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OCS STUDY
MMS-90-0051

FINAL REPORT

DISTRIBUTION, ABUNDANCE AND BEHAVIOR OF ENDANGERED WHALES IN THE ALASKAN CHUKCHI AND WESTERN BEAUFORT SEA, 1989

AUGUST 1990

SAN DIEGO, CA.

Prepared for:

Minerals Management Service
Alaska OCS Region
U.S. Department of Interior
Anchorage, Alaska 99508-4302

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This report summarizes the 1989 investigations of the distribution, abundance, migration timing and route, behavior, and habitat relationships of endangered whales in the Alaskan Chukchi and western Beaufort Sea (hereafter, study area); 1989 was the first year of a three year (1989-91) study. Data were collected during transect and search surveys flown in a specially modified Grumman Goose (model G21G) aircraft over the study area from 20 September through 3 November. The Bering Sea stock of bowhead whales (Balaena mysticetus) was the principal species studied. Gray whales (Eschrichtius robustus) were also studied, with incidental sightings of all other marine mammals routinely recorded. Data collected during the 1989 study were subsequently integrated with the results of surveys conducted from 1980-88.

In 1989, there were 69 sightings of 131 bowhead whales and 59 sightings of 170 gray whales in the study area from 20 September through October. Over eight survey seasons (1982-89) there were 226 sightings of 501 bowhead whales and 137 sightings of 397 gray whales. Bowheads were seen from 18 September (1983) to 29 October (1989), with ca. 10-day oscillations in daily sighting rate suggesting that whales migrate in pulses. Bowheads migrate westerly (276°T) close to shore in the western Beaufort Sea, then most disperse southwest (247°T) across the Chukchi Sea, with a few sightings north of 72°N latitude suggesting that some whales take a northerly route across the Chukchi Sea. Most gray whales (85%) were feeding either along the coast or near relatively shallow shoals in the north and south-central Chukchi Sea. Distribution of random bowhead and belukha sightings indicate migratory routes in the northeastern Chukchi Sea may be influenced by current patterns.

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Balaena mysticetus	Endangered whales	Belukha	Behavior
Gray whale	Beaufort Sea	Pinniped	
Eschrichtius robustus	Chukchi Sea	Distribution	

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DISCLAIMER

This report has been reviewed by the Alaskan Outer Continental Shelf Region, Minerals Management Service, U.S. Department of the Interior and approved for publication. The opinions, findings, conclusions or recommendations expressed in this report are those of the authors, and do not necessarily reflect the views of the Minerals Management Service. Mention of trade names or commercial products does not constitute endorsement or recommendation for use. This report has not been edited for conformity with Minerals Management Service editorial standards.

PROJECT ORGANIZATION AND ACKNOWLEDGEMENTS

This report is an account of afield study of endangered whales in the Alaskan Chukchi and western Beaufort Sea conducted by SEACO, a Division of SAIC (hereafter SEACO/SAIC), for the U.S. Minerals Management Service (MMS), Alaska Outer Continental Shelf (OCS) Region. The report describes results from field work conducted in late September, October and early November 1989, These results are subsequently integrated with results obtained from similar studies conducted by the Naval Ocean Systems Center and SEACO, Inc., with D. Ljungblad as Principal Investigator from 1980-88.

At the MMS, Anchorage, AK, we appreciate the encouragement, advice and support of J. Imm, C. Cowles and J. Montague. For logistic support, we are especially grateful to pilots G. Candee, J. Gustafson and D. Moore, and the administrative and maintenance staffs at the Office of Aircraft Services (OAS), Anchorage, AK, for providing the Grumman Goose (N780) survey aircraft. We also thank the Bensons at the Barrow Airport Inn, Barrow, AK for their assistance during field operations. M. Johnson, M. Newcomer and J. Bennett of SEACO/SAIC were excellent field observers and aided in the acquisition of all data upon which the results of this study rest. S. Hooton of SEACO/SAIC provided graphics and illustrations, and J. Candler and J. La Nell of SEACO/SAIC assisted in travel logistics and report preparation. Our thanks to all.

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ACRONYMS AND ABBREVIATIONS

ACW	Alaskan Coastal Water
ADC	American Digital Cartography
ADFG	Alaska Department of Fish and Game
BE	Belukha
BH	Bowhead Whale
BS	Bearded Seal
BSW	Bering Sea Water
CPUE	Calves Per Unit Effort
CT	Unidentified Cetacean
GARR	Gross Annual Recruitment Rate
GNS	Global Navigation System
GW	Gray Whale
IDL	International Date Line
IWC	International Whaling Commission
MMS	Minerals Management Service
M LR	Multiple Linear Regression
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
NOSC	Naval Ocean Systems Center
NTIS	National Technical Information Service
Ocs	Outer Continental Shelf
PN	Unidentified Pinniped
PR	Polar Bear
RCW	Resident Chukchi Water
RS	Ringed Seal
s.d.	Standard Deviation
SPUE	Sightings Per Unit Effort
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
WPUE	Whales Per Unit Effort
WS	Walrus

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EXECUTIVE SUMMARY

This report summarizes the 1989 investigations of the distribution, abundance, migration timing and route, behavior, and habitat relationships of endangered whales in the Alaskan Chukchi and western Beaufort Sea (hereafter, study area). Data presented herein were collected during transect and search surveys flown in a specially modified Grumman Goose (model G21 G) aircraft over the study area from 20 September through 3 November. The Bering Sea stock of bowhead whales (Balaena mysticetus), estimated by the International Whaling Commission (lWC) to number 7,800 whales, was the principal species studied. The California-Chukotka stock of gray whales (Eschrichtius robustus), estimated by the IWC to number over 21,000 whales, was also studied, with incidental sightings of all other marine mammals routinely recorded. Data collected during the 1989 study were subsequently compared to and integrated with the results of surveys conducted from 1980-88.

There were 69 sightings of 131 bowhead whales in the study area from 20 September through 29 October 1989. Six bowheads were seen in September, and 125 whales were seen in October. The bowhead sighting in the Chukchi Sea on 20 September was one day earlier than in prior years. Survey effort shifted from northern to southern Chukchi Sea waters in late October, but no bowheads were seen there. The bowhead migration through the study area extended at least from 20 September through 29 October. Biologists conducting bird surveys just east of Point Barrow, Alaska reported seeing bowheads in the study area as early as 23 July, and the whales seen on 28-29 October were in the north-central portion of the study area, indicating that the migratory period likely extended beyond the limits of the survey period. However, a daily sighting rate histogram indicated that the survey period probably coincided with the major portion of the migration period.

Most bowhead whales were seen along a migratory route that was nearshore (< 10 km) east of Point Barrow, extending southwest from Point Barrow across the Chukchi Sea to roughly 120 km offshore northwest of Icy Cape. Swimming direction was significantly clustered about 257” T west of Point Barrow, but was not significantly clustered for whales seen east of Point Barrow. Four bowheads were seen north of720 N latitude, suggesting that some whales take a northerly route across the Chukchi Sea. Most bowheads seen were swimming, but occurrences of feeding, breaching, flipper slapping and log playing were also observed. An aggregation of feeding and milling bowheads remained northeast of Point Barrow from early through mid-October. Survey effort and all bowhead sightings are depicted in daily flight maps and tabularized summaries and presented in Appendix A.

There were 59 sightings of 170 gray whales in the study area in 1989, from 0.5 to 240 km offshore. Gray whale distribution along the Chukchi coast was similar to past years. Gray whales were seen in a localized area approximately 180 to 210 km northwest of Barrow, as in 1986-87, with the distribution of "offshore" grays extending farther north (to 240 km) than in prior years due to the extension of survey effort into these waters. A large aggregation of gray whales was seen in the south-central Chukchi Sea in late October. Peak abundance estimates were calculated for offshore blocks (14, 14N) in the northeastern Chukchi Sea and for blocks (23,24) in the Hope Basin Planning Area in the southern Chukchi Sea. Most gray whales seen were feeding (90%, n= 153). One gray whale calf was seen in the northeastern Chukchi Sea, approximately 175 km northwest of Point Barrow.

Four large cetaceans seen in the study area in late September and October 1989 were too far from the aircraft for positive identification and were recorded as "unidentified", as both bowhead and gray whales were seen in the study area during this period.

Over eight survey seasons (1982-89), there were 226 sightings of 501 bowhead whales in the study area. Bowheads were not seen during ca. 20 hours of surveys conducted in 1980-81. The earliest sighting was 18 September 1983 in the western Beaufort Sea and latest sighting was on 29 October 1989 in the north-central Chukchi Sea. Bowheads were often seen on the first and/or last survey from 1982-89, so these dates cannot be inferred as an absolute period for bowheads in the study area. Highest bowhead relative abundance was calculated for survey block 12 near Point Barrow, with highest annual indices in 1984 and 1989 coincident with bowheads feeding there. Comparatively high relative abundance was also calculated for survey blocks 13 and 18, west and southwest of Point Barrow. Estimates of bowhead densities for 1980-89 are presented in Appendix B.

Patterns of distribution and swimming direction for 1982-89 indicate bowhead whales migrate westerly (276 'T, p <0.001) close to shore between Smith Bay and Point Barrow, then disperse southwest (247 "T, p <0.001) from Point Barrow across the Chukchi Sea. The principal migration route is roughly 1 to 30 km offshore between Barrow and Wainwright, extending to roughly 120 km offshore northwest of Icy Cape. However, eight bowhead sightings north of 720 N latitude suggest some whales do not disperse southwest after passing Point Barrow, but take a more northerly route across the Chukchi Sea. Major currents in the Chukchi Sea may influence bowhead migration route(s). Distribution of random bowhead sightings are similar to the pattern of bathymetrically directed current flow in the northeastern Chukchi Sea, although the association between sightings and current pattern could not be supported statistically. Oscillations in daily sighting rates indicate that bowhead whales migrate through the study area in pulses, with approximate ten-day intervals between sighting rate peaks starting in late September.

Over eight survey seasons (1982-89), there were 137 sightings of 397 gray whales in the study area during September and October. Relative abundance was highest in nearshore blocks near Point Hope and Point Barrow. The majority of gray whales seen were feeding (85%, n= 339), and were in open water or light (< 10%) ice cover, Feeding gray whales were seen in offshore blocks 14 and 14N in 1986-87 and 1989. Distribution and bathymetry indicated the whales feeding offshore were near the boundary of Hanna Shoal. Gray whales were not seen in the study area in 1980-81, although large aggregations were seen in the northern Bering Sea in early November 1980.

There were 83 sightings of 421 belukhas (Delphinapterus leucas) in the study area in 1989. Belukhas were seen relatively nearshore southwest of Point Barrow and well offshore north and west of Point Barrow. Swimming direction was significantly clustered about 2780 T in the Chukchi Sea, and was not significantly clustered about any direction in the western Beaufort Sea. There were 307 sightings of 3,387 belukhas in the study area over eight survey seasons (1982-89). The pattern of distribution suggests bifurcated migration route(s) across the northeastern Chukchi Sea similar to that discussed for bowhead whales. Cumulative (1982-89) relative abundance indices were two to five times higher for Chukchi Sea survey blocks north of 720 N than for areas further south, Cumulative (1982-89) random belukha sightings were significantly ($p < 0.001$) associated with the relatively deep-water (≥ 37 m) troughs that channel currents in the Chukchi basin, suggesting that currents may influence the belukha migratory route.

There were 126 sightings of 2,001 walruses in the northern Chukchi Sea throughout the 1989 study period, with most animals associated with the ice edge in the extreme northern portion of the study area. There were 13 sightings of 17 bearded seals, and 152 sightings of 1,060 unidentified pinnipeds in 1989. An especially large aggregation (>800) of unidentified pinnipeds was seen north of west of Kotzebue Sound on 2 November 1989.

INTRODUCTION

The Outer Continental Shelf (OCS) Lands Act (67 Stat. 462) established Federal jurisdiction over the submerged lands of the continental shelf seaward of state boundaries in 1953, and charged the Secretary of the Interior with responsibility for administering minerals exploration and development of the OCS. In keeping with the National Environmental Policy Act (1969), the Marine Mammal Protection Act (1972) and the Endangered Species Act (1973), the OCS Lands Act Amendments (1978) established a management policy that included studies in OCS lease sale areas to ascertain potential environmental impacts of oil and gas development on OCS marine coastal environments. The Minerals Management Service (MMS) is the agency responsible for these studies and for the leasing of submerged Federal lands.

The first OCS oil and gas lease sale entirely in the Chukchi Sea (Sale 109) was held in May 1988, with additional lease sales scheduled in 1991 and 1992. Lessees were advised in the Notice of Sale for Sale 109 that the MMS intends to continue a monitoring program in the Chukchi Sea for whale species listed as endangered during exploration activities. In September 1989, the MMS awarded SEACO, a Division of SAIC (hereafter SEACO/SAIC) a 3-year contract to monitor the distribution of endangered whales, and secondarily all other marine mammals, in the Alaskan Chukchi and western Beaufort Sea via aerial surveys. This report constitutes a summary of the results of the first year of field work under this contract.

The Alaskan Chukchi and western Beaufort Sea from the Bering Strait to 730 N latitude between 1540 W and 169 °W longitude (hereafter, study area) seasonally supports several marine mammal species. This region incorporates the Chukchi and Hope Basin OCS Planning Areas and a portion of the Beaufort Sea OCS Planning Area (Fig. 1). In fall, bowhead whales (Balaena mysticetus) and gray whales (Eschrichtius robustus), both listed as endangered species, co-occur at least in the northeastern portion of the study area (Moore et al. 1986a), and belukhas and several species of pinnipeds occur throughout the region (Ljungblad et al. 1988).

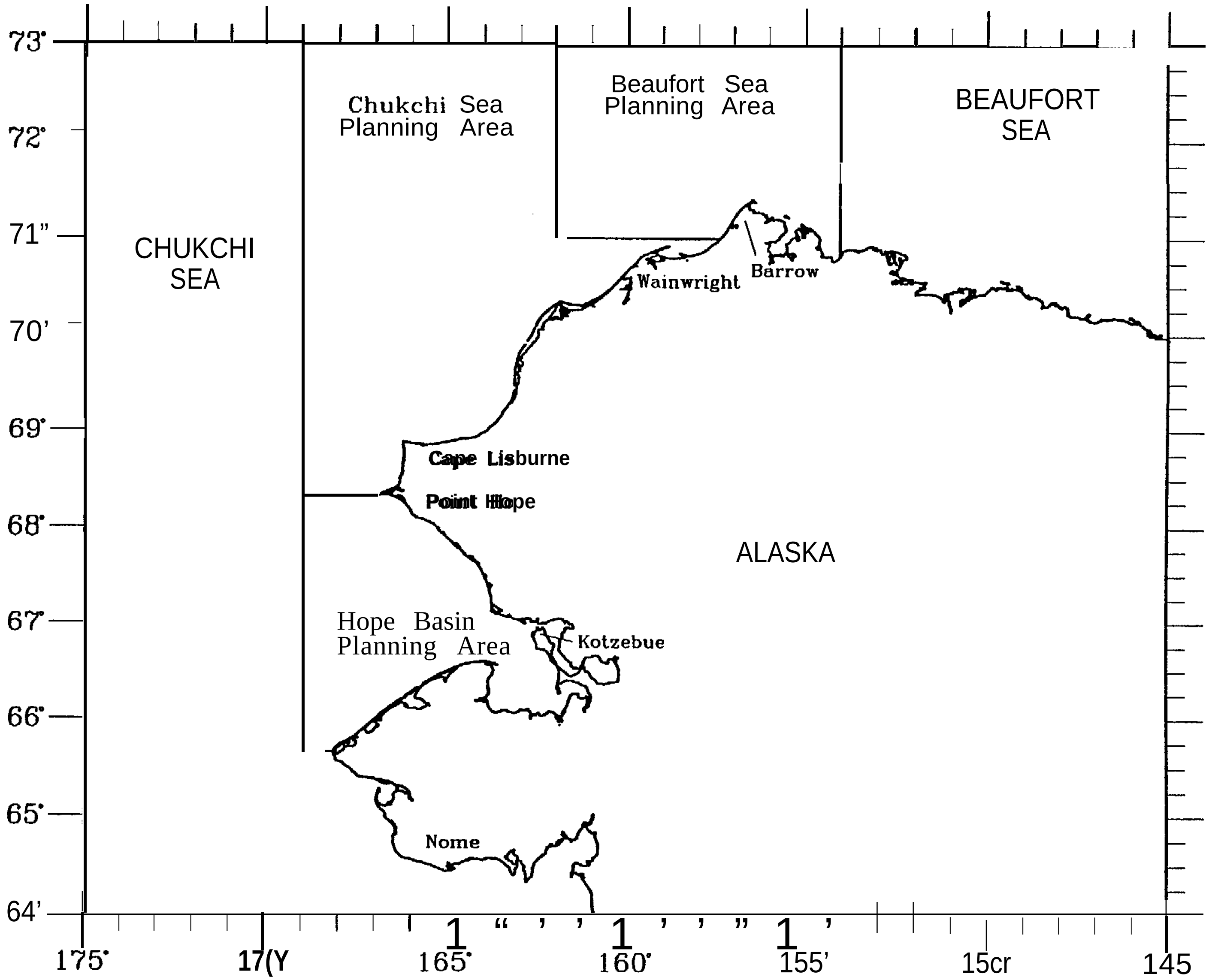


Figure 1. Chukchi Sea study area depicting the boundaries of the Chukchi and Hope Basin OCS Planning Areas, and the westernmost portion of the Beaufort Sea OCS Planning Area.

Bowhead whales are the species of principal interest due to their endangered status and because they are the focus of an annual subsistence hunt by Alaskan Eskimos. Historically, bowheads had a nearly circumpolar distribution north of 600 N latitude, but a long history of exploitation seriously reduced the number of whales in each of five geographically separate stocks (Breiwick et al. 1981; Bockstoce and Botkin 1983; Bockstoce 1986). The Bering Sea stock, estimated by the International Whaling Commission (lWC) to contain 7,800 whales (IWC 1989) is the population monitored in this study. This stock annually migrates around western and northern Alaska between wintering areas in the northern Bering Sea and summer feeding grounds in the Canadian Beaufort Sea. The spring migration generally occurs from early April through June along open-water lead systems that annually develop relatively nearshore in the Chukchi Sea (Ljungblad et al. 1986c; Braham et al. 1984). The timing and route of the fall migration across the Chukchi Sea is less well-defined. It appears that most whales swimsouth-southwest after passing Point Barrow crossing roughly south of Herald Shoal in the central Chukchi Sea (Moore et al. 1986a), while a second component may take a more westerly course towards Herald and Wrangel Islands before heading south along the Chukotka coast (Braham et al. 1984). The migration likely occurs from late September through at least early November.

Gray whales are also classified as endangered, although estimates of their number in recent years indicate that the California-Chukotka stock has completely recovered from the commercial harvest of the late nineteenth century (Breiwick et al. 1988). The Chukchi Sea represents the northernmost feeding ground for gray whales, although a few whales have been seen occasionally as far east as Herschel Island (Rugh and Fraker 1981; Wursig et al. 1983). Dense aggregations of feeding whales are common in the northern Bering Sea (Moore et al. 1986 b), just south of the study area. Gray whales routinely feed along the Chukchi coast and in some years in the north-central Alaskan Chukchi Sea (Clarke et al. 1989). Furthermore, there is evidence that cows with calves segregate from the main population and are found more often along the Chukchi coast than among whales feeding in the northern Bering Sea (Moore et al. 1986 b), as has been reported for the Chukotka coast (Bogoslovskaya 1986). These findings suggest that portions of the Chukchi Sea may be important habitat for calf weaning, as well as feeding, for a population of whales that has recently expanded in number.

This report is a summary of 1989 field results on aerial surveys of bowhead and gray whale distribution, relative abundance, density, migration and behavior in the Alaskan Chukchi and western Beaufort Sea in accordance with the objectives outlined below. Belukha distribution, relative abundance, habitat relationships and behavior are also reported, as well as incidental information on all other marine mammals seen. Flight tracks and descriptive captions, presented in Appendix A, provide an overview of daily survey efforts and results. Density estimates for bowhead and gray whales for 1989 and for all data collected in the study area from 1980-88 (Ljungblad et al. 1988) are provided in Appendix B.

Objectives

The primary objectives of the 1989 aerial survey study were to:

- determine seasonal distribution, migration timing and route, relative abundance, behavior and habitat characteristics of bowhead and gray whales (hereafter, endangered whales) in or near existing and proposed Federal lease sale areas in the study area;
- derive estimates of relative and/or absolute abundance of endangered whales to describe spatial and temporal distribution patterns;
- describe behavioral characteristics of endangered whales as observed in or near existing and proposed Federal lease sale areas, with special emphasis on locating potential feeding areas and migration pathways;
- record locations and numbers of other marine mammals incidental to sightings of endangered whales;
- consult and coordinate field activities with other Federal agencies, state or local government organizations, or other endangered species researchers to maximize productivity of this study and minimize conflict with other resource uses;
- synthesize and further analyze endangered whale data obtained on surveys conducted in the study area since 1980 to describe temporal variation in fall sighting rates and to determine if any shift in the migration routes have been induced by human activities.

METHODS AND MATERIALS

Project Rationale and Design

The timing and route of the fall bowhead migration across the Chukchi Sea is ill-defined compared to the spring migration (Ljungblad et al. 1986c; Braham et al. 1984). Further, bowhead whales feed in the western Beaufort Sea in fall of some years, but not in others (Ljungblad et al. 1986a). Coastal and offshore areas in the northern Chukchi Sea are important feeding habitat for gray whales (Clarke et al. 1989), but their movements to and from these areas are poorly understood. Therefore, the primary objective of this project was to determine distribution and relative abundance, define fall migratory timing and route, and identify feeding areas for bowhead and gray whales in the study area. Related objectives included describing whale behaviors and recording their proximity, and reaction if any, to ongoing offshore industrial operations. Lastly, in mid-October the survey aircraft was equipped with receivers for detecting signals from radio tags attached to five bowhead whales in the eastern Beaufort Sea by industry-sponsored researchers. These receivers were monitored during aerial surveys for the remainder of the field season.

Aerial surveys conducted from Barrow and Kotzebue, Alaska were designed to (a) monitor the progress of the bowhead migration across the western Beaufort Sea and Alaskan Chukchi Sea, (b) determine when bowheads entered the Chukchi Sea, and (c) maximize information on the distribution, movements and behavior of bowhead and gray whales in the study area from late September through early November. Secondarily, the distribution, abundance and behavior of belukhas were studied and incidental sightings of all marine mammals were recorded. Data for all marine mammals were compiled with that collected on MMS-sponsored aerial surveys conducted in the study area by the Naval Ocean Systems Center and SEACO, Inc. from 1980-88 (Ljungblad et al. 1988), to provide the broadest possible data set for analyses. Aerial surveys to assess the status of the fall bowhead migration in the Alaskan Beaufort Sea east of 154°W were conducted by MMS personnel from Deadhorse, Alaska (Treaty 1990). Daily coordination and data transfer between the Chukchi Sea and Beaufort Sea projects provided the MMS with real-time information required for implementation of lease stipulation and permit regulations.

Study Area and Aerial Survey Procedure

The study area included the western Beaufort Sea from 157” W east to 154” W offshore to 730 N, and the Alaskan Chukchi Sea from 1570 W west to the International Date Line (IDL, approximately 168058’W) between 65” 40’N and 730 N. This area was divided into survey blocks (Fig. 2), such that one or, with favorable conditions, two blocks could be surveyed completely on one flight. Survey blocks 12 through 22 are identical to those surveyed since 1983 (Ljungblad et al. 1988), facilitating comparisons of data between years.

Two types of aerial surveys were conducted to accomplish the listed objectives:

1. Line transect surveys were flown in survey blocks to determine distribution and estimate relative and absolute abundance. Line transect is one available survey method from which statistical inferences can be made, provided the starting and turning points of the line are selected randomly (Cochran 1963). Survey blocks were divided into sections that were 30 minutes of longitude or 10 minutes of latitude wide, and each section was divided into 10 equal segments. Random transect lines were derived for each section by matching two numbers from a random numbers generator to the numbered segments and drawing a line between them. The same procedure was followed for each section of the survey block, and all transect lines were then linked together with connecting lines at the top and bottom. When bowhead or gray whales were encountered while surveying a transect line, the aircraft diverted from transect for brief periods (< 10 minutes) and circled above the whales to observe behavior, obtain an accurate count, and determine whether calves were present. Only bowheads seen initially before diverting from the transect line were included in density calculations.

2. Search surveys were flown to locate whales and observe their behavior or when in transit to a transect block or a new base of operations. These surveys did not follow a preset paradigm, by instead were dependent upon weather, sea state, and ice conditions, or previous patterns of whale sightings.

The aircraft used for the surveys was a Grumman Turbo Goose (model G21 G) with a call sign of N780. The aircraft was equipped with a Global Navigation System

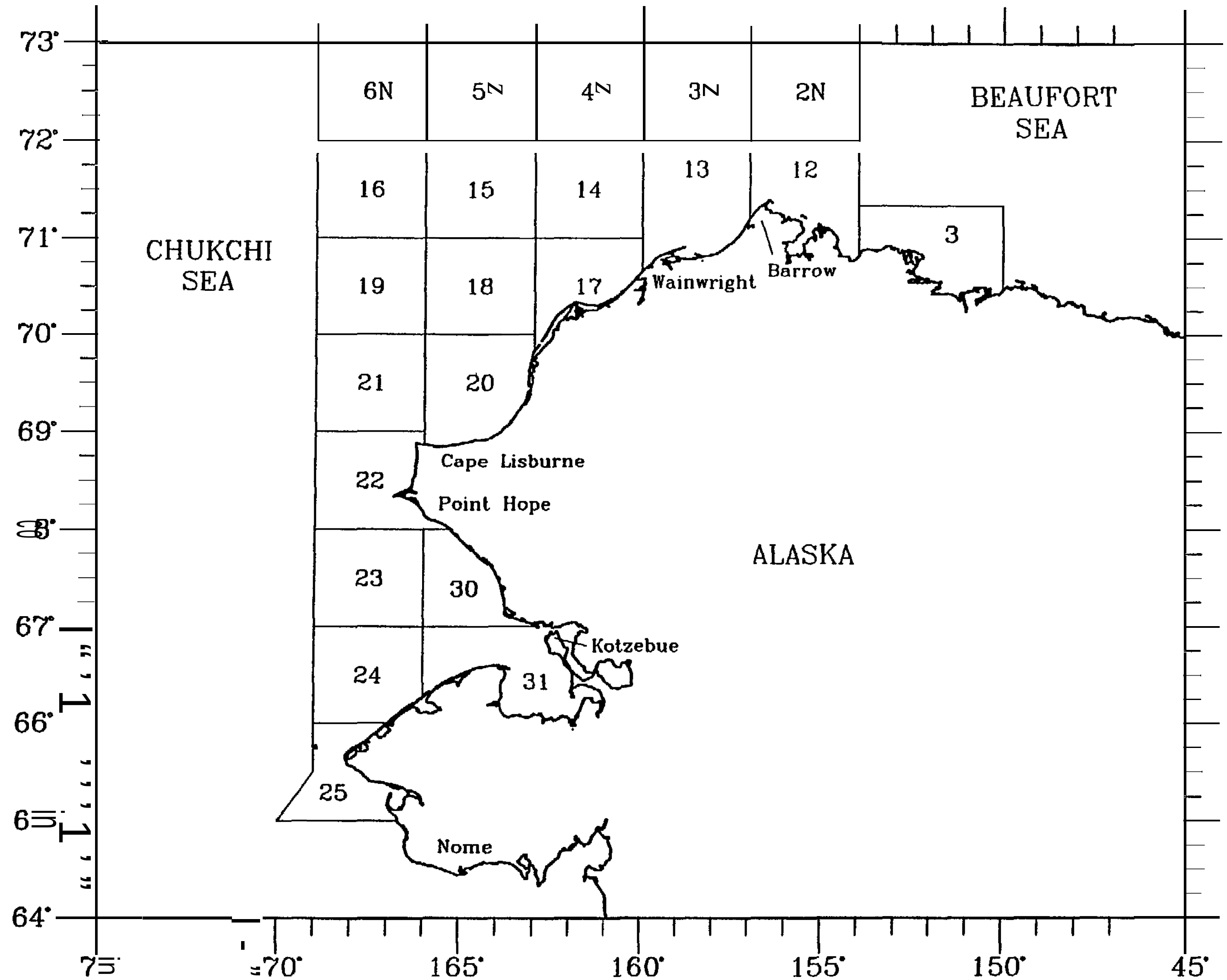


Figure 2. Survey blocks derived for the Chukchi Sea study area. Block 3 is part of the Alaskan Beaufort Sea study area (Treacy 1989) and was surveyed only to check radio tracking equipment.

(GNS) 500 that provided continuous position updating (0.6 km/survey hr, precision) and transect turning point programming. The aircraft cockpit was outfitted with four seats, each of which afforded excellent visibility through large side windows for the two principal observers and pilots. A long rectangular window behind the cockpit provided good visibility for the observer-recorder. Each observer had a clinometer to take angles on all whale sightings abeam of the aircraft which, along with altitude, were used to compute animal distance from the survey track line. Observers and pilots were linked to a common communication system. Surveys were flown at 100 m to 458 m altitude, at speeds of 222 to 296 km/hr. The higher altitudes were maintained when weather permitted in order to maximize visibility and to minimize disturbance to marine mammals.

A portable computing system (Hewlett Packard 85) was used aboard the aircraft to store and later analyze flight data. 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 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 the 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 environmental conditions changed, or, in the absence of sighting data, every 10 minutes. All entries were coded as to the type of survey being conducted (Table 1: No. 7). During a typical flight (Fig. 3), a search leg was flown to the survey block, followed by a series of random transect legs that were joined together by connect legs, with search leg(s) conducted back to the base of operations. Sea state was recorded according to the Beaufort scale outlined in Chapman (1971). Ice type was identified using terminology present in the Naval Hydrographic Office Publication Number 609 (1956), and ice cover was estimated in percent.

Data Analysis

Distribution and Abundance

Observed bowhead and gray whale distribution was plotted for trimonthly periods and in relation to OCS oil and gas lease areas for the survey season on maps generated by Hewlett Packard and AutoCAD (Bauer 1989) computer systems. Trimonthly and

Table 1. Data entry sequence on the portable flight computer.

No.	Data entry
1.	**Entry number**
2.	**Time**
3.	**Latitude**
4,	**Longitude**
5.	**Altitude**
6.	**Reason for entry**
7.	**Survey type (flag)**
8.	Weather
9.	Visibility right
10.	Visibility left
11.	Ice coverage
12.	Ice type
13.	Sea state
14.	Water color
15.	Water depth
16.	**Species**
17.	**Clinometer**
18.	Sighting cue
19.	Behavior
20.	**Total number**
21.	Estimated size class
22.	Total number calves
23.	Swim direction
24.	Estimated swim speed
25.	Response to aircraft
26.	Repeat sighting
27.	Photo roll number
28.	Photo frame numbers

Position/environmental update (13-key) [bracket: items 1–13]

Sighting update (20-key) [bracket: items 1–7 and 16–28]

Rapid sighting update (9-key)

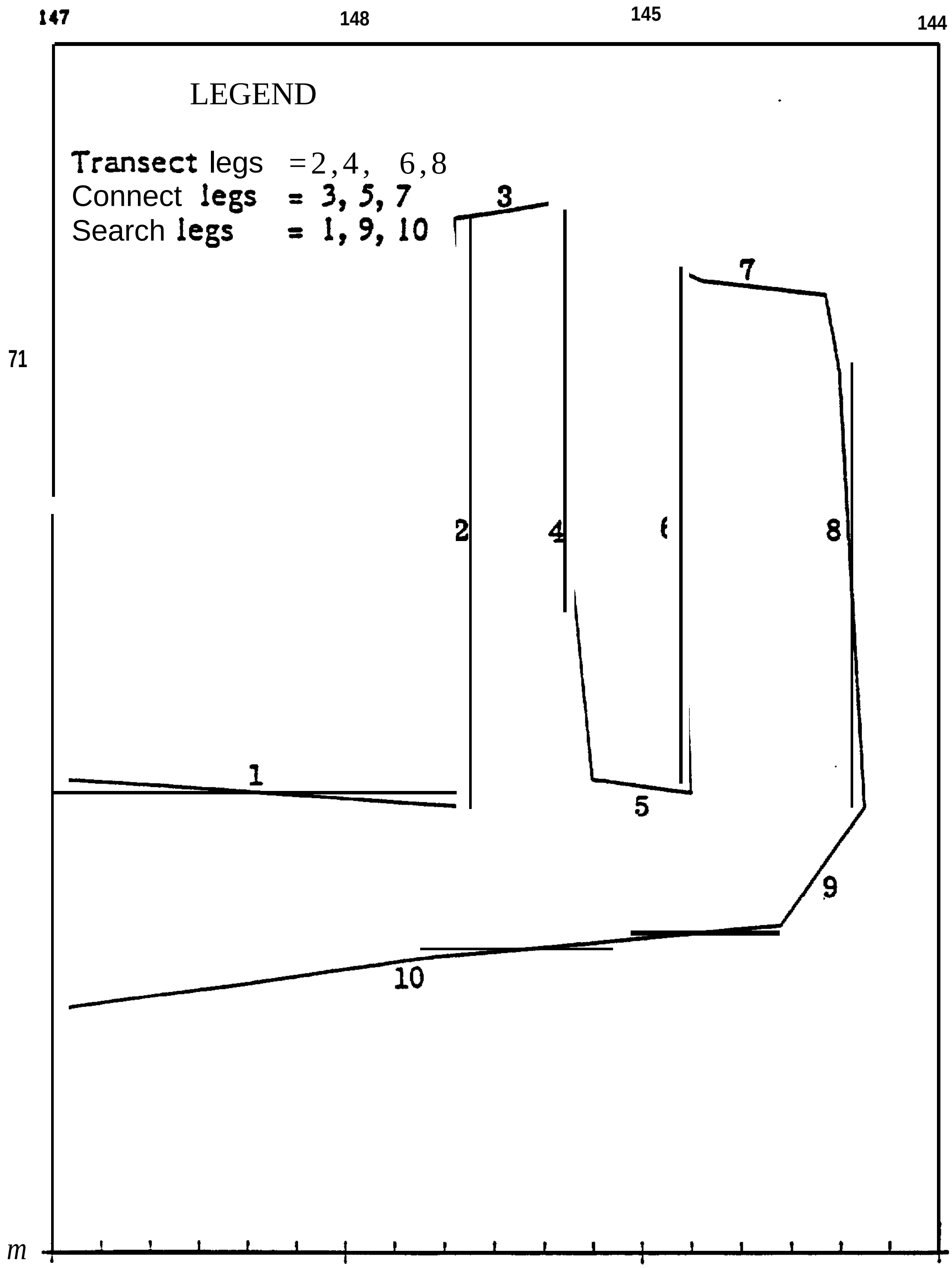


Figure 3. Example of an aerial survey flight track depicting transect, connect and search survey legs.

seasonal relative abundance indices were calculated as whales per unit effort (WPUE = no. whales/survey hour) per survey block for bowhead whales, gray whales and belukhas. Bowhead and gray whale density estimates were derived for survey blocks using strip transect methods and are presented in Appendix B. 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 WPU E represent the total sighting database in relation to the total survey effort. Density estimates, on the other hand, require that sightings used in their derivation be collected at random (Cochran 1963). Therefore, only sightings made on random transect legs were used to derive density estimates; if no sightings were made on random transects within a survey block, density was not calculated for that block.

Migration Timing and Route

The timing of the 1989 bowhead migration through the study area was analyzed as sightings per unit effort (SPUE = no. sightings/survey hour) and as WPUE per date. Annual indices of migratory timing were analyzed by calculating SPUE and WPUE for the study area using the 1982-89 data set, followed by a cumulative index reflecting the combined 7-year database.

Migration route across the Alaskan Chukchi Sea was defined by fitting lines to all random bowhead sightings east of Point Barrow (ca., 156°30' W longitude) for each year 1982-1989 by the method of least squares, Differences in migration route (i.e. line slope) among years was tested using multiple linear regression, followed by the Tukey "honestly different" test to analyze differences between all possible pairs of years (Zar 1984). Definition of migratory route was further explored by analyzing swimming direction. Whale swimming direction was analyzed using descriptive statistics for circular distributions (Zar 1984). Because whales that are milling, feeding or resting often change headings several times while at the surface, swimming direction for whales exhibiting those behaviors were omitted from the analyses.

Behavior and Calf Sightings

Behaviors were cataloged into two types for purposes of discussion: migratory behaviors, including swimming and diving; and social behaviors (typically observed in groups), such as milling, feeding, cow-calf association, resting, displaying and mating (Table 2). Displays included breaches, spy-hops, tail and flipper slaps, rolls, underwater blows, and log-play. 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/rein corresponded to an estimated speed of 1 km/hr, one body length/30 sec was estimated at 2 km/hr, and so on. Swimming speed and whale size were recorded by relative category (i.e., still, O km/hr; slow, O-2 km/hr; medium, 2-4 km/hr; or fast, >4 km/hr; and calf, immature, adult or large adult, respectively) rather than on absolute scale.

In compliance with condition B.4-6 of permit No. 459 to “take” endangered marine mammals, any sudden overt change in whale behavior observed coincident 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.

Calf sightings were tabularized for 1989 and plotted for 1982-89. To determine if there was any pattern of temporal segregation, an index of calves per unit effort (CPUE = no. calves/hours of survey) was derived for semi-monthly time periods for the 1982-89 data set.

Habitat Relationships

Habitat preference was described as percentage of whales/ice class and percentage of whales/depth regime. Whale distribution was related to published accounts of Chukchi Sea current patterns by determining the proportion of random sightings that were in water c 37 m and ≥37 m (20 fathoms) deep, and comparing these ratios to the approximate availability of habitat in the two depth categories using Chi-square analysis (Zar 1984). Habitat availability in the two depth categories in areas where whales were

Table 2. Operational definitions of observed whale behaviors.

MIGRATORY:	
Swimming	Forward movement through the water propelled by tail pushes.
Diving	Change of swimming direction or body orientation relative to the water surface resulting in submergence; may or may not be accompanied by lifting of the tail out of the water.
SOCIAL:	
Milling	Whales swimming slowly near one another in close proximity (within 100m) at the water surface.
Feeding	Whale(s) diving repeatedly in the same general area sometimes accompanied by mud streaming from the mouth and defecation upon surfacing; nearly synchronous diving and surfacing have been noted as have echelon formation surface feeding with swaths of clearer water noted behind the whales; and open mouth surface swimming,
Mating	Ventral-ventral orientation of a pair of whales often with at least one other whale present to stabilize the mating couple; often within a group of milling whales; pairs appear to hold each other with their pectoral flippers and may entwine their tails.
Cow-Calf	Calf nursing; calf swimming within 20m of an adult.
Resting	Whale(s) at the surface with head, or head and back exposed, showing no movement; more commonly observed in heavy-ice conditions than in open water.
Displaying:	
Rolling	Whale rotated on longitudinal axis, sometimes associated with mating.
Flipper-Slapping	Whale on its side striking the water surface with its pectoral flipper one or many times; usually seen in groups, sometimes when whale is touching another whale.
Tail-Slapping	Whale hanging horizontally or vertically in the water with tail out of water waving back and forth striking the water surface; usually seen in groups.
spy-Hopping	Whale rising vertically from the water such that the head and up to one-third of the body, including the eye, is exposed.
Breaching	Whale exiting vertically from the water such that half to nearly all of the body is exposed then falling back into the water, usually on its side, creating a large splash and presumably some sounds.
Underwater Blow	Exhalation of breath while submerged creating a visible bubble.

seen in the northeastern Chukchi Sea (70020'-73" N, 156 °30-q660 N) was determined through use of a grid format, whereby the study area was overlaid with a grid in which each box measured 3' of latitude by 10' of longitude (ca. 5.6 km^2). One depth, read off NOAA bathymetric charts 16004 and 16005, was assigned to each box, and the number of boxes in each depth category was totaled. The possible relationship between whale distribution and currents is inferred, as major currents in the Chukchi Sea are bathymetrically directed around shoals, where water depth is generally <37 m (Aagaard 1987; Stringer and Groves 1987; Paquette and Bourke 1981). Additional statistical comparisons, correlations, and regressions were performed as appropriate (Zar 1984).

RESULTS

Survey Effort, Conditions and Bowhead Sighting Summary

A total of 135.2 hours of surveys were flown in 1989, with 118.5 hours (88%) of this effort in the Chukchi Sea (i.e., waters west of 1570 W) and 16.7 hours (12Yo) in the western Beaufort Sea (Table 3). Line transect surveys were conducted on most flights, with time spent on random lines alone accounting for 50% (67.4 h) of the total survey time. Surveys were based out of Barrow from 20 September through 29 October, and out of Kotzebue from 30 October to 3 November to focus survey effort in the Hope Basin. Survey effort is depicted in 10 or 11-day increments in Figure 4, and ice conditions encountered during the survey season are represented in Figure 5. Daily survey effort is summarized in Table A-1 in Appendix A.

In late September, 38.6 hours of surveys were conducted (Appendix A: Flights 1-9) in the study area, with nearly three-quarters (74%, 28.4 h) of the effort in the Chukchi Sea (Table 3). Line transect surveys were flown in blocks 12 and 12N in the Beaufort Sea, and blocks 13, 13N, 14N, 15N, and 16N in the Chukchi Sea. Survey conditions were generally good. Visibility was usually >5 km under overcast or partly cloudy skies, and unacceptable weather prevented flying on only two often days. There was no ice in most of the study area. The ice edge was north of all blocks except 14N and 15N. Bowheads were seen in blocks 14N (1 whale), 15N (1 whale) and 12 (4 whales).

Flight effort from 1-10 October (Appendix A: Flights 10-14) was directed almost solely to the Chukchi Sea (91 %, 19.0 h). Line transect surveys were flown in blocks 14, 14N, 15 and 15N, with a search survey in block 12. Survey conditions were poor. Fog, freezing rain and high winds prevented flying on four days and a failure of the aircraft navigation system caused survey cancellation on a fifth day. The ice edge remained north of most of the study area. Bowheads were seen in blocks 12 (41 whales) and 14N (1 whale). In mid-October (Appendix A: Flights 15-19), flight effort again was concentrated on the Chukchi Sea (79%, 16.6 h), with line transect surveys flown in blocks 13N, 15N and 17, and search surveys in block 12 and outside the study area in block 3 of the Beaufort Sea study area (see Fig. 2). Survey conditions were similar to those in early October, with

Table 3. Summary of flight effort conducted in the Chukchi Sea study area, 1989.

	September	October			November	Total
	20-30	1-1o	11-20	21-31	1-3	
Number of flights	9	5	5	9	3	31
Unacceptable Weather (days)	2	4	3	2	0	11
Aircraft Maintenance (days)	O	1	2	0	0	3
Flight Effort Summary						
Chukchi Sea						
Transect (km)	3729	2403	2002	5159	1092	14385
Connect (km)	415	270	258	782	169	1894
Search (km)	2511	1875	1546	3867	1366	11165
Transect (H)	15.78	9.87	8.57	22.17	4.46	60.85
Flight (H)	28.40	19.01	16.59	43.62	10.91	118.53
Beaufort Sea						
Transect (km)	1521	0	0	0	0	1521
Connect (km)	114	0	0	0	0	114
Search (km)	740	242	954	91	0	2027
Transect (H)	6.52	0	0		0	6.52
Flight (H)	10.21	1.82	4.32	0.3:	0	16.71
Total						
Transect (km)	5250	2403	2002	5159	1092	15906
Connect (km)	529	270	258	782	169	2008
Search (km)	3251	2117	2500	3958	1366	13192
Transect (H)	22.30	9.87	8.57	22.17	4.46	67.37
Flight (H)	38.61	20.83	20.91	43.98	10.91	135.24

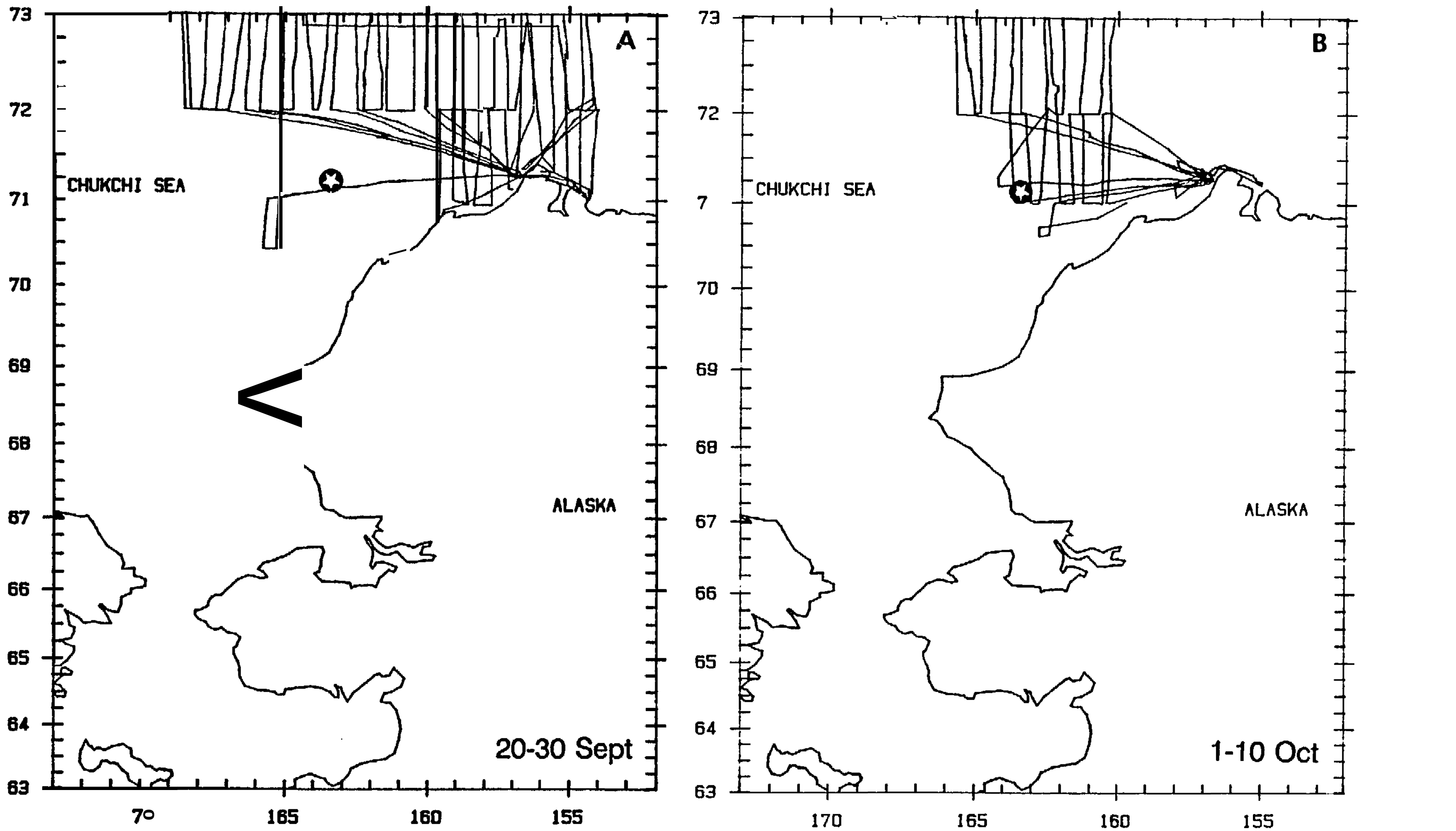


Figure 4. Composite flight tracks depicting flight effort comprising 9 surveys, 20-30 September 9᠎᠎᠎᠎᠎⊟9 (A); 5 surveys, 1-10 October 1989 (B); [✪= 'Burger' exploratory site]

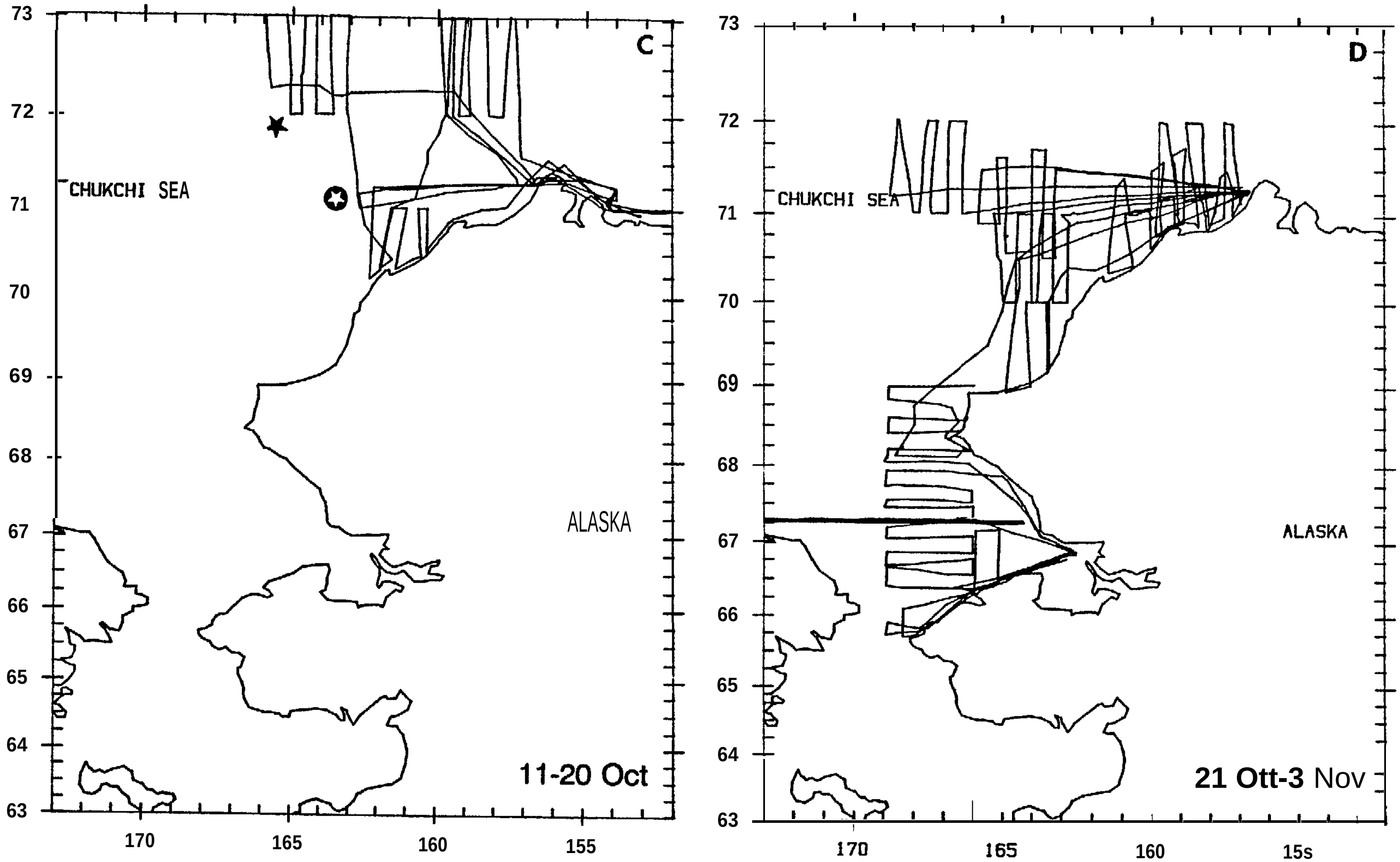


Figure 4 (contd). 5 surveys, 11-20 October 1989 (C); and 9 surveys, 21-31 October 1989 (north of solid lineat670 15'N) and 3 surveys, 1-3 November 1989 (D). [★= 'Popcorn' exploratory site; ✪= 'Burger' exploratory site]

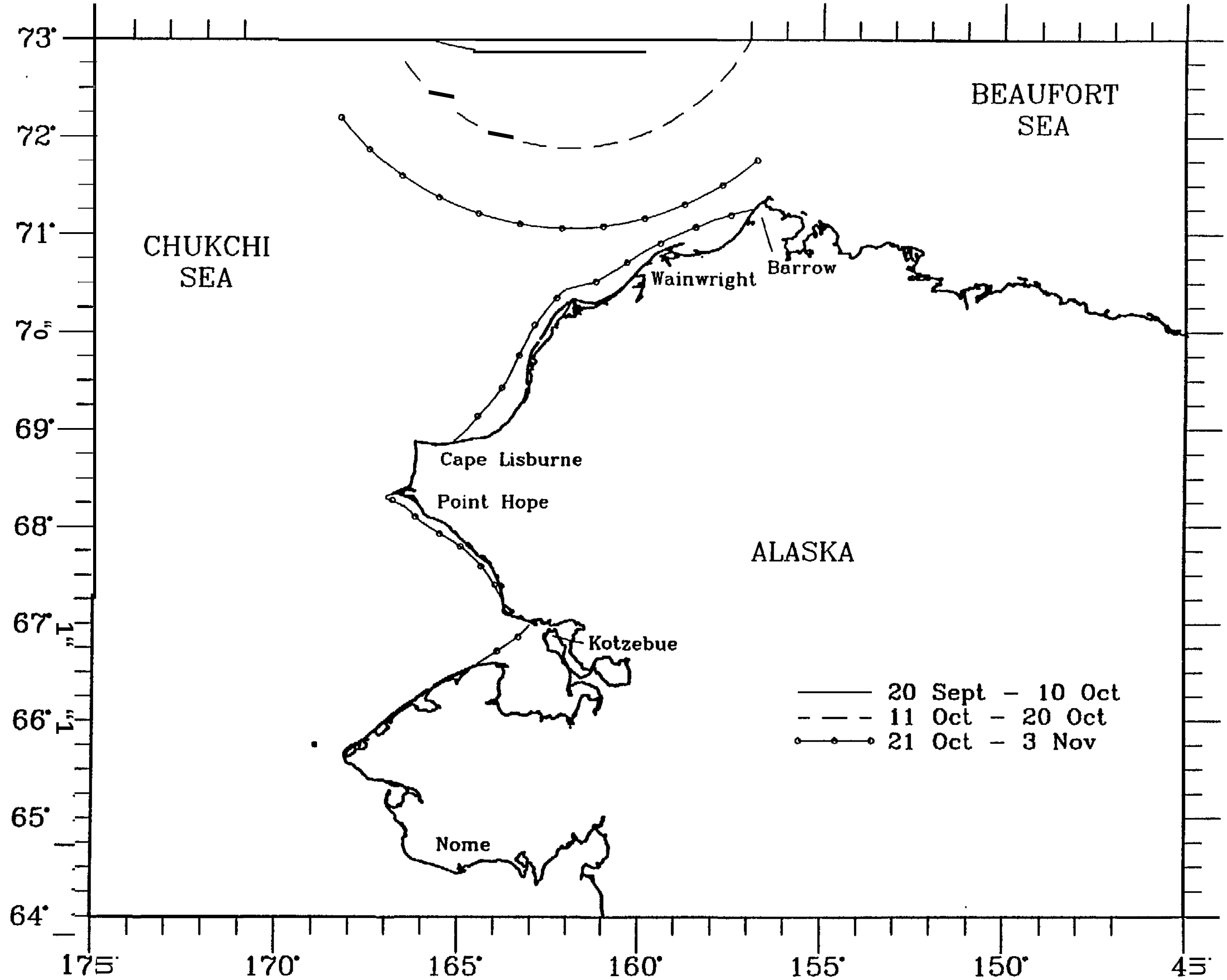


Figure 5. Approximate location of the ice edge (≥ 90% ice conditions) during the 1989 survey season.

low ceilings and high winds causing cancellation of survey efforts on three days. A scheduled 100-hour aircraft maintenance check and subsequent repair prevented surveying on two days. Ice conditions remained light, with 95% grease ice beginning to form north of 72015'N in blocks 13, 13N, 14, 14N, 15, and 15N, and open water everywhere else. Sea states remained high (Beaufort 04-06) in open water areas, often times breaking up newly formed grease ice. Bowheads were seen in blocks 12 (43 whales) and 15N (1 whale).

Flight effort from 21-31 October (Appendix A: Flights 20-28) was almost exclusively devoted to the Chukchi Sea (99%, 43.6 h), with line transect surveys in blocks 13, 15, 16, 17, 18, 20, 22, and 23. Survey conditions were greatly improved compared to earlier in the month. Consistently cold temperatures brought on the formation of sea ice around 21 October, effectively dampening sea states and improving survey conditions, especially south of 72" N where surveying had been difficult due to high sea states. Weather and visibility improved, and surveys were curtailed on only two days due to weather. The ice edge, consisting of new grease ice and broken floe, was located at approximately 71" 10'N and as far west as 1670 W; west of there the ice edge was approximately 100 km north. Slushy new ice also formed nearshore west of Barrow, although wide expanses of open water less than 5 km offshore were consistently opened by wind and currents. High sea states still persisted in the southern Chukchi Sea where there was no ice except just south of Point Hope. Bowheads were seen in blocks 13 (22 whales), 14 (4 whales), 17 (1 whale) and 18 (12 whales).

In early November (Appendix A: flights 29-31), flight effort was concentrated on the southern Chukchi Sea (100Y0, 10.9 h), with line transect surveys conducted in portions of blocks 23, 24, 25 and 30. Survey conditions remained good. Intermittent snow squalls and fog caused some surveys to be truncated, and high sea states persisted especially near the Bering Strait. There was no ice in the southern Chukchi Sea except in Kotzebue Sound, which was completely frozen. No bowheads were seen during these flights.

Seasonal ice conditions in 1989 were extremely light and comparable to those in 1986-87. Fall ice cover averaged over 29 years (1953-81) indicate that ice is usually more extensive in the Chukchi Sea study area than conditions prevalent in 1989 (La Belle et al.

1983). Pease (1988) described both 1986 and 1987 as extremely light ice years that set a new 30-year minimum, and 1989 would likely be added to that description. Just as 1980, 1983 and 1988 have been considered years of exceptionally heavy ice cover (Ljungblad et al. 1986c; Treaty 1989), the 1989 season stands out as a year of extensive open water most similar to 1987 and 1986.

Exploratory drilling was conducted at three sites in 1989, but only two of these sites were active during the aerial survey field season. The drillship Canmar Explorer III and attendant supply vessels and helicopters worked at 'Klondike' site (ca. 700 15'N, 1650 15'W) from 9 July to 15 September, prior to the commencement of aerial surveys. During the survey season, exploratory operations were conducted at 'Burger' site (ca. 710 15'N, 1630 12'W) from 22 September to 14 October, and at 'Popcorn' site (ca. 71051 'N, 165043'W) from 14 October to 19 October. Surveys were conducted in the vicinity of these operations on 28 September, 1 October and 10 October (Appendix A: Flights 7, 10 and 14), but no bowhead or gray whales were seen.

Search surveys east of Point Barrow were conducted on 14 and 15 October (Appendix A: Flights 16 and 17) in an attempt to radio track bowhead whales tagged earlier in the fall by industry-sponsored researchers (Wartzok 1990). A tagged whale was radio-tracked by these researchers to waters north of Smith Bay, and was part of the feeding and milling aggregation resident there in early and mid-October. The survey aircraft (N780) was outfitted with an industry-supplied receiver, recorder and antenna to continue tracking the whale through the Chukchi Sea. Unfortunately, although the system operated sufficiently when tested on the ground, it had almost no range in the air; test signals were received only when the aircraft was directly over the test tag, rendering the system nearly useless for tracking. Nevertheless, the system was kept onboard and monitored during all subsequent flights. No tagged bowheads were ever detected. The reason for the inoperability of the tracking system is unknown, but maybe due to the type of antenna used or to the design of the aircraft (K. Fristrup, pers. comm.).

Bowhead Whale (Balaena mysticetus)
Distribution and Abundance

There were 69 sightings of 131 bowhead whales in the study area during the 1989 survey season (Fig. 6; Table A-2). Four sightings of six bowheads were made in late September. Two whales were seen over 175 km northwest of Point Barrow in the Chukchi Sea, with four whales seen nearshore at Point Barrow and Smith Bay. There were 10 sightings of 42 bowheads from 1-10 October; all but one were part of a milling and feeding aggregation seen nearshore between Point Barrow and Smith Bay. The single bowhead was seen 230 km offshore northwest of Point Barrow swimming south. There were 29 sightings of 44 bowheads from 11-20 October; the majority of which were part of the aggregation seen earlier in the month east of Point Barrow. Fourteen of these whales were seen east of the study area (i.e. east of 1540 W) during surveys conducted to check radio tracking equipment and attempt to radio track tagged whales. A single sighting of one bowhead was made 370 km offshore northwest of Point Barrow in the Chukchi Sea. There were 26 sightings of 39 bowheads from 21-31 October, all in the northeastern Chukchi Sea. Most whales were dispersed southwest of Point Barrow, with 12 bowheads roughly 120 km northwest of Icy Cape. No bowhead whales were seen in November.

Bowhead distribution in 1989 was similar to past years, with the exception of sightings north of 720 N latitude. Some sightings overlapped the boundaries of OCS oil and gas lease areas, especially those in the western Beaufort Sea (Fig. 7). No exploratory drilling operations were conducted in the western Beaufort Sea in 1989, however. In the Chukchi Sea, bowheads were seen near OCS lease areas, but none *were* near active drilling sites. The twelve bowheads seen at ca. 70045'N, 164053'W on 29 October (Appendix A: Flight 26) were near the 'Klondike' site, which had been active from 9 July to 15 September. These whales were in survey block 18, which also had a relatively high abundance index in 1988, indicating that this area may be important to bowheads during the fall migration. Bowheads seen north of 72" N latitude were near or overlapped OCS lease area boundaries, although no drilling activities were conducted there in 1989.

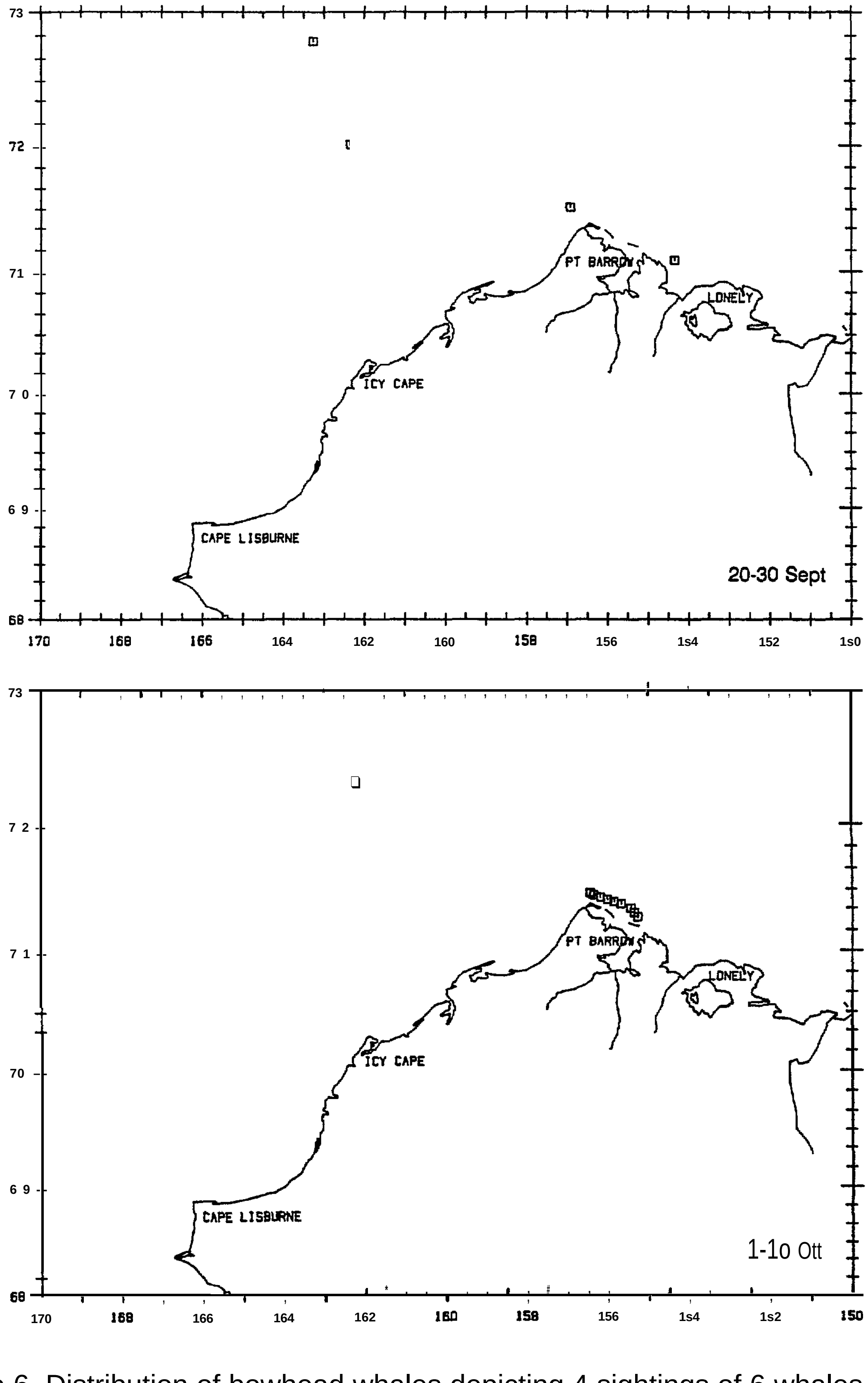


Figure 6. Distribution of bowhead whales depicting 4 sightings of 6 whales, 20-30 September; 10 sightings of 42 whales, 1-10 October;

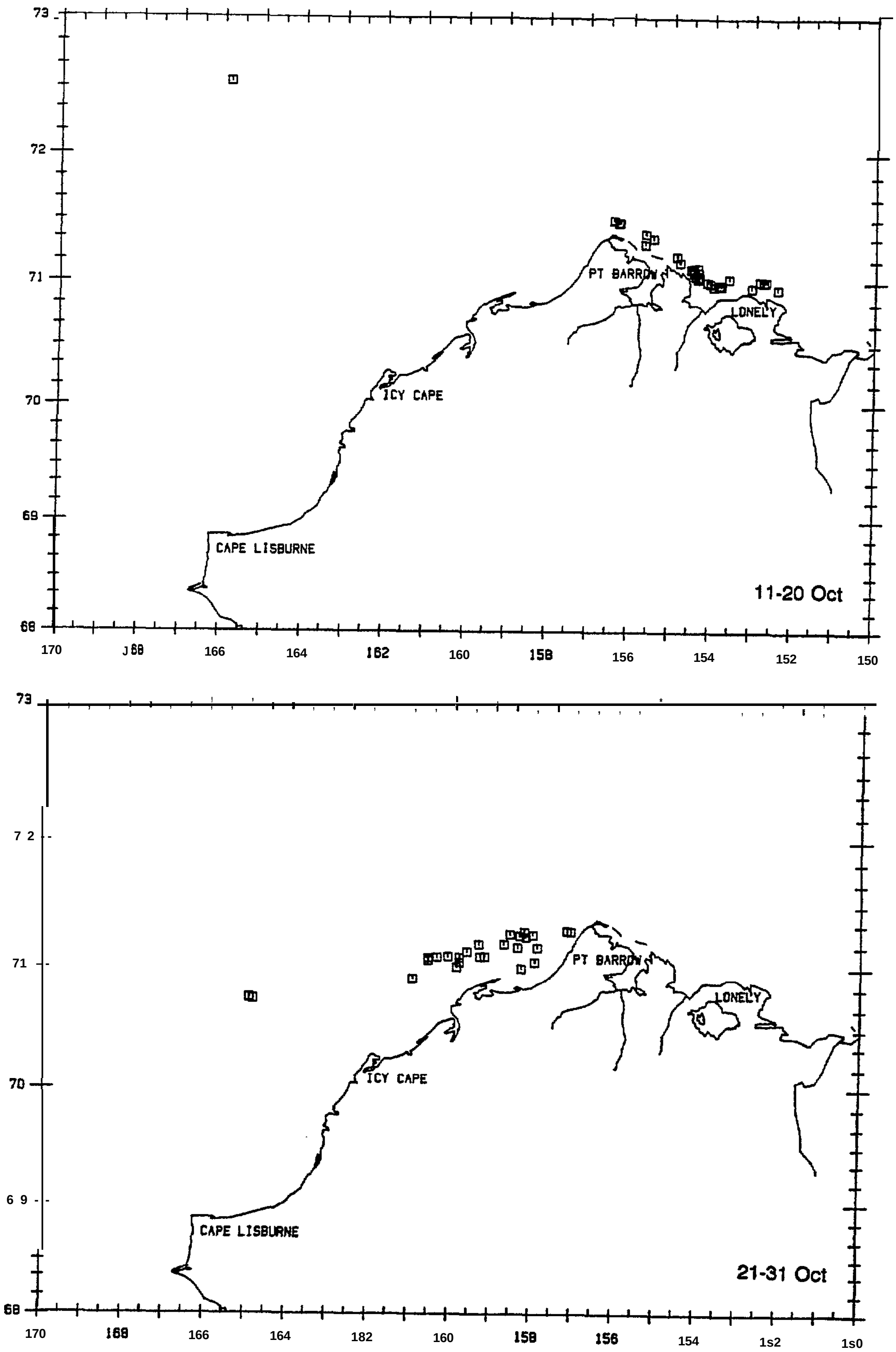


Figure 6 (contd). 29 sightings of 44 whales, 11-20 October; and 26 sightings of 39 whales, 21-31 October, 1989.

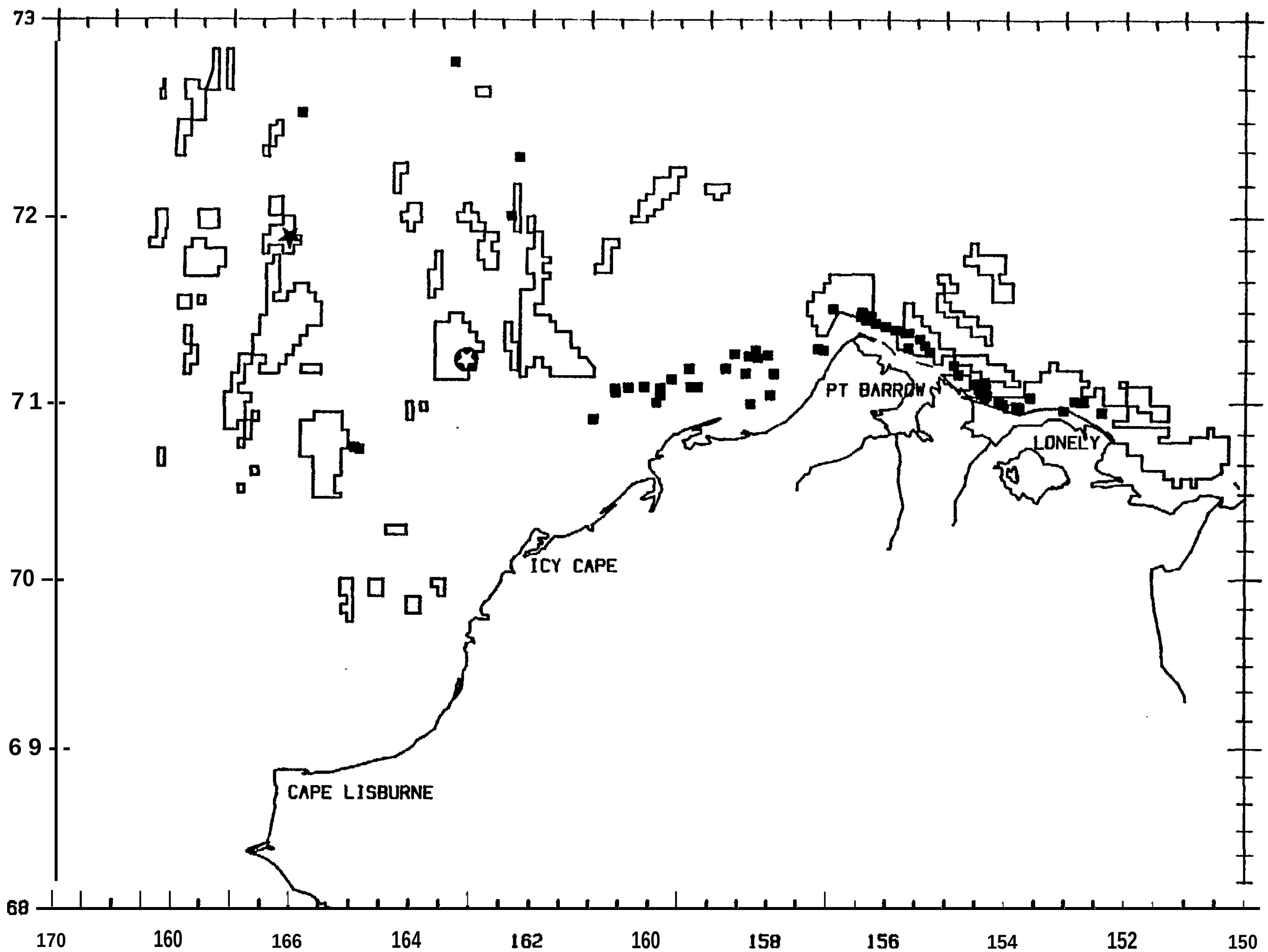


Figure 7. Distribution of 69 sightings of 131 bowhead whales in relation to OCS lease areas and active drilling sites during the 1989 survey season. [★ = 'Popcorn' exploratory site; ✪ = 'Burger' exploratory site]

An index of relative abundance (WPUE = no. whales/survey hour) and a density estimate (no. whales/km^2) were calculated for bowhead whales by survey block. As described in the Methods section, all whale sightings were used when calculating relative abundance regardless of the type of survey being conducted. The calculation of density estimates using strip transect methods, however, requires that 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 transect leg. Estimates of bowhead whale density were calculated in blocks 14N (0.07 whales/100 km^2) and 15N (0.06 whales/100 km^2) for late September and blocks 13 (0.24 whales/100 km^2) and 15N (0.08 whales/1 00 km^2) for late October, and are presented and discussed in Appendix B.

Bowhead whale relative abundance was highest in block 12 in late September (WPUE=0.74), early October (WPUE=22.53) and late October (WPUE=2.78), and highest in block 3 (located directly east of block 12; see Fig. 2) in mid-October (WPUE= 13.59) (Table 4). The high abundance values in blocks 3 and 12 were due to repeated sightings of the aggregation of whales that remained nearshore east of Point Barrow through mid-October. Bowhead seasonal relative abundance ranged from 13.59 (block 3) to 0.14 (block 14 N). Highest seasonal abundance for Chukchi Sea survey blocks was in block 18 (WPUE = 1.84), with lesser indices calculated for block 13 (WPUE = 0.77), block 14 (WPUE = 0.35), block 15N (WPUE = 0.19) and block 17 (WPUE = 0.17). This pattern of relative abundance reflects the dispersive nature of bowhead distribution evident in the scattergram plots (see Figs. 6 and 7).

Migration Timing and Route

The timing of the bowhead migration through the study area extended at least from 20 September, when the first bowhead was seen on the first aerial survey in block 14N, through 29 October when the last bowheads were seen in block 18. Daily sighting rate (SPUE) and daily relative abundance WPUE peaked on 5,14 and 27 October (Fig. 8). The peaks on 5 and 14 October coincided with the sighting of the bowhead aggregation in

Table 4. Bowhead whale relative abundance (WPUE = no. whales/survey hour) by survey block, 1989.

	20-30 Sept			1-10 Ott			11-20 Ott			21-31 Ott			1-3 Nov			Total		
Block	HRS	BH	WPUE	HRS	BH	WPUE	HRS	BH	WPUE	HRS	BH	WPUE	HRS	BH	WPUE	HRS	BH	WPUE
3	0.00	·	·	0.00			1.03	14	13.59	0.00			0.00	-	-	1.03	14	13.59
12	5.41	4	0.74	1.82	41	22.53	3.29	29	8.81	0.36	1	2.78	0.00			10.88	75	6.90
12N	4.61	0	0	0.00			0.00			0.00			0.00			4.61	0	0
13	7.81	0	0	4.17	0	0	3.66	0	0	11.57	21	1.82	0.00	-		27.21	21	0.77
13N	3.07	0	0	0.00	-		4.14	0	0	0.00			0.00	-	-	7.21	0	0
14	3.17	0	0	5.63	1	0.18	1.82	0	0	3.78	4	1.06	0.00	-		14.40	5	0.35
14N	3.36	1	0.30	3.43	0	0	0.41	0	0	0.00			0.00			7.20	1	0.14
15	2.06	0	0	2.15	0	0	0.15	0	0	3.88	0	0	0.00	-	-	8.24	0	0
15N	3.73	1	0.27	3.03	0	0	3.73	1	0.27	0.00			0.00	-		10.49	2	0.19
16	0.32	0	0	0.00	·	·	0.00		·	3.45	0	0	0.00	-		3.77	0	0
16N	3.08	0	0	0.00			0.00			0.00			0.00	-	-	3.08	0	0
17	0.00			0.62	0	0	2.47	0	0	2.79	1	0.36	0.00			5.88	1	0.17
18	0.68	0	0	0.00	·	·	0.00		·	5.85	12	2.05	0.00			6.53	12	1.84
20	0.00	·		0.00	·	·	0.00			2.29	0	0	0.00	-	-	2.29	0	0
21	0.00	·	·	0.00			0.00			0.24	0	0	0.00		-	0.24	0	0
22	0.00			0.00	-		0.00	-		4.84	0	0	0.00		-	4.84	0	0
23	0.00	·	·	0.00	·	·	0.00	·	·	2.49	0	0	1.11	0	0	3.60	0	0
24	0.00		·	0.00	·	·	0.00			0.00	·	·	4.04	0	0	4.04	0	0
25	0.00		·	0.00	·	·	0.00			0.00	·	·	1.32	0	0	1.32	0	0
30	0.00		-	0.00		-	0.00			1.97	0	0	0.77	0	0	2.74	0	0
31	0.00		-	0.00	-		0.00			0.47	0	0	3.68	0	0	4.15	0	0
Unblk	1.31	0	0	0.00		·	0.21			0.00			0.00	·	·	1.52	0	0
Total	38.61	6	0.16	20.85	42	2.01	20.91	44	2.10	43.98	39	0.89	10.92	0	0	135.27	131	0.97

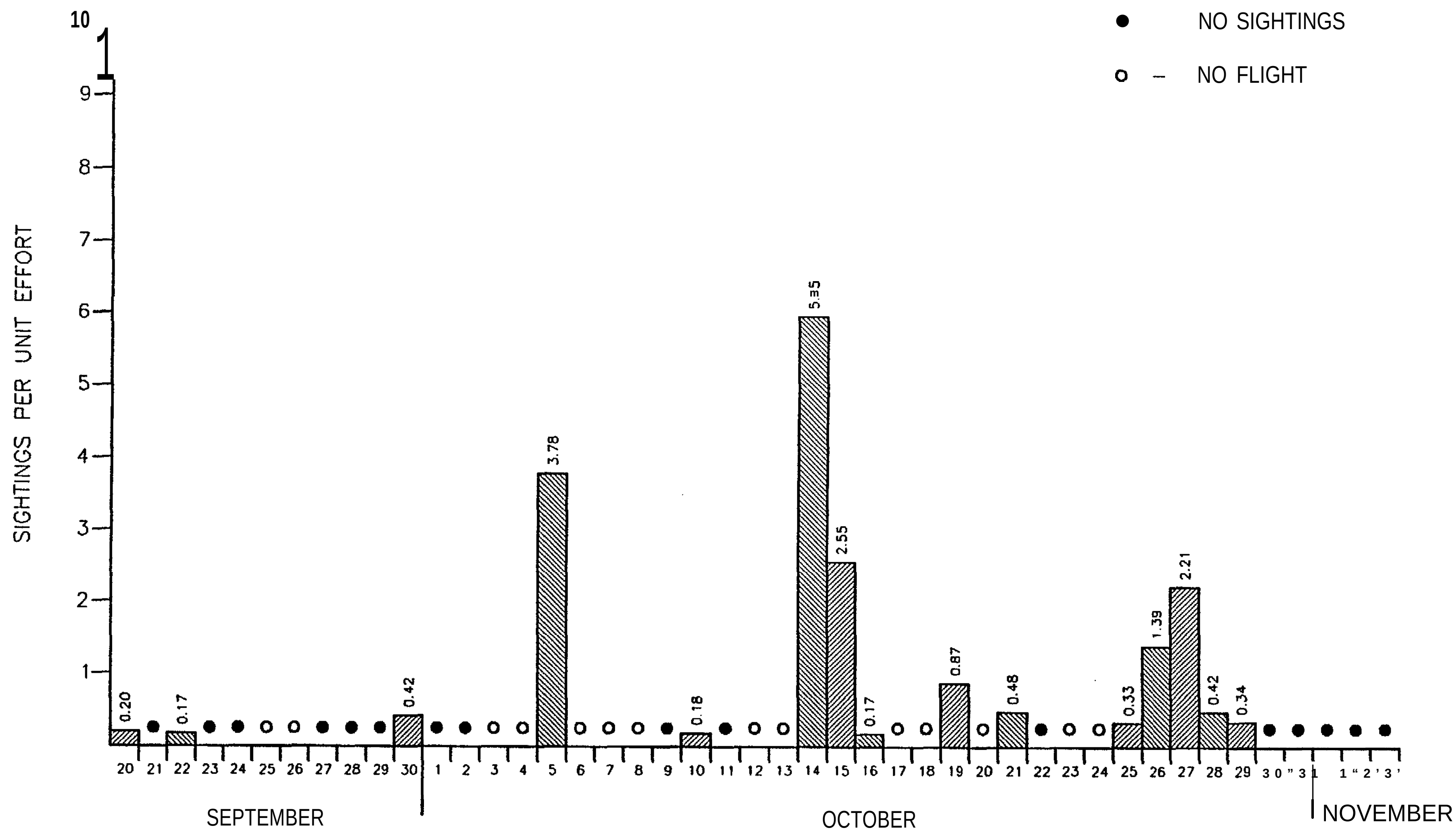


Figure 8. Daily bowhead whale sightings per unit effort **(SPUE);** and

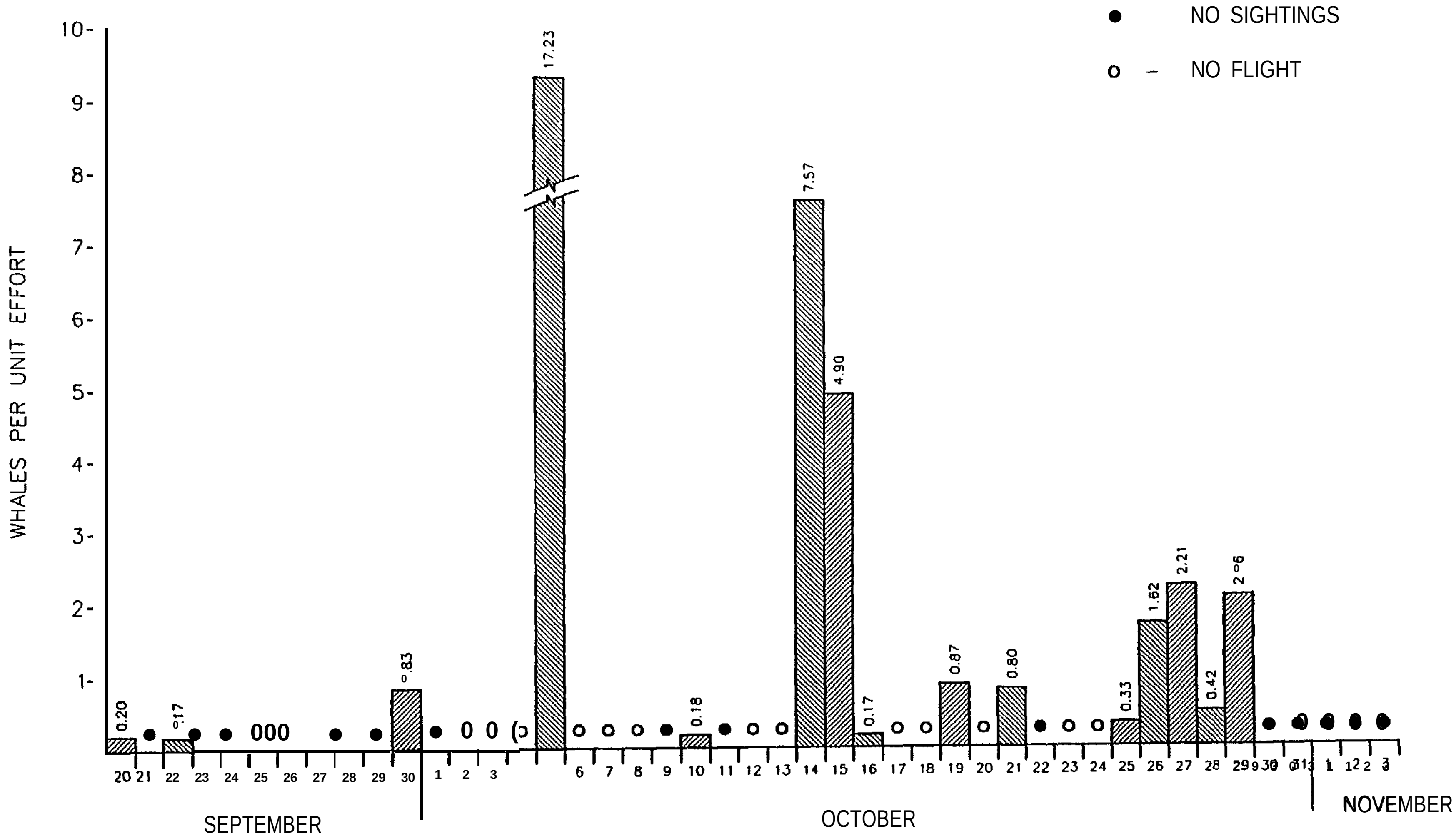


Figure 8 (contd). whales per unit effort (WPUE) in the study area, 1989.

blocks 3 and 12. Sighting and relative abundance rates for the northeastern and north-central Chukchi Sea were highest on 26-27 and 29 October, comprising the third peak.

Reports of bowhead whales seen in the study area in late summer, and the aggregation of whales east of Point Barrow through mid-October, somewhat confounded clear definition of the temporal features of the fall migration. Bowheads were repotted roughly 37 km (20 nmi) east of Point Barrow as early as 23 July by biologists conducting bird surveys on Cooper Island, and groups of 2 to 15 whales that seemed to be feeding were reported for the southeastern quadrant of block 12 from 12-15 August (George and Carroll 1989). The occurrence of bowheads near Point Barrow in July and August was considered unusual and it was suggested that heavy ice cover in the eastern Beaufort Sea may have influenced "early movement" of whales to the area. Secondly, whales were lingering and not migrating through the study area east of Point Barrow through mid-October. The radio-tagged member of the group, in fact, moved ca. 40 mi (75 km) to the east between 5 October and 10 October (K. Fristrup, pers. comm.). Thus, the daily SPUE and WPUE indices (Fig. 8) may better reflect patterns of survey effort of the whale aggregation than of migratory timing.

The detection of whales during both the first and last surveys conducted in the northeastern Chukchi Sea (20 Sep., 29 Oct.) indicates that the migration across the Chukchi Sea had likely already begun when surveys were initiated, and that the migration was probably not completed by the time the base of operation moved south to Kotzebue on 30 October. As in past studies (Ljungblad et al. 1987), the criterion used to define the beginning of the fall bowhead migration was the sighting of one or more whales swimming in a westerly or northwesterly direction on two separate surveys within a 5-day period. The end of the migration was simply defined as the date of the last bowhead sighting in the study area. Although the repeated sighting of the whale aggregation near Barrow may have partially obscured the temporal features of the 1989 migration, the peaks in sighting rate on 27 and 29 October, coincident with surveys in the northeastern and north-central Chukchi Sea, indicate that the migration across the Chukchi Sea was at least well underway at that time. Additionally, the Poisson-shape of the sighting rate histogram (Fig. 8) suggests that most of the migratory period was probably covered.

The distribution and swimming direction of whales cataloged as migrating indicates the 'primary' migration route generally follows the coast between Smith Bay and Barrow, then is centered roughly 30 km offshore between Barrow and Wainwright, to about 120 km offshore northwest of Icy Cape. Swimming direction was significantly clustered about a southwesterly heading in the Chukchi Sea (257 'T, p c 0.001; Fig. 9). Swimming direction was not significantly clustered about any heading for whales in the western Beaufort Sea. Although not statistically significant, the average easterly (39 "T) swimming direction for whales east of Point Barrow was in agreement with the aforementioned eastern shift of the tagged whale reported by the industry-funded researchers.

The four whales seen north of720 N in 1989 add significantly to the small data set of whales seen far to the north, and suggest there may be a 'secondary' migration route across the Chukchi Sea north of the route described by the southwest dispersion pattern seen closer to shore. The four 'offshore' whales exhibited headings of 324 "T (20 September), 204 "T (22 September), 324 "T (10 October) and 264 'T (16 October), with an average direction of 283 'T. The range in dates of the sightings from 20 September to 16 October indicates that these whales do not represent only one 'pulse' of whales, but that whales may have been moving west along a relatively northerly route throughout the fall. A migratory route roughly following the ice edge across the northern Chukchi Sea has been suggested by several researchers (e.g. Braham 1984), but has little data to support it.

Behavior and Calf Sightings

Observed behaviors were nearly equally divided between migratory (42%, n =55) and social (58%, n= 76) behaviors (Fig, 10; Table 5). Swimming was recorded most often and diving least often. Most whales (72%, n = 95) were judged to be swimming slowly throughout the fall (Table 5). Whales not swimming slowly were resting (14%, n = 18), or swimming at medium (4%, n= 5) or fast (1%, n= 1) speeds. Swimming speed was not recorded for 12 whales (1%).

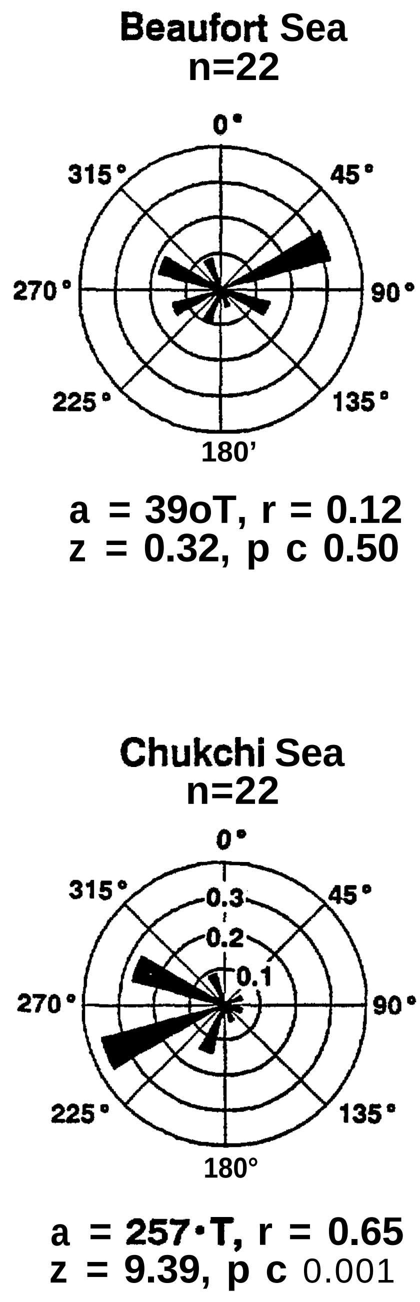


Figure 9. Bowhead whale swimming direction in the western Beaufort and northeastern Chukchi Sea, 1989. a = vector mean; r = vector length; z = statistic

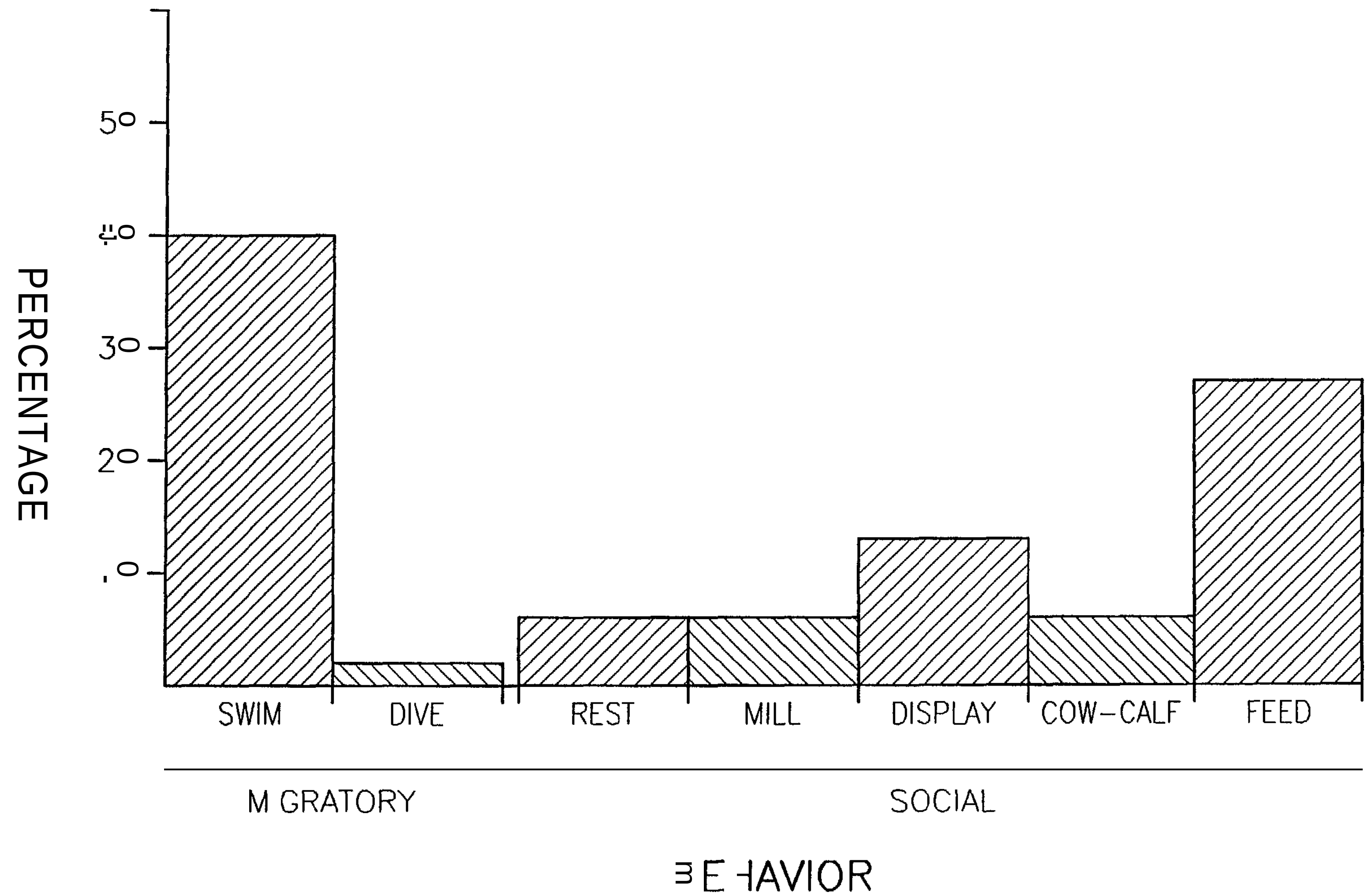


Figure 10. Summary of bowhead whale behavior, 1989.

Table 5. Summary of bowhead whale behavior and swimming speed, 1989.

	20-30 Sept No. (%)	1-10 Ott No. (%)	11-20 Ott No. (%)	21-31 Ott No. (%)	Total No. (%)
BEHAVIOR					
Migratory					
Swim	2 (33)	5 (12)	28 (63)	18 (46)	53 (40)
Dive	1 (17)	o	o	1 (3)	2 (2)
Social					
Mill	3 (50)	5 (12)	0	o	8 (6)
Display	o	3 (7)	0	14 (36)	17 (13)
Rest	0	2 (5)	2 (5)	4 (1 0)	8 (6)
Feed	0	21 (50)	14 (32)	0	35 (27)
Cow-calf	0	6 (14)	o	2 (5)	8 (6)
TOTAL	6	42	44	39	131

SWIMMING SPEED					
Still O km/h	o	0	2 (5)	16 (41)	18 (14)
slow < 2 km/h	5 (83)	42 (100)	31 (70)	17 (43)	95 (72)
Medium 24 km/h	o	0	1 (2)	4 (1 o)	5 (4)
Fast > 4 km/h	o	0	0	1 (3)	1 (1)
Unknown	1 (17)	o	10 (23)	1 (3)	12 (9)
TOTAL	6	42	44	39	131

Feeding whales were seen east of Point Barrow on 5, 14, and 15 October (Appendix A: Flights 12, 16 and 17). Whales appeared to be bottom feeding, as defined in Wursig et al. (1985), on 5 October. These whales were associated with suspended sediment, and mud was seen on the head or rostrum and as mud trails behind the whales. Bottom feeding whales usually made tight turns at the surface and repeatedly dived in a localized area usually in pairs or groups of three. Underwater blows were common. Sea birds dived in and rafted along the sediment brought to the surface by the whales, probably to feed on prey brought to the surface. A similar association of seabirds and mud plumes brought to the surface by gray whales has been described (Harrison 1979). The whales seen feeding on 14 and 15 September were observed during search surveys east of Point Barrow (Appendix A: Flights 16 and 17) during attempts to radio track one of the bowhead whales tagged earlier by industry-sponsored researchers. High sea states (B04-05) on 14 October and survey priorities in the Chukchi Sea on 15 October precluded extensive behavioral observations. Suspended sediment was not as evident as on 5 October, and the whales were probably bottom- and water-column feeding on both days. Industry-sponsored researchers attempted bottom- and water-column sampling on 13 October to collect prey in the area where bowheads were feeding, but inclimate weather conditions prevented the obtaining of useful results; divers believed the whales were feeding on mysid swarms in the water column (K. Fristrup, pers. comm.).

Evidence of skim feeding, such as elevated rostrums and clear water behind the whales, was not apparent and not clearly identified during any of the feeding observations, However, a significant proportion of whales were noted as milling at the surface and some of these whales may have been skim feeding. Milling whales were seen most often in groups of 3 to 6 whales swimming very slowly. It is important to note that extended behavioral observations were not conducted. When observers were confident that accurate behaviors had been recorded, the survey aircraft was directed back to transect surveying. Aggregations of feeding whales have been seen east of Point Barrow in intermittent years, usually in years of comparatively light ice cover such as 1989 (Ljungblad et al. 1986a). These occurrences are further discussed in the summary section of this report.

Log play was observed on 5 October (Appendix A: Flight 12) when a bowhead seen among the feeding and milling aggregation east of Point Barrow repeatedly pushed and dived under a log. Attention was drawn to this whale when the log appeared to "breach" out of the water creating a large splash. It is likely that the whale had pushed the log beneath the surface with it's chin until it popped out and into the air. The whale later rested it's chin on the log, dived under it such that the log rolled down it's back, pushed the log at the surface with it's rostrum and spy hopped next to the log. The whale was observed playing for over five minutes and remained with the log as the aircraft departed. Log play has been observed only rarely. Wursig et al. (1989) describe only two instances of log play observed over five summer survey seasons in the Canadian Beaufort Sea.

A variety of aerial displays were observed among a group of 12 bowheads seen in block 18 on 29 October (Appendix A: Flight 26). Single breaches and series of breaches, flipper and tail slaps, rolls, lunges, and spyhopping were observed over a 30 minute period, The initial sighting cue was a circular water disturbance resulting from a breach, indicating that the display behaviors were ongoing as the survey aircraft arrived. The whales had just come out from an area of 10-1 5% slushy new ice, beyond which was 80-90% new grease ice. Observations from the aircraft continued for approximately 30 minutes with no apparent reactions from the whales. After 30 minutes, display behaviors abruptly ceased, and the whales became extremely hard to resight. It is possible that none of these whales would have been sighted had the displays not been so prominent because of the relatively high sea state (B04-05). Every whale sighted exhibited some type of display behavior; possibly more whales were in the immediate area and were not detected because they were not displaying, Aerial displays have been previously documented on summer feeding grounds in the Canadian Beaufort Sea (Wursig et al. 1989) and during the spring and fall migrations (Ljungblad et al. 1986c). The significance of such behaviors is not known, although they may be related *to* high levels of social-sexual activities (Wursig et al. 1985).

Four bowhead calves were seen over the course of the season, three of them among the milling and feeding aggregation east of Point Barrow on 5 October (Table 6). All three calves seen on 5 October were completely black, which was somewhat unusual

Table 6. Bowhead whale calf sightings, 1989.

Flight	Date	Position (Lat., Long.)	No.	Comment
12	5 Ott	710 22.0'N, 155°35.0'W	1	milling, in group of 5 adults
12	5 Ott	71°23.0'N 155°45.0'W	2	milling, in group of 3 adults
20	21 Ott	710 14.7'N 158°15.3'W	1	swimming, heading 285 "T, cow-calf pair

as calves seen on past surveys often had distinctive white chin patches and occasionally even white chevrons on their caudal peduncle. The three calves were seen very close together and among a group of eight adult whales, three of which were assumed to be the cows. At one point, however, a large adult from a nearby group of three whales swam very quickly over to one of the calves and appeared to nudge it away from the group. The reason for this action was not clear, but was not thought to be related to the aircraft which was passing to the side and not directly overhead of the group. When the calf was aligned next to the large adult, both appeared to stop and rest at the surface. The fourth calf seen was with a large adult, swimming northwest in block 13 on 21 October (Appendix A: Flight 20). The adult surfaced first from underneath a large pan of new ice, heading 2850 T. After surfacing, the large whale turned 450 towards the right, and met up with a calf who had surfaced behind the larger whale, also heading 2850 T. The large whale reoriented itself to the original swim direction, within a body length of the calf, and the pair swam slowly across the open water lead and dove under a large ice pan and were not resighted. The calf was less than one-half the size of the adult and was a lighter grey color.

Only one bowhead appeared to respond to the aircraft during the 1989 survey season. The whale was resting near four whales that were milling and feeding just east of Point Barrow on 5 October (Appendix A: Flight 12). At the approach of the aircraft, the

Table 7. Number and percent of bowhead whales in shallow and transitional water depths, 1989.

SEA	Shallow (0-50 m)	Transition (>50 m)	Range (m)
W. Beaufort Sea	88 (67)	1 (1)	7-144
Chukchi Sea	27 (21)	15 (11)	18-101
Total	115 (88)	16 (12)	7-144

whale appeared to "startle", turned about900 at the surface, then dived. No other whales appeared to respond to the aircraft.

Habitat Relationships

Most bowheads (88%,n=115) were in shallow water (< 50 m deep) throughout the season, with all others (12Y0, n= 16) in water >50 m (Table 7). These results were strongly influenced by the feeding and milling aggregation that remained east of Point Barrow in very shallow water (7 to 16 m deep) through mid-October. Depth at bowhead sightings ranged from 7 to 144 m deep in the western Beaufort Sea and from 18 to 101 m in the Chukchi Sea. Mean depth at bowhead sightings was significantly deeper ($t=7.12, p<0.001$) in the Chukchi Sea (50.2 m, 18.9 s.d., n=29) than in the Beaufort Sea (15.1 m, 21.2 s.d., n =40), due at least in part to the relatively large number of bowheads in shallow water east of Point Barrow. The average depth calculated for bowhead sightings in the Chukchi Sea (50.2 m) was somewhat deeper than expected. The Chukchi Sea is relatively shallow, with depths in the study area ranging from roughly 16 to 92 m (9 to 40 fathoms). Of the 42 bowheads seen in the Chukchi Sea, 15 (36%) were seen in water >51 m deep (Table 7).

Major ocean currents that enter the Chukchi basin through the Bering Strait are channeled around shoals (water depth c37 m) along relatively deeper water troughs (237 m) in the Chukchi Sea (Aagaard 1987). Approximately 86 percent of the northeastern Chukchi Sea portion of the study area is at least 37 m or deeper, while only 14 percent

Table 8. Number and percent of bowhead whales in each ice cover class, 1989.

Ice Cover (%)	20-30 Sept No. (%)	1-10 Ott No. (%)	11-20 Ott No. (%)	21-31 Ott No. (%)	Total No. (%)
o-1o	5 (83)	42 (100)	43 (98)	13 (33)	103 (79)
11-20	o	o	o	1 (3)	1 (1)
21-30	0	0	0	o	o
31-40	0	0	0	0	0
41-50	0	0	0	1 (3)	1 (1)
51-60	0	0	0	o	o
61-70	0	0	0	0	0
71-80	0	0	0	7 (18)	7 (5)
81-90	0	0	1 (2)	2 (5)	3 (2)
91-99	1 (17)	0	o	15 (38)	16 (12)
TOTAL	6	42	44	39	131

is shallower than 37 m. Of the 16 bowheads seen on-transect in the Chukchi Sea, 11 (69%) were in water ≥37 m and 5 (31%) were in water <37 m. When compared to the percentage of shallow water habitat available in the area, there was a significantly disproportionate number of bowhead whales seen in shallow water ($X^2 = 4.41$, $p < 0.025$).

Most bowheads (79%, n= 103) were in open water in 1989 (Table 8), largely due to the extremely light ice conditions that prevailed over most of the survey season (see Fig. 5). Only two whales were seen in ice > 81% prior to 21 October, all others were in open water. The remaining whales in moderate (71 -80%) to heavy ice (> 80%) were seen after 21 October when freeze-up began in the Chukchi Sea.

Gray Whale (<u>Eschrichtius robustus</u>)
Distribution and Abundance

There were 59 sightings of 170 gray whales in the study area from late September to late October (Fig. 11; Table A-2). Twenty four gray whales were seen in late September in three localized areas: nearshore off Point Franklin, offshore approximately 180-210 km west-northwest of Point Barrow, and offshore approximately 240 km northwest of Point Barrow. The fourteen gray whales seen in early October were found in two localized areas, both well offshore in the northcentral Chukchi Sea. In mid-October, 13 gray whales were seen nearshore near Point Franklin, with a single sighting of one whale in Peard Bay. All gray whales sighted in late October (n= 119) were in the southcentral Chukchi Sea, despite survey effort in the northeastern part of the study area. Gray whale sightings in the southcentral Chukchi Sea extended from <u>ca</u>. 167" W to the IDL between 67 °25'N and68020'N, and several mudplumes and blow exhalations could be seen on the horizon west of the IDL.

Gray whale distribution in September 1989 was similar to that seen in 1986 and 1987, when ice cover was also very light. Distribution was even farther offshore than documented before, possibly due to increased survey effort in offshore areas. Unlike some past years (Ljungblad et al. 1987), gray whales were not seen in the immediate vicinity of Point Barrow. Distribution in October was also similar to that seen previously, with the exception of the dense aggregations in the southcentral Chukchi Sea, which may be due to increased survey effort there in 1989. Gray whales were not found directly south of Point Hope nor were they seen between Point Franklin and the southcentral Chukchi Sea as in previous years. Gray whale sightings overlapped the boundaries of OCS oil and gas lease areas in the north-central Chukchi Sea (Fig. 12), but none were near active drilling sites.

Gray whale relative abundance was highest in blocks 23 (WPUE = 18.06) and 22 (WPUE = 11 .16) in the southcentral Chukchi Sea (Table 9). Relative abundance in the northeastern Chukchi Sea was highest in block 14N (WPUE = 1.94); roughly ten times lower there than in block 22. Estimates of gray whale density were calculated in block 13 for late September (0.14 whales/100 km^2), block 14N for early October (0.51 whales/100

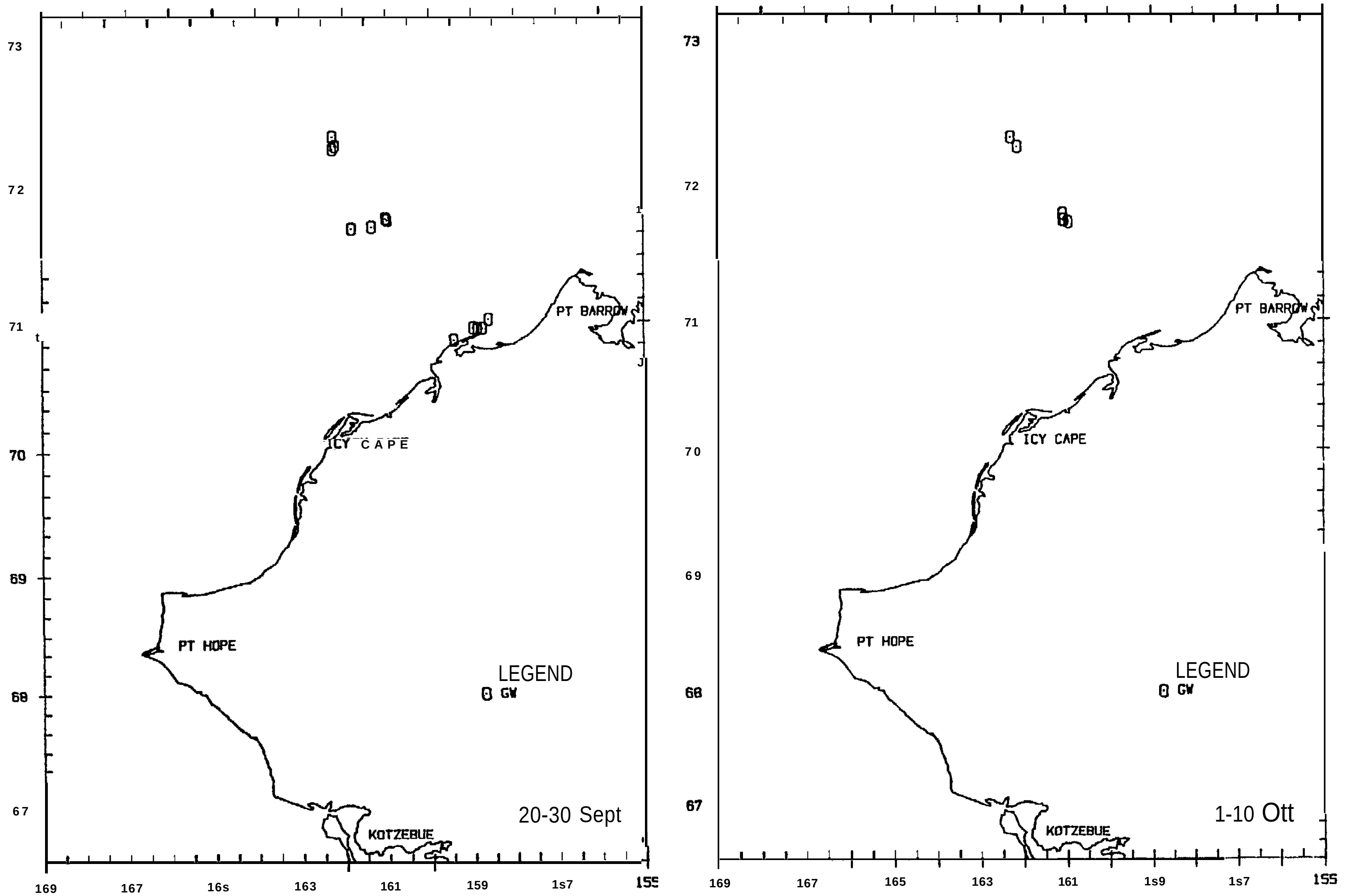


Figure 11. Distribution of gray whales depicting 12 sightings of 24 whales, 20-30 September; 6 sightings of 14 whales, 1-10 October;

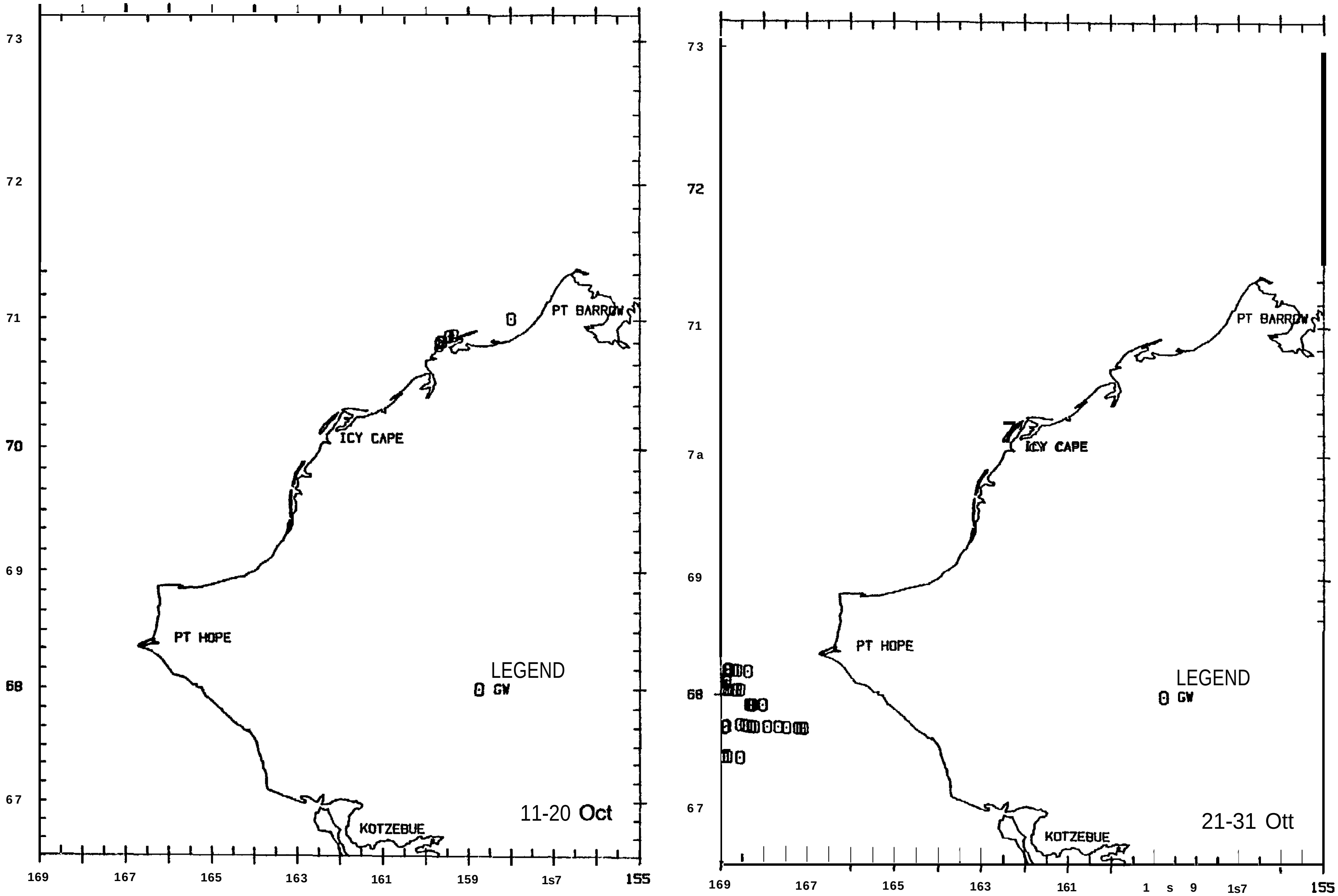


Figure 11 (contd). 6 sightings of 13 whales, 11-20 October; and 35 sightings of 119 whales, 21-31 October, 1989.

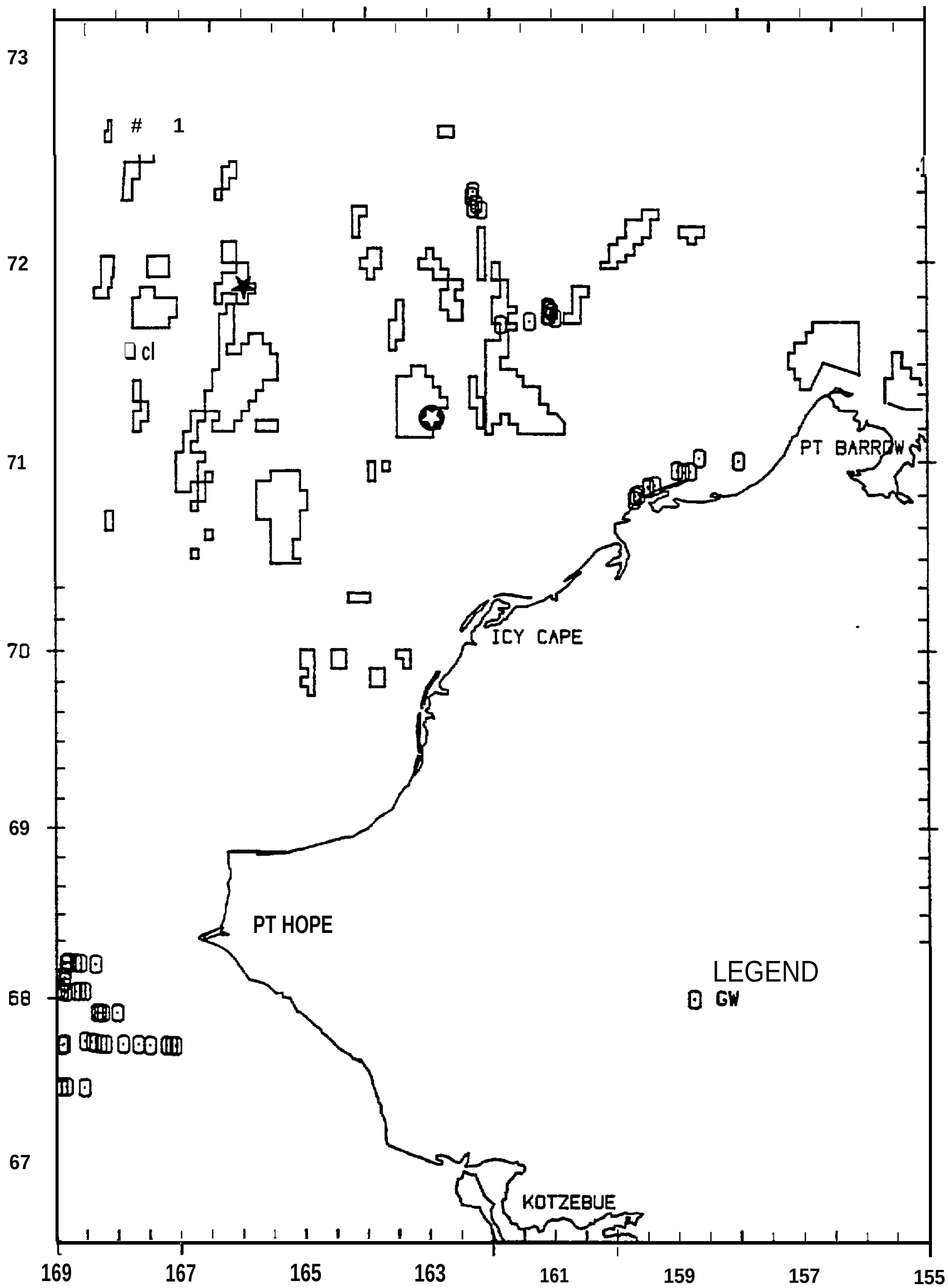


Figure 12. Distribution of 59 sightings of 170 gray whales in relation to OCS lease areas and active drilling sites during the 1989 survey season. [★= 'Popcorn' exploratory site; ✪= 'Burger' exploratory site]

Table 9. Gray whale relative abundance (WPUE = no. whales/survey hour) by survey block, 1989.

	20-30 Sept			1-1o Ott			11-20 Ott			21-31 Ott			1-3 Nov			Total		
Block	HRS	GW	WPUE	HRS	GW	WPUE	HRS	GW	WPUE	HRS	GW	WPUE	HRS	GW	WPUE	HRS	GW	WPUE
3	0.00	-	-	0.00			1.03	0	0	0.00			0.00			1.03	0	0
12	5.41	0	0	1.82	0	0	3.29	0	0	0.36	0	0	0.00			10.88	0	0
12N	4.61	0	0	0.00		·	0.00		-	0.00			0.00			4.61	0	0
13	7.81	9	1.15	4.17	0	0	3.66	13	3.55	11.57	0	0	0,00	-	-	27.21	22	0.81
13N	3.07	0	0	0.00			4.14	0	0	0.00			0.00			7.21	0	0
14	3.17	8	2.52	5.63	7	1.24	1.82	0	0	3.78	0	0	0.00			14.40	15	1.04
14N	3.36	7	2.08	3.43	7	2.04	0.41	0	0	0.00			0.00	-		7.20	14	1.94
15	2.06	0	0	2.15	0	0	0.15	0	0	3.88	0	0	0.00			8.24	0	0
15N	3.73	0	0	3.03	0	0	3.73	0	0	0.00			0.00			10.49	0	0
16	0.32	0	0	0.00	-	·	0.00	·	·	3.45	0	0	0.00	-	-	3.77	0	0
16N	3.08	0	0	0.00			0.00			0.00			0.00			3.08	0	0
17	0.00	·	·	0.62	0	0	2.47	0	0	2.79	0	0	0.00			5.88	0	0
18	0.68	0	0	0.00	·	·	0.00	·	·	5.85	0	0	0.00	-	-	6.53	0	0
20	0.00	·		0.00			0.00			2.29	0	0	0.00	-		2.29	0	0
21	0.00		·	0.00			0.00		-	0.24	0	0	0.00	-		0.24	0	0
22	0.00		·	0.00		·	0.00		-	4.84	54	11.16	0.00	-	-	4.84	54	11.16
23	0.00	·	·	0.00			0.00		-	2.49	65	26.10	1.11	0	0	3.60	65	18.06
24	0.00	·		0.00			0.00		-	0.00			4.04	0	0	4.04	0	0
25	0.00			0.00			0.00		-	0,00			1.32	0	0	1.32	0	0
30	0.00	·		0.00			0.00		-	1.97	0	0	0.77	0	0	2.74	0	0
31	0.00	·	·	0.00	·	·	0.00	·		0.47	0	0	3.68	0	0	4.15	0	0
Unblk	1.31	0	0	0.00	·	·	0.21	0	0	0.00	·	-	0.00	·		1.52	0	0
Total	38.61	24	0.62	20.85	14	0.67	20.91	13	0.62	43.98	119	2.71	10.92	0	0	135.27	170	1.26

km^2), and blocks 22 (0.07 whales/100 km^2) and 23 for late October (0.10 whales/100 km^2), and are discussed in Appendix B. The relatively low densities calculated for blocks 22 and 23 are misleading; most of the gray whale sightings in those blocks were made while surveying random transect lines, but the rapidity of sightings due to the density of whales prevented recording clinometer angles in lieu of recording other pertinent information such as total number and behavior. In areas of extremely high density, random line transects may not be the most adequate method available for censusing (Hiby and Hammond 1989); random stratified surveys maybe more applicable.

Abundance estimates indicated that gray whales remained in blocks 14 and 14N through early October. Gray whales seen in these blocks in 1989, as in 1986 and 1987, were commonly seen with mud plumes indicating that the whales were feeding. These survey blocks overlie the general area of Hanna Shoal (Stringer and Groves 1987), and walrus "feeding traces" have been reported for this area (Phillips 1987). The distribution of gray whales within the blocks indicate that it is along the boundary of the shoal that gray whales are feeding. Thus, this area may be important both to gray whales and walrus as feeding habitat in the north central Chukchi Sea.

Migration Timing and Route

The timing of the gray whale migration to and from the northeastern and northcentral Chukchi Sea extended at least from 20 September, when gray whales were sighted offshore on the first aerial survey in the area, to 15 October when the last gray whales were sighted nearshore between Point Barrow and Point Franklin. Poor surveying conditions (high sea states and fog) precluded transect survey effort in high abundance areas (blocks 14 and 14N) in the northeastern Chukchi Sea after 10 October, and it is possible that gray whales remained in that area until much later in October. Additionally, gray whale utilization of feeding areas appears to be quite variable within any given year. In 1989, grays were often (Appendix A: Flights 1, 3, 4, 13 and 14) but not always (Appendix A: Flights 10, 15, 18,22, and 26) found in blocks 14 and 14N during search and transect surveys, indicating movement into and out of the area. Localized movements, as suggested here, complicate the documentation of gray whale migration out of the study area. In the south-central Chukchi Sea, the migration extended through

31 October when feeding gray whales were sighted in block 23. The extent to which gray whales use this area prior to late October could not be determined due to a lack of survey effort in the area.

The clumping of gray whale sightings in 1989 into four distinct areas yields insufficient data to postulate on the migration route of gray whales out of the Chukchi Sea. A nearshore coastal route seems the most likely based on the propensity for gray whales to migrate along the shoreline in other parts of their range (Swartz 1986). The extent to which gray whales migrate through offshore waters in the Chukchi Sea is unknown.

Behavior and Calf Sightings

Gray whales were either feeding (90%, n= 153) or swimming (10%, n= 17; Table 10), Swimming direction was not significantly clustered around any heading; whales that were feeding were not included in analysis because these whales often exhibited several headings within one surfacing. Feeding was inferred anytime whales were seen with mud plumes, which are billows of sediment brought to the surface by whales feeding on infaunal prey, providing excellent sighting cues. The presence of mud plumes may bias data toward "feeding" whales, although whales feeding on epibenthic prey may not create large mud plumes and therefore some feeding whales may go undetected. It is interesting to note that gray whales seen in the northeastern Chukchi Sea after 11 October were swimming; prior to that, most whales had been feeding. All of the whales seen in the southcentral Chukchi Sea were feeding. Although benthic communities in the Chukchi Sea have not been extensively sampled, the prey probably consists of mixed crustacean communities including the Ampelisca amphipods that constitute much of the gray whale diet in the northern Bering Sea (Nerini 1984).

One gray whale calf was seen on 22 September (Appendix A: Flight 3) approximately 175 km northwest of Point Barrow. The calf was associated with two adults that were assumed to be feeding due to the presence of mud plumes. This was the first calf sighting in the study area away from the Chukchi coast.

Table 10. Summary of gray whale behavior, 1989.

	20-30 Sept No. (%)	1-10 Ott No. (%)	11-20 Ott No. (%)	21-31 Ott No. (%)	Total No. (%)
MIGRATORY					
Swim	3 (13)	o	13 (loo)	1 (1)	17 (lo)
SOCIAL					
Feed	21 (87)	14 (loo)	o	118 (99)	153 (90)
TOTAL	24	14	13	119	170

Habitat Relationships

Gray whales were seen approximately 0.5 to 240 km from shore in water 18 to 59 m deep ($\bar{x}$=43.4 m, 12.6 s.d., n =59). Grays in the northeastern Chukchi Sea were in significantly shallower water ($\bar{x}$=30.0m, 6.3 s.d., n =24, range 18-38m) than those in the southcentral Chukchi Sea ($\bar{x}$=52.5 m, 5.6 s.d., n =35, range 37-59; t= 14.43, p <0.001), due to the existing bathymetry in these areas. In the northeastern Chukchi Sea, gray whales were either seen nearshore, where depths are generally shallow, or offshore along the boundaries of Hanna Shoal, where the depths are shallower than those surrounding the shoal (Stringer and Groves 1987). The sixteen gray whales seen on-transect in the northeastern Chukchi Sea were all in water <37 m. When compared to the percentage of shallow (<37 m) habitat available in the area (14%), there was a significantly disproportionate number of gray whales seen in shallow water (x^2= 96.57, p <0.001), indicating a preference for waters overlying shoals. Most gray whales (92%, n= 156) were seen in open water. Seven (4%) were in 10 percent ice cover, one (<1 %) in 25 percent ice cover, and six (4%) in 30 percent ice cover. All but one whale seen with ice were feeding.

Other Marine Mammals

Belukha, or White Whale (Delphinapterus leucas)

There were 83 sightings of 421 belukhas in the study area in 1989 (Fig. 13; Table A-2). Observed belukha distribution from 20 September to 20 October was between 170 and 370 km offshore northwest of Point Barrow, between 95 and 150 km offshore north of Point Barrow, and considerably closer to shore (40-90 km) just west of Point Barrow. Belukhas were seen both relatively nearshore and far to the north in the Chukchi Sea on some flights (e.g. Appendix A: Flights 13 and 14). There was no flight effort northof720 N after 20 October, so the occurrence of belukhas in the northern survey blocks in the latter part of October is unknown. After 21 October, observed belukha distribution was scattered from nearshore between Point Barrow and Point Franklin, to 460 km offshore west of Point Barrow. No belukhas were seen in the southern Chukchi Sea.

Belukha abundance was highest in northern survey blocks 14N (WPUE = 13.61), 12N (WPUE = 13.23), 15N (WPUE = 7.82), and 13N (WPUE = 5.55; Table 11). Abundance in blocks 13 through 18 increased after 20 October, indicating that belukhas were migrating south through those areas at that time. Overall, relative abundance was five to ten times higher in northern survey blocks than in all other blocks indicating relatively high use of northern waters.

The first belukhas were seen in the study area on 21 September (Appendix A: Flight 2) and the last were seen on 29 October (Appendix A: Flight 26). Daily WPUE peaked on 28 September and 10 October, with relatively high WPUE on 16 and 22 October (Fig. 14). Belukha migratory route(s), based on distribution and swimming direction, was similar to that described for bowheads. The pattern of distribution was bifurcated west of Point Barrow, but with relatively more belukhas seen along the northern 'offshore' migration route and fewer whales migrating 'nearshore' southwest across the Chukchi Sea. Belukha swimming direction was significantly clustered about 278 "T ($p<0.001$, n = 59) in the Chukchi Sea, but was not significantly clustered about any direction in the western Beaufort Sea.

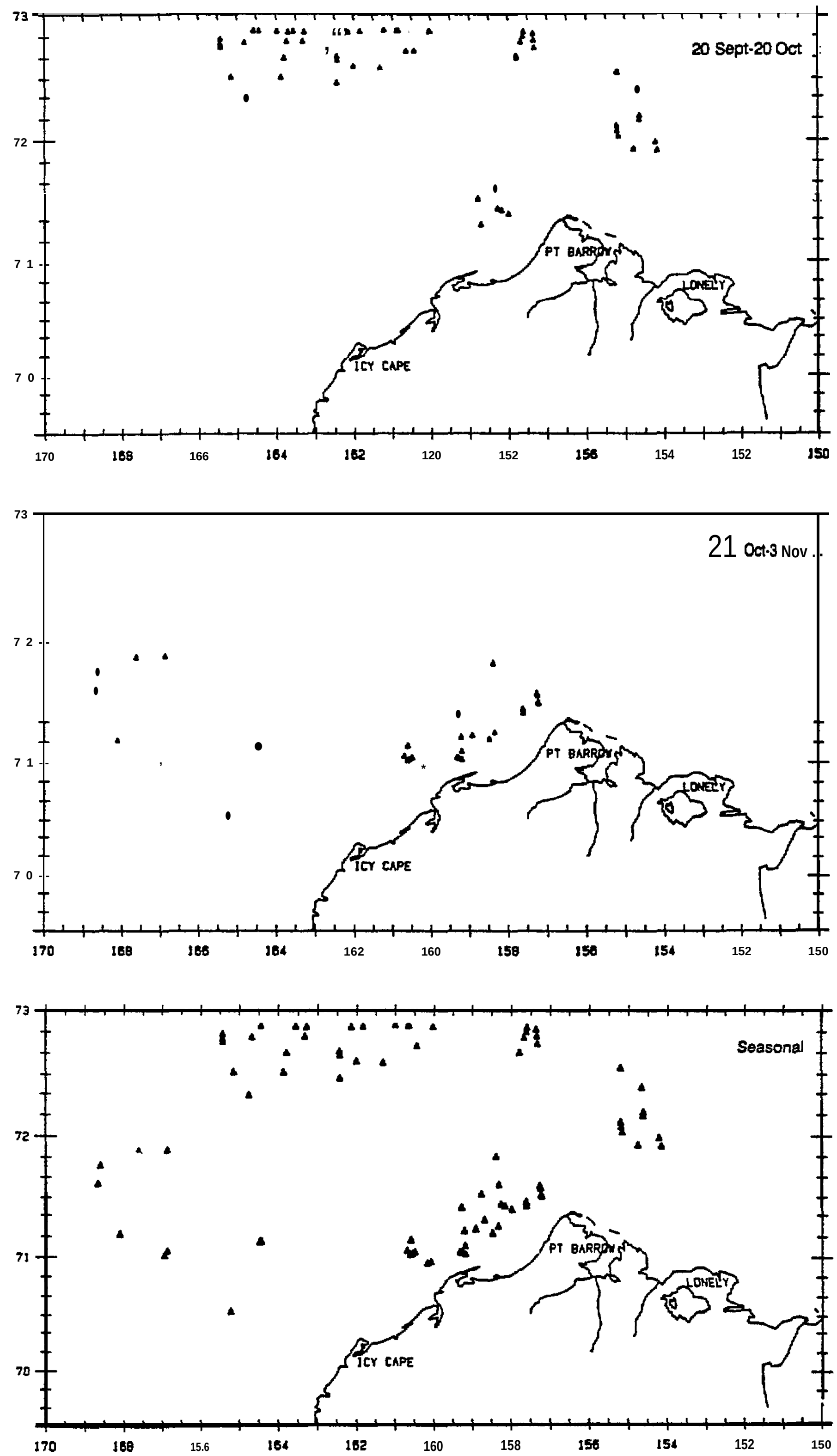


Figure 13. Distribution of belukhas depicting 49 sightings of 322 whales from 20 September to 20 October **when the study area was largely ice-free;** 34 **sightings** of 99 whales from 21 October to 3 November after ice formation; and 83 sightings of 421 whales for the 1989 season.

Table 11. Belukha relative abundance (WPUE = no. whales/survey hour) by survey block, 1989.

	20-30 Sept			1-10 Ott			11-20 Ott			21-31 Ott			1-3 Nov			Total		
Block	HRS	BE	WPUE	HRS	BE	WPUE	HRS	BE	WPUE	HRS	BE	WPUE	HRS	BE	WPUE	HRS	BE	WPUE
3	0.00			0.00			1.03	0	0	0.00			0.00			1.03	0	0
12	5.41	17	3.14	1.82	0	0	3.29	0	0	0.36	0	-	0.00			10.88	17	1.56
12N	4.61	61	13.23	0.00	·	·	0.00	·	·	0.00	·		0.00		-	4.61	61	13.23
13	7.81	0	0	4.17	24	5.76	3.66	0	0	11.57	50	4.32	0.00	-		27.21	74	2.72
13N	3.07	31	10.10	0.00			4.14	9	2.17	0.00			0.00			7.21	40	5.55
14	3.17	0	0	5.63	0	0	1.82	0	0	3.78	23	6.08	0.00			14.40	23	1.60
14N	3.36	15	4.46	3.43	83	24.20	0.41	0	0	0.00	·	·	0.00	-	-	7.20	98	13.61
15	2.06	0	0	2.15	0	0	0.15	0	0	3.88	5	1.29	0.00			8.24	5	0.61
15N	3.73	17	4.56	3.03	16	5.28	3.73	49	13.17	0.00			0.00			10.49	82	7.82
16	0.32	0	0	0.00	·	·	0.00		·	3.45	11	3.19	0.00			3.77	11	2.92
16N	3.08	0	0	0.00			0.00			0.00			0.00			3.08	0	0
17	0.00			0.62	0	0	2.47	0	0	2.79	5	1.79	0.00			5.88	5	0.85
18	0.68	0	0	0.00	·	·	0.00		·	5.85	5	0.85	0.00	-		6.53	5	0.77
20	0.00	·	·	0.00			0.00			2.29	0	0	0.00			2.29	0	0
21	0.00			0.00			0.00			0.24	0	0	0.00			0.24	0	0
22	0.00		-	0.00			0.00	·		4.84	0	0	0.00	-	-	4.84	0	0
23	0.00	-	-	0.00	·	·	0.00	·		2.49	0	0	1.11	0	0	3.60	0	0
24	0.00	-	-	0.00	·	·	0.00	·	·	0.00			4.04	0	0	4.04	0	0
25	0.00	-		0.00			0.00			0.00			1.32	0	0	1.32	0	0
30	0.00	-		0.00			0.00			1.97	0	0	0.77	0	0	2.74	0	0
31	0.00	-	-	Oslo			0.00			0.47	0	0	3.68	0	0	4.15	0	0
Unblk	1.31	0	0	0.00			0.21	0	0	0.00			0.00			1.52	0	0
Total	35.61	141	3.96	20.85	123	5.90	20.91	58	2.77	43.98	99	2.25	10.92	0	0	135.27	421	3.11

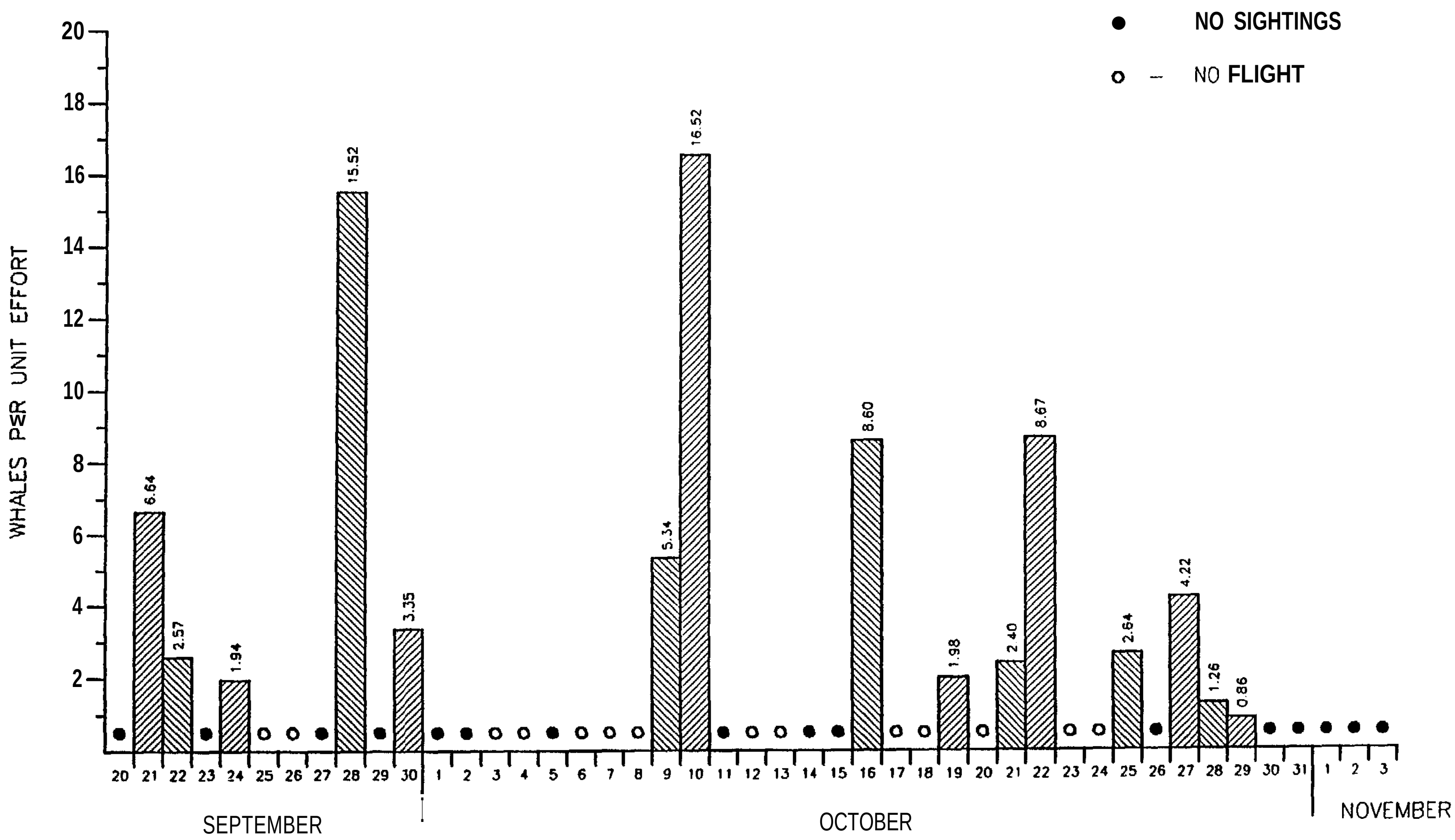


Figure 14. Daily belukha abundance (WPUE) in the study area, 1989.

Belukhas were in water depths ranging from 38-2012m, with mean depth at sightings in the Chukchi Sea (R=115.8m, 178 s.d., n =73) significantly shallower than in the Beaufort Sea ($\bar{x}$=662.8m, 672 s.d., n= 10; $t=5.80, p<0.001$), due to the bathymetry of the study area. Belukhas in the Beaufort Sea were offshore over the continental slope, while those in the Chukchi Sea were offshore over the shallower continental shelf.

As with bowheads, belukha migration route(s) may be related to current patterns. The 54 belukhas seen on transect in the northeastern Chukchi Sea were all in water ≥37 m. When compared to the percentage of ≥37 m habitat available in the area (86%), there was a significantly disproportionate number of belukhas seen in deep water (χ^2 = 42.47, p <0.001), indicating that belukhas swim along troughs that channel major currents in the Chukchi Sea (Aagaard 1987). Northward current flow in fall is roughly one-half the peak flow in summer, so belukhas would not be swimming against a strong current. Belukhas may rely on current cues during the fall migration across the Chukchi Sea, and avoid shallower waters over shoals where currents are not as prevalent. This suggestion is further developed in the summary section of the report.

Belukhas were seen mostly in either very light (0-10%) ice cover (33%, n= 121) or very heavy (91 -99%) ice cover (43%, n =181) depending on when they were seen during the study period. A greater proportion (63%) were seen in heavy ice cover after 21 October, when freeze-up occurred.

Unidentified Cetaceans

Four large whales were recorded as unidentified cetaceans because they were too far from the aircraft when seen to be positively identified. The first was seen on 21 September (Appendix A: Flight 2) in block 13N. A substantial blow was seen and the observer felt that the whale was “likely” a bowhead, but because the whale was not resighted, identification could not be confirmed. Two unidentified whales were recorded on 15 October (Appendix A: Flight 17) and another on 21 October (Appendix A: Flight 20). The two whales seen on 15 October were among gray whales, but only the blow of one whale was seen and a glimpse of the body of the second “appeared darker” than that of a gray whale. The whale seen on 21 October was swimming at 264 “T just southwest of bowheads. Although three ‘footprints’ were evident where the whale surfaced to breathe, the whale was not resighted during twenty minutes of circling, so identification could not be confirmed.

Bowhead and gray whales co-occur in the northeastern Chukchi Sea each fall (Moore et al. 1986a). Unless some part of the whale is clearly seen, an observer cannot positively identify whales by observing blows from an aircraft. In one instance, a bowhead surfaced next to a gray whale mud plume in 10 % ice in block 14N (Appendix A: Flight 14), underscoring the proximity with which the two species can occur in the Chukchi Sea in fall.

Walrus (*Odobenus rosmarus*)

There were 126 sightings of 2001 walruses during the 1989 survey season (Fig. 15). Walruses were strongly associated with the ice edge, which was found only in blocks 14N and 15N over much of the survey season (see Fig. 5). Nearly 1000 were seen on 10 October (Appendix A: Flight 14) in block 14N. This distribution effectively kept most walruses north of the exploratory drilling activities conducted in the Chukchi Sea in 1989. Sightings of walrus south of720 N occurred after 21 October, when freeze-up began in the northeastern Chukchi Sea and after drilling activities had ceased for the season.

Bearded seals (*Erignathus barbatus*)

There were 13 sightings of 17 bearded seals in 1989 (Fig. 16A). Most bearded seals were seen near or on ice in the northern survey blocks. As noted below, positively identifying pinnipeds from altitudes greater than ca. 155 m (500 ft) is generally not possible.

Unidentified Pinnipeds

There were 152 sightings of 1060 unidentified pinnipeds during the survey season (Fig. 16 B). When surveying at the target altitude of 458 m (1500 ft.), it is usually impossible to positively identify pinnipeds. On 1 October (Appendix A: Flight 10), over 100

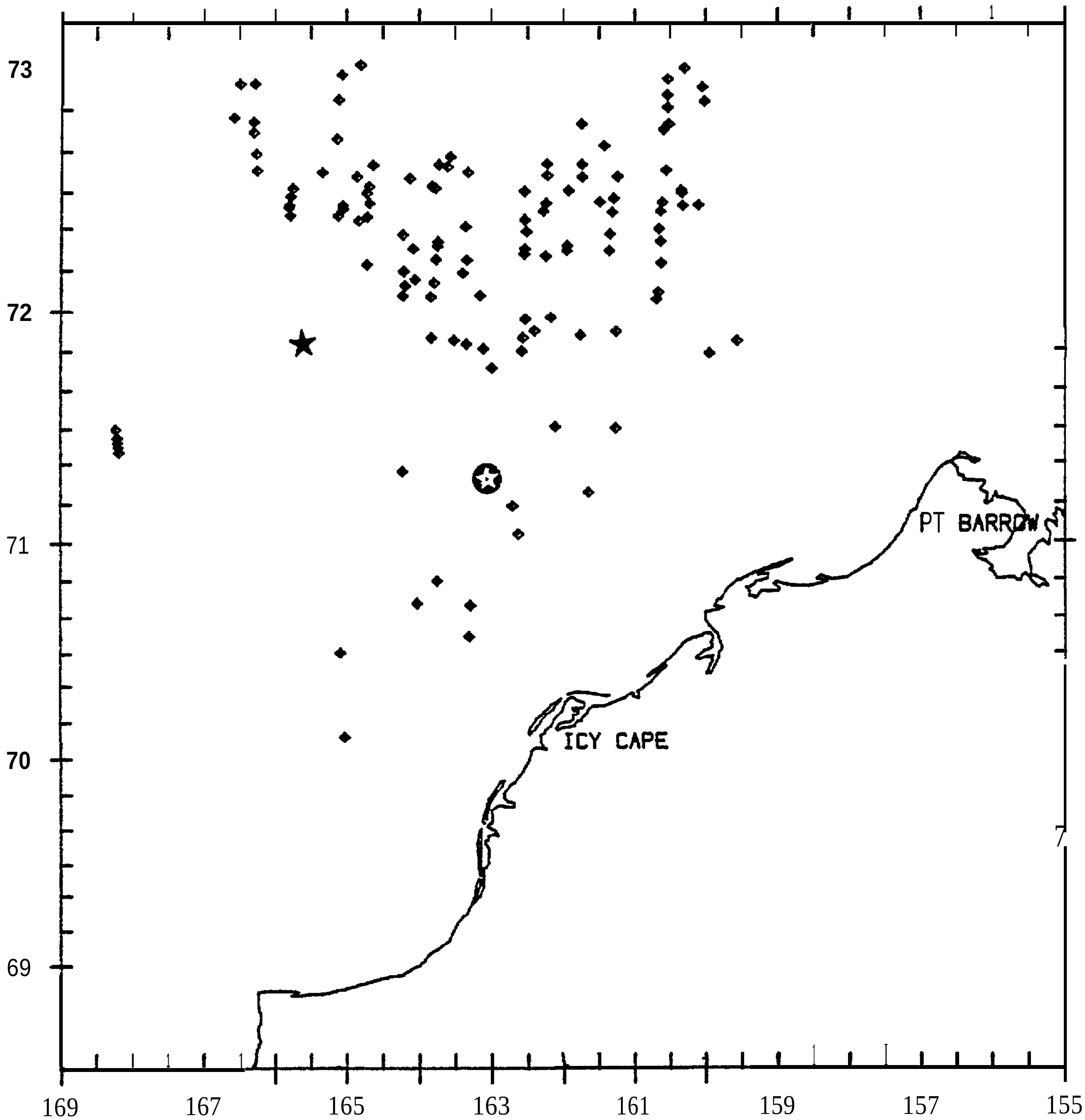


Figure 15. Distribution of 126 sightings of 2001 walruses, 1989. [★ = 'Popcorn' exploratory site; ✪ = 'Burger' exploratory site]

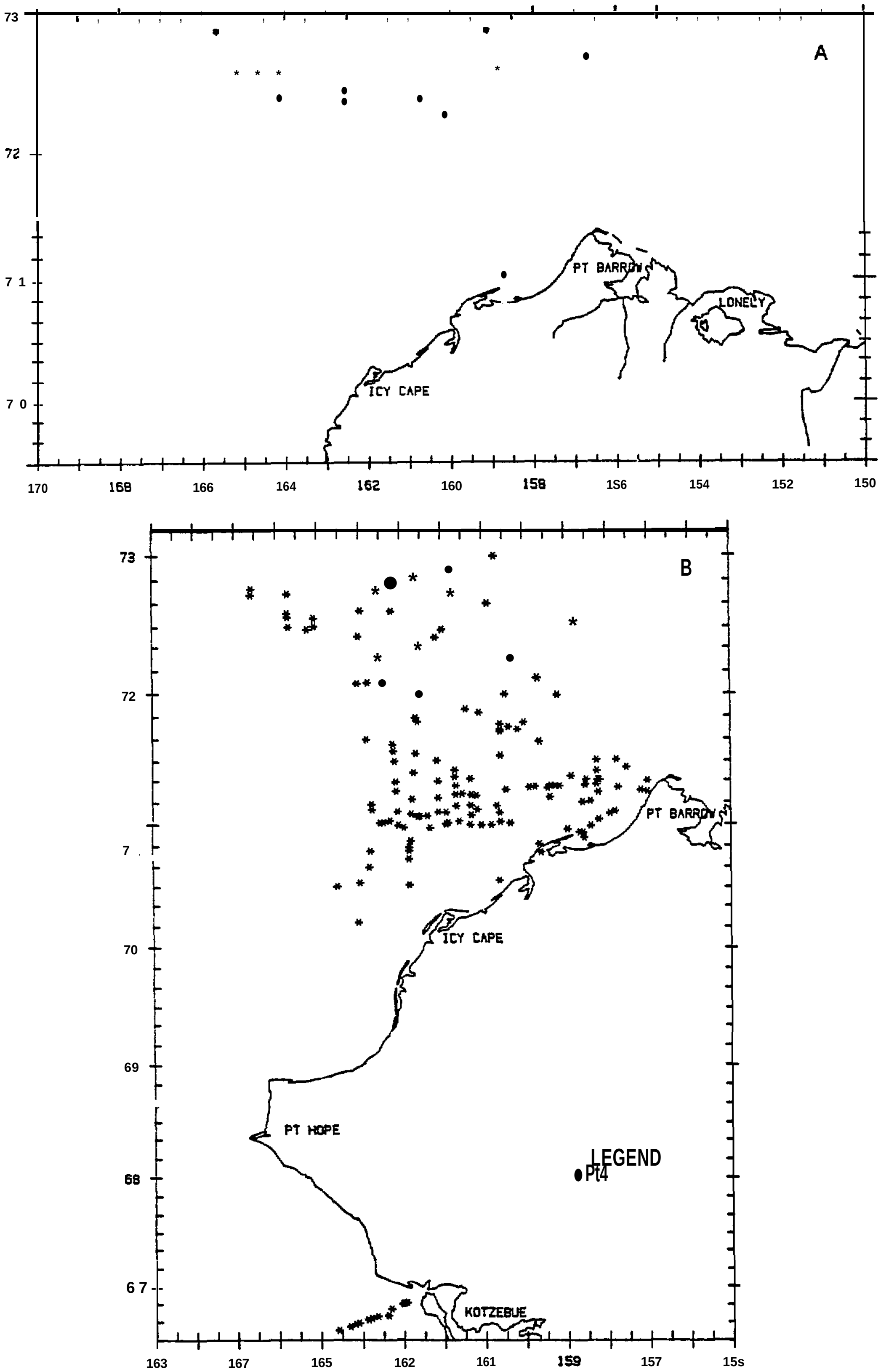


Figure 16. Distribution of 13 sightings of 17 bearded seals (A), and 152 sightings of 1060 unidentified pinnipeds (B), 1989.

pinnipeds were seen from ca. 1500 ft during a survey of block 14 on an exceptionally calm day. In higher sea conditions, many of these seals would probably have been missed. These pinnipeds were likely ringed seals (K. Frost, pers. comm.), which are commonly associated with ice, although there was none in the area. Seals were seen near the 'Burger' exploratory drill site, and seemed associated with windrows of flotsam on which sea birds rafted. On two occasions seals came up underneath birds as if trying to catch them. Over 800 unidentified pinnipeds were seen on 2 November (Appendix A: Flight 30) hauled out on ice floes in Kotzebue Sound. In some instances, the seals appeared to be within 1 m of each other and rimmed the perimeter of large pans of ice. None exhibited any reaction to the aircraft, even when it flew directly overhead at 450 m. Seals were not seen in the area the day before or the day after, although the flight path to and from Kotzebue was very similar all three days.

Polar Bear (*Ursus maritimus*)

There were 24 sightings of 37 polar bears during the 1989 season (Fig. 17). Five bears were seen on the first survey (Appendix A: Flight 1); three were swimming along the ice edge and two were on the ice in block 14N. Seventeen bears were seen on 16 October (Appendix A: Flight 18), associated with the ice edge in blocks 14N and 15N. After ice began to form in the Chukchi Sea on 21 October, eight bears were seen in block 13,5 on 22 October (Appendix A: Flight 21) and 3 on 27 October (Appendix A: Flight 24).

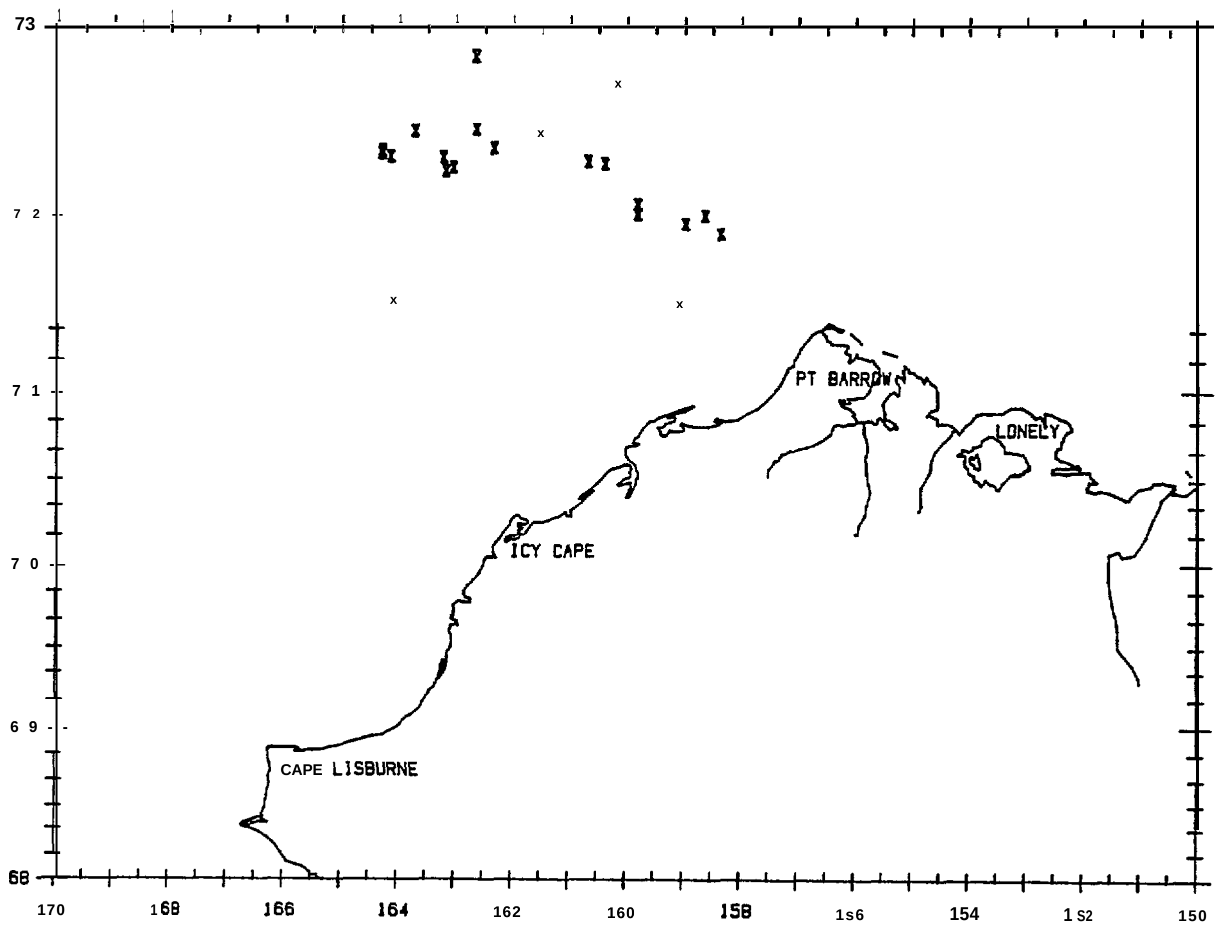


Figure 17. Distribution of 24 sightings of 37 polar bears, 1989.

DISCUSSION AND 1980-89 REVIEW

Survey Effort, Conditions and Bowhead Sighting Summary

Nearly 537 hours of aerial survey effort has been conducted in the study area from mid-September through mid-November 1980-89 during MMS-funded studies (Table 12; Ljungblad et al. 1988). Survey effort in the study area varied greatly among years. Less than 0.5 hours was flown in 1981, roughly 20 hours in 1980, from 32 to 89 hours between 1982-88, and nearly 134 hours in 1989. Annual differences in survey effort resulted from varied task priorities. For example, in 1980 and 1981, surveys were directed toward the eastern Alaskan Beaufort Sea to document the timing and route of the fall bowhead migration there. In 1980, survey effort in the Chukchi study area was confined to a coastal search survey and ca. 2 hours of surveys to determine gray whale distribution in block 25 in late October and early November. In 1981, only 0.37 hours of survey was conducted in block 12 in early October. Substantial survey effort was first directed toward the Chukchi Sea in 1982. Between 1982-88, survey effort varied with ongoing offshore activities in the Alaskan Beaufort Sea. In some years (1982, 1984-85), the survey aircraft had to allocate time to both the Chukchi Sea and Beaufort Sea, while in other years (1 983, 1986-88) surveys in the Chukchi Sea were less interrupted.

Annual ice conditions have ranged from light, with little or no ice in the study area during the survey season, to heavy, when the study area had >50 % ice cover throughout the survey season (Table 12). In 1985, a storm in the latter half of September dramatically changed conditions from "average" to "heavy" by pushing ice towards shore and into the study area. An ice-edge frequency map for the study area depicts ice conditions commonly encountered during the mid-point of the survey season (Fig. 18). The median ice-free period is 84 days at Barrow, 91 days at Point Lay and 154 days at the Bering Strait (Stringer and Groves 1987). Based on a 12-year ice limit data set from satellite observations, Stringer and Groves (1987) suggested that "the ice edge configuration in parts of the Chukchi Sea is influenced by bathymetrically steered currents". Variation in the northward intrusion of currents, channeled around the major shoals of the Chukchi basin, appears to be responsible for annual ice melt-back patterns, and for the location of sharp temperature and salinity fronts associated with the ice edge

Table 12. Summary of survey effort, general ice **conditions and bowhead whale sightings (S1) and number (No.) in the study area, 1980-89.**

Year	Survey Effort (hours)	Ice Condition	Bowhead Whales (s1)	(No.)
1980	19.93	heavy	0	0
1981	0.37	average	0	0
1982	31.71	average	19	30
1983	61.96	heavy	34	50[1]
1984	38.10	average	45	192
1985	32.11	avg/hvy	10	10
1986	79.20	light	11	15
1987	87.85	light	24	32
1988	51.95	heavy	25	55
1989	133.72	light	58	117[2]
1980-89	536.90	--	226	501

[1] Includes 5 sightings of 7 bowheads in block 12 on 18 September
[2] Excludes 11 sightings of 14 bowheads in block 3 on 14-15 October

(Paquette and Bourke 1981; Bourke 1983). The southernmost border of the ice edge constituted an arc through survey blocks 14N and 15N for much of the 1989 season (see Fig. 5).

There were 226 sightings of 501 bowhead whales in the study area from mid-September through October 1982-89 (Table 12). This total includes 5 sightings of 7 bowheads in block 12 on 18 September 1983, two days prior to the beginning of the 1989 survey season, and excludes 11 sightings of 14 bowheads in block 3 in 1989, made in the Beaufort Sea study area (see Fig. 2) while testing radio tracking equipment. No bowheads were seen in the study area in 1980 or 1981 during 20.3 hours of survey. Therefore, the data summary which follows is based on the 1982-89 data base.

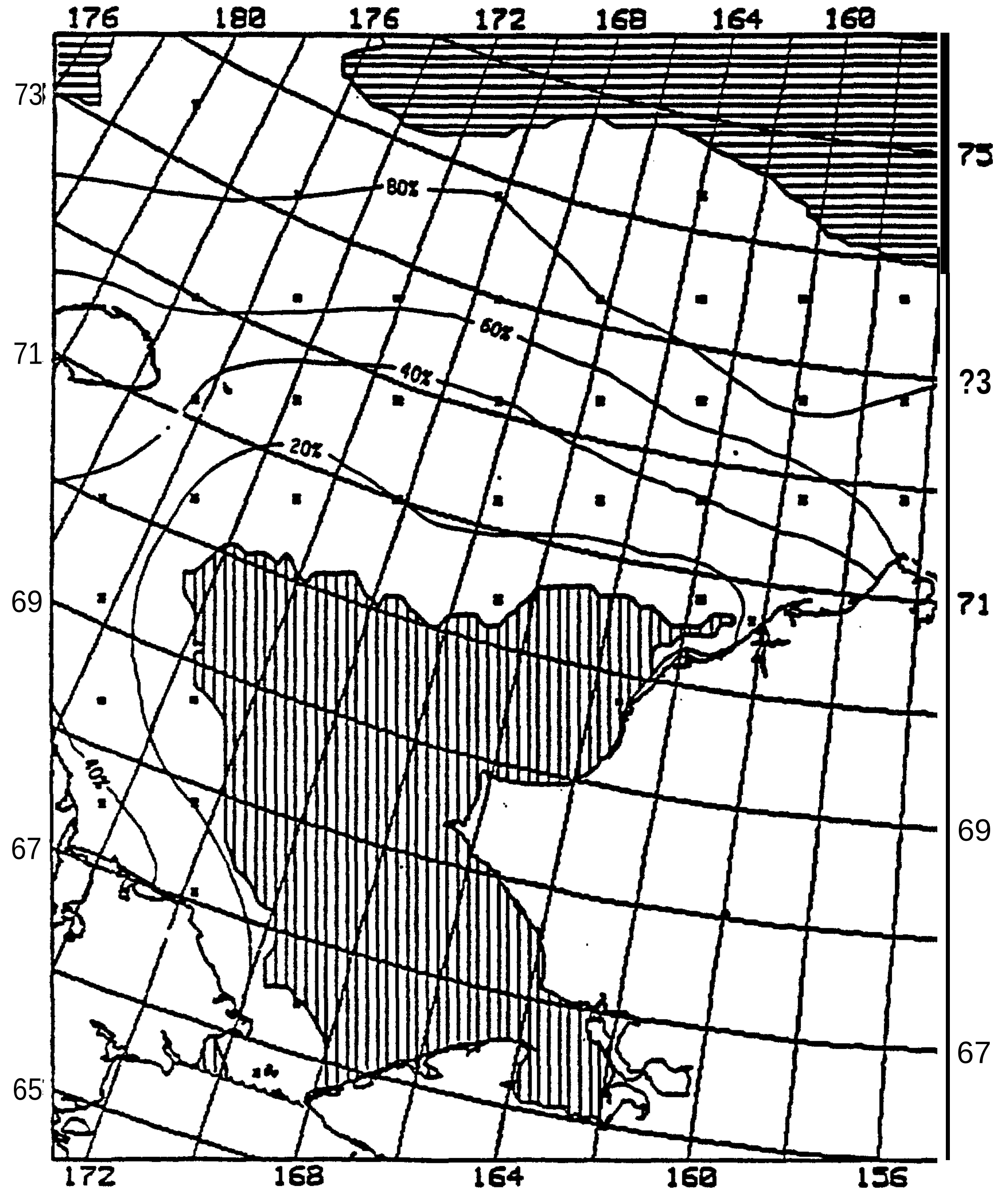


Figure 18. Chukchi Sea ice-edge frequency map for the second week of October, derived from a 12-year (1972-83) satellite data base (from Stinger and Groves 1987). The isopleths represent the frequency with which oceanic locations were within the ice edge in mid-October; vertical lines represent areas that were ice-free in all years and horizontal lines depict areas that were ice covered in all years.

Bowhead Whale

Patterns of Distribution and Abundance

There were 46 sightings of 187 bowhead whales in the study area from 16 to 30 September; 123 sightings of 232 whales from 1 to 15 October; and 57 sightings of 82 whales from 16 to 31 October, 1982-89 (Fig. 19). Bowhead distribution in all time periods overlapped OCS lease areas northeast of Point Barrow and whales were seen near or in OCS lease areas in the northeastern Chukchi Sea. The overall distribution highlights the importance of the nearshore waters northeast of Point Barrow, and southwest of Point Barrow to@ 120 km (65 nmi) northwest of Icy Cape. Most sightings southwest of Point Barrow were east of OCS lease area boundaries, but whales swimming a southwesterly course from these waters would likely pass through at least some lease areas on their fall migration.

Waters north of720 N latitude were surveyed only in 1988 and 1989. No bowheads were seen in the northern blocks (i.e., 12N-16N) in 1988, a heavy-ice year. As discussed earlier in this report, four bowheads were seen in the northern blocks in 1989 between 20 September and 16 October. In addition, one bowhead was seen in block 12N on 27 September 1987 and three sightings in northern areas were made by U.S. Fish and Wildlife Service (USFWS) biologists (see ● , Fig. 19) while conducting walrus surveys over the Chukchi Sea in 1985 (Ljungblad et al. 1986b). Although few in number, these eight sightings suggest that in some years some bowheads remain far to the north and take a migration route through the Chukchi Sea that may cross the northernmost boundaries of OCS lease areas.

Cumulative (1982-89) relative abundance was highest in block 12 (WPUE = 2,91), block 13 (WPUE = 0.75) and block 18 (WPUE = 1.05; Table 13). These comparatively high indices reflect the general pattern of distribution, with most whales seen nearshore northeast of Point Barrow and dispersing to the southwest from Point Barrow. Lesser cumulative abundance indices for block 14 (WPUE = 0.29), block 14N (WPUE = 0,19), block 15N (WPUE = 0.13) and block 17 (WPUE = 0.17) also reflect the bifurcated nature of bowhead distribution west of Point Barrow. Bowheads were not seen in blocks 13N, 15, 16, 16N, 19-25, 30 and 31 in any year (see Table 13 for effort).

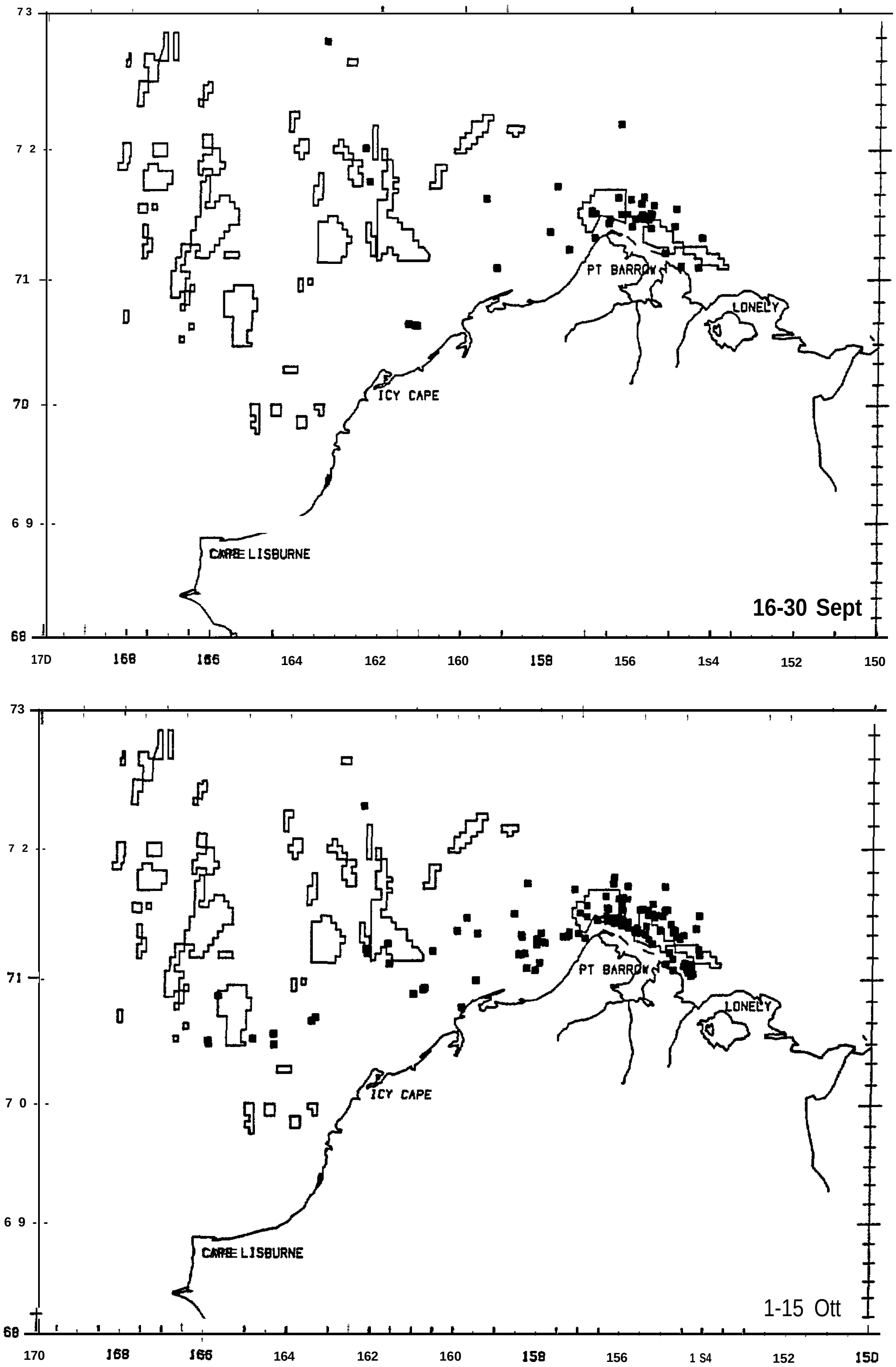


Figure 19. Cumulative **(1982-89)** bowhead whale distribution relative to OCS lease areas depicting 46 sightings of 187 whales, 16-30 September; 123 sightings of 232 whales, 1-15 October;

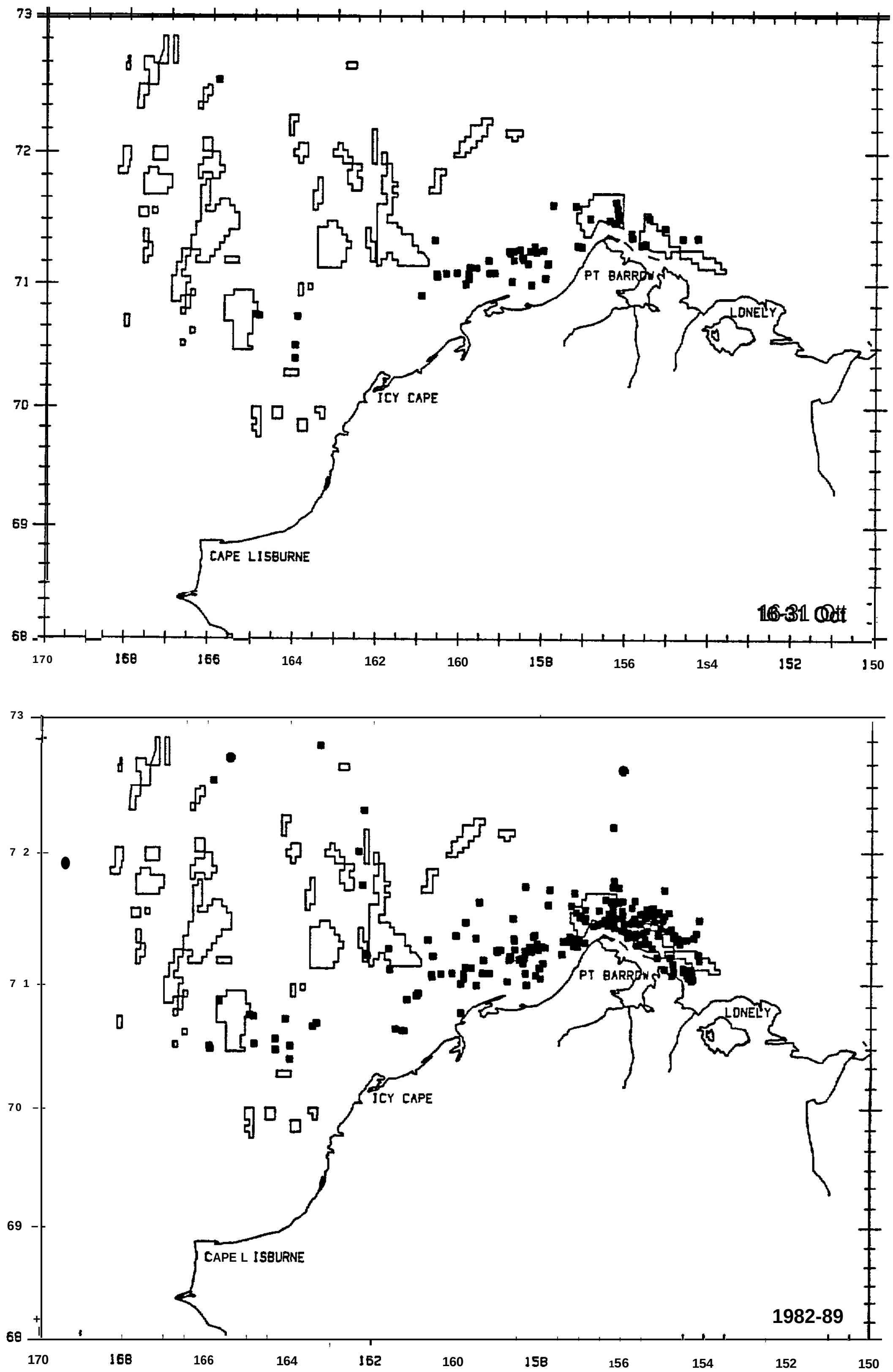


Figure 19 (contd). 57 sightings of 82 whales, 16-31 October; and 226 sightings of 501 whales. [• = USFWS sightings 1985]

Table 13. Bowhead whale relative abundance (WPUE = no. whales/survey hour) by survey block, 1982-89.

1982

	16-30 Sept			1-15 Ott			16-31 Ott			1-15 Nov			Total		
Block	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE
12	4.58	2	0.44	5.85	15	2.56	2.17	0	0	0.00		-	12.60	17	1.35
12N	0.00	-	-	0.07	0	0	0.08	0	0	0.00	.	-	0.15	0	-
13	1.49	0	0	3.58	12	3.35	0.76	0	0	0.00		-	5.83	12	2,06
14	0.00	-	-	1.98	0	0	0.48	1	2.08	0.00		-	2.46	1	0.41
15	0.00	-	-	0.12	0	0	0.00	-	-	0.00		-	0.12	0	0
17	0.00	-	-	3.81	0	0	0.00	-	-	0.00	.	-	3.81	0	0
18	0.00	-	-	2.00	0	0	0.00	-	-	0.00	.	-	2.00	0	0
20	0.00	-	-	3.39	0	0	0.00	-	-	0.00		-	3.39	0	0
21	0.00	-	-	1.35	0	0	0.00	-	-	0.00	.	-	1.35	0	0
Total	6.07	2	0.33	22.15	27	1.22	3.49	1	0.29	0.00		-	31,71	30	0.95

1983

	16-30 Sept			1-15 Ott			16-31 Ott			1-15 Nov			Total		
Block	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE
12	7.88	18	2.28	8.20	8	0.98	2.45	0	0	0.00		-	18.53	26	1.40
12N	0.28	0	0	0.77	0	0	0.12	0	0	0.00	.		1.17	0	0
13	3.29	3	0.91	5.14	4	0.78	3.73	9	2.41	0.00	-	-	12.16	16	1.32
13N	0.00	-	-	0.10	0	0	0.10	0	0	0.00			0.20	0	0
14	0.87	0	0	1.52	0	0	1.93	0	0	0.00			4.32	0	0
15	0.00	-	-	3.83	0	0	0.39	0	0	0.00			4.22	0	0
15N	0.00	-	-	0.56	0	0	0.00	.	-	0.00	-	.	0.56	0	0
17	0.96	3	3.13	3.85	3	0.78	0.44	0	0	0.00			5.25	6	1.14
18	0.00	-	-	1.51	0	0	3.09	2	0.65	0.00	.		4.60	2	0.43
19	0.00	-	-	0.32	0	0	0.04	0	0	0.00	.		0.36	0	0
20	0.00	-	-	0.76	0	0	2.21	0	0	0.00			2.97	0	0
21	0,00	-	-	0.36	0	0	1.37	0	0	0.00			1.73	0	0
22	0.00	-	-	3.22	0	0	0.38	0	0	0.00			3.60	0	0
23	0.00	-	-	0.23	0	0	0.36	0	0	0.00	.		0.59	0	0
24	0.00	-	-	0.00		-	0.34	0	0	0.00	.		0.34	0	0
25	0.00	-	-	0.00	.	-	0.51	0	0	0.00	.	.	0.51	0	0
30	0.00	-	-	0.85	0	0	0.00	.	-	0.00	.	.	0.85	0	0
Total	13.28	24	1.81	31.22	15	0.48	17.46	11	0.63	0.00	.	-	61.96	50	0.81

1984

	16-30 Sept			1-15 Ott			16-31 Ott			1-15 Nov			Total		
Block	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE
12	5.64	148	26.24	7.63	25	3.28	7.96	12	1.51	0.00	-	-	21.23	185	8.71
12N	0.09	0	0	0.31	0	0	0.13	0	0	0.00	-	-	0.53	0	0
13	4,76	2	0.42	3.14	3	0.96	2.63	2	0.76	0.00	-	-	10.53	7	0.66
13N	0.03	0	0	0.03	0	0	0.20	0	0	0.00	-	-	0.26	0	0
14	2.79	0	0	0.11	0	0	0.00	-	-	0.00	-	-	2.90	o	0
17	0.75	0	0	1.90	0	0	0.00	-	-	0.00	-	-	2.65	0	0
Total	14.06	150	10.65	13,12	28	2.13	10.92	14	1.28	0.00	-	-	38.10	192	5.01

Table 13 (contd).

1985

Block	16-30 Sept Hrs	BH	WPUE	1-15 Ott Hrs	BH	WPUE	16-31 Ott Hrs	BH	WPUE	1-15 Nov Hrs	BH	WPUE	Total Hrs	BH	WPUE
12	3.08	0	0	6.08	6	0.99	7.17	1	0.14	0.00	-	-	16.33	7	0.43
12N	0.07	0	0	0.64	0	0	0.00	-	-	0.00	-	-	0.71	0	0
13	0.00	-	-	2.79	2	0.72	3.62	0	0	0.00	-	-	6.41	2	0.31
14	0.00	-	-	2.04	1	0.49	0.00	-	-	0.00	-	-	2.04	1	0.49
15	0.00	-	-	1.03	0	0	0.00	-	-	0.00	-	-	1.03	0	0
17	0.00	-	-	2.65	0	0	0.00	-	-	0.00	-	-	2,65	0	0
18	0.00	-	-	2.74	0	0	0.00	-	-	0.00	-	-	2.74	0	0
Total	3.15	0	0	18.17	9	0.50	10.79	1	0.09	0.00	-	-	32.11	10	0.31

1986

Block	16-30 Sept Hrs	BH	WPUE	1-15 Ott Hrs	BH	WPUE	16-31 Ott Hrs	BH	WPUE	1-15 Nov Hrs	BH	WPUE	Total Hrs	BH	WPUE
12	3.33	0	0	8.33	11	1.32	3.76	0	0	0.00	-	-	15.42	11	0.71
12N	0.10	0	0	1.34	0	0	0.12	0		0.00	-	-	1.56	0	0
13	11.15	0	0	9.09	0	0	6.60	2	0.3:	0.00	-	-	26.84	2	0.07
13N	0.52	0	0	1.82	0	0	0.00	-	-	0.00	-	-	2.34	0	0
14	4.46	1	0.22	7.28	1	0.14	0.62	0	0	0.00	-	-	12.38	2	0.16
14N	0.06	0	0	0.16	0	0	0.00	-	-	0.00	-	-	0.22	0	0
15	2.72	0	0	0.20	0	0	0.19	0	0	0.00	-	-	3.11	0	0
17	3.77	0	0	3.95	0	0	3.43	0	0	0.00	-	-	11.15	0	0
18	1.04	0	0	2.17	0	0	0.53	0	0	0.00	-	-	3.74	0	0
20	1.59	0	0	0.00	-	-	0.05	0	0	0.00	-	-	1.64	0	0
22	0.80	0	0	0.00	-	-	0.00	-	-	0.00	-	-	0.80	0	0
Total	29.56	1	0.03	34.34	12	0.35	15.30	2	0.13	0.00	-	-	79.20	15	0.19

1987

Block	16-30 Sept Hrs	BH	WPUE	1-15 Ott Hrs	BH	WPUE	16-31 Ott Hrs	BH	WPUE	1-15 Nov Hrs	BH	WPUE	Total Hrs	BH	WPUE
12	7.70	2	0.26	7.09	21	2.96	8.10	5	0.62	0.00	-	-	22.89	28	1.22
12N	2.75	1	0.36	3.37	0	0	4.16	0	0	0.00	-	-	10.28	1	0.10
13	10.95	1	0.09	8.04	0	0	4.85	2	0.41	0.00	-	-	23.64	3	0.13
13N	1.75	0	0	1.09	0	0	2.38	0	0	0.00	-	·	5.22	0	0
14	5.31	0	0	2.62	0	0	0.00	-	-	0.00	-	·	7.93	0	0
15	3.38	0	0	0.00	-	-	0.00	-	-	0.00	-	-	3.38	0	0
16	0.41	0	0	0.00	-	-	0.00	-	-	0.00	-		0.41	0	0
17	2.60	0	0	0.95	-	-	2.68	0	0	0.00	-	·	6.43	0	0
18	2.91	0	0	0.00	-	-	0.54	0	0	0.00	-	·	3.45	0	0
20	1.66	0	0	0.00	-	-	0.00	-	-	0.00	-	·	1.66	0	0
22	2.34	0	0	0.00	-	-	0.00	-	-	0.00	-	·	2.34	0	0
Total	41.78	4	0.10	23.16	21	0.91	22.91	7	0.31	0.00	-	-	87.85	32	0.36

Table 13 (contd).

1988

Block	18-30 Sept Hrs	BH	WPUE	1-15 Ott Hrs	BH	WPUE	18-31 Ott Hrs	BH	WPUE	1-15 Nov Hrs	BH	WPUE	Total Hrs	BH	WPUE
12	0.00	-	-	2.73	3	1.10	0.19	0	0	0	-	-	2.92	3	1.03
12N	0.00	-	-	3.10	0	0	0.00	-	·	0			3.10	0	0
13	0.00	-	-	8.85	29	3.28	1.12	0	0	0	-	-	9.97	29	2.91
13N	0.00	-	-	3.60	0	0	0.00	0	0	0	-	-	3.60	0	0
14	0.00	-	-	5.11	7	1.37	0.16	0	0	0	-	-	5.27	7	1.33
14N	0.00	-	-	2.76	0	0	0.00	-	·	0	-		2.76	0	0
15	0.00	-	-	3.66	0	0	0.00	-	·	0	-	-	3.66	0	0
15N	0.00	-	-	3.63	0	0	0.00	-	·	0	-	-	3.63	0	0
16	0.00	-	-	3.18	0	0	0.00	-	·	0			3.18	0	0
16N	0.00	-	"	3.92	0	0	0.00	-	·	0	-	-	3.92	0	0
17	0.00	-	-	2.41	0	0	1.36	0	0	0	-		3.77	0	0
18	0.00	-	-	4.37	14	3.20	1,18	2	1.69	0	-	-	5.55	16	2.88
19	0.00	-	-	0.62	0	0	0.00	-		0	-		0.62	0	0
Total	0.00	-	-	47.93	53	1.11	4.00	2	0.50	0			51.95	55	1.06

1989

Block	16-30 Sept Hrs	BH	WPUE	1-15 Ott Hrs	BH	WPUE	16-31 Ott Hrs	BH	WPUE	1-15 Nov Hrs	BH	WPUE	Total Hrs	BH	WPUE
12	5.40	4	0.74	4.29	66	15.38	1.19	5	4.20	0.00		-	10.88	75	6.89
12N	4.77	0	0	0.00	-	-	0.00	-	·	0.00			4.77	0	0
13	7.81	0	0	6.51	0	0	12.86	21	1.63	0.00		-	27.18	21	0.77
13N	3.45	0	0	0.92	0	0	3.24	0	0	0.00	-	-	7.61	0	0
14	3.17	0	0	6.85	0	0	4.39	4	0.91	0.00	-	-	14.41	4	0.28
14N	3.73	1	0.27	3.39	1	0.29	0.41	0	0	0.00	-	-	7.53	2	0.27
15	2.06	0	0	2.15	0	0	4.03	0	0	0.00		-	8.24	0	0
15N	3.95	1	0.25	3.03	0	0	3.73	1	0.80	0.00	-	-	10.71	2	0.19
16	0.32	0	0	0.00	·	-	3.39	0	0	0.00		-	3.71	0	0
16N	3.08	0	0	0.00	·	-	0.00	-	·	0.00		-	3.08	0	0
17	0.00		-	3.06	0	0	2.79	1	0.36	0.00		-	5.85	1	0.17
18	0.68	0	0	0.00		-	5.85	12	2.05	0.00		-	6.53	12	1.84
20	0.00		-	0.00	·	-	2.29	0	0	0.00		-	2.29	0	0
21	0.00	·	-	0.00	·	-	0.24	0	0	0.00		-	0.24	0	0
22	0.00		-	0.00		-	4.64	0	0	0.00			4.84	0	0
23	0.00	·	-	0.00	·	-	2.49	0	0	1.11	0	0	3.60	0	0
24	0.00		-	0.00	·	-	0.00	-	·	4.04	0	0	4.04	0	0
25	0.00	·	-	0.00	·	-	0.00	-		1.32	0	0	1.32	0	0
30	0.00	·	-	0.00	·	·	1.97	0	0	0.77	0	0	2.74	0	0
31	0.00	·	-	0.00	·	-	0.47	0	0	3.68	0	0	4.15	0	0
Total	38.42	6	0.16	30.20	67	2.22	54.18	44	0.81	10.92	0	0	133.72	117	0.87

Table 13 (contd).

CUMULATIVE 1982-89

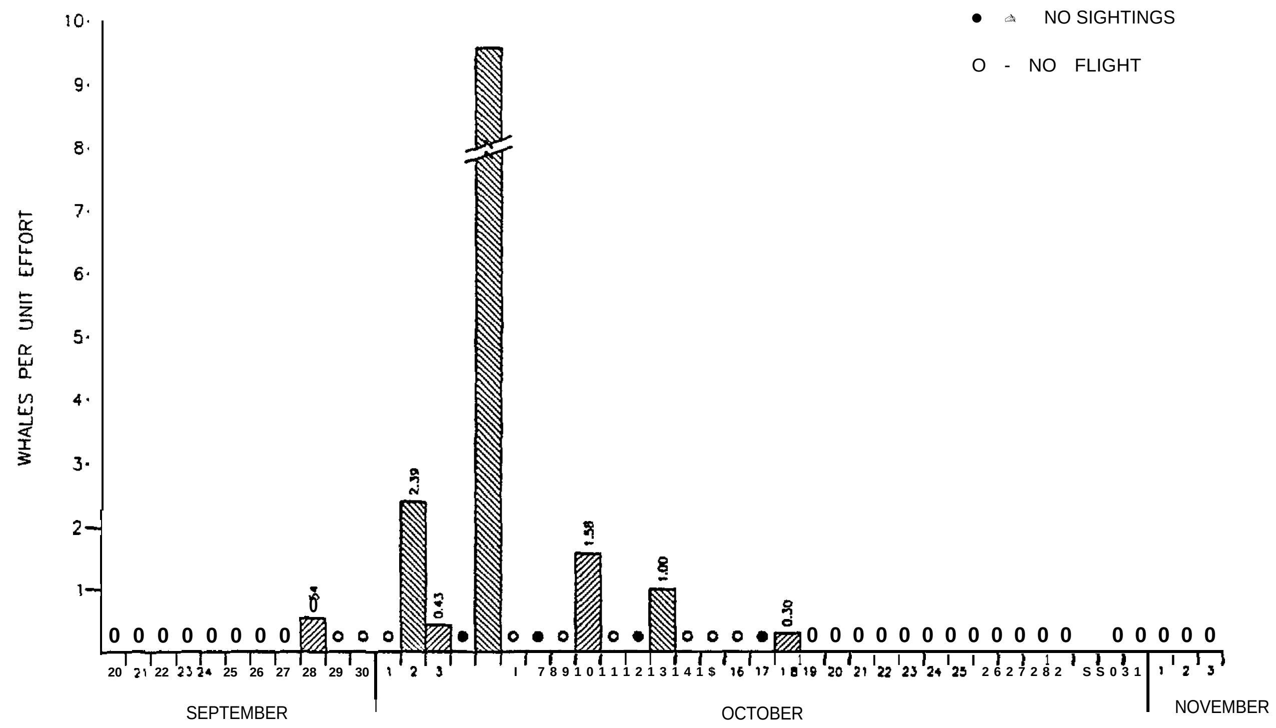
Block	16-30 Sept Hrs	BH	WPUE	1-15 Ott Hrs	BH	WPUE	16-31 Ott Hrs	BH	WPUE	1-15 Nov Hrs	BH	WPUE	Total Hrs	BH	WPUE
12	37.61	174	4.63	50.20	155	3.09	32.99	23	0.70	0.00			120.80	352	2.91
12N	8.06	1	0.12	9.60	0	0	4.61	0	0	0.00	-		22.27	1	0.04
13	39.45	6	0.15	47.14	50	1.06	36.17	36	1.00	0.00			122.76	92	0.75
13N	5.75	0	0	7.56	0	0	5.92	0	0	0.00	-		19.23	0	0
14	16.62	1	0.06	27.51	9	0.33	7.58	5	0.66	0.00			51.71	15	0.29
14N	3.79	1	0.26	6.31	1	0.16	0,41	0	0	0.00	-		10.51	2	0.19
15	8.16	0	0	10.99	0	0	4.61	0	0	0.00	-		23.76	0	0
15N	3.95	1	0.25	7.22	0	0	3.73	1	0.80	0.00			14.90	2	0.13
16	0.73	0	0	3.18	0	0	3,39	0	0	0.00			7.30	0	0
16N	3,08	0	0	3.92	0	0	0.00	-	-	0,00	-		7.00	0	0
17	8.08	3	0.37	22.78	3	0.13	10.90	1	0.09	0.00			41.76	7	0.17
18	4.63	0	0	12.79	14	1,09	11.19	16	1.43	0,00			28.61	30	1.05
19	0.00		-	0.94	0	0	0.04	0	0	0.00			0.98	0	0
20	3.27	0	0	4.15	0	0	4.55	0	0	0.00			11.97	0	0
21	0.00	-	·	1.71	0	0	1.61	0	0	0.00			3.32	0	0
22	3.14	0	0	3.22	0	0	5.22	0	0	0.00			11.58	0	0
23	0.00		-	0.23	0	0	2.85	0	0	1.11	0	0	4.19	0	0
24	0.00		·	0	·	-	0.34	0	0	4.04	0	0	4.38	0	0
25	0.00			0		-	0.51	0	0	1.32	0	0	1.83	0	0
30	0.00	·	-	0.85		-	1.97	0	0	0.77	0	0	3.59	0	0
31	0.00	-		0	0	0	0.47	0	0	3,68	0	0	4.15	0	0
Total	146.32	187	1.28	220.30	232	1.05	139.06	82	0.59	10.92	0	0	516.60	501	0.97

Although relative abundance indices varied somewhat between years, there was no distinct pattern that could be associated with ice condition. Relative abundance in block 13 averaged higher in heavy-ice years (1983, 1988; avg. WPUE = 2.11) compared to average-ice years (1982, 1984, 1985; avg. WPUE = 1.01) and light-ice years (1986, 1987, 1989; avg. WPUE = 0.32), but these differences were not statistically significant. The greatest annual variation in relative abundance was calculated for block 12 and was related to the occurrence of feeding aggregations there. Relative abundance indices for block 12 in 1984 and 1989 were roughly six to eight times higher than in other years when feeding whales were not seen there. These differences in relative abundance reflect the positive correlation between feeding and WPUE reported in Ljungblad et al. (1986a).

Migration Timing and Route

Migration timing through the study area, as represented by daily sighting rates, has varied somewhat annually (Fig. 20). As mentioned previously, annual differences in task priorities resulted in varied effort in the study area (see Table 12), which undoubtedly affected daily sighting rates. Bowheads were seen on the first or second survey in the study area in all years but 1986. Peak sighting rates occurred in early October in 1982, while in 1983 there appeared to be pulses of bowheads passing through in late September, early, and mid-October. Sighting rates in 1984 were highest in late September, as a result of bowhead feeding aggregations seen east of Point Barrow, and in mid-October; the majority (96%) of whales seen in the study area in 1984 were in block 12. Sighting rates in 1985, 1986, and 1987 were comparatively low, with single-day peaks in early, mid- and early October, respectively. in 1988, there were two peaks in sighting rate in early and mid-October. However, survey effort was limited to just 15 days, which restricts interpretation of migration timing throughout the fall season. In 1989, peak sighting rates occurred in early, mid- and late October; the first two peaks resulting from sightings of the bowhead feeding aggregation east of Point Barrow and the last peak representing sightings in the northeastern Chukchi Sea. Even with these annual variations, sighting rates peaked from 4-6 October and from 14-17 October in all years but 1984 and 1986.

1982



1983

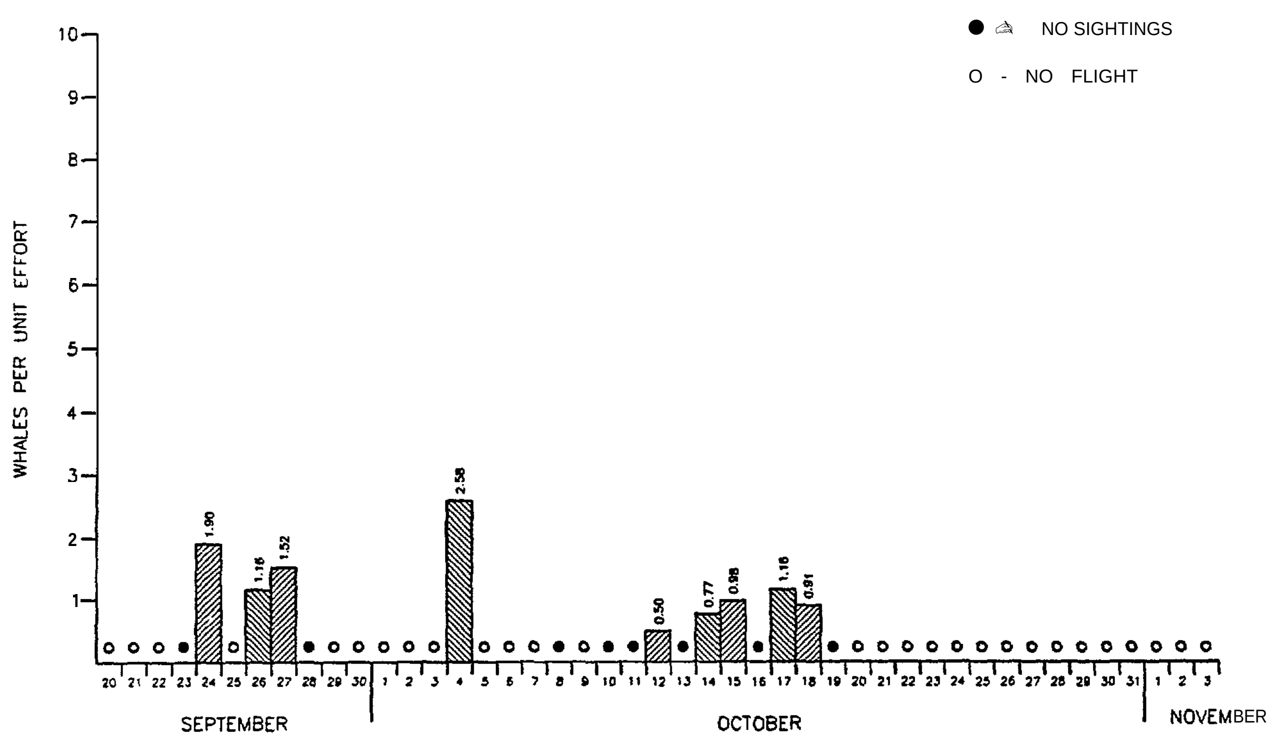
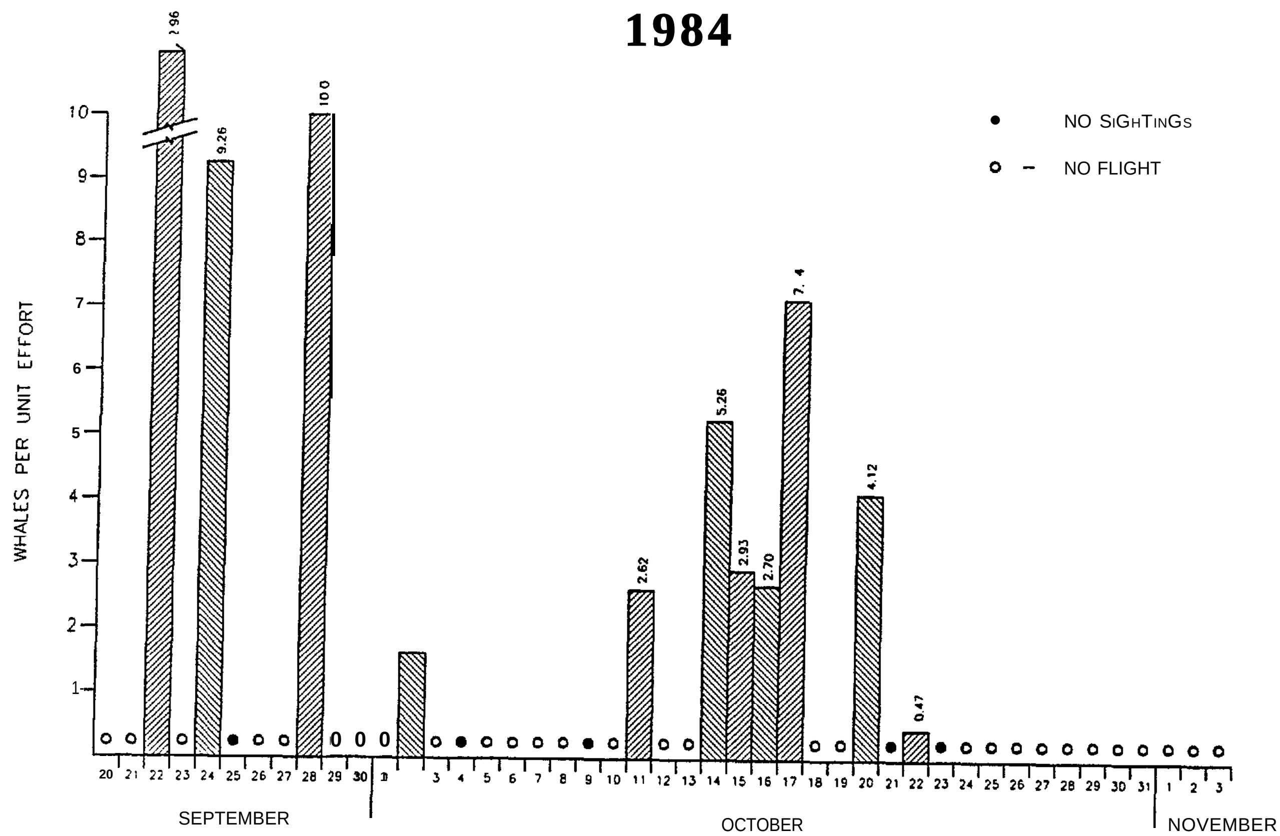


Figure 20. Annual bowhead whale daily sighting rate in the study area, 1982-89.

1984



1985

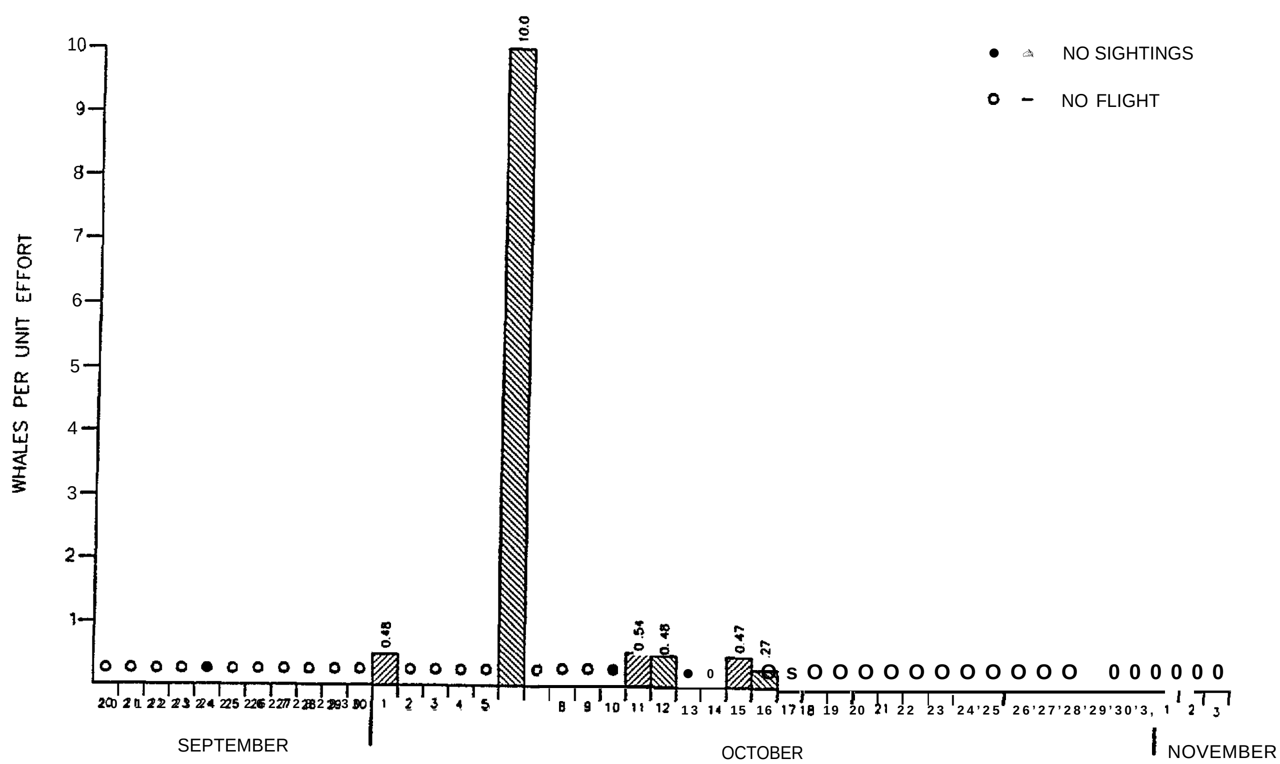
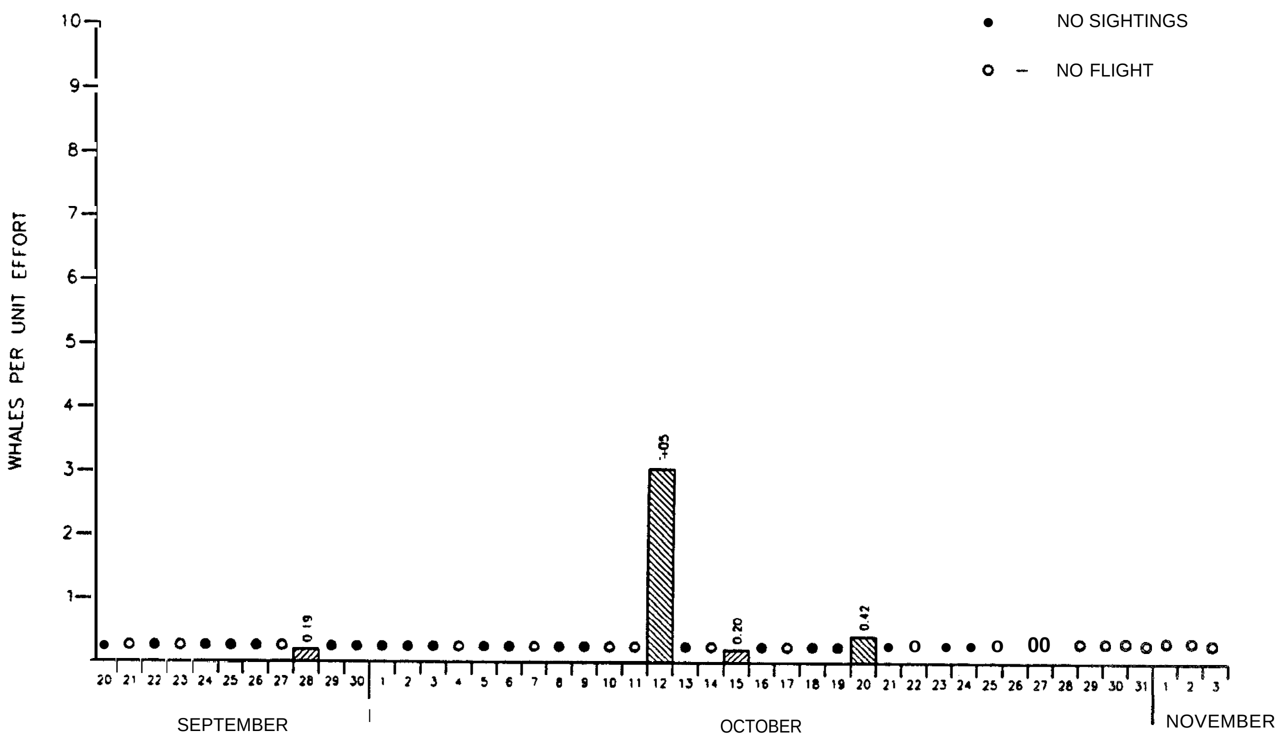


Figure 20 (contd).

1986



198'7

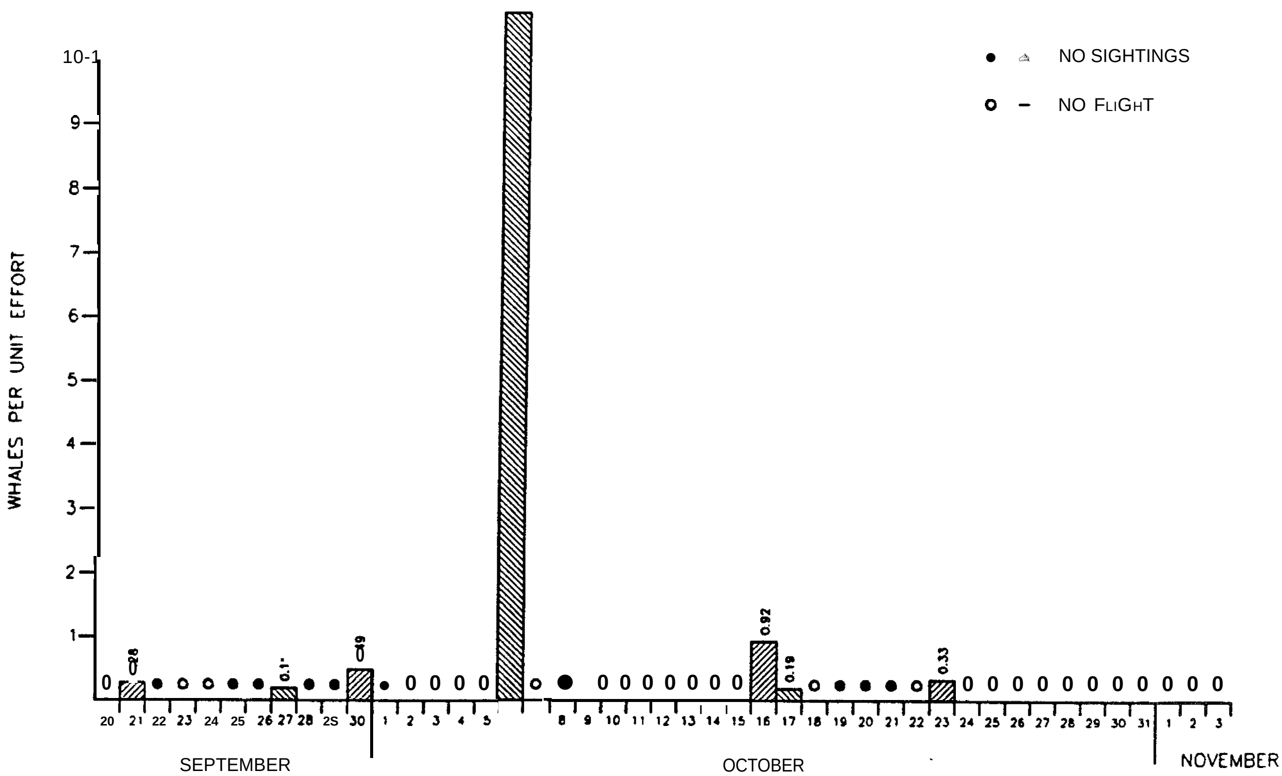
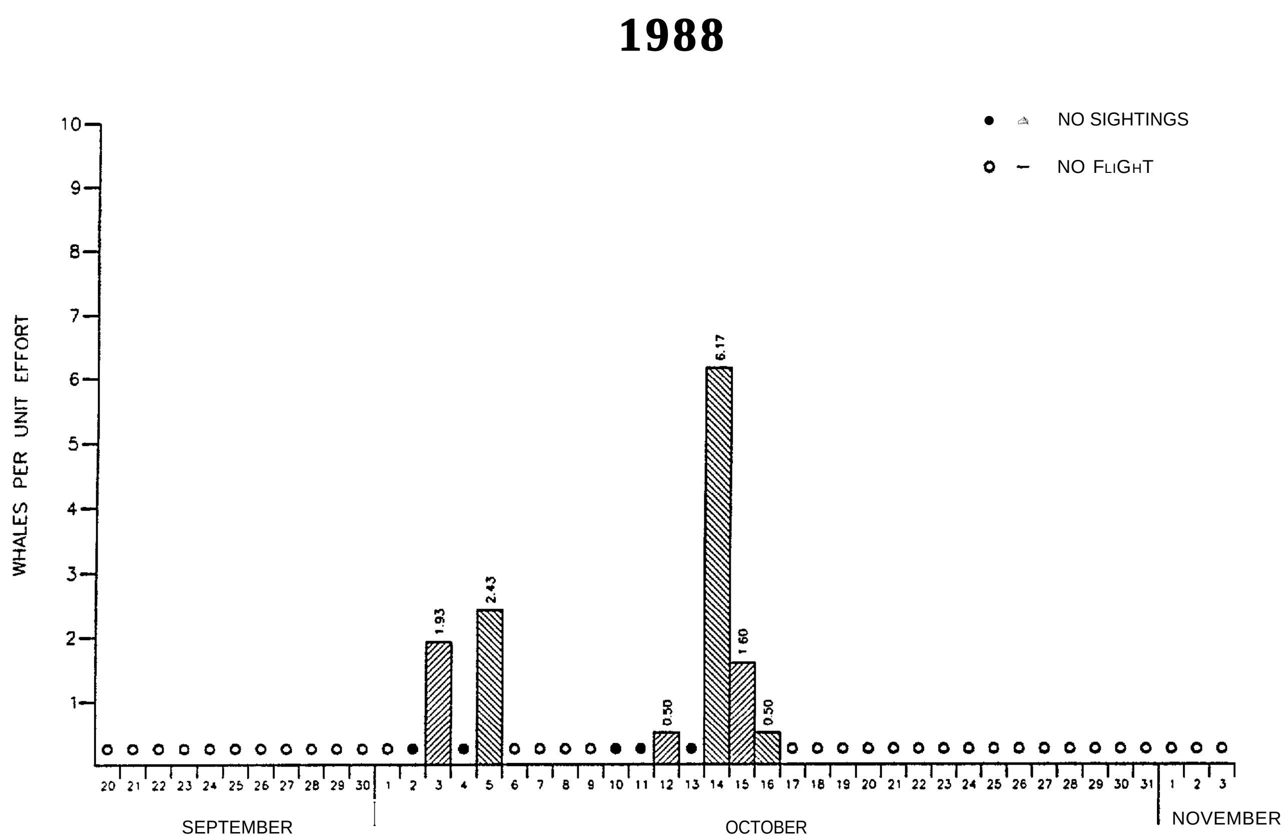


Figure 20 (contd).



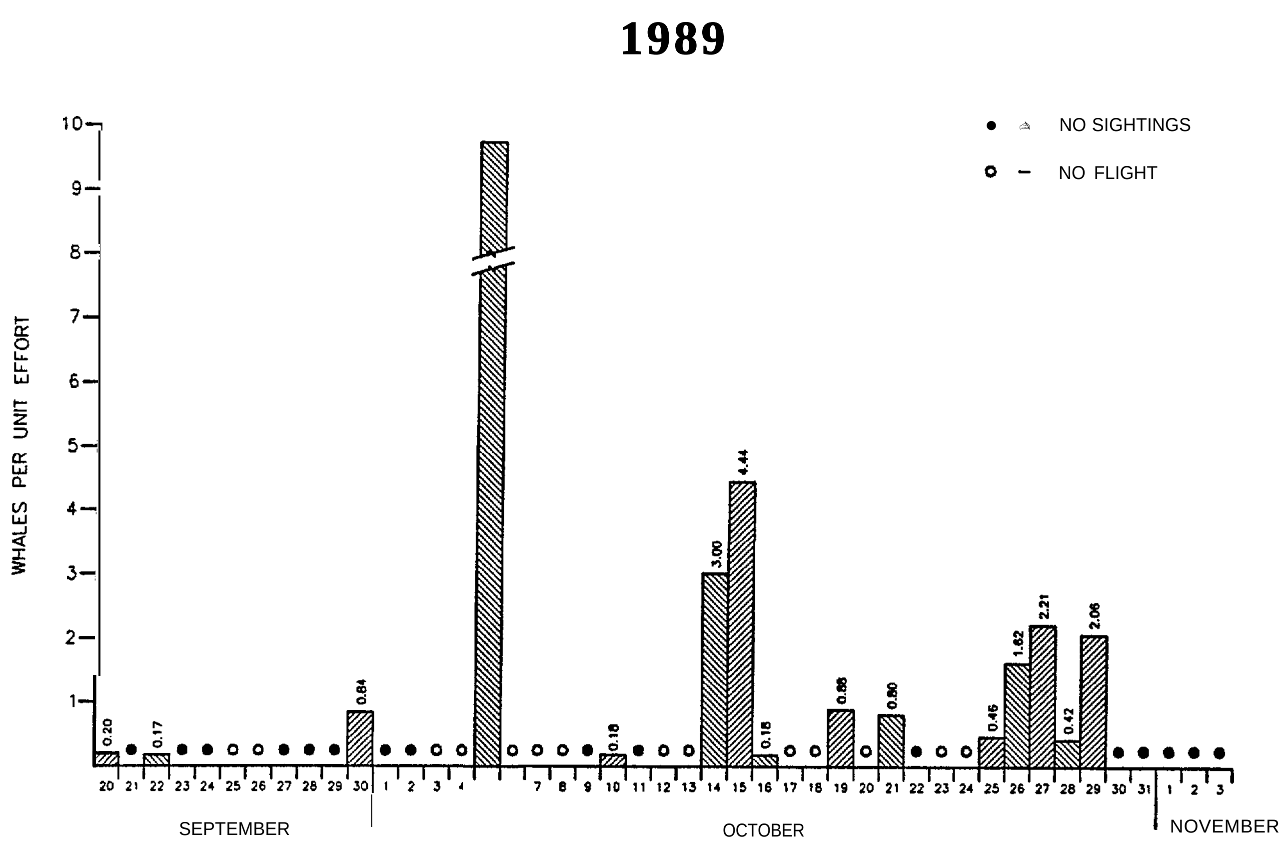


Figure 20 (contd).

Cumulative (1982-89) sighting rates were calculated separately for the western Beaufort and Alaskan Chukchi Seas (Fig. 21). Bowheads have been seen during MMS-funded aerial surveys in the western Beaufort Sea from 18 September through 26 October. Peak periods occur on 22-24 September, 5-6 October and 26 October, with a lesser peak in mid-October. In the Chukchi Sea, bowheads have been seen from 20 September to 29 October. Smaller peaks, coincident with those for the western Beaufort Sea, occur on 5 October, 14 October and 26-29 October. The oscillation in sighting rate at approximately 10-day intervals suggests that bowheads migrate through the study area in pulses, as has been described for the spring migration past Barrow and for the fall migration across the Alaskan Beaufort Sea (Braham et al. 1984; Ljungblad et al. 1986c). Peak sighting rates in the Beaufort Sea were seven to ten times greater than in the Chukchi Sea, principly due to the feeding aggregations seen northeast of Point Barrow, which positively skew WPUE indices as described in the previous section.

Often bowheads were seen on the first and/or last survey conducted in the study area, so beginning and ending dates on Figures 20 and 21 cannot be taken as the absolute time period that bowheads occur in the study area. In 1987, bowhead calls were detected via passive acoustic monitoring three days before the first bowhead sighting of the season (Moore et al. 1989). Although whales have been seen in the vicinity of Point Barrow as early as late July and mid-August (George and Carroll 1989), semi-monthly sighting rate peaked during the 1-15 October period in most years (Fig. 20 and Table 13) complementing the cumulative migration timing analysis represented by daily WPUE (Fig. 21). In contrast, sighting rate was highest for the 16-30 September period in 1983 and 1984. The migration across the Alaskan Beaufort Sea was somewhat earlier in 1983, a heavy-ice year, compared to years of lighter ice (Ljungblad et al. 1986c). This “earlier” movement likely contributed to the higher WPUE in the Chukchi study area for the late September time period that year. Surveys were not conducted in September 1988, so comparisons of WPUE between heavy-ice years cannot be made. The extremely high WPUE in late September 1984 was due to the large feeding aggregation seen east of Point Barrow that year (Ljungblad et al. 1986a). When these data are removed, WPUE in 1984 was highest during 1-15 October.

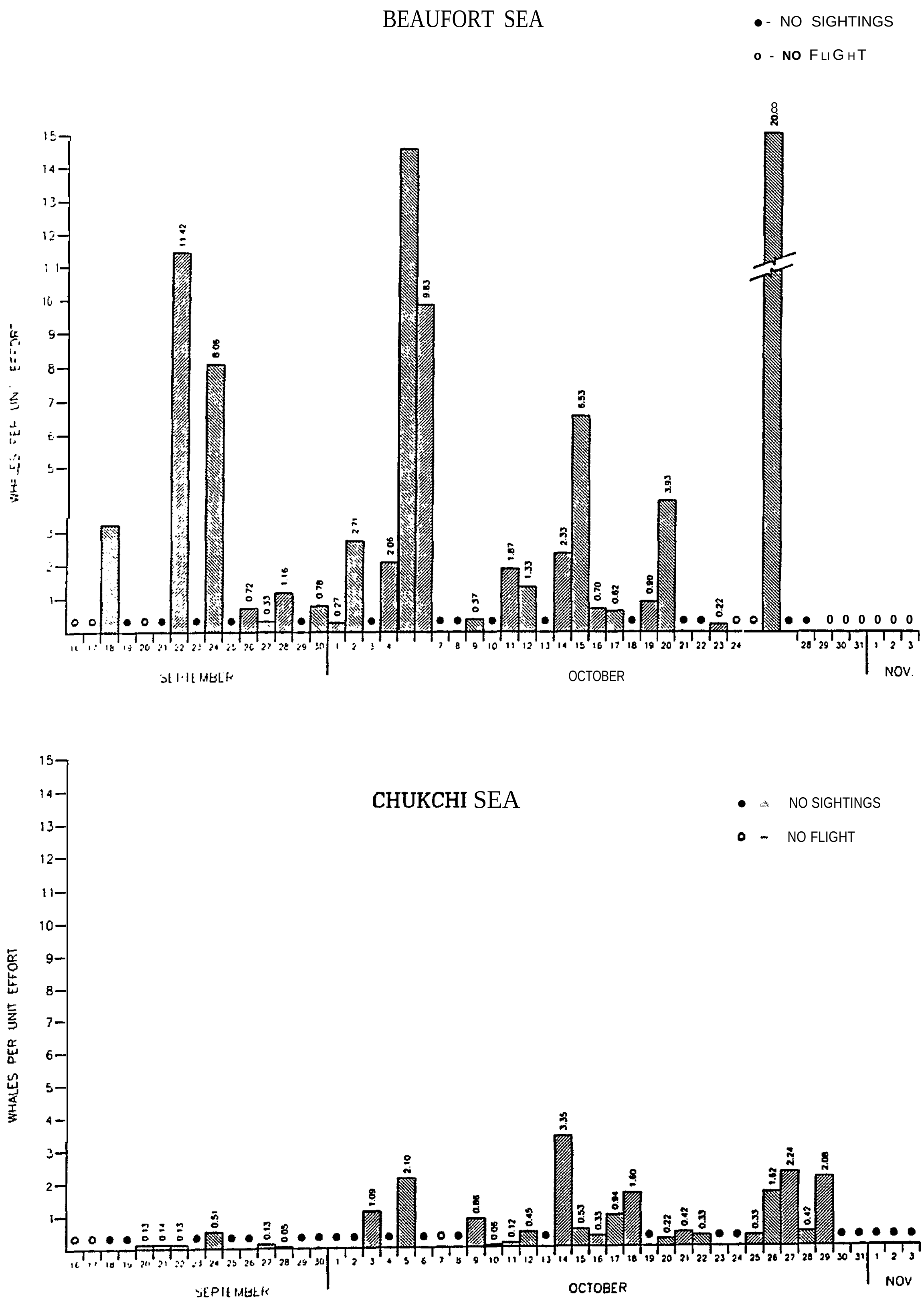


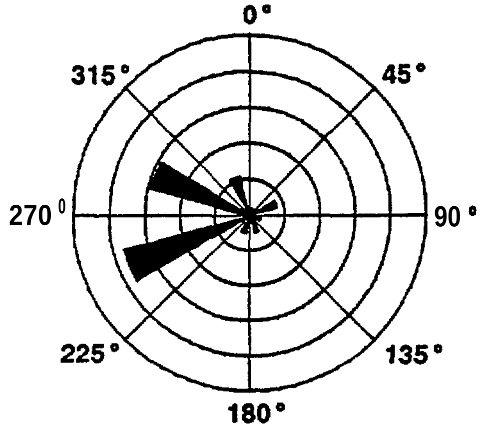
Figure 21. Cumulative (1982-89) bowhead whale daily sighting rate (WPUE) in the western Beaufort (survey block 12) and northeastern Chukchi Sea.

Bowhead whale swimming direction in the western Beaufort Sea was significantly clustered about 276 “T (p c 0.001, n = 93), while in the Chukchi Sea swimming direction was significantly clustered about 2470 T (p< 0.001, n = 61; Fig. 22). The strong statistical significance in both data sets implies that most bowheads approach Point Barrow on a westerly course then turn and swim southwest after passing the point. The whales seen north of 720 N latitude in 1989 were incorporated in the overall swimming analysis. Individually, however, these whales exhibited swimming in all directions except east (see earlier Migration Timing and Route section), with an average heading of 2830 T. When swimming direction for the whale seen in 1987 was added (only other datum), average swimming direction for whales seen north of720 N (n =5) was 261 “T.

A primary task of this study is to define the bowhead fall migration route across the Chukchi Sea and to determine if the route is affected by OCS oil and gas development activities. A two-fold approach to this task has been taken; the first is descriptive and the second analytical. A plot of random bowhead sightings (n= 55) west of Point Barrow (Fig. 23) reveals the same general pattern of distribution as that for all whales (see Fig. 19), Only random sightings west of Point Barrow (ca. 156 °30'W) can be used to statistically test for differences in migration route between years, however, so it is this smaller data set that is analyzed to describe the Chukchi Sea migration route.

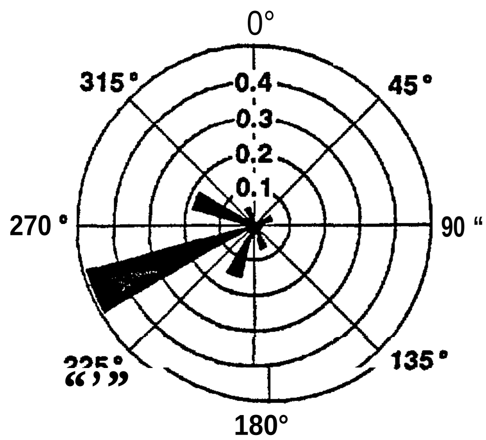
The distribution pattern of random bowhead sightings is roughly similar to patterns of current flow in the northeastern Chukchi Sea (Fig. 24). Two principal water masses enter the Chukchi Sea through the Bering Strait (Aagaard 1987), the saline Bering Sea water (BSW) and the low-salinity Alaskan coastal water (ACW). The inflow of the two water masses diverges near the latitude of Point Hope (Fig. 24A). Both flow northward along bathymetrically guided routes, the ACW to the northeast along the Alaskan coast, and the BSW through Herald Canyon in the central Chukchi Sea, west of the study area. Filaments of the ACW branch off the main coastal flow at three locations: west of Point Lay (ca. 69 °30'N, 167 “W); west of Peard Bay@ 71” N, 1620 W); and northwest of Point Barrow (71 °30'N, 157 °30'W). It is this pattern of branching that bowhead whale distribution seems to roughly follow (Fig 24B).

Beaufort Sea
n=93



a = 276°T, r = 0.57
z = 30.15, p c 0.001

Chukchi Sea
n=61



a = 247°T, r = 0.7(3
z = 30.09, p <0.001

Figure 22. Cumulative (1982-89) bowhead whale swimming direction in the western Beaufort and northeastern Chukchi Sea. a = vector mean; r = vector length; z = statistic

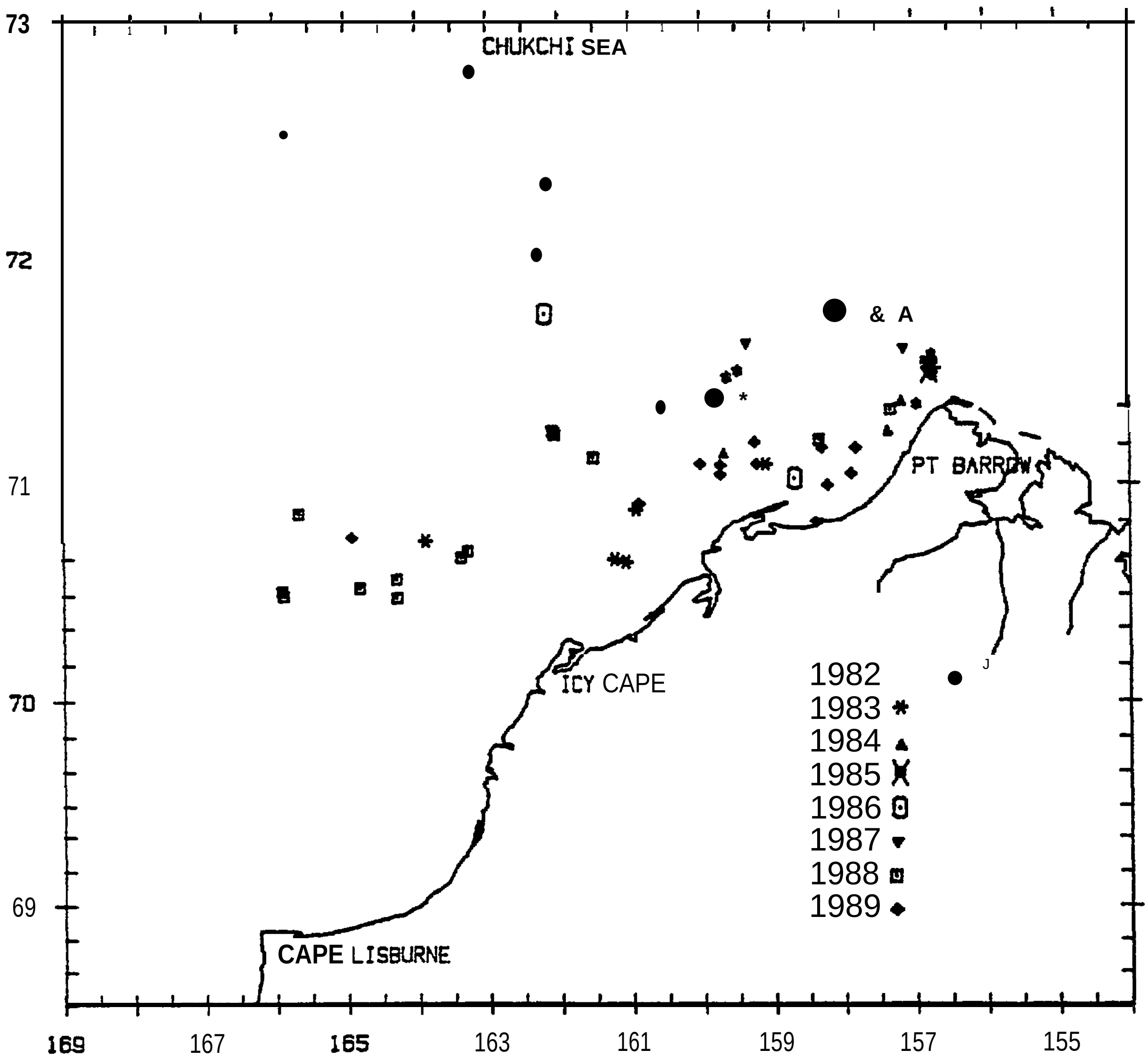


Figure 23. Distribution of 55 sightings of 77 bowhead whales seen on random transects west of Point Barrow (156" 30'W), 1982-89.

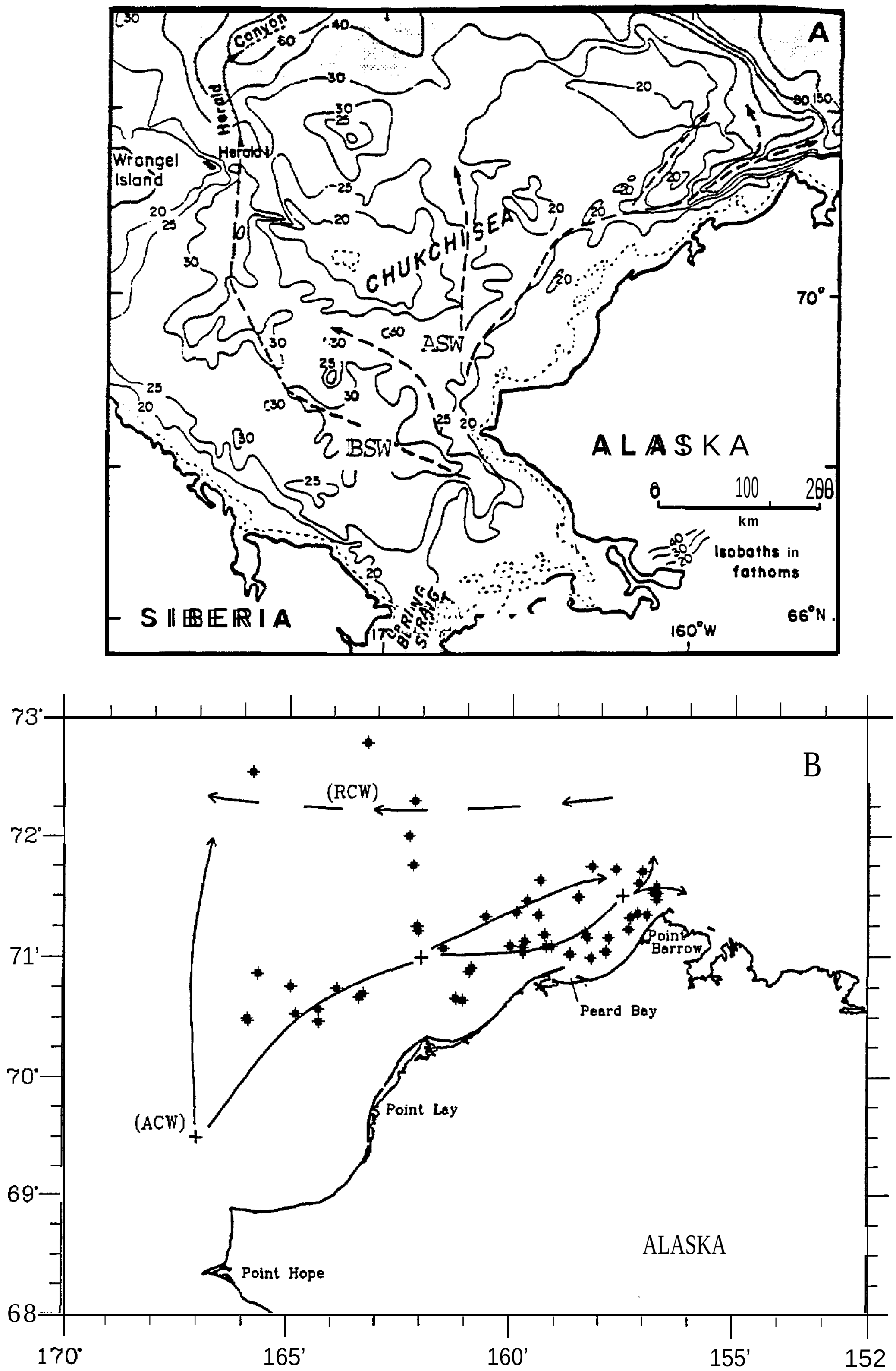


Figure 24. Chukchi Sea bathymetry (in fathoms) and major currents (arrows) (from Bourke 1983) (A); and cumulative (1982-89) random bowhead sightings west of Point Barrow (156°30'W) with major northeastern Chukchi Sea currents (B). [+ = branching points for ACW; +- ← = approximate location of RCW]

Although the suggestion that current patterns may influence the bowhead fall migration is generally supported by the distribution pattern, it was not borne out by statistical analyses of depth at random bowhead sightings. As mentioned in the earlier Habitat Relationships section of this report, the Chukchi Sea is a relatively uniform shallow basin, with the major relief provided by Herald Shoal, Hanna Shoal, Long Strait and Herald Canyon. Shoal areas typically have water depths <37 m (20 fathoms), with the major currents channeled in the relatively deeper troughs (237 m) around them. Random sightings of bowhead whales following the path of current flow would be expected to occur more often in water ≥37 m deep. The proportion of random bowhead sightings in water ≥37 m (88%, n =68) from 1982-89 was not significantly different from the proportion of available ≥37 m depth habitat (86%; $X^2 = 0.81$, $p<0.25$). Thus bowheads were seen in expected proportions in waters overlying shoals and troughs that direct currents. However, small sample size coupled with annual variability in current flow (Aagaard 1987) may obscure the relationship suggested in Fig. 24.

Current patterns may indirectly affect bowhead migratory route by creating interfaces, or fronts, where whale prey may become concentrated (Fissel et al. 1987). Fronts, formed where differing water masses abut, can occur over spatial scales as small as tens of meters and are often the sites of intense biological activity (Bowman and Esaias 1978; Parsons et al. 1977). Further, potentially high nutrient levels can occur when two currents meet and diverge, causing upwelling. The convergence of oceanic fronts and eddies has been hypothesized to be good baleen whale feeding grounds (Nasu 1974; Gaskin 1982). Specifically, bowhead whales appear to rely on finding relatively dense patches of prey associated with water mass boundaries, at least in the eastern Beaufort Sea (Richardson 1987). Bowheads continue to feed in fall as they migrate west across the Beaufort Sea, with one record of feeding in the Chukchi Sea west of Barrow in September 1983 (Ljungblad et al. 1986c). Migrating along a route where oceanographic fronts are expected may provide bowheads with feeding opportunities throughout the fall.

The location of oceanic fronts, like the ice edge, varies annually in the Chukchi Sea (Paquette and Bourke 1981). The inflow of relatively warm southern water through the Bering Strait directly influences the irregular contour of the ice edge. Embayments in the ice edge tend to occur in the same places year after year over relatively deeper-water troughs in the sea floor, for example near 167°W (Bourke 1983). The resident Chukchi water (RCW), that remains on the shelf from the previous winter, is associated with the ice edge. A sharply-defined surface boundary is formed roughly parallel to the ice edge where ACW meets RCW (Bourke 1983). Fronts do not always coincide exactly with the ice edge, however, because wind-driven ice moves faster than the fronts and can overlie or drift some distance away (≤1 O km) from the front. At the core of the ACW intrusion, warm southern water often flows strongly enough to penetrate far into the ice edge, with filaments of the warm water flow measured in October as far north as 730 N north of the Bering Strait and to 72°30'N north of Point Barrow (Ahlnas and Garrison 1984).

Current flow and ice conditions throughout the Chukchi Sea appears to vary greatly with wind conditions (Aagaard 1987; Muench et al. 1991). Although the underlying cause for the northward flow through the Bering Strait is the higher sea level in the North Pacific relative to the Arctic Ocean, major differences in flow rate are driven atmospherically with summer transport about 50% greater than during the winter (Aagaard 1987). Mean monthly flow rates in September and October are nearly identical to those in April and May, which are only about half that of peak inflow in July. Therefore, bowheads would not be swimming against a strong current inflow in fall. If the bowhead migration route is, in part, current-associated, annual variability in atmospheric conditions may lead to variability in migratory route.

Migration route was analytically defined for each year by fitting lines to random sighting data (Fig. 25), using the method of least squares (Zar 1984). Lines could be fit only for years with three or more random sightings, therefore 1985 (n = 1), 1986 (n= 2) and 1987 (n= 2) were excluded from the analysis. Two lines were fit to the 1989 data, one for random sightings south of 72° N latitude (1989s; n = 12) and the second for sightings north of720 N latitude (1989n; n= 4), to reflect the aforementioned bifurcation in distribution. All but the line fit to 1989(n) indicate a migration route directed southwest from Point Barrow, as in the analysis of swimming direction (see Fig. 22). The line fit to the 1989(n) data was northwest-directed, as was mean swimming direction (n= 283" T) for that small sample.

Comparison of route among years was accomplished by multiple regression analysis of line slopes (Fig. 26). Although regression results indicated significant

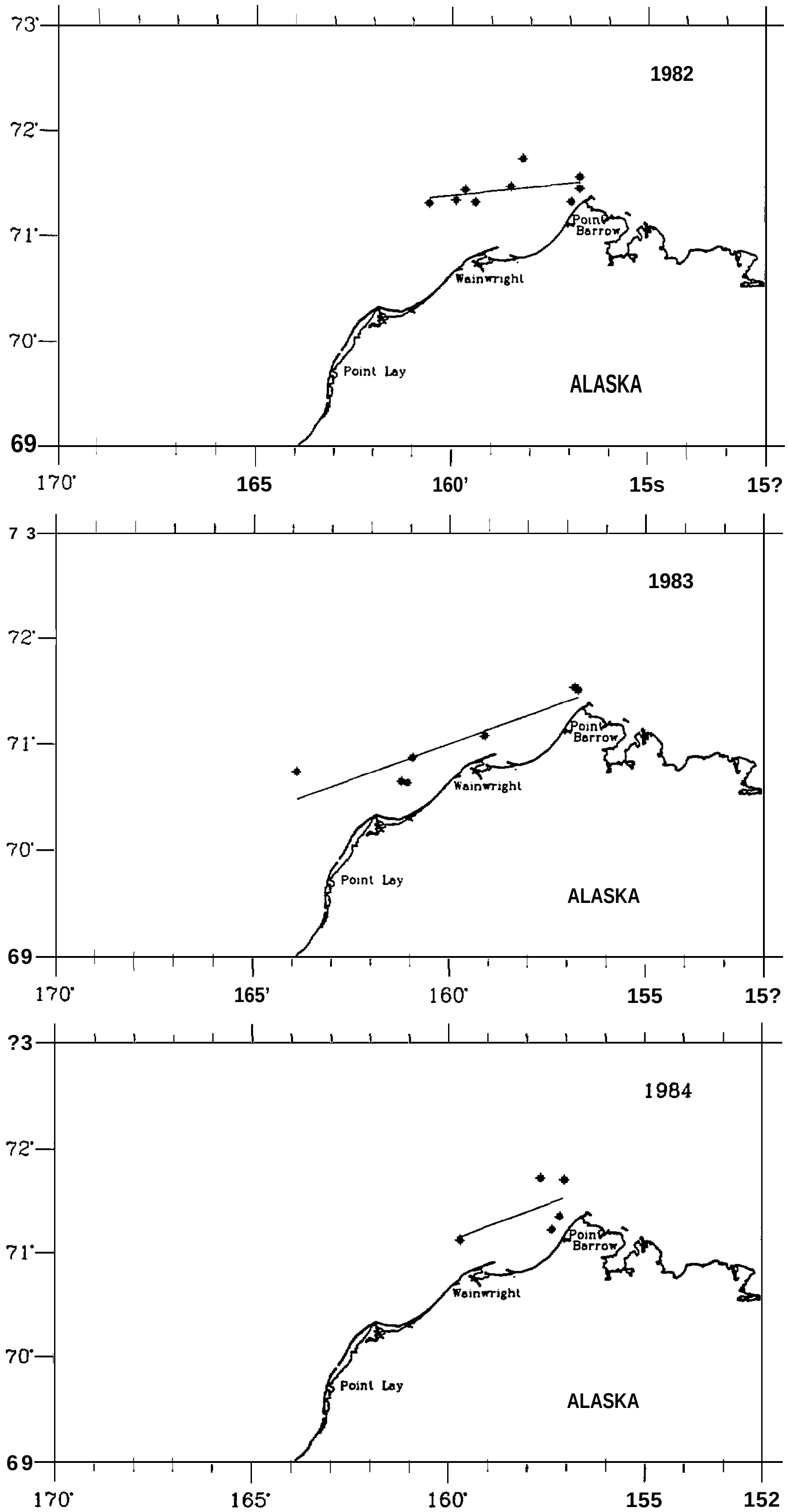


Figure 25. Random bowhead whale sightings west of Point Barrow(156030'W), with best-fit lines depicting migration route for years 1982-1984, 1988-1989 and cumulative (1982-89).

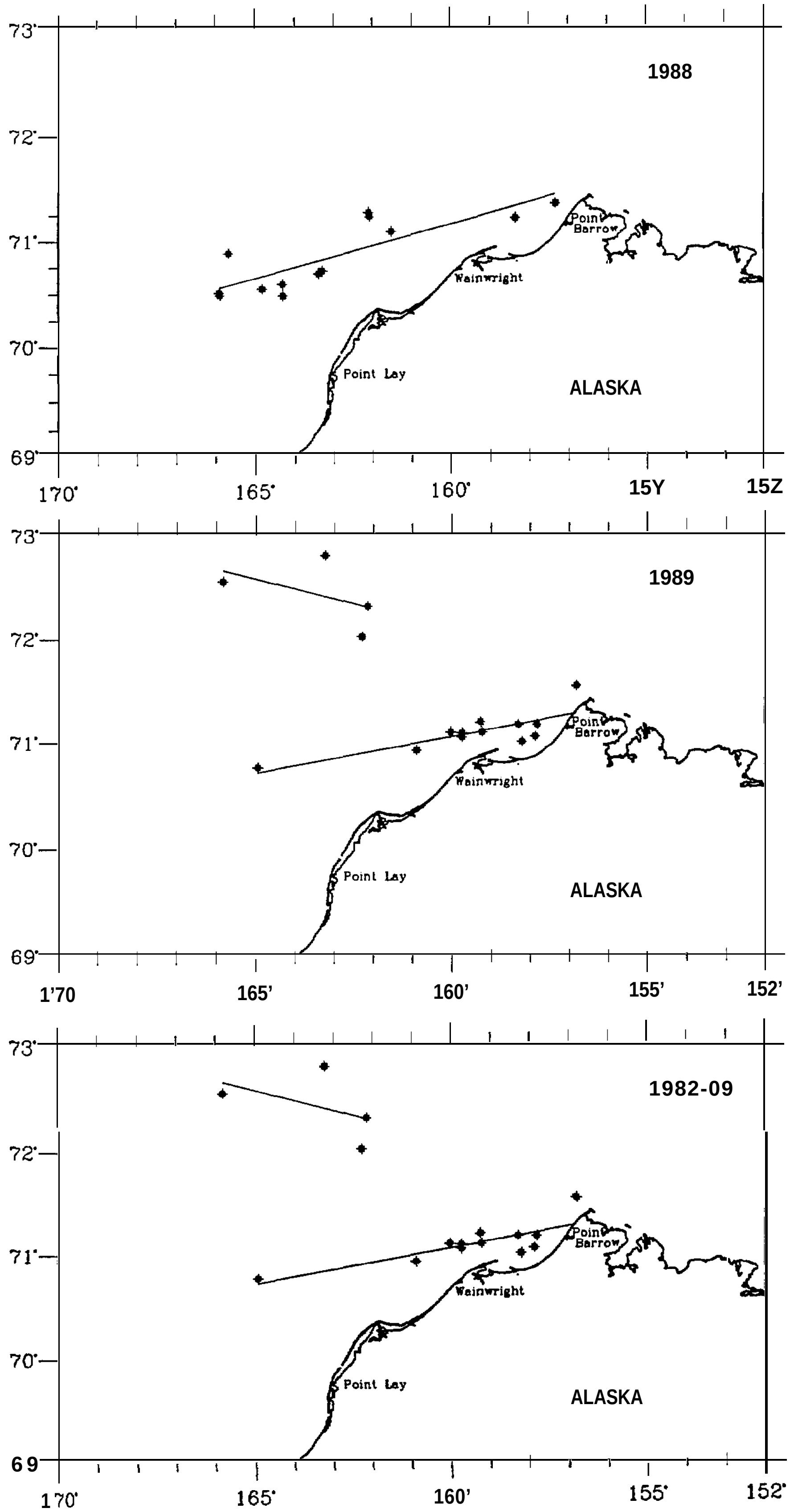


Figure 25 contd.

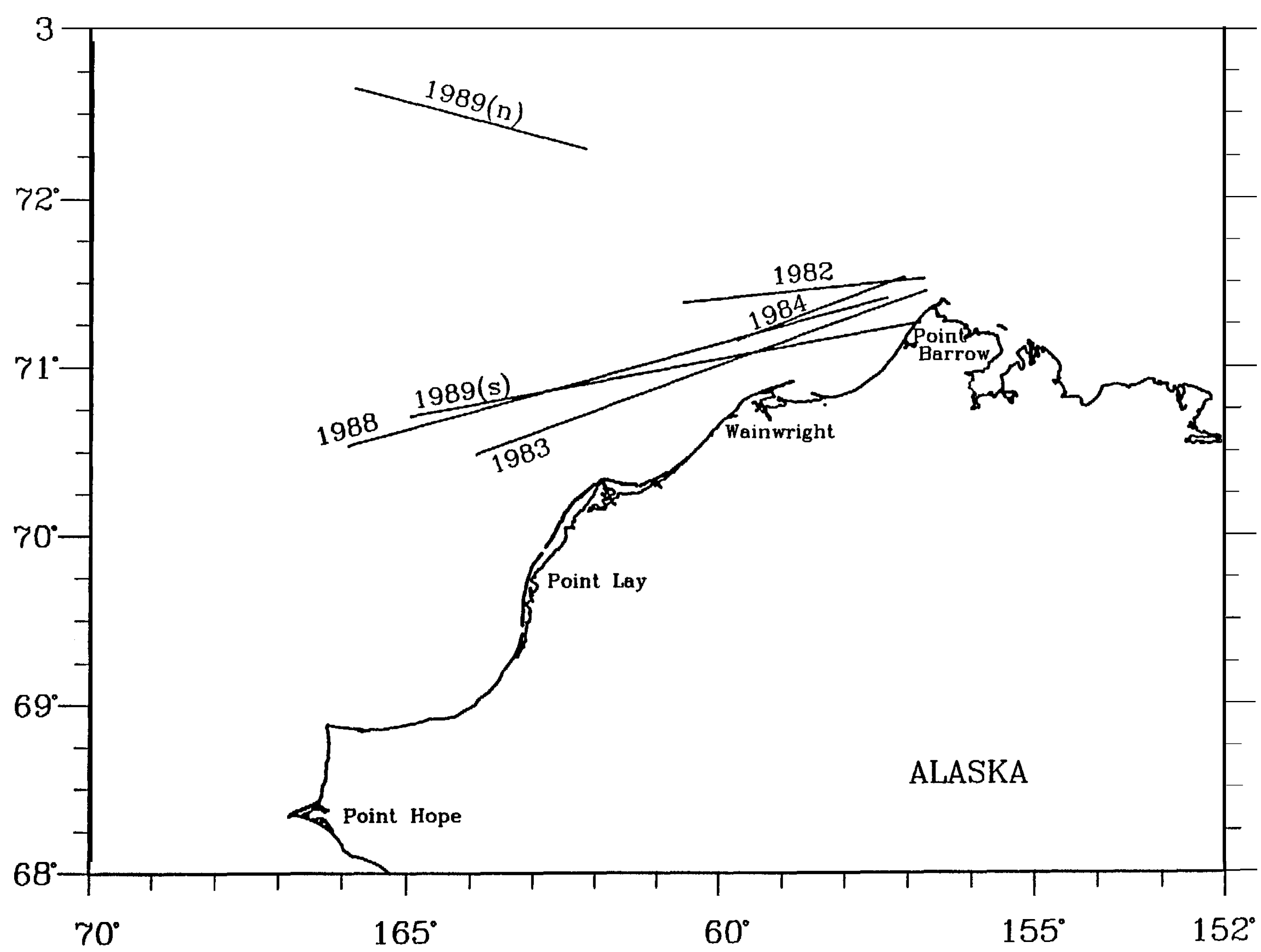


Figure 26. Lines representing bowhead whale annual migration routes for 1982-1984 and 1988 989 Lines were by methods of least squares (see Fig. 25).

differences among lines ($F=2.72$, $p <0.05$), there was no significant difference in migratory route, as defined by fitted lines, between any pair of years (Tukey $0.101 \leq q \leq 2.233$, p c 0,50). There was a trend for the line fit to 1989(n) to be different from all other years (Tukey $1.534 \leq q \leq 2.233$). Lack of significant differences between 1989(n) and all other lines was likely due to small sample size (n =4). Tukey "q" values are derived by placing differences in slope over standard error (SE) which is derived from analysis of variance. Small sample size dampens variation (Zar 1984). Braham et al. (1984) suggested that bowheads migrate across the Chukchi Sea along a northerly route to Herald and Wrangel Islands, then south along the Chukotka coast to the Bering Sea. Additional data from subsequent years may augment the northern sample and thereby clarify the question of a bifurcated migration route.

Behavior and Calf Sightings

Observed behaviors in the Chukchi Sea study area were nearly equally divided between migratory (44%, n =215) and social (56%, n =279) behaviors (Fig. 27). Swimming was recorded most often (42%, n= 205), with feeding (38%, n =187) the activity next most common. The proportion of feeding and milling whales was strongly influenced by the bowhead aggregations seen near Point Barrow in 1984 and 1989. Little feeding activity was seen in the study area in other years. Nine bowheads were seen feeding in block 13 in 1983 and three whales were observed feeding north of Smith Bay in 1987.

Waters near Point Barrow may be inconsistent in annual productivity, a possible explanation of the intermittent observations of bowheads feeding there. Prior to 1989, bowhead feeding aggregations were seen east of Point Barrow in 1984, 1978, 1976, and Durham (1979) reported that Eskimo whalers occasionally saw groups of 50 to 60 whales near Point Barrow in the fall, as summarized in Ljungblad et al. (1986a). The Point Barrow area incorporates a topographic promontory, an oceanic front or eddy, a steep shelf break (i.e. Barrow Canyon) and the convergence of ACW with the Beaufort Sea gyre (Soloman and Ahlnas 1980). These oceanic features may create conditions in some years that support relatively high euphausid densities, the principal prey found in stomachs of bowheads taken near Barrow in fall (Lowry and Frost 1984). An attempt to sample prey near feeding bowheads was made in late October 1989 (C. George, pers.

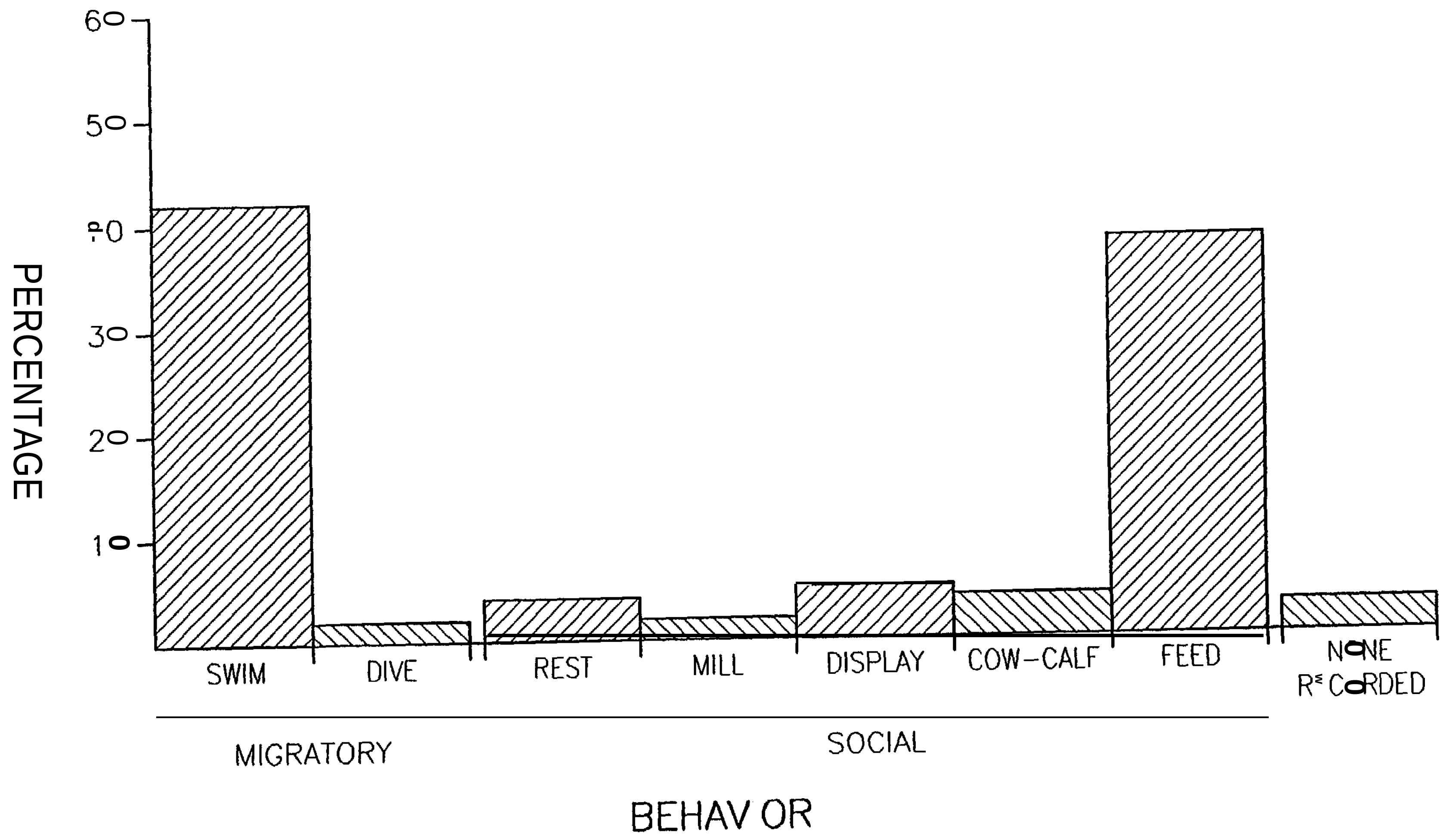


Figure 27. Summary of bowhead whale behavior, 1982-89.

comm.), supported by industry and the North Slope Borough. Unfortunately, very poor diving conditions made sampling nearly impossible and useful data were not obtained.

There were nine sightings of ten bowhead calves in the Chukchi Sea study area since 1982 (Fig. 28). Calf distribution was similar to that for all whales (see Fig. 19), with the exception of no calf sightings far to the north. No calves were seen in 1982, 1985 and 1987; sightings in other years ranged from one to four.

All bowhead calves have been seen in October, with no significant difference in CPUE indices between the first and second half of the month (Table 14). These results are similar to those summarized by Clarke et al. (1987) for bowhead calf spatial and temporal distribution in the Alaskan Beaufort Sea. No clear segregation was found in either geographic or temporal occurrence for four years (1982-85) of calf sighting data in the Alaskan Beaufort Sea. Annual variability in calf number or distribution may obscure spatial and/or temporal segregation (Nerini et al. 1984). Segregation of cow-calf pairs has been documented during the spring migration past Point Barrow (Rugh 1990), and for at least one year on the summer feeding grounds in the Canadian Beaufort Sea (Cubbage and Calambokidis 1987). Further, Eskimo whalers at Kaktovik, Alaska state that cows with calves pass Barter Island later in the season than other whales (Braham et al. 1984). This tendency for cows with calves to occur later in the fall migration is supported by the lack of September calf sightings in the study area.

Habitat Relationships

Bowheads were seen most often (63%, n = 316) in shallow (c 50 m deep) water east of Point Barrow (Table 15). Only 7% (n= 37) of all sightings occurred in transitional water (> 50 m) in the western Beaufort Sea. Feeding bowheads are commonly seen in significantly shallower water than non-feeding whales (Ljungblad et al. 1986a). The association of bowheads with shallow water in the western Beaufort Sea coincides with the aforementioned aggregations of whales seen feeding there. Sightings in the Chukchi Sea were nearly equally divided between whales seen in shallow water (19%, n = 95) and transitional water (1 1%, n = 53; Table 15).

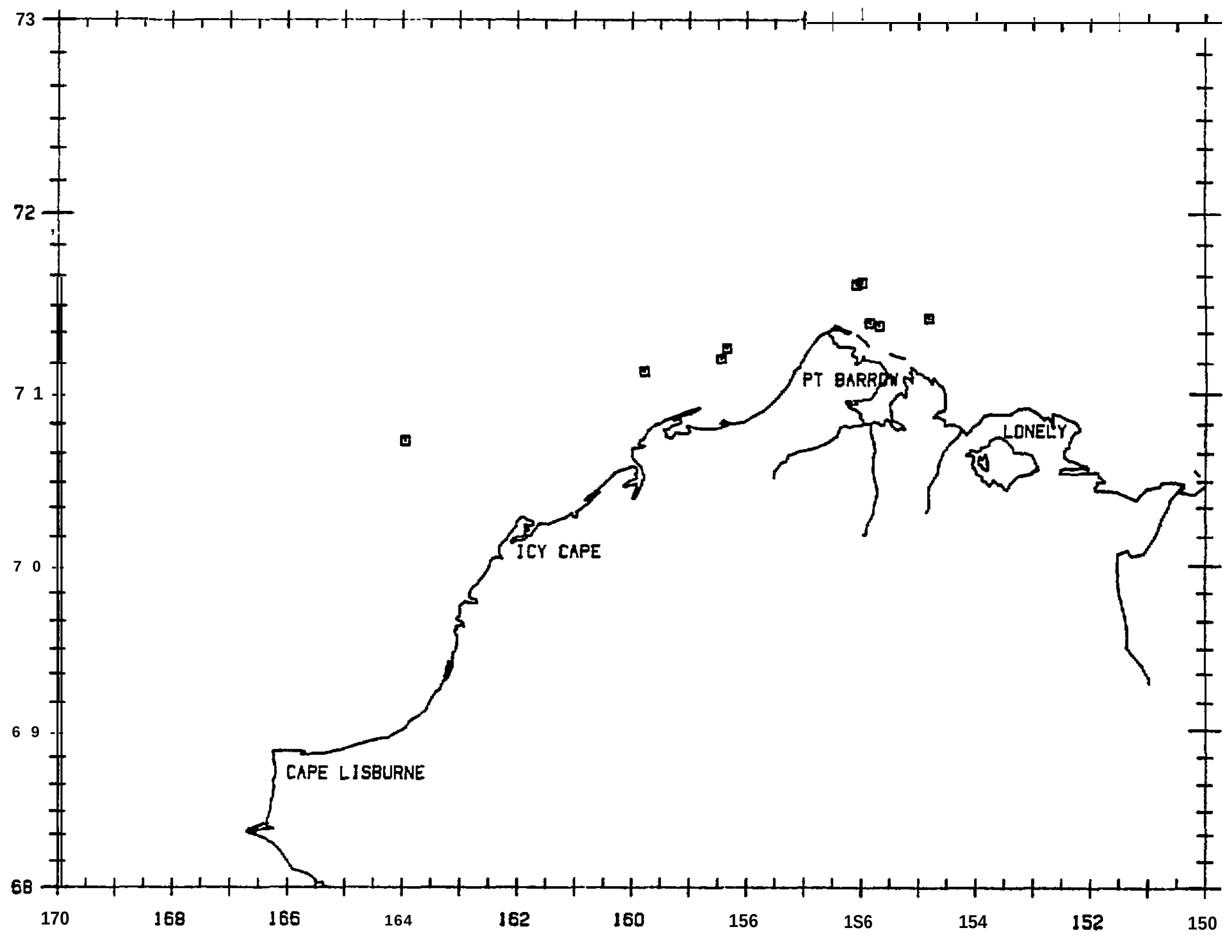


Figure 28. Distribution of nine sightings of 10 bowhead calves, 1982-89.

Bowheads were seen most often (68%, n=340) in open water or very light (< 10%) ice cover (Table 16). Overall, only 24% (n= 121) of all whales were seen in ice cover > 70%. Whales were seen in heavy ice mostly in 1982, 1983 and 1988. In general, bowhead were seen each year in whatever ice cover predominated during the latter part of September and October when most surveys were conducted, as reported in past years (Ljungblad et al. 1988). Changes in study area boundaries can affect inferences regarding the use of particular habitat by wildlife (Porter and Church 1987). Inferences regarding the use of particular ice habitat by bowhead whales may also be affected by the annual variability of the habitat within the study area and by the timing of the survey season.

Table 14. Semi-monthly summary of calves per unit effort (CPUE = no. calves/survey hour) in the study area, 1982-89.

	1-15 October No. (CPUE)	16-30 October No. (CPUE)	Total No. (CPUE)
1982	o	o	o
1983	0	1 (0.06)	1 (0.02)
1984	1 (0.08)	1 (0.09)	2 (0.05)
1985	o	o	o
1986	2 (0.06)	0	2 (0,03)
1987	o	0	o
1988	1 (0.02)	0	1 (0.02)
1989	3 (0.10)	1 (0.02)	4 (0.03)
Total	7 (0.03)	3 (0.02)	10 (0.02)

Table 15. Number and percent of bowhead whales in shallow and transitional water depths in the study area, 1982-89.

	W. Beaufort Sea			Chukchi Sea		
Year	Shallow (0-50m)	Transitional (>50m)	Range (m)	Shallow (0-50m)	Transitional (> 50m)	Range (m)
1982 (n=30)	12 (40)	5 (17)	7-210	3 (lo)	10 (33)	18-59
1983 (n =50)	19 (38)	7 (14)	7-199	10 (20)	14 (28)	29-97
1984 (n= 192)	175 (92)	10 (5)	7-221	3 (1)	4 (2)	38-91
1985 (n=10)	4 (40)	3 (30)	13-144	3 (30)	o (-)	27-38
1986 (n=15)	7 (47)	4 (27)	9-181	4 (27)	0 (-)	20-42
1987 (n =32)	25 (78)	4 (12)	9-181	0 (-)	3 (9)	51-75
1988 (n =55)	0 (-)	3 (2)	134	45 (82)	7 (16)	33-91
1989 (n=117)	74 (63)	1 (1)	9-144	27 {23)	15 (13)	18-101
Total (n=501)	316 (63)	37 (7)	7-221	95 (19)	53 (11)	18-101

Table 16. **Number and percent of bowhead whales in each ice cover class in the study area, 1982-89.**

Ice Cover Class	1982 No.(%)	1983 No.(%)	1984 No.(%)	1985 No.(%)	1986 No.(%)	1987 No.(%)	1988 No.(%)	1989 No.(%)	Total No.(%)
0-10	9 (30)	17 (34)	168 (88)	10 (100)	12 (80)	31 (97)	3 (5)	90 (77)	340 (68)
11-20	0	0	0	0	0	0	0	1 (1)	1 (<1)
21-30	0	0	1 (1)	0	0	0	0	0	1 (<1)
31-40	0	3 (6)	5 (2)	0	0	0	0	0	8 (1)
41-50	2 (7)	0	7 (4)	0	2 (13)	0	0	1 (1)	12 (2)
51-60	0	0	2 (1)	0	0	0	1 (2)	0	3 (<1)
61-70	4 (13)	11 (22)	0	0	0	0	0	0	15 (3)
71-80	7 (23)	8 (16)	0	0	1 (7)	1 (3)	18 (33)	7 (6)	42 (8)
81-90	7 (23)	11 (22)	2 (1)	0	0	0	10 (18)	3 (2)	33 (7)
91-99	1 (4)	0	7 (4)	0	0	0	23 (42)	15 (13)	46 (9)
Total	30	50	192	10	15	32	55	117	501

Gray Whale
Patterns of Distribution and Abundance

There were 147 sightings of 397 gray whales over seven survey seasons (1982-84, 86-89), with no sightings in 1985. The only three gray whales seen in 1988 were trapped in heavy ice north of Point Barrow (Carroll et al. 1989). Gray whales were also seen immediately south of the study area in November 1980 (Clarke and Moore 1990). Gray whale distribution and abundance data for July, August and early September 1982-87 were reviewed in Clarke et al. (1989), and are discussed here as appropriate.

The distribution of gray whales in late September (42 sightings of 166 whales) was primarily nearshore between Point Barrow and Point Franklin (approx. 70” 55'N, 1550 W), with two distinct offshore groups in the northeastern Chukchi Sea, and a cluster of sightings near Point Hope (Fig. 29). The distribution in early October (51 sightings of 96 whales) was more widespread, with sightings along much of the northwestern Alaskan coast between Point Barrow and Point Hope, as well as offshore to 225 km. In late October, gray whales (44 sightings of 135 whales) were seen nearshore between Point Barrow and Point Franklin and in the south-central Chukchi Sea. Gray whales were seen in the southernmost Chukchi Sea and northern Bering Sea, between the Bering Strait and St. Lawrence Island, in October and November 1980 (Clarke and Moore 1990).

Gray whale distribution in offshore areas of the northcentral Chukchi Sea appears to be related to the presence of shoals in those areas, and is probably strongly influenced by prey availability. Gray whales have been found offshore near Hanna Shoal (see Fig. 24) each year (1986, 1987, 1989) that substantial survey effort was allocated to the region, with the exception of 1988. Notably, 1988 was a year of extremely heavy ice cover, which may have affected prey availability or gray whale access to the area. The distribution of gray whales in offshore areas of the northcentral Chukchi Sea may also be a response to recent increases in population size causing the whales to expand their habitat to areas previously unoccupied, a theory proposed for variation in distribution in the Soviet Chukchi Sea (Berzin 1984; Miller et al. 1985).

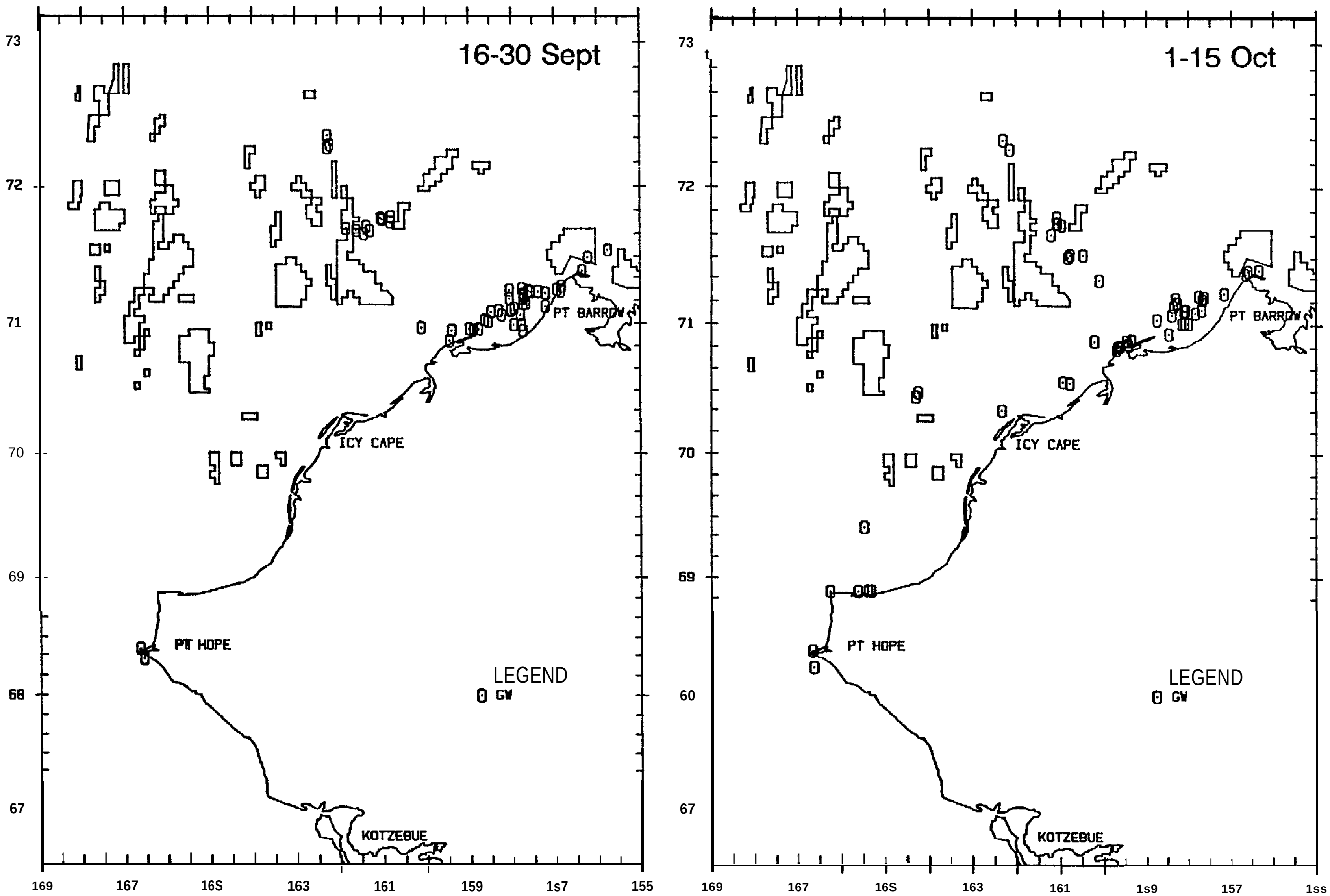


Figure 29. Cumulative (1982-89) gray whale distribution relative to OCS lease areas depicting 42 sightings of 166 whales, 16-30 September;51 sightings of 96 whales, 1-15 October;

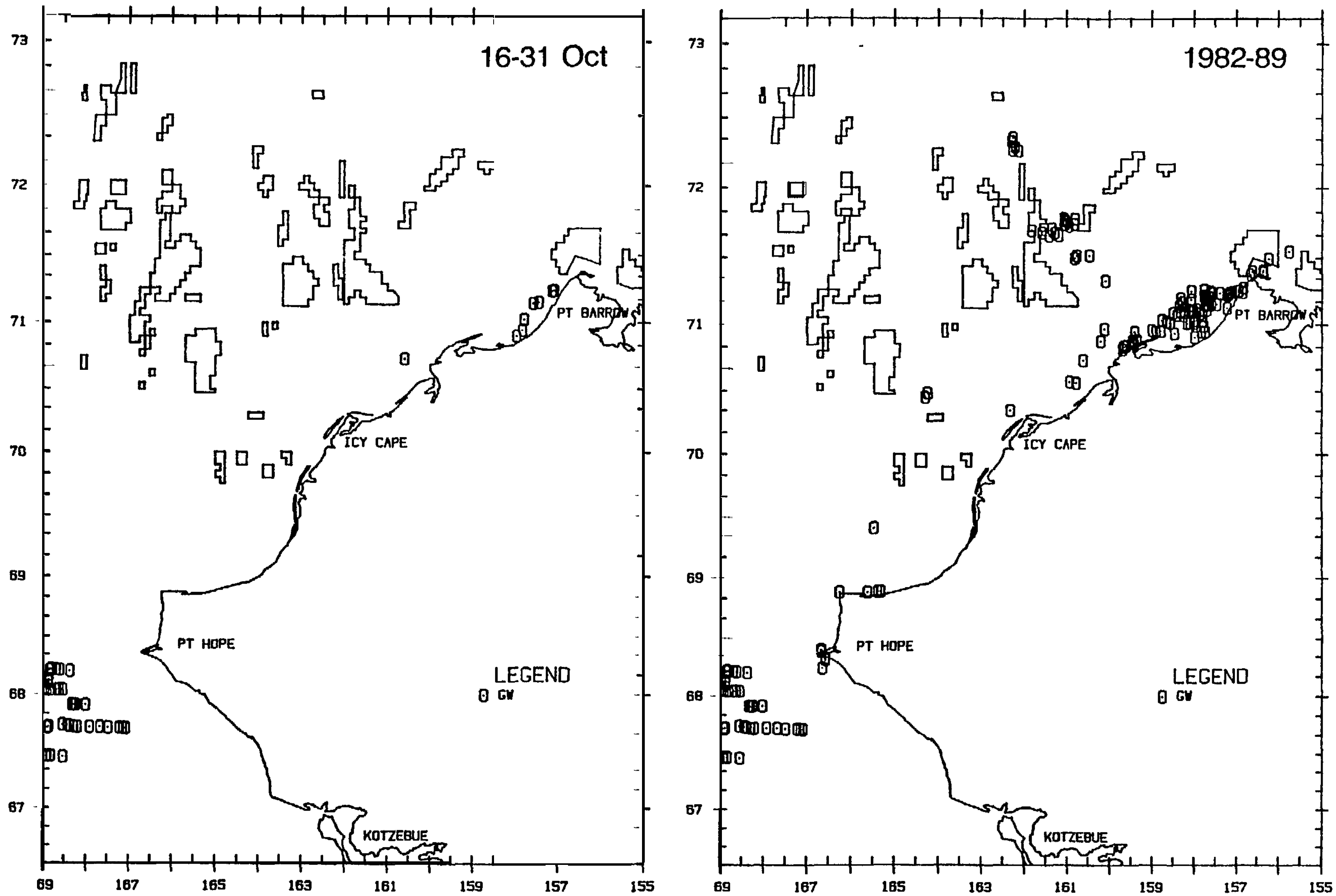


Figure 29 (contd). 44 sightings of 55 whales, 16-31 October; and 147 sightings of 397 whales.

As mentioned earlier, survey effort in the study area in fall has varied annually since 1980 (see Table 12), which undoubtedly affected the observed gray whale distribution. The overall distribution highlights the importance of nearshore waters between Point Barrow and Point Franklin and offshore areas, especially those near Hanna Shoal. The distribution of gray whales overlapped, and was east of, some OCS lease areas in the northeastern Chukchi Sea. Gray whales swimming to or from the offshore areas undoubtedly pass through several OCS areas offered for lease.

The highest gray whale relative abundance in the Chukchi Sea was calculated for blocks 23 (WPUE= 15.51) and 22 (WPUE=6.13), with lesser indices calculated for blocks 13 (WPUE = 1.43) and 14N (WPUE= 1.33) (Table 17). Semi-monthly WPUE values were highest in blocks 22 (WPUE=3.18) and 13 (WPUE=2.94) in late September, block 22 (WPUE=2.17) in early October, and blocks 23 (WPUE=22.81) and 22 (WPUE = 10.34) in late October. Overall relative abundance was higher in late September (WPUE = 1.13) than in early October (WPUE = 0.44). The somewhat higher overall relative abundance in late October (WPUE = 0.97) was strongly influenced by the aggregation of feeding whales seen in blocks 22 and 23 in 1989.

Relative abundance in all northern blocks (12, 13,14, 14N) decreased substantially in late October, and increased in southern blocks (22, 23). These temporal changes in abundance indices suggest that gray whales probably begin their fall migration from Chukchi feeding grounds by mid-October. Comparisons of bowhead and gray whale abundance indices indicated that the majority of gray whales appeared to have migrated out of the northern Chukchi Sea by October as bowheads began migrating into the area (Moore et al. 1986a). In addition, monthly gray whale abundance in the northern Bering Sea was higher in August, October and November than that in the southern Chukchi Sea (Clarke and Moore 1990).

Migration Timing and Route

Gray whales have been observed in the northeastern and northcentral Chukchi Sea from July through October (Clarke et al. 1989). Maher (1960) reported that gray whales were seen nearshore between Barrow and Icy Cape by late June or early July, and were

Table 17. Gray whale relative abundance (WPUE = no. whales/survey hour) by survey Mock, 1982-89.

1982

	16-30 Sept			1-15 Ott			16-31 Ott			1-15 Nov			Total		
Block	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE
12	4.58	0	0	5.85	0	0	2.17	0	0	0.00	-	-	12.60	0	0
12N	0.00	-	-	0.07	0	0	0.08	0	0	0.00	-	-	0.15	0	-
13	1.49	18	12.08	3.58	3	0.84	0.76	0	0	0.00	-	-	5.83	21	3.60
14	0,00	-	-	1.98	0	0	0.48	0	0	0.00	-	-	2.46	0	0
15	0.00	-	-	0.12	0	0	0.00	-	-	0.00	-	-	0.12	0	0
17	0.00	-	-	3.81	3	0.79	0.00	-	-	0.00	-	-	3.81	3	0.79
18	0.00	-	-	2.00	0	0	0.00	-	-	0.00	-	-	2.00	0	0
20	0.00	-	-	3.39	2	0.59	0.00	-	-	0.00	-	-	3.39	2	0.59
21	0.00	-	-	1.35	0	0	0.00	-	-	0.00	-	-	1.35	0	0
Total	6.07	18	2.97	22.15	8	0.36	3.49	0	0	0.00	-	-	31.71	26	0.82

1983

	18-30 Sept			1-15 Ott			16-31 Ott			1-15 Nov			Total		
Block	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE
12	7.88	0	0	8.20	0	0	2.45	0	0	0.00		-	18.53	0	0
12N	0,28	0	0	0.77	0	0	0.12	0	0	0.00	-		1.17	0	0
13	3.29	2	0.61	5.14	0	0	3.73	0	0	0.00	-	-	12.16	2	0.16
13N	0,00		-	0.10	0	0	0.10	0	0	0.00	-	-	0.20	0	0
14	0.87	0	0	1.52	0	0	1.93	0	0	0.00	-	-	4.32	0	0
15	0.00	-	-	3.83	0	0	0.39	0	0	0.00	-	-	4.22	0	0
15N	0.00	·	-	0.56	0	0	0.00	·		0.00	-	-	0.56	0	0
17	0.96	·	-	3.85	0	0	0.44	0	0	0.00	-	-	5.25	0	0
18	0.00			1.51	0	0	3.09	0	0	0.00	-	-	4.60	0	0
19	0.00		-	0.32	0	0	0.04	0	0	0.00	-	-	0.36	0	0
20	0.00		-	0.76	3	3.95	2.21	0	0	0.00	-	-	2.97	3	1.01
21	0.00	·	-	0.36	0	0	1.37	0	0	0.00	-	·	1.73	0	0
22	0.00	·	-	3.22	7	2.13	0.38	0	0	0.00	-	-	3.60	7	1.94
23	0.00	·	-	0.23	0	0	0.36	0	0	0.00	-	-	0.59	0	0
24	0.00	·	-	0.00	-	-	0.34	0	0	0.00	-	-	0.34	0	0
25	0.00		-	0.00	·	-	0.51	0	0	0.00	-	-	0.51	0	0
30	0.00	·	-	0.85	0	0	0.00	·	-	0.00	-	-	0.35	0	0
Total	13.28	2	0.15	31.22	10	0.32	17.46	0	0	0.00	-	-	61.96	12	0.19

1984

	16-30 Sept			1-15 Ott			18-31 Ott			1-15 Nov			Total		
Block	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE
12	5.64	0	0	7.63	0	0	7.96	0	0	0.00	·	-	21.23	0	0
12N	0.09	0	0	0.31	0	0	0.13	0	0	0.00		-	0.53	0	0
13	4.76	66	14.29	3.14	12	3.82	2.63	0	0	0.00	·	-	10.53	80	7.60
13N	0.03	0	0	0.03	0	0	0.20	0	0	0.00	·	-	0.26	0	0
14	2.79	0	0	0.11	0	0	0.00	-	-	0.00	·	-	2.90	0	0
17	0.75	2	2.67	1.90	0	0	0.00	-	-	0.00	·	-	2.65	2	0.75
Total	14.06	70	4,98	13.12	12	0.91	10.92	0	0	0.00	·	-	38.10	82	2.15

Table 17 (contd).

1985

Block	16-30 Sept Hrs	GW	WPUE	1-15 Ott Hrs	GW	WPUE	18-31 Ott Hrs	GW	WPUE	1-15 Nov Hrs	GW	WPUE	Total Hrs	GW	WPUE
12	3.08	0	0	6.08	0	0	7.17	0	0	0.00	-	-	16.33	0	0
12N	0.07	0	0	0.64	0	0	0.00	-	-	0.00	-	-	0.71	0	0
13	0,00	-	-	2.79	0	0	3.62	0	0	0.00	-	-	6.41	0	0
14	0,00	-	-	2.04	0	0	0.00	-	-	0.00	-	-	2.04	0	0
15	0.00	-	-	1.03	0	0	0.00	-	-	0.00	-	-	1.03	0	0
17	0.00	-	-	2.85	0	0	0.00	-	-	0.00	-	-	2.85	0	0
18	0.00	-	-	2.74	0	0	0.00	-	-	0.OO	-	-	2.74	0	0
Total	3.15	0	0	18.17	0	0	10.79	0	0	0,00	-	-	32.11	0	0

1986

Block	16-30 Sept Hrs	GW	WPUE	1-15 Ott Hrs	GW	WPUE	16-31 Ott Hrs	GW	WPUE	1-15 Nov Hrs	GW	WPUE	Total Hrs	GW	WPUE
12	3.33	7	2.10	8.33	3	0.36	3.76	0	0	0.00	-	-	15.42	10	0.65
12N	0.10	0	0	1.34	0	0	0,12	0	0	0.00	-	·	1.56	0	0
13	11.15	10	0.90	9.09	1	0.11	6.60	5	0.30	0.00	-	-	26.84	16	0.60
13N	0.52	0	0	1.82	0	o	0.00	-	-	0,00	-		2.34	0	0
14	4.48	12	2.68	7,28	12	1.65	0.62	0	0	0.00	-	-	12.38	24	1.94
14N	0.06	0	0	0.16	0	0	0.00	-	-	0.00	-	·	0.22	0	0
15	2.72	0	0	0.20	0	0	0,19	0	0	0.00	-		3.11	0	0
17	3.77	0	0	3.95	1	0.25	3.43	1	0.29	0.00	-	-	11.15	2	0.18
18	1.04	0	0	2.17	3	1.38	0.53	0	0	0.00	-	·	3.74	3	0.80
20	1.59	0	0	0.00	-	-	0.05	0	0	0.00	-		1.64	0	0
22	0.80	0	0	0.00	-	-	0.00		-	0,00	-	·	0.80	0	0
Total	29.56	29	0.98	34.34	20	0.58	15.30		0.69	0.00	-	-	79.20	55	0.69

1987

Block	18-30 Sept Hrs	GW	WPUE	1-15 Ott Hrs	GW	WPUE	16-31 Ott Hrs	GW	WPUE	1-15 Nov Hrs	GW	WPUE	Total Hrs	GW	WPUE
12	7,70	0	0	7.09	o	0	8.10	0	0	0.00	-	-	22.89	o	0
12N	2.75	0	0	3.37	0	0	4.16	0	0	0.00	-	-	10.28	0	0
13	10,95	9	0.82	8.04	19	2.36	4.85	7	1.44	0.00	-	-	23.64	35	1.47
13N	1.75	0	0	1.09	0	0	2.38	0	0	0.00	-	-	5.22	0	0
14	5.31	4	0.75	2.62	0	0	0.00	-	-	0.00	-	-	7.93	4	0.50
15	3.38	0	0	0,00	-		0.00	-	0	0.00	-	-	3.38	0	0
16	0.41	0	0	0.00	-	-	0.00	-	0	0.00	-	-	0.41	0	0
17	2.60	0	0	0.95	0	0	2.88	0	0	0.00	-	-	6.43	0	0
18	2.91	0	0	0.00			0.54	0	0	0.00	-	-	3.45	0	0
20	1.68	0	0	0.00	-	-	0.00	-	-	0.00	-	·	1.68	0	0
22	2.34	10	4.27	0.00		-	0.00	-	-	0.00	-	-	2.34	10	4.27
Total	41.78	23	0.55	23.16	19	0.82	22.91	7	0.31	0.00	-	-	87.85	49	0.56

Table 17 (contd).

1988

Block	16-30 Sept Hrs	GW	WPUE	1-15 Ott Hrs	GW	WPUE	18-31 Ott Hrs	GW	WPUE	1-15 Nov Hrs	GW	WPUE	Total Hrs	GW	WPUE
12	0.00	-	-	2.73	0	0	0.19	3	15.79	0.00		·	2.92	3	1.03
12N	0.00	-	-	3.10	0	0	0.00	-	-	0.00	·	·	3.10	0	0
13	0.00	-	-	8.85	0	0	1.12	0	0	0.00			9.97	0	0
13N	0.00	-	-	3.60	0	0	0.00	-	-	0.00		-	3.60	0	0
14	0.00	-	-	5.11	0	0	0.16	-	-	0.00			5.27	0	0
14N	0.00	-	-	2.76	0	0	0.00	0	0	0.00		·	2.76	0	0
15	0.00	-	-	3.66	0	0	0.00	-	-	0.00	·	-	3.66	0	0
15N	0.00	-	-	3.63	0	0	0.00	-	-	0.00	-	-	3.63	0	0
16	0.00	-	-	3.18	0	0	0.00	-	-	0.00			3.18	0	0
16N	0.00	-	-	3.92	0	0	0.00	-	-	0.00	·	-	3.92	0	0
17	0.00	-	-	2.41	0	0	1,36	0	0	0.00	-	·	3.77	0	0
18	0.00	-	-	4.37	0	0	1,18	0	0	0.00	·	·	5.55	0	0
19	0.00	-	-	0.62	0	0	0.00	0	0	0.00	·	·	0.62	0	
Total	0.00	-	-	47.93	0	0	4,00	3	0.75	0.00	·	-	51.95	3	0.0:

1989

Block	16-30 Sept Hrs	GW	WPUE	1-15 Ott Hrs	GW	WPUE	16-31 Ott Hrs	GW	WPUE	1-15 Nov Hrs	GW	WPUE	Total Hrs	GW	WPUE
12	5.40	0	0	4.29	o	o	1.19	0	0	0.00			10,88	o	0
12N	4.77	0	0	0.00			0.00			0.00			4,77	0	0
13	7.81	9	0.34	6.51	13	2.00	12.86	0	0	0.00	-	-	27.18	22	0.81
13N	3.45	0	0	0.92	0	0	3.24	0	0	0.00	·		7.61	0	0
14	3.17	8	2.52	6.85	7	1.02	4.39	0	0	0.00		·	14.41	15	1.04
14N	3.73	7	1.88	3.39	7	2.06	0.41	0	0	0.00			7.53	14	1.86
15	2.06	0	0	2.15	0	0	4.03	0	0	0.00	·		8.24	0	0
15N	3.95	0	0	3.03	0	0	3.73	0	0	0.00		·	10.71	0	0
16	0.32	0	0	0.00		-	3.39	0	0	0.00	·	·	3.71	0	0
16N	3.08	0	0	0.00	·	-	0.00	·		0.00	·		3.08	0	0
17	0.00	-	-	3.06	0	0	2.79	0	0	0.00		-	5.85	0	0
18	0.68	0	o	0,00	-	-	5.85	0	0	0.00	·		6.33	0	0
20	0.00	·	-	0.00	·	-	2.29	0	0	0.00	-		2.29	0	0
21	0.00	·	-	0.00		-	0.24	0	0	0.00	·	·	0.24	0	0
22	0.00	·	-	0.00	·	-	4.84	54	11.16	0.00	·	·	4.64	5 4	11.16
23	0.00	·	-	0.00	·	-	2.49	65	26.10	1.11	0	0	3.60	65	18.05
24	0.00		-	0.00		-	0.00	·	·	4.04	0	0	4.04	0	0
25	0.00		-	0.00	·	-	0.00	-	-	1.32	0	0	1.32	0	0
30	0.00	·	-	0.00	·	·	1.97	0	0	0.77	0	0	2.74	0	0
31	0.00	·	-	0.00	·	-	0.47	0	0	3.68	0	0	4.15	0	0
Total	38.42	24	0.62	30.20	27	0.89	54.18	119	2.20	10.92	0	0	133.72	170	1.27

Table 17 (contd).

TOTAL 1980-89

	1&30 Sept			1-15 Ott			16-31 Ott			1-15 Nov			Total		
Block	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE
12	37.61	7	0.19	50.20	3	0.06	32.99	3	0.09	0.00		-	120.80	13	0.11
12N	8.06	0	0	9.60	0	0	4.61	0	0	0.00		-	22.27	0	0
13	39.45	116	2.94	47.14	48	1.02	36.17	12	0.33	0.00		-	122.76	176	1.43
13N	5.75	0	0	7.56	0	0	5.92	0	0	0.00		-	19.23	0	0
14	16.62	24	1.44	27.51	19	0.69	7.58	0	0	0.00		-	51.71	43	0.83
14N	3.79	7	1.85	6.31	7	1.11	0.41	0	0	0.00		-	10.51	14	1.33
15	8.16	0	0	10.99	0	0	4.61	0	0	0.00		-	23.76	0	0
15N	3.95	0	0	7.22	0	0	3.73	0	0	0.00		-	14.90	0	0
16	0.73	0	0	3.18	0	0	3.39	0	0	0.00		-	7.30	0	0
16N	3.08	0	0	3.92	0	0	0.00		·	0.00		-	7.00	0	0
17	8.08	2	0.25	22.78	4	0.18	10.90	1	0.09	0.00		-	41.76	7	0.17
18	4.63	0	0	12.79	3	0.23	11.19	0	0	0.00		-	28.61	3	0.10
19	0.00	-	-	0.94	0	0	0.04	0	0	0.00		-	0.98	0	0
20	3.27	0	0	4.15	5	1.20	4.55	0	0	0.00		-	11.97	5	0.42
21	0.00	-	·	1.71	0	0	1.61	0	0	0.00		-	3.32	0	0
22	3.14	10	3.18	3.22	7	2.17	5.22	54	10.34	0.00		-	11.58	71	6.13
23	0.00	-	-	0.23	0	0	2.85	65	22.81	1.11	0	0	4.19	65	15.51
24	0.00	-	-	0.00	-	-	0.34	0	0	4.04	0	0	4.38	0	0
25	0.00	-	-	0.00	·	-	0.51	0	0	1.32	0	0	1.83	0	0
30	0.00	-	-	0.85	0	0	1,97	0	0	0.77	0	0	3.59	0	0
31	0.00	-	-	0.00		-	0.47	0	0	3.68	0	0	4.15	0	0
Total	146.32	166	1.13	220.30	96	0.44	139.06	135	0.97	10.92	0	0	516.60	397	0.77

considered common along that part of the coast. Gray whales probably migrate from northernmost blocks in early October, as evidenced by decreased semimonthly abundance in those areas, when environmental conditions such as colder water, increasing ice cover or changes in current patterns reduce opportunities for feeding in the area. Gray whales have been seen moving southwest along the coast near Barrow by early August (Maher 1960), but the timing of their departure from the area probably varies as a result of the different environmental conditions from year to year.

The migration route of gray whales in the study area is poorly understood. Gray whale swimming direction for 1982-89 data was not significantly clustered about any one heading, although the mean swimming direction was southwesterly (221 'T, $p < 0.50$). Sightings of gray whales nearshore in early October suggests that whales use a coastal migratory route, as in other parts of their range (Swartz 1986; Poole 1984). However, the route taken by whales seen offshore in the northcentral Chukchi Sea is unknown. Whales may swim south-southeast past Cape Lisburne into the southern Chukchi Sea, or perhaps take a more southwesterly route across the Chukchi Sea to the Chukotka peninsula. The migration route through the southern Chukchi Sea is similarly ill-defined. Gray whales have been seen along the coast between Kotzebue and Point Hope in July (Ljungblad et al. 1986b), and may use the shallow coastal areas as calf-weaning areas similar to those reported along the Chukotka coastline (Bogoslovskaya, 1986; Moore et al. 1986b). Presumably, gray whales continue to use both coastal and offshore waters during the southward migration, taking advantage of localized prey availability along the way.

Behavior and Calf Sightings

The majority (85%, n =339) of gray whales were seen feeding (Fig. 30), as evidenced by conspicuous mud plumes. Most feeding whales (59%, n= 200) were seen in nearshore survey blocks 12 and 13 and offshore survey blocks 14 and 14N in the northern Chukchi Sea, with 39% (n= 131) in survey blocks 22 and 23 in the southcentral Chukchi Sea. Grays have also been seen swimming (12%), diving (l%), as part of a cow-calf association (1 %) and resting (1 %).

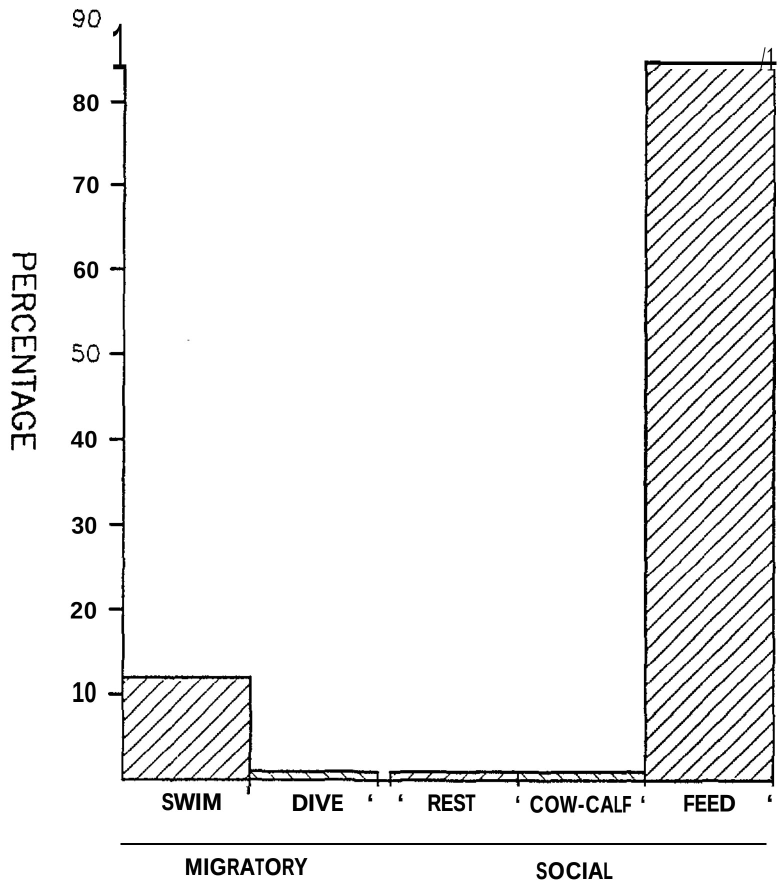


Figure 30. Summary ofgraywhale behavior, 1982-89.

Feeding opportunities in the northern Chukchi Sea likely influence gray whale distribution and abundance. Whales may forage along the coast as they migrate into the Chukchi Sea in July and August, then move to shallow **offshore areas overlying shoals,** such as Hanna Shoal **in the northcentral Chukchi Sea, in September and October to** take advantage of additional rich feeding areas exposed by receding ice (Clarke et al. 1989). Prey communities in the Chukchi Sea are generally less dense but composed of a greater variety of species than those in the Bering Sea, and include preferred prey species such as amphipods of the genera Ampelisca, Anonyx and Pontoporeia (Gill and Hall 1983; Nerini and Oliver 1983; Oliver et al. 1983; Nerini 1984; Stoker 1990). Gray whale benthic feeding traces have been identified by Phillips (1987) from south of icy Cape to north of Point Franklin, especially at depths between 23 and 24 m.

Gray whale foraging may play an important role in structuring the benthic community (Nerini and Oliver 1983), and thereby in inter-annual variation in gray whale abundance. Patterns of infaunal community composition were correlated with the size and age of feeding pits created by gray whales in the northern Bering Sea. Abundance of the dominant prey species, Ampelisca macrocephala, was depressed in high-pit areas, implying that the same areas could not support as many gray whales year after year. This may account for some of the variability in gray whale abundance in survey blocks 13 and 14. For example, relatively high gray whale WPUE was calculated for block 13 in 1982, 1984, and 1987, with low indices there in alternate years 1983, 1985-86 and 1988-89 (see Table 14). Similarly, abundance in block 14 was relatively high in 1986 and 1989, but not in 1987 or 1988. These oscillations in survey block relative abundance suggest that gray whale foraging may indeed influence the benthic communities on which they feed and thereby affect patterns of whale abundance.

The gray whale calf seen on 22 September 1989 was the only calf seen in the study area from the latter half of September through early November. Two calves were seen in early September, and one in August, with all others (89%, n= 33) seen in July (Clarke et al. 1989). Calves were found in significantly higher ratios along the northeastern Chukchi coast than in the northern Bering Sea in July (Moore et al. 1986b). Spatial segregation of calves has also been described for the southern Chukotka peninsula (Krupnik et al. 1983; Bogoslovskaya 1986). Gray whale calves may not be seen in appreciable numbers after July because the majority are weaned and migrate out of the area, either south to the southern Chukchi and/or northern Bering Seas or southwestward to the Chukotka peninsula. Bogoslovskaya (1986) reported that calves are weaned in July and August and assemble in localized areas along the Chukotka peninsula. Also, newly weaned calves may not be positively identified as “calves” when not accompanied by a large adult. Obtaining absolute whale sizes from an aircraft not equipped for photogrammetry is impossible. In addition, estimates of gray whale calf length at weaning and at one year are quite variable (Sumich 1986).

Habitat Relationships

Most gray whales (95%, n =248) in the northern Chukchi Sea were seen in shallow (<50 m deep) water either nearshore between Point Franklin and Point Barrow or offshore in shallow waters bordering Hanna Shoal. In the southern Chukchi Sea, gray whales were found nearly equally in shallow (< 50 m) depths (49%, n=66) and transitional (> 50 m) depths (51%, n =70). Only 13% (n= 17) were in shallow nearshore water just south of Point Hope. Overall, mean depth for gray whales was 34.1 m (15.6 s.d., n= 147, range 2-91 m).

To describe gray whale distribution in relation to bathymetric-steered currents and shoals in the northern Chukchi Sea, the proportion of random gray whale sightings in water <37 m was compared to the proportion of of c37 m habitat available (14Yo). There were significantly more gray whales (38%) than expected in water c 37 m (x^2 = 98.57, p <().001), indicating a preference for the shallower areas. The relatively shallow shoals seem to support adequate gray whale prey communities to make them important offshore feeding habitat.

Most gray whales (93%, n= 371) were seen in open water or very light (<10%) ice cover. Two percent (n= 7) were in 21 -30% ice and five percent (n= 19) were seen in heavy (71 -99%) ice cover. Although gray whales seem to prefer ice-free water, whales in ice often continue to feed. In some years, gray whales have been seen feeding in 80-90% ice cover through mid-October (Moore et al. 1986b).

Other Marine Mammals

Belukha

There were 307 sightings of 3,387 belukhas in the study area in late September and October 1982-89 (Fig. 31). Over half (60%, n =2024) were seen in 1983 and 1988, both heavy ice years. Belukhas were seen from approximately 6 to 460 km offshore. Some belukhas swim relatively nearshore and seem to follow the 50 m depth contour between Smith Bay and Point Barrow, then disperse southwest from Point Barrow to waters roughly 130 km northwest of Icy Cape. Other whales swim west well offshore along a migratory route north of 720 N latitude. The bifurcated distribution seems to 'merge' at 166-169" W between700 30' and71030'N latitude, the approximate location of one branch of the Alaska Coastal Water current that flows between Herald Shoal and Hanna Shoal (see Fig. 24).

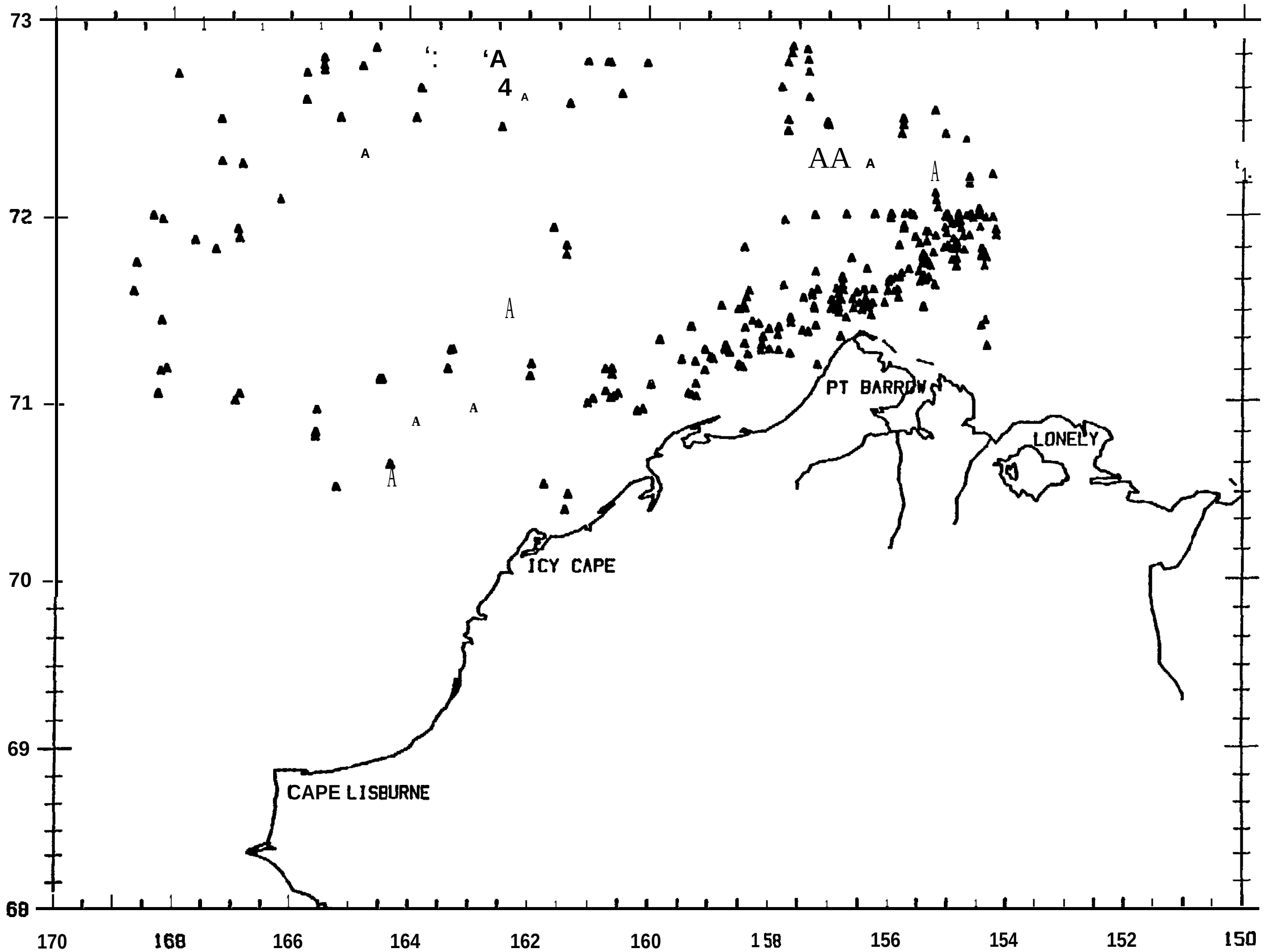


Figure 31. Cumulative (1982-89) distribution of 307 sightings of 3,387 belukhas.

Table 18. Belukha relative abundance (WPUE = no. whales/survey hour) by survey block, 1982-89.

Block	Hours	No. Belukha	WPUE
12	120.80	1479	12,24
12N	22.27	162	7.27
13	122.76	1222	9.95
13N	19.23	79	4.11
14	51.71	102	1,97
14N	10.51	98	9.32
15	23.76	18	0.76
15N	14,90	88	5,91
16	7.30	26	3.56
16N	7.00	71	10.14
17	41.76	15	0.36
18	28.61	27	0.94
19	0.98	o	0
20	11.97	0	0
21	3,32	0	0
22	11.58	0	0
23	4.19	0	0
24	4.38	0	0
25	1.83	0	0
30	3.59	0	0
31	4.15	0	0
Total	516.60	3387	6.56

The bifurcated belukha distribution is reflected in the overall pattern of relative abundance (Table 18). Highest abundance was calculated for block 12 (WPUE = 12.24), with nearly identical indices for block 13 (WPUE = 9.95) and block 14N (WPUE = 9.32) supporting the “split” in the distribution discussed above. Relatively high indices calculated for blocks 15N (5.91) and 16N (WPUE = 10.14), and low indices in block 14 (WPUE = 1.97), block 15 (WPUE = 0.76) and block 16 (WPUE = 3.56) indicate that belukhas are swimming around and not over Hanna Shoal.

The low abundance indices in block 17 (WPUE = 0.36) and block 18 (WPUE = 0.94), and the lack of sightings south of 700 N latitude, may be due to the timing of surveys relative to the belukha migration. Belukhas seen in the western Beaufort and northeastern Chukchi Seas in late September and October are part of a population estimated at 11,500 whales that summers in the Canadian Beaufort and overwinters in the Bering and southern Chukchi Seas (Davis and Evans, 1982). Migration west from the Canadian Beaufort Sea apparently begins in mid-August (Harwood and Ford 1983; Norton and Harwood 1985), and the peak of the fall belukha migration through the western Alaskan Beaufort Sea (150-1570 W) occurs in late September (Clarke and Moore 1989). Substantial numbers of belukhas may not pass through blocks 17 and 18 until late October or early November, when surveys have either been directed toward the Hope Basin (1989), or completed.

The pattern of belukha distribution suggests a bifurcated migration route across the northeastern Chukchi Sea (Fig. 32), similar to that discussed earlier for bowhead whales. Random belukha sightings in the study area were disproportionately in water ≥37 m (98%) when compared to the amount of available habitat ($X^2 = 97.0$, p c 0.001), indicating that belukhas were swimming along the relatively deeper troughs in the Chukchi basin that channel northward flowing currents (see Fig. 24). Swimming direction was significantly clustered about a southwesterly heading (248 ‘T, p< 0.001) in the western Beaufort Sea. In the Chukchi Sea swimming direction was clustered about 264 ‘T (p <0.001), reflecting the offshore migration described by distribution and relative abundance indices. Belukhas were seen in significantly deeper water ($\bar{x}$ = 253.8m, 315 s.d., n =153) in the western Beaufort Sea than in the northeastern Chukchi Sea ($\bar{x}$ = 88.1 m, 129 s.d., n= 154; t =6.03, p< 0.001) due to the Barrow Canyon. Belukhas were seen in all ice cover classes, with most (63%, n =2143) whales in heavy (81 -99%) ice **cover** and 17% (n= 594) in open water.

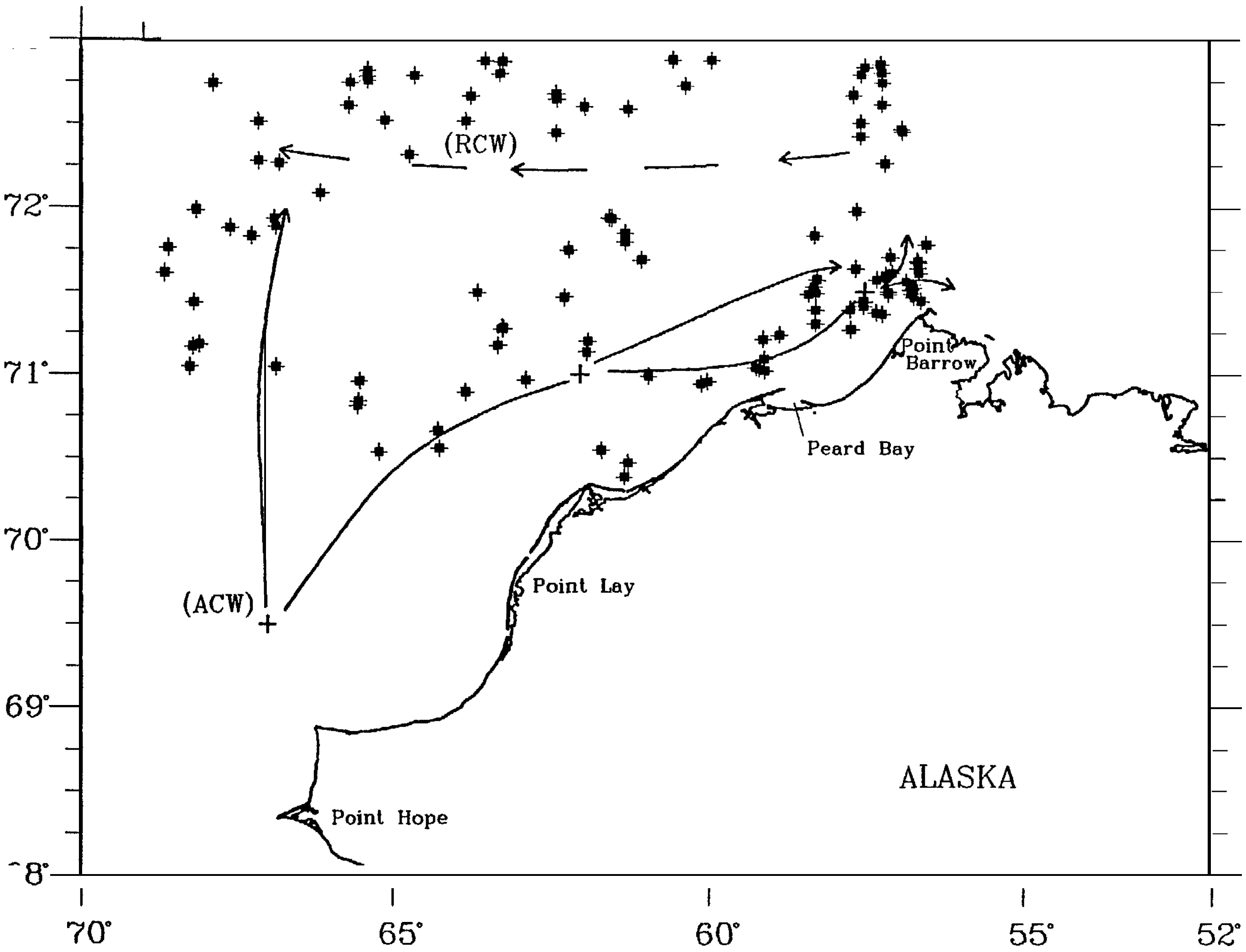


Figure 32. Cumulative (1982-89) random belukha sightings west of Point Barrow (156°30'W) with major northeastern Chukchi Sea currents. [+ = branching points for ACW; ←- ←- = approximate location of RCW)

CONCLUSIONS AND RECOMMENDATIONS

Aerial surveys for endangered whales have been flown over the Alaskan Chukchi and western Beaufort Sea study area since 1980, with transect surveys beginning in 1982. Survey effort in the study area varied each year with task priorities. Although there are obvious limitations inherent to aerial surveys, flying remains the best means of sampling large OCS Planning Areas over a short time period. An endangered whale sighting data base compiled over several seasons provides **an overview to patterns of distribution, relative abundance, and habitat preference** necessary for decision making relative to the leasing and development of the Alaskan OCS. The following is a conclusions summary and recommendations for future field efforts in the study area.

Conclusions

1. Bowhead whales occur in the study area from at least mid-September through the end of October, and likely into November. Distribution is predominantly nearshore east of Point Barrow, and bifurcated west of Point Barrow. Most sightings in the Chukchi Sea suggest a dispersive distribution southwest of Point Barrow, with a few sightings far offshore northwest of Point Barrow.

2. Bowhead whales swim along a westerly course (2760 T, p< 0.001) and follow a nearshore migration route between Smith Bay and Point Barrow. At Point Barrow, most bowheads take up a southwesterly heading (2470 T, p c 0.001) and disperse across the Chukchi Sea, with the migratory corridor to about 30 km offshore at Barrow and about 120 km offshore northwest of Icy Cape. The migration corridor at latitudes south of ca.70° 30'N is ill-defined. Some whales maintain a more northerly course west of Barrow (261 °T) and may cross the Chukchi Sea north of 720 N latitude,

3. The bowhead whale migration route across the Chukchi Sea maybe influenced by the pattern of major currents in the basin. Major currents in the Chukchi Sea are bathymetrically channeled between shoals (water depth <37 m), with filament branches occurring west of Icy Cape, Peard Bay and Point Barrow. The pattern

of distribution for cumulative (1982-89) random bowhead whale sightings is similar to current patterns in the northeastern Chukchi Sea. Fronts associated with current interfaces may consolidate prey and provide feeding opportunities for bowheads, or temperatures and salinity differences between water masses may provide migratory cues for whales during the fall migration. The association of random bowhead sightings with relatively deeper-water troughs that channel currents was not supported statistically, but this may be due to small sample size.

4. Although regression results indicated significant differences ($F=2.72, p<0.05$) among bowhead whale annual migratory routes (1982-89) across the Chukchi Sea, there was no significant difference between any pair of years (Tukey $0.101 \leq q \leq 2.233$). There was a trend for a “northwesterly route”, defined solely from 1989 data, to be different from the “southwesterly route” documented for all other years of data.

5. Bowhead whales feed in coastal waters between Point Barrow and Smith Bay. In some years, such as 1984 and 1989, feeding aggregations can number ca. 40-70 whales and may remain in the same general area for ten days or more.

6. Bowhead whales have exhibited all social behaviors, except mating, in the study area. Log play and a >30 minute bout of aerial displays was observed in 1989.

7. Bowhead calves have been seen in the study area only in October, but there is no clear evidence of spatial or temporal segregation within the month.

8. Bowhead whale and gray whale distribution overlaps in the Chukchi Sea in fall, as described in Moore et al, (1986a), and occasionally the two species are seen together.

9. Gray whales feed along the coast from Point Franklin to Point Barrow and near Cape Lisburne and Point Hope, ca. 150-200 km offshore near Hanna Shoal, and in the south-central Chukchi Sea (Hope Basin) throughout the fall. Most gray whales seen in fall are feeding and not migrating, although grays in the northern Chukchi Sea were more often swimming than feeding after 11 October in 1989. Conversely,

all whales seen on 30-31 October 1989 in the south-central Chukchi Sea were feeding and not migrating.

10. Few gray whale calves are seen in the study area in fall. One calf was seen in late September 1989 with adult whales feeding in waters near Hanna Shoal; all other calves have been seen before 16 September near adults along the coast. Calves occur in disproportionatley high ratios along the Chukchi coast in July (Moore et al., 1986b) indicating that the Chukchi Sea may be an important weaning area. Bogoslovskaya (1986) suggests gray whales wean calves along the Chukotka coast. The dearth of calf sightings in the study area in fall may indicate that weaning is nearly complete by then.

11. Belukhas migrate through the study area from at least mid-September through October, and probably into November. Belukha distribution was bifurcated in the Chukchi Sea, similar to bowhead whale distribution. Cumulative (1982-89) random belukha sightings were significantly ($p < 0.001$) associated with the relatively deep-water troughs that channel currents in the Chukchi basin, suggesting that major currents may influence the belukha migration route. Relative abundance north of 720 N latitude was similar to that nearshore north and west of Point Barrow. Abundance south of 70” N latitude was 5 to 10 times lower than areas farther north.

Recommendations

1. The timing of the onset of the bowhead whale migration into the Chukchi Sea study area will not likely be defined **by surveys** that begin in late September. Although the present survey season very likely covers most of the migratory period, sightings of bowhead whales feeding east of Point Barrow in mid-August 1989 (George and Carroll 1989) suggest whales sometimes occur in the study area four to five weeks before the onset of surveys. Surveys in August, or passive acoustic monitoring near Barrow similar to studies carried out there the fall of 1987 (Moore et al. 1989), could document occurrence of bowheads in the study area earlier in the fall season.

2. Passive acoustic monitoring conducted during the survey season from the field station in Barrow, as in 1987, would augment sighting data and increase the likelihood of detecting bowhead whales passing Barrow. In 1987, bowhead calls were recorded three days before the first bowhead sighting of the season, and 75% of all calls were recorded between 1900 and 2200 hours when surveys could not be conducted due to darkness (Moore et al. 1989). Acoustic monitoring, unlike aerial surveys, is fully operational during darkness and bad weather, and provides robust data to support visual sightings.

3. Predicting the occurrence of bowhead feeding aggregations east of Point Barrow would benefit future planning for OCS lease sites in the area. Some oceanographic features coincident with years that bowheads were seen feeding near Barrow may be definable via archived satellite data, depending on the images available for any given year. In addition, efforts to sample waters near feeding whales would clarify the type of prey available to whales in that area. Both avenues of research require focused effort and funding if bowhead feeding patterns in this fall feeding area are to be better described.

4. Bowhead whales have not been seen in the Hope Basin OCS Planning Area during fall aerial surveys, due either to the timing and extent of survey effort there or to bowhead migratory patterns. Surveys directed toward blocks 22-25 in early October might better elucidate bowhead occurrence there. However, surveys in the Hope Basin in early October would take away from the current focus of surveys north of 720 N latitude in the Chukchi Sea OCS Planning Area, also a high priority if an “offshore” bowhead migration route is to be defined.

5. Gray whale use of discrete feeding sites in the north and south-central Chukchi Sea has been described, but the relative importance of these areas, and movements of whales between sites is ill-defined. Although description of gray whale movements through the Chukchi basin are probably best left to satellite telemetry studies (eg. Mate and Nieukirk 1989), the use of feeding areas near Point Hope and in the southcentral Chukchi Sea could be better defined with survey effort in the Hope Basin OCS Planning Area in late September and early October. As

mentioned above, early-October surveys in the Hope Basin detract from the current focus of efforts on the northern and offshore areas of the Chukchi Sea Planning Area, however. A two-aircraft effort should be considered to collect information on bowhead and gray whale use of Hope Basin in late September and early October while simultaneously focusing effort in the offshore survey blocks of the Chukchi Sea.

6. Correlation of migratory route with currents in the Chukchi Sea may be approached by analyzing random belukha sightings as well as random bowhead sightings. Although belukha data are usually of relatively low priority, the similarity in distribution and the larger data set for belukha suggest that analyzing belukha data, as in the bathymetric analysis for 1982-89 data presented herein (see Conclusion 11) may provide insights to the bowhead migration route as well.

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APPENDIX A

AERIAL SURVEY FLIGHT CAPTIONS, SURVEY TRACKS, AND SIGHTING SUMMARIES, 1989

CONTENTS

INTRODUCTION

This appendix consists of flight tracks 1 through 31, depicting aerial surveys flown over the Chukchi Sea from mid-September through early November 1989. Maps were prepared using a series of computer programs consisting of BASIC subroutines implemented on a Hewlett-Packard (HP 85) microcomputer connected to a 7470A printer/plotter. Each map shows the flight track as a line drawn through position updates and/or sighting locations, as recorded on the aircraft computer system. Each symbol on the flight track/sighting charts represents one sighting of one or more animals. A caption describing the flight's objectives, survey conditions and sightings accompanies each map. Additionally, summary information on bowhead and gray whale sightings is presented beneath the flight caption in the tabularized format:

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, MP = Mud Plumes BW = Blow, DY = Display SP = Splash, IT = Ice Track
BEH	Behavior: SW = Swim, DY = Display, SH = Spyhop DI = Dive, MT = Mate, TS = Tail-Slap RE = Rest, FE = Feed, BR = Breach MI = Mill, CC = Cow-Calf, RL = Roll UB = Underwater Blow, DE = Dead, NA = None
HDG	Heading in degrees, magnetic
ICE	Ice cover in percent
SS	Sea State (Beaufort scale)
DEPTH	Depth in meters

Dashes (-) indicate data were not recorded

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Summaries of daily flight effort (Table A-1) and marine mammal sightings (Table A-2) precede the flight tracks and provide an overview of survey effort and sighting data for the 1989 field season. Species abbreviations used in Table A-2 and on the flight track keys are as follows:

BH = Bowhead Whale

GW = Gray Whale

BE = Belukha

CT = Unidentified Cetacean

WS = Walrus

BS = Bearded Seal

RS = Ringed Seal

PN = Unidentified Pinniped

PR = Polar Bear

Table A-1. Summary of daily flight effort in the Chukchi Sea, 1989.

DATE	Flt No.	Transect (km)	Connect (km)	Search (km)	Total (km)	Transect Time (h)	Total Time (h)
20 Sep	1	696	97	350	1,143	3.10	5.00
21 Sep	2	855	91	209	1,155	3.62	4.67
22 Sep	3	666	56	568	1,290	3.07	5.90
23 Sep	4	665	61	788	1,514	2.75	6.27
24 Sep	5	16	0	229	245	0.05	1.03
27 Sep	6	701	101	126	928	2.85	3.97
28 Sep	7	675	40	754	1,469	2.65	6.11
29 Sep	8	17	0	149	166	0.12	0.93
30 Sep	9	959	83	80	1,122	4.10	4.80
1 Ott	10	908	115	393	1,416	3.70	5.88
2 Ott	11	130	12	237	379	0.33	1.28
5 Ott	12	0	0	399	399	0.00	2.38
9 Ott	13	678	67	569	1,314	2.70	5.62
10 Ott	14	684	76	519	1,279	3.13	5.67
11 Ott	15	298	3	532	833	1.25	3.48
14 Ott	16	0	0	380	380	0.00	1.85
15 Ott	17	356	84	710	1,150	1.40	5.10
16 Ott	18	638	92	554	1,284	2.95	5.88
19 Ott	19	709	79	324	1,112	2.97	4.60
21 Ott	20	674	54	550	1,278	2.97	6.25
22 Ott	21	720	82	128	930	3.18	4.15
25 Ott	22	642	59	768	1,469	2.68	6.07
26 Ott	23	285	16	718	1,019	1.20	4.33
27 Ott	24	776	244	109	1,129	3.45	4.98
28 Ott	25	406	67	644	1,117	1.80	4.78
29 Ott	26	634	103	515	1,252	2.67	5.83
30 Ott	27	462	93	196	751	1.90	3,58

DATE	Flt No.	Transect (km)	Connect (km)	Search (km)	Total (km)	Transect Time(h)	Total Time (h)
31 Ott	28	559	64	330	943	2.32	4.00
1 Nov	29	141	19	518	678	0.57	2.89
2 Nov	30	764	116	312	1,192	3.12	4.85
3 Nov	31	192	34	534	760	0.79	3.17
Total		15,906	2,008	13,192	31,106	67.39	135.24

Table A-2. Summary of daily marine mammal sightings by species, 1989. Number of sightings/number of animals.

DATE	Fit. No.	BH	GW	BE	CT	WS	BS	PN	PB
20 Sep	1	1/1	3/7	0	o	19/385	2/2	10/14	4/5
21 Sep	2	o	o	6/31	1/1	o	2/2	1/1	o
22 Sep	3	1/1	2/6	5/15	o	19/358	5/8	11/15	1/2
23 Sep	4	o	2/2	o	0	7/24	o	2/2	o
24 Sep	5	0	o	1/2	0	o	0	o	0
27 Sep	6	o	5/9	o	o	0	1/2	11/12	0
28 Sep	7	0	o	11/77	0	4/8	1/1	2/2	1/1
29 Sep	8	0	0	o	0	o	o	o	o
30 Sep	9	2/4	0	3/16	0	0	0	0	0
1 Ott	10	o	0	o	0	10/23	0	57/114	0
2 Ott	11	0	0	0	0	o	0	2/2	0
5 Ott	12	9/41	0	0	0	0	0	2/4	0
9 Ott	13	o	4/7	9/30	0	10/41	0	4/6	0
10 Ott	14	1/1	2/7	9/93	0	26/948	1/1	14/26	1/1
11 Ott	15	o	o	o	0	1/1	o	2/3	o
14 Ott	16	11/14	o	0	o	o	0	o	0
15 Ott	17	13/25	6/13	0	2/2	0	0	3/3	0
16 Ott	18	1/1	o	3/49	o	17/185	1/1	1/2	8/17
19 Ott	19	4/4	0	2/9	0	o	o	o	1/1
21 Ott	20	3/5	0	4/15	1/1	8/17	0	11/18	o
22 Ott	21	o	0	12/36	o	o	0	3/4	4/5
25 Ott	22	2/2	0	9/16	0	5/1 1	0	o	1/1
26 Ott	23	6/7	0	o	0	0	0	0	o
27 Ott	24	11/11	0	7/21	0	0	0	0	2/3
28 Ott	25	2/2	0	1/6	0	0	0	0	o

DATE	Flt. No.	BH	GW	BE	CT	WS	BS	PN	PB
29 Ott	**26**	**2/12**	o	1/5	o	0	0	4/5	1/1
30 Ott	27	0	14/54	o	0	0	0	0	0
31 Ott	28	0	21/65	O	0	0	0	0	0
1 Nov	29	0	0	0	0	0	0	0	0
2 Nov	30	0	0	0	0	0	0	11 /826	O
3 Nov	31	0	0	0	0	0	0	1/1	o
Total		69/131	59/1 70	83/421	4/4	126/2001	13/17	152/1060	24/37

Flight 1: 20 September 1989

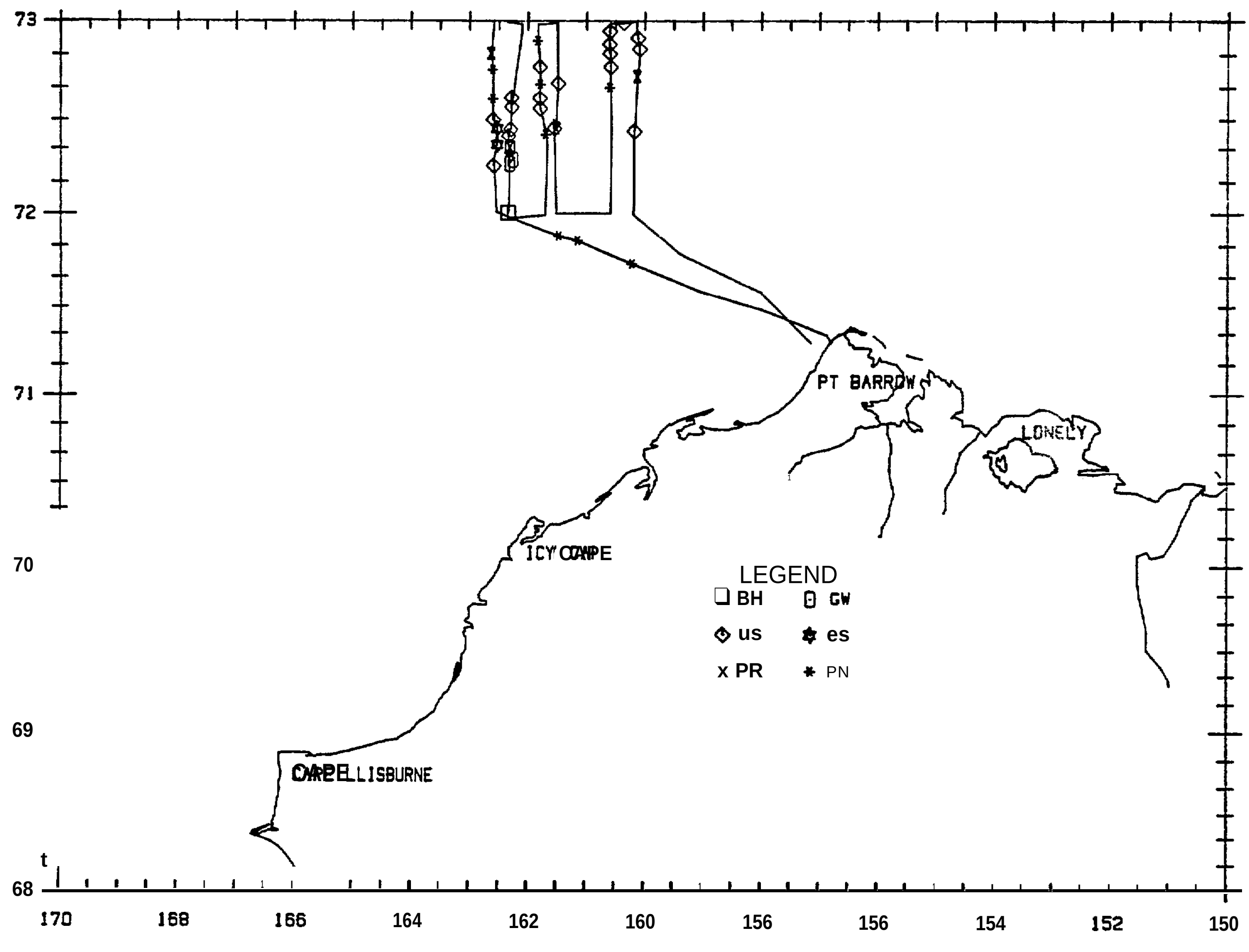
Flight was a transect survey in block 14N, with a search survey through blocks 13 and 14. Weather was overcast with areas of low ceiling and fog; visibility ranged from <1 to 10 km. Ice cover was 5 to 70% in the northern half of block 14N. Sea state ranged from Beaufort 01 to 04. One bowhead was seen in block 14N swimming north in ice-free waters. Feeding gray whales, walrus, bearded seals, unidentified pinnipeds and polar bears were also seen.

Bowhead Whales

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	72°00.4'	162°17.5'	176	BO	DI	300	1	B4	32

Gray Whales

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
4/0	72°15.6'	162°15.9'		MP	FE	90	30	B1	33
2/0	72°16.8'	162°12.6'		MP	FE	150	30	B1	33
1/0	72°20.5'	162°15.8'		BO	SW	90	25	B1	33



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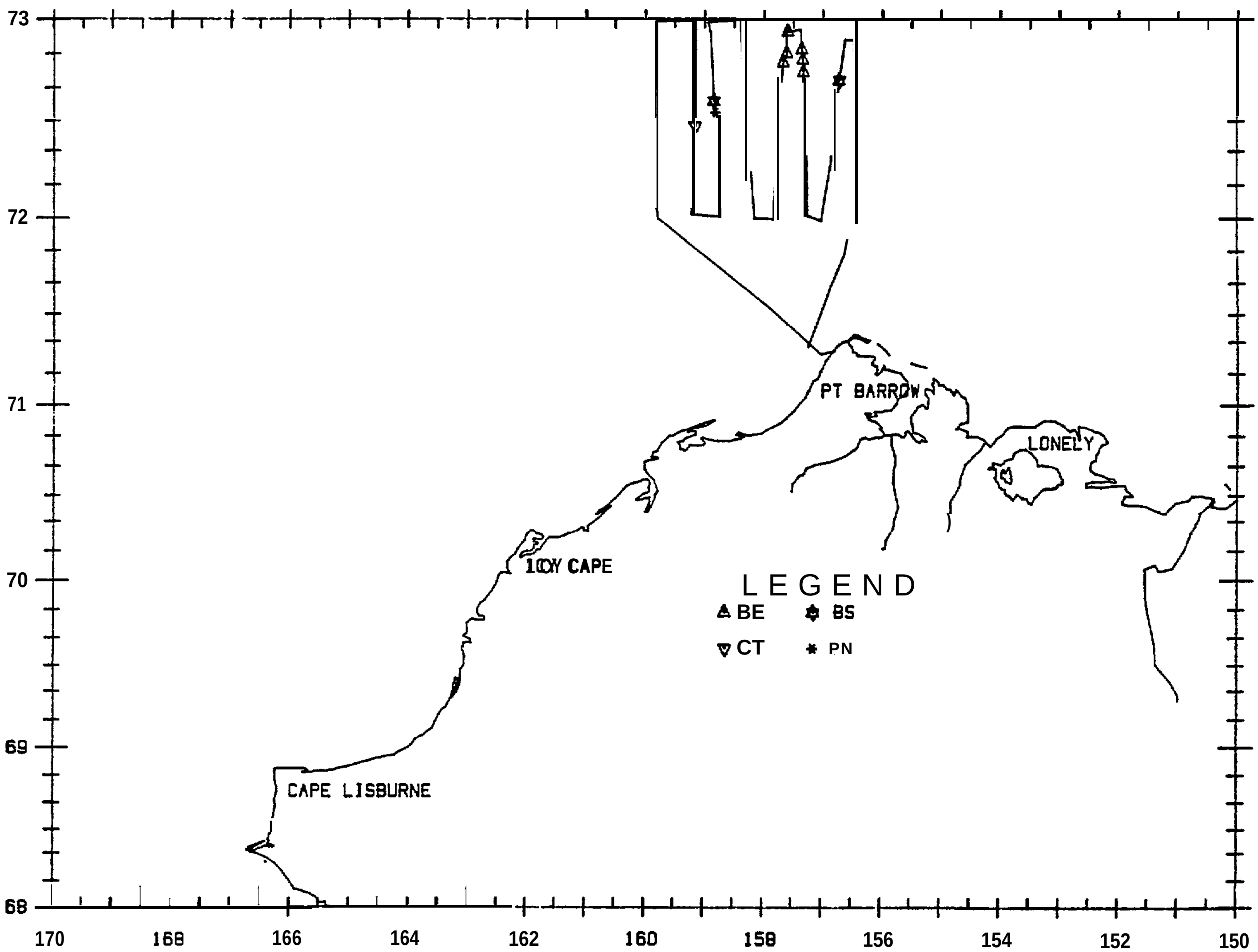
Flight 2: 21 September 1989

Flight was a transect survey of block 13N and the western one third of 12N, with a search survey across block 13. Weather was overcast with areas of low ceiling and fog; visibility ranged from unacceptable to 5 km. Ice cover was 5 to 70% in the northern half of block 13N and 1 to 40% in the northern third of block 12N. Sea state ranged from Beaufort 01 to 04. A large whale was seen in block 13N, but was not resighted for positive identification. Belukhas, bearded seals and an unidentified pinniped were also seen.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Flight 3: 22 September 1989

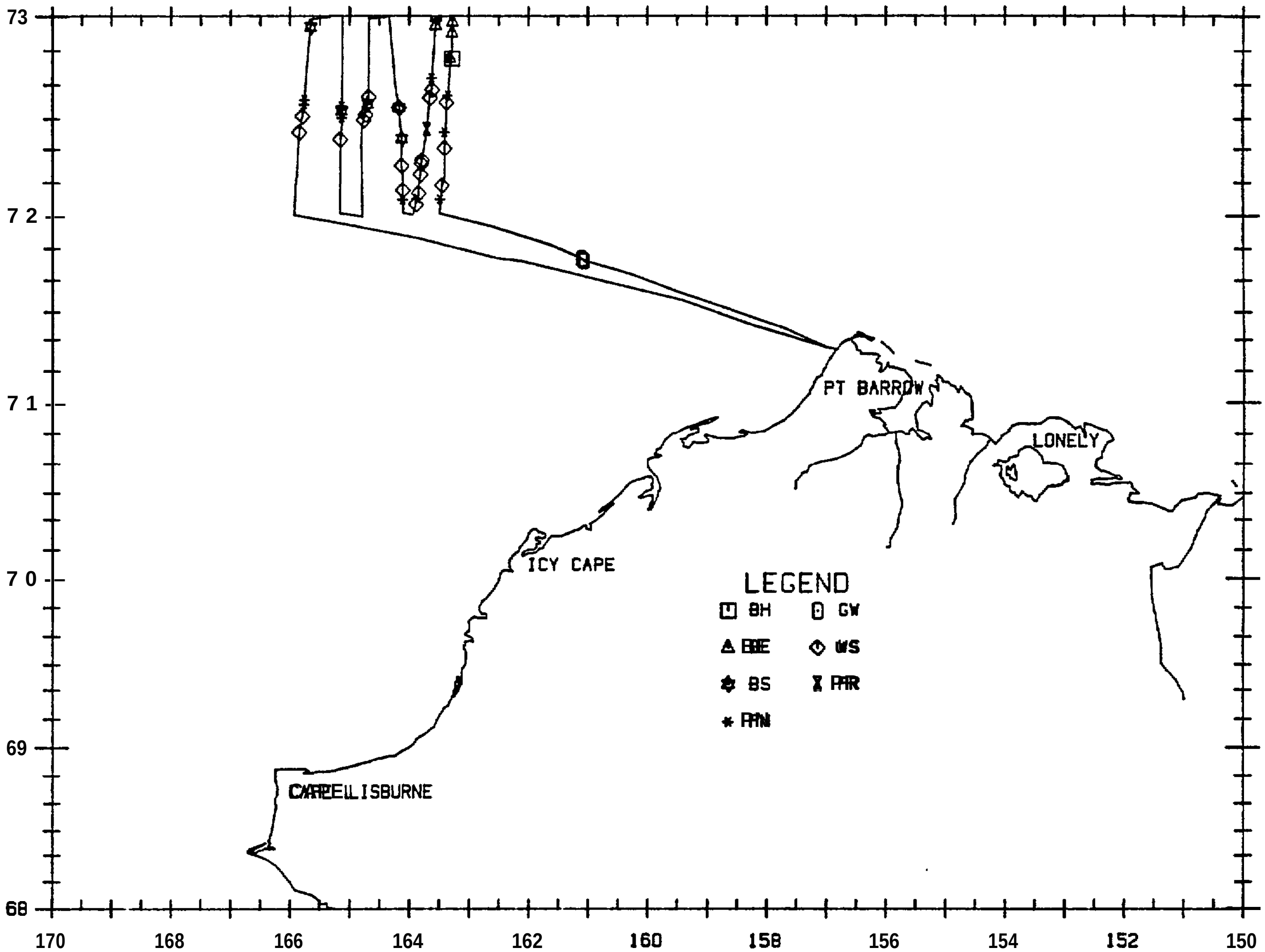
Flight was a transect survey of block 15N, with a search survey across blocks 13, 14 and 15. Weather was mostly clear with some areas of overcast and low ceilings; visibility ranged from <1 km to unlimited. Ice cover ranged from 20 to 95% in the northern two thirds of the block, all other areas were ice free. Sea state ranged from Beaufort 00 to 05. One bowhead was seen in block 15N swimming south in 95% ice. Feeding gray whales, belukhas, walrus, bearded seals, unidentified pinnipeds and polar bears were also *seen*.

Bowhead Whales

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	72°47.6'	163" 14.0'	792	BO	SW	180	95	B1	63

Gray Whales

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
3/0	71046.6'	161002.2'		MP	FE		0	B5	35
3/1	71 "45.9'	160"59.9'		MP	FE		0	B5	37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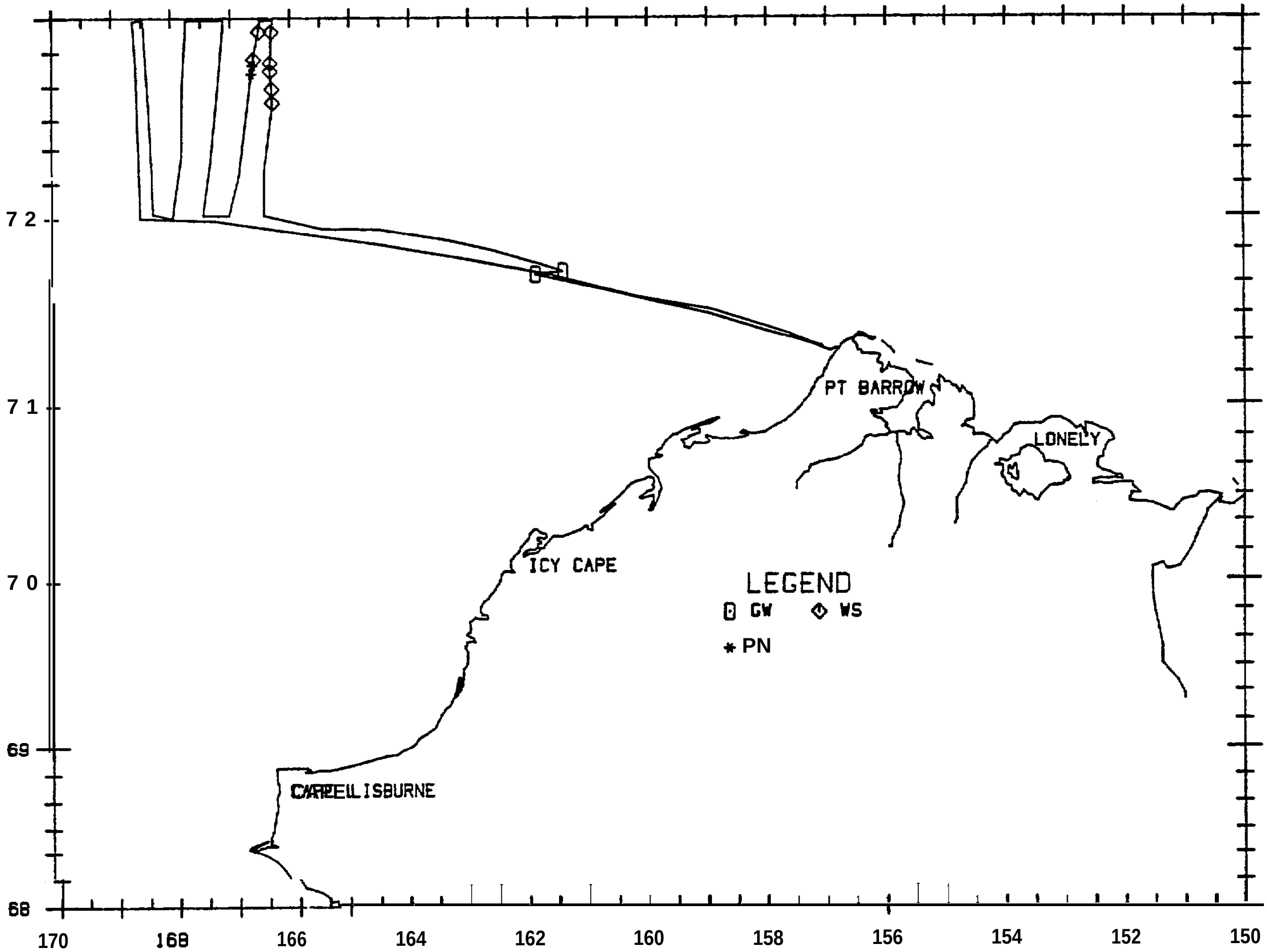
Flight 4: 23 September 1989

Flight was a transect survey of block 16N, with a search survey through blocks 13, 14 and 15. Weather was mostly clear with some areas of overcast and low ceilings; visibility ranged from 1 km to unlimited. The only area with ice was the northeastern corner of block 16N where coverage was 20 to 25%. Sea state ranged from Beaufort 01 to 05. Feeding gray whales, walrus and unidentified pinnipeds were seen.

Gray Whales

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71 “43.0’	161021.9’		MP	FE		0	64	35
1/0	71042.1 ‘	161°49,7’		MP	FE		0	64	33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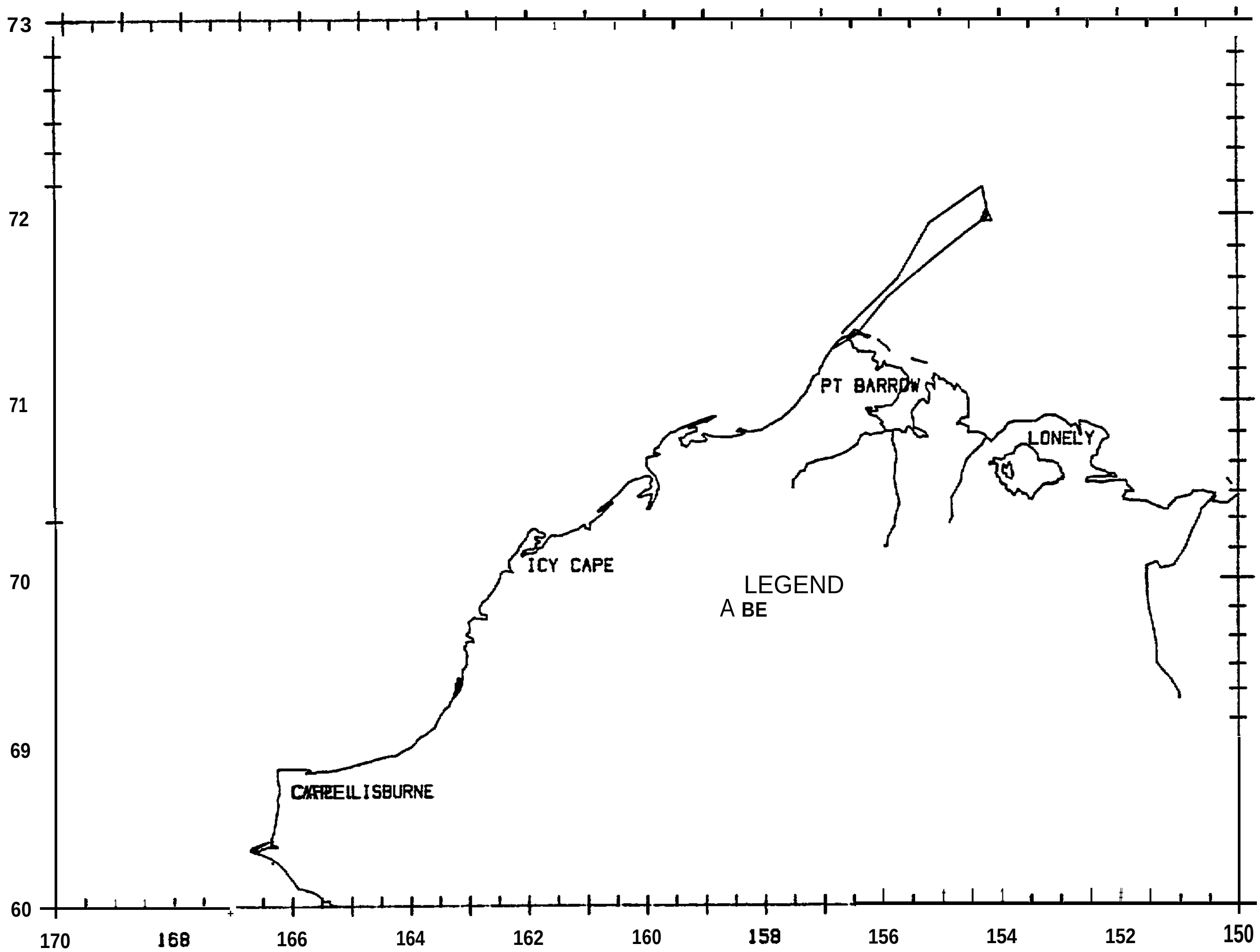
Flight 5: 24 September 1989

Flight was a search survey through block 12 and a brief transect survey in block 12N that was terminated due to fog and high sea state. Weather was low ceiling and fog; visibility ranged from 2 km to unacceptable. There was no ice and sea state ranged from Beaufort 05 to 06. Two belukhas were seen.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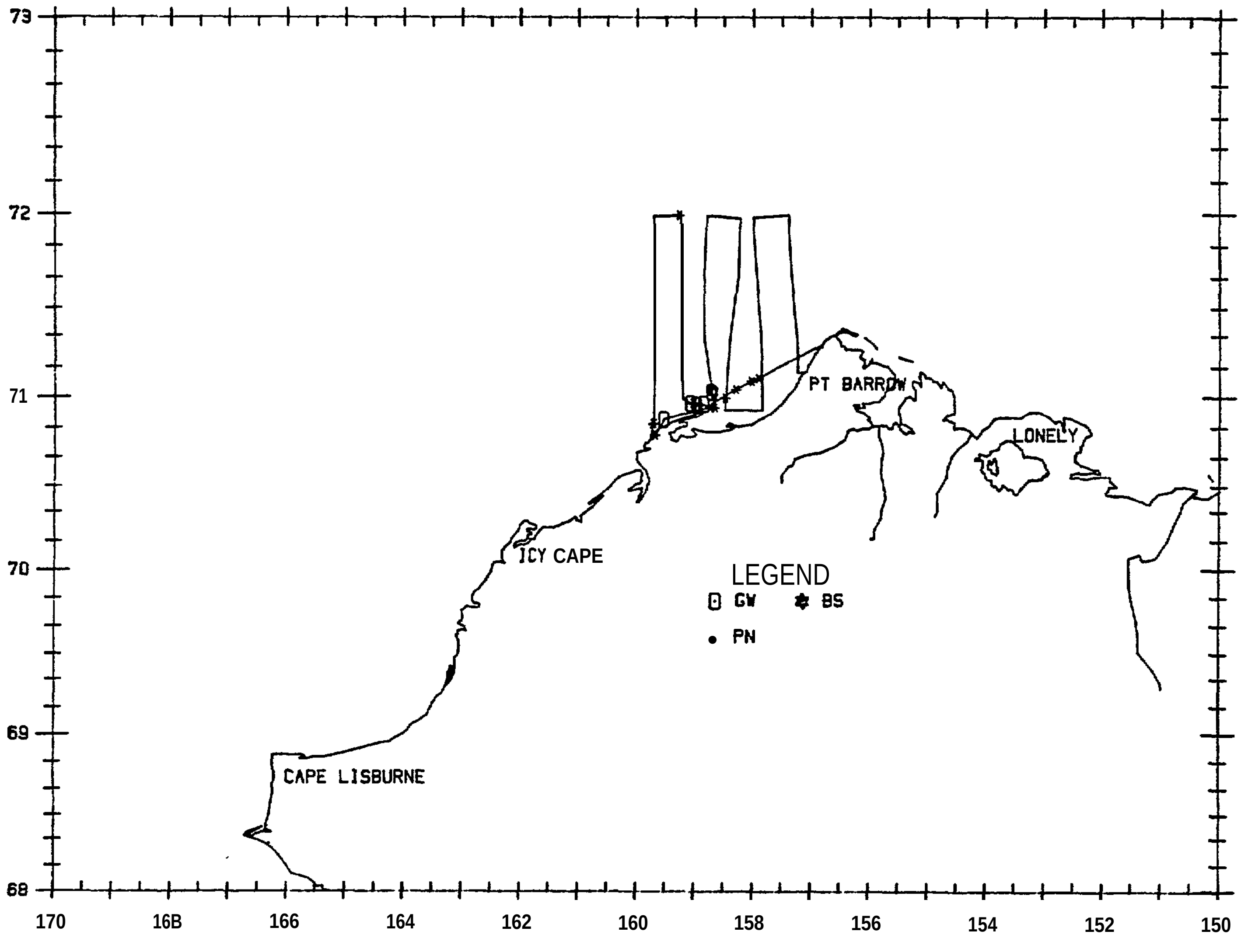
Flight 6: 27 September 1989

Flight was a transect survey of block 13. Weather was overcast and visibility ranged from 5 km to unlimited. There was no ice and sea state ranged from Beaufort 01 to 04. Feeding gray whales, bearded seals and unidentified pinnipeds were seen.

Gray Whales

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	70°52.3'	159°27.3'	1132	BW	SW	290	0	B1	29
1/0	70°57.6'	158°59.7'		BW	Sw		o	B1	27
4/0	70"57.1'	158°53.5'		MP	FE	240	0	B1	27
1/0	70"57.4'	158°46.4'		MP	FE	210	0	B1	18
2/0	71 "01 .4'	158°37.9'	585	MP	FE		o	61	20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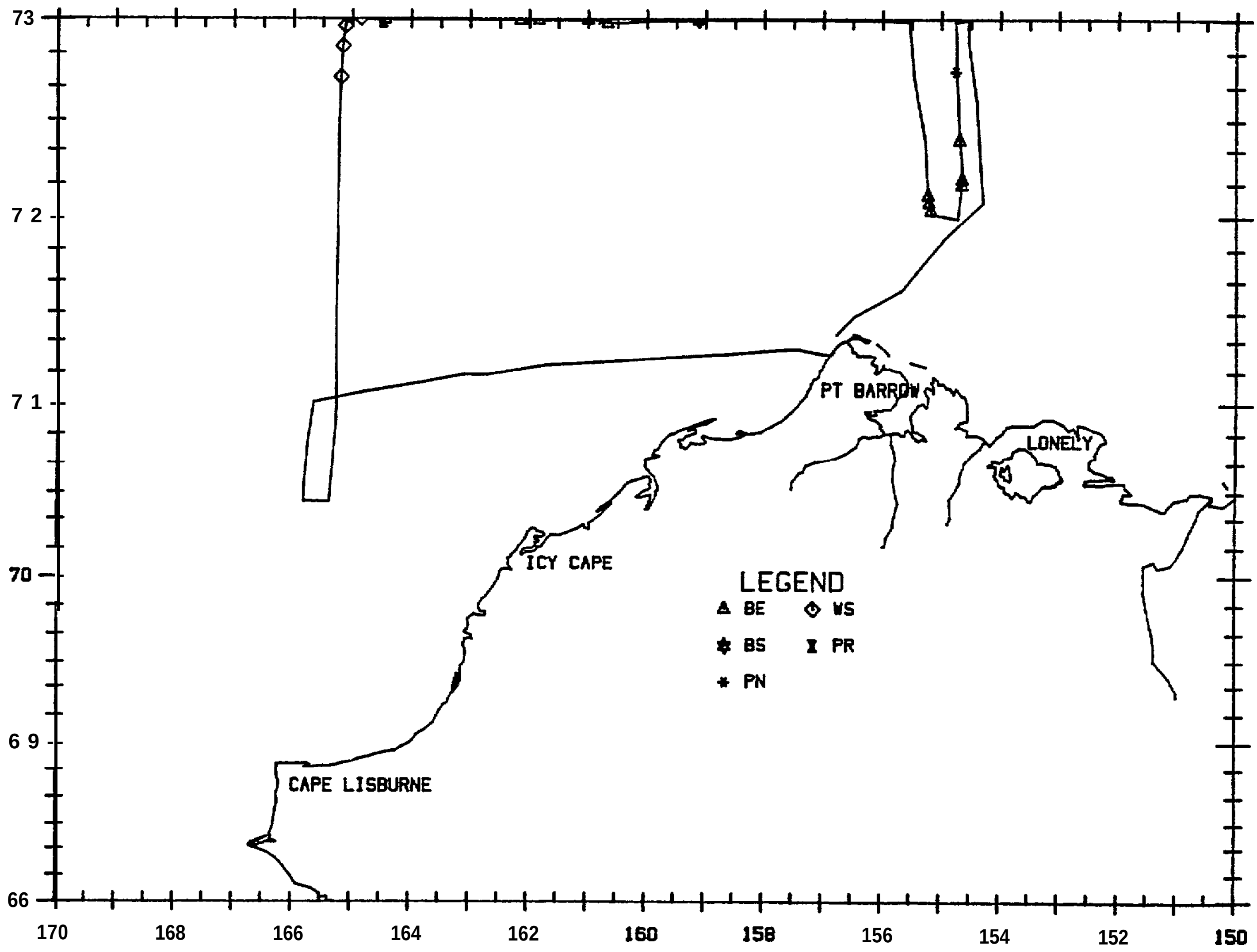
Flight 7: 28 September 1989

Flight was a partial transect survey in the western third of block 18, a single transect leg in blocks 15 and 15N, a search survey near or at the ice edge along 73" N, and a transect survey in the eastern half of block 12N. Weather enroute and in block 18 was overcast with low ceilings, fog and high sea states; elsewhere weather was mostly overcast with visibility 3 km to unlimited. Sea state ranged from Beaufort 01 to 06. Belukhas, walrus, a bearded seal, unidentified pinnipeds and a polar bear were seen. The drillship Explorer III was seen with attendant support vessels near710 12'N, 1630 10'W.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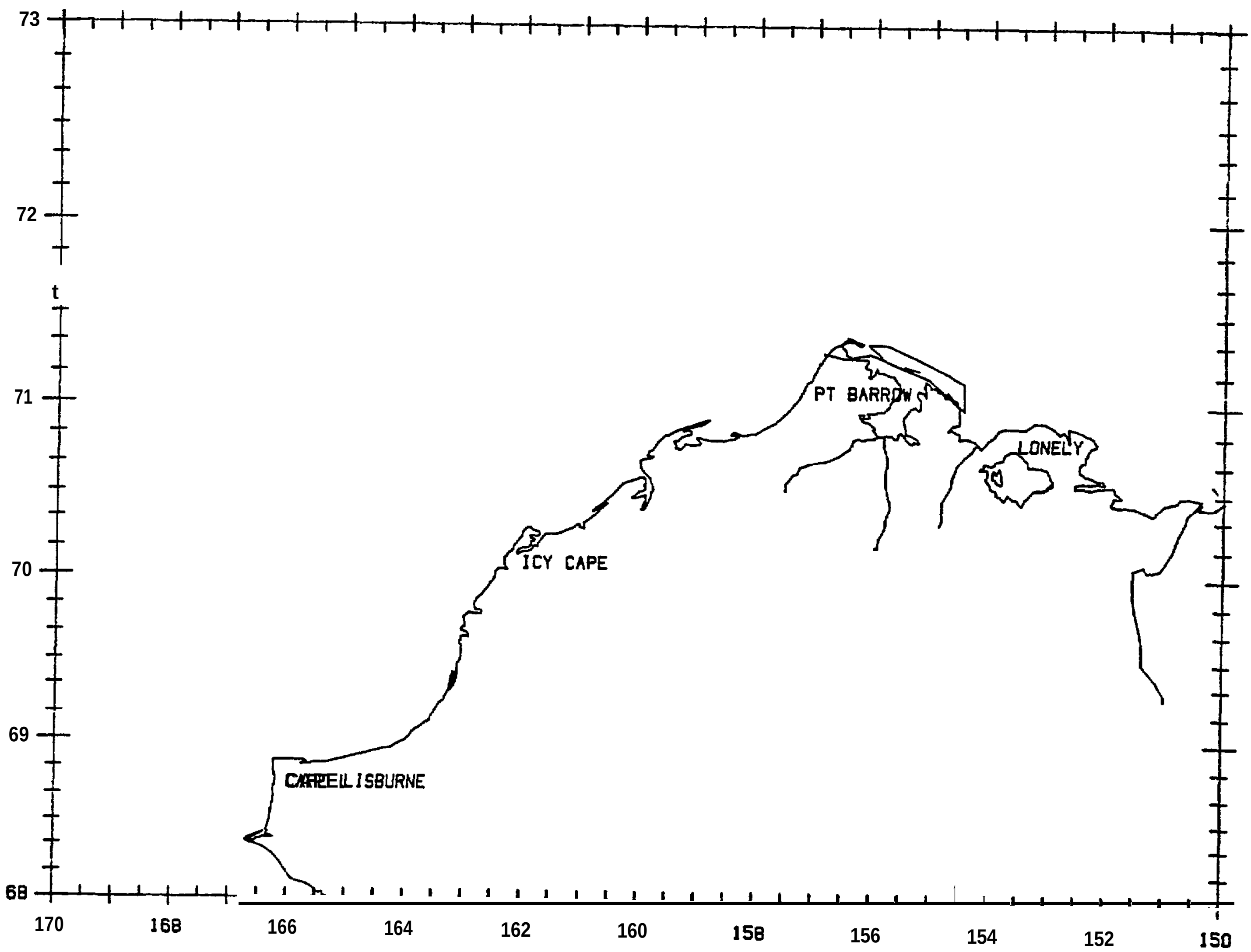
Flight 8: 29 September 1989

Flight was a search and brief transect survey in block 12 that was terminated due to the failure of the aircraft's navigation equipment. No marine mammals were seen.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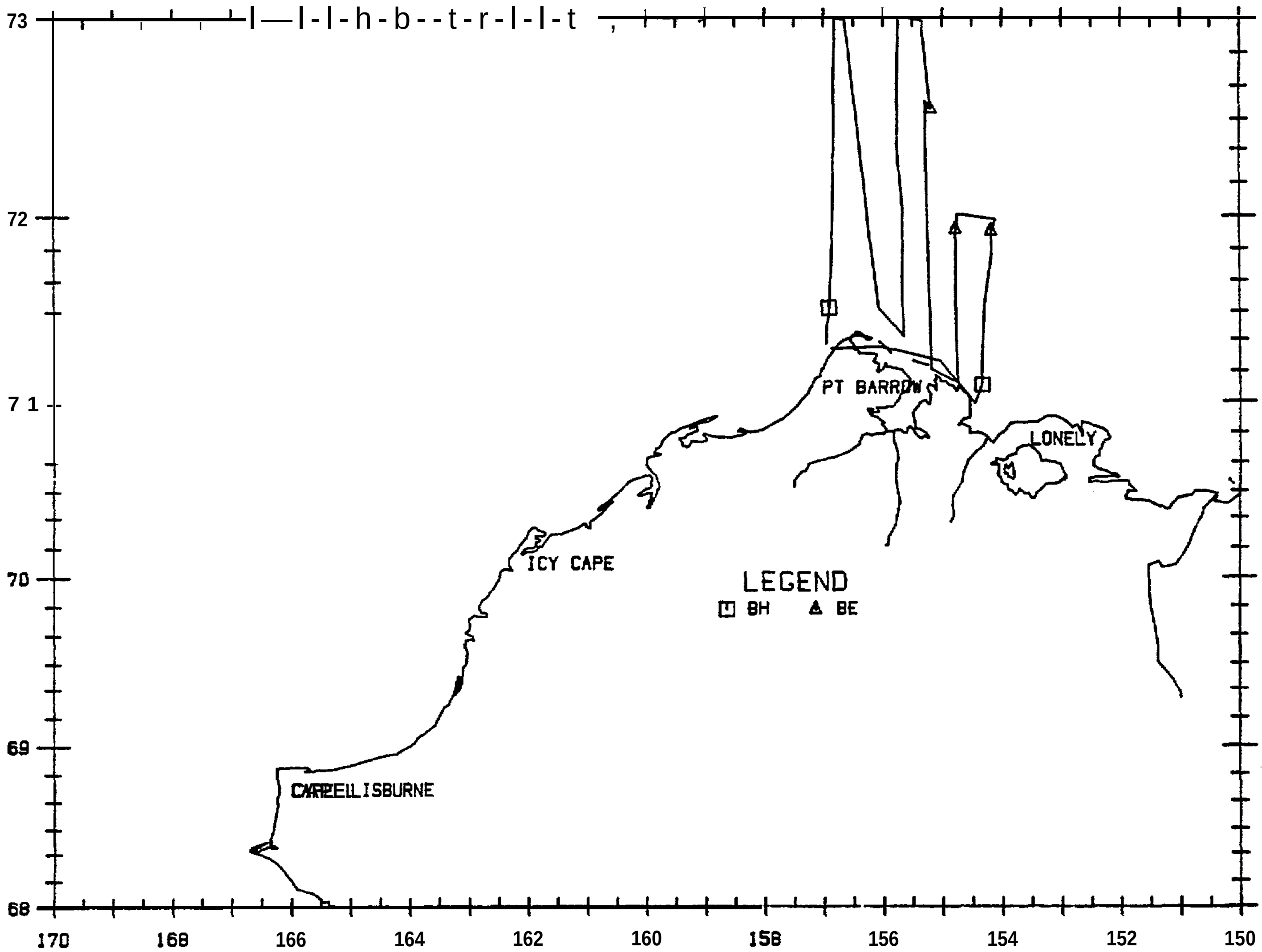
Flight 9: 30 September 1989

Flight was a transect survey in block 12 and the western two-thirds of 12N. Weather was clear to partly cloudy and visibility 3 km to unlimited. Sea state was Beaufort 01 to 02. Four bowheads were seen, all within 20 km of shore. Belukhas were also seen.

Bowhead Whales

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
3/0	71005.2'	154°13.2'	1132	BW	MI		o	B2	11
1/0	71"31.0'	156°49.0'	1191	SP	SW	270	0	B1	144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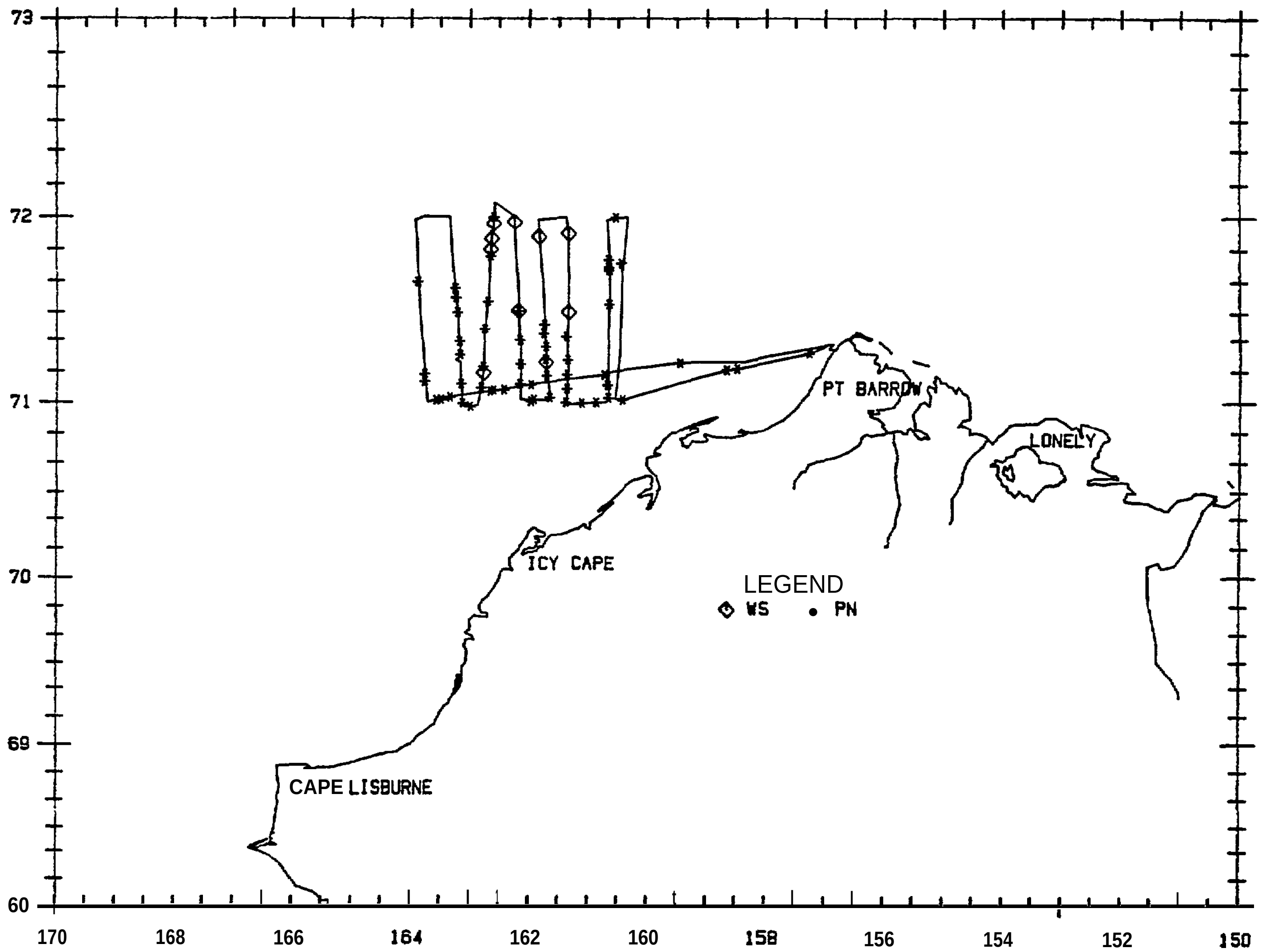
Flight 10: 1 October 1989

Flight was a transect survey of block 14 and the eastern one third of block 15, with a search through block 13. Weather was partly cloudy and visibility unlimited. Sea state was Beaufort 01. Walrus and unidentified pinnipeds were seen.



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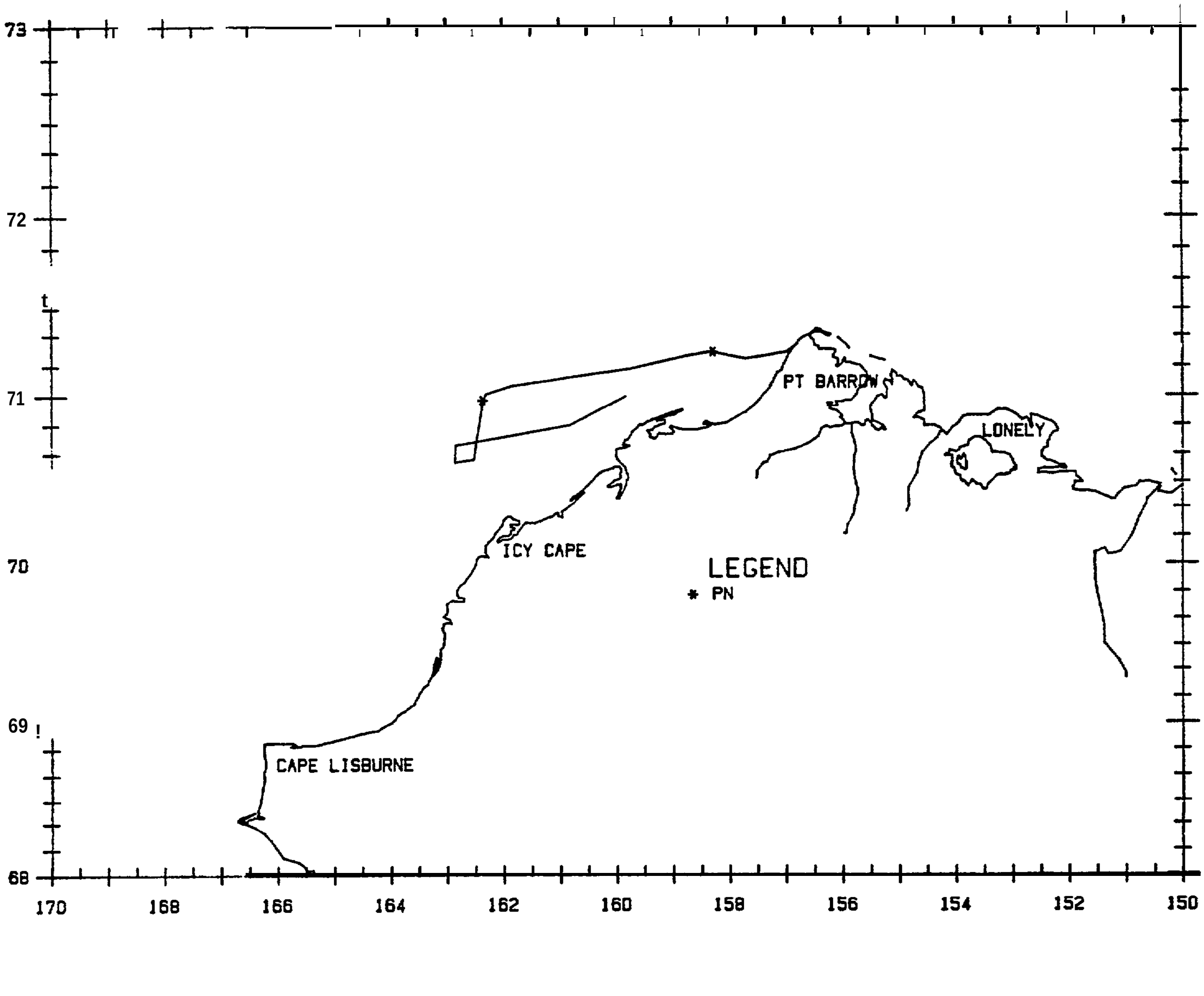
Flight 11: 2 October 1989

Flight was a search through block 13 and a brief transect survey in block 17 that was terminated due to low fog. Weather was persistent low fog and visibility ranged from c 1 km to unacceptable. Sea state was Beaufort 02. Two unidentified pinnipeds were seen.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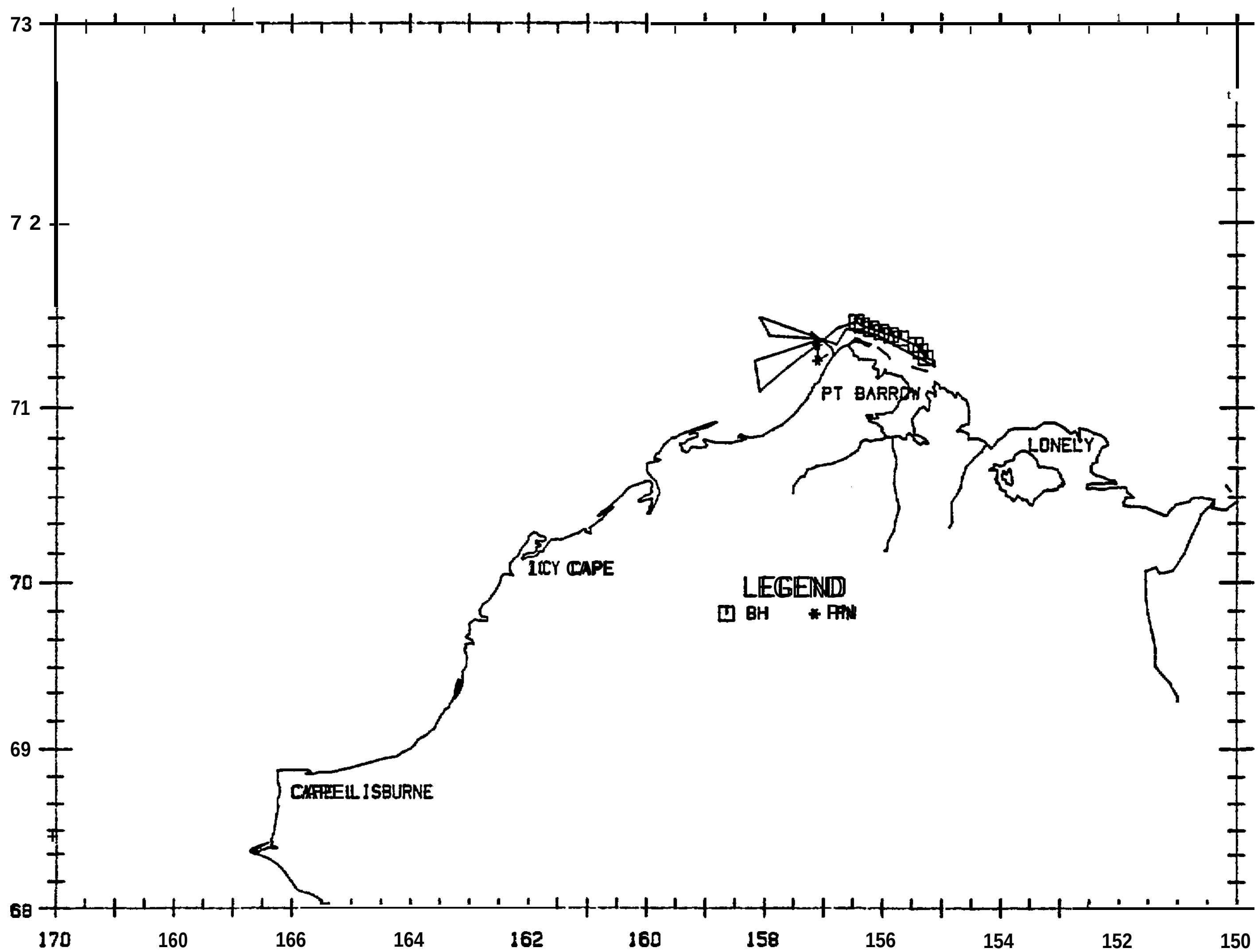
Flight 12: 5 October 1989

Flight was a search survey in blocks 12 and 13. Weather was overcast with patches of fog; visibility ranged from < 1 to 10 km. Sea state was Beaufort 01 to 03. Forty-one bowheads were seen northeast of Point Barrow milling, resting and feeding.

Bowhead Whales

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
3/0	71°16.0'	155" 10.0'		BO	UB		0	B1	13
5/0	71°18.0'	155"15.0'		SP	FE		0	B1	16
2/0	71 "20.0'	155°20.0'		BO	RE		0	B1	16
6/1	71 "22.0'	155"35.0'		BO	MI		0	B1	15
5/2	71 "23.0'	155"45.0'		BO	MI		0	B1	11
7/0	71 "24.0'	155"55.0'		BO	FE		0	B1	9
4/0	71 '25.0'	156°05.0'		SP	SW		0	B1	15
6/0	71026.0'	156°15.0'		BW	FE		0	B1	9
3/0	71027.0'	156°20.0'		BO	FE		0	B1	9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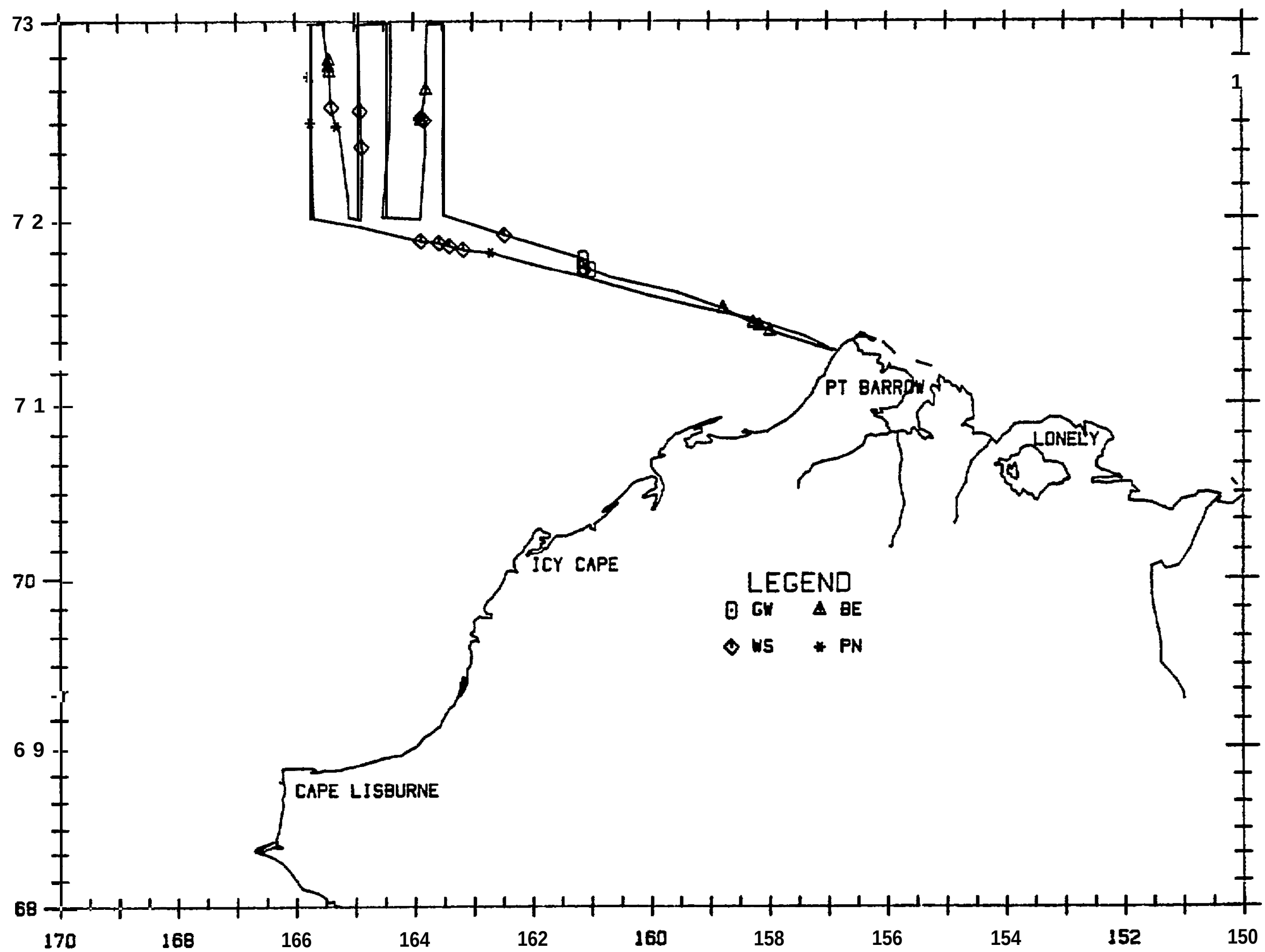
Flight 13: 9 October 1989

Flight was a transect survey of block 15N, with a search survey through blocks 13, 14 and 15. Weather was partly cloudy to overcast with patches of fog; visibility ranged from less than 1 km to unlimited. Sea state was Beaufort 01 to 04. Gray whales, belukhas, walrus and unidentified pinnipeds were seen.

Gray Whales

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71 "47.4'	161°04.1'	2352	BO	FE		0	B2	35
2/0	71 "44.8'	161003.0'		MP	FE		0	B2	37
1/0	71044.8'	161004,6'		MP	FE		0	B2	37
3/0	71 "44.0'	160°56.9'		MP	FE		0	B2	37



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Flight 14: 10 October 1989

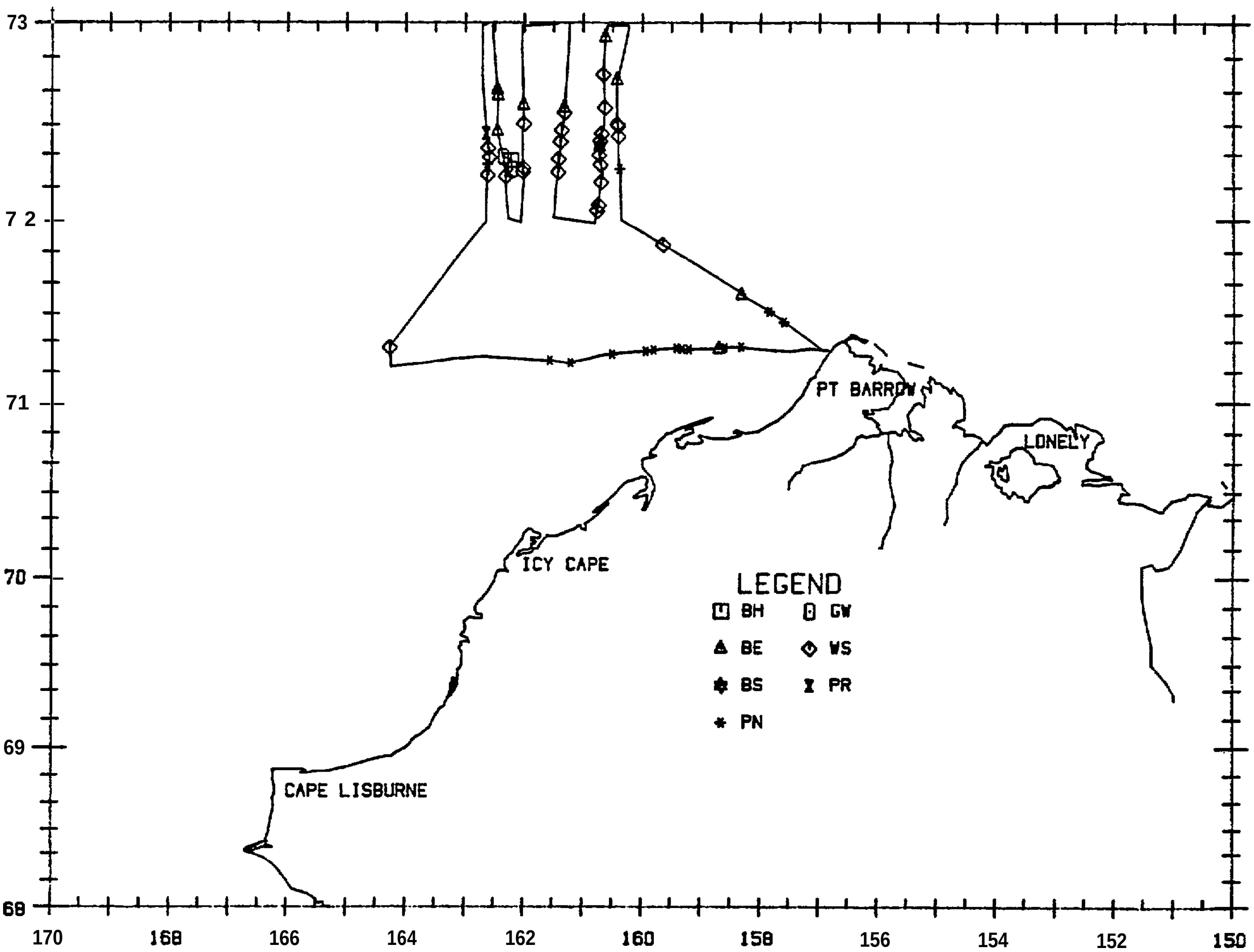
Flight was a transect survey of block 14N, with a search survey in blocks 13, 14 and 15. Weather was partly cloudy to overcast with patches of fog; visibility ranged from unacceptable to unlimited. Sea state was Beaufort 00 to 04. One bowhead was seen near feeding gray whales. Belukhas, walrus, a bearded seal, unidentified pinnipeds and a polar bear were seen.

Bowhead Whale

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	72°18.1'	162"09.6'		BO	SW	300	10	B1	33

Gray Whales

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
6/0	72°19.2'	162" 17.6'	435	MP	FE		10	B1	33
1/0	72°15.3'	162°08.4'	358	MP	FE		10	B1	33



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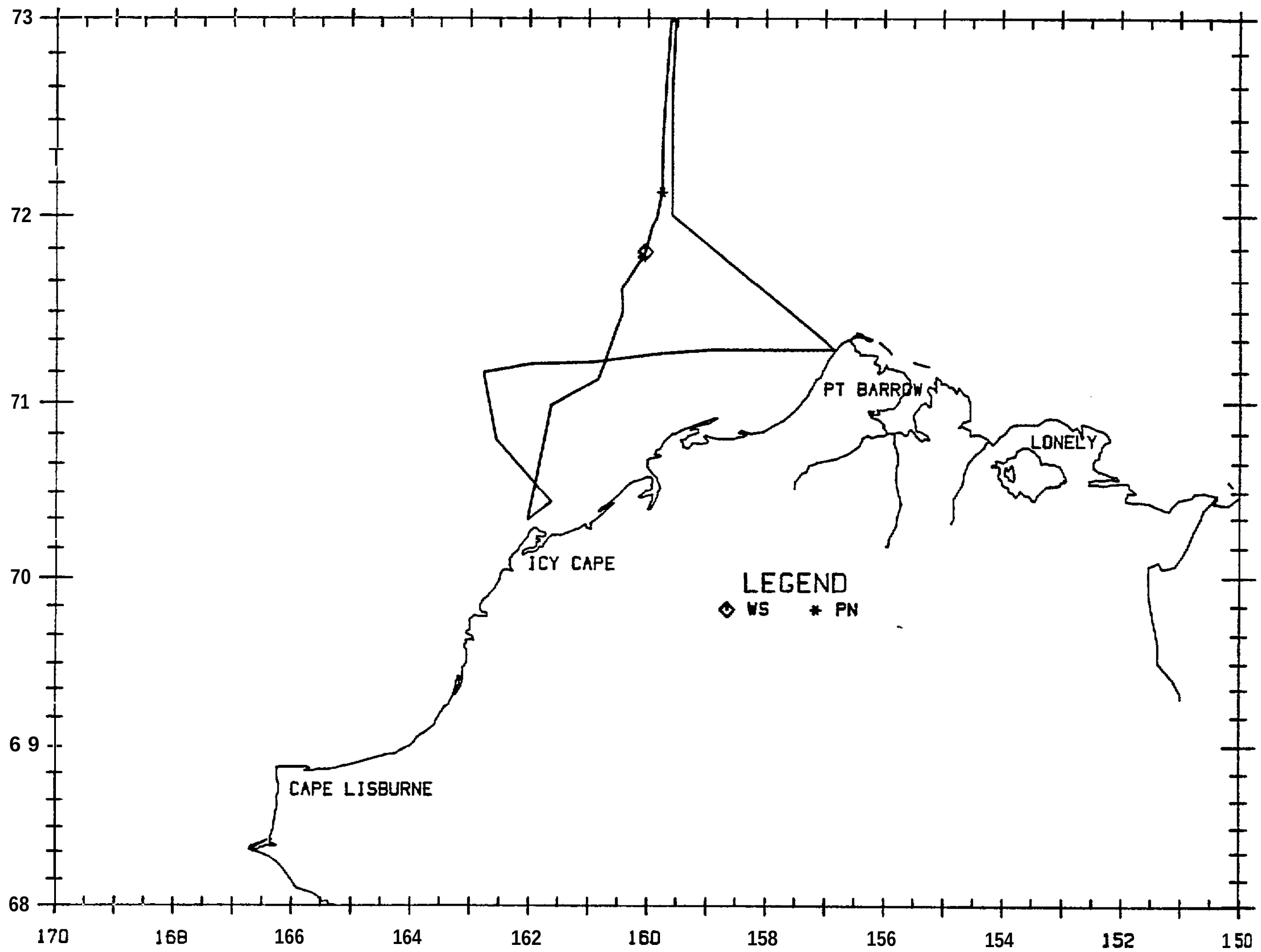
Flight 15: 11 October 1989

Flight was a transect survey of the western two-thirds of block 13N and a brief transect of block 17 that was terminated due to high sea states. Weather was overcast wtih patches of fog; visibility ranged from unacceptable to unlimited. Ice coverage was **95** percent north of 720 N, and sea state ranged from Beaufort 01 in areas with ice to Beaufort 05 in areas of open water. Unidentified pinnipeds and a walrus were seen.



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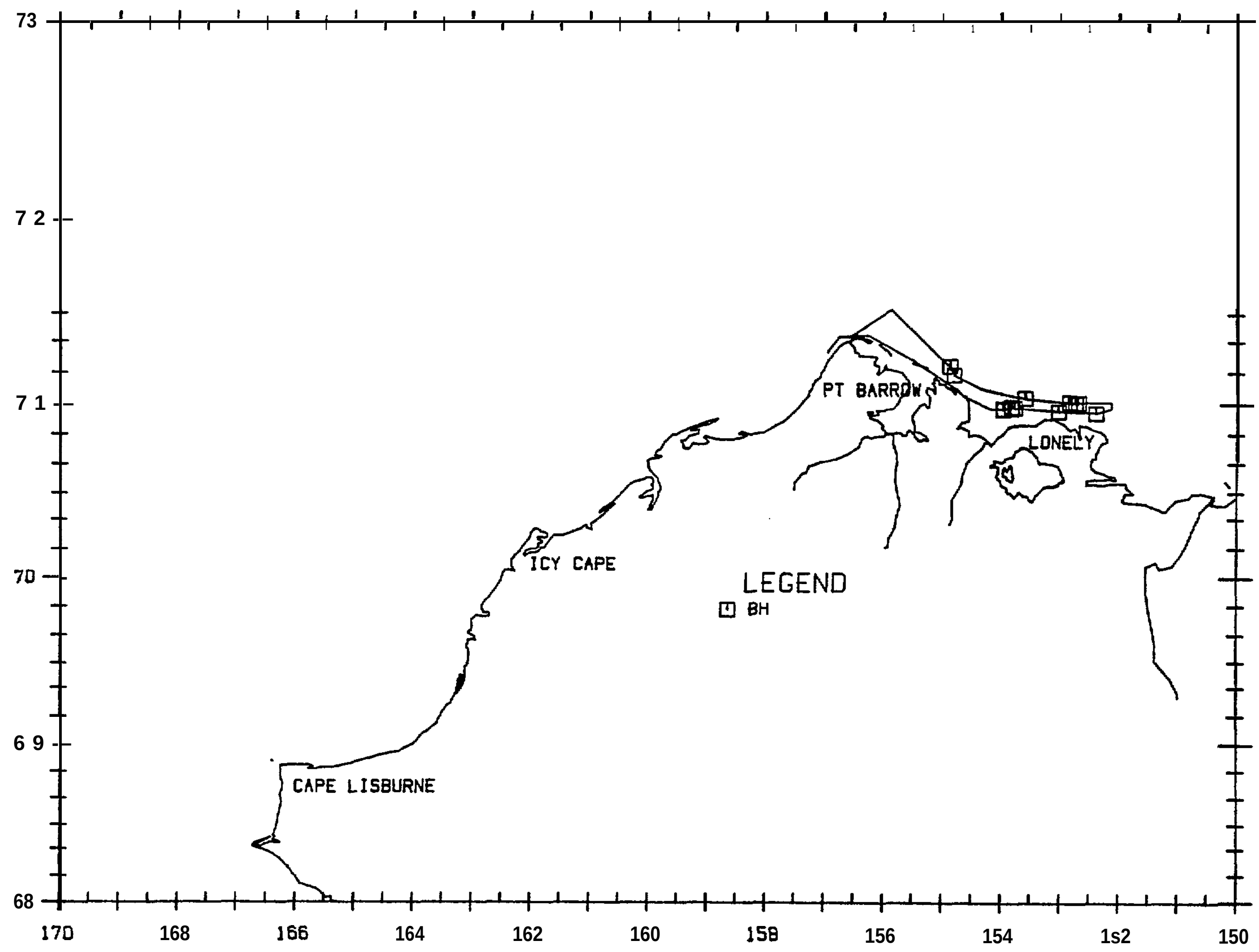
Flight 16: 14 October 1989

Flight was *a* search survey of block 12. Weather was overcast; visibility *was* unlimited. There **was** no ice and sea state was Beaufort 04 to 05. Fourteen bowheads were seen nearshore between Elson Lagoon and Point Lonely,

Bowhead Whales

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	70°58.3'	153"50.0'	938	BO	SW	60	0	B5	7
1/0	70°58.9'	153"41.4'	1434	BO	SW	60	0	B5	7
1/0	70°58.6'	153°38.3'	488	BO	SW	60	0	B5	9
1/0	70"57.5'	152°53.4'	1147	BO	FE		0	B5	7
1/0	70056.9	152°15.1'	1729	BO	FE		0	B5	11
3/0	71 "00.5'	152"42.1'		BO	FE		0	B4	13
1/0	71"00.1'	152"36.2'	1320	BO	SW	270	0	B4	13
1/0	71 "00.2'	152°32.8'	938	BO	SW	45	0	B4	13
1/0	71°01.8'	153°27.6'	938	BO	SW	90	0	B4	11
1/0	71009.2'	154'40.5'	1032	BO	FE		0	B5	11
2/0	71°12.0'	154'45.0'		BO	RE	260	0	B5	15



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Flight 17: 15 October 1989

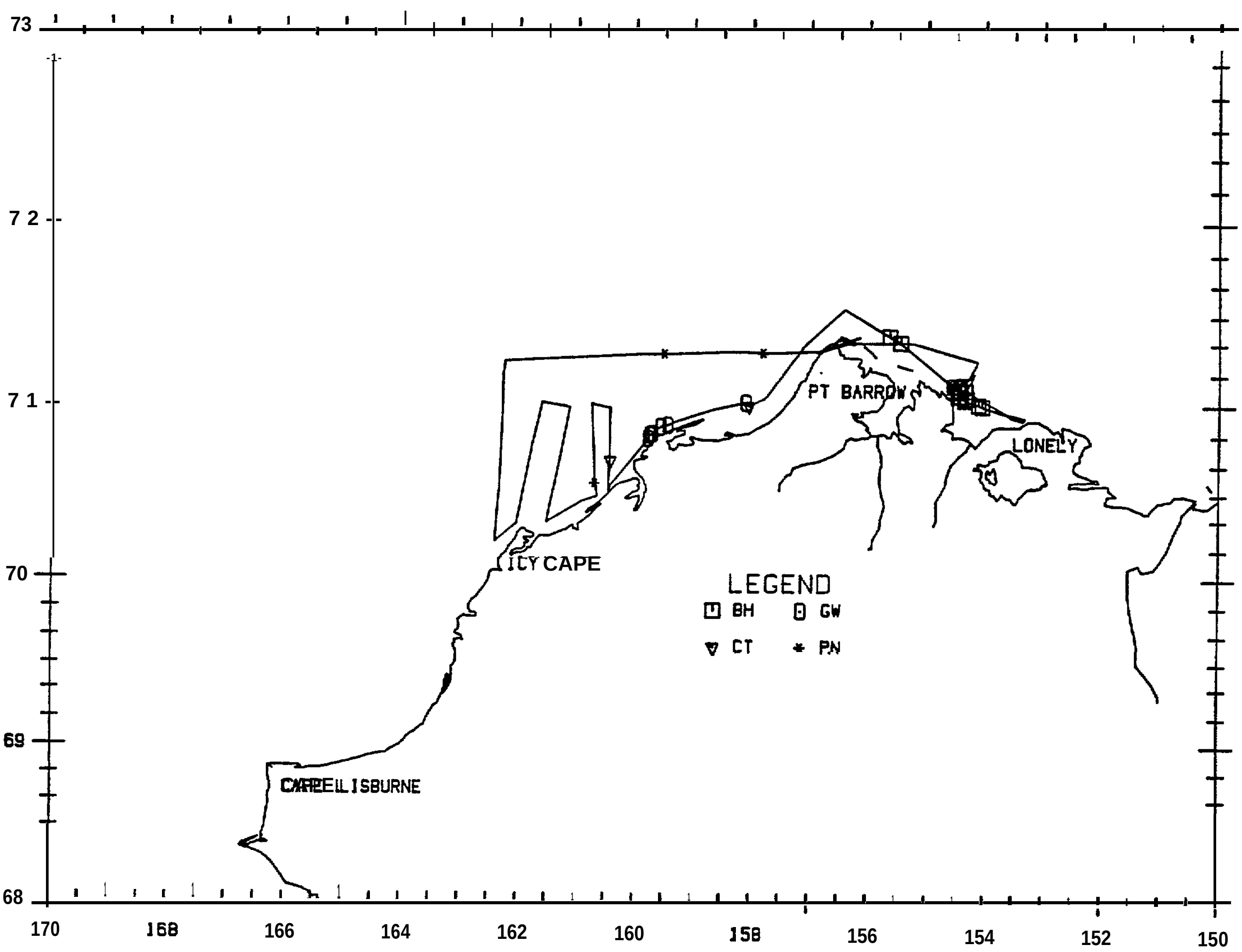
Flight was a transect survey of block 17 with a search survey through blocks 12, 13 and 14. Weather was clear with unlimited visibility. There was no ice and sea state ranged from Beaufort 01 to 04. Twenty-five bowhead whales were seen north of Harrison Bay and northeast of Point Barrow, and gray whales were seen nearshore west of Point Franklin. Two cetaceans were seen which could not be positively identified. Unidentified pinnipeds were also seen.

Bowhead Whales

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
3/0	71006.7'	154"13.7'	1407	BO	FE		o	B3	13
1/0	71002.3'	154°10.8'	1328	BO	SW	290	0	B3	9
1/0	71 "03.0'	154"17.4'	1820	BO	SW	300	0	B3	11
1/0	71 "04.5'	154"19.6'	367	BO	SW	230	0	B3	11
3/0	71006.4'	154°21.2'		BO	Sw	260	0	B3	13
5/0	71004.8'	154°12.3'		BO	FE		0	B3	11
2/0	70"59.7'	153"55.3'	471	BO	SW	70	0	B2	8
1/0	71 "00.2'	153"59.1 '	457	BO	SW	170	0	B2	13
1/0	71"01.1'	154"13.6'		BW	SW	70	0	B2	9
3/0	71 "05.0'	154"19.5'	2223	BO	SW	140	0	B2	11
1/0	71°06.1'	154°24.2'	262	BO	SW	240	0	B2	13
1/0	71 "20.2'	155019.8'	185	BO	SW	240	0	B2	16
2/0	71 "22.2'	155"31.0'	227	BO	SW	330	0	B2	15

Gray Whales

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	Ss	DEPTH
1/0	71 "00.5'	157"59.9'		BW	SW'	160	o	B2	27
5/0	70"53.1'	159°20.9'	565	BW	SW	250	0	B1	29
1/0	70°52.7'	159"28.0'		BW	SW	70	0	B1	29
4/0	70"50.4'	159°36.7'	213	BO	SW	200	0	B1	18
1/0	70"50,0'	159°39.8'	490	BO	SW	180	0	B1	18
1/0	70°48.8'	159"41.5'	1191	BO	SW		0	B1	27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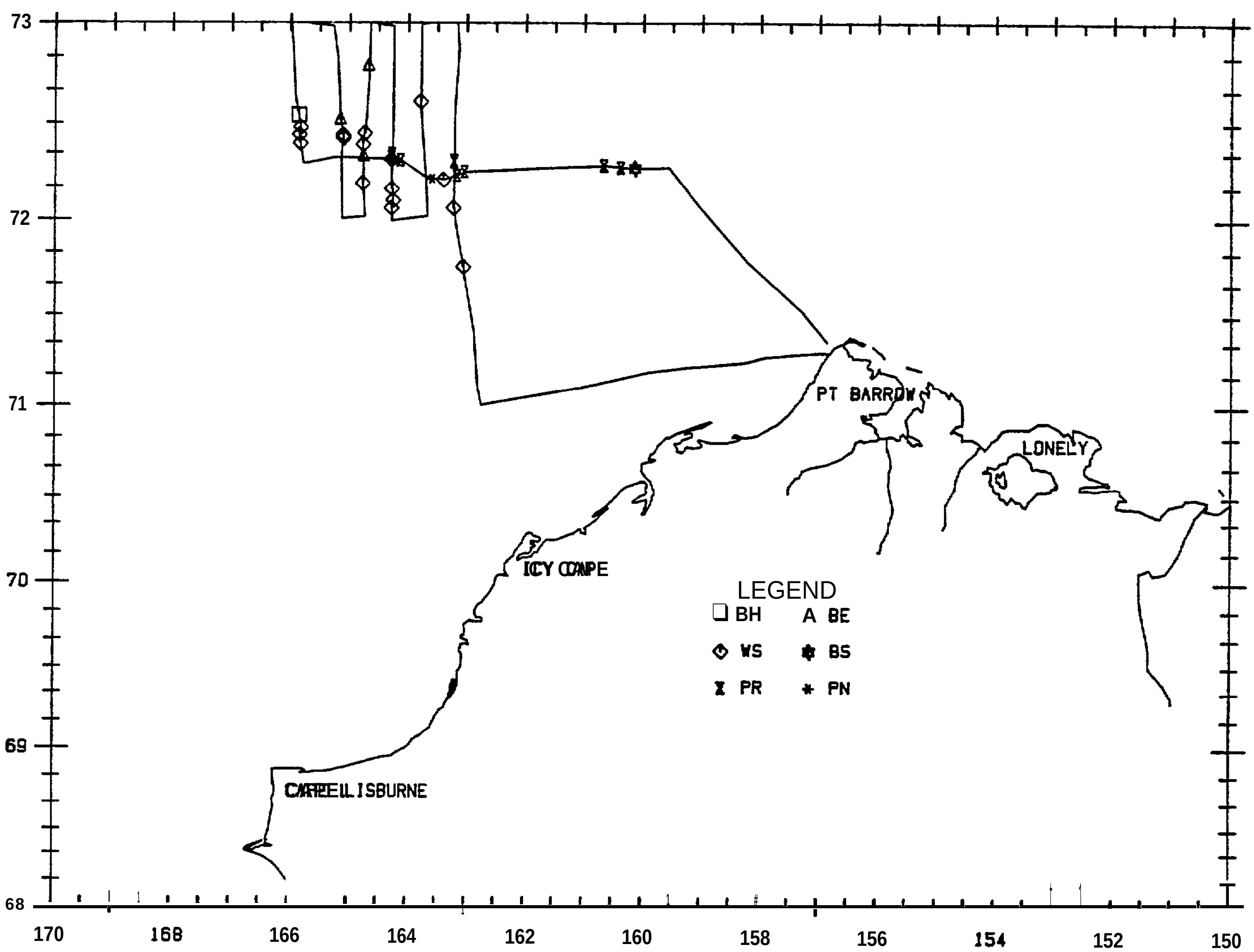
Flight 18: 16 October 1989

Flight was a transect survey in block 15N, with a search survey through blocks 13, 14, and 14N. Weather was overcast with fog; visibility was unlimited in areas of ice and unacceptable over open water. Ice cover was 75-95% north of 720 15'N. Sea state ranged from Beaufort 01 in areas with ice to Beaufort 05 in open water. One bowhead was seen in block 15N swimming slowly west. Belukhas, walrus, polar bears, unidentified pinnipeds and a bearded seal were also seen.

Bowhead Whales

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	72°32.5'	165"49.1'	256	BO	SW	240	85	B5	48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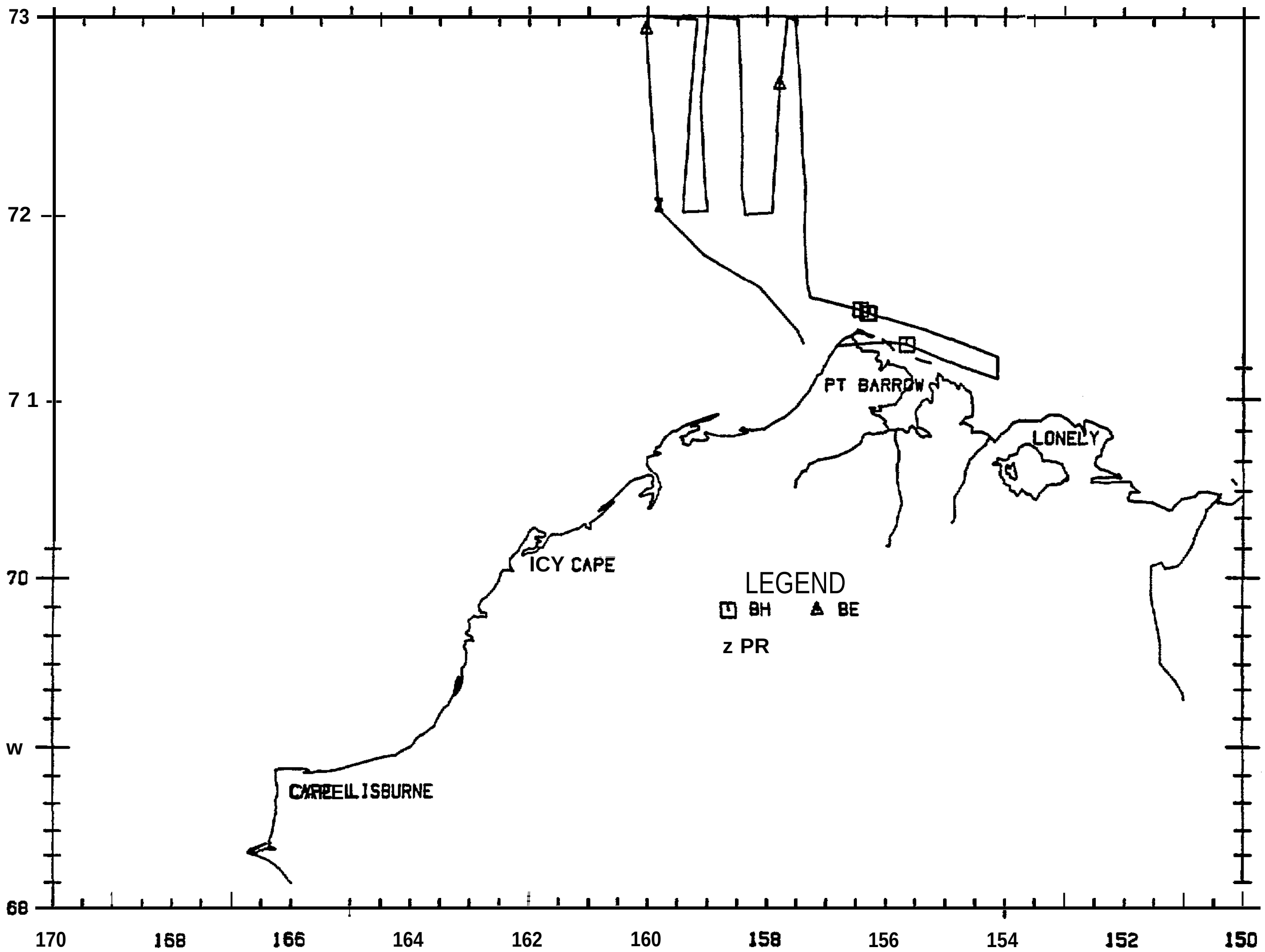
Flight 19: 19 October 1989

Flight was a transect survey in block 13N, with a search survey through blocks 12 and 13. A transect survey of block 13 was aborted due to extremely high sea states. Weather was overcast with fog and snow; visibility varied from < 1 km to 10 km. Ice cover was 95% slushy new ice in the southeast corner of block 13N, and 95-99% grease ice north of there, Sea state was Beaufort 00 to 01 in areas of heavy ice, and Beaufort 05 in the open water. Four bowheads were seen in block 12. Belukhas and a polar bear were also seen.

Bowhead Whales

T#/C#	LA'T(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71 "1 7.4'	155°32.1'	308	BO	SW	45	0	B2	9
1/0	71027.2'	156°09.8'	585	BO	SW	60	0	B3	13
1/0	71027.4'	156°11.8'	860	BO	SW	260	0	B3	9
1/0	71 "28.4	156°18.9'	490	BO	SW	60	0	B3	9



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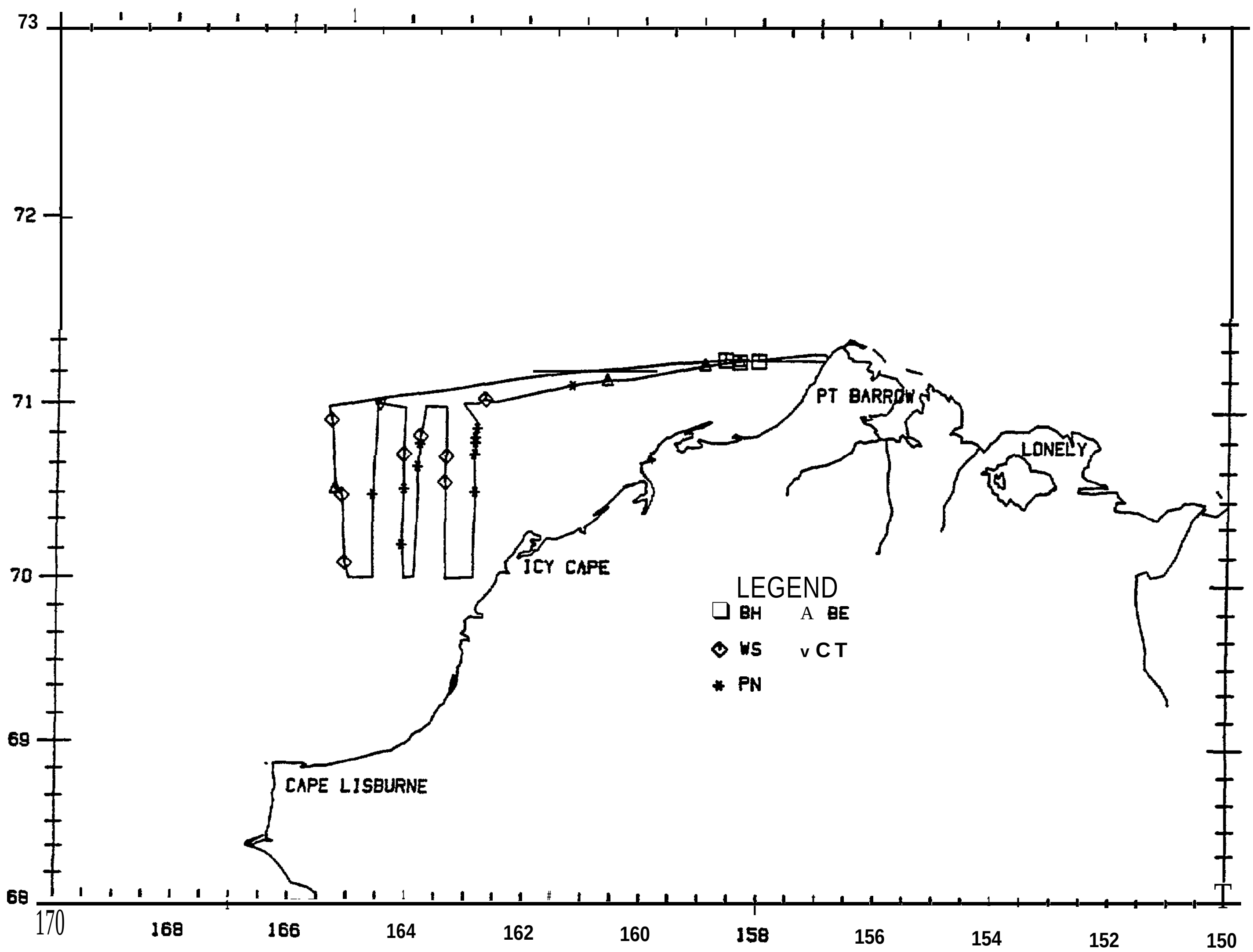
Flight 20: 21 October 1989

Flight was a transect survey in block 18 and the easternmost line in block 17, with a search survey through blocks 13 and 14. Weather was partly cloudy; visibility was unlimited. Ice cover was 85-99% north of 70050'N, with open water south of there. Sea state was Beaufort 01. Five bowheads, including a cow-calf pair, were seen in block 13. A large whale was sighted in block 18, but could not be relocated for positive identification. Belukhas, walrus and unidentified pinnipeds were also seen.

Bowhead Whale

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
2/1	71 "14.7'	158°15.3'	915	BO	SW	280	80	B2	59
2/0	71 "15.4'	158°29.8'	1256	BW	SW	60	98	B1	101
1/0	71015.2'	157"55.9'		BO	SW	240	99	B1	46



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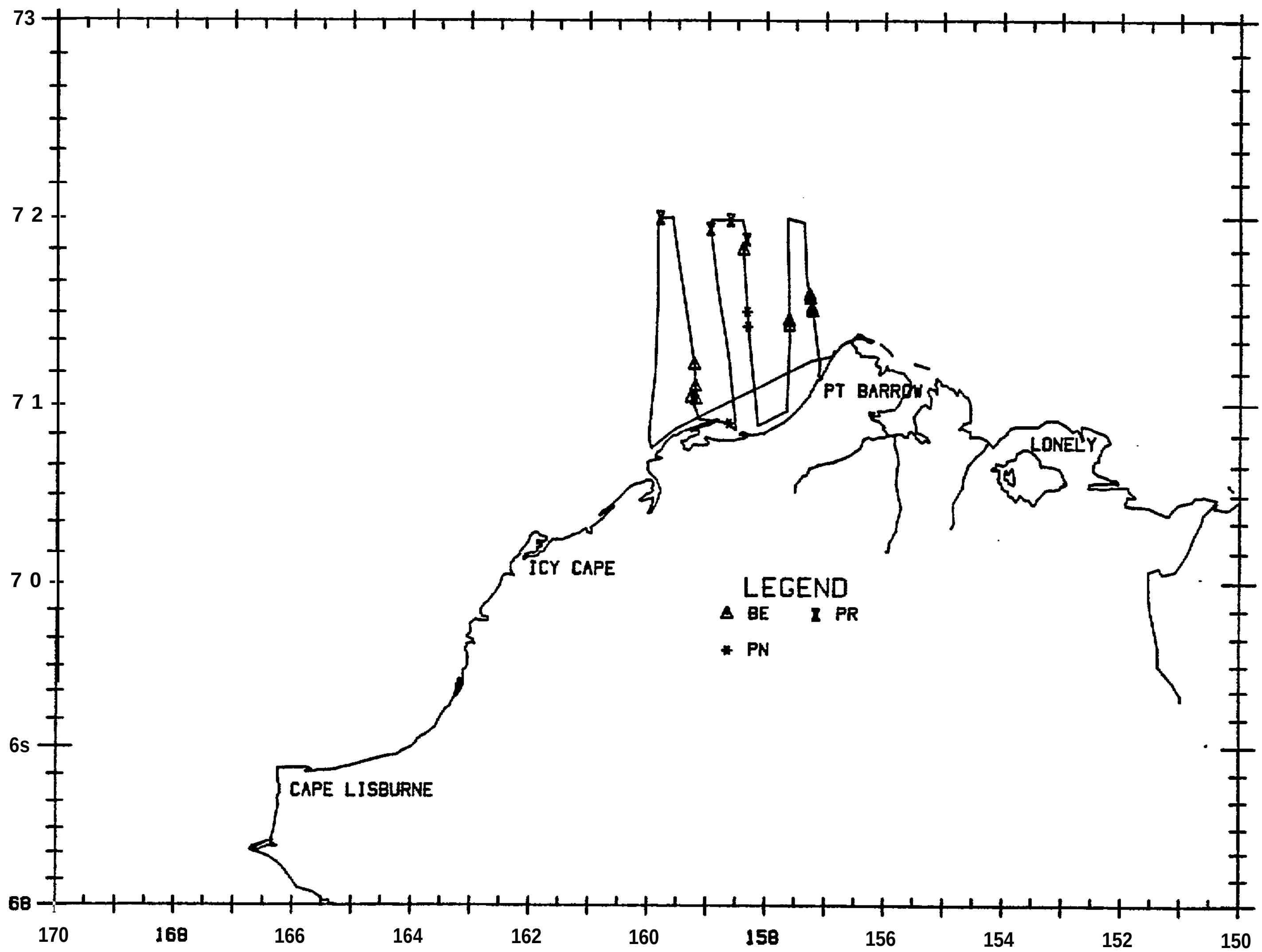
Flight 21: 22 October 1989

Flight was a transect survey of block 13. Weather was clear with unlimited visibility. Ice cover was 95% north of 71” 10’N, with open water south of there. Sea state varied from Beaufort 01 to 03. Belukhas, unidentified pinnipeds and polar bears were seen,



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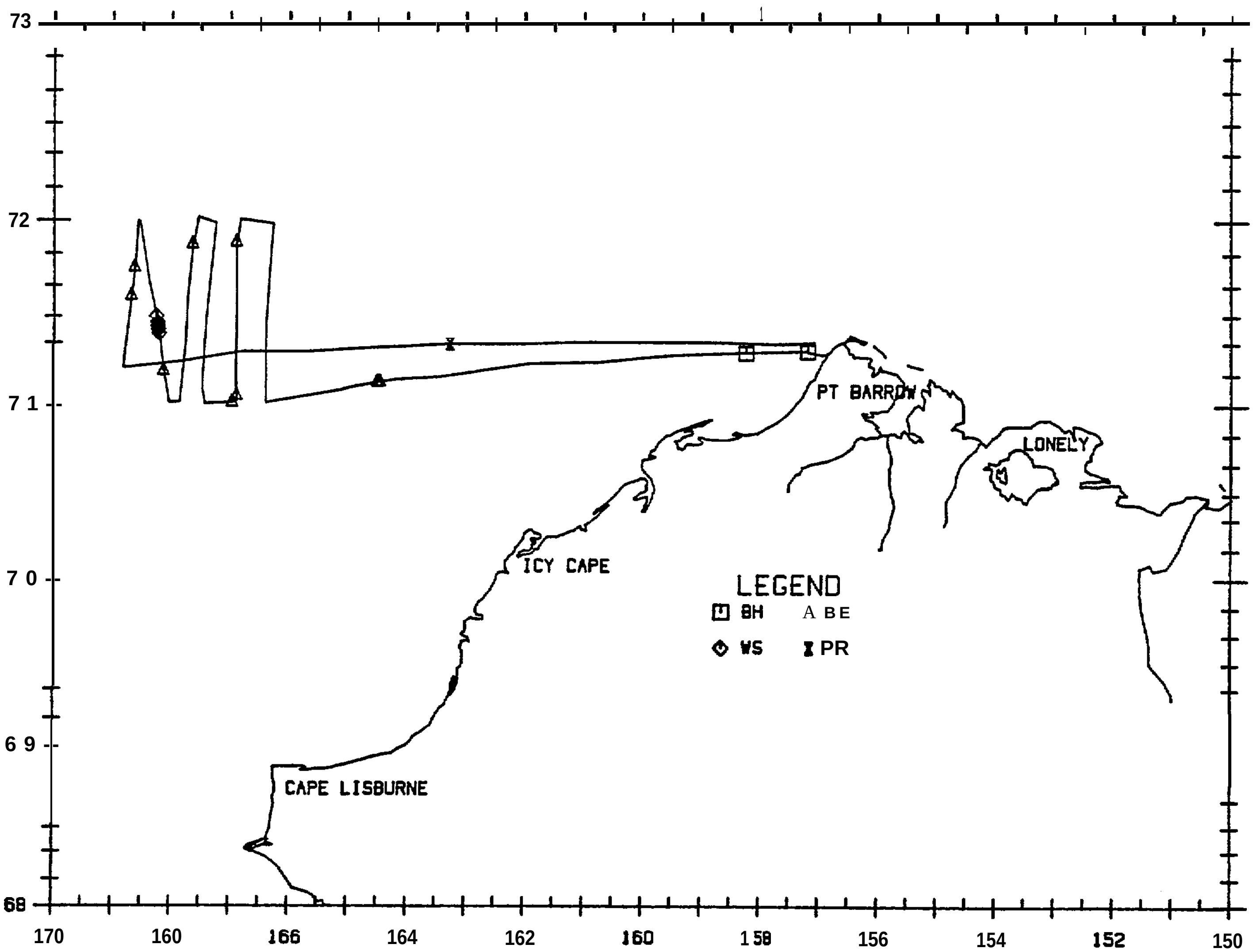
Flight 22: 25 October 1989

Flight was a transect survey in block 16, with a search survey through blocks 13, 14, and 15. Weather varied from overcast with unlimited visibility to frequent snow squalls and fog with visibility <3 km. Ice cover was 80-95% in the northeast corner of the block, with open water elsewhere. Sea state ranged from Beaufort 00 to 03. Two bowheads were seen in block 13. Belukhas, walrus and a polar bear were also seen.

Bowhead Whales

T#/C#	IAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71"17.1'	157"05.1'	329	BO	RE	135	95	B1	37
1/0	71°16.6'	158°08.4'	1077	BO	RE	125	98	BO	59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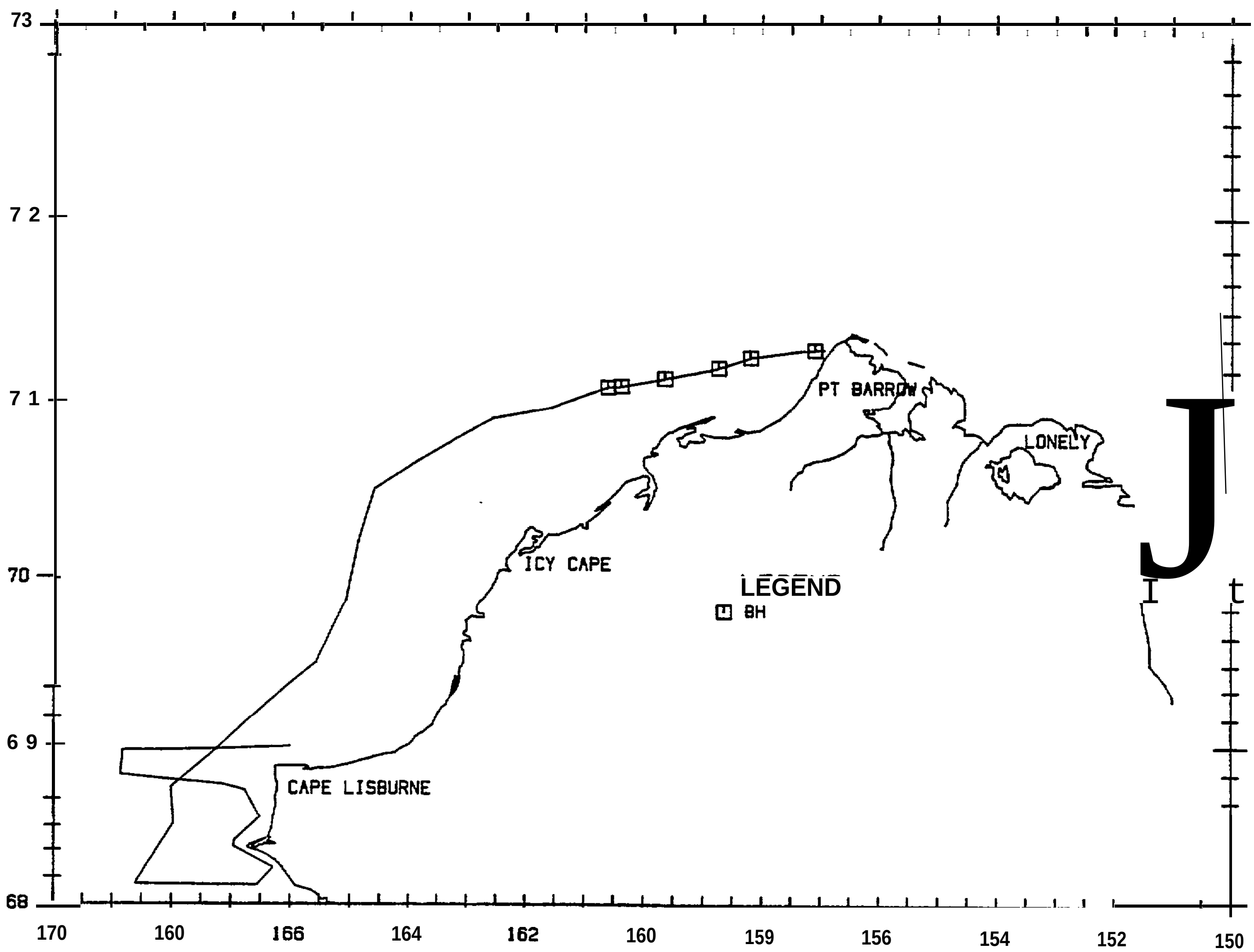
Flight 23: 26 October 1989

Flight was a transect survey of portions of block 22, with a search survey through blocks 13, 14, 18 and 20. Weather was overcast with some fog; visibility varied from unlimited to < 1 km. There was no ice except in the nearshore area south of Point Hope. Sea state was Beaufort 04 to 06. Seven bowheads were seen in blocks 13 and 14, in 85 to 95% slushy ice.

Bowhead Whales

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71 “04.4’	160”31.2	254	SP	RE	270	99	BI	38
1/0	71 “04.8’	160”17.7	148	SP	Sw	270	99	B1	48
2/0	71 “07.4’	159”33.5’	203	SP	Sw	250	75	B1	57
1/0	71”10.9’	158°38.7’	161	BO	Sw	100	99	B1	71
1/0	71 “1 4.3’	158°05.9’	263	BO	RE	300	85	B1	91
1/0	71016.7’	156°59.4’		BW	SW		95	B1	24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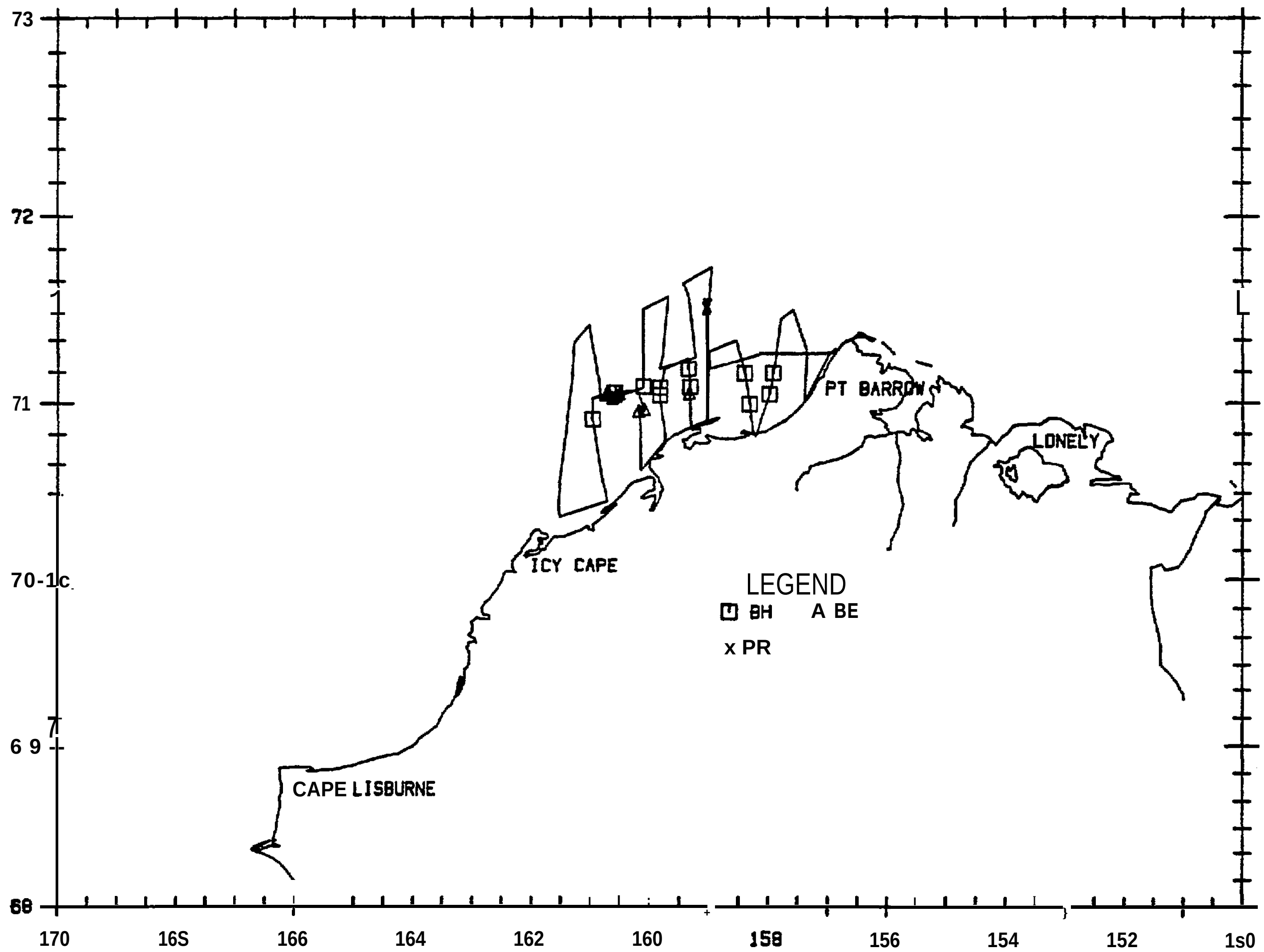
Flight 24: 27 **October 1989**

Flight was a transect survey of portions of blocks **13, 14** and 17. Weather was overcast with snow flurries; visibility varied from < 1 km to 5 km. Ice cover was 90 to 99% north of 700 10'N, with mostly open water south of there. Sea state was Beaufort 03 to 04. Eleven bowheads were seen in blocks 13, 14 and 17. Belukhas and polar bears were also seen.

Bowhead Whales

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71 "09,3'	157"49.3'	598	BO	Sw	220	95	B1	42
1/0	71002.6'	157"52.9'	274	IT	Sw	190	50	B1	27
1/0	70°59.6'	158°13.1'	284	BO	Sw	240	75	B1	18
1/0	71 "09.4'	158" 18.4'	1434	SP	BR	150	20	B2	37
1/0	71 "05.0'	159" 13.9'	281	BO	SW	255	75	B1	68
1/0	71°10.8'	159" 15.8'	347	BW	SW	200	90	B1	79
1/0	71 "04.8'	159°44.6'	1005	IT	Sw	240	85	B1	57
1/0	71002.4'	159°44.6'	958	BW	Sw	250	80	B1	55
1/0	71 "03.3'	160"30.4'	1256	SP	BR	270	98	B1	38
1/0	70"54.7'	160°53.6'	1231	BO	DI		0	B3	46
1/0	71"05.1'	160°01.6'		SP	Sw	190	98	B1	46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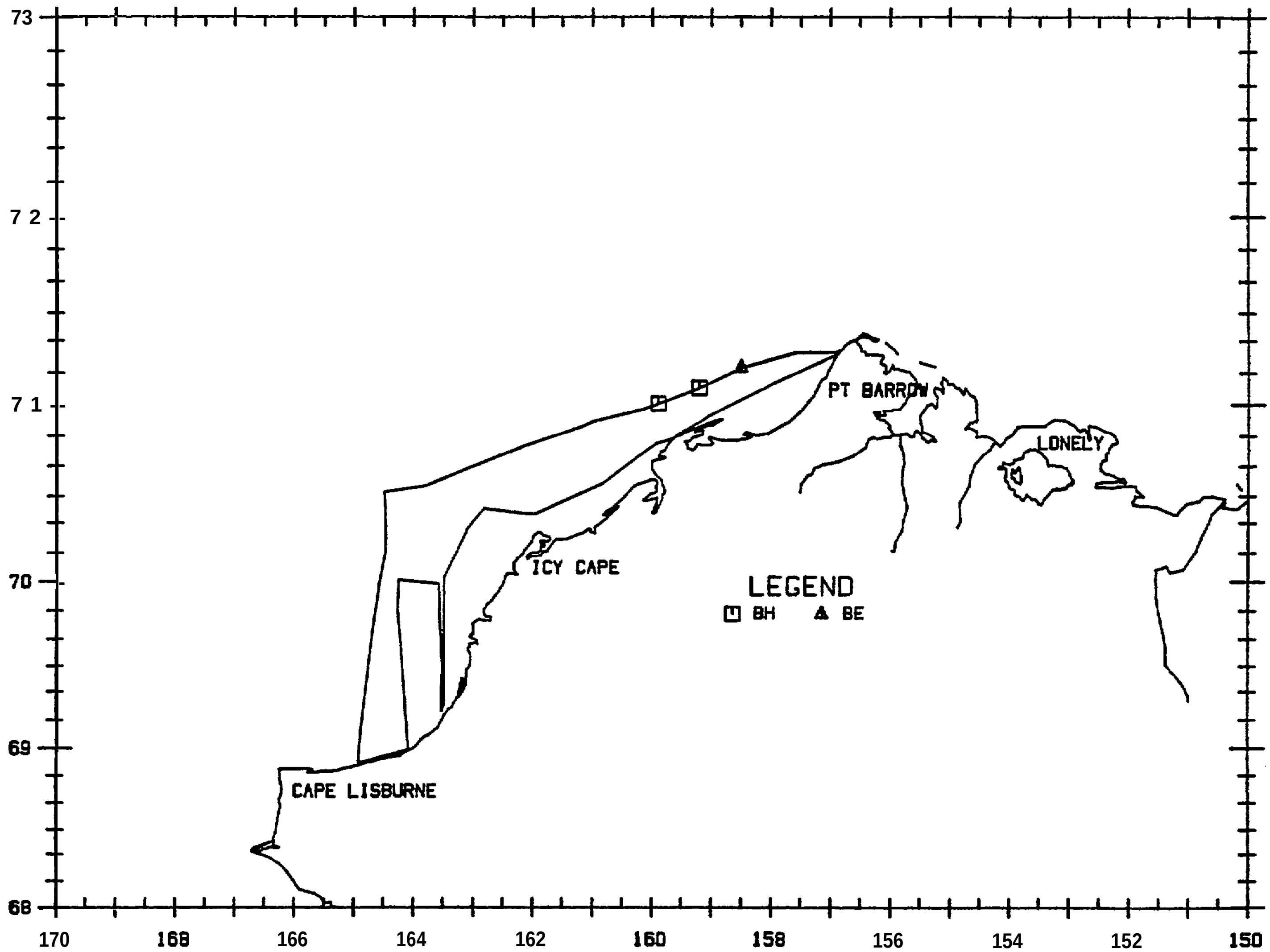
Flight 25: 28 October 1989

Flight was a transect survey in the eastern two-thirds of block 20. Weather was overcast with unlimited visibility. ice cover was 80 to 99% in the eastern half of the block, with open water **in** the **western** half. Sea state was Beaufort 04 to 06 in open water areas. Two bowheads were seen in block 13. Belukhas were also seen.

Bowhead Whales

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71 "00.1 '	159"48.8'	678	SP	SW	240	98	61	55
1/0	71 °05.1 '	159"07.0'	860	SP	Sw	220	95	B1	44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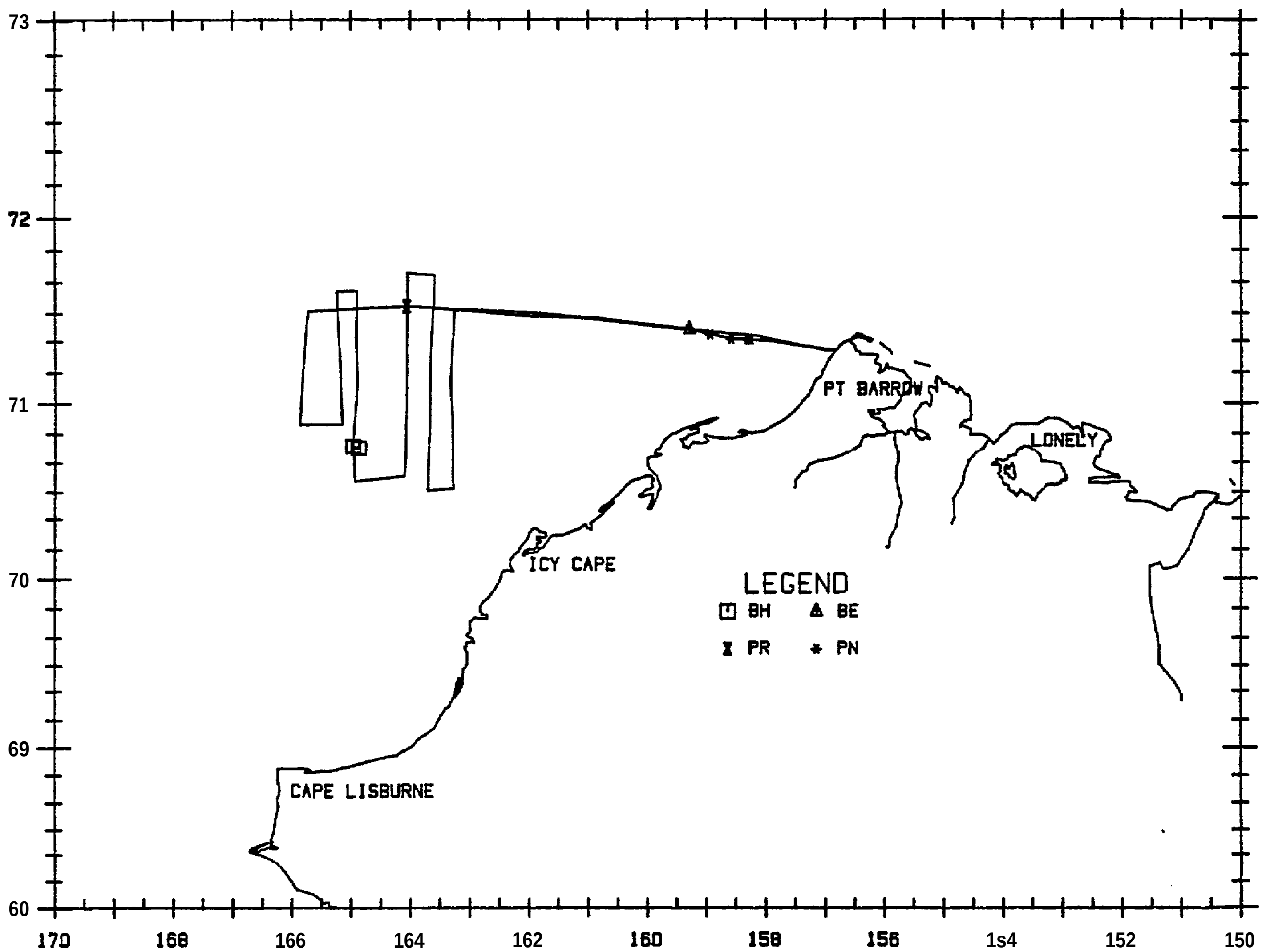
Flight 26: 29 October 1989

Flight was a transect survey of portions of blocks 15 and 18, with a search survey through blocks 13 and 14. Weather was overcast with unlimited visibility. Ice cover was 90 to 99% north of70050'N, with open water south of there. Sea state was Beaufort 04 to 05 in open water areas. Twelve bowheads were seen in block 18. Behaviors exhibited included breaching, tandem breaching, tail slaps, flipper slaps, lunges, and spy hops. Belukhas, unidentified pinnipeds and a polar bear were also seen.

Bowhead **Whales**

T#/C#	IAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	70"45.5'	164"55.6'	1634	SP	BR		0	B4	33
11/0	70"45.0'	164"50.0'		SP	BR		0	B4	29



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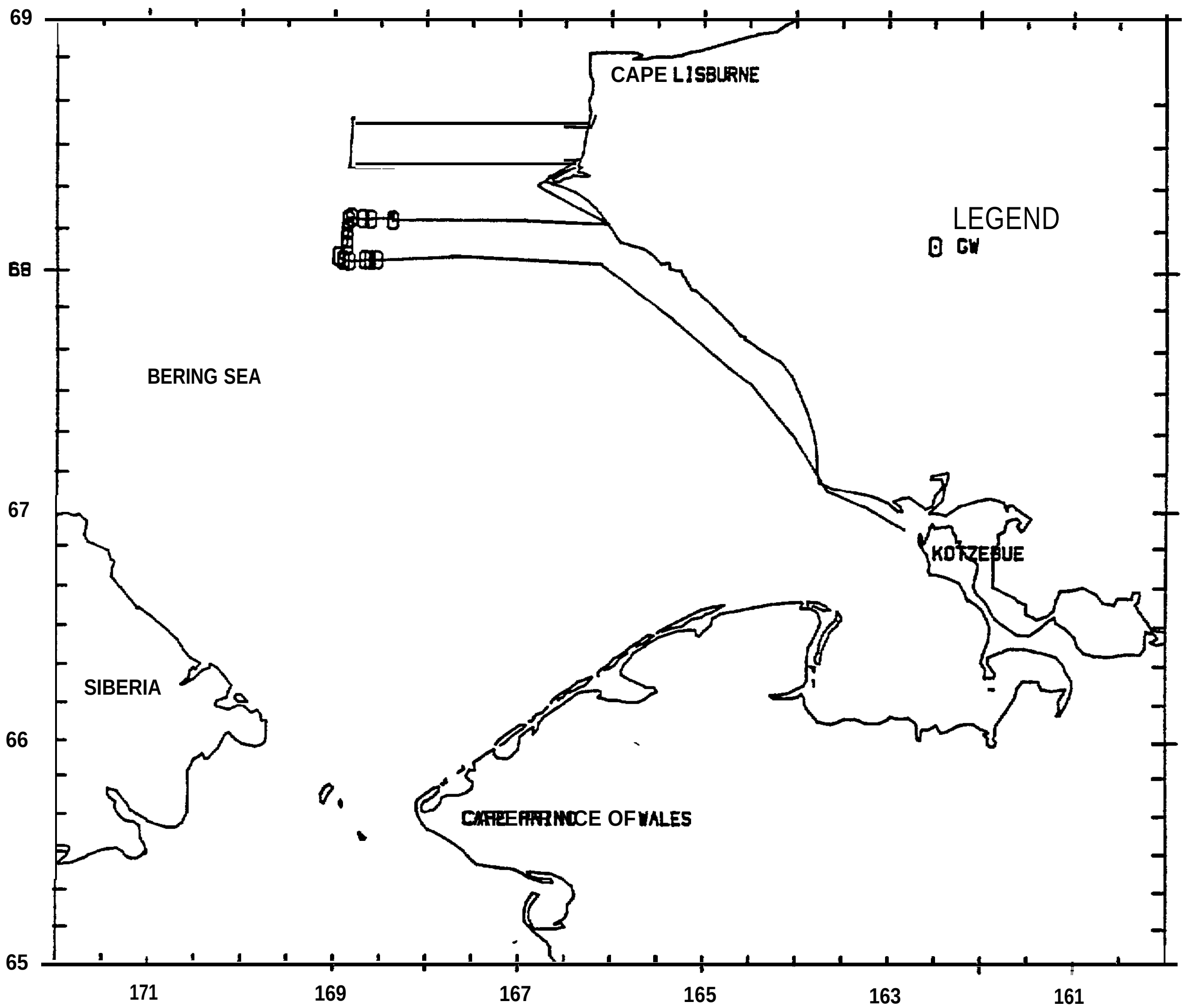
Flight 27: 30 October 1989

Flight was a transect survey of the southern two-thirds of block 22, with a search survey through blocks 30 and 31. Weather was clear with unlimited visibility. Ice cover was 30 to 90% **slushy new ice south of** the **Point** Hope peninsula; all other areas were ice **free. Sea state was Beaufort 02. Fifty-four gray whales** were seen feeding **in block 22.**

Gray Whales

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
2/0	68"11.9'	168"22.0'	2593	BW	FE		o	B2	57
1/0	68"12.2'	168836.3'	474	BW	FE	120	0	B1	57
5/0	68°12.3'	168"41 .4'		BW	FE		0	BI	55
1/0	68"12.6'	168°48.8'		BW	FE		0	B1	55
4/0	68"12.0'	168"50,9'		BW	FE		0	B2	57
1/0	68"09.7'	168"51.3'	2151	BW	FE		0	B2	55
2/0	68"07.5'	168"51.9'		BW	FE		0	B2	59
3/0	68°05.9'	168°51.8'		BW	FE		0	B2	59
9/0	68"03.3'	168"57.5'		BW	FE		0	B2	59
1/0	68"02.5'	168"54.3'		BW	Sw		0	B2	57
6/0	68"02.2'	168°50.2'		BW	FE		0	62	57
5/0	68"02.5'	168"40.4'		BW	FE		0	B2	57
4/0	68"02.5'	168"37.0'		BW	FE		0	B2	57
1 0/0	68'02.5'	168°32.2'		BW	FE		0	B2	57



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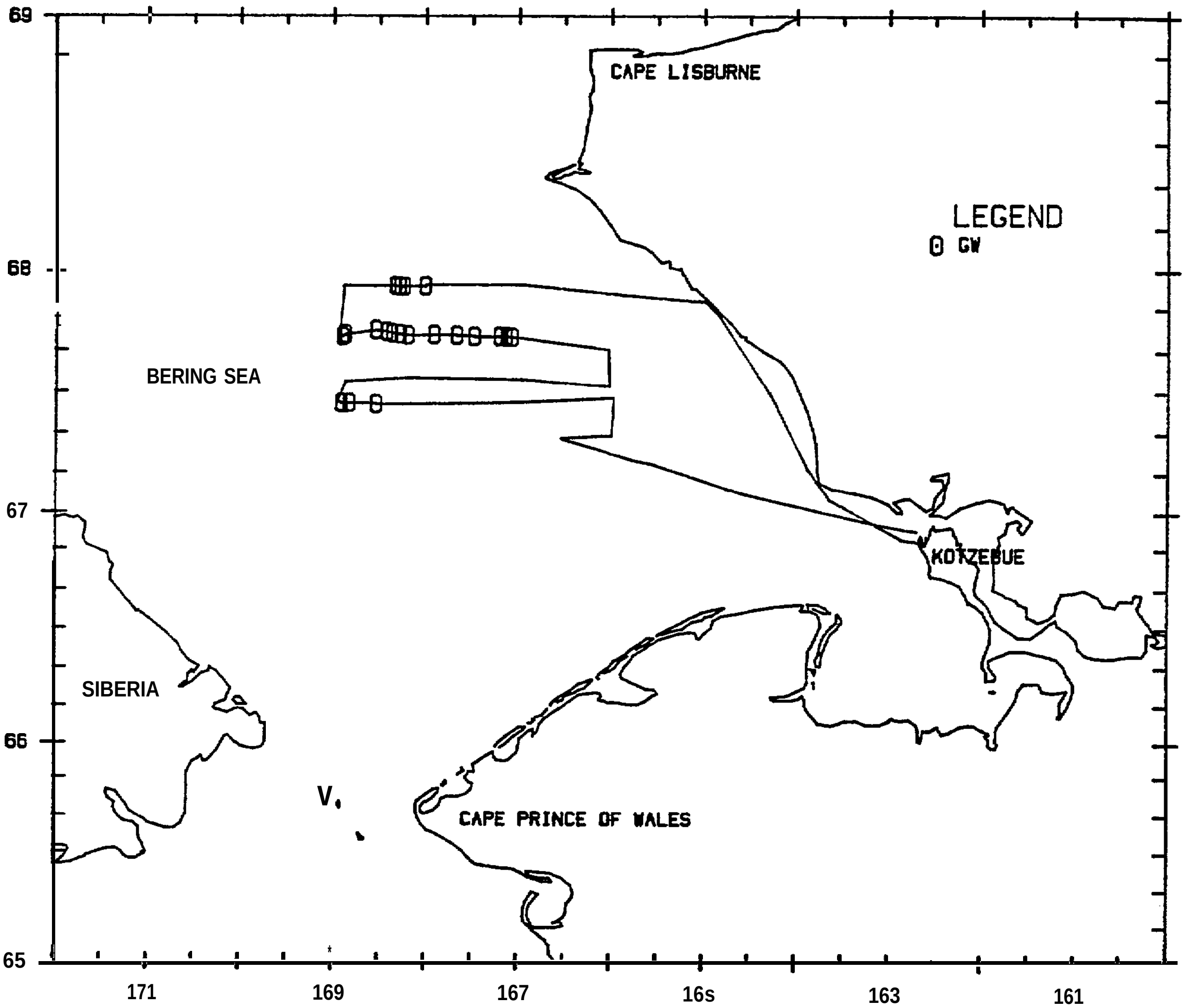
CAPE PRINCE OF WALES

Flight 28: 31 October 1989

Flight was a transect survey of the northern two-thirds of block 23. Weather was clear with unlimited visibility. There was no ice, and sea state ranged from Beaufort 02 to 05. Sixty-five gray whales were seen feeding in block 23.

Gray Whales

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	67°54.9'	168°00.8'	3599	BW	FE		o	62	59
1/0	67°54.8'	168"00.9'	937	BW	FE		0	B2	59
1/0	67"54.7'	168"14.3'	1328	BW	FE		0	62	55
1/0	67"54.8'	168"17.4'	1231	MP	FE		0	B2	55
5/0	67"54.9'	168"20.0'		BW	FE		0	B2	55
3/0	67 °43.1 '	168°54.2'		BW	FE		0	B2	51
2/0	67°43.5'	168°52.2'		BW	FE		0	62	51
5/0	67"44.6'	168°32.6'		BW	FE		0	62	49
5/0	67°44.2'	168°25.7'		BW	FE		0	62	49
3/0	67°43.9'	168°22.3'		BW	FE		0	B2	49
6/0	67"43,6'	168°16.9'		BW	FE		0	62	49
3/0	67°43.4'	168"11.9'		BW	FE		0	B2	49
2/0	67°43.5'	167°55.0'		BW	FE		0	B2	40
9/0	67"43.4'	167°40.3'		BW	FE		0	62	46
1/0	67"43.1'	167°29.1'		BW	FE		0	B2	37
2/0	67"43.1'	167°12.8'		BW	FE		0	63	44
3/0	67°43.0'	167°08.3'		BW	FE		0	B2	48
3/0	67°42.9'	167°04.5'		BW	FE		0	B2	48
2/0	67°27.0'	168°55.0'		BW	FE		0	B4	51
6/0	67°27.0'	168"50.0'		BW	FE		0	B4	49
1/0	67°26.7'	168°32.6'		BW	FE		0	B4	48



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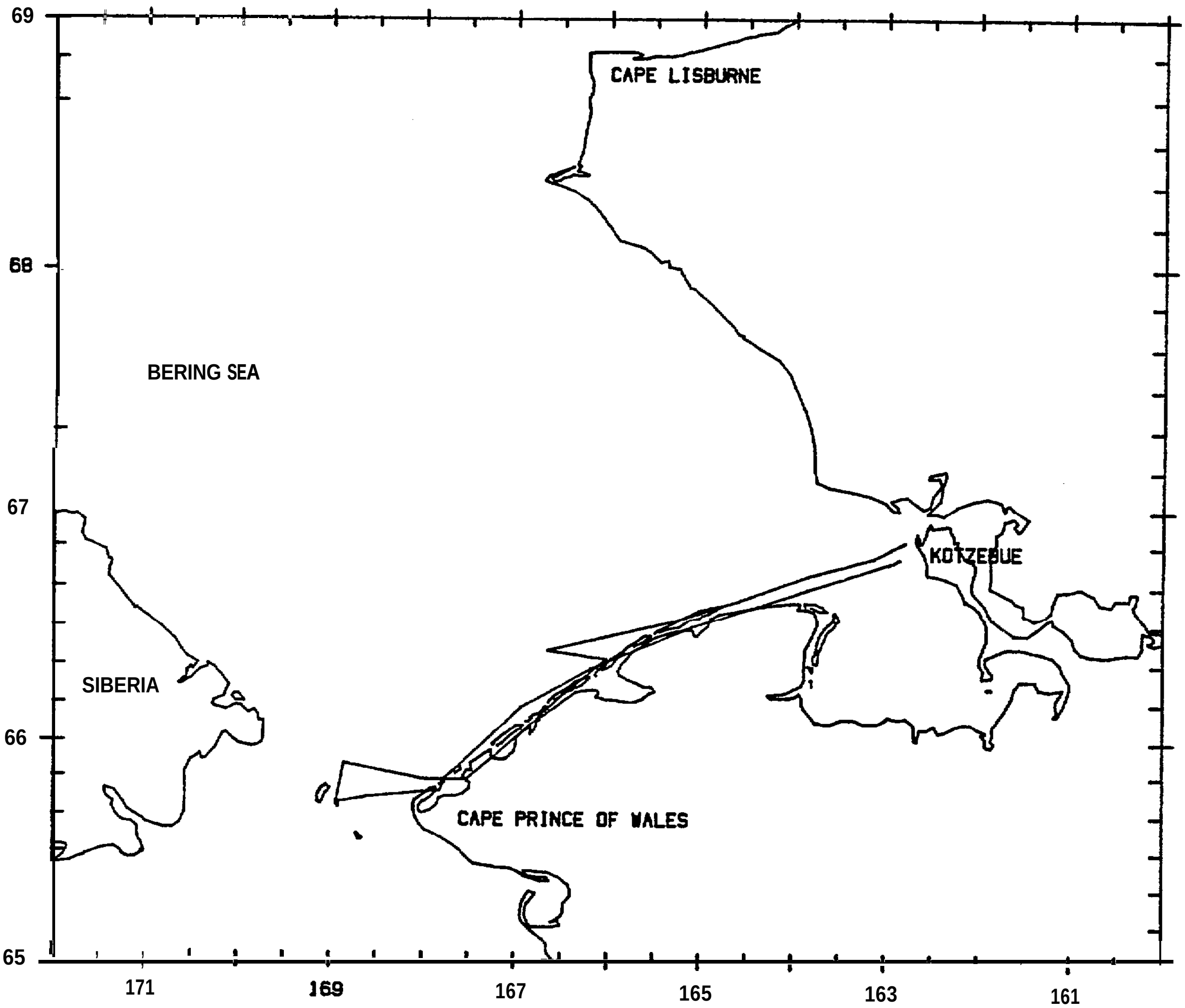
Flight 29: 1 November 1989

Flight was a transect survey of portions of block 25, and a search survey through blocks 30 and 31. The transect survey was aborted due to high sea states (Beaufort 05 to 06), Weather was partly cloudy with some fog; visibility varied from <1 km to unlimited.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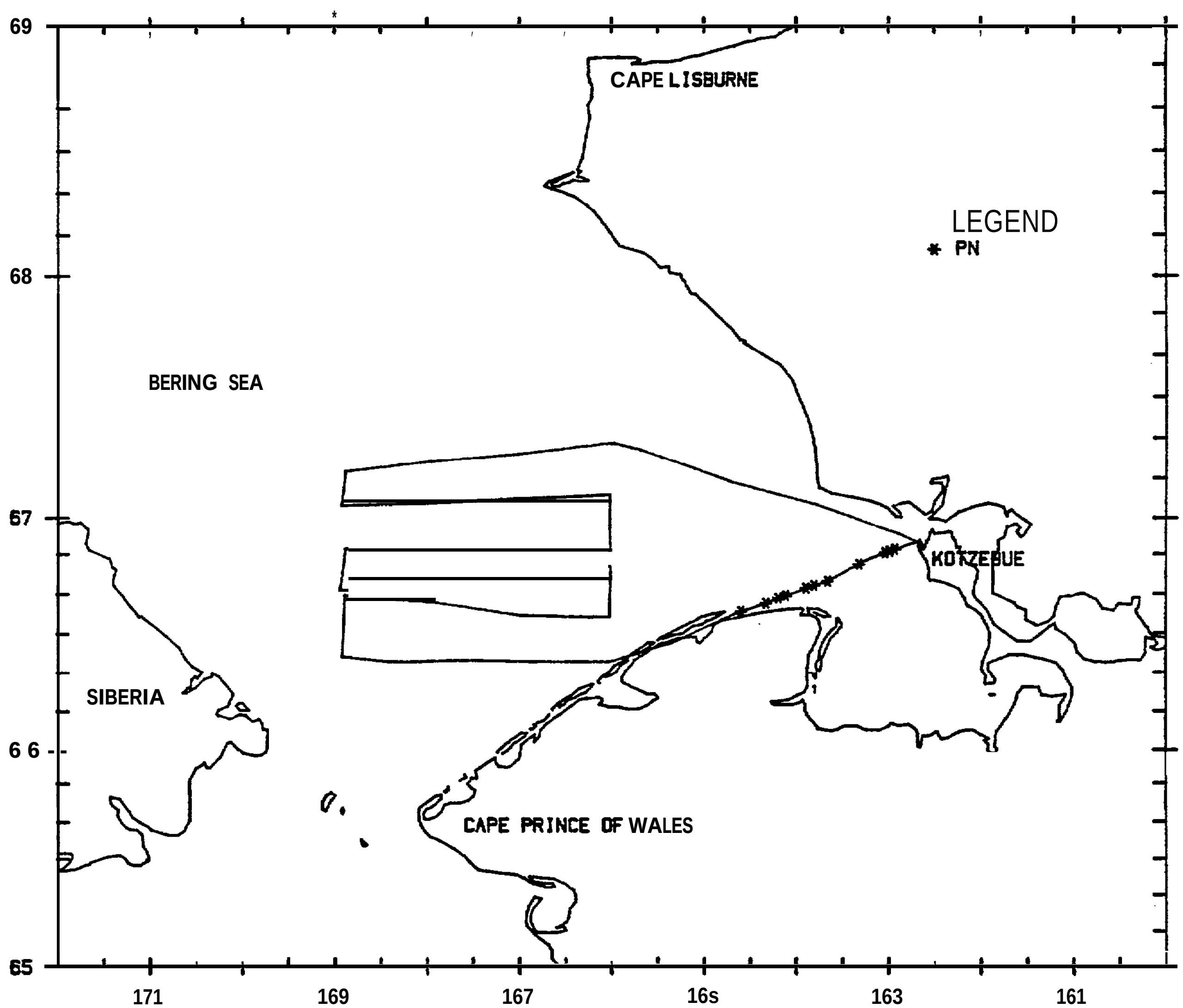
Flight 30: 2 **November 1989**

Flight was a transect survey of the southern one-third of block 23 and the northern two-thirds of block 24, with a search survey in blocks 30 and 31. Weather was overcast; visibility was 10 km. There was no ice, and the sea state was Beaufort 02 to 04. Several hundred unidentified pinnipeds were seen hauled out on ice floes in Kotzebue Sound.



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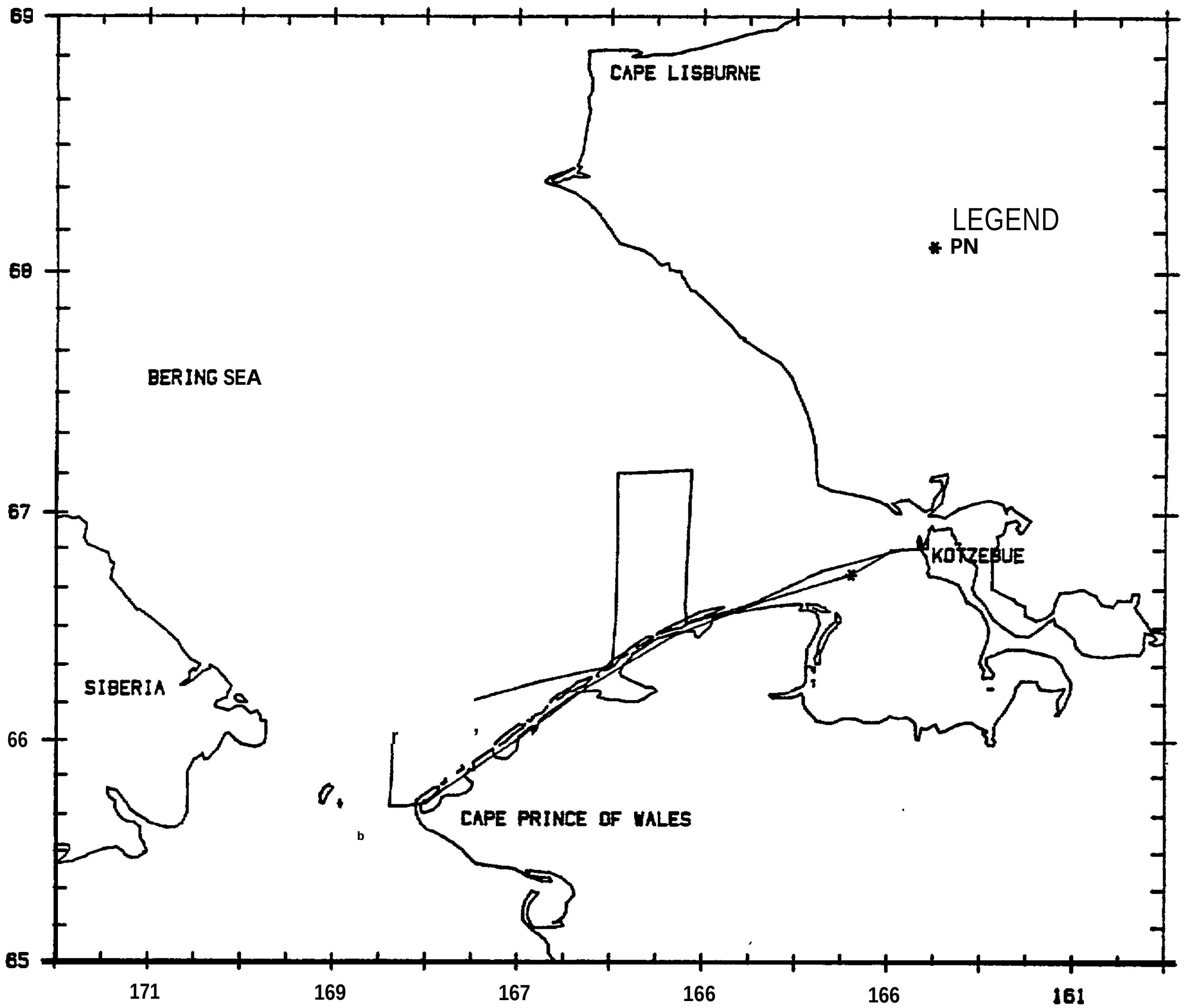
Flight 31: 3 November 1989

Flight was an attempted transect survey of blocks 25,30 and 31, which was aborted due to high sea states (Beaufort 06). Weather was overcast with fog; visibility was 2 to 3 km. One unidentified pinniped was seen,



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APPENDIX B

ESTIMATED BOWHEAD AND GRAY WHALE DENSITIES IN THE ALASKAN CHUKCHI SEA, 1980-89

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CONTENTS

FIGURES

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TABLES

INTRODUCTION

This appendix presents the results of density estimates for bowhead and gray whales in the Chukchi Sea study area for 1989, and for all years 1980-88 where data were available. Density estimates provide an evaluation of the relative importance of specific sampling units (i.e. survey blocks) to the population. Sequential density estimates provide an index of a population's response to it's environment over time.

The density estimates presented here were compared to indices of abundance presented in the body of the report (see Tables 13 and 17), in an effort to relate the two measures of abundance estimation. in brief, density estimates and abundance indices were strongly correlated each year, but there was no overall predictive relationship that could be applied across years. It is important to reiterate the differences between density estimates and indices of relative abundance. Density can only be estimated for those survey blocks where whales were seen within 1 km of a random transect survey leg, while relative abundance can be calculated for any block in which whales were seen, since it is simply the number of whales seen divided by survey time. Hence indices of abundance are more robust, but they are not based upon a random sampling design and therefore not appropriate for statistical analyses.

METHODS

Prior to calculating density estimates, aerial survey data files were screened for obvious errors in geographic position by separately plotting each survey flight. A computer program (SPEED) was used to calculate flight speeds and distances on a point-to-point basis, and listing of these values were scanned for suspiciously slow or fast speeds. The listings and maps were compared, errors flagged and edited, and the process was repeated until data files were error-free with respect to these conditions.

Density Estimates

Semi-monthly density estimates were calculated for Chukchi Sea survey blocks (Fig. B-1) for the period 16 September through 15 November using strip transect methods as described in Estes and Gilbert (1978), where:

$$D = \Sigma yi / \Sigma xi \qquad (1)$$

where D is the observed density of whales per unit area,

yi is the number of whales observed in the ith strip transect, and

xi is the area of the ith strip transect.

A confidence interval, although not tabularized, may be calculated for each estimate using the equation:

$$CI. = D \pm t_{0.05}(2)V\sqrt{V(D)} \qquad (2)$$

where CI. is the confidence interval about the density estimate, and

$t_{0.05}(2)V$ is the critical value of t where alpha is 0.05 based on a two-tailed test with V degrees of freedom. Degrees of freedom equalled the total number of transects minus one.

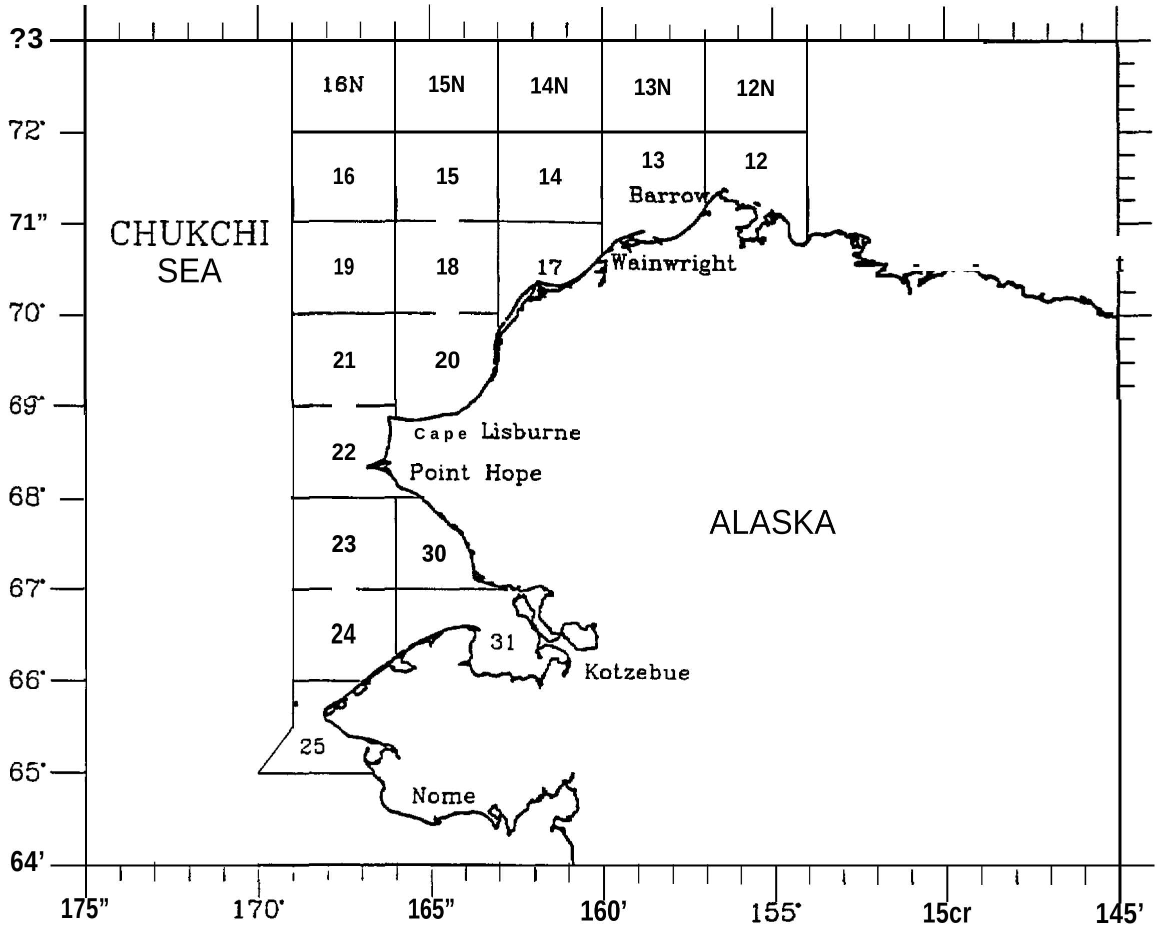

Figure B-1. Survey blocks in the Chukchi Sea study area for which bowhead and gray whale density estimates were derived.

Density estimates require that whale sightings are random (ie. that sightings be made while on a random transect leg; see Fig. 3), and that they occur within a predetermined distance from the aircraft (Hayne 1949). A 2 km strip width (1 km on each side of the aircraft) was used to calculate density for both bowhead and gray whales. This strip width is defensible based on a histogram derived from the sighting distance database from which the estimates were calculated (Fig. B-2). Over 71% of all sightings made on random transects were within the 1 km/side strip and there was a marked drop off in sightings beyond 1 km validating the assumption that surfaced whales within 1 km of the aircraft were counted.

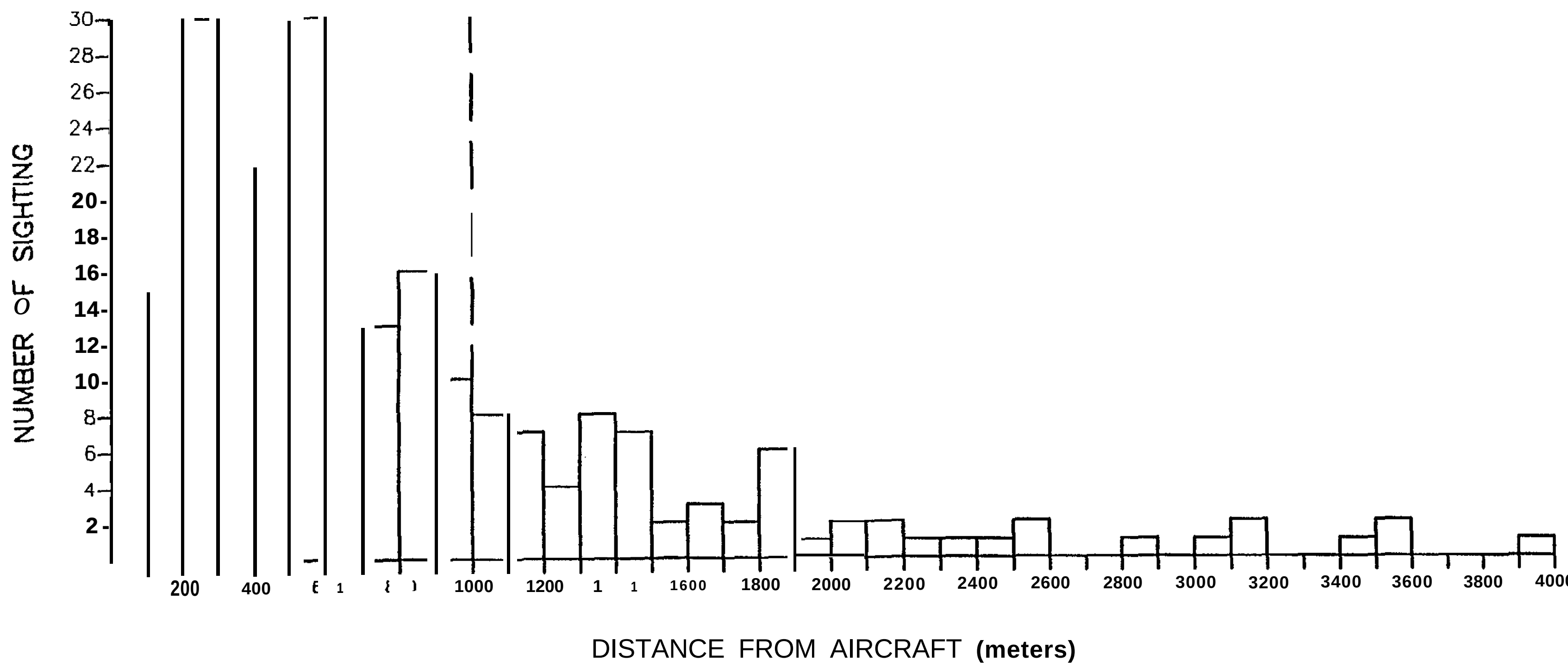

Figure B-2. Histogram relating sighting distance of bowhead whales from the survey aircraft, 1980-89.

Statistics Presented in Tables

The parameters listed below were calculated for semi-monthly periods, mid-September through October, for each year 1980-89 that data were available for the Chukchi Sea study area. Surveys were conducted during the first 3 to 4 days of November only in 1980 and 1989, and results of these surveys are presented separately.

Block Area (km^2) - Areas were approximated by straightline integration and are accurate to within about one percent of the true area.

Transect Distance (km) - Linear distance surveyed on transect legs.

Percent of Area Surveyed - The percent of area surveyed is a relative measure of survey effort expended per survey region. Strip width was defined as 2 kilometers (1 km on either side of the aircraft), therefore the number of square kilometers surveyed equalled twice the total number of kilometers flown. The percent of total area was calculated as divided by the region area and multiplied by 100.

Transect time (h) - Time in hours spent on random transect survey legs.

No. Transects Flown - The total number of transect legs flown in a block; each leg or leg segment with random starting and ending points is counted as one transect leg.

No. **Whales Observed -** Number of bowhead or gray whales observed within 1 km of the aircraft while surveying a random transect leg.

Density (No./100 km^2) - Number of bowhead or gray whales per 100 square kilometers as calculated using equation (1).

A table summarizing density estimates and all other parameters noted above was prepared for each year 1980-89 where data were available. For example, there is no table for 1981 because there were no random transect surveys flown in the Chukchi Sea study area that year. Conversely, tables are provided even where no whales were seen within one kilometer of the aircraft while on random transect to document transect survey effort conducted in each block for that time period. Cumulative estimates were derived by dividing the total number of whales seen on transect by the summation of total area surveyed in each block for all years 1980-89. These estimates provide an overall density index for each block for each semi-monthly period. Such cumulative estimates incorporate rounding errors inherent in estimated percent area surveyed and so are less-precise than the annual estimates.

RESULTS

Results are presented by species beginning with 1989 and working backward to 1980. Annual summary tables for bowhead whales (Table B-1) and gray whales (Table B-3) are followed by a table of cumulative estimates (Tables B-2 and B-4) for each species. The reader should refer to Figure B-1 for the location of survey blocks.

Bowhead Whales

In 1989, highest bowhead density was calculated for block 13 during the latter half of October (Table B-1). Lower estimates were calculated for blocks 14N and 15N during the latter half of September, and for block 15N again in the latter half of October. There were no density estimates for the first half of October, or the first three days of November.

For years 1980-88, highest densities were most often calculated for blocks 12 and 13 (Table B-1). Exceptions include the relatively high density for block 18 during the first half of October 1988, block 17 during the latter half of September in 1983, and in block 14 during the latter half of October 1982.

Cumulative bowhead density estimates were highest in blocks 12, 13, 14 and 18 (Table B-2). Lower densities were calculated for blocks 12N, 14N, 15N and 17. This overall pattern of relative density is similar to that of relative abundance summarized in the body of the report (Table 13).

Table B-1. Semi-monthly estimates of bowhead whale densities, by survey block, 1980-89.

1989

Block No.	Block Area (km²)	Transect Distance (km)	Percent Area Surveyed	Transect Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km²)
16-30 Sept							
12	11,163	524	9.40	2.38	11	0	0.00
12N	11,453	993	17.34	4.12	11	0	0.00
13	13,673	702	10.27	2.65	8	0	0.00
13N	11,453	650	11.35	2.75	6	0	0.00
14N	11,453	691	12.07	3.04	6	1	0.07
15	11,755	112	1.91	0.32	3	0	0.00
15N	11,453	774	13.52	3.41	7	1	0.06
16N	11,453	663	11.57	2.74	6	0	0.00
18	12,367	129	2.08	0.60	2	0	0.00
1-15 Ott							
13N	11,453	221	3.86	0.91	2	0	0.00
14	11,755	677	11.52	2.77	13	0	0.00
14N	11,453	689	12.03	3.11	9	0	0.00
15	11,755	226	3.85	0.94	4	0	0.00
15N	11,453	677	11.83	2.69	7	0	0.00
17	9,685	562	11.61	2.08	10	0	0.00
16-31 Oct							
13	13,673	1,228	17.96	5.49	17	6	0.24
13N	11,453	660	11.53	2.74	7	0	0.00
14	11,755	146	2.48	0.64	6	0	0.00
15	11,755	408	6.95	1.70	9	0	0.00
15N	11,453	632	11.03	2.92	7	1	0.08
16	11,755	639	10.88	2.67	6	0	0.00
17	9,685	295	6.09	1.30	4	0	0.00
18	12,367	784	12.67	3.39	14	0	0.00
20	13,08a	403	6.17	1.79	5	0	0.00
22	12,712	746	11.74	3.10	8	0	0.00
23	14,420	516	7.16	2.16	5	0	0.00
1-3 Nov							
23	14,420	251	3.48	1.00	2	0	0.00
24	14,031	540	7.70	2.22	5	0	0.00
25	10,930	131	2.39	0.53	3	0	0.00

Table B-1. Semi-monthly estimates of bowhead whale densities, by survey block, 1980-89 (Cent'd).

1988

Block No.	Block Area (km²)	Transect Distance (km)	Percent Area Surveyed	Transect Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km²)
1-15 Ott							
12	11,163	343	6.15	1.29	6	0	0.00
12N	11,453	556	9.70	2.61	8	0	0.00
13	13,673	723	10.58	3.59	15	4	0.28
13N	11,453	765	13.36	2.80	7	0	0.00
14	11,755	666	11.34	2.78	10	1	0.08
14N	11,453	483	8.43	2.19	5	0	0.00
15	11,755	556	9.45	2.09	12	0	0.00
15N	11,453	685	11.96	2.90	10	0	0.00
16	11,755	661	11.24	2.55	9	0	0.00
16N	11,453	776	13.54	3.33	10	0	0.00
17	9,685	255	5.27	1.19	6	0	0.00
18	12,367	746	12.07	3.56	8	10	0.67
19	12,367	163	2.63	0.69	4	0	0.00

Table B-1. Semi-monthly estimates of bowhead whale densities, by survey block, 1980-89 (Cent'd).

1987

Block No.	Block Area (km^2)	Transect Distance (km)	Percent Aree Surveyed	Transect Time {h)	No. Transects Flown	No. Whales Observed	Density (No./100km^2)
16-30 Sept							
12	11,163	976	17.49	4.05	16	1	0.05
12N	11,453	534	9.32	2.27	10	1	0.09
13	13,673	1,423	20.82	5.84	13	1	0.04
13	11,453	354	6.17	1.37	9	0	0.00
14	11,755	658	11.20	2.58	7	0	0.00
15	11,755	550	9.35	2.22	6	0	0.00
16	11,755	109	1.85	0.38	1	0	0.00
17	9,685	418	8.63	1.71	7	0	0.00
18	12,367	664	10.73	2.80	9	0	0.00
20	13,088	114	1.74	0.47	4	0	0.00
22	12,712	302	4.75	1.27	6	0	0.00
1-15 Ott							
12	11,163	476	8.53	1.91	10	0	0.00
12N	11 *453	669	11.69	2.83	8	0	0.00
13	13,673	1,025	15.00	4.17	10	0	0.00
13N	11,453	220	3.85	0.93	6	0	0.00
14	11,755	438	7.44	1.82	6	0	0.00
17	9,685	112	2.31	0,47	2	0	0.00
16-31 Ott							
12	11,163	1,084	19.43	4.40	16	3	0.14
12N	11,453	858	14.98	3.45	12	0	0.00
13	13,673	569	8.32	2.37	5	1	0.09
13N	11,453	519	9.07	2.02	6	0	0.00
17	9,685	443	9.15	1.91	6	0	0.00
18	12,367	110	1.78	0.42	1	0	0.00

Table B-1. Semi-monthly estimates of bowhead whale densities, by survey block, 1980-89 (Cent'd).

1986

Block No.	Block Area (km')	Transect Distance (km)	Percent Area Surveyed	Transect Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km²)
16-30 Sept							
12	11,163	566	10.15	2.23	8	0	0.00
13	13,673	1,206	17.64	5.00	11	0	0.00
14	11,755	679	11.55	2.95	6	1	0.07
15	11,755	472	8.03	1.80	6	0	0.00
17	9,685	453	9.35	1.89	7	0	0.00
18	12,367	170	2.76	0.70	2	0	0.00
1-15 Ott							
12	11,163	1,027	18.40	4.43	15	4	0.19
13	13,673	1,117	16.34	4.53	15	0	0.00
13N	11,453	193	3.37	0.73	9	0	0.00
14	11,755	1,149	19.56	4.60	18	0	0.00
17	9,685	742	15.32	3.15	12	0	0.00
18	12,367	398	6.43	1.55	5	0	0.00
16-31 Ott							
12	11,163	529	9.48	2.13	6	0	0.00
13	13,673	910	13.31	3.77	13	0	0.00
17	9,685	532	10.99	2,19	8	0	0.00
18	12,367	110	1.78	0.53	1	0	0.00

Table B-1. Semi-monthly estimates of bowhead whale densities, by survey block, 1980-89 (Cent'd).

1985

Block No.	Block Area (km')	Transect Distance (km)	Percent Area Surveyed	Transect Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km^2)
16-30 Sept							
12	11,163	536	9.61	2.26	6	0	0.00
1-15 Ott							
12	11,163	896	16.06	3.85	10	3	0.17
17	9,685	426	8.80	1.74	6	0	0.00
18	t 2,367	556	9.00	2.22	9	0	0.00
16-31 Ott							
12	?1,163	1,088	19.50	4.57	12	1	0.05
13	13,673	701	10.26	2.93	6	0	0.00

Table B-1. Semi-monthly estimates of bowhead whale densities, by survey block, 1980-89 (Cent'd).

1984

Block No.	Block Area (km^2)	Transect Distance (km)	Percent Area Surveyed	Transect Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km^2)
16-30 Sept							
12	11,163	546	9.78	2.45	7	3	0.27
13	13,673	744	10.88	2.93	8	2	0.13
14	11,755	548	9.32	203	5	0	0.00
17	9,685	157	3.25	0.65	4	0	0.00
1-15 Ott							
12	11,163	921	16.50	3.59	12	13	0.71
13	13,673	472	6.90	2.01	5	3	0.32
17	9,685	409	8.45	1.59	5	0	0.00
16-31 Ott							
12	11,163	1,353	24.25	5.45	18	6	0.22
13	13,673	431	6.31	1.76	9	0	0.00

Table B-1. Semi-monthly estimates of bowhead whale densities, by survey block, 1980-89 (Cent'd).

1983

Block No.	Block Area (km^2)	Transect Distance (km)	Percent Area Surveyed	Transect Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km²)
16-30 Sept							
12	11,163	1,160	20.79	4.64	20	5	0.22
13	13,673	418	6.11	1.72	5	2	0.24
14	11,755	148	2.51	0.58	3	0	0.00
17	9,665	122	2.52	0.54	4	2	0.82
1-15 Ott							
12	11,163	1,510	27.05	5.78	19	4	0.13
13	13,673	434	6.35	1.66	4	0	0.00
14	11,755	113	1.92	0.53	3	0	0.00
15	11,755	773	13.16	3.07	7	0	0.00
15N	11,453	112	1.95	0.41	3	0	0.00
17	9,685	451	9.30	1.66	6	0	0.00
18	12,367	115	1.66	0.55	2	0	0.00
22	12,712	626	9.84	2.19	8	0	0.00
16-31 Ott							
12	11,163	443	7.94	1.85	6	0	0.00
13	13,673	456	6.67	1.72	4	0	0.00
14	11,755	220	3.74	0.83	2	0	0.00
18	12,367	662	10.71	2.61	9	0	0.00
20	13,088	488	7.45	1.91	7	0	0.00
21	12,975	315	4.86	1.22	3	0	0.00

Table B-1. Semi-monthly estimates of bowhead whale densities, by survey block, 1980-89 (Cent'd).

1982

Block No.	Block Area (km^2)	Transect Distance (km)	Percent Area Surveyed	Transect Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km^2)
16-30 Sept							
12	11,163	695	12.45	2.67	10	3	0.22
1-15 Ott							
12	11,163	1,036	18.55	3.88	17	5	0.24
13	13,673	652	9.54	2.47	11	10	0.77
14	11,755	290	4.94	1.22	8	0	0.00
17	9,885	738	15.23	2.74	17	0	0.00
18	12,367	384	6.22	1.32	8	0	0.00
20	13,088	857	13.09	3.21	8	0	0.00
21	12,975	238	3.68	0.89	6	0	0.00
16-31 Ott							
12	11,163	386	6.92	1.51	6	0	0.00
13	13,673	189	2.76	0.72	2	0	0.00
14	11,755	98	1.66	0.41	2	1	0,51

Table B-1. Semi-monthly estimates of bowhead whale densities, by survey block, 1980-89 (Cent'd).

1980

Block No.	Block Area (km')	Transect Distance (km)	Percent Area Surveyed	Transect Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km²)
1-15 Ott							
12	11,183	110	1.97	0.42	3	0	0.00
18-31 Ott							
24	14,031	213	3.03	1.03	2	0	0.00
25	10,930	81	1.48	0.50	2	0	0.00
1-4 Nov							
25	10,930	97	1.78	0.42	2	0	0.00

Table B-2. Semi-monthly estimates of bowhead whale densities, by survey block for the combined data 1980-89.

Block No.	Block Area (km^2)	Transect Distance (km)	Percent Area Surveyed	Transect Time (h)	No. Transects Flown	No. Whales Observed	Density ($No./100km^2$)
16-30 Sept							
12	11,163	5,003	69.67	20.66	78	12	0.12
12N	11,453	1,527	26.66	6.39	21	1	0.03
13	13,673	4,493	65.72	18.34	45	5	0.06
13N	11,453	1,004	17.52	4.12	15	0	0.00
14	11,755	2,033	34.58	8.14	21	1	0.02
14N	11,453	691	12.07	3.04	6	1	0.07
15	11,755	1,134	19.29	4.34	15	0	0.00
15N	11,453	774	13.52	3.41	7	1	0.06
16	11,755	109	1.85	0.38	1	0	0.00
16N	11,453	663	11.57	2.74	6	0	0.00
17	9,685	1,150	23.75	4.79	22	2	0.09
18	12,367	1,618	26.16	8.75	25	0	0.00
20	13,088	517	7.91	2.26	9	0	0.00
22	12,712	1,048	16.49	4.37	14	0	0.00
23	14,420	516	7.16	2.16	5	0	0.00
1-15 Ott							
12	11,163	6,319	113.21	25.15	92	29	0.23
12N	11,453	1,225	21.39	5.44	16	0	0.00
13	13,673	4,423	64.71	15.96	60	17	0.19
13N	11,453	1,399	24.44	5.37	24	0	0.00
14	11,755	3,333	56.72	13.72	58	1	0.01
14N	11,453	1,172	20.46	5.30	14	0	0.00
15	11,755	1,555	26.46	6.10	23	0	0.00
15N	11,453	1,474	25.74	6.00	20	0	0.00
16	11,755	661	11.24	2.55	9	0	0.00
16N	11,453	776	13.54	3.33	10	0	0.00
17	9,685	3,695	76.29	14.62	64	0	0.00
18	12,367	1,643	26.58	6.98	23	10	0.30
19	12,367	163	2.63	0.69	4	0	0.00
20	13,088	857	13.09	3.21	8	0	0.00
21	12,975	238	3.86	0.69	6	0	0,00
22	12,712	626	9.64	2.19	8	0	0.00

Table B-2. Semi-monthly estimates of bowhead whale densities, by survey block for the combined data 1980-89 (Continued).

Block No.	Block Area (km^2)	Transect Distance (km)	Percent Area Surveyed	Transect Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km^2)
16-31 Oct							
12	11,163	4,883	87.52	19.91	64	10	0.10
12N	11,453	858	14.98	3.45	12	0	0.00
13	13,673	4,484	65.59	18,76	56	7	0.08
13N	11,453	1,179	20.60	4.76	13	0	0.00
14	11,755	464	7.88	1.88	10	1	0.11
15	11,755	408	6.95	1.70	9	0	0.00
15N	11,453	632	11.03	2.92	7	1	0.08
16	11,755	639	10.88	2.67	6	0	0.00
17	9,685	1,270	26.23	5.40	18	0	0.00
18	12,367	1,666	26.94	6.95	25	0	0.00
20	13,068	891	13.62	3.70	12	0	0.00
21	12,975	315	4.86	1.22	3	0	0.00
22	12,712	746	11.74	3.10	8	0	0.00
23	14,420	516	7.16	2.16	5	0	0.00
24	14,031	213	3.03	1.03	2	0	0.00
25	10,930	81	1.48	0.50	2	0	0.00
1-4 Nov							
23	14,420	251	3.48	1.00	2	0	0.00
24	14,031	540	7.70	2.22	5	0	0.00
25	10,930	228	4.17	0.95	5	0	0.00

Gray Whales

In 1989, **highest** gray whale density was calculated for block 14N during the first half of October (Table B-3). Lower densities were estimated for block 13 during the latter half of September and for blocks 22 and 23 during the latter half of October. There were no gray whale density estimates for the first three days of November.

For years 1980-88, relatively high densities were calculated for blocks 13, 14, 17, 18, and 22 (Table B-3). Notably, block 14N was surveyed only in 1989 thus far so it is not known if gray whales were there in prior years.

Cumulative gray whale density estimates were highest in blocks 13,14 and 14N (Table B-4). Somewhat lower densities were calculated for blocks 17, 18,20,22 and 23. As with bowhead density estimates, the overall pattern for abundance is similar to that summarized in the relative abundance table (see Table 17).

Table B-3. Semi-monthly estimates of gray whale densities, by survey block, 1980-89.

1989

Block No.	Block Area (km')	Transect Distance (km)	Percent Area Surveyed	Transect Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km²)
16-30 Sept							
12	11,163	524	9.40	2.38	11	0	0.00
12N	11,453	993	17.34	4.12	11	0	0.00
13	13,673	702	10.27	2.85	8	2	0.14
13N	11,453	650	11.35	2.75	6	0	0.00
14N	11,453	691	12.07	3.04	6	0	0.00
15	11,755	112	1.91	0.32	3	0	0.00
15N	11,453	774	13.52	3.41	7	0	0.00
16N	11,453	663	11.57	2.74	6	0	0.00
18	12,367	129	2.08	0.60	2	0	0.00
1-15 Ott							
13N	11,453	221	3.86	0.91	2	0	0.00
14	11,755	677	11.52	2.77	13	0	0.00
14N	11,453	689	12.03	3.11	9	7	0.51
15	11,755	226	3.85	0.94	4	0	0.00
15N	11,453	677	11.83	2.69	7	0	0.00
17	9,685	562	11.61	2.08	10	0	0.00
16-31 (let							
13	13,673	1,228	17.96	5.49	17	0	0.00
13N	11,453	660	11.53	2.74	7	0	0.00
14	11,755	146	2.46	0.64	6	0	0.00
15	11,755	408	6.95	1.70	9	0	0.00
15N	11,453	632	11.03	2.92	7	0	0.00
16	11,755	639	10.88	2.67	6	0	0.00
17	9,685	295	6.09	1.30	4	0	0.00
18	12,367	784	12.67	3.39	14	0	0.00
20	13,088	403	6.17	1.79	5	0	0.00
22	12,712	746	11.74	3.10	8	1	0.07
23	14,420	516	7.16	2.16	5	1	0.10
1-3 Nov							
23	14,420	251	3.48	1.00	2	0	0.00
24	14,031	540	7.70	2.22	5	0	0.00
25	10,930	131	2.39	0.53	3	0	0.00

Table B-3. Semi-monthly estimates of gray whale densities, by survey block, 1980-89 (Cent'd).

1988

Block No.	Block Area (km^2)	Transect Distance (km)	Percent Area Surveyed	Transect Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km^2)
1-15 Ott							
12	11,163	343	6.15	1.29	6	0	0.00
12N	11,453	556	9.70	2.61	8	0	0.00
13	13,673	723	10.58	3.59	15	0	0.00
13N	11,453	765	13,36	2.80	7	0	0.00
14	11,755	666	11.34	2.78	10	0	0.00
14N	11,453	483	8.43	2.19	5	0	0.00
15	11,755	556	9.45	2.09	12	0	0.00
15N	11,453	685	11.96	2.90	10	0	0.00
16	11,755	661	11.24	2.55	9	0	0.00
16N	11,453	776	13.54	3.33	10	0	0.00
17	9,685	255	5.27	1.19	6	0	0.00
18	12,367	746	12.07	3.56	8	0	0.00
19	12,367	163	2.63	0.69	4	0	0.00

Table B-3. Semi-monthly estimates of gray whale densities, by survey block, 1980-89 (Cent'd).

1987

Block No.	Block Area (km²)	Transect Distance (km)	Percent Area Surveyed	Transect Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km²)
16-30 Sept							
12	11,163	976	17.49	4.05	16	0	0.00
12N	11,453	534	9.32	2.27	10	0	0.00
13	13,673	1,423	20.82	5.84	13	5	0.18
13	11,453	354	6.17	1.37	9	0	0.00
14	11,755	658	11,20	2.58	7	0	0.00
15	11,755	550	9.35	2.22	6	0	0.00
16	11,755	109	1.85	0.38	1	0	0.00
17	9,685	418	8.63	1.71	7	0	0.00
18	12,367	664	10.73	2.60	9	0	0.00
20	13,088	114	1.74	0.47	4	0	0.00
22	12,712	302	4.75	1.27	6	1	0.17
1-15 Ott							
12	11,163	476	8.53	1.91	10	0	0.00
12N	11,453	669	11.69	2.83	8	0	0.00
13	13,673	1,025	15.00	4.17	10	0	0.00
13N	11,453	220	3.85	0.93	6	0	0.00
14	11,755	438	7.44	1,82	6	0	0.00
17	9,685	112	2.31	0.47	2	0	0.00
16-31 Oct							
12	11,163	1,084	19.43	4.40	16	0	0.00
12N	11,453	858	14.98	3.45	12	0	0.00
13	13,673	569	8.32	2.37	5	0	0.00
13N	11,453	519	9.07	2.02	6	0	0.00
17	9,685	443	9.15	1.91	6	0	0.00
18	12,367	110	1.78	0.42	1	0	0.00

Table B-3. Semi-monthly estimates of gray whale densities, by survey block, 1980-89 (Cent'd).

1986

Block No.	Block Area (km')	Transect Distance (km)	Percent Area Surveyed	Transect Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km²)
16-30 Sept							
12	11,163	566	10.15	2.23	8	0	0.00
13	13,673	1,206	17.64	5.00	11	6	0.25
14	11,755	679	11.55	2.95	6	7	0.52
15	11,755	472	8.03	1.80	6	0	0.00
17	9,685	453	9.35	1.89	7	0	0.00
18	12,367	170	2.76	0.70	2	0	0.00
1-15 Ott							
12	11,163	1,027	18.40	4.43	15	0	0.00
13	13,673	1,117	16.34	4.53	15	0	0.00
13N	11,453	193	3.37	0.73	9	0	0.00
14	11,755	1,149	19.56	4.60	18	1	0.04
17	9,685	742	15.32	3.15	12	0	0.00
18	12,367	398	6.43	1.55	5	2	0.25
16-31 Ott							
12	11,163	529	9.48	2.13	6	0	0.00
13	13,673	910	13.31	3.77	13	0	0.00
17	9,685	532	10.99	2.19	8	0	0.00
18	12,367	110	1.78	0.53	1	0	0.00

Table B-3. Semi-monthly estimates of gray whale densities, by survey block, 1980-89 (Cent'd).

1985

Block No.	Block Area (km')	Transect Distance (km)	Percent Area Surveyed	Transect Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km^2)
16-30 Sept							
12	11,163	536	9.61	2.26	6	0	0.00
1-15 Ott							
12	11,163	896	16.06	3.65	10	0	0.00
17	9,685	426	8.80	1.74	6	0	0.00
18	12,367	556	9.00	2.22	9	0	0.00
16-31 Oct							
12	11,163	1,088	19.50	4.57	12	0	0.00
13	13,673	701	10.26	2.93	6	0	0.00

Table B-3. Semi-monthly estimates of gray whale densities, by survey block, 1980-89 (Cent'd).

1984

Block No.	Block Area (km')	Transect Distance (km)	Percent Area Surveyed	Transect Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km^2)
16-30 Sept							
12	11,163	546	9.78	2.45	7	0	0.00
13	13,673	744	10.88	2.93	8	21	1.41
14	11,755	548	9.32	2.03	5	0	0.00
17	9,685	157	3.25	0.65	4	0	0.00
1-15 Ott							
12	11,163	921	16.50	3.59	12	0	0.00
13	13,673	472	6.90	2.01	5	2	0.21
17	9,685	409	8.45	1.59	5	0	0.00
16-31 Ott							
12	11,163	1,353	24.25	5.45	18	0	0.00
13	13,673	431	6.31	1.76	9	0	0.00

Table B-3. Semi-monthly estimates of gray whale densities, by survey block, 1980-89 (Cent'd).

1983

Block No.	Block Area (km')	Transect Distance (km)	Percent Area Surveyed	Transect Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km²)
16-30 Sept							
12	11,163	1,160	20.79	4.64	20	0	0.00
13	13,673	418	6.11	1.72	5	0	0.00
14	11,755	148	2.51	0.58	3	0	0.00
17	9,685	122	2.52	0.54	4	0	0.00
1-15 Ott							
12	11,163	1,510	27.05	5.78	19	0	0.00
13	13,673	434	6.35	1.66	4	0	0.00
14	11,755	113	1.92	0.53	3	0	0.00
15	11,755	773	13.16	3.07	7	0	0.00
15N	11,453	112	1.95	0.41	3	0	0.00
17	9,685	451	9.30	1.66	6	0	0.00
18	12,367	115	1.86	0.55	2	0	0.00
22	12,712	626	9.84	2.19	8	0	0.00
16-31 Oct							
12	11,163	443	7.94	1.85	6	0	0.00
13	13,673	456	6.67	1.72	4	0	0.00
14	11,755	220	3.74	0.63	2	0	0.00
18	12,367	662	10,71	2.61	9	0	0.00
20	13,088	488	7.45	1.91	7	0	0.00
21	12,975	315	4.86	1.22	3	0	0.00

Table B-3. Semi-monthly estimates of gray whale densities, by survey block, 1980-89 (Cent'd).

1982

Block No.	Block Area (km²)	Transect Distance (km)	Percent Area Surveyed	Transect lime (h)	No. Transects Flown	No. Whales Observed	Density (No./100km²)
16-30 Sept							
12	11,163	695	12.45	2.67	10	0	0.00
1-15 Ott							
12	11,163	1,036	18.55	3.88	17	0	0.00
13	13,673	652	9.54	2.47	11	2	0.15
14	11,755	290	4.94	1.22	8	0	0.00
17	9,685	738	15.23	2.74	17	2	0.14
18	12,367	384	6.22	1.32	8	0	0.00
20	13,088	857	13.09	3.21	8	2	0.12
21	12,975	238	3.68	0.89	6	0	0.00
16-31 Ott							
12	11,163	386	6.92	1.51	6	0	0.00
13	13,673	189	2.76	0.72	2	0	0.00
14	11,755	98	1.66	0.41	2	0	0.00

Table B-3. Semi-monthly estimates of gray whale densities, by survey block, 1980-89 (Cent'd).

1980

Block No.	Block Area (km')	Transect Distance (km)	Percent Area Surveyed	Transect Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km²)
1-15 Ott							
12	11,163	110	1.97	0.42	3	0	0.00
16-31 Ott							
24	14,031	213	3.03	1.03	2	0	0.00
25	10,930	81	1.48	0.50	2	0	0.00
1-4 Nov							
25	10,930	97	1.78	0.42	2	0	0.00

Table B-4. Semi-monthly estimates of gray whale densities, by survey block for the combined data 1980-89.

Block No.	Block Area (km^2)	Transect Distance (km)	Percent Area Surveyed	Transect lime (h)	No. Transects Flown	No. Whales Observed	Density (No./100km^2)
16-30 Sept							
12	11,163	5,003	89.67	20.68	78	0	0.00
12N	11,453	1,527	26.66	6.39	21	0	0.00
13	13,673	4,493	65.72	18.34	45	34	0.38
13N	11,453	1,004	17.52	4.12	15	0	0.00
14	11,755	2,033	34.58	8.14	21	7	0.17
14N	11,453	691	12.07	3.04	6	0	0.00
15	11,755	1,134	19.29	4.34	15	0	0.00
15N	11,453	774	13.52	3.41	7	0	0.00
16	11,755	109	1.85	0.38	1	0	0.00
16N	11,453	663	11.57	2.74	6	0	0.00
17	9,685	1,150	23.75	4.79	22	0	0.00
18	12,367	1,618	26.16	8.75	25	0	0.00
20	13,088	517	7.91	2.26	9	o	0.00
22	12,712	1,048	16.49	4.37	14	1	0.05
23	14,420	516	7.16	2.16	5	0	0.00
1-15 Ott							
12	11,163	6,319	113.21	25.15	92	0	0.00
12N	11,453	1,225	21.39	5.44	16	0	0.00
13	13,673	4,423	64.71	15.98	60	4	0.05
13N	11,453	1,399	24.44	5.37	24	0	0.00
14	11,755	3,333	56.72	13.72	58	1	0.01
14N	11,453	1,172	20.46	5.30	14	7	0.30
15	11,755	1,555	26.46	6.10	23	0	0.00
15N	11,453	1,474	25.74	6.00	20	0	0.00
16	11,755	661	11.24	2.55	9	0	0.00
16N	11,453	776	13.54	3.33	10	0	0.00
17	9,685	3,695	76.29	14.62	64	2	0.03
18	12,367	1,643	26.58	6.98	23	2	0.06
19	12,367	163	2.63	0.69	4	0	0.00
20	13,088	857	13.09	3.21	8	2	0.12
21	12,975	238	3.66	0.89	6	0	0.00
22	12,712	626	9.84	2.19	8	0	0.00

Table B-4. **Semi-monthly estimates of gray whale densities, by survey block for the combined data 1980-89 (Continued).**

Block No.	Block Area (km^2)	Transect Distance (km)	Percent Ares Surveyed	Transect Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km^2)
16-31 Oct							
12	11,163	4,683	87.52	19.91	64	0	0.00
12N	11,453	658	14.98	3.45	12	0	0.00
13	13,673	4,464	65.59	18.76	56	1	0.01
13N	11,453	1,179	20.60	4.76	13	0	0.00
14	11,755	464	7.88	1.68	10	0	0.00
15	11,755	408	6.95	1.70	9	0	0.00
15N	11,453	632	11.03	2.92	7	0	0.00
16	11,755	639	10.88	2.67	6	0	0.00
17	9,685	1,270	26.23	5.40	18	0	0.00
18	12,367	1,666	26,94	6.95	25	0	0.00
20	13,088	891	13.62	3.70	12	0	0.00
21	12,975	315	4.86	1.22	3	0	0.00
22	12,712	746	11.74	3.10	8	1	0.07
23	14,420	516	7.16	2.16	5	1	0.10
24	14,031	213	3.03	1.03	2	0	0.00
25	10,930	81	1.48	0.50	2	0	0.00
14 Nov							
23	14,420	251	3.48	1.00		0	0.00
24	14,031	540	7.70	2.22		0	0.00
25	10,930	228	4.17	0.95		0	0.00

DISCUSSION

Even the highest density estimates provided here imply that density of endangered whales in the Chukchi Sea is extremely low. At least in part, this is likely due to the procedures involved in density estimation. Density estimates have long been used by wildlife biologists, even though satisfying the assumptions underlying the statistic is often a difficult or impossible task in the field. Eberhardt and Simmons (1987) describe the problems and cost inherent in density estimation for terrestrial mammals, and suggest methods of double-counting so that indices of abundance can be calibrated against density estimates.

Two factors inherent in a study of cetaceans that cause an individual to be missed during a survey are sightability and submergence. Sightability means an individual at the surface may be missed by an observer. Although the sighting distance histogram (Fig. b-2) indicates that the probability of sighting surfaced bowheads within one kilometer of the aircraft is very high, some whales are likely missed. As the distance increases between the observer and a whale, the chance of sighting the whale decreases (Doi, 1974). For example, a double-count trial conducted by Davis et al. (1982) in the Canadian Beaufort Sea indicated that surfaced bowheads were missed by observers 30 to 35 % of the time. Whales are also missed on surveys because they are submerged. Submerged whales are never calculated in density estimates. These whales represent a source of known but unmeasurable error in the total population estimate. Best estimates have been derived using measures of surface and dive times gathered for bowheads summering in the Canadian Beaufort Sea and while feeding in the Alaskan Beaufort Sea (Dorsey et al. 1989; Ljungblad et al. 1987), but no one set of correction factors will be right for every circumstance.

Four additional assumptions peculiar to estimating cetacean density and potential biases that result when they are not met include:

1) Whale behavior does not change during the period **for** which an estimate is calculated. This assumption is critical, but difficult to satisfy because whales' behaviors do change during the study period; net bias may be upward or downward largely depending on surface time associated with the behaviors exhibited (Dorsey et al. 1989).

2) Observers are equally effective on both sides of the aircraft and in all areas of the sighting sector. This assumption is necessary since observer's sightings are equally weighted by formulas used in calculating density estimates. Deviation from this assumption will cause a negative or downward bias on the final estimates. Visibility bias associated with observer fatigue, eyesight and experience can lead to significant underestimation of population abundance from aerial survey data (Samuel et al., 1987; Pollock and Kendall, 1987).

3) Group size does not affect detection of whales. A violation of this assumption causes a negative bias since larger groups have a greater likelihood of being sighted because the larger the group the higher the probability of having a whale at the surface.

4) Whales do not evade the aircraft. This assumption is probably met because the speed of the aircraft is so much greater than that of the whale.

The problems in meeting the assumptions outlined above are not unique to the task of estimating bowhead whale density. The Scientific Committee of the IWC has struggled with various models to estimate **density and population number for a variety of** cetacean species over the years (IWC 1989). As mentioned earlier, Eberhardt and Simmons (1987) note that in practice most wildlife managers rely on abundance indices to assess populations, and suggest a method of "double sampling" as a means of calibrating absolute abundance estimates. The double sampling method requires random sampling be observed in the derivation of both indices, however, so although estimates of endangered whale density can be compared to WPUE (Tables 14 and 17), they can not be compared statistically.

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