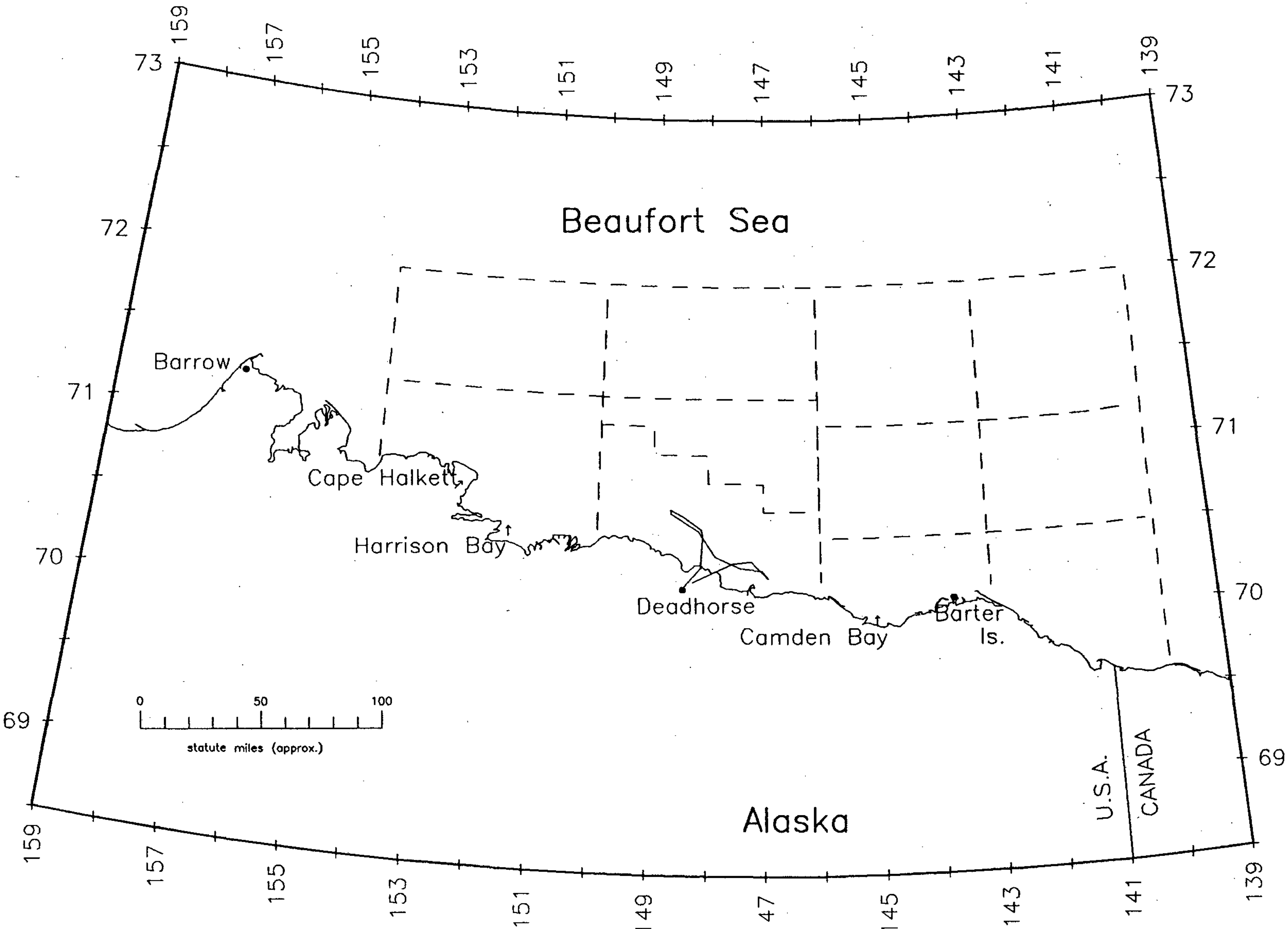
Flight No.	Date	Total Whales	No. Calves	Latitude (North)	Longitude (West)	Sighting Cue	Behavior	Heading	Ice (%)	Sea State
17	28 Sep	5	0	70°41.8'	147°07.1'	blow	swim	180	0	2
17	28 Sep	1	0	70°38.1'	147°04.6'	blow	swim	130	0	2
17	28 Sep	1	0	70°38.6'	147°07.9'	[1]	swim	100	0	2
17	28 Sep	7	1	70°39.6'	147°14.5'	blow	mill	290	0	2
17	28 Sep	2	0	70°37.0'	147°19.0'	blow	swim	80	0	2
18	29 Sep	1	0	70°30.3'	142°10.3'	body	swim	260	0	3
18	29 Sep	1	0	70°25.5'	140°28.2'	body	swim	240	0	2
18	29 Sep	2	0	70°27.9'	140°26.3'	blow	swim	240	0	2
18	29 Sep	2	0	70°30.3'	141°30.6'	splash	breach	[1]	0	3
18	29 Sep	1	0	70°30.9'	141°26.8'	body	swim	[1]	0	3
18	29 Sep	1	0	70°21.3'	143°41.0'	blow	swim	300	0	2
18	29 Sep	1	0	70°21.7'	143°42.5'	splash	swim	190	0	2
18	29 Sep	1	0	70°22.4'	145°17.9'	body	swim	240	0	2
18	29 Sep	2	0	70°23.1'	145°31.2'	slick	swim	240	0	2
18	29 Sep	1	0	70°22.1'	145°43.0'	slick	swim	250	0	2
18	29 Sep	1	0	70°22.1'	145°51.9'	blow	swim	280	0	2
19	30 Sep	2	0	70°24.0'	145°28.3'	body	rest	250	0	2
19	30 Sep	3	0	70°22.1'	145°26.9'	body	rest	300	0	2
19	30 Sep	1	0	70°24.3'	145°27.6'	body	swim	250	0	2
19	30 Sep	1	0	70°22.9'	145°24.3'	body	rest	360	0	2
19	30 Sep	1	0	70°22.1'	145°29.0'	body	swim	360	0	2
19	30 Sep	1	0	70°24.0'	144°18.6'	body	swim	100	0	2
19	30 Sep	1	0	70°23.7'	144°21.6'	blow	swim	150	0	2
19	30 Sep	1	0	70°25.2'	144°20.3'	body	swim	230	0	2
19	30 Sep	1	0	70°26.3'	144°22.9'	body	swim	300	0	2
19	30 Sep	1	0	70°27.0'	144°18.4'	body	swim	280	0	2
19	30 Sep	1	0	70°23.4'	144°23.8'	[1]	swim	330	0	2
19	30 Sep	3	0	70°21.1'	143°11.6'	body	mill	[1]	0	2
19	30 Sep	1	0	70°19.8'	142°54.1'	body	swim	240	0	2
19	30 Sep	1	0	70°19.4'	143°01.7'	body	swim	270	0	2
19	30 Sep	3	0	70°21.5'	143°00.4'	body	roll	240	0	2
19	30 Sep	2	0	70°14.4'	141°12.5'	slick	swim	[1]	0	2
19	30 Sep	2	0	70°14.8'	141°12.2'	slick	swim	240	0	2
20	1 Oct	11	0	71°08.5'	151°57.3'	slick	mill	[1]	0	2
20	1 Oct	1	0	71°06.9'	152°00.9'	blow	swim	[1]	0	2
20	1 Oct	1	0	71°08.2'	152°01.1'	body	swim	120	0	2
20	1 Oct	1	0	71°07.4'	152°03.0'	blow	swim	90	0	2
20	1 Oct	2	0	71°07.0'	152°10.7'	blow	swim	[1]	0	2
20	1 Oct	1	0	71°03.9'	152°06.3'	blow	swim	[1]	0	2
20	1 Oct	3	0	71°07.3'	151°45.6'	slick	swim	270	0	2
20	1 Oct	3	0	71°08.5'	151°45.5'	body	swim	240	0	2

Table B-1
Selected Sighting Data for Bowhead Whales Observed, September-October 1989
(Page 3 of 3)

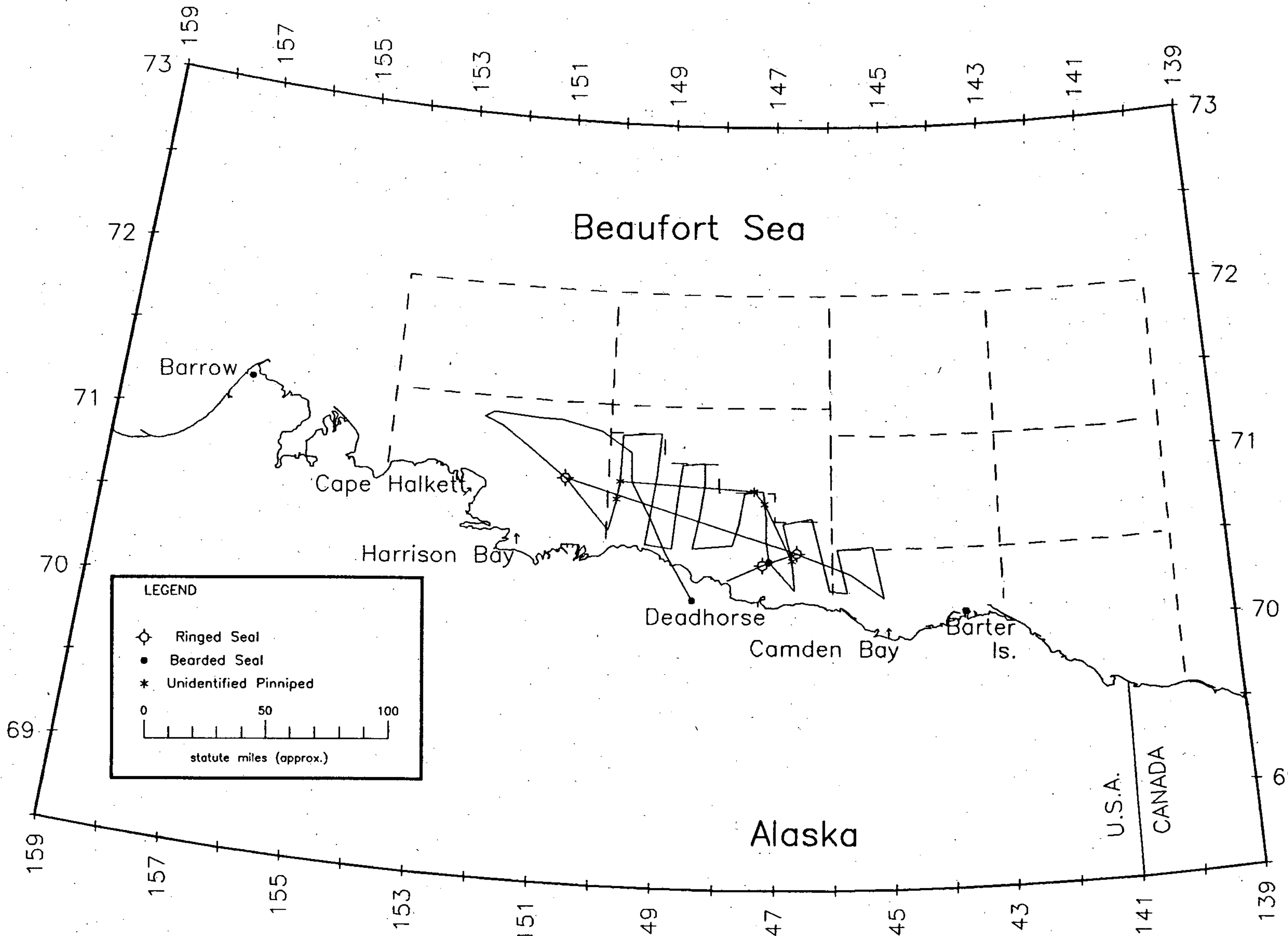
Flight No.	Date	Total Whales	No. Calves	Latitude (North)	Longitude (West)	Sighting Cue	Behavior	Heading	Ice (%)	Sea State
20	1 Oct	3	0	71°08.7'	151°49.5'	body	swim	240	0	2
20	1 Oct	1	0	71°05.2'	151°49.1'	body	swim	240	0	2
20	1 Oct	2	0	70°49.5'	150°42.6'	body	swim	270	0	2
20	1 Oct	2	0	71°07.6'	150°50.0'	slick	swim	90	0	2
20	1 Oct	2	0	71°07.3'	150°51.1'	body	swim	[1]	0	2
20	1 Oct	2	0	71°07.8'	150°47.0'	body	swim	[1]	0	2
20	1 Oct	1	0	71°08.5'	150°45.9'	body	swim	160	0	2
22	6 Oct	4	0	70°30.2'	148°53.6'	body	swim	190	0	2
22	6 Oct	4	0	70°31.7'	148°58.0'	body	swim	60	0	2
22	6 Oct	1	0	70°31.7'	148°58.0'	splash	dive	60	0	2
22	6 Oct	2	0	70°31.4'	148°48.9'	body	swim	10	0	2
22	6 Oct	1	0	70°30.4'	149°00.2'	[1]	swim	100	0	2
27	13 Oct	15	0	70°56.0'	152°24.5'	body	mill	[1]	0	3
27	13 Oct	2	0	70°54.1'	152°25.1'	body	swim	150	0	3
27	13 Oct	3	0	70°55.7'	152°26.1'	splash	mill	[1]	0	3
27	13 Oct	1	0	70°46.4'	151°38.9'	body	swim	[1]	0	4
28	15 Oct	3	0	70°58.3'	152°42.7'	body	swim	240	0	4
28	15 Oct	1	0	70°59.4'	152°49.4'	body	swim	240	0	4
28	15 Oct	2	0	71°02.6'	153°45.0'	body	swim	230	0	5
28	15 Oct	1	0	70°39.4'	149°59.0'	body	[1]	[1]	0	4
31	19 Oct	1	0	70°59.2'	152°38.7'	body	dive	[1]	0	5
31	19 Oct	1	0	71°00.3'	152°52.9'	body	swim	330	0	5

[1] not recorded

[2] repeat sightings



FLIGHT 1 3 SEPTEMBER 1989
Survey Track and Sightings



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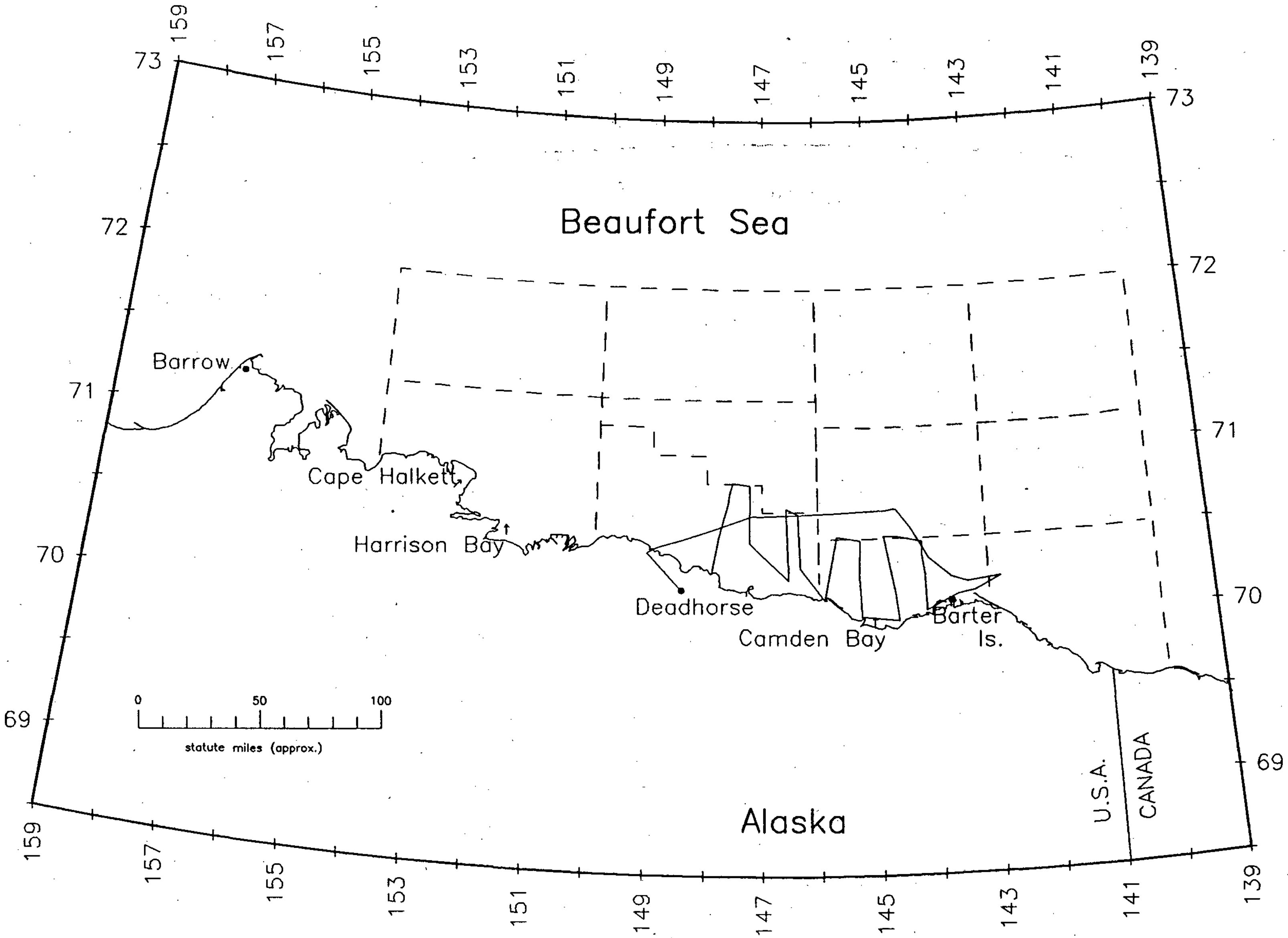
Survey Track and Sightings



FLIGHT 3 5 SEPTEMBER 1989
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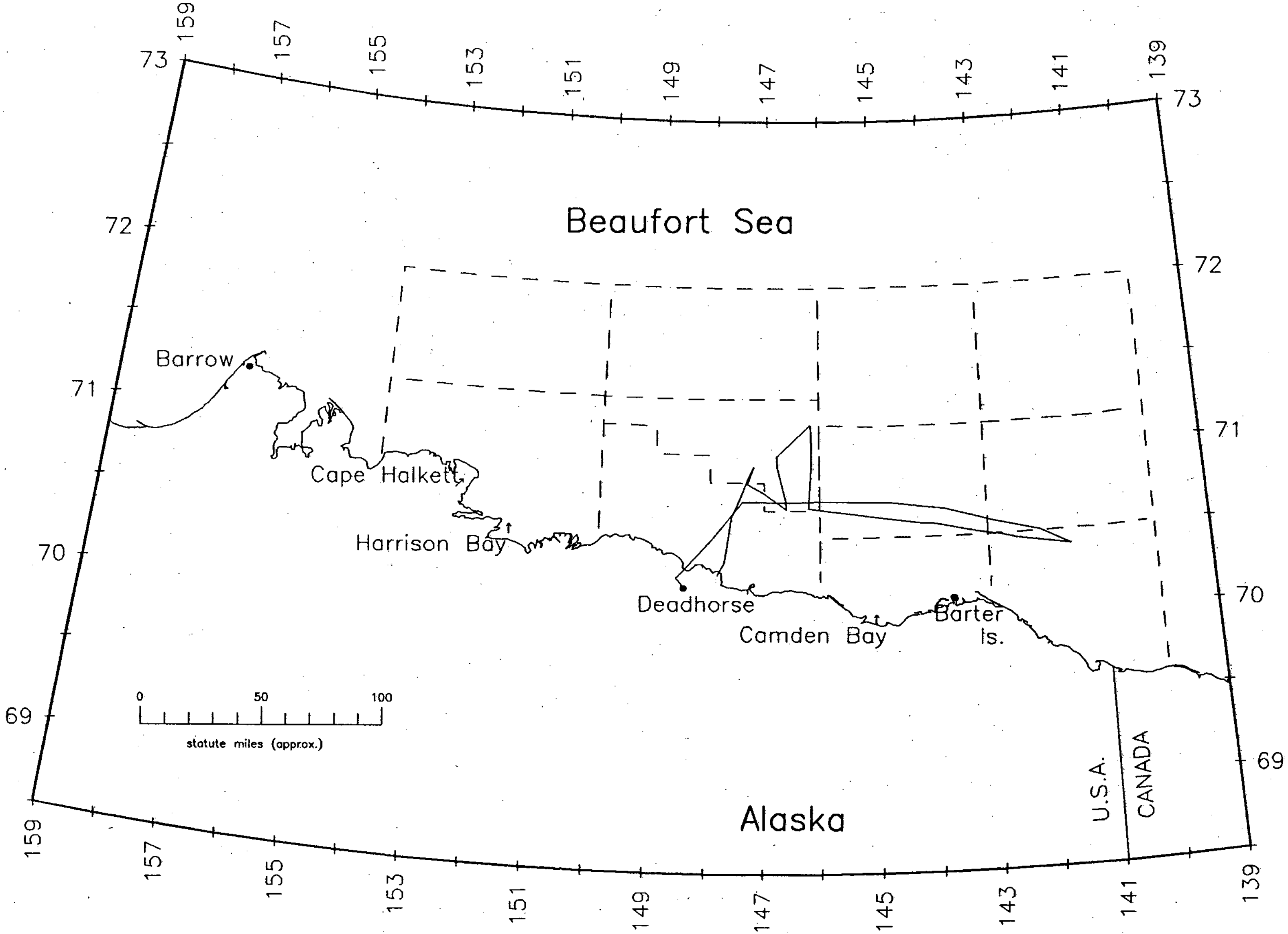

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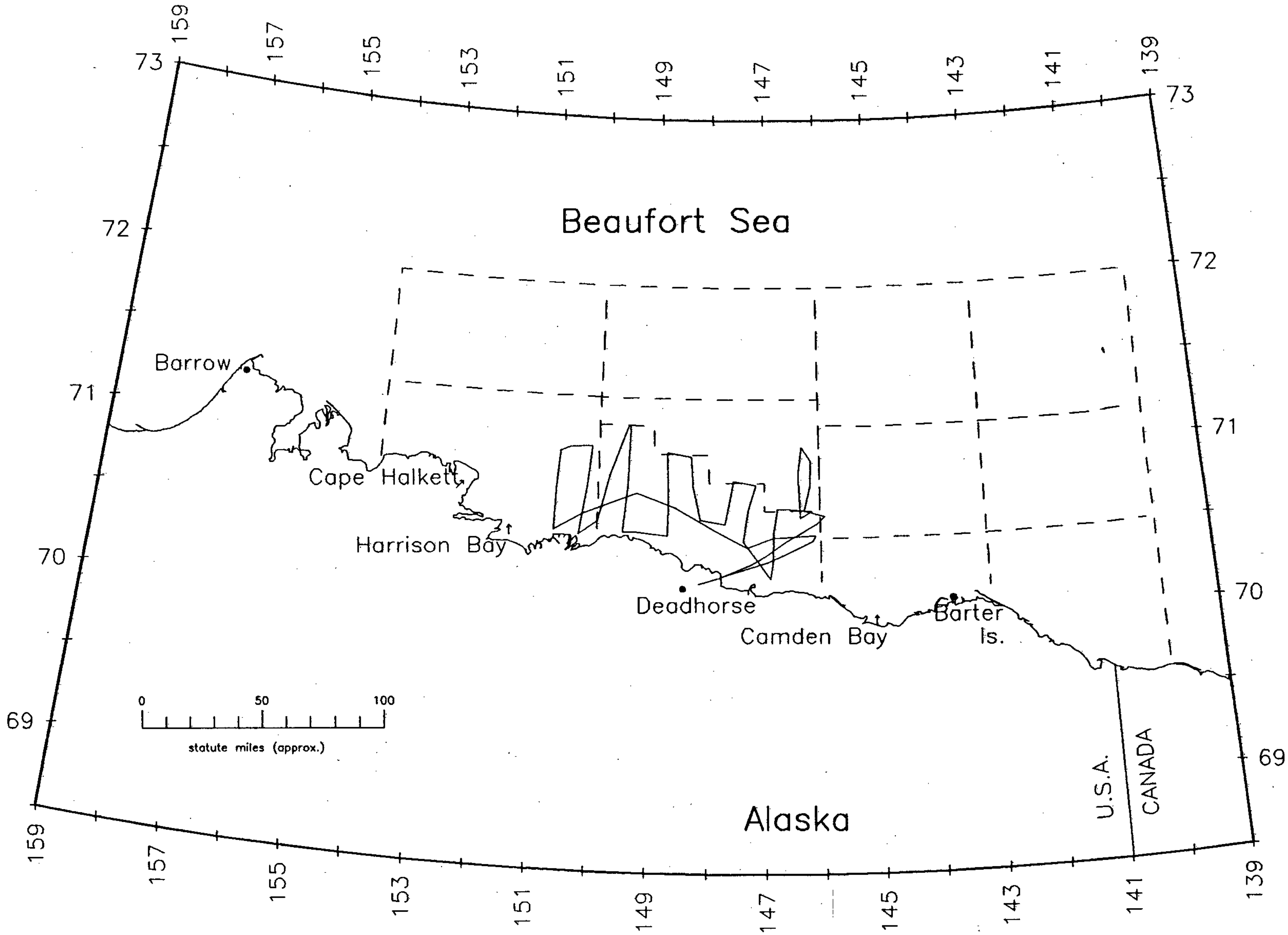
Survey Track and Sightings



FLIGHT 5 7 SEPTEMBER 1989
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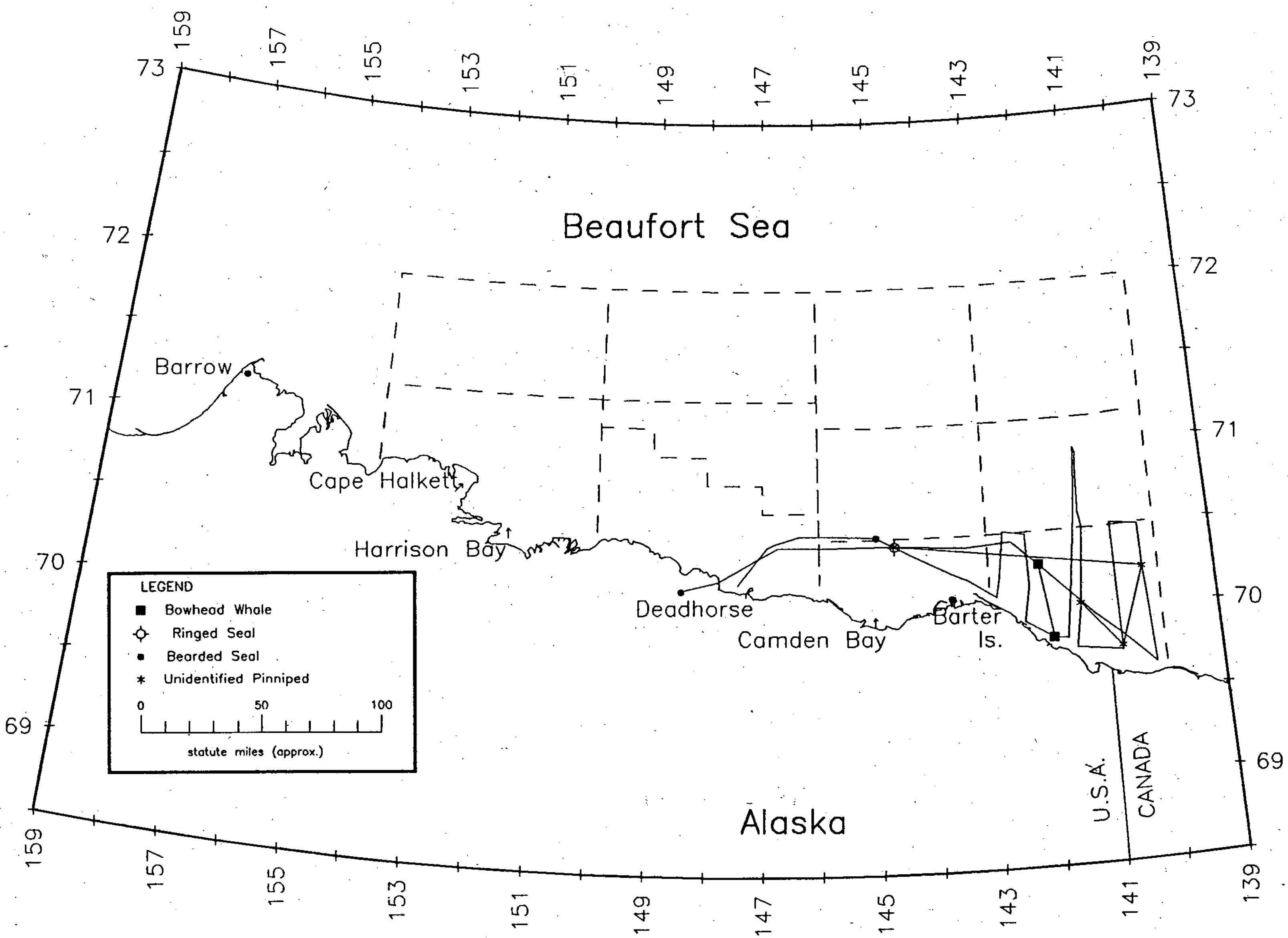
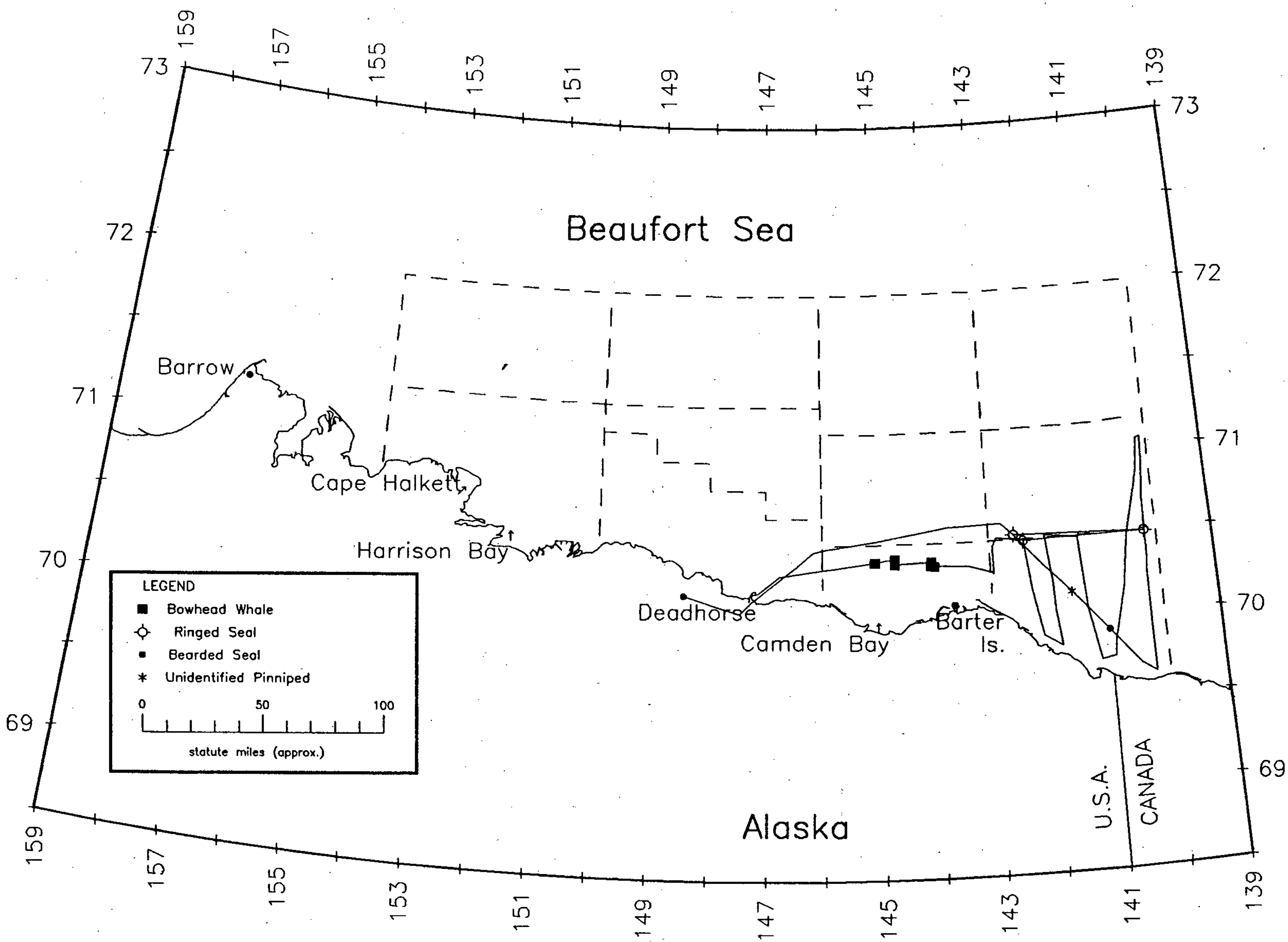
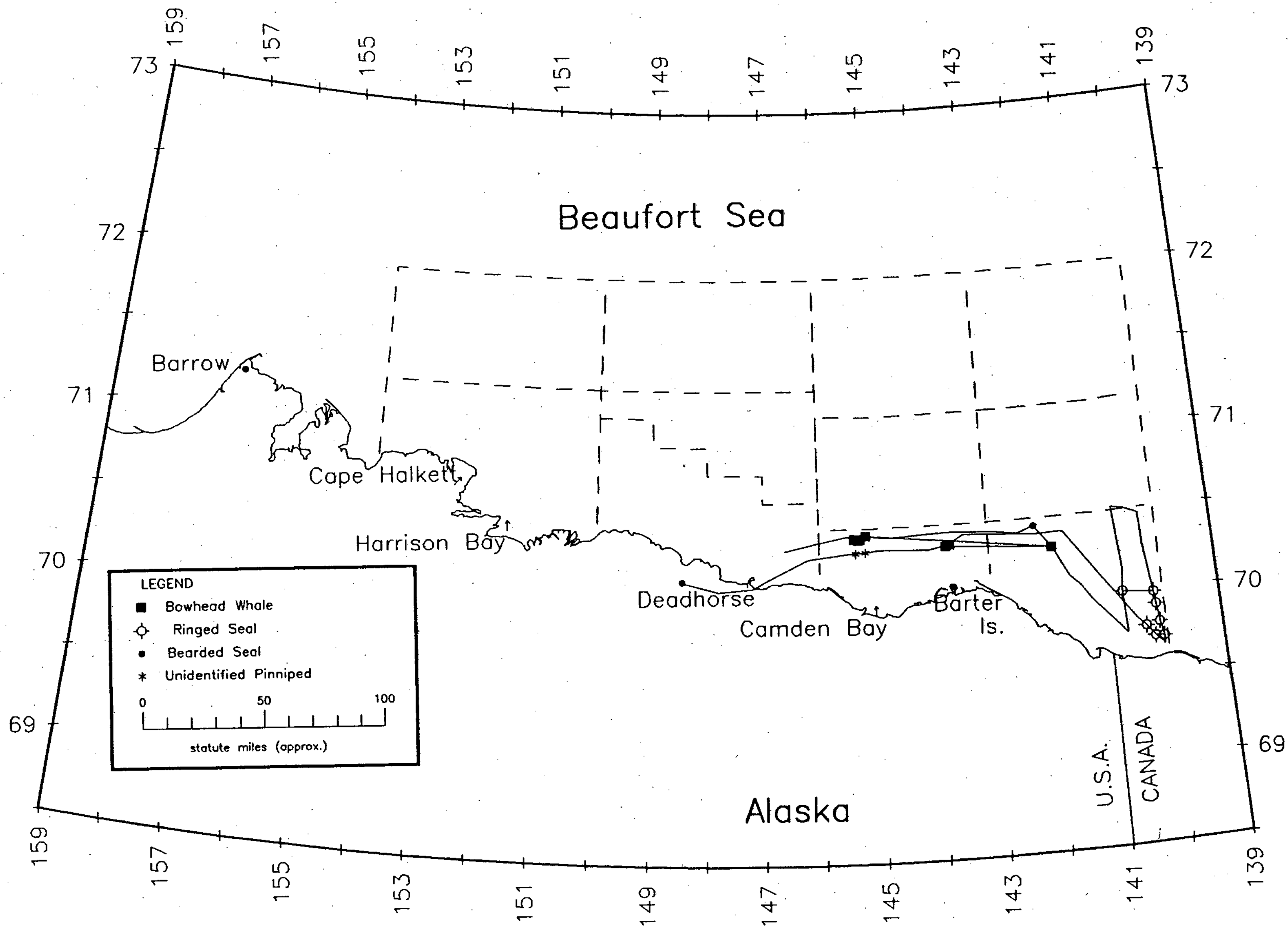


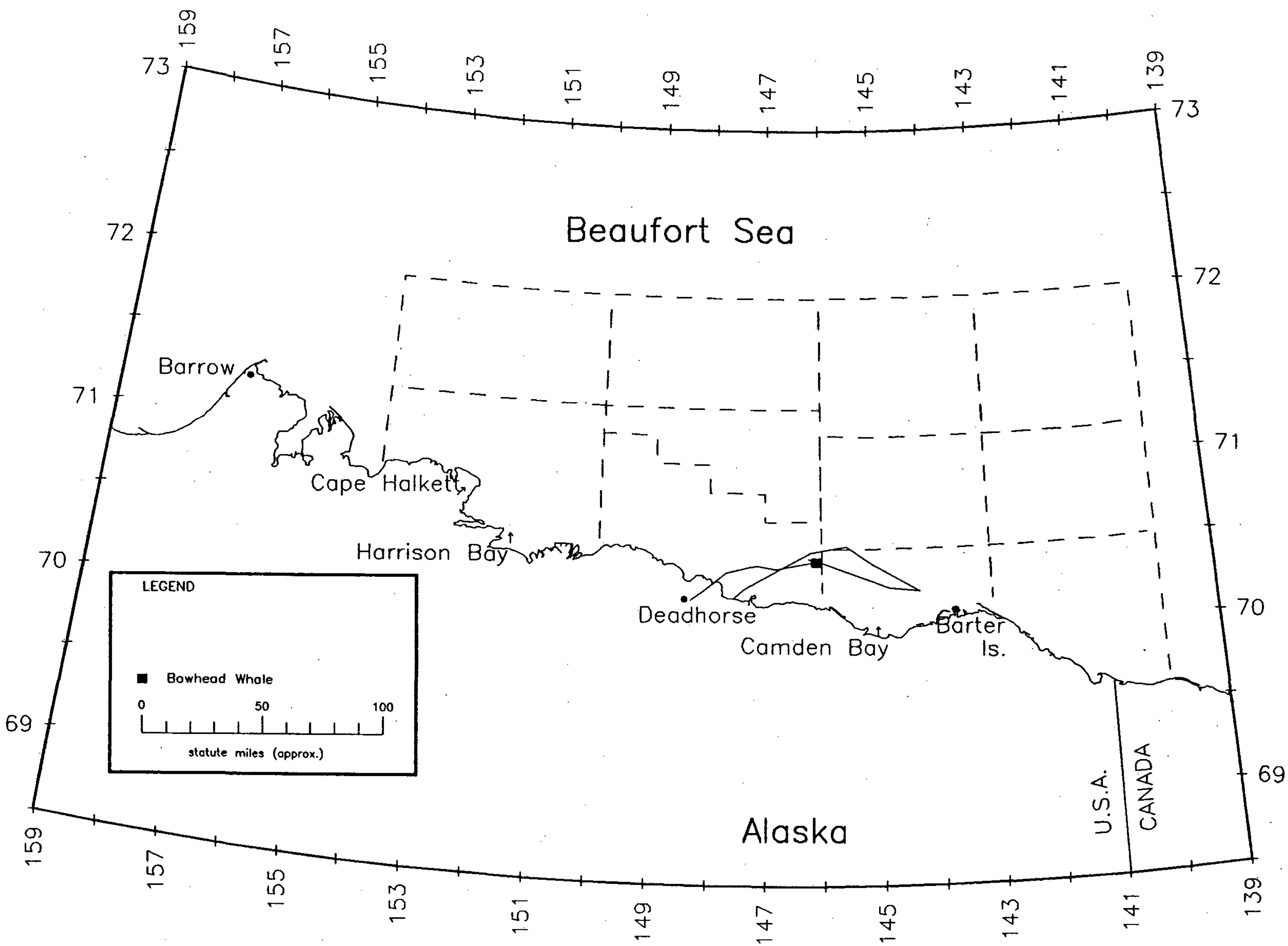
FLIGHT 6 8 SEPTEMBER 1989
Survey Track and Sightings



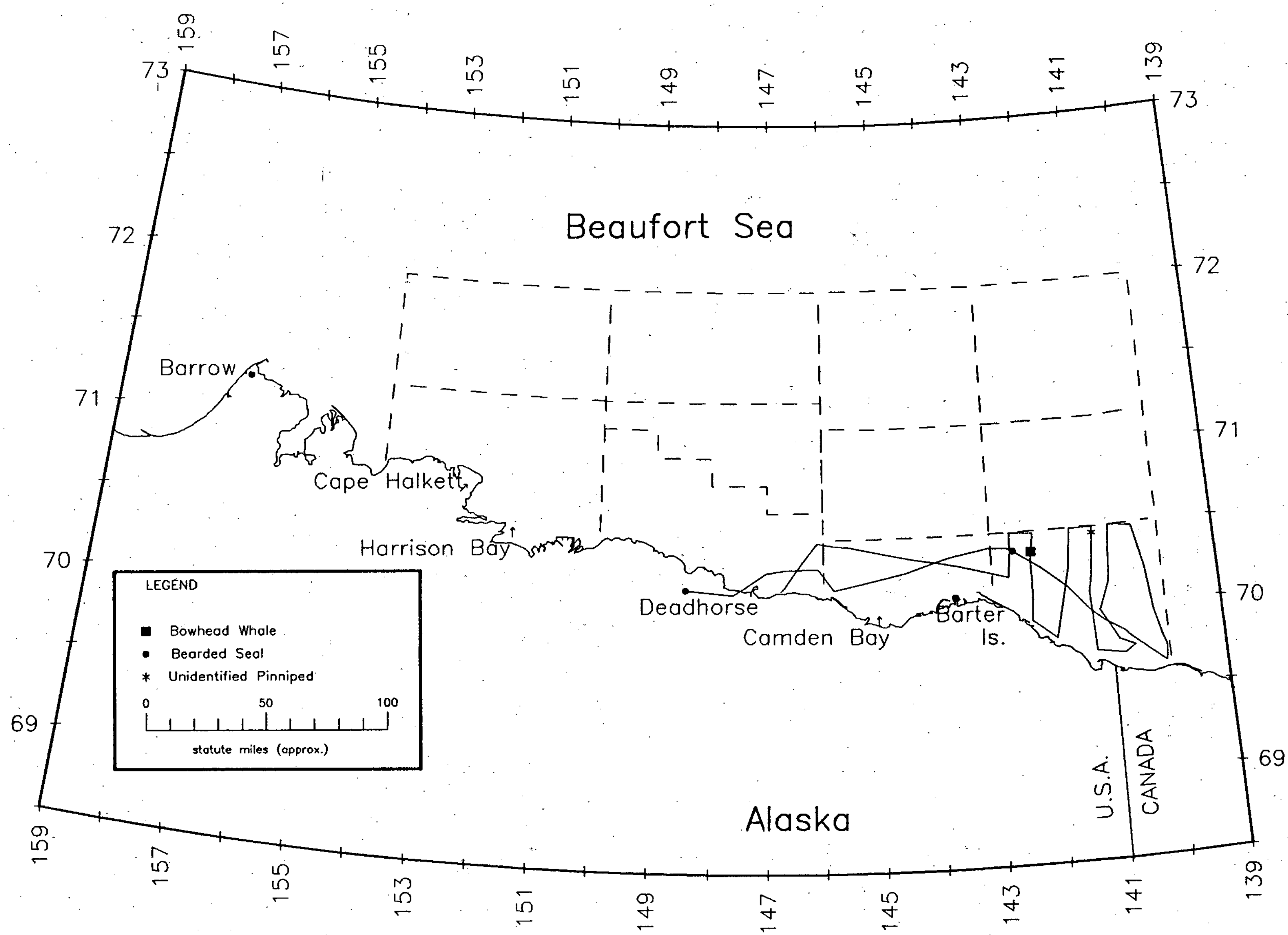
FLIGHT 7 9 SEPTEMBER 1989
Survey Track and Sightings



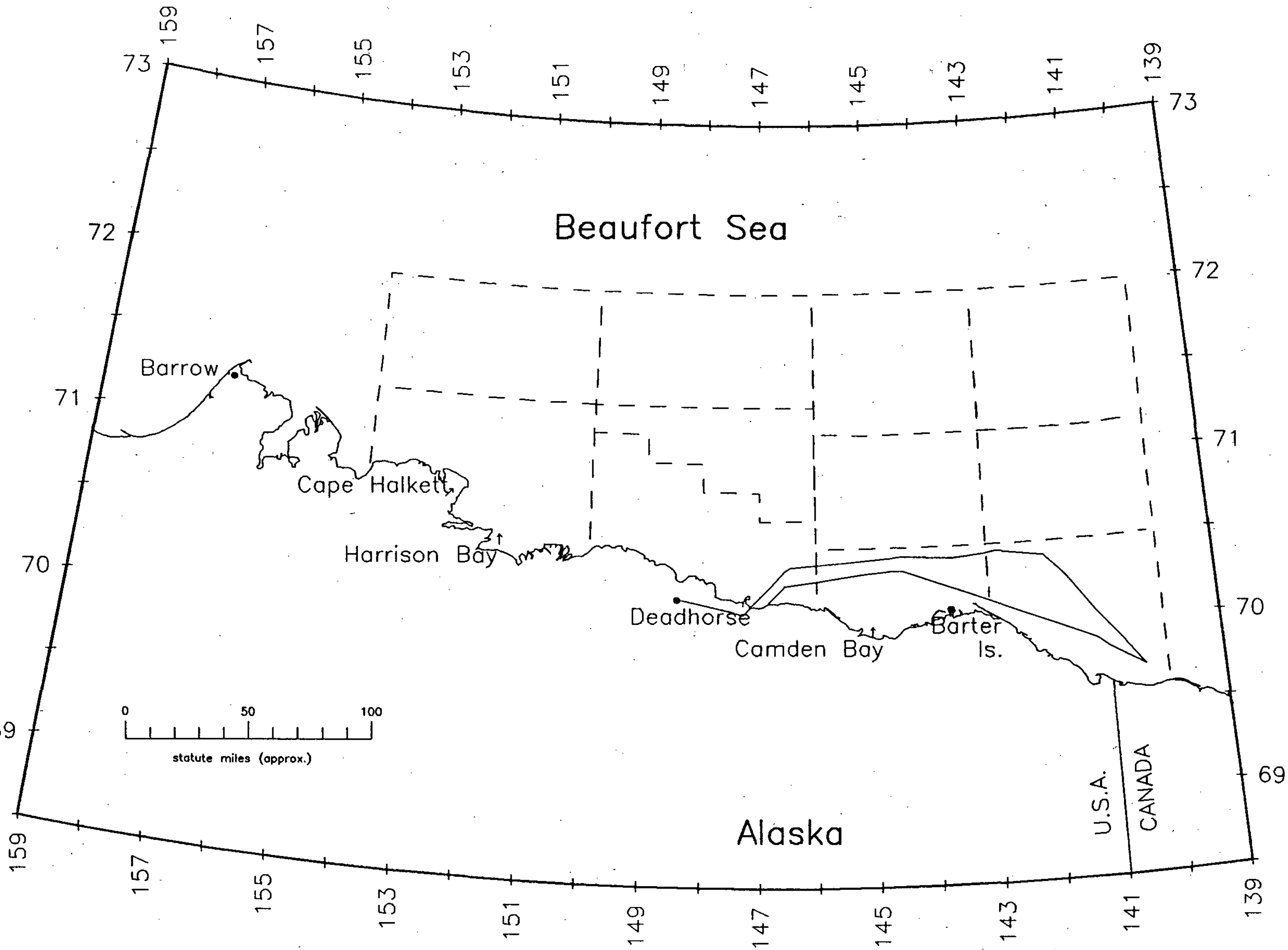
FLIGHT 8 10 SEPTEMBER 1989
Survey Track and Sightings



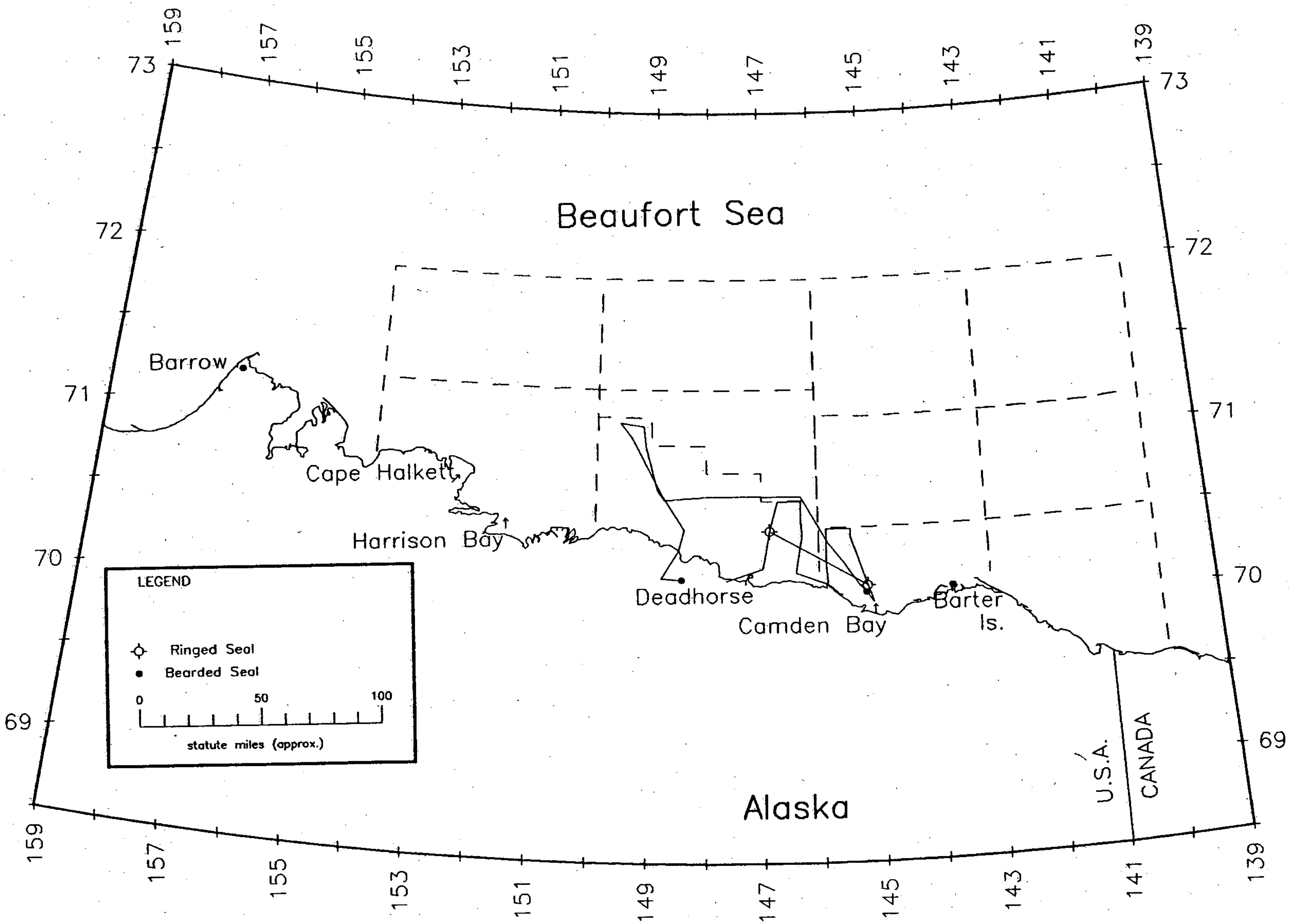
FLIGHT 9 15 SEPTEMBER 1989
Survey Track and Sightings



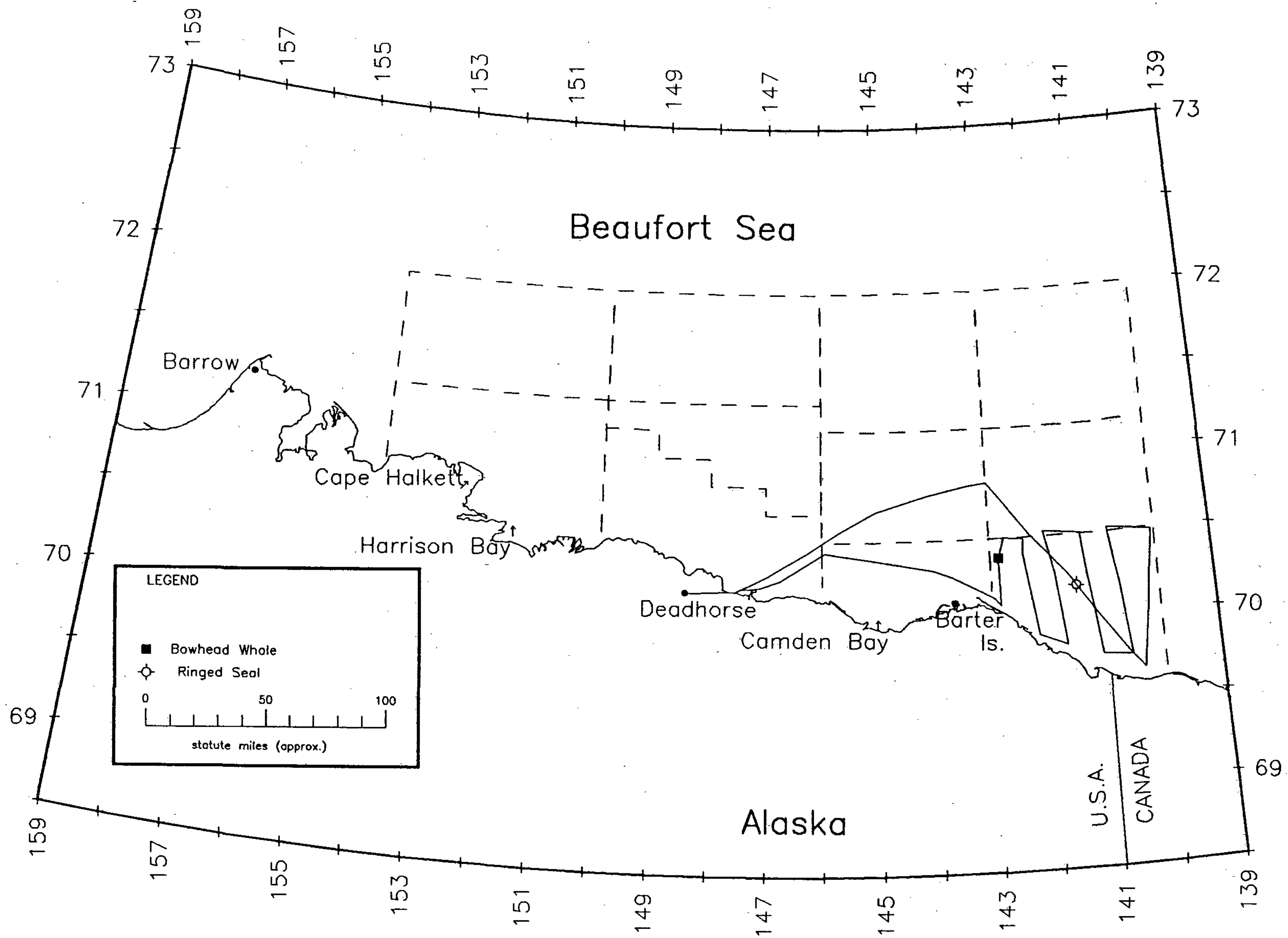
FLIGHT 10 17 SEPTEMBER 1989
Survey Track and Sightings



FLIGHT 11 18 SEPTEMBER 1989
Survey Track and Sightings



FLIGHT 12 19 SEPTEMBER 1989
Survey Track and Sightings



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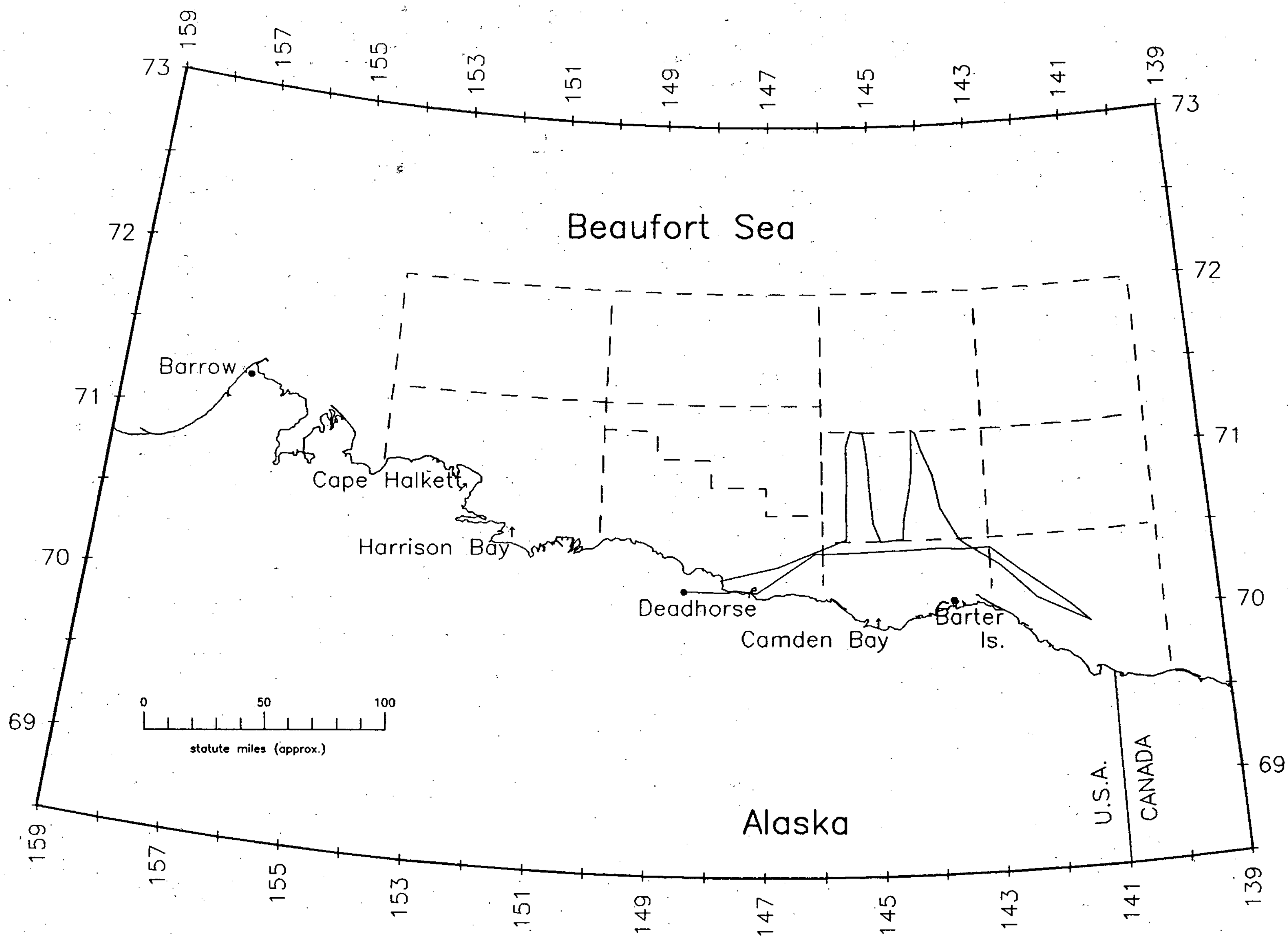
Survey Track and Sightings



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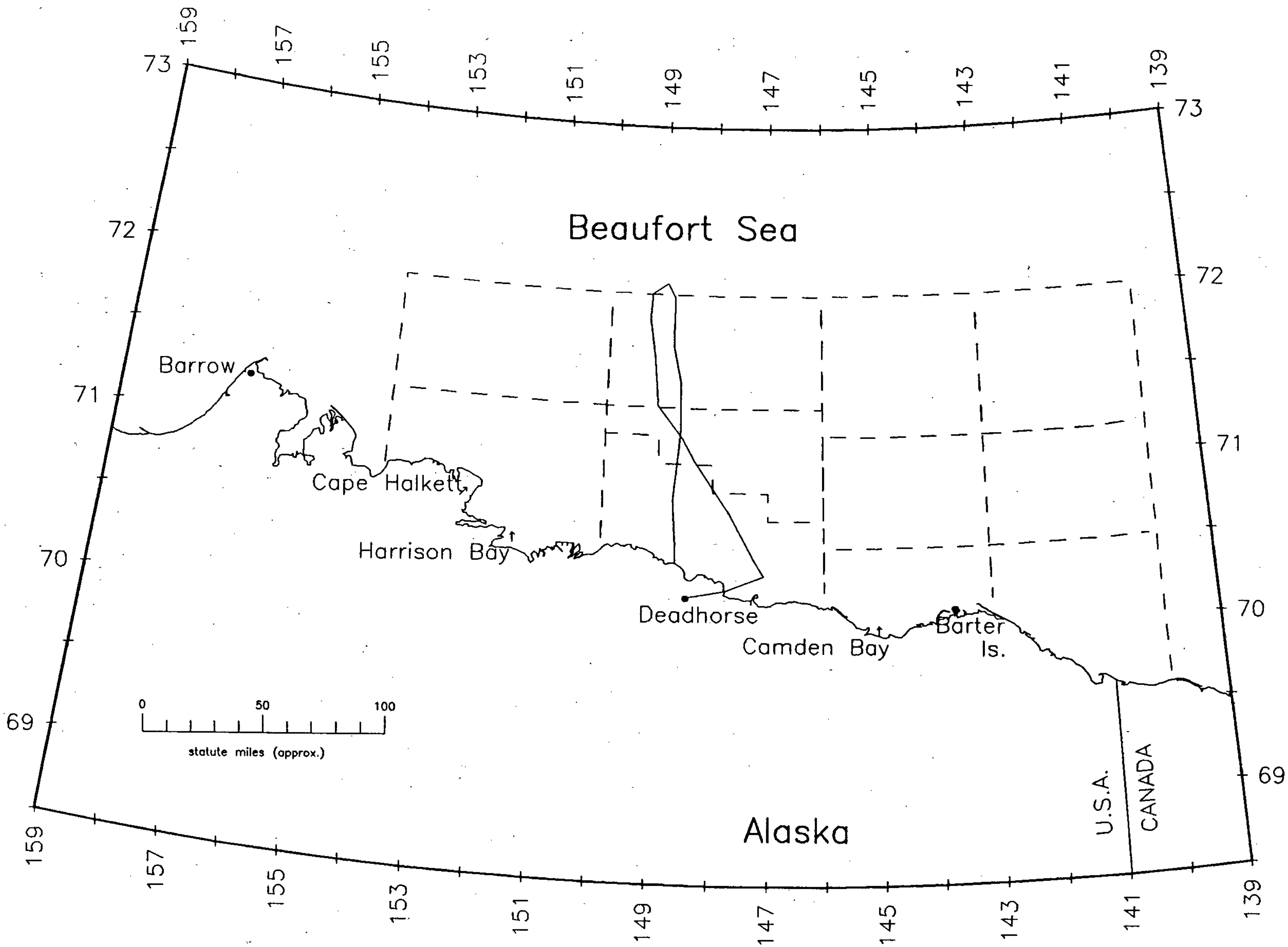
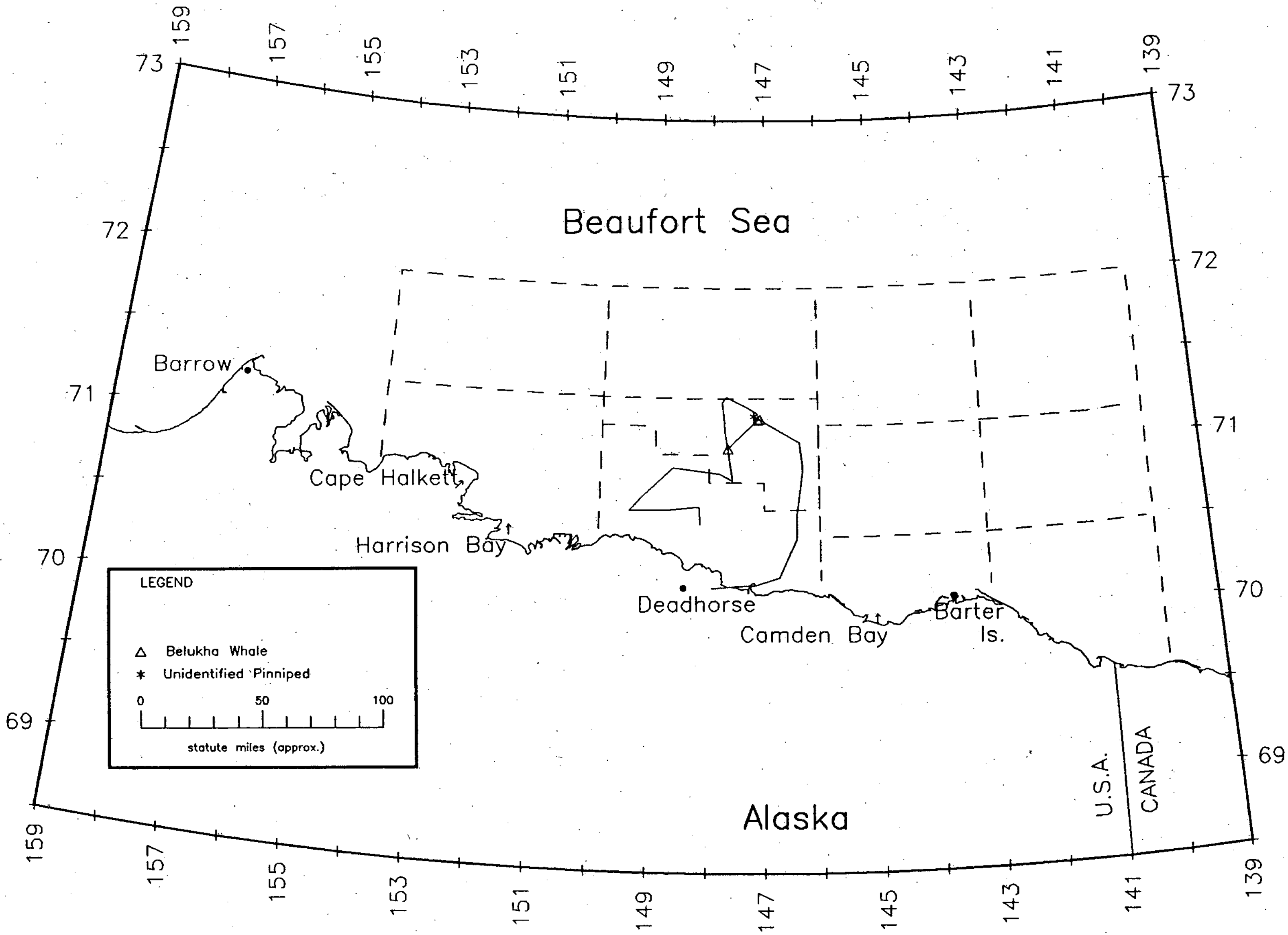
Survey Track and Sightings



FLIGHT 15 22 SEPTEMBER 1989
Survey Track and Sightings



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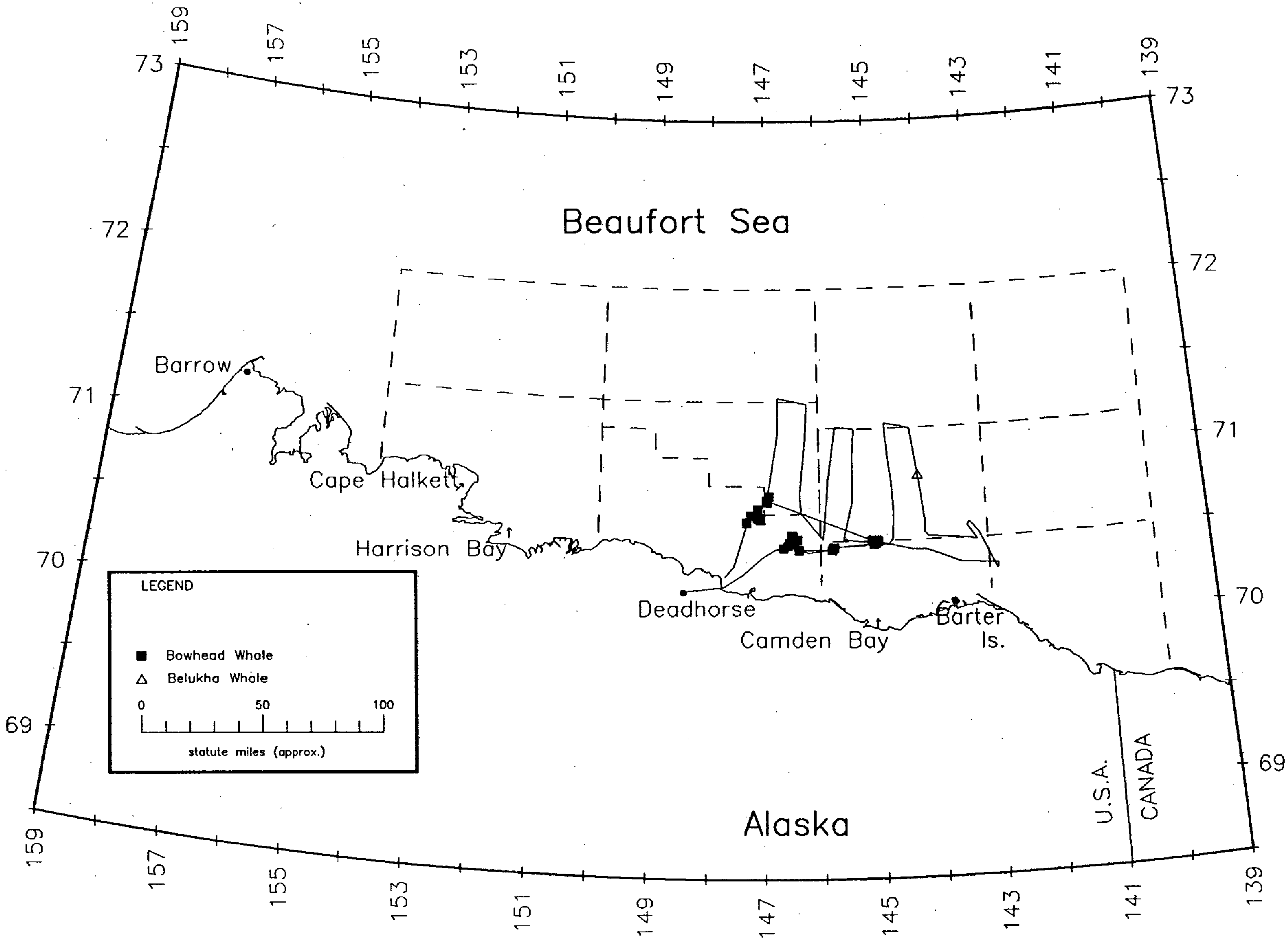
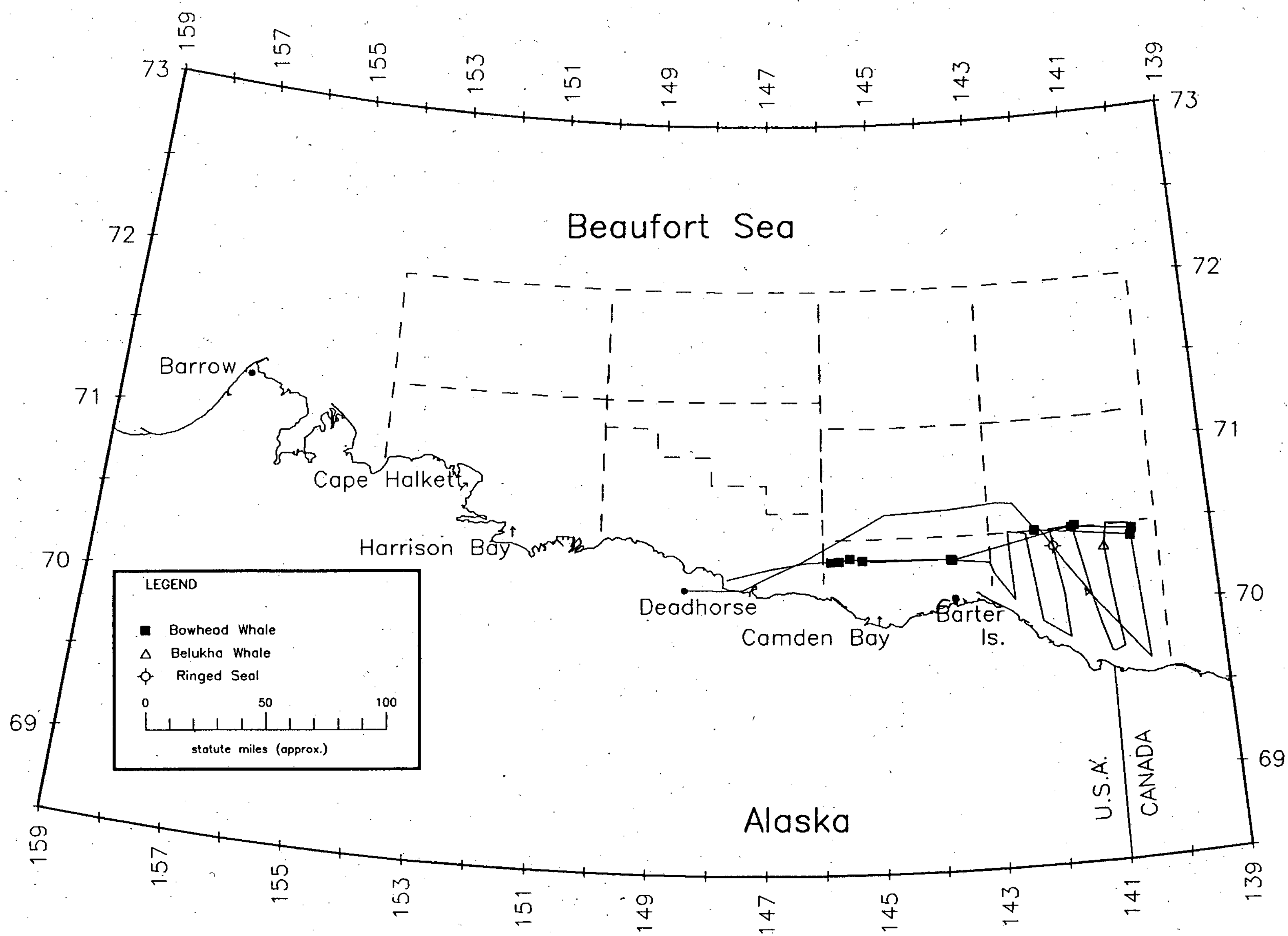
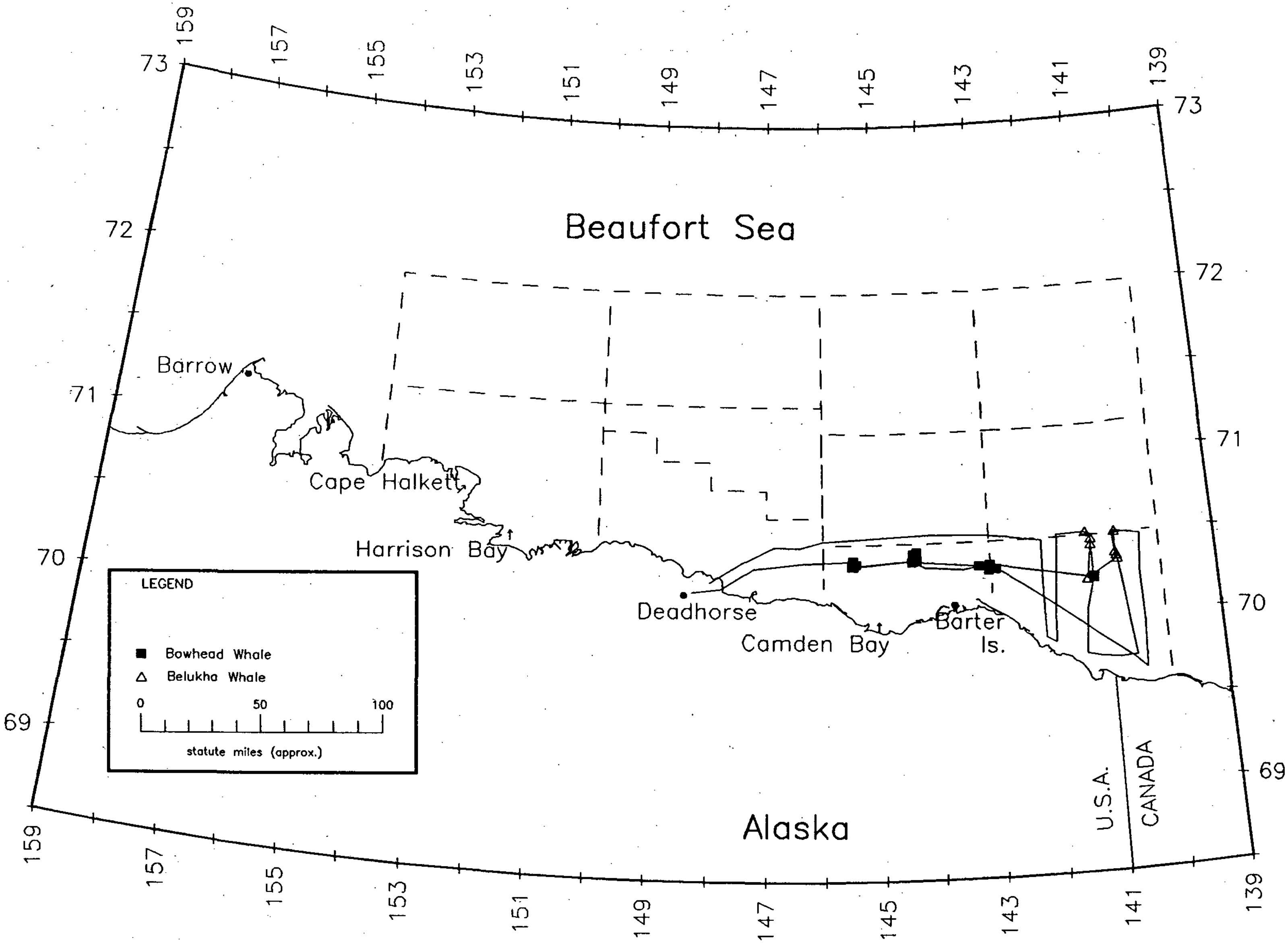
Survey Track and Sightings



FLIGHT 17 28 SEPTEMBER 1989
Survey Track and Sightings



FLIGHT 18 29 SEPTEMBER 1989
Survey Track and Sightings



FLIGHT 19 30 SEPTEMBER 1989
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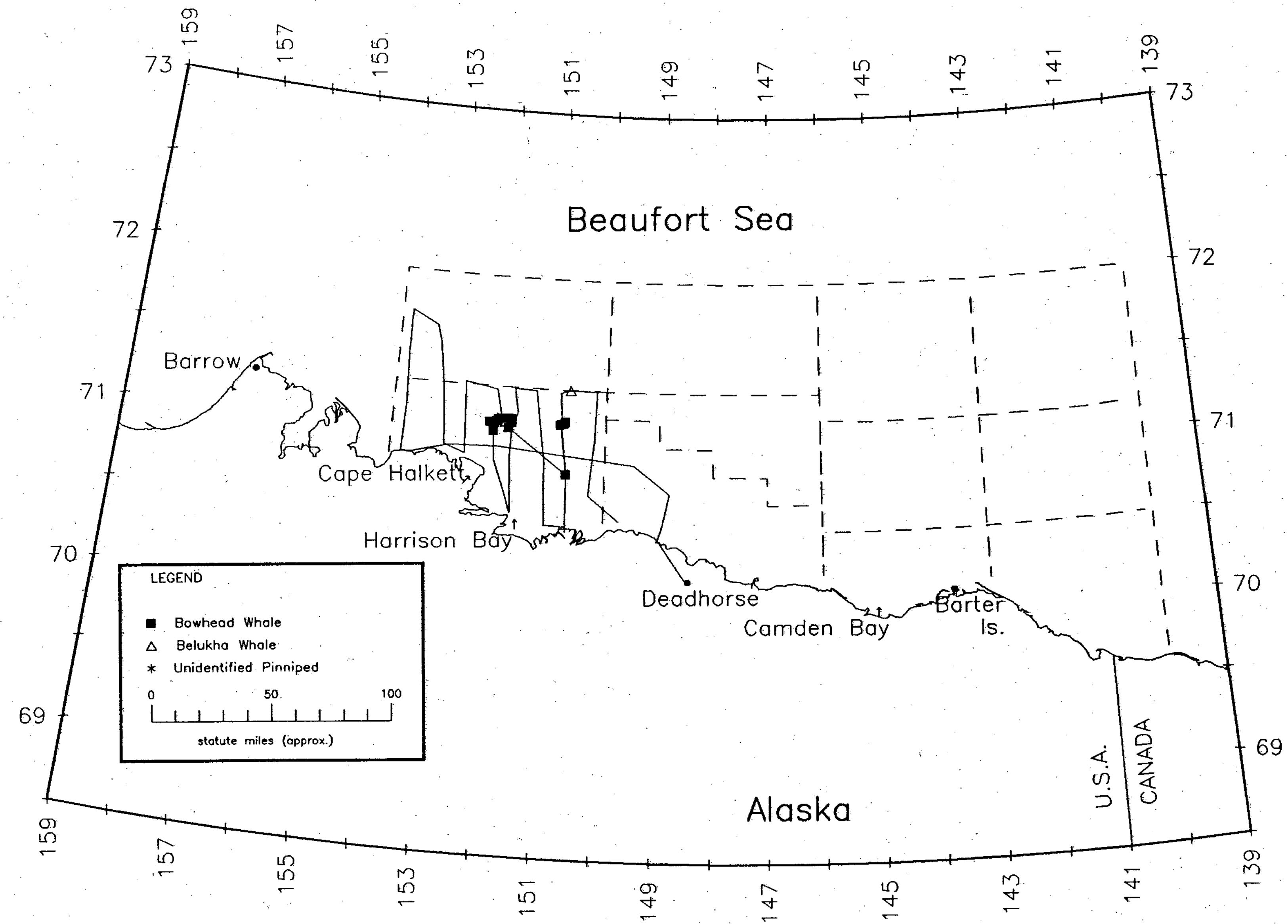
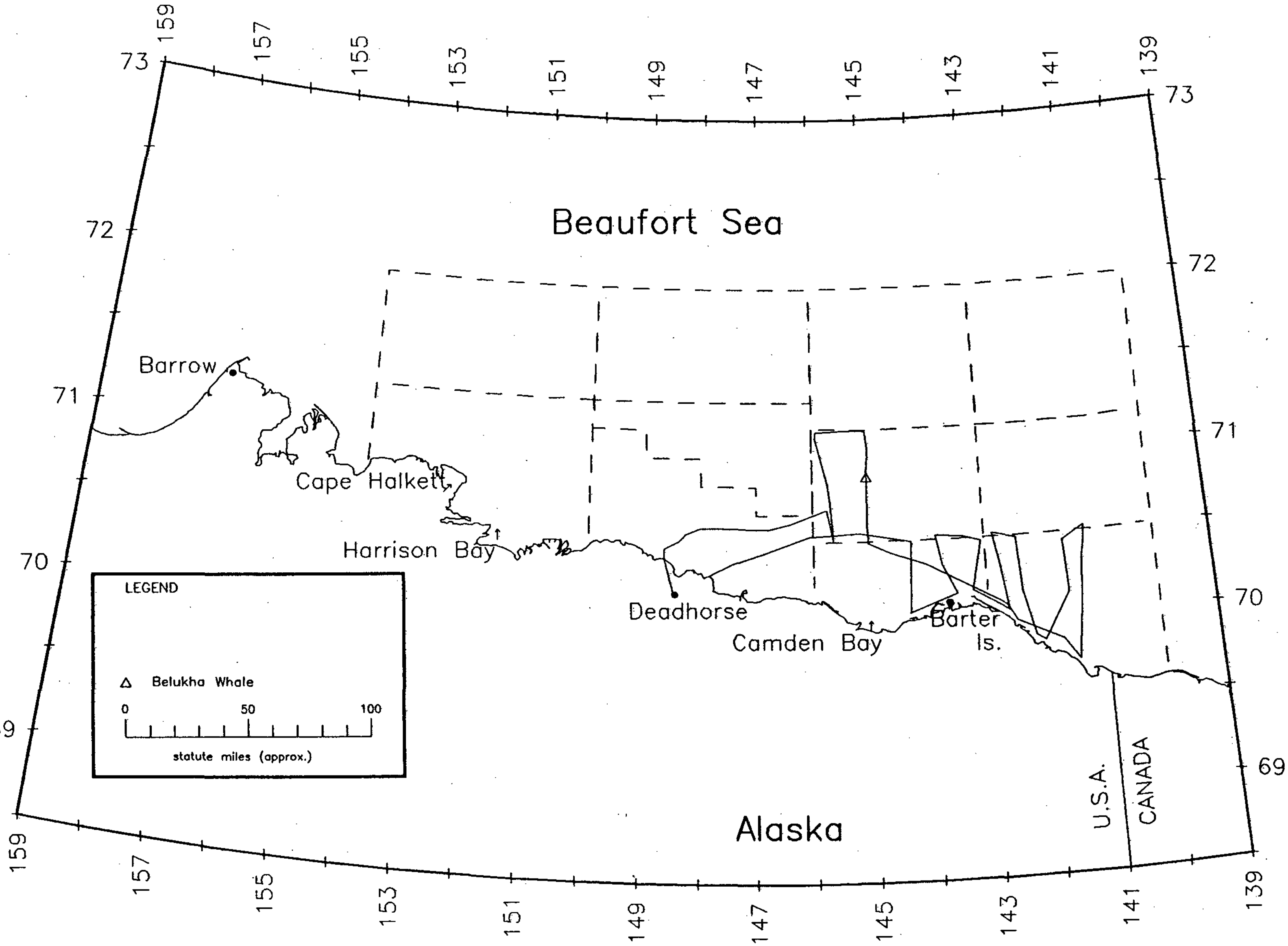


FLIGHT 20 1 OCTOBER 1989
Survey Track and Sightings



FLIGHT 21 5 OCTOBER 1989
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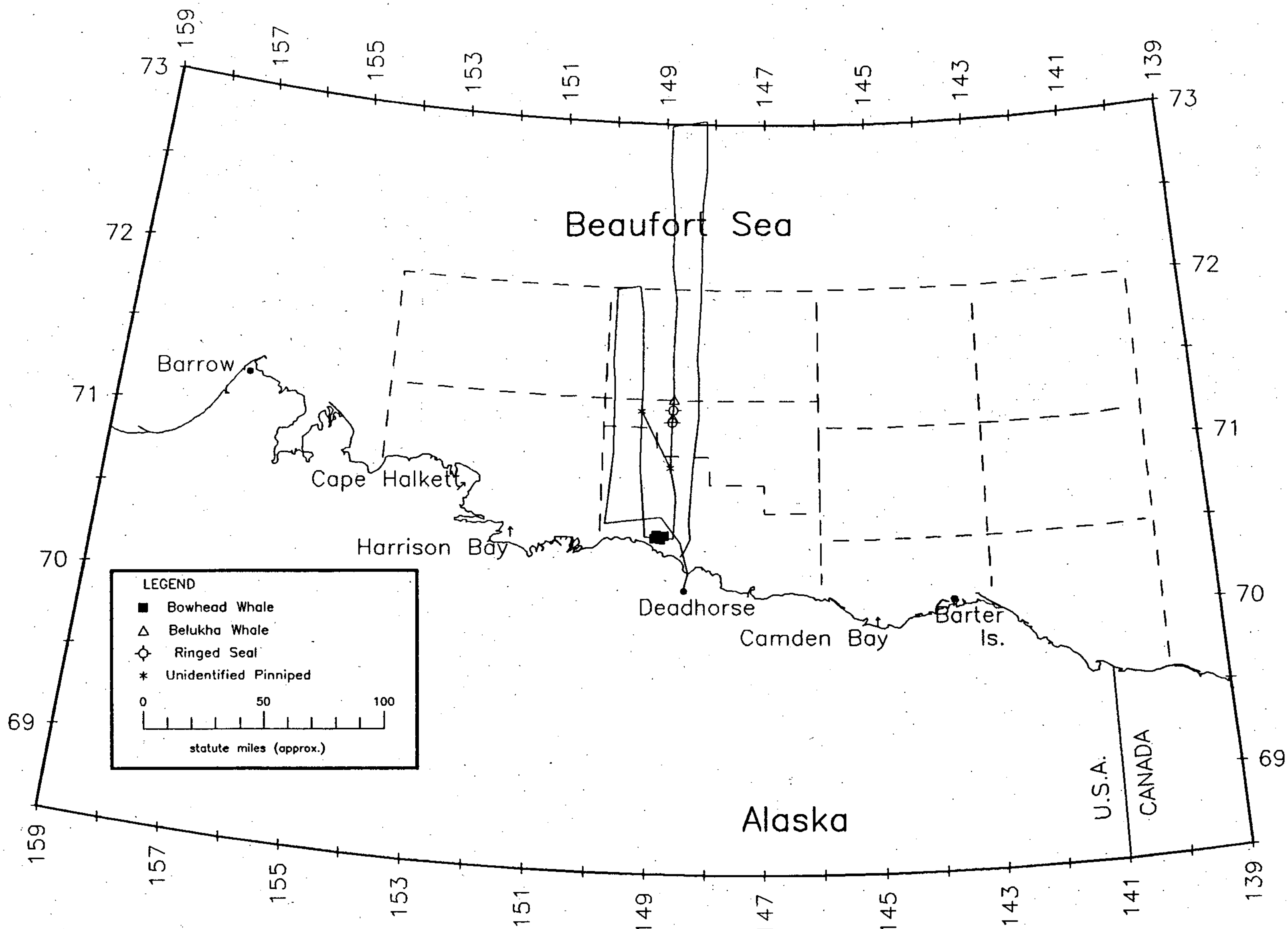

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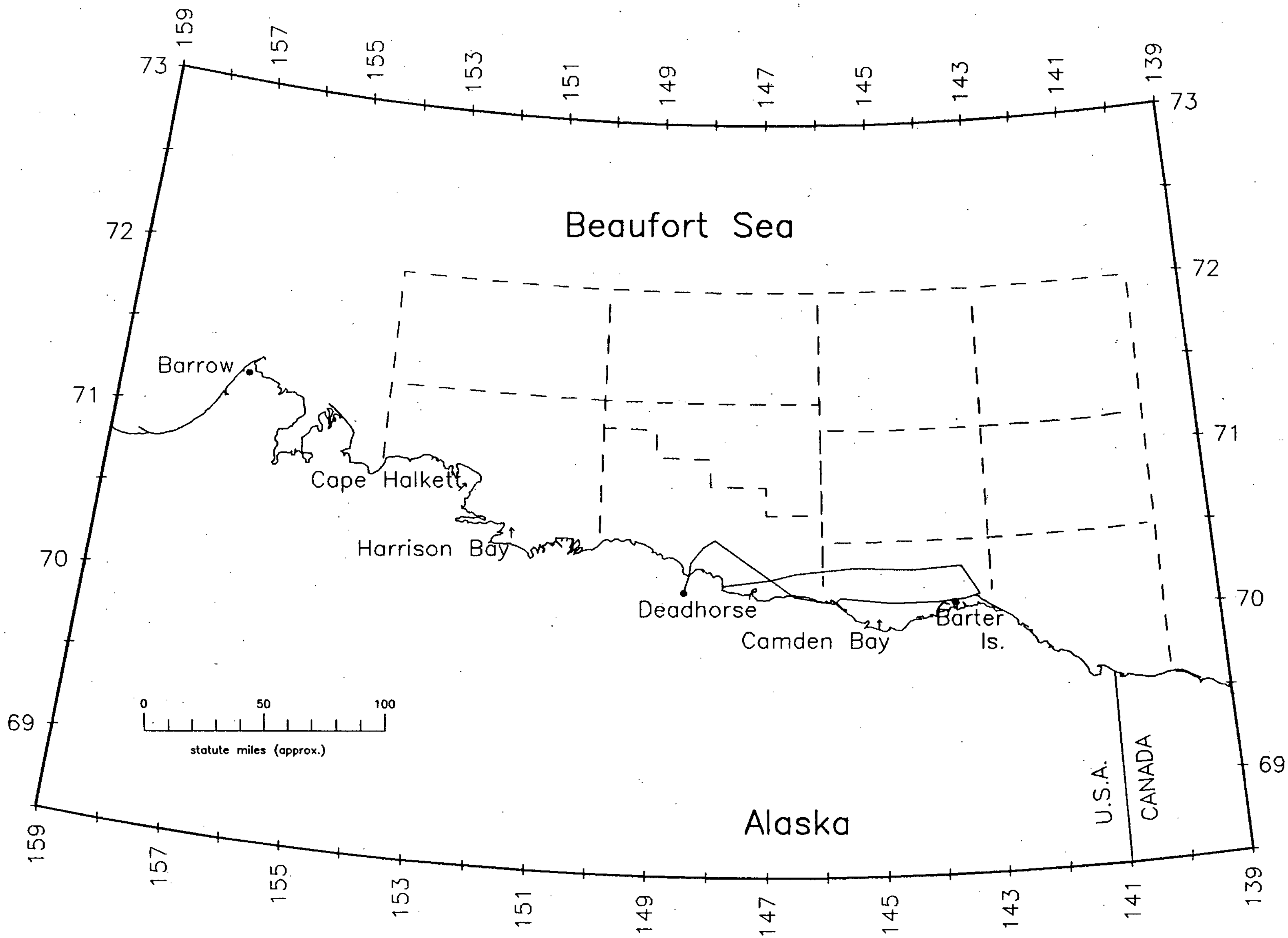

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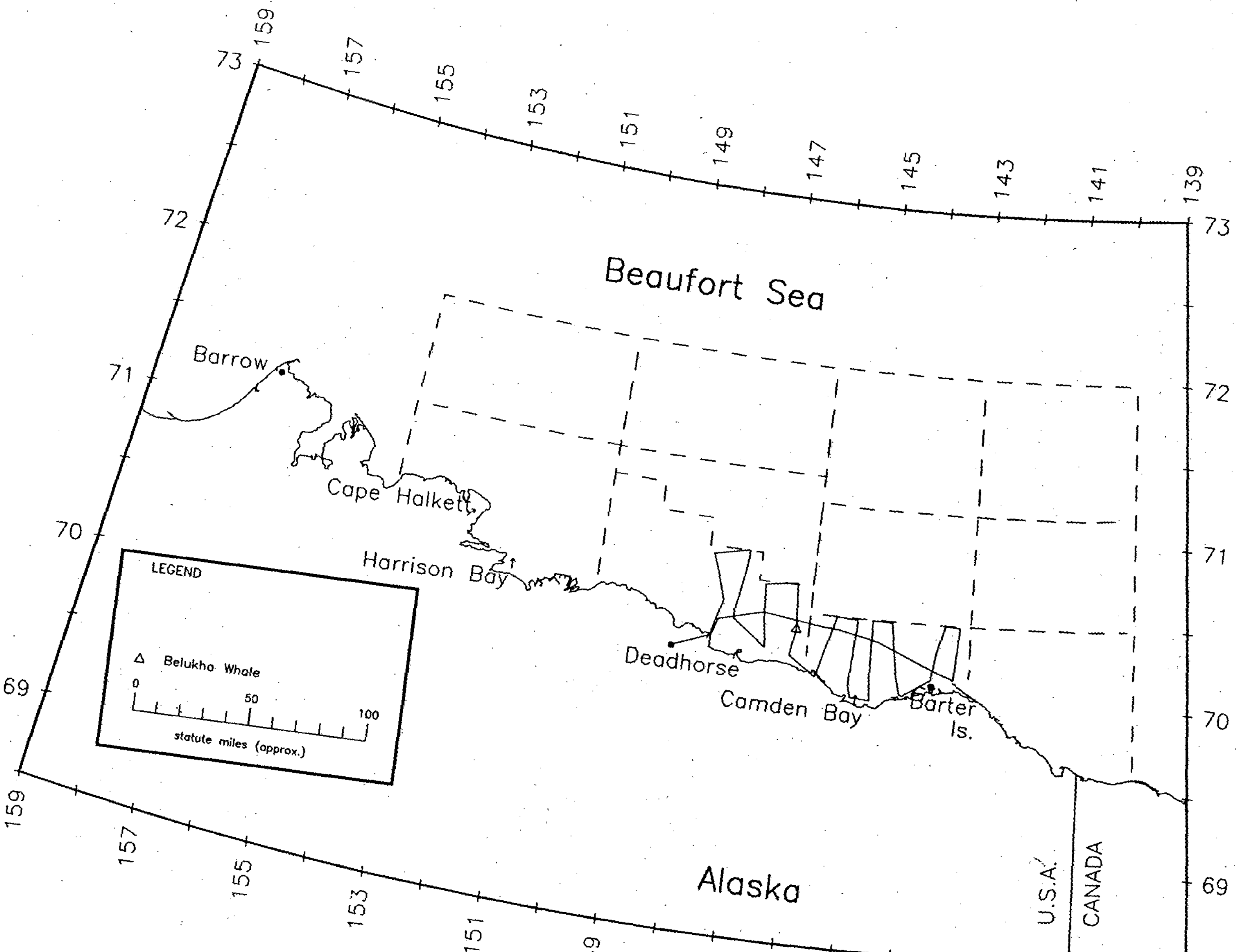
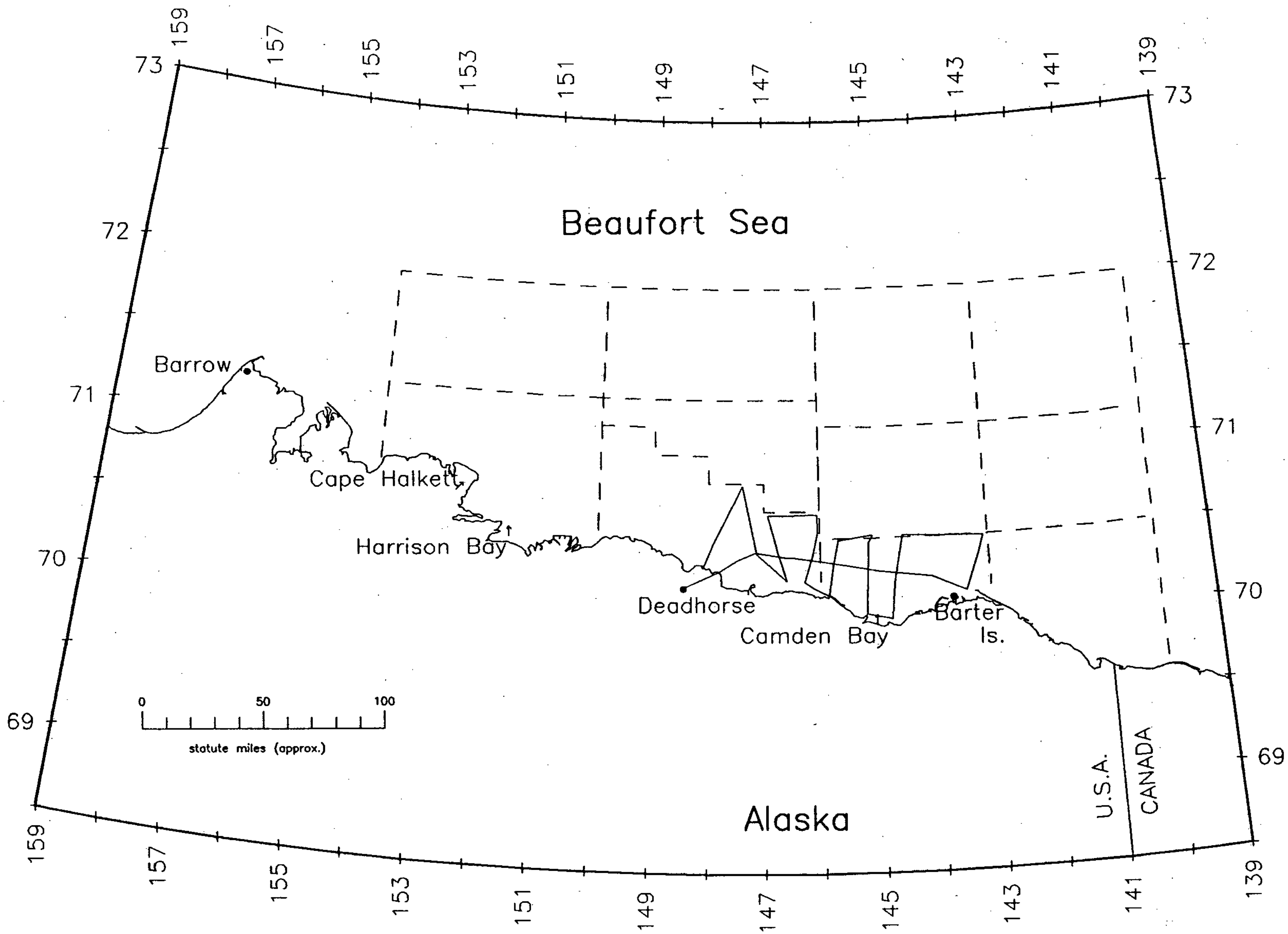
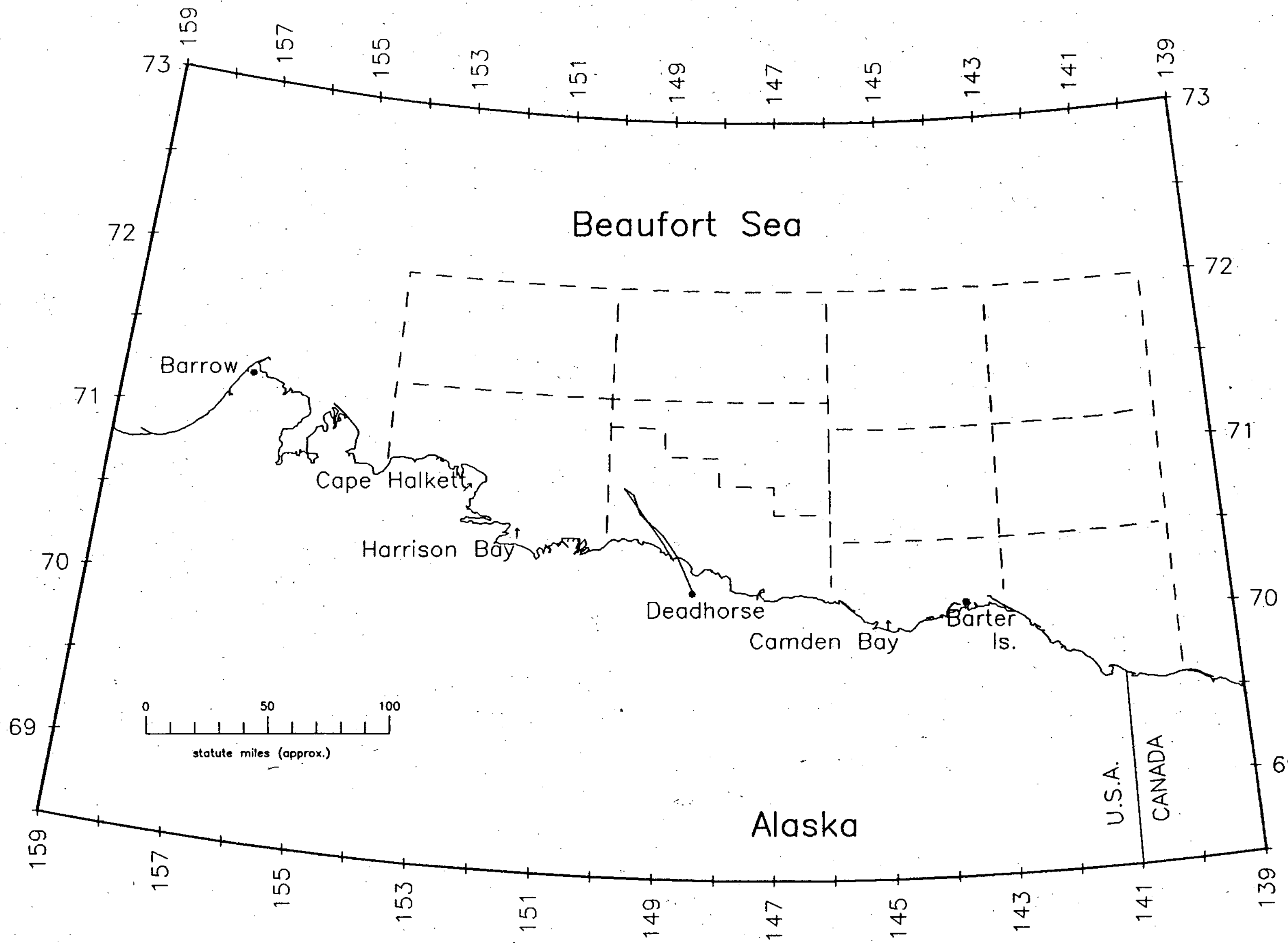
Survey Track and Sightings



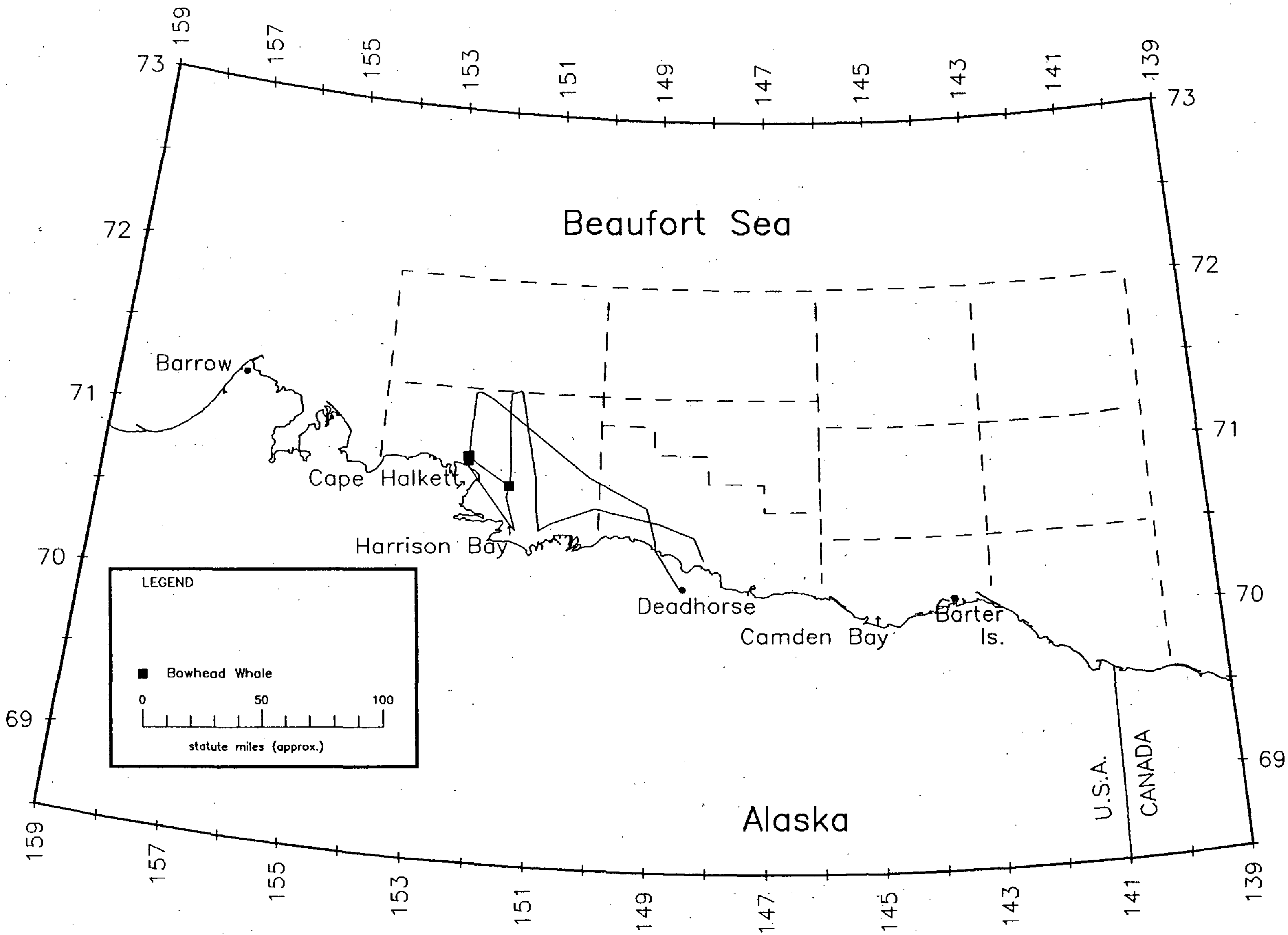
FLIGHT 24 10 OCTOBER 1989
Survey Track and Sightings



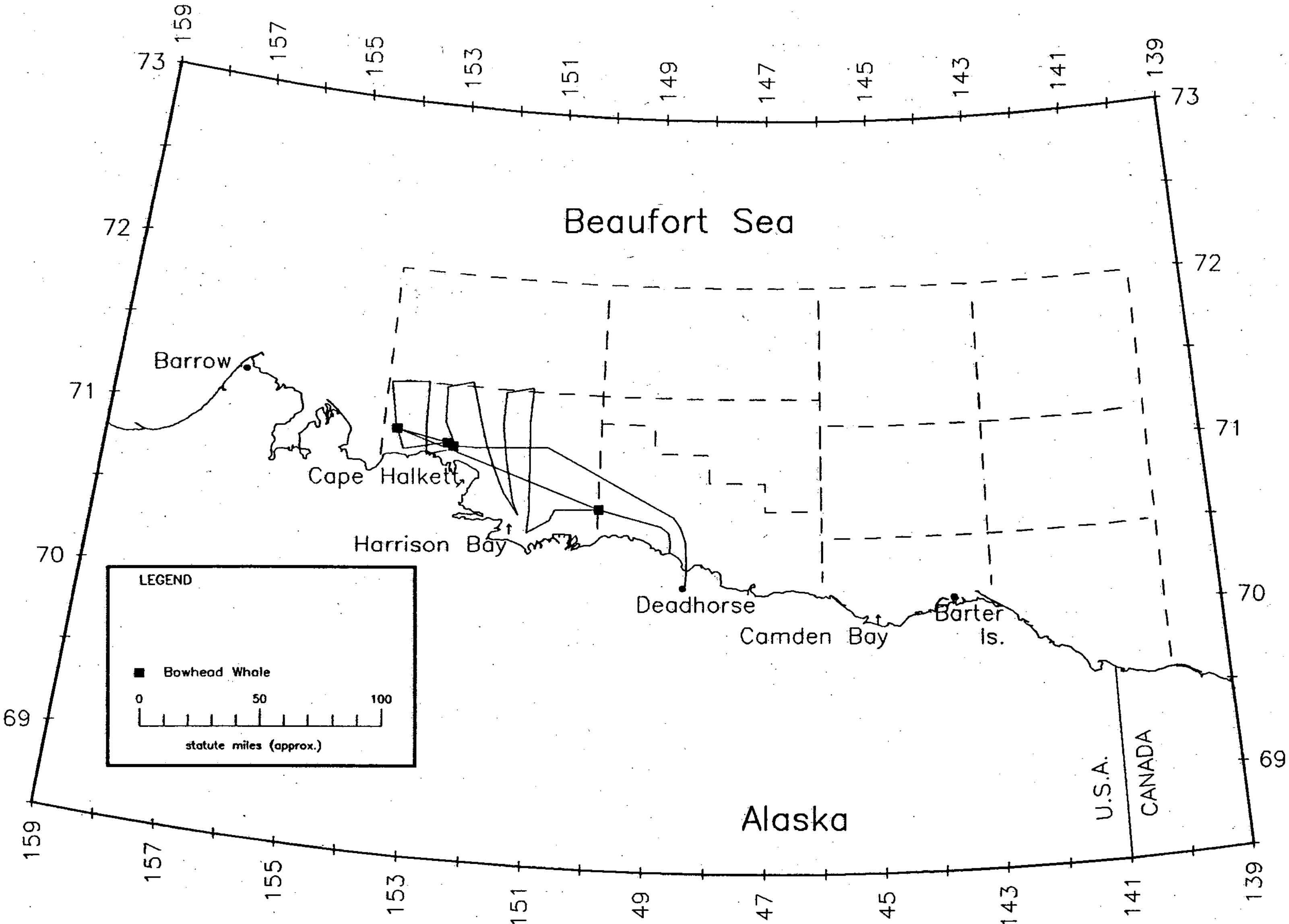
FLIGHT 25 11 OCTOBER 1989
Survey Track and Sightings



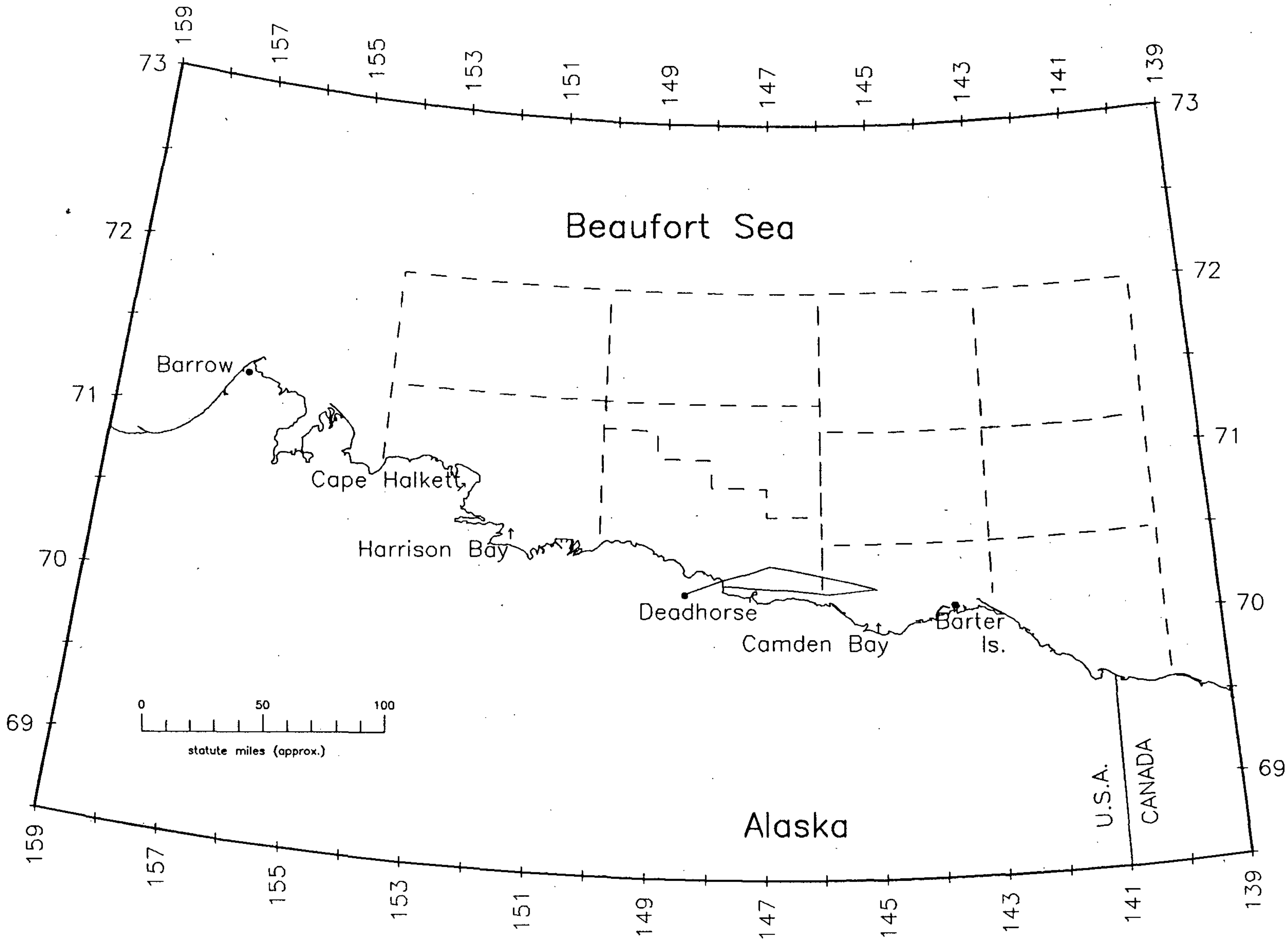
FLIGHT 26 12 OCTOBER 1989
Survey Track and Sightings



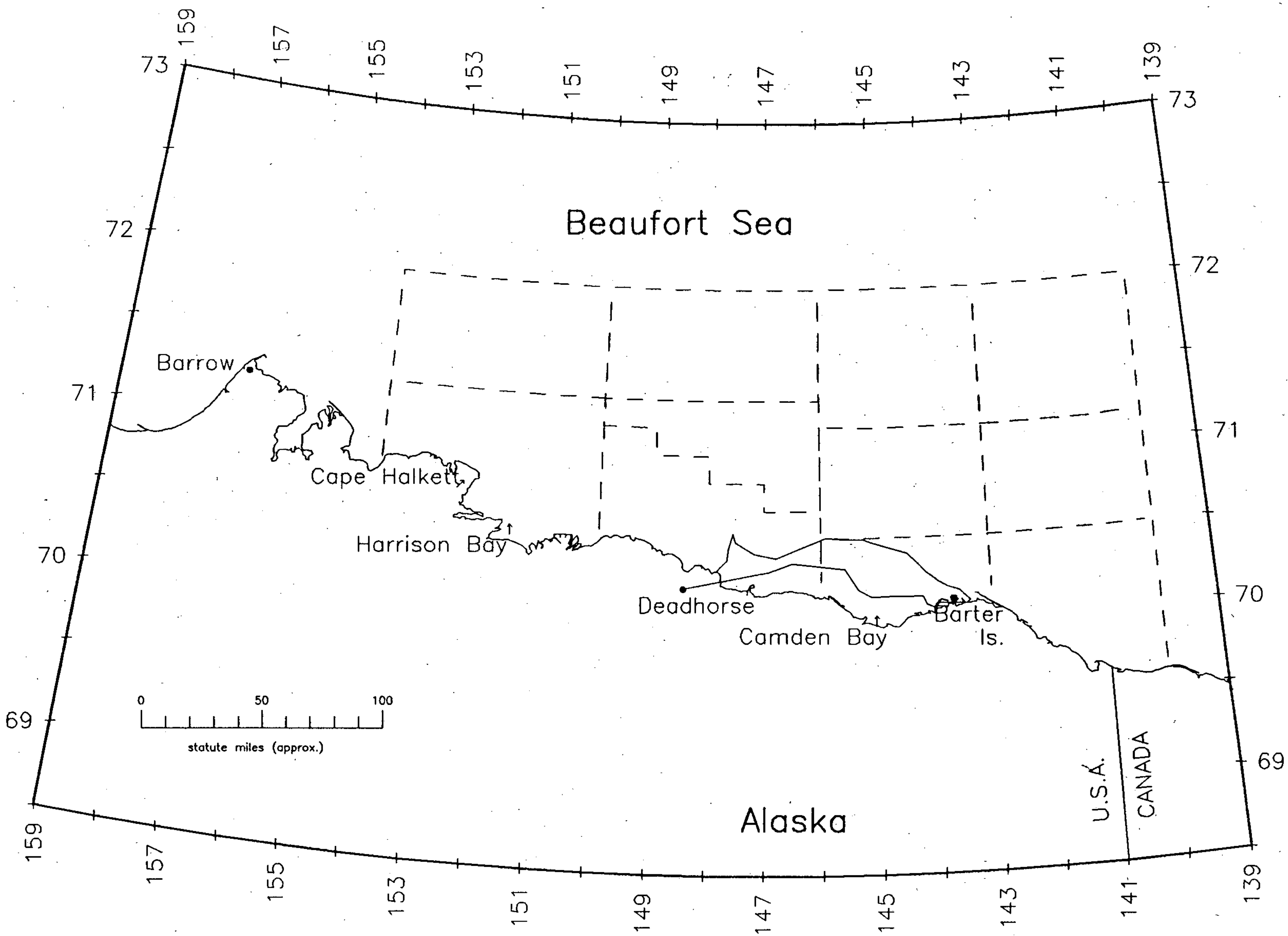
FLIGHT 27 13 OCTOBER 1989
Survey Track and Sightings



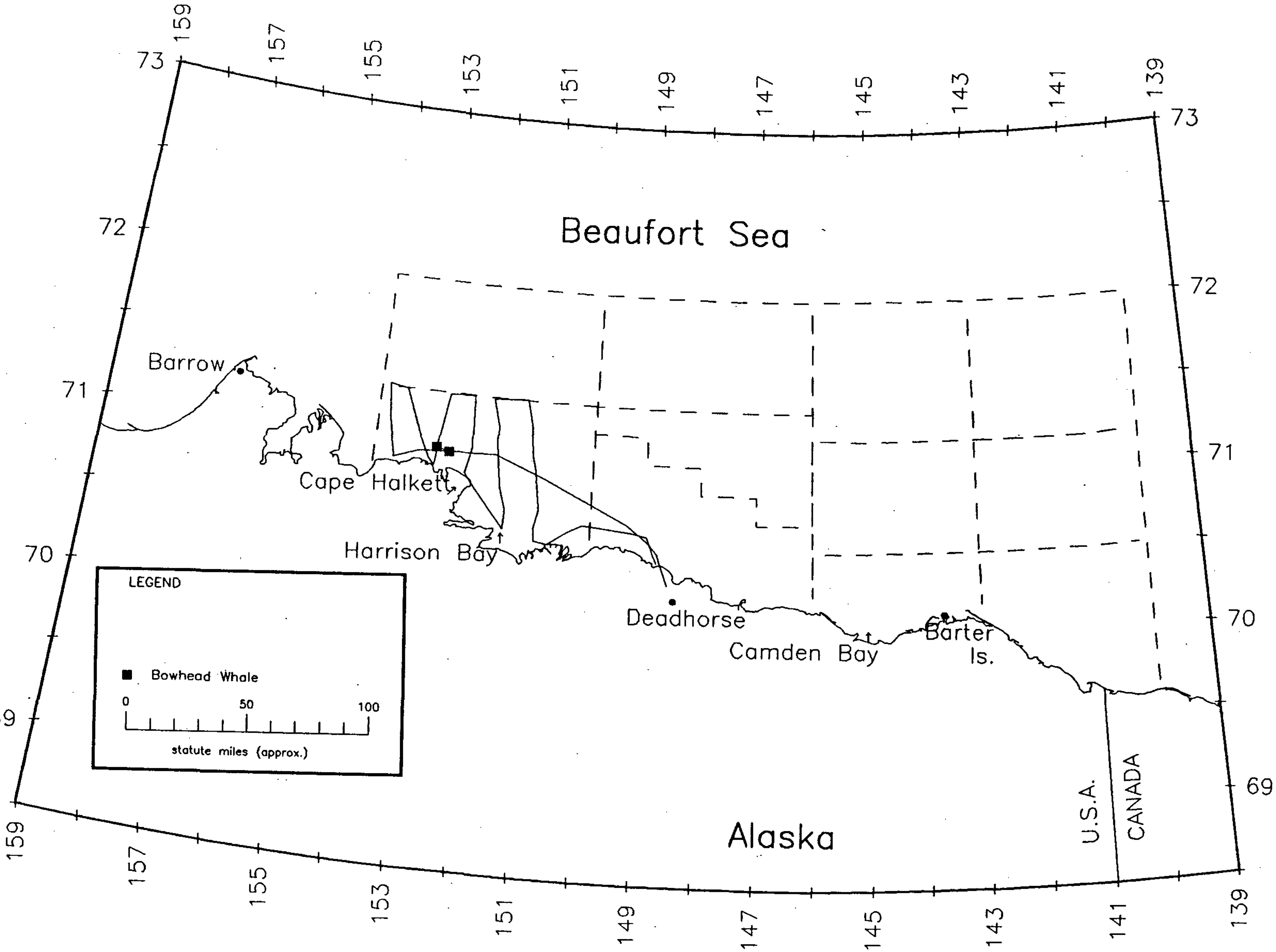
FLIGHT 28 15 OCTOBER 1989
Survey Track and Sightings



FLIGHT 29 17 October 1989
Survey Track and Sightings



FLIGHT 30 18 OCTOBER 1989
Survey Track and Sightings



FLIGHT 31 19 OCTOBER 1989
Survey Track and Sightings

APPENDIX C

COMPUTER SYSTEM IMPROVEMENTS

COMPUTER SYSTEM IMPROVEMENTS

By John Dunlap

For many years, the Minerals Management Service (MMS) endangered whale monitoring program has funded the use of onboard, computerized equipment to collect sighting and environmental data. This system, based on Hewlett Packard HP Series 80 computers, is described in reports for previous years. Following the Fall 1988 field season, the MMS Bowhead Whale Aerial Survey Project (BWASP) decided to redesign the data-collection and analysis system that had been used for the field portion of the study. The desire for increased reliability, speed, accuracy, and operator convenience as well as the desire to use more modern technology, motivated this conversion.

The new system was designed and tested during the spring and summer of 1989 and was successfully employed during the Fall 1989 field season. The new system proved highly reliable and the increased speed of data entry allowed the data recorder to spend significantly more time in observing the marine environment. Additional benefits of using modern computer equipment include greatly increased speed and accuracy in data analysis and the ability to analyze data in a wide variety of statistical, graphics, and database computer applications. This appendix describes the new system and how its implementation has affected the data-collection process and subsequent analysis. Changes to the data elements are also discussed.

An important criterion for the conversion to the new system was that only minimal changes be introduced into the data elements to allow direct comparison with the previous 10 years of data collected by this project. There are a few more data elements than were used in previous surveys, with some minor changes introduced primarily to clarify the data. Position and altitude information is still obtained directly from the aircraft instruments using a more modern interface to the computer.

The hardware system used on the aircraft consists of an International Business Machines (IBM)-compatible laptop computer, a small portable ink-jet printer, and an electrical signal converter (interface) for connection to the aircraft instruments. All of these items need 115 V AC power, which is supplied by a DC→AC inverter connected to the aircraft electrical bus.

Position information is supplied by a Global Navigation System (GNS) 500A VLF-Omega radio navigation system. Most navigation systems, such as LORAN, are of questionable reliability at low altitude in the Beaufort and Chukchi Seas; but the very-low-frequency radio navigation provided by the GNS 500A is usually accurate to within a few tenths of a mile. Longitude and latitude are available from the unit on an ARINC 429 bus. Altitude information is obtained as an analog signal from an onboard radar altimeter.

Electric signals from the GNS 500A and the radar altimeter are converted into an RS232 serial stream by an ARINC 429 to RS 232 interface built by AACO Incorporated of Renton, Washington. Data were polled from this unit every second. The GNS 500A is used for navigation during the survey, with transect-leg corners being entered as "way points" before and during flight. Other than its normal operation as a navigation instrument, no action is required by the operator to send navigation and altitude information to the data-recording computer. In the event of a system failure, the data recorder can read this information from the aircraft instrument panel and manually enter the information into the computer.

The computer used on this study is a Mitsubishi MP 286L. The following features add to its convenience:

1. The laptop design is far easier to transport than the previous larger model and probably more durable. Project computers must be removed from the plane after every flight, both to protect them from freezing and to use them for post-flight data analysis.

2. The LED, EGA screen is very easy to read while on the aircraft in a wide variety of weather conditions. It also allows graphic display of daily flight tracks and sightings.

3. A separate 10-key pad is easier to use than the number pads found on regular keyboard.

Hard-copy printouts of all collected data were printed on a Kodak Diconix 150 ink-jet printer. This unit performed very well with standard tractor-feed paper.

The method of collecting data while onboard the aircraft is basically the same as described in Section II.E. of this report, with the data recorder answering a series of questions relating to a particular sighting or location. The data-collection program runs throughout the flight but collects data only when initiated by the data recorder. Time of day is maintained by the computer and is recorded at each entry.

The data-collection software is designed to run on any IBM-compatible computer supporting serial communications. After some preliminary questions about the flight, the program presents its main menu. Greenwich Time, local time, latitude, longitude, and altitude as well as the full question list and the main menu selections are shown continuously. Selections from the main menu include:

F1 - This key initiates the data-collection sequence.

F3 - This key also initiates the data-collection sequence but copies position and environmental data from the previous entry. This key is used primarily when events occur nearly simultaneously, such as marking a corner and making a sighting. The data-collection scheme requires separate entries for each event.

F5 - This key involves an editor, which allows either viewing or changing of previous entries. This feature proved extremely useful during times when numerous sightings occurred because the data recorder could enter partial information for several entries, then return when more information was available.

F8 - This key prints text comments on the printed copy. This information was not stored on disk file.

F10 - The options menu allows toggling on or off of the printer and interface with exiting of the program.

When the F1 key is pressed, questions A through D (as labeled on the left side of screen on Fig. C-1) are collected through the interface; then the Reason For Entry screen is displayed. The response to this question and, if a sighting, the species question determine the questions that will be prompted by the computer. Responses are always entered as numbers from the keypad and are displayed as text next to the appropriate field. Questions yet to be answered are marked with an asterisk, and the program drops from one prompted question to the next. Although the questions are prompted in order down the screen, any question can be answered, skipped, or changed at any time during the entry sequence. Questions can be reached by means of the arrow keys or by pressing the corresponding letter on the keyboard. When all prompted questions have been answered or "x" has been pressed, the operator is queried to save the entry or not. Entries were sometimes abandoned when a suspected sighting proved to be false. An example of a bowhead whale sighting using the 1989 data-entry program is shown in Figure C-1.

Daily data analysis is performed by a program that provides summations of sightings and individuals for both bowhead whales and other species, plus calculation of time and distance on transect legs, connect legs, and general search portions of the flight. This information, along with other general information, is stored in a "header" in the data file for later retrieval. The analysis program provides the options for (1) editing the data file; (2) calculating and/or displaying the summary values; (3) printing of a flight synopsis, including sighting and a full data dump; and (4) reproducing part or all of the inflight printed record.

The format is a slightly enlarged version of that used previously. Questions on habitat, side of plane, and observer were added to clarify sighting information. A few questions were rearranged or expanded to add accuracy and to speed operator input. Table C-1 shows both the 1989 data-entry sequence and the questions prompted for various types of entries.

Table C-1
Data-Entry Sequence on the Portable Flight Computer

Sequence	Position Update	Large Whale Sightings	Polar Bear/ Belukha 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

ENTRY 8

A	Time(GMT)	18:46
B	Latitude	70°18.1
C	Longitude	142°06.6
D	Altitude	1673
E	Reason For Entry	Sight Search Survey
F	Species	Bowhead
G	Sighting Cue	Blow
H	Habitat	Open Water
I	Behavior	Swim
J	Size	Immature
K	Total Number	1
L	Calf Number	0
M	Clinometer Angle	8° Left
N	Swim Direction	98
O	Swim Speed	Medium - 1-3 knots
P	Aircraft Resp.	No
Q	Repeat Sighting	No
R	Observer	LL
S	Weather	Partly Cloudy
T	Visibility	L Unlimit R Unlimit
U	Ice	0% No Ice
V	Sea State	B2 Sm Waves
W	Water Color	Dark Blue

9/8/1989	FLT6.90
12:30:45 Local	
20:30:45 GMT	70°19.4'
	142°16.7'
INTERFACE ON	1604

Reason For Entry

0 : Flight Aborted
1 : Sight on Transect
2 : Sight off Transect
3 : Sight Search Survey
4 : Position - On Transect
5 : Position - On Connect
6 : Position - On Search
7 : Start Transect
8 : End Transect
9 : Divert Transect
10 : Resume Transect
11 : Deadhead
==>

Figure C-1. Example of a Bowhead Whale Sighting Using the 1989 Data Entry Program

An outline of the complete 1989 data-entry format, including all data-entry options, follows:

Time (hours and minutes)

Latitude (degrees, minutes, and tenths of minutes)

Longitude (degrees, minutes, and tenths of minutes)

Altitude (feet)

Reason For Entry

0: Flight Aborted	1: Sight On Transect	2: Sight Off Transect
3: Sight Search Survey	4: Position - On Transect	5: Position - On Connect
6: Position - On Search	7: Start Transect	8: End Transect
9: Divert Transect	10: Resume Transect	11: Deadhead

Search Type - corresponds to "Flag" field on HP system

1: On Transect	2: On Connect	3: On Search
4: N/A	5: Deadhead (over land or end of flight)	

Species

0: No Sighting	1: Bowhead Whale	2: Gray Whale
3: Belukha Whale	4: Walrus	5: Bearded Seal
6: Ringed Seal	7: Polar Bear	8: Unknown Cetacean
9: Unknown Pinniped	10: Orca Whale	11: Minke Whale
12: Fin Whale	13: Vessel	

Sighting Cue

0: No Cue	1: Splash	2: Blow
3: Body	4: Ice Tracks	5: Mud Plume
6: Birds or Fish	7: Kill Sight	8: Slick

Habitat

0: Open Water	1: Tide Rip	2: On Ice
3: On Land		

Behavior

0: Unknown	1: Dive	2: Rest
3: Swim	4: Mate	5: Feed
6: Mill	7: Spy Hop	8: Breach
9: Roll	10: Slap	11: Underwater Blow
12: Cow With Calf	13: Dead	14: Run
15: Thrash		

Size

0: Unknown	1: Calf of Year	2: Immature
3: Adult	4: Large Adult	5: Cow/Calf Pair

Total Number (individual animals)

Calf Number (total number of calves)

Clinometer Angle (degrees 0 - 90)

Side Of Plane

1: Right	2: Left

Swim Direction

Swim Speed

0: Unknown	1: Still - 0 knot (kt)	2: Slow - <1 kt
3: Medium - 1-3 kt	4: Fast - >3 kt	

Aircraft Response

1: Yes	2: No	3: Unknown

Repeat Sighting

1: Yes	2: No	3: Unknown

Observer (person making initial observation)

Weather

1: Clear	2: Partly Cloudy	3: Fog
4: Overcast	5: Precipitation	6: Low Ceiling
7: Haze	8: Glare	

Visibility Left

0: L 0 km	1: L <1 km	2: L 1-2 km
3: L 2-3 km	4: L 3-5 km	5: L 5-10 km
6: L Unlimited		

Visibility Right (same as above)

Ice Coverage (percent of surface covered by ice)

Ice Type

0: No Ice	1: Floe	2: Broken Floe
3: Pack	4: Pack/Floe	5: Grease/New
6: Shorefast	7: Lead	8: Broken Floe+New
9: New+Broken Floe		

Sea State

0: B0 Glassy <1 kt	1: B1 Light Ripples 1-3 kt	2: B2 Small Waves 4-6 kt
3: B3 Scattered Caps 7-10kt	4: B4 Numerous Caps 11-16 kt	5: B5 Many Caps 17-21 kt
6: B6 All Caps 22-27 kt	7: B7 Breaking Waves 28-33 kt	8: B8 Foam 34-40 kt
9: Not Applicable		

Water Color

0: Not Applicable	1: Light Blue	2: Dark Blue
3: Light Green	4: Dark Green	5: Black
6: Muddy	7: Tideline	

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GLOSSARY OF ACRONYMS, INITIALISMS, AND ABBREVIATIONS

BLM	Bureau of Land Management
C	Celsius
CI	confidence interval
cm	centimeter
EIS	environmental impact statement
ESA	Endangered Species Act
GNS	Global Navigation System
hr	hour
HP	Hewlett-Packard
km	kilometer
kt	knot
m	meter
MMS	Minerals Management Service
NOAA	National Oceanic and Atmospheric Administration
NOSC	Naval Ocean Systems Center
NMFS	National Marine Fisheries Service
nm	nautical miles
OAS	Office of Aircraft Services
OCS	Outer Continental Shelf
OCSEAP	Outer Continental Shelf Environmental Assessment Program
OCSLA	Outer Continental Shelf Lands Act
SD	standard deviation
SPUE	sightings per unit effort (number of whale sightings counted per hour)
USDOC	U.S. Department of Commerce
USDOD	U.S. Department of Defense
USDOI	U.S. Department of the Interior
USGS	U.S. Geological Survey
WPUE	whales per unit effort (number of whales counted per hour)

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 the wisest use of our land and water resources, protecting our fish and wildlife, 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 assure that their development is in the best interest of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. Administration.