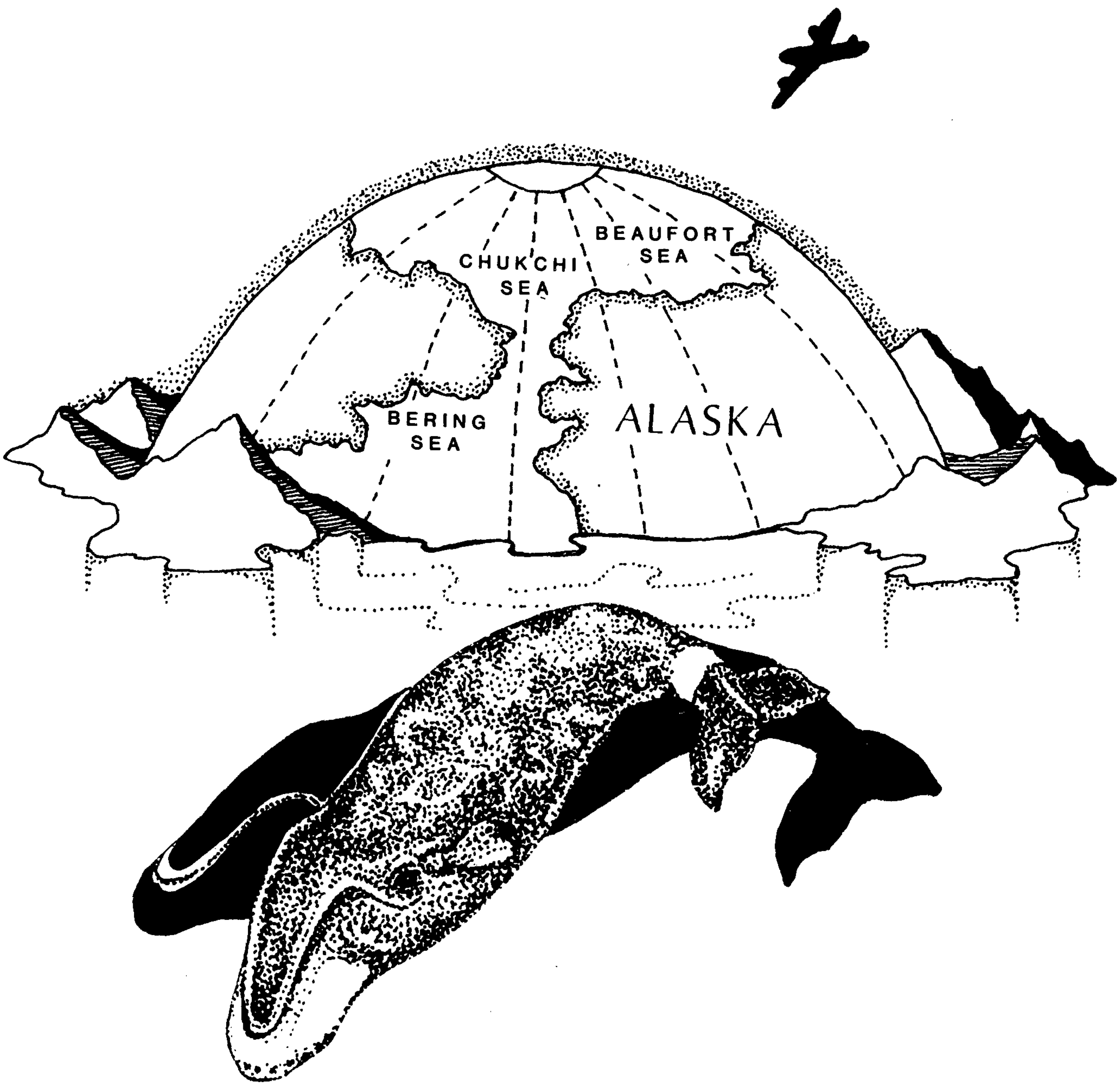
Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 1991

OCS Study
MMS 92-0017



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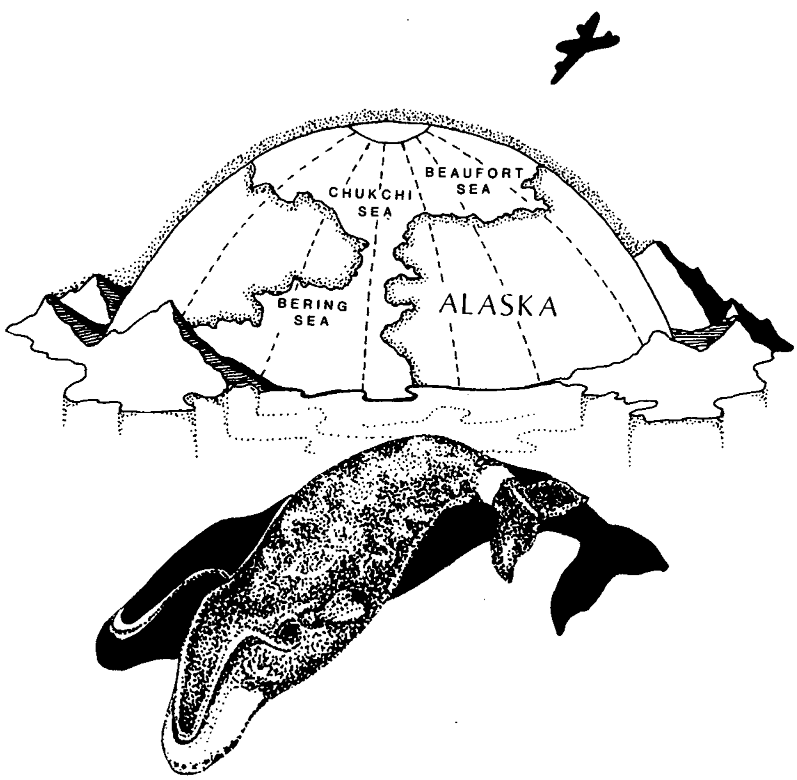
By Stephen D. Treacy, Project Manager
MMS Bowhead Whale Aerial Survey



U.S. Department of the Interior
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Anchorage, Alaska
1992

ABSTRACT

This report describes field activities and data analyses for aerial surveys of bowhead whales conducted between 31 August 1991 and 20 October 1991 in the Beaufort Sea, primarily between 140°W. and 154°W. longitudes south of 72°N. latitude. General ice cover during September and October 1991 was very heavy, limiting the counts of marine mammals. A total of 69 bowhead whales, 63 belukha whales, 6 bearded seals, 2 ringed seals, and 8 unidentified pinnipeds were observed in 1991 during 79.48 hours of survey effort that included 31.43 hours on randomized transects. The initial sighting of bowhead whales in Alaskan waters occurred on 16 September 1991. Half (median) of the total bowheads observed had been counted by 19 September. The peak count (mode) of 33 bowhead whales also occurred on 19 September 1991, in waters east of 138°W. longitude. The last sighting of a bowhead whale made during this survey occurred in 5-percent ice on 4 October 1991. Estimated median and mean ($\bar{x}$) water depths at the location of bowhead whales sighted on randomized line transects in 1991, 66.0 meters and 129.2 meters, respectively, are consistent with a previously noted trend for whales to be located in deeper water during years of heavy ice cover.

ACKNOWLEDGMENTS

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I. INTRODUCTION

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

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

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

In June 1978, BLM entered into an ESA Section 7 consultation with the National Marine Fisheries Service (NMFS). The purpose of the consultation was to determine the likely effects of the proposed Beaufort Sea Oil and Gas Lease Sale on endangered bowhead (*Balaena mysticetus*) and gray (*Eschrichtius robustus*) whales. After reviewing available information on the two species, NMFS determined that insufficient information existed to conclude whether the proposed Beaufort Sea sale was or was not likely to jeopardize the continued existence of bowhead and gray whales. In August 1978, NMFS recommended studies to BLM that would fill the information needs identified during the Section 7 consultation. Subsequent biological opinions for Arctic Region sales--including a regional biological opinion; a revised opinion relative to the joint Federal/State lease area; and opinions on Sales 71 (issued in 1982), 87 (issued in 1983), 97 (issued in 1987), and Arctic Region Sales (issued in 1988)--recommended continuing studies of whale distribution and OCS-industry effects on bowhead whales (USDOC, NOAA, NMFS, 1982, 1983, 1987, 1988). These opinions also requested monitoring of bowhead whale presence during periods when geophysical exploration and drilling may be occurring.

Following several years when drilling was limited to the period 1 November through 31 March (USDOI, MMS, 1979), a variable 2-month seasonal-drilling restriction on fall exploratory activity in the joint Federal/State Beaufort Sea sale area was implemented. The period of restriction would vary depending on bowhead whale presence, and "this determination would require development of a monitoring program..." (USDOI, MMS, 1982). Subsequently, MMS (Alaska OCS Region) adopted an endangered whale-monitoring plan that required aerial surveys. The Diapir Field Sale 87 Notice of Sale (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) and Beaufort Sea Sale 124 Notice of Sale (1991) do not contain a seasonal offshore-drilling restriction but state that "MMS intends to continue its areawide endangered whale monitoring program in the Beaufort Sea during exploration activities. The program will gather information on whale distribution and abundance patterns and will provide additional assistance to determine the extent, if any, of adverse effects to the species" (USDOI, MMS, 1988, 1991).

From 1979 to 1987, the MMS (formerly BLM) funded annual monitoring of endangered whales in arctic waters under Interagency Agreements with the Naval Ocean Systems Center (NOSC) and through subcontracts to SEACO, Inc. On 15 April 1987, a proposal for MMS scientists to conduct aerial surveys of endangered whales was approved by the Associate Director for Offshore Minerals Management. The MMS uses agency personnel to perform field work and reporting activities for the Beaufort Sea on an annual basis. A concurrent study, conducted by Science Applications International Corporation, Maritime Services Division, under contract to MMS in 1991 (Moore and Clarke, In Prep), employs identical aerial-survey and data-analysis methodologies to monitor whales in arctic waters west of 154°W. longitude. 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 program for monitoring endangered whales are to:

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

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

3. Provide annual analyses of long-term interyear trends in the median depth (or north-south positioning) of the migration axis of bowhead whales;

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

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

II. METHODS AND MATERIALS

A. Study Area

The annual survey program is based on a design of random field transects within established geographic blocks in and adjacent to Chukchi and Beaufort Sea sale areas offshore of Alaska. The present study, which was focused on the bowhead whale migration from 31 August 1991 to 20 October 1991, 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, with mean temperatures at the Alaskan Beaufort Sea coast communities of Barrow, Lonely, Oliktok, and Barter Island from -0.9°C to -0.1°C during September and -9.7°C to -8.5°C during October. Precipitation in these communities occurred an average of 10 to 34 percent of the time during September (snow with some rain) and 13 to 43 percent during October (almost all snow), with the heaviest precipitation at Barrow and Barter Island during both months. Fog (without precipitation) reduces visibility approximately 11 to 19 percent of the time during September and 6 to 8 percent of the time during October. Mean windspeed in the same communities is from 5 to 6 m per second during September and 5 to 7 m per second during October (Brower et al., 1988).

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

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

B. Equipment

The survey aircraft was a de Havilland Twin Otter Series 300 N301EH. The aircraft was equipped with medium-size bubble windows aft that afforded complete trackline viewing for a port observer and a starboard data recorder-observer. A third observer-navigator occupied the copilot seat, which provided good forward and side viewing. Each observer was issued a hand-held clinometer (Suunto) for measuring

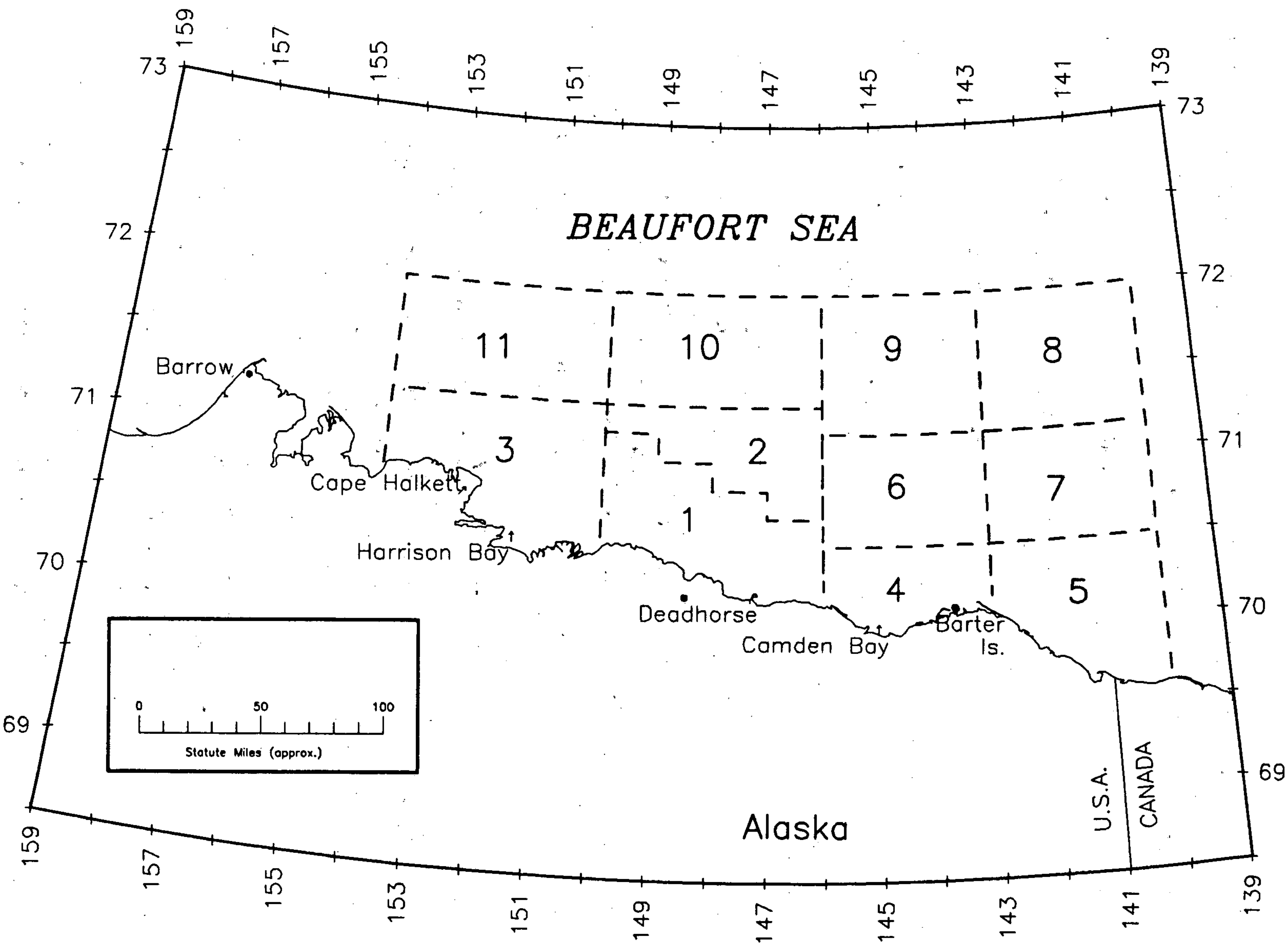


Figure 1. Fall 1991 Study Area Showing Survey Blocks

the angle of inclination to the sighting location of endangered whales. Observers and pilots were linked to common communication systems, and commentary could be recorded. The aircraft's maximum time aloft under normal survey load was extended to approximately 6.5 hours (hr) through the use of a supplemental onboard fuel tank.

Avionics included a Global Navigation System (GNS) 500A. This very low-frequency Omega system provided continuous position updating (0.6-km/hr precision) and survey navigation through preprogramming of transect start and end points. Electric signals from the GNS 500A and the radar altimeter were converted into an RS 232 serial stream by an ARINC 429 to RS 232 interface (AACO Incorporated). Data were polled from this unit every second for automatic input of time, latitude, and longitude and from the radar altimeter for analog input of flight altitude. In the event of a system failure, the data recorder could read this information from the aircraft instrument panel and manually enter the information into the computer. System components required 115-volt alternating current (AC) power, which was supplied by a direct current→AC invertor connected to the aircraft electrical bus.

A portable Mitsubishi MP 286L computing system was used aboard the aircraft to store and analyze flight and observational data. A small, portable Kodak Diconix 150 Plus inkjet printer was used to produce tractor-fed hard copy and to plot onboard flight maps.

Onboard safety equipment included an impact-triggered emergency location transmitter (ELT) installed in the aircraft, a portable ELT in a 6-person Switlik Search and Rescue Life Raft, a portable aircraft-band transceiver, flotation suits, Nomex flightsuits, and emergency crash helmets.

Flight-following equipment included the onboard very high-frequency aircraft-band radio, which was used to transmit position data to Deadhorse Flight Service when entering a new survey block and, if possible, when ending southbound transect lines. The onboard high-frequency radio was used to transmit hourly position data to OAS Flight Operations, Anchorage. The onboard transponder was set at a discrete identification code for radar tracking by air-traffic-control personnel.

C. Aerial-Survey Design

Aerial surveys were based out of Deadhorse, Alaska, from 31 August to 20 October 1991. The field schedule was designed to monitor the progress of the Fall 1991 bowhead migration across the Alaskan Beaufort Sea. All bowhead (and belukha) whales observed were recorded, along with incidental sightings of other marine mammals. Particular emphasis was placed on regional surveys to assess fine-scale shifts in the migration pathway of bowhead whales in this area and on the coordination of effort and management of data necessary to support seasonal offshore-drilling regulations.

Daily flight patterns were based on sets of unique transect grids produced for each survey block. Transect grids were derived by dividing each survey block into sections 30 minutes of longitude across. One of the minute marks along the northern edge of each section was selected at random to designate one end of a transect leg. The other endpoint of the transect leg was determined similarly using a separate randomly generated number along the southern edge of the same section. A straight line, representing one transect leg, was drawn between the two points. The same procedure was followed for all sections of the survey block. Transect legs were then connected alternately at their northernmost or southernmost ends to produce one continuous flight grid within each survey block. The use of random-transect grids is a requirement for later analyses of median water depths at bowhead sightings based on line-transect theory (Cochran, 1963) and analyses of absolute densities based on strip-transect theory (Estes and Gilbert, 1978).

The selection of the survey blocks to be flown on a given day was nonrandom, based primarily on criteria such as reported or observed weather conditions over the study area, the level of offshore oil industry activity in various areas, and a semimonthly flight-hour goal for each survey block. Flight-hour goals were allocated proportionately for survey blocks and semimonthly time periods based on relative abundance of bowhead whales as determined from earlier fall migrations (1979-1986). Such allocations greatly favor survey coverage in inshore Survey Blocks 1 through 7 and 11 (Fig. 1), since bowheads were rarely sighted north of these blocks in previous surveys. The purpose of these survey-effort allocations was to increase the sample size (n) of whale sightings within the primary migration corridor, thus increasing the power of statistical analysis within these inshore blocks.

Random-transect legs were used for obtaining data to analyze the migration axis, using a line-transect model, and to estimate whale density, using a strip-transect model. Nonrandom surveys were flown to further identify whales and their behaviors when sighted adjacent to a transect line or when in transit to a transect block. Data from nonrandom surveys were considered combinable with random-transect data to obtain behaviors and general 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 clinometer was used to measure the angle of inclination to each initial sighting of endangered whales when the sighting location (or whale-dive site) was abeam of the aircraft.

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

E. Data Entry

A computer program developed by project personnel was used to record all data. Time of day was maintained by the computer and recorded at each entry. Greenwich Time, local time, latitude, longitude, and altitude as well as a question list and the main menu selections were shown continuously on the computer monitor. The program is menu-driven, facilitating entry of a complete data sequence for sightings of endangered whales. An abbreviated data-entry format was available whenever several whale pods were sighted within a short period of time. To avoid lumping of sightings in areas where whales were extremely concentrated, an even shorter rapid-sighting update was used. A position-update format including data on weather, visibility, ice cover, and sea state was entered at turning points, when changes in environmental conditions were observed, and otherwise within 10-minute intervals. All entries were coded to reflect the type of survey being conducted. Table 1 shows the data-entry sequence used in 1991 and the questions used to prompt entry of observational data. All data entered were simultaneously printed out in hard copy.

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

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

Table 1
Data-Entry Sequence on the Portable Flight Computer

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

Table 2
Operational Definitions of Observed Whale Behaviors

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

F. General Data Analyses

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

Application software (Grapher, Golden Software, Inc.) was used to plot daily maps of aircraft tracklines and positions of marine mammals observed. To function as a mapping package, coastlines were mapped using an Altec digitizer and all points on the maps were based on number of meters north or to one side of a central meridian for Universal Transverse Mercator Zone 6. Observed bowhead distribution was plotted semimonthly over the Beaufort Sea study area. September-October sightings of belukha whales, ringed and bearded seals, and other marine mammals were depicted on separate maps. Maps in this report were plotted on a Hewlett-Packard (HP) Laser Jet II printer equipped with an HP 7475A plotter emulator cartridge.

Ice concentrations in the Beaufort Sea were digitized or hand-drafted as either 0-percent, 0- to 25-percent, 26- to 50-percent, 51- to 75-percent, or 76- to 100-percent ice cover from U.S. Navy-NOAA Joint Ice Center Southern Ice Limit charts. These charts were available for every seventh day from 27 August through 22 October 1991.

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 1991 bowhead migration through the study area was analyzed as sightings per unit effort (SPUE = number of sightings counted/hr of survey effort) and WPUE per date. Because chance sightings of a few large groups of whales in a short period of time might produce artificially high WPUE values in certain blocks, values based on at least 4.00 hr of survey effort were distinguished when discussing relative abundance between areas.

All whale sightings were entered into the distribution and relative-abundance analyses, regardless of the type of survey leg being conducted or the prevailing environmental conditions (sea state, ice cover, etc.) 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 group headings was analyzed using Rayleigh's test (Batschelet, 1972) for all pods, excluding those that were resting, sleeping, or milling. Probabilities were interpolated from alpha values shown for calculated critical values of Rayleigh's z (Zar, 1984: Table B.32). Additional statistical comparisons, correlations, and regressions (Zar, 1984) were performed as appropriate.

Raw density estimates were calculated using a computer program--DENSITY--and are presented only for relative comparison with similar values from previous survey reports. The program was based on strip-transect-analyses methods using only sightings made on random-transect legs (Estes and Gilbert, 1978). Density estimates were derived by survey block and are presented, with a description of density-estimate methodologies, in Appendix A.

The water depth at each bowhead sighting in the 1982-1991 database was derived using a computer program--DEPTH--that assigned a metric depth value averaged over gridded areas (each 5.6 km^2) in the Beaufort Sea west of 139°W. longitude and south of 72°N. latitude. Values assigned to each grid block were subjective and were averaged from depths read from NOAA Provisional Chart 16004.

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 was initially described in Chapters 4.2.3 and 5.3.3 of "Beaufort Sea Monitoring Program Workshop Synthesis and Sampling Design Recommendations" (Houghton, Segar, and Zeh, 1984). The null hypotheses tested via median-depth analysis were prescribed in Houghton, Segar, and Zeh (1984) as:

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

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

To define the migration axis, a separate file was created for bowhead whale sightings made while on random transects, regardless of distance from the transect line. The Beaufort Sea was divided into three regions in order to analyze east-west components of the known fall-migration corridor. Region I was delimited by 150°W. and 153°30′W. longitudes, south of 72°N. latitude. Region II was between 146°W. and 150°W. longitudes south of 71°20′N. latitude. Region III was between 141°W. and 146°W. longitudes, south of 71°10′N. latitude (Fig. 2). Because of the bathymetry of the Alaskan Beaufort Sea, a seaward displacement of the fall-migration route would be represented, via this analysis, as a shift to a deeper median depth. Selected isobaths (20 m, 40 m, 100 m, 400 m, 1,000 m, 2,000 m, and 3,000 m), after a Beaufort Sea Planning Area Map (USDOI, MMS, 1985), are included for general reference (Fig. 2).

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

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

The NEWSTAT program employed the Mann-Whitney U test to address the question of potential fine-scale shifts in the axis of the bowhead whale fall-migration route. The Mann-Whitney U test is a nonparametric procedure performed on ranked samples (Zar, 1984). A series of Mann-Whitney paired comparisons were made on annual depth values, with each year compared to all others such that annual and/or interannual shifts in migration route from 1982 to 1991 could be evaluated. Similar paired comparisons were made by region (I, II, and III) such that annual variations or potential shifts in median depth could be assessed for these smaller areas. Probabilities were interpolated from alpha values shown for calculated critical values of the Mann-Whitney U distribution (Zar, 1984: Table B.10).

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

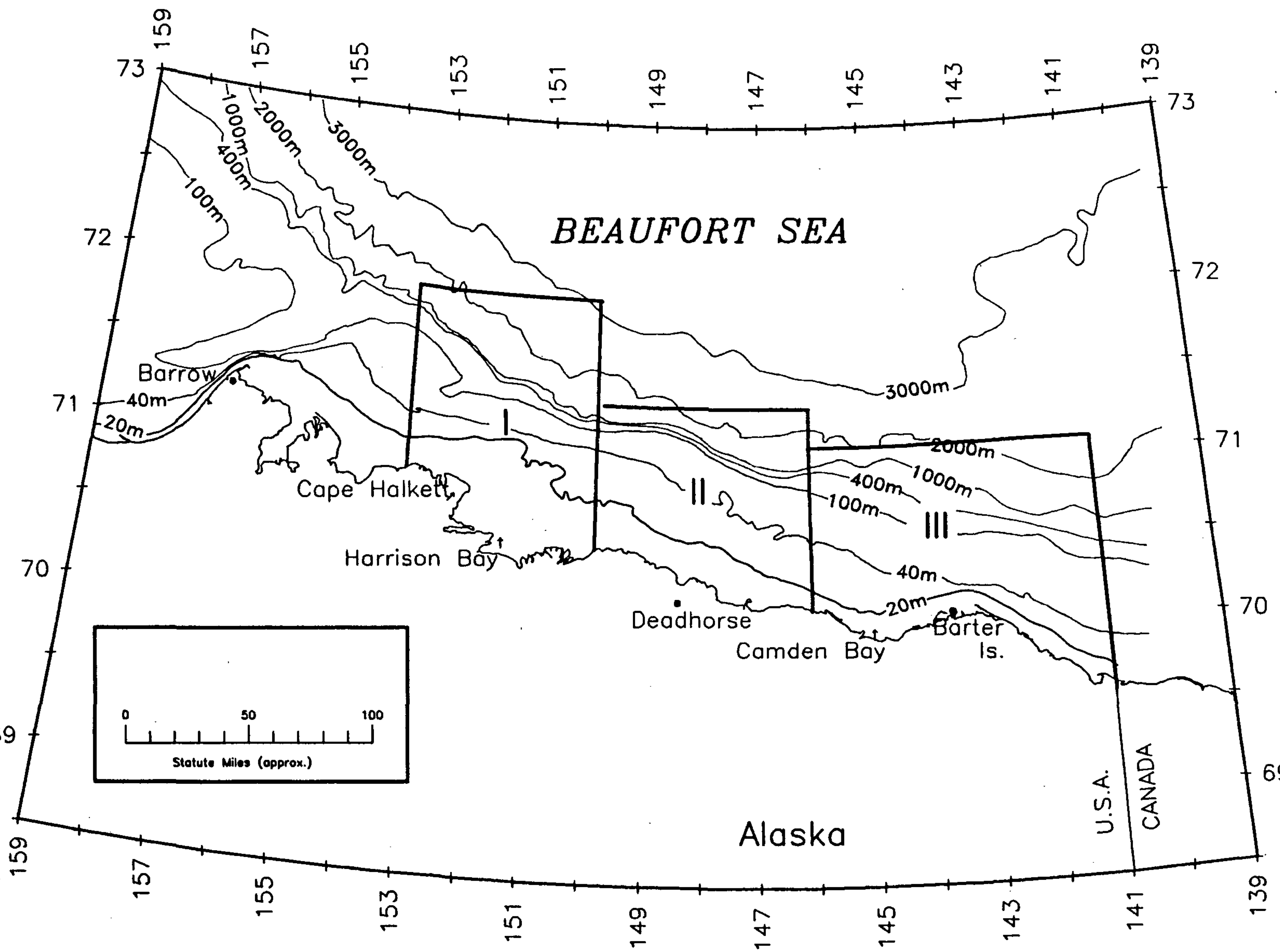


Figure 2. Regions I, II, and III (used in median-water-depth analyses) and Selected Isobaths

III. RESULTS

A. Environmental Conditions

General ice coverage in the Alaskan Beaufort Sea was very heavy during the Fall 1991 surveys (Figs. 3-11). The nearshore area opened up following a period of increased northeast winds on 14 and 15 September 1991. By early October, ice concentrations increased near shore, with higher proportions of new ice observed during survey flights. The general ice severity during Fall 1991, especially broken floe ice, may have reduced the ability of observers to spot whales near the surface or at great distances from the transect centerline. Ice percent and sea state at each sighting of endangered whales are shown in Appendix B (Table B-1).

Cloud ceilings over the study area were often lower than the target-survey altitude of 458 m and the 305-m altitude recommended by NMFS to avoid disturbance to whales.

B. Survey Effort

Daily totals of kilometers and hours flown per survey flight are shown in Table 3. A total of 18,954 km of surveys were flown in 79.48 hours (Table 3) in the Beaufort Sea at an average speed of 238.5 km/hr. A total of 7,532 km of random-transect lines were flown in 31.43 hours (Table 3) at an average speed of 239.6 km/hr. These random transects constituted 39.7 percent of the total kilometers flown and 39.5 percent of the total flight hours. The number of flight hours over each survey block is shown in subsequent analyses.

Day-to-day flight tracks are shown in Appendix B. Survey flight lines are summarized by semimonthly period in Figures 12 through 16.

On 31 August, one flight was made between Deadhorse and 140°W. longitude (Fig. 12) to record the initial part of the westward migration of the bowhead whale. There were 1.90 hours of random transects flown from 4.45 total flight hours on this day (Table 3), constituting 6.0 percent and 5.6 percent, respectively, of the total Fall-1991 study effort for those categories.

During the first half of September, flight effort was limited to three survey blocks between 143°W. and 150°W. longitudes, south of 71°20′N. latitude (Fig. 13), due primarily to unacceptable survey conditions. There were 4.62 hours of random transects flown from a total of 10.59 flight hours during this period (Table 3), constituting 14.7 percent and 13.3 percent, respectively, of the total fall effort for those categories.

During the second half of September, survey coverage extended from Harrison Bay, Alaska, to Canadian waters, mostly south of 71°20′N. latitude (Fig. 14). There were 7.60 hours of random transects flown from 23.57 total flight hours during this period (Table 3), constituting 24.2 percent and 29.7 percent, respectively, of the total fall effort for those categories.

During the first half of October, survey coverage extended across the primary study area, with some effort in each of the survey blocks (Fig. 15). A flight on 14 October included survey coverage in Canadian waters east of 140°W. longitude (Appendix B: Flight 24). There were 17.32 hours of random transects flown from 40.25 total flight hours during this period (Table 3), constituting 55.1 percent and 50.6 percent, respectively, of the total fall effort for those categories.

From 16 through 20 October, one search flight was made (18 October) near the northwestern corner of the primary study area (Fig. 16). Transit time to and from the search area consisted of deadhead flight (whales were not looked for) at high altitudes. There were 0.00 hours of random transects flown from 0.63 total flight hours during this period (Table 3), constituting 0.0 percent and 0.8 percent, respectively, of the total fall effort for those categories.

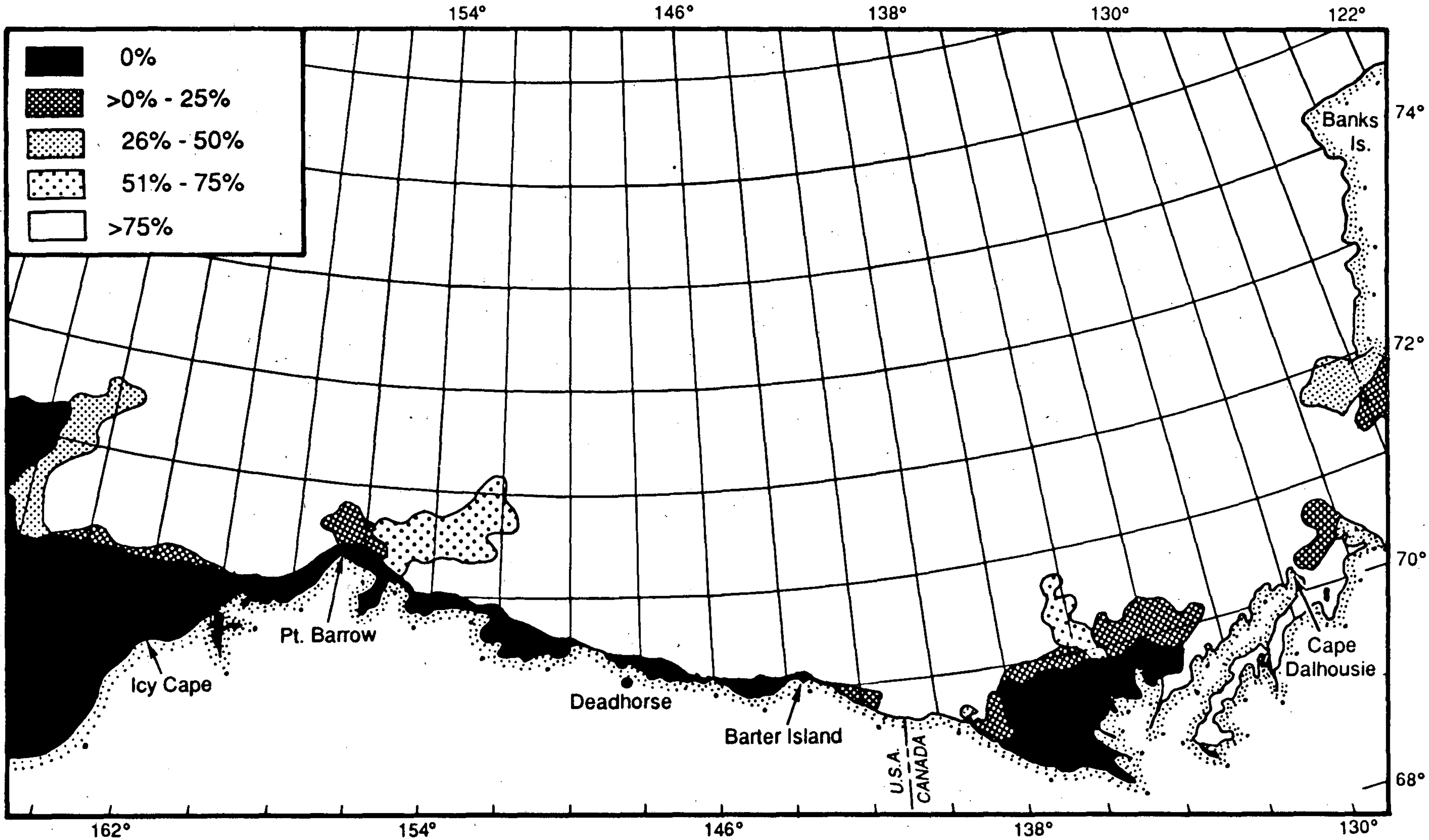


Figure 3. Map of Ice Concentrations in the Beaufort Sea, 27 August 1991

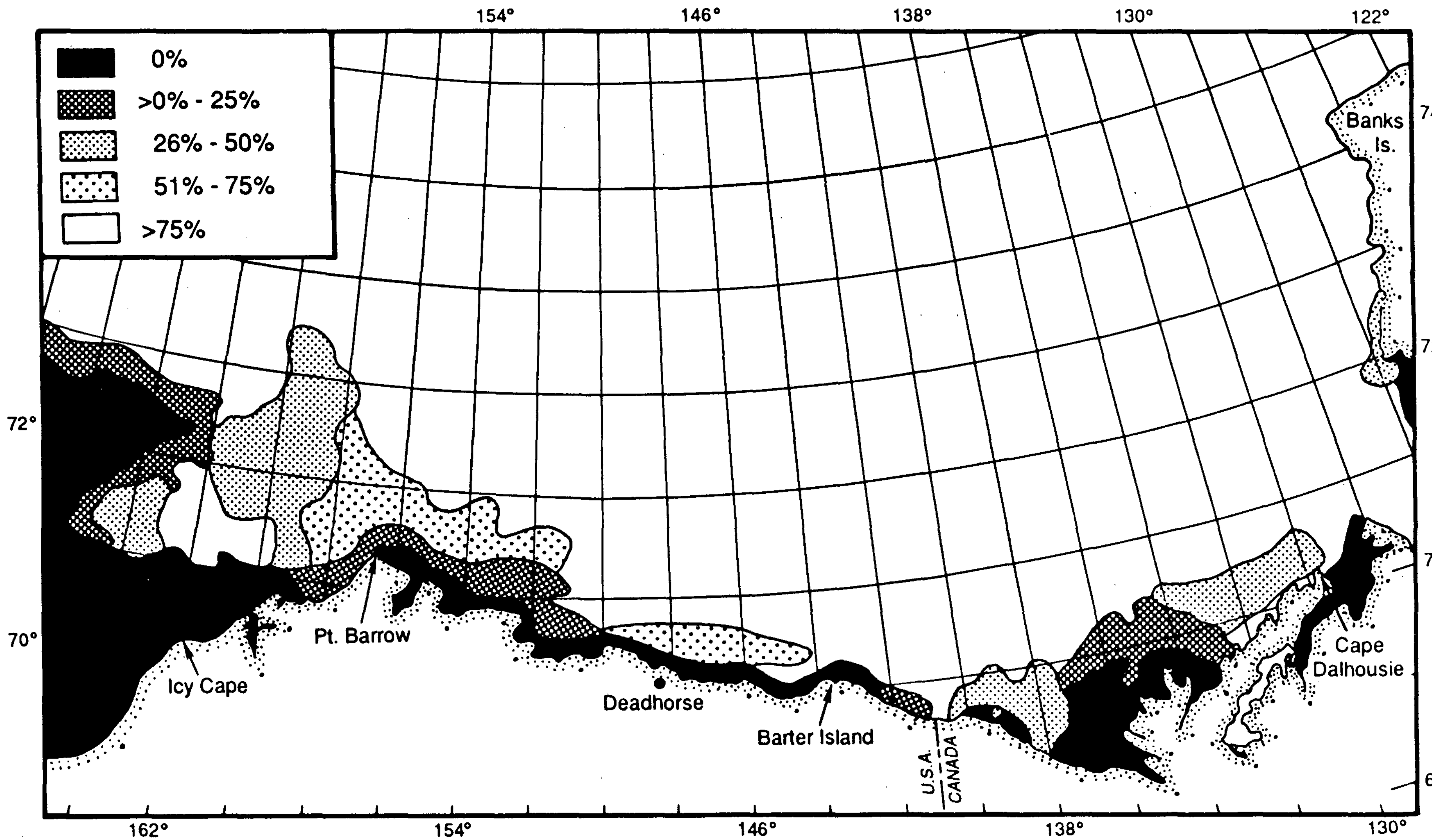


Figure 4. Map of Ice Concentrations in the Beaufort Sea, 3 September 1991

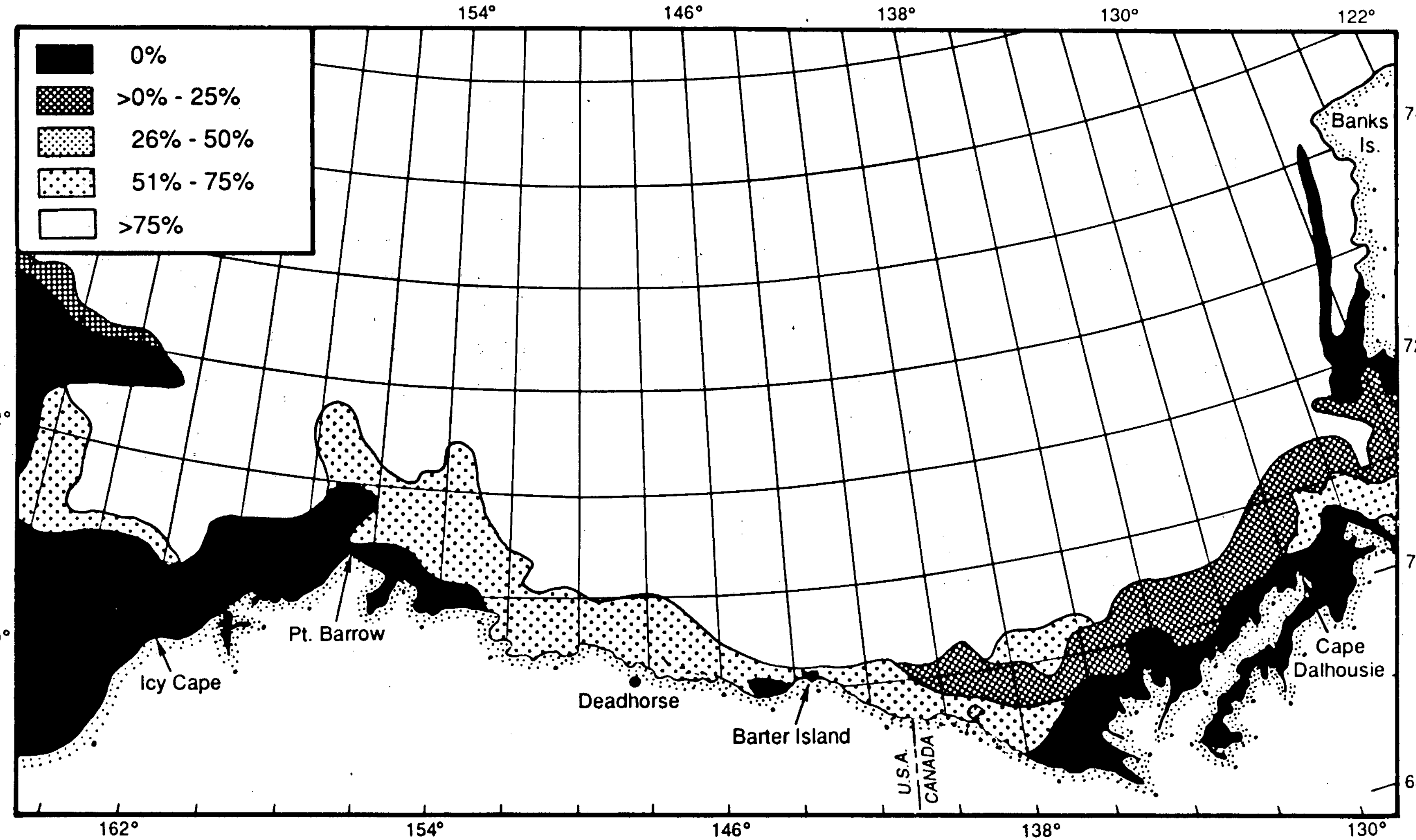


Figure 5. Map of Ice Concentrations in the Beaufort Sea, 10 September 1991

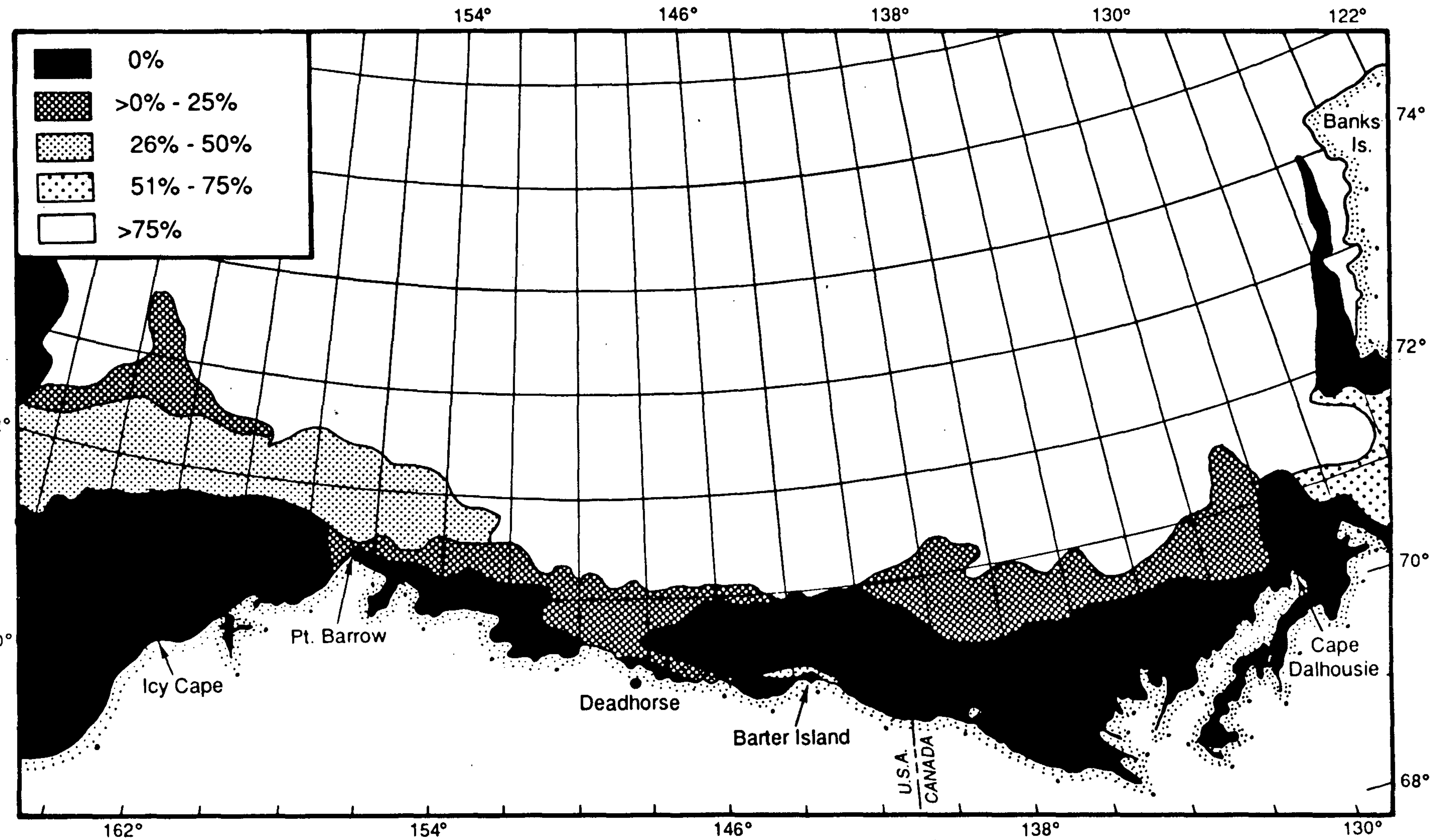


Figure 6. Map of Ice Concentrations in the Beaufort Sea, 17 September 1991

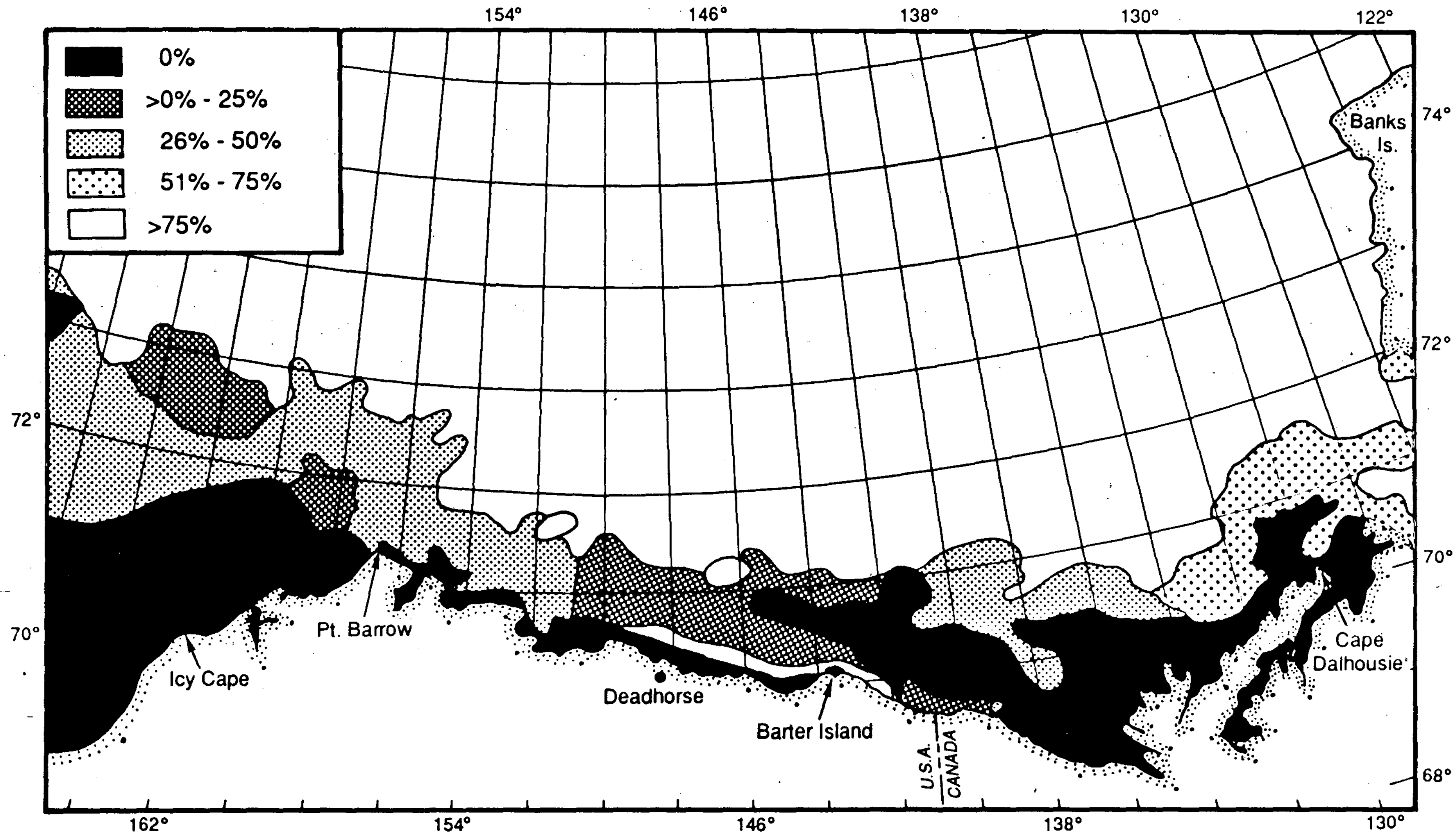


Figure 7. Map of Ice Concentrations in the Beaufort Sea, 24 September 1991

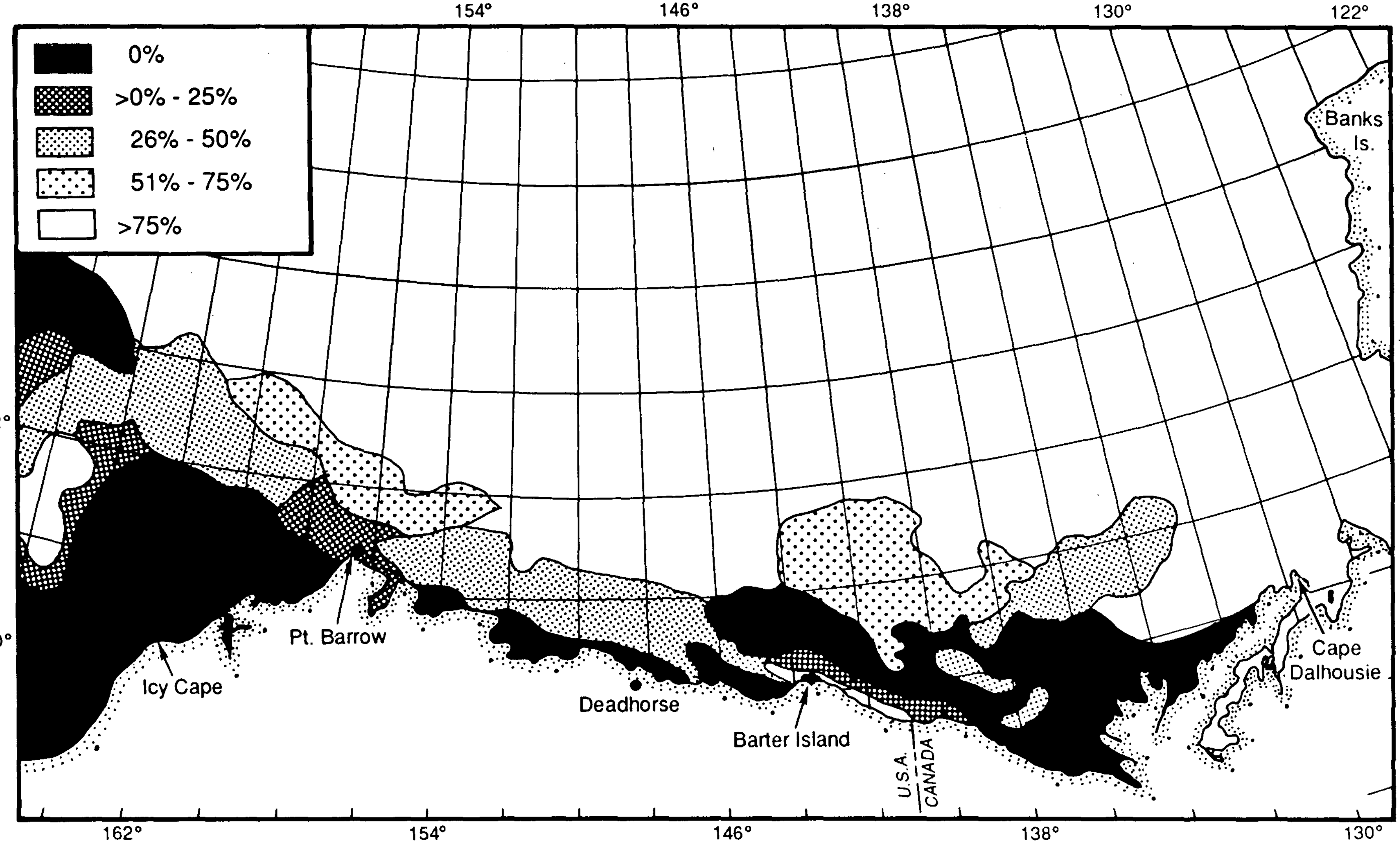


Figure 8. Map of Ice Concentrations in the Beaufort Sea, 1 October 1991

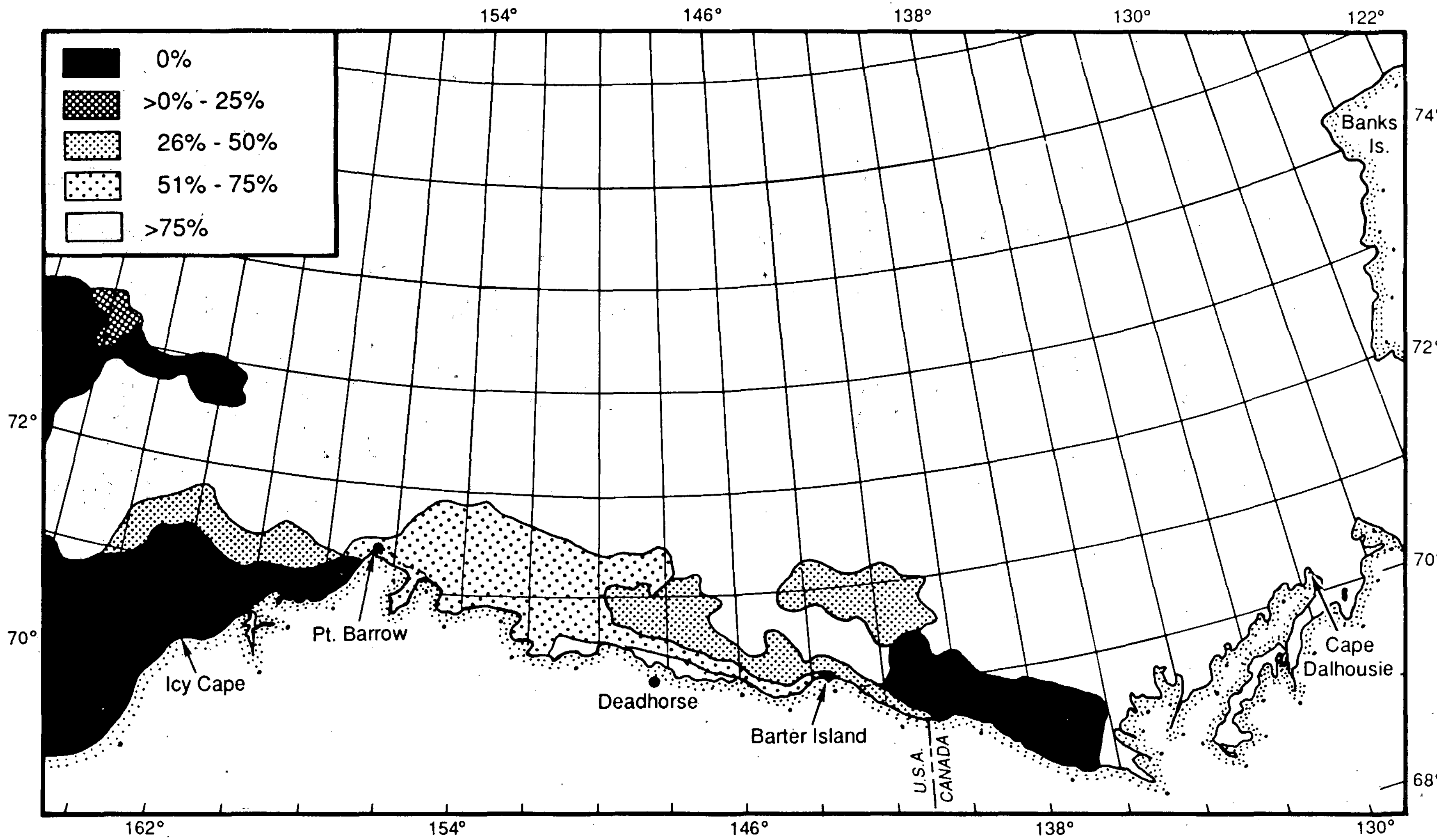


Figure 9. Map of Ice Concentrations in the Beaufort Sea, 8 October 1991

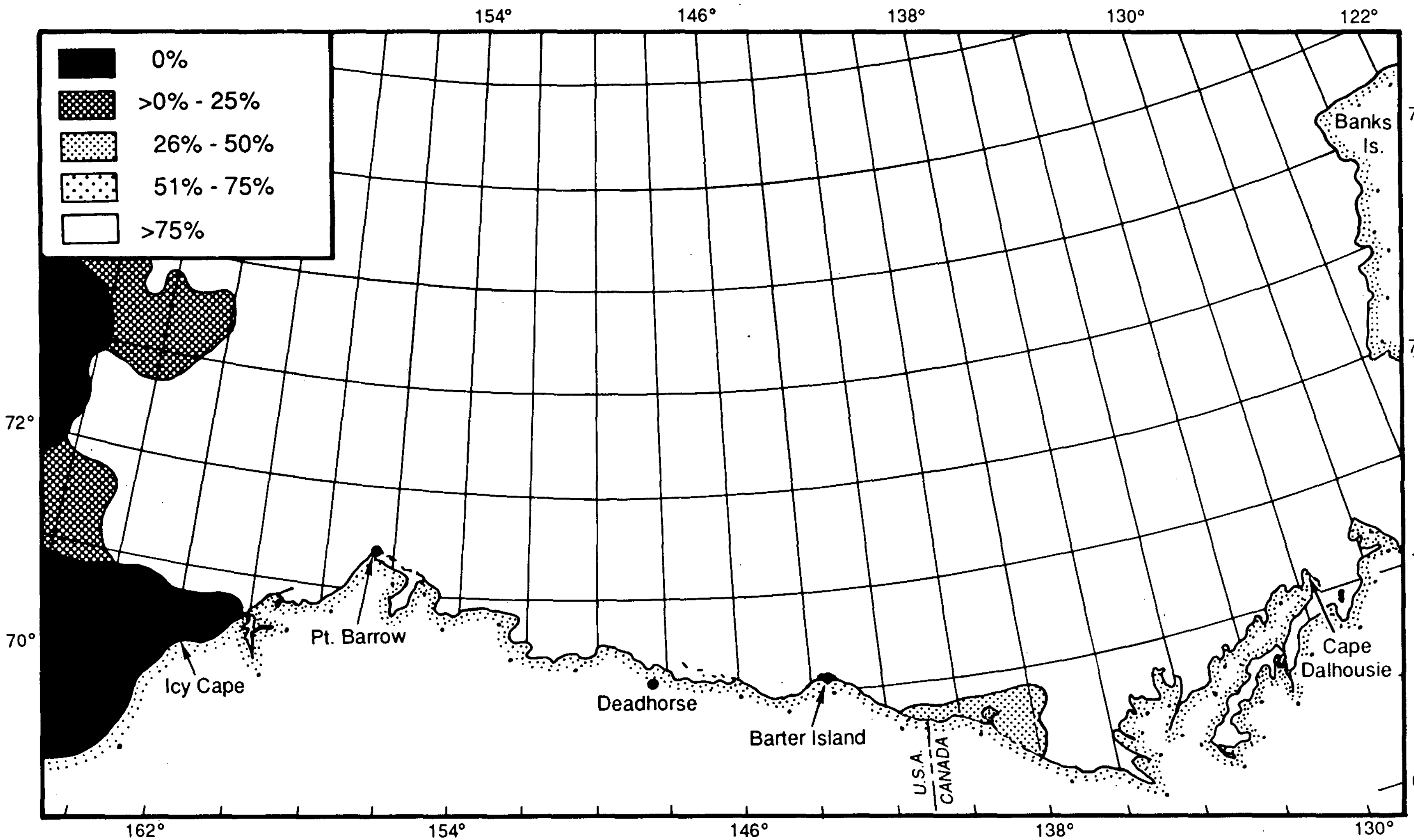


Figure 10. Map of Ice Concentrations in the Beaufort Sea, 15 October 1991

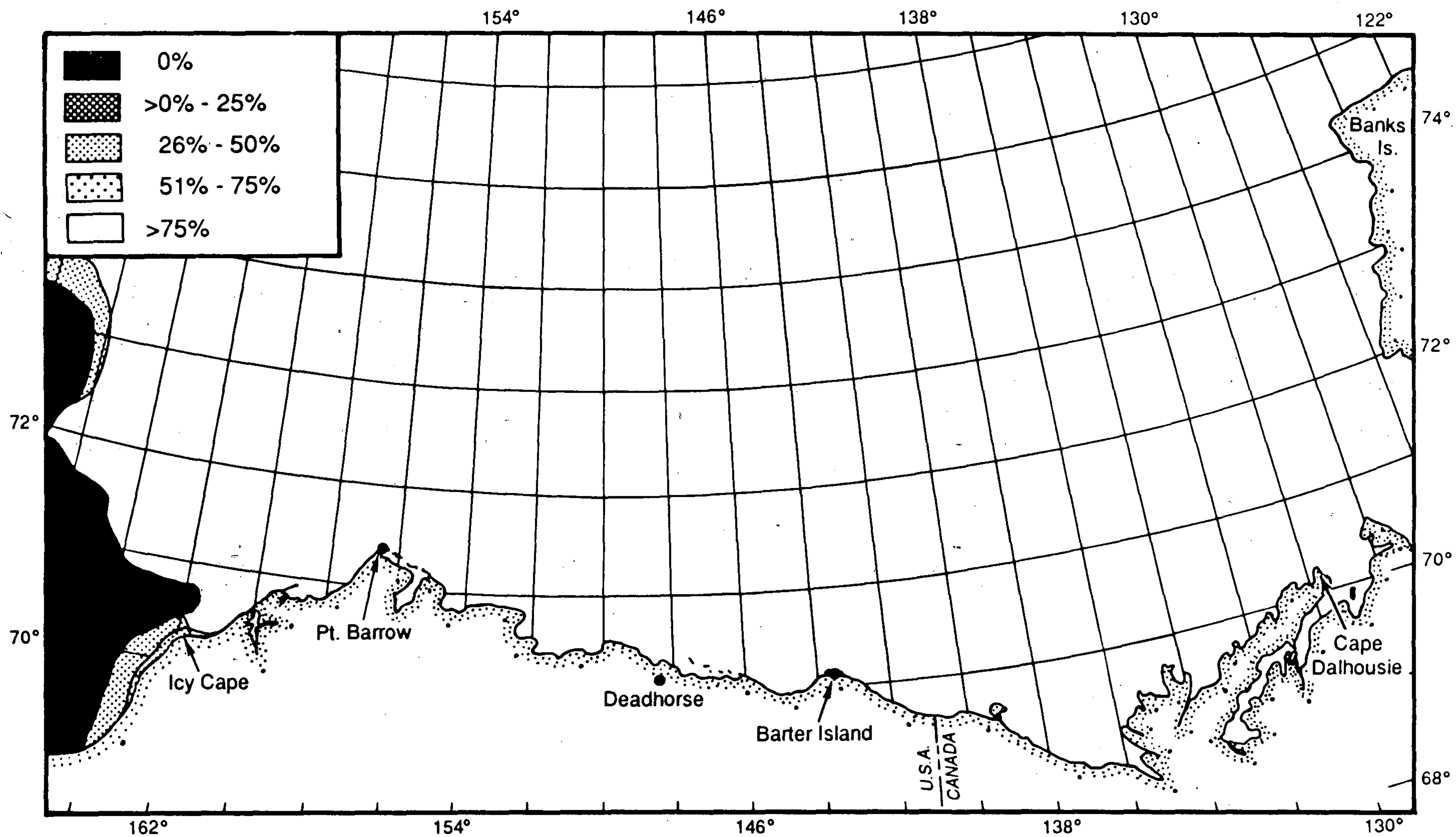


Figure 11. Map of Ice Concentrations in the Beaufort Sea, 22 October 1991

Table 3
Aerial-Survey Effort in the Beaufort Sea, August-October 1991, by Survey Flight

Day	Flight No.	Transect (km)	Connect (km)	Search (km)	Total (km)	Transect Time (hr)	Total Survey Time (hr)
31 Aug	1	437	58	503	998	1.90	4.45
1 Sep	2	438	84	408	930	1.83	3.98
5 Sep	3	0	0	77	77	0.00	0.33
6 Sep	4	652	110	349	1,111	2.78	4.57
11 Sep	5	0	0	360	360	0.00	1.70
16 Sep	6	436	89	431	956	1.82	3.88
17 Sep	7	829	116	227	1,172	3.32	4.68
18 Sep	8	596	120	279	995	2.37	4.02
19 Sep	9	0	0	964	964	0.00	4.13
22 Sep	10	27	0	606	633	0.10	2.35
24 Sep	11	0	0	604	604	0.00	2.48
25 Sep	12	0	0	451	451	0.00	2.02
1 Oct	13	0	0	458	458	0.00	1.87
1 Oct	14	325	46	458	829	1.40	3.63
2 Oct	15	436	67	94	597	1.87	2.55
3 Oct	16	392	54	571	1,017	1.77	4.73
4 Oct	17	1,004	58	100	1,162	4.13	4.78
7 Oct	18	0	0	191	191	0.00	0.72
8 Oct	19	328	75	140	543	1.47	2.50
9 Oct	20	408	68	367	843	1.82	3.68
11 Oct	21	498	160	475	1,133	2.08	4.87
12 Oct	22	559	0	617	1,176	2.10	4.45
13 Oct	23	167	0	665	832	0.68	3.20
14 Oct	24	0	0	762	762	0.00	3.27
18 Oct	25	0	0	160	160	0.00	0.63
Total Semimonthly Survey Effort							
31 Aug		437	58	503	998	1.90	4.45
1-15 Sep		1,090	194	1,194	2,478	4.62	10.59
16-30 Sep		1,888	325	3,562	5,775	7.60	23.57
1-15 Oct		4,117	528	4,898	9,543	17.32	40.25
16-20 Oct		0	0	160	160	0.00	0.63
TOTAL		7,532	1,105	10,317	18,954	31.43	79.48

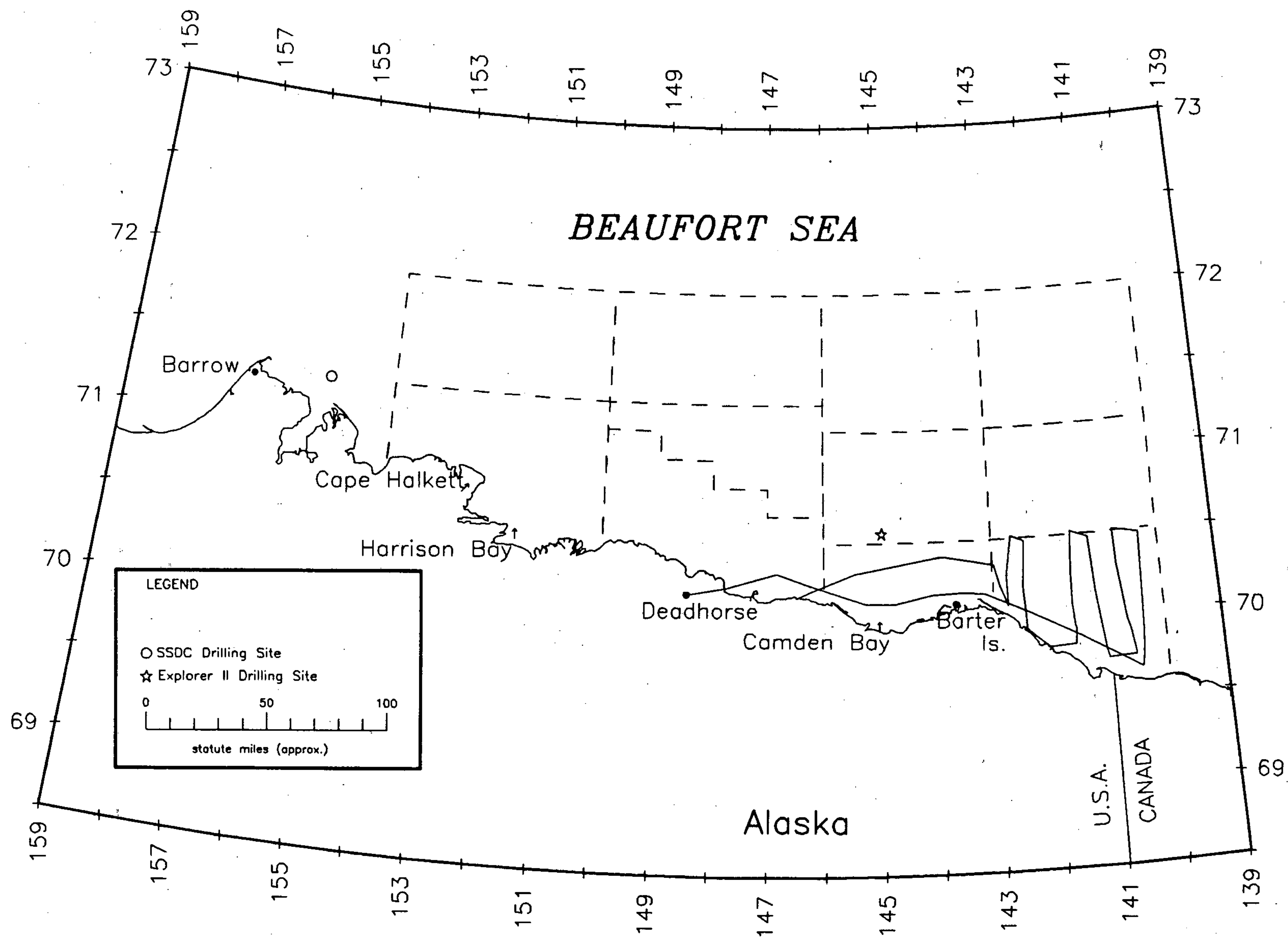


Figure 12. Combined Flight Tracks, 31 August 1991

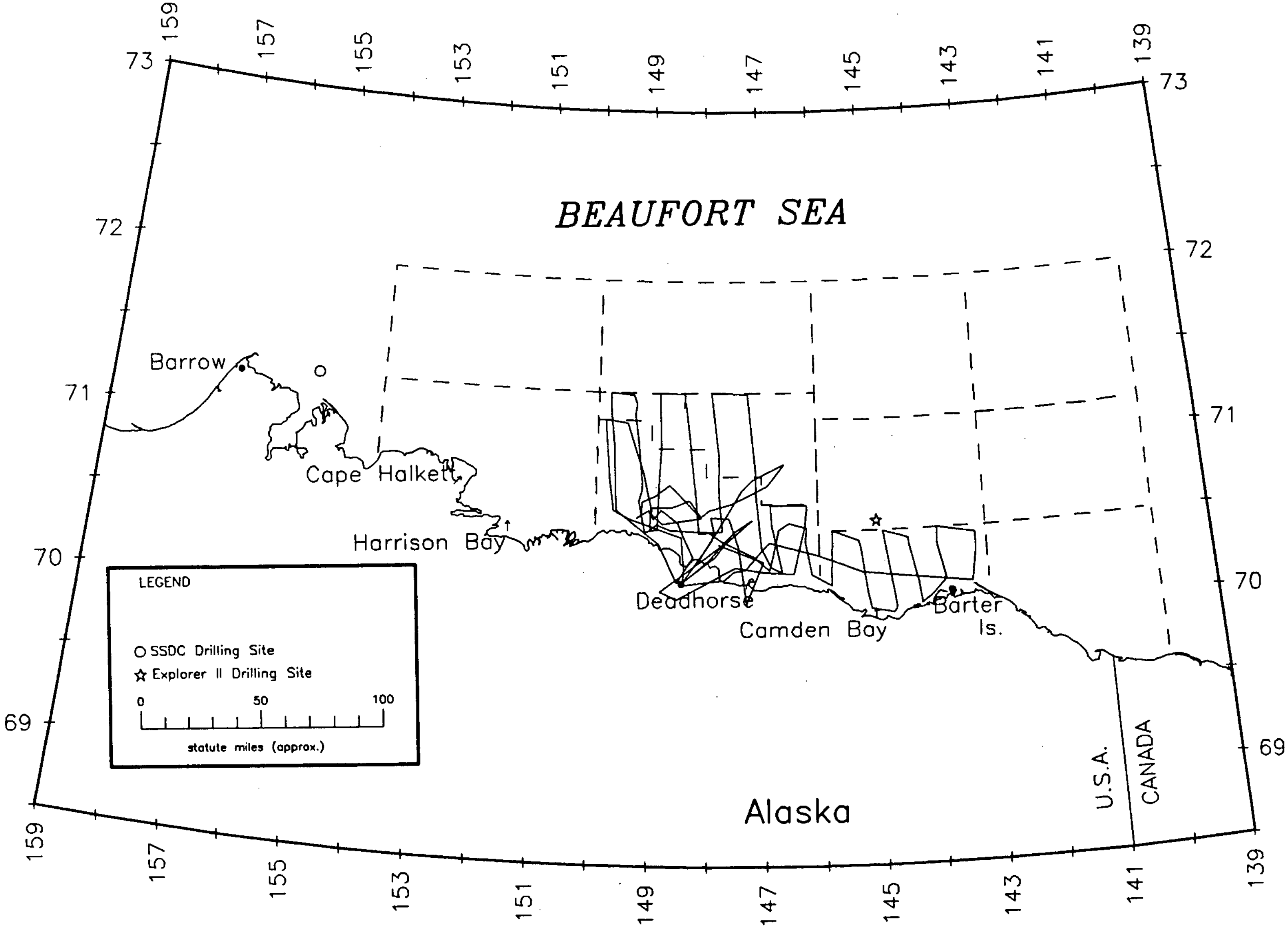


Figure 13. Combined Flight Tracks, 1–15 September 1991

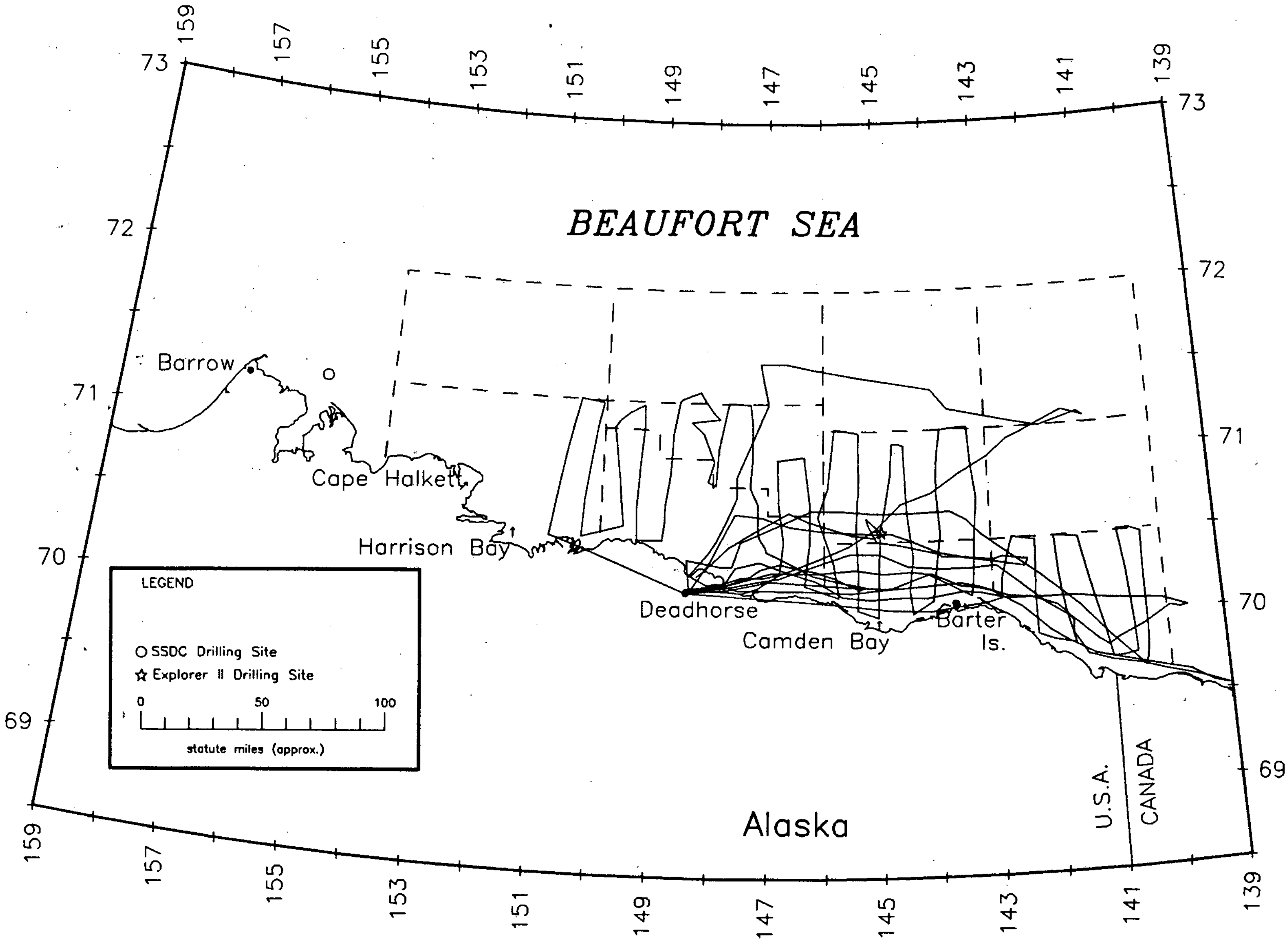


Figure 14. Combined Flight Tracks, 16–30 September 1991

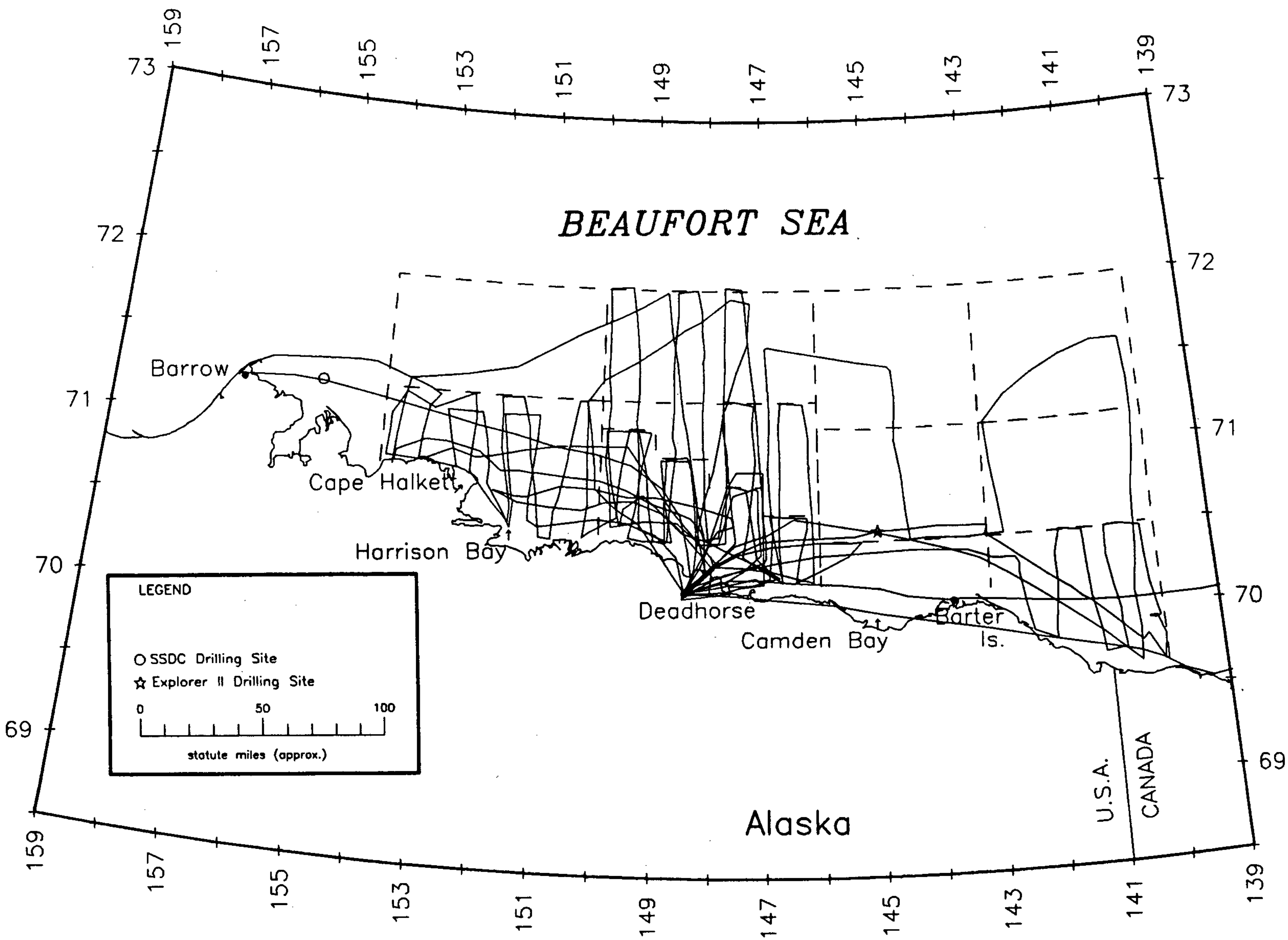


Figure 15. Combined Flight Tracks, 1–15 October 1991

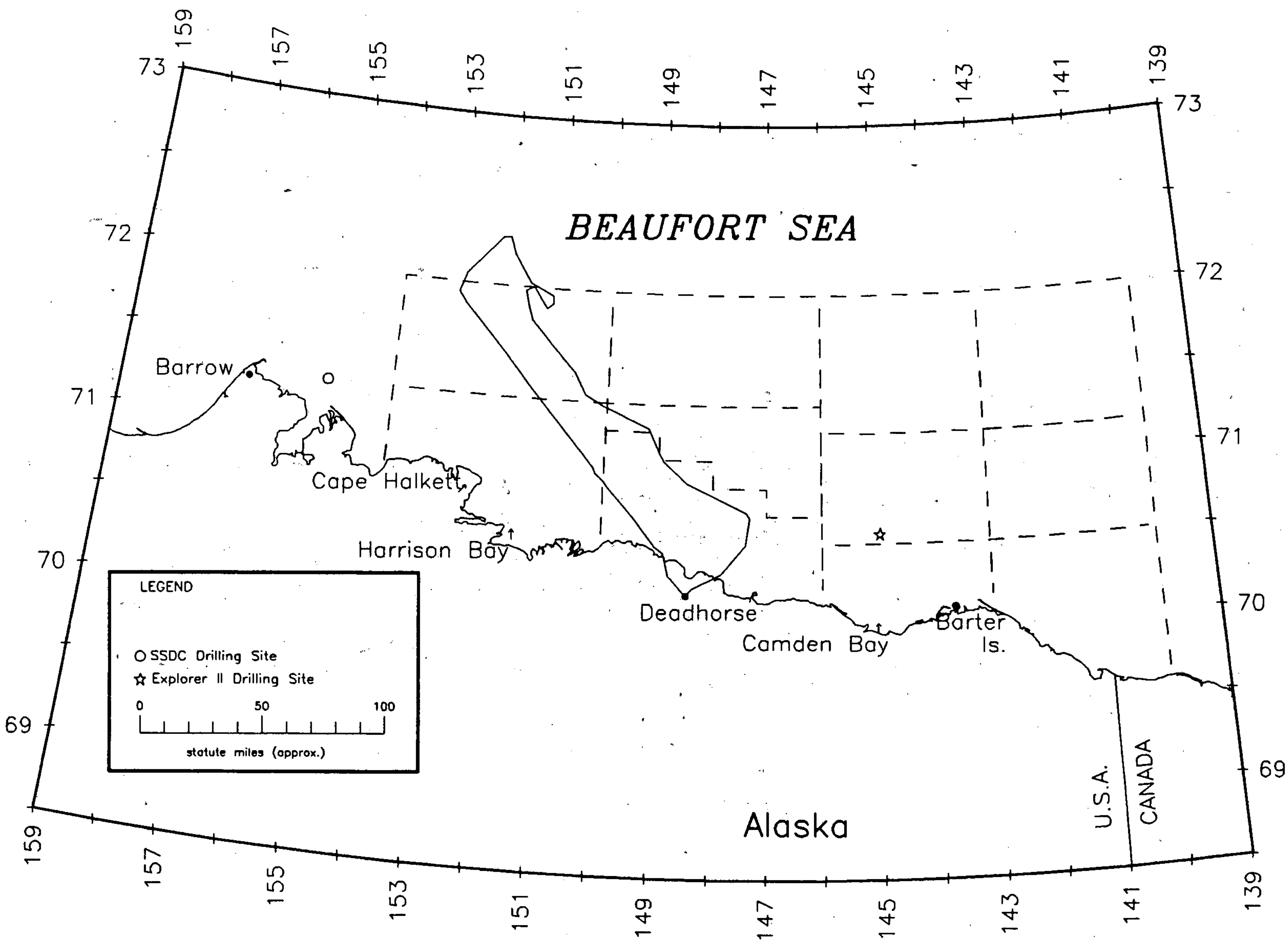


Figure 16. Combined Flight Tracks, 16–20 October 1991

C. Bowhead Whale (*Balaena mysticetus*) Observations

1. Distribution: Forty-one sightings were made for a total of 69 bowhead whales observed during Fall-1991 surveys in the study area (Table 4 and Figs. 17-19). Two of these whales were identified as calves (Appendix B: Table B-1), resulting in a seasonal calf ratio (number calves/total whales) of 0.03. Daily sightings are shown on individual maps in Appendix B.

From 31 August through the first half of September, no sightings were made of bowhead whales (Table 4).

During the second half of September, 19 sightings were made for a total of 42 bowheads (Table 4), with sightings between 136°51′W. and 145°55.4′W. longitudes (Appendix B: Table B-1; Alaskan sightings are shown in Figure 17; some additional sightings east of the general study area are shown in Appendix B: Flight 9), based on survey coverage extending west to 151°W. longitude (Fig. 14). The first bowheads in the Alaskan Beaufort were sighted on 16 September north or east of Barter Island (Appendix B: Flight 6). The westernmost sighting during this period was made midway between Deadhorse and Barter Island (145°55.4′W.) on 17 September (Appendix B: Table B-1; Flight 7). Pod sizes ranged from 1 to 10 whales (Appendix B: Table B-1), with a mean of 2.21 (SD = 2.20, n = 19), although all pods within the primary study area consisted of either 1 or 2 whales. No bowhead whale calves were observed during this period (Appendix B: Table B-1).

During the first half of October, 22 sightings were made for a total of 27 bowheads (Table 4), with sightings somewhat evenly distributed across the primary study area (Fig. 18), based on widespread survey coverage (Fig. 15). The last bowhead seen in the Beaufort Sea during the study occurred on 4 October at 71°07.7′N. latitude and 148°41.5′W. longitude (Appendix B: Table B-1). Pod sizes ranged from 1 to 3 whales (Appendix B: Table B-1), with a mean of 1.23 (SD = 0.53, n = 22). Two bowhead whale calves were observed during this period, one at 71°01.4′N. latitude, 147°40.5′W. longitude and one at 70°10.7′N. latitude, 141°47.9′W. longitude (Appendix B: Table B-1).

From 16 through 20 October, no sightings were made of bowhead whales (Table 4).

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 5 and graphically depicted in Figure 20. 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 16 September. The daily sighting rate peaked at 2.91 SPUE on 19 September. The last sighting of a bowhead in the study area was made on 4 October, followed by 8 flights in which no bowhead whales were sighted.

The data for day-to-day relative 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 19 September (Table 5). The peak relative abundance (mode) of 7.99 WPUE also occurred on 19 September (Table 5 and Fig. 20).

The most prominent difference in pattern between the graph for relative abundance and that for sighting rate occurred on 19 September (Fig. 20), due to inconsistently large pod sizes in Canadian waters east of the primary study area (Appendix B: Table B-1). Otherwise, pod sizes were fairly consistent over the Fall-1991 field season.

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 (east of 154°W. longitude), was calculated in Table 6.

Table 4
Summary of Marine Mammal Sightings, August-October 1991, 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
31 Aug	1	0	0	0	1/1	1/1	0	0
1 Sep	2	0	0	0	0	0	0	0
5 Sep	3	0	0	0	0	0	0	0
6 Sep	4	0	0	6/26	0	0	1/1	0
11 Sep	5	0	0	0	0	0	0	0
16 Sep	6	2/3	0	0	0	0	0	0
17 Sep	7	3/4	0	2/2	0	0	2/5	0
18 Sep	8	0	0	5/7	0	0	0	0
19 Sep	9	12/33	0	0	0	0	0	0
22 Sep	10	0	0	2/6	0	0	0	0
24 Sep	11	0	0	0	0	0	0	0
25 Sep	12	2/2	0	0	1/1	0	0	0
1 Oct	13	0	0	0	0	0	0	0
1 Oct	14	2/2	0	1/1	1/1	0	0	0
2 Oct	15	4/5	0	2/4	2/2	0	0	0
3 Oct	16	13/17	0	0	0	0	2/2	0
4 Oct	17	3/3	0	10/17	0	0	0	0
7 Oct	18	0	0	0	0	0	0	0
8 Oct	19	0	0	0	0	0	0	0
9 Oct	20	0	0	0	0	1/1	0	0
11 Oct	21	0	0	0	0	0	0	0
12 Oct	22	0	0	0	1/1	0	0	0
13 Oct	23	0	0	0	0	0	0	0
14 Oct	24	0	0	0	0	0	0	0
18 Oct	25	0	0	0	0	0	0	0

Total Semimonthly Sightings

	Bowhead Whale	Gray Whale	Belukha Whale	Bearded Seal	Ringed Seal	Unidentified Pinniped	Polar Bear
31 Aug	0	0	0	1/1	1/1	0	0
1-15 Sep	0	0	6/26	0	0	1/1	0
16-30 Sep	19/42	0	9/15	1/1	0	2/5	0
1-15 Oct	22/27	0	13/22	4/4	1/1	2/2	0
16-20 Oct	0	0	0	0	0	0	0
TOTAL	41/69	0	28/63	6/6	2/2	5/8	0

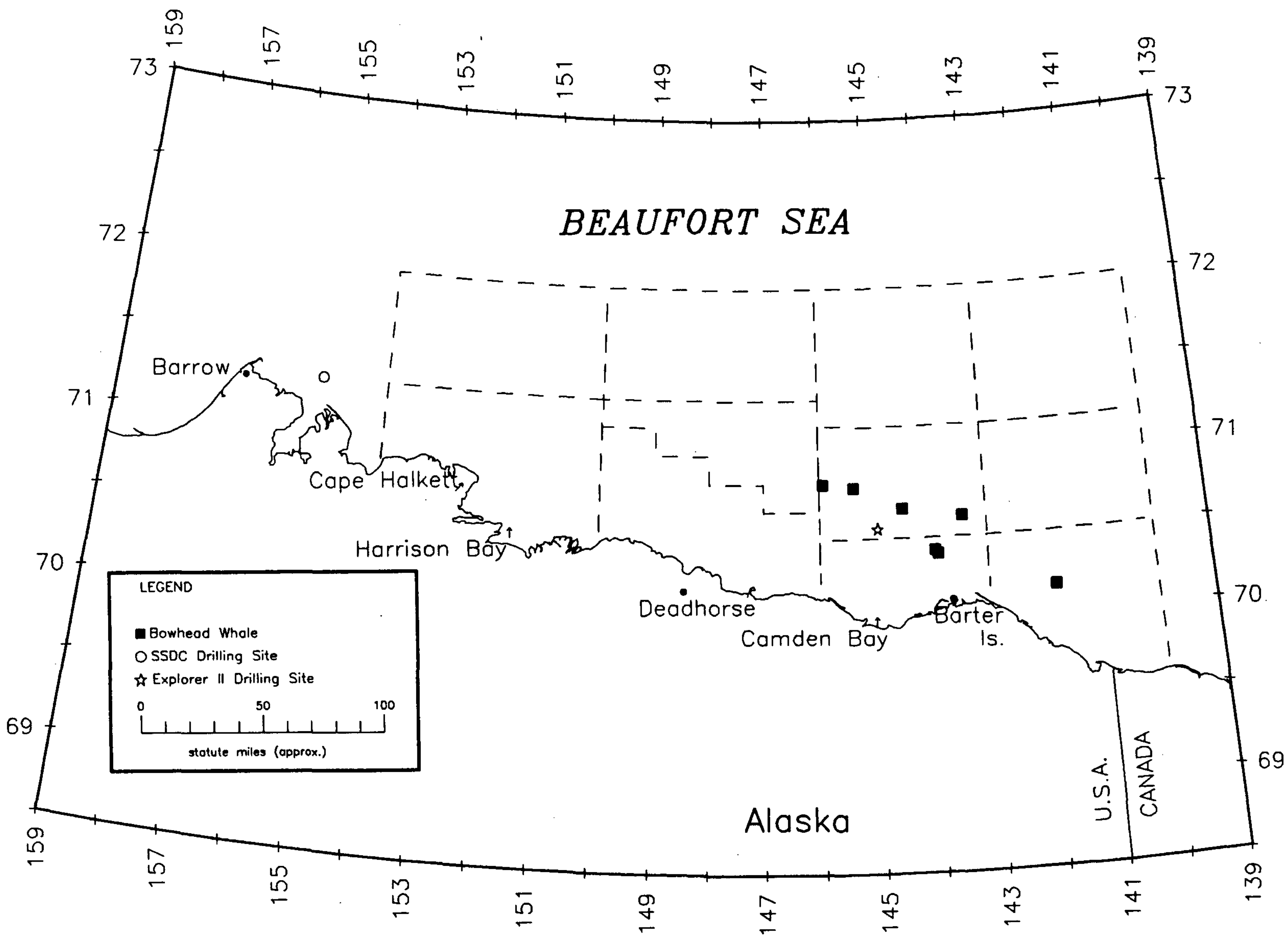


Figure 17. Map of Bowhead Whale Sightings, 16–30 September 1991

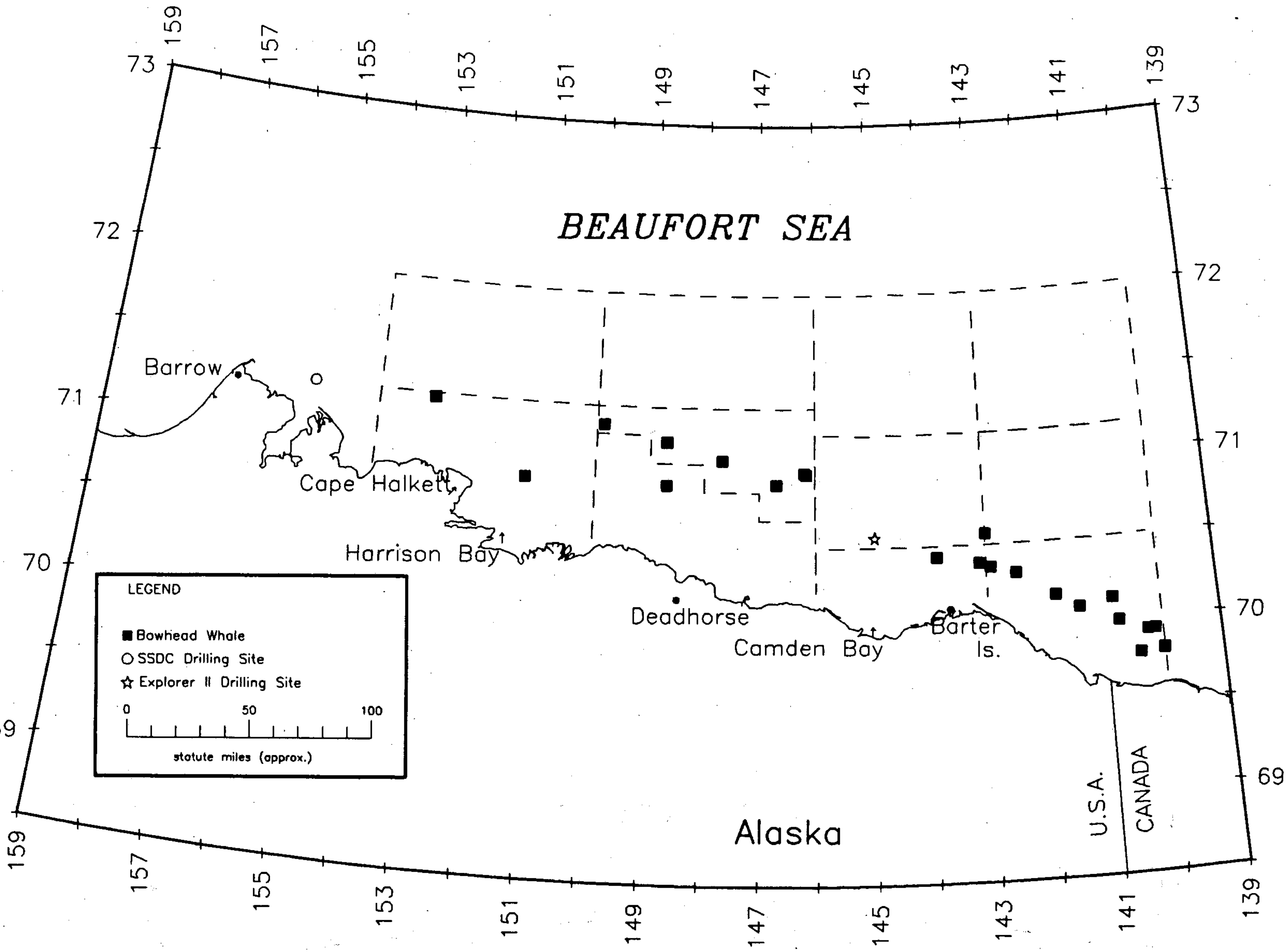


Figure 18. Map of Bowhead Whale Sightings, 1-15 October 1991

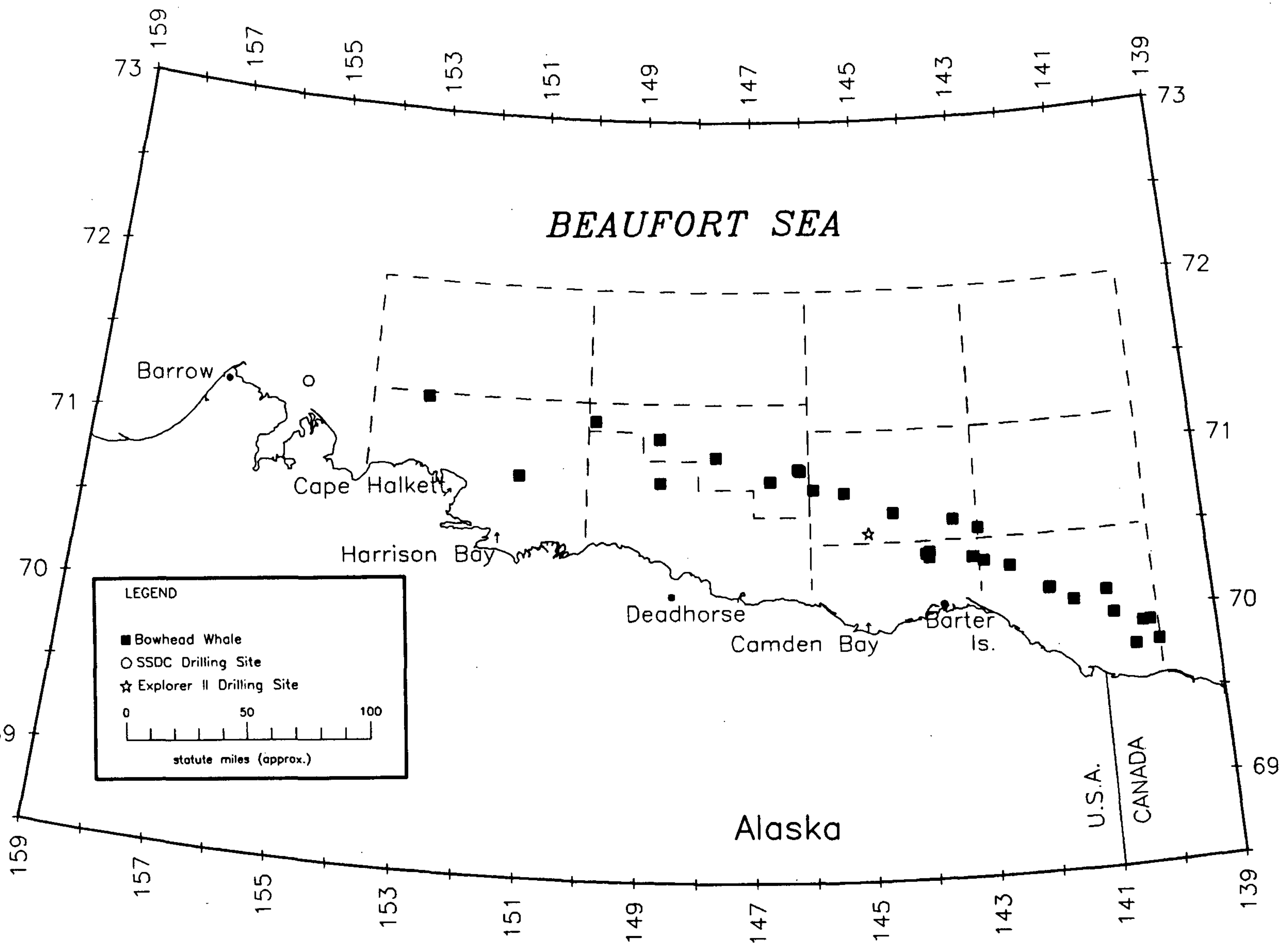


Figure 19. Map of Bowhead Whale Sightings, 31 August–20 October 1991

Table 5
Number of Sightings and Total Bowhead Whales Observed per Hour, August-October 1991, by Flight Day

Day	No. of Sightings	No. of Whales	Total Survey Time (hr)	Sightings/ Hour (SPUE)	Whales/ Hour (WPUE)
31 Aug	0	0	4.45	0.00	0.00
1 Sep	0	0	3.98	0.00	0.00
5 Sep	0	0	0.33	0.00	0.00
6 Sep	0	0	4.57	0.00	0.00
11 Sep	0	0	1.70	0.00	0.00
16 Sep	2	3	3.88	0.52	0.77
17 Sep	3	4	4.68	0.64	0.85
18 Sep	0	0	4.02	0.00	0.00
19 Sep	12	33	4.13	2.91	7.99
22 Sep	0	0	2.35	0.00	0.00
24 Sep	0	0	2.48	0.00	0.00
25 Sep	2	2	2.02	0.99	0.99
1 Oct	2	2	5.50	0.36	0.36
2 Oct	4	5	2.55	1.57	1.96
3 Oct	13	17	4.73	2.75	3.59
4 Oct	3	3	4.78	0.63	0.63
7 Oct	0	0	0.72	0.00	0.00
8 Oct	0	0	2.50	0.00	0.00
9 Oct	0	0	3.68	0.00	0.00
11 Oct	0	0	4.87	0.00	0.00
12 Oct	0	0	4.45	0.00	0.00
13 Oct	0	0	3.20	0.00	0.00
14 Oct	0	0	3.27	0.00	0.00
18 Oct	0	0	0.63	0.00	0.00
TOTAL	41	69	79.48	0.52	0.87

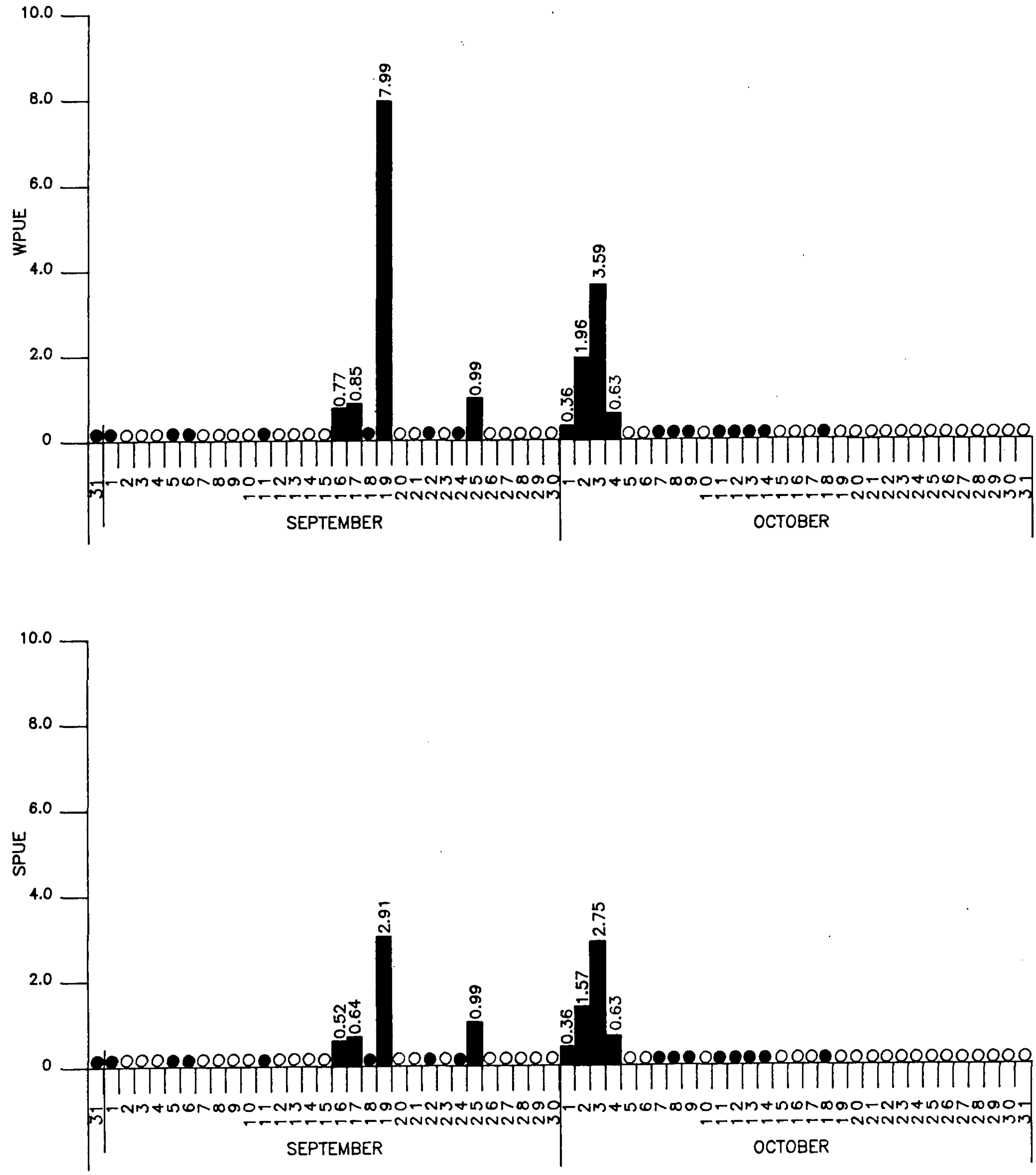


Figure 20. Daily Relative Abundance (WPUE) and Sighting Rate (SPUE) of Bowhead Whales (Fall 1991)

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

Table 6
Semimonthly Relative Abundance (WPUE) of Bowhead Whales (BH), by Survey Block (Fall 1991)

Block	31 Aug			1-15 Sep			16-30 Sep			1-15 Oct			16-20 Oct			Total		
	Hr	BH	WPUE	Hr	BH	WPUE	Hr	BH	WPUE	Hr	BH	WPUE	Hr	BH	WPUE	Hr	BH	WPUE
1	0.37	0	0.00	7.18	0	0.00	5.09	0	0.00	14.15	1	0.07	*	*	*	26.79	1	0.04
2	*	*	*	1.36	0	0.00	1.61	0	0.00	3.14	7	2.23	*	*	*	6.11	7	1.15
3	*	*	*	*	*	*	0.97	0	0.00	7.38	2	0.27	0.02	0	0.00	8.36	2	0.24
4	1.05	0	0.00	2.00	0	0.00	4.61	2	0.43	1.35	2	1.48	*	*	*	9.00	4	0.44
5	2.93	0	0.00	*	*	*	4.93	1	0.20	4.36	13	2.98	*	*	*	12.22	14	1.15
6	*	*	*	0.01	0	0.00	3.18	6	1.89	1.23	0	0.00	*	*	*	4.42	6	1.36
7	0.10	0	0.00	*	*	*	0.24	0	0.00	0.72	1	0.00	*	*	*	1.06	1	0.94
8	*	*	*	*	*	*	0.41	0	0.00	0.58	0	0.00	*	*	*	0.99	0	0.00
9	*	*	*	*	*	*	0.52	0	0.00	0.31	0	0.00	*	*	*	0.83	0	0.00
10	*	*	*	0.04	0	0.00	0.38	0	0.00	3.44	0	0.00	*	*	*	3.86	0	0.00
11	*	*	*	*	*	*	0.02	0	0.00	0.74	0	0.00	0.30	0	0.00	1.06	0	0.00
Other Canadian Areas	*	*	*	*	*	*	1.61	33	20.50	2.04	1	0.49	*	*	*	3.65	34	9.32
Other Alaskan Areas	*	*	*	*	*	*	*	*	*	0.82	0	0.00	0.32	0	0.00	1.14	0	0.00
TOTAL	4.45	0	0.00	10.58	0	0.00	23.57	42	1.78	40.25	27	0.67	0.63	0	0.00	79.48	69	0.89

* No survey effort.

On 31 August, there were no survey blocks or areas in which ≥4.00 hr of survey effort were made, and no bowhead whales were observed during 4.45 hr of survey effort (Table 6).

During the first half of September, Block 1 was the only survey block in which ≥4.00 hr of survey effort were made (Table 6). No bowhead whales were observed in 10.58 hr of survey effort during this period.

During the second half of September, there were three blocks in which ≥4.00 hr of survey effort were made (Table 6). Of these coastal blocks (Blocks 1, 4, and 5), none showed a relative abundance >0.50 WPUE. There were two areas in which whales were observed during this period in <4.00 hr of survey effort that showed relative abundances >0.50. It was notable that 33 bowheads were observed in only 1.61 hr of survey effort in Canadian waters east of the primary study area, for a high relative abundance of 20.50. Six bowheads were observed during a total of 7.33 hr of survey effort in the remaining blocks (Blocks 2, 3, 6, 7, 8, 9, 10, and 11) or in other Alaskan areas. All six of these whales were observed in Block 6, for a relative abundance in that block of 1.89 WPUE.

During the first half of October, there were three blocks in which ≥4.00 hr of survey effort were made (Table 6). Of these coastal blocks (Blocks 1, 3, and 5), only Block 5 had a relative abundance (2.98 WPUE) <0.50. Eleven bowheads were observed during a total of 14.37 hr of survey effort in the remaining blocks (Blocks 2, 4, 6, 7, 8, 9, 10, and 11) or in other Alaskan and Canadian areas. Seven of these 11 whales were observed in Block 2, for a relative abundance in that block of 2.23 WPUE.

From 16 through 20 October, there were no survey blocks or areas in which ≥4.00 hr of survey effort were made. No bowhead whales were observed during 0.63 hr of survey effort during this period (Table 6).

3. Habitat Relationships: Of 69 bowhead whales sighted during Fall 1991, 54 (78%) were in shallow water (0-50 m deep). Of the remainder, 9 whales (13%) were sighted in waters ranging from 51 m to 200 m and 6 (9%) were sighted in deeper water (>200 m) (Table 7). A fuller description of depth associated with the bowhead migration appears in the discussion on median-water-depth analysis in Section IV.B.

In addition to general ice coverage for arctic waters (Figs. 3-11), the percentage of ice cover visible from the aircraft at each bowhead sighting was summarized (Appendix B: Table B-1). Forty-three bowheads (62%) were sighted in association with 0-percent sea ice, and 22 (32%) were in 1- to 5-percent sea ice. None of 4 additional whales were associated with sea ice that was greater than 20 percent. Of 27 bowheads observed during 1 through 15 October, 21 (78%) were associated with some sea ice (Table 8).

4. Behavior, Swim Direction, and Speed: Of 69 bowhead whales observed during Fall 1991, 35 (51%) were swimming (Table 9), i.e., moving forward in an apparently deliberate manner, when first sighted. Swim direction over the fall season was significantly ($p < 0.001$) west-northwest (Fig. 21), consistent with a directed migration in rough parallel to Alaska's Beaufort Sea coastline. Bowheads were judged to be moving at either slow (42%), medium (39%), or fast (4%) speeds or were still (6%) (Table 10). Other behaviors noted for bowhead whales were milling (25%), breaching (6%), cow-calf association (6%), resting (4%), underwater blow (4%), diving (3%), and feeding (1%) (Table 9). All behaviors noted are defined in Table 2.

From 31 August through 15 September, no sightings were made of bowhead whales (Table 9).

During the second half of September, 21 of 41 (50%) bowheads were observed swimming (Table 9) and were headed significantly ($p < 0.05$) west-northwest (Fig. 21). Bowheads were mostly moving at slow (60%) or medium (29%) speed (Table 10). Other behaviors noted were breaching (3%) or feeding (2%) (Table 9).

During the first half of October, 14 of 27 (52%) bowheads were observed swimming (Table 9) and headed significantly ($p < 0.001$) west-northwest (Fig. 21). Bowheads were moving mostly at medium (56%) speed, with others moving at slow (15%) or fast (7%) speeds or being still (11%) (Table 10). Other behaviors noted were cow-calf association (15%), resting (11%), underwater blow (11%), diving (7%), or breaching (4%) (Table 9).

Table 7
Semimonthly Summary of Bowhead Whales Observed,
by Water Depth at Sighting Location (Fall 1991)

Water Depth	31 Aug No. (%)	1-15 Sep No. (%)	16-30 Sep No. (%)	1-15 Oct No. (%)	16-20 Oct No. (%)	Total No. (%)
Shallow (0-50 m)	0	0	36 (86)	18 (66)	0	54 (78)
Transitional (51-200 m)	0	0	1 (2)	8 (30)	0	9 (13)
Deep (>200 m)	0	0	5 (12)	1 (4)	0	6 (9)
TOTAL	0	0	42 (100)	27 (100)	0	69 (100)

Table 8
Semimonthly Summary of Bowhead Whales Observed,
by Percent Ice Cover Present at Sighting Location (Fall 1991)

% Ice Cover	31 Aug No. (%)	1-15 Sep No. (%)	16-30 Sep No. (%)	1-15 Oct No. (%)	16-20 Oct No. (%)	Total No. (%)
0	0	0	37 (88)	6 (22)	0	43 (62)
1-5	0	0	3 (7)	19 (70)	0	22 (32)
6-10	0	0	2 (5)	1 (4)	0	3 (4)
11-20	0	0	0	1 (4)	0	1 (2)
21-30	0	0	0	0	0	0
31-40	0	0	0	0	0	0
41-50	0	0	0	0	0	0
51-60	0	0	0	0	0	0
61-70	0	0	0	0	0	0
71-80	0	0	0	0	0	0
81-90	0	0	0	0	0	0
91-99	0	0	0	0	0	0
TOTAL	0	0	42 (100)	27 (100)	0	69 (100)

Table 9
Semimonthly Summary of Bowhead Whales Observed, by Behavioral Category (Fall 1991)

Behavior	31 Aug No. (%)	1-15 Sep No. (%)	16-30 Sep No. (%)	1-15 Oct No. (%)	16-20 Oct No. (%)	Total No. (%)
Breaching	0	0	3 (7)	1 (4)	0	4 (6)
Cow-Calf	0	0	0	4 (15)	0	4 (6)
Diving	0	0	0	2 (7)	0	2 (3)
Feeding	0	0	1 (2)	0	0	1 (1)
Milling	0	0	17 (41)	0	0	17 (25)
Resting	0	0	0	3 (11)	0	3 (4)
Swimming	0	0	21 (50)	14 (52)	0	35 (51)
Underwater Blow	0	0	0	3 (11)	0	3 (4)
TOTAL	0	0	42 (100)	27 (100)	0	69 (100)

Table 10
Semimonthly Summary of Bowhead Whales Observed, by Swimming Speed (Fall 1991)

Swim Speed	31 Aug No. (%)	1-15 Sep No. (%)	16-30 Sep No. (%)	1-15 Oct No. (%)	16-20 Oct No. (%)	Total No. (%)
Still (0 km/hr)	0	0	1 (2)	3 (11)	0	4 (6)
Slow (<2 km/hr)	0	0	25 (60)	4 (15)	0	29 (42)
Medium (2-4 km/hr)	0	0	12 (29)	15 (56)	0	27 (39)
Fast (>4 km/hr)	0	0	1 (2)	2 (7)	0	3 (4)
(not noted)	0	0	3 (7)	3 (11)	0	6 (9)
TOTAL	0	0	42 (100)	27 (100)	0	69 (100)

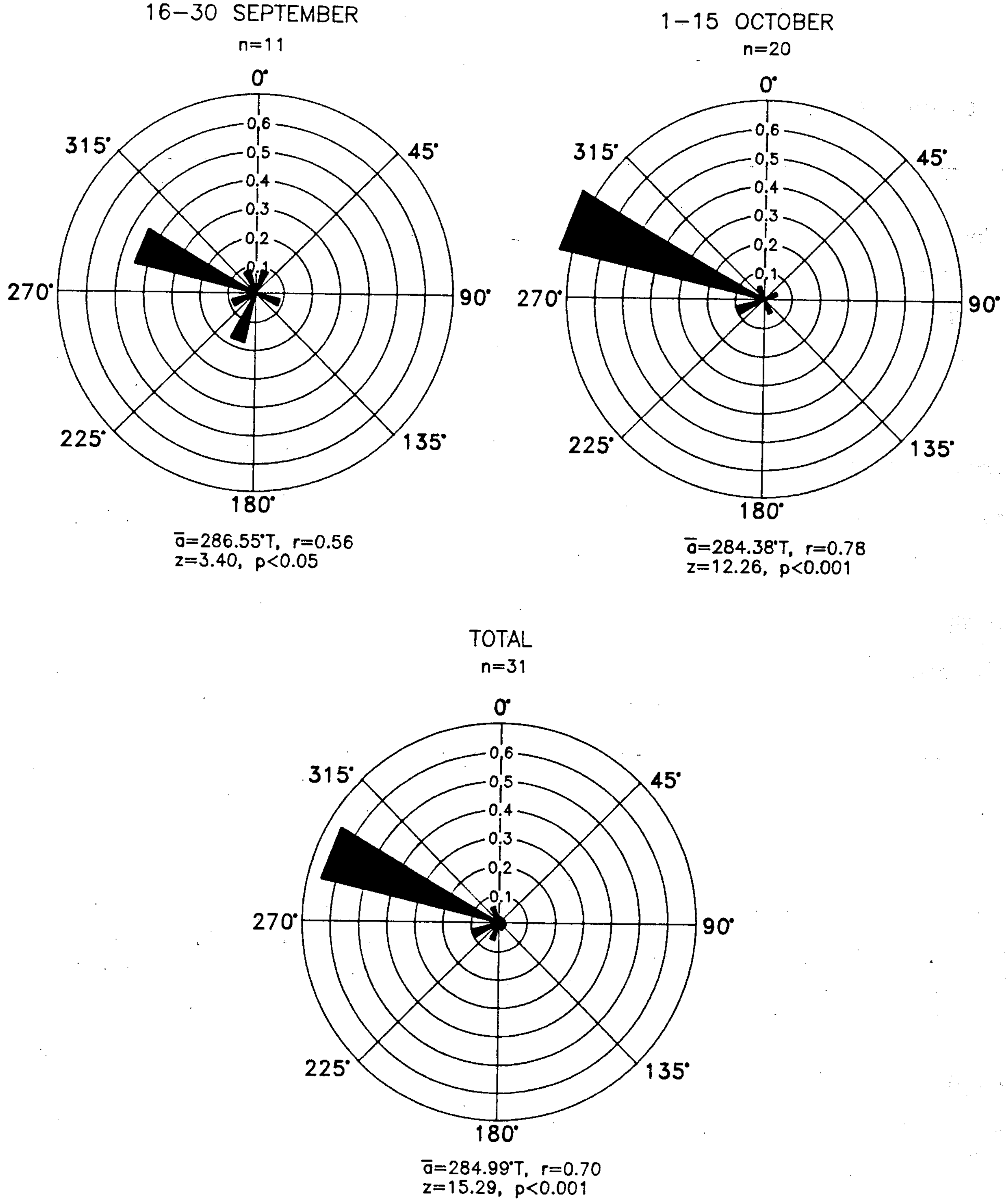


Figure 21. Semimonthly Summary of Swim Directions for Bowhead Whales (Fall 1991)

From 16 through 20 October, no sightings were made of bowhead whales (Table 9).

D. Other Marine Mammal Observations

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

2. Belukha Whale (*Delphinapterus leucas*): Although the study area and survey altitude were designed to record the fall migration of bowhead whales, belukha whales, which undertake a somewhat parallel migration, were always looked for and were considered suitable for selected analyses. Twenty-eight sightings were made for a total of 63 belukha whales (Table 4) between 142°W. and 152°W. longitude and extending north from the shoreline to the northern limit of the primary study area (72°N. latitude) (Fig. 22), coinciding with isobaths ranging from <20 m to >3,000 m (Fig. 2). Pod sizes ranged from 1 to 15 whales, with a mean of 2.25 (SD = 2.73, n = 28).

On 31 August, no sightings were made of belukha whales (Table 4) during 4.45 hr of survey effort (Table 3).

During the first half of September, 6 sightings were made for a total of 26 belukhas (Table 4) during 10.59 hr of survey effort (Table 3). The first belukhas in the Alaskan Beaufort were sighted on 6 September north of Deadhorse (Appendix B: Flight 4). The relative abundance of belukha whales during this period was 2.46 WPUE. Pod sizes ranged from 1 to 15 whales. One belukha calf was noted during this period (Appendix B: Table B-1). Belukha whales were observed in association with 80- to 95-percent sea ice (all broken floe with new ice), with a mean of 92.50 percent (SD = 6.12, n = 6).

During the second half of September, 9 sightings were made for a total of 15 belukhas (Table 4) during 23.57 hr of survey effort (Table 3). The relative abundance of belukha whales during this period was 0.64 WPUE. Pod sizes ranged from 1 to 3 whales. No belukha calves were noted during this period (Appendix B: Table B-1). Belukha whales were observed in association with 30- to 95-percent sea ice (all broken floe with some new ice), with a mean of 72.22 percent (SD = 25.75, n = 9).

During the first half of October, 13 sightings were made for a total of 22 belukhas (Table 4) during 40.25 hr of survey effort. One belukha, sighted 1 October very near shore in Harrison Bay (Appendix B: Flight 14), was well inside the 20-m isobath (Fig. 2). The relative abundance of belukha whales during this period was 0.55 WPUE. Pod sizes ranged from 1 to 4 whales. One belukha calf was noted during this period (Appendix B: Table B-1). Belukha whales were observed in association with 0- to 99-percent sea ice (all broken floe with some new ice), with a mean of 72.22 percent (SD = 44.63, n = 13).

From 16 through 20 October, no sightings of belukha whales were made (Table 4) during 0.63 hr of survey effort.

3. Ringed Seal (*Phoca hispida*): Two incidental sightings for a total of 2 ringed seals (Table 4) were made near shore, within the 40-m isobath (Figs. 2 and 23). These sightings were made on 31 August and 9 October.

4. Bearded Seal (*Erignathus barbatus*): Six incidental sightings were made between 141°W. and 148°W. longitudes for a total of 6 bearded seals, 5 of which were within the 100-m isobath (Figs. 2 and 24). These were observed from 31 August through 12 October.

5. Unidentified Pinnipeds: Five incidental sightings for a total of 8 unidentified pinnipeds were made between 141°W. and 149°W. longitude, within the 100-m isobath (Figs. 2 and 25). These sightings were made from 6 September through 3 October (Table 4).

6. Polar Bear (*Ursus maritimus*): No polar bears were sighted during Fall 1991, even though ice conditions were considered suitable for supporting them.

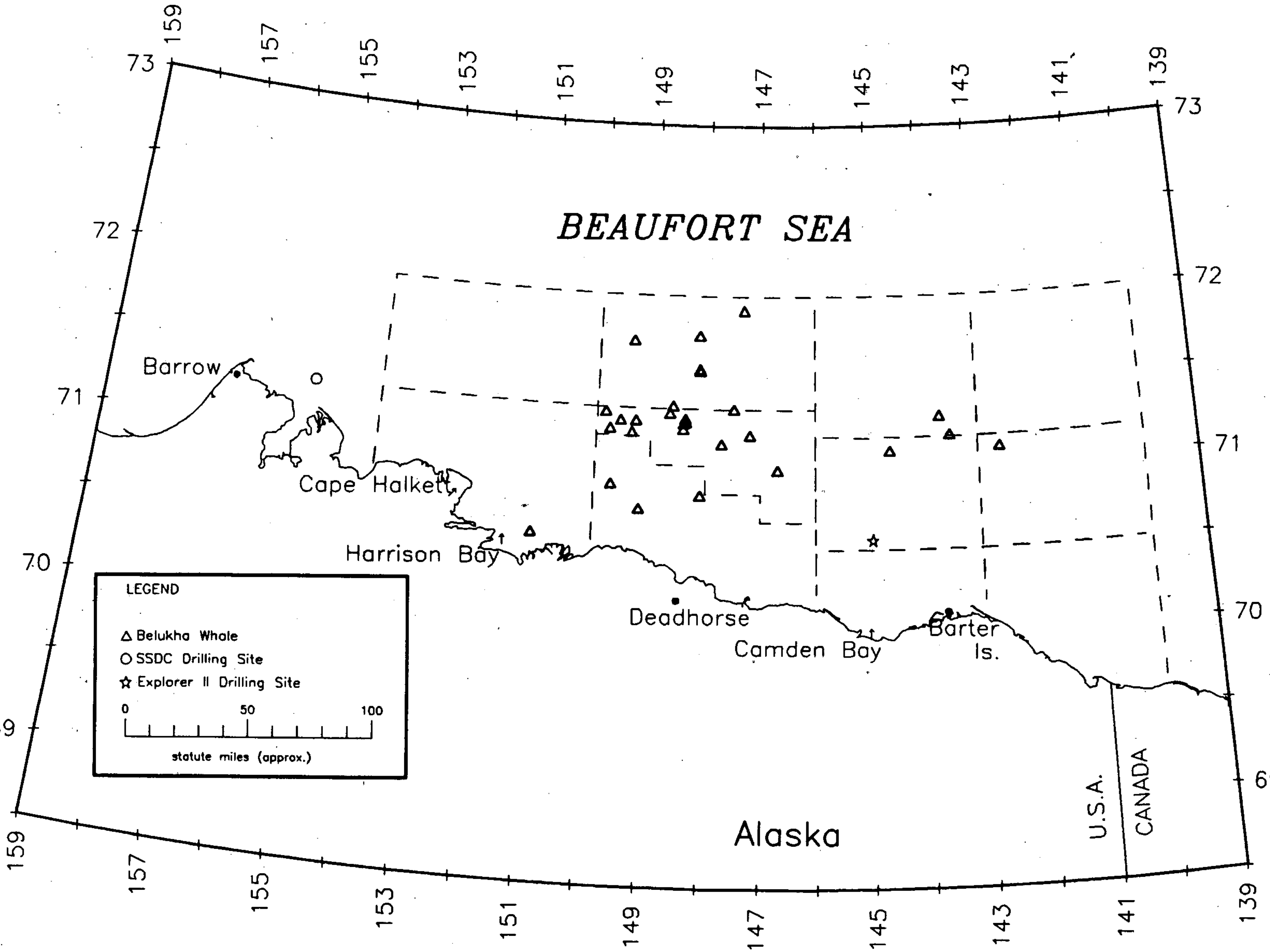


Figure 22. Map of Belukha Whale Sightings, 31 August–20 October 1991

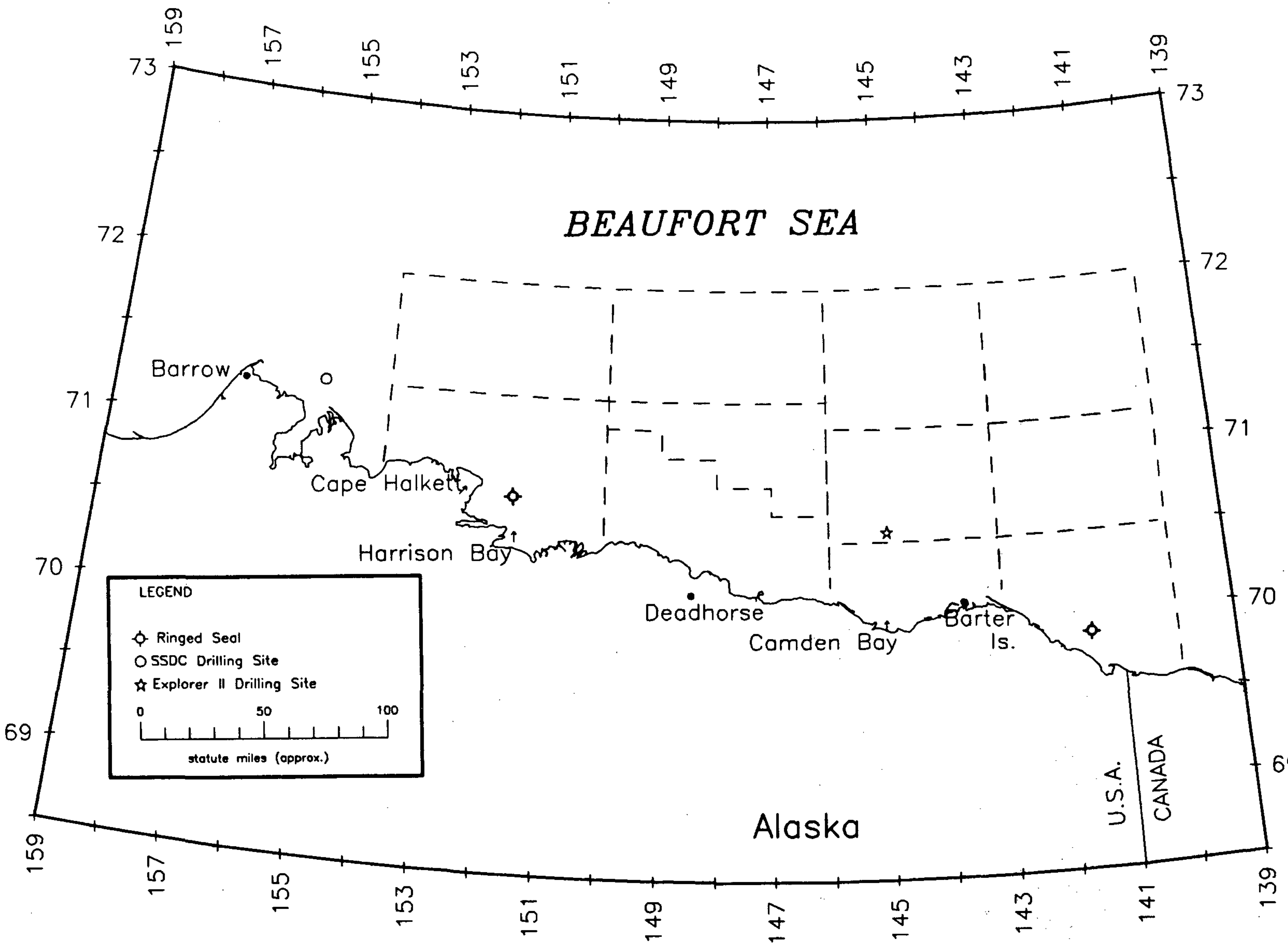


Figure 23. Map of Ringed Seal Sightings, 31 August–20 October 1991

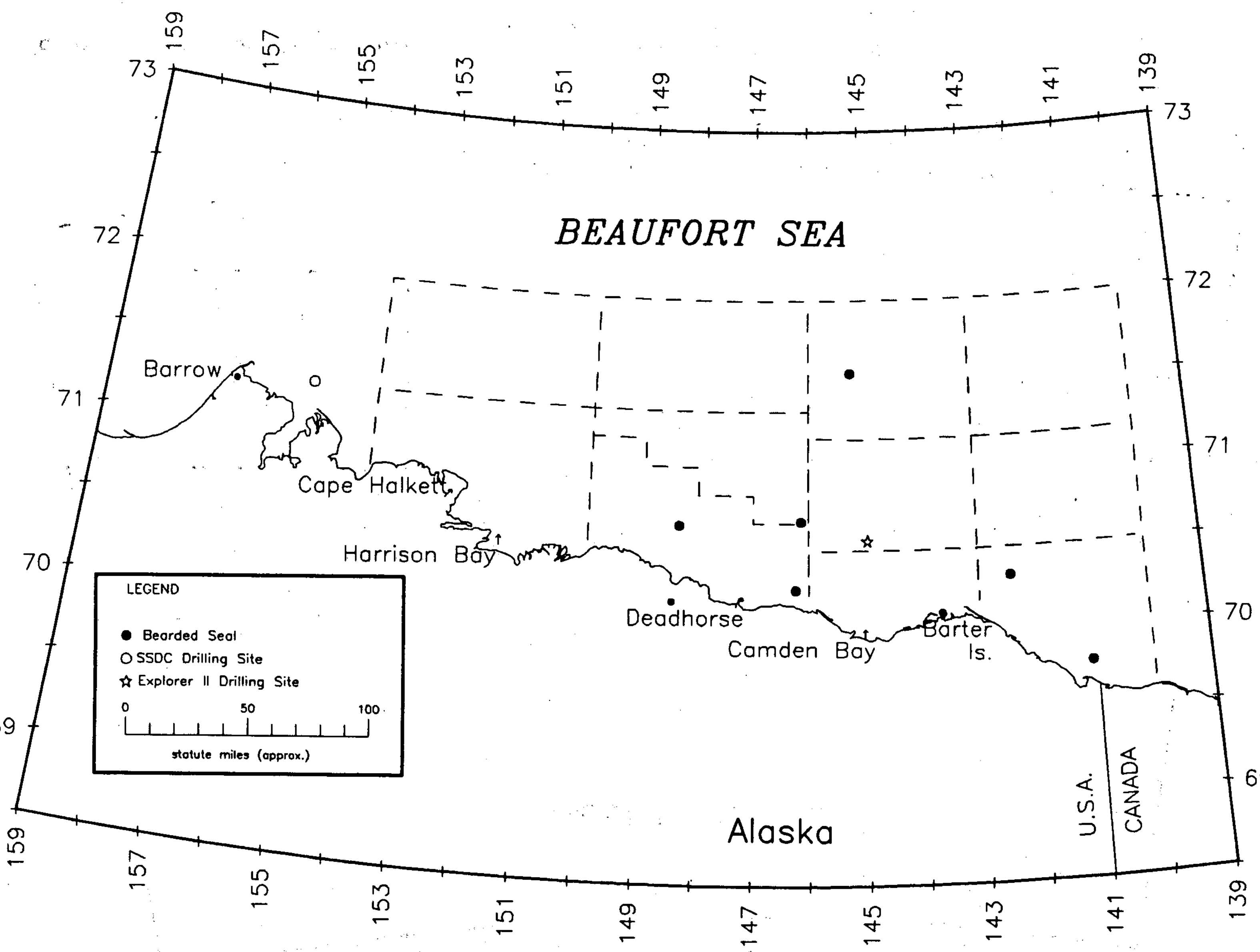


Figure 24. Map of Bearded Seal Sightings, 31 August–20 October 1991

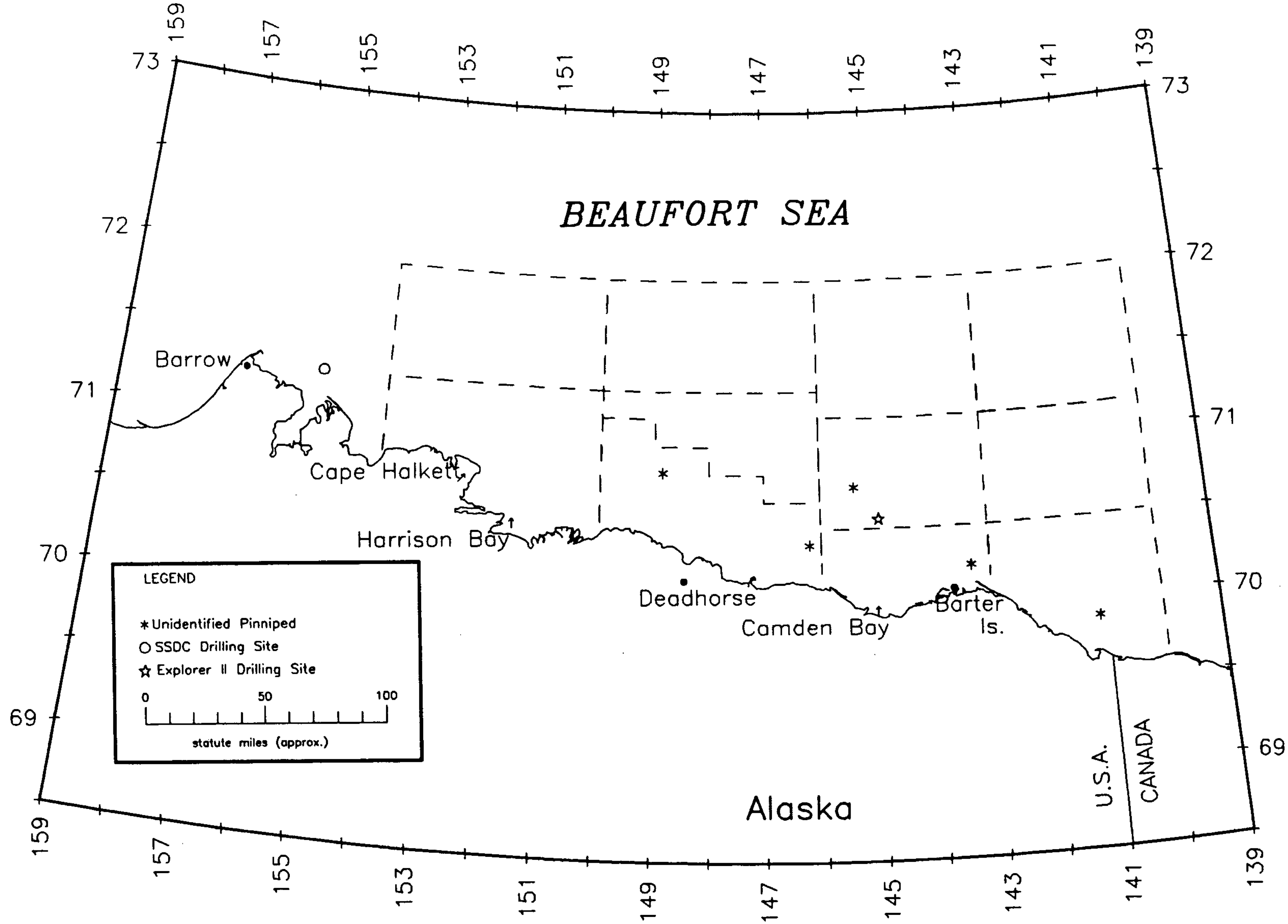


Figure 25. Map of Unidentified-Pinniped Sightings, 31 August-20 October 1991

IV. DISCUSSION

A. General Comparisons with Previous Surveys (1979-1990)

Most 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 (1979-1990) in the Beaufort Sea (Ljungblad et al., 1987; Treacy, 1988, 1989, 1990, 1991). The areas of greatest deviation from previous values are described below.

The general ice coverage along the northern coast of Alaska during the 1991 navigation season was the third most severe (after 1983 and 1988) since MMS began bowhead whale monitoring in 1979 (USDOD, Navy, Naval Polar Oceanography Center, 1992).

Values for relative abundance of bowhead whales during September 1991 in Block 1 (0.00 WPUE) were lower (although within one SD of the mean) than values for 1979 through 1990 (Table 11). The relative abundance during September for Canadian areas east of 140°W. longitude (20.50 WPUE) was the third highest value noted for any survey block or adjacent area since the survey began in 1979 (Table 11). This high value was obtained in only 1.61 hr (Table 6) and presumably would have been lower if more flight effort had been logged in that area. Values for relative abundance of bowhead whales during October 1991 in Block 2 (2.23 WPUE) and Block 5 (4.36 WPUE) were higher than values for 1979 through 1990 (Table 11) and were at least 5 SD and 8 SD higher, respectively, than the previous mean for each block. Values for relative abundance in all other survey blocks during September or October 1991 were within the range of values observed for the years 1979 through 1990 (Table 11).

The percentage of bowhead whales engaged in "milling" behavior in 1991 (25%) was the highest for the Beaufort Sea surveys (1979-1991), primarily as a result of a pod of 10 and a pod of 5 bowhead whales observed milling on 19 September east of the primary study area (approximately 137°W. longitude) (Appendix B: Table B-1).

Polar bears, previously seen in greater abundance during more severe ice years such as 1983 and 1988, were not sighted during 1991. This might have been influenced by limitations on survey effort due to adverse survey conditions, especially in Block 11.

B. Median Water Depth at Bowhead Sightings (1982-1991)

The median water depth at 13 sightings of bowhead whales made on randomized line transects in Regions II and III (combined) during September and October 1991 was 66 m (Table 12). No bowhead whales were observed during line transects in Region I.

The areawide median depth for 1991 (66 m) was within the range of areawide median depths for the years 1982 through 1990 (previous values ranged from 18 to 347 m). A comparison of median values for the years 1982 through 1991 (Table 12) showed that median water depths at random sightings in Region II (66 m), Region III (118 m), and all regions combined (66 m) during 1991 were greater than for other years, except for 1983, when median depths in these regions were 1,289 m, 797 m, and 347 m, respectively. The median depth for 1991 (66 m) also was higher than the cumulative median depth (38 m) at all sightings (n = 321) made on line transect during the same timeframe.

To determine whether any of the differences between the median water depth for 1991 and previous years were statistically significant, these values 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 1991 and the years 1982, 1986, 1987, 1989, and 1990 (Table 13), all of which were considered years of milder general ice cover (see Sec. IV.D). Analysis by region (Table 13) showed a high degree of statistical significance ($p < 0.005$) between the values for 1991 and those for 1982, 1987, and 1990 in Region II

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

	Survey Block											Other	Other
Year	1	2	3	4	5	6	7	8	9	10	11	Canadian Areas	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
1990	5.54	0.00	0.72	7.61	18.51	3.35	1.72	*	0.00	0.00	0.00	63.64	0.00
1991	0.00	0.00	0.00	0.30	0.20	1.88	0.00	0.00	0.00	0.00	0.00	20.50	*
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
1990	3.00	0.00	2.14	2.17	*	2.86	*	*	*	0.00	0.97	*	0.00
1991	0.07	2.23	0.27	1.48	4.36	0.00	1.39	0.00	0.00	0.00	0.00	0.49	0.00

* No survey effort.

Table 12
Central-Tendency Statistics for Water Depth (in meters) at Random Sightings of Bowhead Whales (September-October), by Year and Region, 1982-1991

Year	Region	SI[1]	Median	CI[2]	Mean	SD[3]	Range
1982	I	8	17	11-457	113.4	176.23	11-457
	II	30	27	22-38	30.6	9.03	16-51
	III	5	40	[4]	43.4	11.24	29-59
	All 3	43	29	22-38	47.5	79.22	11-457
1983	I	9	69	22-2,323	393.7	740.61	22-2,323
	II	5	1,289	[4]	945.0	858.85	53-2,021
	III	9	797	49-1,902	969.7	740.24	49-1,902
	All 3	23	347	49-1,737	738.9	782.96	22-2,323
1984	I	15	42	27-69	53.3	41.43	18-177
	II	9	38	22-82	43.7	18.73	22-82
	III	14	48	22-274	90.4	130.05	18-485
	All 3	38	43	27-59	64.7	84.09	18-485
1985	I	3	183	[4]	219.3	221.74	18-457
	II	9	31	20-38	30.4	5.00	20-38
	III	1	[4]	[4]	[4]	[4]	64[5]
	All 3	13	31	20-183	76.6	122.13	18-457
1986	I	4	18	[4]	51.0	69.37	13-155
	II	12	17	9-40	60.8	144.79	7-519
	III	22	34	22-48	34.0	13.91	11-57
	All 3	38	26	18-44	44.3	82.99	7-519
1987	I	4	20	[4]	19.2	4.86	13-24
	II	9	27	15-38	27.3	7.60	15-38
	III	20	41	29-55	49.8	41.38	18-219
	All 3	33	37	24-44	40.0	34.54	13-219
1988	I	4	36	[4]	40.5	15.11	29-62
	II	4	44	[4]	44.8	13.60	29-62
	III	5	46	[4]	90.4	116.40	24-298
	All 3	13	42	29-62	61.0	72.17	24-298
1989	I	15	18	9-20	16.0	4.58	9-24
	II	1	[4]	[4]	[4]	[4]	44[5]
	III	3	49	[4]	49.3	9.50	40-59
	All 3	19	18	13-40	22.7	14.39	9-59
1990	I	3	31	[4]	29.3	13.58	15-42
	II	17	37	29-38	33.6	7.05	15-38
	III	68	40	37-48	40.5	10.49	16-60
	All 3	88	38	37-38	38.8	10.43	15-60

Table 12
Central-Tendency Statistics for Water Depth (in meters) at Random Sightings of Bowhead Whales (September-October), by Year and Region, 1982-1991
(Continued)

Year	Region	SI[1]	Median	CI[2]	Mean	SD[3]	Range
1991	I	0	[4]	[4]	[4]	[4]	[4]
	II	7	66	[4]	126.7	100.04	27-274
	III	6	118	[4]	132.2	92.05	48-232
	All 3	13	66	48-238	129.2	92.42	27-274
Cumulative	I	65	27	18-40	102.8	300.18	9-2,323
(1982-1991)	II	103	37	29-38	87.1	265.30	7-2,021
	III	153	42	38-48	105.7	280.61	11-1,902
	All 3	321	38	37-40	99.1	279.16	7-2,323

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

Table 13
Interyear Correlation (nonparametric) of the Median Water Depths at Random Bowhead Whale Sightings (September-October) Using the Mann-Whitney U Test, 1982-1991
(Page 1 of 4)

REGION I	1982	1983	1984	1985	1986	1987	1988	1989	1990
1983	U'= 54.0								
	p ≤ 0.10								
1984	U'= 81.5	U = 92.5							
	p < 0.20	p < 0.20							
1985	U'= 18.0	U = 14.5	U' = 30.5						
	p > 0.20	p > 0.20	p > 0.20						
1986	U = 16.0	U = 31.0	U = 45.0	U = 10.0					
	p > 0.20	p < 0.10	p < 0.20	p > 0.20					
1987	U = 16.5	U = 34.5	U = 55.5	U = 9.5	U'= 8.5				
	p > 0.20	p < 0.02	p < 0.01	p > 0.20	p > 0.20				
1988	U'= 21.0	U = 23.0	U'= 30.5	U = 8.0	U'= 12.0	U'= 16.0			
	p > 0.20	p > 0.20	p > 0.20	p > 0.20	p > 0.20	p < 0.05			
1989	U = 76.5	U = 134.0	U = 216.5	U = 39.0	U = 37.0	U = 41.5	U = 60.0		
	p > 0.20	p < 0.001	p < 0.001	p < 0.10	p > 0.20	p > 0.20	p ≤ 0.001		
1990	U = 13.0	U = 20.0	U = 31.5	U = 7.0	U'= 7.0	U'= 9.0	U = 7.5	U'= 35.5	
	p > 0.20	p > 0.20	p > 0.20	p > 0.20	p > 0.20	p > 0.20	p > 0.20	p < 0.20	
1991	*	*	*	*	*	*	*	*	*

Table 13
Interyear Correlation (nonparametric) of the Median Water Depths at Random Bowhead Whale Sightings (September-October) Using the Mann-Whitney U Test, 1982-1991
(Page 2 of 4)

REGION II	1982	1983	1984	1985	1986	1987	1988	1989	1990
1983	U'= 150.0 p < 0.001								
1984	U'= 193.0 p < 0.10	U = 42.0 p ≤ 0.01							
1985	U = 136.0 p > 0.20	U = 45.0 p ≤ 0.001	U = 62.0 p < 0.10						
1986	U = 254.0 p < 0.05	U = 58.0 p ≤ 0.002	U = 86.5 p < 0.05	U = 76.5 p < 0.20					
1987	U = 155.0 p > 0.20	U = 45.0 p ≤ 0.001	U = 63.5 p < 0.10	U = 53.0 p > 0.20	U'= 70.5 p > 0.20				
1988	U'= 103.0 p ≤ 0.02	U'= 19.0 p ≤ 0.05	U'= 20.5 p > 0.20	U'= 29.0 p < 0.20	U'= 41.0 p ≤ 0.05	U'= 33.0 p ≤ 0.02			
1989	U'= 29.0 p < 0.20	U = 5.0 *	U'= 5.5 p > 0.20	U'= 9.0 p ≤ 0.20	U'= 11.0 p > 0.20	U'= 9.0 p ≤ 0.20	U = 2.0 *		
1990	U'= 280.0 p > 0.20	U = 85.0 p < 0.001	U = 101.5 p < 0.20	U'= 108.5 p < 0.10	U'= 146.0 p < 0.10	U'= 114.0 p ≤ 0.05	U = 54.0 p < 0.10	U = 17.0 p ≤ 0.20	
1991	U'= 195.0 p < 0.001	U = 26.00 p < 0.20	U'= 51.0 p ≤ 0.05	U'= 56.0 p ≤ 0.01	U'= 74.0 p < 0.01	U'= 58.5 p < 0.005	U'= 22.0 p < 0.20	U'= 6.0 *	U'= 104.0 p < 0.005

Table 13
Interyear Correlation (nonparametric) of the Median Water Depths at Random Bowhead Whale Sightings (September-October) Using the Mann-Whitney U Test, 1982-1991
(Page 3 of 4)

REGION III	1982	1983	1984	1985	1986	1987	1988	1989	1990
1983	$U' = 43.5$ $p < 0.005$								
1984	$U' = 36.5$ $p > 0.20$	$U = 117.0$ $p < 0.001$							
1985	$U' = 5.0$ *	$U = 8.0$ $p > 0.20$	$U' = 11.0$ $p > 0.20$						
1986	$U = 77.0$ $p \leq 0.20$	$U = 195.5$ $p < 0.001$	$U = 216.0$ $p < 0.05$	$U = 22.0$ $p \leq 0.10$					
1987	$U = 54.5$ $p > 0.20$	$U = 173.0$ $p < 0.001$	$U = 159.0$ $p > 0.20$	$U = 19.0$ $p \leq 0.20$	$U' = 284.0$ $p < 0.10$				
1988	$U = 13.0$ $p > 0.20$	$U = 43.0$ $p \leq 0.005$	$U = 38.0$ $p > 0.20$	$U = 4.0$ *	$U' = 70.5$ $p > 0.20$	$U' = 56.0$ $p > 0.20$			
1989	$U' = 10.0$ $p > 0.20$	$U = 25.5$ $p < 0.02$	$U' = 24.5$ $p > 0.20$	$U = 3.0$ *	$U' = 54.0$ $p \leq 0.10$	$U' = 41.5$ $p > 0.20$	$U' = 10.0$ $p > 0.20$		
1990	$U = 200.5$ $Z = 0.66$ $p > 0.20$	$U = 596.5$ $Z = 4.60$ $p < 0.001$	$U = 572.5$ $Z = 1.18$ $p > 0.20$	$U = 68.0$ $Z = 1.68$ $p < 0.10$	$U' = 946.0$ $Z = 1.85$ $p < 0.10$	$U = 732.0$ $Z = 0.51$ $p > 0.20$	$U = 189.0$ $Z = 0.40$ $p > 0.20$	$U = 154.0$ $Z = 1.47$ $p < 0.20$	
1991	$U' = 25.0$ $p \leq 0.10$	$U = 47.5$ $p < 0.02$	$U' = 58.0$ $p > 0.20$	$U = 3.0$ *	U' 121.0 $p \leq 0.001$	$U' = 100.0$ $p < 0.02$	$U' = 24.0$ $p < 0.20$	$U' = 13.0$ $p > 0.20$	$U' = 354.0$ $Z = 2.96$ $p < 0.005$

Table 13
Interyear Correlation (nonparametric) of the Median Water Depths at Random Bowhead Whale Sightings (September-October) Using the Mann-Whitney U Test, 1982-1991
(Page 4 of 4)

ALL THREE REGIONS (COMBINED)

	1982	1983	1984	1985	1986	1987	1988	1989	1990
1983	U'= 882.0 Z = 5.21 p < 0.001								
1984	U'=1,138.5 Z = 3.04 p < 0.005	U = 717.5 Z = 4.17 p < 0.001							
1985	U'= 316.5 Z = 0.71 p > 0.20	U = 249.5 p < 0.001	U = 297.5 p > 0.20						
1986	U = 898.0 Z = 0.76 p > 0.20	U = 786.0 Z = 5.19 p < 0.001	U = 1043.0 Z = 3.33 p < 0.001	U = 314.0 p < 0.20					
1987	U'= 798.5 Z = 0.93 p > 0.20	U = 666.5 Z = 4.77 p < 0.001	U = 809.5 Z = 2.10 p < 0.05	U = 223.0 p > 0.20	U'= 760.5 Z = 1.53 p < 0.20				
1988	U'= 414.0 Z = 2.60 p < 0.01	U = 245.5 p < 0.002	U'= 248.0 p > 0.20	U'= 104.5 p > 0.20	U'= 356.5 p < 0.02	U'= 291.0 p < 0.10			
1989	U = 598.0 Z = 2.89 p < 0.005	U = 417.5 p < 0.001	U = 617.0 p < 0.001	U = 198.5 p < 0.005	U = 457.0 p < 0.20	U = 480.5 p < 0.002	U = 214.0 p < 0.001		
1990	U'=2,473.5 Z = 2.85 p < 0.005	U = 1,729.5 Z = 8.10 p < 0.001	U = 1,949.5 Z = 1.47 p < 0.20	U'= 682.5 Z = 1.12 p > 0.20	U'= 2,227.5 Z = 2.95 p < 0.005	U'= 1,717.5 Z = 1.54 p < 0.20	U = 674.5 Z = 1.03 p > 0.20	U'= 1,353.0 Z = 4.21 p < 0.001	
1991	U'= 503.0 Z = 4.33 p < 0.001	U = 213.0 p < 0.05	U'= 373.5 p < 0.01	U'= 134.5 p < 0.02	U'= 446.0 p < 0.001	U'= 377.0 p < 0.001	U'= 135.0 p ≤ 0.01	U'= 236.0 p < 0.001	U'= 999.0 Z = 4.33 p < 0.001

* Insufficient sample size.

(between 146°W. and 150°W. longitudes) and for 1986 and 1990 in Region III (between 141°W. and 146°W. longitudes).

This probability of difference due to chance ($p < 0.005$) also was noted between the 1983 median value (all 3 regions combined) and medians for all other years tested, except for 1991, using this nonparametric test. The difference between the median water depths at bowhead sightings for 1983 (347 m) and 1991 (66 m) was less than for other years (Table 12), but it also was considered statistically significant ($p < 0.05$). A high degree of significance ($p < 0.005$) between 1983 and other years was shown, to a lesser extent, in the bathymetric regions (especially between 141°W. and 150°W. longitudes).

A high level of significance ($p < 0.005$) was noted between the 1989 median value (all 3 regions combined) and the median values for all other years except 1986 (Table 13) due to the fact that the 1989 median of 18 m (Table 12) was clearly lower than the median for other years. Such attained levels ($p < 0.005$) between 1989 and other years also was shown in Region I (between 150°W. and 153°30′W. longitudes).

Mean water depths also were calculated for Regions I, II, and III (Table 12). Mean values, although less descriptive of the apparent "axis" of the migration, were considered more robust for demonstrating significant differences between years. The mean water depth at 13 sightings of bowhead whales made on randomized line transects in Regions II and III (combined) during September and October 1991 was 129.2 m (Table 12). No bowhead whales were observed during line transects in Region I.

The areawide mean depth for 1991 (129.2 m) was within the range of areawide mean depths for the years 1982 through 1990 (previous values ranged from 22.7 to 738.9 m). A comparison of mean values for the years 1982 through 1991 (Table 12) showed that mean water depths at random sightings in Region II (126.7 m), Region III (132.2 m), and all regions combined (129.2 m) during 1991 were greater than for other years, except for 1983, when mean depths in these areas were 945.0 m, 969.7 m, and 738.9 m, respectively. The areawide mean depth for 1991 (129.2 m) also was higher than the cumulative mean depth (99.1 m) at all sightings ($n = 321$) made on line transect during the same timeframe.

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 1991) were considered highly significant ($p < 0.005$) in all three regions combined and in Regions II and III (Table 14), thus mirroring differences noted between median values in those regions. Differences in mean water depths between all other years, including 1991, were not considered statistically significant.

The reasons for the offshore (deep-water) migratory route of 1983 and the comparatively shallower route followed in 1991 (and other years) may be attributable to general ice cover (see Sec. IV.D). Differences in human activity levels, oceanographic conditions, and the possible indirect effect of heavy ice cover on prey availability are additional potential factors. Ice cover probably has the greatest potential for interacting with environmental conditions that, in turn, may have biological significance to migrating bowhead whales (e.g., net primary production, availability of leads, water temperature). During 1983, the most severe ice year since 1975 (USDOD, Navy, Naval Polar Oceanography Center, 1992), the bowhead migration was observed in water almost an order of magnitude deeper than for other years (Table 12). During 1991, the third most severe ice year since the beginning of the surveys in 1979 (USDOD, Navy, Naval Polar Oceanography Center, 1992), the bowhead migration was observed at a greater than average median and mean water depth (Table 12).

C. Potential Responses of Bowheads to Survey Aircraft

During September and October, there were no sightings of bowhead whales for which responses to the survey aircraft were apparent. Although it was not possible to determine if any responses would have been a direct result from overflight by survey aircraft, sudden overt changes in whale behavior were looked for. Such changes included an abrupt dive, course diversion, or cessation of behavior ongoing at first sighting.

Table 14
Interyear Correlation (parametric) of the Mean Water Depths at Random Bowhead Whale Sightings (September-October) Using Analysis of Variants (ANOVA) and the Tukey Test, 1982-1991

REGION I[1]
ANOVA F = 1.509, $p < 0.50$

Tukey Test:

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

REGION II
ANOVA F = 12.504, $p << 0.001$

Tukey Test:

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

(1984)–(1983): ($p < 0.005$)

REGION III
ANOVA F = 24.184, $p << 0.001$

Tukey Test:

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

(1987)–(1983): ($p < 0.001$)

ALL THREE REGIONS (COMBINED)
ANOVA F = 24.209, $p << 0.001$

Tukey Test:

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

(1982)–(1983): ($p << 0.001$)

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

D. Potential Effect of General Ice Cover on WPUE (1979-1991)

The number of bowhead whales observed (n = 35) and the survey effort spent (70.25 hr) during the combined months of September and October 1991 in Survey Blocks 1 through 11 were lower than for any previous year since the survey began in 1979. This resulted primarily from the record low number of bowheads observed (n = 9) and the record low number of survey effort spent (32.54 hr) in Blocks 1 through 11 during the month of September (Table 15).

The relative abundance of bowheads for 1991 (0.50 WPUE) was a relatively low value for a single fall season and was considered representative of the lower values found during heavy-ice years, when bowheads were harder to spot. The relative abundance of bowheads for Fall 1991 was particularly low during September (0.27 WPUE), showing the lowest value during that month for the years 1979-1991 (Table 15).

The low level of survey effort was related to environmental factors such as the heavy general ice cover in 1991 (USDOD, Navy, Naval Polar Oceanography Center, 1992) and the low cloud ceilings over the Alaskan Beaufort Sea.

The years 1980, 1983, 1988, and 1991 were categorized as having "heavy" ice cover during the navigation season. These four years are ranked as having the severest seasonal ice for the years 1979 through 1991 and show distances between Point Barrow and the five-tenths ice concentration on 15 September ranging from 10 nautical miles (nm) to 25 nm (USDOD, Navy, Naval Polar Oceanography Center, 1992).

The years 1984 and 1985, categorized as having "medium" ice cover during the open-water season, are ranked as having the fourth- and fifth-severest seasonal ice for the years 1979 through 1991 and show distances between Point Barrow and the five-tenths ice concentration on 15 September ranging from 50 nm to 55 nm (USDOD, Navy, Naval Polar Oceanography Center, 1992).

The years 1979, 1981, 1982, 1986, 1987, 1989, and 1990, categorized as having "light" ice cover during the open-water season, are ranked as having the least severe seasonal ice for the years 1979 through 1991 and show distances between Point Barrow and the five-tenths ice concentration on 15 September ranging from 85 nm to 125 nm (USDOD, Navy, Naval Polar Oceanography Center, 1992).

Table 15 shows a relatively low cumulative number of bowhead whales observed per hour of survey effort in the primary study area (Survey Blocks 1-11) during September and October for years of heavy ice cover (0.40 WPUE), a middle-range value for moderate ice years (0.97 WPUE), and a relatively high value for light ice years (2.05 WPUE). A Kruskal-Wallis single factor analysis of variance by ranks (Zar, 1984) showed that these ice-year categories were significantly related ($p < 0.05$) to WPUE.

Although cumulative values for the three ice-year categories (Table 15) and the Kruskal-Wallis test suggest a relationship to WPUE, it is clear that WPUE is not totally dependent on general ice coverage. Although the mean WPUE for heavy ice years ($\bar{x}$ = 0.42, SD = 0.10, n = 4) appears separable from other ice-year categories, the SD of the mean WPUE for years with light ice ($\bar{x}$ = 2.28, SD = 1.63, n = 7) overlaps that for moderate ice years ($\bar{x}$ = 0.97, SD = 0.05, n = 2). Likewise, a nonparametric Tukey-type test (Zar, 1984) for comparing unequal sample sizes showed that while WPUE in light ice years was significantly different ($p < 0.05$) from that in heavy ice years, neither of these two categories was significantly different from WPUE in moderate ice years. A separate comparison of ice concentrations at the location of bowhead sightings (1981-1986) with the observability of whales showed that sighting distance was significantly affected by local ice cover only in 1982 and 1983 (Ljungblad et al., 1987).

E. Management Use of Real-Time Field Information

During 1991, MMS issued one geological (coring) permit, one on-ice geophysical (VIBROSEIS) permit, one vessel geophysical (deep-seismic air gun) permit, and one vessel geological-geophysical (shallow-seismic air gun) permit to industry for exploration in the central to western portions of the Alaskan Beaufort Sea.

Table 15
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, 1979-1991 (after Ljungblad et al. [1987] and Treacy [1988, 1989, 1990, 1991])

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
1990	54.85	401	7.31	31.97	70	2.19	86.82	471	5.43
1991[1]	32.54	9	0.27	37.70	26	0.69	70.25	35	0.50
Ice Coverage									
Heavy Ice Years[1] (Σ)	267.75	114	0.43	169.79	63	0.37	437.55	177	0.40
Moderate Ice Years[2] (Σ)	132.30	120	0.91	92.85	98	1.06	225.15	218	0.97
Light Ice Years (Σ)	493.44	1,234	2.50	312.44	415	1.33	805.88	1,649	2.05

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

Of the geophysical permits, on-ice seismic exploration was permitted from the first part of February through mid-April and seismic vessels were permitted to operate during August and September.

In order to prevent 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.

ARCO Alaska Inc. operated a Single Steel Drilling Caisson (SSDC) north of Dease Inlet and west of the primary study area at the Cabot drilling site (71°19.4'N. latitude, 155°12.8'W. longitude). The main body of the structure is approximately 162 m long, 53 m wide, and 25 m high. The SSDC rests on a subsurface mat (MAT) that permits drilling in water depths of 9 to 23 m without bottom preparation. The MAT has a seafloor dimension of 162 m by 110 m and is 13 m high, excluding a system of skirts that penetrates the seabed. The SSDC was moved on location at the Cabot site on 27 August 1991 and was not permitted to drill during the bowhead whale migration. Drilling was begun on 1 November. The well was abandoned on 26 February 1992 and the SSDC was left in place over the winter.

In addition, Amoco Production Company conducted drilling operations at its Galahad Prospect in Camden Bay (70°33.6'N. latitude, 144°57.6'W. longitude). Drilling operations began on 14 September 1991, and the well was abandoned on 13 October 1991. Drilling was conducted by using an ice-reinforced drillship--Explorer II (Canadian Marine Drilling Ltd. [CANMAR])--supported by four ice-management vessels. The CANMAR Explorer II is approximately 115 m in length and is moored by eight 5,900-kg moorfast anchors with wires that are 7 cm in diameter.

Bowhead whales observed in the general study area, including those in the vicinity of drill sites, are shown for each bimonthly period of the Fall-1991 survey in Figures 17 through 19. The closest sighting of bowheads to a drill site was noted on 17 September 1991 (Appendix B: Flight 7) at a distance of 21.8 km northeast of the operational CANMAR Explorer II drillship. This adult whale was swimming slowly at a 250° heading in 0-percent ice when observed.

Daily summaries of field information from this survey, and other arctic surveys being conducted concurrently, were transferred by the MMS Team Leader to MMS Field Operations in Anchorage. The MMS and NMFS reviewed daily reports to determine the beginning of the bowhead whale migration relative to geological and geophysical exploration activities, migratory patterns of bowheads in the vicinity of oil and gas industry activities, and the end of the bowhead whale migration in relation to the Cabot and Galahad drilling sites. Drilling operations at Cabot began after the Fall-1991 bowhead migration and drilling operations at Galahad were conducted during the bowhead migration. Daily summaries of survey information provided by the present study indicated that the Fall-1991 bowhead migration began by 16 September. The NMFS determined that the official ending date of the Fall-1991 bowhead whale migration across the Alaskan Beaufort Sea occurred on 17 October.

Information summaries also were provided to various requesting agencies and private sector organizations, including the USDOD Naval Polar Oceanography Center, the Alaska Eskimo Whaling Commission, and Western Geophysical Company.

V. LITERATURE CITED

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

USDOD, Navy, Naval Polar Oceanography Center. 1992. U.S. Navy-NOAA Joint Ice Center, Seasonal Outlook, Western Arctic Ice, 1992. Washington, D.C., 6 pp.

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

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

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

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

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

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

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

BOWHEAD WHALE DENSITIES

This appendix presents estimated bowhead whale densities in the Beaufort Sea for the period 31 August through 20 October 1991. Present survey goals do not include estimation of absolute population abundance; therefore, raw density values found in this report were not adjusted to account for submergence of whales, sighting variability, etc., and are presented only for relative visual comparison with similarly calculated values from previous survey reports. Also, sample sizes for determining density in individual survey blocks were considered too small to stratify by category (sea state, ice cover, etc.) or to make statistical correlations having real biological significance.

METHODS

A computer program--DENSITY--was used to calculate raw density estimates for survey blocks previously shown for the Beaufort Sea (Fig. 1). The program was based on strip-transect methodologies that use only sightings made on random-transect legs (Estes and Gilbert, 1978) and that were within a predetermined distance from the aircraft (Hayne, 1949). Distance from the transect line was calculated trigonometrically from the altitude of the survey plane at the time of sighting and the clinometer angle recorded for each initial sighting location. Only endangered whale sightings within 1 km of random-transect legs were used to derive density estimates. The number of sightings made from project aircraft decreased markedly much beyond that distance, with 69 percent of sightings from the Twin Otter made within 1 km of the trackline. The basic assumptions for use of this formula, and the degree to which these assumptions were met in the Fall-1991 and previous MMS-funded arctic whale surveys, are incorporated by reference (Ljungblad et al., 1987: Appendix B).

RESULTS

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

On 31 August, no block received more than 10-percent survey coverage and no bowheads were observed in any of the survey blocks.

During the first half of September, over 10 percent of the area was surveyed for Block 1. No bowheads were observed in Block 1 within 1 km of the randomly generated transect line, for an estimated density of 0.00 whales per 100 km^2. No bowhead whales were observed within 1 km of the transect line in other blocks during this period.

During the second half of September, no block received more than 10-percent survey coverage. Five bowhead whales were observed within 1 km of the transect line in other blocks during this period.

During the first half of October, over 10 percent of the area was surveyed for Blocks 1, 2, 3, 5, and 10. One bowhead was observed in Block 1 within 1 km of the transect line, for an estimated density of 0.04 whales per 100 km^2. Five bowheads were observed in Block 2, for an estimated density of 0.44. No bowheads were observed in Block 3, for an estimated density of 0.00. Two bowheads were observed in Block 5, for an estimated density of 0.21. No bowheads were observed in Block 10, 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.

From 16 through 20 October, no transects were flown.

Table A-1
Semimonthly Estimates of Bowhead Whale Densities, by Survey Block (Fall 1991)
(strip width = 2 km)

Block No. (by Semi-monthly Period)	Block Area (km^2)	Transect Distance (km)	Percent of Area Surveyed	Transect Time (hr)	Percent of Total Time	No. of Transects Flown	No. of Whales Observed	Density (Whales/ 100 km^2)
31 Aug								
5	9,481	430	9.06	1.87	98.65	7	0	0.00
7	8,109	6	0.14	0.03	1.35	3	0	0.00
1-15 Sep								
1	10,222	613	12.00	2.62	56.65	12	0	0.00
2	6,672	227	6.82	0.98	21.28	7	0	0.00
4	5,714	244	8.55	1.02	22.00	6	0	0.00
6	8,109	0	0.00	0.00	0.02	1	0	0.00
10	10,358	1	0.01	0.00	0.05	1	0	0.00
16-30 Sep								
1	10,222	326	6.37	1.30	17.05	7	0	0.00
2	6,672	272	8.17	1.06	14.01	9	0	0.00
3	11,475	184	3.20	0.76	10.05	2	0	0.00
4	5,714	265	9.27	1.07	14.06	6	0	0.00
5	9,481	432	9.12	1.81	23.77	6	1	0.12
6	8,109	370	9.13	1.47	19.37	6	4	0.54
7	8,109	2	0.06	0.01	0.13	3	0	0.00
9	9,753	3	0.06	0.01	0.17	2	0	0.00
10	10,358	28	0.53	0.10	1.34	3	0	0.00
11	10,358	1	0.01	0.00	0.04	1	0	0.00
1-15 Oct								
1	10,222	1,360	26.61	5.78	33.41	26	1	0.04
2	6,672	568	17.02	2.44	14.12	15	5	0.44
3	11,475	814	14.18	3.53	20.38	14	0	0.00
5	9,481	481	10.15	2.10	12.14	7	2	0.21
6	8,109	74	1.83	0.28	1.60	1	0	0.00
7	8,109	149	3.66	0.58	3.35	3	0	0.00
8	9,753	50	1.03	0.17	0.97	2	0	0.00
9	9,753	38	0.78	0.12	0.71	1	0	0.00
10	10,358	556	10.74	2.26	13.08	9	0	0.00
11	10,358	7	0.13	0.02	0.12	1	0	0.00
16-20 Oct	No transects flown during this period.							

LITERATURE CITED

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

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

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

DAILY FLIGHT SUMMARIES

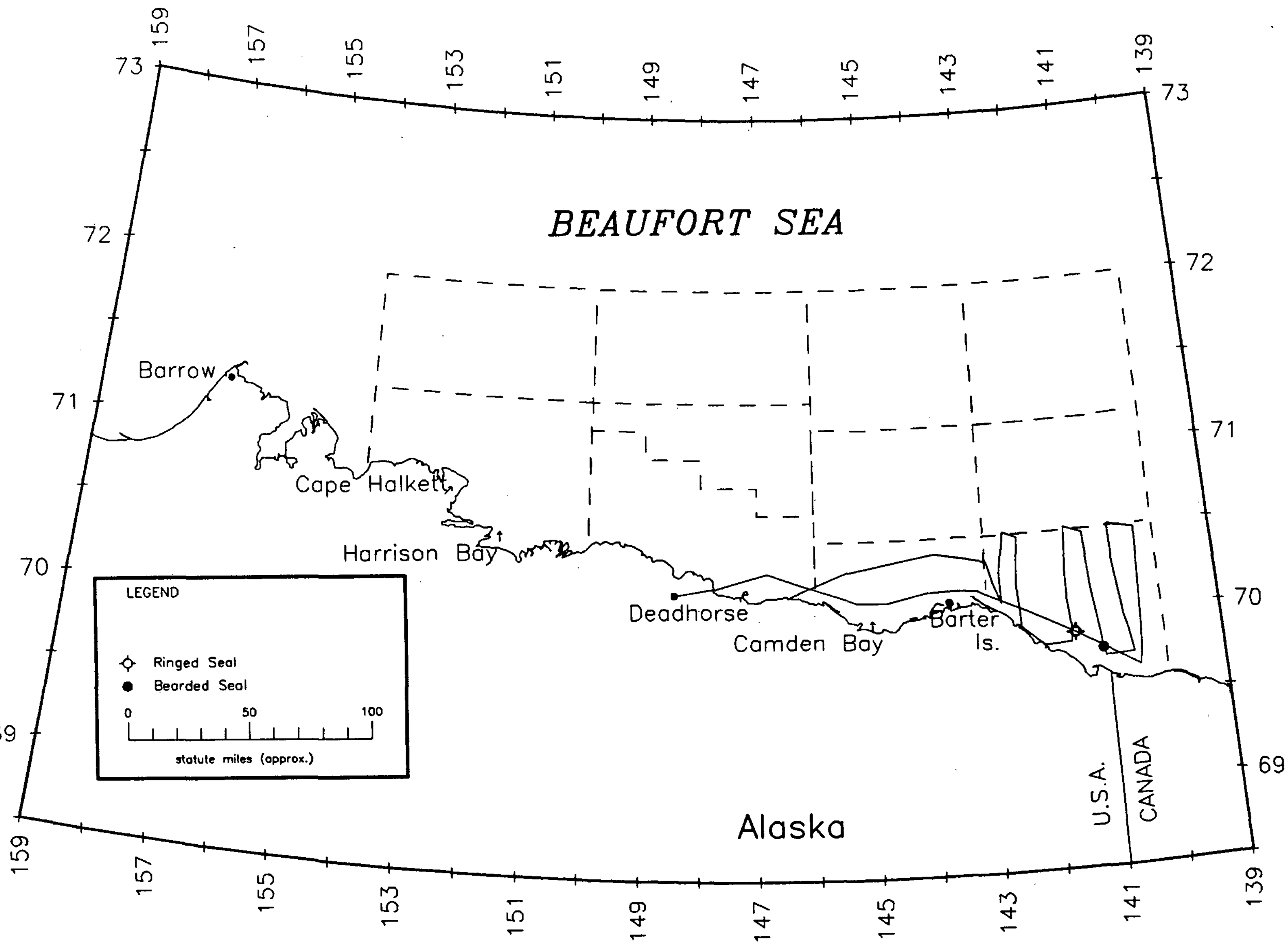
This appendix consists of Flight Tracks 1 through 25, depicting aerial surveys flown over the study area from 31 August through 20 October 1991 aboard a Twin Otter aircraft. Daily maps show survey tracks and the position of all marine mammal sightings.

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

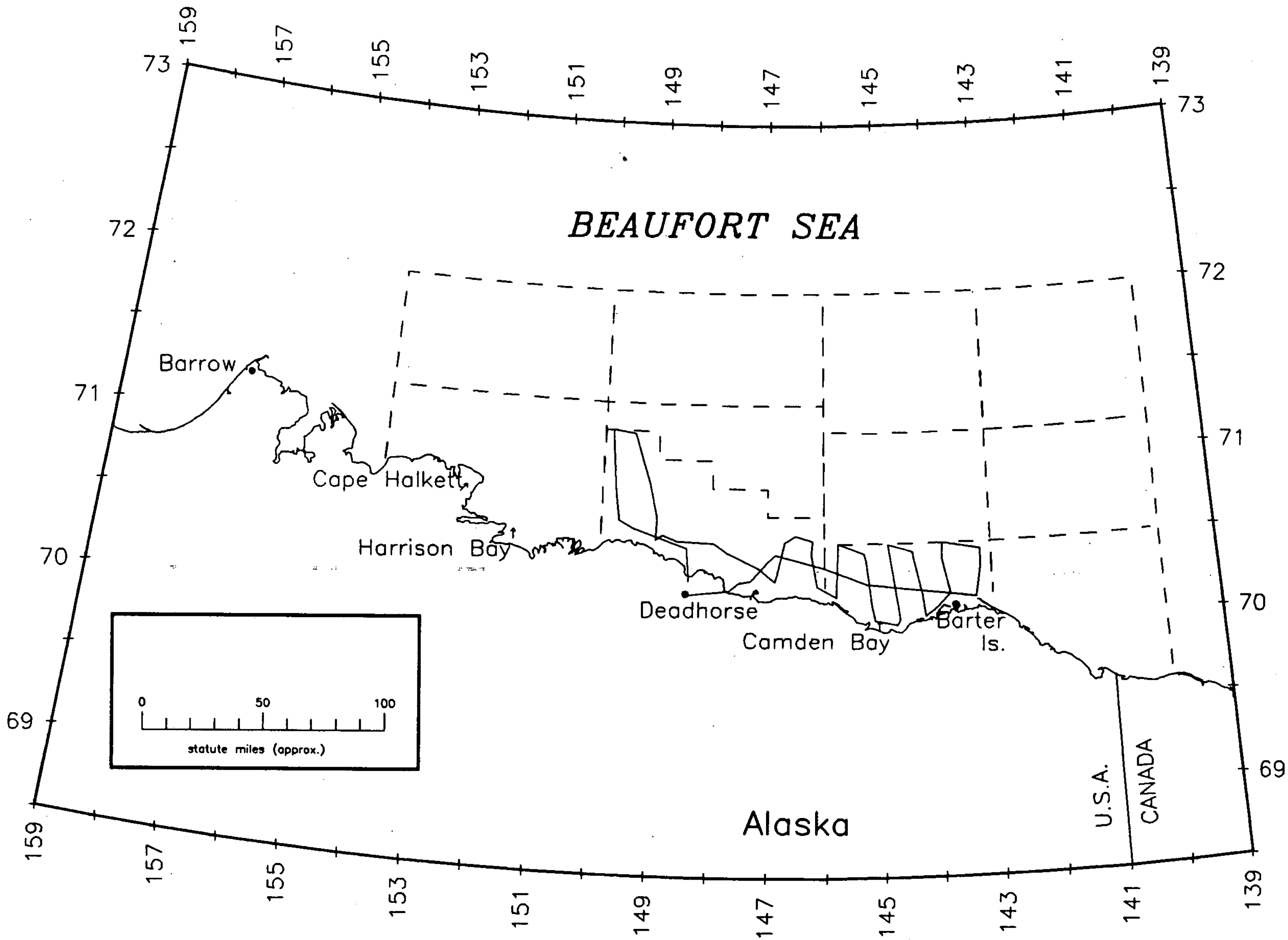
Table B-1
Selected Sighting Data for Bowhead Whales Observed, August-October 1991

Flight No.	Date	Total Whales	No. Calves	Latitude (North)	Longitude (West)	Sighting Cue	Behavior	Heading	Ice (%)	Sea State
6	16 Sep	2	0	70°37.4'	143°25.1'	body	mill	60	0	3
6	16 Sep	1	0	70°10.4'	141°48.8'	body	swim	190	0	3
7	17 Sep	1	0	70°40.7'	144°29.5'	body	swim	250	0	1
7	17 Sep	2	0	70°48.3'	145°21.8'	splash	swim	270	5	1
7	17 Sep	1	0	70°49.8'	145°55.4'	body	swim	260	1	1
9	19 Sep	1	0	69°07.2'	137°05.9'	body	swim	[1]	0	2
9	19 Sep	4	0	69°09.6'	137°07.0'	body	swim	[1]	0	2
9	19 Sep	10	0	69°11.4'	137°03.8'	body	mill	190	0	2
9	19 Sep	2	0	69°14.9'	136°57.2'	splash	swim	[1]	0	2
9	19 Sep	2	0	69°16.0'	136°55.3'	body	swim	270	0	2
9	19 Sep	3	0	69°17.2'	136°57.0'	body	swim	[1]	0	2
9	19 Sep	5	0	69°16.6'	137°00.6'	body	mill	190	0	2
9	19 Sep	1	0	69°17.1'	137°04.3'	splash	breach	340	0	2
9	19 Sep	1	0	69°19.4'	136°56.8'	splash	feed	[1]	0	2
9	19 Sep	1	0	69°20.1'	136°51.9'	splash	swim	180	0	2
9	19 Sep	1	0	69°19.9'	136°52.9'	body	swim	60	0	2
9	19 Sep	2	0	69°24.4'	137°54.3'	splash	breach	310	0	2
12	25 Sep	1	0	70°24.2'	143°52.5'	splash	swim	250	10	5
12	25 Sep	1	0	70°25.4'	143°55.8'	body	swim	220	10	3
14	1 Oct	1	0	70°53.0'	151°15.4'	body	dive	240	15	2
14	1 Oct	1	0	71°18.6'	152°59.7'	splash	breach	280	10	3
15	2 Oct	1	0	70°57.0'	146°11.2'	body	swim	260	1	2
15	2 Oct	1	0	70°56.3'	146°09.0'	splash	swim	240	1	2
15	2 Oct	1	0	70°52.8'	146°41.8'	body	swim	240	0	1
15	2 Oct	2	1	71°01.4'	147°40.5'	blow	cow with calf	270	1	1
16	3 Oct	1	0	70°33.9'	142°59.2'	body	swim	210	0	3
16	3 Oct	1	0	70°05.7'	141°24.1'	blow	swim	290	1	3
16	3 Oct	1	0	69°47.8'	140°24.6'	splash	swim	270	1	2
16	3 Oct	1	0	69°48.7'	140°00.0'	splash	swim	270	1	2
16	3 Oct	1	0	69°56.0'	140°07.4'	splash	swim	270	1	2
16	3 Oct	1	0	69°55.8'	140°14.9'	body	rest	240	1	2
16	3 Oct	3	0	70°08.2'	140°49.4'	body	[1]	260	2	3
16	3 Oct	2	0	69°59.9'	140°44.3'	body	rest	270	1	2
16	3 Oct	2	1	70°10.7'	141°47.9'	blow	cow with calf	260	1	1
16	3 Oct	1	0	70°19.5'	142°27.7'	body	swim	250	0	1
16	3 Oct	1	0	70°21.9'	142°54.7'	blow	swim	50	0	1
16	3 Oct	1	0	70°23.5'	143°06.4'	body	swim	270	0	3
16	3 Oct	1	0	70°26.0'	143°51.7'	blow	swim	230	1	4
17	4 Oct	1	0	71°13.3'	149°51.9'	blow	dive	240	0	1
17	4 Oct	1	0	70°52.2'	148°40.5'	splash	swim	240	1	2
17	4 Oct	1	0	71°07.7'	148°41.5'	body	swim	140	5	2

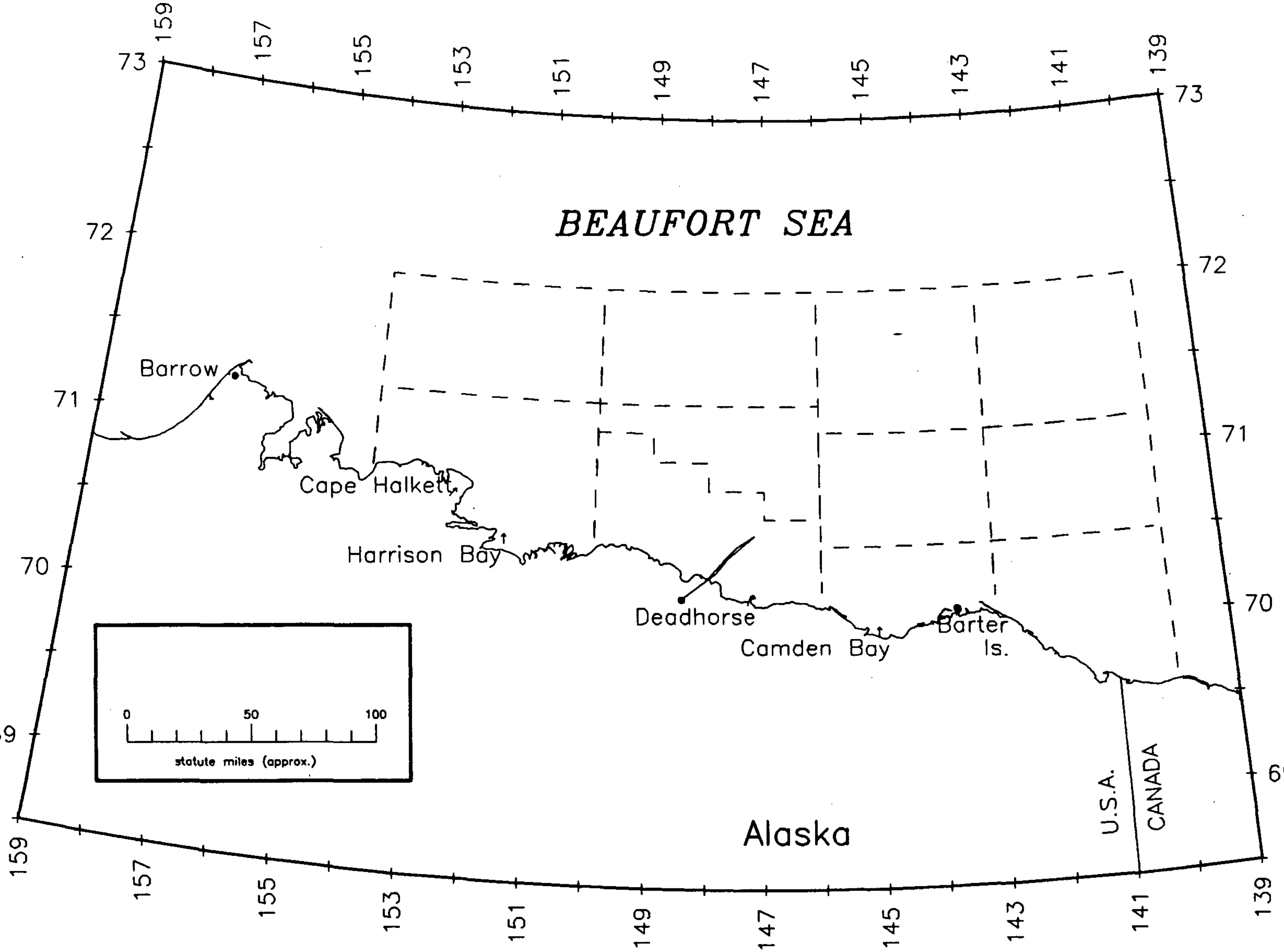
[1] Not recorded.



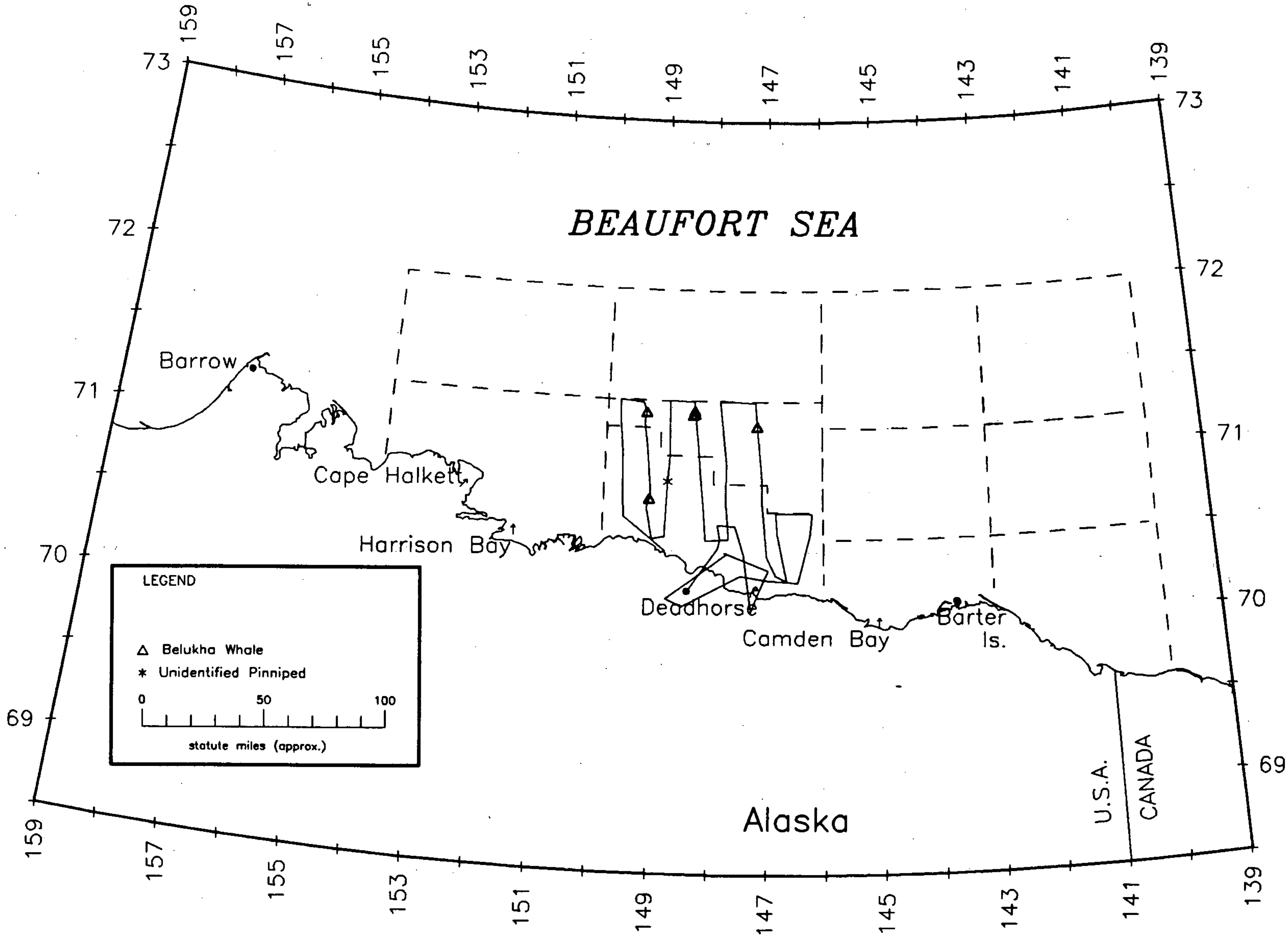
FLIGHT 1 31 August 1991
Survey Track and Sightings



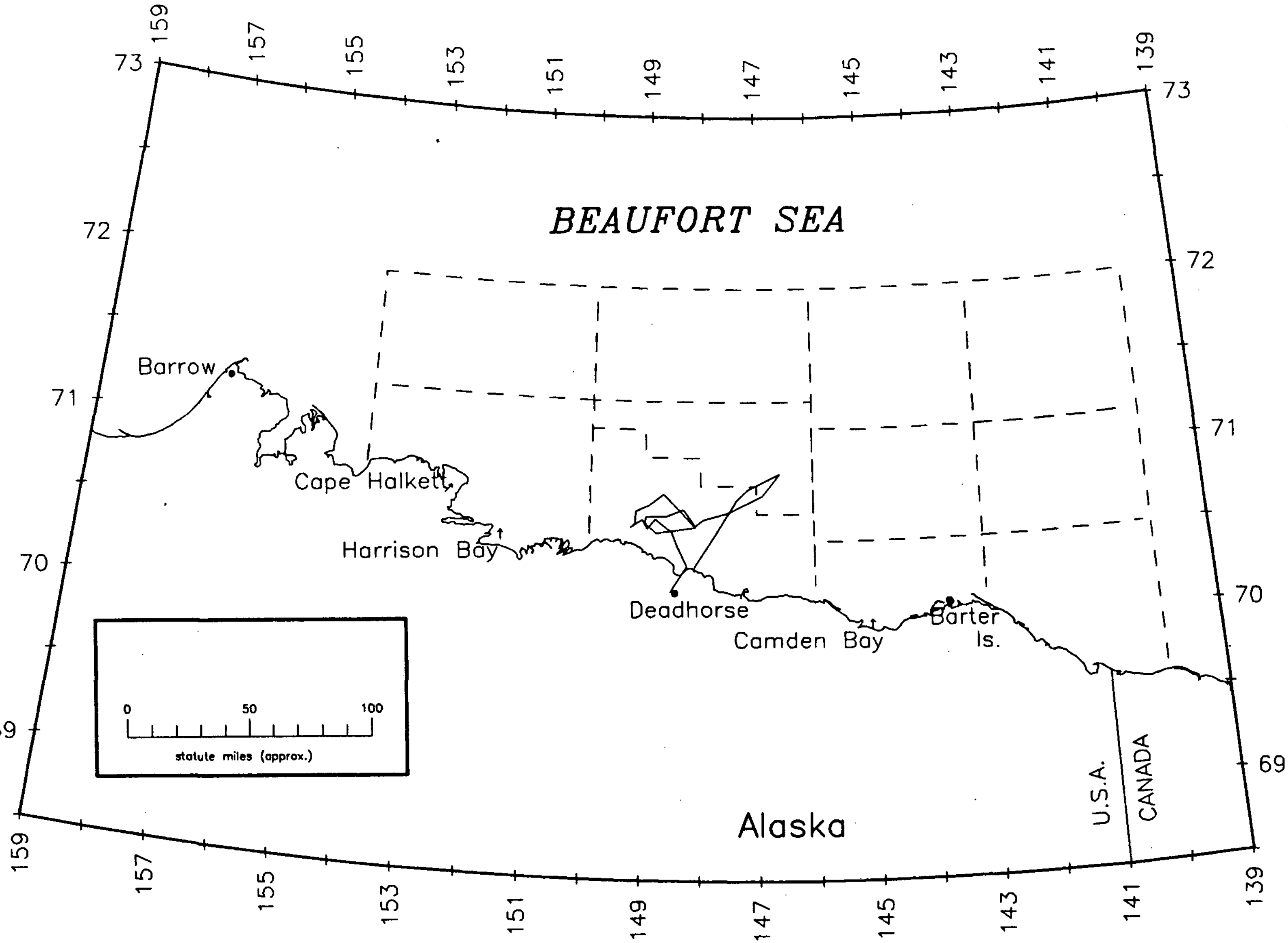
FLIGHT 2 1 September 1991
Survey Track and Sightings



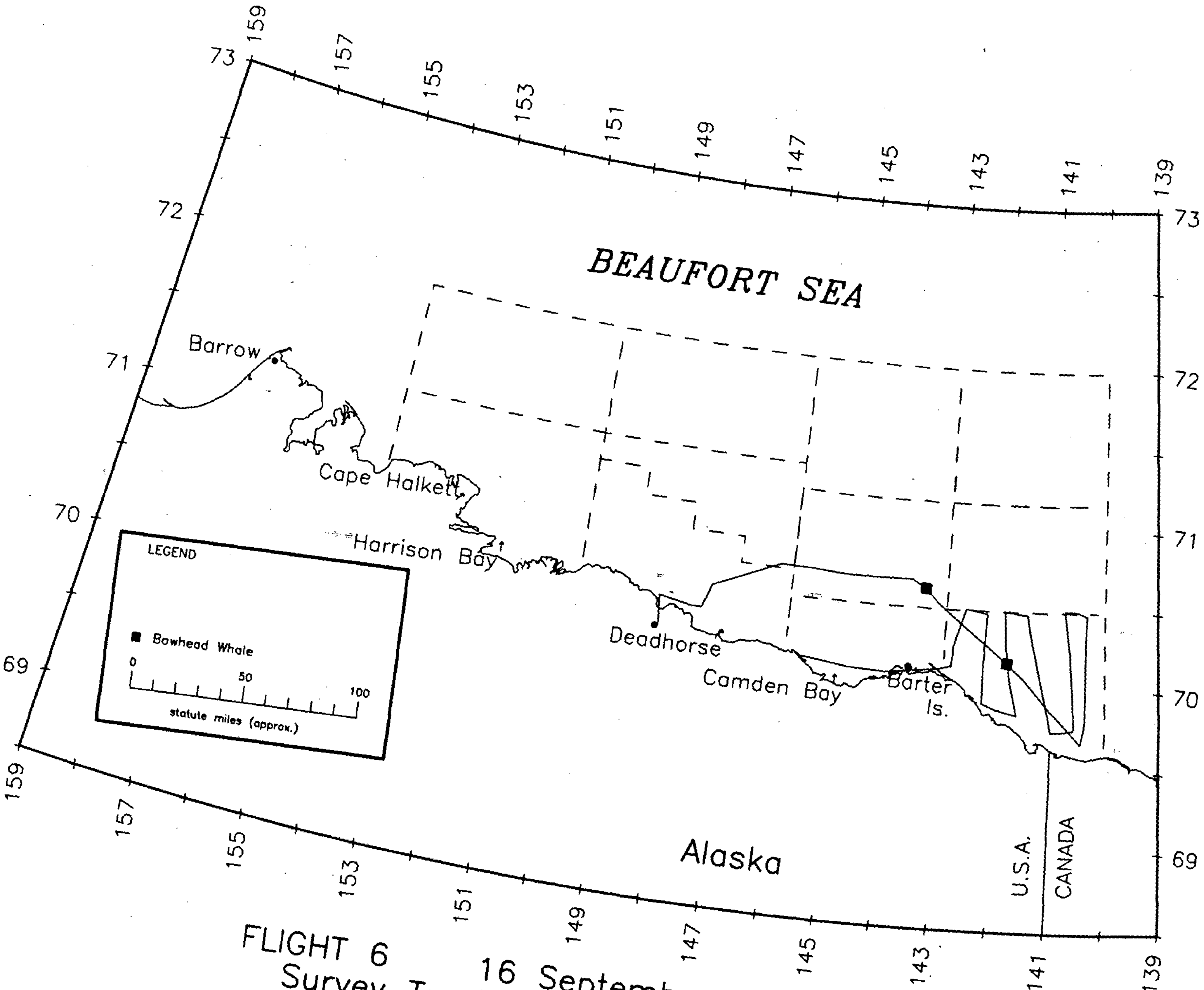
FLIGHT 3 5 September 1991
Survey Track and Sightings



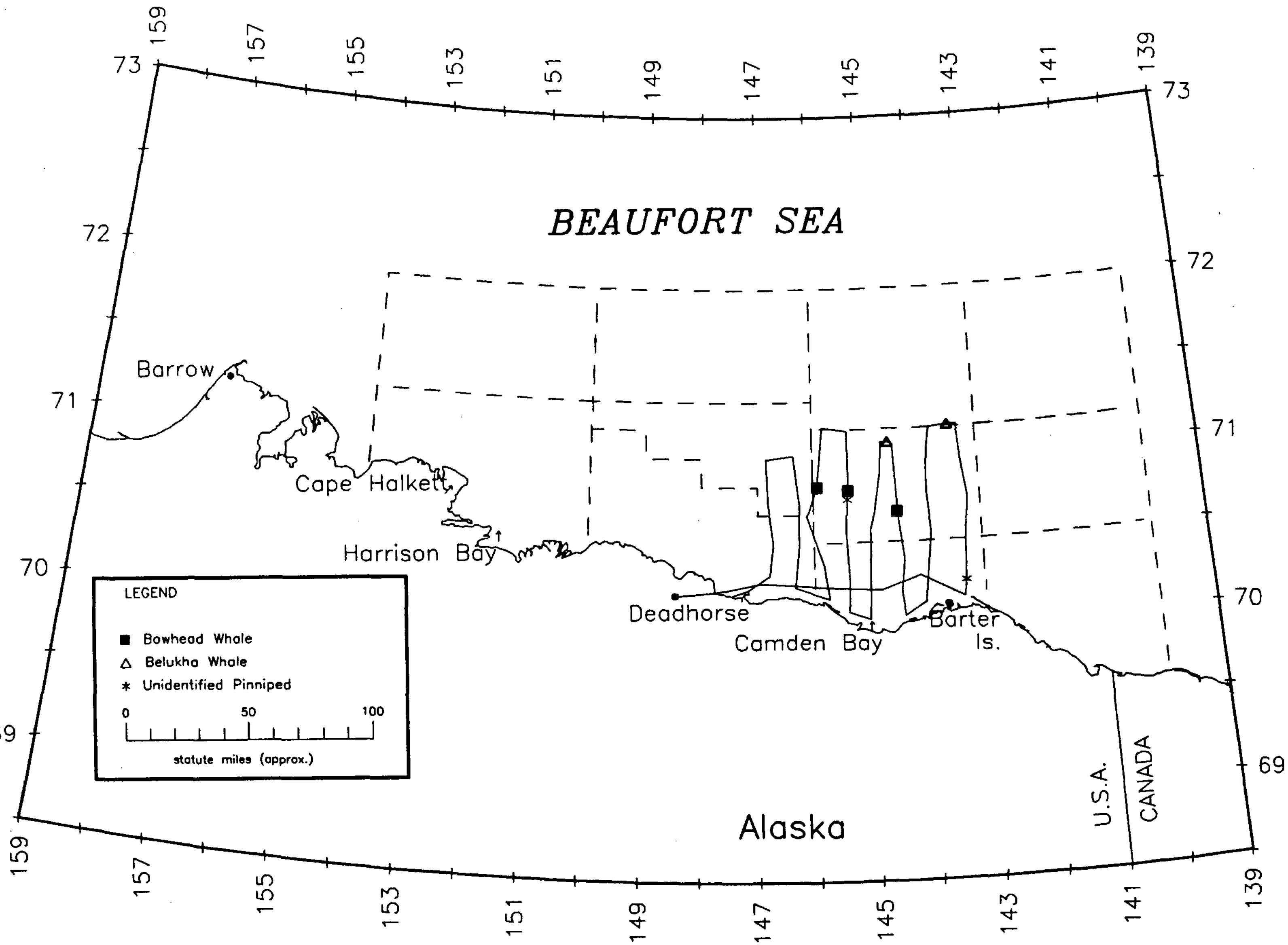
FLIGHT 4 6 September 1991
Survey Track and Sightings



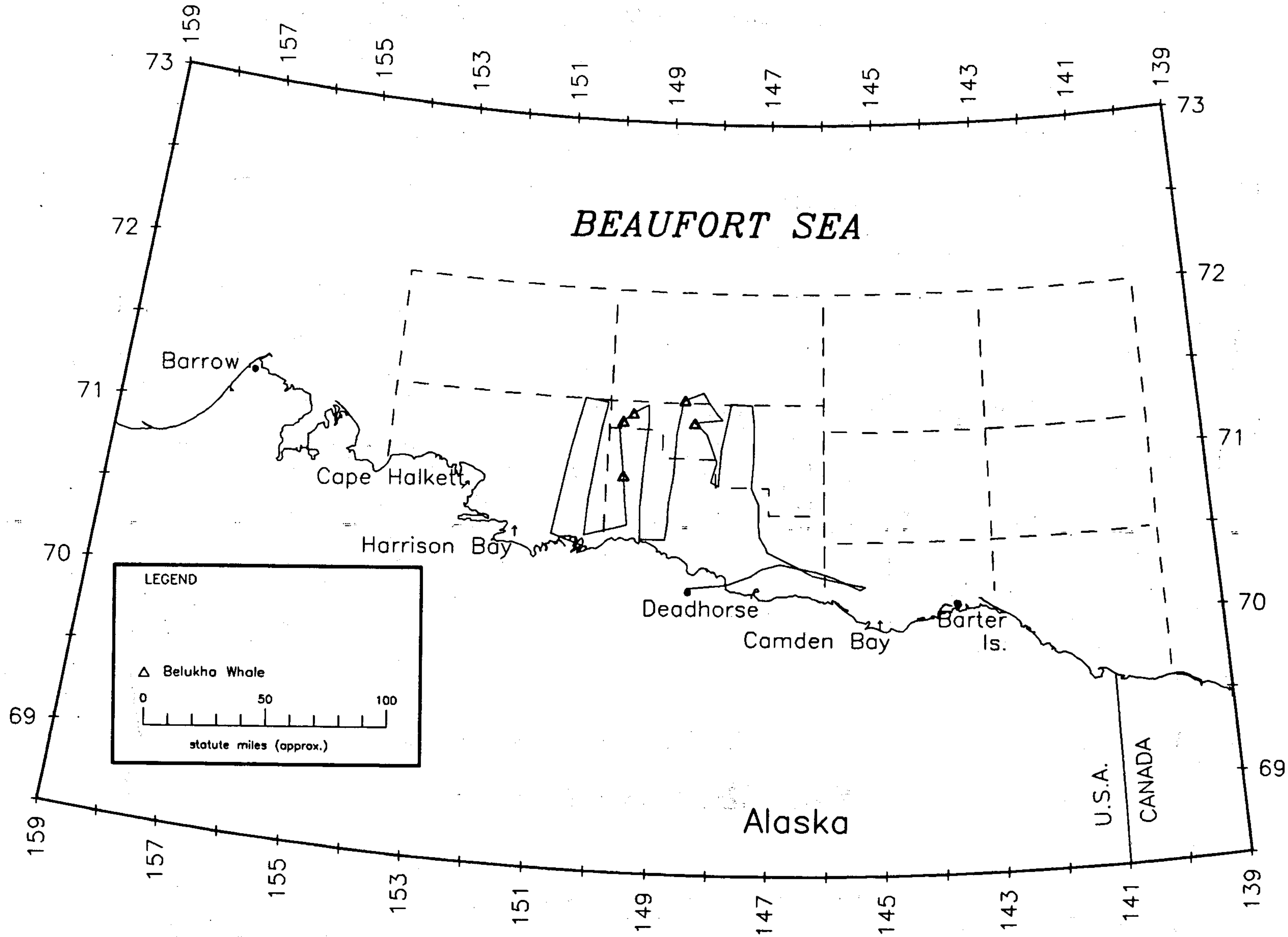
FLIGHT 5 11 September 1991
Survey Track and Sightings



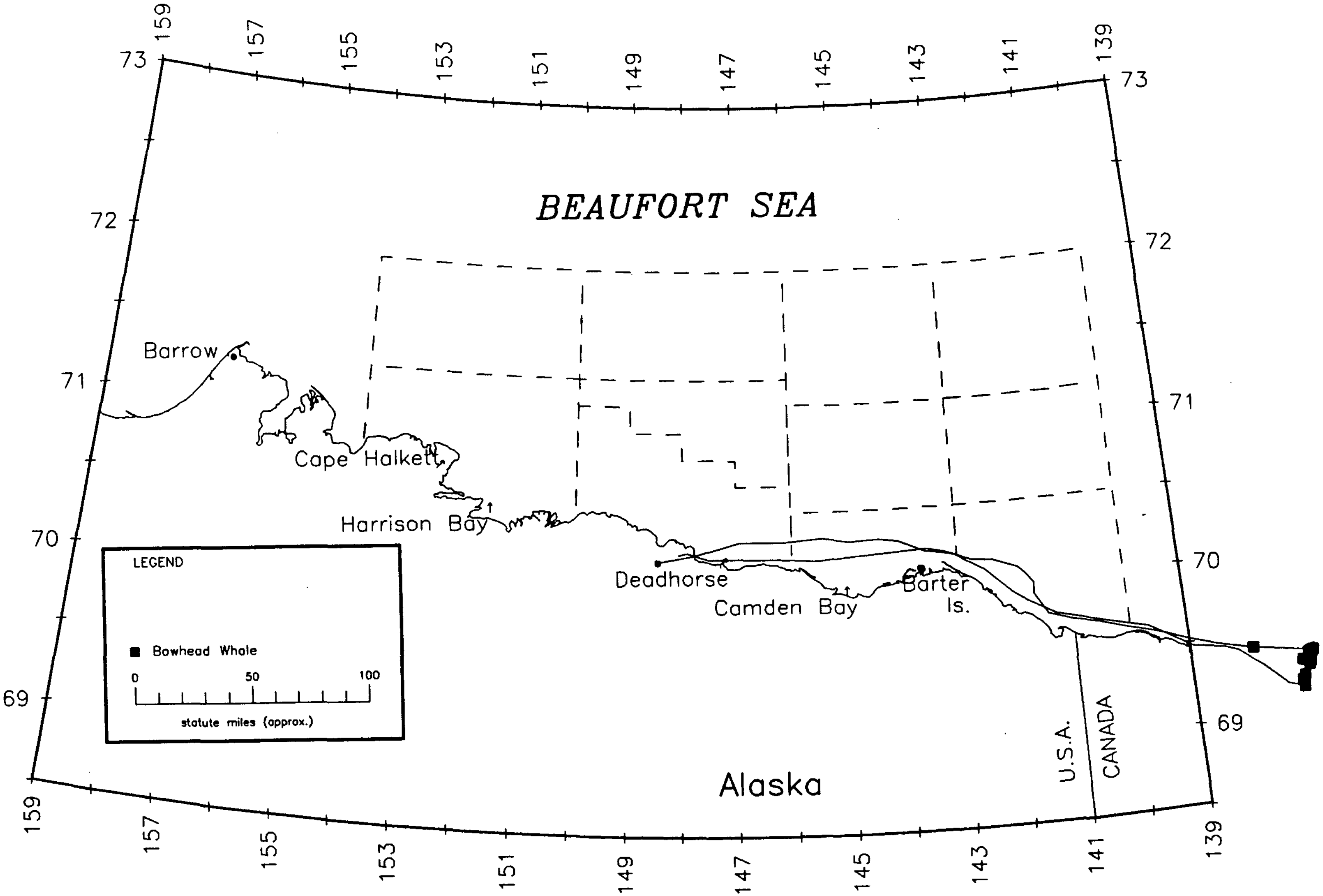
FLIGHT 6 16 September 1991
Survey Track and Sightings



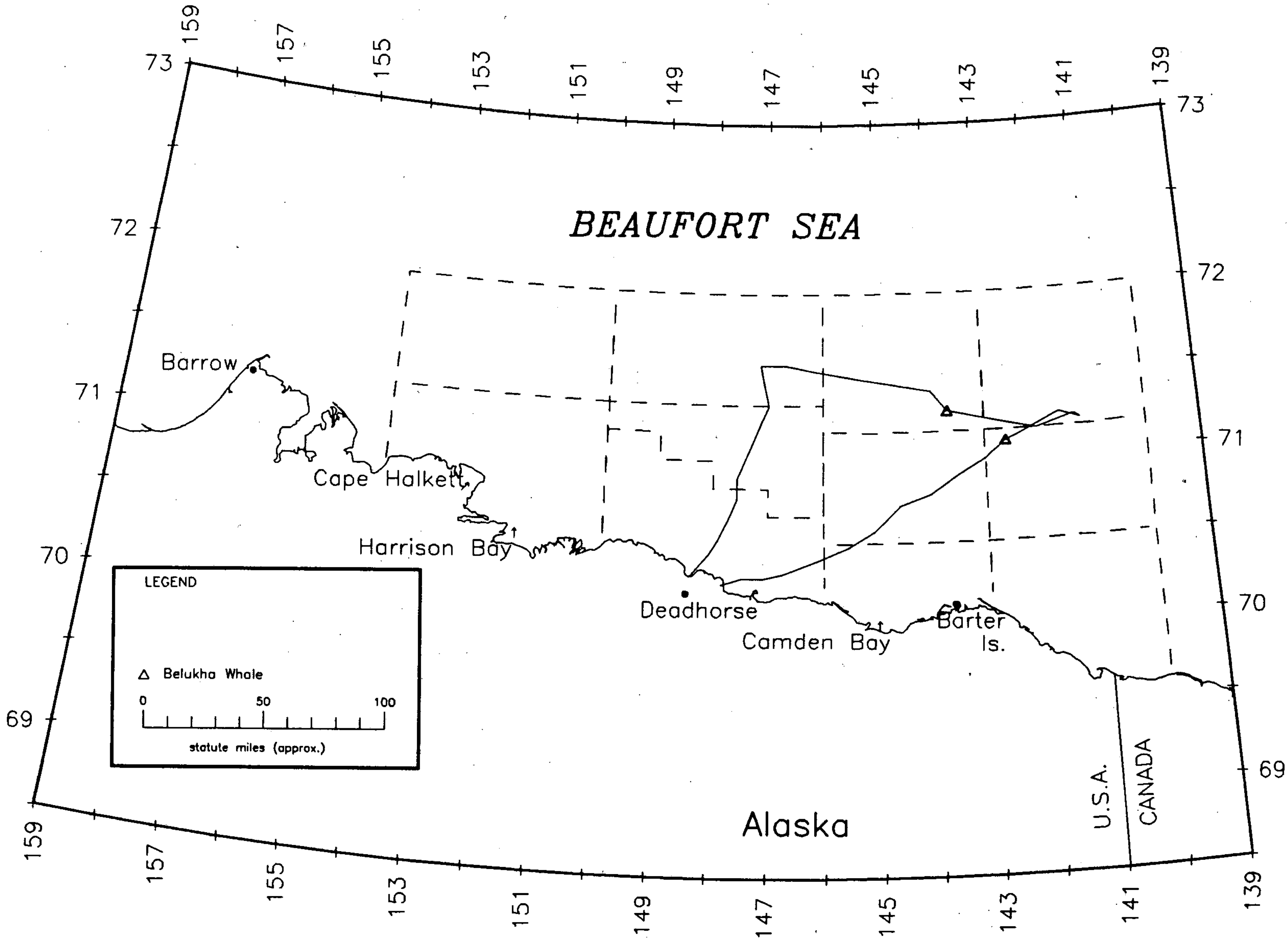
FLIGHT 7 17 September 1991
Survey Track and Sightings



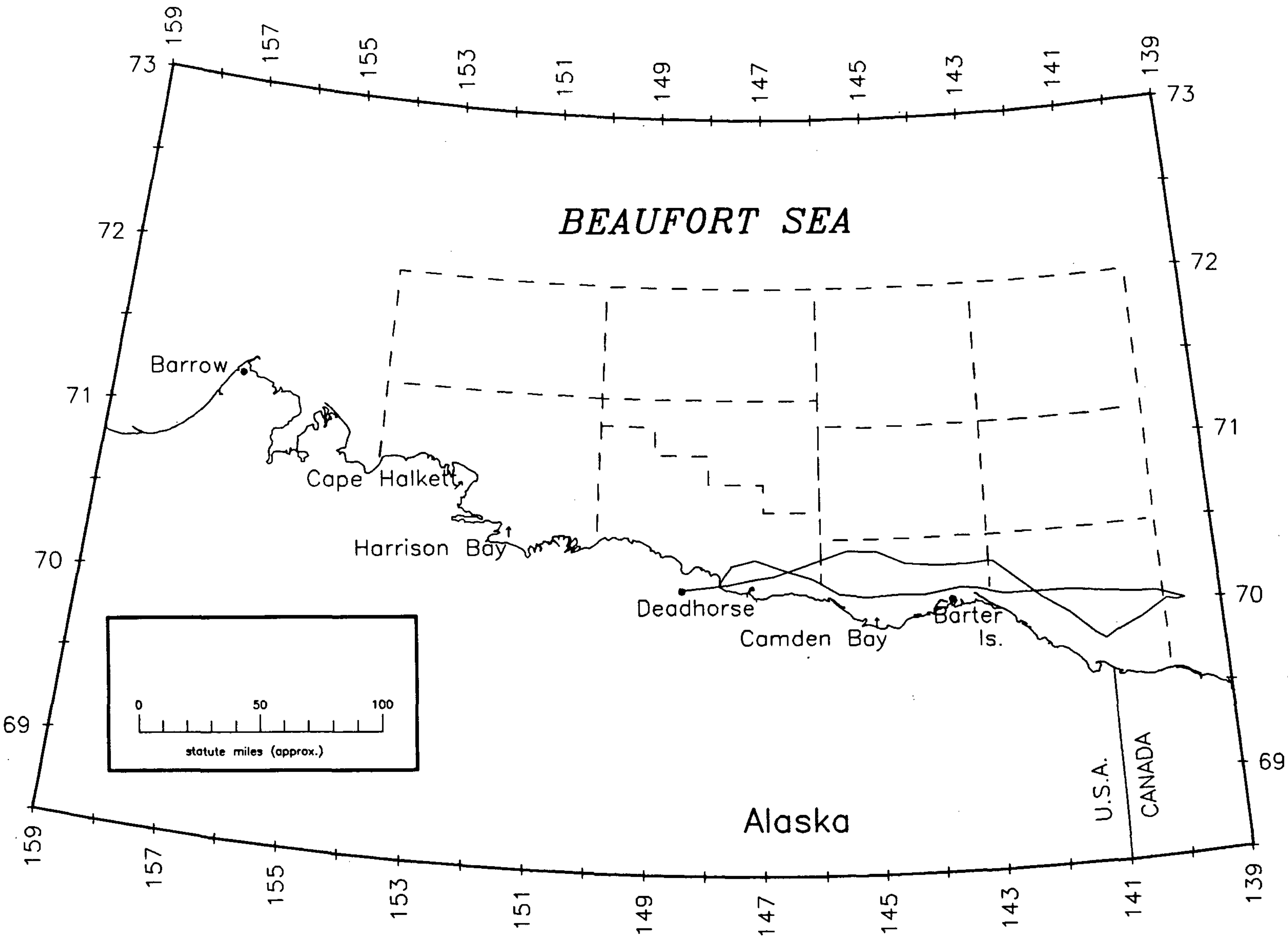
FLIGHT 8 18 September 1991
Survey Track and Sightings



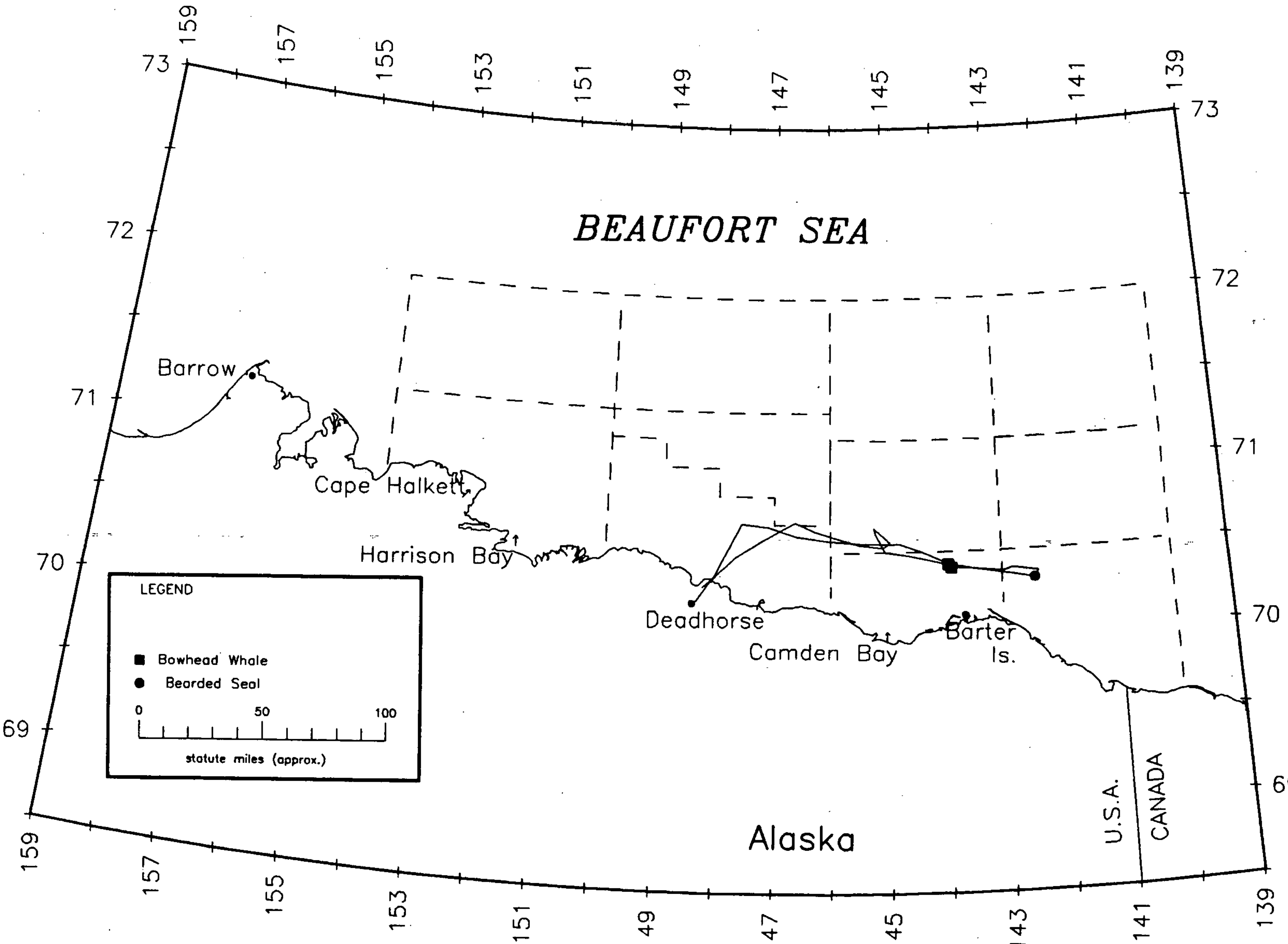
FLIGHT 9 19 September 1991
Survey Track and Sightings



FLIGHT 10 22 September 1991
Survey Track and Sightings



FLIGHT 11 24 September 1991
Survey Track and Sightings



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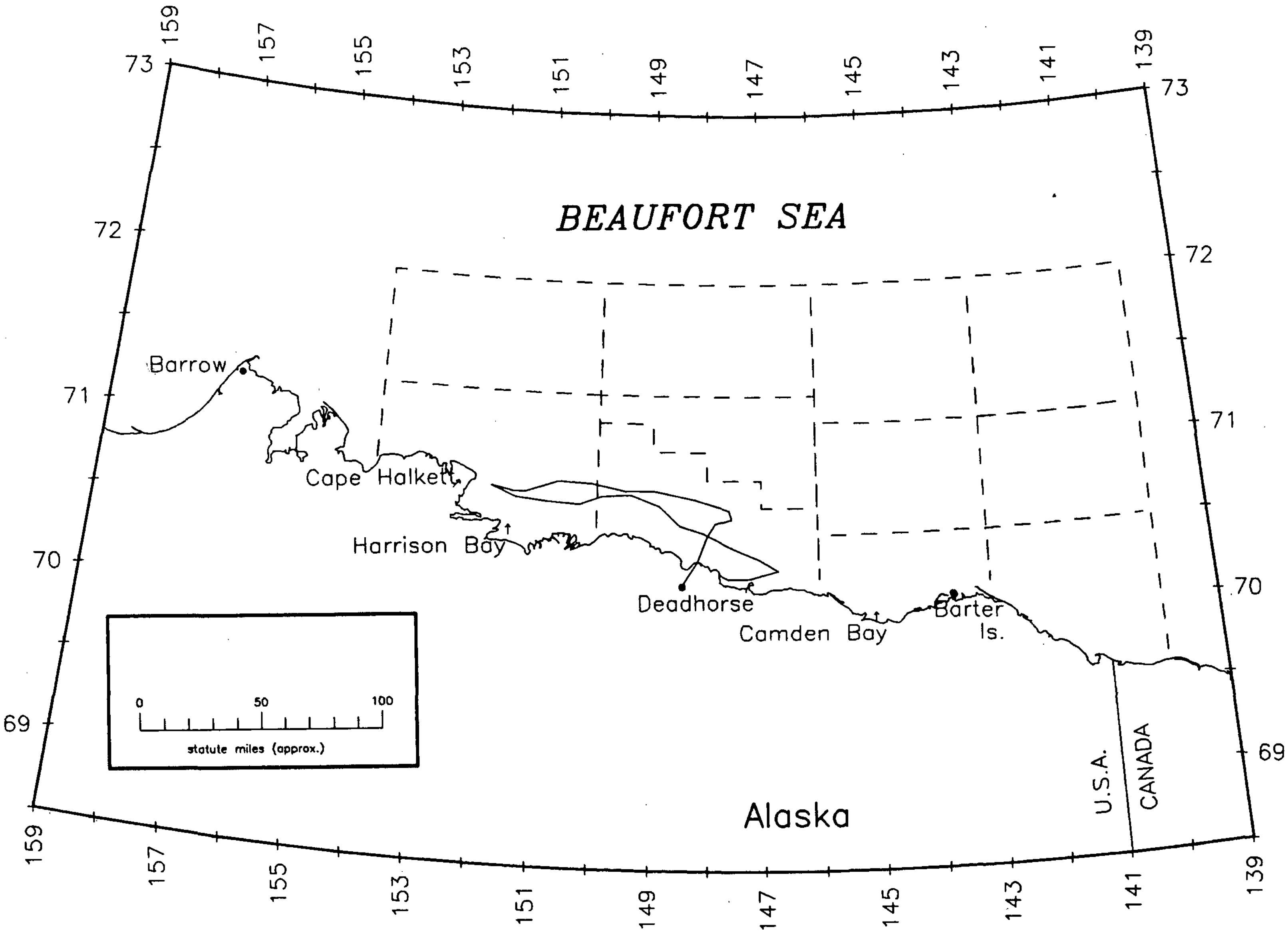
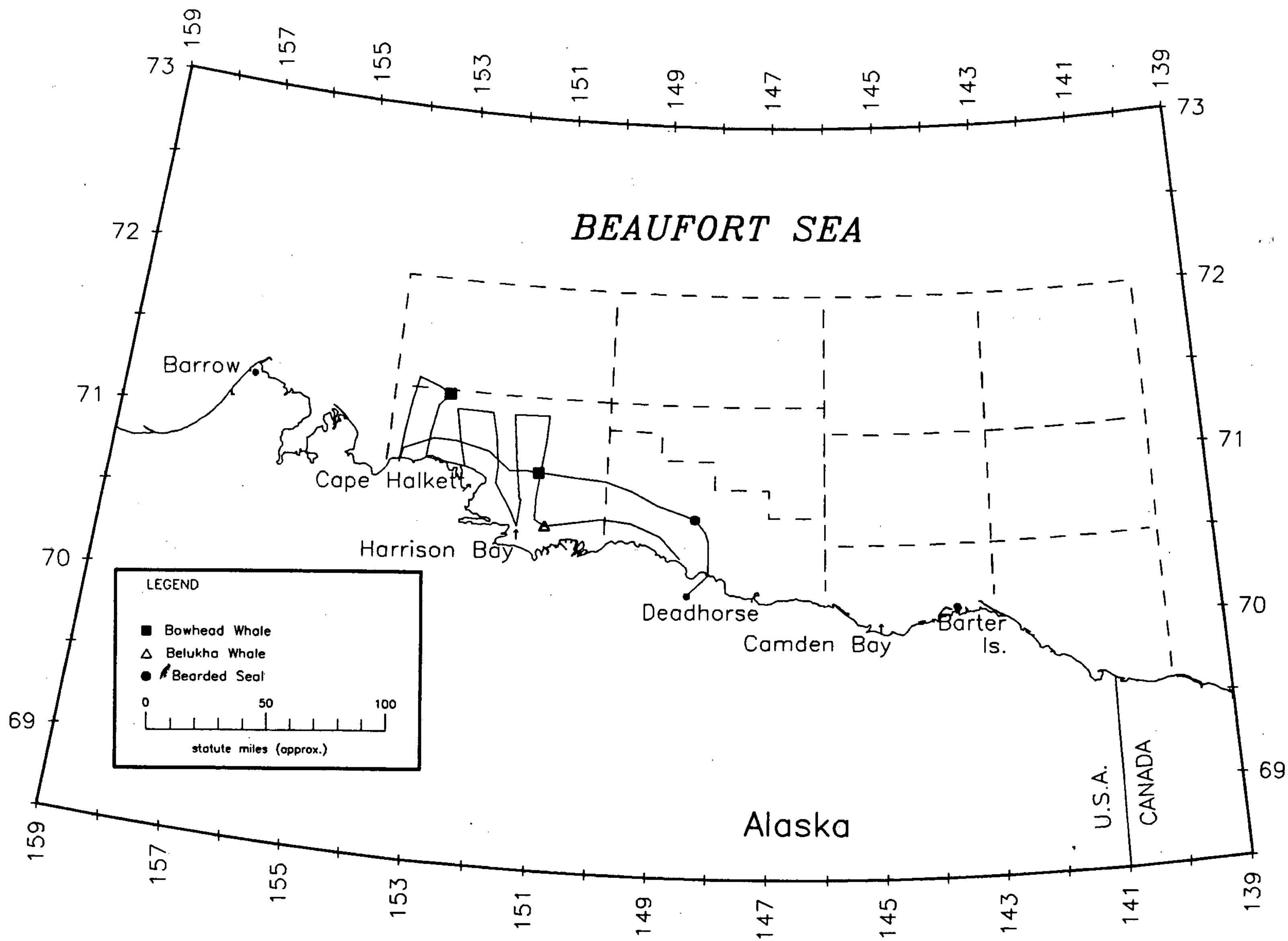
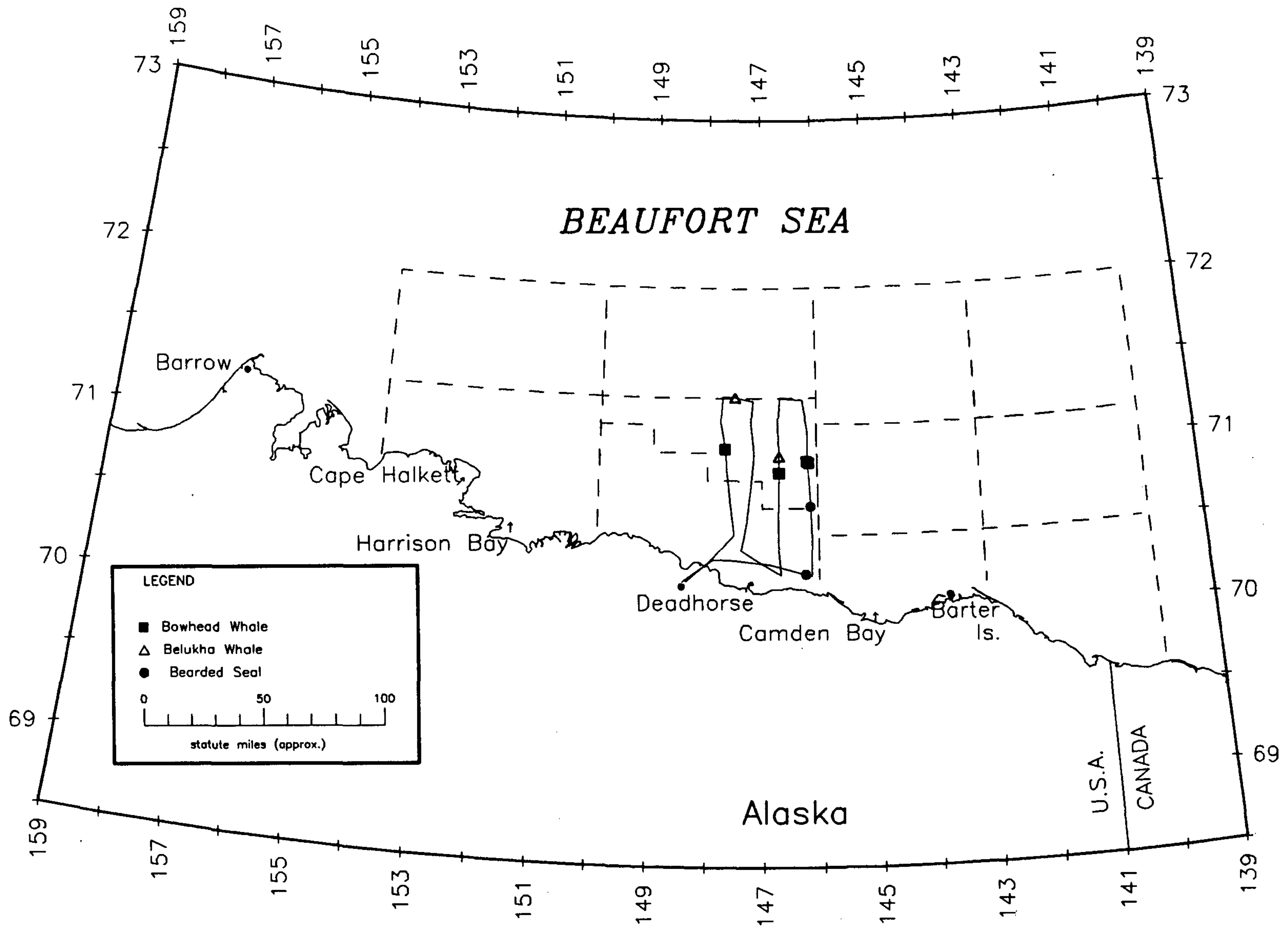
Survey Track and Sightings



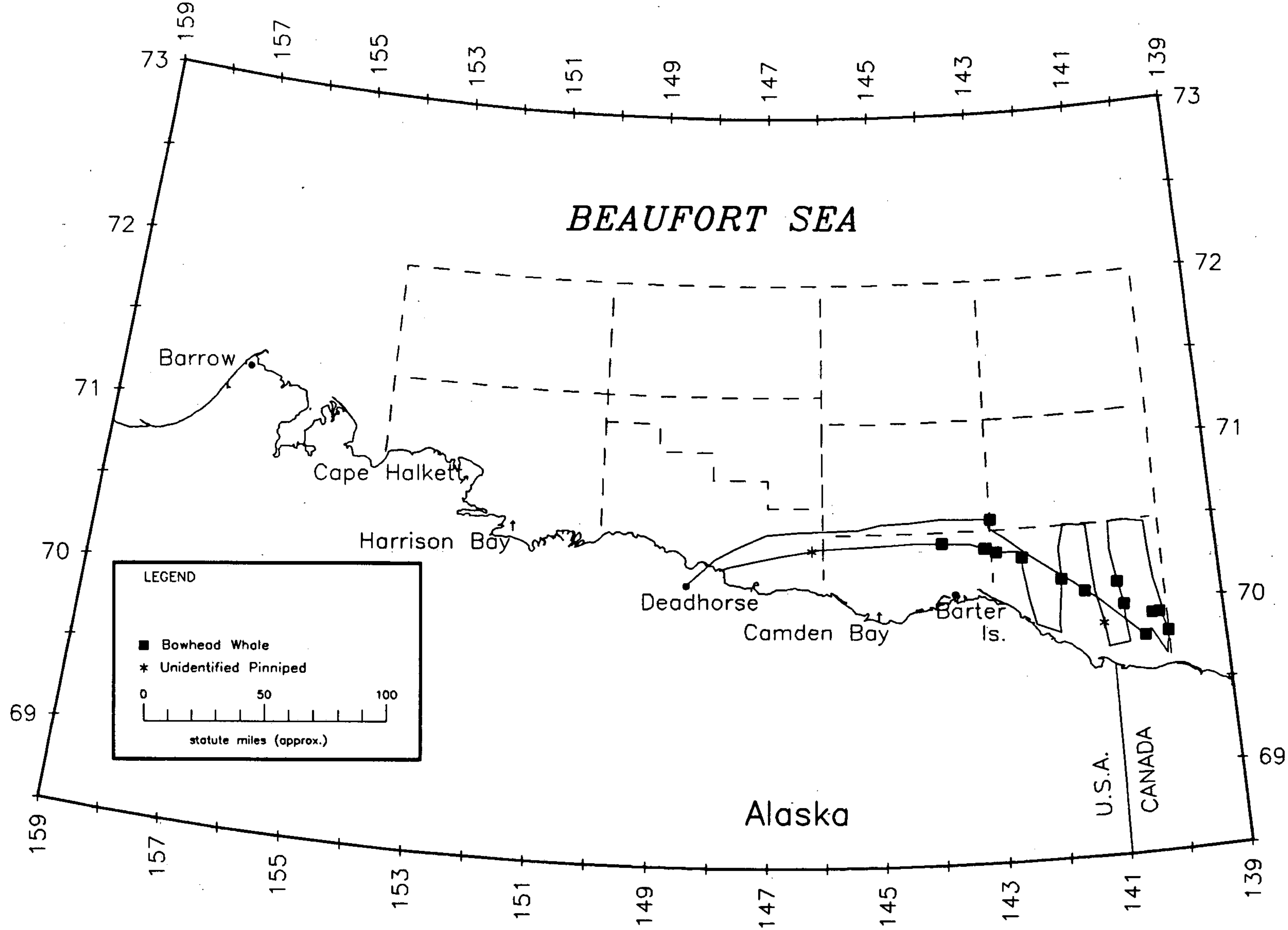
FLIGHT 13 1 October 1991
Survey Track and Sightings



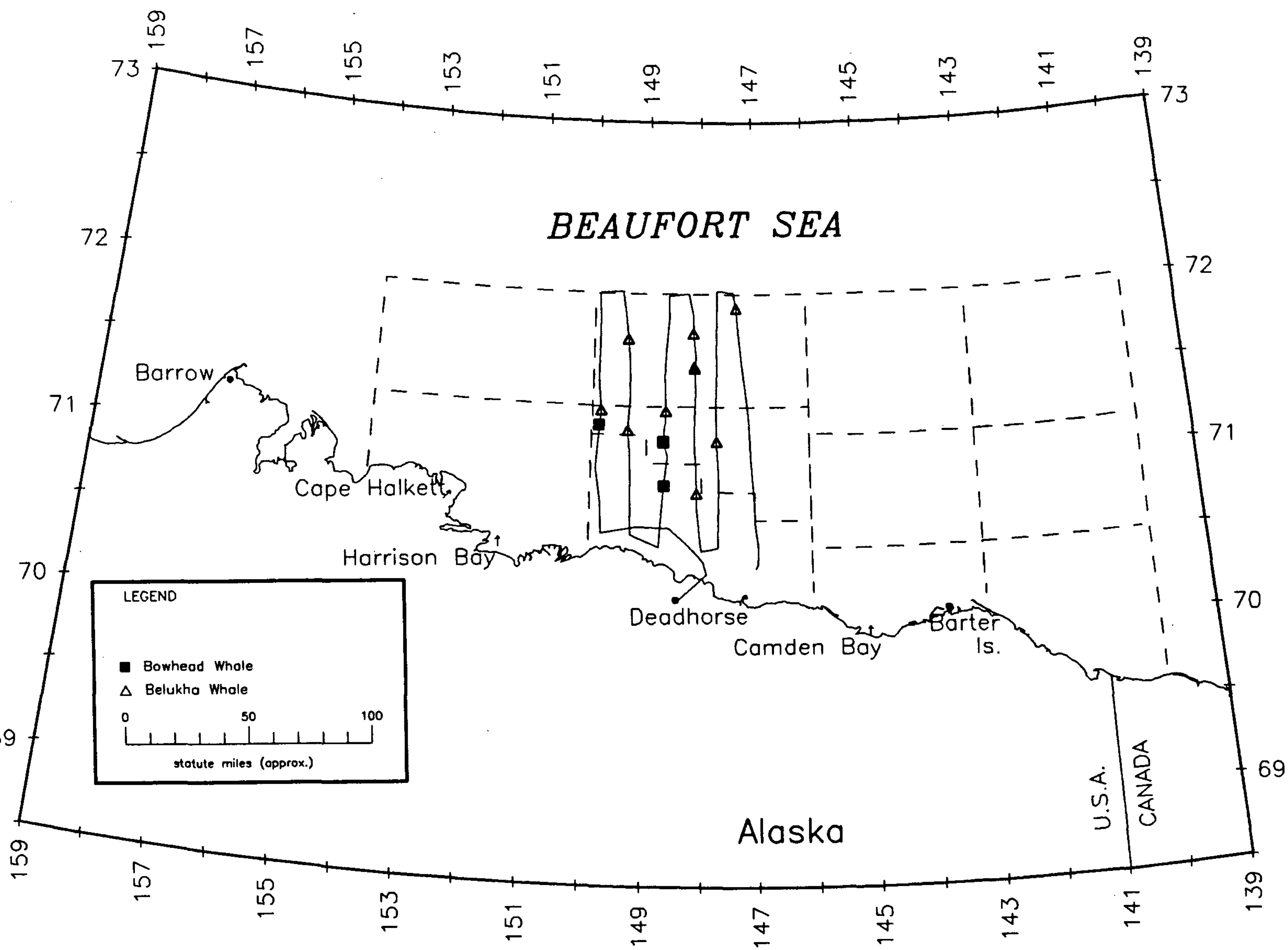
FLIGHT 14 1 October 1991
Survey Track and Sightings



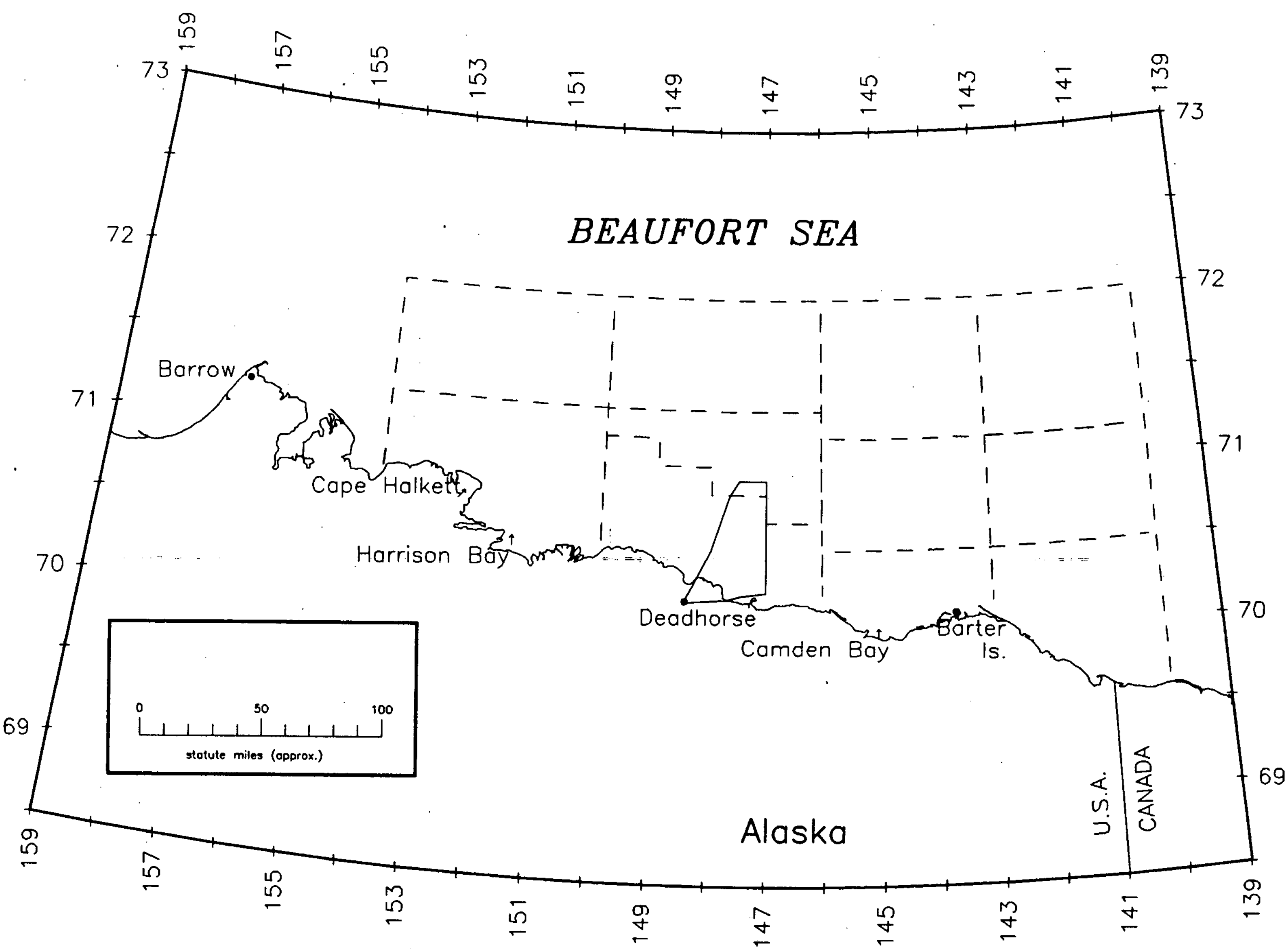
FLIGHT 15 2 October 1991
Survey Track and Sightings



FLIGHT 16 3 October 1991
Survey Track and Sightings



FLIGHT 17 4 October 1991
Survey Track and Sightings



FLIGHT 18 7 October 1991
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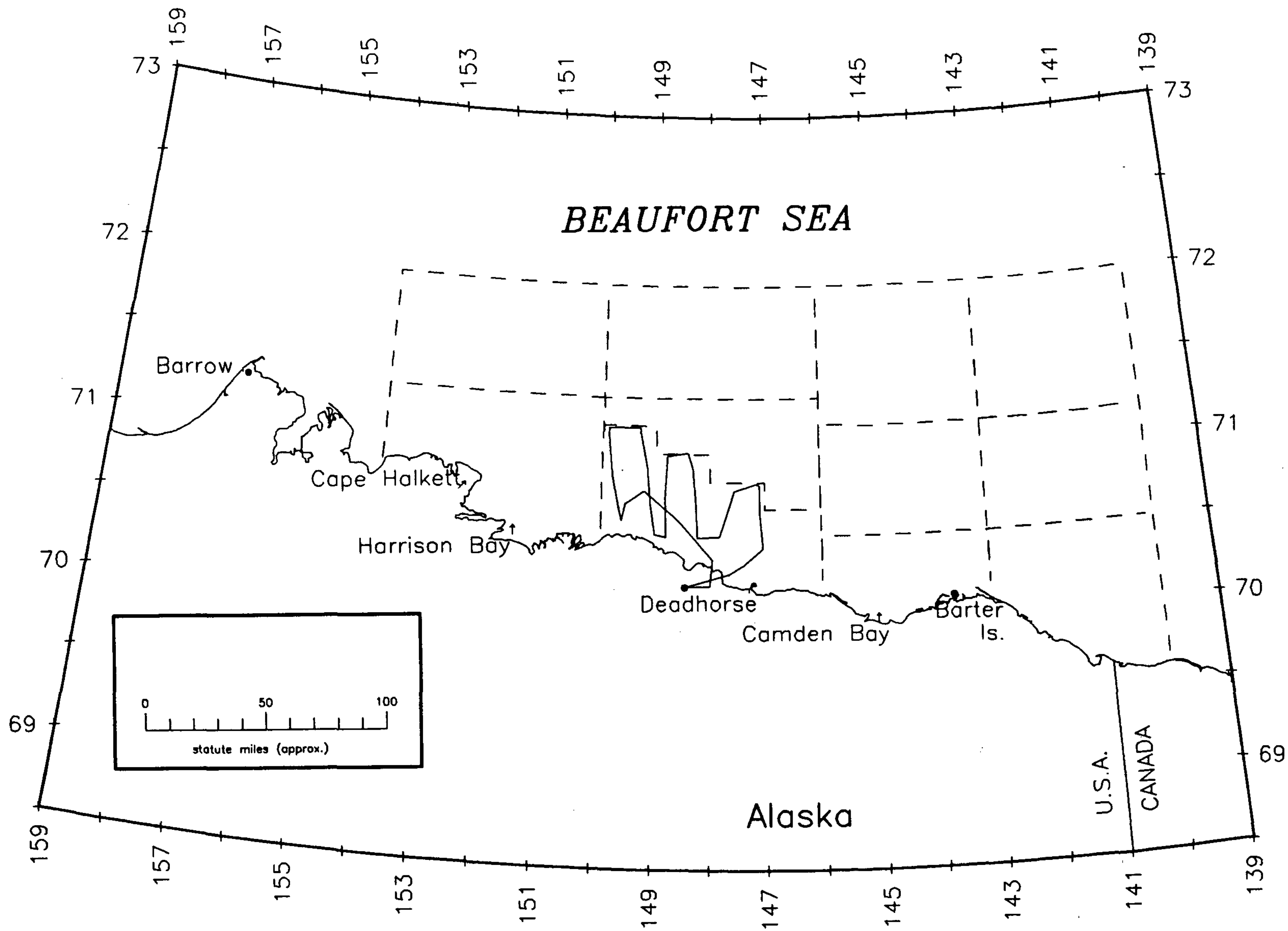
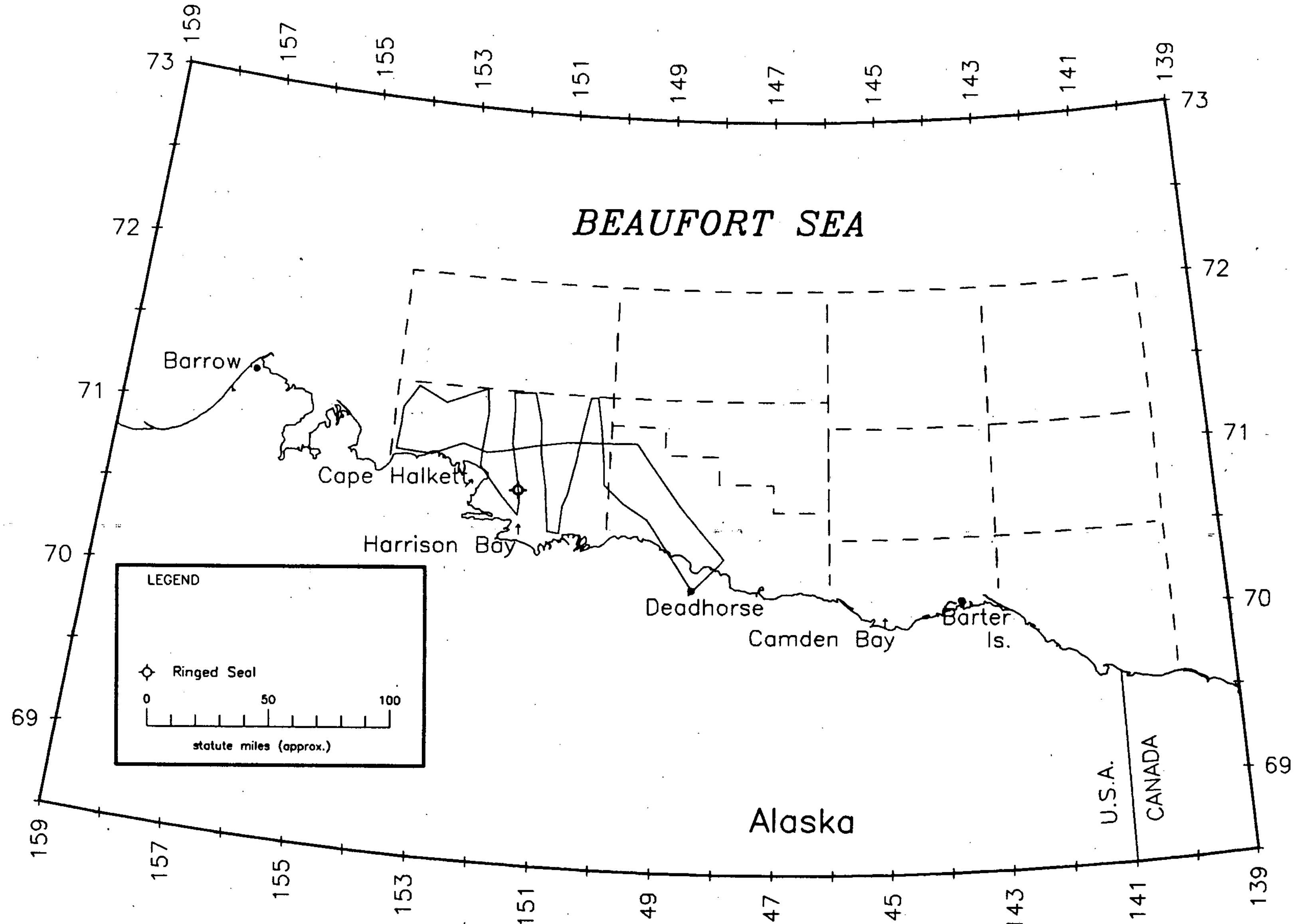
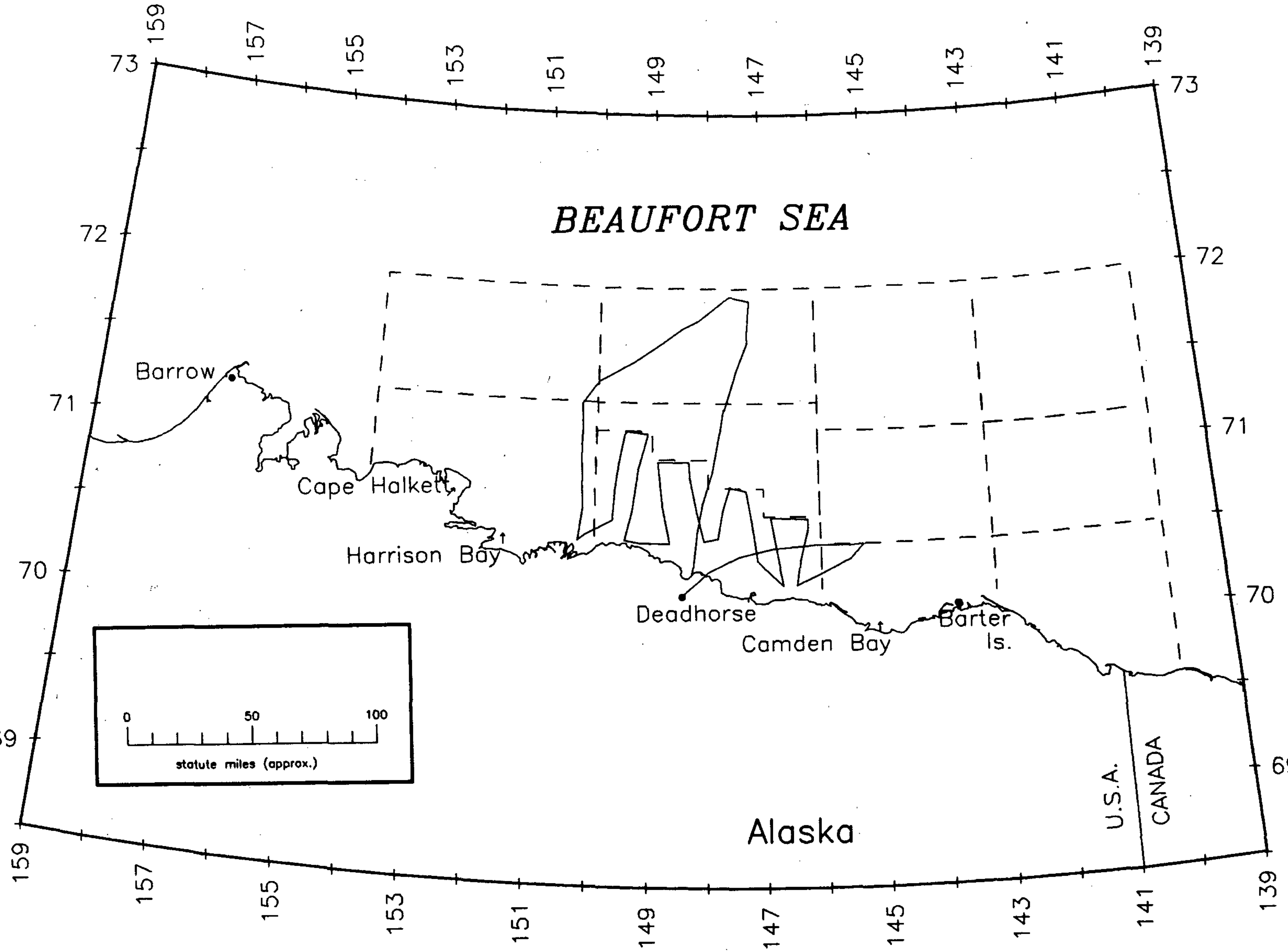


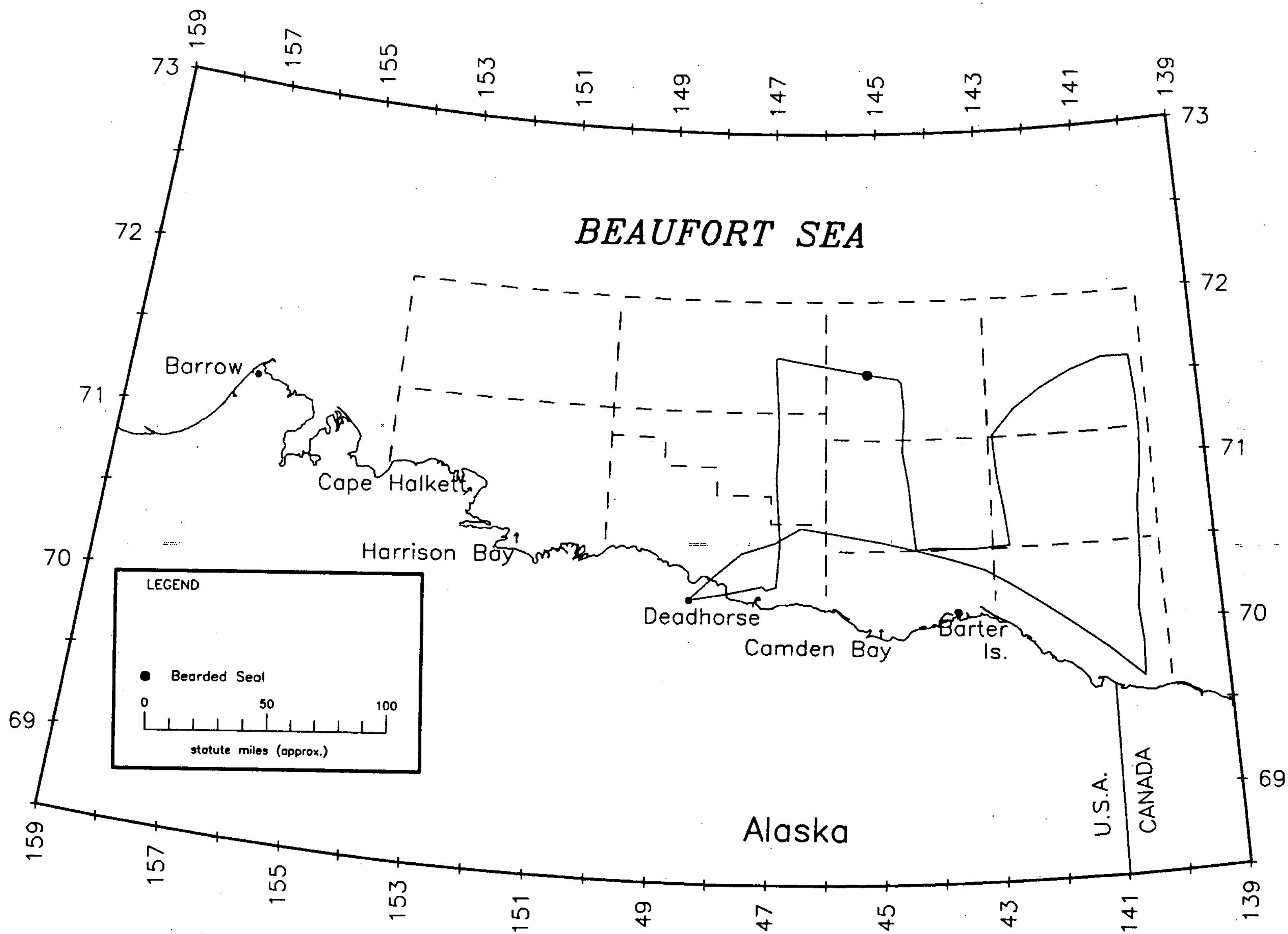
FLIGHT 19 8 October 1991
Survey Track and Sightings



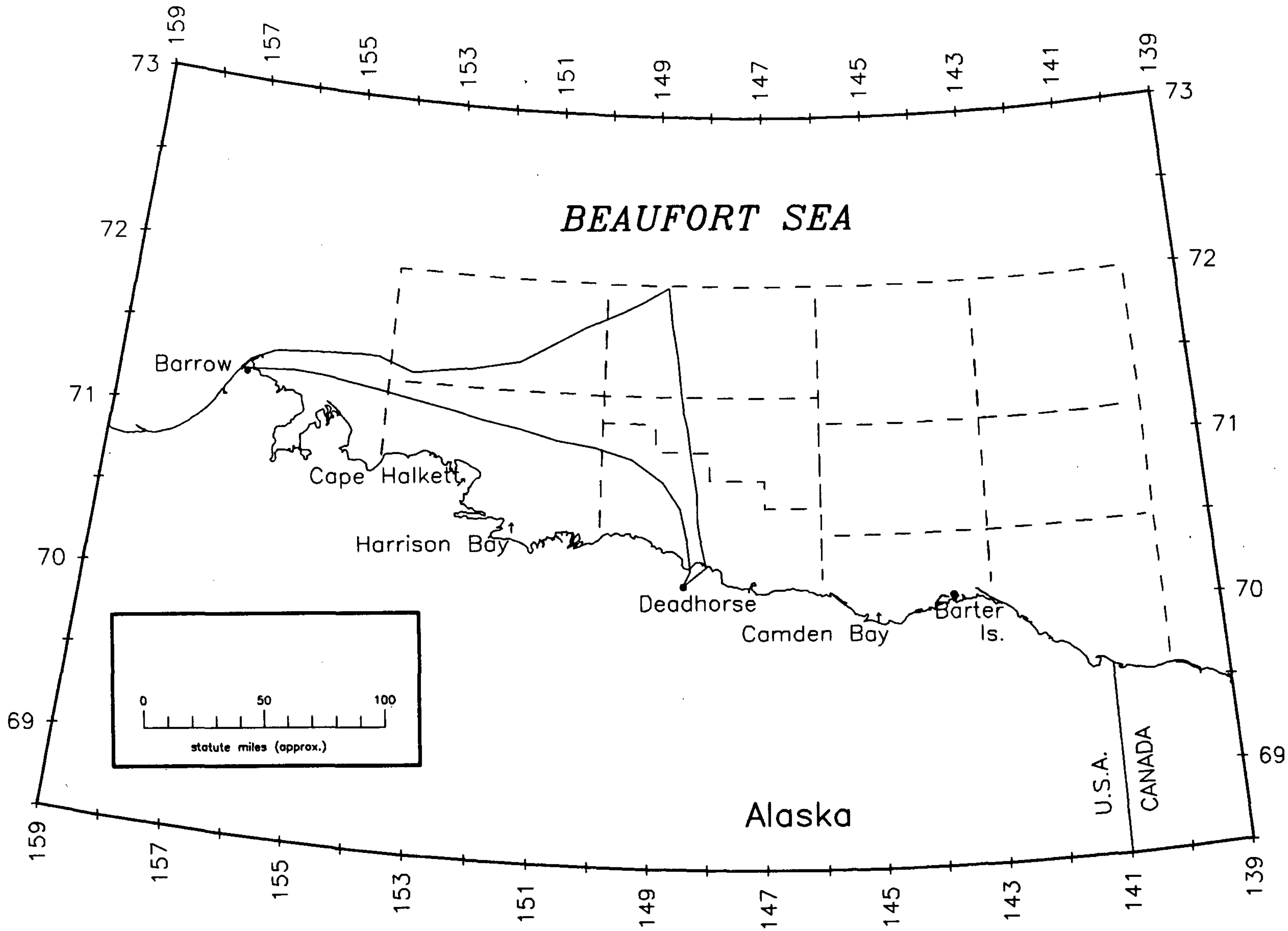
FLIGHT 20 9 October 1991
Survey Track and Sightings



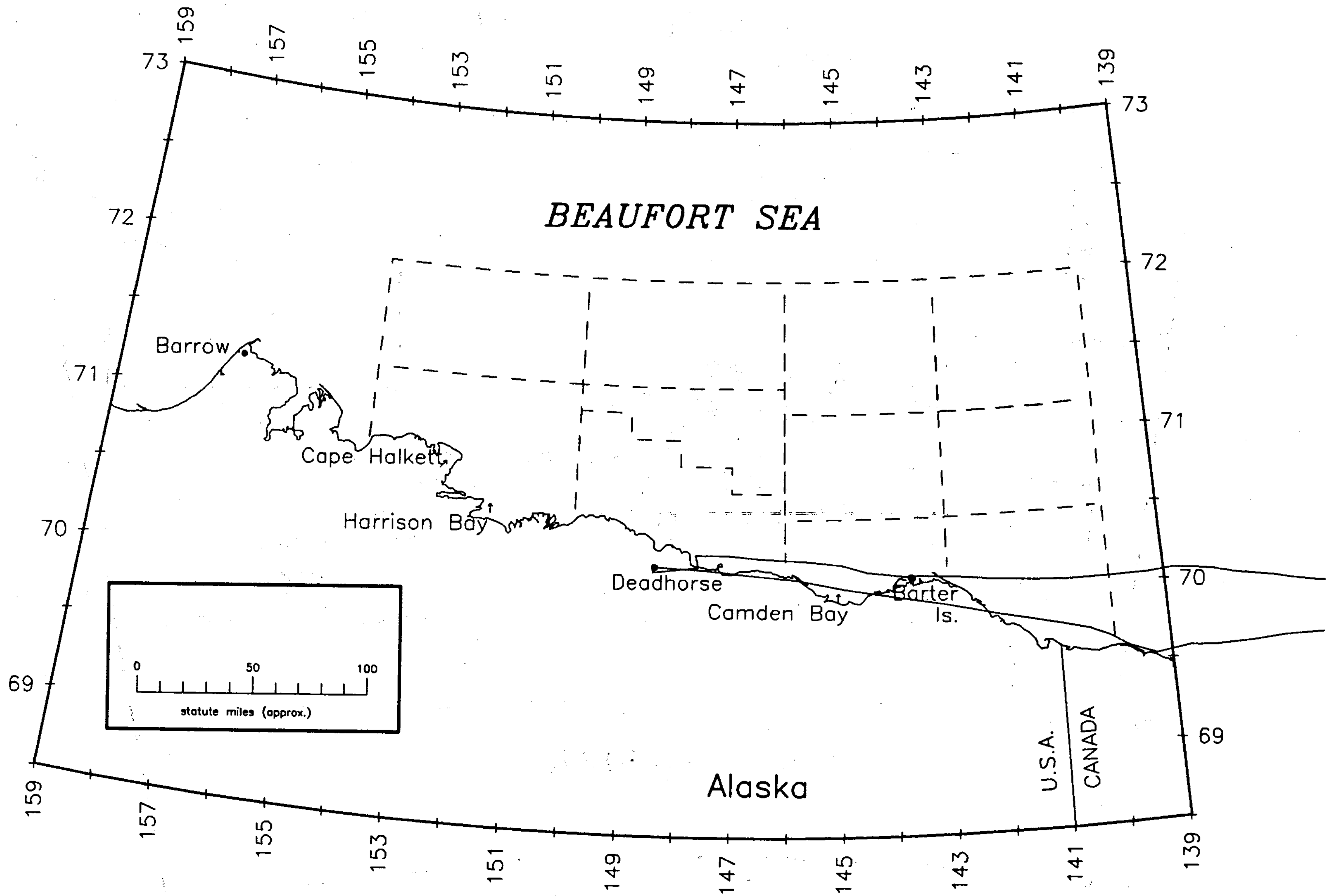
FLIGHT 21 11 October 1991
Survey Track and Sightings



FLIGHT 22 12 October 1991
Survey Track and Sightings



FLIGHT 23 13 October 1991
Survey Track and Sightings



FLIGHT 24 14 October 1991
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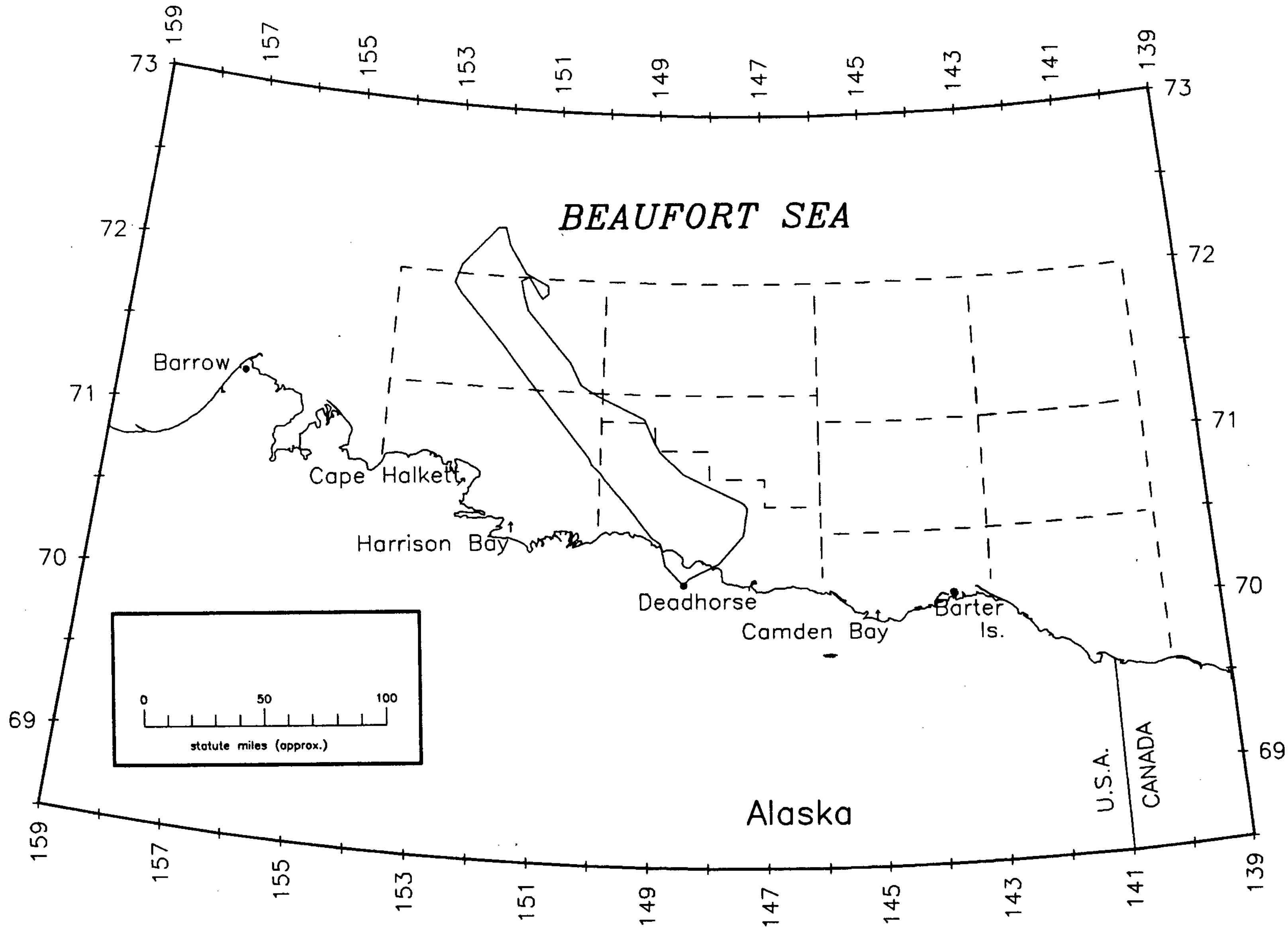

FLIGHT 25 18 October 1991
Survey Track and Sightings

GLOSSARY OF ACRONYMS, INITIALISMS, AND ABBREVIATIONS

AC	alternating current
ANOVA	analysis of variance
BLM	Bureau of Land Management
C	Celsius
CANMAR	Canadian Marine Drilling Ltd.
CI	confidence interval
cm	centimeter
ELT	emergency location transmitter
ESA	Endangered Species Act
FR	Federal Register
GNS	Global Navigation System
hr	hour
HP	Hewlett-Packard
km	kilometer
kt	knot
m	meter
MAT	an underwater mat or platform for the SSDC
MMS	Minerals Management Service
n	sample size
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
OCSLA	Outer Continental Shelf Lands Act
p	probability
SAIC	Science Applications International Corporation
SD	standard deviation
SPUE	sightings per unit effort (number of whale sightings counted per hour)
SSDC	Single Steel Drilling Caisson
USC	U.S. Code
USDOC	U.S. Department of Commerce
USDOD	U.S. Department of Defense
USDOI	U.S. Department of the Interior
WPUE	whales per unit effort (number of whales counted per hour); relative abundance

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