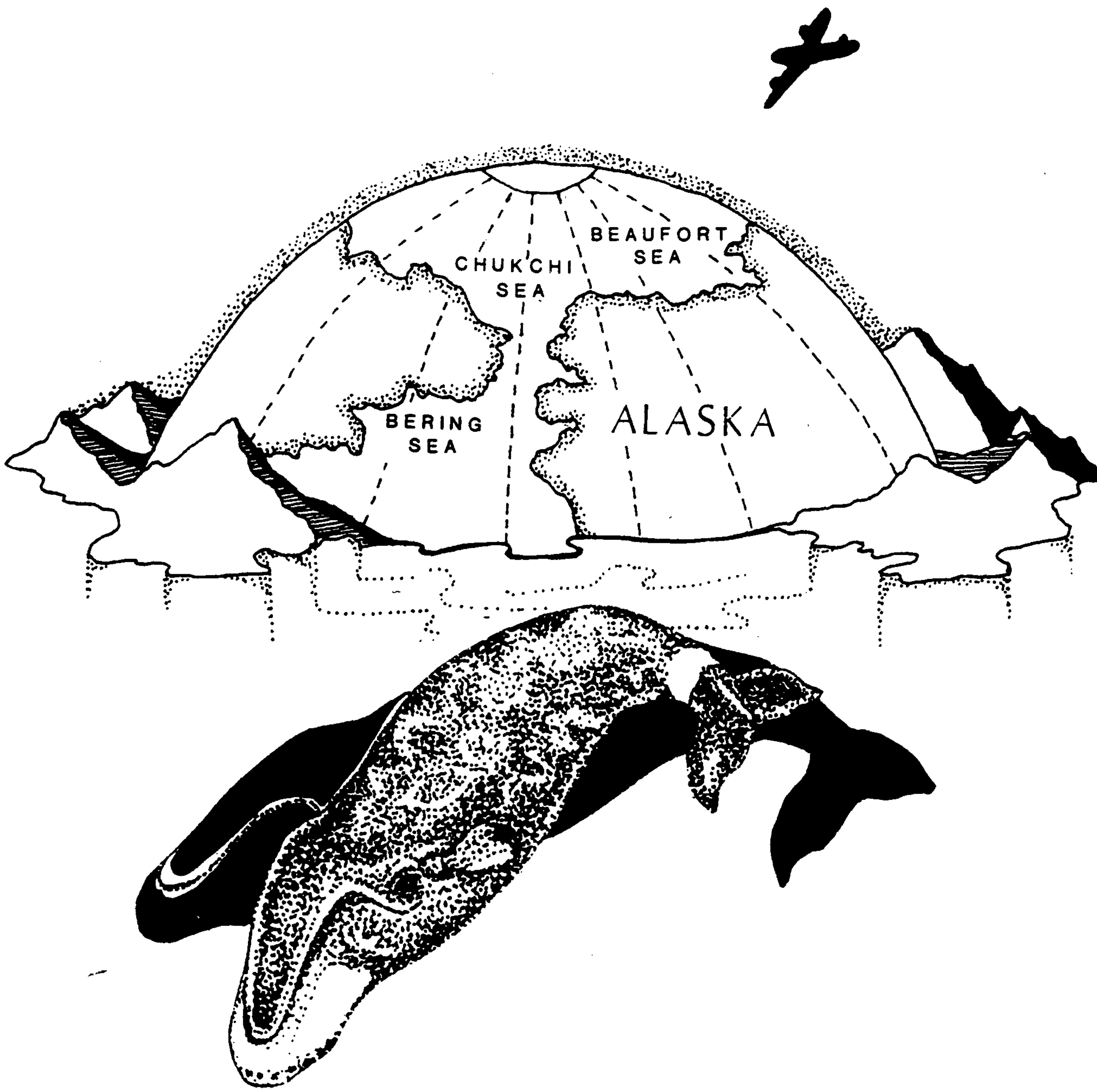
Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 1990

OCS Study
MMS 91-0055



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

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

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

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ABSTRACT

This report describes field activities and data analyses for aerial surveys of bowhead whales conducted between 1 September 1990 and 20 October 1990 in the Beaufort Sea, primarily between 140° W. and 154° W. longitudes south of 72° N. latitude. General ice cover during September and October 1990 was extremely light, the mildest since monitoring began in 1979. A total of 478 bowhead whales, 38 belukha whales, 40 bearded seals, 133 ringed seals, and 232 unidentified pinnipeds were observed in 1990 during 87.14 hours of survey effort that included 33.77 hours on randomized transects. The initial sighting of bowhead whales in Alaskan waters occurred on 2 September 1990. Half (median) of the 478 bowheads observed had been counted by 22 September. The peak count (mode) of 125 bowhead whales also occurred on 22 September 1990. The last sighting of a bowhead whale made during this survey occurred in open water on 19 October 1990. Estimated median and mean ($\bar{x}$) water depths at the location of bowhead whales sighted on line transects in 1990, 38.0 meters and 38.8 meters, respectively, are consistent with a previously noted trend for whales to be located in shallower water during years of light ice cover.

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I. INTRODUCTION

In 1953, the Outer Continental Shelf Lands Act (OCSLA) (43 USC 1331-1356) charged the Secretary of the Interior with the responsibility for administering minerals exploration and development of the OCS. 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), and 97 (issued in 1987)--recommended continuing studies of whale distribution and OCS-industry effects on bowhead whales (USDOC, NOAA, NMFS, 1982, 1983, 1987). These opinions also requested monitoring of bowhead whale presence during periods when geophysical exploration and drilling may be occurring.

On 14 May 1982, the Secretary of the Interior imposed an approximately 2-month seasonal-drilling restriction on exploratory activity in the joint Federal/State Beaufort Sea sale area. The period of restriction would vary depending on bowhead whale presence, and "this determination would require development of a monitoring program. . ." (USDOI, MMS, 1982). Subsequently, MMS (Alaska OCS Region) adopted 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) does not contain a seasonal offshore-drilling restriction but states that "MMS intends to continue its areawide endangered whale monitoring program in the Beaufort Sea during exploration activities. The program will gather information on whale distribution and abundance patterns and will provide additional assistance to determine the extent, if any, of adverse effects to the species" (USDOI, MMS, 1988).

From 1979 to 1987, the MMS (formerly BLM) funded annual monitoring of endangered whales in arctic waters under Interagency Agreements with the Naval Ocean Systems Center (NOSC) and through subcontracts to SEACO, Inc. On 15 April 1987, a proposal for MMS scientists to conduct aerial surveys of endangered whales was approved by the Associate Director for Offshore Minerals Management. The MMS uses agency personnel to perform field work and reporting activities for the Beaufort Sea on an annual basis.

A concurrent study, conducted under contract to MMS in 1990 (Moore and Clarke, 1991), 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 overall annual survey program is based on a design of random field transects within established geographic blocks in and adjacent to Chukchi and Beaufort Sea sale areas offshore of Alaska. The present study, which was focused on the bowhead whale migration from 1 September 1990 to 20 October 1990, included Beaufort Sea Survey Blocks 1 through 11 (Fig. 1) between 140° W. and 154° W. longitude south of 72° N. latitude.

A large-scale Beaufort Gyre moves waters clockwise from the Canadian Basin westward in the deeper offshore regions. Nearshore surface currents tend to follow local wind patterns and bathymetry, moving from the east in winter, with an onshore component, and to the west in summer, with an offshore component (Brower et al., 1988).

In the Beaufort Sea, landfast ice forms during the fall and may eventually extend up to 50 kilometers (km) offshore by the end of winter (Norton and Weller, 1984). The pack ice, which includes multiyear ice 4 meters (m) thick, on average, with pressure ridges up to 50 m thick (Norton and Weller, 1984), becomes contiguous with the new and fast ice in late fall--effectively closing off the migration corridor to westbound bowhead whales. From early November to mid-May, the Beaufort Sea normally remains almost totally covered by ice considered too thick for whales to penetrate. In mid-May, a recurring flaw lead can form just seaward of the stable fast ice, followed by decreasing ice concentrations (LaBelle et al., 1983) and large areas of open water in summer.

Local weather patterns affect the frequency and effectiveness of all marine aerial surveys. The present study area is in the arctic climate zone, where the mean annual temperature is about -12° C (Brower et al., 1977). Total precipitation (rain and snow) ranges from 12 centimeters (cm) at Barrow to 16 cm at Barter Island and occurs mostly as summer rain (Brower et al., 1988). Fog frequently reduces visibility along the coast during the open-water season. The prevailing wind direction at Barrow and Barter Island is from the east. Mean annual windspeed is 6 m per second at Barrow and 7 m per second at Barter Island (Brower et al., 1988). Sea breezes occur during about 25 percent of the summer and extend to at least 20 km offshore (Brower et al., 1977).

Sea state is another environmental factor affecting visibility during aerial surveys. Ocean waves, which are generally from the northeast and east, are limited to the open-water season, during which the ice pack continues to limit fetch. Because of the pack ice, significant wave heights are reduced by a factor of 4 from heights that would otherwise be expected in summer. Wave heights greater than 0.5 m occurred in only 22 percent of the observations summarized by Brower et al. (1977). Wave heights greater than 5.5 m are not reported within this Beaufort Sea database of 2,570 observations.

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

B. Equipment

The survey aircraft was a de Havilland Twin Otter Series 300 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 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

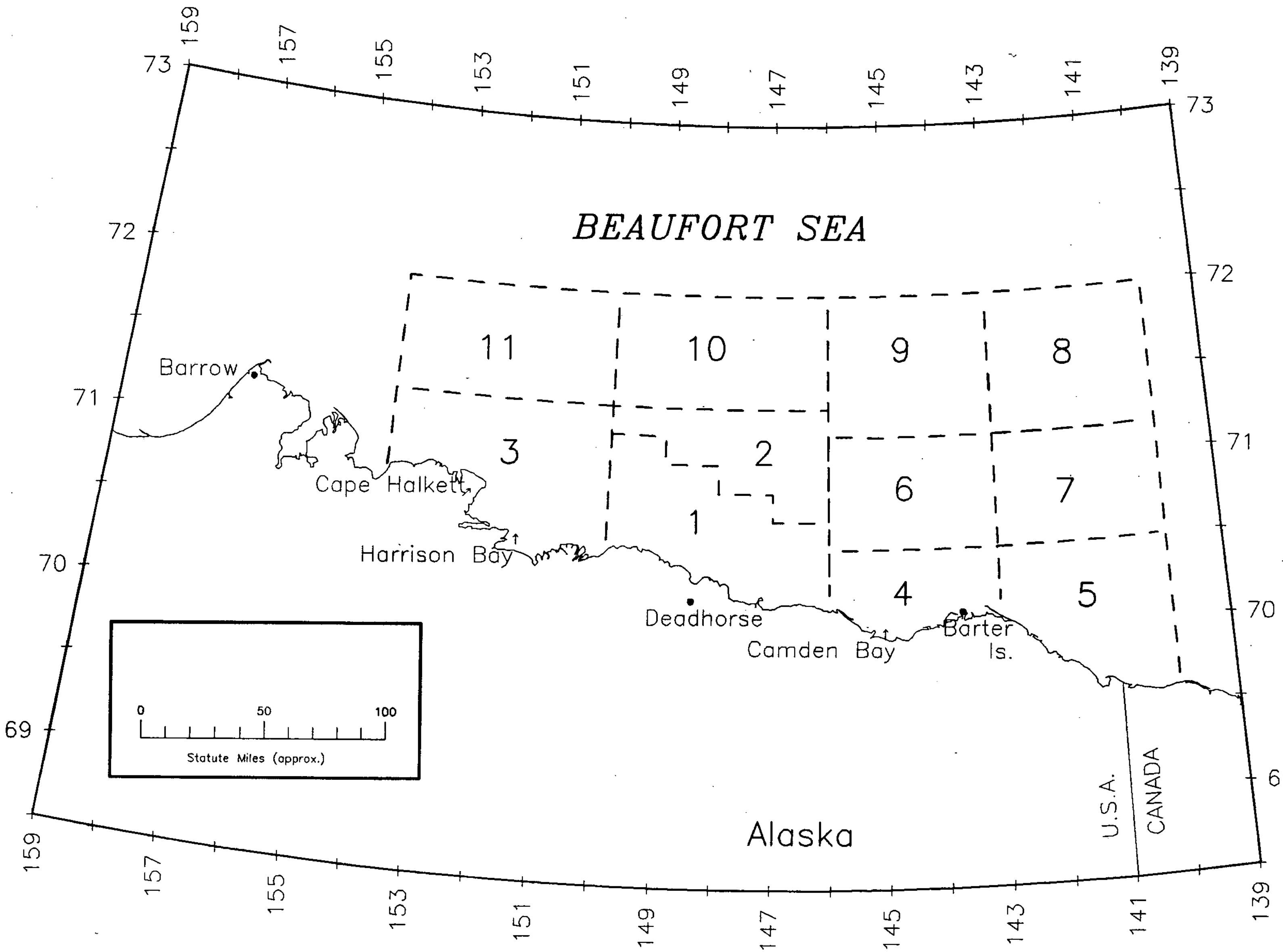

Figure 1. Fall 1990 Study Area Showing Survey Blocks

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 inverter 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 and flight-following 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. The onboard transponder was set at a discrete identification code for radar tracking by air-traffic-control personnel. The onboard very high-frequency aircraft-band radio was used to transmit hourly position data to Deadhorse Flight Service, either directly or through relay stations.

C. Aerial-Survey Design

Aerial surveys were based out of Deadhorse, Alaska, from 1 September to 20 October 1990. The field schedule was designed to monitor the progress of the Fall 1990 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 implementation of seasonal offshore-drilling regulations.

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

The selection of 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. During Fall 1990, survey-block selection and effort hours were additionally affected (11-20 October 1990) by project participation in an aerial search, coordinated by the U.S. Coast Guard and Fish and Wildlife Service (FWS), for two polar bear biologists and a pilot downed in arctic waters. 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 overall behaviors and distribution patterns of marine mammals and to obtain an index of relative whale abundance (whales per unit effort).

D. Survey-Flight Procedures

During a typical flight, a "search" leg was flown to the target survey block, beginning a series of random-transect legs (above) joined together by "connect" legs, followed by a search leg back to Deadhorse. Surveys generally were flown at a target altitude of 458 m. This altitude was maintained--when weather permitted--in order to maximize visibility and minimize potential disturbance to marine mammals. A 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 1990 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), and ice cover was estimated in percent.

Table 1
Data-Entry Sequence on the Portable Flight Computer

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

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 as either zero to 25-percent, 26- to 50-percent, 51- to 75-percent, or 76- to 100-percent ice cover from U.S. Navy-NOAA Joint Ice Center Southern Ice Limit charts. These charts were available for every seventh day from 28 August through 23 October 1990.

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 1990 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 1982-1990 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.

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 overall shifts in migration route from 1982 to 1990 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).

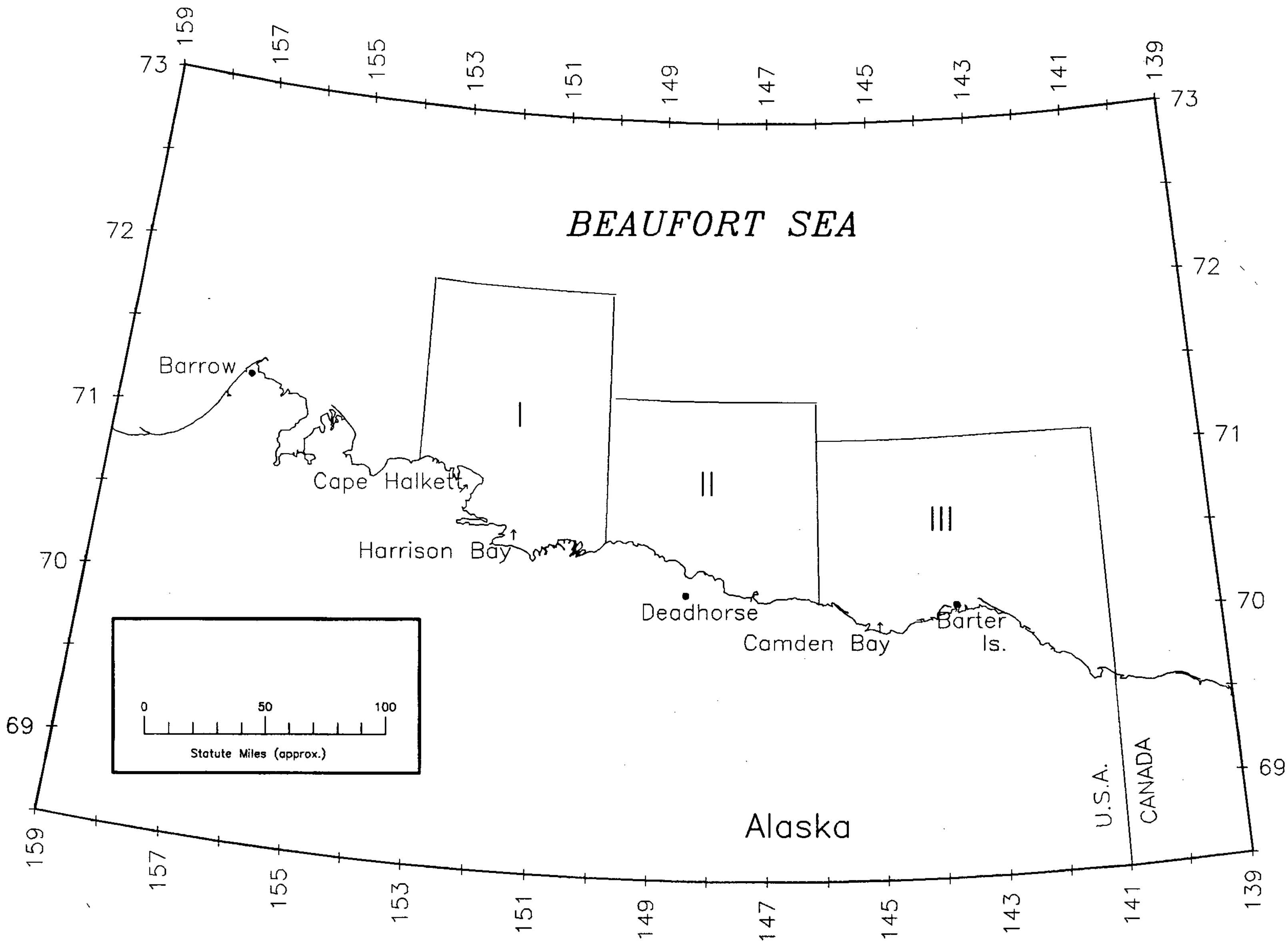

Figure 2. Regions I, II, and III (used in median–water–depth analyses)

III. RESULTS

A. Environmental Conditions

Ice coverage was extremely light during September and October 1990 in the Alaskan Beaufort Sea (Figs. 3-11), permitting good observation of whales. Ice percent and sea state at each sighting of endangered whales are shown in Appendix B (Table B-1).

B. Survey Effort

Daily totals of kilometers and hours flown per survey flight are shown in Table 3. A total of 20,424 km of surveys were flown in 87.14 hours (Table 3) in the Beaufort Sea east of 154°W. longitude at an overall average speed of 234.4 km/hr. A total of 8,287 km of random-transect lines were flown in 33.77 hours (Table 3) at an average speed of 245.4 km/hr. These random transects constituted 40.6 percent of the total kilometers flown and 38.8 percent of the total flight hours. The number of flight hours over each survey block is shown in subsequent analyses.

Day-to-day flight tracks for the Twin Otter aircraft are shown in Appendix B. Survey flight lines are summarized by semimonthly period in Figures 12 through 15. Portions of flights extending west of 154°W. longitude (west of the study area) were analyzed separately (Moore and Clarke, 1991) and were not included in tabular or statistical analyses in the present report.

During the first half of September, flight effort extended across the study area but was most concentrated between Deadhorse and Barter Island, Alaska, south of 70°40′N. latitude (Fig. 12) to provide additional coverage in those survey blocks where seismic exploration by the oil and gas industry was occurring. Surveys extending east to 140°W. longitude were flown to record the initial part of the westward migration of the bowhead whale. There were 10.50 hours of random transects flown from a total of 31.58 flight hours during this period (Table 3), constituting 31.1 percent and 36.2 percent, respectively, of the total Fall-1990 study effort for those categories.

During the second half of September, flight effort was similar to that for the first half of September, with a similar concentration between Deadhorse and Barter Island, Alaska (Fig. 13). There were 7.65 hours of random transects flown from 23.48 total flight hours during this period (Table 3), constituting 22.7 percent and 26.9 percent, respectively, of the total fall effort for those categories.

During the first half of October, survey coverage extended from Barter Island to 154°W. longitude, mostly concentrated west of Deadhorse and south of 71°20′N. latitude (Fig. 14). There were 8.05 hours of random transects flown from 18.74 total flight hours during this period (Table 3), constituting 23.8 percent and 21.5 percent, respectively, of the total fall effort for those categories.

From 16 through 20 October, survey coverage extended from Camden Bay to the western edge of the study area, mostly south of 71°20′N. latitude (Fig. 15). There were 7.57 hours of random transects flown from 13.34 total flight hours during this period (Table 3), constituting 22.4 percent and 15.3 percent, respectively, of the total fall effort for those categories.

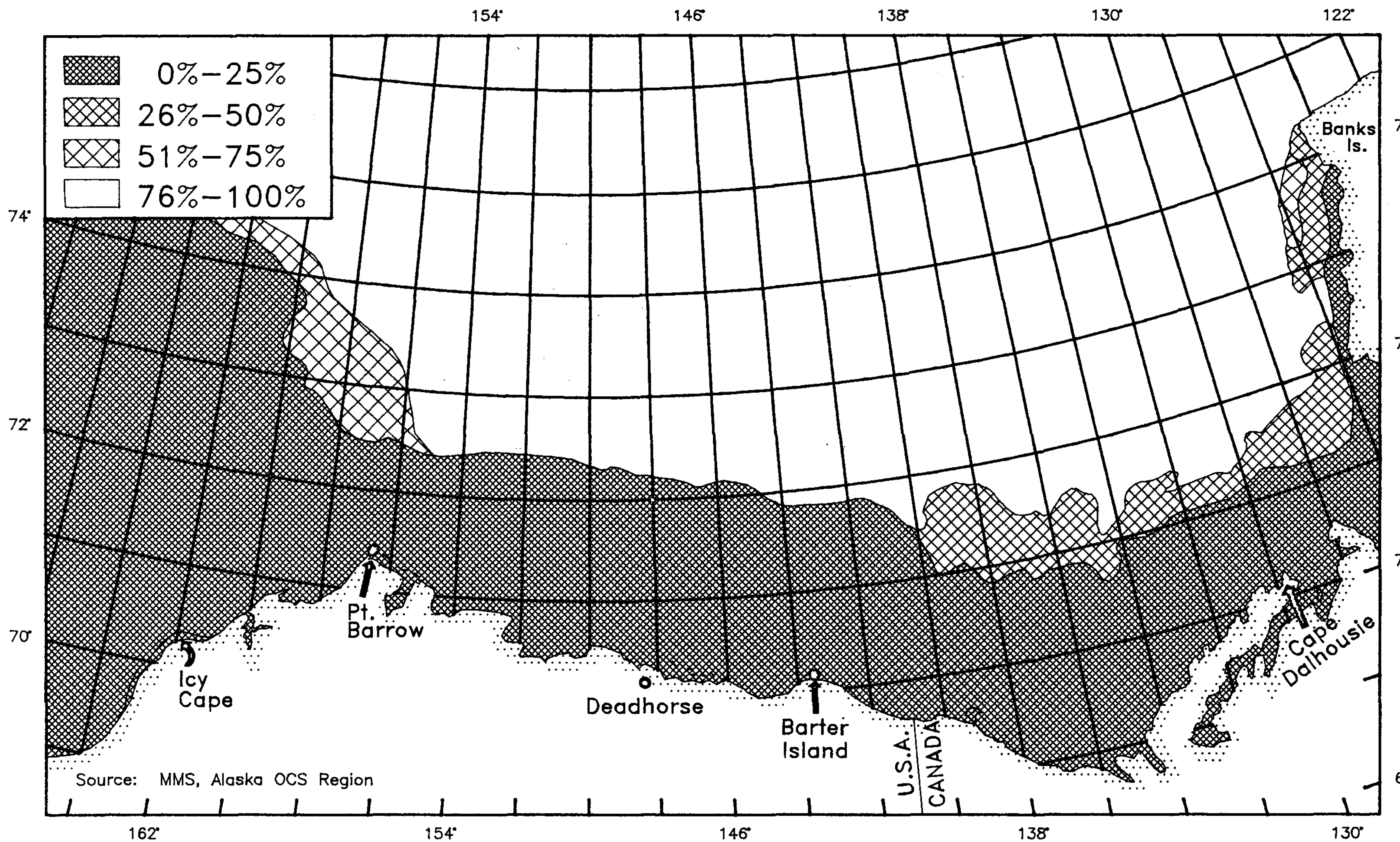

Figure 3. Map of Ice Concentrations in the Beaufort Sea, 28 August 1990

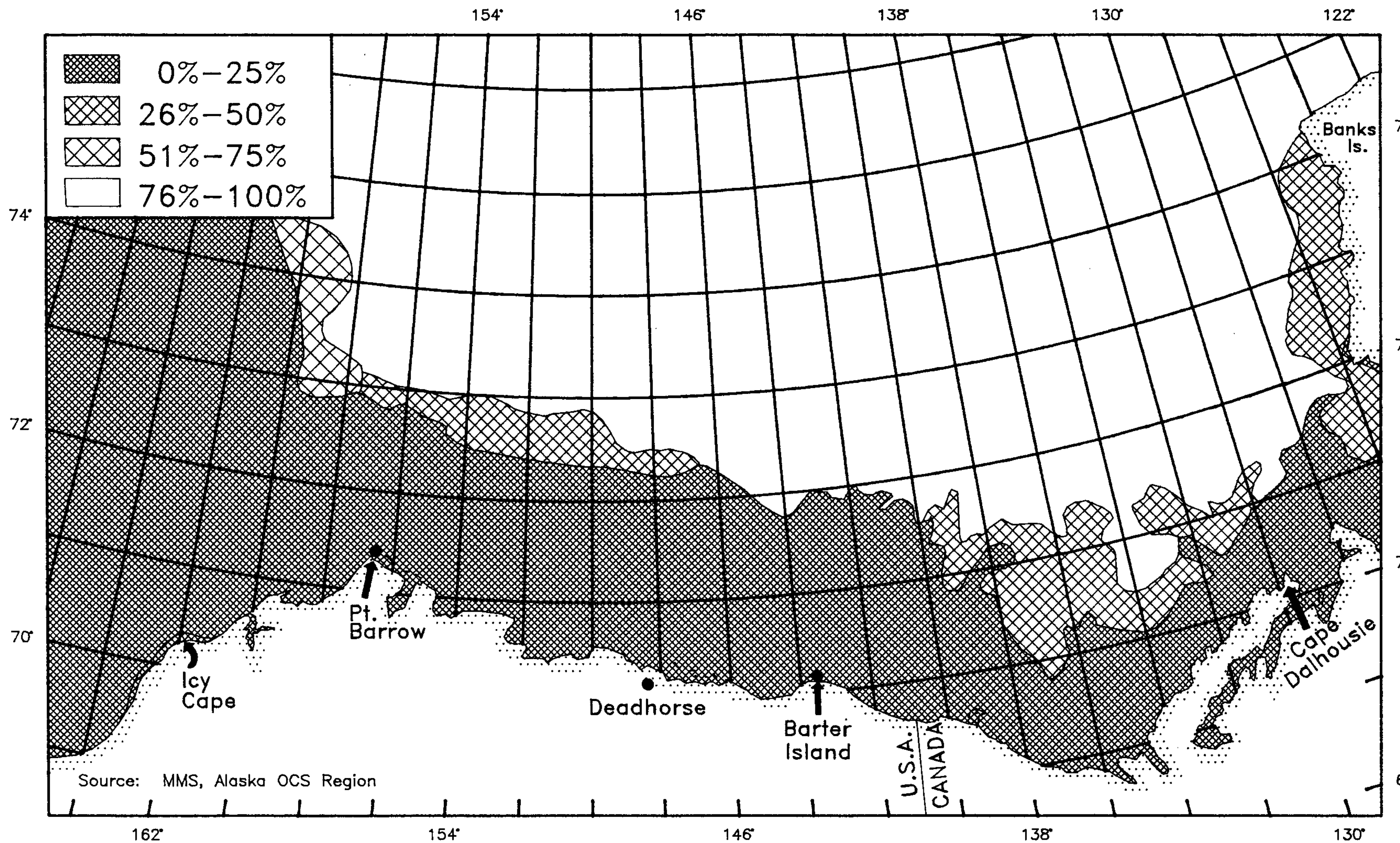

Figure 4. Map of Ice Concentrations in the Beaufort Sea, 4 September 1990

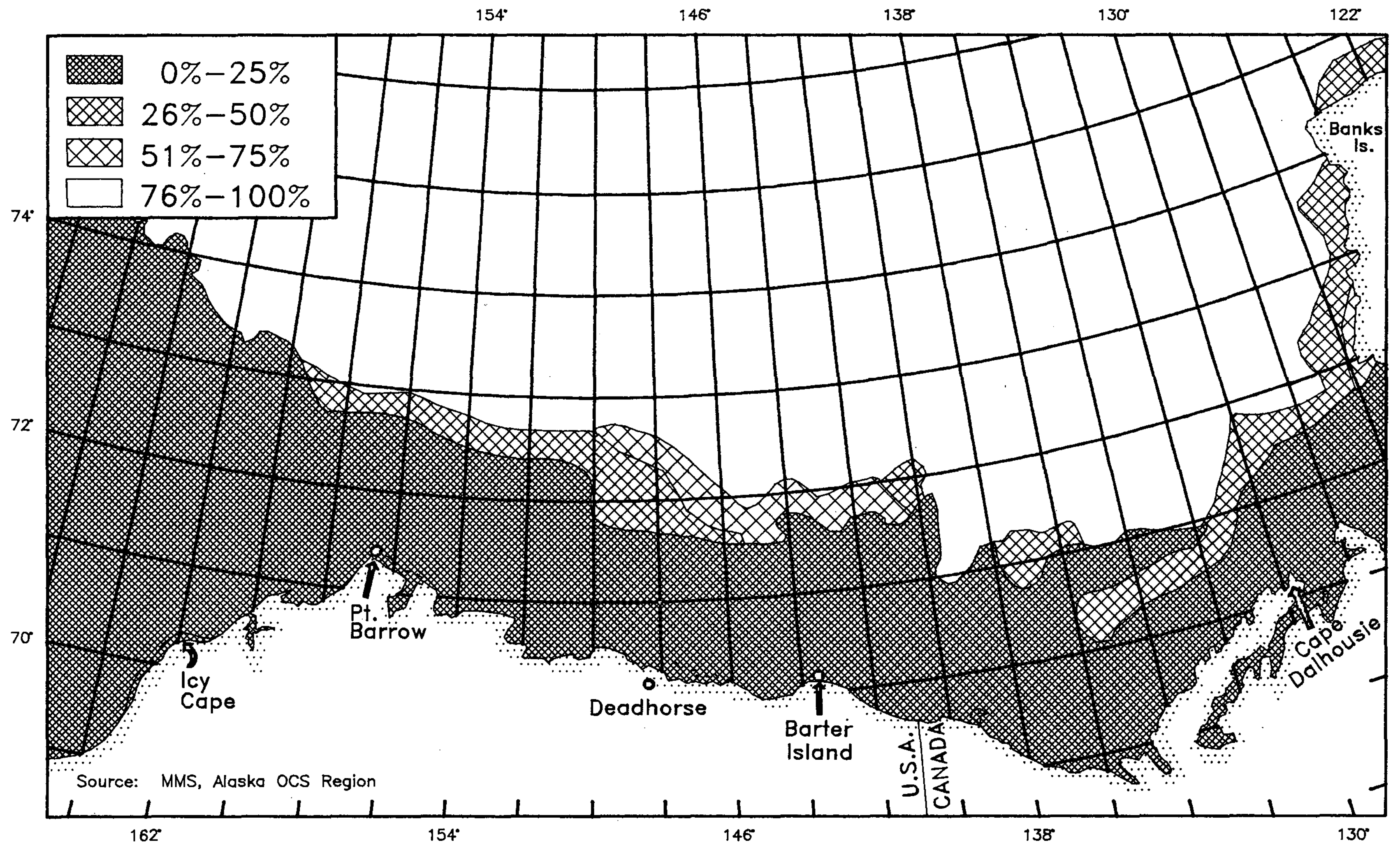

Figure 5. Map of Ice Concentrations in the Beaufort Sea, 11 September 1990

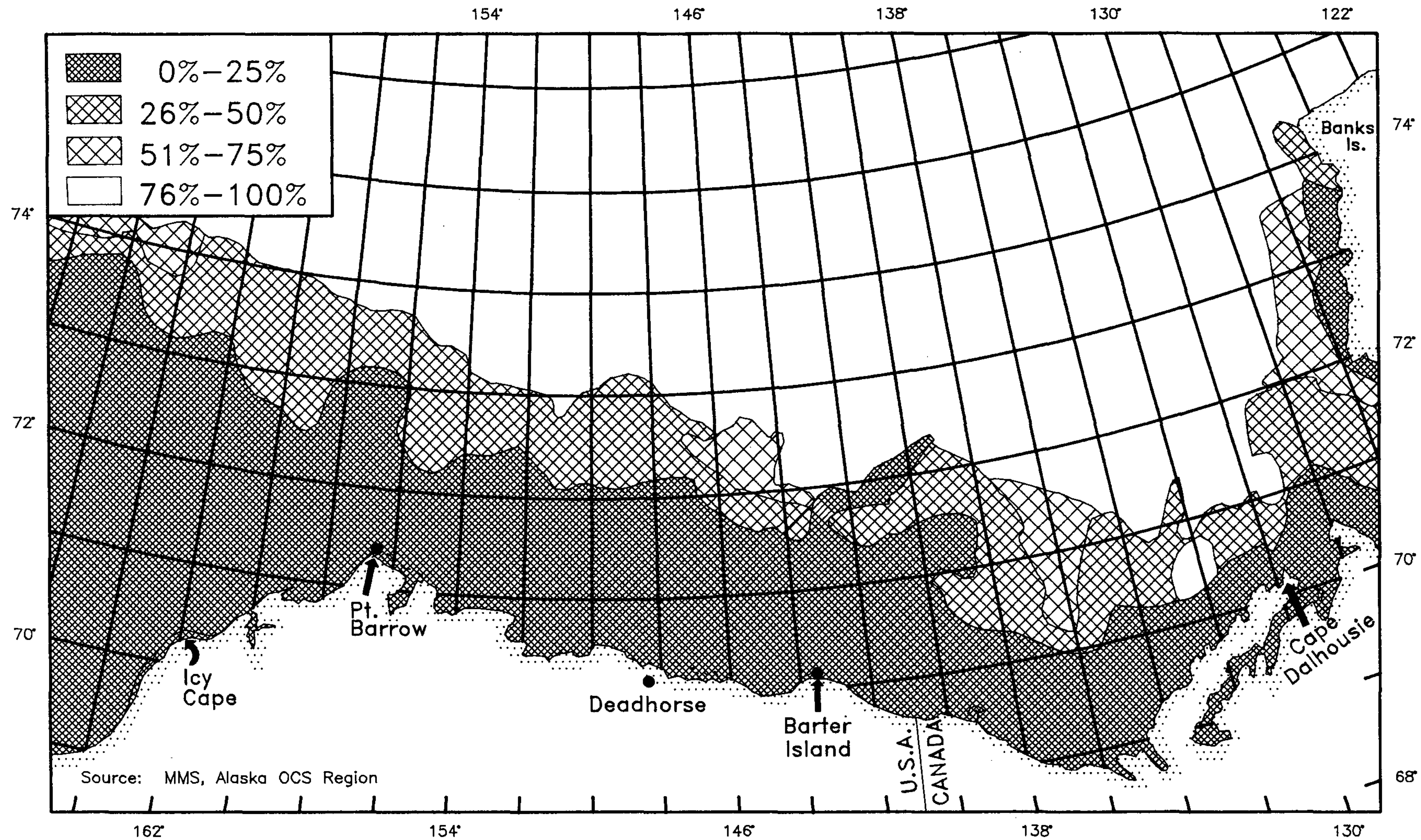

Figure 6. Map of Ice Concentrations in the Beaufort Sea, 18 September 1990

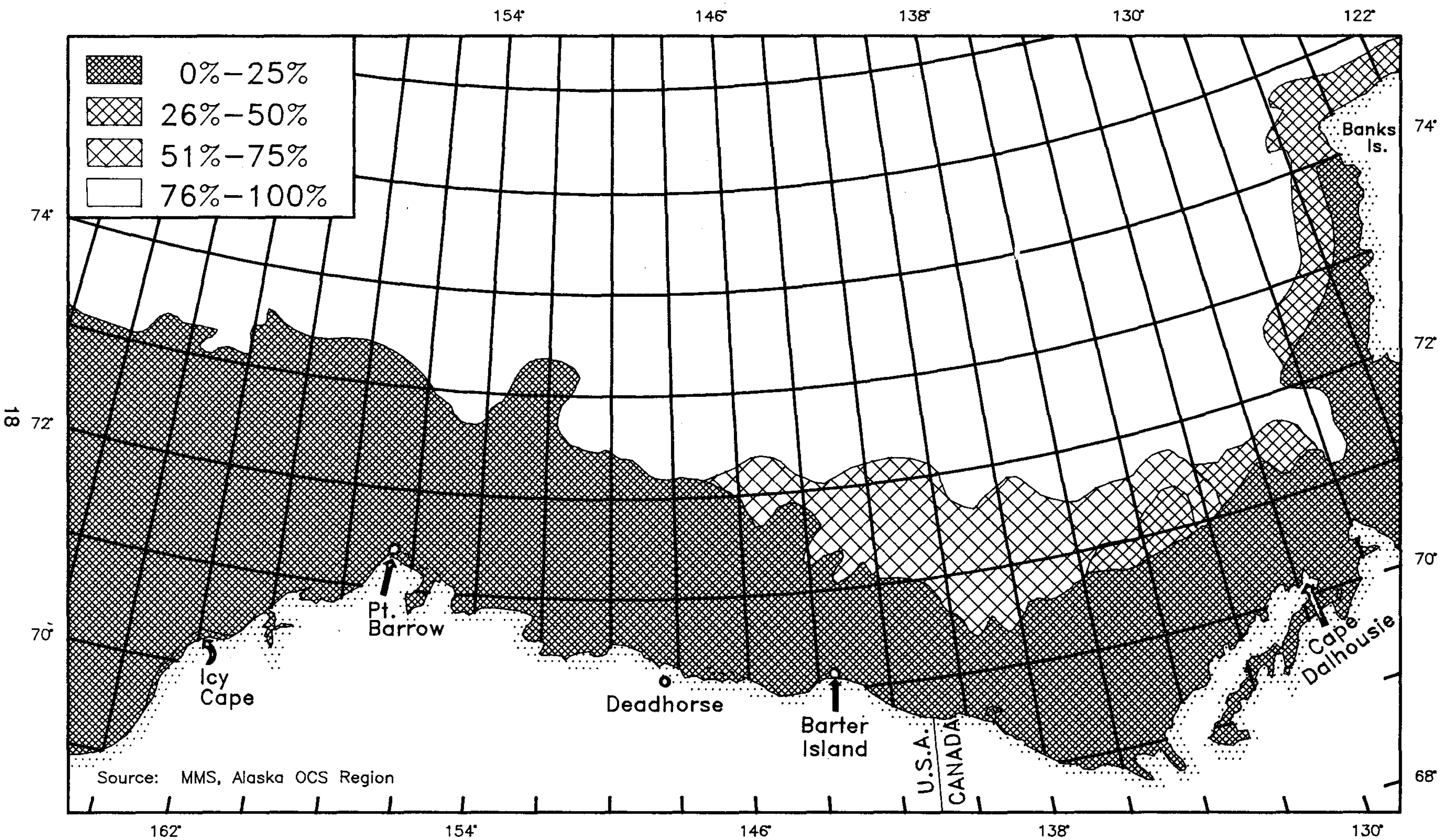

Figure 7. Map of Ice Concentrations in the Beaufort Sea, 25 September 1990

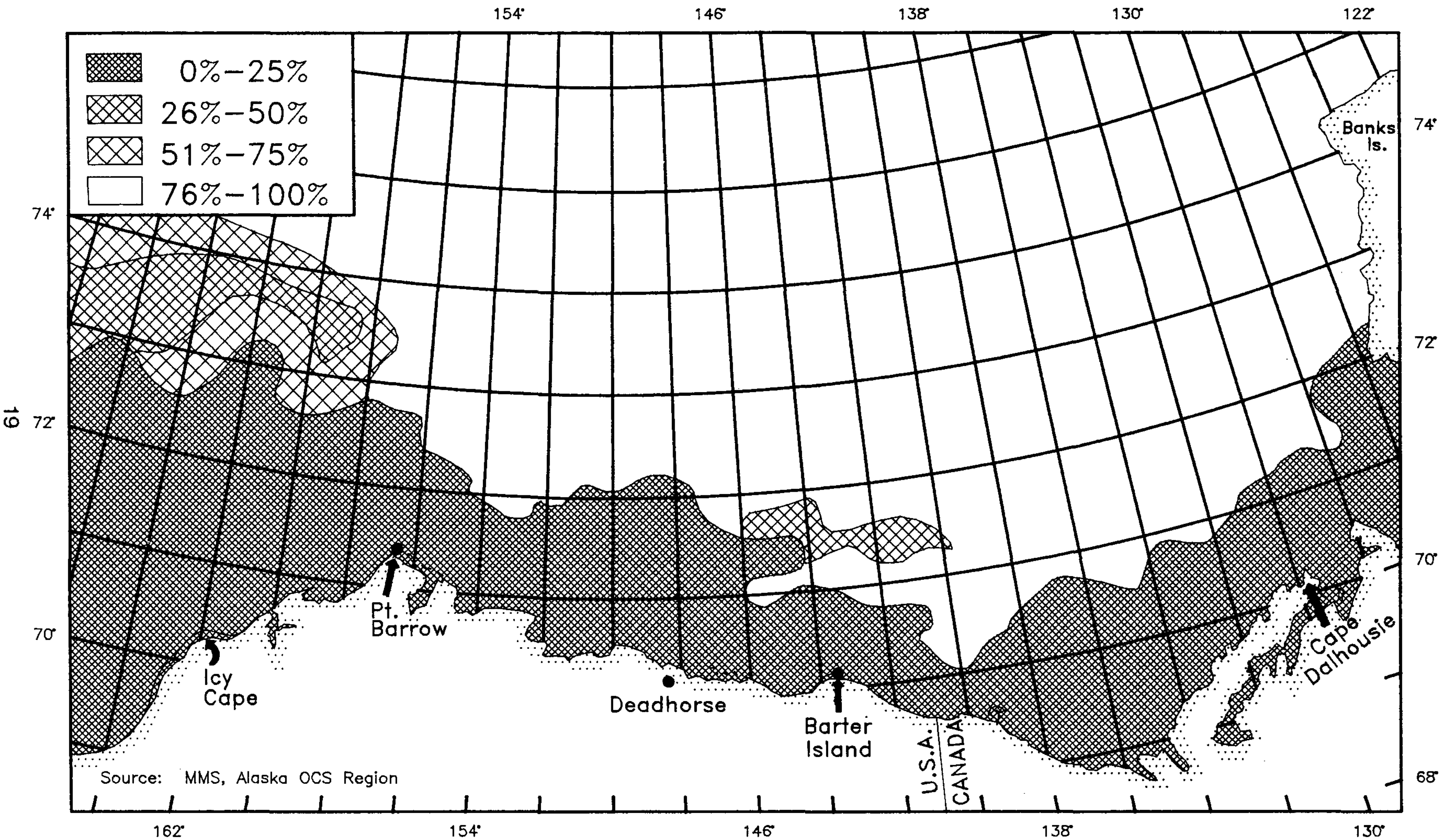

Figure 8. Map of Ice Concentrations in the Beaufort Sea, 2 October 1990

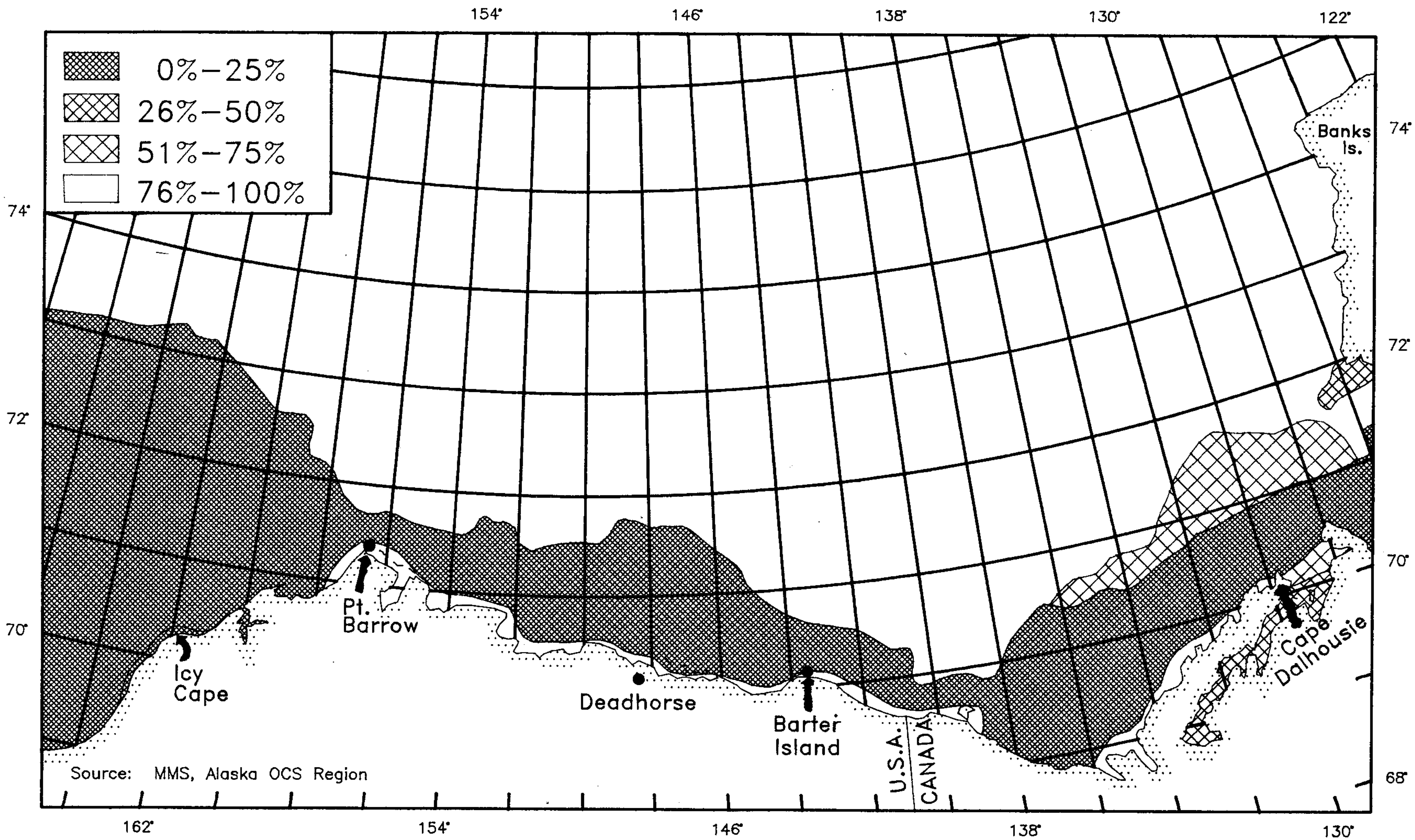

Figure 9. Map of Ice Concentrations in the Beaufort Sea, 9 October 1990

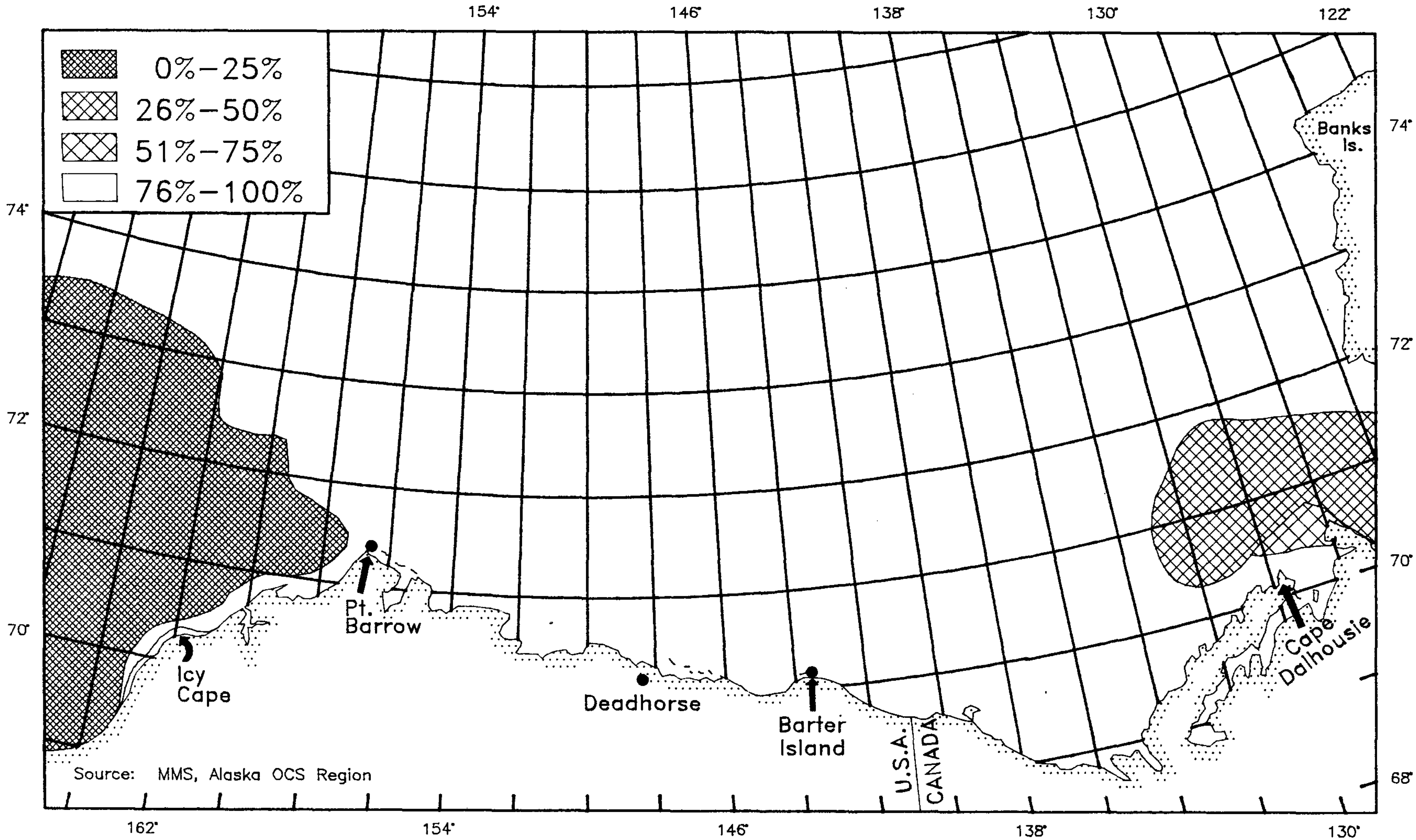

Figure 10. Map of Ice Concentrations in the Beaufort Sea, 16 October 1990

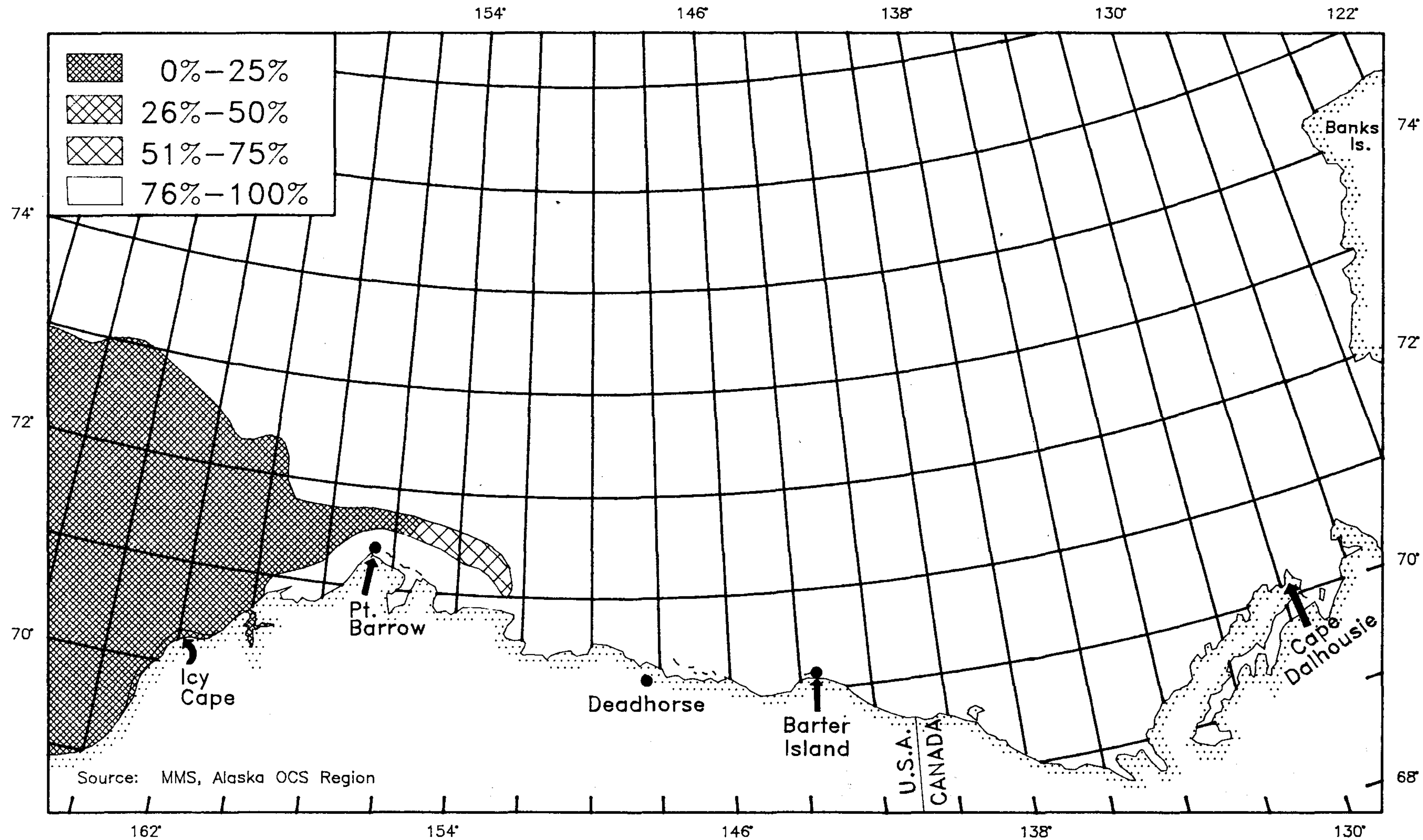

Figure 11. Map of Ice Concentrations in the Beaufort Sea, 23 October 1990

Table 3
Aerial-Survey Effort in the Beaufort Sea, September-October 1990, by Survey Flight

Day	Flight No.	Transect (km)	Connect (km)	Search (km)	Total (km)	Transect Time (hr)	Total Survey Time (hr)
2 Sep	1	267	34	699	1,000	1.07	4.30
3 Sep	2	347	159	230	736	1.62	3.33
7 Sep	3	0	0	300	300	0.00	1.38
9 Sep	4	289	50	440	779	1.17	3.15
9 Sep	5	234	85	273	592	0.92	2.18
10 Sep	6	211	35	713	959	0.85	4.82
11 Sep	7	0	0	76	76	0.00	0.32
12 Sep	8	541	205	243	989	2.22	4.32
13 Sep	9	367	63	770	1,200	1.48	5.07
14 Sep	10	306	39	353	698	1.18	2.72
16 Sep	11	374	102	638	1,114	1.67	5.00
22 Sep	12	495	202	427	1,124	2.13	5.18
24 Sep	13	265	99	618	982	1.13	4.17
26 Sep	14	329	112	703	1,144	1.27	4.73
27 Sep	15	330	129	276	735	1.30	3.05
28 Sep	16	0	0	89	89	0.00	0.35
30 Sep	17	37	0	207	244	0.15	1.00
1 Oct	18	0	0	528	528	0.00	2.23
2 Oct	19	463	183	190	836	1.83	3.33
3 Oct	20	194	114	100	407	0.78	1.54
9 Oct	21	218	103	151	473	0.89	1.94
10 Oct	22	686	188	121	995	2.72	3.95
11 Oct	23	0	0	204	204	0.00	0.88
13 Oct	24	0	0	284	284	0.00	1.18
14 Oct	25	0	0	177	177	0.00	0.70
15 Oct	26	466	54	254	774	1.83	2.98
16 Oct	27	542	89	178	809	2.27	4.30
17 Oct	28	774	158	86	1,018	3.08	4.18
18 Oct	29	552	89	293	934	2.22	4.02
19 Oct	30	0	0	224	224	0.00	0.84
Total Semimonthly Survey Effort							
1-15 Sep		2,562	480	4,097	7,329	10.50	31.58
16-30 Sep		1,830	644	2,958	5,432	7.65	23.48
1-15 Oct		2,027	642	2,009	4,678	8.05	18.74
16-20 Oct		1,868	336	781	2,985	7.57	13.34
TOTAL		8,287	2,102	21,510	20,424	33.77	87.14

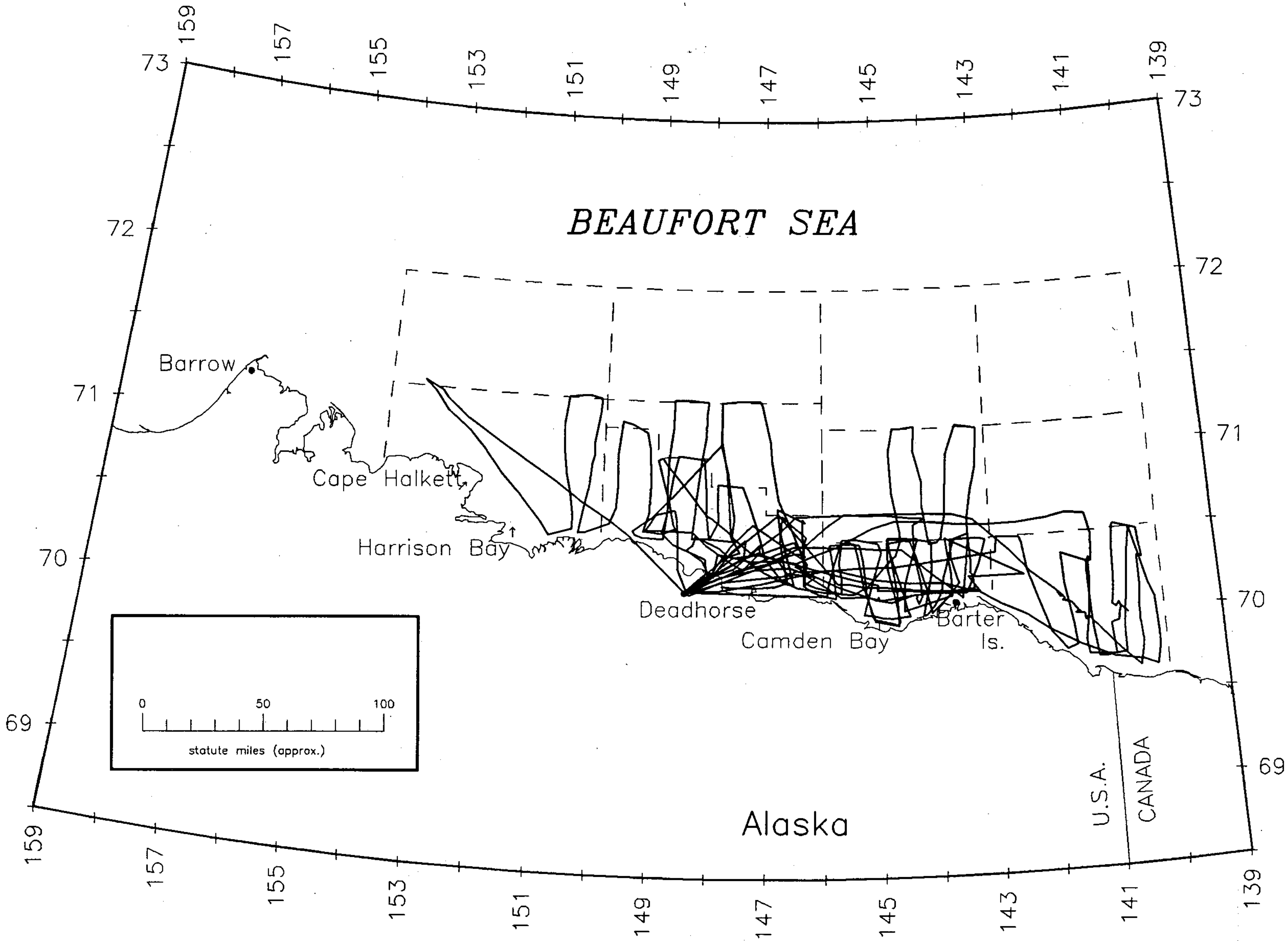

Figure 12. Combined Flight Tracks, 1–15 September 1990

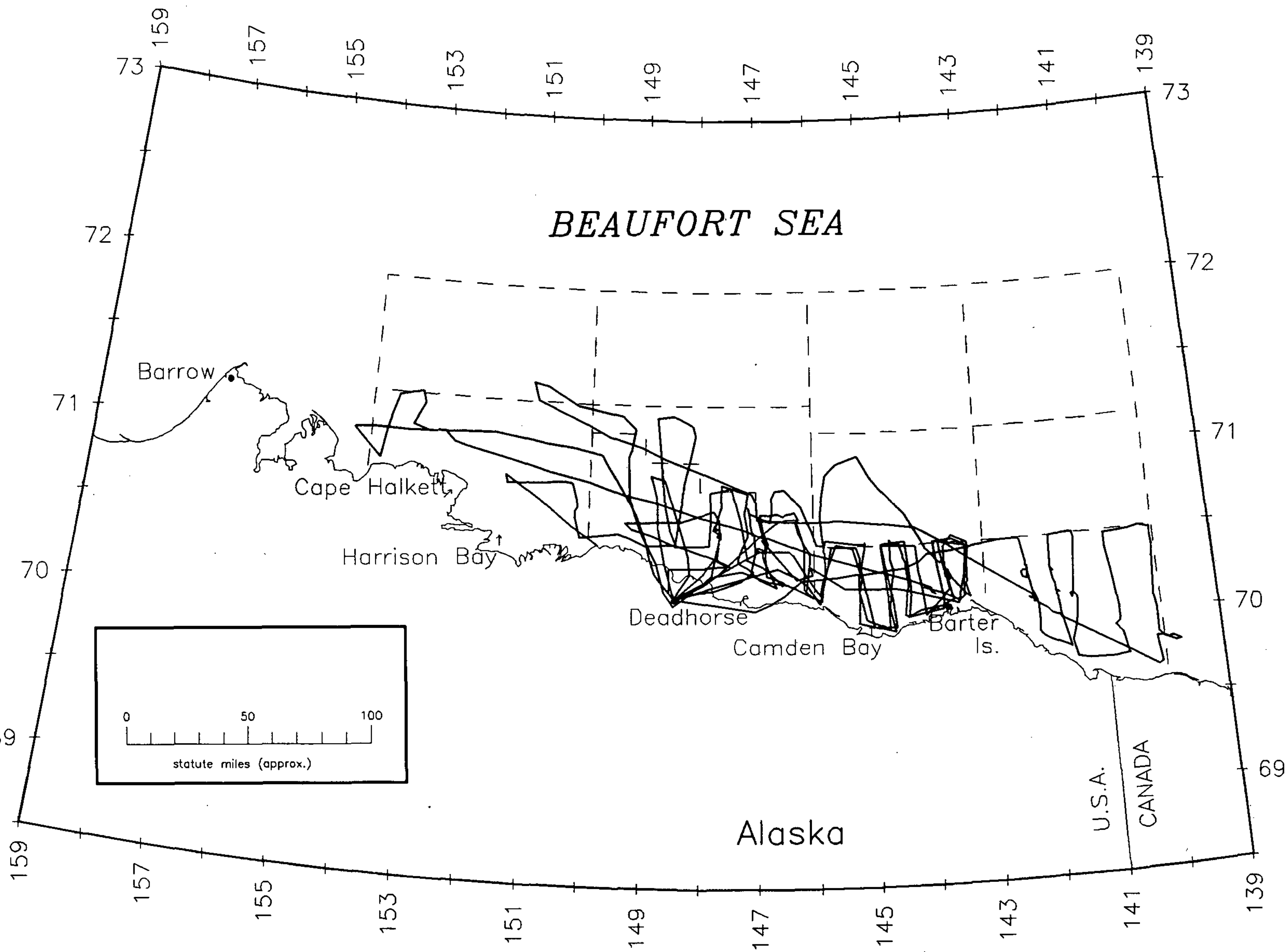

Figure 13. Combined Flight Tracks, 16–30 September 1990

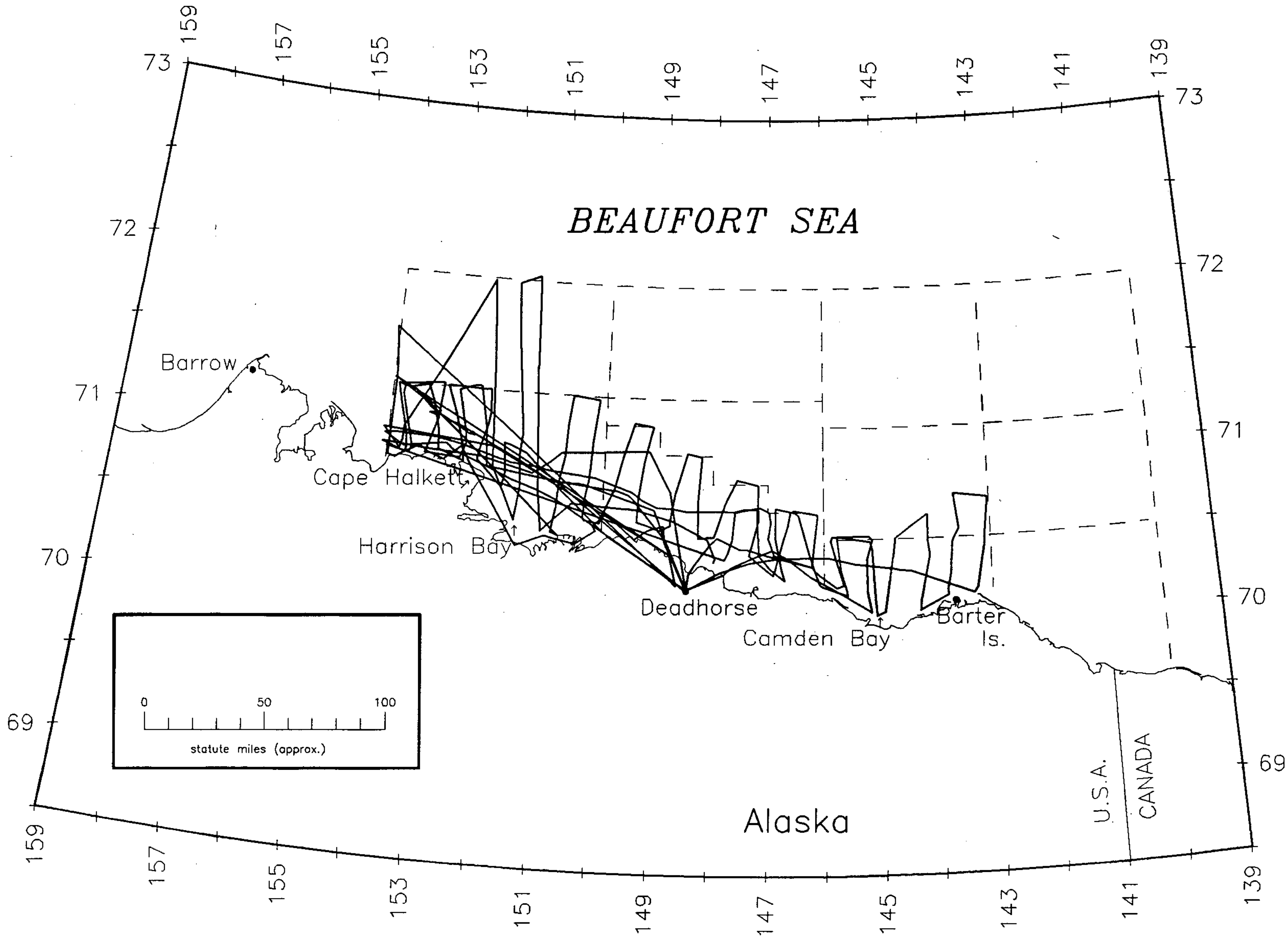

Figure 14. Combined Flight Tracks, 1–15 October 1990

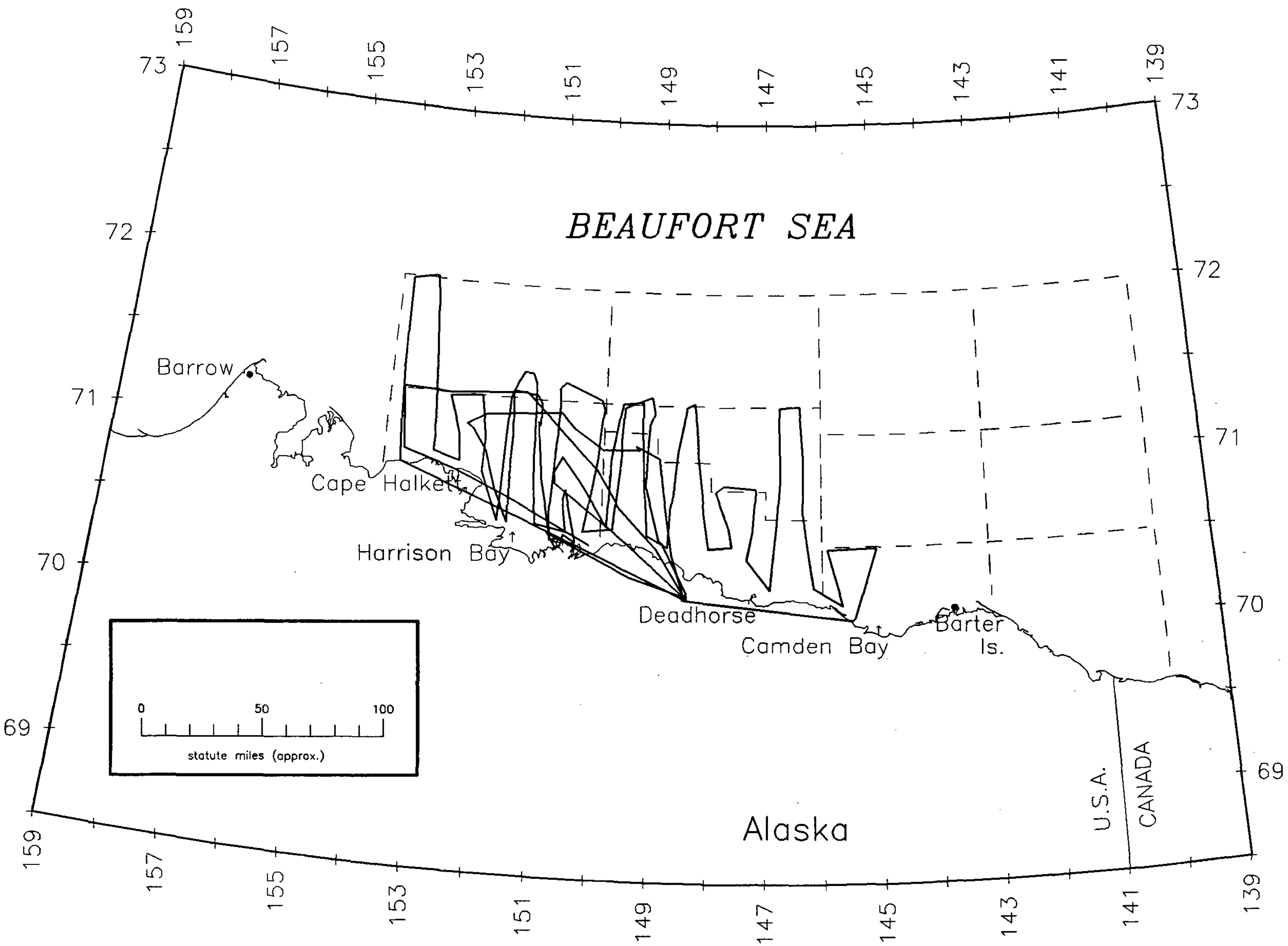

Figure 15. Combined Flight Tracks, 16–20 October 1990

C. Bowhead Whale (*Balaena mysticetus*) Observations

1. Distribution: Three hundred and twenty-six sightings were made for a total of 478 bowhead whales observed during Fall-1990 surveys in the study area (Table 4 and Figs. 16-20). Five of these whales were identified as calves (Appendix B: Table B-1), resulting in an overall calf ratio (number calves/total whales) of 0.01. Daily sightings are shown on individual maps in Appendix B.

During the first half of September, 72 sightings were made for a total of 103 bowhead whales (Table 4), with all sightings east of Deadhorse (Fig. 16). The first bowheads in the Alaskan Beaufort were sighted on 2 September near or east of Barter Island (Appendix B: Flight 1). The westernmost sighting during this period was made north of Deadhorse, on 7 September (Appendix B: Flight 3). Pod sizes were small, ranging from 1 to 4 whales (Appendix B: Table B-1), with a mean of 1.43 (SD = 0.80, n = 72). Two bowhead whale calves were observed during this period (Appendix B: Table B-1).

During the second half of September, 198 sightings were made for a total of 305 bowheads (Table 4), with sightings somewhat evenly distributed in the eastern half of the study area (Fig. 17). The westernmost sighting during this period (Fig. 17), northeast of Harrison Bay on 30 September, was the only sighting west of Deadhorse during September (Appendix B: Flight 17). Pod sizes ranged from 1 to 9 whales (Appendix B: Table B-1), with a mean of 1.54 (SD = 1.03, n = 198). Three bowhead whale calves were observed during this period (Appendix B: Table B-1).

During the first half of October, 54 sightings were made for a total of 68 bowheads (Table 4), with sightings from Barter Island to the western edge of the study area (Fig. 18), reflecting survey effort in that area (Fig. 14). Pod sizes ranged from 1 to 6 whales (Appendix B: Table B-1), with a mean of 1.26 (SD = 0.78, n = 54).

From 16 through 20 October, only 2 sightings were made for a total of 2 bowheads (Table 4), with both sightings in the westernmost survey blocks (Fig. 19). The last bowhead seen in the Beaufort Sea during the study occurred on 19 October at 71°20.6'N. latitude and 153°45.8'W. longitude (Appendix B: Table B-1).

2. Relative Temporal and Spatial Abundance: The day-to-day timing of the bowhead whale migration was calculated over the entire study area in Table 5 and graphically depicted in Figure 21. A daily sighting rate, or sightings per unit effort (SPUE), and an index of relative abundance, or whales per unit effort (WPUE), were determined.

The sighting-rate data show that an initial sighting was made on 2 September. The daily sighting rate peaked at 17.37 SPUE on 22 September. The last sighting of a bowhead in the study area was made on 19 October, the last day on which a flight was made.

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 22 September (Table 5). The peak relative abundance (mode) of 24.80 WPUE occurred on 16 September (Table 5 and Fig. 21).

There were no great differences in pattern between the graph for relative abundance and that for sighting rate (Fig. 21), thus further indicating that pod sizes were fairly consistent over the Fall-1990 field season.

The relative abundance of bowhead whales in each survey block (Fig. 1), 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.

During the first half of September, there were three survey blocks in which ≥4.00 hr of survey effort were made (Table 6). Of these coastal blocks (Blocks 1, 4, and 5), Block 5 had the greatest relative abundance (9.69 WPUE), with Block 4 (4.30 WPUE) and Block 1 (0.84 WPUE) each having a relative abundance >0.50. Five whales were observed during a total of 7.00 hr of survey effort in Blocks 2, 3, 6, 7, 9, 10, and 11.

Table 4
Summary of Marine Mammal Sightings, September-October 1990, 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
2 Sep	1	4/4	0	0	0	0	0	0
3 Sep	2	5/8	0	0	0	0	2/2	0
7 Sep	3	1/1	0	0	0	0	0	0
9 Sep	4	0	0	0	0	0	1/1	0
9 Sep	5	2/2	0	0	0	8/42	6/9	0
10 Sep	6	36/52	0	0	2/4	4/21	7/17	0
11 Sep	7	0	0	0	0	0	0	0
12 Sep	8	9/10	0	0	3/4	9/17	4/14	0
13 Sep	9	15/26	0	0	0	1/1	1/3	0
14 Sep	10	0	0	1/13	0	0	0	0
16 Sep	11	71/124	0	2/3	11/28	9/50	11/61	0
22 Sep	12	90/125	0	0	2/4	2/2	4/5	0
24 Sep	13	6/7	0	0	0	0	1/1	0
26 Sep	14	29/45	0	0	0	0	1/6	0
27 Sep	15	1/1	0	0	0	0	0	0
28 Sep	16	0	0	0	0	0	0	0
30 Sep	17	1/3	0	0	0	0	0	0
1 Oct	18	24/30	0	0	0	0	7/8	0
2 Oct	19	11/12	0	0	0	0	1/1	0
3 Oct	20	1/1	0	0	0	0	0	0
9 Oct	21	3/3	0	0	0	0	1/1	0
10 Oct	22	1/1	0	0	0	0	0	0
11 Oct	23	12/19	0	0	0	0	0	0
13 Oct	24	1/1	0	0	0	0	1/2	0
14 Oct	25	1/1	0	0	0	0	0	0
15 Oct	26	0	0	0	0	0	0	0
16 Oct	27	0	0	1/4	0	0	0	0
17 Oct	28	0	0	5/6	0	0	0	0
18 Oct	29	1/1	0	3/12	0	0	1/1	0
19 Oct	30	1/1	0	0	0	0	0	0
Total Semimonthly Sightings								
1-15 Sep		72/103	0	1/13	5/8	22/81	21/146	0
16-30 Sep		198/305	0	2/3	13/32	11/52	17/73	0
1-15 Oct		54/68	0	0	0	0	10/12	0
16-20 Oct		2/2	0	9/22	0	0	1/1	0
TOTAL		326/478	0	12/38	18/40	33/133	49/232	0

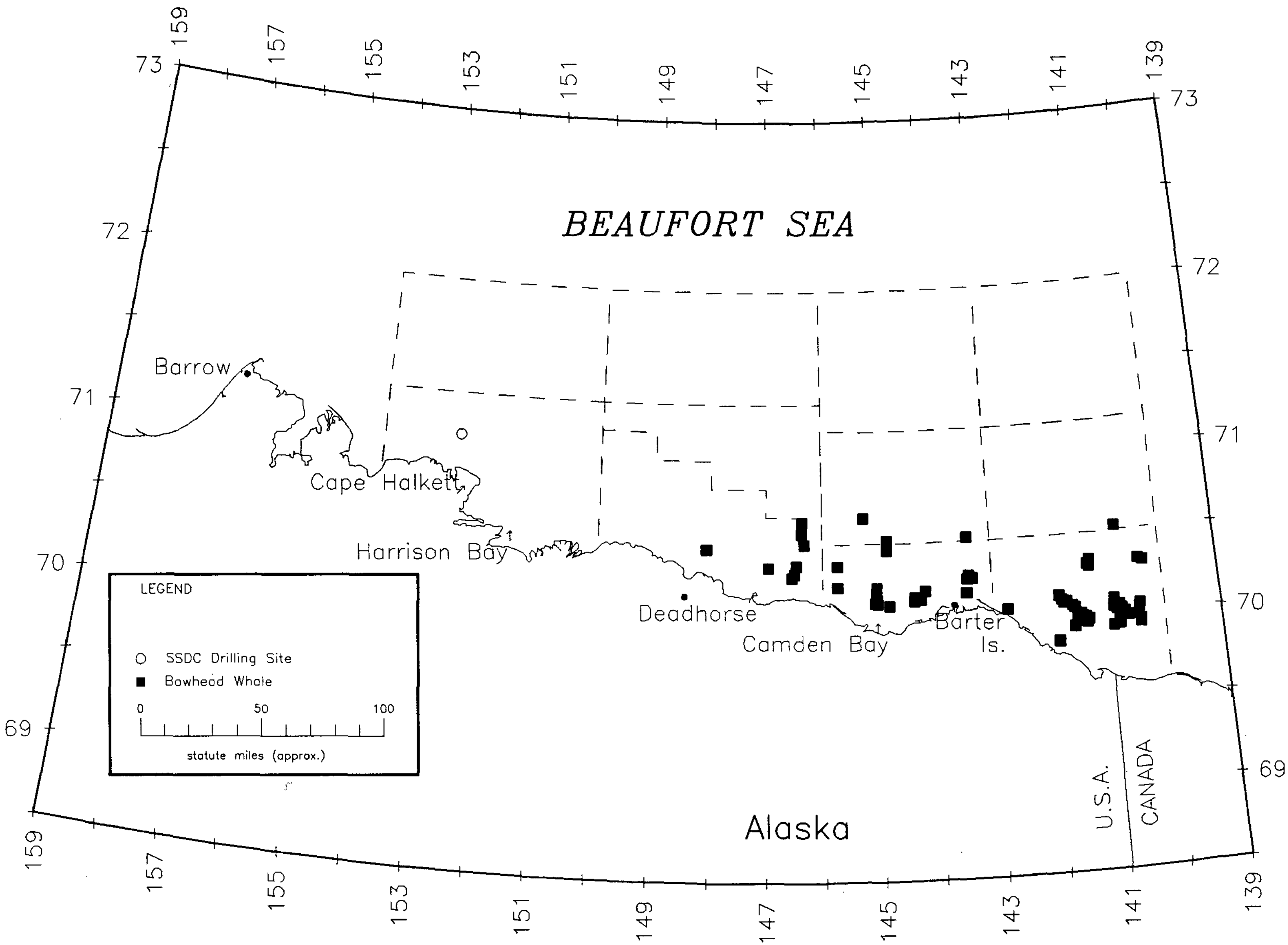

Figure 16. Map of Bowhead Whale Sightings, 1–15 September 1990

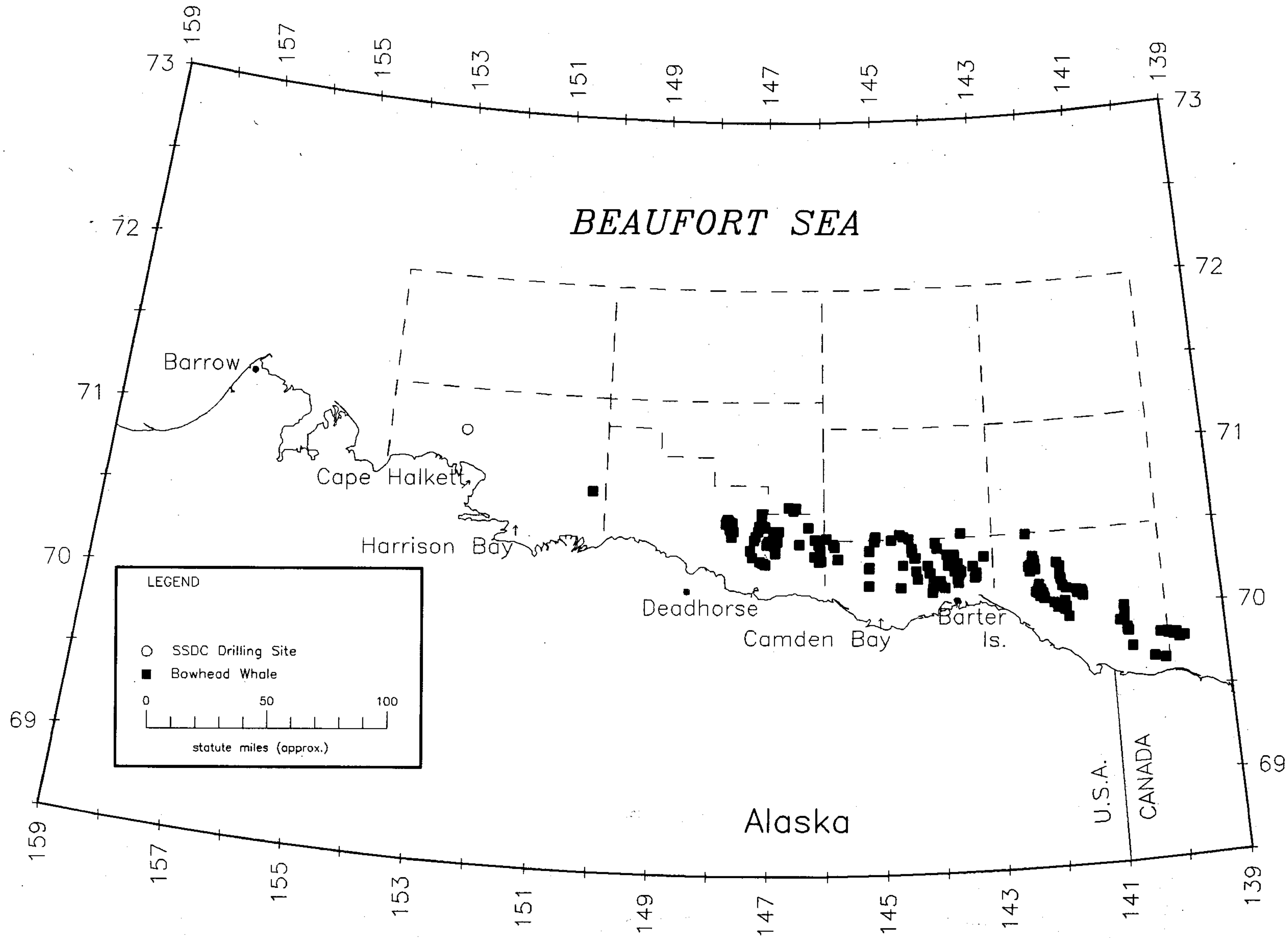

Figure 17. Map of Bowhead Whale Sightings, 16–30 September 1990

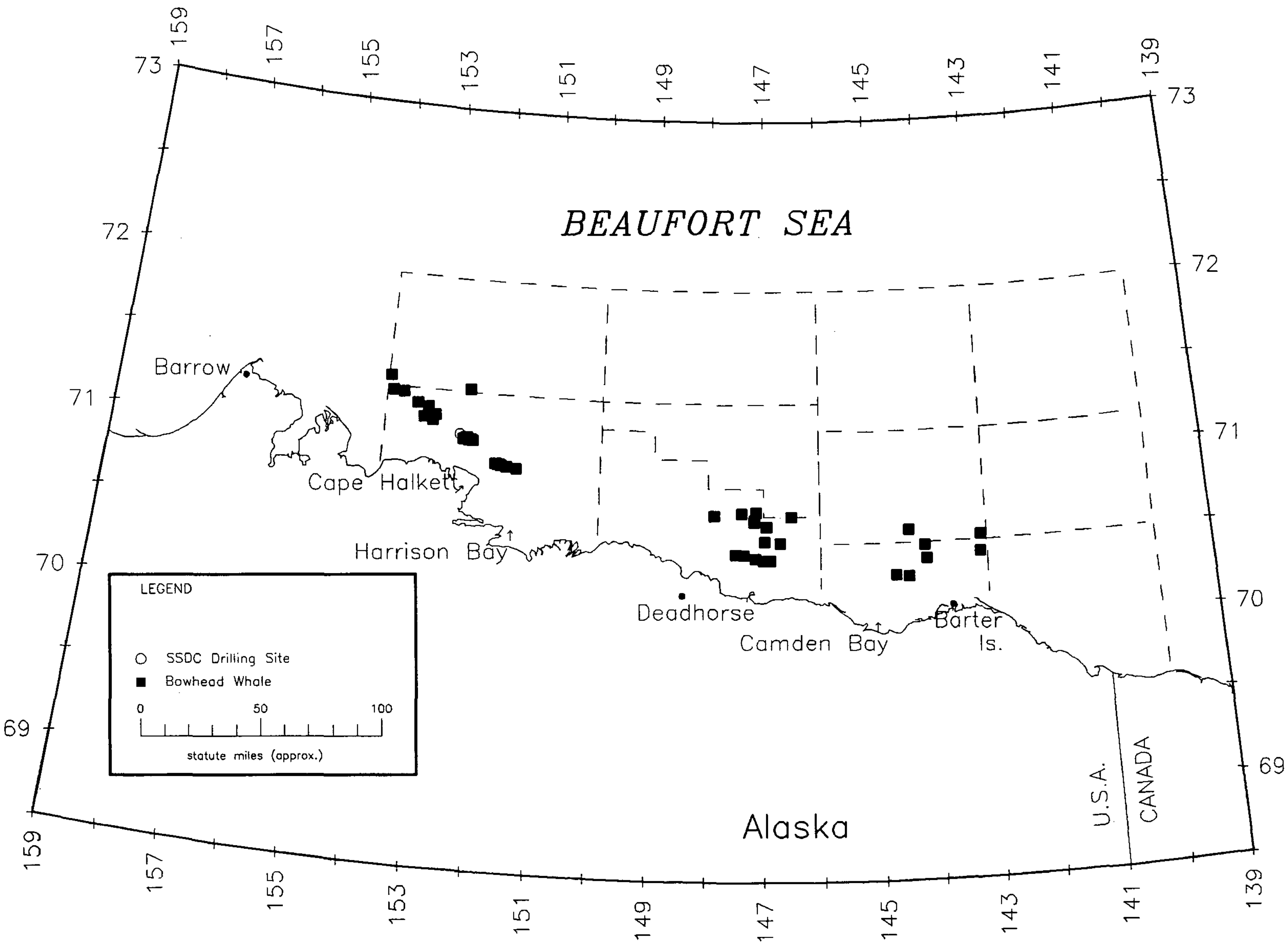

Figure 18. Map of Bowhead Whale Sightings, 1–15 October 1990

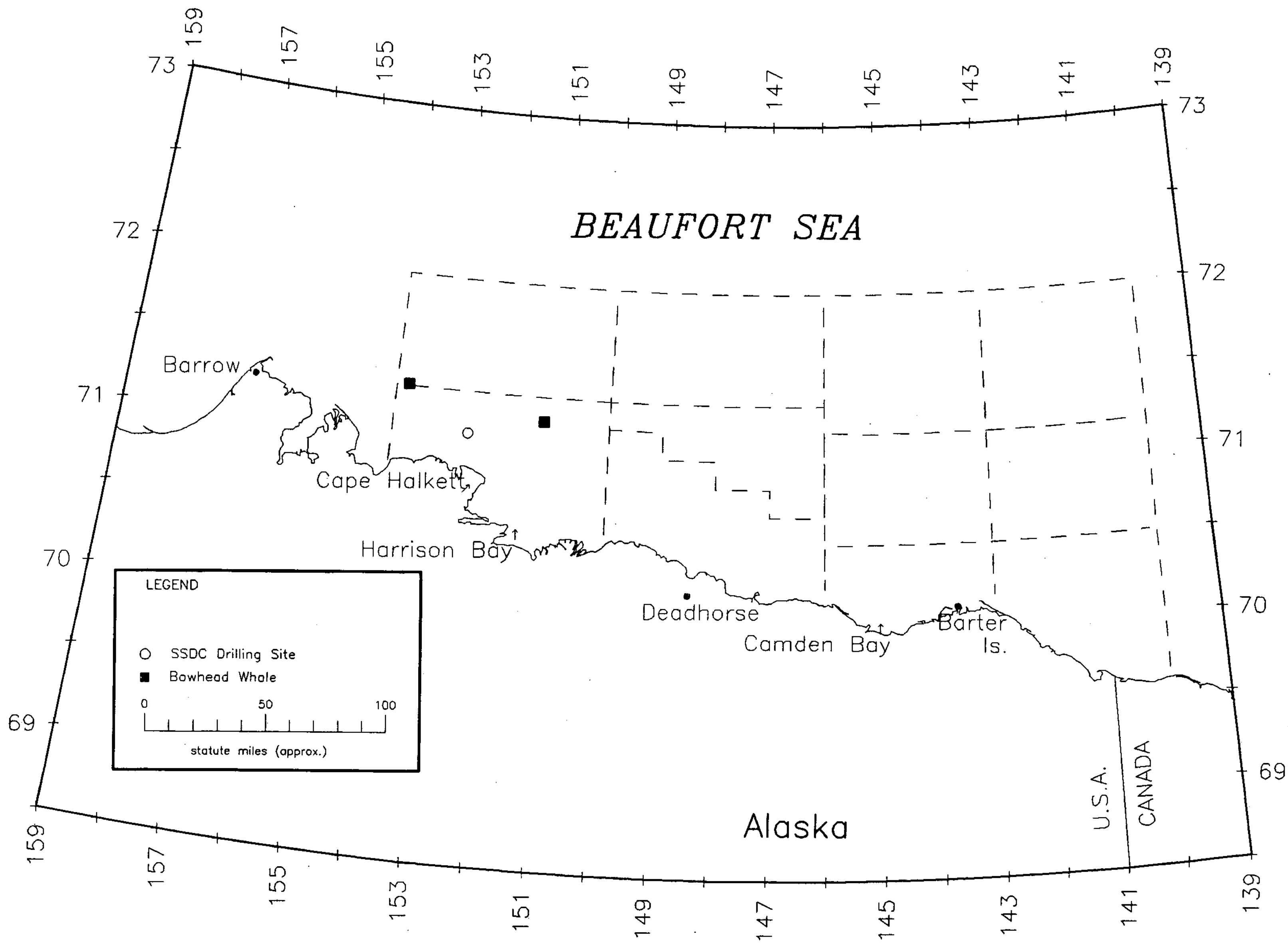

Figure 19. Map of Bowhead Whale Sightings, 16–20 October 1990

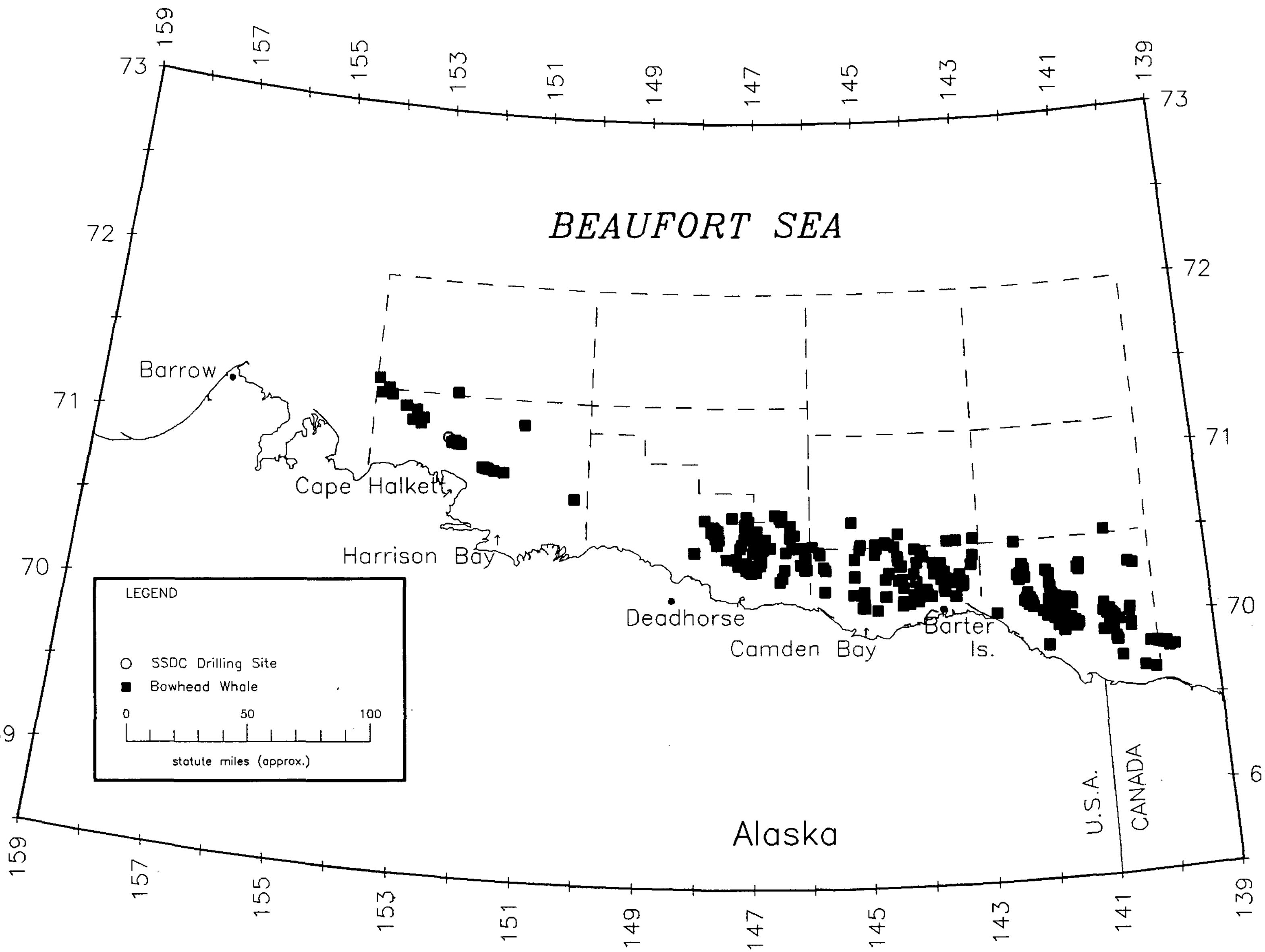

Figure 20. Map of Bowhead Whale Sightings, 1 September–20 October 1990

Table 5
Number of Sightings and Total Bowhead Whales Observed per Hour, September-October 1990, by Flight Day

Day	No. of Sightings	No. of Whales	Total Survey Time (hr)	Sightings/ Hour (SPUE)	Whales/ Hour (WPUE)
2 Sep	4	4	4.30	0.93	0.93
3 Sep	5	8	3.33	1.50	2.40
7 Sep	1	1	1.38	0.72	0.72
9 Sep	0	0	3.15	0.00	0.00
9 Sep	2	2	2.18	0.92	0.92
10 Sep	36	52	4.82	7.49	10.79
11 Sep	0	0	0.32	0.00	0.00
12 Sep	9	10	4.32	2.08	2.31
13 Sep	15	26	5.07	2.96	5.13
14 Sep	0	0	2.72	0.00	0.00
16 Sep	71	124	5.00	14.20	24.80
22 Sep	90	125	5.18	17.37	24.13
24 Sep	6	7	4.17	1.44	1.68
26 Sep	29	45	4.73	6.13	9.51
27 Sep	1	1	3.05	0.33	0.33
28 Sep	0	0	0.35	0.00	0.00
30 Sep	1	3	1.00	1.00	3.00
1 Oct	24	30	2.23	10.76	13.45
2 Oct	11	12	3.33	3.30	3.60
3 Oct	1	1	1.54	0.65	0.65
9 Oct	3	3	1.94	1.55	1.55
10 Oct	1	1	3.95	0.25	0.25
11 Oct	12	19	0.88	13.64	21.59
13 Oct	1	1	1.18	0.85	0.85
14 Oct	1	1	0.70	1.43	1.43
15 Oct	0	0	2.98	0.00	0.00
16 Oct	0	0	4.30	0.00	0.00
17 Oct	0	0	4.18	0.00	0.00
18 Oct	1	1	4.02	0.25	0.25
19 Oct	1	1	0.84	1.19	1.19
TOTAL	326	478	87.14	3.74	5.49

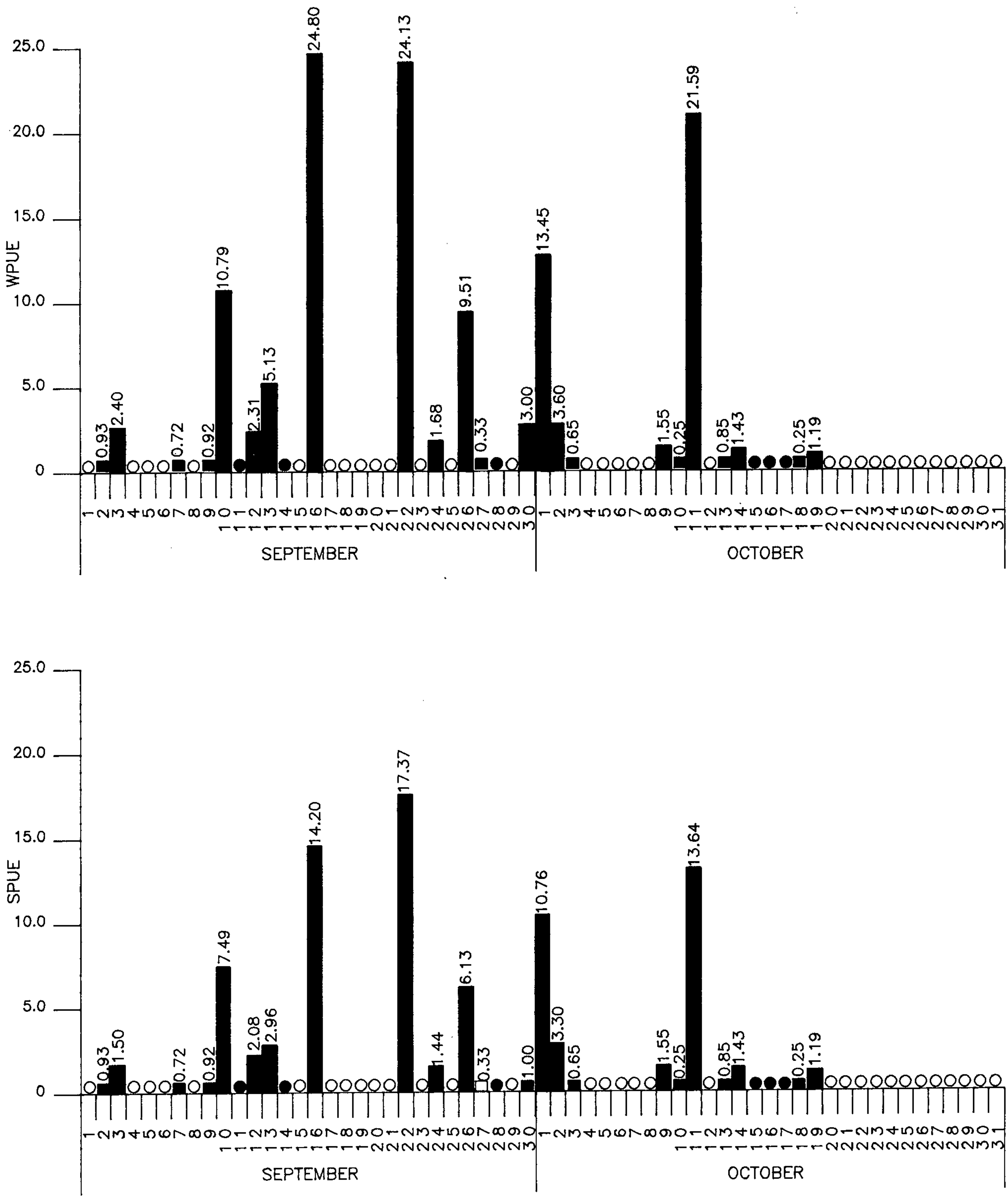

Figure 21. Daily Relative Abundance (WPUE) and Sighting Rate (SPUE) of Bowhead Whales (Fall 1990)

(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 1990)

Block	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
1	10.75	9	0.84	8.40	97	11.55	5.67	28	4.94	3.65	0	0.00	28.48	134	4.71
2	1.24	0	0.00	0.95	0	0.00	0.15	0	0.00	1.26	0	0.00	3.60	0	0.00
3	1.85	0	0.00	2.31	3	1.30	8.34	30	3.60	6.15	1	0.16	18.70	34	1.82
4	8.37	36	4.30	6.34	76	11.99	2.21	6	2.71	0.55	0	0.00	17.47	118	6.75
5	5.47	53	9.69	3.39	111	32.74	*	*	*	*	*	*	8.86	164	18.51
6	2.94	4	1.36	1.54	11	7.14	0.70	2	2.86	*	*	*	5.17	17	3.28
7	0.46	1	2.17	0.12	0	0.00	*	*	*	*	*	*	0.58	1	1.72
8	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
9	0.11	0	0.00	*	*	*	*	*	*	*	*	*	0.11	0	0.00
10	0.21	0	0.00	*	*	*	*	*	*	0.20	0	0.00	0.41	0	0.00
11	0.19	0	0.00	0.21	0	0.00	1.59	2	1.26	1.50	1	0.67	3.44	3	0.87
Other Canadian Areas	*	*	*	0.11	7	63.64	*	*	*	*	*	*	0.11	7	63.64
Other Alaskan Areas	*	*	*	0.12	0	0.00	0.07	0	0.00	0.03	0	0.00	0.22	0	0.00
TOTAL	31.59	103	3.26	23.49	305	12.98	18.73	68	0.28	13.34	2	0.15	87.15	478	5.49

* No survey effort.

During the second half of September, there were two blocks in which ≥4.00 hr of survey effort were made (Table 6). Of these coastal blocks (Blocks 1 and 4), Block 4 had the greatest relative abundance (11.99 WPUE), with Block 1 also having a relative abundance (11.55 WPUE) >0.50. Although only 3.39 hours of survey effort were made in coastal Block 5, it was notable that 111 whales were observed for a very high relative abundance (32.74 WPUE). Fourteen whales were observed during a total of 5.25 hr of survey effort in the remaining blocks (Blocks 2, 3, 6, 7, and 11) or in other Alaskan areas. It was also notable that seven whales were observed during only 0.11 hours in other Canadian areas for an extremely high relative abundance (63.64 WPUE).

During the first half of October, there were two blocks in which ≥4.00 hr of survey effort were made (Table 6). Of these coastal blocks (Blocks 1 and 3), Block 1 had the greatest relative abundance (4.94 WPUE), with Block 3 also having a relative abundance (3.60 WPUE) >0.50. Ten whales were observed during a total of 4.72 hr of survey effort in the remaining blocks (Blocks 2, 4, 6, and 11) or in other Alaskan areas.

From 16 through 20 October, coastal Block 3--the only block in which ≥4.00 hr of survey effort were made (Table 6)--had a low relative abundance (0.16). Only one whale was observed during a total of 7.19 hr of survey effort in the remaining blocks (Blocks 1, 2, 4, 10, and 11) or in other Alaskan areas.

3. Habitat Relationships: Almost all the bowheads (93%) were sighted in shallow water (0-50 m deep). The remainder (7%) were sighted in water ranging from 51 m to 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 overall ice coverage (Figs. 3-11), the percentage of ice cover visible from the aircraft at each bowhead sighting was summarized (Appendix B: Table B-1). All bowheads sighted during the study were in zero-percent sea ice (Table 8).

4. Behavior, Swim Direction, and Speed: Overall, 385 of 478 bowheads (80%) observed during Fall 1990 (Table 9) were swimming, i.e., moving forward in an apparently deliberate manner, when first sighted. Swim direction over the fall season was significantly west-northwest (Fig. 22), consistent with a directed migration in rough parallel to Alaska's Beaufort Sea coastline. Bowheads were judged to be moving at either slow (30%), medium (44%), or fast (5%) speeds or were still (10%) (Table 10). Other behaviors noted for bowhead whales were milling (7%), resting (6%), diving (3%), breaching (1%), and tail-slapping (1%) (Table 9). All behaviors noted are defined in Table 2.

During the first half of September, 76 of 103 (73%) bowheads were observed swimming (Table 9) and headed predominantly west-northwest or south-southwest, with a small proportion (approx. 0.2) headed east-southeast toward Canada (Fig. 22). Bowheads were moving mostly at medium (42%) or slow (31%) speed (Table 10). A few were still (7%) or moving at fast (3%) speed (Table 10). Other behaviors were milling (9%), resting (6%), diving (4%), or tail-slapping (2%) (Table 9).

During the second half of September, 257 of 305 (84%) bowheads were observed swimming (Table 9) and headed significantly west-northwest (Fig. 22). Bowheads were mostly moving at medium (52%) or slow (23%) speed (Table 10). A few were still (9%) or moving at fast (6%) speed (Table 10). Other behaviors noted were resting (6%), milling (5%), diving (3%), or breaching (1%).

During the first half of October, 51 of 68 (75%) bowheads were observed swimming (Table 9) and headed significantly west-northwest (Fig. 22). Bowheads were moving mostly at slow (61%) speed with others being still (18%) or moving at medium (15%) speed (Table 10). Other behaviors noted were milling (13%), breaching (4%), resting (4%), diving (2%), or tail-slapping (2%).

From 16 through 20 October, only 2 whales were observed. One was swimming and the other was tail-slapping (Table 9).

Table 7
Semimonthly Summary of Bowhead Whales Observed,
by Water Depth at Sighting Location (Fall 1990)

Water Depth	1-15 Sep No. (%)	16-30 Sep No. (%)	1-15 Oct No. (%)	16-20 Oct No. (%)	Total No. (%)
Shallow (0-50 m)	94 (91)	289 (95)	61 (90)	2 (100)	446 (93)
Transitional (51-200 m)	9 (9)	16 (5)	7 (10)	0	32 (7)
Deep (>200 m)	0	0	0	0	0
TOTAL	103 (100)	305 (100)	68 (100)	2 (100)	478 (100)

Table 8
Semimonthly Summary of Bowhead Whales Observed,
by Percent Ice Cover Present at Sighting Location (Fall 1990)

% Ice Cover	1-15 Sep No. (%)	16-30 Sep No. (%)	1-15 Oct No. (%)	16-20 Oct No. (%)	Total No. (%)
0	103 (100)	305 (100)	68 (100)	2 (100)	478 (100)
1-5	0	0	0	0	0
6-10	0	0	0	0	0
11-20	0	0	0	0	0
21-30	0	0	0	0	0
31-40	0	0	0	0	0
41-50	0	0	0	0	0
51-60	0	0	0	0	0
61-70	0	0	0	0	0
71-80	0	0	0	0	0
81-90	0	0	0	0	0
91-99	0	0	0	0	0
TOTAL	103 (100)	305 (100)	68 (100)	2 (100)	478 (100)

Table 9
Semimonthly Summary of Bowhead Whales Observed, by Behavioral Category (Fall 1990)

Behavior	1-15 Sep No.	(%)	16-30 Sep No.	(%)	1-15 Oct No.	(%)	16-20 Oct No.	(%)	Total No.	(%)
Breaching	0		2	(1)	3	(4)	0		5	(1)
Diving	4	(4)	8	(3)	1	(2)	0		13	(3)
Milling	9	(9)	16	(5)	9	(13)	0		34	(7)
Resting	6	(6)	18	(6)	3	(4)	0		27	(6)
Tail-Slapping	2	(2)	0		1	(2)	1	(50)	4	(1)
Swimming	76	(73)	257	(84)	51	(75)	1	(50)	385	(80)
(not noted)	6	(6)	4	(1)	0		0		10	(2)
TOTAL	103	(100)	305	(100)	68	(100)	2	(100)	478	(100)

Table 10
Semimonthly Summary of Bowhead Whales Observed, by Swimming Speed (Fall 1990)

Swim Speed	1-15 Sep No.	(%)	16-30 Sep No.	(%)	1-15 Oct No.	(%)	16-20 Oct No.	(%)	Total No.	(%)
Still (0 km/hr)	7	(7)	28	(9)	12	(18)	1	(50)	48	(10)
Slow (<2 km/hr)	32	(31)	69	(23)	42	(61)	0		143	(30)
Medium (2-4 km/hr)	43	(42)	158	(52)	10	(15)	1	(50)	212	(44)
Fast (>4 km/hr)	3	(3)	19	(6)	0		0		22	(5)
(not noted)	18	(17)	31	(10)	4	(6)	0		53	(11)
TOTAL	103	(100)	305	(100)	68	(100)	2	(100)	478	(100)

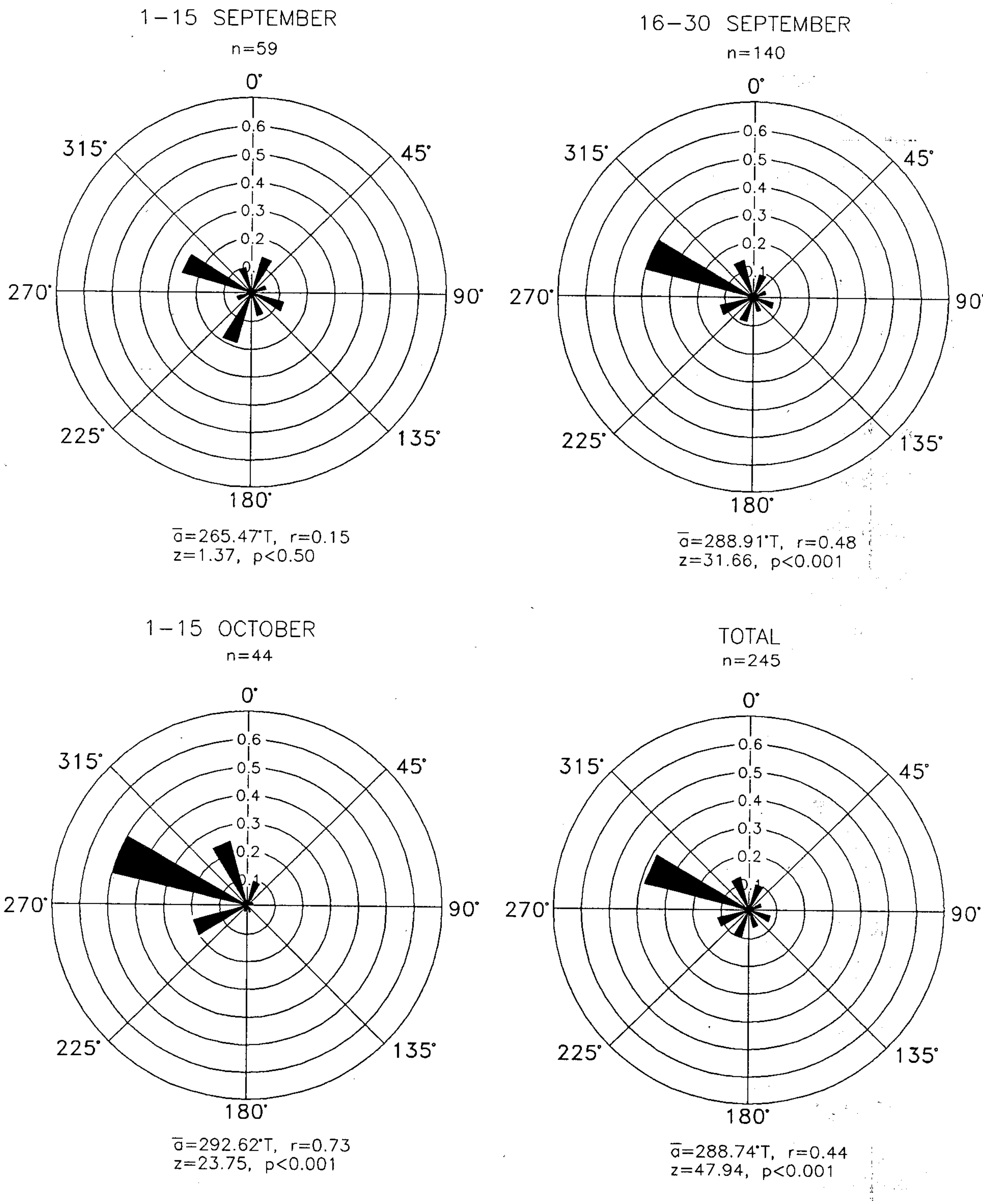

Figure 22. Semimonthly Summary of Swim Directions for Bowhead Whales (Fall 1990)

D. Other Marine Mammal Observations

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

2. Belukha Whale (*Delphinapterus leucas*): Twelve sightings for a total of 38 belukha whales were made east of 152° W. longitude, approximately 50 statute miles from shore (Fig. 23). Pod sizes ranged from 1 to 13 whales (Table 4).

All sightings of belukhas in September occurred on 14 and 16 September, when 1 sighting of 13 whales and 2 sightings for a total of 3 whales were made, respectively (Table 4). The relative abundance of belukha whales was 0.41 WPUE during the first half of September and 0.13 WPUE during the last half of September.

All sightings of belukhas in October occurred from 16 through 18 October, when 9 sightings for a total of 22 whales were made (Table 4). The relative abundance of belukha whales was 0.00 WPUE during the first half of October and 1.65 WPUE during the second half of October.

3. Ringed Seal (*Phoca hispida*): Thirty-three incidental sightings for a total of 133 ringed seals were made east of 151° W. longitude, within 40 statute miles of shore (Fig. 24). All of these were observed from 9 through 22 September (Table 4).

4. Bearded Seal (*Erignathus barbatus*): Eighteen incidental sightings for a total of 40 bearded seals were made east of 148° W. longitude, within 30 statute miles of shore (Fig. 25). All of these were observed from 10 through 22 September.

5. Unidentified Pinnipeds: Forty-nine incidental sightings for a total of 232 unidentified pinnipeds were made east of 152° W. longitude, within 50 statute miles of shore (Fig. 26). Of these, 38 sightings for a total of 219 pinnipeds were made during September (Table 4).

6. Polar Bear (*Ursus maritimus*): No polar bears were sighted during the study. This may have been due to generally ice-free conditions prevalent in the study area during 1990.

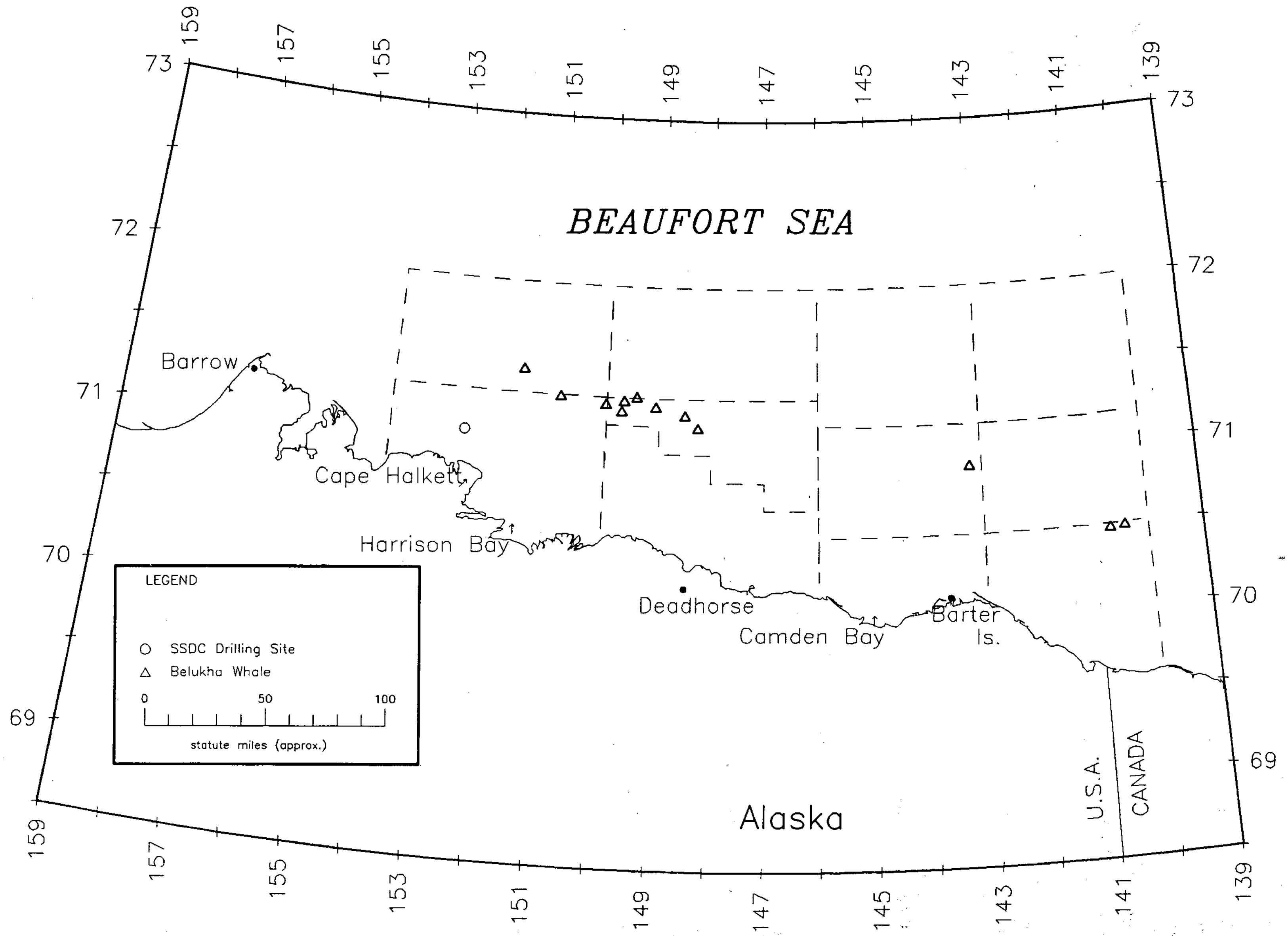

Figure 23. Map of Belukha Whale Sightings, 1 September—20 October 1990

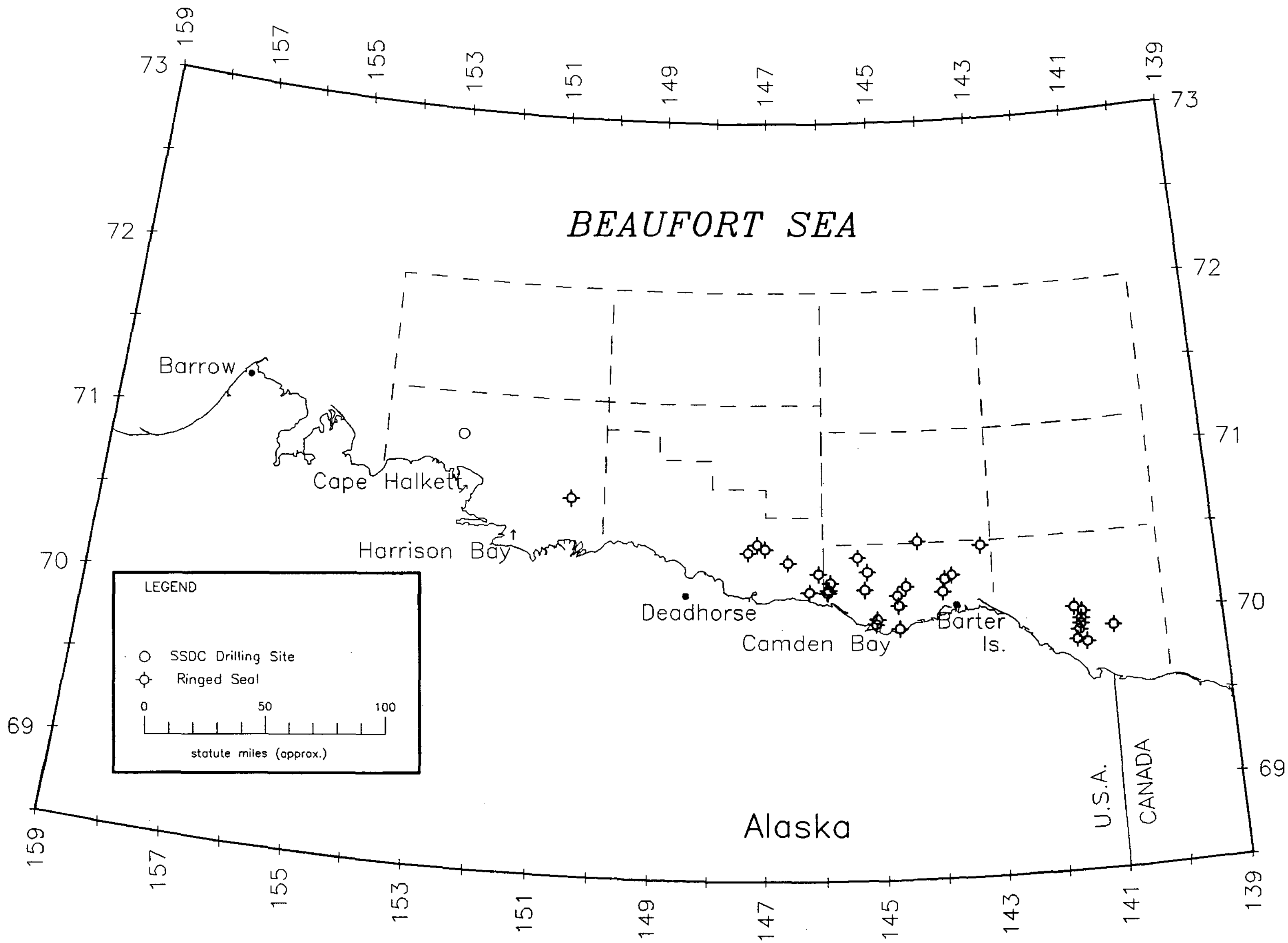

Figure 24. Map of Ringed Seal Sightings, 1 September–20 October 1990

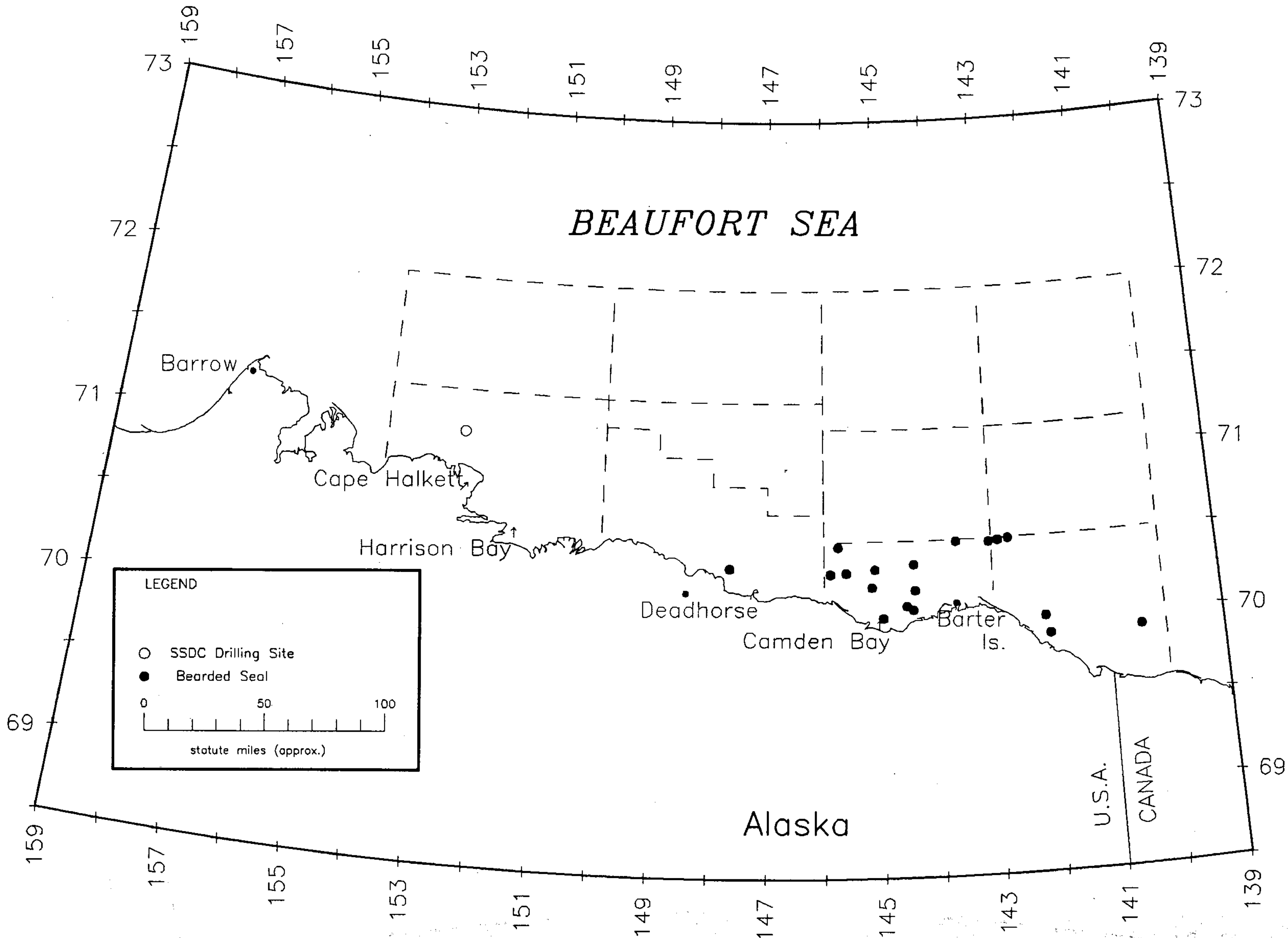

Figure 25. Map of Bearded Seal Sightings, 1 September–20 October 1990

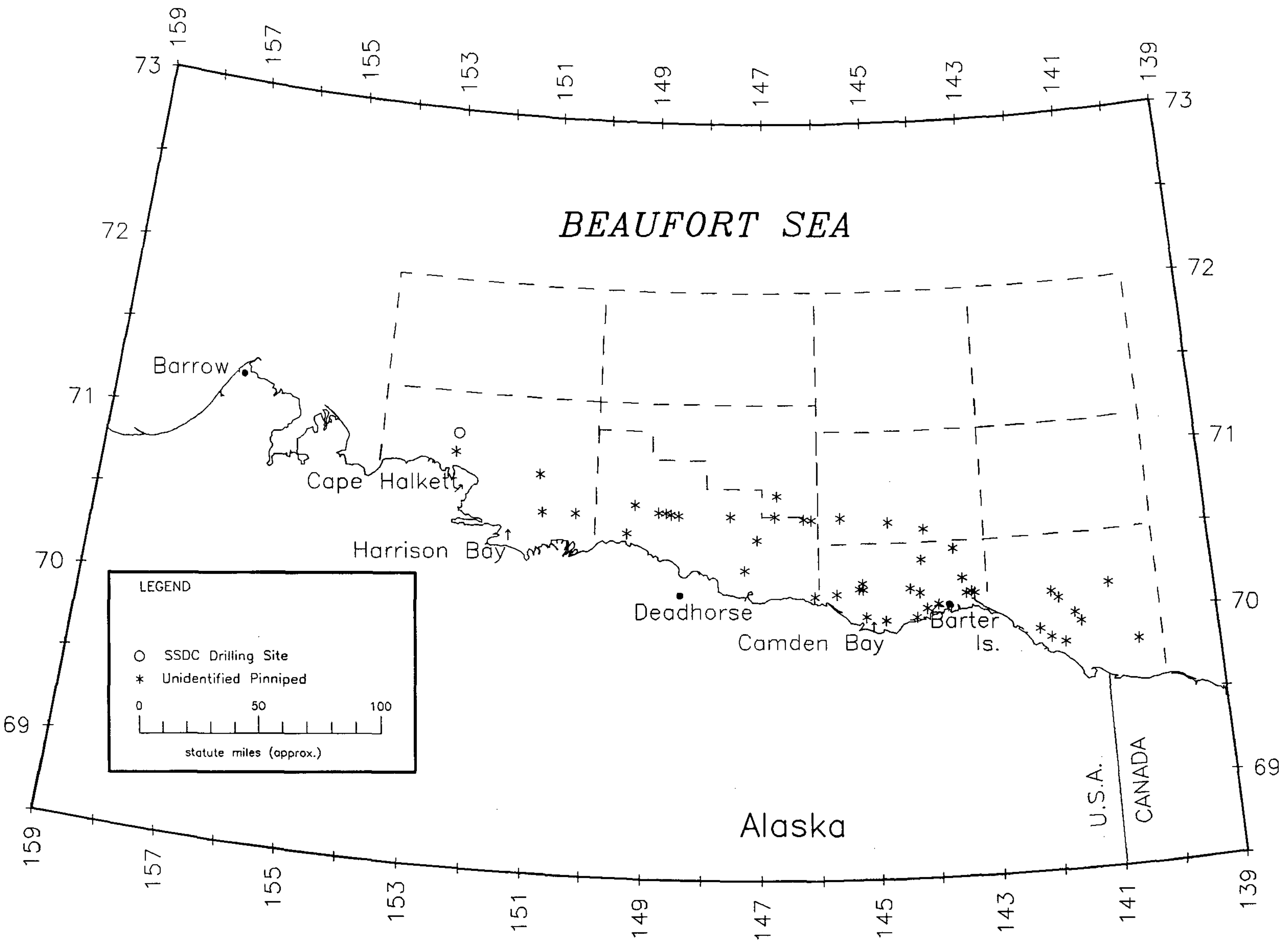

Figure 26. Map of Unidentified–Pinniped Sightings, 1 September–20 October 1990

IV. DISCUSSION

A. General Comparisons with Previous Surveys (1979-1989)

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

The general ice coverage in 1990 during the navigation season was the seventh mildest in the Arctic Ocean for the years 1953 through 1990 and the mildest since the MMS surveys began in 1979 (USDOD, Navy, Naval Polar Oceanography Center, 1991).

The total number of flight hours during 1990 (87.82 hr) represented the least survey effort for September and October (combined) since the surveys began in 1979 (Table 15). This was due primarily to the necessary shared use of the survey aircraft between Beaufort Sea and Chukchi Sea projects and participation in an aerial search for a missing FWS aircraft.

The number of bowhead whale pods (326) and total number of bowhead whales (478) observed for the combined months of September and October 1990 in the study area (Table 4) were higher than for any previous year since the survey began in 1979 (Ljungblad et al., 1987; Treacy, 1988, 1989, 1990). A record number of bowhead whales (401) was observed in Survey Blocks 1 through 11 for the month of September even though survey effort (54.85 hr) was relatively low (Table 15). These high numbers may have been related to environmental factors such as the extreme mildness of the general ice coverage in 1990 (USDOD, Navy, Naval Polar Oceanography Center, 1991) (see Sec. IV. D.).

Similarly, values for relative abundance in many of the component survey blocks and adjacent areas were higher during 1990, suggesting an increase in the number of whales in these areas over previous years. Values for relative abundance of bowhead whales during September 1990 in Block 4 (7.61 WPUE), Block 5 (18.51 WPUE), and Block 6 (3.35 WPUE) were higher than values for 1979 through 1989 (Table 11) and were at least 2 SD, 3 SD, and 4 SD higher, respectively, than the previous mean for each block. The relative abundance during September for Canadian areas east of 140° W. longitude (63.64 WPUE) was the highest value noted for any survey block or adjacent area since the survey began in 1979 (Table 11) and was at least 3 SD higher than the previous mean for that area. This extreme value was obtained in only 0.11 hr and presumably would have been much lower if more flight effort had been logged in that area. Values for relative abundance of bowhead whales during October 1990 in Block 1 (3.00 WPUE) and Block 6 (2.86 WPUE) were higher than values for 1979 through 1989 (Table 11) and were at least 3 SD and 35 SD higher, respectively, than the previous mean for each block. Values for relative abundance in all other survey blocks during September or October 1990 were within the range of values observed for the years 1979 through 1989 (Table 11).

The percentage of bowhead whales engaged in "swimming" behavior in 1990 (80%) was the second highest for the Beaufort Sea surveys (highest = 89% in 1988).

The ratio of bowhead calves for 1990 (0.01) was relatively low, although identical to the 1981, 1984, 1987, and 1989 ratios.

B. Median Water Depth at Bowhead Sightings (1982-1990)

The median water depth at 88 sightings of bowhead whales made on line transects in Regions I, II, and III (combined) during September and October 1990 was 38 m (Table 12). This was well within the range of median water depths for previous years (previous median values ranged from 18-347 m) and was almost identical to the cumulative median depth (37 m) at all sightings (n = 308) made on line transect during the same timeframe.

IV

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

	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
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

* 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

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
(Continued)

Year	Region	SI[1]	Median	CI[2]	Mean	SD[3]	Range
Cumulative	I	65	27	18-40	102.8	300.18	9-2,323
(1982-1990)	II	96	33	27-37	84.2	273.52	7-2,021
	III	147	42	38-48	104.6	382.18	11-1,902
	All 3	308	37	37-38	97.8	284.35	7-2,323

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

To determine whether any of the differences between the median water depth for 1990 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 the value for 1990 and the values for years 1982, 1983, 1986, and 1989 (Table 13). Analysis by region (Table 13) showed that this level of difference ($p < 0.005$) was found between 1990 and 1983 in Region II (between 146° W. and 150° W. longitudes) and Region III (between 141° W. and 146° W. longitudes).

Differences with a high degree of statistical significance ($p < 0.005$) were also noted (all 3 regions combined) between the median for 1984 and the medians for 1982, 1983, 1986, and 1989 (Table 13).

This probability of difference due to chance ($p < 0.005$) was also noted between the 1983 median value (all three regions combined) and medians for all other years tested using this nonparametric test. This was due to the fact that the 1983 median of 347 m (Table 12) was higher by far than the median for other years. This level of significance ($p < 0.005$) between 1983 and other years also occurred in Regions II and III (between 141° W. and 150° W. longitudes).

This level of significance ($p < 0.005$) was noted between the 1989 median value (all 3 regions combined) and the medians 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 occurred 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 migration "axis," were considered more robust for demonstrating significant differences between years. Comparison of the means using ANOVA and the Tukey test (Zar, 1984) showed that 1983 was unique among other years in the spatial distribution of the fall bowhead migration. Differences between mean values for 1983 and some of the other years (including 1990) 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. A comparison of mean values (Table 12) showed that the mean water depth at random sightings (all three regions combined) during 1990 (38.8 m) was less than the mean for each of the previous years, except for 1989 (22.7 m), and well below the cumulative mean for all years combined (97.8 m).

The reasons for the offshore (deep-water) migratory route of 1983 and the comparatively shallower route followed in 1990 (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, 1991), the bowhead migration was observed in water almost an order of magnitude deeper than for other years (Table 12). During 1990, the mildest ice year since the beginning of the surveys in 1979 (USDOD, Navy, Naval Polar Oceanography Center, 1991), the bowhead migration was observed at an average median and a comparatively shallow 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 13
Interyear Correlation (nonparametric) of the Median Water Depths at Random Bowhead Whale Sightings (September-October), Using the Mann-Whitney U Test
(Page 1 of 4)

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

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

REGION II	1982	1983	1984	1985	1986	1987	1988	1989
1983	$U = 150.0$ $p < 0.001$							
1984	$U = 193.0$ $p < 0.10$	$U' = 42.0$ $p \le 0.01$						
1985	$U' = 136.0$ $p > 0.20$	$U' = 45.0$ $p \le 0.001$	$U' = 62.0$ $p < 0.10$					
1986	$U' = 254.0$ $p < 0.05$	$U' = 58.0$ $p \le 0.002$	$U' = 86.5$ $p < 0.05$	$U' = 76.5$ $p < 0.20$				
1987	$U' = 155.0$ $p > 0.20$	$U' = 45.0$ $p \le 0.001$	$U' = 63.5$ $p < 0.10$	$U' = 53.0$ $p > 0.20$	$U = 70.5$ $p > 0.20$			
1988	$U = 103.0$ $p \le 0.02$	$U' = 19.0$ $p \le 0.05$	$U = 20.5$ $p > 0.20$	$U = 29.0$ $p < 0.20$	$U = 41.0$ $p \le 0.05$	$U = 33.0$ $p \le 0.02$		
1989	$U = 29.0$ $p < 0.20$	$U' = 5.0$ *	$U = 5.5$ $p > 0.20$	$U = 9.0$ $p \le 0.20$	$U = 11.0$ $p > 0.20$	$U = 9.0$ $p \le 0.20$	$U = 2.0$ *	
1990	$U = 280.0$ $p > 0.20$	$U' = 85.0$ $p < 0.001$	$U' = 101.5$ $p < 0.20$	$U = 108.5$ $p < 0.10$	$U = 146.0$ $p < 0.10$	$U = 114.0$ $p \le 0.05$	$U' = 54.0$ $p < 0.10$	$U' = 17.0$ $p \le 0.20$

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

REGION III	1982	1983	1984	1985	1986	1987	1988	1989
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 ≤ 0.20	U'= 195.5 p < 0.001	U'= 216.0 p < 0.05	U'= 22.0 p ≤ 0.10				
1987	U'= 54.5 p > 0.20	U'= 173.0 p < 0.001	U'= 159.0 p > 0.20	U'= 19.0 p ≤ 0.20	U = 284.0 p < 0.10			
1988	U'= 13.0 p > 0.20	U'= 43.0 p ≤ 0.005	U'= 38.0 p > 0.20	U'= 4.0 *	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 ≤ 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 = 1.48 p < 0.20

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

ALL THREE REGIONS (COMBINED)

	1982	1983	1984	1985	1986	1987	1988	1989
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

* Insufficient sample size.

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

REGION I
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 = 13.367, p << 0.001

Tukey Test:

(1987)	(1985)	(1982)	(1990)	(1984)	(1989)	(1988)	(1986)	(1983)
27.3	30.4	30.6	33.6	43.7	44.0*	44.8	60.8	945.0

(p < 0.005)

REGION III
ANOVA F = 26.476, p << 0.001

Tukey Test:

(1986)	(1990)	(1982)	(1989)	(1987)	(1985)	(1984)	(1988)	(1983)
34.1	40.5	43.4	49.3	49.9	64.0*	90.4	90.4	969.8

(p < 0.001)

ALL THREE REGIONS (COMBINED)
ANOVA F = 26.338, p << 0.001

Tukey Test:

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

(p << 0.001)

* One datum

D. Potential Effect of General Ice Cover on WPUE

The years 1980, 1983, and 1988 were categorized as having "heavy" ice cover during the navigation season. These three years are ranked as having the severest seasonal ice for the years 1979 through 1989 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, 1991).

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 1989 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, 1991).

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 1990 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, 1991).

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 (WPUE = 0.30), a middle-range value for moderate ice years (WPUE = 0.97), and a relatively high value for light ice years (WPUE = 2.05). The relative abundance of bowheads for 1990 (WPUE = 5.43)--the highest value for a single fall season--was considered representative of the higher values found during light ice years, when bowheads were easier to spot. 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 ($\bar{x}$ = 0.39, SD = 0.11, n = 3) 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 sightability 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 1990, MMS issued one geological permit, four on-ice geophysical permits, and eight vessel (airgun) geophysical permits to industry for exploration in the Beaufort Sea. Of the geophysical permits, on-ice seismic exploration was permitted from the first part of January through mid-May, and airgun vessels were permitted to operate from mid-July through the end of October in the central portion of the Alaskan Beaufort Sea.

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.

Prior to the Fall-1990 survey, ARCO Alaska Inc. operated a Single Steel Drilling Caisson (SSDC) north of Cape Halkett at the Fireweed drilling site (71° 05.2′N. latitude, 152° 36.1′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

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 (after Ljungblad et al. [1987] and Treacy [1988, 1989, 1990])

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
Ice Coverage									
Heavy Ice Years[1] (Σ)	235.21	105	0.45	132.09	37	0.28	367.30	142	0.30
Moderate Ice Years[2] (Σ)	132.30	120	0.91	92.85	98	1.06	225.15	218	0.97
Light Ice Years(Σ)	493.44	1,234	2.50	312.44	415	1.33	805.88	1,649	2.05

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

(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 Fireweed site on 28 August 1990, drilling was begun on 19 October, and the well was plugged on 25 December 1990 and left in place over the winter. No other exploratory drilling occurred in the study area during the survey.

Bowhead whales observed in the general study area, including those in the vicinity of the SSDC, are shown for each bimonthly period of the Fall-1990 survey in Figures 16 through 20. The closest sighting of bowhead whales was noted on 11 October 1990 (Appendix B: Flight 23) at a distance of 3.6 km southeast of the nonoperational drilling structure. This group of three whales was exhibiting milling behavior when observed.

Daily summaries of field information from the present and other arctic surveys 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, the 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 Fireweed drilling site. Drilling operations at Fireweed began after the Fall-1990 bowhead migration. Daily summaries of survey information provided by the present study indicated that the Fall-1990 bowhead migration began on or about 2 September. The NMFS determined that the official ending date of the Fall-1990 bowhead whale migration across the Alaskan Beaufort Sea occurred on 19 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.

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APPENDIX A

BOWHEAD WHALE DENSITIES

BOWHEAD WHALE DENSITIES

This appendix presents estimated bowhead whale densities in the Beaufort Sea for the period 1 September through 20 October 1990. 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-1990 and previous MMS-funded arctic whale surveys, are incorporated by reference (Ljungblad et al., 1987: Appendix B).

RESULTS

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

During the first half of September, over 10 percent of the area was surveyed for Blocks 1 and 4. Three bowheads were observed in Block 1 within 1 km of the randomly generated transect line, for an estimated density of 0.21 whales per 100 km^2. Three bowheads were observed in Block 4, for an estimated density of 0.20. In Block 5, where just under 10 percent (9.97%) of the area was surveyed, 4 bowheads were observed for an estimated density of 0.42. Only one bowhead whale was observed within 1 km of the transect line in other blocks during this period.

During the second half of September, over 10 percent of the area was surveyed for Block 4. Twenty-two bowheads were observed in Block 4 within 1 km of the transect line, for an estimated density of 1.41 whales per 100 km^2. The highest density during 1990 was during this period in Block 5, where 24 whales were observed and only 7.85% of the block was surveyed, for an estimated density of 3.23. Seven 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, 3, and 4. Three bowheads were observed in Block 1 within 1 km of the transect line, for an estimated density of 0.29 whales per 100 km^2. One bowhead was observed in Block 3, for an estimated density of 0.06. Four bowheads were observed in Block 4, for an estimated density of 0.58. No bowhead whales were observed within 1 km of the transect line in other blocks during this period.

From 16 through 20 October, over 10 percent of the area was surveyed for Blocks 1 and 3. No bowheads were observed in either block within 1 km of the transect line, for estimated densities of zero whales per 100 km^2. No bowhead whales were observed within 1 km of the transect line in other blocks during this period.

Table A-1
Semimonthly Estimates of Bowhead Whale Densities, by Survey Block (Fall 1990)
(strip width = 2 km)

Block No. (by Semi-monthly Period)	Block Area (km^2)	Transect Distance (km)	Percent of Area Surveyed	Transect Time (hr)	Percent of Total Time	No. of Transects Flown	No. of Whales Observed	Density (Whales/ 100 km^2)
1-15 Sep								
1	10,222	701	13.72	2.91	27.74	16	3	0.21
2	6,672	136	4.09	0.57	5.39	6	0	0.00
3	11,475	178	3.11	0.73	6.94	2	0	0.00
4	5,714	747	26.14	3.14	29.92	20	3	0.20
5	9,481	473	9.97	1.90	18.12	14	4	0.42
6	8,109	308	7.59	1.21	11.55	11	1	0.16
7	8,109	3	0.08	0.01	0.13	3	0	0.00
9	9,753	3	0.07	0.01	0.12	3	0	0.00
10	10,358	1	0.02	0.00	0.05	1	0	0.00
11	10,358	1	0.02	0.00	0.04	2	0	0.00
16-30 Sep								
1	10,222	433	8.47	1.74	22.79	13	4	0.46
2	6,672	69	2.07	0.26	3.36	5	0	0.00
3	11,475	102	1.78	0.41	5.30	3	3	1.47
4	5,714	783	27.39	3.33	43.56	19	22	1.41
5	9,481	372	7.85	1.66	21.76	12	24	3.23
6	8,109	63	1.55	0.23	3.06	9	0	0.00
7	8,109	1	0.01	0.00	0.03	1	0	0.00
11	10,358	2	0.03	0.01	0.14	1	0	0.00
1-15 Oct								
1	10,222	523	10.24	2.07	19.09	12	3	0.29
2	6,672	7	0.21	0.03	0.29	4	0	0.00
3	11,475	824	14.36	3.28	30.24	16	1	0.06
4	5,714	343	12.01	1.37	12.66	8	4	0.58
6	8,109	76	1.87	0.29	2.72	6	0	0.00
11	10,358	225	4.35	0.91	8.40	7	0	0.00
16-20 Oct								
1	10,222	576	11.27	2.31	30.49	10	0	0.00
2	6,672	276	8.29	1.05	13.89	9	0	0.00
3	11,475	729	12.71	3.08	40.68	12	0	0.00
4	5,714	86	3.02	0.35	4.63	2	0	0.00
10	10,358	10	0.18	0.04	0.56	4	0	0.00
11	10,358	183	3.53	0.73	9.64	9	0	0.00

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APPENDIX B

APPENDIX B

DAILY FLIGHT SUMMARIES

DAILY FLIGHT SUMMARIES

This appendix consists of Flight Tracks 1 through 30, depicting aerial surveys flown over the study area from 2 September through 19 October 1990 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, September-October 1990
(Page 1 of 9)

Flight No.	Date	Total Whales	No. Calves	Latitude (North)	Longitude (West)	Sighting Cue	Behavior	Heading	Ice (%)	Sea State
1	2 Sep	1	0	70°11.7'	143°26.4'	body	swim	[1]	0	3
1	2 Sep	1	0	70°04.9'	142°43.9'	splash	swim	300	0	4
1	2 Sep	1	0	69°57.2'	141°35.3'	blow	swim	340	0	4
1	2 Sep	1	0	69°52.4'	141°52.7'	body	dive	60	0	3
2	3 Sep	4	1	70°14.4'	145°01.5'	blow	swim	150	0	3
2	3 Sep	1	0	70°12.6'	145°02.5'	body	swim	310	0	2
2	3 Sep	1	0	70°12.9'	144°10.3'	splash	swim	300	0	3
2	3 Sep	1	0	70°22.4'	145°43.4'	body	swim	145	0	3
2	3 Sep	1	0	70°30.2'	146°19.1'	body	swim	120	0	3
3	7 Sep	1	0	70°28.7'	148°04.1'	body	dive	360	0	5
5	9 Sep	1	0	70°14.9'	145°44.0'	body	swim	270	0	3
5	9 Sep	1	0	70°16.6'	143°25.1'	body	swim	60	0	3
6	10 Sep	1	0	70°07.1'	141°47.7'	body	swim	240	0	3
6	10 Sep	1	0	70°08.5'	141°50.1'	body	swim	210	0	3
6	10 Sep	1	0	70°06.4'	141°42.7'	blow	swim	285	0	2
6	10 Sep	2	0	70°05.8'	141°45.0'	body	swim	300	0	2
6	10 Sep[2]	1	0	70°05.9'	141°45.4'	body	swim	180	0	2
6	10 Sep	1	0	70°04.7'	141°36.1'	body	rest	150	0	2
6	10 Sep	1	0	70°03.9'	141°34.1'	body	swim	240	0	2
6	10 Sep	1	0	70°01.0'	141°27.2'	slick	swim	360	0	2
6	10 Sep	2	1	70°01.6'	141°28.1'	body	mill	[1]	0	2
6	10 Sep	1	0	70°01.0'	141°32.2'	body	swim	90	0	2
6	10 Sep	3	0	70°00.5'	141°23.3'	body	swim	150	0	2
6	10 Sep	1	0	69°58.5'	141°22.3'	body	swim	330	0	2
6	10 Sep	1	0	69°59.2'	141°22.7'	body	dive	150	0	2
6	10 Sep	1	0	69°58.4'	141°22.2'	blow	swim	270	0	2
6	10 Sep	1	0	69°58.3'	141°21.5'	body	swim	60	0	2
6	10 Sep[2]	1	0	69°59.5'	141°19.8'	body	swim	170	0	2
6	10 Sep	2	0	69°56.8'	140°25.7'	body	swim	150	0	2
6	10 Sep	1	0	69°57.8'	140°25.4'	body	swim	180	0	2
6	10 Sep[2]	2	0	70°02.2'	140°26.1'	body	swim	[1]	0	3
6	10 Sep[2]	1	0	70°03.4'	140°25.0'	blow	swim	[1]	0	3
6	10 Sep	1	0	70°19.6'	140°23.4'	body	swim	100	0	4
6	10 Sep	1	0	70°18.9'	140°18.2'	body	swim	270	0	4
6	10 Sep	1	0	70°31.7'	140°45.4'	blow	[1]	[1]	0	4
6	10 Sep	1	0	70°05.9'	140°51.8'	slick	[1]	[1]	0	2
6	10 Sep	2	0	70°03.1'	140°53.4'	blow	mill	[1]	0	2
6	10 Sep	1	0	70°02.0'	140°49.8'	body	swim	30	0	2
6	10 Sep	4	0	70°03.6'	140°46.6'	body	swim	330	0	2

Table B-1
Selected Sighting Data for Bowhead Whales Observed, September-October 1990
(Page 2 of 9)

Flight No.	Date	Total Whales	No. Calves	Latitude (North)	Longitude (West)	Sighting Cue	Behavior	Heading	Ice (%)	Sea State
6	10 Sep	4	0	70°02.2'	140°45.1'	blow	swim	120	0	2
6	10 Sep	1	0	69°59.7'	140°37.3'	body	rest	180	0	2
6	10 Sep	3	0	70°01.1'	140°41.6'	body	mill	[1]	0	2
6	10 Sep	1	0	70°02.1'	140°44.5'	body	rest	[1]	0	2
6	10 Sep	1	0	69°58.9'	140°47.4'	body	swim	150	0	2
6	10 Sep	1	0	69°57.1'	140°47.4'	body	rest	[1]	0	2
6	10 Sep	2	0	69°56.9'	140°48.1'	body	swim	240	0	2
6	10 Sep	1	0	69°56.3'	140°54.4'	body	swim	240	0	2
6	10 Sep	1	0	70°18.3'	141°16.0'	blow	swim	200	0	2
6	10 Sep	1	0	70°20.5'	141°15.4'	body	swim	150	0	2
6	10 Sep	1	0	70°19.8'	141°15.7'	body	rest	[1]	0	2
6	10 Sep	2	0	70°19.1'	141°18.1'	body	mill	[1]	0	2
6	10 Sep	1	0	70°22.7'	146°27.5'	blow	dive	140	0	2
8	12 Sep	2	0	70°18.5'	146°32.6'	body	swim	210	0	3
8	12 Sep	1	0	70°19.8'	146°30.0'	body	swim	240	0	3
8	12 Sep	1	0	70°16.8'	143°19.8'	body	swim	280	0	3
8	12 Sep	1	0	70°17.9'	143°23.3'	splash	swim	160	0	3
8	12 Sep	1	0	70°31.4'	143°24.0'	body	rest	310	0	4
8	12 Sep	1	0	70°31.1'	144°49.4'	body	swim	180	0	2
8	12 Sep	1	0	70°27.7'	144°50.1'	body	swim	100	0	2
8	12 Sep	1	0	70°34.0'	146°21.8'	body	swim	140	0	3
8	12 Sep	1	0	70°38.2'	146°21.1'	body	swim	150	0	4
9	13 Sep	1	0	70°22.1'	146°57.9'	body	swim	240	0	5
9	13 Sep	2	0	70°39.3'	145°14.2'	blow	swim	270	0	7
9	13 Sep	2	0	70°09.8'	144°15.0'	blow	swim	30	0	5
9	13 Sep	1	0	70°09.9'	144°15.6'	body	swim	270	0	5
9	13 Sep	1	0	70°09.4'	144°21.9'	body	swim	150	0	4
9	13 Sep	1	0	70°09.9'	144°20.5'	body	swim	270	0	4
9	13 Sep	4	0	70°10.3'	144°20.6'	body	swim	240	0	4
9	13 Sep	2	0	70°10.7'	144°21.5'	blow	swim	360	0	4
9	13 Sep	1	0	70°10.7'	144°21.5'	[1]	swim	330	0	2
9	13 Sep	2	0	70°07.9'	144°48.3'	[1]	[1]	310	0	2
9	13 Sep	2	0	70°07.9'	144°48.3'	[1]	[1]	360	0	2
9	13 Sep	2	0	70°08.8'	145°01.3'	body	slap	260	0	4
9	13 Sep	2	0	70°10.1'	145°01.9'	body	swim	100	0	4
9	13 Sep	2	0	70°09.5'	145°02.2'	body	swim	30	0	4
9	13 Sep	1	0	70°08.9'	145°03.7'	body	swim	270	0	6
11	16 Sep	2	1	70°22.7'	143°09.2'	body	rest	40	0	2
11	16 Sep	3	0	70°09.8'	142°12.5'	body	swim	25	0	2

Table B-1
Selected Sighting Data for Bowhead Whales Observed, September-October 1990
(Page 3 of 9)

Flight No.	Date	Total Whales	No. Calves	Latitude (North)	Longitude (West)	Sighting Cue	Behavior	Heading	Ice (%)	Sea State
11	16 Sep	1	0	70°08.2'	142°10.6'	body	swim	270	0	2
11	16 Sep	1	0	70°10.0'	142°11.4'	body	swim	300	0	[3]
11	16 Sep	1	0	70°09.7'	142°09.4'	body	swim	[1]	0	2
11	16 Sep	1	0	70°08.3'	142°09.9'	body	swim	[1]	0	2
11	16 Sep	2	0	70°08.3'	142°12.2'	body	swim	300	0	2
11	16 Sep	4	0	70°08.8'	142°15.0'	body	swim	220	0	2
11	16 Sep	1	0	70°08.4'	142°12.0'	body	swim	260	0	2
11	16 Sep	4	0	70°08.3'	142°11.8'	body	swim	260	0	2
11	16 Sep	1	0	70°06.4'	142°05.8'	body	swim	335	0	2
11	16 Sep	3	0	70°04.5'	141°56.2'	body	swim	270	0	2
11	16 Sep	2	0	70°02.7'	141°52.0'	body	swim	280	0	2
11	16 Sep	2	0	70°01.8'	141°44.5'	body	swim	250	0	2
11	16 Sep	1	0	69°42.4'	140°15.2'	body	swim	300	0	2
11	16 Sep	1	0	69°41.4'	140°04.3'	body	dive	270	0	3
11	16 Sep	1	0	69°50.7'	140°07.1'	body	swim	240	0	3
11	16 Sep	2	0	69°50.6'	140°00.1'	blow	swim	240	0	3
11	16 Sep	1	0	69°49.5'	139°54.0'	[1]	swim	250	0	3
11	16 Sep	1	0	69°50.0'	139°53.5'	body	swim	[1]	0	3
11	16 Sep	1	0	69°50.2'	139°50.5'	body	swim	250	0	3
11	16 Sep	1	0	69°48.7'	139°42.8'	blow	swim	240	0	3
11	16 Sep	2	0	69°48.4'	139°47.6'	body	swim	240	0	3
11	16 Sep	1	0	69°50.1'	139°59.0'	body	swim	220	0	3
11	16 Sep	2	0	70°01.4'	140°43.1'	body	swim	[1]	0	4
11	16 Sep	1	0	69°59.0'	140°43.2'	body	swim	240	0	4
11	16 Sep	1	0	69°57.5'	140°43.8'	body	swim	240	0	4
11	16 Sep	3	0	69°56.4'	140°48.4'	body	swim	330	0	4
11	16 Sep	1	0	69°53.7'	140°41.5'	body	swim	240	0	[3]
11	16 Sep	1	0	69°52.9'	140°41.2'	body	swim	210	0	[3]
11	16 Sep	3	0	69°52.3'	140°40.7'	body	mill	[1]	0	[3]
11	16 Sep	1	0	69°46.7'	140°37.5'	body	swim	350	0	2
11	16 Sep	2	0	70°06.4'	141°25.2'	body	swim	270	0	2
11	16 Sep	4	0	70°07.3'	141°25.4'	body	swim	300	0	2
11	16 Sep	1	0	70°07.8'	141°25.7'	body	swim	270	0	2
11	16 Sep	3	0	70°08.5'	141°26.8'	body	mill	[1]	0	2
11	16 Sep	2	0	70°08.7'	141°31.6'	body	swim	190	0	2
11	16 Sep	2	0	70°07.5'	141°30.9'	splash	swim	300	0	2
11	16 Sep	1	0	70°18.8'	141°50.8'	body	swim	270	0	3
11	16 Sep	1	0	70°17.5'	141°47.7'	body	swim	300	0	[3]
11	16 Sep	2	0	70°18.9'	141°50.9'	blow	swim	[1]	0	3

Table B-1
Selected Sighting Data for Bowhead Whales Observed, September-October 1990
(Page 4 of 9)

Flight No.	Date	Total Whales	No. Calves	Latitude (North)	Longitude (West)	Sighting Cue	Behavior	Heading	Ice (%)	Sea State
11	16 Sep	1	0	70°14.5'	141°48.5'	body	rest	80	0	3
11	16 Sep	1	0	70°13.3'	141°47.7'	body	swim	260	0	3
11	16 Sep	4	0	70°12.8'	141°47.1'	body	swim	240	0	3
11	16 Sep	3	0	70°10.6'	141°46.4'	body	swim	250	0	3
11	16 Sep	1	0	70°09.5'	141°42.3'	body	swim	270	0	2
11	16 Sep	1	0	70°05.0'	141°44.2'	body	rest	360	0	2
11	16 Sep	1	0	70°02.9'	141°43.3'	body	swim	325	0	2
11	16 Sep	1	0	69°59.1'	141°41.1'	body	swim	290	0	2
11	16 Sep	2	1	70°06.3'	142°06.1'	body	mill	[1]	0	2
11	16 Sep	1	0	70°08.0'	142°07.0'	body	swim	[1]	0	[3]
11	16 Sep	2	0	70°08.3'	142°07.4'	body	mill	[1]	0	[3]
11	16 Sep	1	0	70°07.2'	142°10.4'	body	rest	260	0	[3]
11	16 Sep	1	0	70°07.0'	142°06.9'	body	rest	[1]	0	[3]
11	16 Sep	1	0	70°08.0'	142°07.0'	body	swim	260	0	2
11	16 Sep	3	0	70°09.5'	142°08.6'	body	swim	250	0	2
11	16 Sep	1	0	70°11.4'	142°11.3'	body	swim	240	0	2
11	16 Sep	1	0	70°16.9'	142°14.3'	body	swim	180	0	2
11	16 Sep	7	0	70°17.1'	142°14.5'	body	swim	[1]	0	2
11	16 Sep	1	0	70°18.2'	142°15.2'	body	rest	[1]	0	2
11	16 Sep	1	0	70°18.5'	142°17.2'	body	swim	330	0	[3]
11	16 Sep	2	0	70°18.3'	142°19.5'	body	swim	[1]	0	[3]
11	16 Sep	1	0	70°17.9'	142°21.5'	body	rest	130	0	[3]
11	16 Sep	1	0	70°16.2'	142°19.9'	body	swim	270	0	2
11	16 Sep	1	0	70°16.9'	142°14.8'	body	swim	[1]	0	2
11	16 Sep	4	0	70°17.8'	142°14.8'	body	swim	230	0	2
11	16 Sep	1	0	70°19.1'	142°14.9'	body	swim	[1]	0	[3]
11	16 Sep	1	0	70°20.1'	142°15.3'	body	swim	[1]	0	[3]
11	16 Sep	2	0	70°21.7'	142°16.5'	body	swim	270	0	2
11	16 Sep	1	0	70°29.8'	142°22.7'	body	swim	180	0	2
11	16 Sep	4	0	70°26.3'	143°59.5'	slick	swim	230	0	2
12	22 Sep	1	0	70°21.7'	147°03.4'	body	swim	250	0	3
12	22 Sep	2	0	70°22.2'	147°05.6'	body	swim	[1]	0	3
12	22 Sep	1	0	70°35.0'	147°03.1'	blow	swim	230	0	3
12	22 Sep	1	0	70°35.5'	147°03.8'	body	swim	230	0	3
12	22 Sep	1	0	70°38.8'	147°07.2'	body	swim	[1]	0	3
12	22 Sep[2]	1	0	70°40.0'	147°06.8'	body	swim	[1]	0	3
12	22 Sep	2	0	70°30.8'	145°57.4'	blow	swim	40	0	3
12	22 Sep	1	0	70°28.4'	144°01.1'	body	dive	240	0	4
12	22 Sep	1	0	70°24.0'	143°49.1'	body	rest	260	0	5

Table B-1
Selected Sighting Data for Bowhead Whales Observed, September-October 1990
(Page 5 of 9)

Flight No.	Date	Total Whales	No. Calves	Latitude (North)	Longitude (West)	Sighting Cue	Behavior	Heading	Ice (%)	Sea State
12	22 Sep	1	0	70°23.2'	143°46.4'	body	swim	120	0	5
12	22 Sep	1	0	70°23.3'	143°41.2'	body	rest	190	0	5
12	22 Sep	1	0	70°21.8'	143°41.8'	blow	swim	280	0	5
12	22 Sep	2	0	70°18.3'	143°36.2'	body	swim	[1]	0	4
12	22 Sep	2	0	70°17.1'	143°35.7'	body	swim	20	0	4
12	22 Sep	1	0	70°18.1'	143°40.9'	body	swim	290	0	4
12	22 Sep	2	0	70°19.8'	143°41.7'	body	swim	250	0	4
12	22 Sep	1	0	70°20.6'	143°37.8'	blow	swim	60	0	5
12	22 Sep	1	0	70°17.7'	143°34.1'	body	swim	120	0	5
12	22 Sep	2	0	70°15.4'	143°19.6'	blow	swim	140	0	5
12	22 Sep	1	0	70°16.0'	143°18.1'	body	dive	200	0	5
12	22 Sep	1	0	70°17.0'	143°18.4'	body	swim	230	0	5
12	22 Sep	1	0	70°23.9'	143°41.6'	blow	swim	120	0	5
12	22 Sep	1	0	70°22.4'	143°42.4'	blow	swim	180	0	5
12	22 Sep	2	0	70°23.7'	143°44.6'	splash	breach	80	0	5
12	22 Sep	2	0	70°21.8'	143°41.4'	body	swim	270	0	5
12	22 Sep	1	0	70°15.5'	144°20.6'	body	swim	210	0	2
12	22 Sep	1	0	70°18.5'	144°21.9'	splash	dive	90	0	2
12	22 Sep	1	0	70°23.1'	144°23.5'	body	swim	240	0	2
12	22 Sep	1	0	70°23.3'	144°22.6'	body	swim	150	0	2
12	22 Sep	1	0	70°25.4'	144°26.0'	body	swim	220	0	2
12	22 Sep	1	0	70°26.7'	144°26.1'	body	swim	150	0	2
12	22 Sep	1	0	70°30.2'	144°29.4'	body	swim	40	0	3
12	22 Sep	2	1	70°30.9'	144°35.4'	body	swim	170	0	3
12	22 Sep	1	0	70°31.8'	144°39.0'	body	dive	240	0	3
12	22 Sep	2	0	70°20.8'	144°35.9'	slick	rest	290	0	2
12	22 Sep	1	0	70°19.9'	145°12.4'	body	rest	140	0	2
12	22 Sep	1	0	70°20.3'	145°11.9'	body	swim	120	0	2
12	22 Sep	1	0	70°29.5'	145°06.2'	body	dive	260	0	2
12	22 Sep	2	0	70°31.2'	145°05.0'	body	swim	240	0	2
12	22 Sep	2	0	70°30.7'	145°05.6'	body	swim	[1]	0	2
12	22 Sep	2	0	70°28.8'	145°50.5'	slick	swim	[1]	0	2
12	22 Sep	1	0	70°27.9'	145°49.0'	blow	swim	280	0	2
12	22 Sep	1	0	70°22.7'	146°05.6'	body	rest	360	0	2
12	22 Sep	2	0	70°24.3'	146°04.7'	body	rest	[1]	0	2
12	22 Sep	3	0	70°26.7'	146°04.1'	slick	[1]	[1]	0	2
12	22 Sep	1	0	70°28.6'	146°05.8'	body	swim	360	0	2
12	22 Sep	1	0	70°30.5'	146°09.3'	body	swim	330	0	2
12	22 Sep	1	0	70°35.0'	146°16.7'	body	swim	330	0	2

Table B-1
Selected Sighting Data for Bowhead Whales Observed, September-October 1990
(Page 6 of 9)

Flight No.	Date	Total Whales	No. Calves	Latitude (North)	Longitude (West)	Sighting Cue	Behavior	Heading	Ice (%)	Sea State
12	22 Sep	1	0	70°42.0'	146°29.7'	blow	swim	170	0	2
12	22 Sep	1	0	70°41.1'	146°32.6'	blow	swim	90	0	2
12	22 Sep	2	0	70°42.1'	146°37.9'	blow	swim	150	0	2
12	22 Sep	3	0	70°30.0'	146°49.8'	body	swim	270	0	2
12	22 Sep	2	0	70°28.6'	146°51.9'	body	swim	100	0	2
12	22 Sep	1	0	70°28.9'	146°52.3'	body	swim	130	0	2
12	22 Sep	1	0	70°29.5'	146°53.1'	body	swim	[1]	0	2
12	22 Sep	1	0	70°30.1'	146°58.8'	body	swim	[1]	0	2
12	22 Sep	2	0	70°30.1'	146°59.1'	body	swim	260	0	2
12	22 Sep	1	0	70°28.8'	147°01.4'	body	swim	280	0	2
12	22 Sep	3	0	70°29.2'	146°58.6'	body	mill	[1]	0	2
12	22 Sep	3	0	70°29.4'	147°00.6'	body	mill	[1]	0	2
12	22 Sep	1	0	70°28.5'	146°54.1'	body	swim	320	0	2
12	22 Sep	3	0	70°25.7'	146°52.3'	body	swim	220	0	2
12	22 Sep	1	0	70°22.8'	147°09.4'	blow	swim	[1]	0	2
12	22 Sep	1	0	70°24.3'	147°17.5'	body	swim	330	0	2
12	22 Sep	2	0	70°26.7'	147°19.6'	body	rest	250	0	2
12	22 Sep	1	0	70°30.5'	147°15.3'	body	swim	[1]	0	2
12	22 Sep	1	0	70°31.8'	147°13.8'	blow	swim	[1]	0	2
12	22 Sep	1	0	70°33.6'	147°10.8'	body	swim	[1]	0	2
12	22 Sep	2	0	70°34.8'	147°09.8'	body	swim	300	0	2
12	22 Sep	1	0	70°35.4'	147°09.7'	body	swim	300	0	2
12	22 Sep	1	0	70°37.2'	147°44.1'	blow	swim	[1]	0	2
12	22 Sep	1	0	70°36.3'	147°44.6'	body	swim	260	0	2
12	22 Sep	1	0	70°36.2'	147°44.6'	body	swim	[1]	0	2
12	22 Sep	1	0	70°36.8'	147°41.3'	body	swim	250	0	4
12	22 Sep	1	0	70°37.1'	147°42.4'	body	dive	[1]	0	2
12	22 Sep	2	0	70°37.1'	147°45.2'	body	swim	250	0	2
12	22 Sep	1	0	70°36.3'	147°46.5'	body	swim	300	0	2
12	22 Sep	1	0	70°37.9'	147°44.3'	body	swim	[1]	0	2
12	22 Sep	1	0	70°37.7'	147°43.9'	body	swim	260	0	2
12	22 Sep	1	0	70°35.9'	147°43.8'	body	swim	230	0	2
12	22 Sep	1	0	70°35.2'	147°40.7'	body	swim	[1]	0	2
12	22 Sep	3	0	70°35.0'	147°40.7'	body	swim	20	0	2
12	22 Sep	2	0	70°34.1'	147°41.8'	body	swim	[1]	0	2
12	22 Sep	2	0	70°33.5'	147°38.1'	body	swim	240	0	2
12	22 Sep	1	0	70°36.7'	147°39.6'	blow	swim	220	0	2
12	22 Sep	1	0	70°35.5'	147°40.1'	body	swim	340	0	2
12	22 Sep	2	0	70°34.9'	147°39.8'	body	swim	[1]	0	2

Table B-1
Selected Sighting Data for Bowhead Whales Observed, September-October 1990
(Page 7 of 9)

Flight No.	Date	Total Whales	No. Calves	Latitude (North)	Longitude (West)	Sighting Cue	Behavior	Heading	Ice (%)	Sea State
12	22 Sep	1	0	70°34.5'	147°39.3'	body	swim	'	0	2
12	22 Sep	1	0	70°34.3'	147°39.4'	body	swim	'	0	2
12	22 Sep	1	0	70°34.3'	147°39.4'	body	swim	340	0	2
12	22 Sep	1	0	70°31.6'	147°40.2'	body	swim	70	0	2
13	24 Sep	1	0	70°31.4'	146°51.4'	blow	'	'	0	5
13	24 Sep	2	0	70°32.9'	146°54.6'	splash	swim	310	0	5
13	24 Sep	1	0	70°22.9'	146°03.5'	body	dive	'	0	5
13	24 Sep	1	0	70°20.2'	143°48.6'	body	swim	250	0	6
13	24 Sep	1	0	70°13.6'	145°12.9'	blow	swim	240	0	5
13	24 Sep	1	0	70°28.9'	146°26.4'	blow	swim	190	0	6
14	26 Sep	1	0	70°33.6'	146°53.8'	blow	swim	180	0	5
14	26 Sep	1	0	70°33.6'	146°53.8'	body	swim	70	0	5
14	26 Sep	9	0	70°33.6'	146°48.7'	body	swim	170	0	6
14	26 Sep	3	0	70°33.6'	146°48.7'	body	swim	70	0	6
14	26 Sep	1	0	70°14.6'	143°56.6'	blow	swim	'	0	4
14	26 Sep	1	0	70°12.9'	143°55.9'	body	swim	'	0	0
14	26 Sep	1	0	70°12.9'	143°55.9'	body	swim	210	0	4
14	26 Sep	1	0	70°12.2'	143°52.0'	body	swim	310	0	4
14	26 Sep	1	0	70°12.2'	143°52.0'	body	swim	330	0	4
14	26 Sep	2	0	70°13.5'	143°56.3'	body	swim	300	0	4
14	26 Sep	1	0	70°14.5'	143°59.7'	body	swim	300	0	4
14	26 Sep	1	0	70°14.7'	144°04.1'	body	swim	270	0	4
14	26 Sep	2	0	70°14.7'	144°04.1'	body	swim	240	0	0
14	26 Sep	1	0	70°19.4'	143°21.6'	body	swim	150	0	3
14	26 Sep	1	0	70°31.4'	143°33.0'	blow	swim	60	0	4
14	26 Sep	1	0	70°20.6'	143°41.8'	body	swim	200	0	3
14	26 Sep	1	0	70°20.1'	143°41.1'	body	swim	240	0	3
14	26 Sep	1	0	70°15.1'	143°38.1'	body	swim	270	0	3
14	26 Sep	1	0	70°15.1'	143°38.1'	body	swim	270	0	3
14	26 Sep	1	0	70°13.7'	143°37.2'	body	swim	30	0	3
14	26 Sep	1	0	70°10.6'	144°05.6'	blow	swim	240	0	3
14	26 Sep	1	0	70°12.0'	144°05.0'	body	swim	305	0	3
14	26 Sep	1	0	70°17.5'	144°07.6'	blow	swim	305	0	3
14	26 Sep	1	0	70°20.4'	144°09.5'	blow	swim	'	0	3
14	26 Sep	1	0	70°29.9'	144°48.1'	blow	swim	270	0	4
14	26 Sep	2	0	70°12.7'	144°38.8'	blow	swim	'	0	4
14	26 Sep	1	0	70°12.7'	144°38.8'	blow	swim	270	0	4
14	26 Sep	1	0	70°26.2'	145°11.9'	body	swim	70	0	4
14	26 Sep	4	0	70°23.4'	145°45.6'	blow	swim	220	0	4

Table B-1
Selected Sighting Data for Bowhead Whales Observed, September-October 1990
(Page 8 of 9)

Flight No.	Date	Total Whales	No. Calves	Latitude (North)	Longitude (West)	Sighting Cue	Behavior	Heading	Ice (%)	Sea State
15	27 Sep	1	0	70°24.5'	146°10.3'	blow	swim	340	0	3
17	30 Sep	3	0	70°46.4'	150°13.8'	body	swim	220	0	3
18	1 Oct	1	0	70°26.6'	147°30.3'	splash	swim	270	0	2
18	1 Oct	1	0	70°26.6'	147°30.3'	body	swim	[1]	0	2
18	1 Oct	6	0	70°26.6'	147°30.3'	blow	mill	[1]	0	2
18	1 Oct	1	0	70°26.6'	147°30.3'	body	swim	270	0	2
18	1 Oct	1	0	70°26.6'	147°30.3'	body	dive	[1]	0	2
18	1 Oct	2	0	70°26.5'	147°21.2'	body	swim	[1]	0	2
18	1 Oct	1	0	70°26.5'	147°21.2'	splash	swim	310	0	2
18	1 Oct	1	0	70°26.5'	147°21.2'	body	swim	260	0	2
18	1 Oct	1	0	70°26.5'	147°21.2'	body	swim	270	0	2
18	1 Oct	1	0	70°25.2'	147°09.1'	body	swim	290	0	2
18	1 Oct	1	0	70°24.4'	147°01.1'	blow	swim	300	0	2
18	1 Oct	1	0	70°24.4'	146°53.5'	body	swim	300	0	2
18	1 Oct	1	0	70°31.2'	146°59.5'	splash	swim	310	0	2
18	1 Oct	1	0	70°36.5'	146°57.4'	blow	swim	160	0	2
18	1 Oct	1	0	70°41.7'	147°08.4'	body	swim	260	0	2
18	1 Oct	1	0	70°40.3'	147°53.3'	body	swim	220	0	2
18	1 Oct	1	0	70°40.3'	147°53.3'	body	swim	220	0	2
18	1 Oct	1	0	70°54.2'	151°33.4'	body	swim	270	0	2
18	1 Oct	1	0	70°54.6'	151°44.1'	body	swim	220	0	2
18	1 Oct	1	0	70°55.2'	151°49.8'	body	swim	240	0	2
18	1 Oct	1	0	70°55.4'	151°51.5'	body	swim	230	0	2
18	1 Oct	1	0	70°55.5'	151°53.2'	body	swim	230	0	2
18	1 Oct	1	0	70°55.7'	151°54.8'	body	swim	230	0	2
18	1 Oct	1	0	70°55.7'	151°55.9'	body	swim	230	0	2
19	2 Oct	1	0	70°18.8'	144°39.4'	body	swim	330	0	4
19	2 Oct	1	0	70°18.2'	144°25.5'	body	swim	350	0	4
19	2 Oct	1	0	70°26.0'	143°07.4'	blow	swim	130	0	2
19	2 Oct	1	0	70°32.1'	143°05.9'	body	swim	[1]	0	4
19	2 Oct	1	0	70°24.3'	144°06.2'	body	swim	240	0	4
19	2 Oct	2	0	70°29.1'	144°08.0'	body	swim	240	0	4
19	2 Oct	1	0	70°34.7'	144°24.6'	blow	swim	330	0	4
19	2 Oct	1	0	70°30.7'	146°42.9'	body	swim	340	0	3
19	2 Oct	1	0	70°38.3'	147°10.4'	body	swim	270	0	5
19	2 Oct	1	0	70°38.9'	147°10.2'	body	swim	210	0	3
19	2 Oct	1	0	70°41.2'	147°23.9'	splash	swim	260	0	3
20	3 Oct	1	0	71°21.2'	152°28.7'	body	rest	280	0	5
21	9 Oct	1	0	71°18.7'	153°53.5'	splash	swim	260	0	2

Table B-1
Selected Sighting Data for Bowhead Whales Observed, September-October 1990
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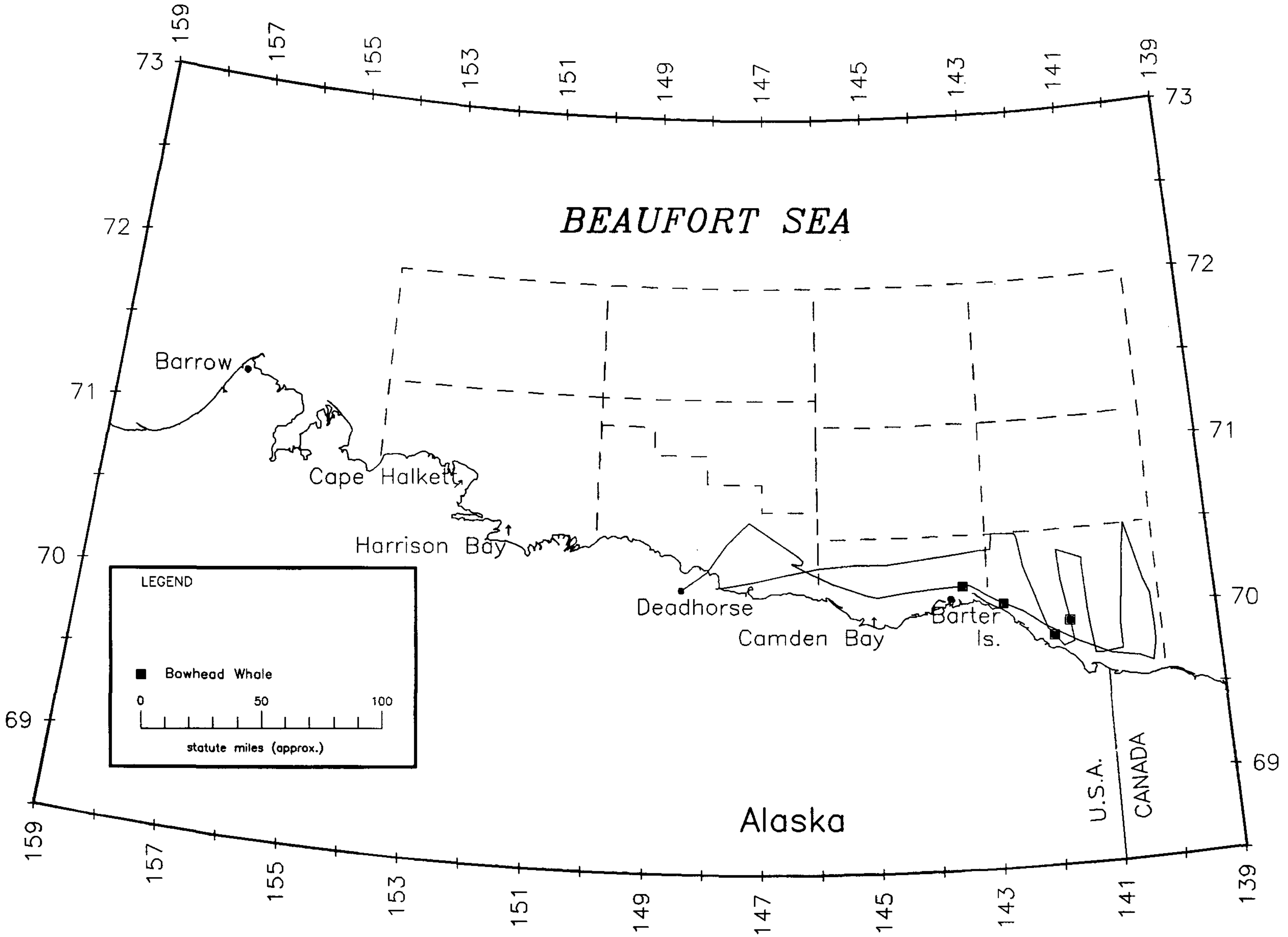
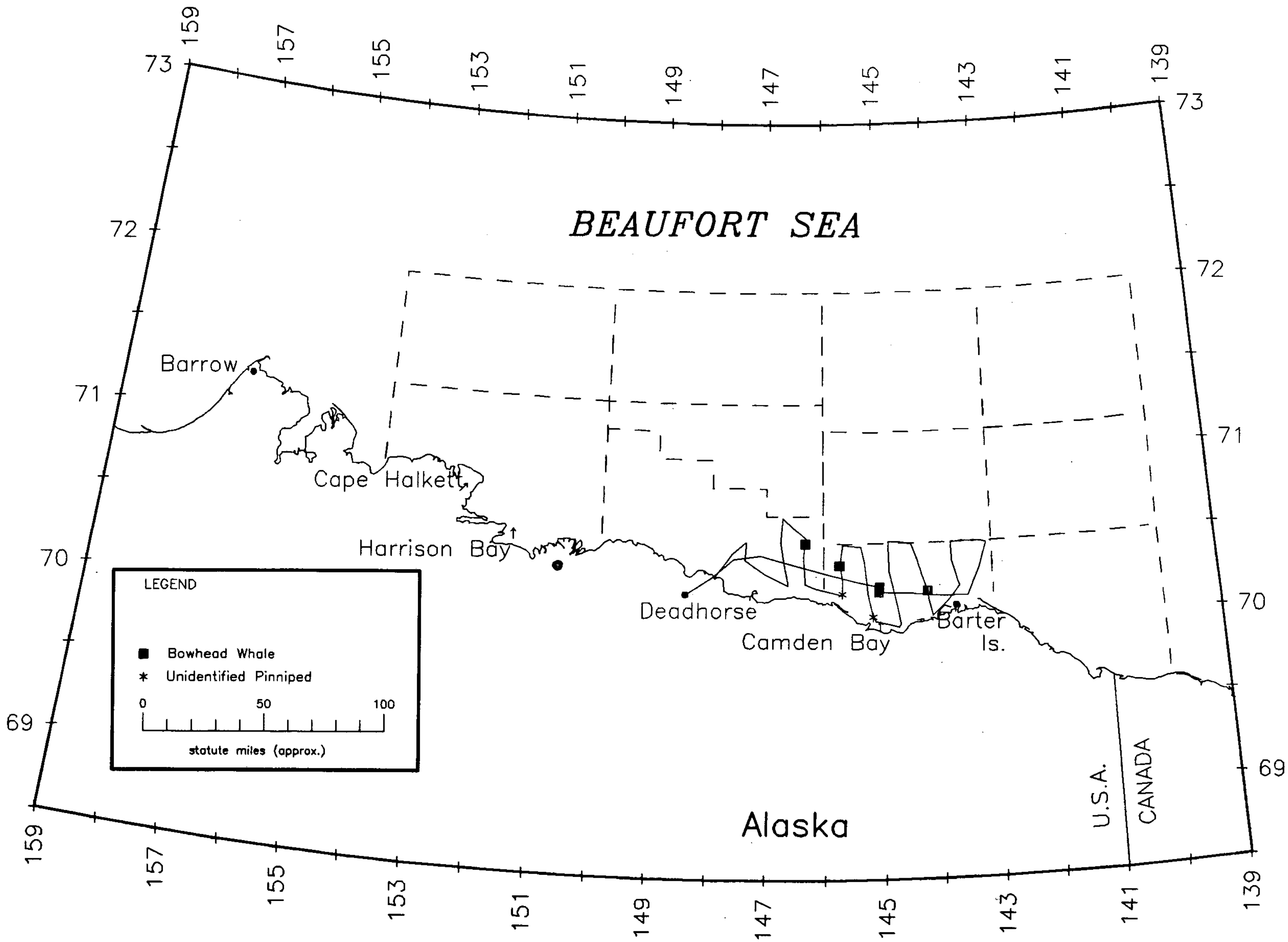
Flight No.	Date	Total Whales	No. Calves	Latitude (North)	Longitude (West)	Sighting Cue	Behavior	Heading	Ice (%)	Sea State
21	9 Oct	1	0	71°18.3'	153°41.6'	splash	breach	[1]	0	2
21	9 Oct	1	0	71°13.8'	153°13.0'	splash	breach	240	0	3
22	10 Oct	1	0	70°39.9'	146°31.1'	splash	swim	300	0	3
23	11 Oct	1	0	71°11.2'	153°05.0'	body	swim	270	0	2
23	11 Oct	1	0	71°09.2'	153°07.4'	body	swim	50	0	2
23	11 Oct	1	0	71°10.1'	153°17.3'	body	breach	270	0	2
23	11 Oct	2	0	71°10.3'	153°08.5'	body	swim	270	0	2
23	11 Oct	3	0	71°03.7'	152°32.3'	body	mill	[1]	0	2
23	11 Oct	2	0	71°03.6'	152°30.4'	body	swim	250	0	2
23	11 Oct	1	0	71°03.6'	152°30.4'	body	swim	240	0	2
23	11 Oct	2	0	71°03.4'	152°26.1'	body	rest	70	0	2
23	11 Oct	2	0	71°03.7'	152°24.5'	body	swim	250	0	2
23	11 Oct	2	0	71°04.4'	152°28.7'	body	swim	220	0	2
23	11 Oct	1	0	71°03.7'	152°24.8'	body	swim	270	0	2
23	11 Oct	1	0	71°03.2'	152°22.0'	body	swim	270	0	2
24	13 Oct	1	0	71°23.6'	153°57.7'	splash	slap	[1]	0	4
25	14 Oct	1	0	71°14.8'	153°25.2'	body	swim	260	0	1
29	18 Oct	1	0	71°11.5'	151°13.1'	blow	swim	270	0	4
30	19 Oct	1	0	71°20.6'	153°45.8'	splash	slap	330	0	4

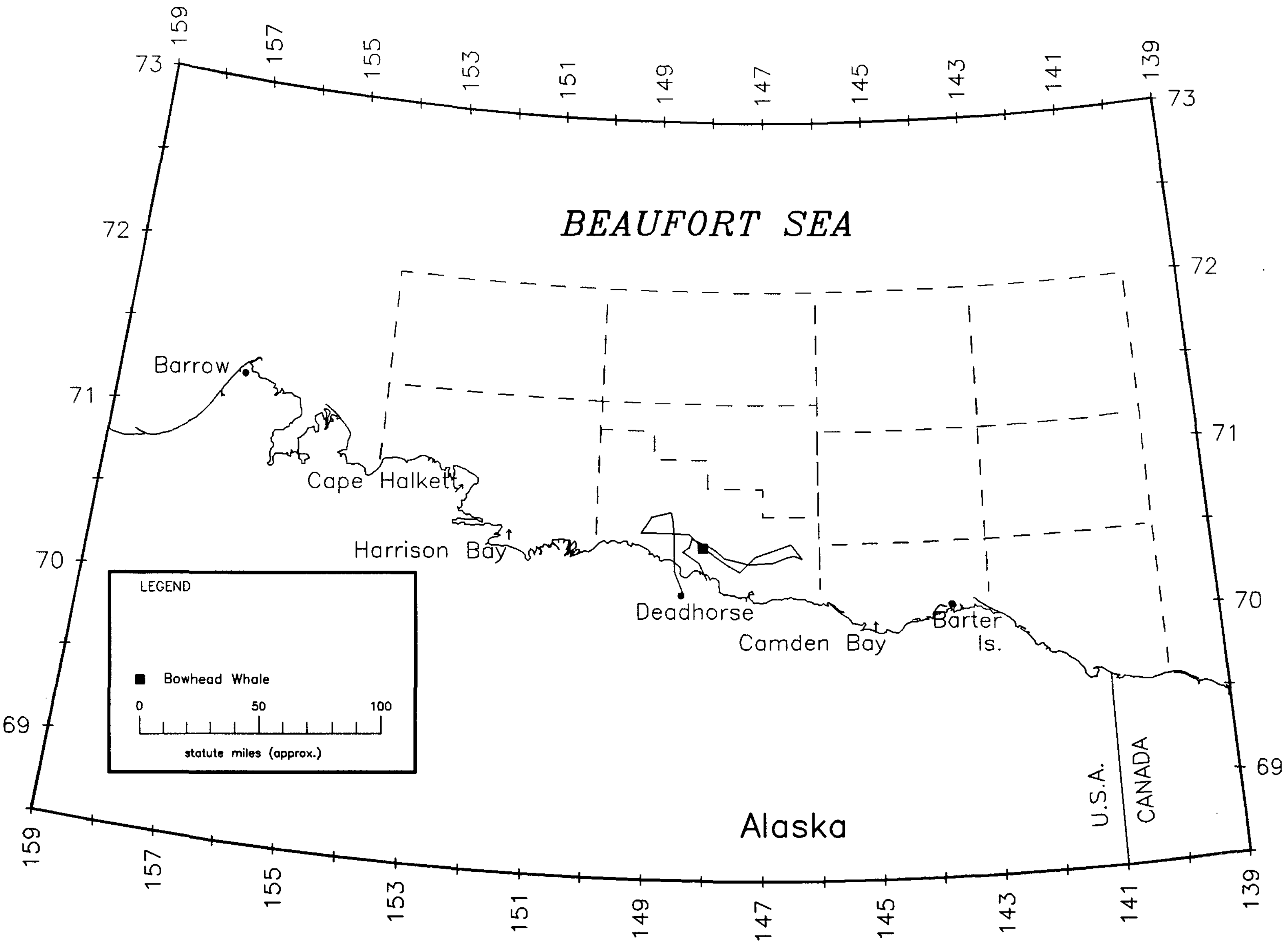
[1] Not recorded.
[2] Repeat sighting.
[3] Not applicable.



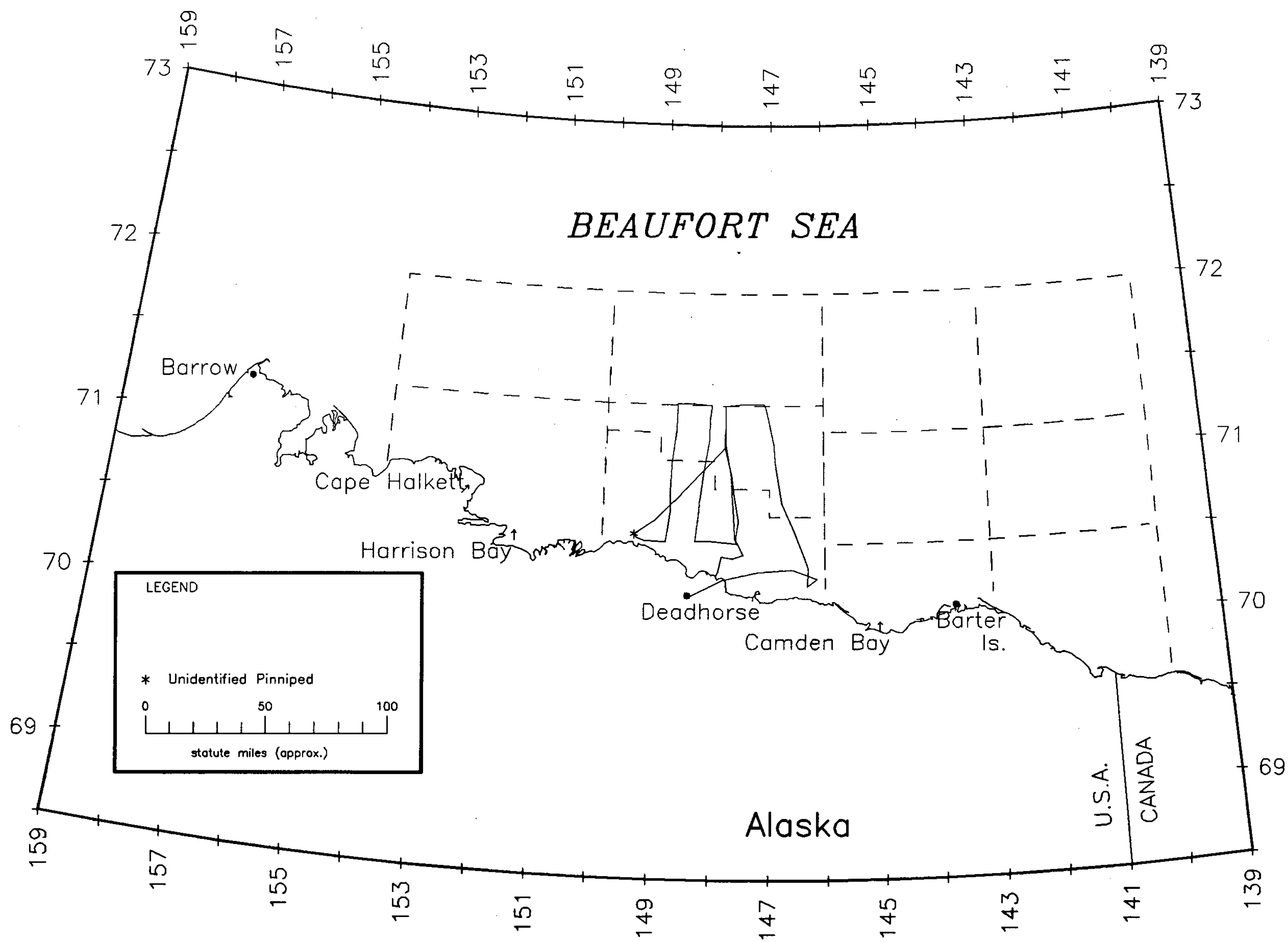
FLIGHT 1 2 September 1990
Survey Track and Sightings



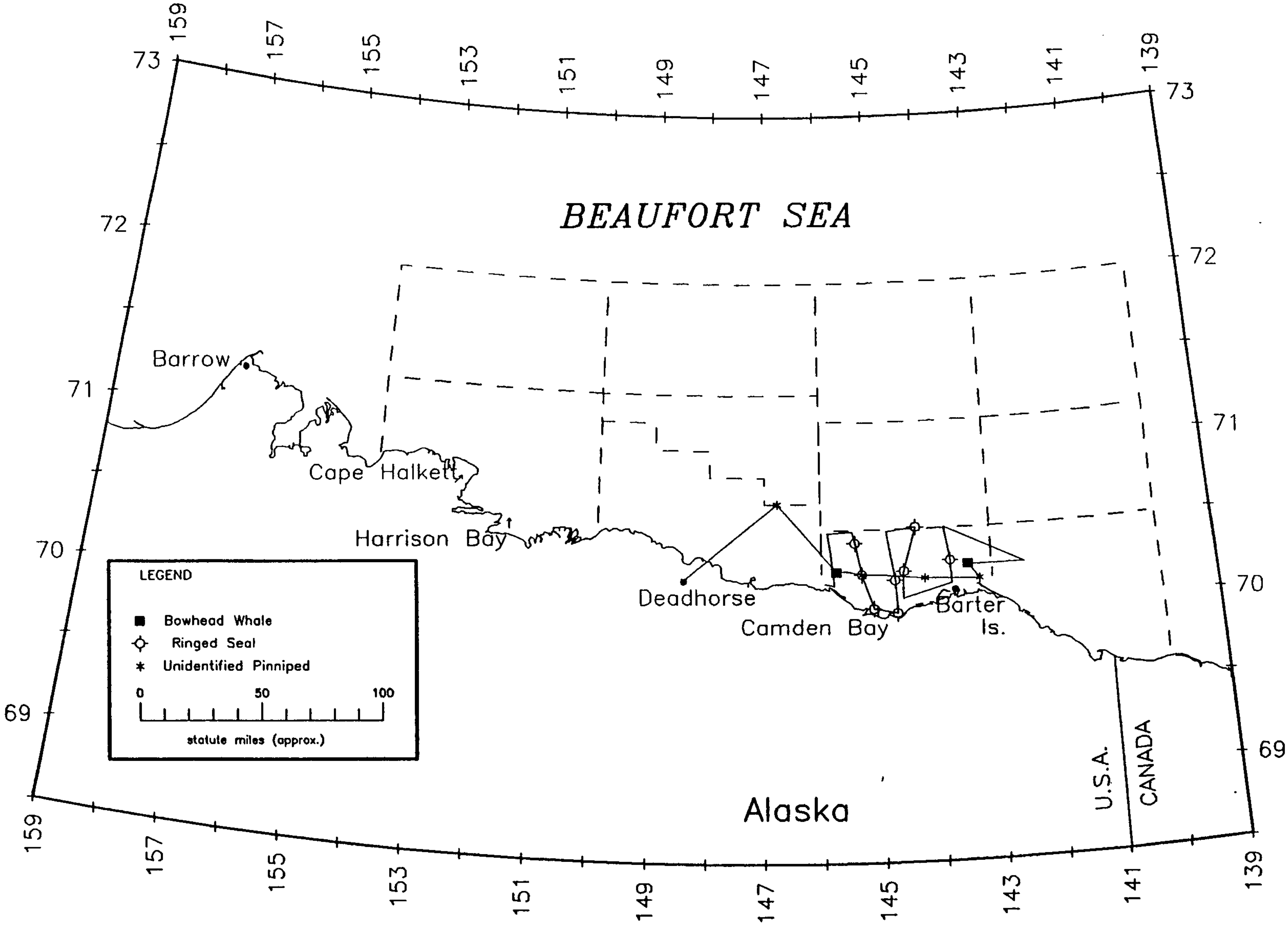
FLIGHT 2 3 September 1990
Survey Track and Sightings



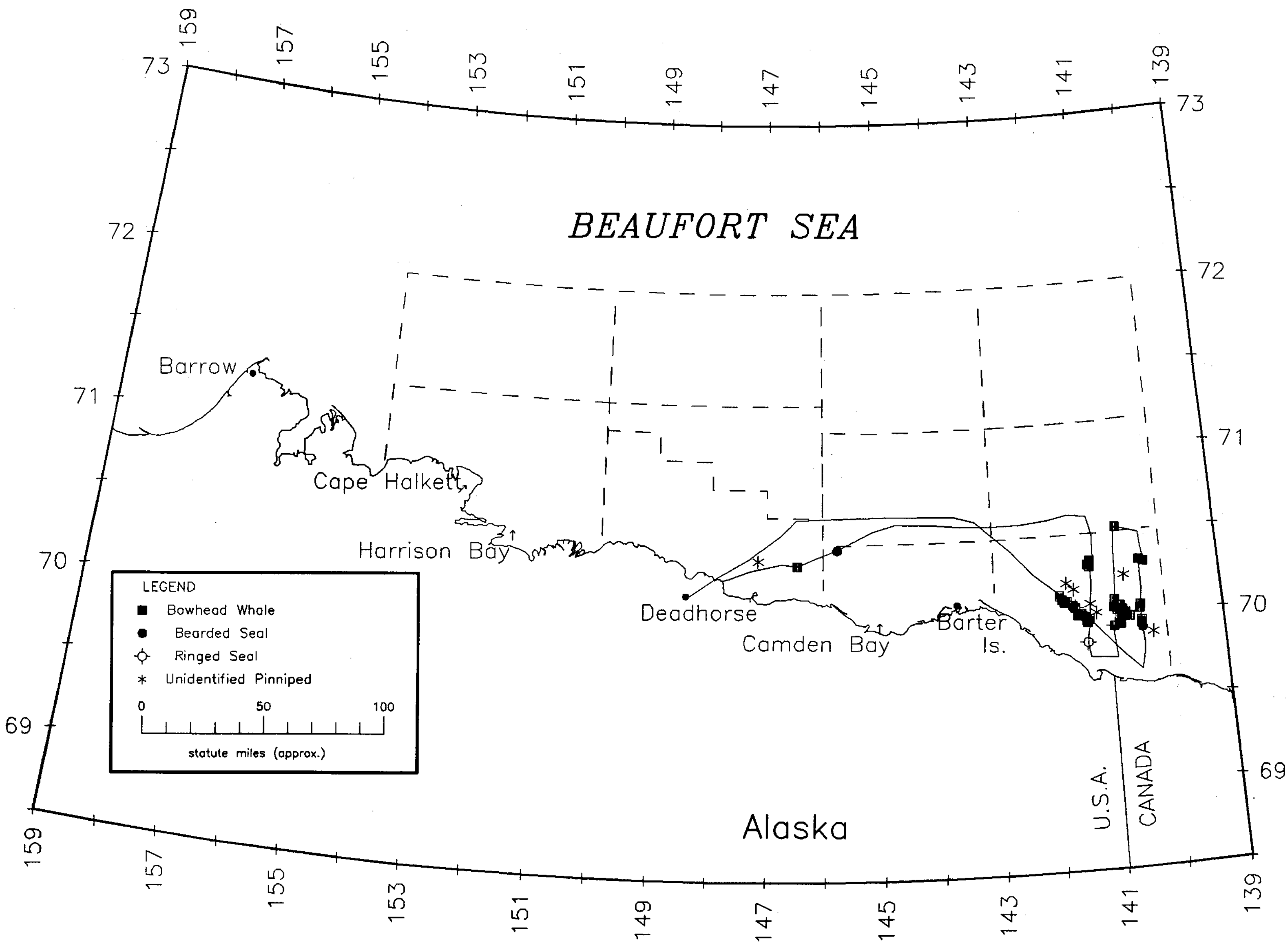
FLIGHT 3 7 September 1990
Survey Track and Sightings



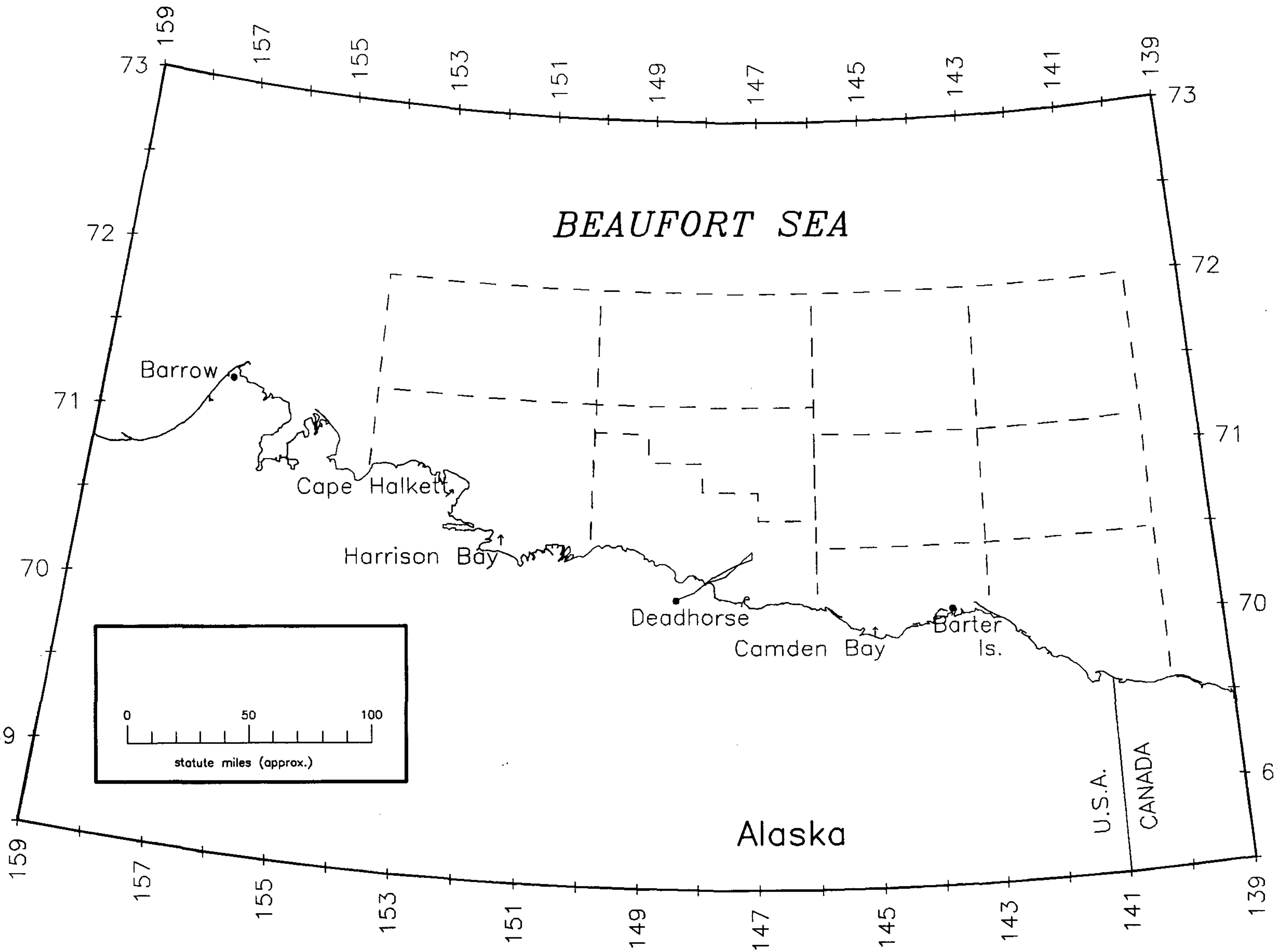
FLIGHT 4 9 September 1990
Survey Track and Sightings



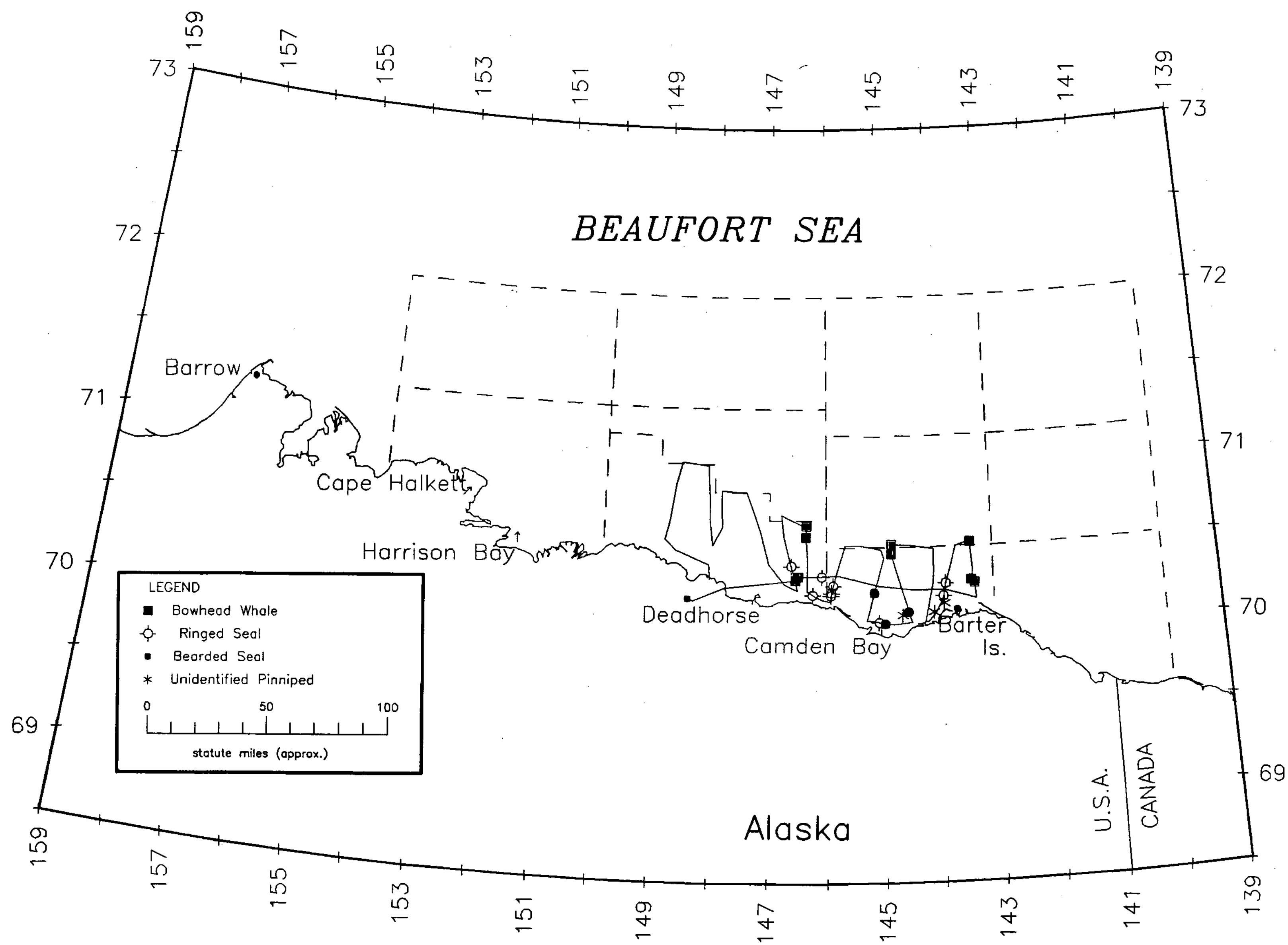
FLIGHT 5 9 September 1990
Survey Track and Sightings



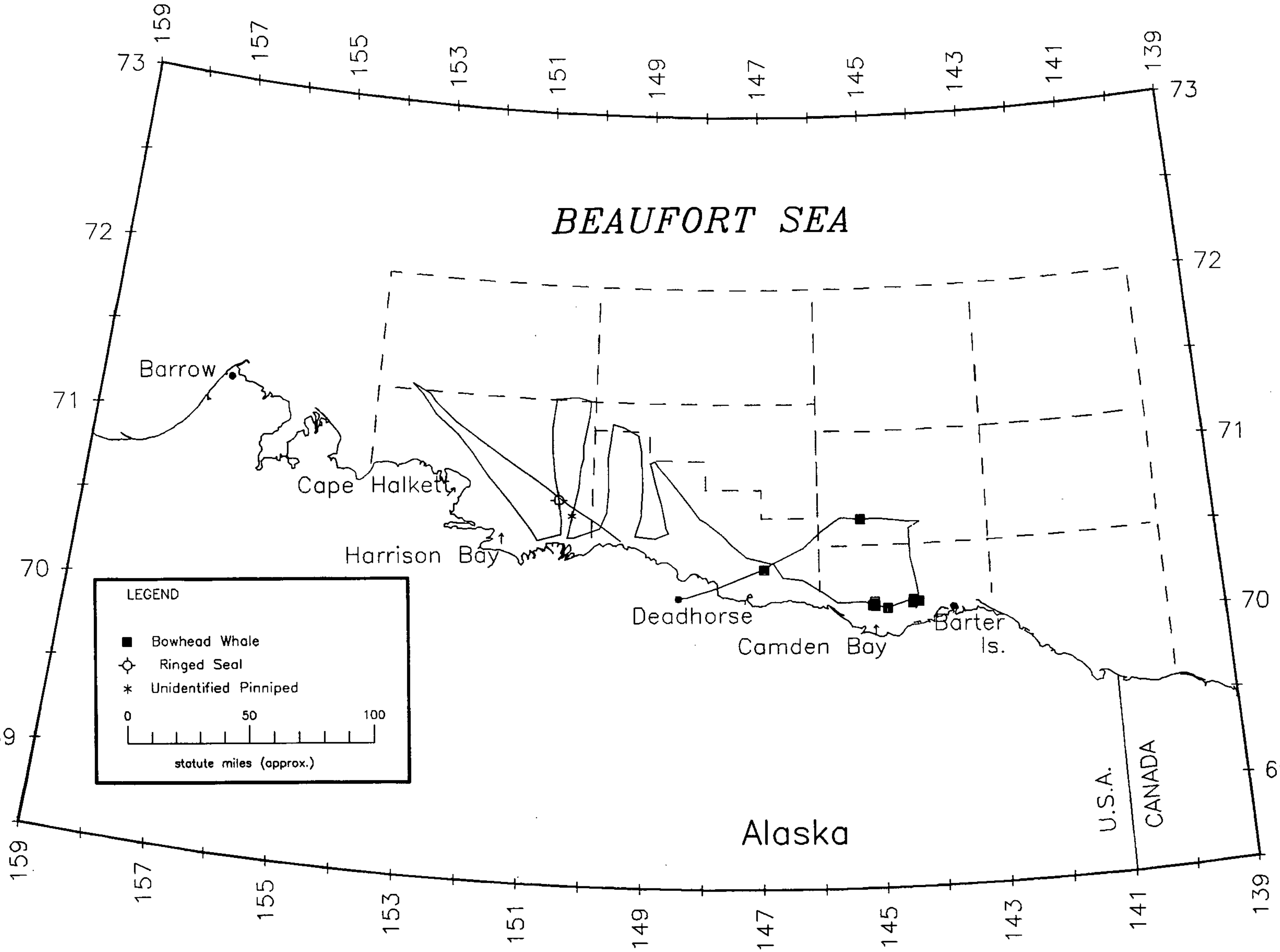
FLIGHT 6 10 September 1990
Survey Track and Sightings



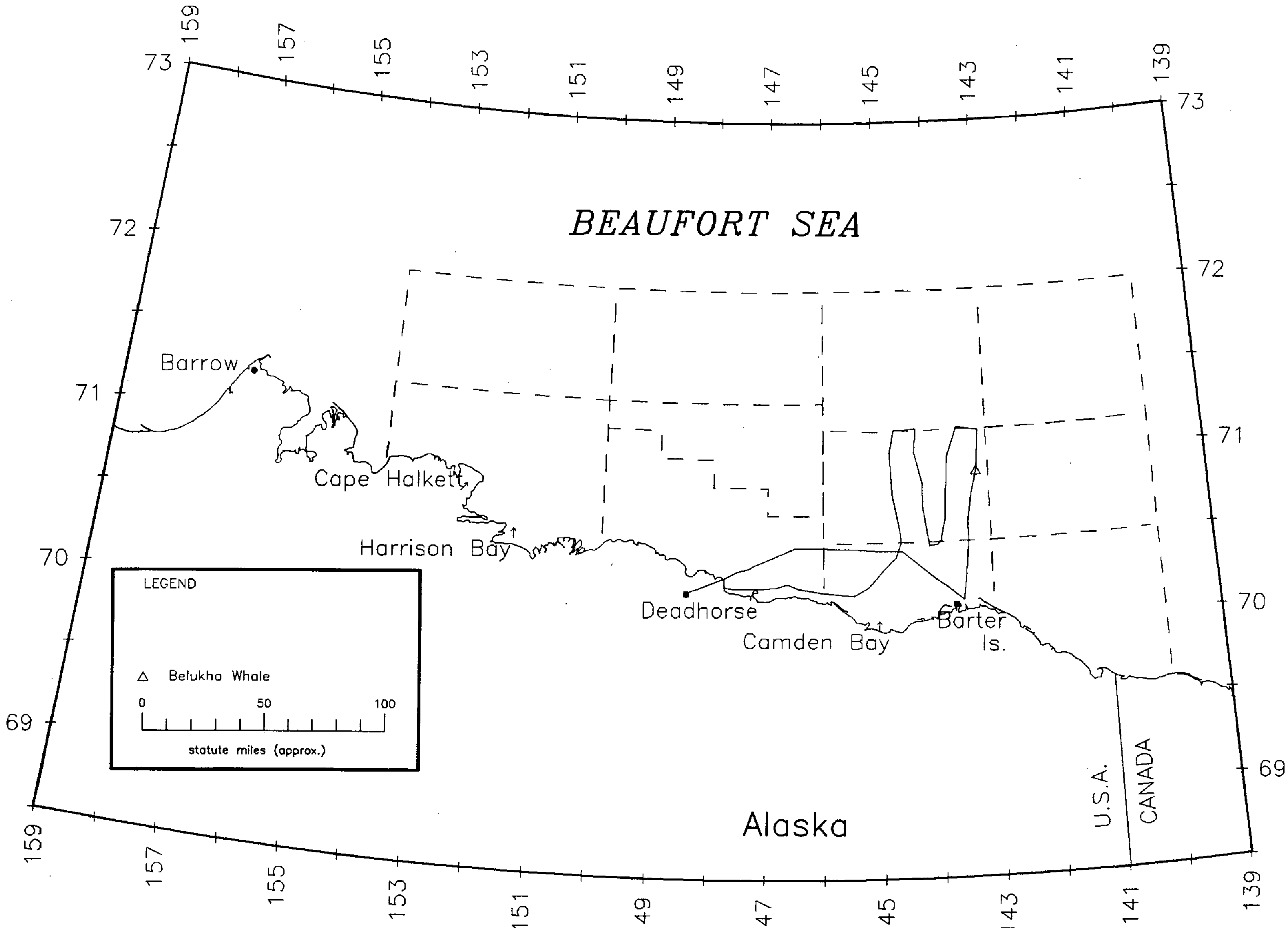
FLIGHT 7 11 September 1990
Survey Track and Sightings



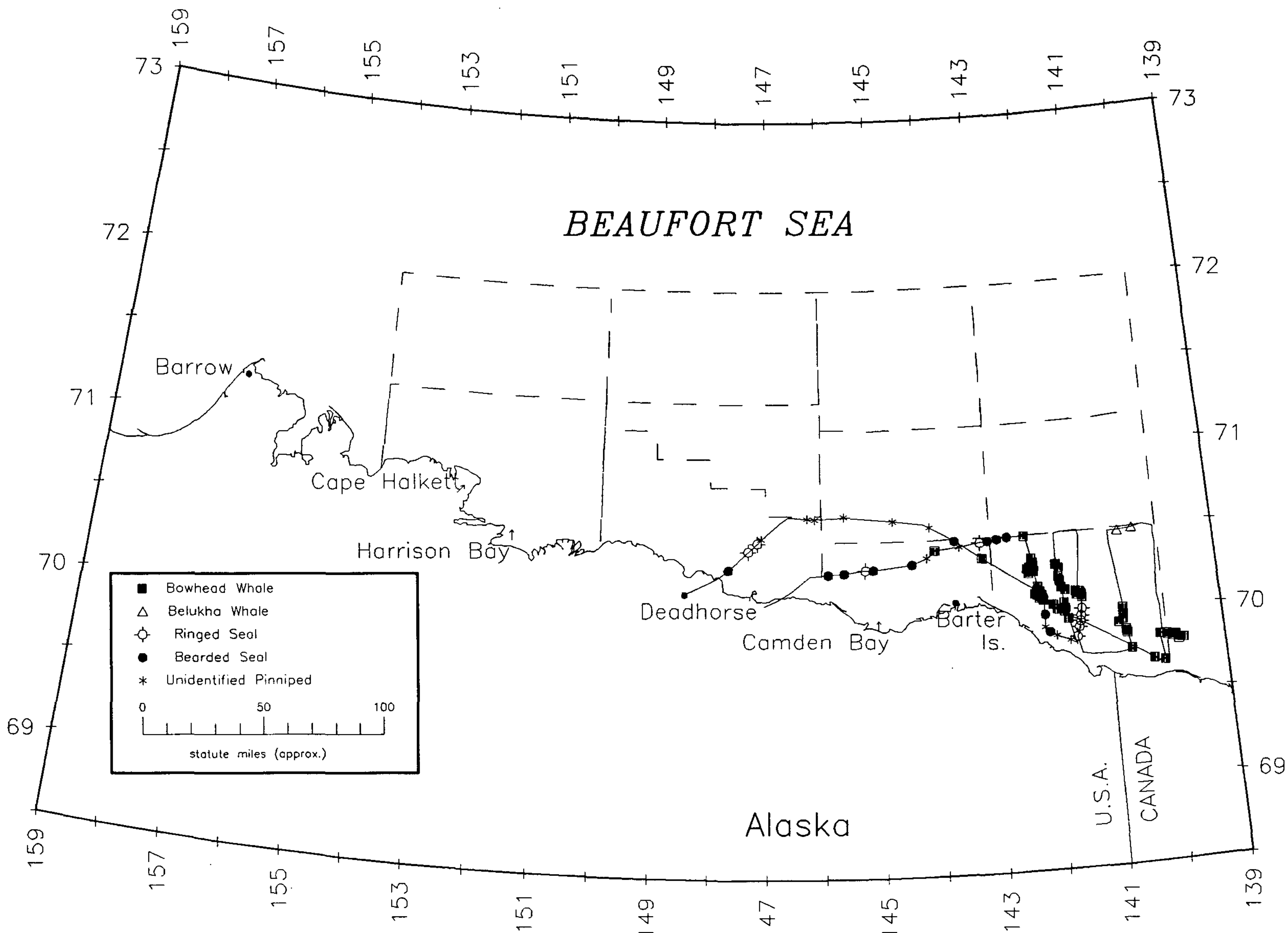
FLIGHT 8 12 September 1990
Survey Track and Sightings



FLIGHT 9 13 September 1990
Survey Track and Sightings



FLIGHT 10 14 September 1990
Survey Track and Sightings



FLIGHT 11 16 September 1990
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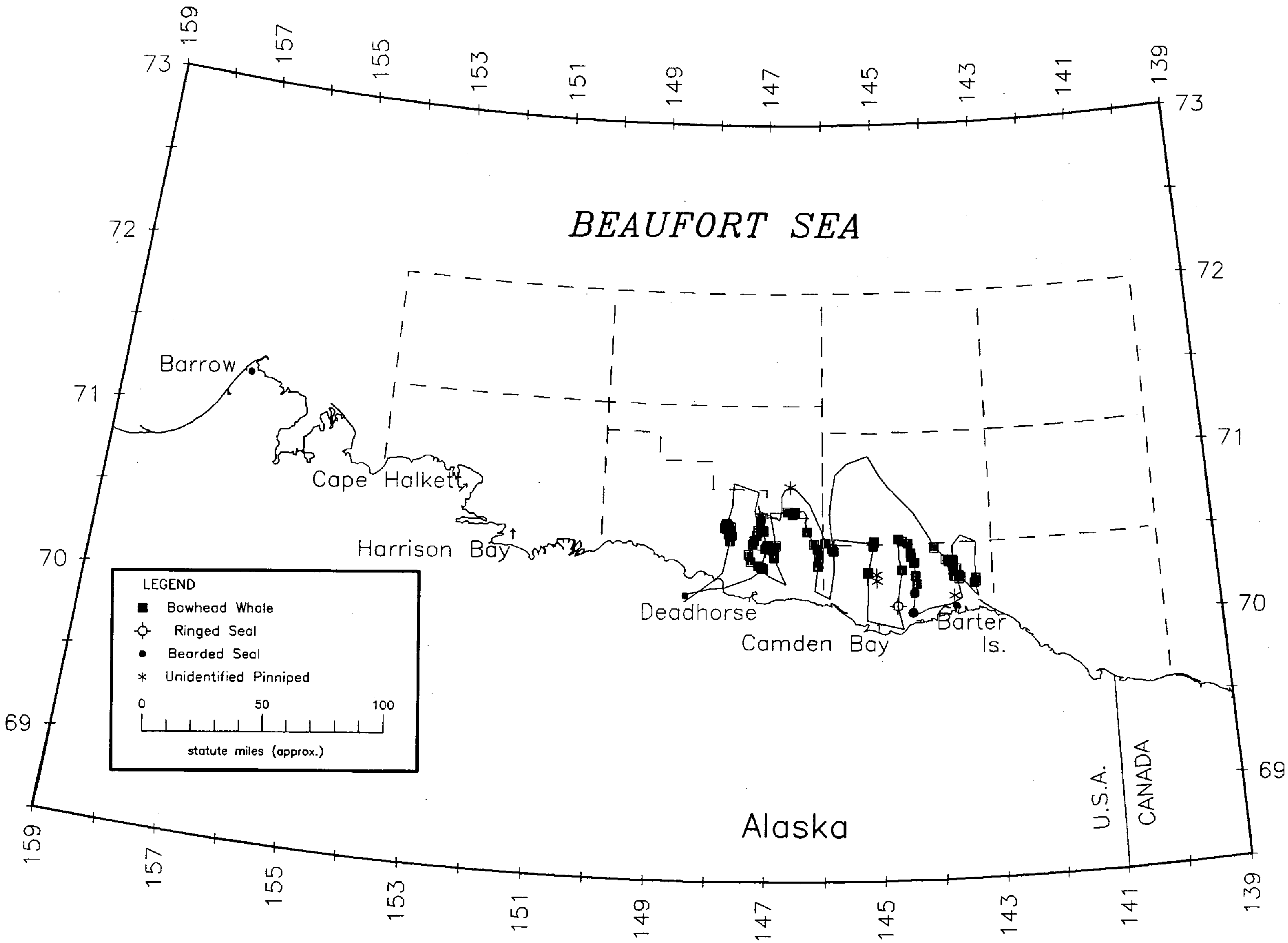
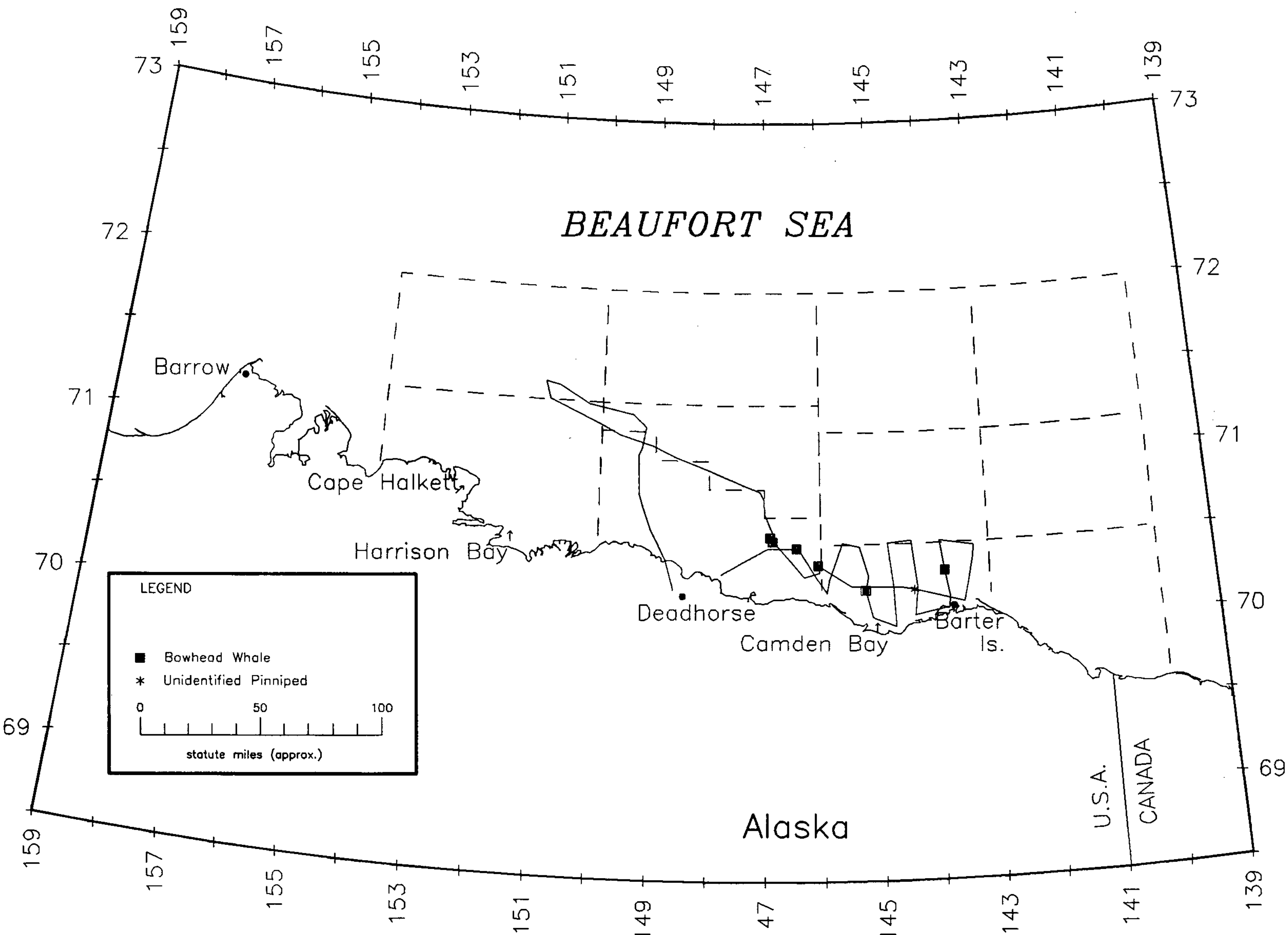
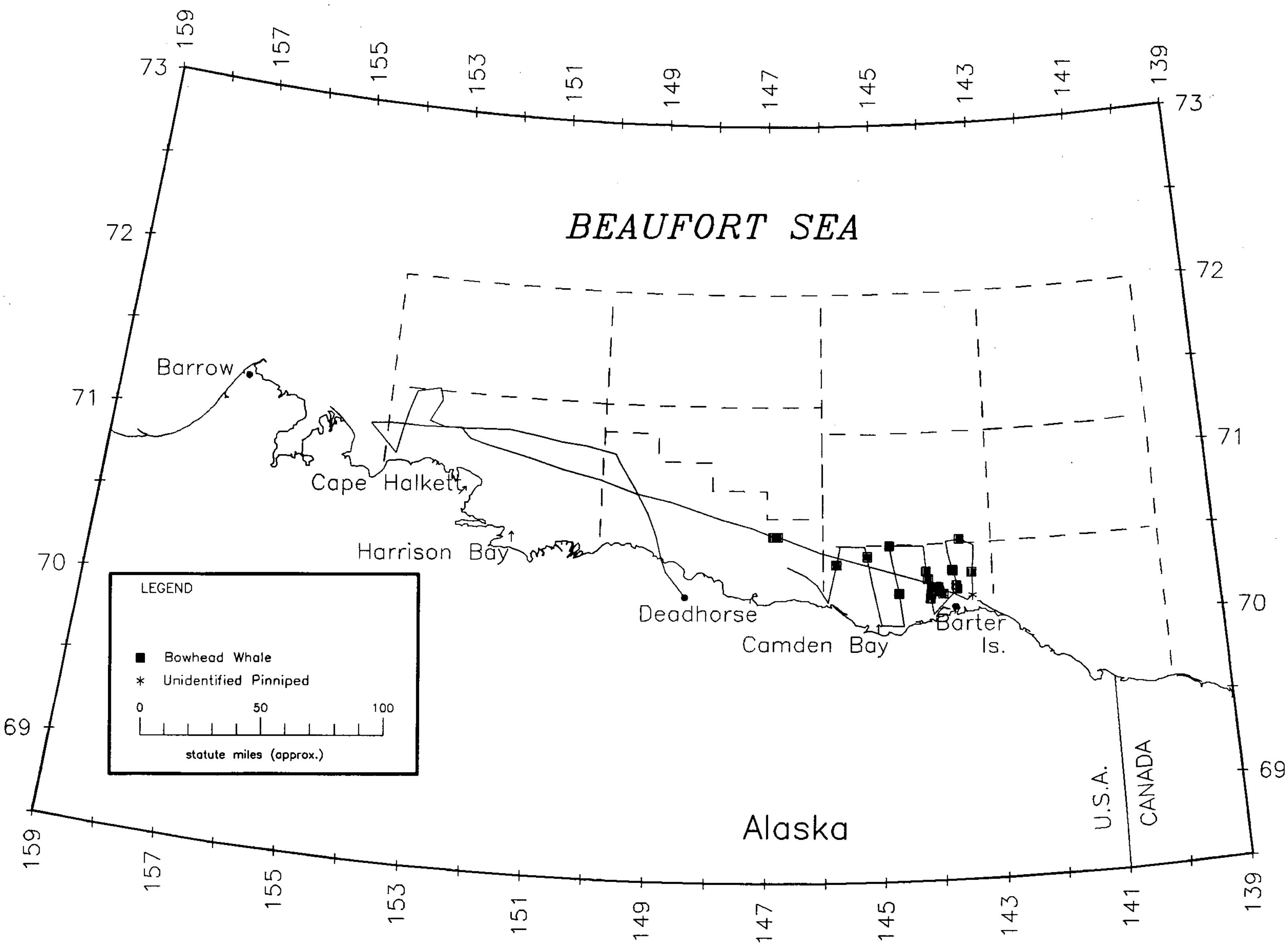


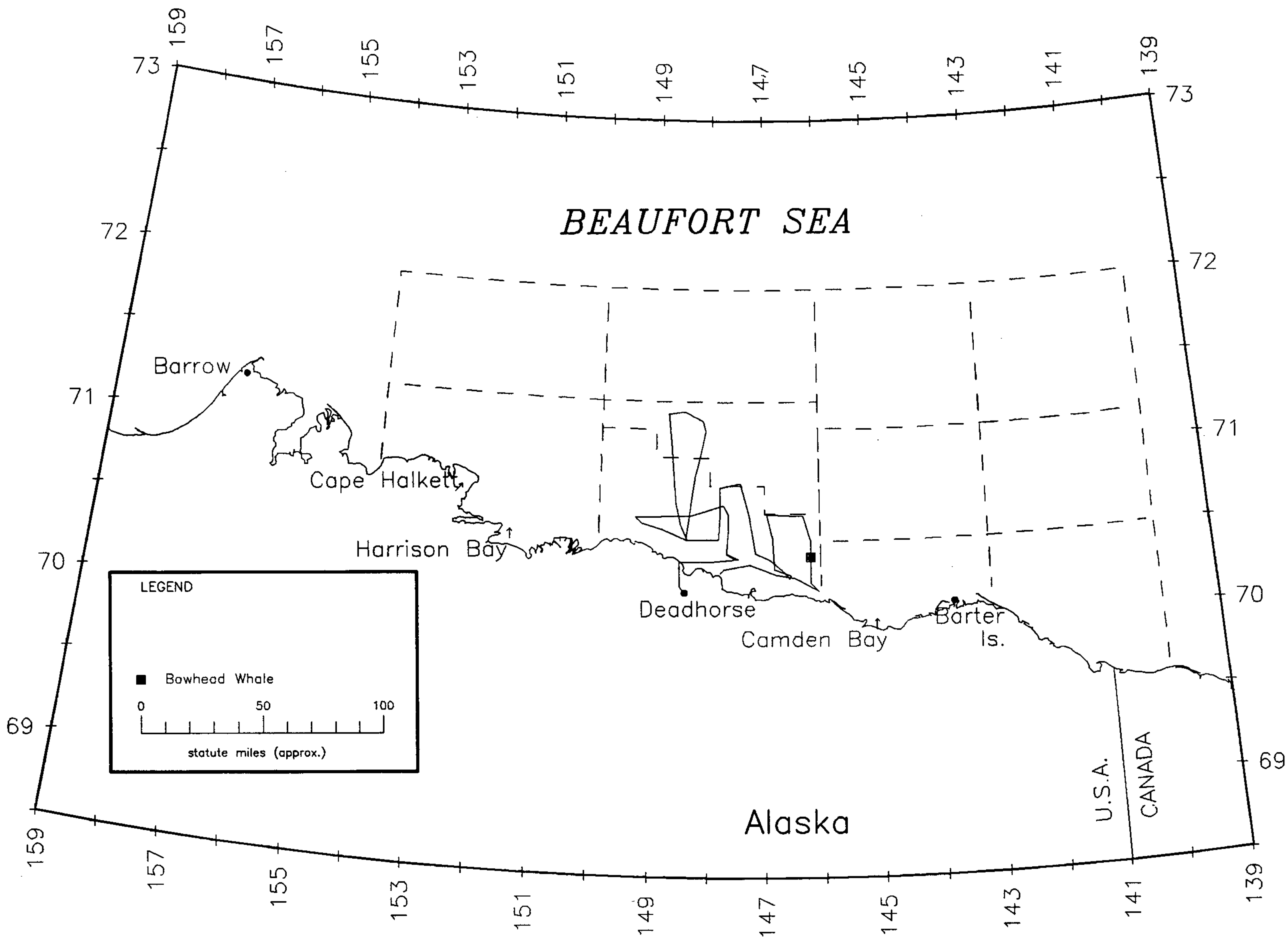
FLIGHT 12 22 September 1990
Survey Track and Sightings



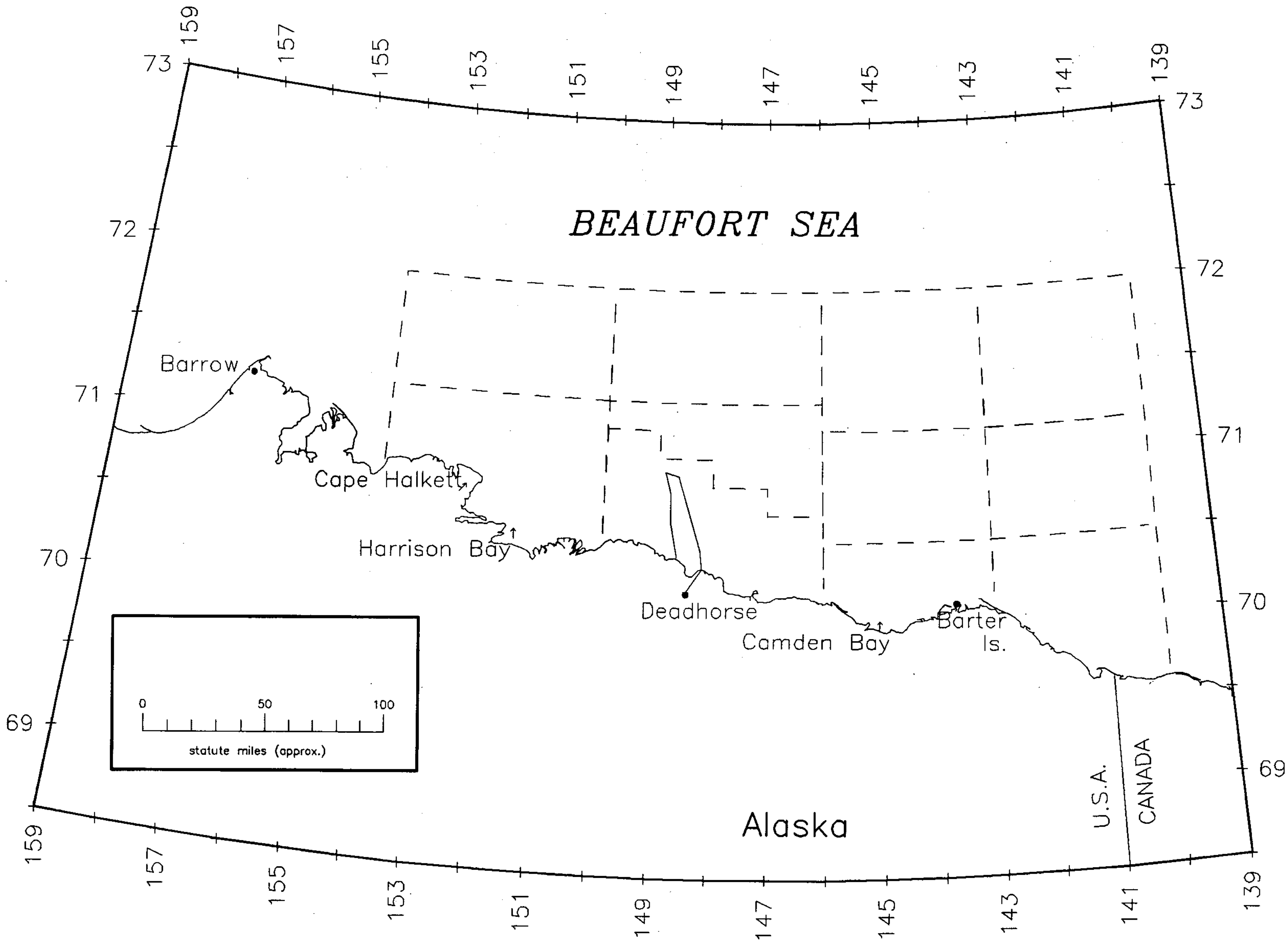
FLIGHT 13 24 September 1990
Survey Track and Sightings



FLIGHT 14 26 September 1990
Survey Track and Sightings



FLIGHT 15 27 September 1990
Survey Track and Sightings



FLIGHT 16 28 September 1990
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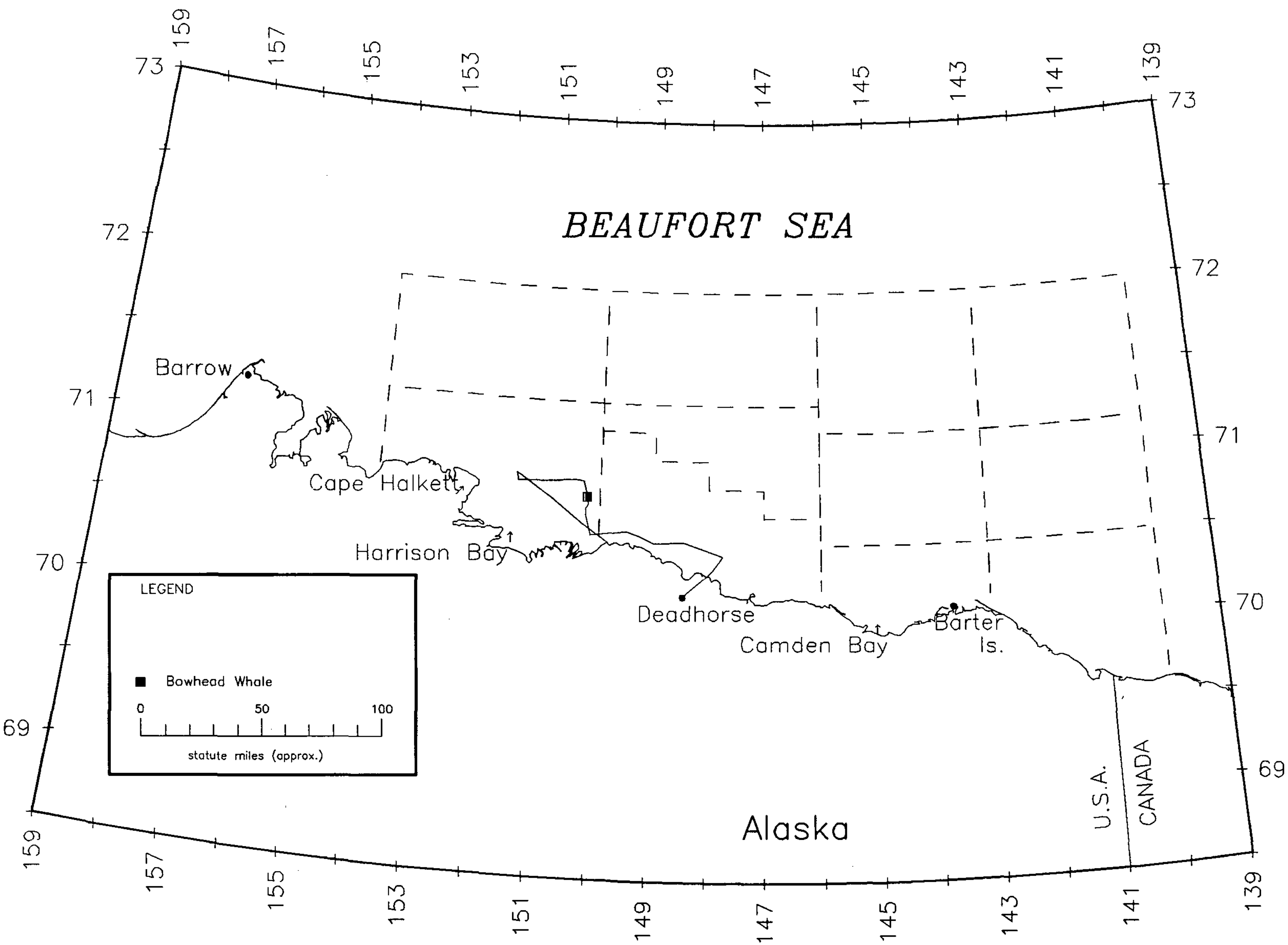

FLIGHT 17 30 September 1990
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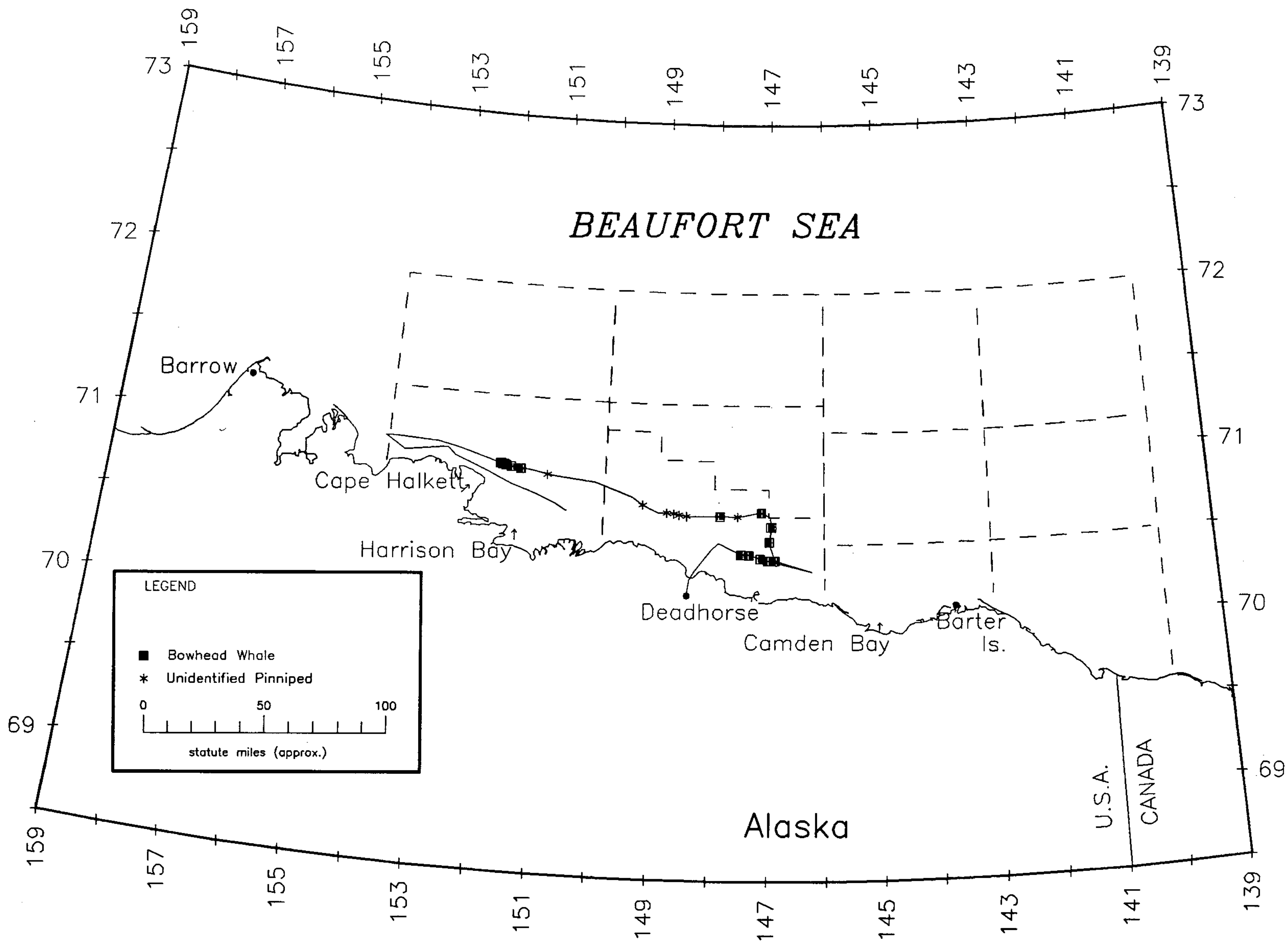
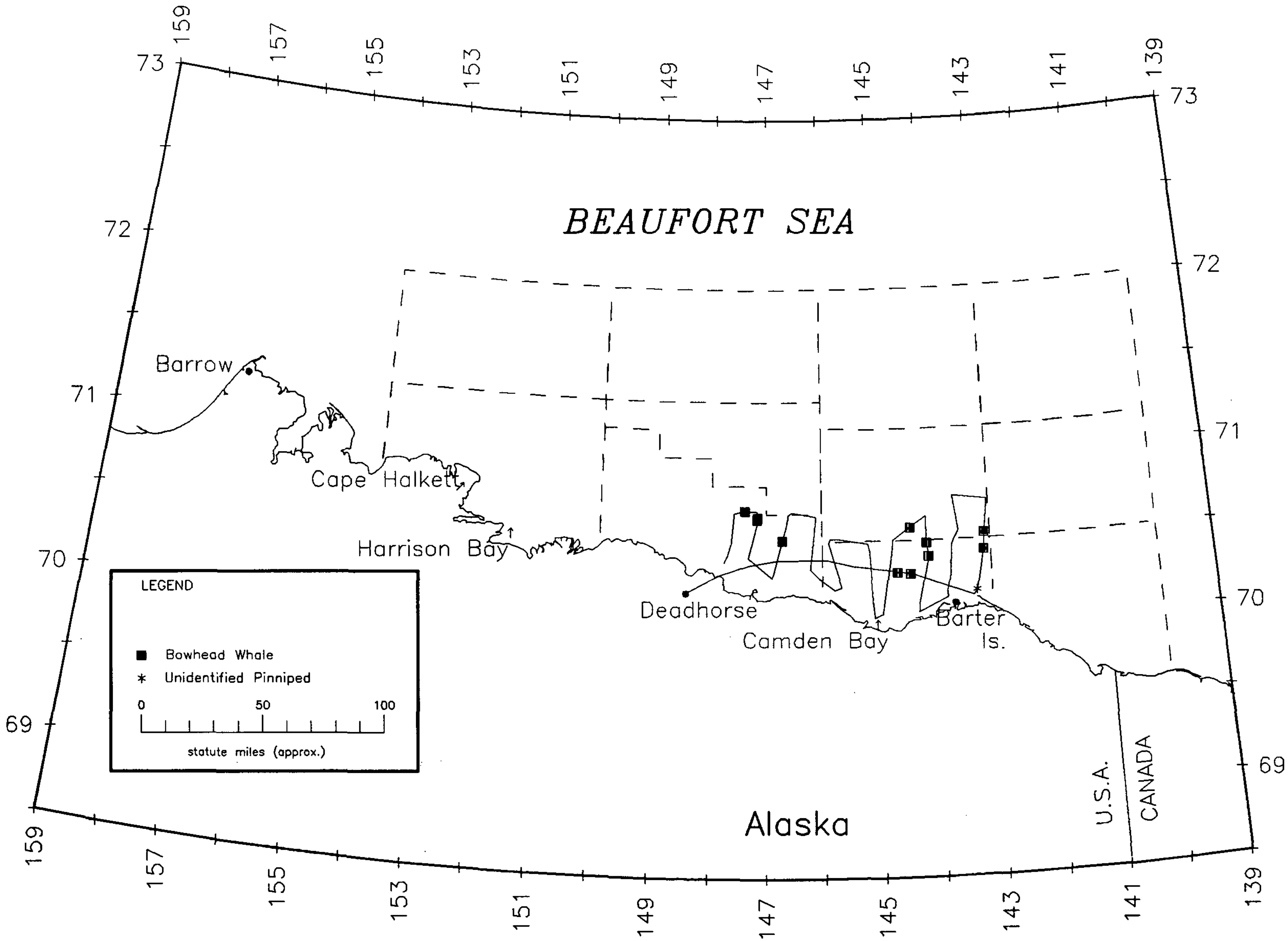
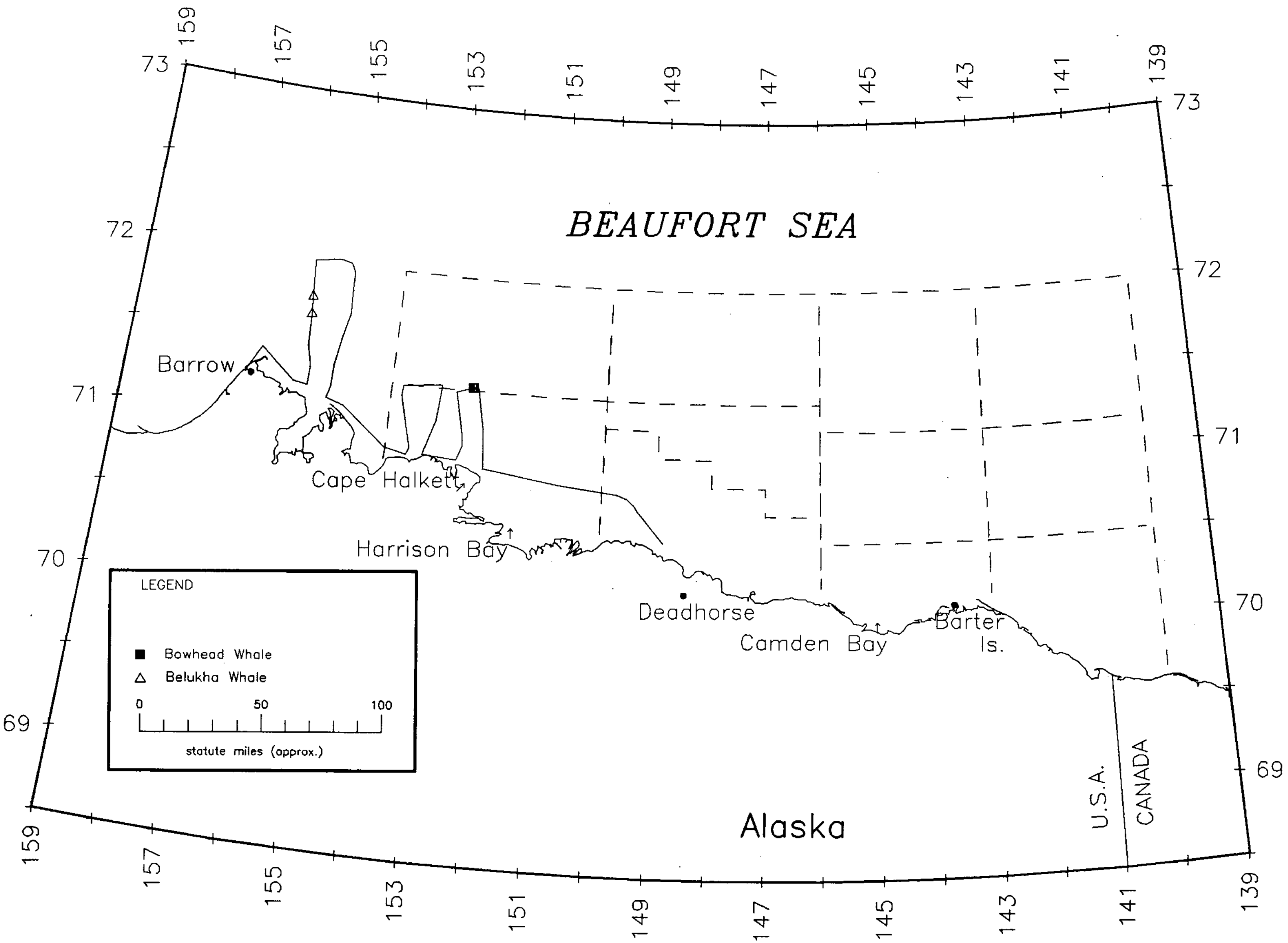


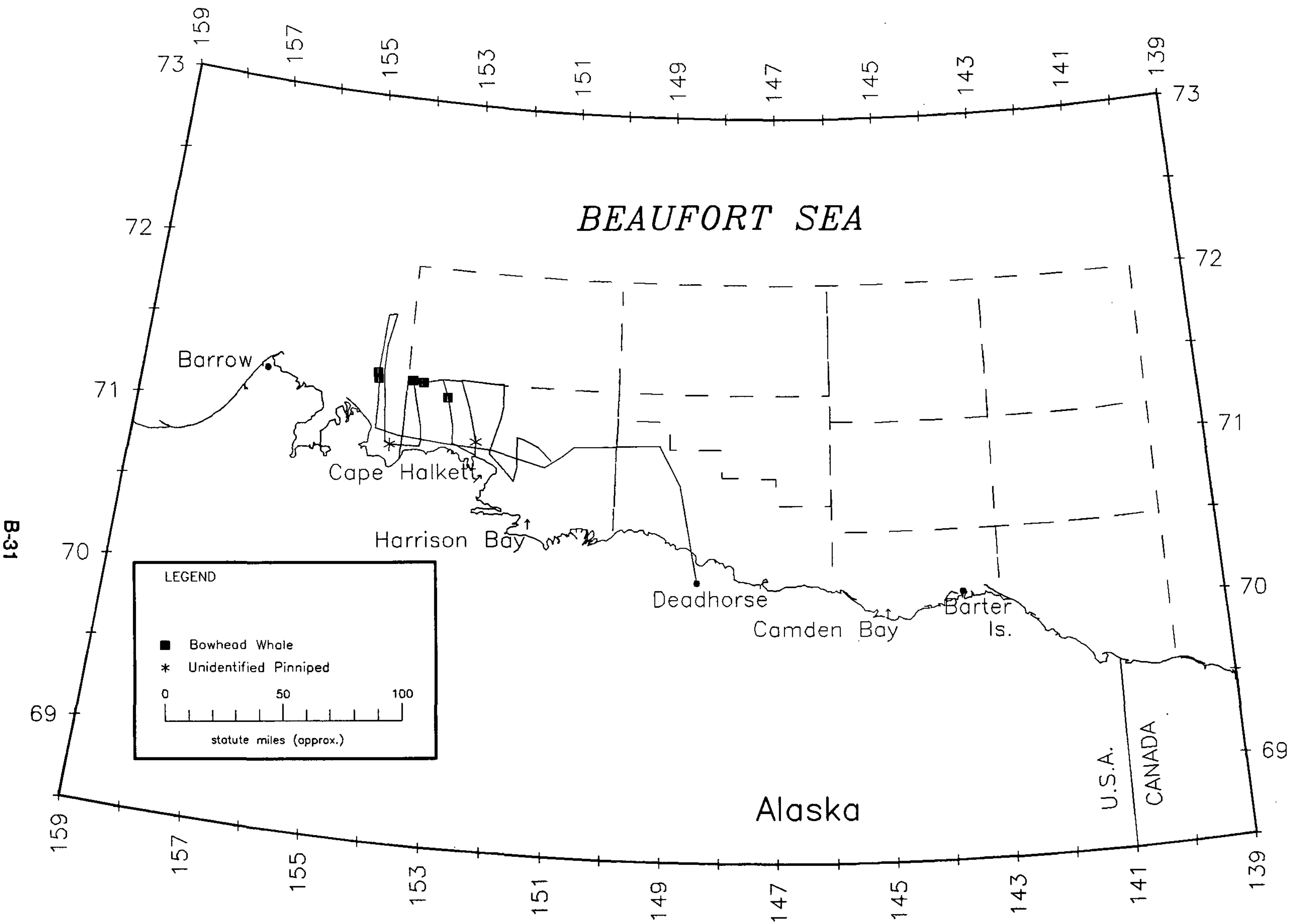
FLIGHT 18 1 October 1990
Survey Track and Sightings



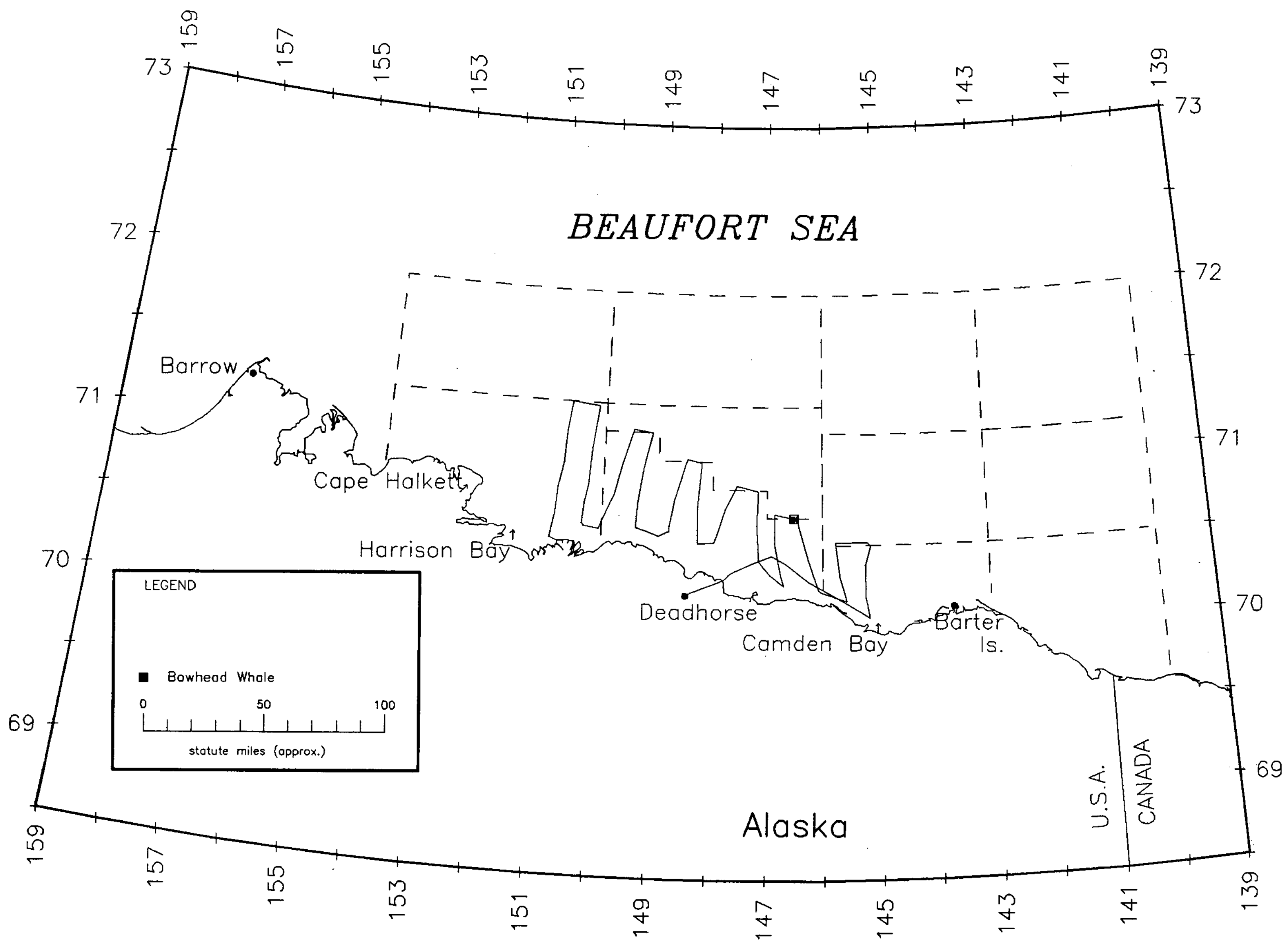
FLIGHT 19 2 October 1990
Survey Track and Sightings



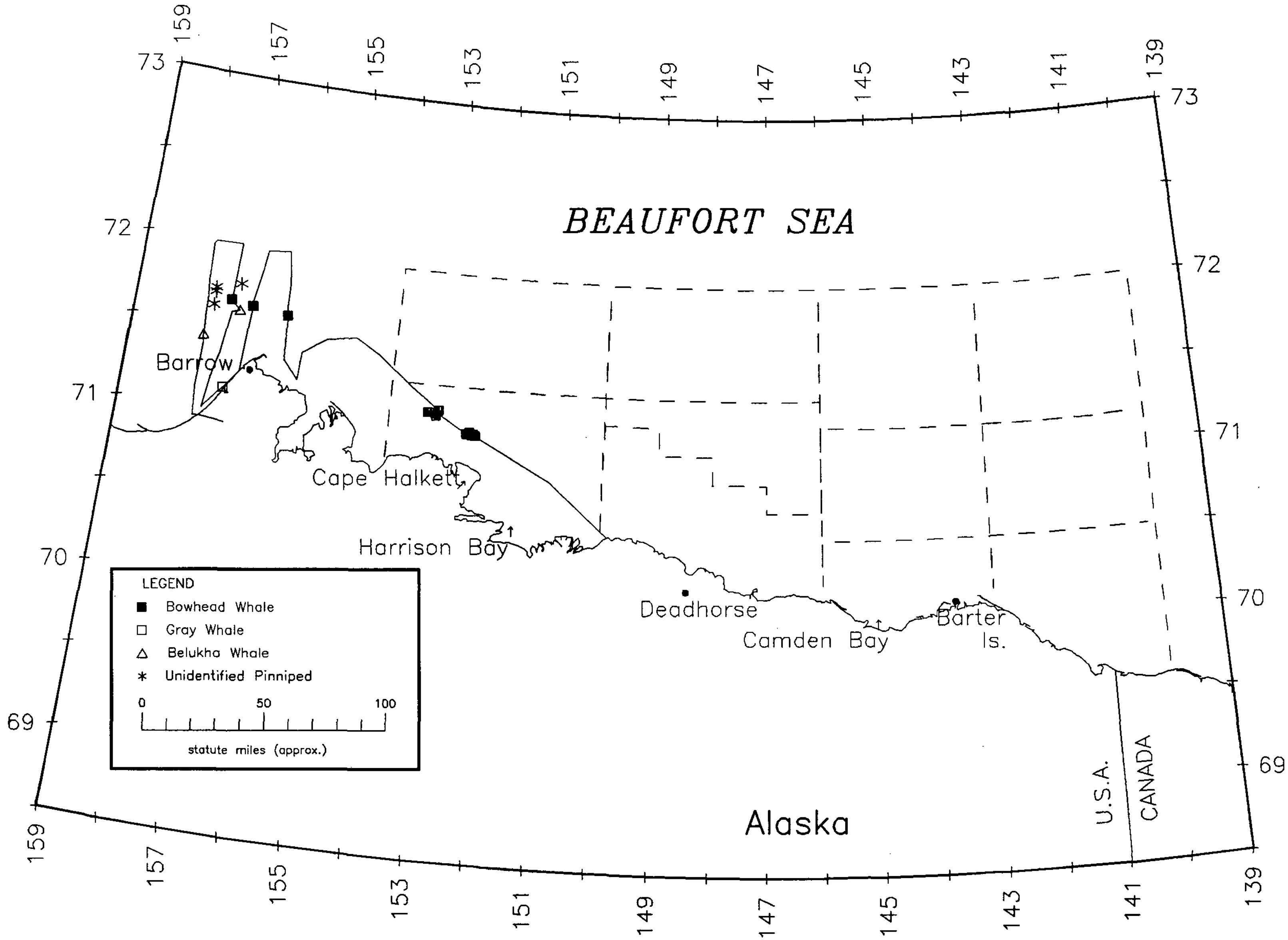
FLIGHT 20 3 October 1990
Survey Track and Sightings



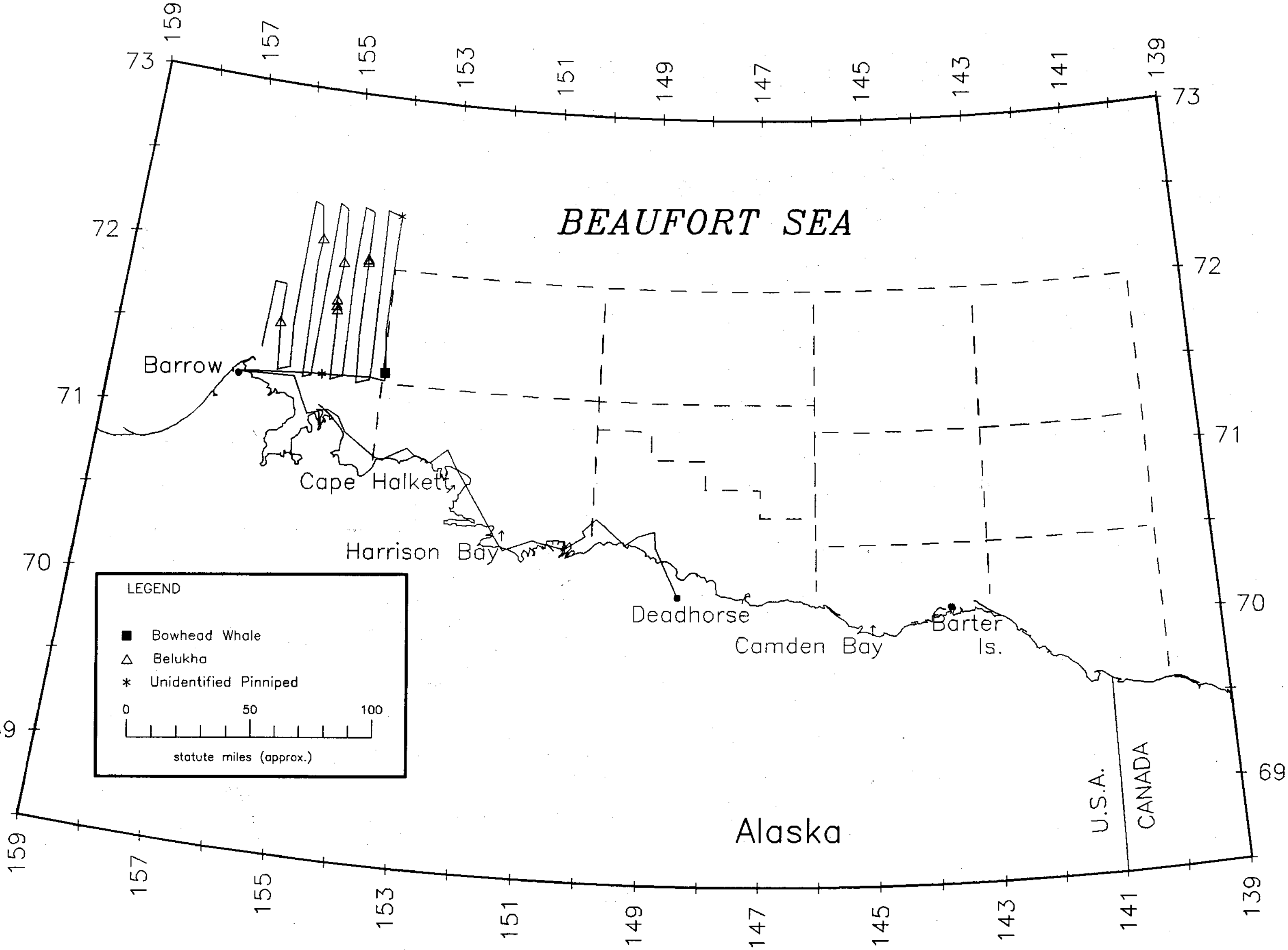
FLIGHT 21 9 October 1990
Survey Track and Sightings



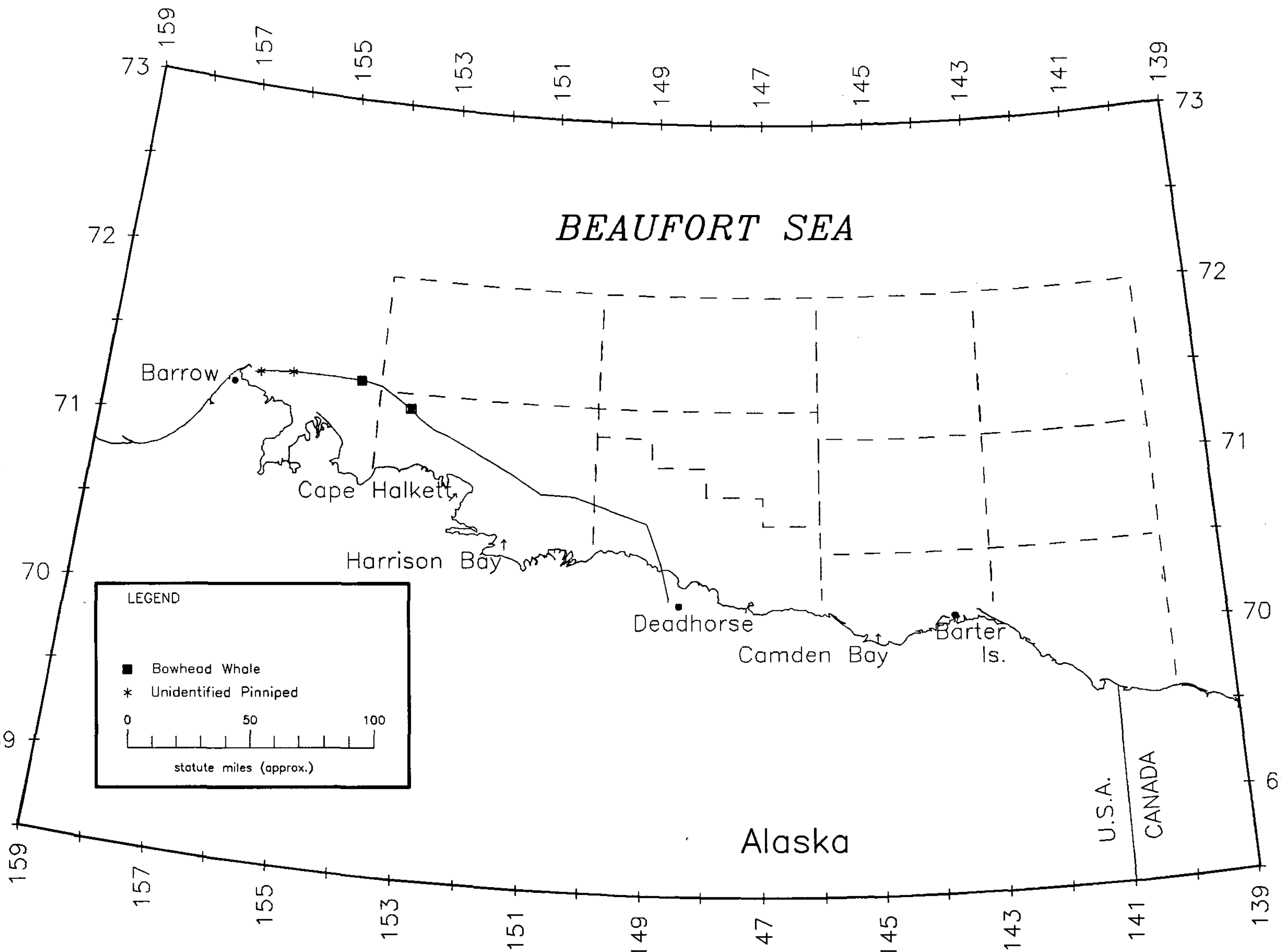
FLIGHT 22 10 October 1990
Survey Track and Sightings



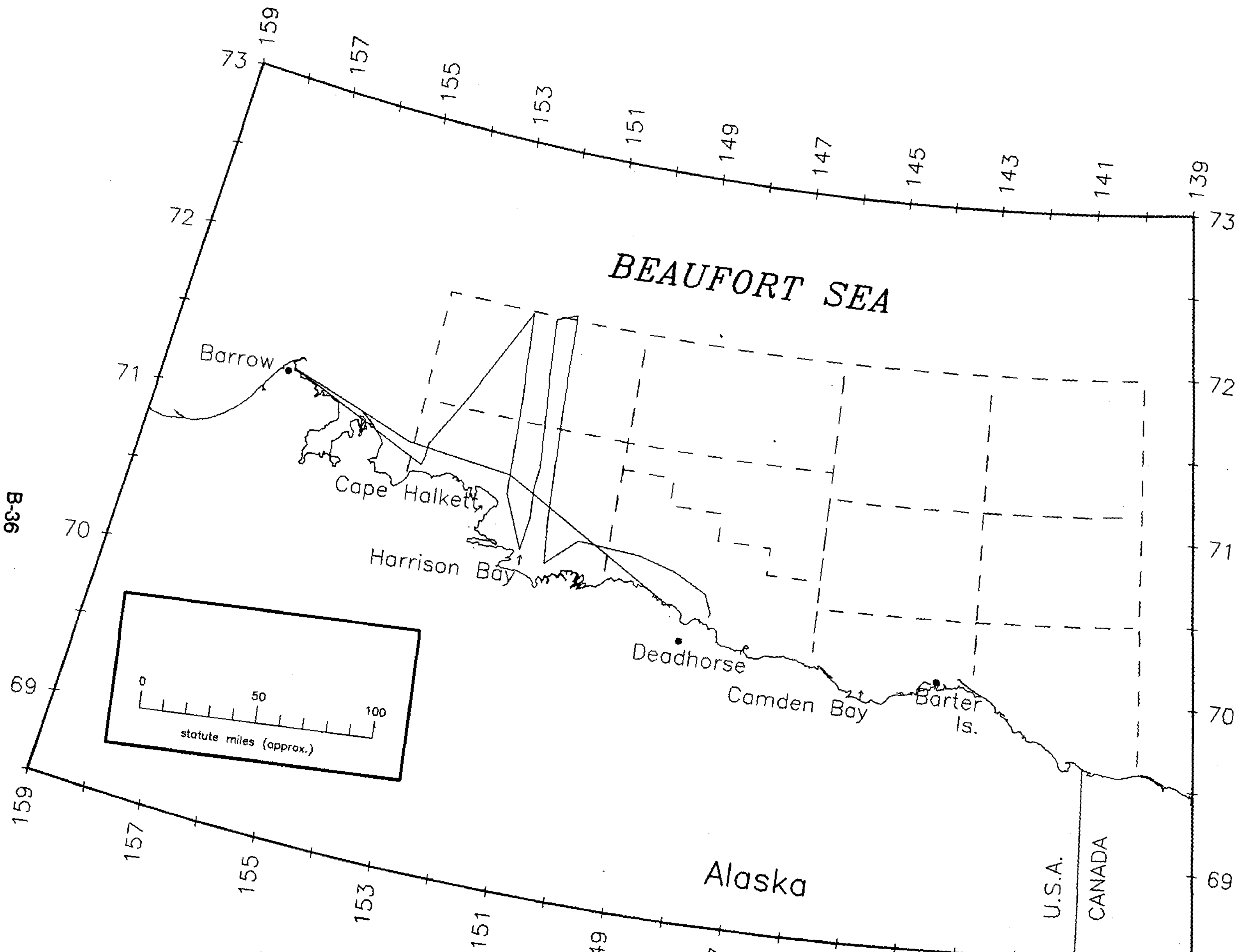
FLIGHT 23 11 October 1990
Survey Track and Sightings



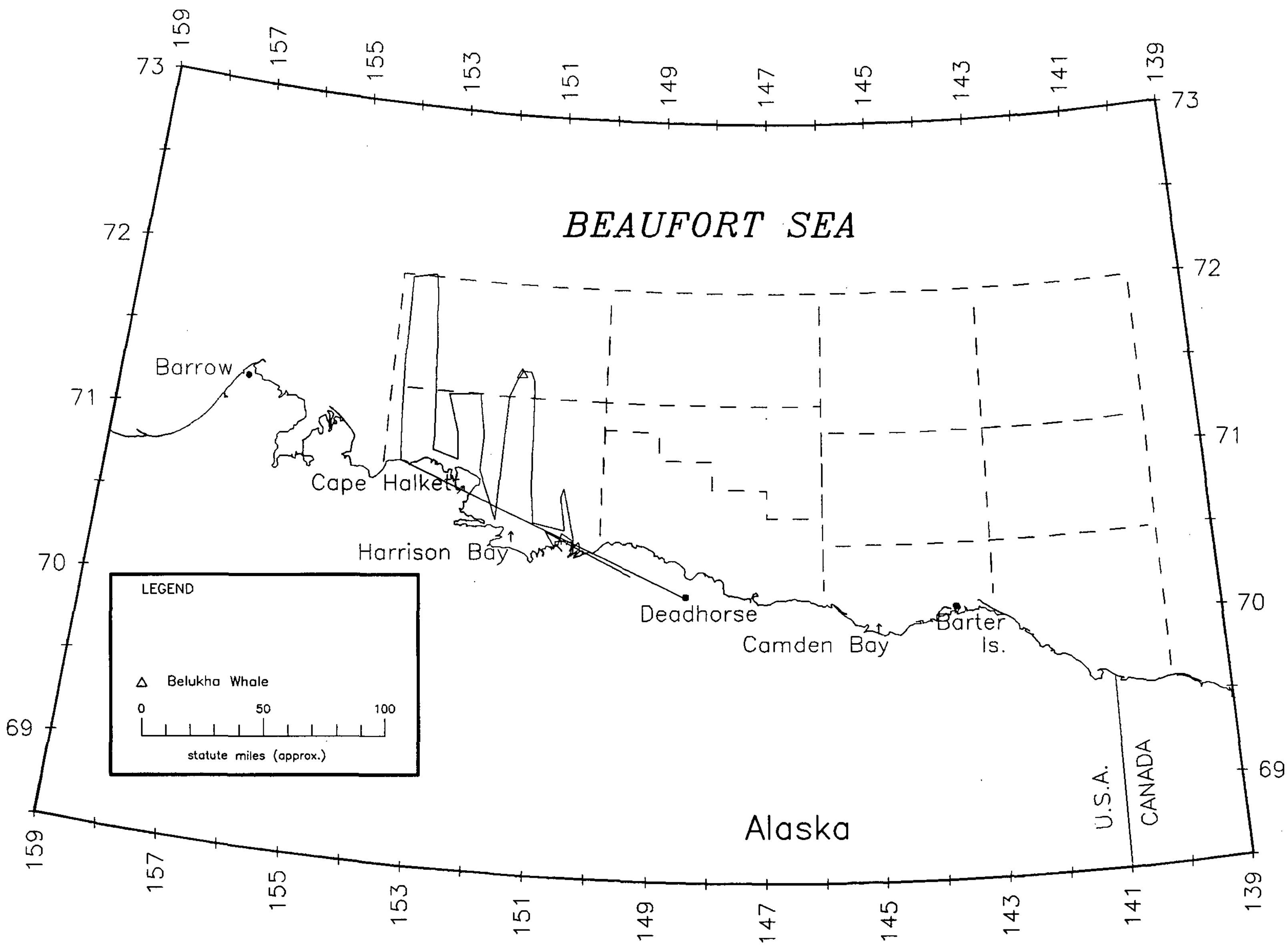
FLIGHT 24 13 October 1990
Survey Track and Sightings



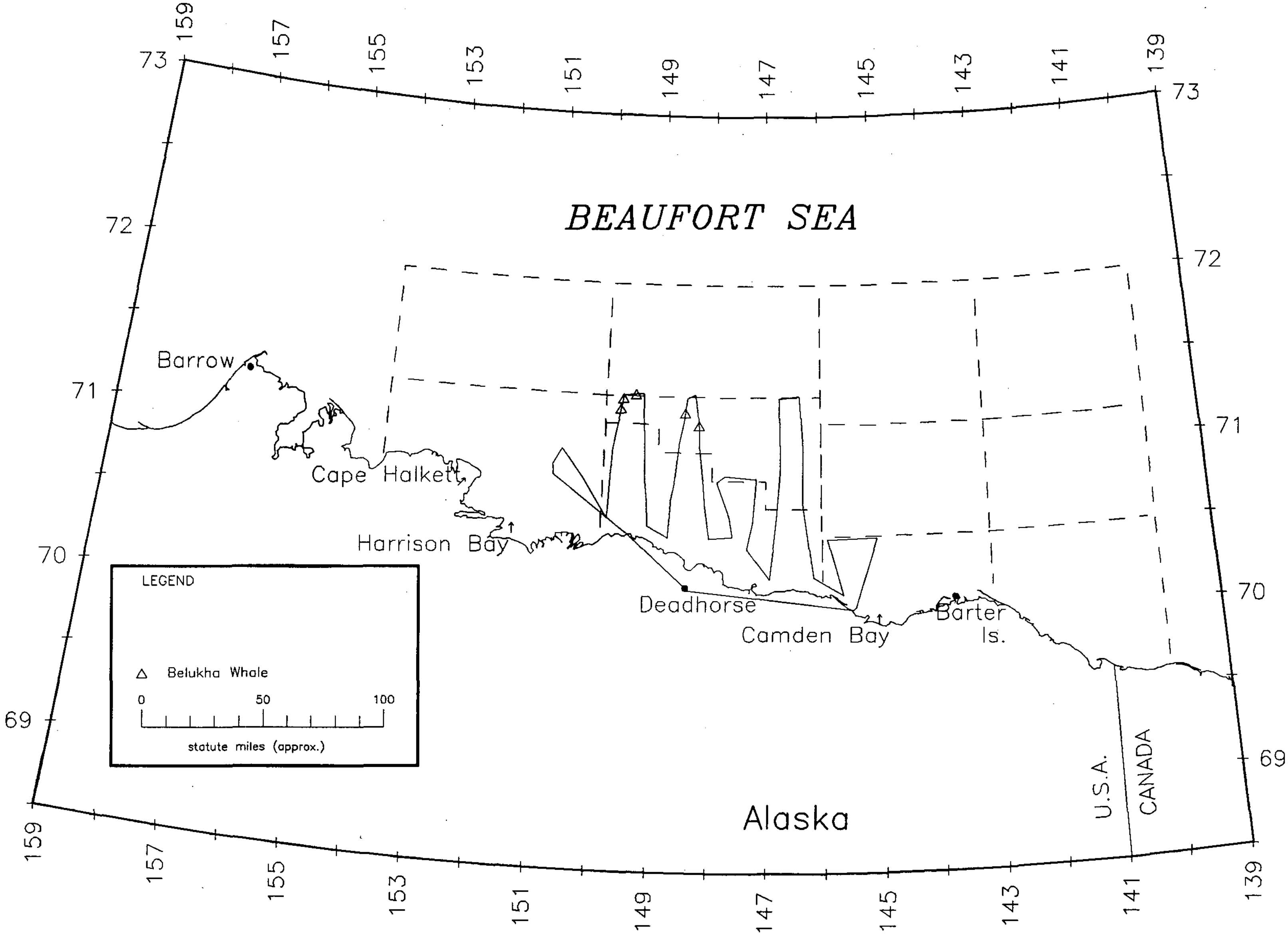
FLIGHT 25 14 October 1990
Survey Track and Sightings



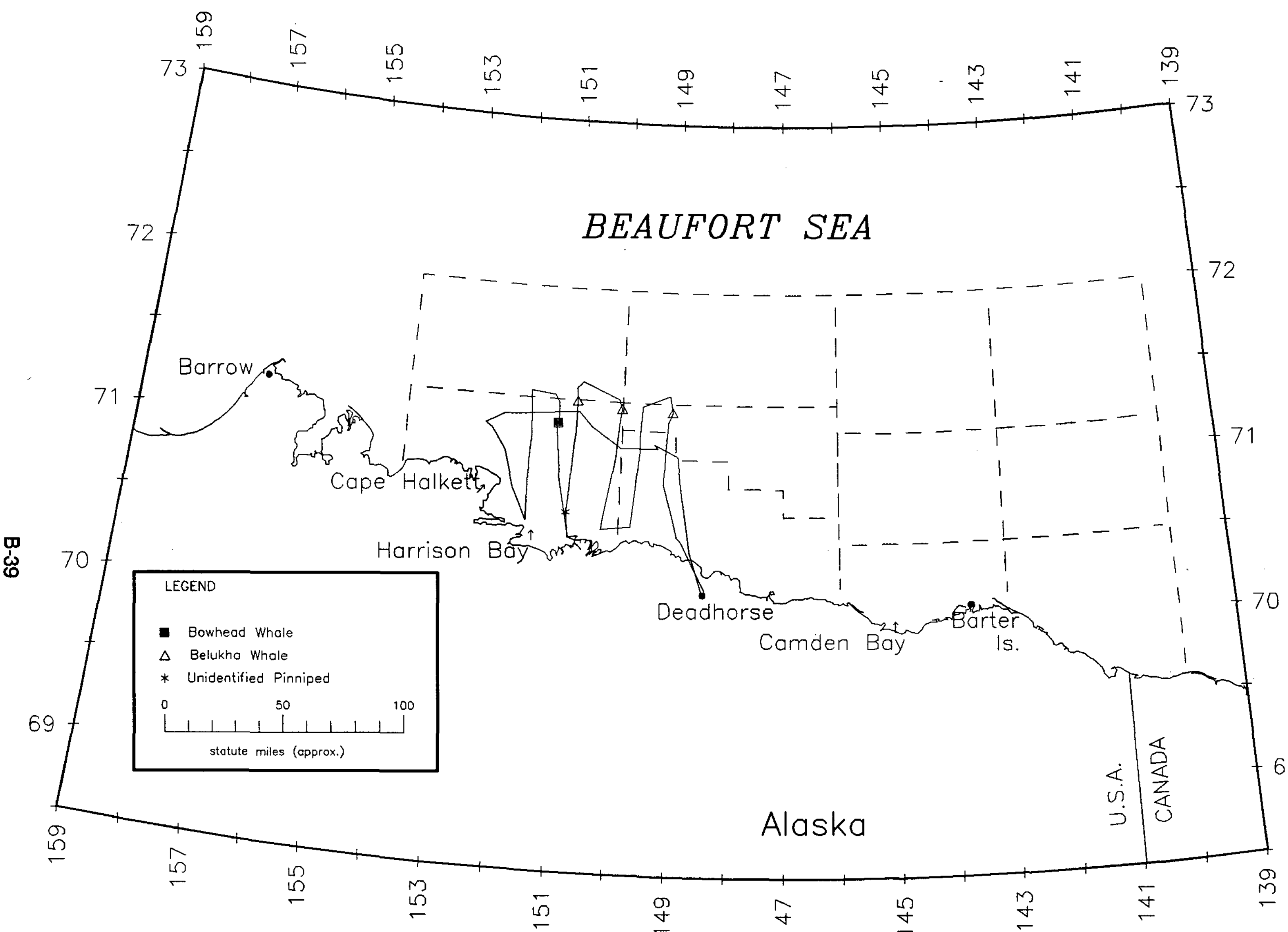
FLIGHT 26 15 October 1990
Survey Track and Sightings



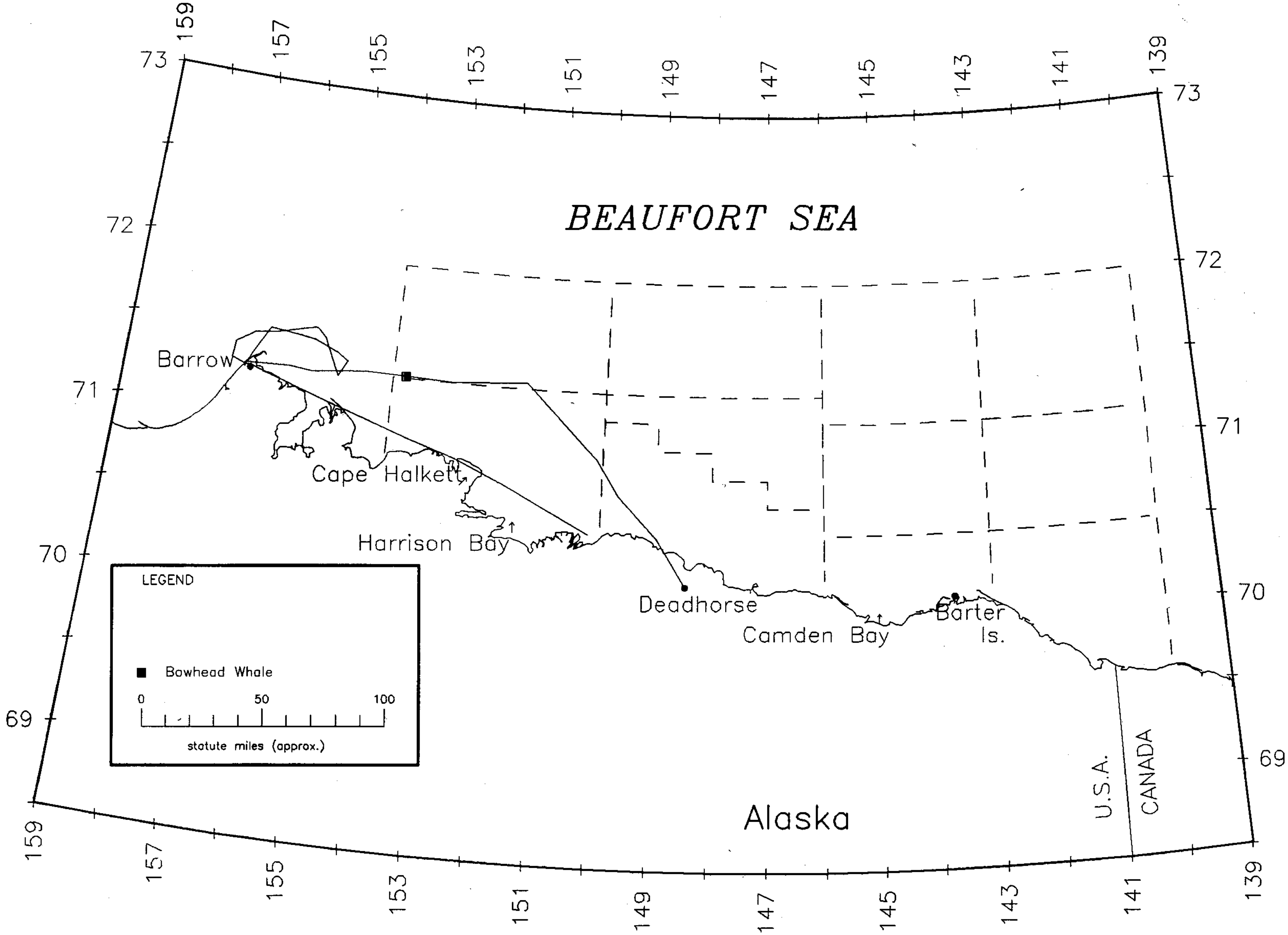
FLIGHT 27 16 October 1990
Survey Track and Sightings



FLIGHT 28 17 October 1990
Survey Track and Sightings



FLIGHT 29 18 October 1990
Survey Track and Sightings



FLIGHT 30 19 October 1990
Survey Track and Sightings

GLOSSARY OF ACRONYMS, INITIALISMS, AND ABBREVIATIONS

AC	alternating current
ANOVA	analysis of variance
BLM	Bureau of Land Management
C	Celsius
CI	confidence interval
cm	centimeter
ELT	emergency location transmitter
ESA	Endangered Species Act
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

GLOSSARY

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As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interest of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. Administration.