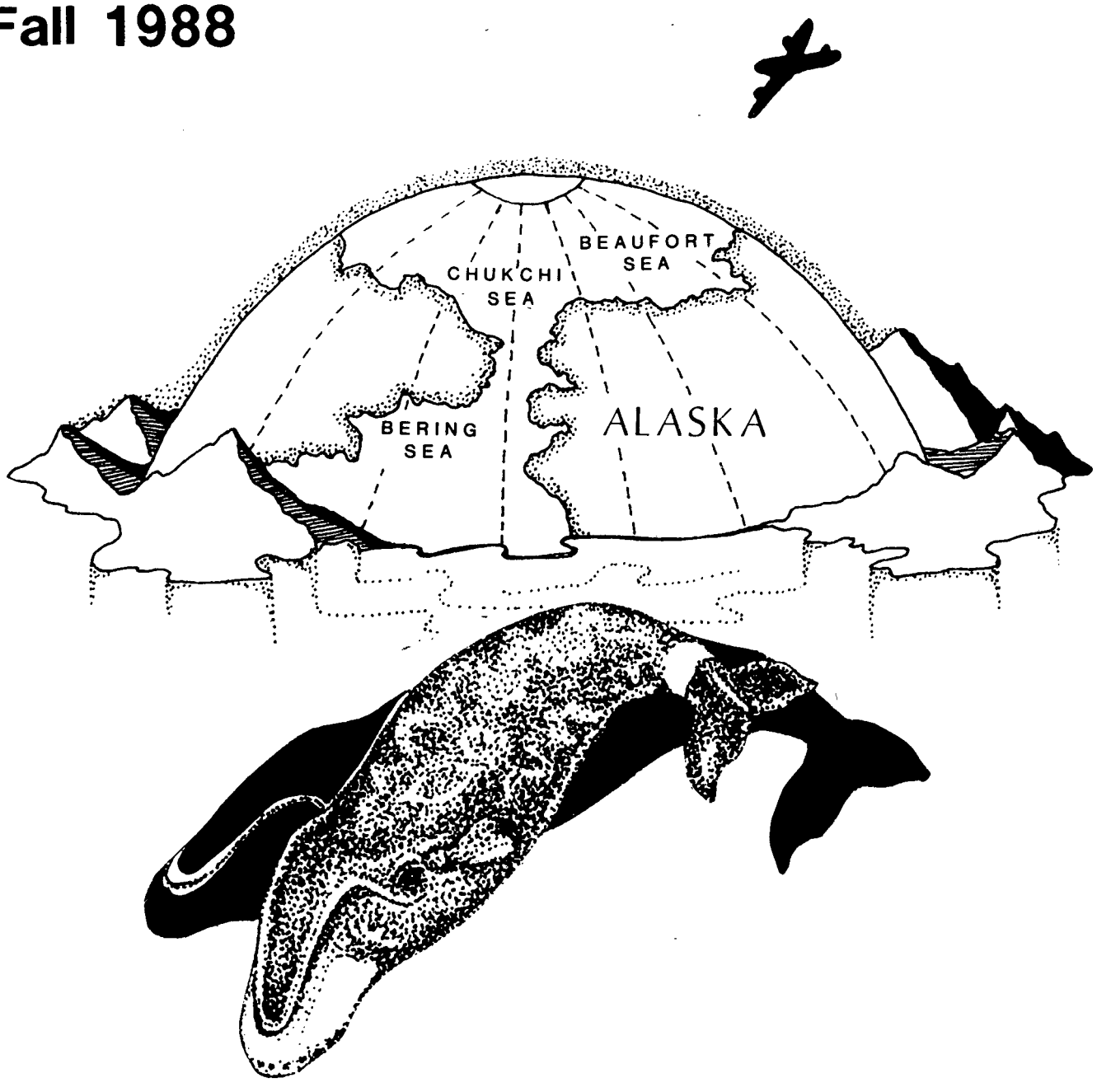
OCS Study
MMS 89-0033

Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 1988



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

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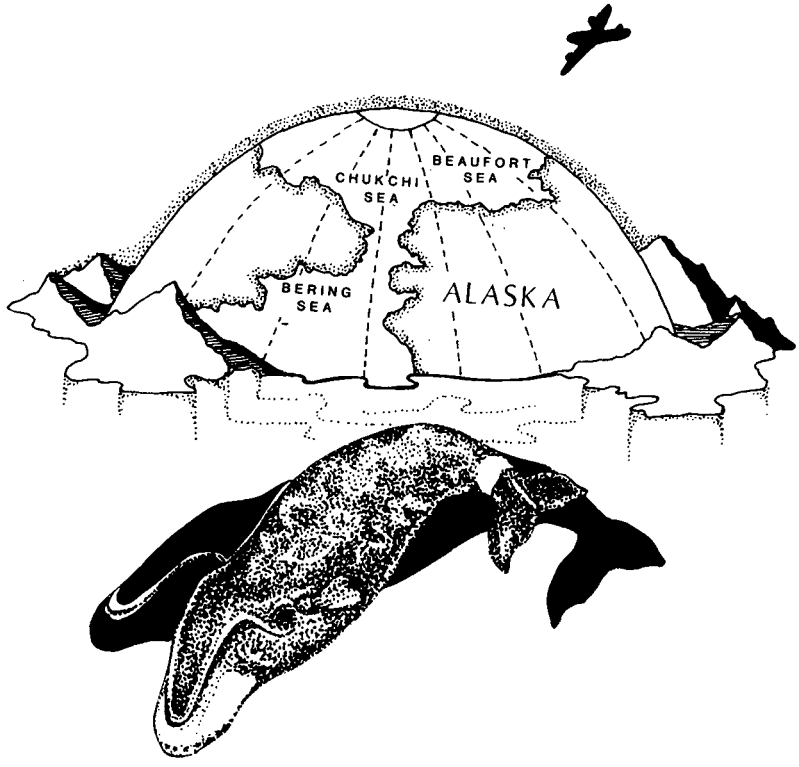
Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 1988

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



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

Anchorage, Alaska
1989

ABSTRACT

This report describes field activities and data analyses for aerial surveys of bowhead whales conducted between 1 September 1988 and 20 October 1988 in the Beaufort Sea, primarily between 140°W. and 154°W. longitudes south of 72°N. latitude. A total of 37 bowhead whales, 4 gray whales (including one dead whale), 180 beluga whales, 16 bearded seals, 51 ringed seals, 34 unidentified pinnipeds, and 21 polar bears were observed in 1988 during 121.44 hours of survey effort that included 54.75 hours on random transects. The initial sighting of bowhead whales in Alaskan waters occurred on 14 September 1988. Half (median) of the 37 bowheads observed had been counted by 30 September, while the peak count (mode) of 8 bowhead whales occurred on 9 October 1988. The last bowhead sighting in the Beaufort Sea occurred on 13 October 1988 in an ice lead (ice cover during September and October 1988 was exceptionally heavy). Except for one truly anomalous year (1983) when the fall migration occurred in relatively deep water, median and mean water depths at random bowhead sightings in 1988 (42 meters and 61 meters, respectively) were generally consistent with values for years of heavy or moderate ice coverage.

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Project Management

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

Project Field Scientists

Stephen D. Treacy, Team Leader (Flights 1-8 and 16-26)
Karen J. Gibson, Team Leader (Flights 9-15 and 26-32)
John Dunlap, Data Recorder-Observer (Flights 1-6 and 8-16)
Don Hansen, Observer (Flights 1-6 and 8-15) and Data Recorder-Observer (Flight 7)
Kevin Banks, Data Recorder-Observer (Flights 15-32)
Gail Irvine, Ph.D., Observer (Flights 16-32)
Brunhilde O'Brien, Alternate Observer (Flights 22-24)
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Contracting Officer's Technical Representative - Supporting Contract

Dale Kenney (MMS/Office of Aircraft Services IA 14-12-0001-30421)

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I. INTRODUCTION

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

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

In response to information needed for environmental impact statements (EIS's) and environmental assessments under the National Environmental Policy Act of 1969, and to assure protection of marine mammals under the Marine Mammal Protection Act of 1972 (16 U.S.C. 1361-1407) and the Endangered Species Act (ESA) of 1973, BLM funded numerous studies involving acquisition and analysis of marine mammal and other environmental data.

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

On 14 May 1982, the Secretary of the Interior imposed an approximately 2-month seasonal-drilling restriction on exploratory activity in the joint Federal/State Beaufort Sea sale area. The period of restriction would vary depending on bowhead whale presence, and "this determination would require development of a monitoring program. . ." (USDOI, MMS, 1982). Subsequently, MMS (Alaska OCS Region) adopted a monitoring plan for endangered whales that required aerial surveys. The Diapir Field Sale 87 Notice of Sale (1984) states that "Bowhead whales will be monitored by the Government, the lessee, or both to determine their locations relative to operational sites as they migrate through or adjacent to the sale area" (USDOI, MMS, 1984). The Beaufort Sea Sale 97 Notice of Sale (1988) does not contain a seasonal-drilling restriction but states that "MMS intends to continue its areawide endangered whale monitoring program in the Beaufort Sea during exploration activities. The program will gather information on whale distribution and abundance patterns and will provide additional assistance to determine the extent, if any, of adverse effects to the species" (USDOI, MMS, 1988).

Between 1979 and 1987, MMS 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 these whales was approved by the Associate Director for Offshore Minerals Management. The MMS will continue using MMS personnel to perform fieldwork and reporting activities for the Beaufort Sea on an annual basis.

To assure consistency with earlier surveys, personnel from NOSC and SEACO, Inc., actively participated in the training of project observers. Initial training included lectures, slide presentations, simulated data-collection and field-analysis workshops with the onboard computer system, and aerial surveys of beluga

whales in Cook Inlet. Previous observers participated as additional observers on some flights and conducted periodic consistency checks of the collected data during 1988 Beaufort Sea surveys. A comparison of sighting rates between MMS and previous observers appears in Appendix C. Following the field season, the contractor for the previous bowhead surveys performed computerized analyses of the raw data using the same computer programs developed for those earlier surveys.

Concurrent studies by NOSC and SEACO, Inc., in the Chukchi Sea have employed identical aerial-survey and data-analysis methodology. Data collected for the Chukchi Sea in 1988 will be analyzed and compared to other data from the same study area following the 1989 field season. These data, as well as previous survey reports, are available for inspection at the Minerals Management Service, Library/Public Information Room, 949 East 36th Avenue, Anchorage, Alaska 99508-4302.

The present goals of the ongoing endangered whale-survey program are to:

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

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

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

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

5. Record and map other marine mammals observed incidentally to endangered whale surveys; and

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

II. METHODS AND MATERIALS

A. Study Area

The overall annual survey program is based on a design of random field transects within established geographic blocks in and adjacent to Chukchi and Beaufort Sea sale areas offshore of Alaska. The present study, which was focused on the bowhead whale migration from 1 September 1988 to 20 October 1988, included Beaufort Sea Survey Blocks 1 through 11 (Fig. 1) between 140° W. and 154° W. longitude south of 72° N. latitude. Occasional flights involved survey coverage in Canada as far east as 137° W. longitude and west to 156° 30 ' W. longitude.

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

Local weather patterns affect the frequency and effectiveness of all marine aerial surveys. The present study area is in the arctic climate zone, where mean annual temperature is about -12° C. Precipitation ranges from 13 centimeters (cm) at Barrow to 18 cm at Barter Island and occurs mostly as summer rain. Fog frequently reduces visibility along the coast during the open-water season. Winds are persistent in direction and speed. Mean annual speed is 5 m per second at Barrow and 6 m per second at Barter Island. 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 aircraft used for the surveys was a de Havilland Twin Otter Series 300 with call sign 302EH. The aircraft was equipped with a Global Navigation System (GNS) 500 that provided continuous position updating (0.6-km/survey-hour [h] precision) and transect-turning-point programming. The Twin Otter's maximum time aloft was approximately 4.5 h extended to 7.5 h through the use of a supplemental onboard fuel tank.

The Twin Otter was equipped with small bubble windows aft for an observer and a data recorder-observer. A third observer-navigator occupied the copilot seat and was afforded good forward and side viewing from that position. Each observer had a hand-held Suunto clinometer to take angles on endangered whale sightings. Observers and pilots were linked to common communication systems, and commentary could be recorded.

A portable (Hewlett-Packard 85) computing system was used aboard the aircraft to store and later to analyze flight data. The computer was interfaced to the GNS for automatic input of entry number, time, latitude, and longitude and to the radar altimeter for precise input of altitude.

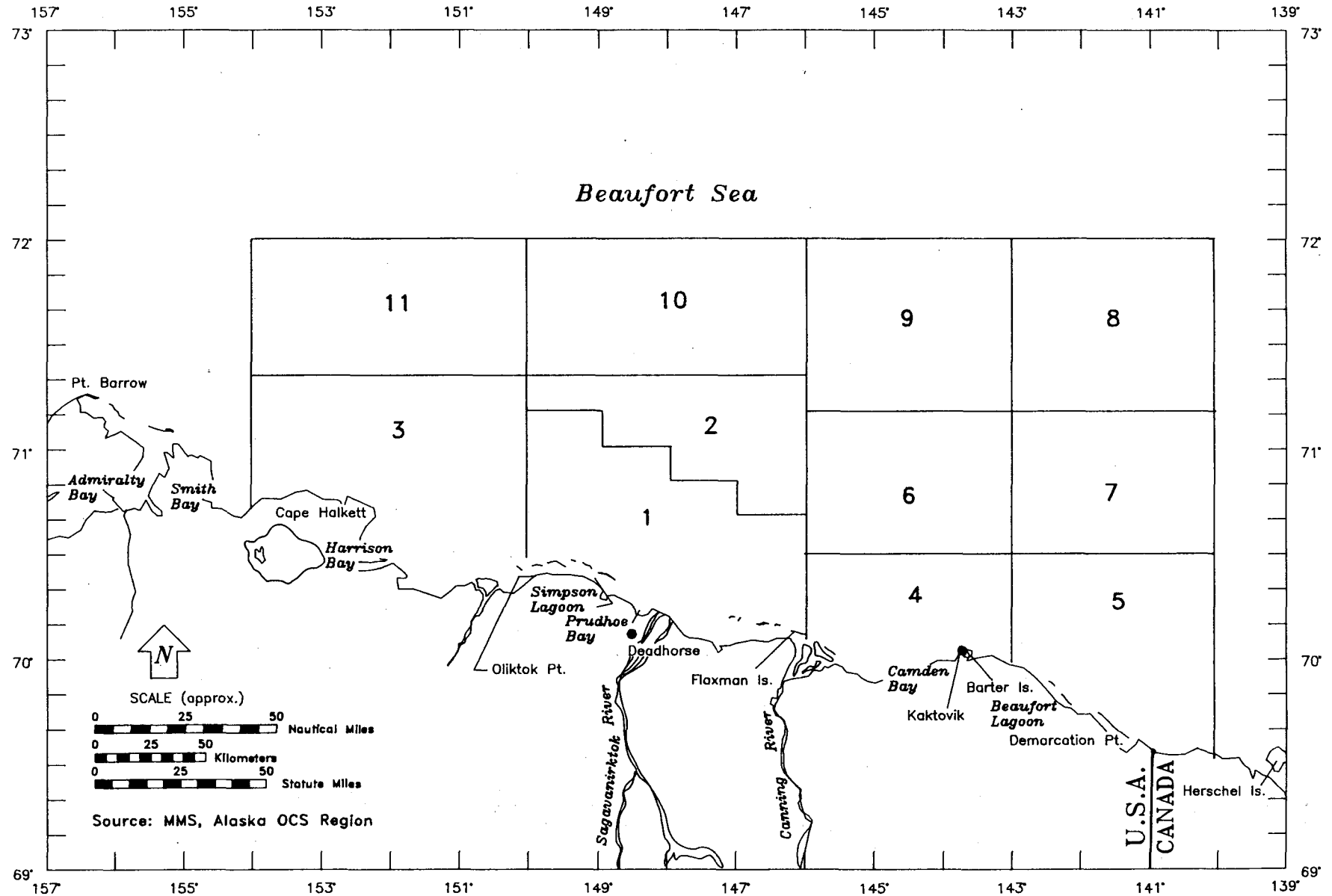


Figure 1. Fall 1988 Study Area Showing Survey Blocks

C. Aerial-Survey Design

Aerial surveys were based out of Deadhorse, Alaska, from 1 September to 20 October 1988. The field schedule was designed to monitor the progress of the Fall 1988 bowhead migration across the Alaskan Beaufort Sea. Particular emphasis was placed on regional surveys to assess fine-scale shifts in the migration pathway of bowhead whales in this area. Additional monitoring entailed the priority coordination and data management necessary to support implementation of seasonal offshore-drilling regulations.

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

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

Nonrandom surveys were flown to further identify whales and their behaviors adjacent to a transect line or when in transit to a transect block. Data from nonrandom surveys were considered combinable with random-transect data to obtain overall distribution patterns, relative abundance, and behavior of whales and other marine mammals.

D. Survey-Flight Procedures

During a typical flight (Fig. 2), a search leg was flown to the survey block, followed by a series of random-transect legs joined together by connect legs, with search legs conducted back to the base of operations. Surveys generally were flown at a target altitude of 458 m. This altitude was maintained, when weather permitted, in order to maximize visibility and minimize potential disturbance to marine mammals.

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

When bowheads were encountered while surveying a transect line, the aircraft sometimes diverted from transect for brief periods (<10 minutes [min]) 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

One of four different data-entry formats was selected on the computer, depending on the reason for entry. Whenever possible, a 28-key entry format was used when whales were seen (Table 1). An abbreviated 20-key sighting-update format was used when several whales were sighted within a short period of time. An even shorter rapid-sighting update (9-key format) was used in areas of extremely high animal concentrations to avoid any lumping of sightings. A position-update, 13-key format including data on weather, visibility, ice cover, and sea state was entered at turning points, when changes in environmental

Table 1

Data-Entry Sequence on the Portable Flight Computer

Sequence	Rapid Sighting Update (9-Key)	Position/Environmental Update (13-Key)	Sighting Update (20-Key)
1. Entry number	X	X	X
2. Time	X	X	X
3. Latitude	X	X	X
4. Longitude	X	X	X
5. Altitude	X	X	X
6. Reason for entry	X	X	X
7. Survey type (flag)	X	X	X
8. Weather		X	
9. Visibility right		X	
10. Visibility left		X	
11. Ice coverage		X	
12. Ice type		X	
13. Sea state		X	
14. Water color			
15. Water Depth			
16. Species	X		X
17. Clinometer angle			X
18. Sighting cue			X
19. Behavior			X
20. Total number	X		X
21. Estimated size class			X
22. Total number calves			X
23. Swim direction			X
24. Estimated swim-speed class			X
25. Response to aircraft			X
26. Repeat sighting			X
27. Photo roll number			X
28. Photo frame numbers			X

Source: MMS, Alaska OCS Region.

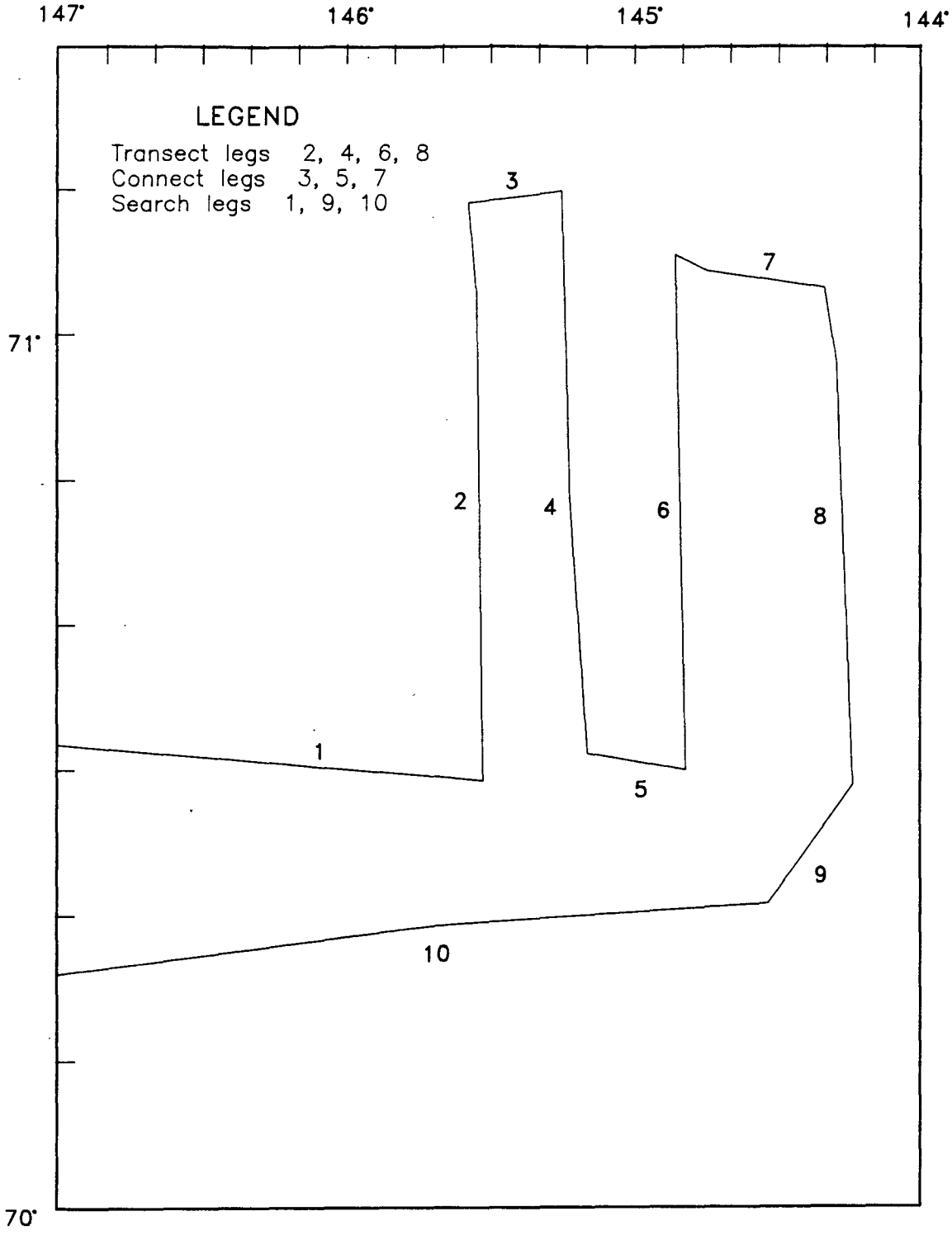


Figure 2. Example of Computer–Generated Flight Track

conditions were observed, and otherwise at 10-minute intervals. All entries were coded to reflect the type of survey being conducted (Table 1: No. 7).

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

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

Sea state was recorded according to the Beaufort scale outline in Piloting, Seamanship, and Small Boat Handling (Chapman, 1971). Ice type was identified using terminology presented in Naval Hydrographic Office Publication Number 609 (USDOD, Navy, 1956), and ice cover was estimated in percent.

F. General Data Analyses

Ice concentrations in the Beaufort Sea were analyzed every seventh day from 30 August through 18 October 1988. Graphics were digitized from U.S. Navy-NOAA Joint Ice Center Southern Ice Limit charts into categories of zero to 25-percent, 26- to 50-percent, 51- to 75-percent, and 76- to 100-percent ice cover.

Observed bowhead distribution was plotted semimonthly in relation to OCS oil and gas lease-sale areas within the Beaufort Sea study area. Sightings of gray and beluga whales, ringed and bearded seals, polar bears, and other marine mammals were depicted on separate maps.

An index of relative abundance was derived as whales per unit effort (WPUE = number of whales counted/h of survey effort) per survey block for bowheads and belugas. The timing of the 1988 bowhead migration through the study area was analyzed as sightings per unit effort (SPUE = number of sightings counted/h of survey effort) and WPUE per date.

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

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

Density estimates were based on strip-transect-analyses methods using only sightings made on random transect legs (Estes and Gilbert, 1978). Distance from the transect line was calculated trigonometrically from the altitude of the survey plane at the time of sighting and the clinometer angle recorded for each initial sighting location. Only endangered whale sightings within 1 km of random-transect legs were used to derive density estimates, since the number of sightings decreases markedly at greater distances from the trackline (Moore, oral comm., 1988). If no sightings were made on random transects within a survey area, that density was not calculated. Density estimates were derived by survey block and are presented, with a description of density-estimate methodologies, in Appendix A.

The general water depth at each bowhead sighting in the 1982-1988 database was initially derived using the computer program DPTH, which assigned a metric depth value averaged over an area 5 minutes (') of latitude by 20 ' of longitude in the Beaufort Sea west of 139 ° W. longitude and south of 72 ° N. latitude.

Table 2

Operational Definitions of Observed Bowhead Whale Behaviors

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

Source: MMS, Alaska OCS Region.

This scaling assigns depth to sighting locations with an accuracy of approximately ±3.5 m over most of the study area. At the shelf break between 100 m and 1,000 m in Regions B and C', the accuracy was approximately ±20 m. Values assigned to each segment were subjectively averaged from depths read off of NOAA Provisional Chart 16004 when the DPTH software was written.

Beginning with this report, a supplemental program "NEW DEPTH" was used to assign more accurate depth values. These "new depths" were generated using a finer grid; the dimensions of this grid were 3' of latitude by 10' of longitude, making each grid box less than one-third the size of the original grid boxes used for "old depths." In offshore areas where depth soundings were far fewer, "new depths" were entered only if there was a depth sounding in, or within the vicinity of (adjacent to), the grid box. Sightings that occur in offshore areas where no "new depth" value has been assigned retain the "old depth" value. In most instances, use of the DPTH and NEW DEPTH programs in series resulted in depth values that tended to be slightly deeper than those shown in previous reports (e.g., the overall median depth reported changed from 31 m for Fall 1987 [Treacy, 1988] to 34 m for this report).

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

The analysis protocol specifying the use of median water depth to detect interannual shifts in the bowhead migration route is described in Chapters 4.2.3 and 5.3.3 of "Beaufort Sea Monitoring Program Workshop Synthesis and Sampling Design Recommendations" (Houghton, Segar, and Zeh, 1984) and is incorporated by reference from Ljungblad et al. (1987).

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

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

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

Because of the bathymetry of the Alaskan Beaufort Sea, a seaward displacement of the fall-migration route would be represented, via this analysis, as a shift to a deeper median depth.

To assess possible fine-scale shifts in the 1988 migration axis over the known fall-migration corridor, the median depth, 99-percent confidence interval (CI), and overall depth range were calculated for Regions B, C', and D' of the study area (Fig. 3). All bowhead sightings made while on random line transects were included in the median-water-depth analyses. Region B is delimited by 150° W. and 153° 30' W. longitudes, south of 72° N. latitude. Region C' is between 146° W. and 150° W. longitudes south of 71° 20' N. latitude. Region D' is between 141° W. and 146° W. longitudes, south of 71° 10' N. latitude.

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

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

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

where $\alpha(2) = 0.01$, C is determined from a table of critical values (Zar, 1984: Table B-26) when sample size $n \geq 8$. The CI's were calculated at the 1-percent level to reduce the probability of incorrectly asserting that a change in migration route had occurred based on comparing any one year to six others. For example, the probability of incorrectly determining a change occurred based on one of five tests is approximately 23 percent, if tested at the 5-percent level, but only about 5 percent if tested at the 1-percent level (Houghton, Segar, and Zeh, 1984).

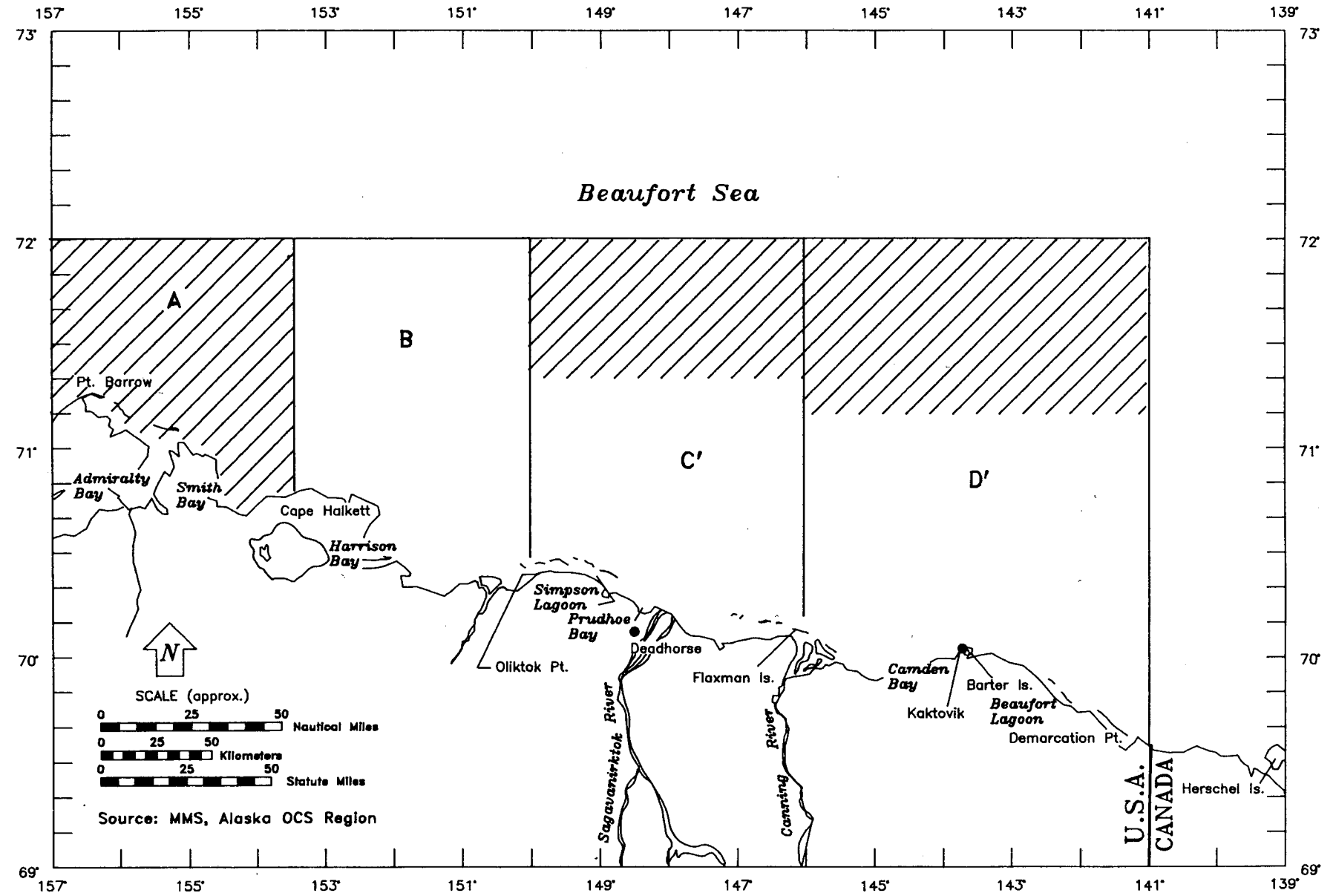


Figure 3. Regions B, C′, and D′ (used in median–water–depth analyses)

The Mann-Whitney U test was then used to address the question of potential shifts in the axis of the bowhead whale fall migration route. The Mann-Whitney test is a nonparametric procedure performed on ranked samples (Zar, 1984). A series of Mann-Whitney paired comparisons were made on annual depth values derived from the MEDEPTH2 data file, with each year compared to all others such that annual and/or overall shifts in migration route over the 1979-1988 study period could be evaluated. Similar paired comparisons were made by region (B, C', and D') such that annual variations or potential shifts in median depth could be assessed for these smaller areas.

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

III. RESULTS

A. Environmental Conditions

Ice coverage was generally heavy during September and October 1988 in the Alaskan Beaufort Sea (Figs. 4 through 11) with some less concentrated ice (0-25%) near the shore during September. High concentrations of floe and broken floe ice throughout the bowhead migration may have reduced observer visibility for whales near the surface or at a wide angle from the transect centerline.

Environmental conditions during survey flights are summarized on a daily basis in Appendix B.

B. Survey Effort

Daily totals of kilometers and hours flown per survey flight are shown in Table 3. A total of 28,598 km of surveys were flown in 121.44 hours (Table 4) in the Beaufort Sea at an overall average speed of 235.5 km/h. A total of 13,396 km of random-transect lines were flown in 54.75 hours (Table 4) at an average speed of 244.7 km/h. These random transects constituted 46.8 percent of the total kilometers flown and 45.1 percent of the total flight hours. The number of flight hours over each survey block is shown in subsequent analyses.

Day-to-day flight tracks for the Twin Otter aircraft are shown in Appendix B. Survey flight lines are shown in Figures 12 through 15. During the month of September (Figs. 12 and 13), transect grids east of 143 ° W. longitude included some near replicates that varied uniformly from a single random flight pattern.

During the first half of September (Fig. 12), all flight effort was concentrated east of Deadhorse in order to record the initial part of the westward migration of the bowhead whale. There were 10.21 hours of random transects flown from a total of 29.99 flight hours during this period (Table 4), constituting 18.6 percent and 24.7 percent, respectively, of the Fall-1988 study effort.
During the second half of September (Fig. 13), flight effort was slightly increased west of Deadhorse as the bowhead migration progressed. There were 17.86 hours of random transects flown from 36.31 total flight hours during this period (Table 4), constituting 32.6 percent and 29.9 percent, respectively, of the overall fall effort.

During the first half of October (Fig. 14), survey coverage was equally balanced east and west of Deadhorse. There were 21.54 hours of random transects flown from 43.37 total flight hours during this period (Table 4), constituting 39.3 percent and 35.7 percent, respectively, of the overall fall effort.

During the last half of October (Fig. 15), flights were divided both east and west of Deadhorse to provide data needed by NMFS in order to determine the end of the fall bowhead migration. There were 5.14 hours of random transects flown from 11.77 total flight hours during this period (Table 4), constituting 9.4 percent and 9.7 percent, respectively, of the overall fall effort.

C. Bowhead Whale (Balaena mysticetus) Observations

1. Distribution: Twenty-nine sightings were made for a total of 37 bowhead whales observed during Fall-1988 surveys in the study area (Table 5 and Figs. 16 through 19). None of the whales were calves. Figures 16 through 19 show sightings relative to lease tracts as delimited at the time of the Fall-1988 field season. Also shown is the location of the Kulluk, the only operative drilling structure in Federal waters during the survey. Daily sightings are shown on individual maps in Appendix B.

During the first half of September (Fig. 16), 3 sightings were made for a total of 7 bowhead whales. The first bowheads in the Alaskan Beaufort were sighted on 14 September north of Camden Bay (Appendix B: Flight 7). The westernmost sighting during this period was made north of Deadhorse, Alaska, on 14 September (Appendix B: Flight 7). Group sizes ranged between 1 and 4 whales.

Table 3

Aerial-Survey Effort in the Beaufort Sea, September-October 1988, by Survey Flight

Day	Flt. No.	Transect (km)	Connect (km)	Search (km)	Total (km)	Transect Time (h)	Total Survey Time (h)
3 Sep	1	442	91	509	1,042	1.73	4.22
4 Sep	2	440	81	456	977	1.80	4.02
7 Sep	3	0	0	911	911	0.00	3.75
8 Sep	4	335	57	660	1,052	1.33	4.38
11 Sep	5	0	0	247	247	0.00	0.95
12 Sep	6	439	87	480	1,006	1.72	4.08
14 Sep	7	481	150	197	828	1.93	4.37
15 Sep	8	430	61	552	1,043	1.70	4.22
16 Sep	9	375	130	169	674	1.52	2.80
17 Sep	10	439	79	516	1,034	1.73	4.07
18 Sep	11	439	71	520	1,030	1.75	4.15
21 Sep	12	0	0	33	33	0.00	0.18
23 Sep	13	589	82	495	1,166	2.32	4.65
24 Sep	14	709	78	256	1,043	2.83	4.17
25 Sep	15	419	109	154	682	1.73	2.93
26 Sep	16	446	85	537	1,068	1.80	4.57
27 Sep	17	267	106	278	651	1.10	2.82
28 Sep	18	287	106	103	496	1.15	2.05
30 Sep	19	446	71	397	914	1.93	3.92
1 Oct	20	893	79	269	1,241	3.55	4.95
3 Oct	21	35	33	363	431	0.13	1.87
5 Oct	22	777	126	93	996	3.30	4.32
6 Oct	23	356	135	290	781	1.47	3.27
7 Oct	24	528	132	389	1,049	2.23	5.07
9 Oct	25	428	196	391	1,015	1.88	4.97
10 Oct	26	526	117	229	872	2.20	3.77
13 Oct	27	255	36	872	1,163	1.12	5.03
14 Oct	28	739	104	306	1,149	3.03	4.82
15 Oct	29	653	97	542	1,292	2.63	5.30
16 Oct	30	295	58	309	662	1.27	2.85
18 Oct	31	532	83	480	1,095	2.22	4.65
20 Oct	32	396	139	420	955	1.65	4.27

Source: MMS, Alaska OCS Region.

Table 4

Semimonthly Summary of Survey Effort, Fall 1988

Period	No. Flights	Transect (km)	Connect (km)	Search (km)	Transect (h)	Total Survey Time (h)
1-15 Sep	8	2,567	527	4,012	10.21	29.99
16-30 Sep	11	4,416	917	3,458	17.86	36.31
1-15 Oct	10	5,190	1,055	3,744	21.54	43.37
16-20 Oct	3	1,223	280	1,209	5.14	11.77
TOTALS	32	13,396	2,779	12,423	54.75	121.44

Source: MMS, Alaska OCS Region.

Table 5

Summary of Marine Mammal Sightings, by Survey Flight (Fall 1988)
(number of sightings/number of animals)

Day	Flight No.	Bowhead Whale	Gray Whale	Beluga Whale	Bearded Seal	Ringed Seal	Unidentified Pinniped	Polar Bear
3 Sep	1	0	1/1*	0	0	1/1	0	0
4 Sep	2	0	0	0	0	0	0	0
7 Sep	3	0	0	0	0	1/1	0	0
8 Sep	4	0	0	0	0	1/3	1/1	0
11 Sep	5	0	0	0	0	0	0	0
12 Sep	6	0	0	0	2/2	0	0	1/1
14 Sep	7	2/5	0	0	1/1	0	1/1	0
15 Sep	8	1/2	0	0	0	0	0	0
16 Sep	9	0	0	4/9	0	0	2/3	0
17 Sep	10	0	0	0	0	1/2	0	0
18 Sep	11	2/3	0	1/1	0	0	0	0
21 Sep	12	0	0	0	0	0	0	0
23 Sep	13	0	0	0	0	0	0	0
24 Sep	14	0	0	2/9	0	0	0	0
25 Sep	15	1/1	0	0	0	0	0	0
26 Sep	16	4/5	0	0	0	0	0	1/1
27 Sep	17	1/1	0	0	0	0	0	2/2
28 Sep	18	0	0	0	0	1/4	3/3	0
30 Sep	19	4/4	0	4/6	0	0	0	1/1
1 Oct	20	0	0	4/4	0	0	0	0
3 Oct	21	1/1	0	0	1/2	0	0	0
5 Oct	22	1/1	0	11/89	0	1/2	1/1	0
6 Oct	23	0	0	0	0	0	0	0
7 Oct	24	3/5	0	2/15	2/2	0	2/2	1/1
9 Oct	25	8/8	0	6/45	2/4	2/7	6/9	0
10 Oct	26	0	0	2/2	0	8/19	0	1/1
13 Oct	27	1/1	0	0	1/1	1/1	2/2	0
14 Oct	28	0	0	0	1/1	3/8	5/7	4/8
15 Oct	29	0	0	0	2/2	0	1/1	5/6
16 Oct	30	0	0	0	1/1	0	0	0
18 Oct	31	0	0	0	0	0	2/2	0
20 Oct	32	0	1/3	0	0	1/3	2/2	0
Total Semimonthly Sightings (1 Sep - 20 Oct)								
1-15 Sep		3/7	1/1*	0	3/3	3/5	2/2	1/1
16-30 Sep		12/14	0	11/25	0	2/6	5/6	4/4
1-15 Oct		14/16	0	25/155	9/12	15/37	17/22	11/16
16-20 Oct		0	1/3	0	1/1	1/3	4/4	0
Total Seasonal Sightings								
Fall 1988		29/37	2/4*	36/180	13/16	21/51	28/34	16/21

Source: MMS, Alaska OCS Region.

* Includes 1 dead gray whale observed onshore.

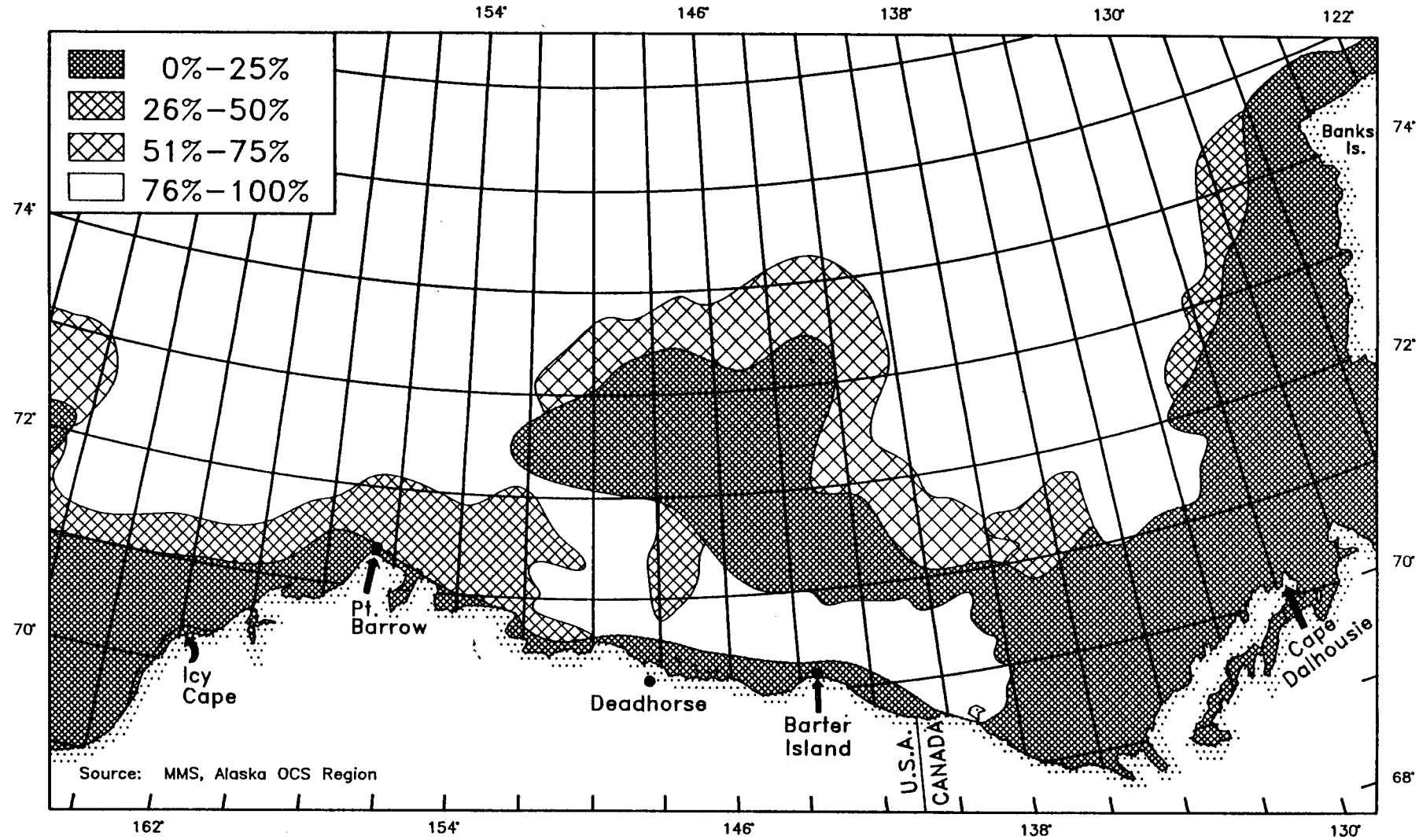


Figure 4. Map of Ice Concentrations in the Beaufort Sea, 30 August 1988

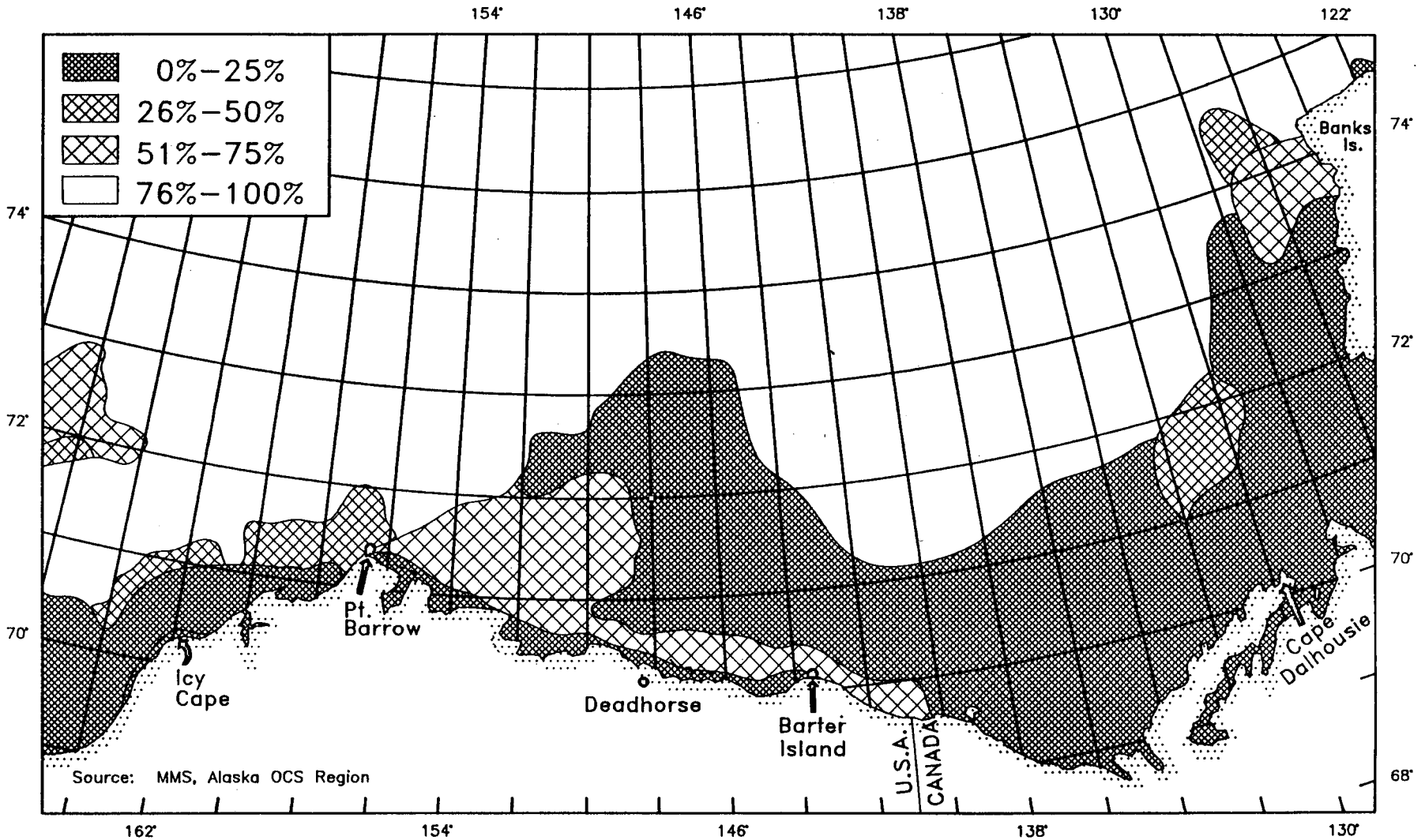


Figure 5. Map of Ice Concentrations in the Beaufort Sea, 6 September 1988

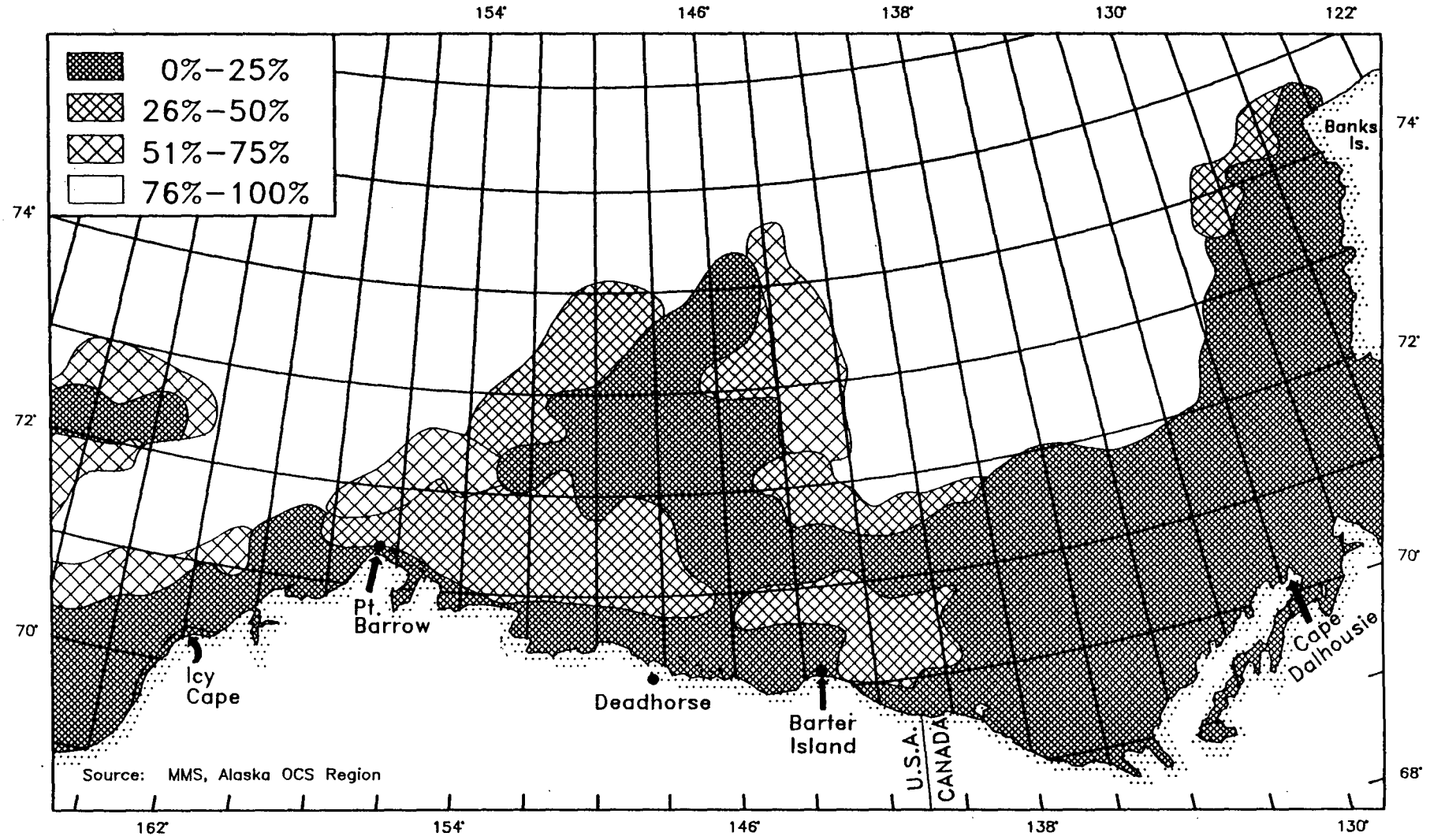


Figure 6. Map of Ice Concentrations in the Beaufort Sea, 13 September 1988

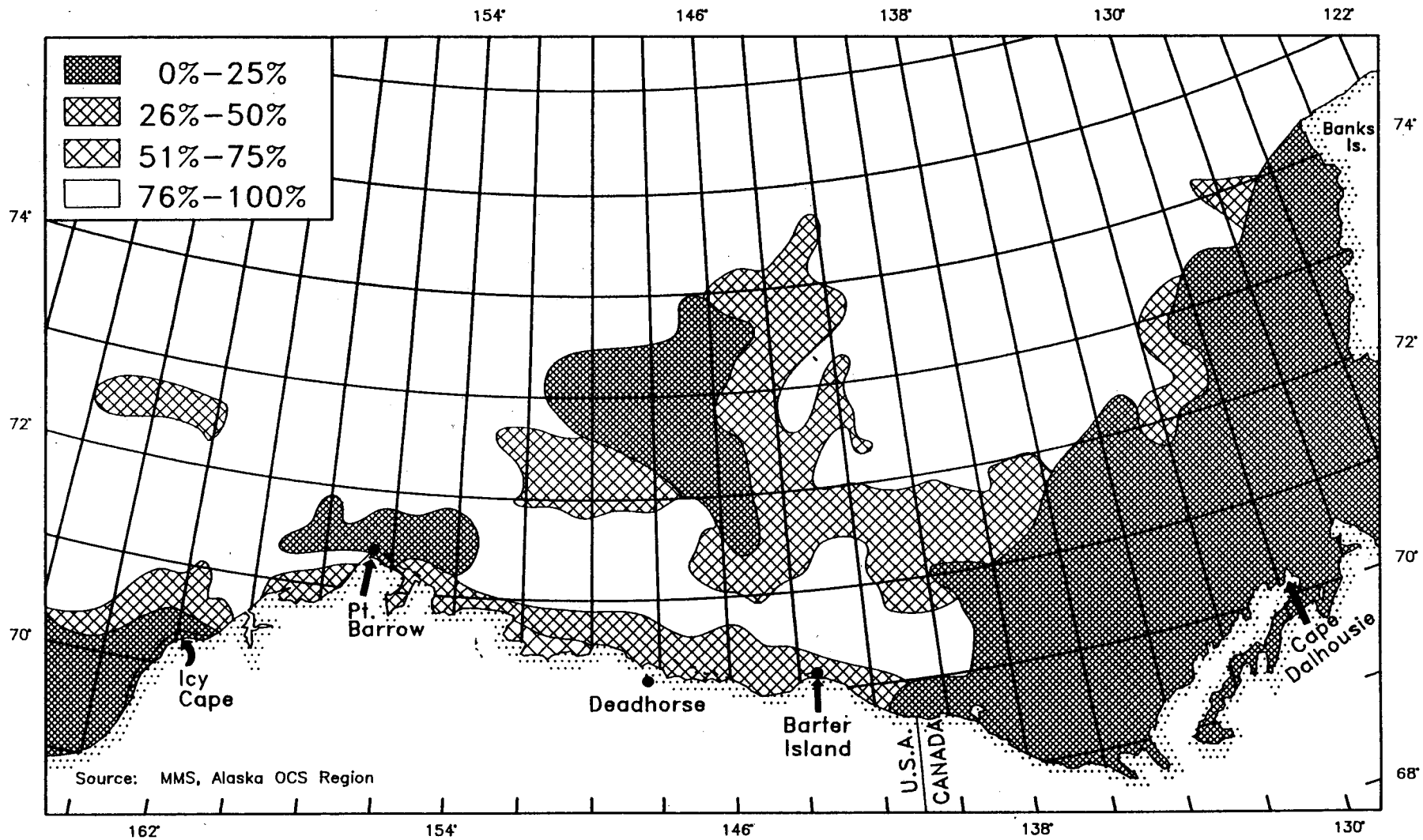


Figure 7. Map of Ice Concentrations in the Beaufort Sea, 20 September 1988

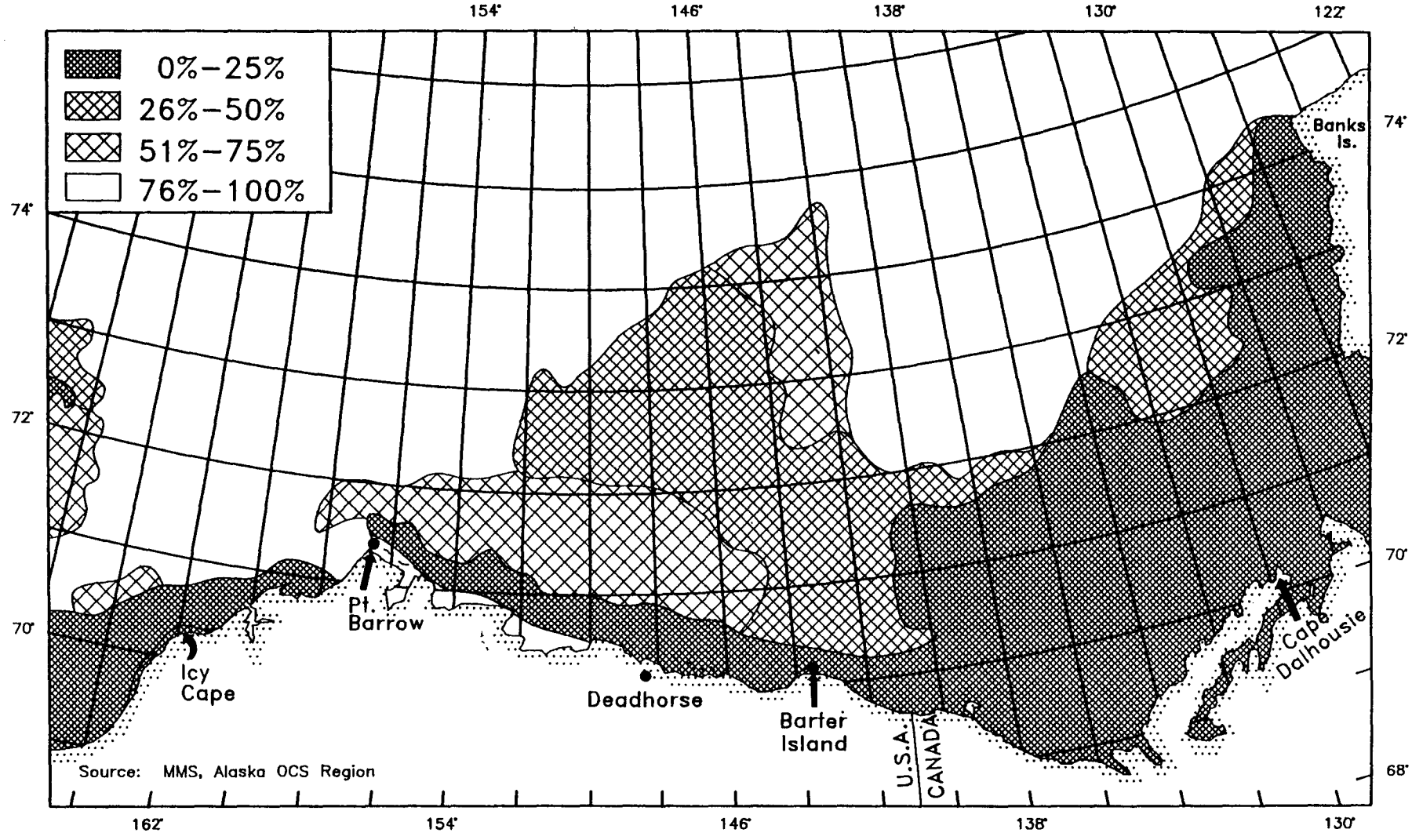


Figure 8. Map of Ice Concentrations in the Beaufort Sea, 27 September 1988

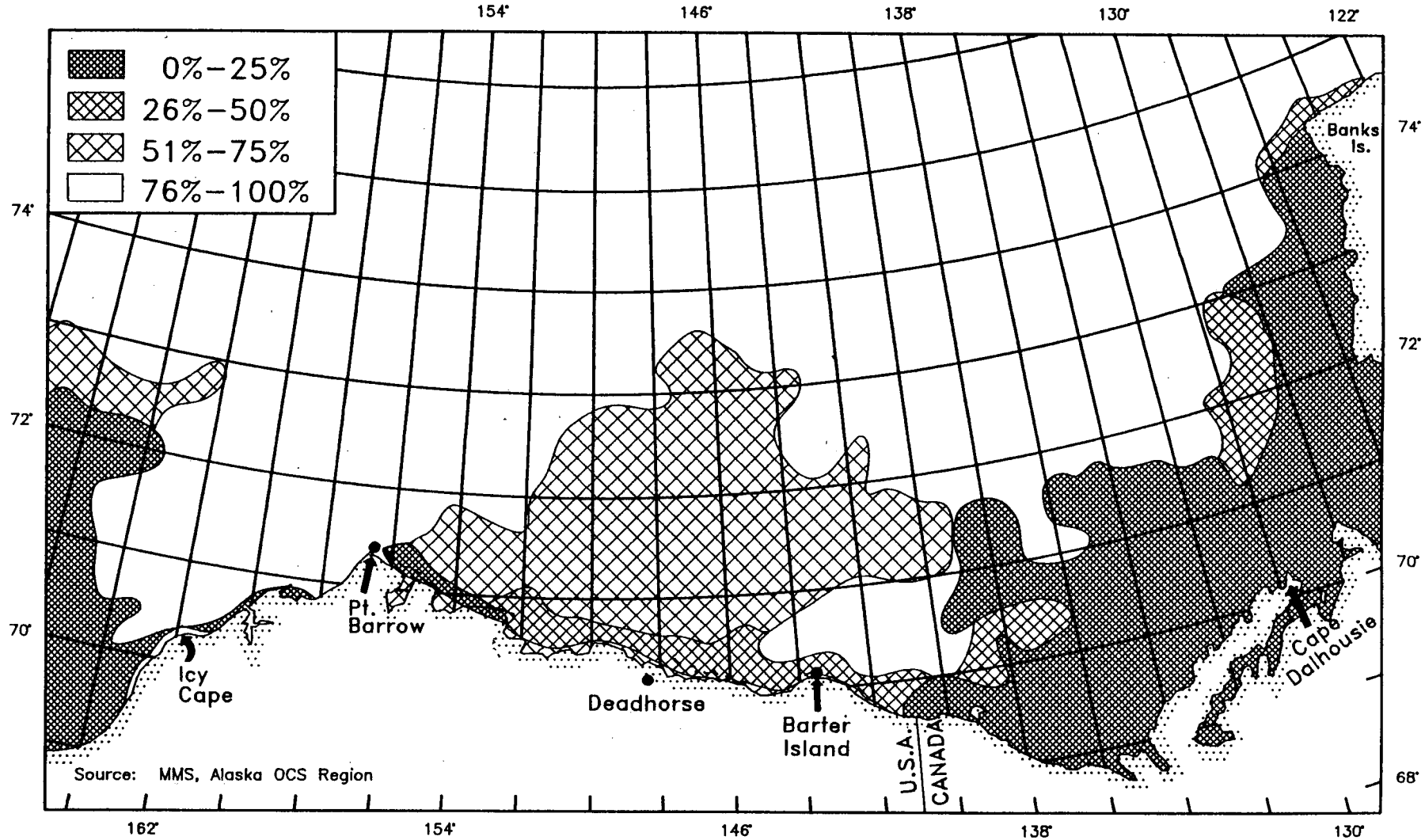


Figure 9. Map of Ice Concentrations in the Beaufort Sea, 4 October 1988

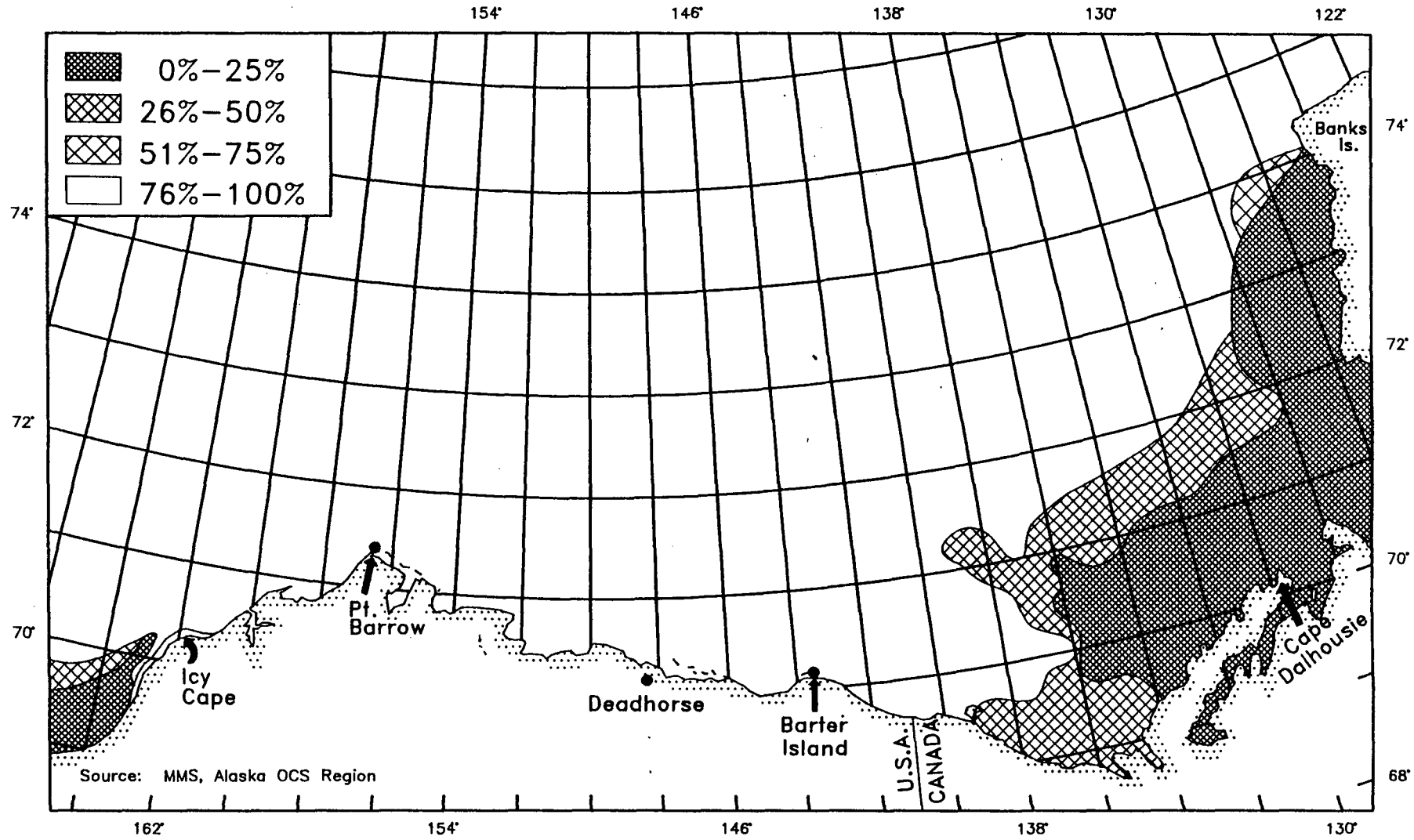


Figure 10. Map of Ice Concentrations in the Beaufort Sea, 11 October 1988

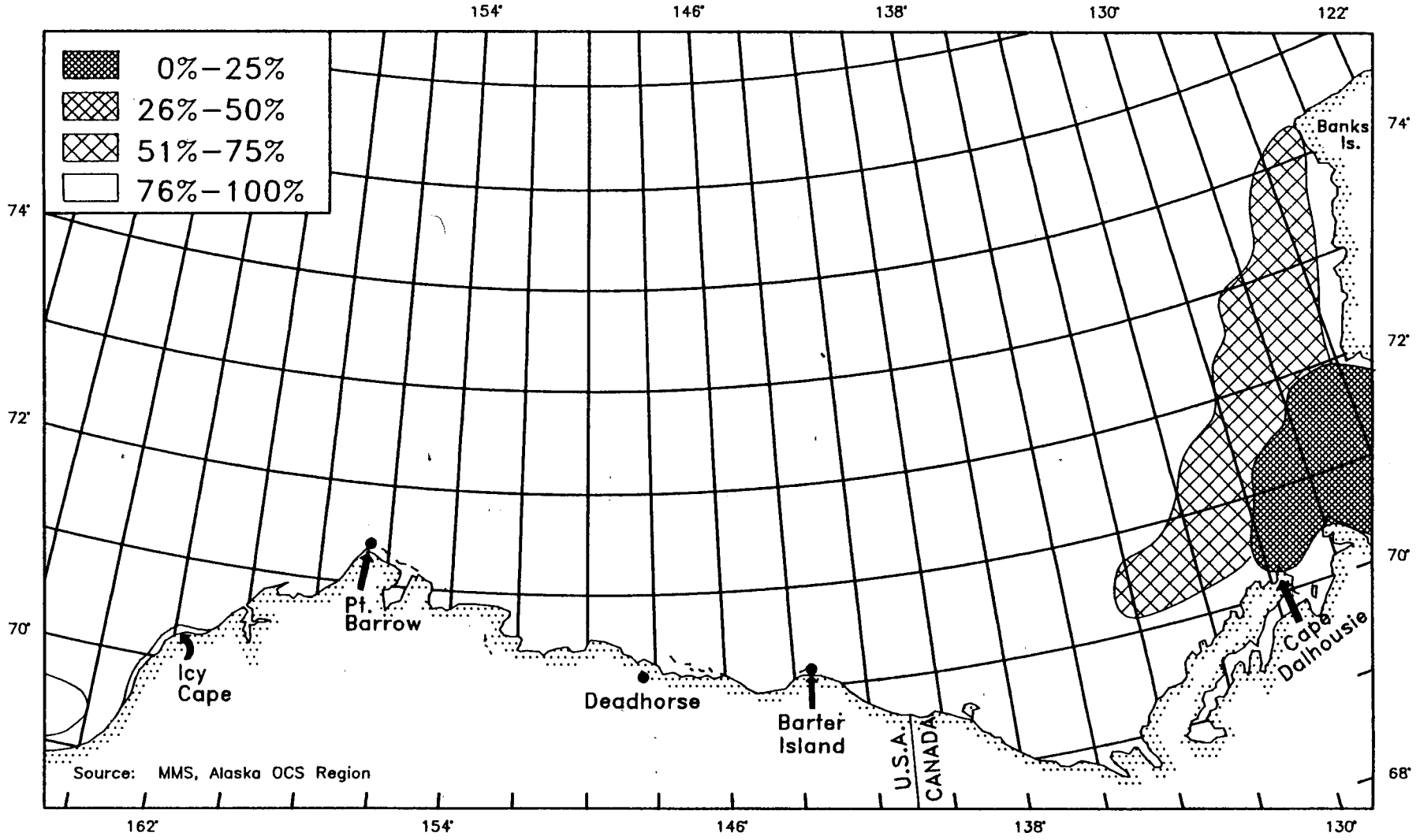


Figure 11. Map of Ice Concentrations in the Beaufort Sea, 18 October 1988

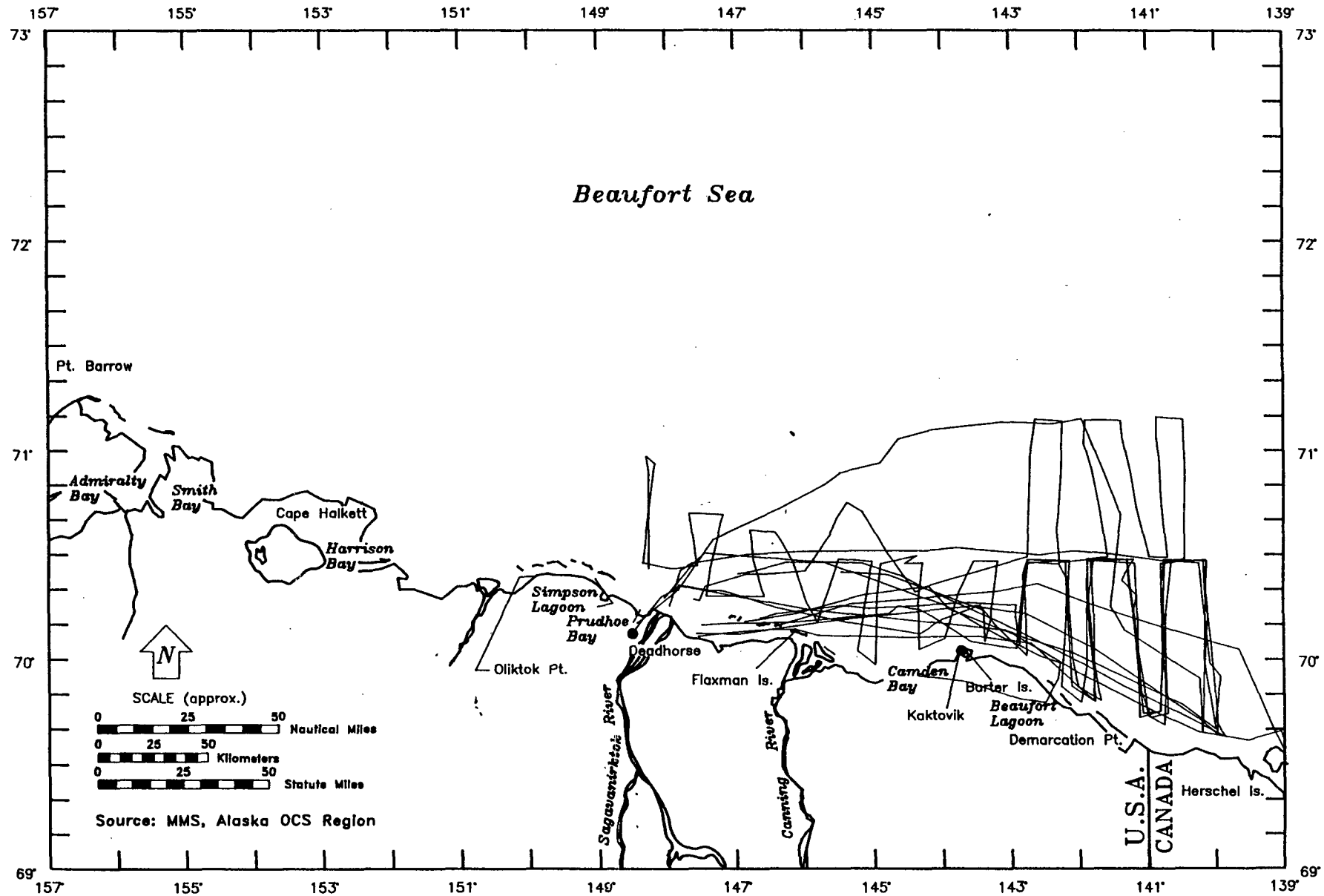


Figure 12. Combined Flight Tracks, 1–15 September 1988

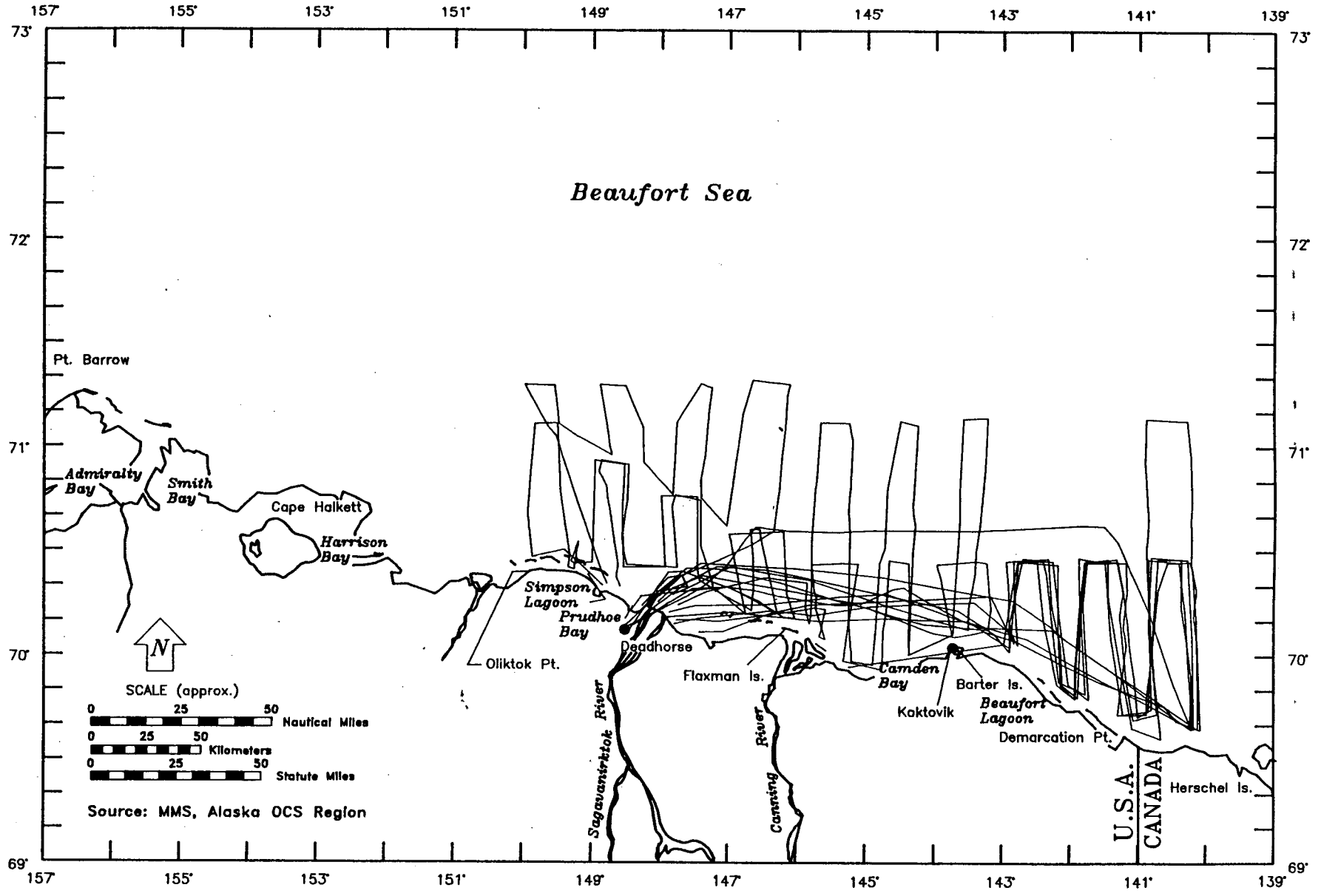


Figure 13. Combined Flight Tracks, 16–30 September 1988

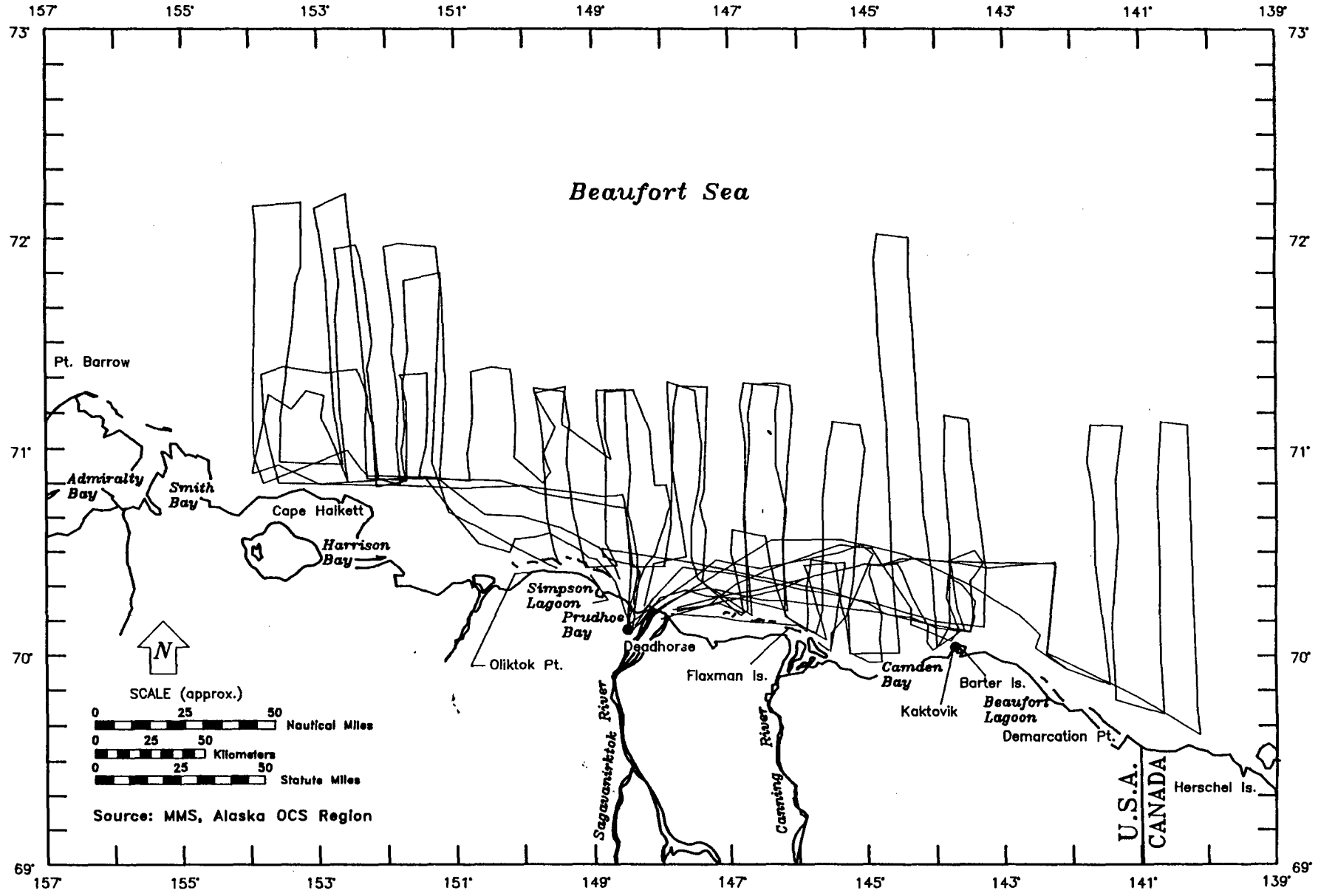


Figure 14. Combined Flight Tracks, 1–15 October 1988

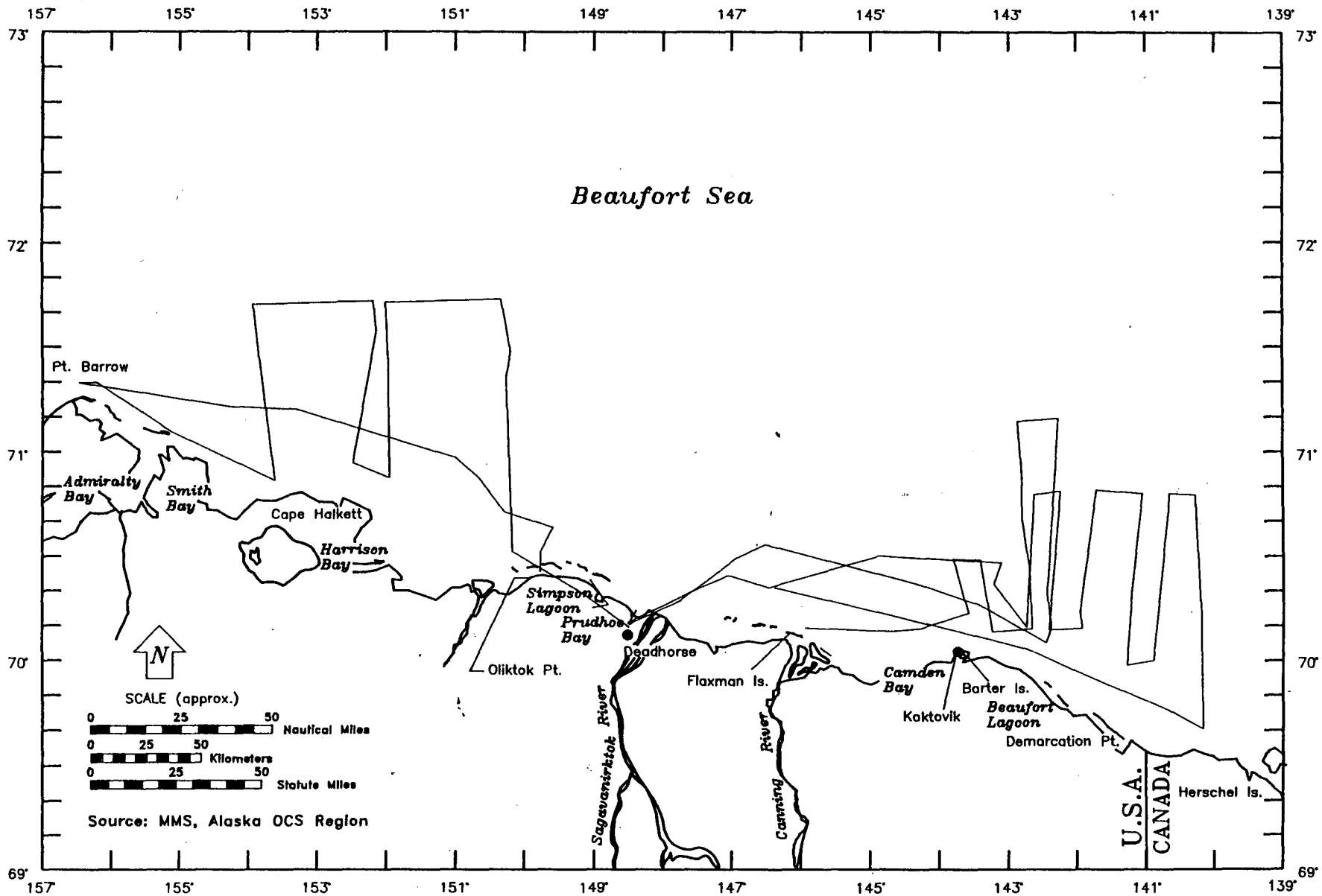


Figure 15. Combined Flight Tracks, 16–20 October 1988

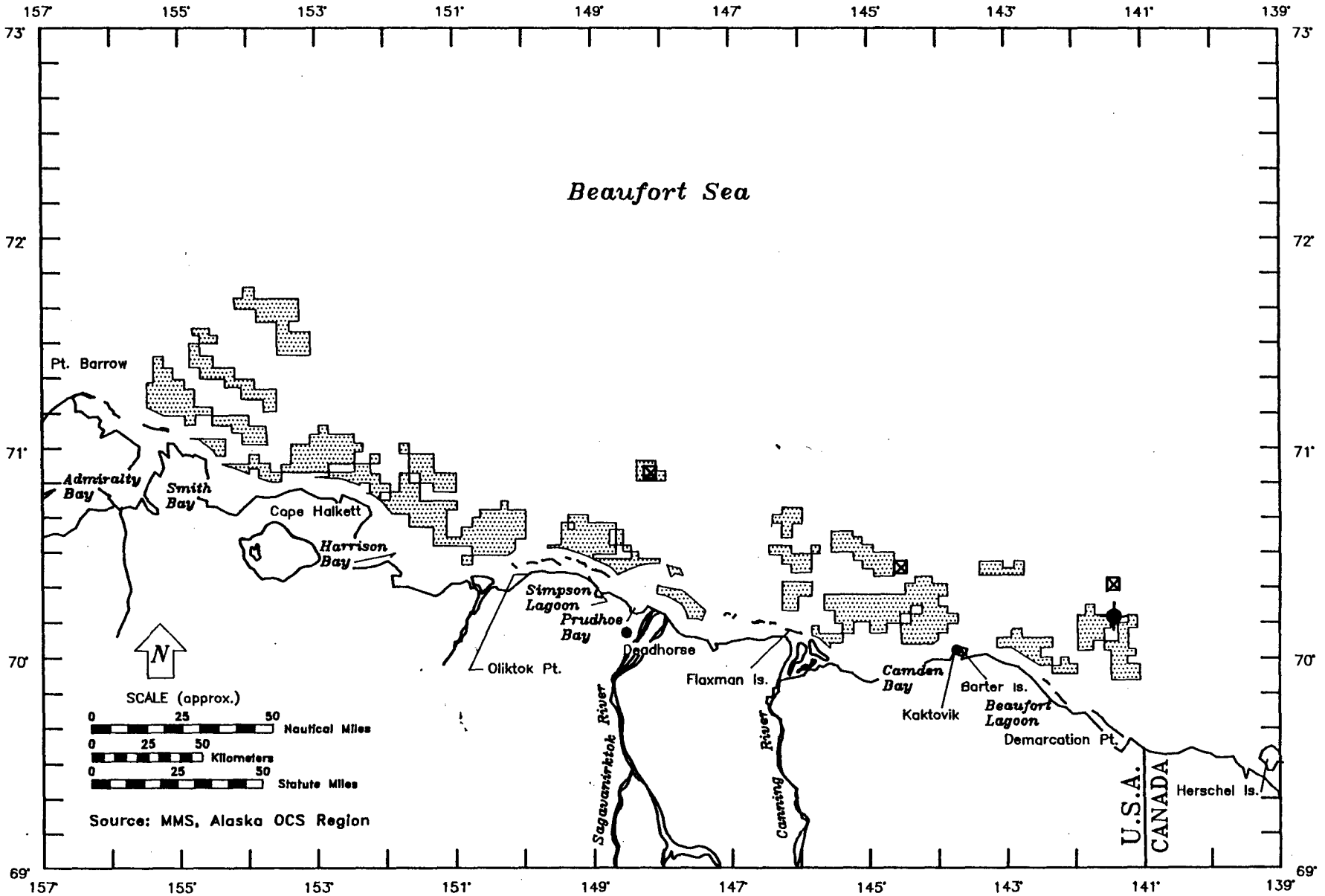


Figure 16. Map of Bowhead Whale Sightings (⊠), 1–15 September 1988, Showing OCS Leases (shaded areas) and Position of Kulluk (⊕)

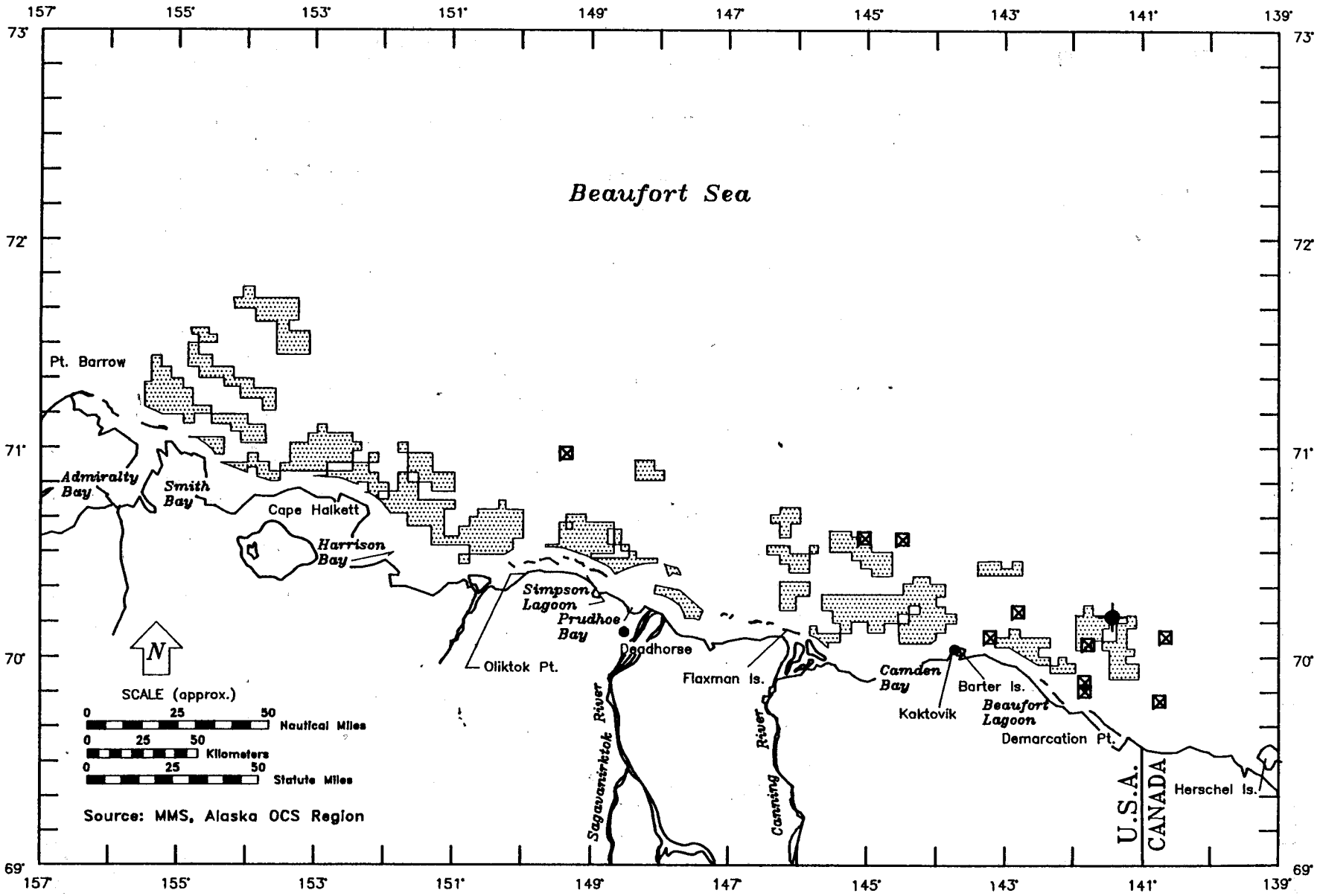


Figure 17. Map of Bowhead Whale Sightings (⊠), 16–30 September 1988, Showing OCS Leases (shaded areas) and Position of Kulluk (⊕)

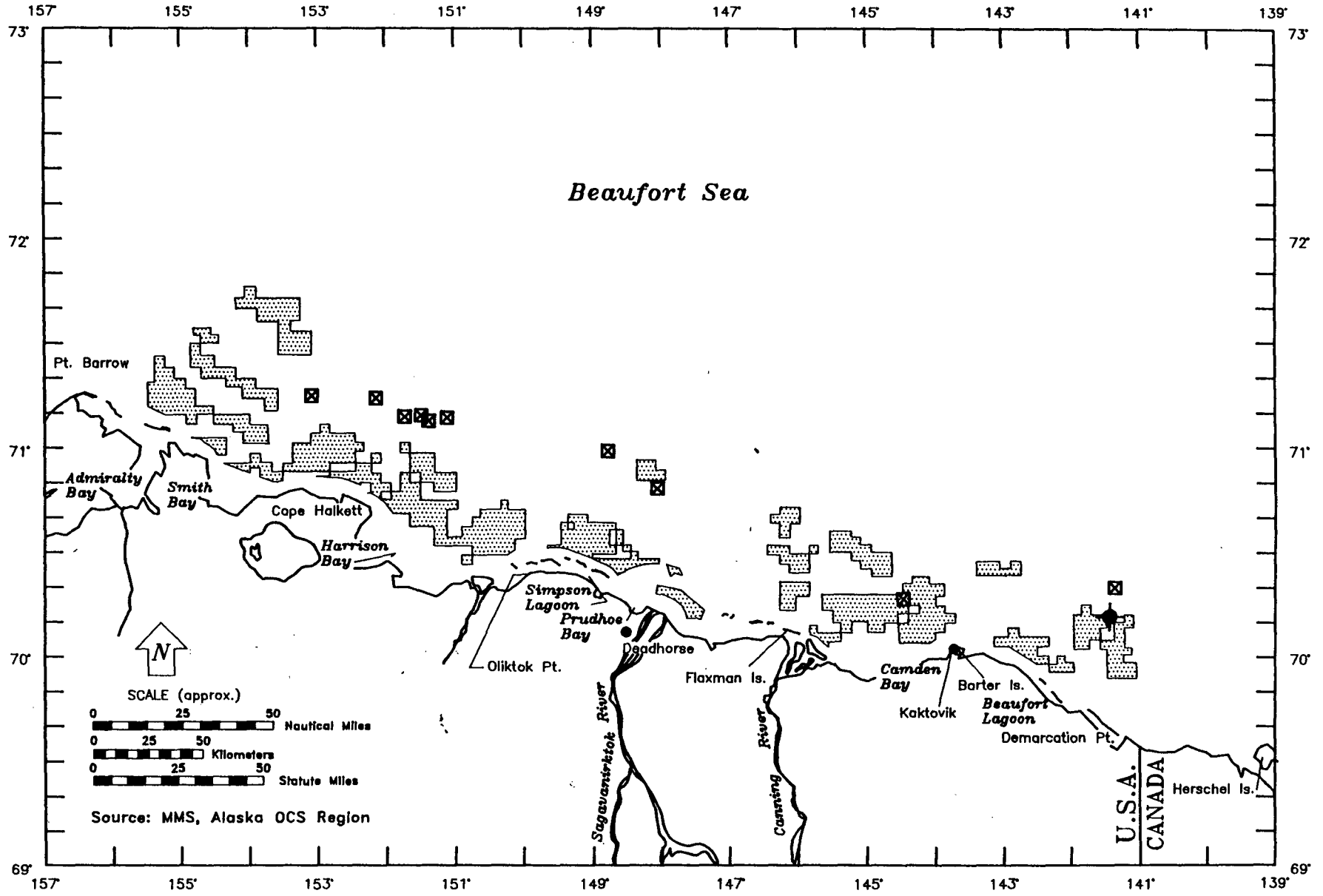


Figure 18. Map of Bowhead Whale Sightings (⊠), 1–15 October 1988, Showing OCS Leases (shaded areas) and Position of Kulluk (⊕)

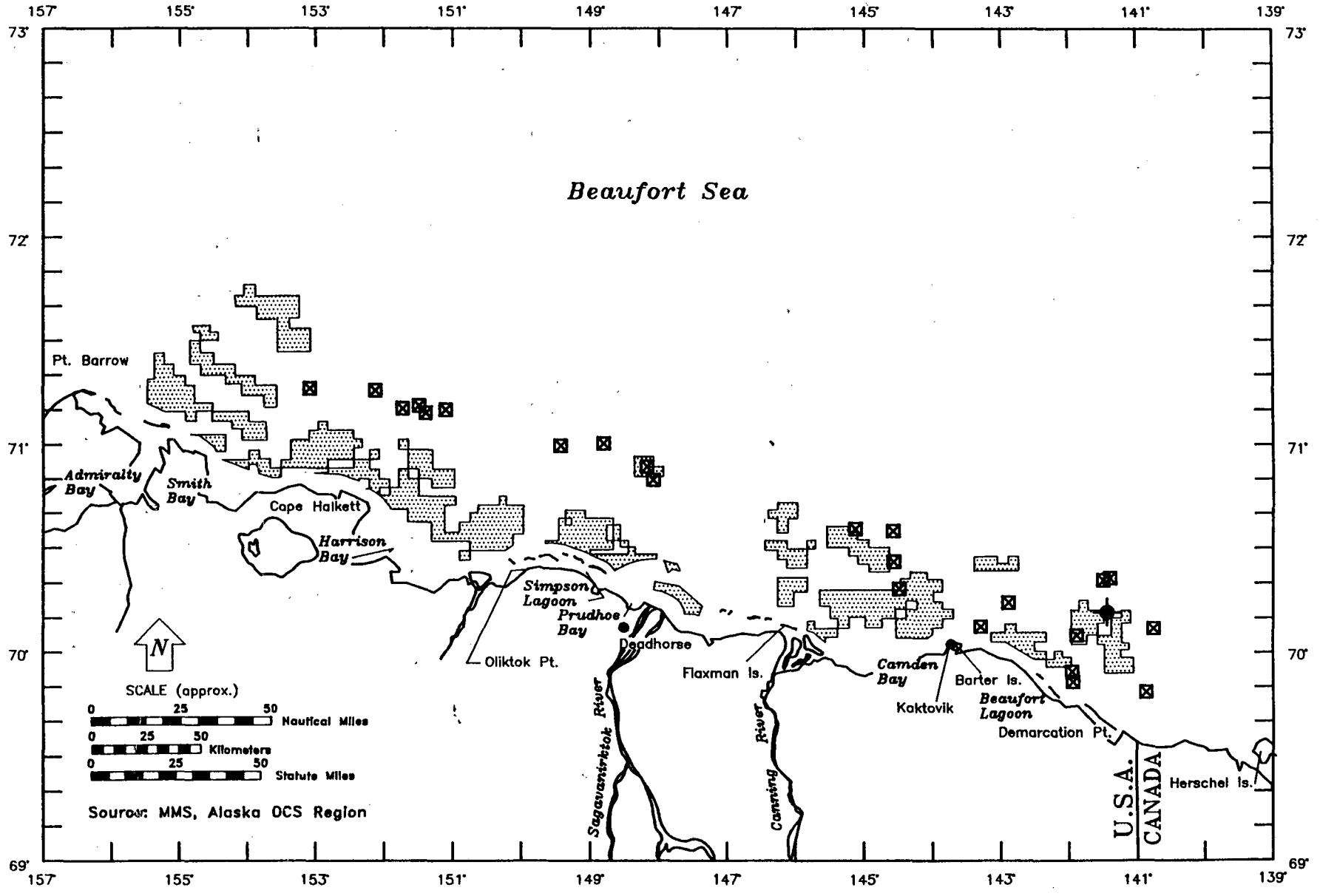


Figure 19. Map of Bowhead Whale Sightings (⊠), 1 September – 20 October 1988, Showing OCS Leases (shaded areas) and Position of Kulluk (✦)

During the second half of September (Fig. 17), 12 sightings were made for a total of 14 bowheads. The westernmost bowhead sighted during this period was north of Simpson Lagoon (Appendix B: Flight 15). Group sizes were small (1-2), with 83.3 percent of the sightings representing single whales.

During the first half of October (Fig. 18), 14 sightings were made for a total of 16 bowheads, with sightings somewhat equally distributed along the length of the coast. Group sizes remained small (1-2), with 85.7 percent of the sightings representing single whales. The last bowhead seen in the Beaufort Sea during the study occurred on 13 October at 70°24.9' N. latitude, 141°22.2' W. longitude (Appendix B: Flight 27).

2. Relative Temporal and Spatial Abundance: A daily index of relative abundance, or whales per unit effort (WPUE), and sightings per unit effort (SPUE) were calculated for bowhead whales (Table 6).

The day-to-day timing of the bowhead whale migration through the overall study area is shown in Table 6 and Figure 20. The initial sighting was made on 14 September. The daily sighting rate, or sightings per unit effort (SPUE), increased to 0.88 on 26 September and 1.02 on 30 September, and peaked at 1.61 SPUE on 9 October. The SPUE decreased markedly to 0.20 on 13 October. The last sighting of a bowhead in the study area was made on 13 October.

The major difference between the relative abundance and the sighting rate for all areas surveyed occurs on 14 September (Fig. 20), when two sightings of five bowheads within only 4.37 hours of survey effort resulted in a relative abundance of 1.14 WPUE, compared to 0.46 SPUE (Table 6) due to a pod size of 4 recorded on that day. The midpoint (median) of the bowhead migration over the entire study area (when 50% of all sighted whales had been recorded) occurred on 30 September (Table 6). The WPUE shows a peak relative abundance (mode) of 1.61 on 9 October (Table 6 and Fig. 20).

The relative abundance of bowhead whales in each survey block, in Canadian waters east of 140°W. longitude, and in Alaskan waters outside of study-area blocks, was calculated for Table 7. A comparison of the total effort-hours in each survey block with the number of bowheads sighted also is shown in Figure 21.

During the first half of September, there were three survey blocks in which 4 or more hours of survey effort were made (Table 7). Of these (Blocks 1, 4, and 5), only coastal Block 4 had a relative abundance (0.58 WPUE) greater than 0.5. No whales were observed during a total of 5.15 hours of survey effort in any of the remaining blocks (Blocks 2, 3, 6, 7, 8, 9, 10, and 11) and none in 1.33 hours outside the primary study area.

During the second half of September, there were three blocks in which 4 or more hours of survey effort were made (Table 7). Of these coastal blocks (Blocks 1, 4, and 5), only Block 5 had a relative abundance (0.75 WPUE) greater than 0.50. Only two whales were observed during a total of 5.6 hours of survey effort in the remaining blocks (Blocks 2, 3, 6, 7, 8, 9, 10, and 11).

During the first half of October, there were four blocks in which 4 or more hours of survey effort were made (Table 7). Of these coastal blocks (Blocks 1, 3, 4, and 5), only Block 3 had a relative abundance greater than 0.50 WPUE (1.37 WPUE). Only two whales were observed during a total of 13.69 hours of survey effort in the remaining blocks (Blocks 2, 6, 7, 8, 9, 10, and 11) and none in 1.58 hours outside the primary study area.

During the last half of October, there were no blocks in which 4 or more hours of survey effort were made (Table 7). No whales were observed during a total of 10.74 hours of survey effort in Blocks 1 through 11 and 1.02 hours outside the primary study area.

3. Habitat Relationships: Most bowheads (76%) were sighted in shallow water (0-50 m deep). The remainder (24%) were sighted in water ranging from 51 m to a maximum depth of 298 m (Table 8). A fuller description of depth associated with the bowhead migration, based on more accurate depth values, appears in the discussion on median-water-depth analysis in Section IV.B.

In addition to overall ice coverage (Figs. 4 through 11), the percentage of ice cover visible from the aircraft at bowhead sightings was summarized (Table 9). All bowheads except one sighted in September were in 41- to 80-percent sea ice (Table 9). Half the bowheads sighted in October were in 61- to 90-percent sea ice and half were in 91- to 99-percent ice.

Table 6

Number of Sightings and Total Bowhead Whales Counted per Hour of Survey Effort, by Flight Day
(3 Sep - 20 Oct 1988)

Day	No. of Sightings	No. of Whales	Total Survey Time (h)	Sightings Hour (SPUE)	Whales Hour (WPUE)
3 Sep	0	0	4.22	0.00	0.00
4 Sep	0	0	4.02	0.00	0.00
7 Sep	0	0	3.75	0.00	0.00
8 Sep	0	0	4.38	0.00	0.00
11 Sep	0	0	0.95	0.00	0.00
12 Sep	0	0	4.08	0.00	0.00
14 Sep	2	5	4.37	0.46	1.14
15 Sep	1	2	4.22	0.24	0.47
16 Sep	0	0	2.80	0.00	0.00
17 Sep	0	0	4.07	0.00	0.00
18 Sep	2	3	4.15	0.48	0.72
21 Sep	0	0	0.18	0.00	0.00
23 Sep	0	0	4.65	0.00	0.00
24 Sep	0	0	4.17	0.00	0.00
25 Sep	1	1	2.93	0.34	0.34
26 Sep	4	5	4.57	0.88	1.09
27 Sep	1	1	2.82	0.35	0.35
28 Sep	0	0	2.05	0.00	0.00
30 Sep	4	4	3.92	1.02	1.02
1 Oct	0	0	4.95	0.00	0.00
3 Oct	1	1	1.87	0.53	0.53
5 Oct	1	1	4.32	0.23	0.23
6 Oct	0	0	3.27	0.00	0.00
7 Oct	3	5	5.07	0.59	0.99
9 Oct	8	8	4.97	1.61	1.61
10 Oct	0	0	3.77	0.00	0.00
13 Oct	1	1	5.03	0.20	0.20
14 Oct	0	0	4.82	0.00	0.00
15 Oct	0	0	5.30	0.00	0.00
16 Oct	0	0	2.85	0.00	0.00
18 Oct	0	0	4.65	0.00	0.00
20 Oct	0	0	4.27	0.00	0.00

Source: MMS, Alaska OCS Region.

Table 7

Semimonthly Relative Abundance (WPUE) of Bowhead Whales (BH), by Survey Block (Fall 1988)

Block	1-15 Sep			16-30 Sep			1-15 Oct			16-20 Oct			Total		
	Hours	BH	WPUE	Hours	BH	WPUE	Hours	BH	WPUE	Hours	BH	WPUE	Hours	BH	WPUE
1	5.01	1	0.20	9.70	1	0.10	9.96	2	0.20	0.95	0	0.00	25.62	4	0.16
2	0.26	0	0.00	1.88	0	0.00	3.88	1	0.26	0.00	*	*	6.02	1	0.17
3	0.00	*	*	0.00	*	*	7.29	10	1.37	1.65	0	0.00	8.94	10	1.12
4	6.84	4	0.58	7.62	1	0.13	6.29	1	0.16	1.94	0	0.00	22.69	6	0.26
5	11.66	2	0.17	13.38	10	0.75	4.54	1	0.22	2.59	0	0.00	32.17	13	0.40
6	1.87	0	0.00	2.59	2	0.77	3.45	0	0.00	0.42	0	0.00	8.33	2	0.24
7	2.99	0	0.00	1.13	0	0.00	1.57	0	0.00	1.85	0	0.00	7.54	0	0.00
8	0.03	0	0.00	0.00	*	*	0.00	*	*	0.00	*	*	0.03	0	0.00
9	0.00	*	*	0.00	*	*	0.86	0	0.00	0.00	*	*	0.86	0	0.00
10	0.00	*	*	0.00	*	*	0.00	*	*	0.00	*	*	0.00	*	*
11	0.00	*	*	0.00	*	*	3.93	1	0.25	1.34	0	0.00	5.27	1	0.19
Other Alaskan Areas	0.00	*	*	0.00	*	*	0.52	0	0.00	1.02	0	0.00	1.54	0	0.00
Other Canadian Areas	1.33	0	0.00	0.00	*	*	1.06	0	0.00	0.00	*	*	2.39	0	0.00
TOTAL	29.98	7	0.23	36.30	14	0.39	43.35	16	0.37	11.77	0	0.00	121.40	37	0.30

Source: MMS, Alaska OCS Region.

* No survey effort.

Table 8

Semimonthly Summary of Bowhead Whales Counted, by Water Depth at Sighting Location (Fall 1988)

Water Depth	1-15 Sep No. (%)	16-30 Sep No. (%)	1-15 Oct No. (%)	Total No. (%)
Shallow (0-50 m)	5 (71)	12 (86)	11 (69)	28 (76)
Transitional (51-200 m)	0	2 (14)	4 (25)	6 (16)
Deep (>200 m)	2 (29)	0	1 (6)	3 (8)
Deepest Sightings	298m	183m	298m	298m
TOTAL	7 (100)	14 (100)	16 (100)	37 (100)

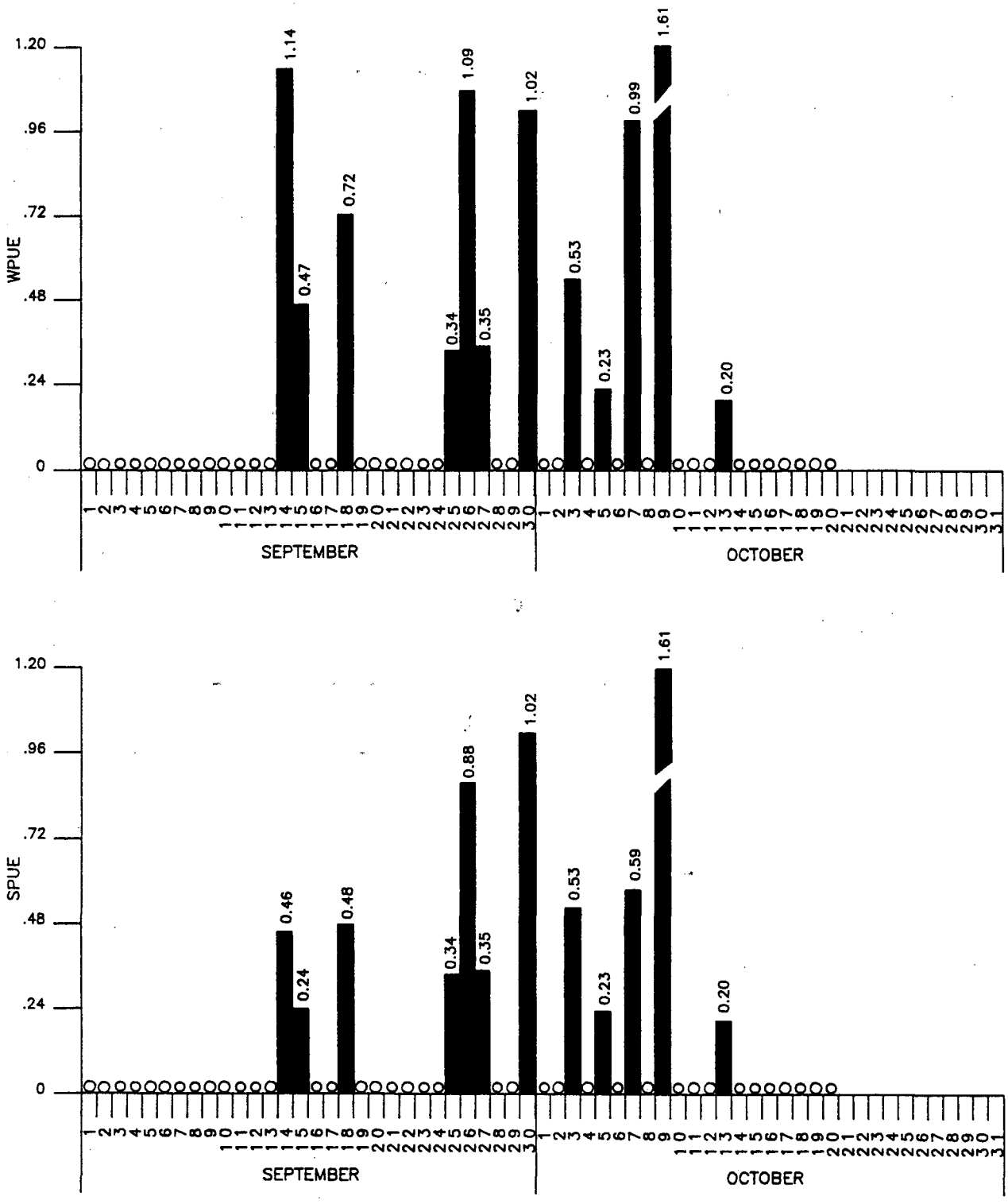
Source: MMS, Alaska OCS Region.

Table 9

Semimonthly Summary of Bowhead Whales Counted,
by Percent Ice Cover Present at Sighting Location (Fall 1988)

% Ice Cover	1-15 Sep No. (%)	16-30 Sep No. (%)	1-15 Oct No. (%)	Total No. (%)
0-20	0	0	0	0
21-30	0	1 (7)	0	1 (3)
31-40	0	0	0	0
41-50	1 (14)	5 (36)	0	6 (16)
51-60	0	2 (15)	0	2 (5)
61-70	6 (86)	3 (21)	2 (12)	11 (30)
71-80	0	3 (21)	0	3 (8)
81-90	0	0	6 (38)	6 (16)
91-99	0	0	8 (50)	8 (22)
TOTAL	7 (100)	14 (100)	16 (100)	37 (100)

Source: MMS, Alaska OCS Region.



Source: MMS, Alaska OCS Region

Figure 20. Total Bowhead Whales Counted per Hour (WPUE) and Sightings per Hour (SPUE), by Calendar Day (Fall 1988)

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

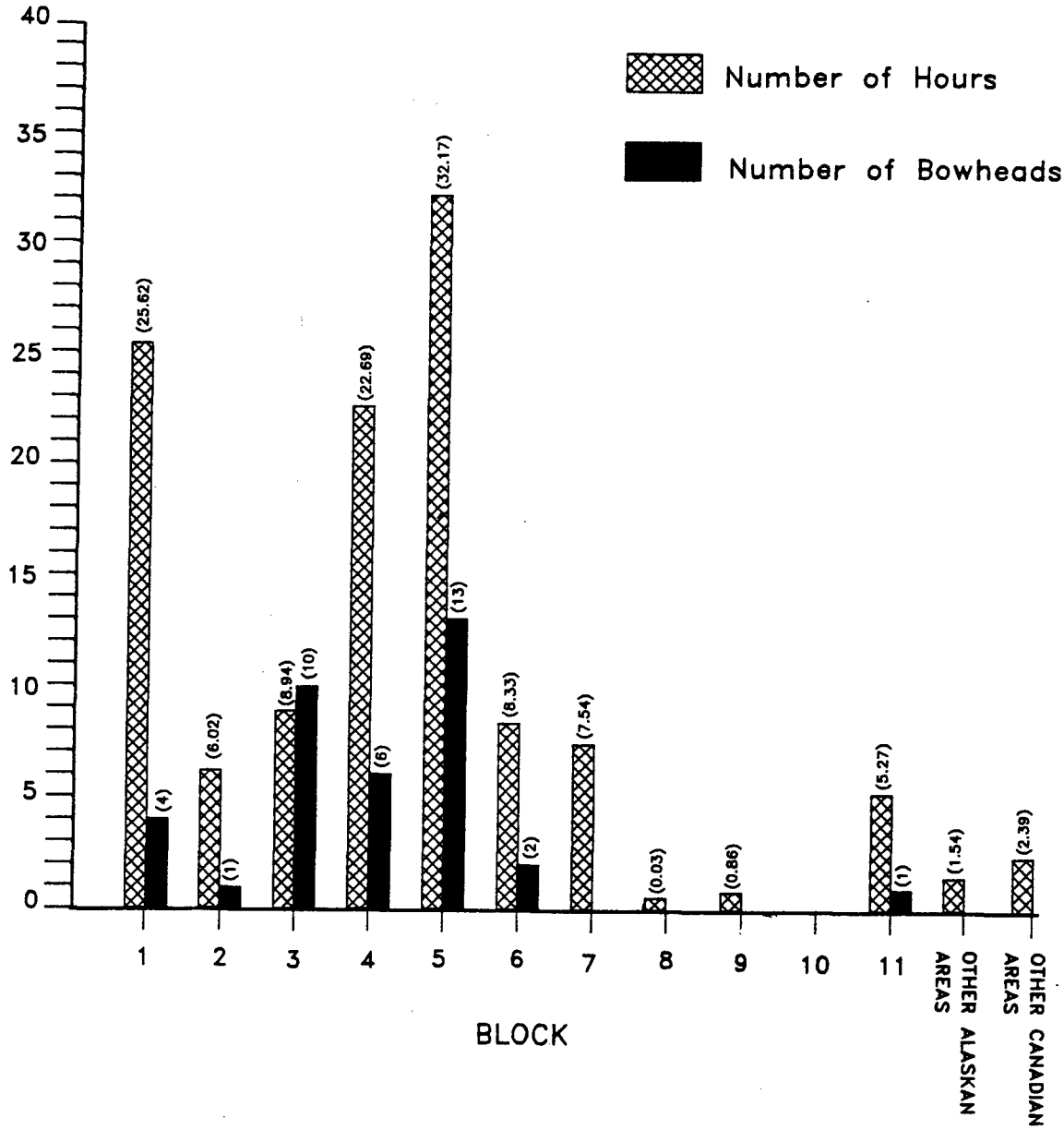


Figure 21. Number of Survey Hours and Number of Bowhead Whales Counted September–October 1988, by Survey Block

4. Behavior, Swim Direction, and Speed: Overall, 33 (89%) of the bowheads observed during Fall 1988 were swimming, i.e., moving forward in an apparently deliberate manner (Table 10), when first sighted. Swim speeds were primarily at a medium rate (2-4 km/h) (Table 11). Swim direction over the fall season was predominantly west-southwest (Fig. 22), consistent with an overall westerly migration.

During the first half of September, six of seven (86%) bowheads were observed swimming (Table 10) primarily west-northwest (Fig. 22), mostly (71%) at medium speed (Table 11). One adult whale sighted on 14 September breached repeatedly in water 38 m deep.

During the second half of September, all but one (93%) of 14 bowheads were observed swimming (Table 10) either in a west-southwesterly or north-northwesterly direction (Fig. 22) at medium (64%) or slow (36%) speeds (Table 11). One whale was diving when first observed (Table 10). During the first half of October, (88%) 14 of 16 bowheads were observed swimming (Table 10), primarily west-southwest (Fig. 22) and mostly (75%) at medium speed (Table 11). Two whales were milling when first observed (Appendix B: Flight 24), and one whale was headed in a northeasterly direction (Appendix B: Flight 25) during this period.

D. Other Marine Mammal Observations

1. Gray Whale (Eschrichtius robustus): Sightings of gray whales consisted of one dead whale at the shoreline east of Deadhorse (Appendix B: Flight 1) and a group of three whales trapped in the ice off Point Barrow, west of the primary study area (Appendix B: Flight 32).

2. Beluga Whale (Delphinapterus leucas): Fall sightings of beluga whales were located primarily between 143 ° W. and 152 ° W. longitudes (Fig. 23) and between the 200-m and 2,000-m isobaths. Pod sizes ranged from 1 to 42 whales.

All sightings of belugas in September occurred during the second half of the month, when 11 sightings were made for a total of 25 whales (Table 5). During the last half of September, the overall relative abundance of beluga whales was 0.69 WPUE.

All sightings of belugas in October occurred during the first half of the month, when 25 sightings were made for a total of 155 whales (Table 5). During the first half of October, the overall relative abundance of beluga whales was 3.57 WPUE. Of the belugas observed in October 1988, 17 sightings of 147 whales were made from 5 to 9 October between 148 ° 25 ' W. and 151 ° 50 ' W. longitudes.

3. Ringed Seal (Phoca hispida): Twenty-one incidental sightings were made for a total of 51 ringed seals during September and October (Table 5). Ringed seals sighted during this period (Fig. 24) were in water less than 2,000 m deep. Most of these (14 sightings of 35 seals) were observed from 9 to 14 October.

4. Bearded Seal (Erignathus barbatus): Thirteen incidental sightings were made for a total of 16 bearded seals during September and October (Table 5 and Fig. 25). Most were sighted during the first half of October.

5. Unidentified Pinnipeds: Twenty-eight incidental sightings were made for a total of 34 unidentified pinnipeds during September and October (Table 5). Distribution of these sightings (Fig. 26) was widespread within the study area.

6. Polar Bear (Ursus maritimus): Sixteen sightings were made for a total of 21 polar bears during September and October (Table 5). Sightings were of individual bears except for 9 sightings of 14 bears made from 14 to 15 October. Most polar bear sightings (Fig. 27) were between 140 ° W. and 147 ° W. longitudes south of 71 ° N. latitude, with a few sightings nearshore between 153 ° W. and 154 ° W. longitudes.

Table 10

Semimonthly Summary of Bowhead Whales Counted, by Behavioral Category (Fall 1988)

Behavior	1-15 Sep No. (%)	16-30 Sep No. (%)	1-15 Oct No. (%)	Total No. (%)
Swimming	6 (86)	13 (93)	14 (88)	33 (89)
Diving	0	1 (7)	0	1 (3)
Milling	0	0	2 (12)	2 (5)
Breaching	1 (14)	0	0	1 (13)
TOTAL	7 (100)	14 (100)	16 (100)	37 (100)

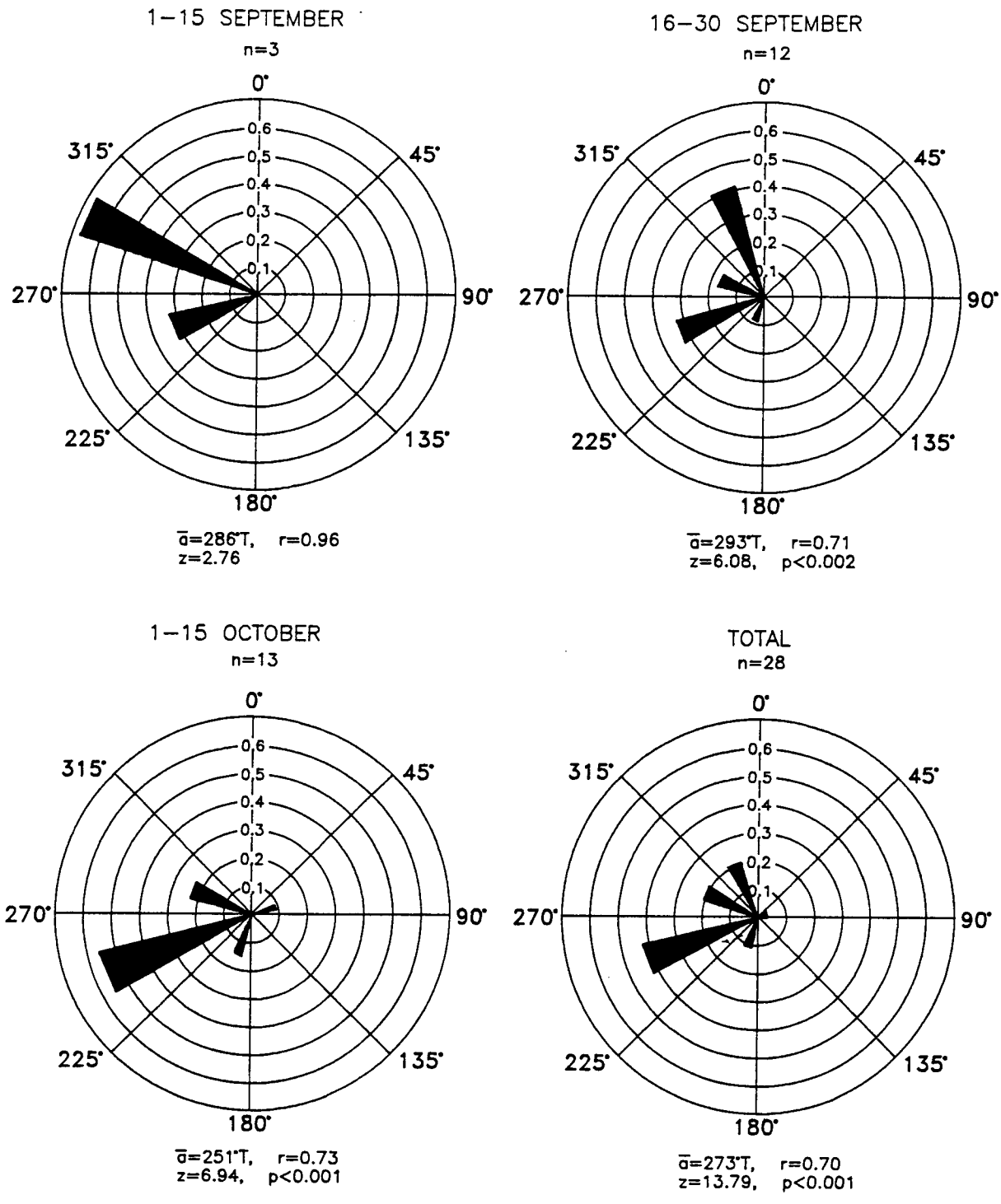
Source: MMS, Alaska OCS Region.

Table 11

Semimonthly Summary of Bowhead Whales Counted, by Swimming Speed (Fall 1988)

Swim Speed	1-15 Sep No. (%)	16-30 Sep No. (%)	1-15 Oct No. (%)	Total No. (%)
Still (0 km/h)	0	0	2 (13)	2 (5)
Slow (<2 km/h)	2 (29)	5 (36)	1 (6)	8 (22)
Medium (2-4 km/h)	5 (71)	9 (64)	12 (75)	26 (70)
Fast (>4 km/h)	0	0	1 (6)	1 (3)
TOTAL	7 (100)	14 (100)	16 (100)	37 (100)

Source: MMS, Alaska OCS Region.



Source: MMS, Alaska OCS Region

Figure 22. Semimonthly Summary of Swim Directions for Bowhead Whales (Fall 1988)

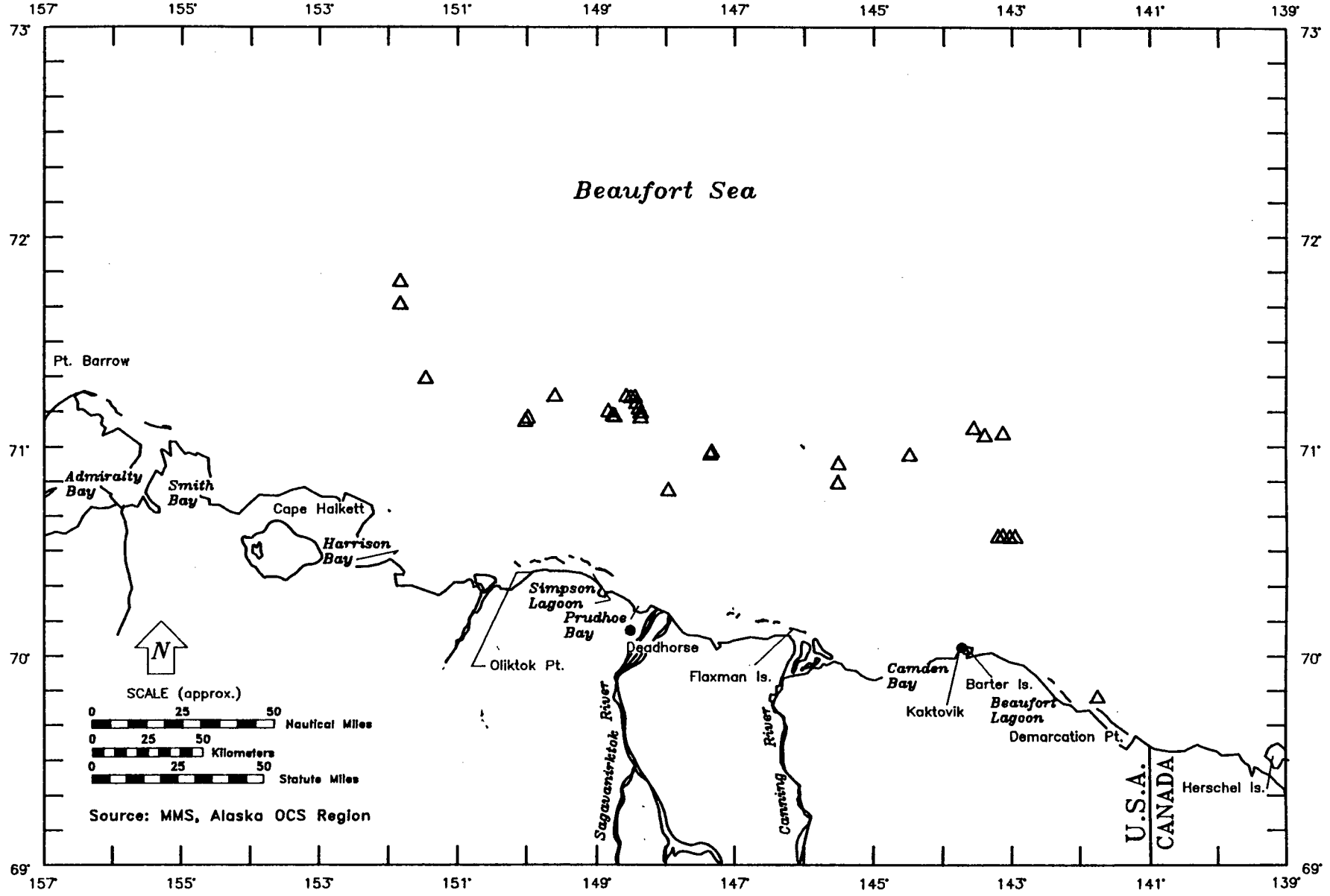


Figure 23. Map of Beluga Whale Sightings (△), September–October 1988

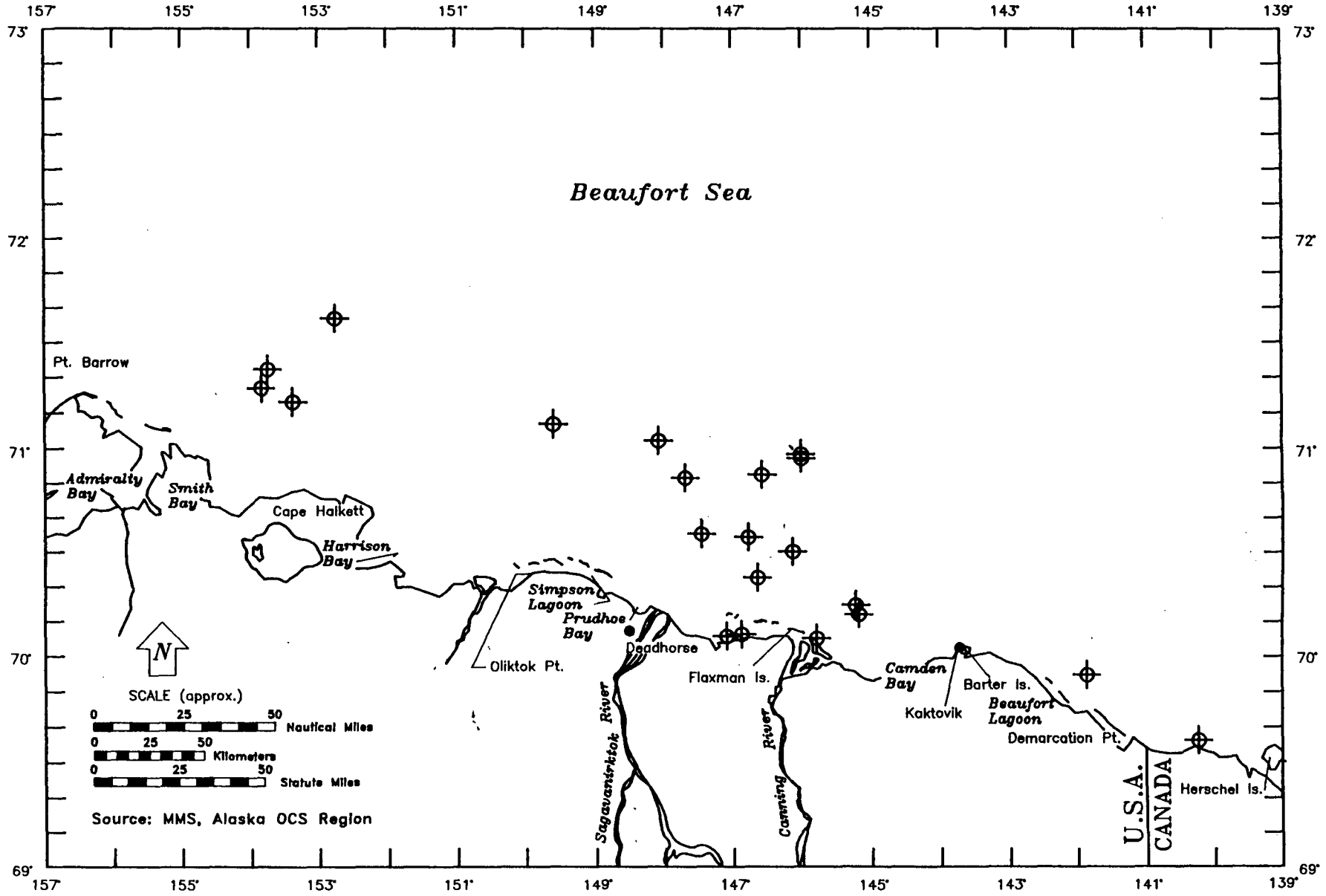


Figure 24. Map of Ringed Seal Sightings (⊕), September–October 1988

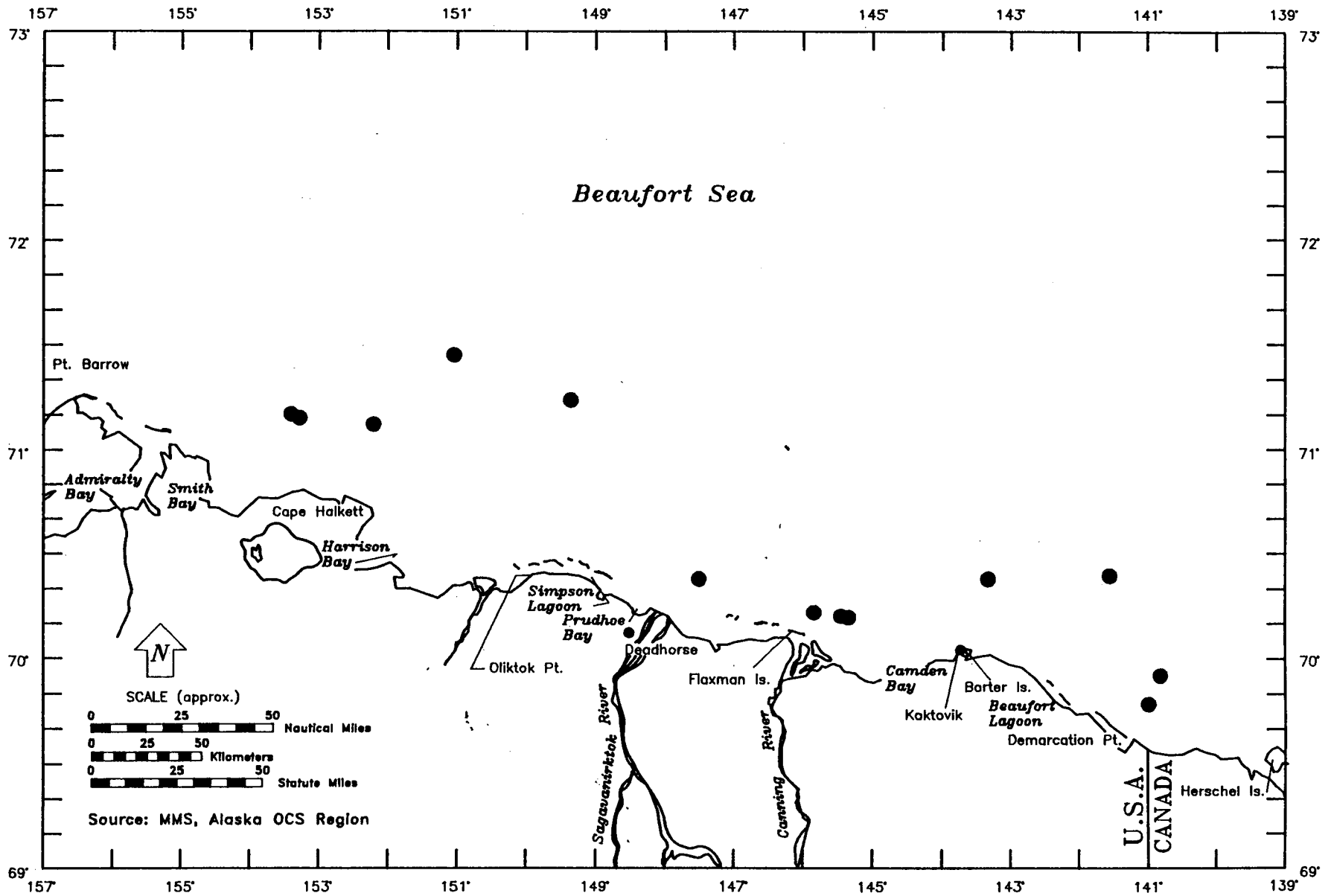


Figure 25. Map of Bearded Seal Sightings (●), September–October 1988

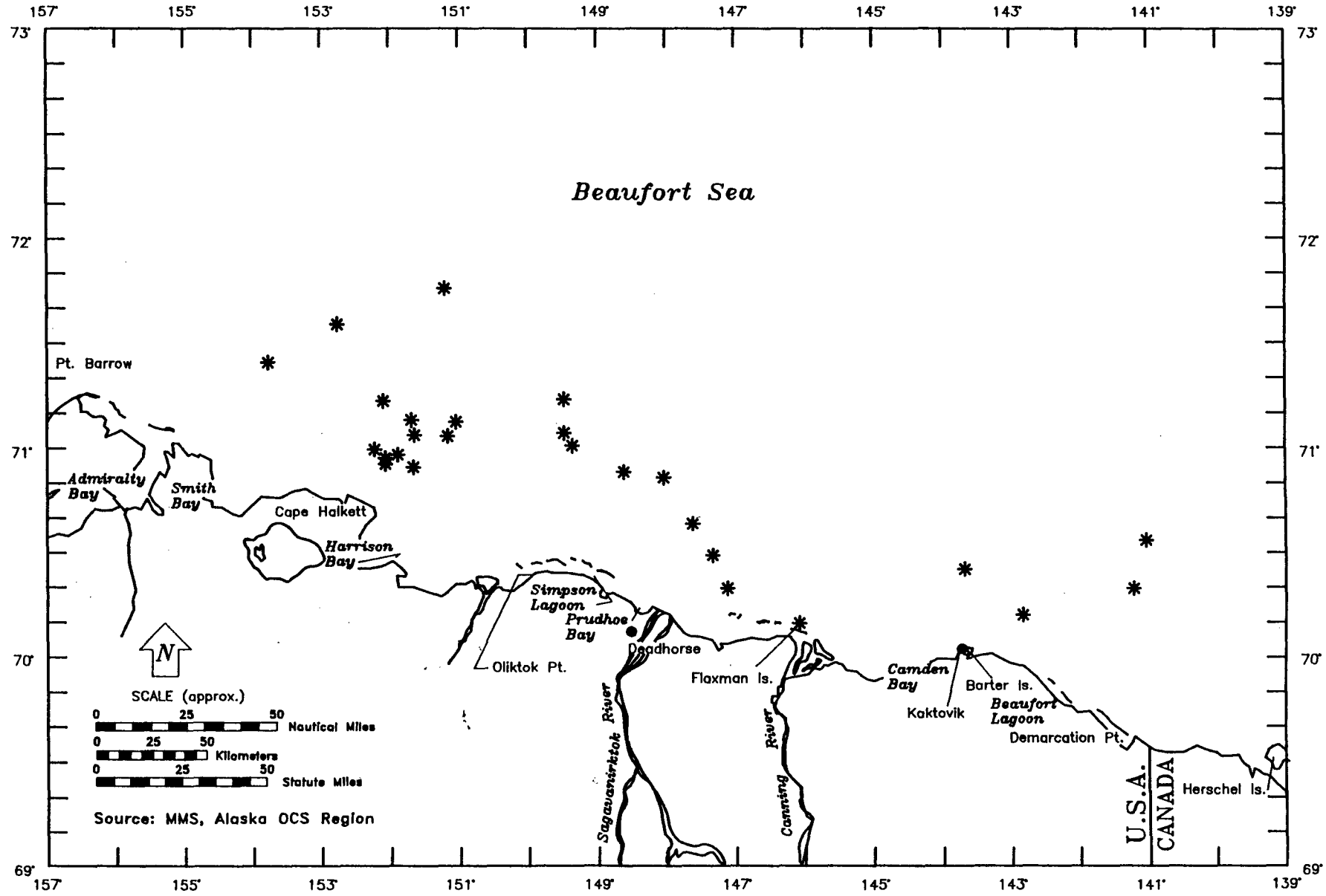


Figure 26. Map of Unidentified–Pinniped Sightings (*), September–October 1988

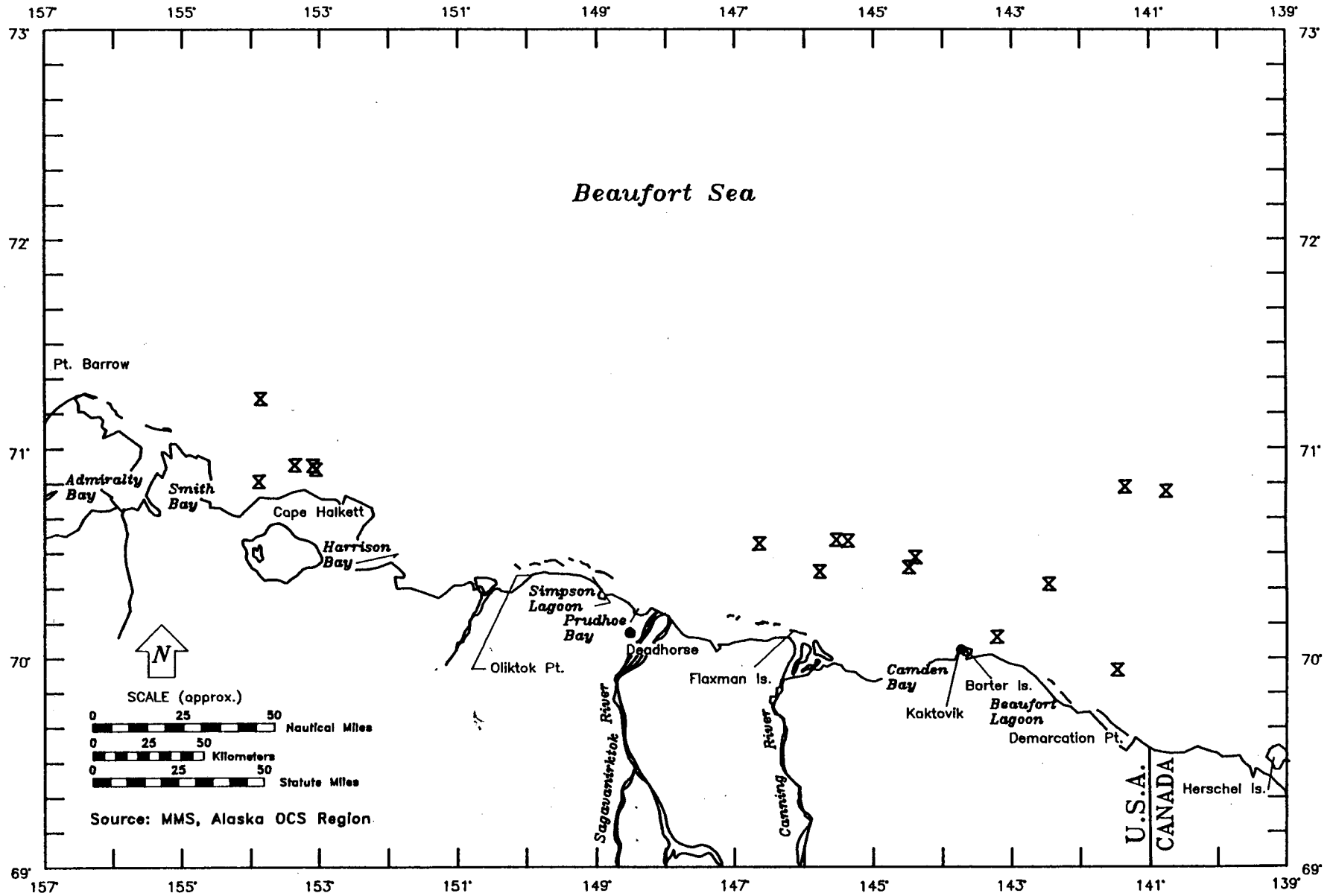


Figure 27. Map of Polar Bear Sightings (⧗), September–October 1988

IV. DISCUSSION

A. General Comparisons with Previous Surveys (1979-1987)

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 (1979-1987) in the Beaufort Sea (Ljungblad et al., 1987; Treacy, 1988).

The general ice coverage in 1988 during the navigation season was the eighth most severe in the Arctic Ocean for the years 1953 through 1988 and was the second most severe (after 1983) since the MMS surveys began in 1979 (USDOD, Navy, Naval Polar Oceanographic Center, 1989).

The relative abundance (WPUE) of bowhead whales in each survey block during both September and October 1988 was within the range of values observed for the years 1979 to 1987 (Table 12) and within 1 standard deviation (SD) of the mean value for previous years (1979-1987) in each area.

The percentage of bowhead whales engaged in "swimming" behavior in 1988 (89%) was the highest noted for this behavioral category compared to previous Beaufort Sea surveys (previous high = 71% in 1987). The cumulative 1979-1987 percentage (September-October) for swimming bowheads was 44 percent.

The ratio of bowhead calves for 1988 (0.00) was low compared to most 1979-1987 fall (September- October) surveys (overall estimate = 0.03), although comparable to the 1981, 1984, and 1987 ratios (0.01).

The total number of polar bears (21) observed during September through October 1988 was the second highest number noted on the 1982-1987 MMS-funded arctic whale surveys. The highest number previously observed was 80 in 1983. The years 1983 and 1988 were the most severe for ice during the navigation season (USDOD, Navy, Naval Polar Oceanographic Center, 1989). The mean number of polar bears observed (September-October) in less severe ice years (1982, 1984, 1985, 1986, and 1987) was 8.6 (SD = 5.7).

B. Median Water Depth at Bowhead Sightings (1982-1988)

The median water depth at 13 sightings of bowhead whales made on line transects in Regions B, C', and D' (combined) during September and October 1988 was 42 m (Table 13). This depth was most similar to the median depth (all three regions combined) for the year 1984 (43 m) and was greater than the cumulative median for all years combined (37 m).

Statistically significant differences ($p \leq 0.05$) between the median water depth for 1988 and previous years using the Mann Whitney U test (Zar, 1984) occurred (all three regions combined) between the value for 1988 and the values for 1982, 1983, 1986, and 1987 (Table 14). Analysis by region showed that this difference was statistically significant primarily between 146° W. and 150° W. longitudes in Region C' (Table 14).

Highly significant differences ($p<0.002$) were noted (all 3 regions combined) between the median for 1984 and the medians for 1982, 1983, and 1986 (Table 14). Highly significant differences ($p<0.002$) were also noted between the 1983 median value and medians for all other years tested using this nonparametric test. The most significant differences between 1983 and other years occurs for Regions C' and D'. The 1983 median (347 m) appears to be a uniquely anomalous value (Table 13).

Mean water depths also were calculated for Regions B, C', and D' (Table 13). 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) confirmed 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 1988) were considered highly significant ($p<0.001$) in Regions C' and D' (Table 15), thus mirroring differences noted between median values in those regions. A separate comparison (Table 13) showed that the mean water depth at random sightings (all regions) during 1988 (61 m) was less than the cumulative mean for all years combined (131.1 m).

Table 12

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

	Survey Block												
Year	1	2	3	4	5	6	7	8	9	10	11	Other Canadian Areas	Other Alaskan Areas
SEPTEMBER													
1979	0.08	0.00	0.00	0.09	10.08	0.73	0.00	*	*	*	*	*	*
1980	0.38	0.00	0.00	0.47	0.99	0.00	0.00	0.00	0.00	0.00	0.00	0.47	*
1981	0.22	0.00	0.00	6.13	6.20	0.00	0.00	0.00	0.00	*	0.00	0.32	0.00
1982	6.83	1.35	0.80	0.93	11.30	0.00	0.00	0.00	1.28	*	0.00	48.65	0.00
1983	0.11	0.87	0.61	0.00	0.00	1.51	1.90	0.00	0.36	0.21	0.53	*	0.00
1984	0.59	1.05	0.18	2.69	3.19	1.94	0.00	0.00	0.00	0.00	0.00	17.00	0.00
1985	0.54	0.00	0.00	2.21	1.74	0.39	0.00	0.00	0.00	0.00	0.00	6.52	0.00
1986	0.10	0.00	0.00	0.94	2.36	0.29	0.10	0.00	0.00	0.00	0.45	7.98	0.00
1987	0.74	0.00	0.00	1.32	0.72	0.31	0.00	*	0.00	*	0.00	0.66	0.00
1988	0.14	0.00	*	0.35	0.48	0.45	0.00	0.00	*	*	*	0.00	*
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

Source: MMS, Alaska OCS Region.

* No survey effort.

Table 13

Central-Tendency Statistics for Water Depth (in meters) at Random Sightings of Bowhead Whales (September-October) in Regions B, C', and D', by Year and Region

Year	Region	SI[1]	Median	CI[2]	Mean	SD[3]	Range
1982	B'	8	17	11-457	113.4	176.23	11-457
	C'	30	27	22-38	30.6	9.03	16-51
	D'	5	40	[4]	43.4	11.24	29-59
	All 3	43	29	22-38	47.5	79.22	11-457
1983	B'	9	69	22-2,323	393.7	740.61	22-2,323
	C'	5	1,289	[4]	945.0	858.85	53-2,021
	D'	9	797	49-1,902	1,010.3	779.73	49-1,902
	All 3	23	347	49-1,737	754.8	801.84	22-2,323
1984	B'	15	42	27-69	53.3	41.43	18-177
	C'	9	38	22-82	43.7	18.73	22-82
	D'	14	48	22-274	90.4	130.05	18-485
	All 3	38	43	27-59	64.7	84.09	18-485
1985	B'	3	183	[4]	219.3	221.74	18-457
	C'	9	31	20-38	30.4	5.00	20-38
	D'	1	[4]		[4]	[4]	64
	All 3	13	31	20-183	76.6	122.13	18-457
1986	B'	4	18	[4]	51.0	69.37	13-155
	C'	12	17	9-40	60.8	144.79	7-519
	D'	22	34	22-48	34.0	13.91	11-57
	All 3	38	26	18-44	44.3	82.99	7-519
1987	B'	4	20	[4]	19.2	4.86	13-24
	C'	9	27	15-38	27.3	7.60	15-38
	D'	23	38	29-55	47.2	39.11	18-219
	All 3	36	34	26-42	39.1	33.17	13-219
1988	B'	4	36	[4]	40.5	15.11	29-62
	C'	4	44	[4]	44.8	13.60	29-62
	D'	5	46	[4]	90.4	116.40	24-298
	All 3	13	42	29-62	61.0	72.17	24-298
				Cumulative Statistics			
1982-1988	B'	47	31	22-62	135.1	348.53	11-2,323
	C'	78	31	26-38	95.7	302.60	7-2,021
	D'	79	44	37-49	163.6	400.22	11-1,902
	All 3	204	37	31-40	131.1	353.13	7-2,323

Source: MMS, Alaska OCS Region.

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

Table 14

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

REGION B	1982	1983	1984	1985	1986	1987
1983	U' = 54 p<0.10					
1984	U' = 82 p<0.20	U = 92 p<0.20				
1985	U = 18 p≤ 0.50	U' = 14 p≤ 0.50	U = 30 p≤ 0.50			
1986	U = 16 p≤ 0.50	U' = 31 p≤ 0.10	U' = 45 p≤ 0.20	U = 10 p≤ 0.50		
1987	U' = 16 p<0.50	U' = 34 p<0.02	U' = 56 p<0.01	U = 10 p<0.50	U' = 8 p<0.50	
1988	U = 21 p<0.50	U' = 23 p<0.50	U = 30 p<0.50	U = 8 p<0.50	U' = 12 p<0.50	U' = 16 p<0.05

REGION C'	1982	1983	1984	1985	1986	1987
1983	U = 150 p<0.001					
1984	U = 193 p<0.10	U = 42 p≤ 0.01				
1985	U' = 136 p<0.50	U = 45 p≤ 0.001	U = 62 p<0.10			
1986	U' = 254 p<0.05	U = 58 p≤ 0.002	U = 86 p = 0.05	U = 76 p<0.20		
1987	U' = 155 p<0.50	U = 45 p≤ 0.001	U = 64 p<0.05	U = 53 p<0.50	U = 70 p<0.50	
1988	U = 103 p<0.02	U' = 19 p<0.05	U = 20 p<0.50	U = 29 p<0.20	U = 41 p<0.05	U = 33 p<0.02

Table 14

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

REGION D[1]	1982	1983	1984	1985	1986	1987
1983	U' = 44 p≤ 0.002					
1984	U' = 36 p<0.50	U = 117 p<0.001				
1985	U = 5[1]	U' = 8	U = 11 p<0.50	p<0.50		
1986	U = 77 p<0.20	U = 196 p<0.001	U = 216 p<0.05	U = 22 p≤ 0.10		
1987	U = 68 p<0.50	U = 200 p<0.001	U = 193 p<0.50	U = 22 p<0.20	U' = 314 Z = 1.40 p<0.20	
1988	U = 13 p<0.50	U' = 43 p<0.005	U' =38 p<0.50	U = 4[1]	U = 70 p<0.50	U = 68 p<0.50

ALL THREE REGIONS (COMBINED)	1982	1983	1984	1985	1986	1987
1983	U = 882 Z = 5.22 p<0.001					
1984	U = 1,138 Z = 3.03 p<0.002	U = 718 Z = 4.19 p<0.001				
1985	U = 316 p<0.50	U' = 250 p<0.002	U = 298 p<0.50			
1986	U' = 898 Z = 0.76 p<0.50	U = 786 Z = 5.20 p<0.001	U = 1,043 Z = 3.34 p<0.001	U = 314 p<0.20		
1987	U = 859 Z = 0.83 p<0.50	U = 728 Z = 4.91 p<0.001	U = 896 Z = 2.30 p<0.01	U = 250 p<0.50	U = 825 Z = 1.53 p<0.20	
1988	U = 414 Z = 2.57 p<0.02	U' = 246 p<0.002	U = 248 p<0.50	U = 104 p<0.50	U = 356 p<0.02	U = 322 p<0.05

Source: MMS, Alaska OCS Region.

[1] Insufficient sample size.

Table 15

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 B
ANOVA F = 1.19, p<0.50

Tukey Test:	(1987)	(1988)	(1986)	(1984)	(1982)	(1985)	(1983)
	19.2	40.5	51.0	53.3	113.4	219.3	393.7

REGION C'
ANOVA F = 14.34, p< <.001

Tukey Test:	(1987)	(1985)	(1982)	(1984)	(1988)	(1986)	(1983)
	27.3	30.4	30.6	43.7	44.8	60.8	945.0

(p<0.001)

REGION D'
ANOVA F = 16.97, p< <.001

Tukey Test:	(1986)	(1982)	(1987)	(1985)	(1988)	(1984)	(1983)
	34.0	43.4	47.2	64.0	90.4	90.4	1,010.3

(p<0.025)

(p<0.001)

ALL THREE REGIONS (COMBINED)
ANOVA F = 21.84, p< <0.001

Tukey Test:	(1987)	(1986)	(1982)	(1988)	(1984)	(1985)	(1983)
	39.1	44.3	47.5	61.0	64.7	76.6	754.8

(p<0.001)

Source: MMS, Alaska OCS Region.

The reasons for the offshore (deep-water) migratory route of 1983 are not fully understood. Several factors--including differences in sampling effort, human activity levels, and oceanographic conditions--might have been involved. The possible indirect effect of heavy ice cover on prey availability has been postulated as a causative factor (Ljungblad et al., 1987). Ice cover would also have associated effects on environmental conditions expected to have biological significance to migrating bowhead whales (e.g., availability of leads, water temperature). During 1983, the most severe ice year since 1975 (USDOD, Navy, Naval Polar Oceanographic Center, 1989), the bowhead migration was observed in water almost an order of magnitude deeper than for other years (Table 13). Also, during the next most severe ice years of 1988, 1984, and 1985 (in that order), mean water depths at random bowhead sightings were greater than during other years (Table 13).

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 observed (Table 16). Although it was not possible to determine if observed responses resulted directly from overflight by survey aircraft, sudden overt changes in whale behavior were looked for and noted. Responses included abrupt dives, course diversion, or cessation of behavior ongoing at first sighting.

D. 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 1988 and show distances between Point Barrow and the five-tenths ice concentration on 15 September ranging from 10 nm to 25 nm (USDOD, Navy, Naval Polar Oceanographic Center 1989). Also, Figures 4 through 11 graphically demonstrate that 1988 was a year when ice coverage was consistently high throughout September and October.

The years 1984 and 1985 were categorized as having "medium" ice cover during the open-water season. These two years are ranked as having the fourth- and fifth-severest seasonal ice for the years 1979 through 1988 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 Oceanographic Center, 1989).

The years 1979, 1981, 1982, 1986, and 1987 were categorized as having "light" ice cover during the open-water season. These five years are ranked as having the least severe seasonal ice for the years 1979 through 1988 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 Oceanographic Center, 1989).

Table 17 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 = 0.39), a middle-range value for moderate ice years (WPUE = 0.97), and a relatively high value for light years (WPUE = 1.55). The relative abundance of bowheads for 1988 (WPUE = 0.31) was the lowest value for a single fall season (next lowest value was 0.34 for 1980) but was considered typical for a heavy ice year when bowheads may have been harder to spot.

It should be noted that although cumulative fall values for the three ice-year categories (Table 17) suggest a relationship, it is clear that general ice coverage does not fully account for variation in WPUE. Even though the mean WPUE for heavy ice years ($\bar{x}$ = 0.39, SD = 0.11, n = 3) is separable from other ice-year categories, the SD of the mean WPUE for years with light ice ($\bar{x}$ = 1.66, SD = 1.02, n = 5) overlaps that for moderate ice years ($\bar{x}$ = 0.97, SD = 0.05, n = 2). In addition, the extremely high relative values (Table 17) for the month of September 1981 (WPUE = 3.29) and September 1982 (WPUE = 3.83) would indicate that factors other than general ice coverage are operative (e.g., it is likely that the high WPUE in September 1981 resulted from the increase in effort made in the search mode, as opposed to random transects).

A comparison of ice concentrations at bowhead sightings (rather than general ice severity) between 1981 and 1986 with the sightability of whales appears in Ljungblad et al. (1987).

Table 16

Semimonthly Summary of Bowhead Whales Potentially Responding to Survey Aircraft (Fall 1988)

Potential Response Observed	1-15 Sep No. (%)	16-30 Sep No. (%)	1-15 Oct No. (%)	Total No. (%)
Yes	0	0	0	0
No	7 (100)	14 (100)	15 (94)	36 (97)
No Data	0	0	1 (6)	1 (3)
TOTAL	7 (100)	14 (100)	16 (100)	37 (100)

Source: MMS, Alaska OCS Region.

Table 17

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])

	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
General 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)	374.22	696	1.86	247.33	267	1.08	621.55	963	1.55

Source: MMS, Alaska OCS Region.

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

During 1988, MMS issued two permits to industry for seismic exploration in the Beaufort Sea. The permits were used between late August and early October in the eastern half 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.

On 6 September 1988, Amoco Production Company emplaced the Kulluk, a semisubmersible drilling barge (Fig. 28) at 70 ° 16.6 ' N. latitude, 141 ° 28.5 ' W. longitude--east-northeast of Barter Island at the Belcher drilling site. The maximum hull diameter of this circular floating structure is 80.8 m and the maximum hull depth is 18.5 m. The Kulluk has a 12-point mooring system employing anchor wire lines that are 8.9 cm in diameter. The drilling structure--operational during the present study--disengaged its anchors on 16 October 1988.

Bowheads seen in the general vicinity of the Kulluk are shown for each bimonthly period of the Fall-1988 survey in Figures 16 through 19. The closest sighting of bowhead whales was noted on 15 September 1988 (Appendix B: Flight 8) at a distance of 14.5 km northeast of the operational drilling structure. The behavior of these two whales appeared normal, i.e., they were swimming at slow speed on a 260 ° heading (magnetic).

Daily summaries of field information from this and other arctic surveys were transferred to MMS Field Operations in Anchorage for use in implementing seasonal drilling restrictions and ensuring that bowhead whales were successfully migrating past the drilling operation. Based largely on daily summaries of survey information provided by the present study, NMFS determined the official starting date (14 September) and ending date (20 October) of the Fall-1988 bowhead whale migration in the Alaskan Beaufort Sea.

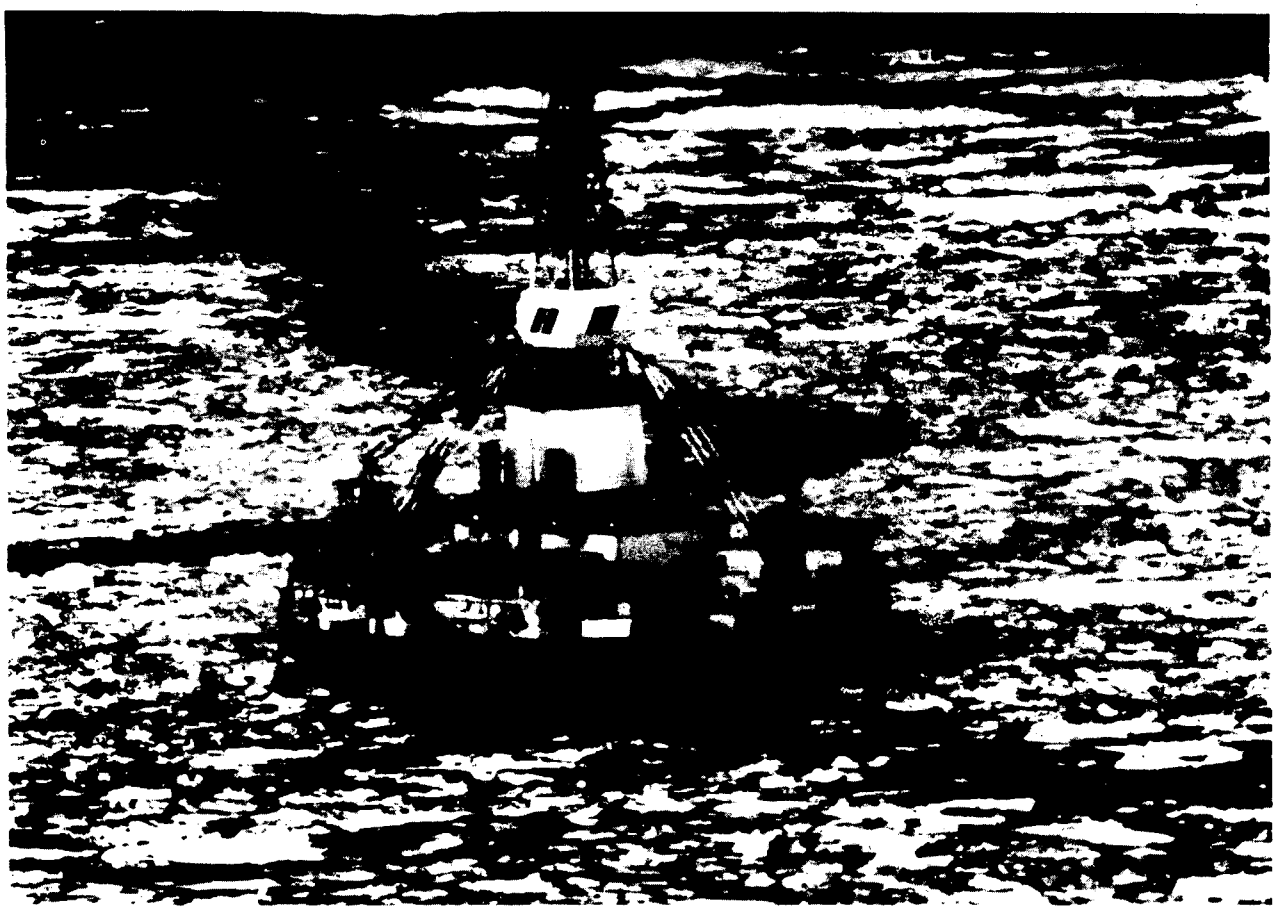


Figure 28. Kulluk Drilling Barge on Location (30 September 1988)

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APPENDIX A

BOWHEAD WHALE DENSITIES

BOWHEAD WHALE DENSITIES

This appendix presents an analysis of bowhead whale densities in the Beaufort Sea for the period 1 September through 20 October 1988.

METHODS

Density estimates were calculated for survey blocks previously shown for the Beaufort Sea (Fig. 1) using strip-transect methodologies. Such estimates require that the sightings be made on transect legs (i.e., that sightings be random) and that they occur within a predetermined distance from the aircraft (Hayne, 1949). Therefore, although abundance was calculated for any block in which bowheads were seen, density was calculated only for survey blocks in which whales were seen within 1 km on either side of the aircraft while on a transect leg. The basic formula for strip-transect estimators (Hayne, 1949) is:

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

where N is the estimated animal population, n is the number of individuals counted, A is the size of the larger area for which the estimate is made, L is the transect length, and H is the mean sighting distance. The basic assumptions for use of this formula, and the degree to which these assumptions were met in the Fall-1988 and previous MMS-funded arctic whale surveys, are incorporated by reference (Ljungblad et al., 1987: Appendix B).

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

RESULTS

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

During the first half of September, over 10 percent of the area in each block was surveyed for Blocks 5 and 7. No bowheads were observed in Blocks 5 and 7 within 1 km of the randomly generated transect line.

During the second half of September, over 10 percent of the area in each block was surveyed for Blocks 1, 2, 4, 5, and 6. Of these, bowheads were observed within 1 km of the transect line in Blocks 1 and 5, for estimated densities of 0.07 and 0.07 whales, respectively, per 100 km^2.

During the first half of October, over 10 percent of the area in each block was surveyed for Blocks 1, 2, 3, 4, 5, 6, and 11. Of these, bowheads were observed within 1 km of the transect line in Blocks 1, 2, and 3, for estimated densities of 0.07, 0.07, and 0.20 whales, respectively, per 100 km^2. From 16 through 20 October, no block received more than 10-percent random-survey coverage. No bowheads were observed within 1 km of the transect line during this period.

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Table A-1

Semimonthly Estimates of Bowhead Whale Densities, by Survey Block (Fall 1988)
(strip width = 2 km)

Block Number (by Semimonthly Period)	Block Area (km^2)	Transect Distance (km)	Percent of Area Surveyed	Transect Time (h)	Percent of Total Time	Number of Transects Flown	Number of Whales Observed	Density (No./100km^2)
1-15 Sep								
1	10,222	208	4.06	0.82	7.99	5	1	0.24
2	6,672	0	0.00	0.00	0.00	0	0	0.00
3	11,475	0	0.00	0.00	0.00	0	0	0.00
4	5,714	272	9.52	1.11	10.88	6	0	0.00
5	9,481	1,639	34.58	6.45	63.15	26	0	0.00
6	8,109	1	0.03	0.00	0.05	2	0	0.00
7	8,109	439	10.83	1.80	17.60	11	0	0.00
16-30 Sep								
1	10,222	725	14.18	2.96	16.58	20	1	0.07
2	6,672	355	10.64	1.44	8.05	11	0	0.00
3	11,475	0	0.00	0.00	0.00	0	0	0.00
4	5,714	534	18.70	2.16	12.06	12	0	0.00
5	9,481	2,207	46.56	8.94	50.05	35	3	0.07
6	8,109	442	10.91	1.78	9.95	8	0	0.00
7	8,109	151	3.72	0.59	3.30	10	0	0.00
1-15 Oct								
1	10,222	743	14.53	3.05	14.17	17	1	0.07
2	6,672	680	20.38	2.93	13.60	19	1	0.07
3	11,475	748	13.03	3.18	14.74	22	3	0.20
4	5,714	647	22.63	2.69	12.49	16	0	0.00
5	9,481	615	12.96	2.57	11.95	9	0	0.00
6	8,109	447	11.03	1.76	8.15	9	0	0.00
7	8,109	293	7.23	1.18	5.45	4	0	0.00
9	9,753	186	3.81	0.73	3.40	4	0	0.00
11	10,358	757	14.61	3.15	14.60	19	0	0.00
16-20 Oct								
3	11,475	211	3.67	0.89	17.36	4	0	0.00
4	5,714	67	2.33	0.30	5.84	2	0	0.00
5	9,481	392	8.28	1.69	32.87	8	0	0.00
6	8,109	0	0.00	0.00	0.00	0	0	0.00
7	8,109	368	9.07	1.50	29.14	8	0	0.00
11	10,358	185	3.58	0.76	14.78	4	0	0.00

Source: MMS, Alaska OCS Region.

APPENDIX B

DAILY FLIGHT SUMMARIES - TWIN OTTER

DAILY FLIGHT SUMMARIES - TWIN OTTER

This appendix consists of Flight Tracks 1 through 36, depicting aerial surveys flown over the study area from 3 September through 20 October 1988, by MMS personnel aboard a Twin Otter aircraft. Maps were prepared using a series of computer programs consisting of BASIC subroutines implemented on a Hewlett-Packard (HP 85) microcomputer connected to an HP 7470A printer/plotter. The coastlines for each map, digitized on an HP 9111A graphics tablet, were formatted to examine the principal study area. As a result, a comparison of flight tracks can be made on a visual basis over the period of the field season to evaluate ongoing patterns of the animal distribution and aircraft coverage. Each map shows the flight track as a line drawn through position updates recorded on the aircraft computer system. Each animal sighting is marked with a species symbol on the flight-track plot. The symbols used can be keyed out to a two-letter abbreviation shown in each map legend representing the following species:

BH = Bowhead Whale
GW = Gray Whale
BE = Beluga Whale
BS = Bearded Seal
RS = Ringed Seal
PN = Unidentified Pinniped
PR = Polar Bear

Summary information on bowhead whale sightings is presented beneath the flight acaption in a tabular format, as follows:

T#/C# Total number of whales/total number of calves seen
LAT/LONG Location (latitude N./longitude W.) in degrees, minutes, and tenths of minutes
DIS Perpendicular distance from the aircraft in meters (altitude x cotangent clinometer angle)
CUE Sighting cue:

BO = Body
BW = Blow
SP = Splash
MP = Mud Plumes
DY = Display

BEH Behavior:

SW = Swim
DI = Dive
RE = Rest
MI = Mill
UB = Underwater Blow
DY = Display
MT = Mate
FE = Feed
CC = Cow-Calf
DE = Dead
SH = Spy-Hop
TS = Tail-Slap
BR = Breach
RL = Roll
NA = No Data

HDG Heading in magnetic degrees

ICE Ice cover in percent

SS Sea state (Beaufort scale)

DEPTH Depth in meters

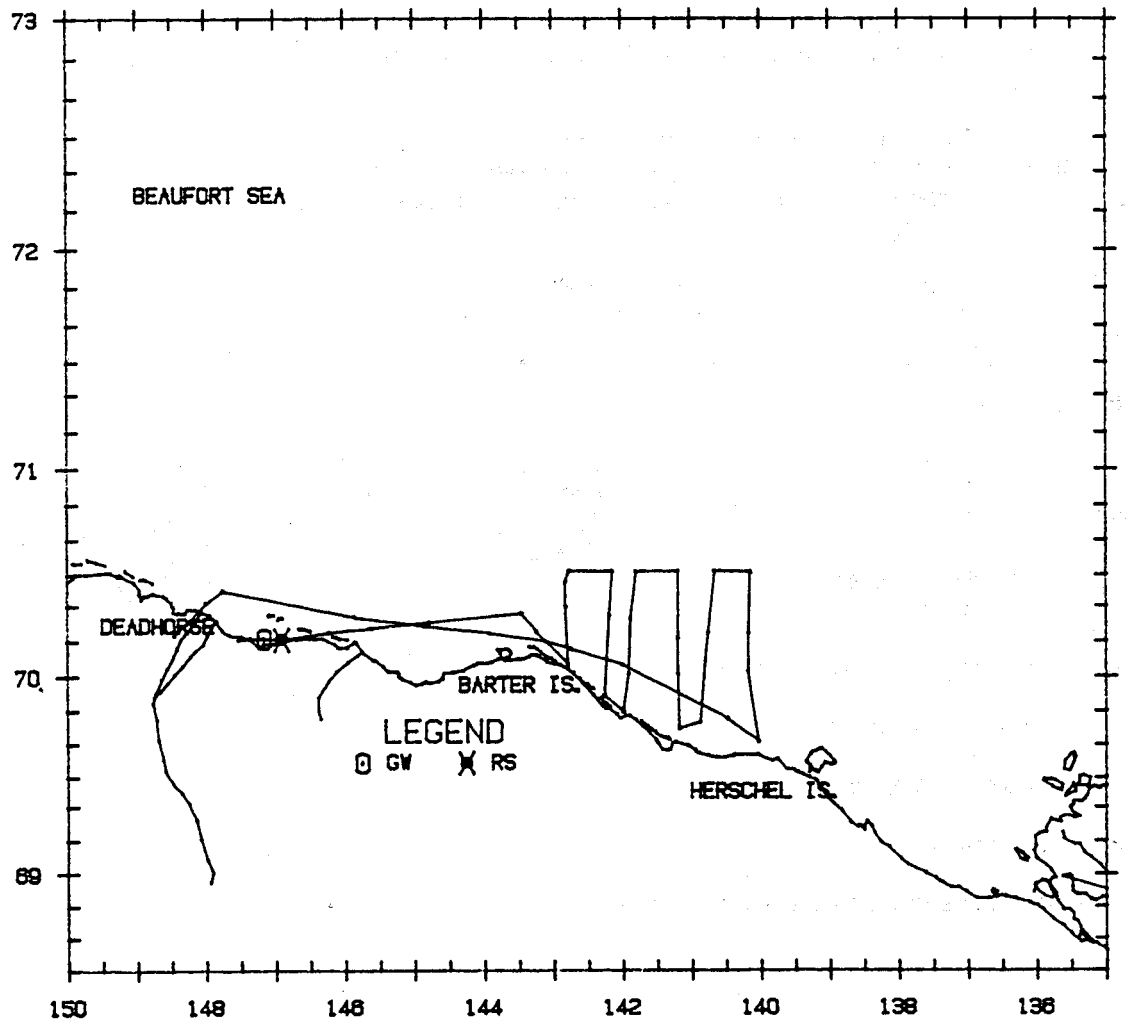
Dash (-) Indicates that data were not recorded

TWIN OTTER FLIGHT 1: 3 SEPTEMBER 1988

Flight was a transect survey of Block 5. Weather was clear, visibility unlimited. Ice cover ranged from 30 to 95 percent, except between shore and the barrier islands, where there was no ice. Sea state was Beaufort 00 to 01. One dead gray whale and one ringed seal were seen along the coast east of Deadhorse.

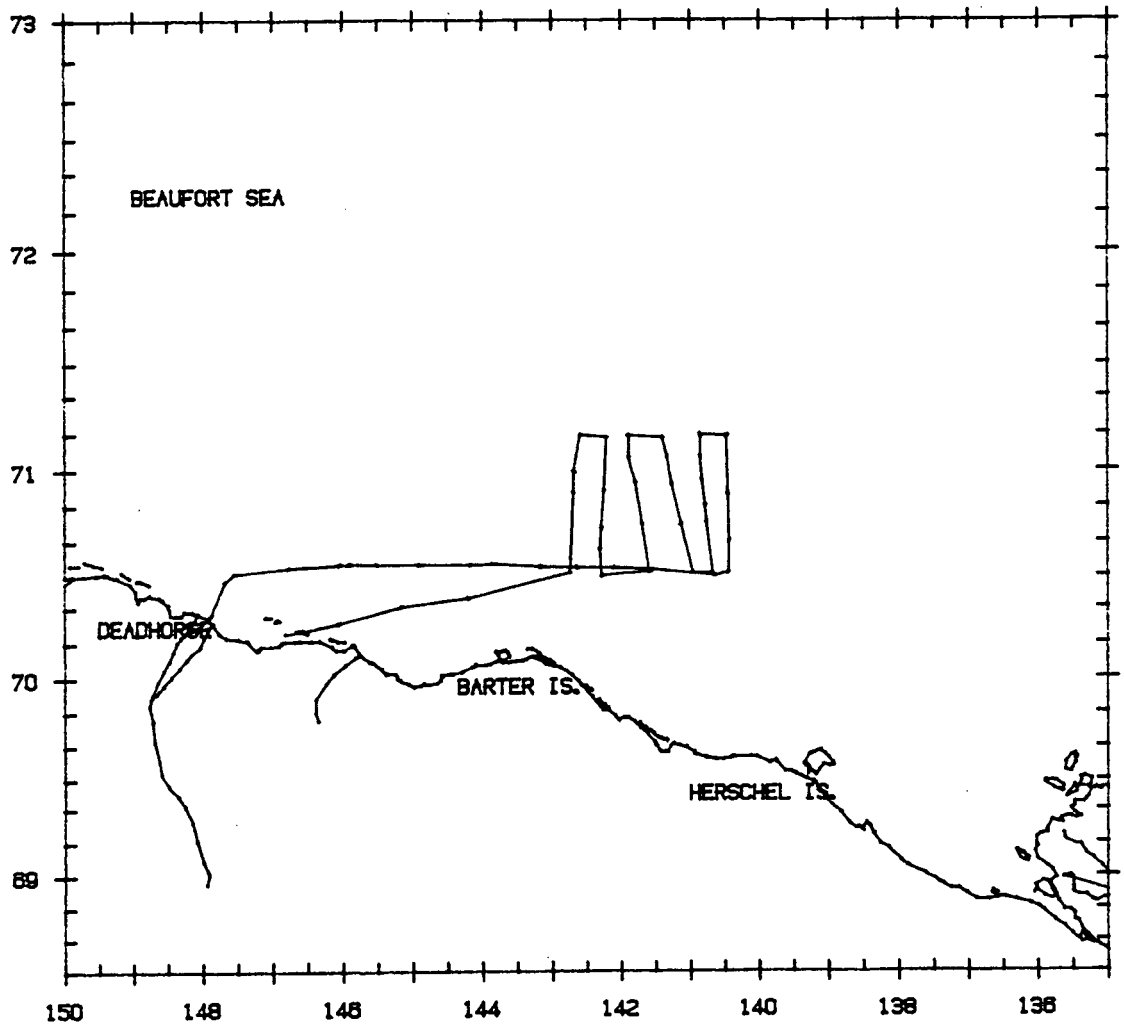
Gray Whale

T#C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	70°10.8'	147°09.7'	-	BF	DE	-	0	B1	4



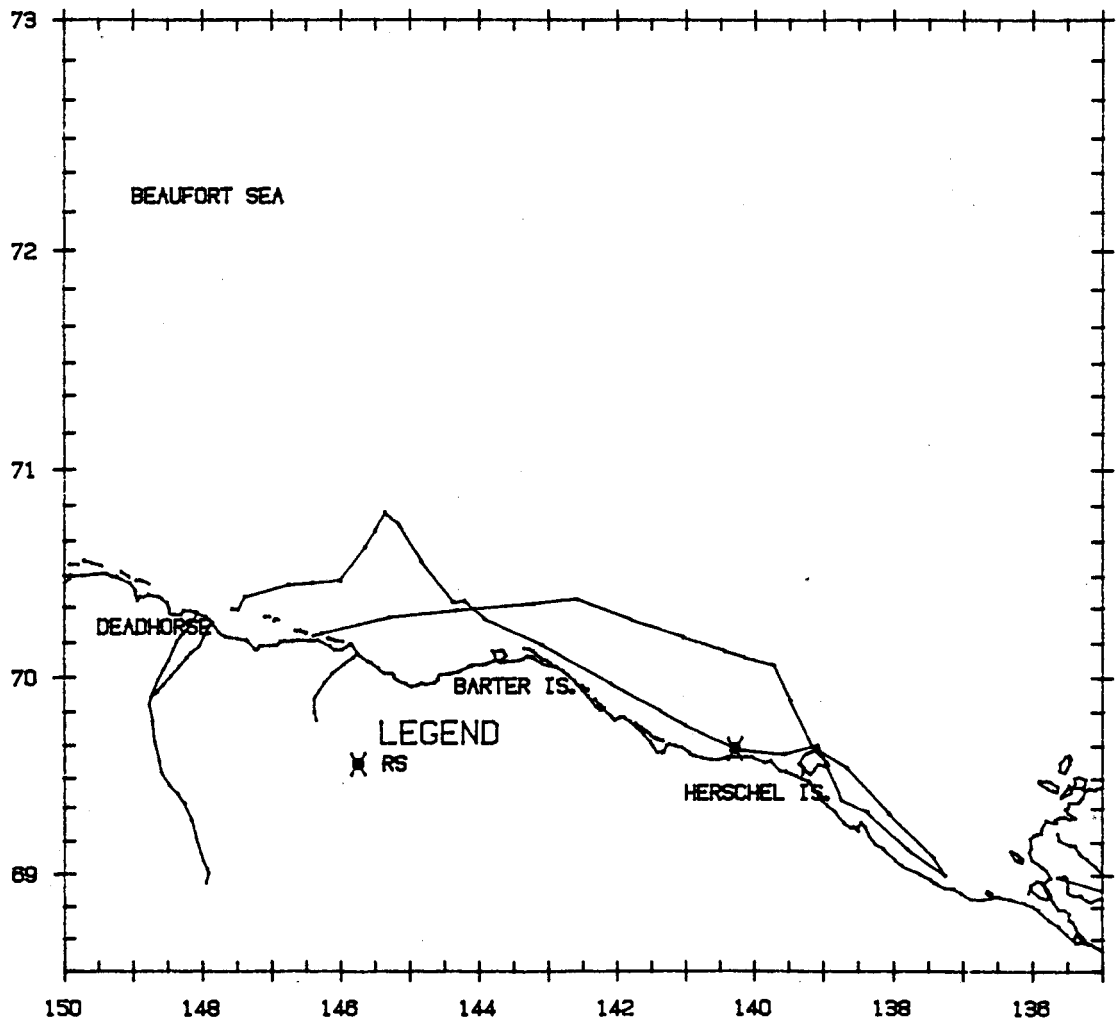
TWIN OTTER FLIGHT 2: 4 SEPTEMBER 1988

Flight was a transect survey of Block 7. Weather was overcast with unlimited visibility. Ice cover ranged from 30 to 90 percent, except between shore and the barrier islands, where there was no ice. Sea state ranged from Beaufort 00 to 04. No marine mammals were seen.



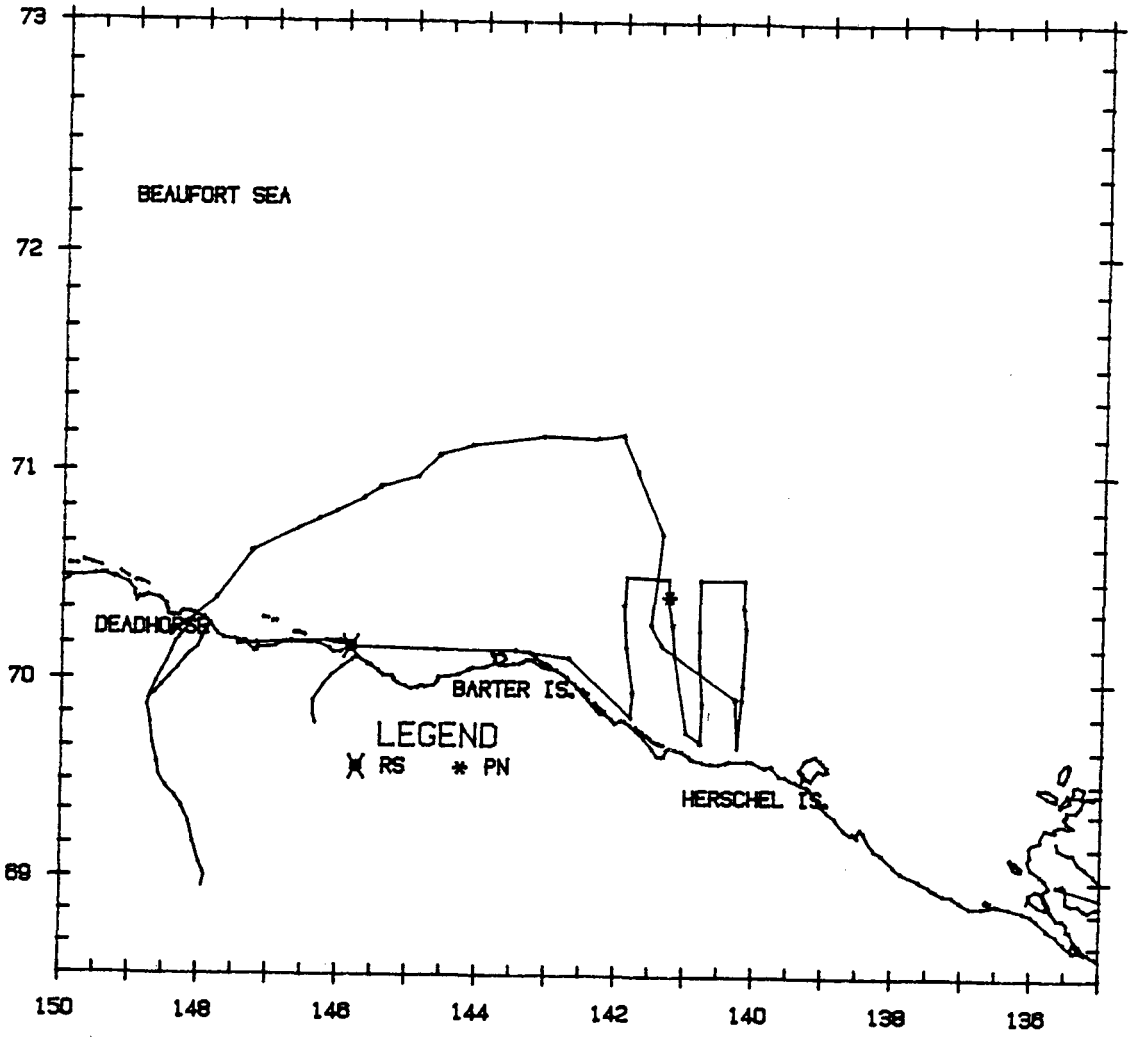
TWIN OTTER FLIGHT 3: 7 SEPTEMBER 1988

Flight was a search survey of Blocks 4 and 5 and into Canadian waters to 137° W. longitude. Weather was overcast with patches of fog; visibility ranged from roughly 20 to 80 percent in Blocks 4 and 5, with Canadian waters generally ice-free. Sea state ranged from Beaufort 01 to 04 but averaged 02. One ringed seal was seen.



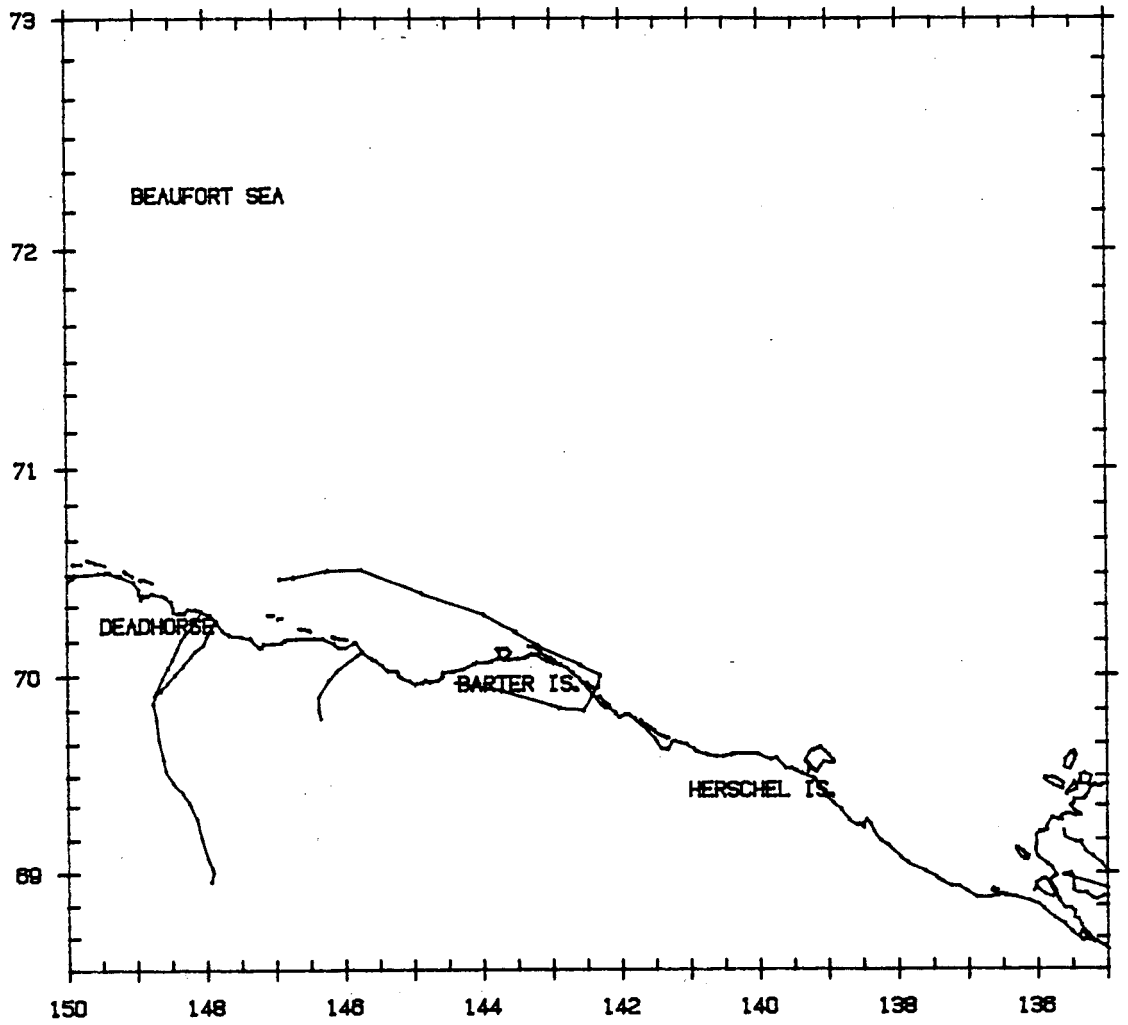
TWIN OTTER FLIGHT 4: 8 SEPTEMBER 1988

Flight was a transect survey of the eastern two-thirds of Block 5 and a search survey through Block 6. Weather ranged from clear to overcast with low ceilings. Visibility was unlimited and ice cover ranged from 20 to 85 percent, except between shore and the barrier islands, where there was no ice. Sea state ranged from Beaufort 00 to 03. Ringed seals and an unidentified pinniped were seen.



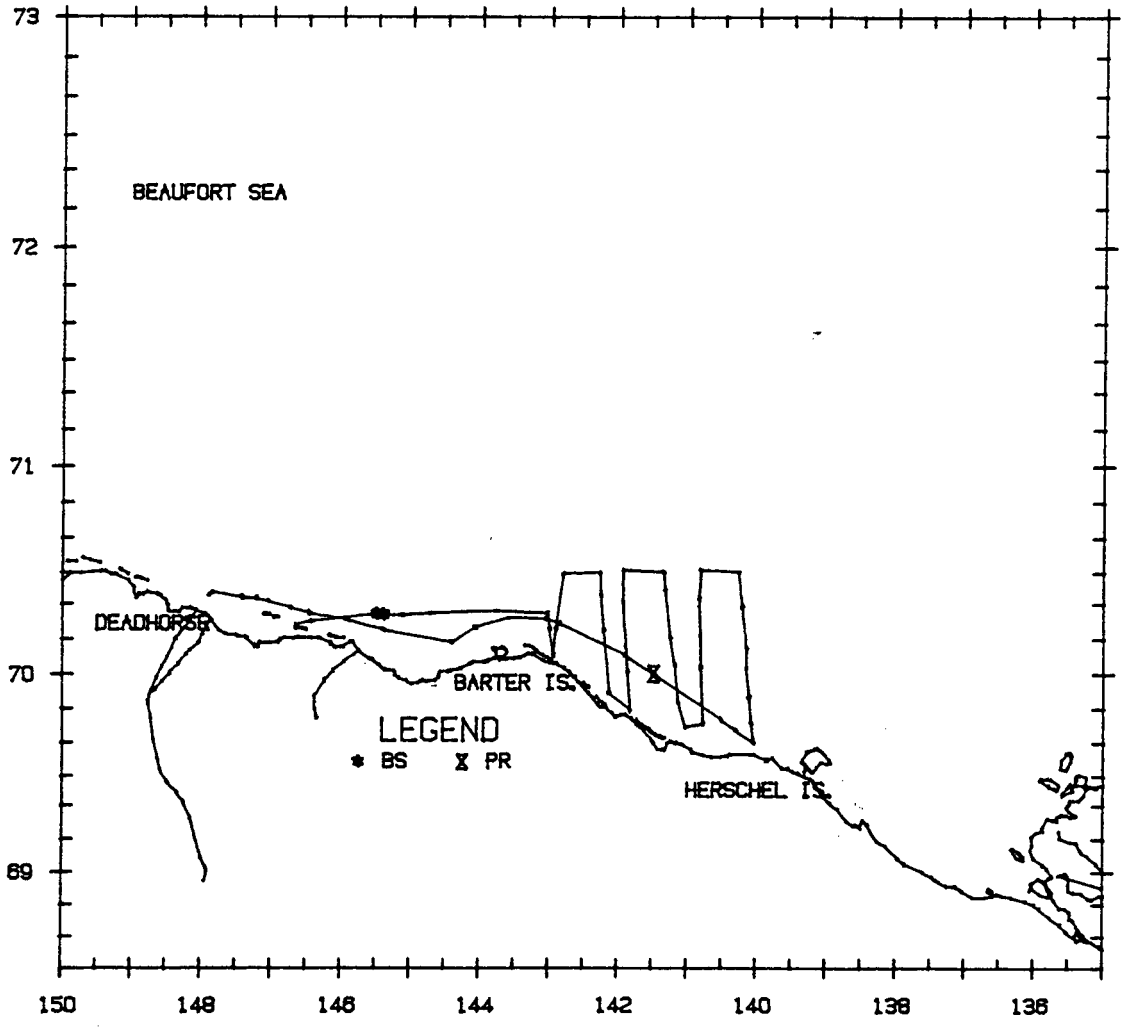
TWIN OTTER FLIGHT 5: 11 SEPTEMBER 1988

Flight was a search survey through Block 4 that was aborted due to low ceilings and fog, resulting in unacceptable visibility. No marine mammals were seen.



TWIN OTTER FLIGHT 6: 12 SEPTEMBER 1988

Flight was a transect survey of Block 5, with a search survey through Block 4. Weather was overcast with patches of fog, and visibility ranged from <1 km to unlimited. Ice cover ranged from 10 to 95 percent, with open water nearshore and between the coast and the barrier islands. Sea state was Beaufort 00 to 03 but averaged 02. Bearded seals and a polar bear were seen.

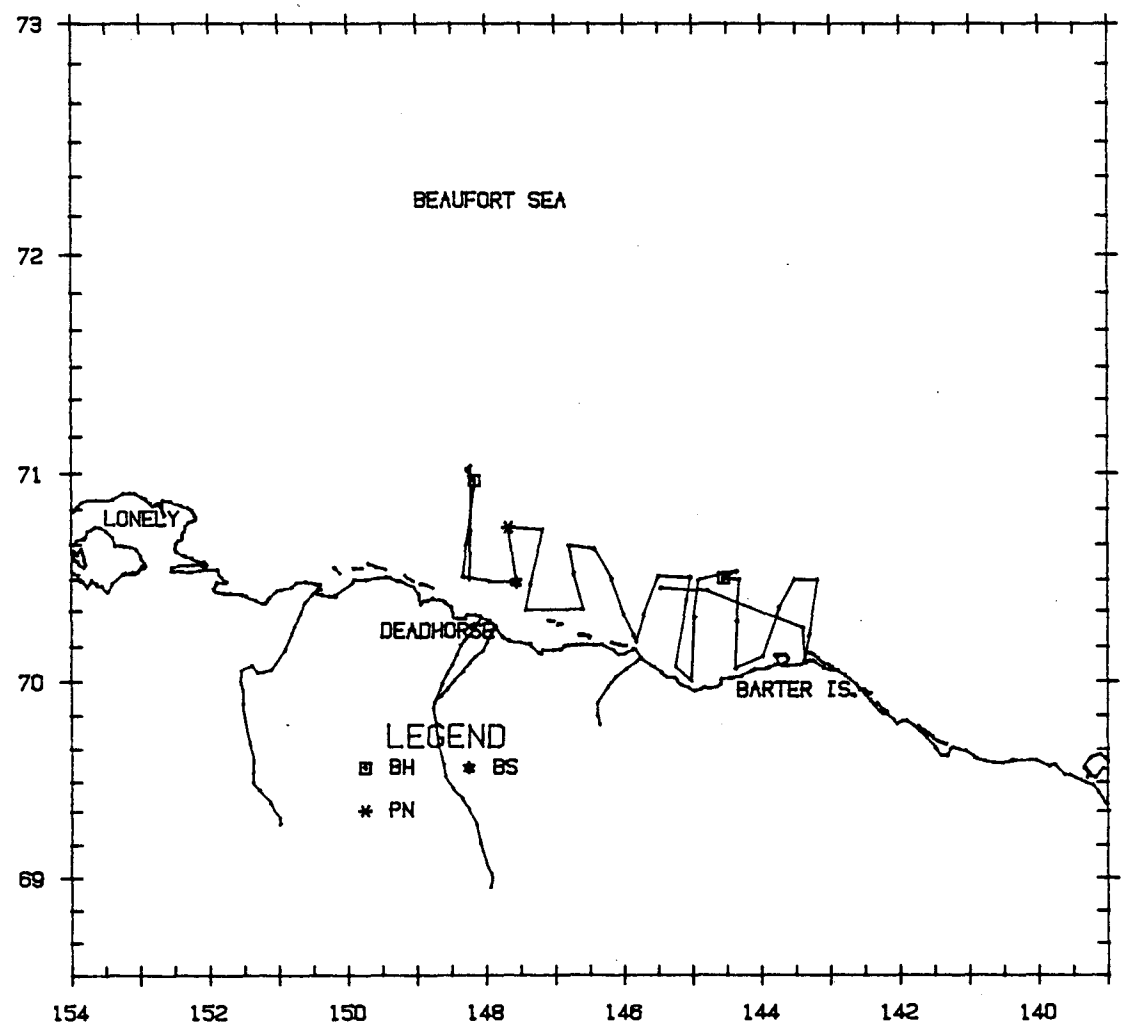


TWIN OTTER FLIGHT 7: 14 SEPTEMBER 1988

Flight was a transect survey of Block 4 and most of Block 1. Weather was partly cloudy and visibility unlimited. Ice cover ranged from 10 to 70 percent, with open water along the coast. Sea state was Beaufort 01 to 02. Five bowheads were seen--four in Block 4 and one breaching whale in Block 1. A bearded seal and an unidentified pinniped were also seen.

Bowhead Whales

T#C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
4/0	70°29.3'	144°32.9'		SP	SW	240	70	B1	42
1/0	70°58.3'	148°09.7'	40	SP	BR	280	50	B2	46

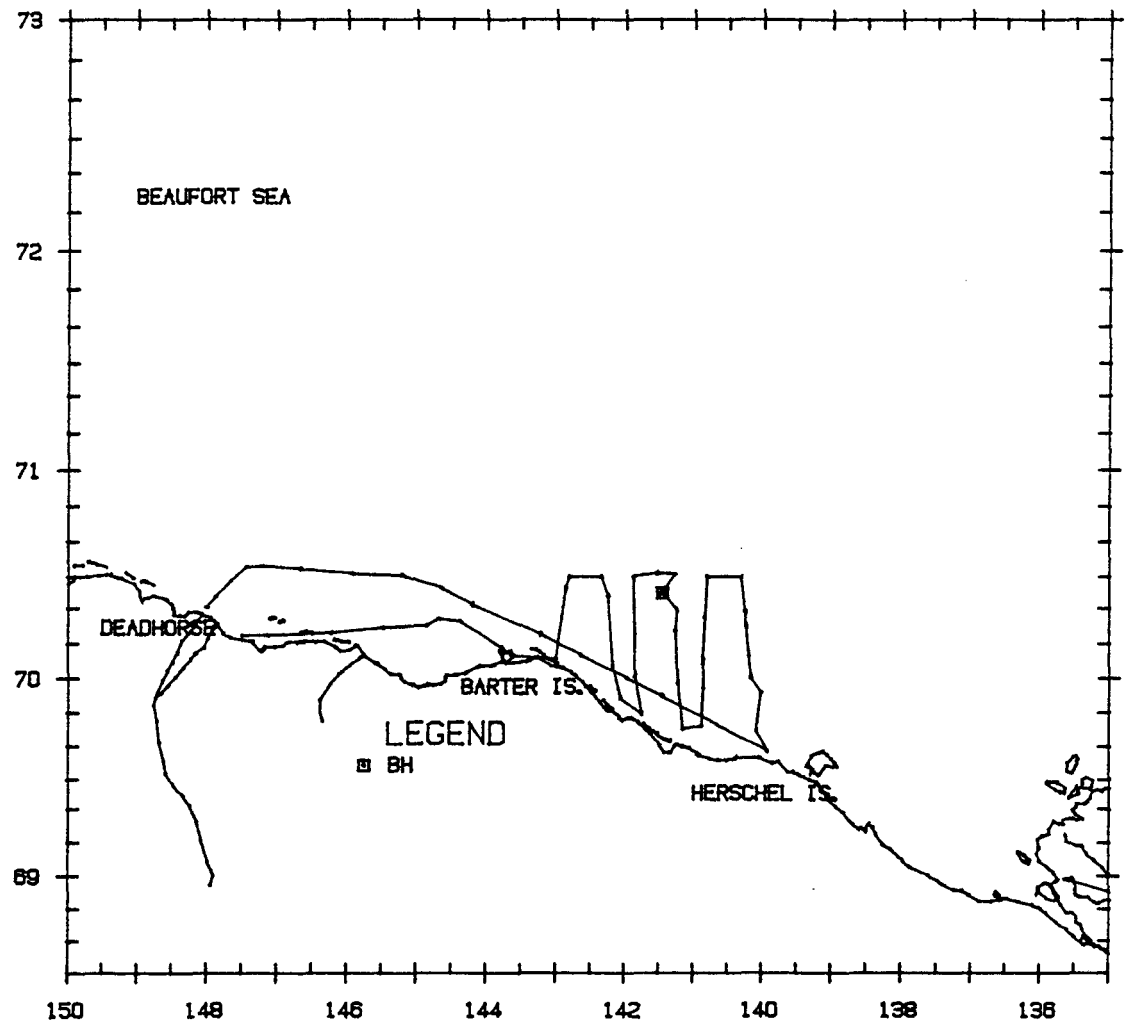


TWIN OTTER FLIGHT 8: 15 SEPTEMBER 1988

Flight was a transect survey of Block 5, with a search survey through Block 4. Weather was partly cloudy, with localized areas of overcast and precipitation. Visibility was mostly unlimited. Ice cover ranged from 10 to 90 percent, with open water nearshore. Sea state was Beaufort 00 to 02. Two bowheads were seen in Block 5.

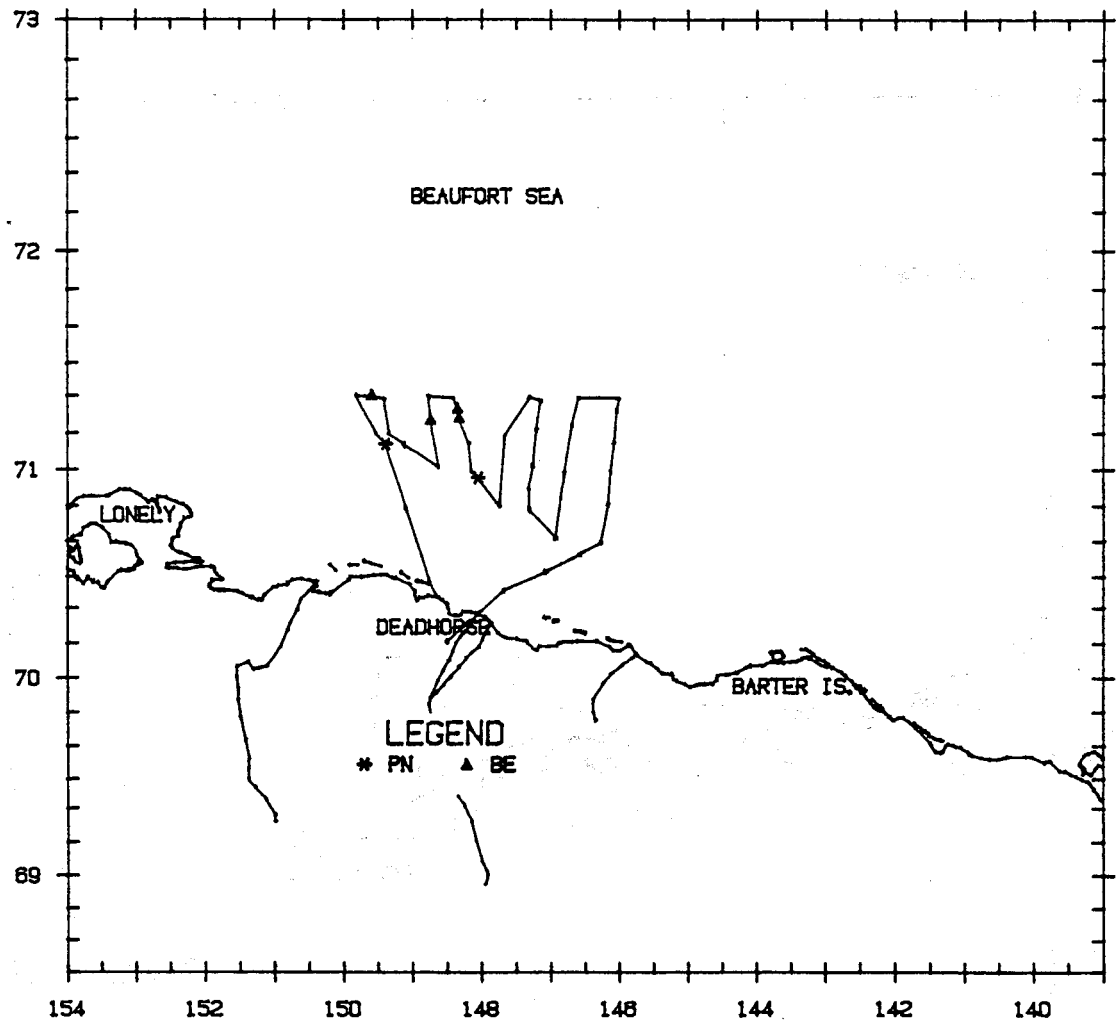
Bowhead Whales

T#C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
2/0	70°24.4'	141°27.3'	424	BW	SW	260	70	B1	298



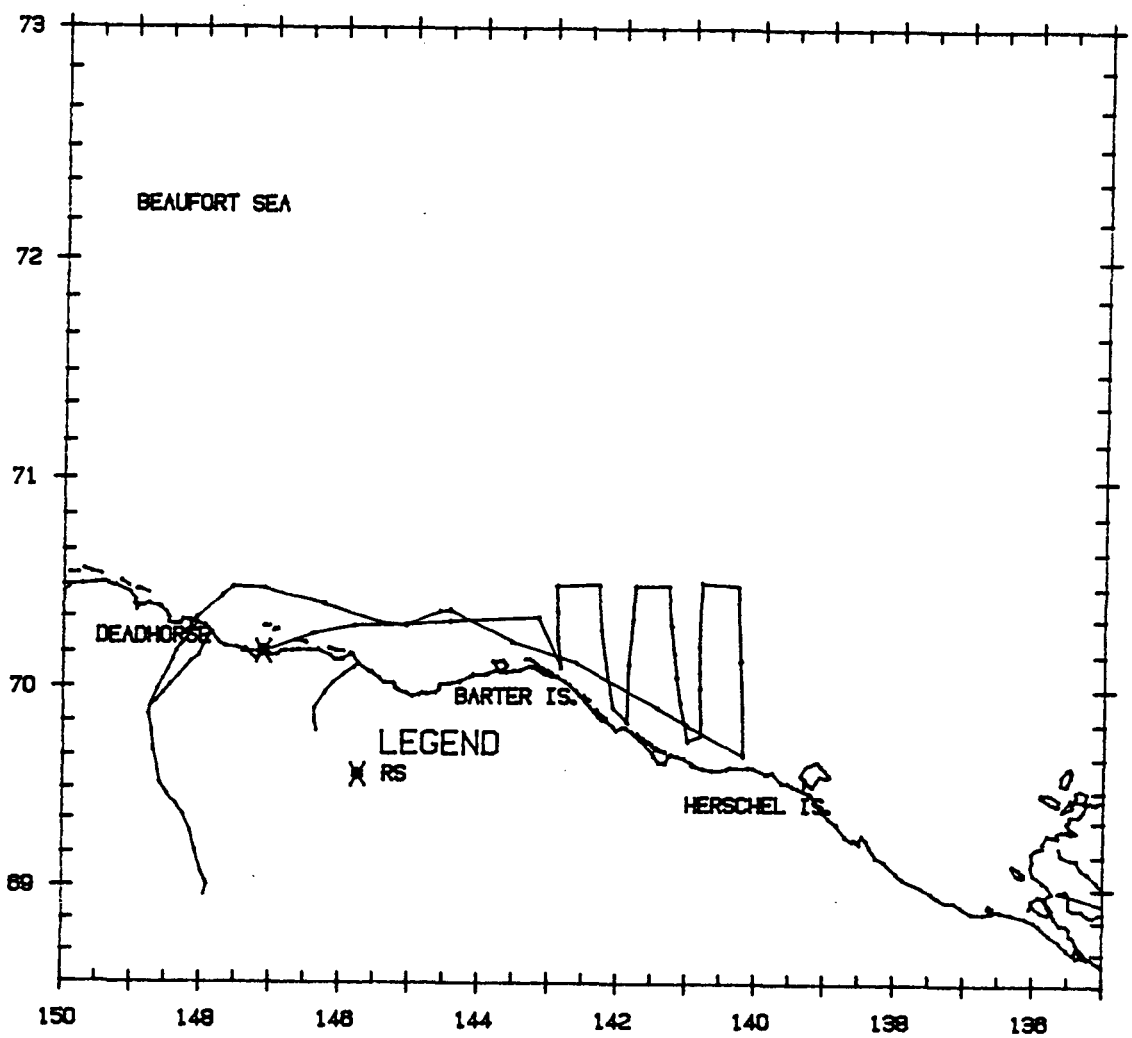
TWIN OTTER FLIGHT 9: 16 SEPTEMBER 1988

Flight was a transect survey of Block 2. Weather was clear and visibility unlimited. Ice cover ranged from 10 to 100 percent but averaged roughly 50 percent. Sea state ranged from Beaufort 01 to 04 but averaged 02. Beluga whales and unidentified pinnipeds were seen.



TWIN OTTER FLIGHT 10: 17 SEPTEMBER 1988

Flight was a transect survey of Block 5, with a search survey through Block 4. Weather was clear and visibility unlimited. Ice cover ranged from 35 to 100 percent, with some open water nearshore and between the coast and the barrier islands. Sea state was Beaufort 01 to 02. Ringed seals were seen along shore east of Deadhorse.

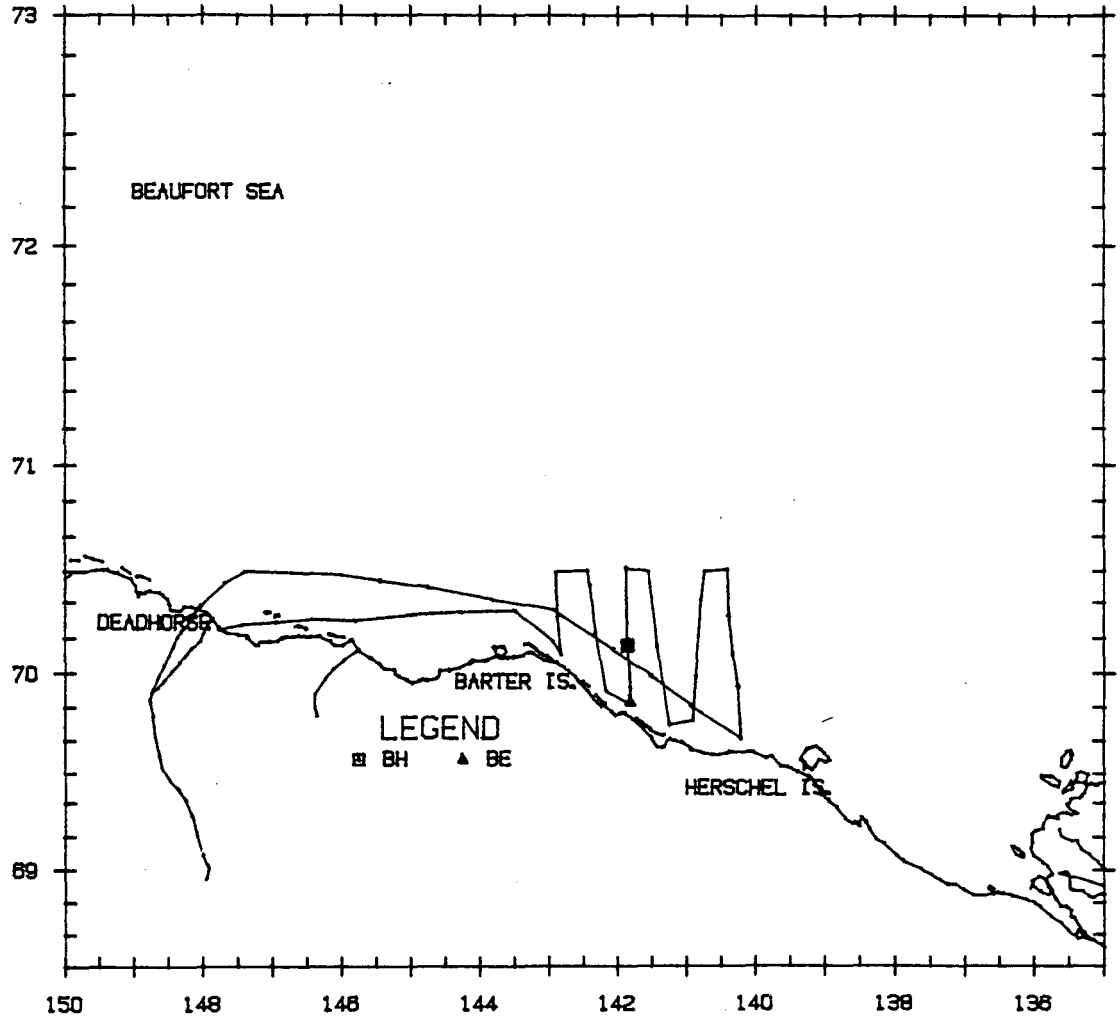


TWIN OTTER FLIGHT 11: 18 SEPTEMBER 1988

Flight was a transect survey of Block 5, with a search survey through Block 4. Weather was partly cloudy with areas of overcast; visibility was unlimited. Ice cover ranged from 35 to 100 percent, with some open water nearshore and between the coast and the barrier islands. Sea state was Beaufort 00 to 01. Three bowheads and a beluga whale were seen.

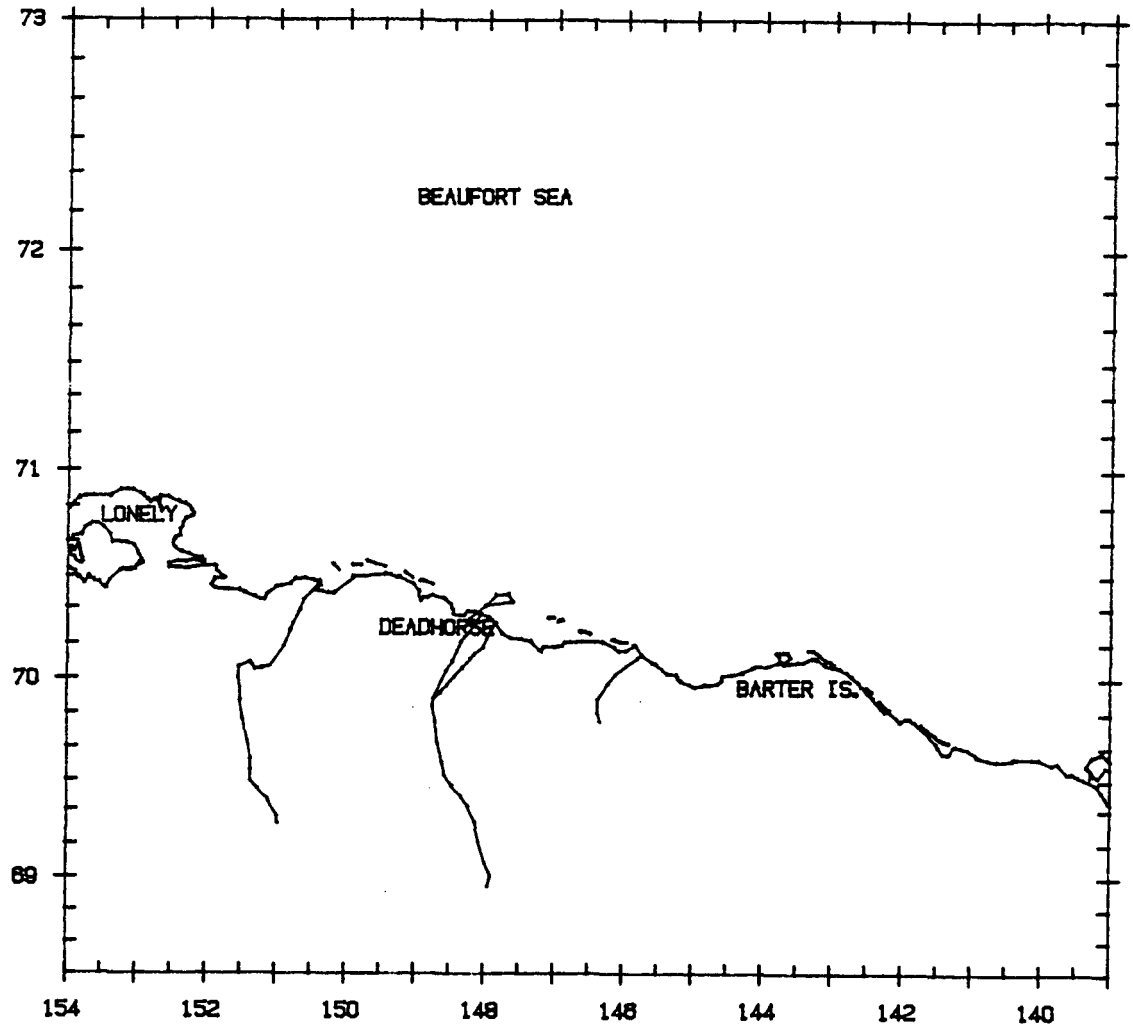
Bowhead Whales

T#C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	70°08.0'	141°51.4'	649	SP	SW	310	70	B0	31
2/0	70°08.3'	141°50.7'	1270	BO	SW	330	75	B0	37



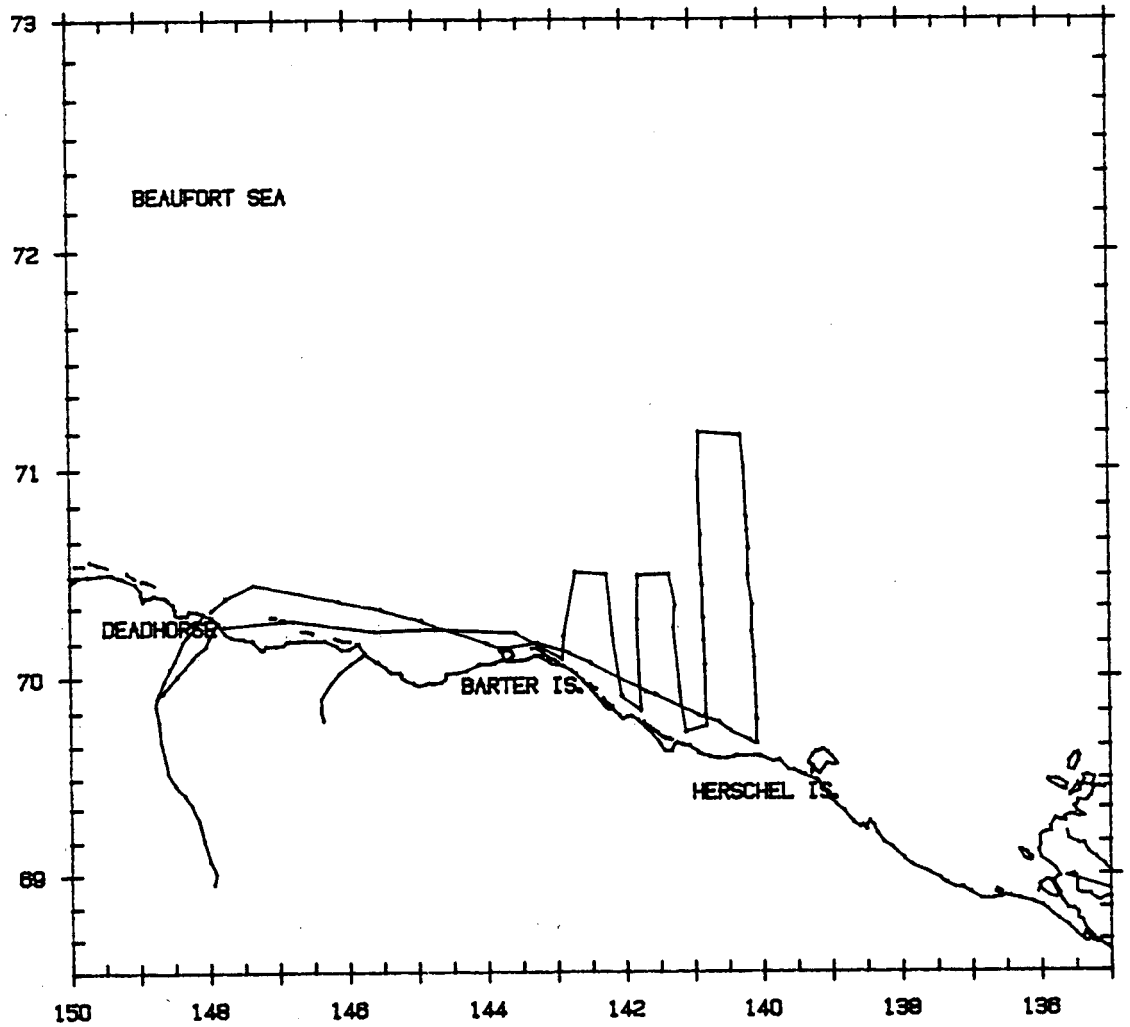
TWIN OTTER FLIGHT 12: 21 SEPTEMBER 1988

Flight was a brief search survey of Block 4 that was aborted due to low ceilings, fog, and precipitation, resulting in unacceptable visibility. No marine mammals were seen.



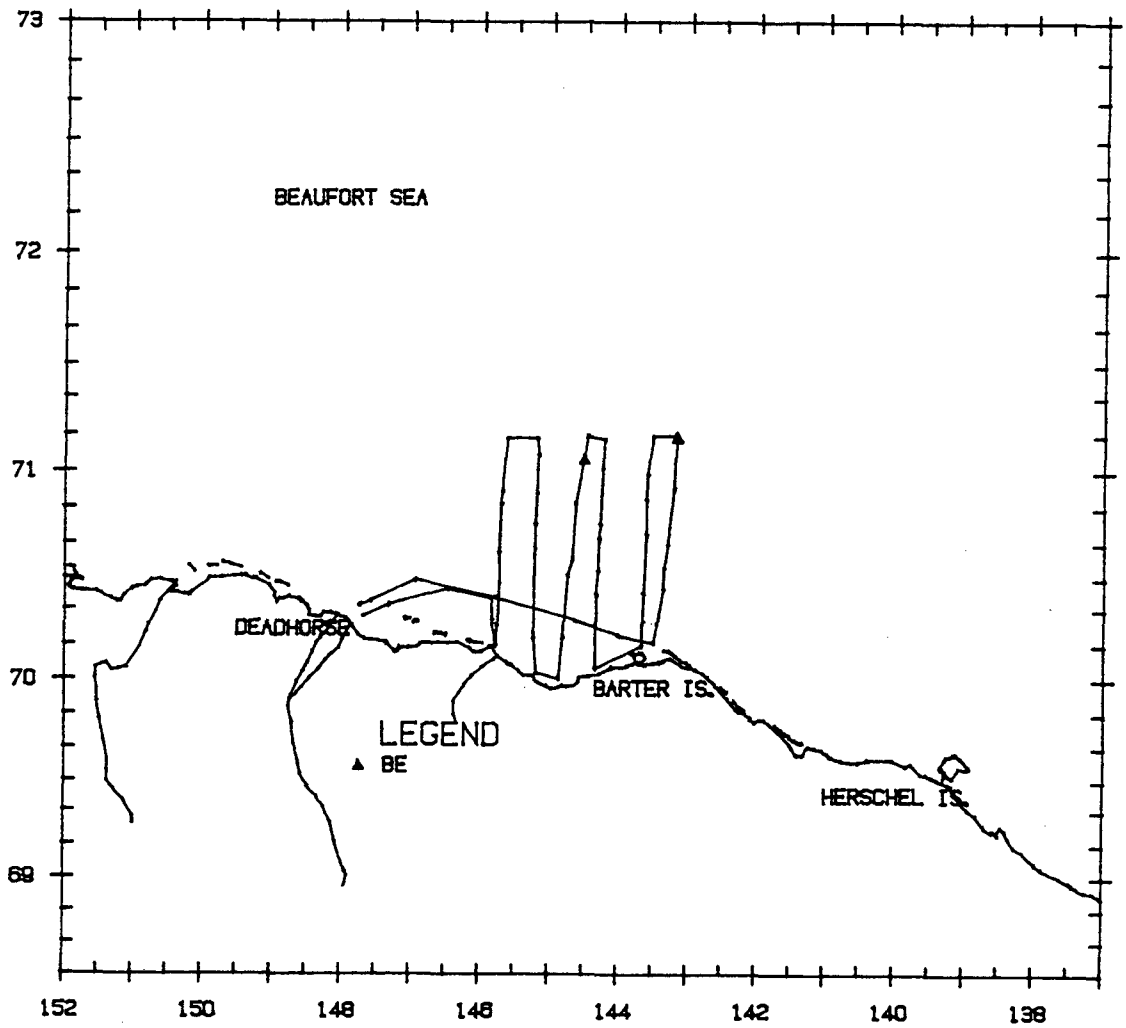
TWIN OTTER FLIGHT 13: 23 SEPTEMBER 1988

Flight was a transect survey of Block 5 and the eastern one-third of Block 7. Weather ranged from partly cloudy to overcast with patches of fog. Visibility ranged from unacceptable to unlimited. Ice cover was 35 to 75 percent, and sea state was Beaufort 00 to 02. No marine mammals were seen.



TWIN OTTER FLIGHT 14: 24 SEPTEMBER 1988

Flight was a transect survey of Blocks 4 and 7. Weather was partly cloudy to overcast and visibility was unlimited. Ice cover ranged from 10 to 95 percent, with open water along shore. Sea state ranged from Beaufort 01 to 04 but averaged 02. Beluga whales were seen in Block 7.

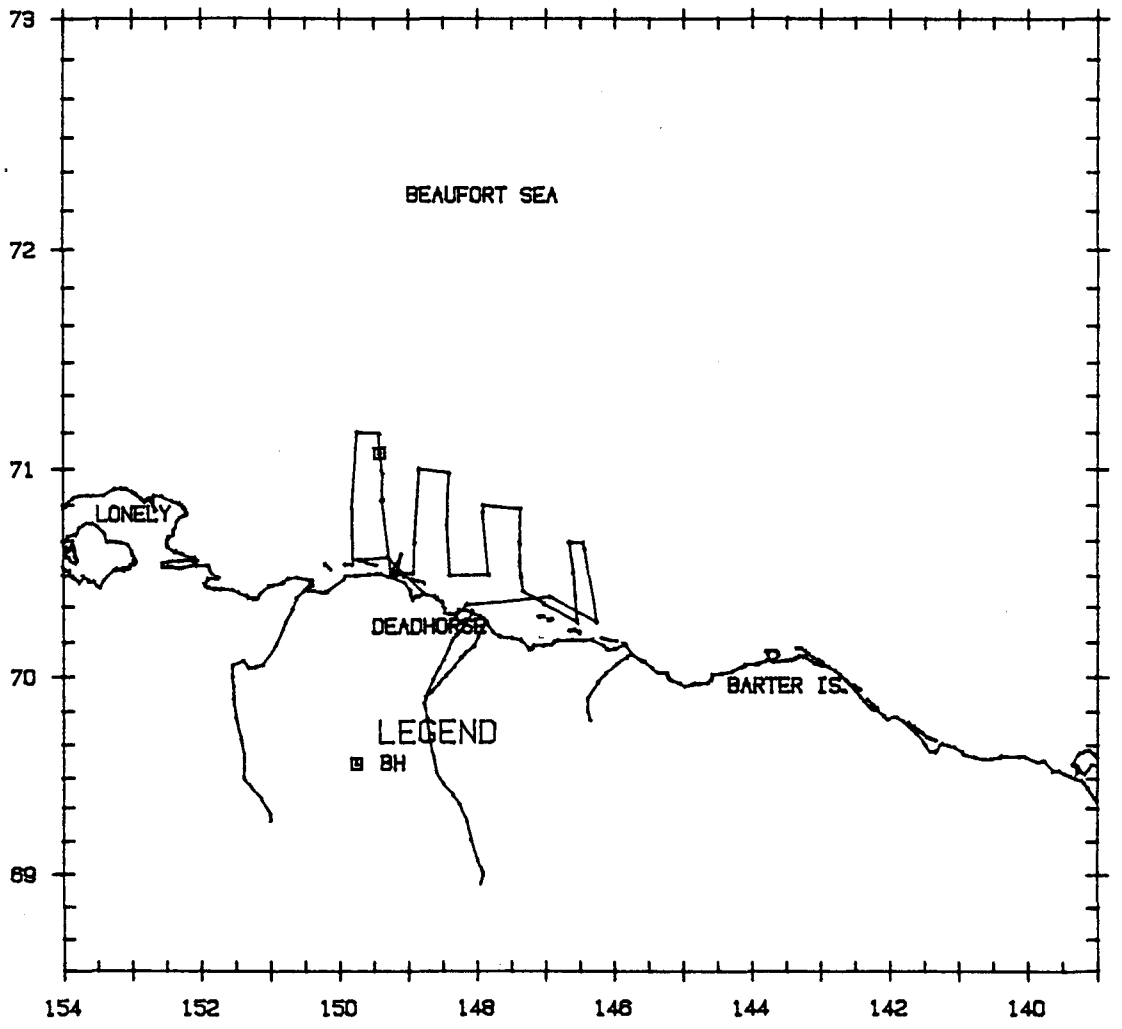


TWIN OTTER FLIGHT 15: 25 SEPTEMBER 1988

Flight was a transect survey of Block 1. Weather ranged from partly cloudy to overcast with patches of fog. Visibility was unlimited. Ice cover was 5 to 75 percent, with open water nearshore and between the coast and the barrier islands. Sea state ranged from Beaufort 01 to 04 but averaged 02. One bowhead was seen.

Bowhead Whales

T#C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71°04.5'	149°24.3	256	BO	SW	240	75	B1	29

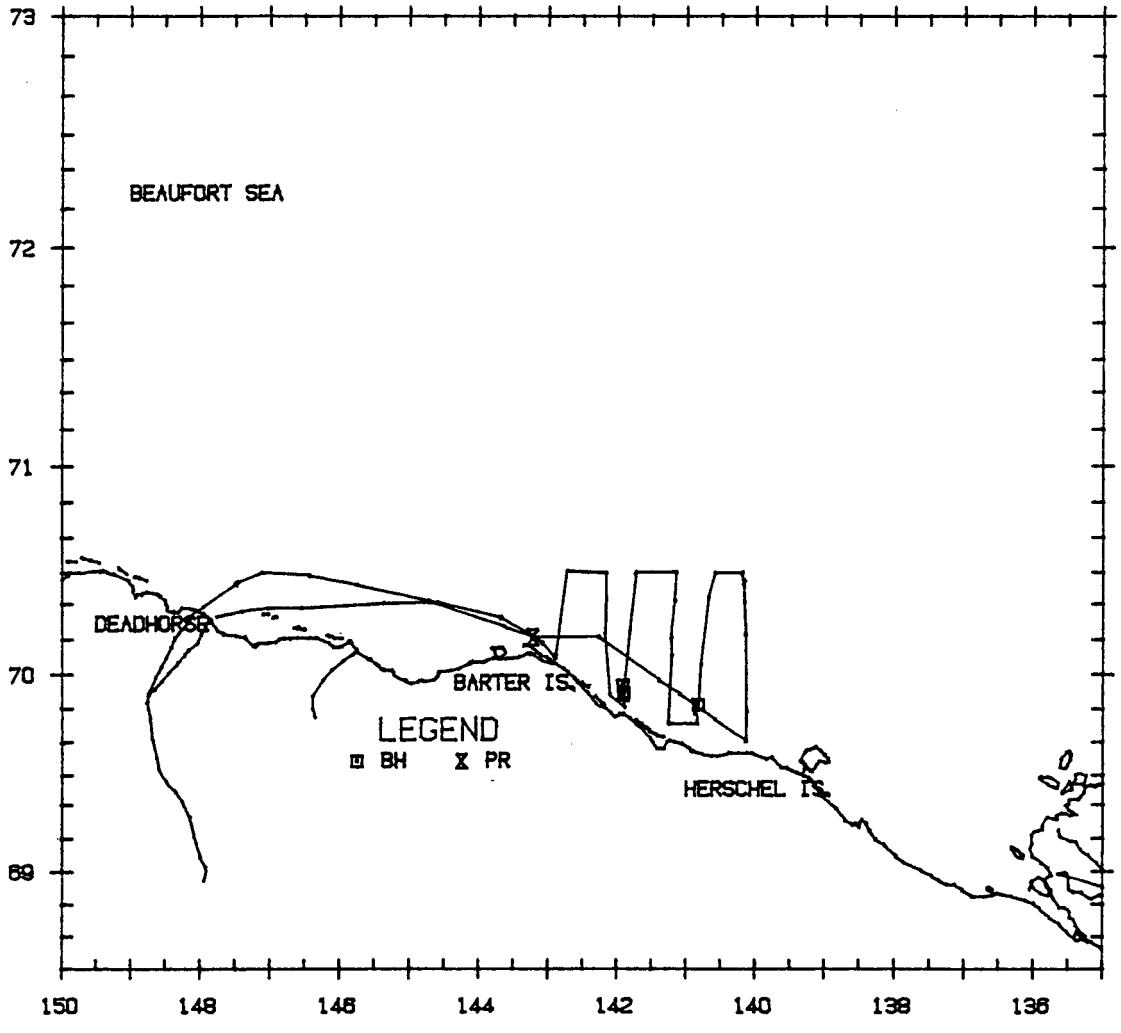


TWIN OTTER FLIGHT 16: 26 SEPTEMBER 1988

Flight was a transect survey of Block 5, with a search survey through Block 4. Weather was overcast with unlimited visibility. Ice cover ranged from 10 to 95 percent, with some open water nearshore. Sea state was Beaufort 00 to 02. Five bowheads and a polar bear were seen.

Bowhead Whales

T#C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	69°51.3'	140°48.9'	607	BO	SW	210	30	B0	37
1/0	69°54.2'	141°54.1'	545	BO	SW	270	50	B0	24
2/0	69°57.0'	141°54.6'		BW	SW	300	50	B0	29
1/0	69°54.9'	141°53.5'		BO	SW	300	50	B0	24

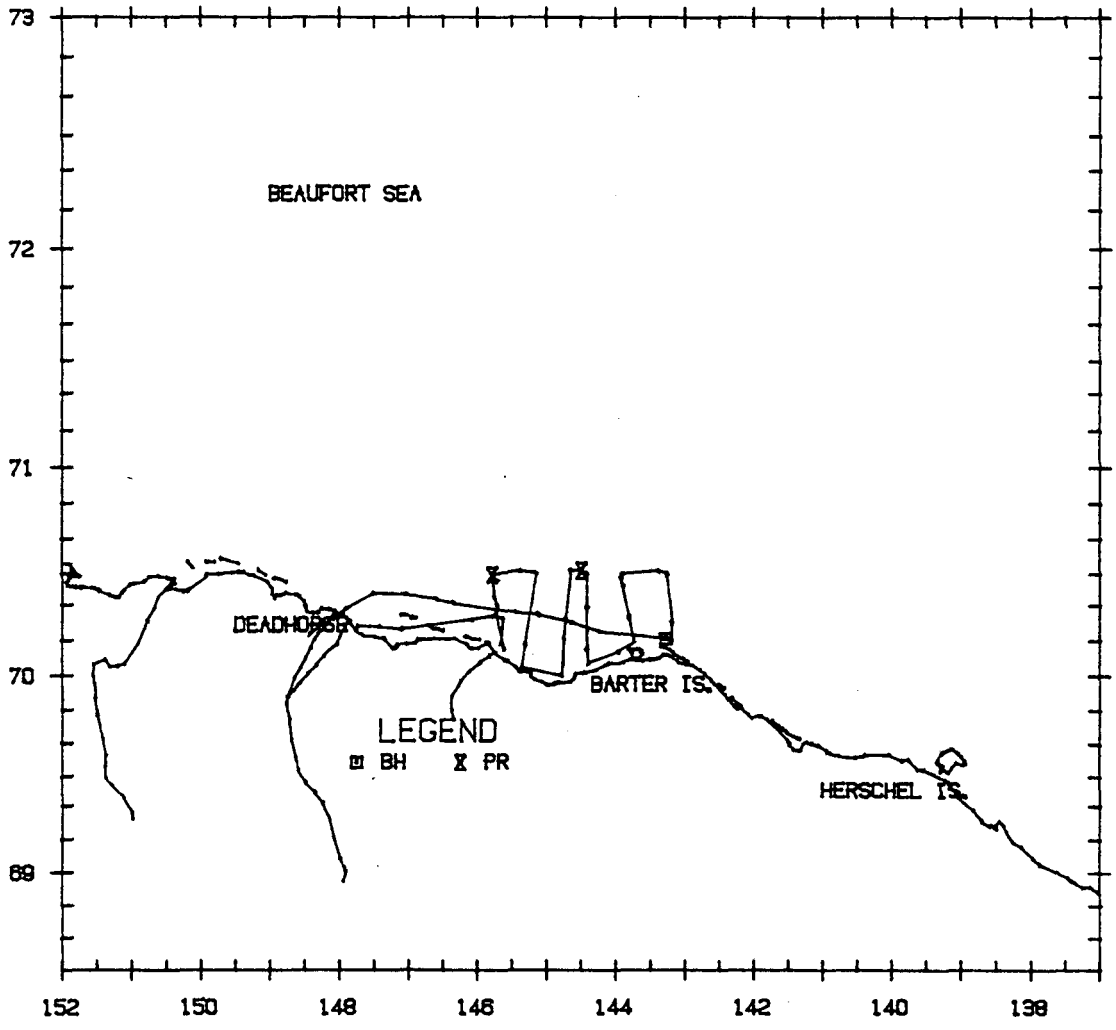


TWIN OTTER FLIGHT 17: 27 SEPTEMBER 1988

Flight was a transect survey of Block 4. Weather ranged from partly cloudy to overcast with patches of fog. Visibility was mostly unlimited. Ice cover ranged from 5 to 75 percent, with open water nearshore. Sea state ranged from Beaufort 02 to 04. One bowhead whale and two polar bears were seen.

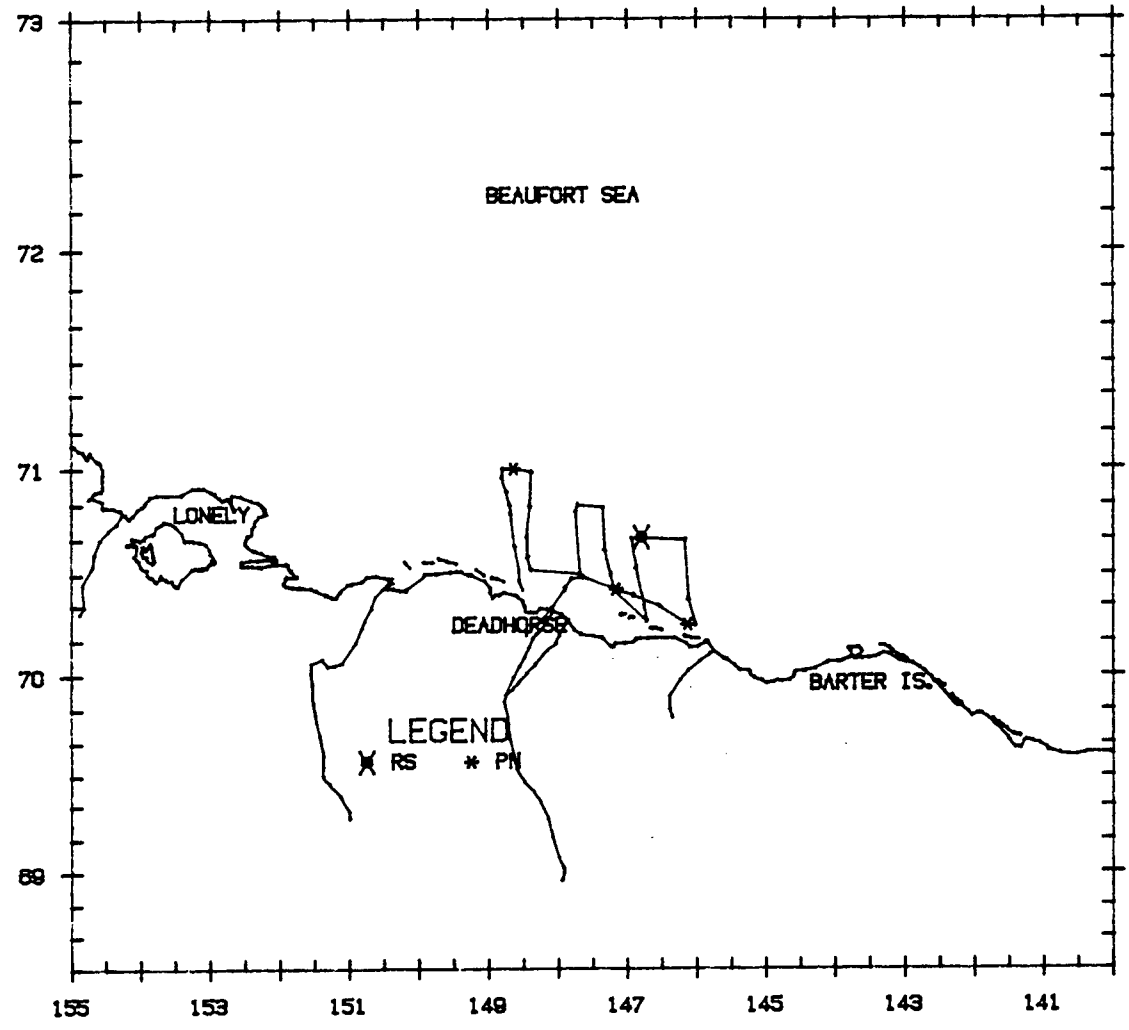
Bowhead Whales

T#C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	70°10.7'	143°16.3'	457	BW	SW	210	50	B2	11



TWIN OTTER FLIGHT 18: 28 SEPTEMBER 1988

Flight was a transect survey of three-quarters of Block 1. Weather was overcast with patches of fog and precipitation. Visibility ranged from unacceptable to unlimited but averaged 3 km. Ice cover ranged from 10 to 100 percent, with some open water nearshore and between the coast and the barrier islands. Sea state was Beaufort 00 to 01. Ringed seals and unidentified pinnipeds were seen.

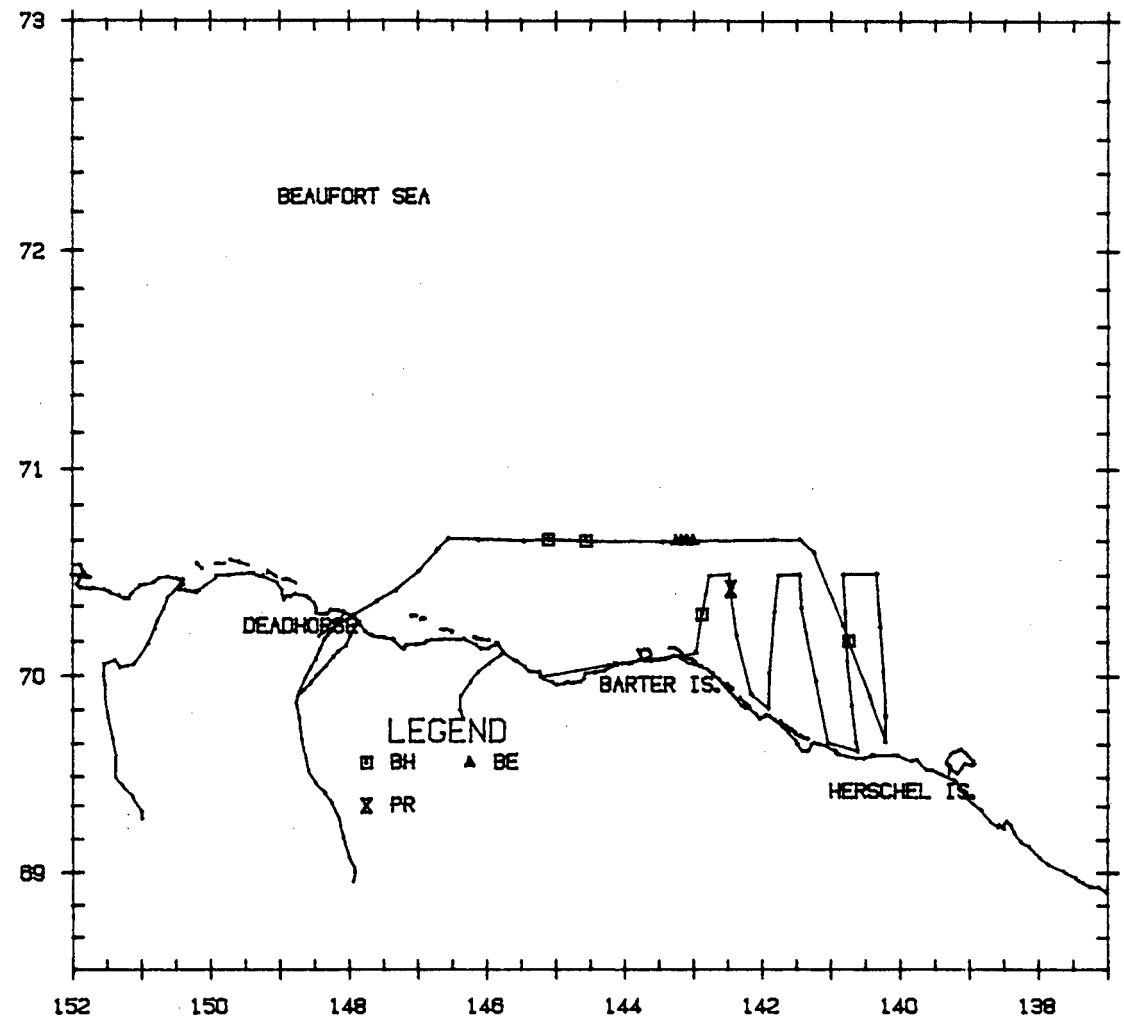


TWIN OTTER FLIGHT 19: 30 SEPTEMBER 1988

Flight was a transect survey of Block 5, with a search survey through Block 6. Weather ranged from clear to overcast with unlimited visibility. Ice cover ranged from 20 to 95 percent, and sea state was Beaufort 00 to 01. Four bowhead whales, beluga whales, and a polar bear were seen.

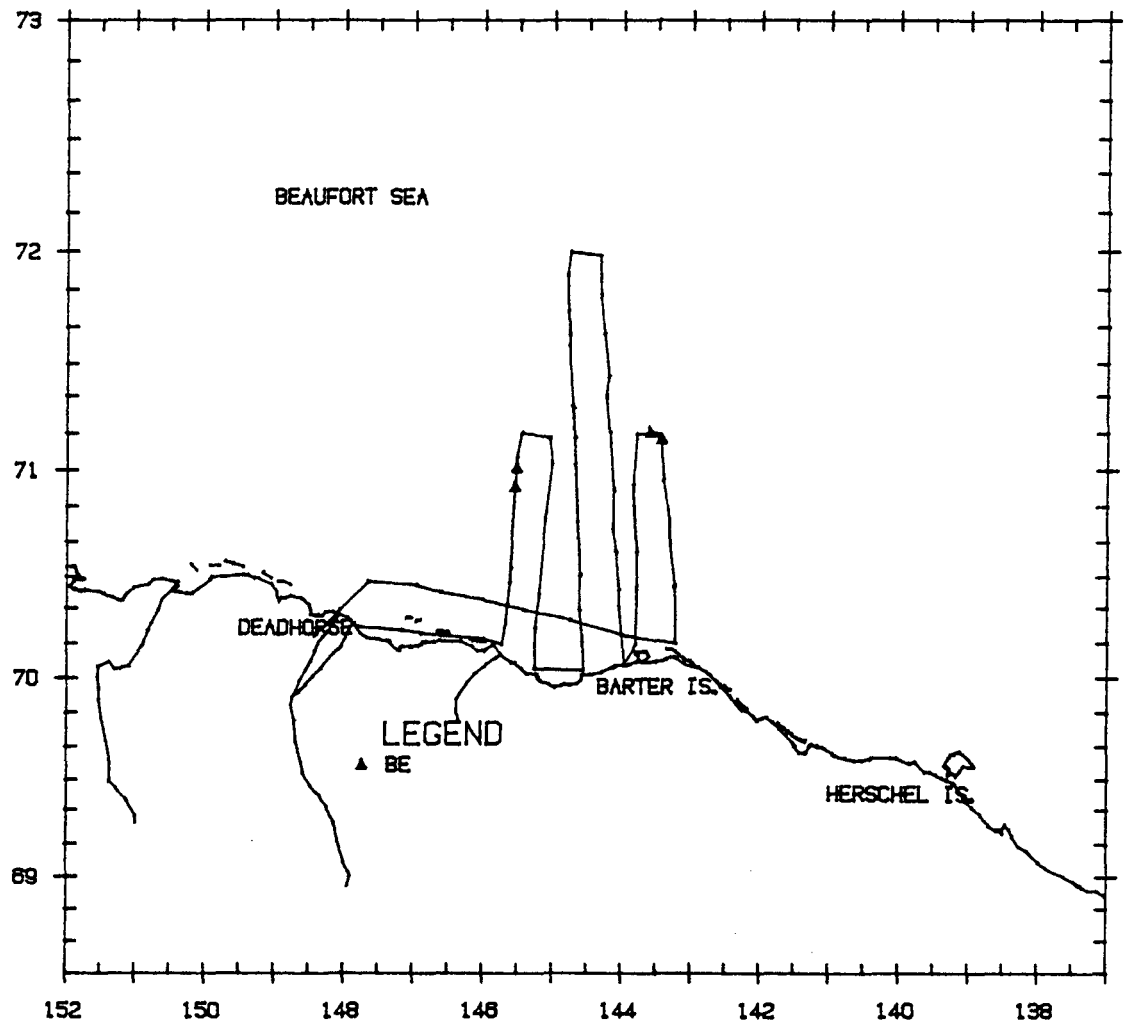
Bowhead Whales

T#C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	70°40.4'	145°06.1'	469	BO	DI	300	60	B3	80
1/0	70°40.0'	144°33.2'	528	BO	SW	290	60	B3	183
1/0	70°10.3'	140°43.8'	545	BO	SW	180	70	B2	48
1/0	70°17.9'	142°52.5'	1027	BO	SW	240	70	B1	38



TWIN OTTER FLIGHT 20: 1 OCTOBER 1988

Flight was a transect survey of Blocks 4 and 6 and the center one-third of Block 9. Weather ranged from clear to overcast with unlimited visibility. Ice cover ranged from 20 to 95 percent, and sea state was Beaufort 00 to 02. Beluga whales were the only marine mammal seen.

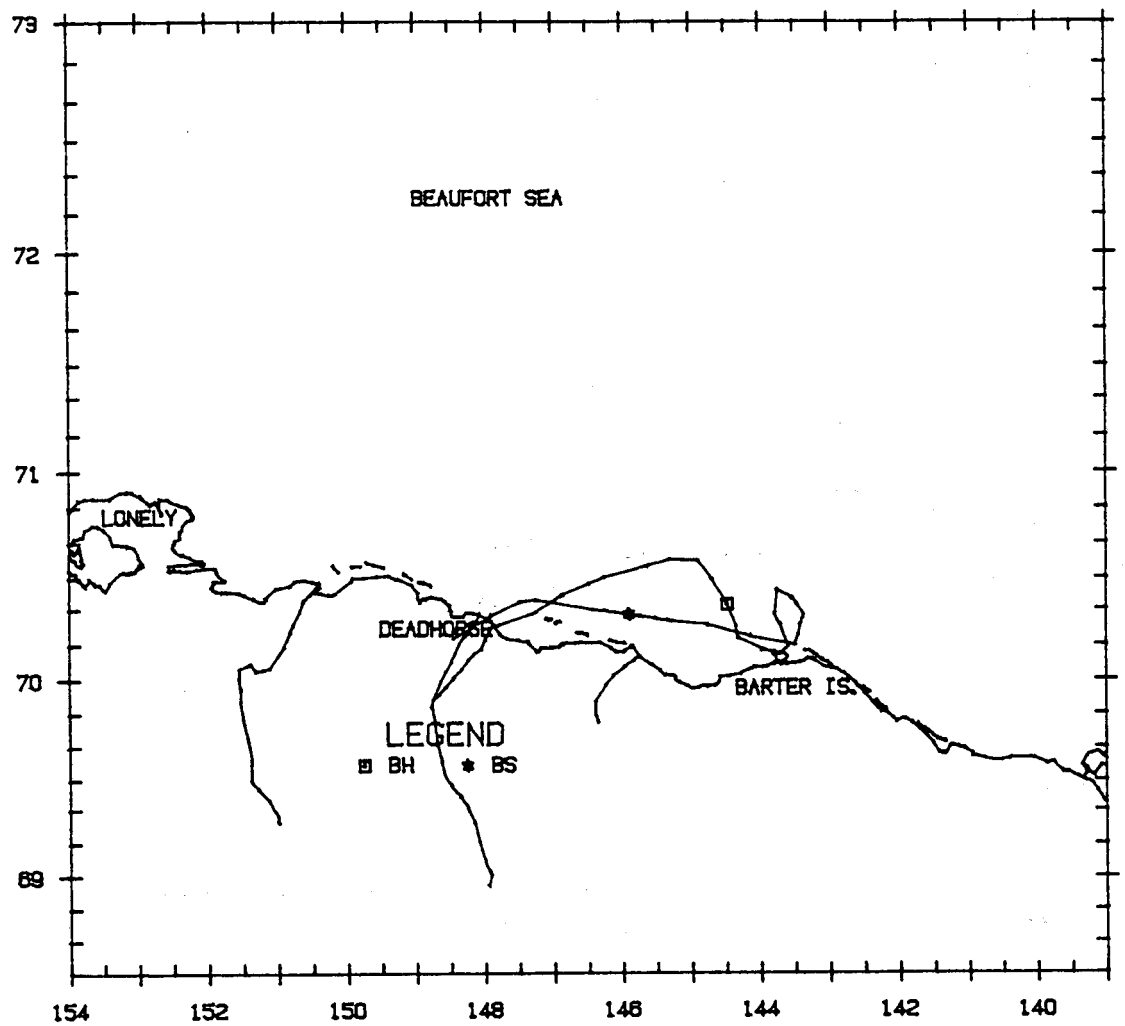


TWIN OTTER FLIGHT 21: 3 OCTOBER 1988

Flight was a search survey through Block 4. Weather was overcast with patches of fog, and visibility ranged from unacceptable to unlimited. Ice cover ranged from 50 to 100 percent, with some open water nearshore. Sea state ranged from Beaufort 00 to 01. One bowhead whale and a bearded seal were seen.

Bowhead Whale

T#C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	70°21.4'	144°28.0'	152	BO	SW	270	70	B1	29

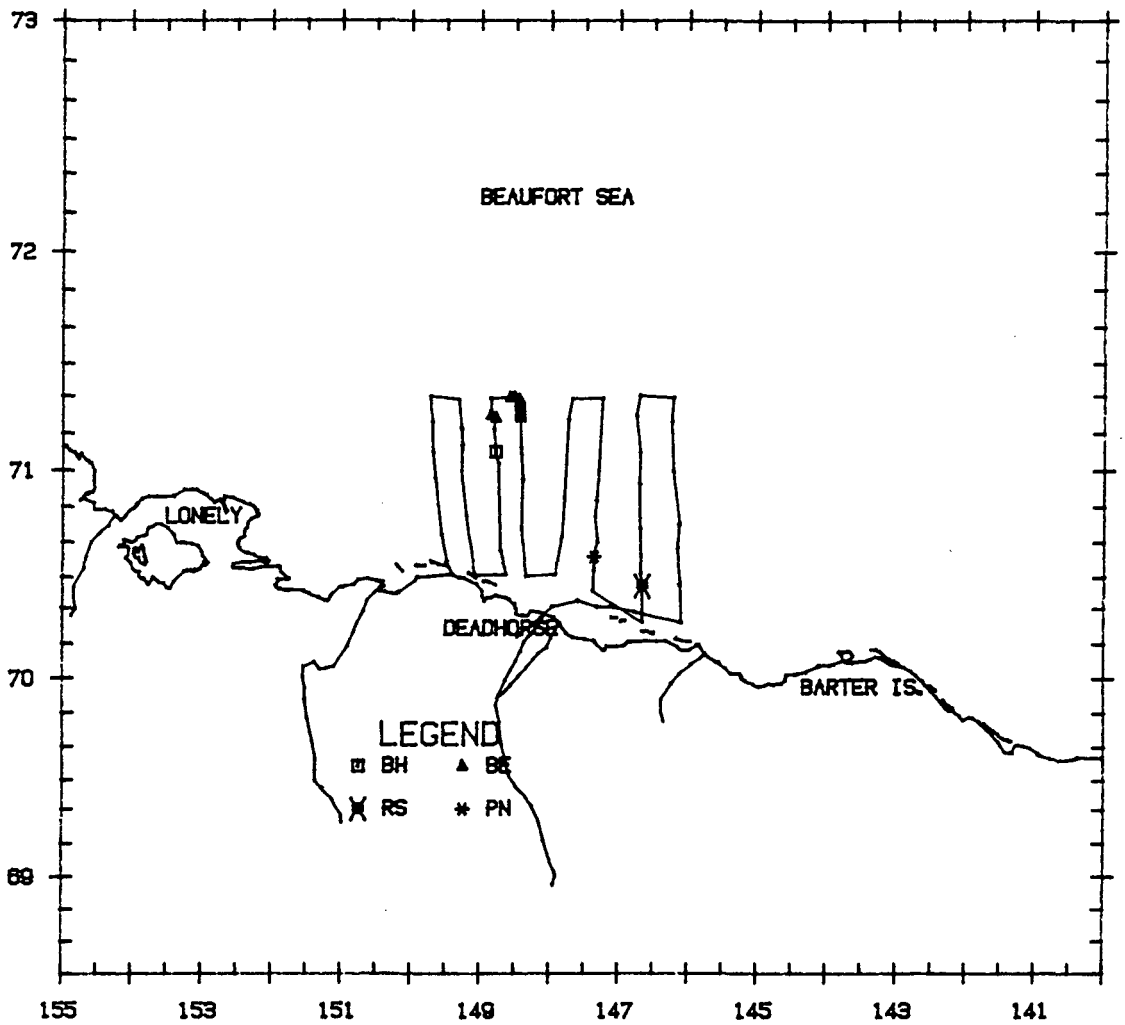


TWIN OTTER FLIGHT 22: 5 OCTOBER 1988

Flight was a transect survey of Blocks 1 and 2. Weather was overcast and visibility generally unlimited. Ice cover was 40 to 95 percent. Sea state ranged from Beaufort 00 to 03 but averaged 02. One bowhead whale, beluga whales, ringed seals, and an unidentified pinniped were seen.

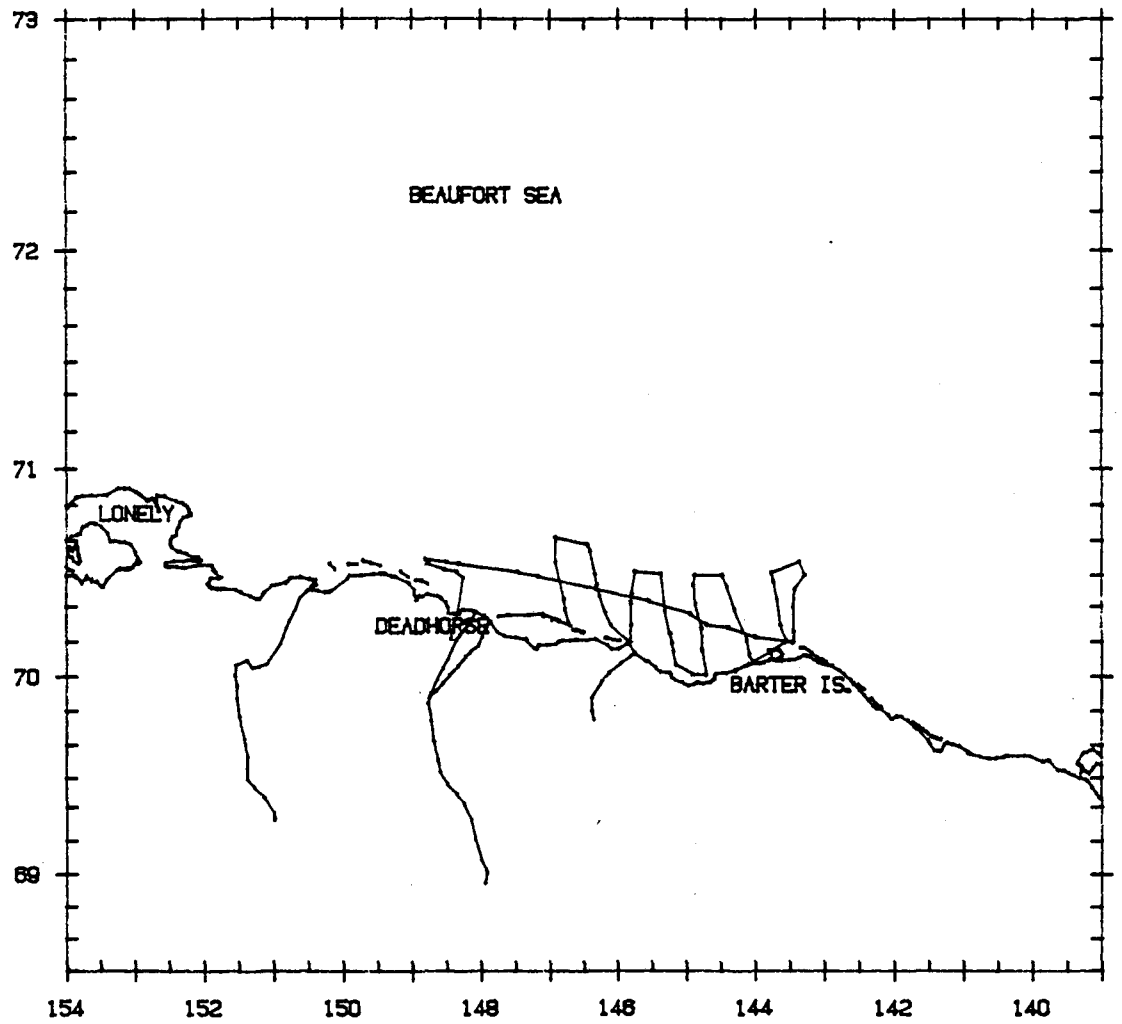
Bowhead Whale

T#C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71°05.0'	148°46.8'	27	BW	SW	210	70	B2	62



TWIN OTTER FLIGHT 23: 6 OCTOBER 1988

Flight was a transect survey of Block 4 and the easternmost one-quarter of Block 1. Weather ranged from partly cloudy to overcast, with areas of fog and precipitation. Visibility ranged from unacceptable to unlimited. Ice cover ranged from 30 to 100 percent, and sea state was Beaufort 00 to 04. No marine mammals were seen.

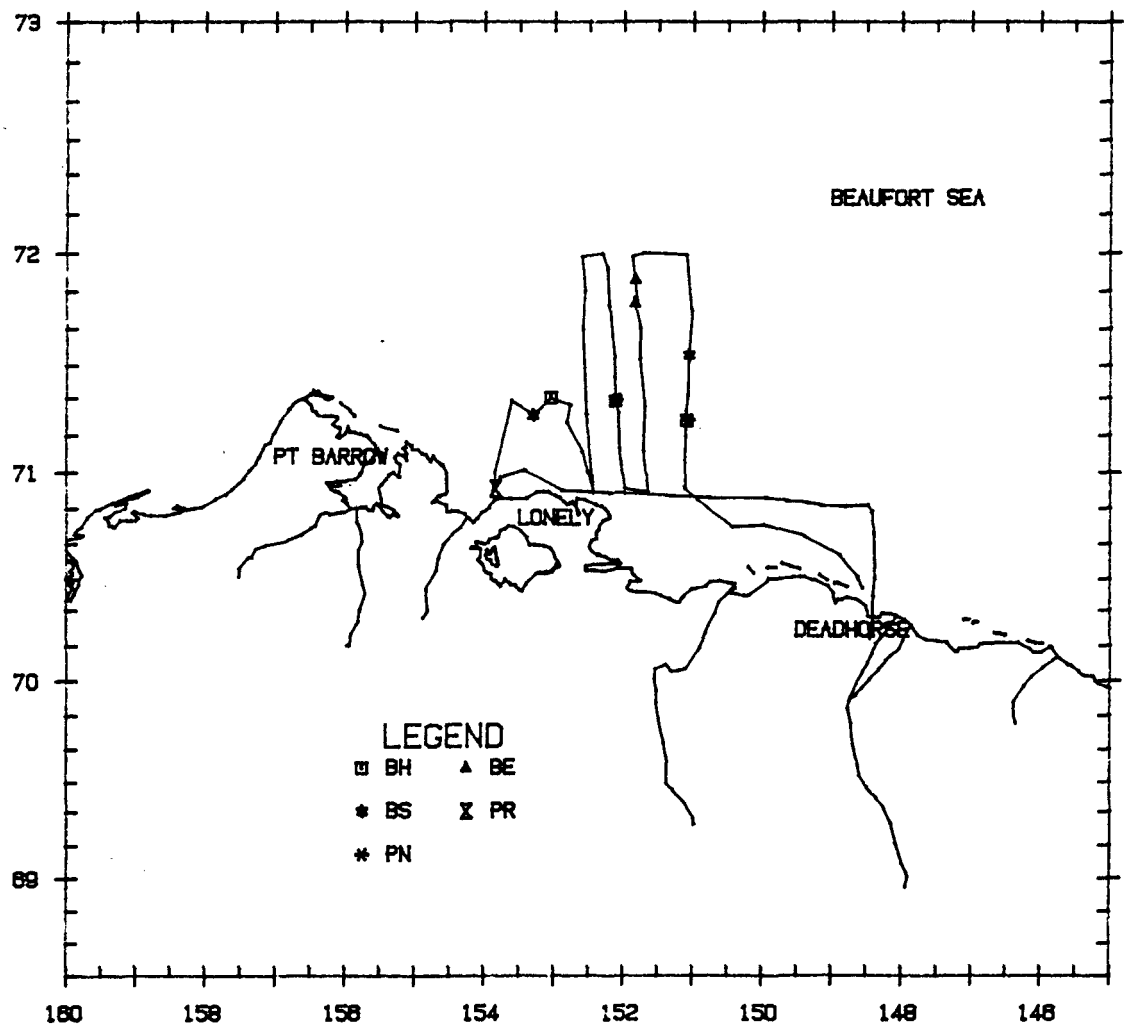


TWIN OTTER FLIGHT 24: 7 OCTOBER 1988

Flight was a transect survey of the eastern two-thirds of Blocks 3 and 11. Weather ranged from clear to overcast with patches of fog. Visibility was generally unlimited, occasionally going to 2 km. Ice cover was 70 to 100 percent, and sea state was Beaufort 00 to 04. Five bowhead whales, beluga whales, bearded seals, unidentified pinnipeds, and a polar bear were seen.

Bowhead Whales

T#C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71°20.2'	153°02.6'	182	BO	SW	180	95	B1	60
2/0	71°19.3'	152°06.5'	213	BO	SW	250	95	B1	62
2/0	71°14.0'	151°05.0'	1004	BO	MI	270	95	B0	31

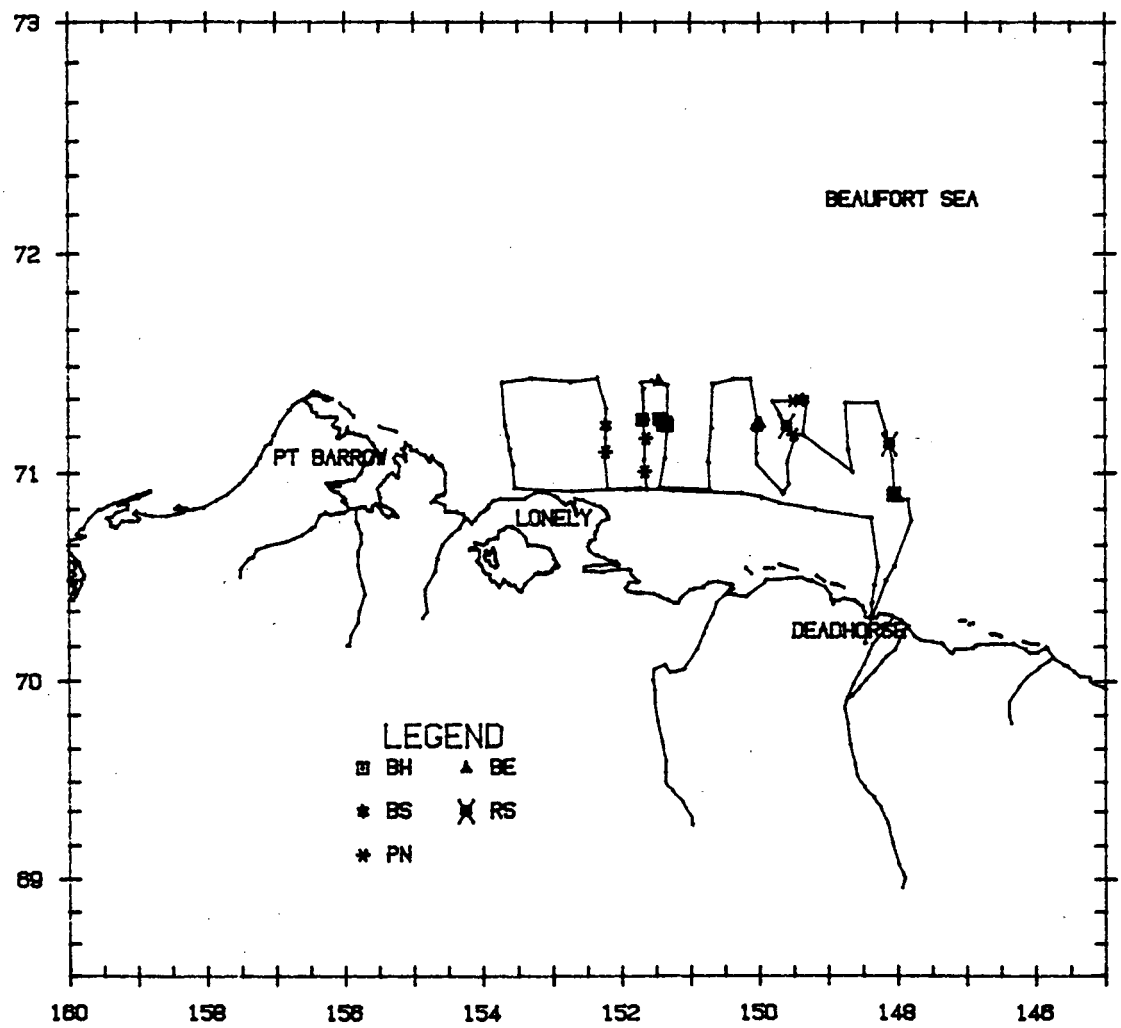


TWIN OTTER FLIGHT 25: 9 OCTOBER 1988

Flight was a transect survey in parts of Blocks 1 and 3. Weather was overcast with areas of fog and precipitation. Visibility was generally unlimited, with areas going from <3 km to unacceptable. Ice cover ranged from 80 to 100 percent, and sea state was Beaufort 00 to 01. Eight bowhead whales, beluga whales, bearded and ringed seals, and unidentified pinnipeds were seen.

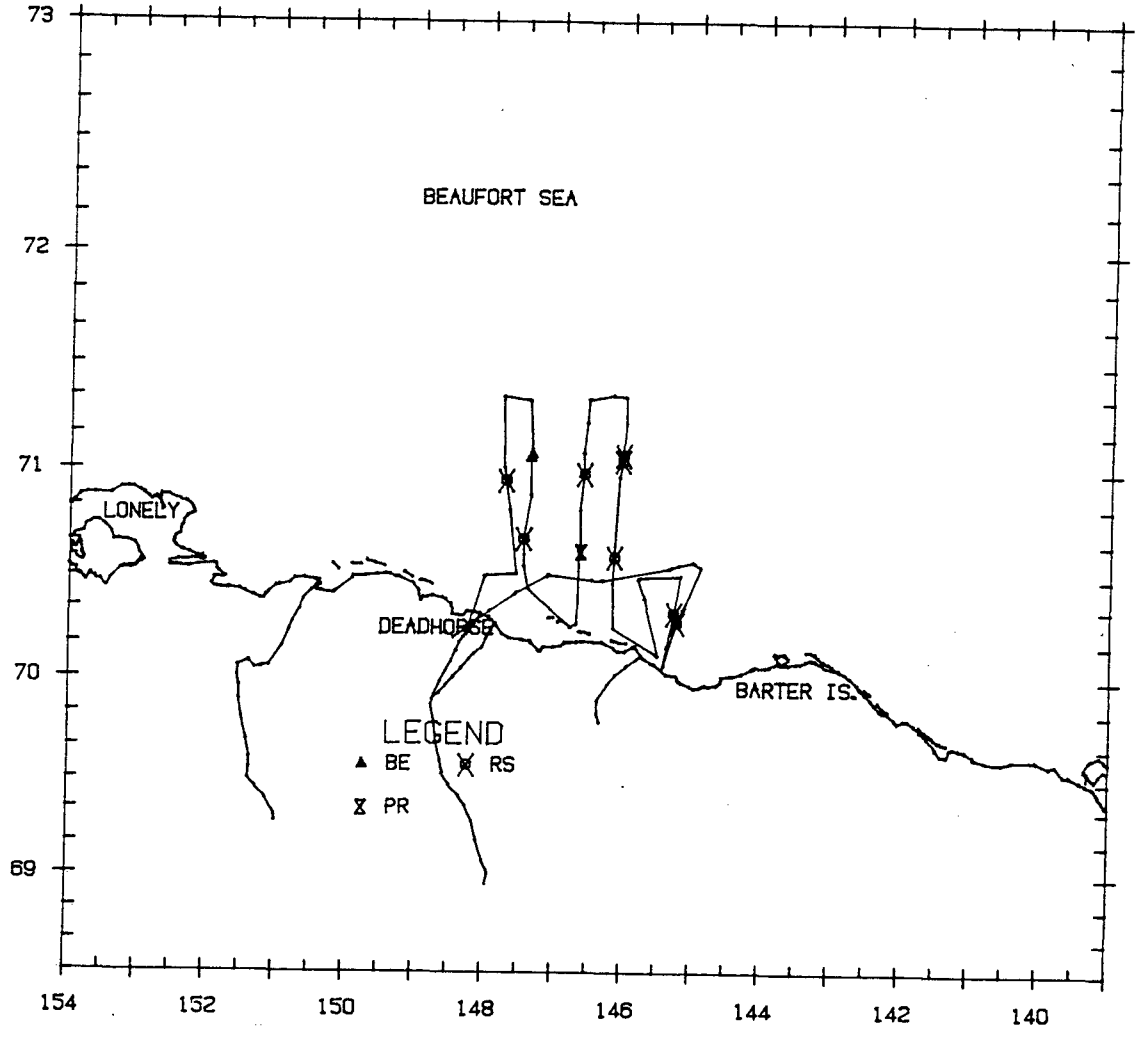
Bowhead Whales

T#C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71°14.6'	151°42.0'	717	BW	SW	240	85	B1	40
1/0	71°13.1'	151°20.1'		BO	SW	210	90	B1	29
1/0	71°13.7'	151°20.9'		BO	SW	210	90	B1	29
1/0	71°14.1'	151°24.3'		BO	SW	180	90	B1	29
1/0	71°14.8'	151°27.1'		BO	SW	270	90	B1	29
1/0	71°13.2'	151°23.8'		BO	SW	050	90	B1	29
1/0	70°54.4'	148°02.3'	143	IT	SW	240	95	B1	42
1/0	70°54.0'	148°03.6'		BO	SW	240	95	B1	42



TWIN OTTER FLIGHT 26: 10 OCTOBER 1988

Flight was a transect survey through parts of Blocks 1, 2, and 4. Weather ranged from partly cloudy to overcast with patches of fog and precipitation. Visibility was mostly unlimited, dropping in some areas to 2 km. Sea state was Beaufort 00 to 01. Beluga whales, ringed seals, and polar bears were seen.

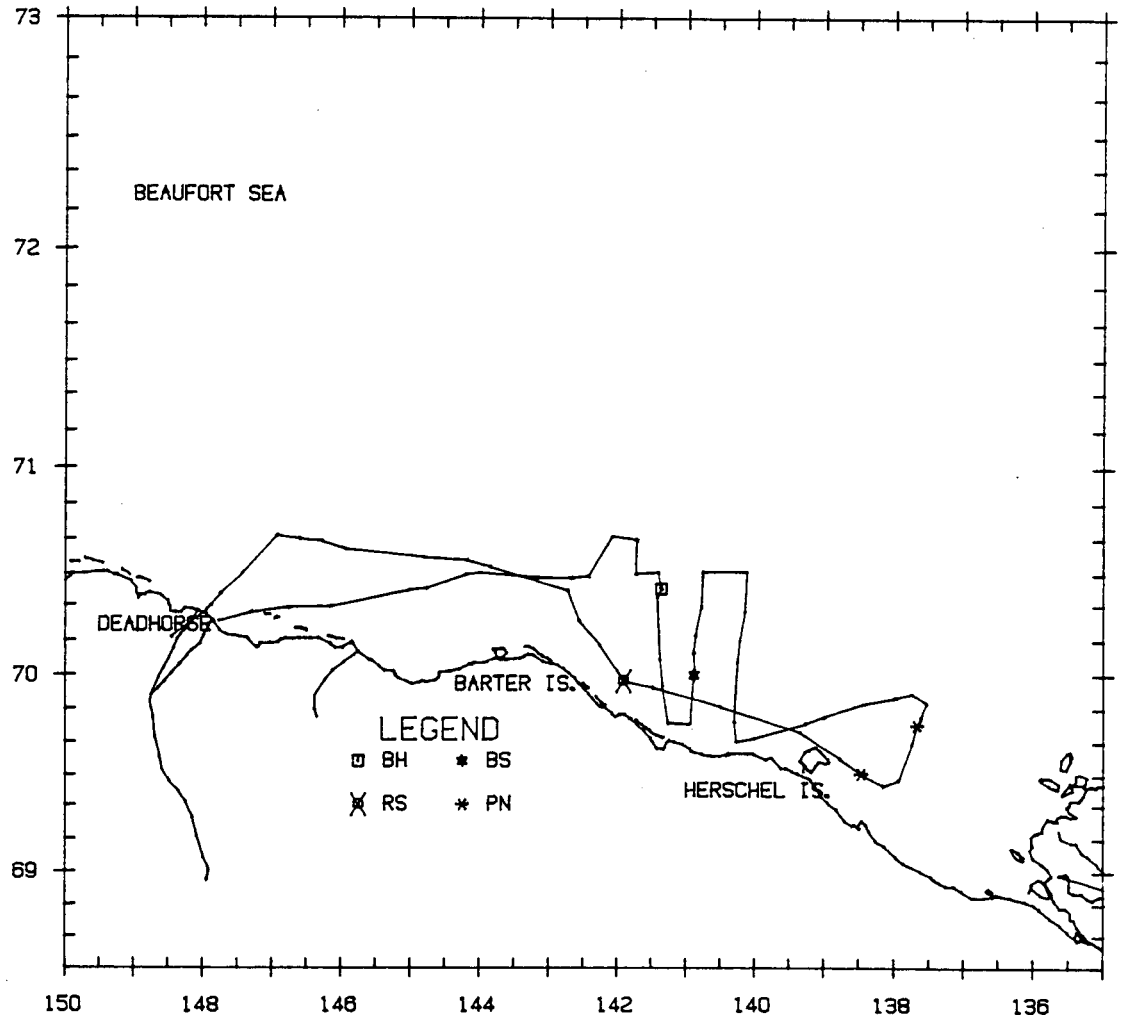


TWIN OTTER FLIGHT 27: 13 OCTOBER 1988

Flight was a transect survey of half of Block 5, with a search through Blocks 4 and 6 and just east of Herschel Island. Weather was overcast with areas of fog and precipitation. Ice cover ranged from 90 to 100 percent, and sea state was Beaufort 00 to 02. One bowhead whale, bearded and ringed seals, and an unidentified pinniped were seen.

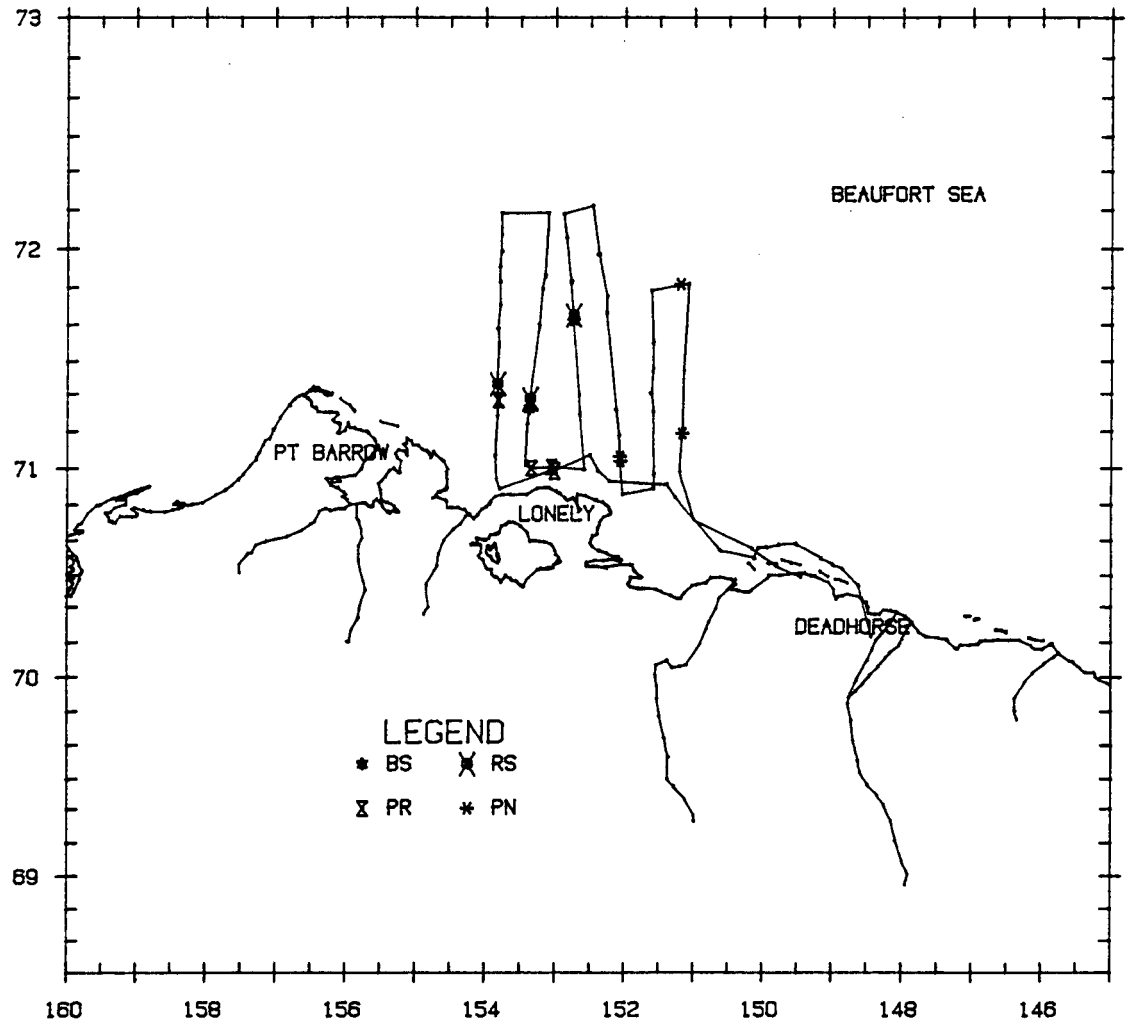
Bowhead Whale

T#C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	70°24.9'	141°22.2'	1147	BO	SW	210	95	B1	298



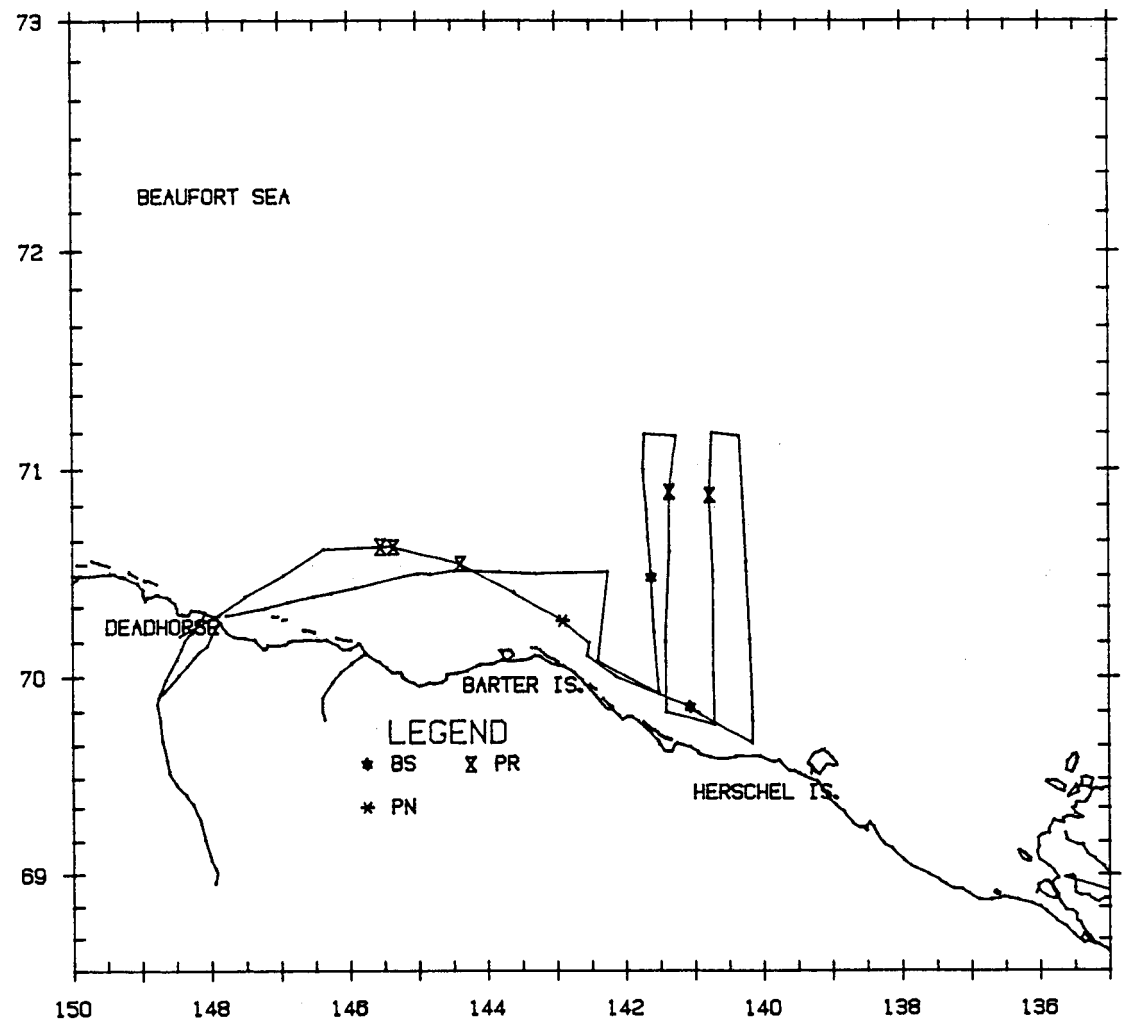
TWIN OTTER FLIGHT 28: 14 OCTOBER 1988

Flight was a transect survey in parts of Blocks 3 and 11. Weather was overcast with patches of fog and precipitation. Ice cover ranged from 80 to 100 percent, and sea state was Beaufort 00 to 03. Bearded and ringed seals, unidentified pinnipeds, and polar bears were seen.



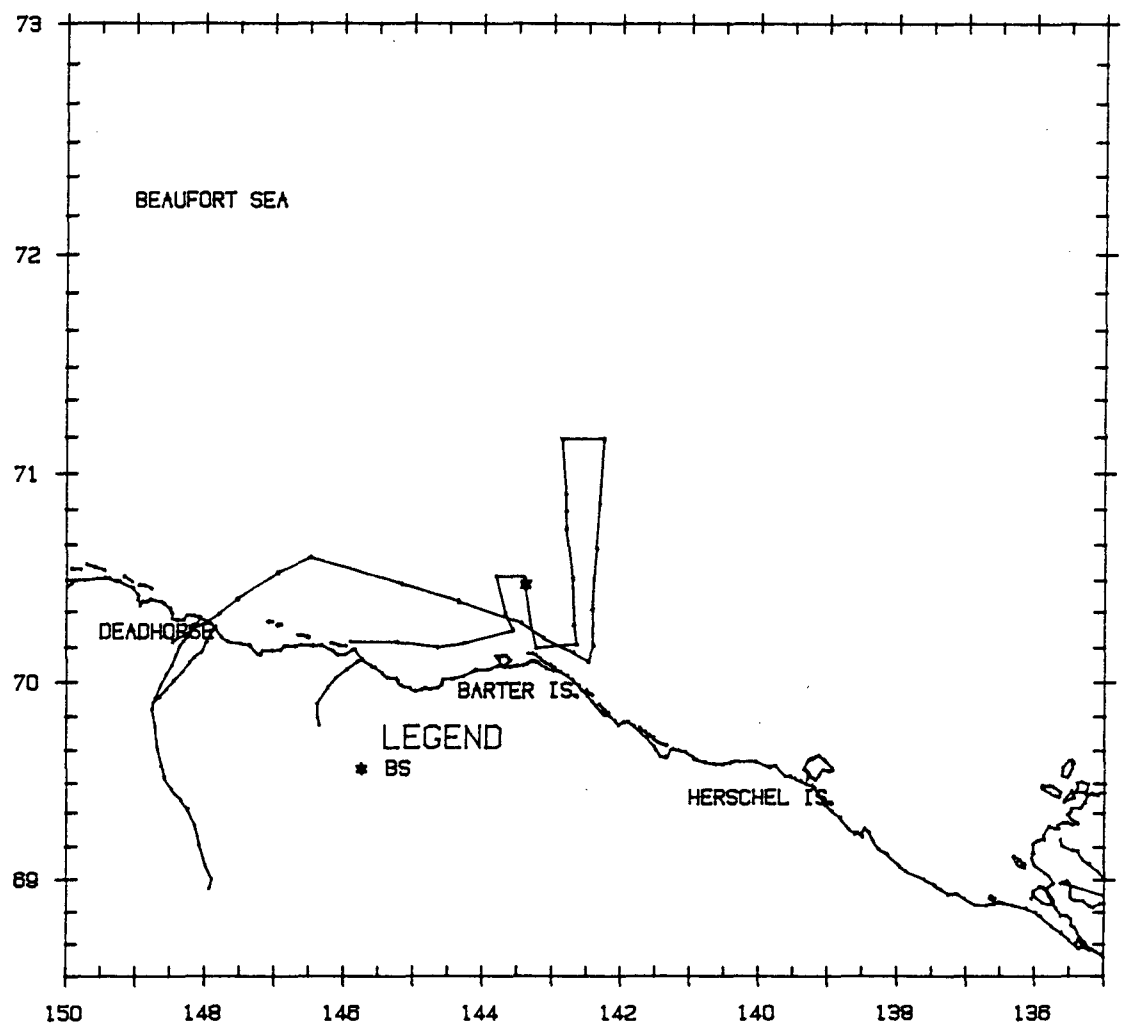
TWIN OTTER FLIGHT 29: 15 OCTOBER 1988

Flight was a transect survey in the eastern two-thirds of Blocks 5 and 7. Weather ranged from clear to overcast with patches of precipitation. Visibility was mostly unlimited, dropping to 1 to 5 km in places. Ice cover was mostly 90 to 100 percent, and sea state was Beaufort 00 to 01. Bearded seals, unidentified pinnipeds, and polar bears were seen.



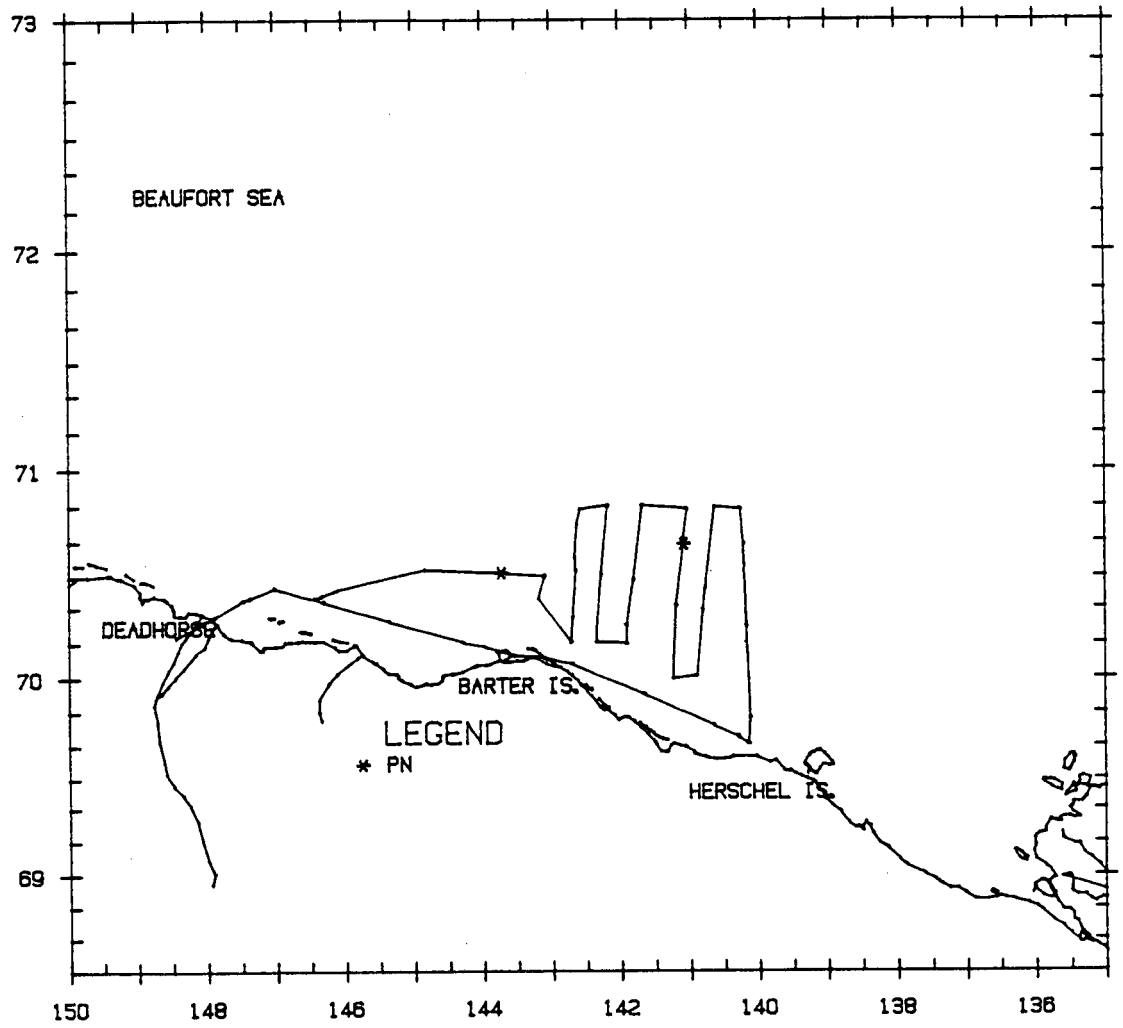
TWIN OTTER FLIGHT 30: 16 OCTOBER 1988

Flight was a transect survey in portions of Blocks 4, 5, and 7. Weather was partly cloudy with patches of low fog. Visibility ranged from 1 to 10 km. Ice cover was 90 to 100 percent, and sea state was Beaufort 02 to 05. One bearded seal was seen.



TWIN OTTER FLIGHT 31: 18 OCTOBER 1988

Flight was a transect survey in parts of Blocks 5 and 7. Weather ranged from clear to overcast with areas of haze and fog. Visibility was generally unlimited, dropping to unacceptable in localized areas. Ice cover was 95 to 100 percent, and sea state was Beaufort 00. Two unidentified pinnipeds were seen.

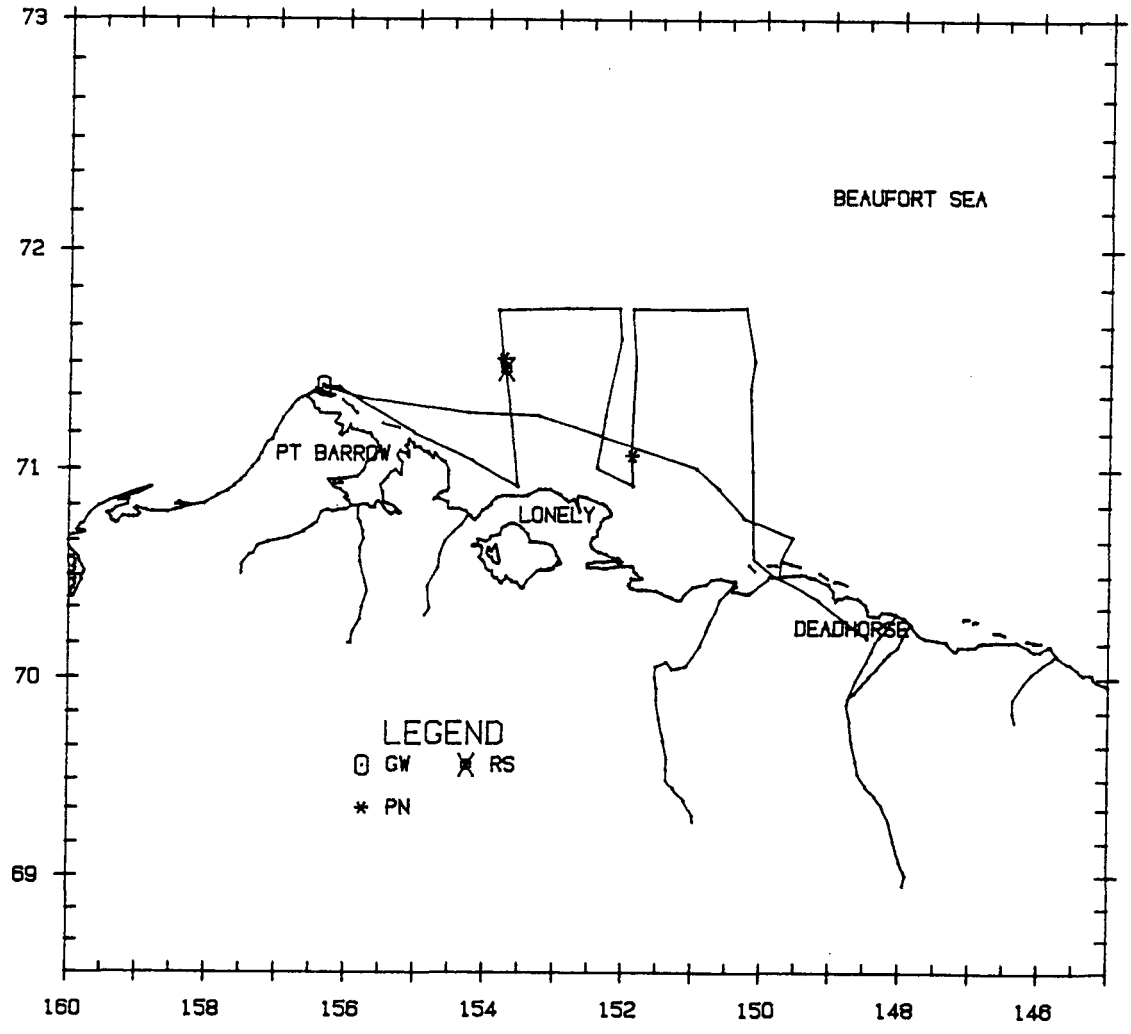


TWIN OTTER FLIGHT 32: 20 OCTOBER 1988

Flight was a transect survey in portions of Blocks 3 and 11, with a search survey through Block 12. Weather was clear and visibility unlimited. Ice cover was 80 to 100 percent, and sea state was Beaufort 00 to 02. Three gray whales trapped in the ice, ringed seals, and unidentified pinnipeds were seen.

Gray Whale

T#C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
3/0	71°22.6'	156°20.8'		NA	RE	99	100	NA	2



APPENDIX C

SUCCESS OF PRIMARY OBSERVERS IN LOCATING WHALES

SUCCESS OF PRIMARY OBSERVERS IN LOCATING WHALES

This appendix presents a comparison of the number of bowhead whale sightings and the total number of bowhead whales observed per hour by MMS and non-MMS primary observers for the period 1 September through 20 October 1988.

The number of whales counted during a survey depends on the success of survey observers in spotting whales. In order to gauge the relative success of selected whale observers in 1988, their productivity was calculated from the whale sighting data assuming that individual observers had an equal opportunity to encounter whales. For purposes of this calculation, sightings and total whales in each group sighted were credited solely to the observer making the initial report, ignoring subsequent or near-simultaneous reports by other observers. The number of sightings credited per hour of effort (SPUE) and the number of whales sighted per hour of effort (WPUE) were then used as measures of relative productivity.

The MMS observer team always consisted of two aircraft pilots, a data recorder, a primary port observer, and a primary starboard observer (who also functioned as team leader). The productivity of the two primary observers was used to represent overall team success (Table C-1), regardless of who occupied the port and starboard positions during the course of the survey. As a comparison, the productivity of two non-MMS observers who had participated in many previous MMS-funded surveys was also calculated (Table C-1).

Both the MMS and non-MMS observers showed identical group-sighting rates of 0.070 SPUE over the entire survey. During Test Period B, when only 1 non-MMS observer was aboard, the sighting rate of the non-MMS observer (SPUE = 0.072) was higher than the MMS group-sighting rate (SPUE = 0.054), although the rate at which all whales were sighted was the same (WPUE = 0.072). The highest group productivity (SPUE = 0.076; WPUE = 0.095) occurred during Test Period C, in the absence of the two non-MMS observers. The highest sighting rate for individual primary observer positions was 0.135 SPUE by both an MMS observer and a non-MMS observer during Test Period A (Table C-1).

Productivity rates for all aircraft personnel combined are shown by flight date in Table 6. To generally assess whether the addition of the non-MMS observers increased the overall sighting rate and number of whales sighted per survey hour, productivity rates were calculated from Table 6 for flights with and without these additional observers. On those days that one or both non-MMS observers were on board (3-4 September, 21-30 September, and 18-20 October), the Fall-1988 cumulative rates (SPUE = 0.236; WPUE = 0.259) were not higher than when these observers were not on board (SPUE = 0.241; WPUE = 0.329).

Table C-1

Productivity Rates for Primary Observers

Productivity Measure	MMS-1	MMS-2	MMS[1] Rates	Non-1	Non-2	Non-MMS[1] Rates
Test Period A (Flights 13, 14, 18, and 19 with two non-MMS observers aboard)						
#Sightings	0	2	1	0	2	1
#Whales Sighted	0	2	1	0	2	1
#Hours Effort	14.79	14.79	14.79	14.79	14.79	14.79
SPUE	0.00	0.135	0.068	0.00	0.135	0.068
WPUE	0.00	0.135	0.068	0.00	0.135	0.068
Test Period B (Flights 1, 2, 12, 15, 16, 17, 31, and 32 with one non-MMS observer aboard)						
#Sightings	1	2	1.5	2	-	2
#Whales Sighted	2	2	2	2	-	2
#Hours Effort	27.66	27.66	27.66	27.66	-	27.66
SPUE	0.036	0.072	0.054	0.072	-	0.072
WPUE	0.072	0.072	0.072	0.072	-	0.072
Test Period C (Flights 3-11 and Flights 20-30 with no non-MMS observers aboard						
#Sightings	4	8	6	-	-	-
#Whales Sighted	4	11	7.5	-	-	-
#Hours Effort	78.99	78.99	78.99	-	-	-
SPUE	0.050	0.101	0.076	-	-	-
WPUE	0.050	0.139	0.095	-	-	-
Test Periods A, B, and C Combined (all flights)						
#Sightings	5	12	8.5	2	2	2
#Whales Sighted	6	15	10.5	2	2	2
#Hours Effort	121.44	121.44	121.44	42.45	14.79	28.62
SPUE	0.041	0.099	0.070	0.047	0.135	0.070
WPUE	0.049	0.124	0.086	0.047	0.135	0.070

Source: MMS, Alaska OCS Region.

[1] Group-productivity rates are calculated from Σ sightings, whales, and effort for each group divided by the number of participating observers.

GLOSSARY OF ACRONYMS, INITIALISMS, AND ABBREVIATIONS

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

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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.