OCS Study
MMS-87-0122

FINAL REPORT

Distribution, Abundance, Behavior and Bioacoustics of Endangered Whales in the Western Beaufort and Northeastern Chukchi Seas, 1979-87

Prepared for:

Minerals Management Service (MMS)
Alaska Outer Continental Shelf Region
U.S. Department of the Interior
Anchorage, Alaska 99508

Prepared by:

Naval Ocean Systems Center (NOSC)
Code 514
San Diego, CA 92152/5000

SEACO, A Division of SAIC
2845-D Nimitz Blvd.
San Diego, California 92106

June 1988

MMS Interagency Agreement No. 14-12-0001-30370
MMS Contract No. 14-12-0001-30320

OCS Study
MMS 87-0122

Distribution, Abundance, Behavior and Bioacoustics of Endangered Whales in the Western Beaufort and Northeastern Chukchi Seas, 1979-87

Donald K. Ljungblad
Naval Ocean Systems Center (NOSC)
Code 514
San Diego, California 92152-5000

Sue E. Moore, Janet T. Clarke, and John C. Bennett
SEACO, A Division of SAIC
2845-D Nimitz Blvd.
San Diego, California 92106

Final Report: June 1988

This study was funded by the Alaska Outer Continental Shelf Region of the Minerals Management Service, U.S. Department of the Interior, Anchorage, AK, under contract No. 14-12-0001-30230.

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. OCS Study MMS 87-0122	2.	3. Recipient's Accession No.

4. Title and Subtitle
Distribution, Abundance, Behavior and Bioacoustics of Endangered Whales in the Western Beaufort and Northeastern Chukchi Seas, 1979-87

5. Report Date July 1988

6.

7. Author(s)
D.K. Ljungblad, S.E. Moore, J.T. Clarke, and J.C. Bennett

8. Performing Organization Rept. No. NOSC TR No. 1232

9. Performing Organization Name and Address
Naval Ocean System Center (NOSC)
Code 514
San Diego, CA 92152-5000

subcontract:
SEACO-a division of SAIC
2845-D Nimitz Blvd.
San Diego, CA 92106

10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.
(C) NOSC IA No. 14-12-0001-30370
(G)

12. Sponsoring Organization Name and Address
U.S. Minerals Management Service
Alaska OCS Region, Environmental Studies
Anchorage, Alaska 99508

13. Type of Report & Period Covered
Final Report
1 SEP-23 OCT 1987

14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

Aerial surveys for bowhead whales, and secondarily other marine mammals were made from 1 September through 23 October 1987 in the western Beaufort and northeastern Chukchi Seas. In addition, a shore-based acoustic monitoring station was maintained at Barrow, Alaska from 9 September through 21 October to record the calls of migrating bowhead whales as they passed into the northeastern Chukchi Sea. Survey results and observations on bowhead whale distribution, relative abundance and density, migration patterns, general behavior and sound production are presented. Presented also are survey results and observations on gray whale distribution, relative abundance and general behavior; and on belukha and walrus distribution and relative abundance. Incidental sightings of all marine mammals are reported.

The report also summarizes the overall study efforts for the period of 1979 through 1987.

17. Document Analysis a. Descriptors

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement:	19. Security Class (This Report)	21. No. of Pages
Unlimited	Unclassified	231
	20. Security Class (This Page) Unclassified	22. Price

(See ANSI-Z39.18) See Instructions on Reverse OPTIONAL FORM 272 (4-77) (Formerly NTIS-35) Department of Commerce

FOREWORD

This report addresses the Naval Ocean Systems Center (NOSC) aerial survey efforts for the U.S. Minerals Management Service (MMS), Alaska outer continental shelf studies of endangered whales in the Beaufort and Chukchi Seas. The report also summarizes the overall study efforts for the period of 1979 through 1987. The reader will find little reference to the fall 1987 Beaufort Sea surveys conducted east of 154°W longitude, as they were conducted under the direction of and staffed by MMS personnel, with the exception of 11 NOSC flights. Data for the Beaufort Sea surveys east of 154°W were analyzed by NOSC under MMS direction and forwarded to MMS. These data will be presented in a separate MMS-generated report (Treacy, in prep.).

PROJECT ORGANIZATION AND ACKNOWLEDGMENTS

This report is an account of field work and data analysis conducted by the Naval Ocean Systems Center (NOSC) and SEACO, A Division of SAIC, for the U.S. Minerals Management Service. The report describes results from field work conducted in September and October 1987, and discusses results obtained from this multiyear (1979-present) study. The report was prepared by S.E. Moore, J.T. Clarke, J.C. Bennett, R.B. O'Hara and K.P. Fearon of SEACO, and edited by D.K. Ljungblad of NOSC.

For logistic support, we are especially grateful to pilots G. Candee, D. Moore, and J. Warren, and the administrative and maintenance staffs at the Office of Aircraft Services (OAS), Anchorage, AK, for providing the Grumman Goose (N780). We also thank the Bensons at the Barrow Airport Inn, Barrow, AK for their assistance during field operations. At the Minerals Management Service (MMS), Anchorage AK, we appreciate the advice and support of C. Cowles, J. Imm, J. Montague and S. Treacy.

Data programming and analysis were ably provided by R. O'Hara of SEACO. K. Fearon and T. Rickman of SEACO assisted with field work. The NOSC graphics department produced report graphics and G. Young of SEACO typed numerous drafts of the manuscript and assisted in its compilation. Our thanks to all.

EXECUTIVE SUMMARY

This report summarizes the 1987 investigations of the distribution, abundance, migration timing, habitat relationships, and behavior of endangered whales in the western Alaskan Beaufort and northeastern Chukchi Seas. The Western Arctic stock of bowhead whales (Balaena mysticetus), estimated by the International Whaling Commission (IWC) to contain 7,800 whales, was the principal species studied. Data presented herein were collected during transect and search surveys flown in a specially modified Grumman Goose over the study area from 1 September through 23 October, and over the eastern Alaskan Beaufort between 25 and 31 October. Additionally, acoustic monitoring for bowhead calls was conducted at Barrow, Alaska on an opportunistic basis from 9 September through 21 October. The acoustic monitoring augmented the visual data collected via aerial surveys and extended periods of data acquisition. Visual and acoustic data collected during the 1987 study are subsequently compared to the results of previous (1979-86) seasonal efforts.

Twenty-four sightings of 32 bowhead whales were made in the western Beaufort and northeastern Chukchi Seas from 21 September through 23 October. The bowhead sighting on 21 September in the Chukchi Sea was 1 day earlier than prior years sightings. Four bowheads were seen in September, three in the western Beaufort Sea and one in the Chukchi Sea. Twenty-eight bowheads were seen from 1-23 October, primarily in the western Beaufort Sea (n = 26). In late October (25-31), survey effort shifted from the primary study area to the eastern Alaskan Beaufort Sea to determine the status of the bowhead migration, and three bowheads were seen there. Results of these surveys are presented in Treacy et al. (in prep.). Survey effort and all bowhead sightings are depicted in daily flight maps and tabularized summaries presented in appendix A.

The bowhead migration through the study area extended from 18 September, when the first bowhead calls were recorded, through 23 October, when the last bowhead was seen in the western Beaufort Sea. Because bowheads were seen in the eastern Alaskan Beaufort Sea as late as 30 October, it was impossible to infer the termination of the fall migration through the study area.

Over 165 hours of underwater sounds were recorded during acoustic monitoring at Barrow between 9 September and 21 October. The first bowhead calls (n = 34) were heard on 18 September, 3 days prior to the first bowhead

sighting. Periods of relatively high calling activity occurred on 5-6 October (n = 314) and 15-16 October (n = 108). These periods of relatively high bioacoustic activity correspond to daily sighting rate (WPUE, SPUE) peaks for the 1987 season. Ambient noise level near Barrow varied by approximately 30 dB between calm and storm sea conditions; the higher ambient levels may have masked some bowhead calls.

Over nine survey seasons (1979-87), 251 sightings of 500 bowheads have been made in the Alaskan Beaufort Sea, west of 150°W, and northeastern Chukchi Seas; 70 sightings of 212 whales during September and 181 sightings of 288 bowheads in October. All but 4 whales were seen during the latter half of September and October and all but 46 were seen between 1982-87. Peak abundance was calculated most often for the survey blocks (12 and 13) near Point Barrow. Estimates of bowhead densities for 1979-87 are presented in appendix B.

Fifty-three sightings of 118 gray whales (Eschrichtius robustus) were made during September and October in the Chukchi Sea in 1987, from 0.5 to 120 km offshore. No grays were seen in the Beaufort Sea. Gray whale distribution along the Chukchi coast was similar to that of past years and grays were again seen in a localized area approximately 140 to 180 km northwest of Barrow as in 1986. Gray whale abundance estimates were highest in nearshore blocks in 1987. Additional gray whale density estimates are presented in appendix B. Grays were either feeding (86%, n = 102), swimming (11%, n = 13), or diving (3%, n = 3). One gray whale calf was seen near Point Hope.

One hundred forty-one sightings of 394 gray whales have been made in the study area during September and October since 1982. Relative abundance was highest in the nearshore blocks near Point Hope and Point Barrow. The majority of grays were seen feeding (85%, n = 335), and were in open water or light (<20%) ice cover (95%, n = 373).

Seven large cetaceans seen in the study area in late September and October 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 time period.

Groups of belukhas, or white whales, some with calves, were seen in the western Beaufort and northeastern Chukchi Seas throughout the fall. Belukhas were distributed farther offshore in significantly deeper water ($\bar{x}$ = 868m) than bowhead whales ($\bar{x}$ = 30m; t = 5.87, p <0.001). Groups of walruses were seen hauled out on broken floe ice or swimming throughout September; only one group was seen in October. Bearded seals, ringed seals, unidentified pinniped and polar bears were seen throughout the fall season. Multiyear reviews of belukha and walrus data are included.

ACRONYMS AND ABBREVIATIONS

ADFG	Alaska Department of Fish and Game
AM	Amplitude Modulated
AMP	A Mapping Package
ASA	American Standards Association
BE	Belukha
BH	Bowhead Whale
BS	Bearded Seal
CPUE	Calves Per Unit Effort
CR	Call Rate
CT	Unidentified Cetacean
dB	Decibel
FM	Frequency Modulated
GARR	Gross Annual Recruitment Rate
GNS	Global Navigation System
GW	Gray Whale
IDL	International Date Line
IWC	International Whaling Commission
MMS	Minerals Management Service
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
RS	Ringed Seal
s.d.	Standard Deviation
SPUE	Sightings Per Unit Effort
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VHF	Very High Frequency
WPUE	Whales Per Unit Effort
WS	Walrus

CONTENTS

Page

FIGURES

Page

Page

TABLES

Page

INTRODUCTION

The Naval Ocean Systems Center (NOSC), San Diego, California, has been funded by the Alaska Outer Continental Shelf (OCS) area office of the Minerals Management Service (MMS), U.S. Department of the Interior, since 1979 to conduct aerial surveys of endangered whales and other marine mammals in the northern Bering (above 63°N), eastern Chukchi, and Alaskan Beaufort Seas. As part of its responsibilities under the OCS Lands Act, National Environmental Policy Act, Marine Mammal Protection Act, and Endangered Species Act, the MMS has continued this work as an extension of previous studies (Ljungblad et al., 1980; Ljungblad, 1981; Ljungblad et al., 1982a, 1983, 1984, 1985, 1986b, 1987). Results of these studies have been useful to MMS in preparing environmental impact statements and in making decisions relative to the leasing, exploration, and development of the Alaskan OCS.

The bowhead whale (Balaena mysticetus) has been the principal species investigated over the past 9 years. Historically, bowheads had a nearly circumpolar distribution north of 60°N. However, 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 Western Arctic stock, estimated by the International Whaling Commission (IWC) to contain 7,800 whales (IWC, 1988), 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 along open-water lead systems that annually develop relatively nearshore in the Chukchi Sea, but offshore and well north of oil exploration activities in the Alaskan Beaufort Sea (Braham et al., 1984; Ljungblad et al., 1986c). During the autumn migration, however, bowheads commonly occur nearshore within or near oil lease areas in the Alaskan Beaufort Sea. Because of this, the MMS has continued to monitor the annual progress and potential interaction of the fall bowhead migration in relation to ongoing oil exploration activities.

The distribution, relative abundance, and behavior of gray whales (Eschrichtius robustus) have also been investigated since 1980 (Ljungblad et al., 1987). Principal areas surveyed have been the summer feeding grounds in the northern Bering Sea and eastern Chukchi Sea (Bogoslovskaya et al., 1981; Nerini, 1984; Moore et al., 1986b), and the northeastern Chukchi Sea (Moore et al., 1986a). This population is now estimated to number 21,113 whales (IWC, 1988).

This report is a summary of 1987 field results on aerial surveys of bowhead and gray whale distribution, relative abundance, density, migration, and behavior in the western Alaskan Beaufort and northeastern Chukchi Seas in accordance with the objectives outlined below. To augment visual information derived from aerial surveys, a sonobuoy drop was routinely made approximately 5 km west of Barrow on days when surveys were flown in an effort to monitor the fall bowhead migration via passive acoustics. Acoustic studies conducted during spring and fall bowhead migrations have provided enhanced descriptions of whale distribution, movements, and habitat relationships (Ljungblad et al., 1987; Clark, 1983; Clark et al., 1985, 1986; Cummings and Holliday, 1983). The results of the acoustic monitoring efforts are presented and integrated with aerial survey sightings as appropriate. 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. Surveys to monitor the progress of the fall bowhead migration across the Alaskan Beaufort Sea were conducted by MMS personnel in 1987. The results of those surveys are reported in Treacy (in prep.).

Objectives

The primary objectives of the 1987 aerial surveys were to

- o determine seasonal distribution, migration routes, relative abundance, and habitat characteristics of endangered whales in or near existing and proposed Federal lease sales in the western Alaskan Beaufort and northeastern Chukchi Seas;
- o derive estimates and indicators of relative and/or absolute abundance of endangered whales in these areas;
- o describe behavioral characteristics of endangered whales observed in these areas;
- o deploy sonobuoys to detect sounds produced by whales, to be used as additional indices of whale presence in these areas;

- o obtain distributional information on nonendangered marine mammals incidental to other investigations;
- o 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;
- o synthesize and further analyze data obtained during the 1979-87 period of investigation.

METHODS AND MATERIALS

Project Rationale and Design

The aerial surveys and acoustic monitoring conducted from Barrow, Alaska were designed to (a) monitor the progress of the bowhead migration across the western Alaskan Beaufort 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 September through late October. Secondarily, the distribution, abundance and behavior of belukhas were studied and compared to past years. In addition, aerial surveys to assess the status of the fall bowhead migration in the eastern Alaskan Beaufort Sea were conducted by MMS personnel from Deadhorse, Alaska (Treacy, in prep.). Survey blocks used in past years were allocated between the two bases of operation (figure 1). Surveys conducted by MMS personnel were flown in blocks 1 through 7, while surveys conducted from Barrow aboard N780 were flown in blocks 11 through 22. Exceptions to this were search surveys conducted through blocks 24, 25, and 28 on 1 September enroute to Barrow, and occasional search surveys through blocks 1, 2 and 3 enroute to Deadhorse. Blocks 1, 4, and 5 were surveyed between 25 and 31 October to assess the status of the bowhead migration. Blocks 8-10 were not routinely surveyed in 1987. Results from all surveys flown east of 154°W (blocks 1-11) by either survey crew are summarized in Treacy (in prep.).

Study Area and Aerial Survey Procedures

The aerial survey study area included the western Alaskan Beaufort Sea from 157°W east to 154°W offshore to 72°N, and the northeastern Chukchi Sea from 157°W west to the International Date Line (IDL, approximately 168°58'W) between

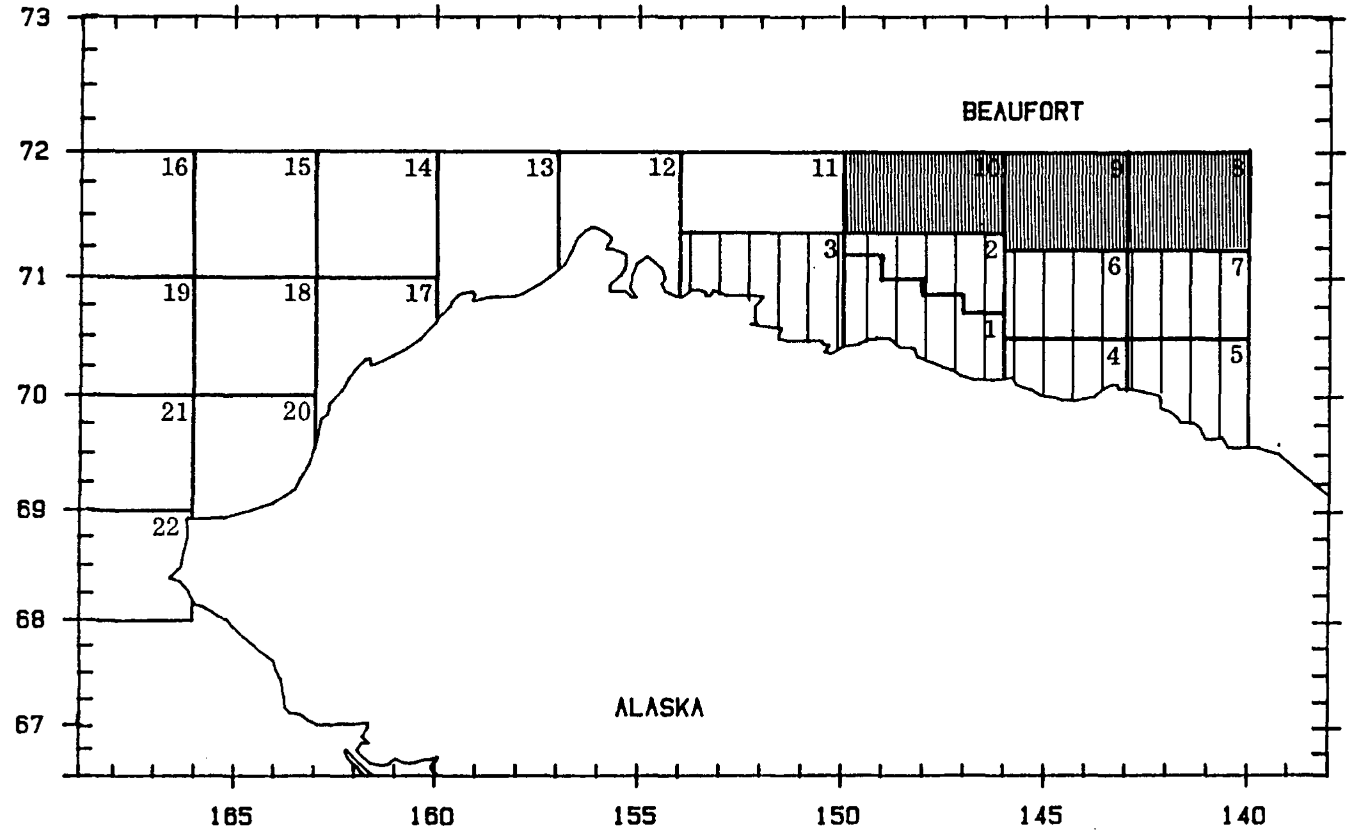


Figure 1. Original aerial survey study area and transect blocks depicting allocation of survey effort to blocks 1-7 for MMS personnel conducting surveys from Deadhorse, and to blocks 11-22 for surveys conducted from Barrow. Blocks 8-10 were not routinely surveyed in 1987.

68°N and 72°N. As referenced in figure 1, this area was divided into survey blocks (figure 2) suitable to line transect surveys (one or, with favorable conditions, two blocks could be surveyed completely on one flight). Because open water extended to the northern boundaries of blocks 12 and 13, and no bowheads had been seen in the study area through mid-September, the MMS requested that surveys of these areas be extended to 73°N after 26 September. To accommodate this request, survey blocks 12-N and 13-N were added to the study area for the period 26 September to 23 October.

Two types of aerial surveys were utilized 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

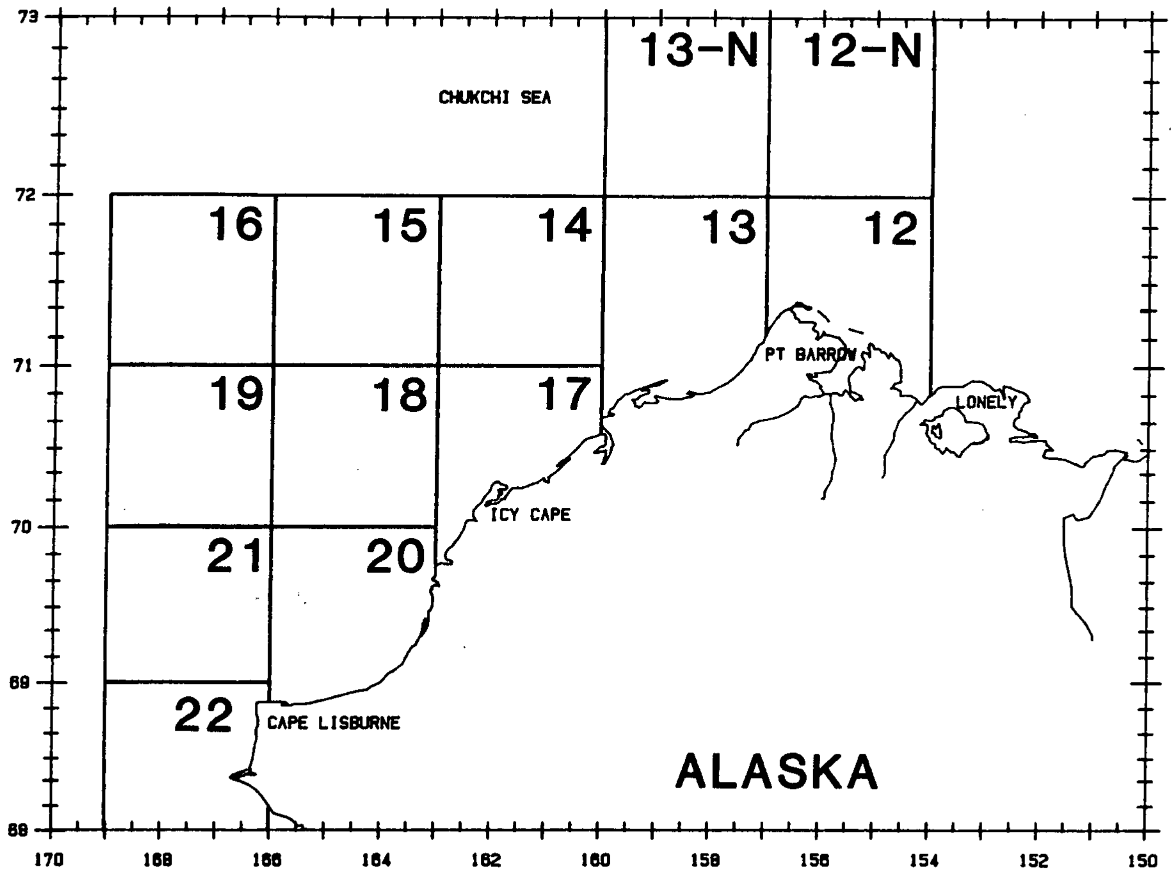


Figure 2. Aerial survey study area and transect blocks in the western Beaufort and eastern Chukchi Seas. Transect surveys were extended to 73°N between 154°W and 160°W (i.e., 12-N and 13-N) only after 26 September.

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 divided into 10 equal segments. Starting and/or turning points were chosen within each section by selecting two numbers from a random number's table and matching them to the numbered segments. A transect line was then drawn between the two segments. The same procedure was followed for each section of the survey block, and all transect lines were then linked together with connecting lines at top and bottom. When bowheads were encountered while surveying a transect line, the aircraft diverted from transect for brief periods ($\leq$ 10 min) and circled the whales to observe behavior, obtain better estimates of their numbers, 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, but instead were dependent upon weather, sea state, and ice conditions, or our previous patterns of whale sightings.

The aircraft used for the surveys was a Grumman Turbo Goose model G21G with a call sign of N780. The aircraft was equipped with a Global Navigation System (GNS) 500 that provided continuous position updating (0.6 km/survey hour, 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, can be used to compute animal distance from the survey track line. Observers and pilots were linked to a common communication system, and commentary on the aircraft could be recorded. 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. The computer was interfaced to the Global Navigation System (GNS) for automatic input of entry number, time, latitude and longitude, and to the radar altimeter for precise input of altitude. One of four different data entry formats was selected on the computer depending on the reason for entry. Whenever possible, a 28-key entry format was used when whales were seen (table 1). An abbreviated 20-key sighting update format was used when several whales were sighted within a short period of time. An even shorter rapid sighting update (9-key format) was used in areas of extremely high animal concentrations to avoid 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 (figure 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

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

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 angle
18.	Sighting cue
19.	Behavior
20.	**Total number**
21.	Estimated size class
22.	Total number calves
23.	Swim direction
24.	Estimated swim speed class
25.	Response to aircraft
26.	Repeat sighting
27.	Photo roll number
28.	Photo frame numbers

Position/environmental update (13-key) — items 1–13

Sighting update (20-key) — items 1–7 and 16–28

Rapid sighting update (9-key) — bold items

Chapman (1971). Ice type was identified using terminology presented in the Naval Hydrographic Office Publication Number 609 (1956), and ice cover was estimated in percent.

Acoustic Monitoring at Barrow

Sonobuoys are passive listening systems containing a hydrophone and a VHF transmitter. These units were routinely dropped 5 km west of Barrow to monitor for bowhead calls. Model AN/SSQ-57A sonobuoys, having 8 hours of endurance and a frequency response of 10 Hz to 20 kHz, were used throughout the season. Sonobuoys are designed to be dropped from aircraft, with their descent slowed by means of a rotochute or parachute. Once in contact with water, the unit is energized by a saltwater-activated battery. At that time the roto/parachute assembly is jettisoned and the hydrophone drops to a preselected

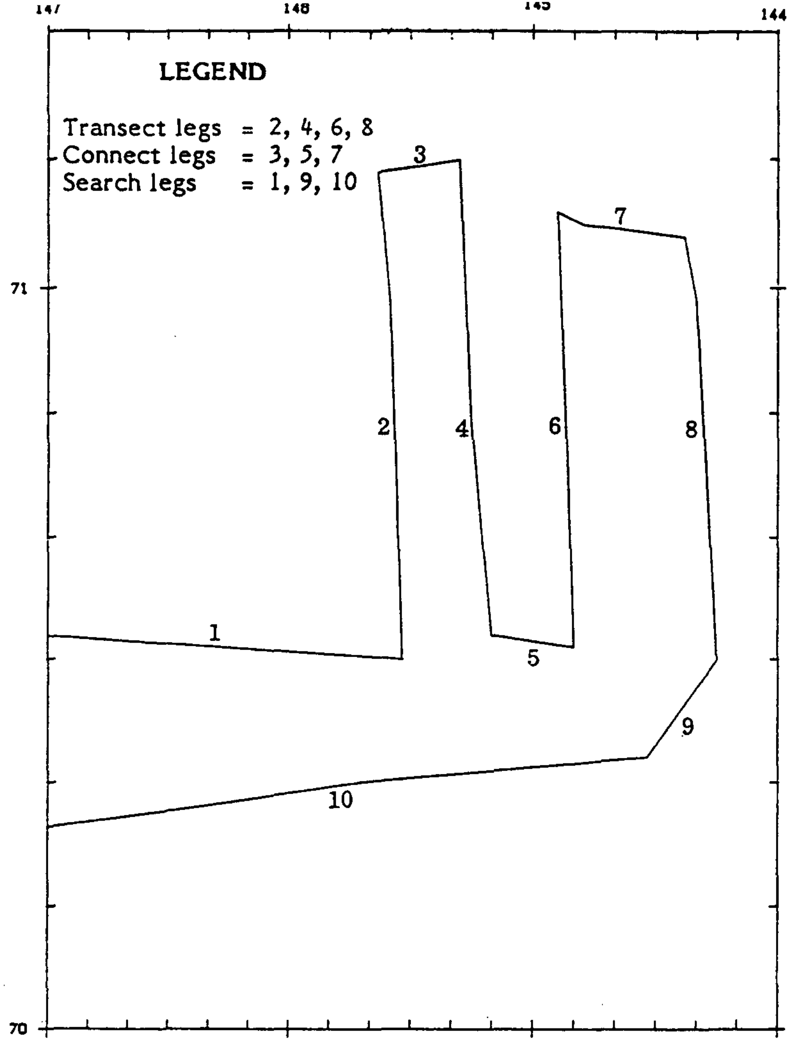


Figure 3. Example of aerial survey flight track delineating transect, connect and search survey legs.

depth of 18.2 m. The sounds picked up by the hydrophone are amplified and transmitted to a Defense Electronics VHF broadband receiver at the field station, or aboard the aircraft. At the field station, the output from the receiver was recorded on an RCA VLP 950 HF video recorder using 6-hour VHS tape speed. The overall response of this recording system was 20 Hz to 10 kHz ±2 dB*, well within the frequency band of bowhead calls. On board the aircraft, the receiver output was recorded on a Nagra IV SJ recorder with a frequency response within 2 dB from 25 Hz to 10 kHz, at a recording speed of 9.5 cm/s. The Nagra recorder has two channels, permitting simultaneous recording of waterborne sounds and observers' verbal comments.

*all dB referenced to 1 μPa, unless otherwise noted

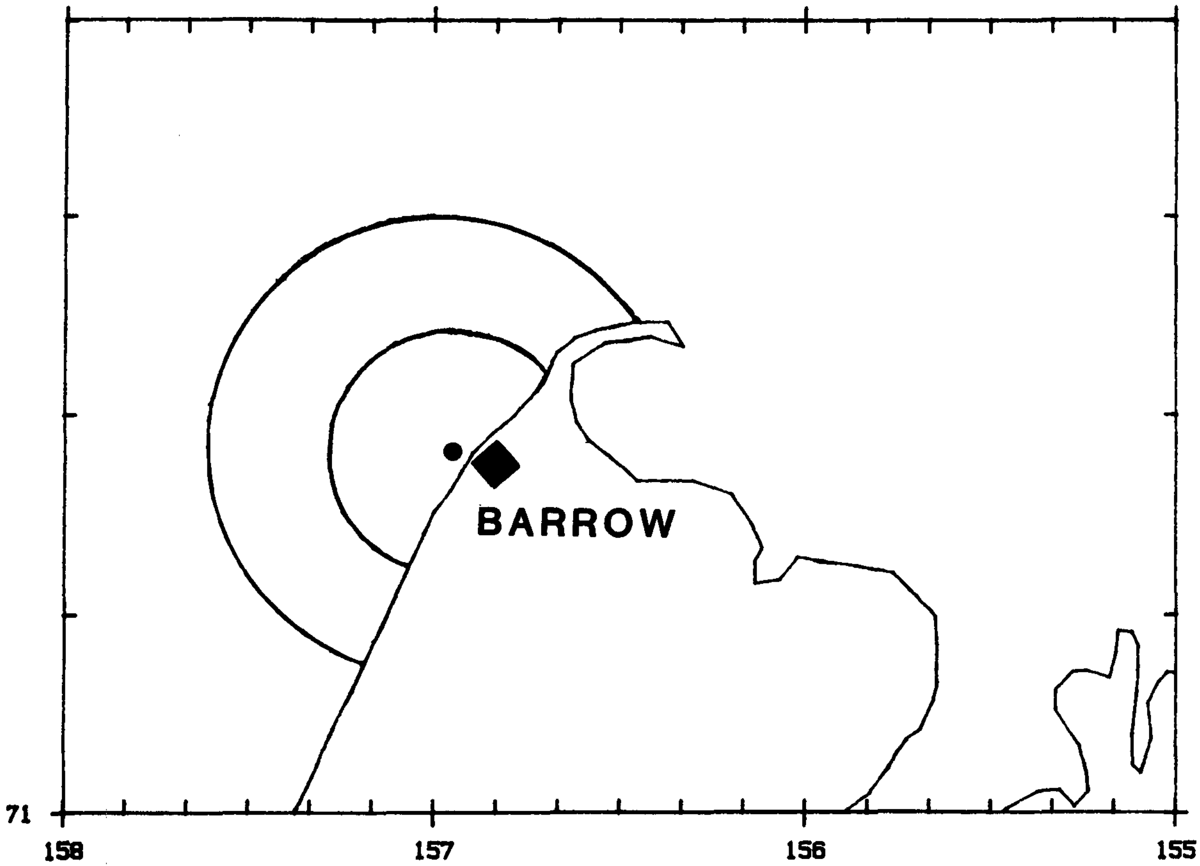


Figure 4. Acoustic monitoring sonobuoy drop site west of Barrow, Alaska.

Sonobuoys were dropped west of Barrow to monitor for bowhead calls because this site afforded both the water depth and the proximity to the field station required for recording. The area monitored by the sonobuoy(s) extended roughly from shore to 157°13'W between 71°13'N and 71°22'N (figure 4). This area describes an approximate 10-km radius around the position of the sonobuoy drop site (71°18'N, 156°57'W), and represents the conservative radial limits of the monitoring effort, based upon the Cummings and Holliday (1983) estimate of bowhead call signal/noise ratio approaching zero at a median distance of 10 km. A 20-km radius around the sonobuoy was considered a secondary zone in which calling bowheads would likely be detected based upon their ability to produce sounds with estimated source levels of 189 dB (Cummings and Holliday, 1983) to 190 dB (Ljungblad and Moore, 1982), and possibly as high as 196 to 200 dB based on a received level of 156 dB at 100-150 m (Clark and Johnson, 1984). The 20-km radial distance extended the boundaries of the acoustic study area from shore to roughly 157°30'W between 71°09'N and 71°28'N. Although bowhead calls with a source level of 189 dB could theoretically be detected at ranges greater than 20 km, local variation in ambient noise levels and sound transmission characteristics deemed it unlikely.

Continuous recordings of the underwater acoustic environment were made whenever the sonobuoys remained operational. Although sonobuoys have a maximum transmission time of 8 hours, recording time was often limited to 3 to 6 hours because sonobuoys were carried away from the drop site by currents and sometimes blown offshore and out of reception range by strong easterly winds.

Aerial Survey and Acoustic Data Analyses

Data collected in 1987 were sorted into two data sets. All aerial survey effort and marine mammal sightings west of 154°W (i.e., blocks 12-22) are presented here; effort and sightings east of 154°W (i.e., blocks 1-11) are summarized in Treacy (in prep.). Observed bowhead and gray whale distribution was plotted semimonthly in relation to OCS oil and gas lease areas within the Beaufort Sea and Chukchi Sea Planning Areas. An index of relative abundance was derived as whales per unit effort (WPUE = no. whales/hours of survey effort) per survey block for bowheads, grays, and belukhas. Bowhead and gray whale density estimates were derived for survey blocks using strip transect methodologies (Estes and Gilbert, 1978). All whale sightings were entered into the distribution and relative abundance analyses, regardless of the type of survey leg being conducted when the sighting was made. Therefore, distribution scattergrams and WPUE represent the total sighting database in relation to the total survey effort. 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. In addition to the survey block analysis, density estimates were also derived for subregions reflecting bathymetrically stratified OCS lease sale planning areas and are presented, with a description of density estimate methodologies, in appendix B.

The timing of the 1987 migration through the study area was analyzed as sightings per unit effort (SPUE = no. sightings/hours of survey effort) and WPUE per date. Habitat preference was depicted as percentage of whales/ice class and percentage of whales/depth regime. Directionality of whale headings was analyzed using descriptive statistics for circular distributions (Zar, 1984), where '$\bar{a}$' represents the vector mean and 'r' is the length of the vector. Additional statistical comparisons, correlations, and regressions were performed as appropriate (Zar, 1984).

Behaviors were catalogued into two types for purposes of discussion: migratory behaviors, including swimming and diving; and social behaviors (typically observed in groups) such as milling, feeding, mating, cow-calf association, resting, and displaying (table 2). Displays included breaches, spy-hops, tail and flipper-slaps, rolls, and underwater blows. 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/min corresponded to an estimated speed of 1 km/hr, one body length/30s was estimated at 2 km/hr, and so on. Swimming speed and whale size were recorded by relative category (i.e., still, 0 km/hr; slow, 0-2 km/hr; medium, 2-4 km/hr; or fast, >4 km/hr; and calf, immature, adult, or large adult respectively) rather than on an absolute scale.

In compliance with condition B.4-6 of 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.

Acoustic data were recorded continuously whenever sonobuoys were operational. All recordings were monitored for bowhead calls. Some tapes were "recycled" in the field when it was determined that no usable data had been recorded. Tapes containing bowhead calls were carefully monitored using the RCA recorder set at real time. The audio signal was played through a Hewlett Packard Dynamics signal analyzer and a visual image of each call was displayed on a HP35721A set at 50- to 850-Hz bandwidth. Simultaneously, the tape was monitored through headphones after being amplified using a Pioneer SA 608 preamplifier. Notation of bowhead calls included date, tape number and count, and sometimes an aural description of call type. Bowhead call rate (CR) was derived as number of calls per hour and related to hours of recording effort by date. Calls produced by bearded seals were also noted. In addition, portions of tape were analyzed for ambient noise level during recording conditions of calm and high sea states to assess local changes in the sea noise environment near Barrow.

Table 2. Operational definitions of observed bowhead 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 100 m) at the water surface.
Feeding	Whale/whales 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 20 m of an adult.
Resting	Whale/whales 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 rotating 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 slapping 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.

Collation of Aerial Survey and Acoustic Monitoring Data

Aerial survey sighting data were plotted in relation to the acoustic monitoring study area. The date and time of sightings were compared to call rates (CR) recorded at the monitoring station. Subsequently, an index to migratory timing past the acoustic station was derived as a combination of daily WPUE and CR for the acoustic study area.

RESULTS

Aerial Surveys in the Western Beaufort and Northeastern Chukchi Seas

Survey Effort and Sighting Summary

A total of 125.5 hours of surveys was flown, with 41.5 hours (33%) of this effort in the Beaufort Sea and 84.0 hours (67%) of effort in the Chukchi Sea (table 3). Line transect surveys were conducted on most flights, with time spent on random lines alone accounting for 56% (70.9 h) of the total survey time. An additional 33.7 hours of survey effort flown east of 154°W between 1 September and 31 October is incorporated into Treacy (in prep.) and summarized in appendix A.

In the first half of September, 37.4 hours of surveys were conducted (appendix A: flights 1-11) in the study area, with over two-thirds (77%, 28.9 h) of the effort in the Chukchi Sea (table 3). Line transect surveys were conducted in block 12 in the Beaufort Sea and blocks 13-15, 17, 20, and 22 in the northeastern Chukchi Sea (figure 5). No bowheads were seen during these flights. In the second half of September, 41.9 hours of surveys were flown (appendix A: flights 12-21), with most (75%, 31.5 h) of the effort in the Chukchi Sea (table 3). Line transect surveys were conducted in block 12 in the Beaufort Sea, and blocks 13-18, 20, and 22 in the Chukchi Sea (figure 5). Blocks 12-N and 13-N were surveyed after 26 September, and accounted for 10 percent of the survey effort for the latter half of September. Bowheads were seen in blocks 12 (2 whales), 12-N (1 whale), and 13 (1 whale).

Flight effort in the first half of October (appendix A: flights 22-30) was divided between the Chukchi (55%, 12.7 h) and western Beaufort (45%, 10.5 h) Seas (table 3). Line transect surveys were flown in blocks 12 and 12-N in the Beaufort Sea, and blocks 13, 13-N, 14, and 17 in the Chukchi Sea (figure 5). Bowheads were

Table 3. Semimonthly summary of flight effort conducted in the Chukchi and western Beaufort Seas, 1987.†

	SEPTEMBER		OCTOBER		
	1-15*	16-30	1-15	16-23	TOTAL
Number of Flights	11	10	9	6	36
Unacceptable Weather (days)	2	2	4	2	10
Aircraft Maintenance (days)	2	3	2	0	7
Flight Effort Summary					
Chukchi Sea					
Transect (km)	3404	4594	1815	1623	11436
Connect (km)	438	595	216	239	1488
Search (km)	3237	2485	1097	641	7460
Transect (H)	13.78	18.47	7.47	6.81	46.53
Flight (H)	28.86	31.49	12.74	10.90	83.99
Beaufort Sea					
Transect (km)	1410	1513	1151	1943	6017
Connect (km)	227	249	158	392	1026
Search (km)	528	702	1038	750	3018
Transect (H)	5.43	6.32	4.76	7.90	24.41
Flight (H)	8.54	10.39	10.50	12.04	41.47
TOTAL					
Transect (km)	4814	6107	2966	3566	17453
Connect (km)	665	844	374	631	2514
Search (km)	3765	3187	2135	1391	10478
Transect (H)	19.21	24.79	12.23	14.71	70.94
Flight	37.40	41.88	23.24	22.94	125.46

*181 km (0.75 h) search survey in the Bering Sea, 1 September

† flight effort east of 154°W (totalling 33.71h) presented in Treacy (in prep.)

seen in block 12 (21 whales). In the latter half of October, flight effort was almost evenly divided between the Beaufort (52%, n = 12.0h) and Chukchi Seas (48%, n = 10.9h). Line transect surveys in the study area were conducted in blocks 12, 12-N, 13, 13-N, and 17 (figure 5), and bowheads were seen in blocks 12 (5 whales) and 13 (2 whales).

Survey Conditions Summary

Survey conditions during the first half of September were generally good. Low ceilings, fog, and snow squalls prevented flying on only two of 15 days (table 3). Visibility was usually >5 km under overcast or partly cloudy skies. Ice cover in the study area was very light, especially in the Chukchi Sea. Bands of

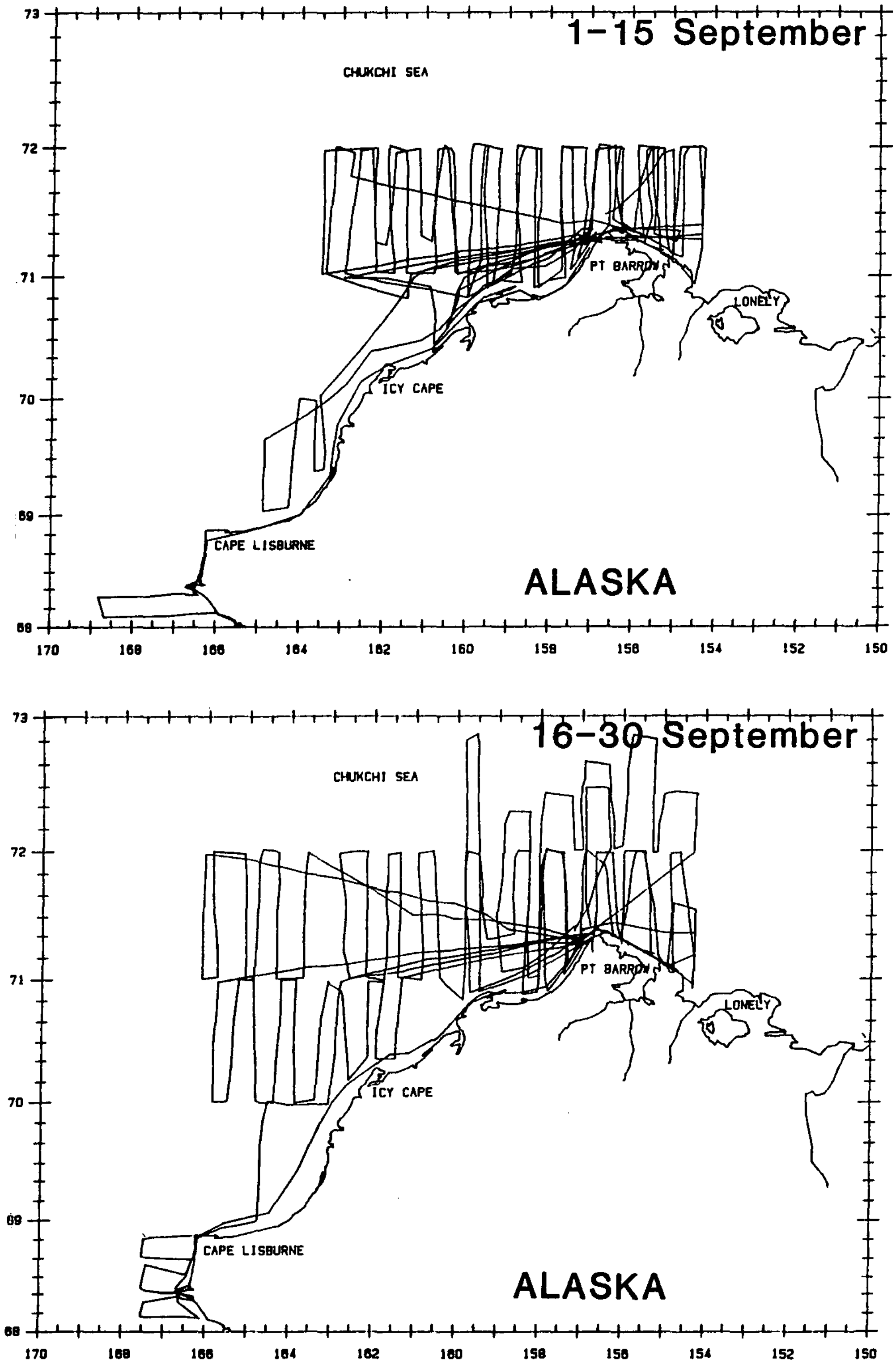


Figure 5. Composite flight tracks depicting semimonthly flight effort comprising: 11 surveys, 1-15 September; 10 surveys, 16-30 September;

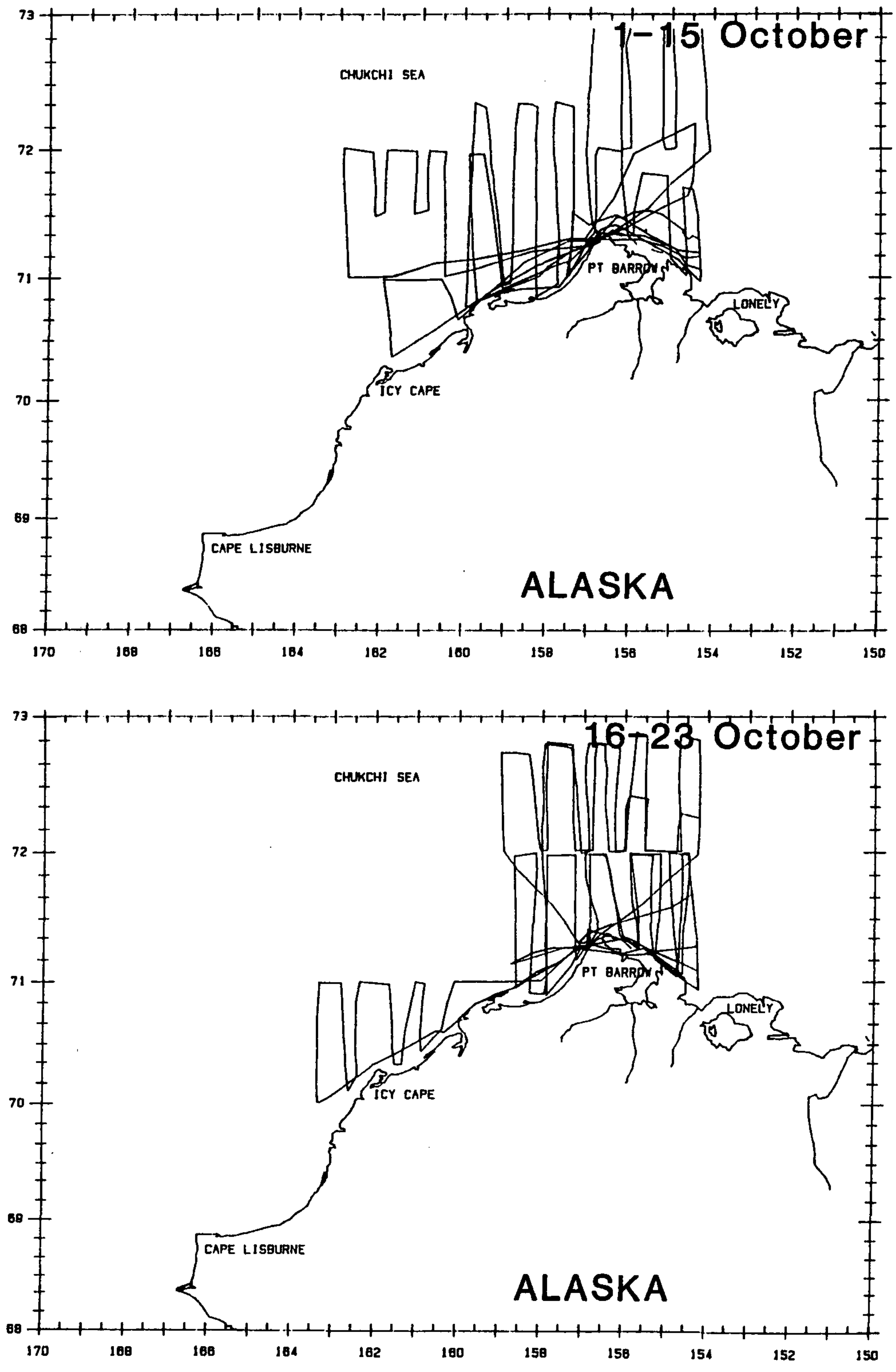


Figure 5 (contd). 9 surveys, 1-15 October; and 6 surveys 16-23 October.

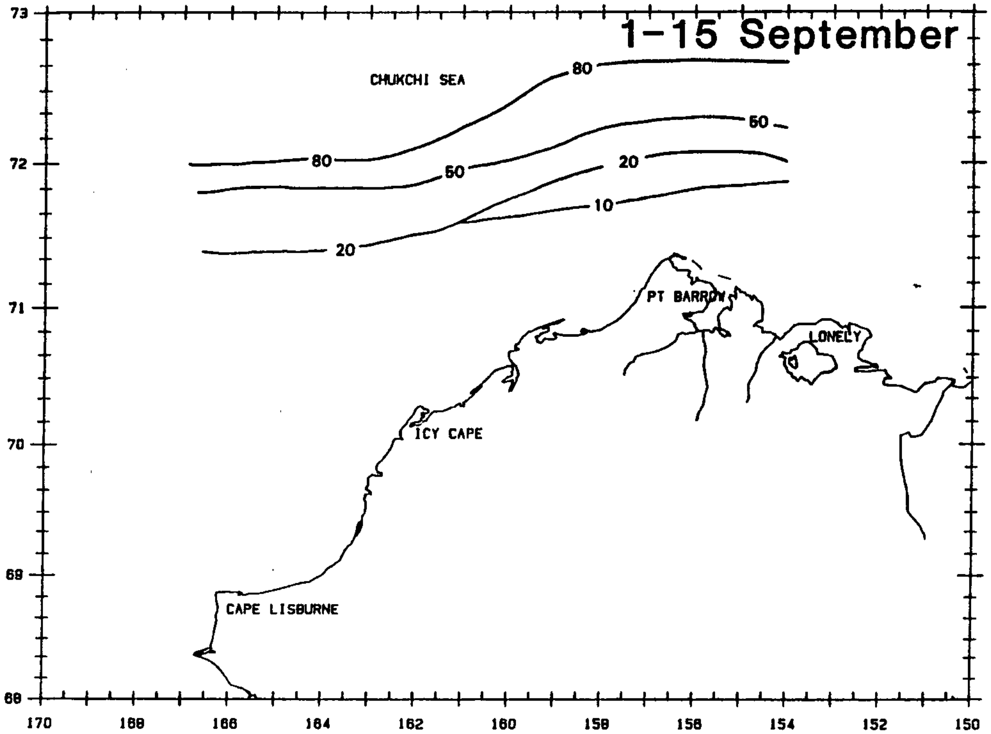
10 percent, ≥20 percent, ≥50 percent, and ≥80 percent broken floe ice were found beginning approximately 45 km north of Point Barrow, with open water south of the ice (figure 6). The lack of ice, combined with high winds (20+ knots), occasionally resulted in relatively high sea states (Beaufort 04-06). Mechanical problems with the aircraft prevented surveying on three days in the middle of the month (15-17 September).

Survey conditions remained generally good through the latter half of September, with inclement weather preventing flying on two days (table 3). Visibility was usually excellent (>10 km), although low ceilings and fog occasionally caused transects to be truncated. Ice conditions remained light, with ≥90 percent broken floe ice north of 72°N (figure 6). Grease ice formed offshore in mid-September during a brief cold spell. However, this grease ice disappeared by the end of the month due to winds, currents, and warmer weather. Sea states in areas of no ice remained relatively high (Beaufort 04-06) when strong winds were present.

Survey conditions in early October were fair to poor and bad weather prevented flying on four days (table 3). Fog, low ceilings, and snow squalls were often encountered, which limited visibility during flights and curtailed surveys to some blocks. The ice edge, consisting of broken floe and new grease ice, remained at least 75 km offshore in all parts of the study area, except for slushy new ice forming in nearshore coastal areas (figure 6). As in September, strong winds occasionally resulted in high sea states.

Survey conditions between 16 and 23 October improved considerably, although inclement weather prevented flying on 3 days (table 3). Snow squalls were frequently encountered during survey flights, but were usually very localized and did not hinder flight effort. The ice edge in the study area remained 120 to 165 km offshore, and temperatures in Barrow were unseasonably warm (30°F). Slushy new ice formed in nearshore coastal areas.

Ice conditions in 1987 were much lighter than those in 1984-85, and comparable to those seen in 1986. Ice boundaries averaged over 29 years (1953-81) reported in Webster (1982), and reproduced by La Belle et al. (1983), indicate that ice is usually heavier in the Alaskan Beaufort and northeastern Chukchi Seas than conditions prevalent in 1987. Pease (1987) described both 1986 and 1987 as extremely light ice years that set a new 30-year minimum. Just as 1980 and 1983 have been considered years of exceptionally heavy ice cover (Ljungblad et al., 1986a), the 1987 season stands out as a year of extensive open water most similar to 1986 and, to a lesser degree, 1982 and 1979.



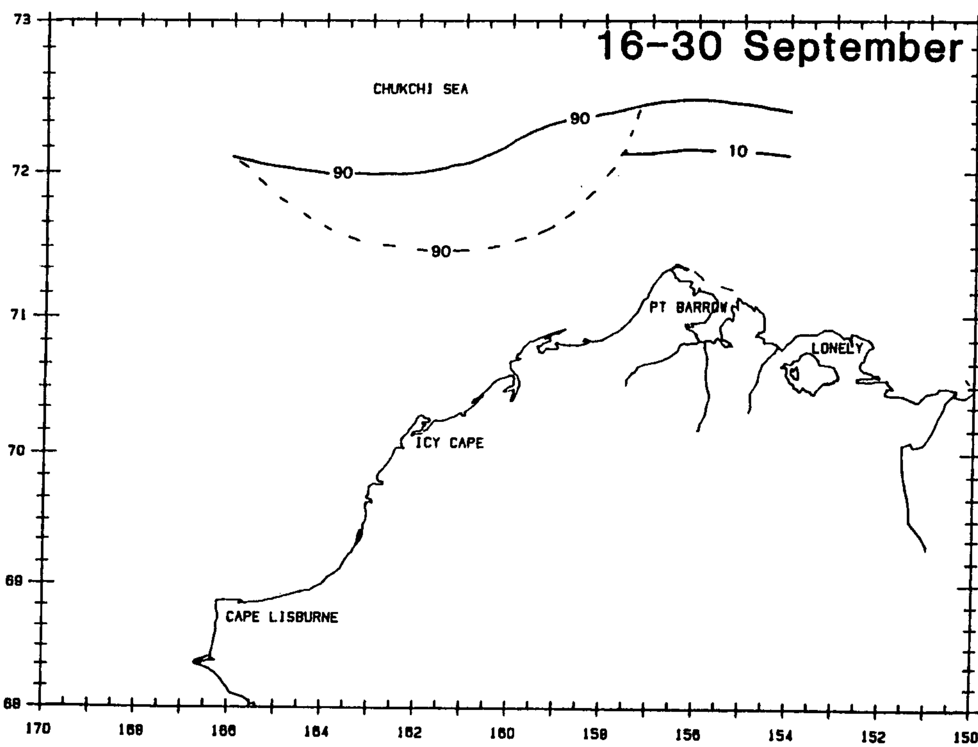


Figure 6. Schematic representation of ice conditions (in percent): 1-15 September; 16-30 September;

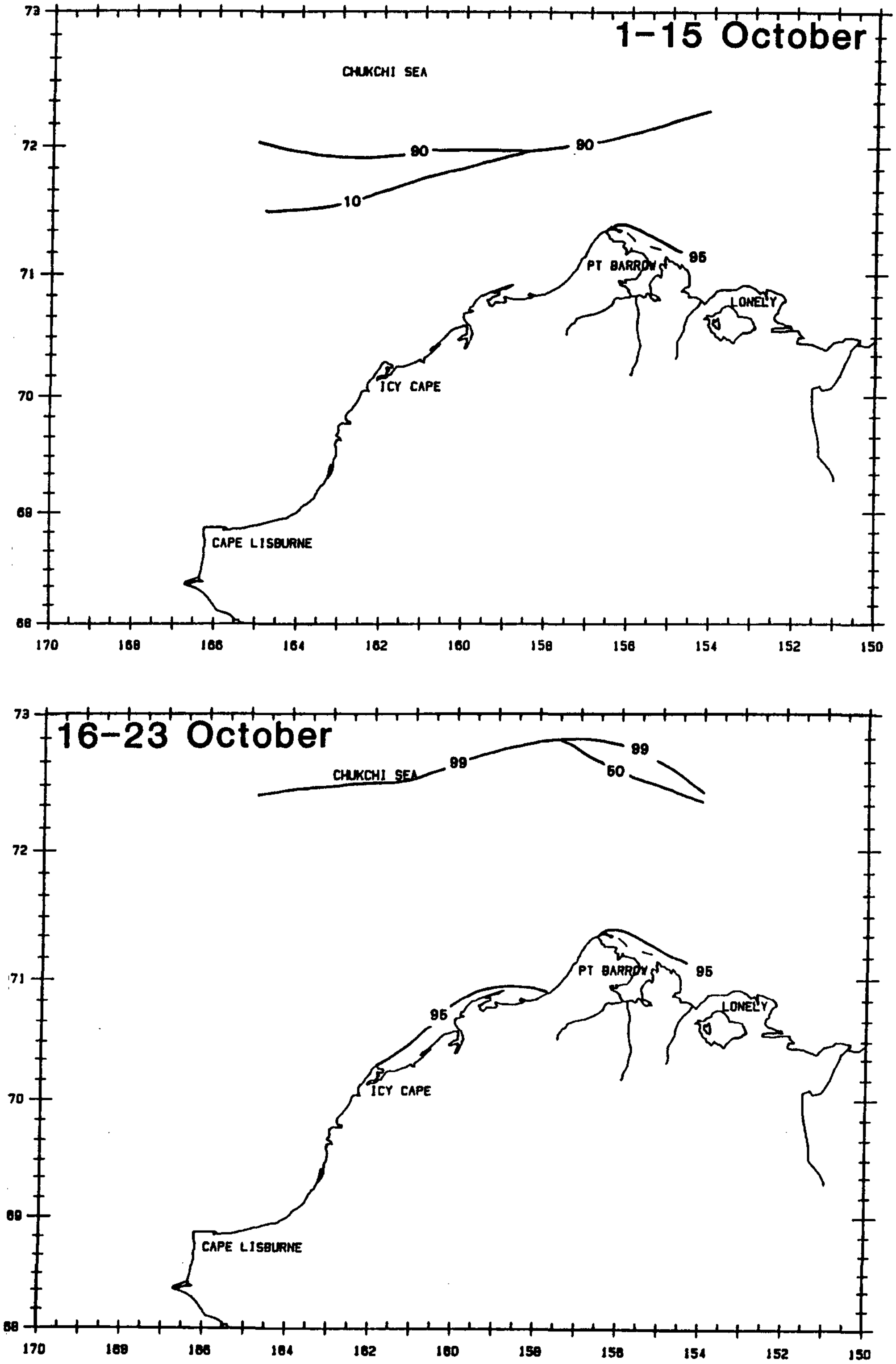


Figure 6 (contd). 1-15 October; 16-23 October.

Acoustic Monitoring at Barrow

Bowhead Calls

Passive acoustic monitoring for bowhead calls was conducted from the field station at Barrow on an opportunistic basis. Sonobuoys were deployed near shore during aerial surveys (see figure 4) and the signal recorded at the field site for as long as the free-floating sonobuoy stayed within range. Over 165 hours of recordings were made on 26 days between 9 September and 21 October (table 4, figure 7). Strong easterly winds sometimes blew the sonobuoy off shore in a matter of a few hours resulting in relatively short (2-3 hr) recording efforts. During calm periods, sonobuoys sometimes stayed within recording range for over 8 hours. Recording periods longer than 8 hours were accomplished by dropping a sonobuoy at the beginning and end of a flight.

A total of 531 bowhead calls were recorded over the course of the field season (table 4). The types of calls recorded were similar to those previously described (Ljungblad et al., 1982; Clark and Johnson, 1984) as either tonal frequency-modulated (FM) "moans", or amplitude-modulated (AM) "growls" and "trumpets". Nearly all sounds recorded were very low level, implying that passing whales were relatively far away ($\geq$10 km) from the hydrophone. The sonobuoy drop site was dictated by the reception range of the equipment, but probably did not optimize the recording of bowhead calls due to the shadowing, by the Point Barrow peninsula, of calls for whales northeast of Barrow.

Three periods of calling activity stood out over the course of the season (figure 7). The first bowhead calls (n = 34) were recorded on 18 September between 1940 and 2300 hours. These calls preceded the first bowhead sighting in the study area by 3 days. The second and highest period of bowhead calling occurred on 3-6 October. Forty-eight calls were recorded between 1630 and 1830 on 3 October. Calls on 5 October were recorded between 1545 and 2145, with 53 of the 76 calls recorded between 1845 and 1945. Of the 238 calls recorded on 6 October between 1445 and 2200, 179 were recorded between 2025 and 2125. The third peak period of bowhead calling occurred on 15-16 October. Twenty seven calls were recorded on 15 October between 1640 and 2140, and 81 calls were recorded on 16 October between 1815 and 2210. Two bowhead calls were recorded on 2 October and seven calls were recorded on 21 October, the last day that a sonobuoy was dropped to monitor underwater sounds near Barrow. Calls on both days were recorded after 2130.

Table 4. Summary of recording effort, bowhead calls and call rate (CR = calls/h) from sonobuoy drops near Barrow, Alaska, 1987.

Date	Hours	No. Calls	Call Rate	Comments
9 Sep	4.2	0	--	Distant airgun sounds; ambient water noise
12 Sep	2.0	0	--	Ambient water noise (high sea state)
14 Sep	2.0	0	--	Ambient water noise (high sea state)
18 Sep	7.1	34	4.79	**Bowhead calls;** ambient water noise
19 Sep	4.8	0	--	Ambient water noise
21 Sep	6.0	0	--	Ambient water noise
22 Sep	0.5	0	--	Ambient water noise (poor signal)
26 Sep	3.5	0	--	Airgun sounds; ambient water noise
27 Sep	6.2	0	--	Airgun sounds
28 Sep	7.4	0	--	Airgun sounds
29 Sep	12.1	0	--	Ambient water noise
30 Sep	11.8	3	0.25	**Bowhead calls** (very weak); airgun sounds
1 Oct	3.0	0	--	Ambient water noise
3 Oct	3.9	48	12.31	**Bowhead calls;** ambient water noise
5 Oct	8.7	76	8.74	**Bowhead calls;** airgun sounds
6 Oct	11.6	238	20.52	**Bowhead calls;** airgun sounds
9 Oct	7.0	0	--	Airgun sounds
10 Oct	7.9	0	--	Airgun sounds
11 Oct	8.1	0	--	Ambient water noise
12 Oct	4.6	0	--	Ambient water noise
15 Oct	8.7	27	3.10	**Bowhead calls;** airgun sounds
16 Oct	7.5	81	10.80	**Bowhead calls**
17 Oct	2.7	0	--	Ambient water noise
19 Oct	7.8	15	1.92	Ambient water noise
20 Oct	8.7	2	0.23	**Bowhead calls;** distant airgun sounds
21 Oct	8.7	7	0.80	**Bowhead calls;** ambient water noise

The three seasonal peaks of bowhead calling (figure 7), or the hourly peaks in calling recorded over 5-6 October (figure 8), could be interpreted as aggregations or pulses of whales passing Barrow. Because the sonobuoys used were equipped with omnidirectional hydrophones however, there was no way to determine if more calls meant more whales, or the same whales stopping and calling for short periods within the range of the sonobuoy. Many of the calls recorded on 5-6 October were "trumpets"; such calls have been recorded more often near socializing rather than migrating whales, although this association is not a statistically significant one (Ljungblad et al., 1987). Thus, we might guess that at least some of the whales recorded on 5-6 October were socializing and not actively migrating past Barrow.

Although it is not possible to infer bowhead number or rate of passage from the acoustic data collected from a single omnidirectional sonobuoy, the data obtained do extend data-gathering periods beyond the limits of a standard survey

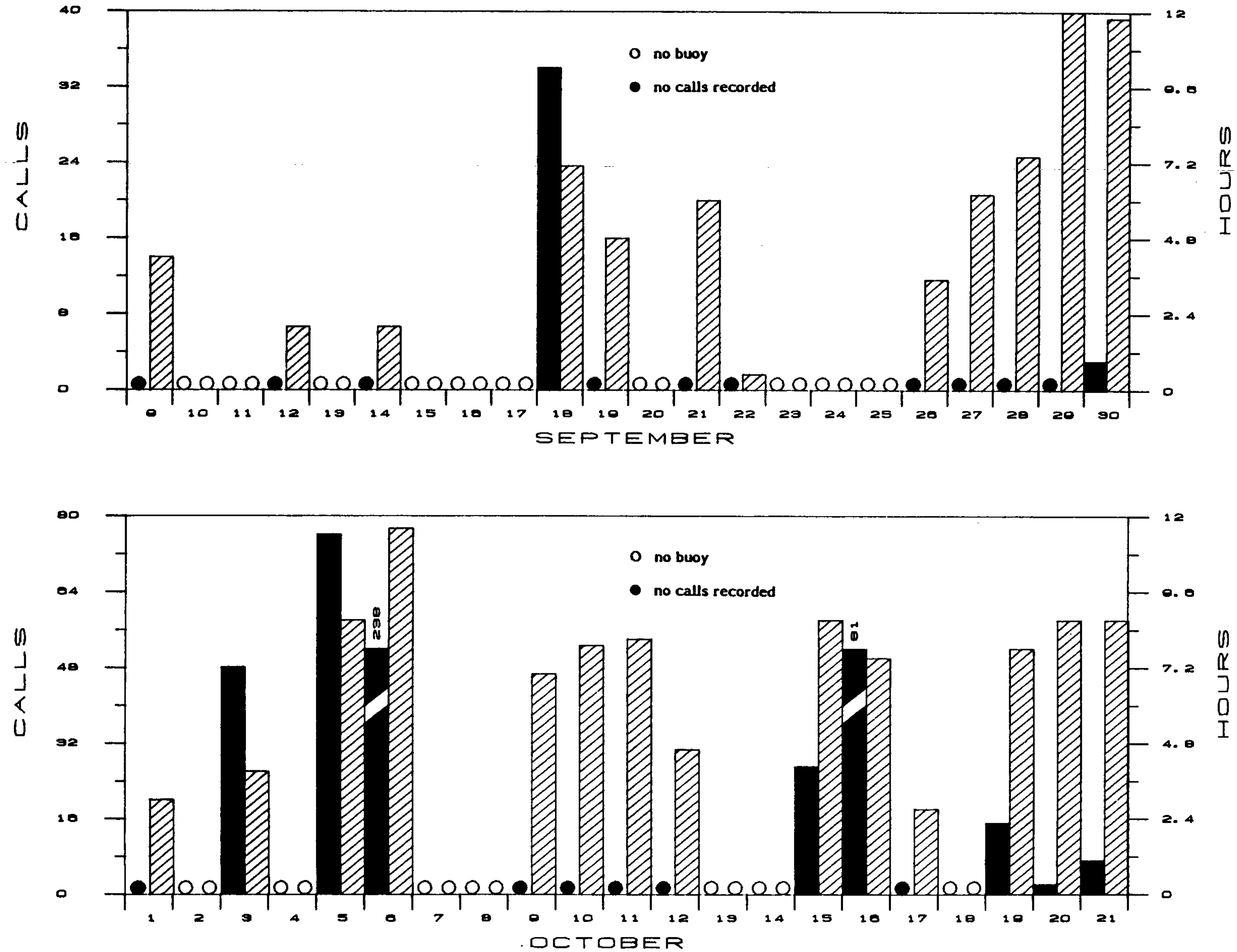


Figure 7. Hours of recording ■ effort and number of bowhead calls ▨ recorded at the Barrow field station.

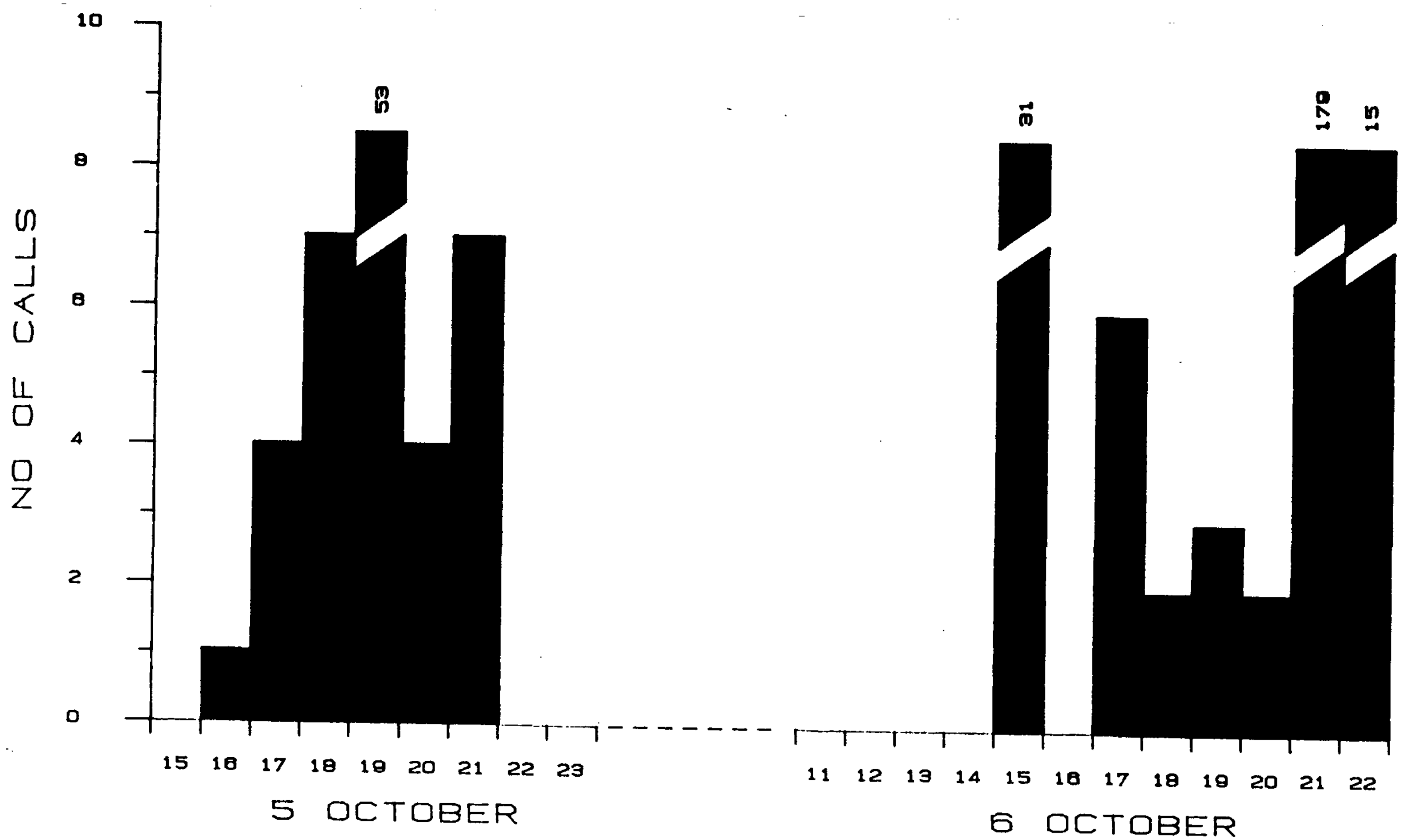


Figure 8. Hourly bowhead call rate over the two-day (5-6 October) peak calling period.

flight. As noted earlier, many of the peak calling periods recorded occurred at night when surveys could not be conducted. The principal attribute of acoustic monitoring, as noted for the longer-term study carried out from Barter Island in 1986 (Ljungblad et al., 1987), is the extension of data gathering through periods of darkness and bad weather and the subsequent collation of acoustical data with visual survey data.

Pinniped Vocalizations

Bearded seal trills were noted on many of the tapes recorded at Barrow. In addition, a "howl"-like call that could not be definitively ascribed to a bearded or a ringed seal was also frequently recorded. This call seemed most like a "short descending trill" of a bearded seal as described by Stirling et al. (1983), but we could not positively identify it. Bearded seal vocalizations have been described as seasonal, with the period of highest call rates in the High Arctic occurring in June (Stirling et al., 1983). Further, geographic variation in bearded seal trills have been reported and suggested as characteristic of discrete breeding stocks (Cleator et al., 1987). Although bearded seal trills have been associated with breeding behavior in the spring, 1987 marks the second fall season when such calls have been routinely recorded as they were also frequently recorded at the Barter Island acoustic station in 1986 (Ljungblad et al., 1987). The function of these calls in the fall is unknown.

Ambient Noise

Ambient noise is background noise that does not have an identifiable source (Urick, 1983). Ambient noise sources include tides and waves, naturally occurring seismic activity, oceanic turbulence, thermal noise, distant ship traffic, and distant biological noise. In coastal waters, wind speed and its resultant sea state have been cited as the strongest factor in determining overall noise level between 10 Hz and 3 kHz (Urick, 1983). This relationship between wind speed and coastal water ambient noise level has been documented both in open water and in partial ice-cover conditions (Milne et al., 1967).

Sea state during the acoustic monitoring study varied from a Beaufort 00-01 during calm-sea periods to 06-08 during storms. A spectrum of the 15- to 500-Hz band indicates that ambient sea noise increased by about 30 dB during storms (figure 9). Ambient noise during calm periods averaged 62 dB in the 15- to 200-Hz band and 54 dB between 200- and 500-Hz band. During storms, ambient noise was approximately 95 dB from 15- to 100-Hz and about 86 dB in the 100- to 500-Hz

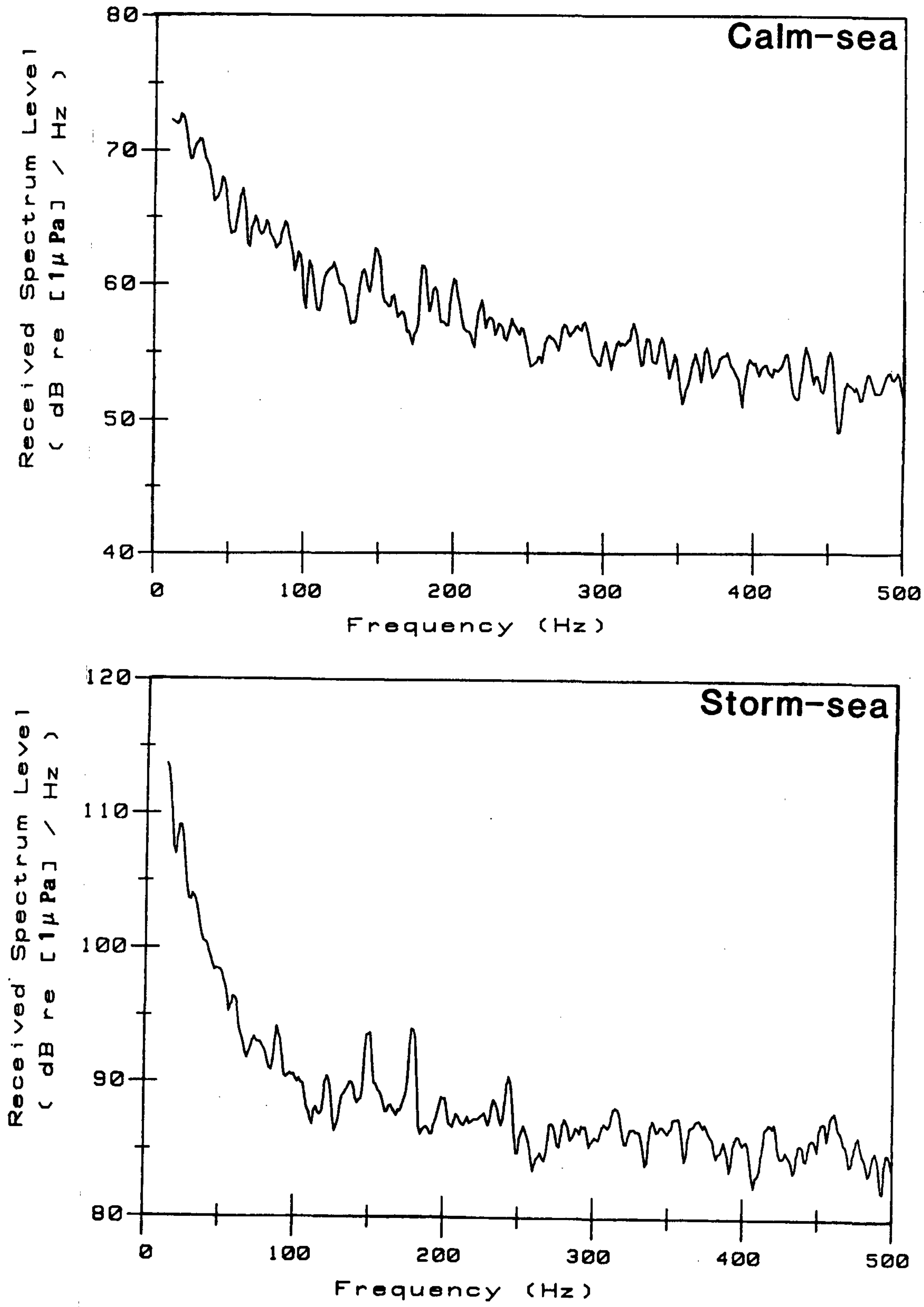


Figure 9. Ambient noise spectrum for data recorded at the sonobuoy drop site near Barrow during calm-sea and storm-sea recording conditions.

band. Peaks in the storm-sea spectrum at 150 Hz and 180 Hz may be due to surf beat, as sonobuoys were dropped near shore to allow reception at the field station (see figure 4). Regular surf-like noise that may be attributable to large storm waves is audible on these tapes. The relatively high ambient noise associated with high seas may have masked some bowhead calls, although the sonobuoys did not remain within reception range very long in high-sea conditions.

Bowhead Whale (Balaena mysticetus)

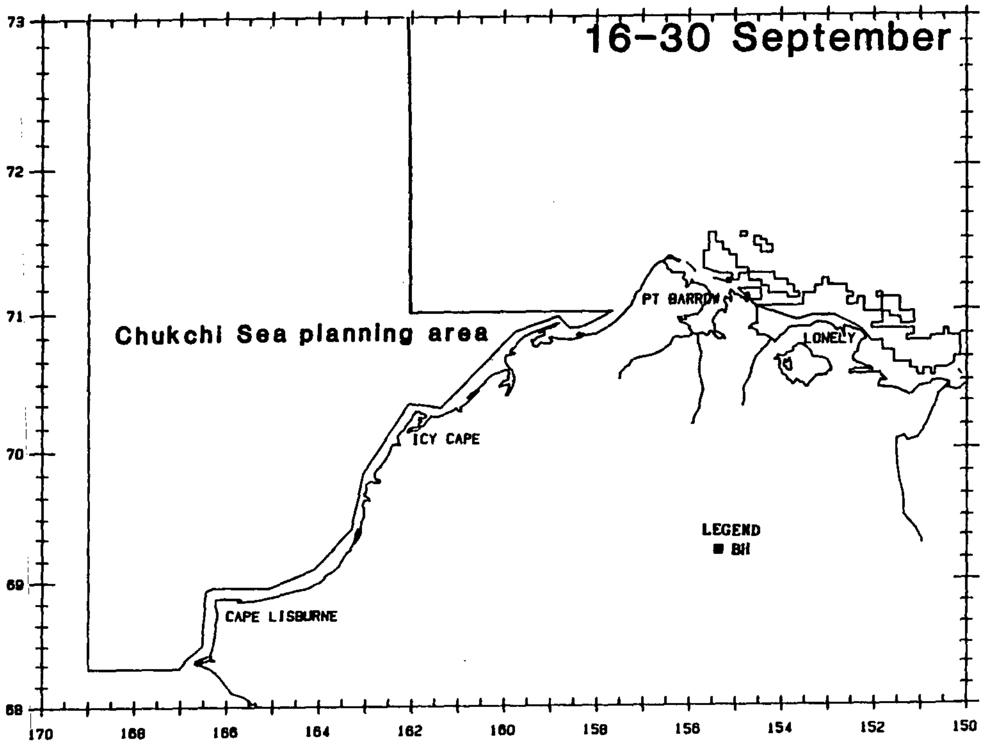
a. Distribution

Twenty-four sightings of 32 bowheads were made in the northeastern Chukchi and western Alaskan Beaufort Seas (figure 10, table 5). No bowheads were seen in the first half of September. In the latter half of September, four sightings of four bowheads were made. Two whales were seen very near shore just west of Smith Bay. One whale was seen in block 12-N at 72°11'N, 156°07'W, and one was seen in the Chukchi Sea at 71°38'N, 159°27'W. This distribution was similar to, though not comprehensive of, that seen in past years.

Twenty-one bowheads were seen in early October, all in the Beaufort Sea between Smith Bay and Point Barrow (figure 10). Most of these whales were swimming westward at moderately fast speeds, except for one group of three feeding at 71° 28'N, 156°05'W (appendix A: flight 25). Seven whales were seen between 16-23 October in blocks 12 and 13 (figure 10). Nine bowheads were seen during surveys east of the study area, including three seen in the eastern Alaskan Beaufort in late October, and are summarized in Treacy (in prep.). Bowhead distribution in October was similar to, though not comprehensive of, past years and some sightings overlapped the boundaries of the western OCS oil and gas lease areas.

b. Association of Bowhead Call Rates with Aerial Survey Sighting Rates

There were 15 sightings of 19 bowheads near the acoustic monitoring area at Barrow (figure 11, table 6). Bowheads were not seen in the area until 30 September, although the first calls were recorded on 18 September. Most whales were seen on 6 October (63%, n = 12) and 16 October (26%, n = 5). These dates correspond with periods of peak calling recorded at the acoustic station (see figure 8), even though none of the whales were seen within the assumed radial boundaries of the sonobuoy. The swimming direction ($\bar{a}$ = 296° T, r = 0.49, z = 3.43,



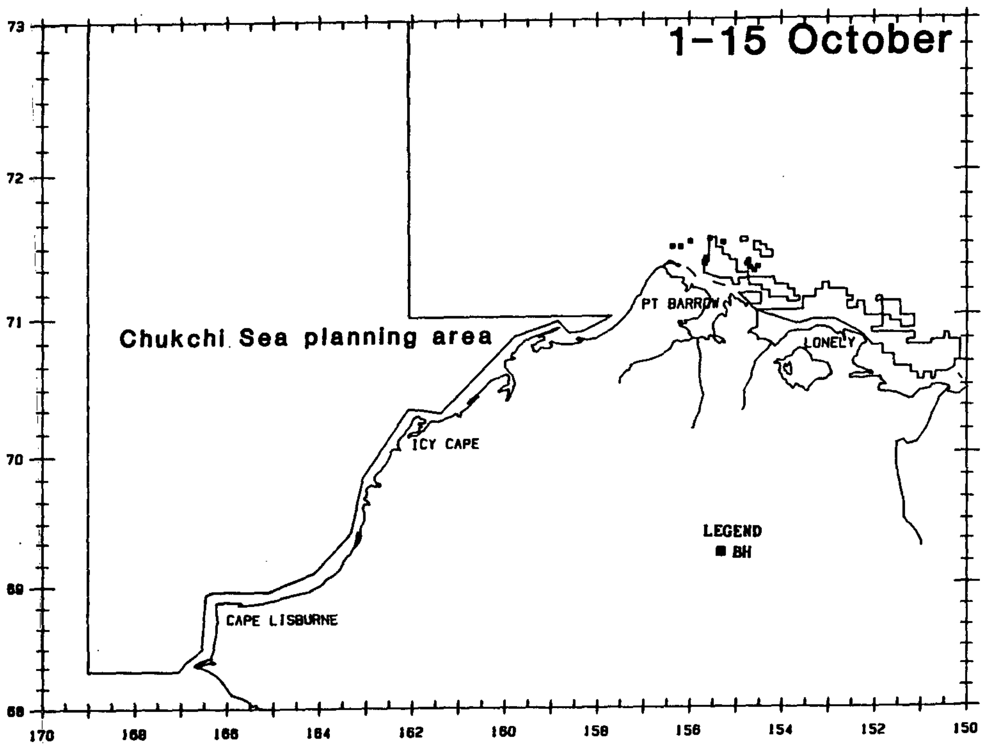


Figure 10. Semimonthly distribution of bowhead whales in relation to OCS planning areas in the western Beaufort and northeastern Chukchi Seas: 4 sightings of 4 bowheads, 16-30 September; 13 sightings of 21 bowheads, 1-15 October;

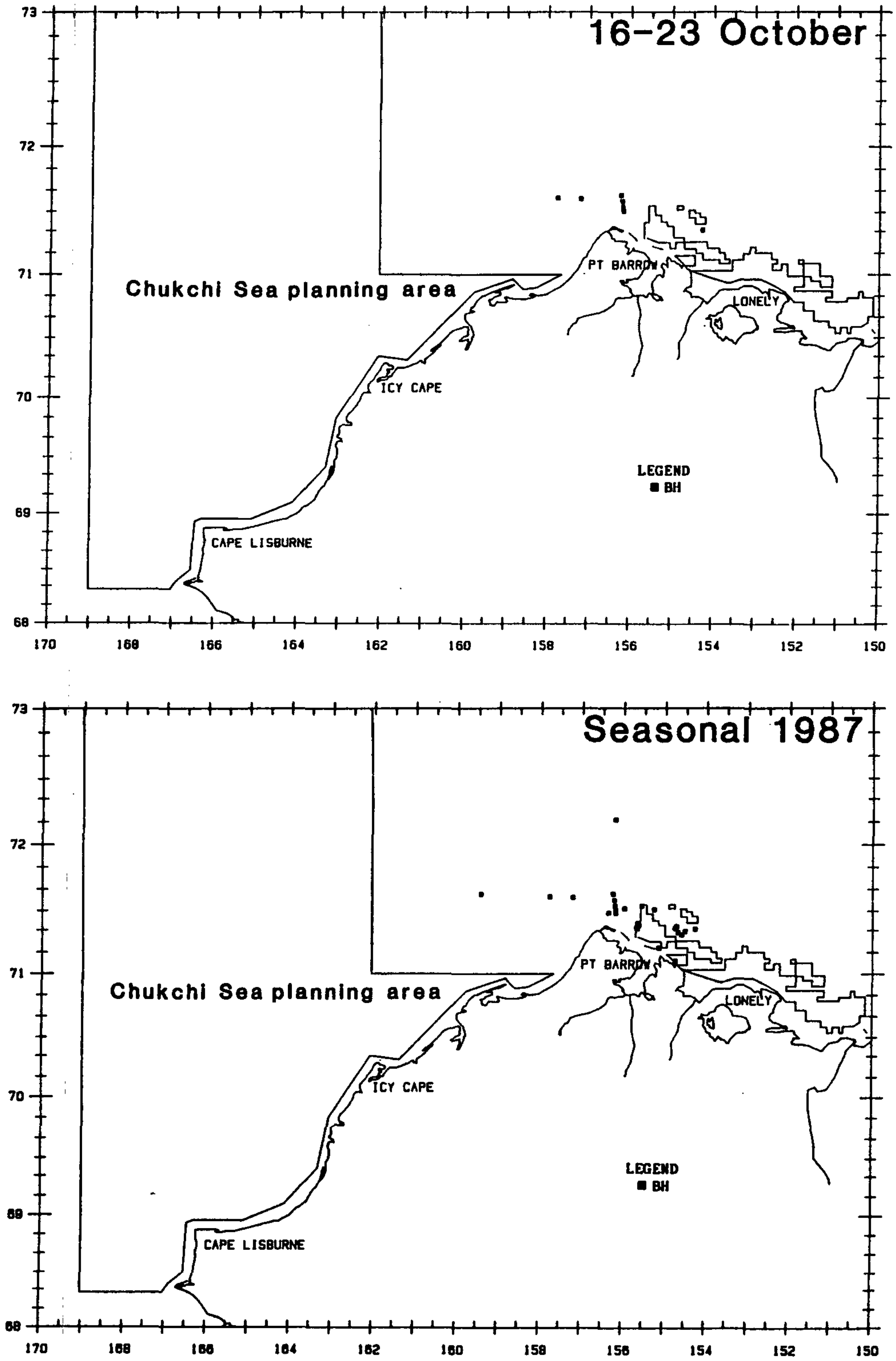


Figure 10 (contd). 7 sightings of 7 bowheads, 16-23 October; 24 sightings of 32 bowheads, 1987 Seasonal. Polygons in the Beaufort Sea represent OCS leasing areas.

Table 5. Summary of marine mammal sightings (number of sightings/number of animals), 1987.

DATE	Flt. No.	Bowhead Whale	Gray Whale	Belukha	Unidentified Cetacean	Walrus	Bearded Seal	Ringed Seal	Unidentified Pinniped	Polar Bear
1 Sep	1	0	3/18	0	0	2/2 (2D)	0	0	0	0
2 Sep	2	0	0	1/1	0	0	0	0	0	0
4 Sep	3	0	3/5	0	0	16/880	0	0	1/1	0
5 Sep	4	0	5/6	0	0	3/13	0	0	0	0
6 Sep	5	0	0	0	0	0	0	0	0	0
7 Sep	6	0	1/5	0	0	2/2	5/5	2/3	5/5	0
8 Sep	7	0	1/2	0	0	0	2/2	0	1/1	0
9 Sep	8	0	10/28	2/3	0	7/43	0	0	5/5	0
10 Sep	9	0	3/3	0	0	1/2	0	0	3/3	0
12 Sep	10	0	2/2	2/13	0	7/94	0	0	0	0
14 Sep	11	0	0	0	0	1/10	0	0	0	0
18 Sep	12	0	0	0	0	2/2	0	0	7/7	0
19 Sep	13	0	1/4	4/5	0	18/696	2/2	0	7/10	0
21 Sep	14	1/1	2/3	0	0	6/73	3/3	2/2	1/1	0
22 Sep	15	0	0	0	0	0	0	0	0	0
25 Sep	16	0	0	1/2	0	0	0	0	0	0
26 Sep	17	0	0	1/19	0	0	0	0	0	0
27 Sep	18	1/1	1/1	5/24	1/1	2/3	0	0	2/2	0
28 Sep	19	0	1/1	2/2	0	11/374	0	0	0	0
29 Sep	20	0	3/10	0	0	1/1	1/1	0	15/16	0
30 Sep	21	2/2	4/4	4/14	0	0	0	0	1/1	0

D = dead

Table 5 (contd).

DATE	Flt. No.	Bowhead Whale	Gray Whale	Belukha	Unidentified Cetacean	Walrus	Bearded Seal	Ringed Seal	Unidentified Pinniped	Polar Bear
1 Oct	22	0	1/1	0	0	0	0	0	0	0
3 Oct	23	0	0	3/11	0	0	2/2	0	1/1	1/3
5 Oct	24	0	0	0	0	0	0	0	0	0
6 Oct	25	13/21	0	0	0	0	0	0	4/4	0
8 Oct	26	0	4/9	0	0	1/30	1/1	2/3	10/15	1/1
10 Oct	27	0	0	0	0	0	0	0	1/1	0
11 Oct	28	0	0	0	0	0	0	0	0	1/1
12 Oct	29	0	0	1/1	0	0	0	0	0	0
15 Oct	30	0	3/9	0	0	0	0	0	5/6	0
16 Oct	31	5/5	5/7	3/6	2/2	0	0	0	2/2	0
17 Oct	32	1/1	0	4/39	1/1	0	0	0	5/6	0
19 Oct	33	0	0	0	0	0	0	0	0	0
20 Oct	34	0	0	0	2/2	0	0	0	3/8	0
21 Oct	35	0	0	0	0	0	0	0	2/4	0
23 Oct	36	1/1	0	0	0	0	0	0	0	0
1-15 Sept subtotal		0	28/69	5/17	0	39/1046	7/7	2/3	15/15	0
16-30 Sept subtotal		4/4	12/23	17/66	1/1	40/1149	6/6	2/2	34/38	0
1-15 Oct subtotal		13/21	8/19	4/12	0	1/30	3/3	2/3	17/27	3/5
16-31 Oct subtotal		7/7	5/7	7/45	5/5	0	0	0	13/21	0
TOTAL		24/32	53/118	33/140	6/6	80/2225	16/16	6/8	79/101	3/5

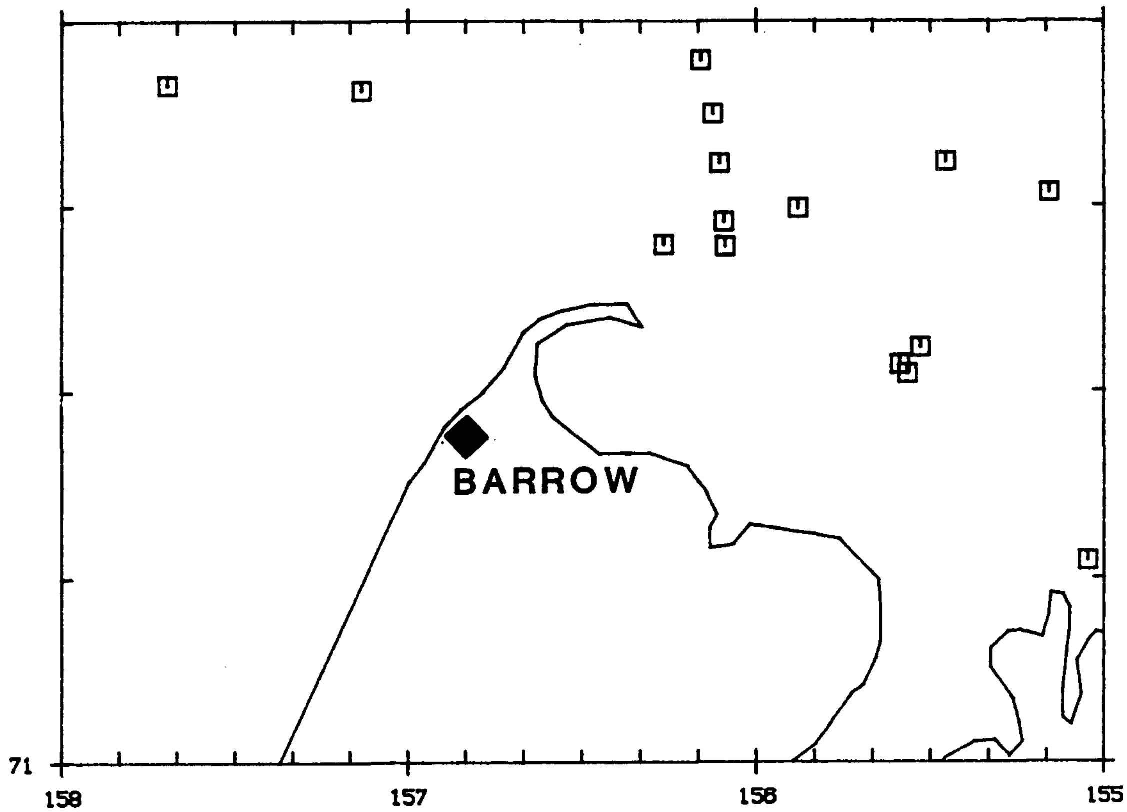


Figure 11. Distribution of bowhead sightings near acoustic monitoring area at Barrow.

$p < 0.05$) and estimated speed of the whales that were seen would have put them in the general vicinity of the acoustic station within an hour or so of the sighting(s), but there is no way to determine if in fact any of the whales seen were also heard. However, it is likely that most of the calls recorded were from whales not seen because (a) as previously mentioned, many calls were recorded late in the evening several hours after the termination of the survey for that day and (b) whales that are under water or far from the aircraft go undetected during aerial surveys, such that whales seen while flying transect surveys almost always under represent the total number of whales in the area (Caughley, 1974; 1977).

Although it is not possible to determine the number of bowheads represented by calls received on an omnidirectional hydrophone such as those used in this study, the association of calls with sightings supports the idea that acoustic monitoring could be developed as a valuable and cost effective tool to augment aerial surveys when assessing bowhead migratory timing. As in the acoustic monitoring study conducted from Barter Island in 1986 (Ljungblad et al., 1987), the greatest number of bowhead calls were associated with periods of high sighting

Table 6. Bowhead sightings near the acoustic monitoring area at Barrow, 1987.

Date	Flt.	No. Bowheads	Position Lat.° N	Long.° W	Swim Direction (°T)	Swim Speed
30 Sep	21	1	71°10.9'	155°02.8'	290	slow
6 Oct	25	1	71°21.4'	155°35.3'	060	medium
		1	71°22.3'	155°31.8'	050	medium
		1	71°20.9'	155°34.0'	060	medium
		2	71°30.7'	155°09.6'	350	slow
		2	71°32.4'	155°27.5'	300	medium
		1	71°29.6'	155°53.0'	270	medium
		3	71°27.6'	156°05.5'	*	slow
		1	71°27.7'	156°16.1'	240	medium
16 Oct	31	1	71°36.3'	157°08.1'	270	fast
		1	71°37.9'	156°09.6'	300	medium
		1	71°35.0	156°07.5'	280	fast
		1	71°32.3'	156°06.5'	310	fast
		1	71°28.9'	156°05.7'	200	*
17 Oct	32	1	71°36.6'	157°41.7'	250	fast

Swim speed estimates: slow <2 km/h; medium 2-4 km/h; fast >4 km/h
*no data recorded

rates, but calls were also recorded when no whales were seen. Using acoustic techniques in addition to aerial surveys to monitor the progress of the bowhead migration extends the period of data acquisition past the limits imposed upon flying (i.e., effort allocation, fuel, darkness, bad weather). In 1986, sonobuoys modified for extended service were deployed from shore independent of survey efforts, and many more sounds were recorded than in 1987, when sonobuoys were deployed only from the aircraft. In addition, the moored sonobuoy site in 1986 was directly in the path of the observed bowhead migratory route north of Barter Island, while in 1987 the drop site was south and somewhat closer to shore; a less-than-optimum placement for detecting whales passing Barrow. Even with these limitations, acoustic monitoring at Barrow provided valuable data on the timing and progression of the bowhead migration.

c. Relative Abundance and Density Estimates

An index of relative abundance (WPUE = no. whales/hours of survey effort) and a density estimate (whales/100 km^2) were calculated for bowheads in survey blocks. When calculating abundance, all whale sightings were used regardless of the type of survey being conducted. The calculation of density estimates using strip transect methodologies, however, requires that the sightings be made on transect legs (i.e., that sightings be random) and that they occur within a predetermined distance from the aircraft (Hayne, 1949). Therefore, although abundance was calculated for any block in which bowheads were seen, density was calculated only for survey blocks in which whales were seen within 1 km on either side of the aircraft while on transect leg.

Bowhead relative abundance in the study area was highest in block 12-N (WPUE = 0.36) in late September, block 12 (WPUE = 2.96) in early October, and block 12 (WPUE = 0.62) in late October (table 7). Bowhead seasonal relative abundance ranged from 0.89 (block 12) to 0.08 (block 13).

There were no bowheads seen on transect during the first half of September, nor the first half of October. During the latter half of September, highest bowhead density was calculated for block 12-N (0.09 whales/100 km^2), with lesser estimates for blocks 12 (0.05 whales/100 km^2) and 13 (0.04 whales/100 km^2). During the latter half of October, bowheads were seen on transect only in blocks 12 and 13 resulting in density estimates of 0.14 whales/100 km^2 and 0.09 whales/100 km^2 respectively.

d. Migration Timing, Route, and Habitat Relationships

The timing of the bowhead migration through the western Beaufort and across the Chukchi Sea extended from 18 September, when the first bowhead calls were heard at Barrow, through 23 October when the last bowhead was seen in block 12. The last three bowhead sightings of the season were made in the eastern Beaufort Sea (blocks 4 and 5) between 25 and 30 October (see Treacy, in prep.; appendix A: flights 37 and 40). Because of these late October sightings, it is impossible to determine when the bowhead migration through the western Beaufort and eastern Chukchi Seas was completed.

The daily sighting rate (SPUE) and daily relative abundance (WPUE) peaked on 6 October (figure 12) when 21 bowheads were seen in block 12. Bowhead call rate was also highest (CR = 20.5) for this time period (see table 4). Lesser peaks were noted on 3 days between 21-30 September and on 3 days between 16-23 October. Acoustic data recorded over this time period had similar peaks (compare figure 12 and figure 7). Both the visual and the acoustic data indicate that bowheads passed Barrow in loose aggregations, or pulses from mid-September through late October with 5 to 10 days between groups.

Table 7. Semimonthly and seasonal relative abundance (WPUE = no. whales/hours of survey effort) of bowheads by survey block, 1987.

Block	1-15 Sept Hours	1-15 Sept No. Whales	1-15 Sept WPUE	16-30 Sept Hours	16-30 Sept No. Whales	16-30 Sept WPUE	1-15 Oct Hours	1-15 Oct No. Whales	1-15 Oct WPUE	16-23 Oct Hours	16-23 Oct No. Whales	16-23 Oct WPUE	TOTAL Hours	TOTAL No. Whales	TOTAL WPUE
12	8.58	0	-	7.70	2	0.26	7.09	21	2.96	**8.10**	5	**0.62**	31.47	28	0.89
12N	0.16	0	-	**2.75**	1	**0.36**	3.37	0	-	4.16	0	-	10.44	1	0.10
13	11.89	0	-	10.95	1	0.09	8.04	0	-	4.85	2	0.41	35.73	3	0.08
13N	0.17	0	-	1.75	0	-	1.09	0	-	2.38	0	-	5.39	0	-
14	6.89	0	-	5.31	0	-	2.62	0	-	0.03	0	-	14.85	0	-
15	0.97	0	-	3.38	0	-	0.00	-	-	0.00	-	-	4.35	0	-
16	0.00	-	-	0.41	0	-	0.00	-	-	0.00	-	-	0.41	0	-
17	3.55	0	-	2.60	0	-	0.95	0	-	2.88	0	-	9.98	0	-
18	0.12	0	-	2.91	0	-	0.00	-	-	0.54	0	-	3.57	0	-
20	2.52	0	-	1.68	0	-	0.00	-	-	0.00	-	-	4.20	0	-
22	1.33	0	-	2.34	0	-	0.00	-	-	0.00	-	-	3.67	0	-
24	0.23	0	-	0.00	-	-	0.00	-	-	0.00	-	-	0.23	0	-
25	0.65	0	-	0.00	-	-	0.00	-	-	0.00	-	-	0.65	0	-
28	0.10	0	-	0.00	-	-	0.00	-	-	0.00	-	-	0.10	0	-
Unblocked	0.99	0	-	0.10	0	-	0.08	0	-	0.00	0	-	1.17	0	-
Total	38.15	0	-	41.88	4	0.10	23.24	21	0.90	22.94	7	0.31	126.21	32	0.25

Bold indicates peak WPUE

Bold indicates peak WPUE

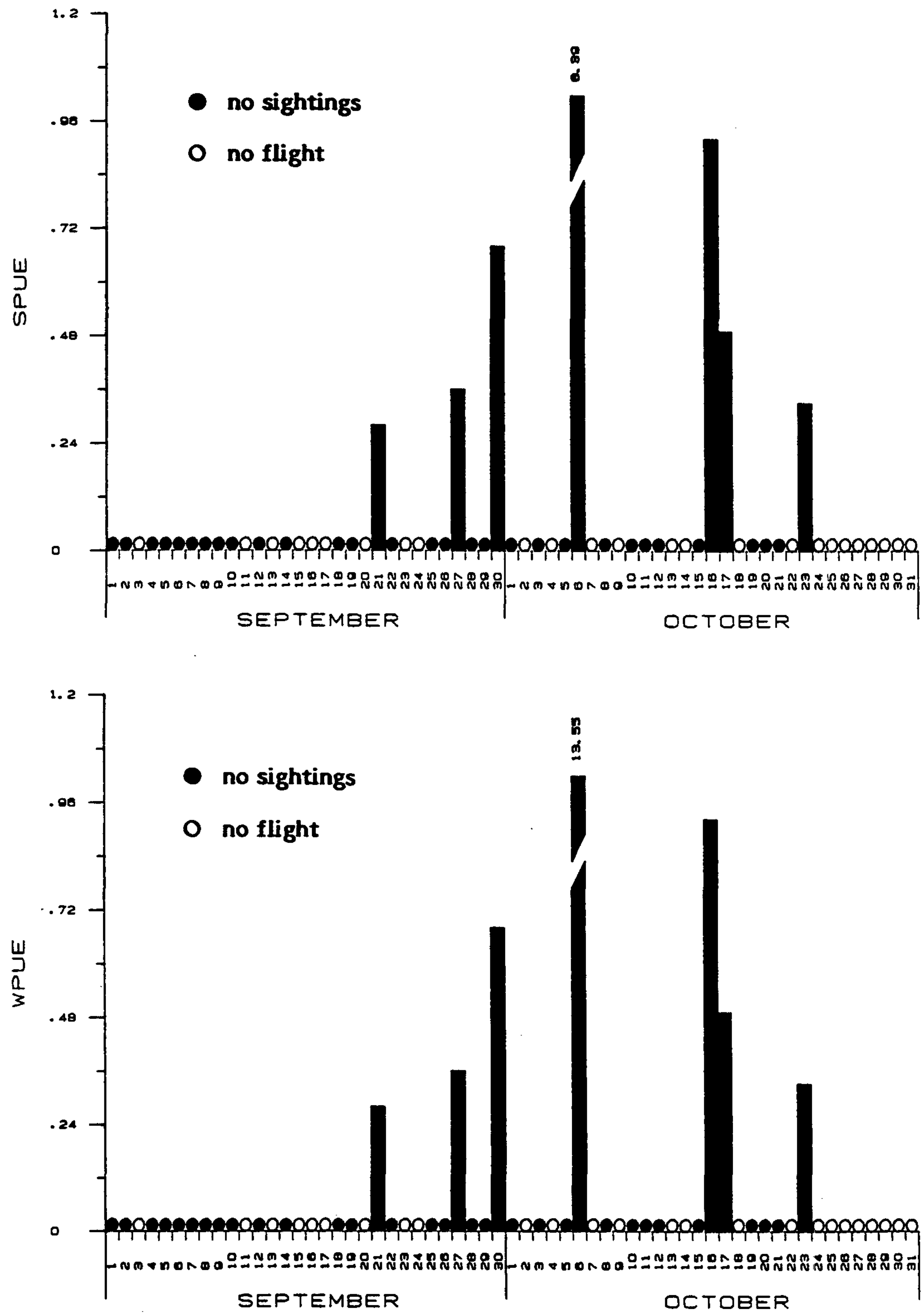


Figure 12. Bowhead daily sightings per unit effort (SPUE) and whales per unit effort (WPUE) in the western Beaufort and northeastern Chukchi Seas.

Table 8. Semimonthly summary of depths at bowhead sightings, 1987.

	16-30 Sep No.(%)	1-15 Oct No.(%)	16-31 Oct No.(%)	Total No.(%)
Shallow (0-50 m)	2(6)	21(65)	4(12)	27(84)
Transition (51-2000 m)	2(6)	0	3(12)	5(16)
TOTAL	4	21	7	32

Bowhead swimming direction in the western Beaufort Sea was significantly clustered ($p < 0.02$) around a northwest (300°T) heading over the course of the survey season (figure 13). Sample sizes collected in late September and late October were too small to test for statistical significance, but whales seen in early October were also significantly clustered ($p < 0.02$) about a northwest (316°T) heading. Mean headings in the western Beaufort Sea throughout the survey season generally followed the coastline. Swimming direction for the three bowheads seen in the Chukchi Sea were 180°T, 270°T, and 250°T, resulting in a mean heading of 235°T. Although the sample size was too small to test for significance, the southwest mean heading for whales in the Chukchi Sea is consistent with data from past years.

Most whales (84%, n = 27) were found in shallow (0-50 m) water throughout the season, with all others (16%, n = 5) in 51-2000 m water (table 8). No whales were seen in water over 2000 m deep because water of this depth was not surveyed, unlike past years (1982-86) when deep-water areas were sampled in blocks 8-10. Mean depth at bowhead sightings was 48 m, with the whales seen in relatively deep water on 27 September (176 m) and 16 October (181 m, 179 m and 165 m).

Bowheads were seen in very light ice cover due to the extremely light ice conditions that prevailed throughout the season (table 9). Except for one whale seen swimming in relatively heavy (75%) ice on 21 September, all bowheads were in open water or very light (< 10%) ice cover.

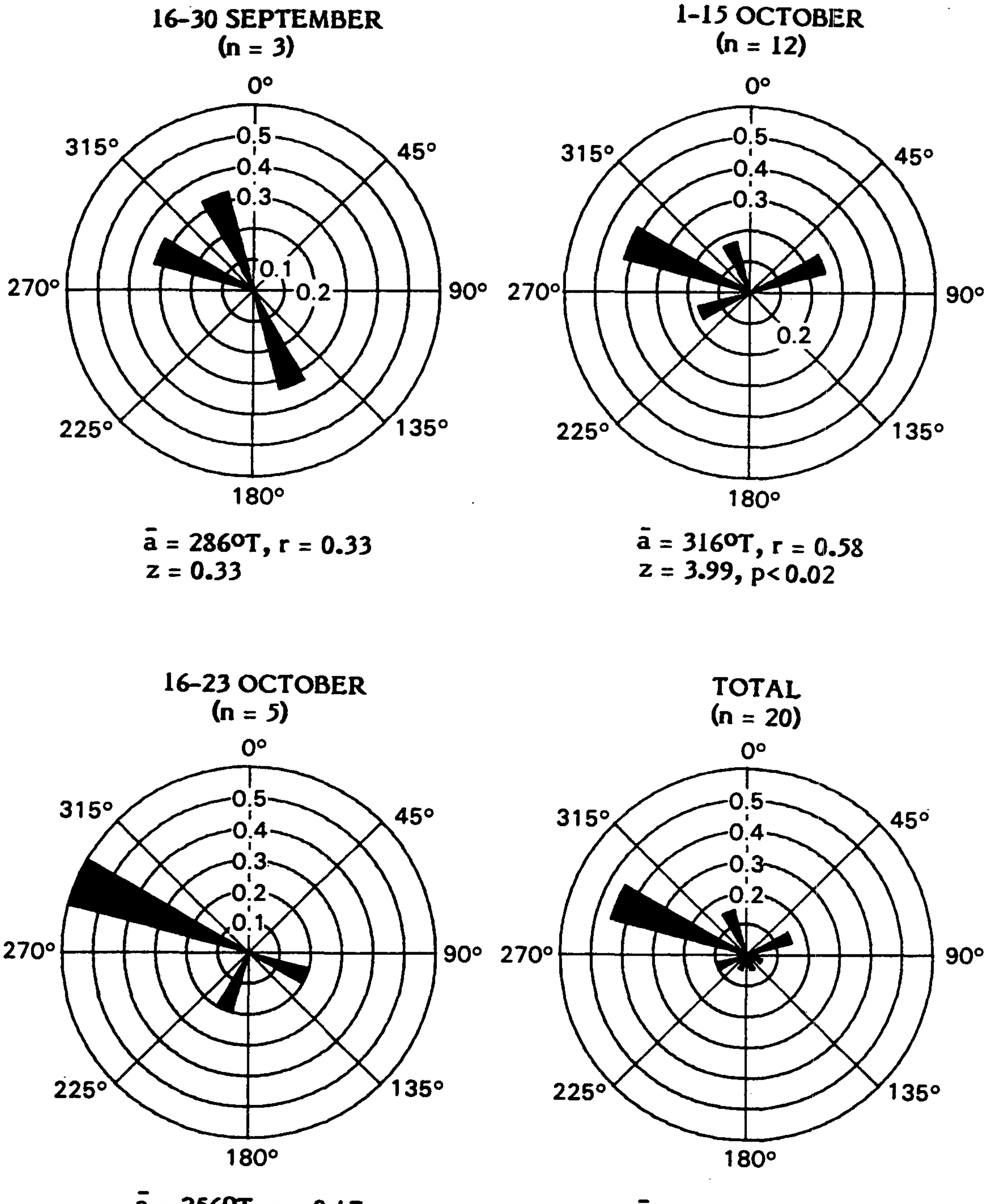


Figure 13. Bowhead swimming direction in the western Beaufort Sea.

Table 9. Number and percent of bowheads found in each ice cover class, 1987.

Ice Cover (%)	16-30 Sep No.(%)	1-15 Oct No.(%)	16-31 Oct No.(%)	Total No.(%)
0-10	3(9)	21(66)	7(22)	31(97)
11-20	0	0	0	0
21-30	0	0	0	0
31-40	0	0	0	0
41-50	0	0	0	0
51-60	0	0	0	0
61-70	0	0	0	0
71-80	1(3)	0	0	1(3)
81-90	0	0	0	0
91-100	0	0	0	0
TOTAL	4	21	7	32

e. Behavior

Most bowheads seen were swimming (91%, n = 29) which, when combined with the predominantly northwesterly heading, indicates that most whales were migrating through and not lingering in the study area. Three bowheads (9%) were seen feeding near Point Barrow on 6 October (appendix A: flight 25; table 10). Notably, whales were not observed resting, milling, or displaying, as in past years. Most of the whales were adults (91%, n = 29), with three immatures. No calves were seen.

Bowheads maintained mostly moderate swimming speeds (56%, n = 18) over the course of the season (table 11). Whales were also seen swimming slow (22%, n = 7) and fast (19%, n = 6), but none were seen just resting in the water. A speed was not estimated for one whale.

Gray Whale (*Eschrichtius robustus*)

a. Distribution

Fifty-three sightings of 118 gray whales were made in the northeastern Chukchi Sea in September and October (figure 14, table 5). Over half of the gray whales (58%, n = 69) were seen during the first half of September, with 36% (n = 42) seen between mid-September and mid-October, and only 7 whales (6%) seen after 16 October. This gradual depletion in the number of whales in the northeastern Chukchi Sea is consistent with past years records (Moore et al., 1986).

Table 10. Semimonthly summary of bowhead behavior, 1987.

	16-30 Sep No.(%)	1-15 Oct No.(%)	16-31 Oct No.(%)	Total No.(%)
MIGRATORY				
Swim	4(13)	18(56)	7(22)	29(91)
SOCIAL				
Feed	0	3(9)	0	3(9)
TOTAL	4	21	7	32

Table 11. Semimonthly summary of bowhead swimming speeds, 1987.

	16-30 Sep No.(%)	1-15 Oct No.(%)	16-31 Oct No.(%)	Total No.(%)
Still 0 km/hr	0	0	0	0
Slow < 2 km/hr	2(6)	5(16)	0	7(22)
Moderate 2-4 km/hr	2(6)	14(44)	2(6)	18(56)
Fast >4 km/hr	0	2(6)	4(13)	6(19)
Unknown	0	0	1(3)	1(3)
TOTAL	4	21	7	32

Gray whale distribution in September was similar to that seen in 1986, as they were again seen consistently 140 to 180 km northwest of Barrow in offshore block 14. Unlike past years, they were not seen north and east of Point Barrow (Ljungblad et al., 1987). Surveys in block 22 near Point Hope (as recommended in Ljungblad et al., 1987) on 1 and 29 September (appendix A: flights 1 and 20)

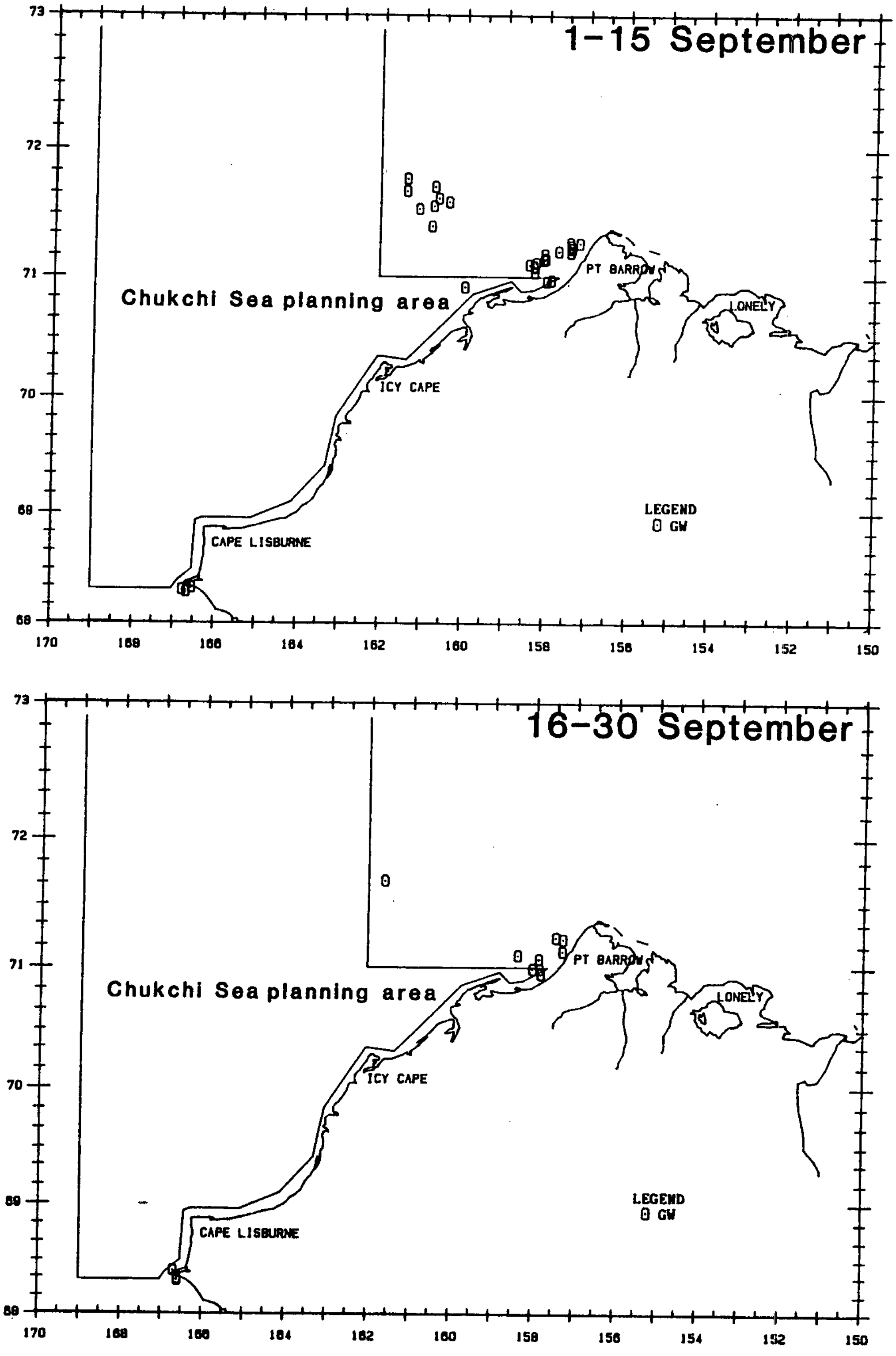


Figure 14. Semimonthly distribution of gray whales in relation to Chukchi Sea planning area in the Chukchi Sea: 28 sightings of 67 gray whales, 1-15 September; 12 sightings of 23 gray whales, 16-30 September;

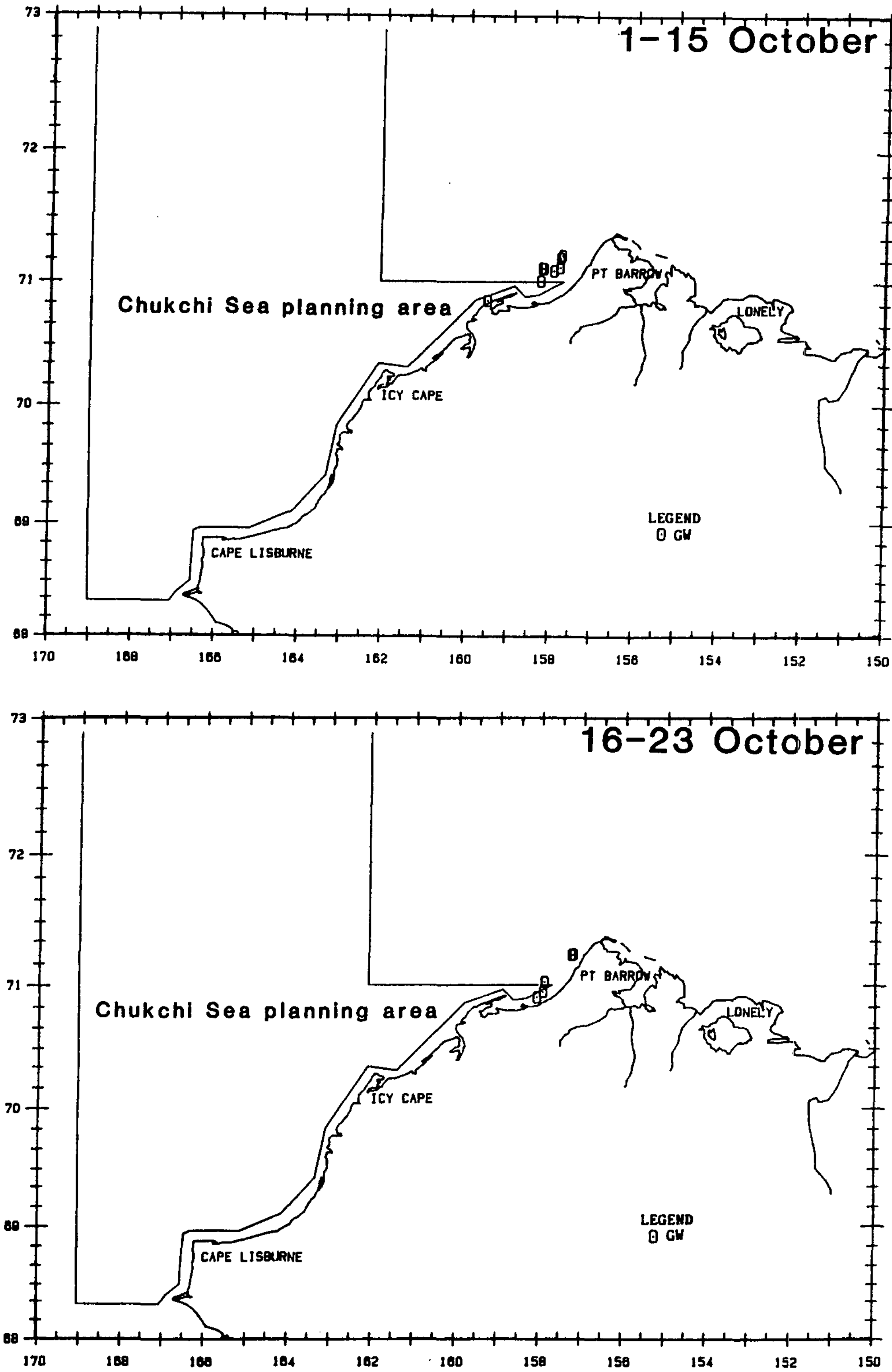


Figure 14 (contd). 8 sightings of 19 gray whales, 1-15 October; 5 sightings of 7 gray whales, 16-23 October.

Table 12. Relative abundance (WPUE = no. whales/hours of survey effort) of gray whales by survey block, 1987.

	September			October			TOTAL		
Block	Hours	No. Whales	WPUE	Hours	No. Whales	WPUE	Hours	No. Whales	WPUE
12	16.28	0	-	15.19	0	-	31.47	0	-
13	22.84	50	2.19	**12.89**	**26**	**2.02**	35.73	76	2.13
14	12.20	14	1.15	2.65	0	-	14.85	14	0.94
15	4.35	0	-	0.00	-	-	4.35	0	-
16	0.41	0	-	0.00	-	-	0.41	0	-
17	6.15	0	-	3.83	0	-	9.98	0	-
18	3.03	0	-	0.54	0	-	3.57	0	-
20	4.20	0	-	0.00	-	-	4.20	0	-
22	**3.67**	**28**	**7.63**	0.00	-	-	**3.67**	**28**	**7.63**
Total	73.13	92	1.26	35.10	26	0.74	108.23	118	1.09

Bold indicates peak WPUE.

resulted in 28 gray whale sightings, including one calf; grays were not previously seen there in September. Grays were also seen closer to shore in Peard Bay, southwest of Point Barrow, than in past years.

Distribution in October was similar to, although not comprehensive of, past years. Grays were seen nearshore between Icy Cape and Point Barrow, and were again seen close to shore in Peard Bay. Grays were not seen in offshore block 14 in October as they were in 1986 even though ice conditions were similar.

b. Relative Abundance and Density Estimates

Gray whale relative abundance was highest in block 22 (WPUE = 7.63), which is the survey block that incorporates the Point Hope area (table 12). Relative abundance in block 13 (WPUE = 2.13) and block 14 (WPUE = 0.94) were over 3 to 8 times lower than that for block 22. Unlike past years, grays were seen in only these three blocks (13, 14, and 22) in September, and only in block 13 in October.

Estimates of gray whale density in September were 0.30 whales/100 km^2 in block 13, 0.06 whales/100 km^2 in block 14, and 1.56 whales/100 km^2 in block 22. Density estimates for the first half of September were over twice those calculated for the second half of the month (e.g., block 13: 0.43 vs. 0.18 whales/100 km^2; block 14: 0.09 vs. 0 whales/100 km^2; block 22: 3.55 vs. 0.17 whales/100 km^2). In October, only one gray whale was seen on transect in block 13, resulting in an estimate of 0.03 whales/100 km^2.

Although grays were seen in block 14 in 1987 as in 1986, both abundance and density estimates indicate that fewer whales used this area in 1987, and that whales left this area earlier in 1987 than in 1986. Grays seen in block 14 in both years were commonly seen with mud plumes indicating that the whales were feeding. There is a slight bathymetric rise located near the area where whales were seen in block 14 (Stringer and Groves, 1987) and walrus "feeding traces" have been reported for this area (Phillips, 1987). It appears that this area may be of variable importance as a gray whale feeding area as well.

c. **Habitat Relationships and Behavior**

Gray whales were seen approximately 0.5 to 120 km from shore in water 9- to 64-m deep ($\bar{x}$ = 26.7 m, s.d. = 12.05, n = 53). Most grays (92%, n = 109) were in ice-free or light-ice ($\leq$10%) cover. Unlike 1986, gray whales were sometimes seen feeding in moderate and relatively heavy-ice cover. Three whales were seen feeding on 10 September in 30 to 40 percent grease ice (appendix A: flight 9), 2 grays were feeding on 12 September in 55 to 60 percent ice (appendix A: flight 10), and 4 whales were seen with mud plumes on 19 September in 90 percent grease ice in block 14 (appendix A: flight 13).

As in past years, grays were usually seen feeding (86%, n = 102; table 13). Feeding was inferred anytime a whale was seen with a mud plume. Mud plumes are billows of sediment brought to the surface by whales feeding on infaunal prey. Plumes are excellent sighting cues and may bias data toward "feeding" whales. Conversely, whales feeding on epibenthic prey may not create large mud plumes and therefore some feeding whales may go undetected. In 1987, mud plumes were often present when no whales were seen at the surface. The distribution of these plume-only sightings was similar to that for gray whales, with the exception of the Pt. Hope area (figure 15) where plumes were not seen. Subjectively, it seemed that the plumes associated with whales near Pt. Hope were not as large nor as distinct as plumes seen near grays feeding in waters farther north. Instead, grays feeding near Pt. Hope were associated with less-compact trails of sediment. 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). The different types and amount of sediment brought to the surface by feeding whales is likely related to the type of prey communities that they are feeding on. For example, grays feeding on dense assemblages of

Table 13. Semimonthly summary of gray whale behavior, 1987.

	1-15 Sep No.(%)	16-30 Sep No.(%)	1-15 Oct No.(%)	16-31 Oct No.(%)	Total No.(%)
MIGRATORY					
Swim	4(3)	3(3)	5(4)	1(1)	13(11)
Dive	3(3)	0	0	0	3(3)
SOCIAL					
Feed	62(53)	20(17)	14(12)	6(5)	102(86)
TOTAL	69	23	19	7	118

burrowing ampeliscid amphipods may produce large sediment plumes, while whales feeding on epifaunal swarms of mycids may create only light sediment trails or even no sediment indicator at all.

Whales that were not feeding were either swimming (11%, n = 13) or diving (3%, n = 3; table 14). Gray whale swimming direction was not significantly clustered around any heading. Swimming direction was not recorded for whales that were feeding because these whales often exhibited several headings within one surfacing period.

Most gray whales seen were adult (75%, n = 89) or immature (24%, n = 28). Interestingly, the majority of immatures seen were in block 22, south of Point Hope (75%, n = 21), indicating that the area may be relatively important as a nursery or weaning area similar to those seen along the Soviet coast (Krupnik et al., 1983).

d. Calf Sightings

One gray whale calf was seen on 1 September very near shore just southeast of Point Hope (appendix A: flight 1). The calf was nearly underneath a large whale believed to be the cow. Both whales were near a group of 15 immature whales that appeared to be feeding in the area.

Other Marine Mammals

a. Belukha or White Whale (Delphinapterus leucas)

Thirty-three sightings of 140 belukhas were made in the western Beaufort and northeastern Chukchi Sea (figure 16). Most (59%, n = 83) were seen in September, with the remaining 57 whales seen in October. Areas of greatest belukha relative

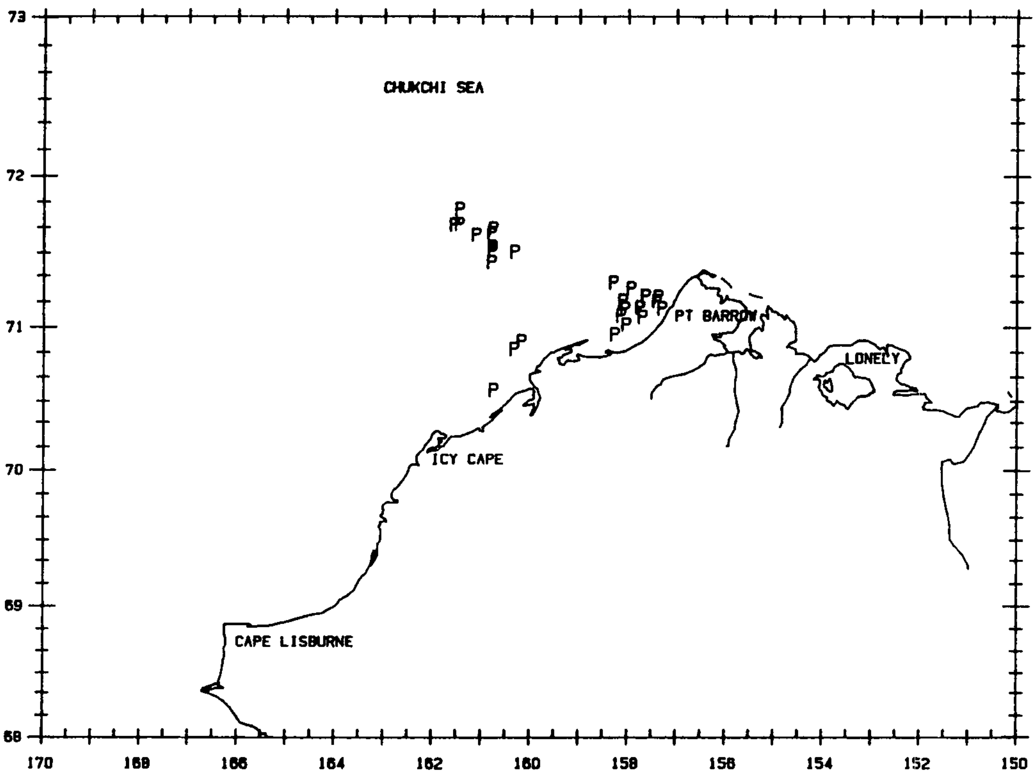


Figure 15. Distribution of plume-only sightings associated with gray whale feeding areas.

abundance were block 12-N (WPUE = 7.28) and block 13-N (WPUE = 3.34; table 14). In September, relative abundance was highest in block 12-N, where WPUE was 15.81. In October, relative abundance in block 13-N (WPUE = 4.61) and block 12-N (WPUE = 3.98) were highest.

Belukhas were seen approximately 30 to 180 km from shore in water 20- to 2195-m deep ($\bar{x}$ = 336.5, s.d. = 482). The observed distribution was farther from shore and in deeper water than in past years, due in part to surveys conducted north of 72°N in blocks 12-N and 13-N, as this was the first year that transect surveys were flown in these areas. Belukhas were seen in ice cover ranging from 0 to 95 percent (table 15), with the majority (76%, n = 106) in $\leq$20 percent cover. The lack of ice in the study area may have contributed to the relatively low abundance of belukhas, as they are generally associated with ice and may have been in ice north of the study area.

Table 14. Monthly and seasonal relative abundance of belukhas (WPUE = no. whales/hours of survey effort) by survey block, 1987.

Block	September		October		TOTAL	
	No. BE	WPUE	No. BE	WPUE	No. BE	WPUE
12	14	0.86	11	0.72	25	0.79
12-N	**46**	**15.81**	30	3.98	76	7.28
13	2	0.09	0	-	2	0.06
13-N	2	1.04	**16**	**4.61**	18	3.34
14	17	1.39	0	-	17	1.14
15	2	0.46	0	-	2	0.46
Total	83	1.37	57	1.37	140	1.37

Bold indicates peak WPUE.

Belukhas were not clustered around any particular heading in September nor October in either the western Beaufort nor northeastern Chukchi Sea.

b. Unidentified Cetacean

There were six sightings of seven unidentified cetaceans made during late September and early October (figure 17). All animals were seen only briefly and were too distant from the aircraft for positive identification. One whale was seen on 27 September (appendix A: flight 18) and two unidentified whales were seen each day on 15 October (appendix A: flight 31), 17 October (appendix A: flight 32) and 20 October (appendix A: flight 34). In each case, repeated efforts to re-sight the whales were unsuccessful. Because both bowhead and gray whales had been seen in the areas where the unidentified cetaceans were sighted, species identification would be no better than a guess for these whales.

c. Walrus (*Odobenus rosmarus*)

Eighty sightings of 2225 walrus were made over the course of the season (figure 18), with the majority (98%, n = 2185) seen in September. Walrus were most often seen swimming in open water and resting in light ice (0-30%; 40%, n = 883) or hauled out in heavy ice (36%, n = 790). The distribution was similar to past years, with the exception that walrus were seen farther to the west (in block 15) in late September when ice was present there.

d. Bearded seal (*Erignathus barbatus*)

Sixteen sightings of 16 bearded seals were made in September and early October, mostly in the northern portions of blocks 12-14 (figure 18). Bearded seals

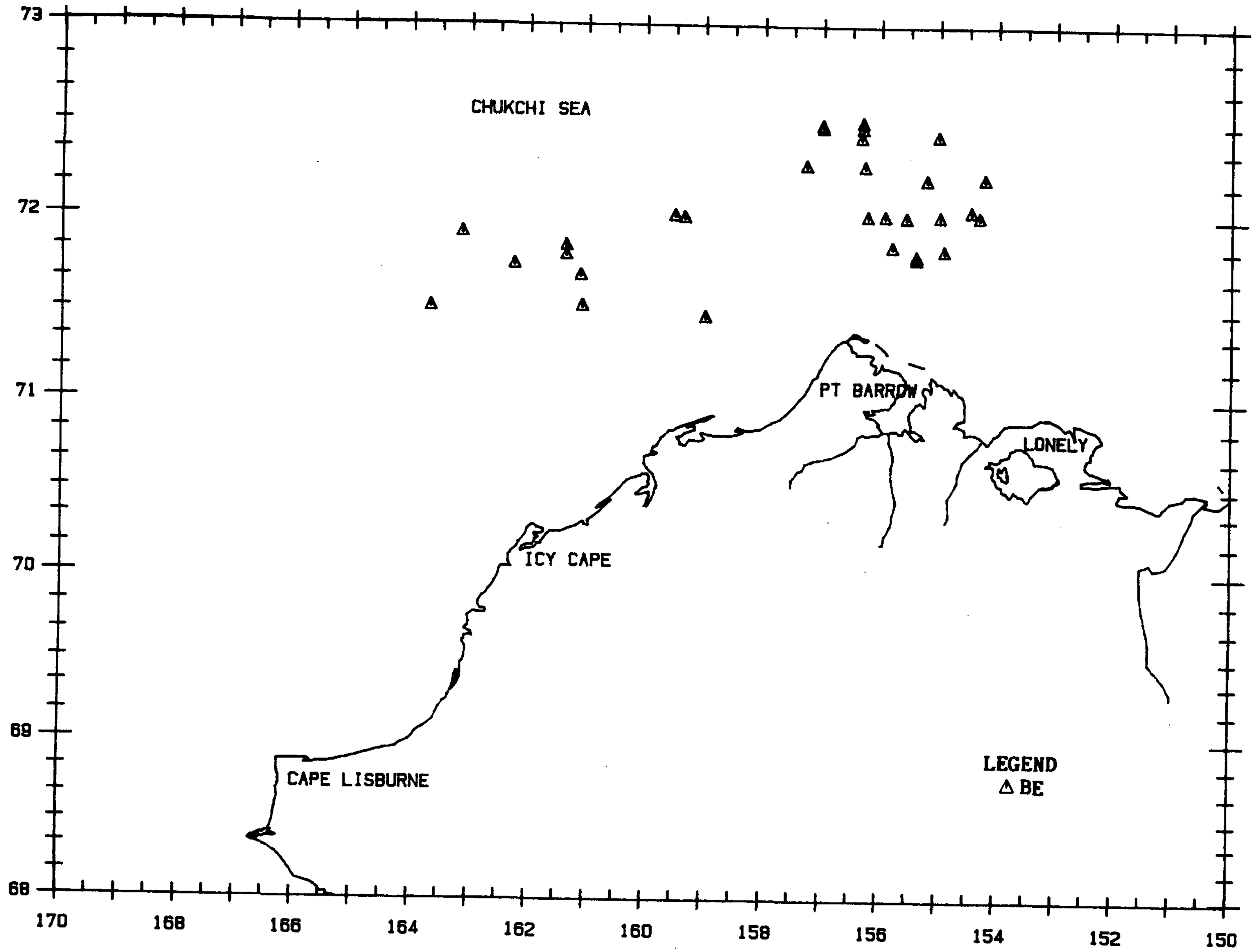


Figure 16. Distribution of 33 sightings of 140 belukhas.

Table 15. Number (No.) and percent (%) of belukhas found in each ice cover class, 1987.

Ice Cover (%)	September No.	September (%)	October No.	October (%)	Total No.	Total (%)
0-10	30	(36)	30	(53)	60	(43)
11-20	30	(36)	16	(28)	46	(33)
21-30	0		0		0	
31-40	0		0		0	
41-50	1	(1)	0		1	(1)
51-60	6	(7)	0		6	(4)
61-70	1	(1)	0		1	(1)
71-80	10	(12)	0		10	(7)
81-90	2	(2)	0		2	(1)
91-99	3	(4)	11	(19)	14	(10)
Total	83		57		140	

were seen both swimming in the water and hauled out near cracks on the ice. No bearded seals were seen after 8 October probably due to the lack of ice in the study area and the difficulty in positively identifying pinnipeds in the water from altitudes greater than about 91 m.

e. Ringed seal (Phoca hispida)

Only 6 sightings of 8 ringed seals were made this year (figure 18). As with the bearded seal, the lack of ice probably influenced this result as ringed seals are difficult to positively identify when they are in the water.

f. Unidentified pinniped

Seventy-nine sightings of 101 unidentified pinnipeds were made over the season (figure 18). Half of the seals (50%, n = 50) were seen swimming in open water. Only fifteen percent (n = 15) were seen in ice conditions $\geq$90 percent.

g. Polar bear (Ursus maritimus)

Three sightings of five polar bears were made in October (table 16). Three bears, a sow and 2 cubs, were seen on 3 October (appendix A: flight 23) at 72°04.8'N, 155°08.5'W running across the ice. Two bears were seen in the northeastern Chukchi Sea: one on 8 October (appendix A: flight 26) at 72°14.3'N, 158°10.4'W and one on 11 October (appendix A: flight 28) at 71°48.8'N, 161°51.5'W.

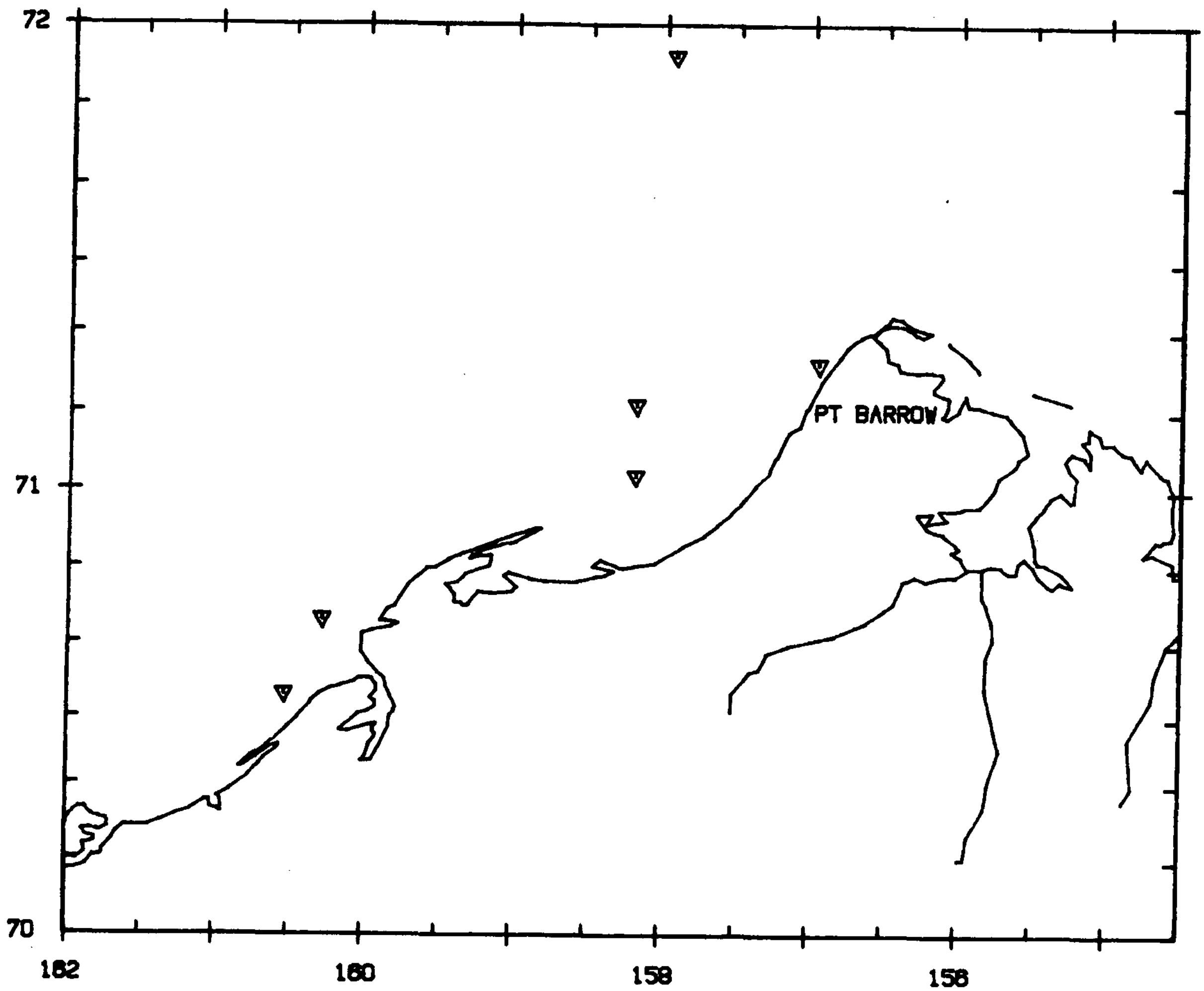
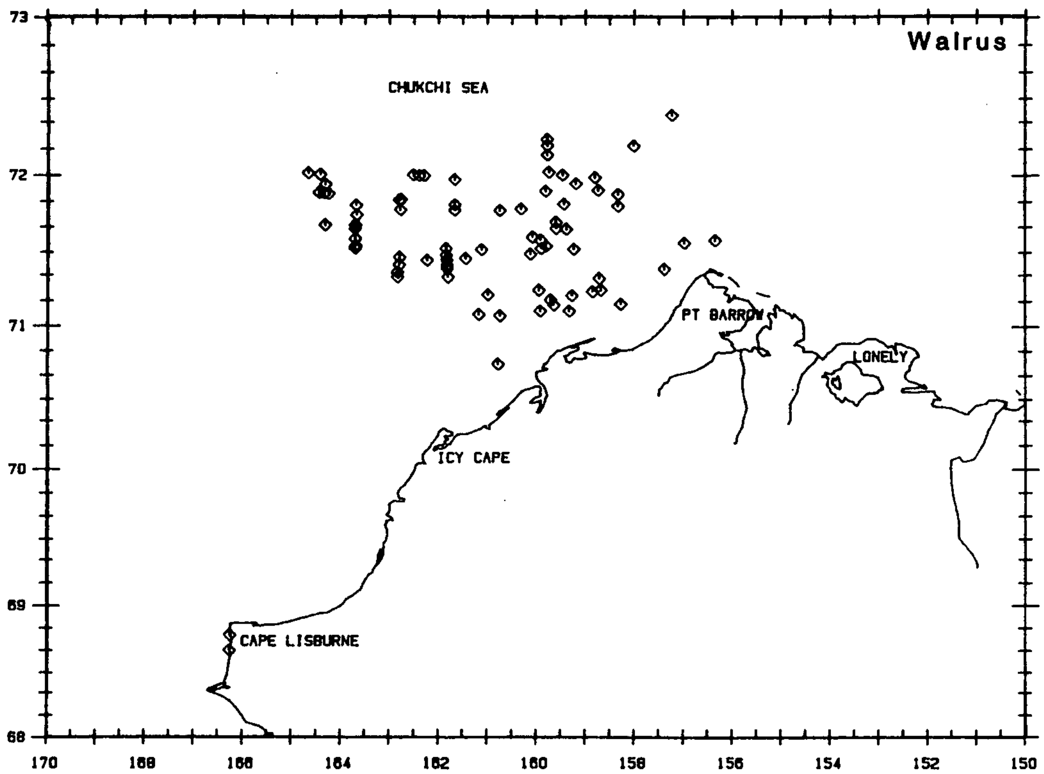


Figure 17. Distribution of 6 sightings of 7 unidentified cetaceans.



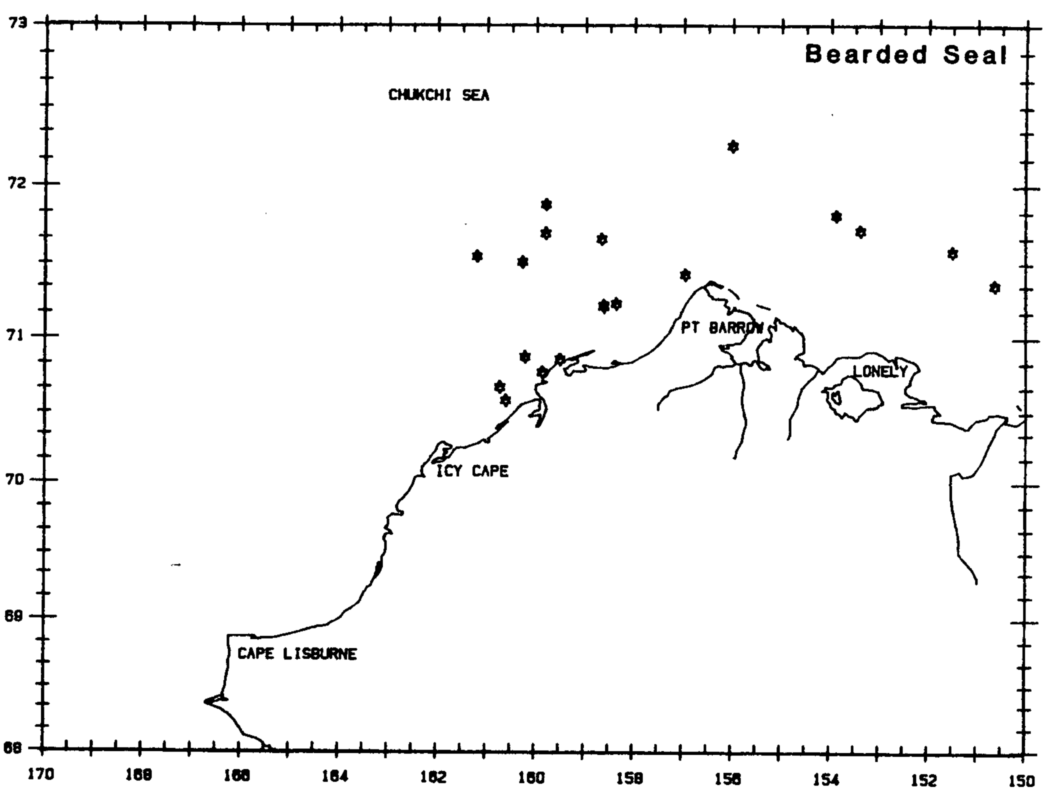
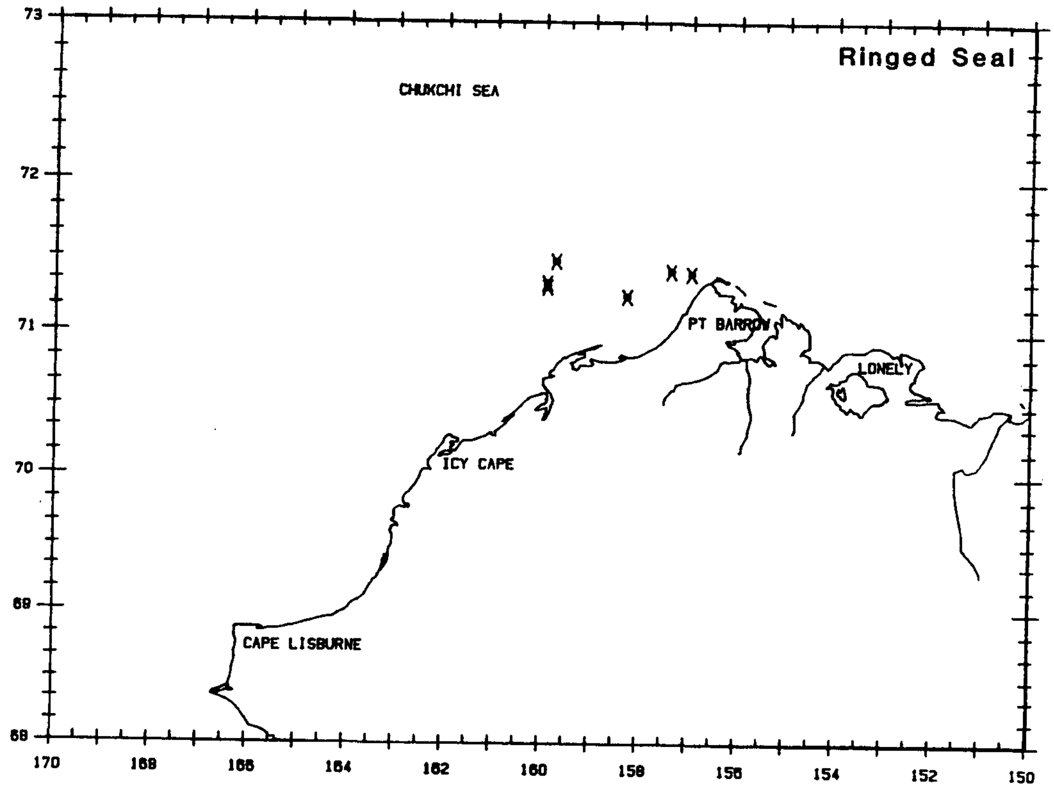


Figure 18. Distribution of walruses, bearded seals,



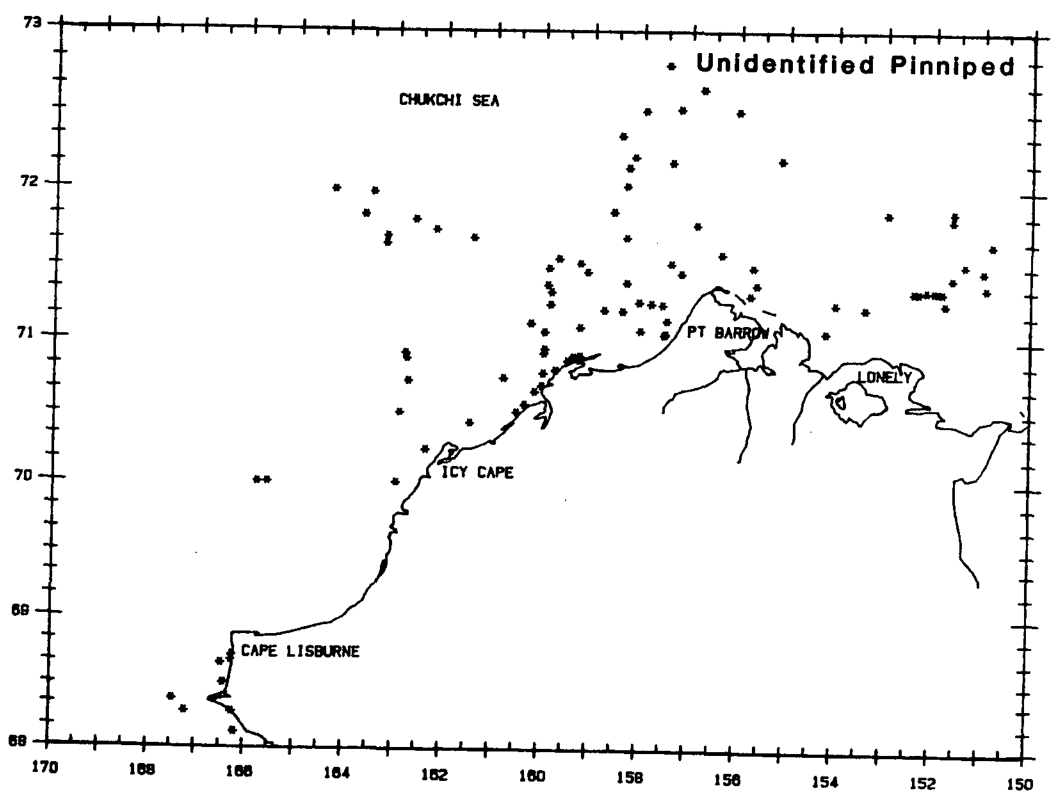


Figure 18 (contd). ringed seals and unidentified pinnipeds.

DISCUSSION AND 1979-87 REVIEW

This section represents a review and synthesis of data gathered on aerial surveys of endangered whales conducted from 1979 to 1987. Results of these surveys have appeared in annual reports for the Minerals Management Service finalized as NOSC technical documents or technical reports (e.g., Ljungblad et al., 1987) as well as in summary manuscripts presented in other articles/forums (e.g., Clarke et al., 1987; Ljungblad et al., 1986a, 1986c; Moore et al., 1986a, 1986b).

The objectives and methods of data collection and analyses on the primary aircraft (N780) have remained similar throughout all years. In 1986, in addition to the primary survey aircraft, a second aircraft (302 EH) flew transect surveys, and an acoustic station was established at Barter Island, Alaska to monitor the nearshore bowhead migration. Data resulting from these efforts have been incorporated into the larger database. Bowhead and gray hales have been the principal species studied over the years, due to their endangered status, and are reviewed here. Additionally, multiyear reviews for belukhas and walrus are also included. Other species seen during fall aerial surveys were reviewed in Ljungblad et al. (1987).

This review follows a species format and covers September and October surveys only. Data are reviewed for the northeastern Chukchi Sea and the Alaskan Beaufort Sea west of 150°W longitude. Objectives of the surveys and a brief overview of survey effort and conditions are presented prior to presentation of species accounts. Eight years of August-October surveys were reviewed in Ljungblad et al. (1987). A review of 6 years of summer (June, July) survey efforts was presented in Ljungblad et al. (1986b) and a review of spring (April, May) survey results was presented in Ljungblad et al. (1985a).

Aerial Survey Objectives, Effort, and Conditions Summary

The primary objectives of the fall aerial surveys have been to determine the distribution and timing of the bowhead migration, to derive relative and absolute abundance estimates in or near proposed or existing federal lease areas, and to describe bowhead whale general behavior and record underwater sound production. In 1986 and 1987, the primary objectives also included documenting the distribution, relative and absolute abundance estimates, and general behavior of gray whales in the northeastern Chukchi Sea. Secondary objectives were to document distribution of other marine mammal species encountered during surveys.

Table 16. Summary of flight effort (h) in the western Beaufort and northeastern Chukchi Seas, 1979-87.

	1979	1980	1981	1982	1983	1984	1985	1986	1987	Total
W. Beaufort	18.1	36.7	19.4	42.8	61.7	60.2	37.6	30.1	53.9	360.5
N.E. Chukchi	0.8	13.7	0.0	19.0	42.7	16.4	15.1	83.5	83.5	274.7
Total	18.9	50.4	19.4	61.8	104.4	76.6	52.7	113.6	137.4	635.2

A total of 635.2 surveys hours have been flown west of 150°W longitude since 1979, with 57 percent (360.5 h) in the western Beaufort Sea and 43 percent (274.7 h) in the Chukchi Sea (table 16). There was little survey effort conducted in the study area from 1979-81 (14%, n = 88.7 h), with increased survey effort dedicated to the area from 1982-87. More transects have been flown in the study area during the latter half of September and the first half of October than during either the first half of September or the last half of October (figure 19). The timing of surveys west of 150°W depended on the progress of the bowhead migration from 1979-85, with surveys conducted independent of the observed progress of the migration only in 1986-87. The termination of surveys in this area has occurred between 15 and 25 October.

Ice conditions have varied annually, but can be generally categorized as heavy (1980, 1983), light (1979, 1981, 1982, 1984), intermediate (1985), or predominantly ice-free (1986-87). In heavy-ice years, ice cover remained heavy (≥70%) throughout the fall season. In light-ice years, ice cover in the study area was ≤30% from early September through early October, while in the intermediate year storms blew relatively heavy ice (≥60%) into the area during the last two weeks of September. During ice-free years, ice cover was <10% during September and through at least mid-October.

Sea states encountered on fall surveys ranged from Beaufort 00 to 06, with Beaufort 01 to 03 conditions the most common. Sea states during heavy-ice years were usually lower (Beaufort 00-02) than during years of light or no ice (Beaufort 01-04) due to the dampening influence of the ice cover. Fog and/or high sea states often caused surveys to be truncated or aborted in the Chukchi Sea, where open water conditions generally extended into the latter part of the survey season.

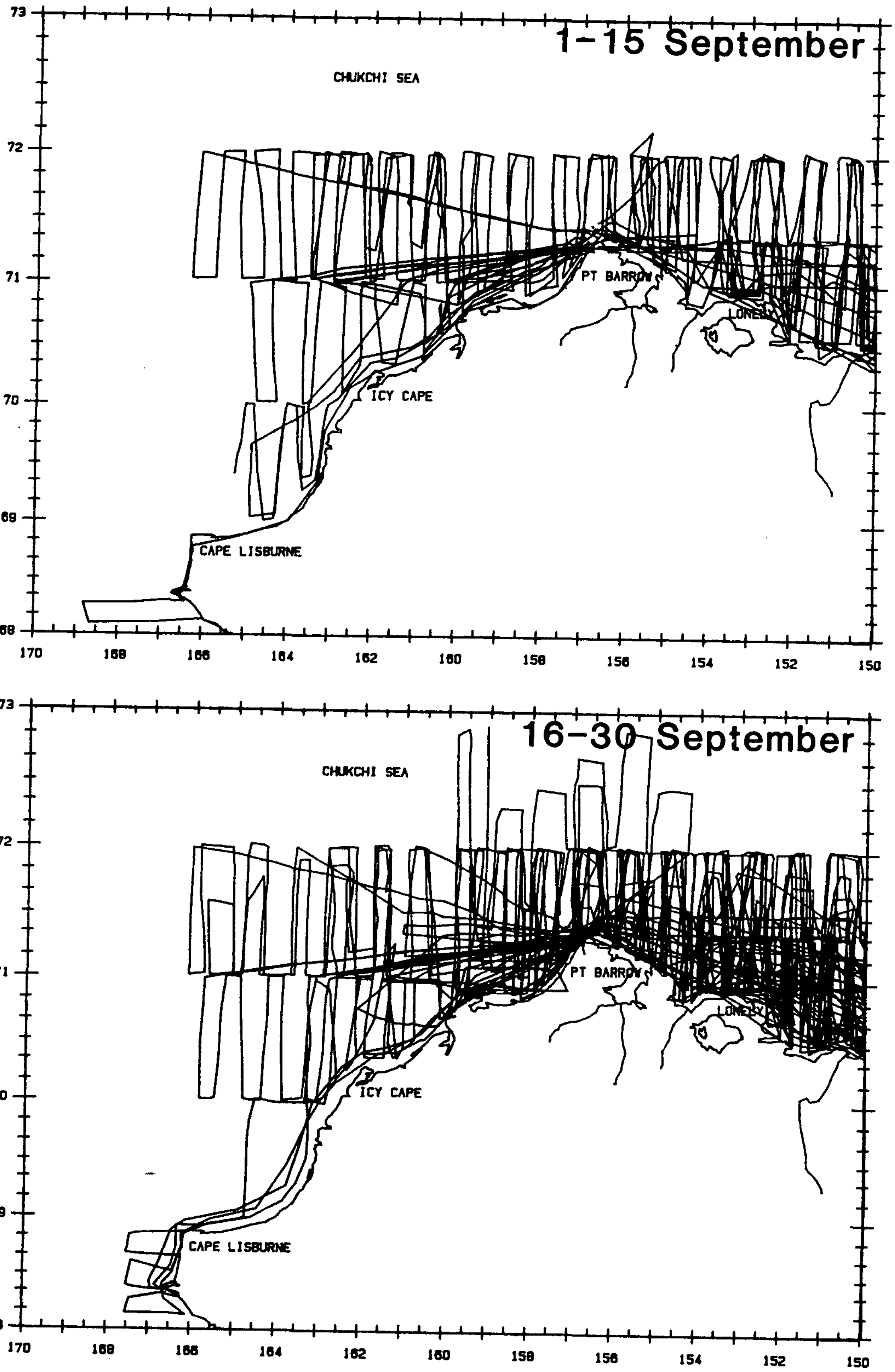
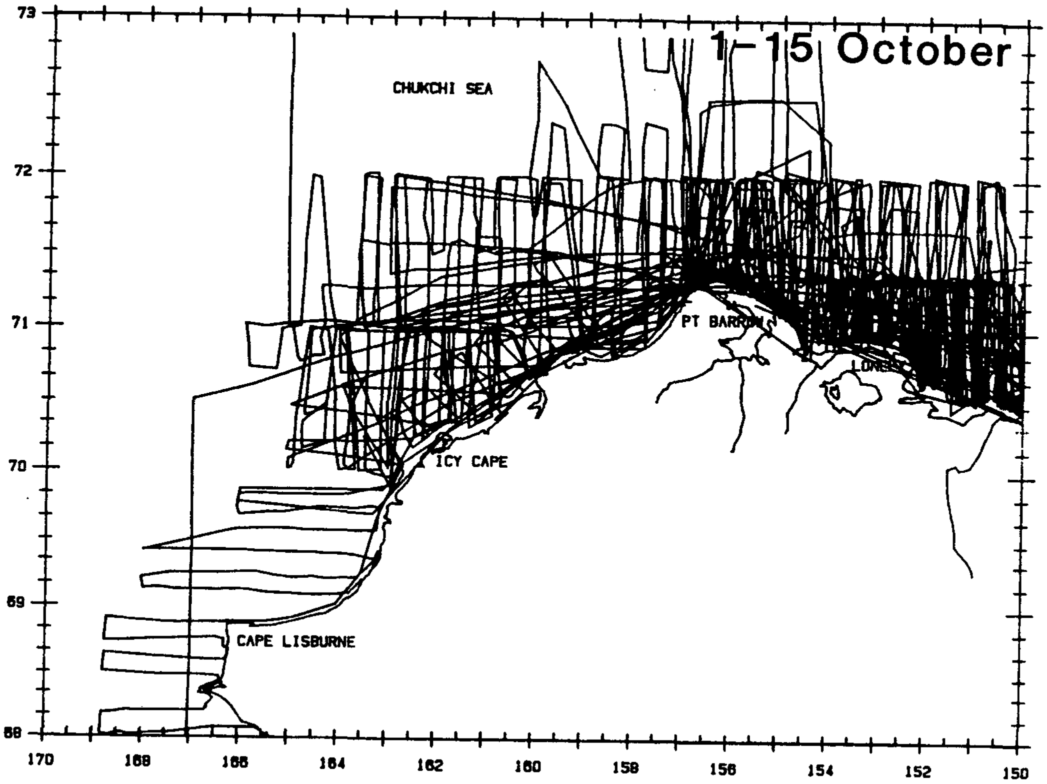


Figure 19. Composite flight tracks depicting semimonthly flight effort, 1979-87: 1-15 September; 16-30 September;



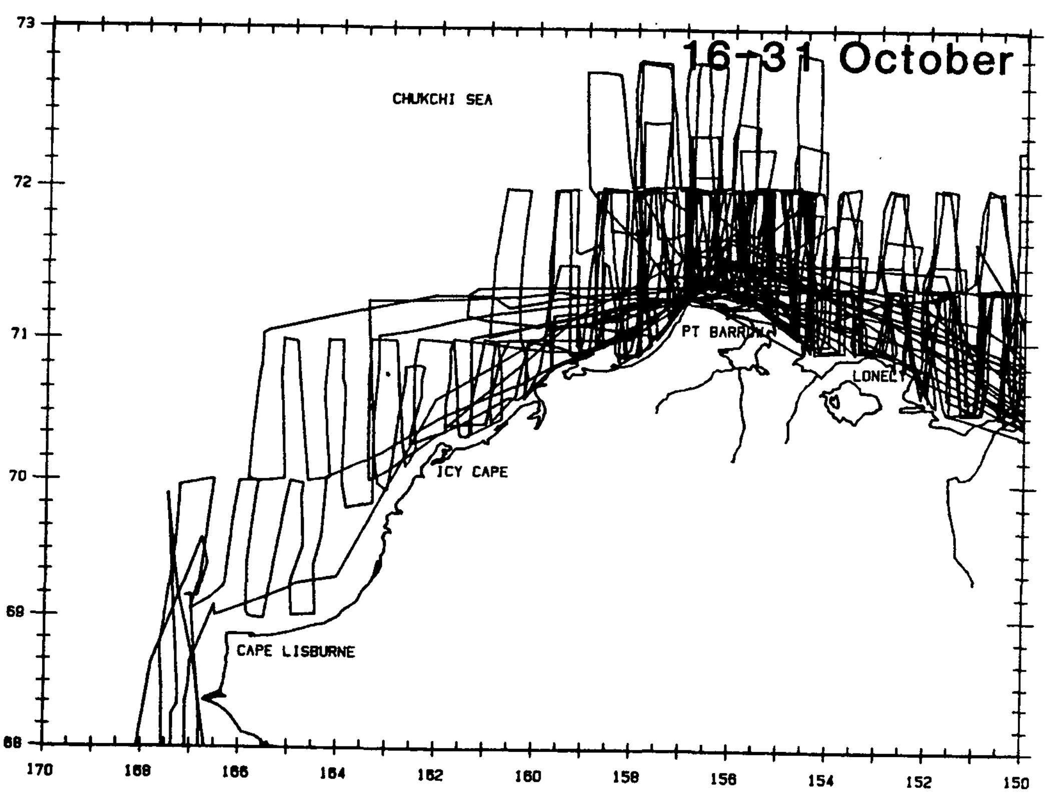


Figure 19 (contd). 1-15 October; 16-31 October.

Table 17. Semimonthly sighting summary (no. sightings/no. whales) of bowheads seen west of 150°W in the Beaufort and northeastern Chukchi Seas, 1979-87.

	September		October		
	1-15	16-30	1-15	16-30	Total
1979	0	0	1/15	15/27	16/32
1980	0	0	5/7	0	5/7
1981	0	0	6/7	0	6/7
1982	0	14/15	23/37	1/1	38/53
1983	2/4	27/35	13/18	7/11	49/68
1984	0	21/152	40/61	11/20	72/233
1985	0	0	21/41	1/1	22/42
1986	0	2/2	12/16	1/2	15/20
1987	0	4/4	17/27	7/7	28/38
Total	2/4	68/208	138/219	43/69	251/500

Bowhead Whale

a. Patterns of Distribution, Relative Abundance, and Density

There were 251 sightings of 500 bowheads made west of 150°W during September and October since 1979 (table 17; figure 20). The distribution of whales in 1987 was similar to, but not comprehensive of, that of past years. Only four bowheads have been seen west of 150°W during the first half of September (figure 20). Notably, these whales were seen in 1983, a year of heavy-ice cover, when the bowhead migration peaked somewhat earlier in September than in light-ice years (Ljungblad et al., 1987). Two hundred eight bowheads have been seen during the latter half of September (figure 20), with most of these whales (73%, n = 152) seen in 1984 when aggregations of feeding whales were seen near Barrow. Two hundred nineteen bowheads have been seen in the first half of October and 69 whales were seen during the latter half of October. As in late September, most bowheads in October were seen relatively near shore (1-50 km) between Lonely and Barrow in the western Beaufort Sea, and dispersed from 2 to 80 km from shore between Barrow and Icy Cape in the eastern Chukchi Sea (figure 20).

Relative abundance was highest in block 12 overall (WPUE = 2.16; table 18). Surveys were not routinely conducted in blocks 11-18 until 1982, and most

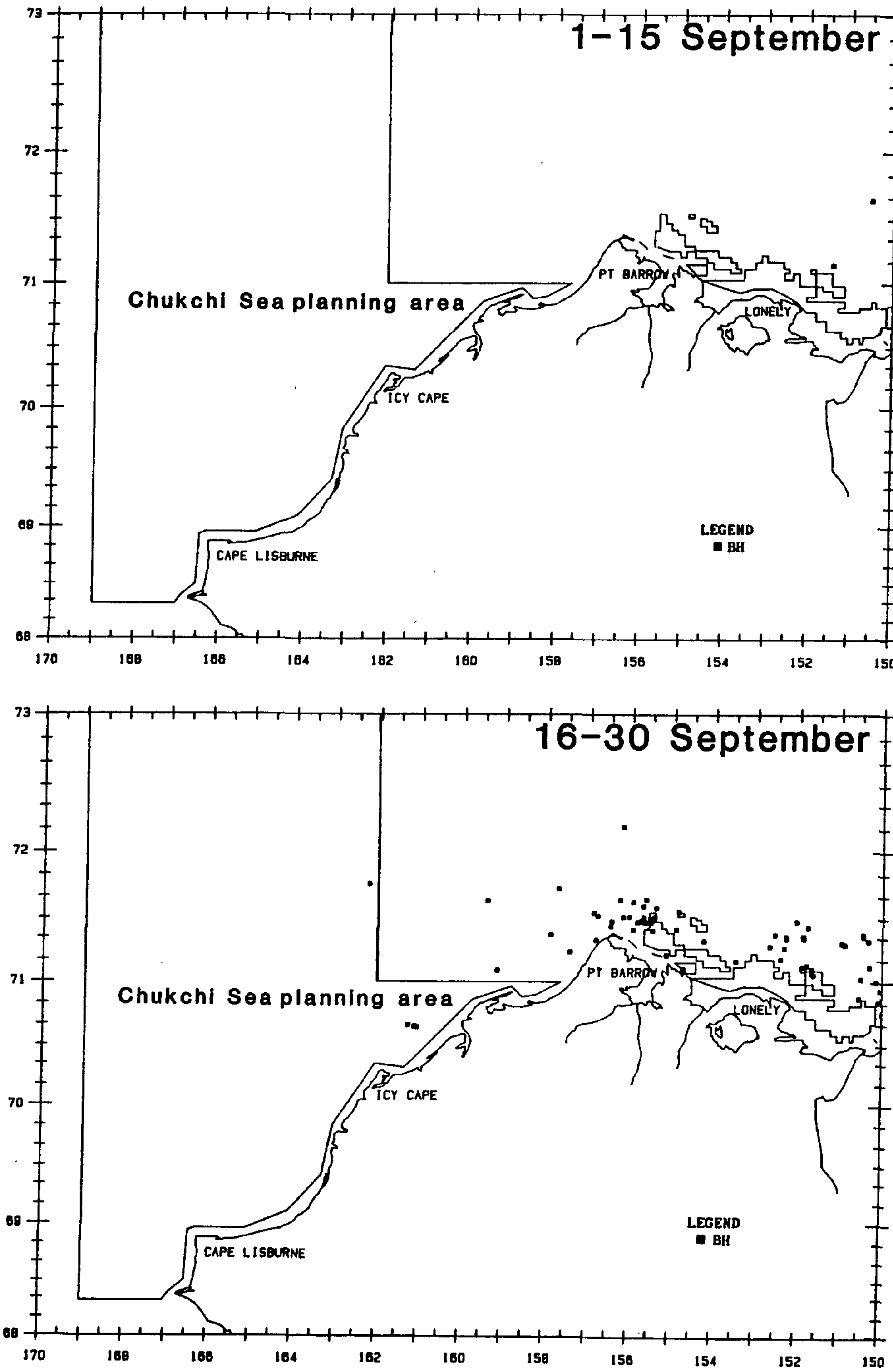


Figure 20. Semimonthly distribution of 251 sightings of 500 bowheads, 1979-87: 2 sightings of 4 bowheads, 1-15 September; 68 sightings of 208 bowheads, 16-30 September;

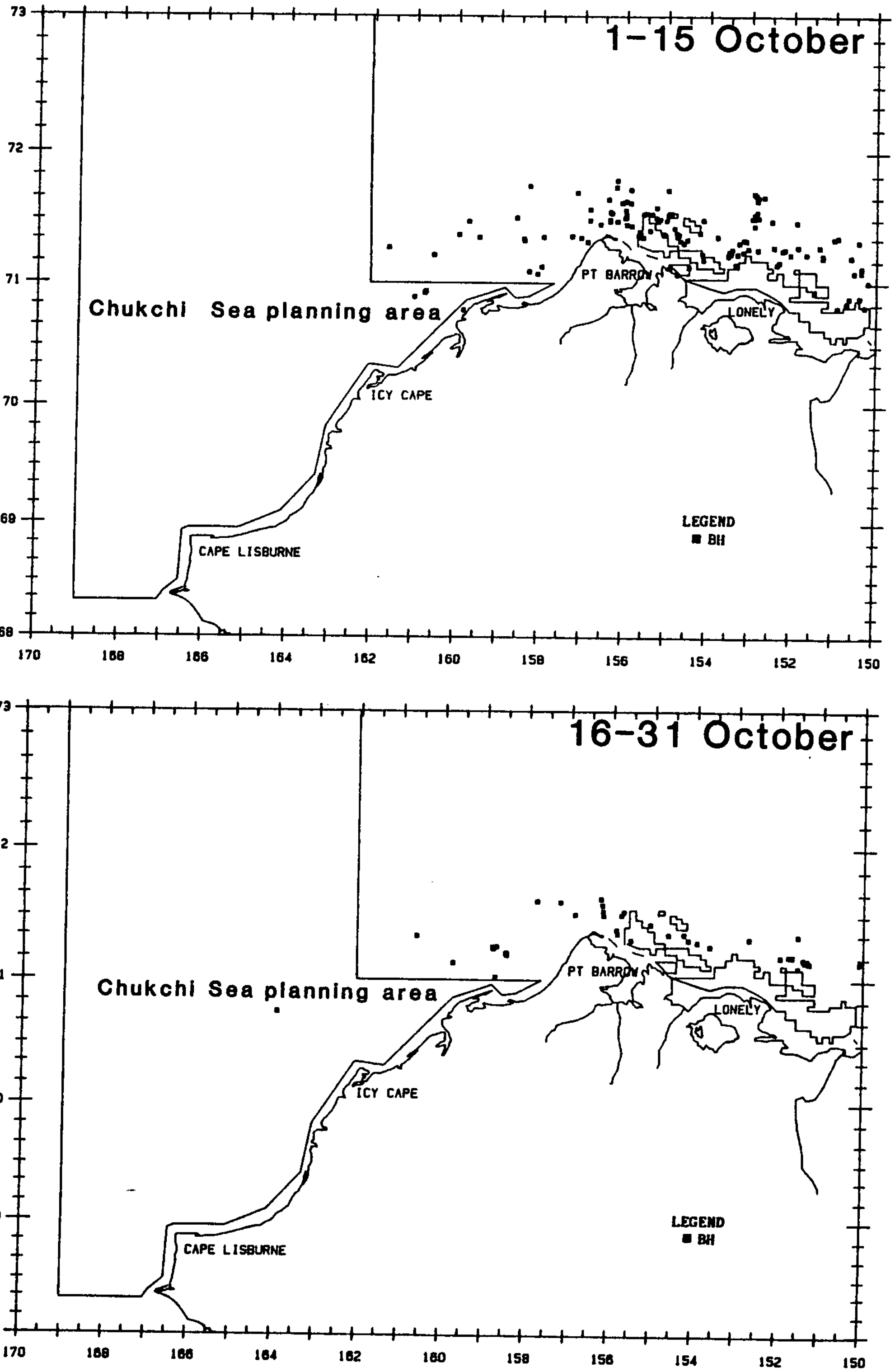


Figure 20 (contd). 138 sightings of 219 bowheads, 1-15 October; 43 sightings of 69 bowheads, 16-31 October. Polygons in the Beaufort Sea represent OCS leasing areas.

Table 18. Bowhead relative abundance (WPUE = no. whales/hours of survey effort) for survey blocks west of 150°W, 1979-87.

1979

	September			October			Total		
Block	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE
3	0.65	0	-	7.36	27	3.67	8.01	27	3.37
11	0.00	0	-	1.29	0	-	1.29	0	-
12	0.42	0	-	7.14	5	0.70	7.56	5	0.66
13	0.00	0	-	0.19	0	-	0.19	0	-
14	0.00	0	-	0.00	0	-	0.00	0	-
15	0.00	0	-	0.00	0	-	0.00	0	-
16	0.00	0	-	0.00	0	-	0.00	0	-
17	0.00	0	-	0.00	0	-	0.00	0	-
18	0.00	0	-	0.00	0	-	0.00	0	-
Block Total	1.07	0	-	15.98	32	2.00	17.05	32	1.88

1980

	September			October			Total		
Block	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE
3	12.41	0	-	20.12	7	0.35	32.53	7	0.22
11	0.12	0	-	1.67	0	-	1.79	0	-
12	0.00	0	-	1.94	0	-	1.94	0	-
13	0.00	0	-	0.50	0	-	0.50	0	-
14	0.00	0	-	0.00	0	-	0.00	0	-
15	0.00	0	-	0.00	0	-	0.00	0	-
16	0.00	0	-	0.00	0	-	0.00	0	-
17	0.00	0	-	0.58	0	-	0.58	0	-
18	0.00	0	-	0.00	0	-	0.00	0	-
Block Total	12.53	0	-	24.81	7	0.28	37.34	7	0.19

1981

	September			October			Total		
Block	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE
3	5.34	0	-	13.34	7	0.52	18.68	7	0.37
11	0.03	0	-	0.28	0	-	0.31	0	-
12	0.00	0	-	0.37	0	-	0.37	0	-
13	0.00	0	-	0.00	0	-	0.00	0	-
14	0.00	0	-	0.00	0	-	0.00	0	-
15	0.00	0	-	0.00	0	-	0.00	0	-
16	0.00	0	-	0.00	0	-	0.00	0	-
17	0.00	0	-	0.00	0	-	0.00	0	-
18	0.00	0	-	0.00	0	-	0.00	0	-
Block Total	5.37	0	-	13.99	7	0.50	19.36	7	0.36

Underline indicates peak WPUE.

Table 18 (contd).

1982

	September			October			Total		
Block	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE
3	16.22	13	0.80	3.63	9	2.48	19.85	22	1.11
11	4.56	0	-	5.35	1	0.19	9.91	1	0.10
12	4.58	2	0.44	8.01	15	1.87	12.59	17	1.35
13	1.48	0	-	4.34	12	2.76	5.82	12	2.06
14	0.00	0	-	2.46	1	0.41	2.46	1	0.41
15	0.00	0	-	0.12	0	-	0.12	0	-
16	0.00	0	-	0.00	0	-	0.00	0	-
17	0.00	0	-	3.81	0	-	3.81	0	-
18	0.00	0	-	2.00	0	-	2.00	0	-
Block Total	26.84	15	0.56	29.72	38	1.28	56.56	53	0.94

1983

	September			October			Total		
Block	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE
3	13.22	8	0.61	6.13	3	0.49	19.35	11	0.57
11	13.10	7	0.53	5.81	0	-	18.91	7	0.37
12	10.69	18	1.68	10.74	8	0.74	21.43	26	1.21
13	3.28	3	0.91	8.88	13	1.46	12.16	16	1.32
14	0.87	0	-	3.95	0	-	4.82	0	-
15	0.00	0	-	3.73	0	-	3.73	0	-
16	0.00	0	-	0.00	0	-	0.00	0	-
17	0.96	3	3.12	4.29	3	0.70	5.25	6	1.14
18	0.00	0	-	4.61	2	0.43	4.61	2	0.43
Block Total	42.12	39	0.93	48.14	29	0.60	90.26	68	0.75

1984

	September			October			Total		
Block	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE
3	10.94	2	0.18	17.68	22	1.24	28.62	24	0.84
11	4.17	0	-	5.57	17	3.05	9.74	17	1.75
12	5.63	148	26.29	15.58	37	2.37	21.21	185	8.72
13	4.76	2	0.42	5.77	5	0.87	10.53	7	0.66
14	2.79	0	-	0.11	0	-	2.90	0	-
15	0.00	0	-	0.00	0	-	0.00	0	-
16	0.00	0	-	0.00	0	-	0.00	0	-
17	0.75	0	-	1.90	0	-	2.65	0	-
18	0.00	0	-	0.00	0	-	0.00	0	-
Block Total	29.04	152	5.23	46.61	81	1.74	75.65	233	3.08

Table 18 (contd).

1985

Block	September Hrs	September BH	September WPUE	October Hrs	October BH	October WPUE	Total Hrs	Total BH	Total WPUE
3	4.90	0	-	12.38	5	0.40	17.28	5	0.29
11	0.19	0	-	**3.00**	**27**	**9.00**	**3.19**	**27**	**8.46**
12	3.08	0	-	13.25	7	0.53	16.33	7	0.43
13	0.00	0	-	6.40	2	0.31	6.40	2	0.31
14	0.00	0	-	2.09	1	0.48	2.09	1	0.48
15	0.00	0	-	1.00	0	-	1.00	0	-
16	0.00	0	-	0.00	0	-	0.00	0	-
17	0.00	0	-	2.69	0	-	2.69	0	-
18	0.00	0	-	2.90	0	-	2.90	0	-
Block Total	8.17	0	-	43.71	42	0.96	51.88	42	0.81

1986

Block	September Hrs	September BH	September WPUE	October Hrs	October BH	October WPUE	Total Hrs	Total BH	Total WPUE
3	6.67	0	-	8.59	4	0.47	15.26	4	0.26
11	**2.20**	**1**	**0.45**	3.80	0	-	6.00	1	0.17
12	4.40	0	-	**12.09**	**11**	**0.91**	**16.49**	**11**	**0.67**
13	15.57	0	-	15.71	2	0.13	31.28	2	0.06
14	9.30	1	0.11	7.80	1	0.13	17.10	2	0.12
15	6.45	0	-	0.39	0	-	6.84	0	-
16	0.44	0	-	0.00	0	-	0.44	0	-
17	6.68	0	-	7.35	0	-	14.03	0	-
18	3.08	0	-	2.70	0	-	5.78	0	-
Block Total	54.79	2	0.04	58.43	18	0.31	113.22	20	0.18

1987

Block	September Hrs	September BH	September WPUE	October Hrs	October BH	October WPUE	Total Hrs	Total BH	Total WPUE
3	0.98	0	-	**2.02**	**6**	**2.97**	**3.00**	**6**	**2.00**
11	5.50	0	-	2.99	0	-	8.49	0	-
12	16.27	2	0.12	15.19	26	1.72	31.46	28	0.89
12N	**2.91**	**1**	**0.34**	7.53	0	-	10.44	1	0.10
13	22.84	1	0.04	12.89	2	0.16	35.73	3	0.08
13N	1.92	0	-	3.47	0	-	5.39	0	-
14	12.20	0	-	2.65	0	-	14.84	0	-
15	4.35	0	-	0.00	0	-	4.35	0	-
16	0.41	0	-	0.00	0	-	0.41	0	-
17	6.15	0	-	3.83	0	-	9.98	0	-
18	3.03	0	-	0.54	0	-	3.57	0	-
Block Total	76.56	4	0.05	51.11	34	0.67	127.66	38	0.30

TOTAL

Block	September Hrs	September BH	September WPUE	October Hrs	October BH	October WPUE	Total Hrs	Total BH	Total WPUE
3	71.33	23	0.32	91.25	89	0.99	162.58	113	0.70
11	29.87	8	0.27	**29.76**	**45**	**1.51**	59.63	53	0.89
12	**45.07**	**170**	**3.77**	84.31	109	1.29	**129.38**	**279**	**2.16**
12N	2.91	1	0.34	7.53	0	-	10.44	1	0.10
13	47.93	6	0.13	54.68	37	0.68	102.61	43	0.42
13N	1.92	0	-	3.47	0	-	5.39	0	-
14	25.16	1	0.04	19.06	3	0.16	44.22	4	0.09
15	10.80	0	-	5.24	0	-	16.04	0	-
16	0.85	0	-	0.00	0	-	0.85	0	-
17	14.54	3	0.21	24.45	3	0.12	38.99	6	0.15
18	6.11	0	-	12.75	2	0.16	18.86	2	0.11
Block Total	256.49	212	0.83	332.50	288	0.87	588.99	500	0.85

bowheads seen from 1979-81 were in block 3 (89%, n = 41). Consequently, highest annual WPUE prior to 1982 was also in block 3 (table 18). Between 1982-87, annual relative abundance has been highest most frequently in blocks 12 (1984 and 1986) and 13 (1982 and 1983); WPUE was highest in block 11 in 1985 and block 3 in 1987.

Annual relative abundance for the study area (i.e., all blocks) ranged from 3.08 in 1984, when large groups of feeding bowheads were seen, to 0.18 in 1986 (table 18). Annual relative abundance for any survey block, or any year, will vary with (a) the timing of survey sampling relative to the migration and (b) bowhead feeding opportunities, because feeding whales are found in larger groups than whales that are not feeding (Ljungblad et al., 1986a). Further variation in the visibility of single and/or groups of bowheads may significantly influence annual abundance indices. Visibility bias in aerial surveys can lead to significant underestimation of population abundance (Samuel et al., 1987; Pollock and Kendall, 1987). 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 against absolute abundance estimates (i.e., density). A calibration of bowhead abundance indices with annual density estimates (see appendix B) could be carried out, if spatial and temporal boundaries were defined. Such a calibration would increase the utility of the annual abundance indices presented in table 18.

b. Migration Route, Timing, and Habitat Relationships

The fall bowhead migration route passes near or through areas in the western Beaufort Sea that are designated for, or currently involved in, oil and gas exploration and development (see figure 20). In past years, the migratory route for bowheads in the Beaufort Sea has been described by analyzing the median depth at bowhead sightings made on random transects (Moore et al., 1987; Ljungblad et al., 1987). The Beaufort Sea has a sloping bathymetry, unlike the rather uniform shelf bathymetry of the Chukchi Sea, which facilitates the use of depth in defining a migratory route. A seaward displacement of the migratory route is represented by a shift to a deeper median depth via this analysis. Between 1979 and 1986, the depth-defined bowhead migration route across the Alaskan Beaufort Sea ranged from 20 to 38 m for all years except 1983 (Ljungblad et al., 1987). In 1983, the median depth at random bowhead sightings was 145 m. The offshore shift to deeper water in 1983 was most pronounced in regions of the Beaufort Sea east of

150°W (regions C and D: see appendix B, figure B-2). For regions west of 150°W, differences in depth-defined migratory route were not consistent and were related to variations in survey effort.

Seven random bowhead sightings were made within region A in 1987. The median depth at random bowhead sightings for region A in 1987 was 20 m, shallower than for any prior year except 1984; the sample size was too small to calculate the 99% confidence limit (table 19). The annual mean depths were tested using a single-factor ANOVA followed by the Tukey test to determine significant difference between years (as suggested by D. Chapman, personal communication[2]). No significant differences in depth were found between any 2 years in region A, although there was a trend ($p < 0.10$) for bowheads to be in shallower water in 1984 and 1986-87.

The occurrence of bowheads in shallow water in region A in 1984 could be attributable to the aggregations of whales seen feeding near Point Barrow that year (Ljungblad et al., 1986a). Similarly, Braham et al. (1984) report that most bowheads (172 of 234 sightings) seen west of 150°W between August and November 1975-78 were in water < 12m deep, and that feeding groups were seen just east of Point Barrow in 3 of the 4 years. In 1977, when feeding bowheads were not seen, bowheads ($n = 7$) were seen farther offshore in water >12m deep. the occurrence of bowheads in shallower water in region A in 1986-87 when few feeding whales were seen in less easily explained. Underwater noise from OCS oil and gas development activities has been suggested as a factor that may displace the bowhead migration offshore (Albert, in ESL, 1986), and several studies have shown that bowheads do apparently respond negatively to various industrial noise sources at ranges of ≤7.5 km (Ljungblad et al., 1984; Richardson et al., 1986; Miles et al., 1987). Concern that underwater noise displaces bowhead whales during the fall migration has been particularly acute in the vicinity of Point Barrow and Barter Island, where a subsistence hunt for bowheads is conducted each fall. Although an analysis of depth-related displacement (Zeh, in Houghton et al., 1984), it only approximates bowhead distribution relative to shore particularly near Point Barrow, because depth and distance from shore are not consistently associated in region A (Moore et al., 1987). A better indicator of annual shifts in bowhead distribution can be described by analyzing the distance of random bowhead sightings from shore (J. Zeh, personal communication[3]). Because, as just mentioned, interest in the potential offshore shift of bowheads near Barrow is most keenly held by native

Table 19. Median water depth, confidence interval (C.I.), mean, standard deviation (s.d.), and range at random bowhead sightings (SI) in the western Alaskan Beaufort Sea, region A (153°30'-157°W).

Region A
(153°30' - 157°W)

	(SI)	Median	C.I. (99%)	Mean	s.d.	Range
1982	(6)	139	*	124	75.8	13-210
1983	(9)	144	18-99	117	72.6	18-199
1984	(22)	20	16-86	48	51.5	13-221
1985	(4)	130	*	110	66.7	15-165
1986	(7)	24	*	44	61.5	13-183
1987	(7)	20	*	73	78.9	5-179
1982-87	(55)	37	20-123	75	69.0	5-221

All depths in meters
* = insufficient sample size

Alaskan Inupiat hunters, an analysis of distance of random bowhead sightings from shore was undertaken for the area in which bowheads are commonly hunted from Barrow in the fall, rather than for region A. Approximate hunting boundaries (figure 21) were determined from published records (Courtrage and Braund, Assoc., 1984; Durham, 1979). The shortest distance to shore for random bowhead sightings within the hunting area was measured using NOAA Navigational Chart No. 16004. To provide a general comparison between years 1982-86, measures of central tendency were tabulated. ANOVA and paired Tukey tests were run to test for significant differences in bowhead distribution within the hunting area for years 1982-86.

Random bowhead sightings between 1982-87 ranged from 1 to 57 km from shore (table 20; figure 21). The annual median distance to shore of random sightings ranged from 18 to 30 km, with a 6-year median of 28 km. Annual mean distances were not significantly different (ANOVA $F = 0.85$, $p < 0.50$). The minimum distance as significant at $p < 0.05$ with 95% precision was 10 km

Table 20. Measures of central tendency for distance of random bowhead whale sightings from shore (km) within the approximate boundaries of the native hunting area at Barrow, 1982-87.

	N	Median	C.I. (99%)	Mean	s.d.	Range
1982	6	18	*	19.7	11.71	6-36
1983	9	30	19-41	29.3	7.73	19-41
1984	26	28	12-39	26.4	13.40	6-54
1985	4	18	*	25.8	21.09	11-57
1986	7	29	*	27.7	11.44	12-48
1987	8	21	1-35	19.2	12.87	1-35
1982-87	60	28	19-31	25.3	12.78	1-57

(Zar, 1984). Thus, the axis of the bowhead migratory route near Barrow falls between 18 and 30 km from shore, with no significant differences detected between years. Interpretations on significant behavioral responses to noise over distances < 10 km are probably best left to site-specific behavioral studies, however, as the power of the ANOVA to detect shifts in aerial survey sighting distribution will not increase appreciably with additional years of data (Zar, 1984).

In the Chukchi Sea, most whales (85%, n = 47) have been seen in the southwesternmost section of the Beaufort Sea planning area, with eight whales (15%) seen in the Barrow Arch planning area (see figure 20). The migratory route of bowheads seen in the Chukchi Sea, as described by distribution and swim direction, has been one of a general southwest dispersion crossing roughly over Herald Shoal (Ljungblad et al., 1987). The three bowheads seen in the Chukchi Sea in 1987 were also swimming in a southwest direction. When these data were added to those from past years, swimming direction was again significantly clustered about a southwest heading (figure 22), indicating that some bowheads disperse southwest across the Chukchi Sea after passing Point Barrow. These observations are in general agreement with those summarized in Braham et al. (1984) that "from Point Barrow the animals appear to move westerly to Herald Shoal and Herald and Wrangel Islands, then south through the Chukchi Sea and into the Bering Sea".

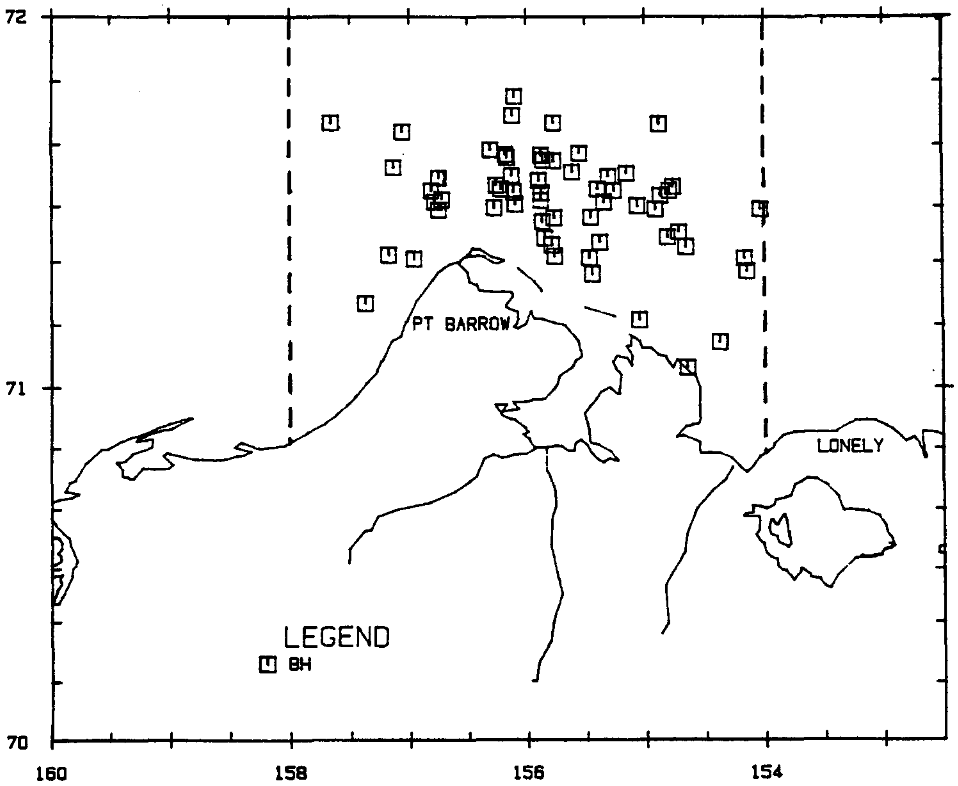


Figure 21. Distribution of random bowhead sightings within the approximate boundaries of the native Alaskan Inupiat fall bowhead hunting area (dashed lines) at Barrow, 1982-87.

The earliest sighting of bowheads west of 150°W was of four whales just north of Harrison Bay (approx. 71°10'N, 151°10'W) on 15 September 1983 (see figure 20). Except for 1983 and 1984, relative abundance in the study area was higher in October than September (see table 18) indicating that most whales pass through the western Beaufort and into the Chukchi Sea in October. Swimming direction in the western Beaufort was significantly clustered about westerly headings in September and October (figure 23), similar to results of analyses of sightings from the entire Alaskan Beaufort Sea in past years (Ljungblad et al., 1987).

The bowhead migration through the western Beaufort and northeastern Chukchi Seas appears to occur in pulses, although the passage of whale aggregations do not appear to be as clearly demarcated as during the spring migration. The timing of daily relative abundance (WPUE) peaks in the study area in 1987 began in late September and were separated by roughly 5 to 10 days (see figure 12). Further interpretation of bowhead movements across and into the western

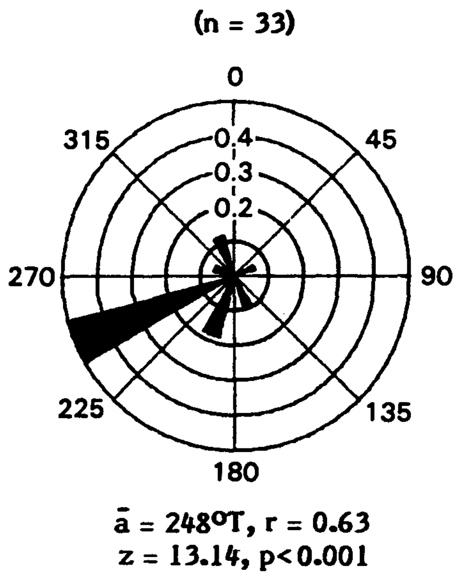


Figure 22. Bowhead swimming direction in the northeastern Chukchi Sea, 1982-87.

Beaufort Sea can be made when WPUE peaks for the western Beaufort are compared to peak daily abundance for the eastern Beaufort Sea. The highest relative abundance peaks were recorded in the western Beaufort Sea on 6 October (see figure 12) and in the eastern Beaufort Sea on 7 October (Treacy, in prep.), indicating two separate aggregations of bowheads were passing through the Alaskan Beaufort Sea in early October. Smaller, but again nearly simultaneous, WPUE peaks occurred in the eastern and western Beaufort Sea study areas between 27-30 September. A bowhead whale swimming approximately 4 to 5 km/h (2 to 3 kn) can travel across the Alaskan Beaufort Sea in roughly 5 days. Thus, it is possible that at least some of the whales seen during the daily abundance peaks of 27-30 September in the eastern Beaufort Sea also comprised part of the aggregation that is represented in the sighting rate peak of 6 October in the western Beaufort Sea. Notably, the first bowhead sighting in the northeastern Chukchi Sea (21 September) occurred 5 days after a small relative abundance peak in the eastern Beaufort Sea on 16 September (Treacy, in prep.).

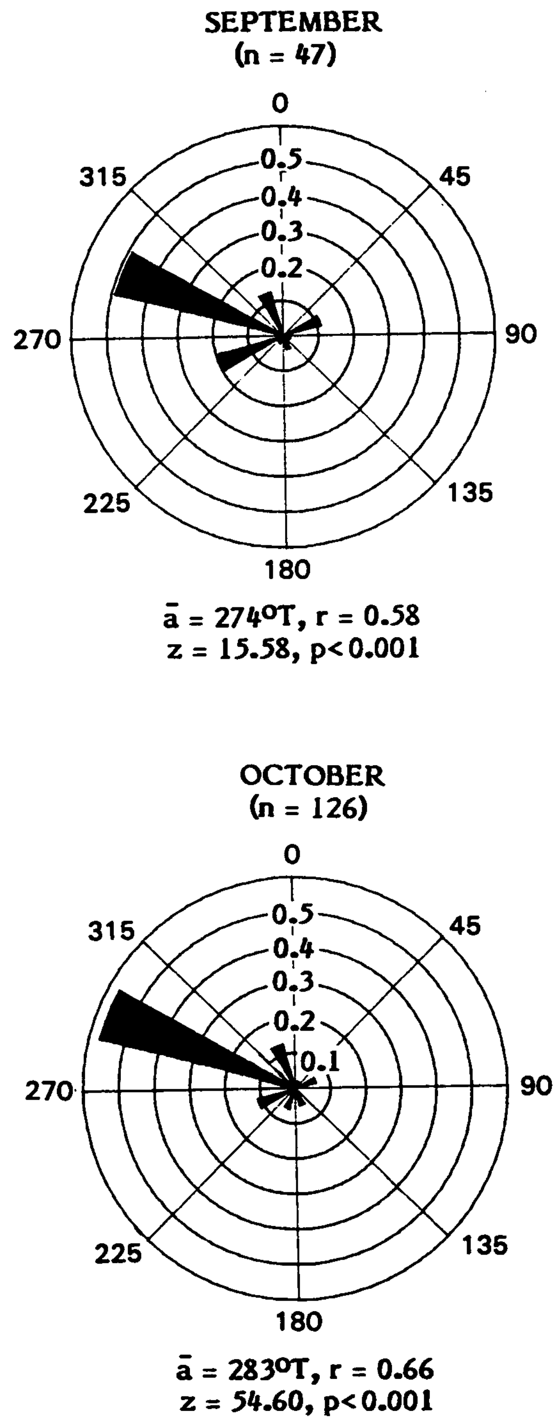


Figure 23. Bowhead swimming direction in the western Alaskan Beaufort Sea, 1979-87.

Native Inupiat whalers at Kaktovik maintain that the autumn bowhead migration is roughly segregated into age classes, with "smaller" whales passing Barter Island in early autumn, followed by "larger" whales including cow/calf pairs (Braham et al., 1984). Notably, neither temporal nor spatial segregation of bowhead calves was demonstrated in an analysis of 4 years of calf-sighting data collected in the alaskan Beaufort Sea (Clarke et al., 1987a). Braham et al. (1984) also indicate that there may be a division in the bowhead fall migration with some whales leaving the Beaufort Sea as early as July or August. This hypothesis is suggested as a possible explanation of "simultaneous sightings" of bowheads in the eastern Beaufort and western Chukchi Seas. Notably, bowheads seen relatively far offshore in the eastern Alaskan Beaufort Sea in August 1982 were swimming in a significantly westerly direction and appeared to be migrating (Ljungblad et al., 1983). It is possible that such an early offshore component passes through the Alaskan Beaufort Sea relatively offshore and undetected each year. As noted in Ljungblad et al. (1986), these whales would not likely encounter OCS industrial activities in the eastern Beaufort Sea, but may be affected by OCS development activities in the western Beaufort Sea if their migratory route brings them closer to shore near Point Barrow.

Bowheads were found most often (60%, n = 278) in open water or light ice (< 10%) in the western Beaufort and eastern Chukchi Seas (table 21). Whales that were not seen in predominantly open water were usually in 71-80 percent ice (14%, n = 66) or 81-90 percent ice (9%, n = 43). As noted for past years (Ljungblad et al., 1987), bowheads were seen each year in whatever ice cover predominated during the latter half of September and October when the majority of migrating whales were observed. Porter and Church (1987) note that changes in study area boundaries can affect inferences regarding the use of particular habitat by wildlife. Perhaps inferences regarding the use of particular habitat for bowhead whales are also affected by the annual variability of that habitat within the study area.

c. Acoustic Detection of Migrating Whales

Passive acoustics were used in conjunction with aerial surveys to detect bowhead whales during the westward fall migration in 1986 and 1987. In 1986, 7,152 bowhead calls were recorded between 3 September and 9 October using sonobuoys modified for extended transmission life and moored approximately 5 km

Table 21. Number (No.) and percent (%) of bowheads found in each ice cover class, 1981-87.

Ice Cover (%)	1981 No.	1981 (%)	1982 No.	1982 (%)	1983 No.	1983 (%)	1984 No.	1984 (%)
0-10	0		24	(45)	18	(26)	171	(73)
11-20	0		0		0		3	(1)
21-30	0		0		1	(2)	2	(1)
31-40	0		0		6	(9)	12	(5)
41-50	0		2	(4)	2	(3)	10	(4)
51-60	0		0		4	(6)	2	(1)
61-70	0		4	(8)	13	(19)	1	(1)
71-80	7	(100)	14	(26)	11	(16)	2	(11)
81-90	0		7	(13)	13	(19)	23	(10)
91-100	0		2	(4)	0		7	(3)
TOTAL	7		53		68		233	

Ice Cover (%)	1985 No.	1985 (%)	1986 No.	1986 (%)	1987 No.	1987 (%)	Total No.	Total (%)
0-10	11	(26)	17	(85)	37	(97)	278	(60)
11-20	0		0		0		3	(0.5)
21-30	0		0		0		3	(0.5)
31-40	0		0		0		18	(4)
41-50	0		2	(10)	0		16	(3)
51-60	0		0		0		6	(2)
61-70	1	(2)	0		0		19	(4)
71-80	30	(72)	1	(5)	1	(3)	66	(14)
81-90	0		0		0		43	(9)
91-100	0		0		0		9	(3)
TOTAL	42		20		38		461	

Table 22. Hours of recording, number of bowhead calls, call rate, and sighting rate (WPUE) for days on which whales were recorded at the acoustic monitoring stations in 1986 and 1987.

1986: Barter Island					1987: Barrow				
Date	Hours	No. Calls	Call Rate	WPUE	Date	Hours	No. Calls	Call Rate	WPUE
3 Sep	10.3	1	0.10	2.99	18 Sep	7.1	34	4.79	0
9 Sep	23.4	2	0.09	0	30 Sep	11.8	3	0.25	0.60
11 Sep	10.0	1	0.10	1.54	3 Oct	3.9	48	12.31	0
12 Sep	8.6	2	0.23	0	5 Oct	8.7	76	8.74	0.46
18 Sep	23.0	32	1.39	*	6 Oct	11.6	238	20.52	12.76
19 Sep	14.6	106	7.26	0.37	15 Oct	8.7	27	3.10	0
20 Sep	23.9	119	4.98	0	16 Oct	7.5	81	10.80	0.91
25 Sep	8.2	52	6.34	1.88	19 Oct	7.8	15	1.92	0
27 Sep	23.1	661	28.61	*	20 Oct	8.7	2	0.23	0
28 Sep	23.8	2100	88.24	5.52	21 Oct	8.7	7	0.80	0
29 Sep	21.7	534	24.61	0					
30 Sep	7.4	55	7.43	*					
1 Oct	22.3	1566	70.22	2.41					
2 Oct	21.9	1373	62.69	*					
3 Oct	23.2	375	16.16	*					
6 Oct	9.4	136	14.47	2.54					
7 Oct	22.1	35	1.58	*					
9 Oct	6.6	2	0.30	0					

* = no flight

north of Barter Island, Alaska. In 1987, 531 bowhead calls were recorded between 18 September and 21 October from standard sonobuoys deployed from the survey aircraft near Barrow, Alaska. Bowhead calls recorded in both years were similar to those described in earlier reports (Ljungblad et al., 1982b; Clark and Johnson, 1984). Most of the calls were tonal frequency-modulated (FM) moans, with the more complex amplitude-modulated (AM) trumpet-type calls recorded much less frequently. The relatively high incidence of tonal calls is in keeping with the reported trend for migrating whales to produce mostly FM type calls, and socializing whales to produce more AM type sounds (Ljungblad et al., 1986b; Würsig et al., 1985).

There was significant correlation between bowhead calling rates (CR) and aerial survey sighting rates (WPUE) in 1986 ($r = 0.700$, $df = 10$, $p < 0.02$), and 1987 ($r = 0.764$, $df = 8$, $p < 0.02$), but not for the combined data from both years ($r = 0.417$, $df = 20$, $p < 0.10$; table 22). Although WPUE and CR were strongly correlated in both years, it appears that the whales seen were not necessarily those

Table 23. Summary of hourly call rates recorded at the acoustic stations from a moored sonobuoy (1986) and from routine sonobuoy drops during aerial surveys (1987).

Hour (local)	1986: Barter Island	1987: Barrow
0000-0100	392	*
0100-0200	401	*
0200-0300	283	*
0300-0400	328	*
0400-0500	315	*
0500-0600	225	*
0600-0700	250	*
0700-0800	312	*
0800-0900	256	*
0900-1000	183	-
1000-1100	219	-
1100-1200	230	-
1200-1300	314	-
1300-1400	257	3
1400-1500	239	1
1500-1600	497	32
1600-1700	252	17
1700-1800	227	50
1800-1900	322	11
1900-2000	309	75
2000-2100	240	151
2100-2200	298	171
2200-2300	451	19
2300-0000	352	1

* = no recording effort; - = no data recorded

recorded. Bowhead WPUE were derived from surveys conducted over waters that included the acoustic monitoring areas, but were not confined to sightings within those areas. In 1986, only 16 whales were seen within 20 km of the acoustic station, and there were no bowhead sightings within the estimated 20-km boundaries of the acoustic station in 1987.

The supposition that observed whales were not necessarily those recorded is further supported by comparisons of the time of sightings versus the time that calls were recorded. In 1986, aerial survey sightings were generally made between 1000 and 1600 local time, when only 25% (n = 1756) of bowhead calls were recorded (table 23). In addition, when calls/hour were cumulated over the course of the 1986 season, mean call rate for night time hours (1800-0600) was higher $\bar{x} = 326$, s.d. = 65) than for daytime (0600-1800) hours ($\bar{x} = 270$, s.d. = 80), although this difference was not statistically significant ($p < 0.10$). In 1987, 75% ($n = 397$) of all calls were recorded between 1900 and 2200, several hours after surveys were terminated due to darkness. Notably, the first calls recorded in 1986 occurred when bowheads were not seen within the boundaries of the acoustic station and in 1987 calls were recorded 3 days before the first bowhead sighting of the season.

These preliminary results are encouraging because they suggest that acoustic monitoring may be a cost effective way to assess the migratory timing of bowheads swimming near shore. Passive acoustics reliably indicated the presence of bowheads at rates comparable to sighting rates derived from aerial surveys, and extended data acquisition through periods when surveys could not be flown due to darkness or bad weather.

Passive acoustic techniques that used an array of three or four hydrophones were utilized during the spring bowhead migrations from 1980-85 (Clark et al., 1986; Cummings and Holliday, 1983) to localize and track calling bowheads, and in this way augment visual sightings recorded at ice-based census camps. Acoustic data were subsequently incorporated in the population size estimate for the Western Arctic bowhead stock reported to the IWC in 1987 (Zeh et al., 1987). It is important to differentiate between the results reported here and those of the passive acoustic tracking work. While it is tempting to interpret the three seasonal peaks of bowhead calling, or the daily peaks within these periods, as corresponding to aggregations or pulses of whales passing the monitoring site, these inferences cannot be supported by data gathered from a single omnidirectional hydrophone. Without directional information on incoming calls, it is impossible to determine if "more" calls corresponds to "more whales", or to just a few whales that remain within range of the hydrophone for a relatively long time. On peak call rate days, it seems likely that at least some bowheads were socializing and calling within range of the hydrophone, and not actively migrating past the monitoring site. Amplitude-modulated "growls" and trumpets" were commonly recorded on days of peak call rates in both years, while calls on other days were usually FM "moans". The AM calls have been recorded more often near socializing rather than migrating whales, although this association is not a statistically significant one (Ljungblad et al., 1986; Würsig, et al., 1985). In addition, AM "growls" were positively correlated with call rate ($r = 0.216$, $df = 85$, $p < 0.05$) in a sample of calls recorded during aerial surveys over several seasons (Ljungblad et al., 1986).

Although it is not possible to infer bowhead number or rate of passage from the acoustic data collected from a single omnidirectional hydrophone, the significant correlation of calling and sighting rates, and the extended period of data gathering supports the contention that passive acoustic monitoring could be developed as a valuable and cost effective tool to assess the timing of the bowhead fall migration.

It is important to note that the success of any acoustic detection study will depend on environmental conditions that are conducive to maintaining the necessary field equipment. The 1986 field season was unusually mild, with ample periods between storms that usually allowed the moored sonobuoy systems to be replaced at timely intervals. In 1987, open water conditions persisted near Barrow until well into October, facilitating sonobuoy deployment. A season of prolonged storms or heavy ice would have likely led to fewer acoustic results in both years.

Passive acoustics is becoming an important supplemental technique for detecting cetaceans, assessing their distribution and inferring something about their behavior. Additional examples of the utility of bioacoustics in the study of marine mammals include an assessment of diurnal haulout patterns for two species of Antarctic seals (Thomas and DeMaster, 1982), and an assessment of winter distribution and relative abundance for walruses, ringed seals, and bearded seals in the High Arctic (Stirling et al., 1983). Thus, as Thomas et al. (1986) notes, bioacoustics is a powerful tool that can extend data-gathering periods beyond visual limitations and enhance our overall understanding of cetacean behavior and movements.

d. Behavior

Most bowheads (51.5%, n = 247) seen in the western Beaufort and Chukchi Sea study area were migrating; 225(47%) were swimming and 22(4.5%) were diving (table 24). Whales that were not migrating were most often feeding (37%, n = 176), with 22(4.5%) whales recorded as resting, 6(1%) milling, 12(2%) involved in cow-calf interactions, and 19(4%) displaying. The ratios of behaviors varied each year. Most notably, the proportion of feeding whales in 1984 (60%, n = 140) far exceeded that of any other year (table 24; figure 24). As described in Ljungblad et al. (1986a), large aggregations of feeding bowheads were seen relatively near shore just east of Point Barrow n 1984. Similar aggregations have not been seen during any other year of this project, but have been reported for years prior to 1979 by other researchers (reviewed in Ljungblad et al., 1986a). The proportion of bowheads seen feeding was also relatively high in 1985 when a group of 18 whales

Table 24. Monthly summary of bowhead behavior, 1979-87.

Behaviour	Year	September	October	Total (%)
Swim	1979	0	5	5 (16)
	1980	0	1	1 (14)
	1981	0	2	2 (29)
	1982	7	26	33 (62)
	1983	31	15	46 (68)
	1984	14	56	70 (30)
	1985	0	16	16 (38)
	1986	0	17	17 (85)
	1987	4	34	35 (92)
	Total	56	172	225 (47)
Dive	1979	0	5	5 (16)
	1980	0	3	3 (43)
	1981	0	3	3 (42)
	1982	1	3	4 (8)
	1983	2	1	3 (4)
	1984	0	3	3 (1)
	1985	0	1	1 (2)
	Total	3	19	22 (4.5)
Rest	1982	2	6	8 (15)
	1984	0	10	10 (4)
	1985	0	4	4 (10)
	Total	2	20	22 (4.5)
Feed	1982	5	0	5 (9)
	1983	0	10	10 (15)
	1984	138	2	140 (60)
	1985	0	18	18 (43)
	1987	0	3	3 (8)
	Total	143	33	176 (37)
Mill	1979	0	3	3 (9)
	1983	0	2	2 (3)
	1985	0	1	1 (2)
	Total	0	6	6 (1)
Cow-calf	1980	0	2	2 (29)
	1981	0	2	2 (29)
	1982	0	2	2 (4)
	1984	0	4	4 (2)
	1986	0	2	2 (10)
	Total	0	12	12 (2)
Display	1979	0	3	3 (9)
	1982	0	1	1 (2)
	1983	6	1	7 (10)
	1984	0	5	5 (2)
	1985	0	2	2 (5)
	1986	0	1	1 (5)
	Total	6	13	19 (4)

*Behavior was not recorded for 18 whales: 16 (50) in 1979; 1 (14) in 1980; and 1 (1) in 1984.

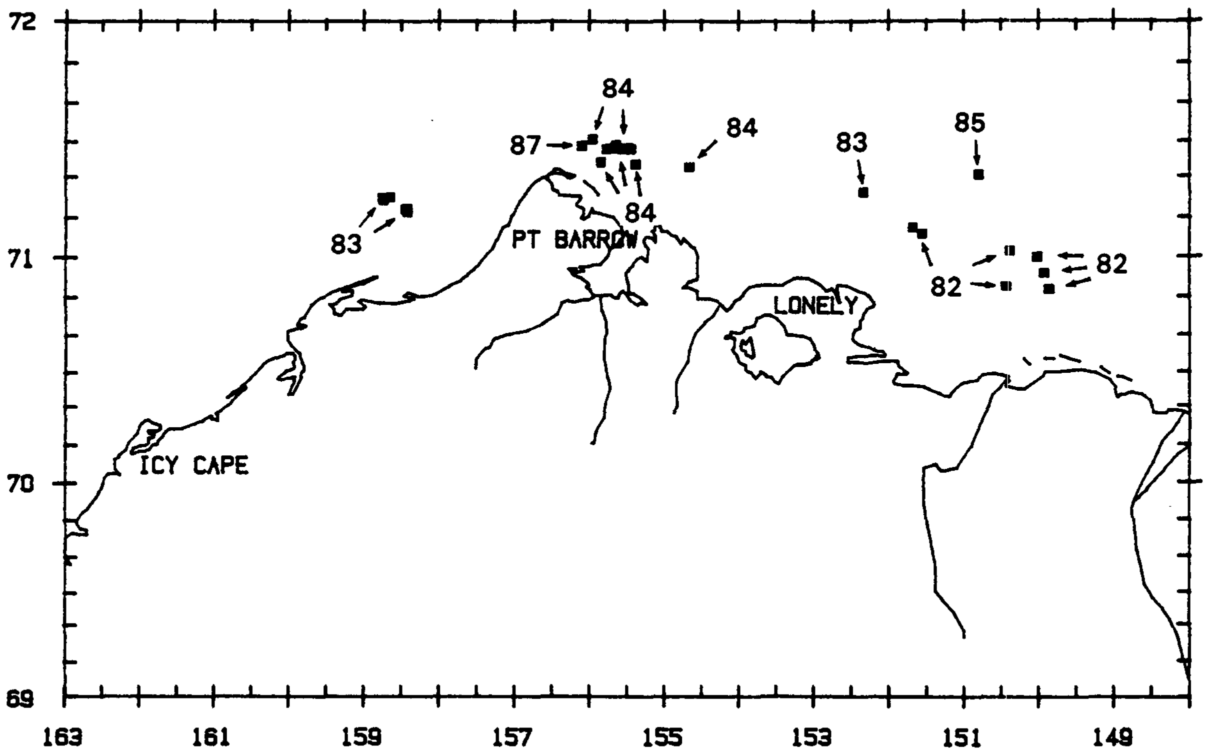


Figure 24. Distribution of feeding bowheads in the western Alaskan Beaufort and northeastern Chukchi Seas, 1979-87.

(43%) were observed repeatedly diving and milling near the shelf break north of Harrison Bay (figure 24). Ten (15%) whales were seen feeding in 1983, nine in the northeastern Chukchi Sea and one just west of the position of the feeding group seen in 1985. Five and three bowheads were noted as feeding in 1982 and 1985, respectively. The whales seen in 1982 were north of Harrison Bay, similar to those areas where feeding whales were seen in 1983 and 1985. The feeding whales seen in 1987 were just west of the Point Barrow peninsula near where the large aggregations were seen in 1984. As reported in Ljungblad et al. (1986a, 1986c, and 1987), migrating bowheads stop to feed opportunistically along their migratory route. In the Alaskan Beaufort Sea, feeding whales were found in shallower water and lighter ice cover than whales that were not feeding, indicating that the annual availability of prey will influence annual bowhead distribution and habitat preference to some degree.

e. Calf Sightings

Fifteen bowhead calves have been seen in the study area since 1979 for an overall ratio of calves to total number of bowheads of 0.03 (table 25). Two calves

Table 25. Monthly summary of bowhead calf sightings and calf-to-total bowhead ratio ( ).

Year	September	October	Total
1979	0	0	0
1980	0	1(0.15)	1(0.15)
1981	0	1(0.15)	1(0.15)
1982	0	1(0.03)	1(0.02)
1983	2(0.05)	2(0.07)	4(0.06)
1984	0	3(0.04)	3(0.01)
1985	0	3(0.07)	3(0.07)
1986	0	2(0.10)	2(0.10)
1987	0	0	0
Total	2(0.01)	13(0.05)	15(0.03)

were seen in September 1983 in the northeastern Chukchi Sea and all others were seen in the western Beaufort Sea in October. The resultant ratio of calves to all bowheads was 0.01 in September and 0.05 in October, values that fell within the range of those calculated for the Alaskan Beaufort Sea (Clarke et al., 1987a). As reported in Clarke et al. (1987a), the distribution of calves was not significantly different, temporally or spatially, from that reported for all bowheads.

Gray Whale

a. Patterns of Distribution, Relative Abundance, and Density

Fall surveys have been conducted in the western Beaufort and northeastern Chukchi Seas in August, September, and October since 1982. There were 159 sightings of 441 gray whales over five survey seasons (1982-84, 86-87), with no sightings in 1985. Within the study area (68°N to 72°N, 150°W to 169°W) in September and October only, 141 sightings of 394 gray whales were made (table 26) and are reviewed here. Gray whale data for July and August were reviewed in Clarke et al. (1987b) and Ljungblad et al. (1986b, 1987).

The distribution of gray whales in September each fall, except 1985, has been primarily nearshore between Point Franklin and Point Barrow (figure 25). In 1986-87, grays were also seen in offshore areas out to 163°W. Grays were seen north and east of Point Barrow in 1986 and south of Point Hope in 1987, the first year considerable flight effort was directed to that area in September. In October, the

Table 26. Monthly summary of gray whale sightings (number of sightings/number of whales), 1982-87.

Year	September	October	Total
1982	5/18	6/8	11/26
1983	1/2	6/10	7/12
1984	7/70	6/12	13/82
1985	0	0	0
1986	42/130	15/26	57/156
1987	40/92	13/26	53/118
Total	95/312	46/82	141/394

distribution of grays was more widespread, with sightings along much of the northeastern Chukchi coast between Point Hope and Point Barrow (figure 25), as well as offshore to 115 km.

The highest gray whale relative abundance in the Chukchi Sea was calculated for block 22 (WPUE = 3.66), with lesser WPUE calculated for blocks 13 (WPUE = 2.37) and 14 (WPUE = 1.67) (table 27). Monthly WPUE values were highest in block 22 in both September and October. Relative abundance decreased from September and October in the three northernmost blocks (12, 13, 14), and increased in the more southerly blocks (17, 18, 20), corresponding with reports that gray whales begin their fall migration from summer feeding grounds in mid-October. Moore et al. (1986a) reported that, based on comparative bowhead and gray whale abundance indices, the majority of grays appeared to have migrated out of the northern Chukchi Sea by October as bowheads began migrating into the area.

Density calculations for 1982-87 reflect relative abundance values. In September, density was highest in block 22 (1.56 whales/100 km^2), with relatively high densities in blocks 13 (0.42 whales/100 km^2) and 14 (0.25 whales/100 km^2). No whales were seen on transect in blocks 12 and 17, so density could not be calculated. Densities were much lower in October, with the highest value in block 20 (0.09 whales/100 km^2), and lower numbers in blocks 18 (0.05 whales/100 km^2), 13 (0.04 whales/100 km^2), and 14 (0.02 whales/ 100 km^2). None of the whales seen in October in blocks 12, 17, or 22 (where abundance was relatively high) were on transect, so no density was calculated for those areas.

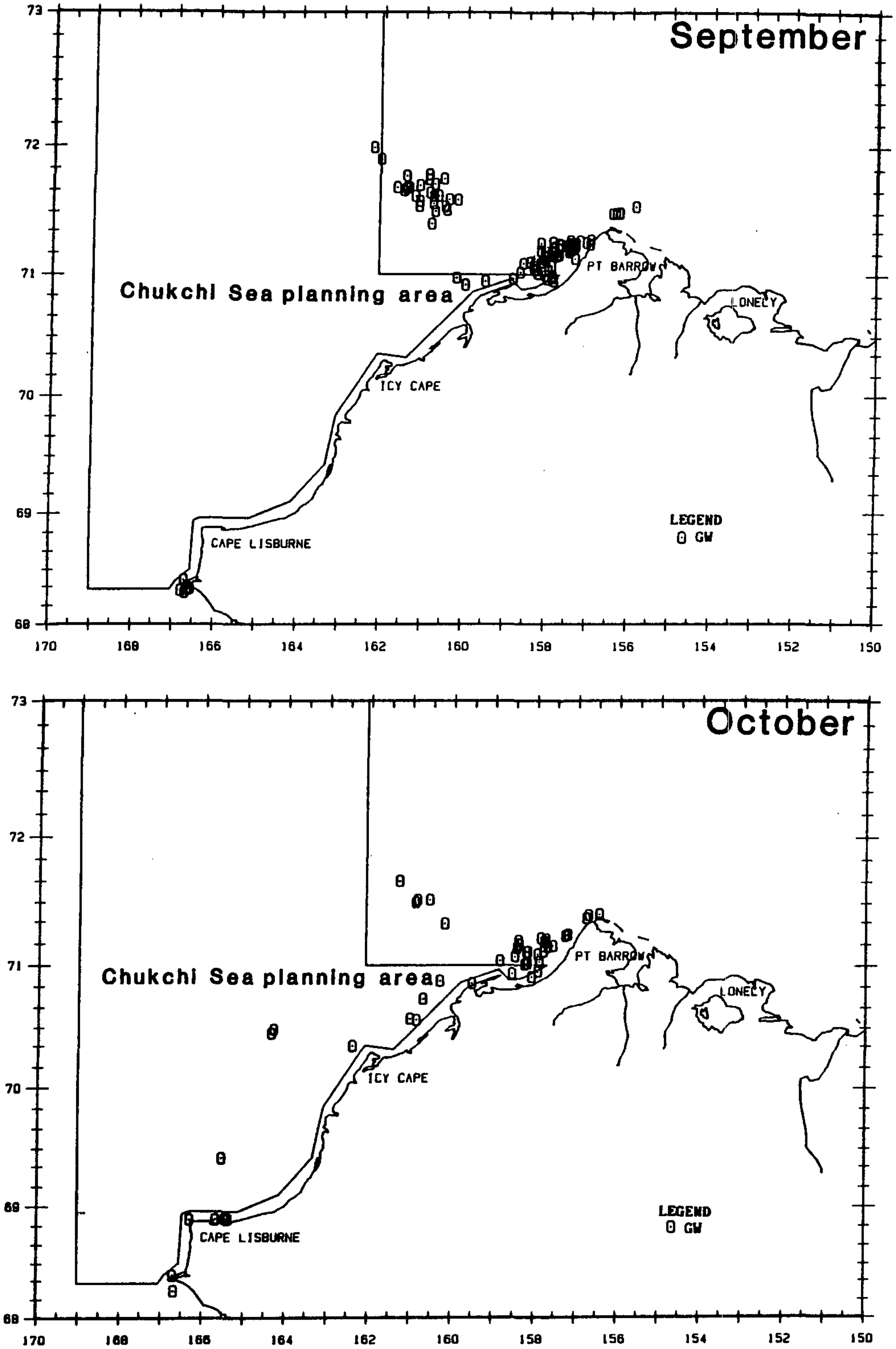


Figure 25. Monthly distribution of gray whales in the western Alaskan Beaufort and northeastern Chukchi Seas in relation to Chukchi Sea planning area, 1982-87: 95 sightings of 312 gray whales, September; 46 sightings of 82 gray whales, October.

Table 27. Monthly gray whale abundance (WPUE = no. whales/hours of survey effort) by block, 1982-87.

Month Block	September No.	 WPUE	October No.	 WPUE	TOTAL No.	 WPUE
12	26	0.58	3	0.04	29	0.24
13	194	4.05	47	0.87	241	2.37
14	62	2.46	12	0.63	74	1.67
17	2	0.14	5	0.21	7	0.18
18	0	-	3	0.24	3	0.16
20	0	-	5	0.78	5	0.35
22	**28**	**4.71**	**7**	**1.66**	**35**	**3.66**
Total	312	1.90	82	0.40	394	1.07

b. Habitat Relationships and Behavior

Most (95%, n = 373) of the 394 gray whales seen in September and October since 1982 were in open water or light (<20%) ice cover, with 4 percent (n = 16) in relatively heavy (71-90%) ice cover, and the remaining one percent (n = 5) in moderate (30-60%) cover. Grays were found in water depths ranging from 5m to 64m ($\bar{x}$ = 26.8, 12.6 s.d., n = 141). Whales seen along the shoreline appeared to be in water shallow enough to allow them to rest on the bottom.

The majority (85%, n = 355) of grays seen were feeding (table 28), and were often sighted in the presence of mud plumes. Sightings may have been biased to areas where mud plumes were seen because of the known association between grays and plumes. However, a number of mud plumes were also seen without any whales present (see figure 15), thereby possibly diminishing any bias introduced by "sightings on mud plumes". Most feeding gray whales (81%, n = 273) were seen in the nearshore areas of blocks 12, 13, 17, and 22, with the remainder (19%) seen offshore in blocks 14 (n = 63) and 18 (n = 1). Grays have also been seen swimming (11%, n = 45), diving (1%, n = 5), and resting (1%, n = 4). Three gray whales were observed involved in mating activity and one was seen breaching.

c. Calf Sightings

Two gray whales calves were seen in September and October over six survey seasons. One was seen on 7 September 1986 among a group of 12 adults feeding northeast of Point Barrow (71°28'N, 156°18'W), farther north than any calves seen during summer surveys from 1980-85 (Ljungblad, et al., 1986b). And one was seen

Table 28. Summary of gray whale behaviour, 1982-87.

Behavior	Year	September	October	Total
Swim	1982	0	1	1
	1983	2	3	5
	1984	4	2	6
	1986	18	2	20
	1987	7	6	13
	Total	31	14	45 (11)
Dive	1982	0	1	1
	1983	0	0	0
	1986	1	0	1
	1987	3	0	3
	Total	4	1	5 (1)
Rest	1986	2	2	4
	Total	2	2	4 (1)
Feed	1982	18	6	24
	1983	0	7	7
	1984	66	10	76
	1986	105	21	126
	1987	82	20	102
	Total	271	64	335 (85)
Display	1986	1	0	1
	Total	1	0	1 (0.5)
Mate	1986	3	0	3
	total	3	0	3 (1)
None Recorded	1986	0	1	1
	Total	0	1	1 (0.5)
Annual Total	1982	18	8	26 (7)
	1983	2	10	12 (2)
	1984	70	12	82 (21)
	1986	130	26	156 (40)
	1987	92	26	118 (30)
	Total	312	82	394

with an accompanying adult on 1 September 1987 just north of Point HOpe, near a group of 15 immature whales that appeared to be feeding. Calves were seen in this same area in July 1985 (Clarke et al., 1987b). Resultant calf-to-total whale ratios were 0.6% in 1986 and 0.8% in 1987.

Gray whale calves have been seen along the coastal Chukchi Sea in past years, often in significantly greater proportions than in the northern Bering Sea (Moore et al., 1986b). Except for the two calves seen during September and one seen in block 13 in August 1983 (Ljungblad et al., 1984), all calves have been seen in July.

Sightings indicate that at least some gray whale cow-calf pairs commonly travel as far north as the northeastern Chukchi and extreme northwestern Beaufort Seas. Segregation of cow-calf groups in Alaskan waters was indicated for data gathered in July 1981-83 with significantly lower gross annual recruitment rates (GARR) in the Bering Sea than in the Chukchi (Moore et al., 1986b). The northeastern Chukchi Sea may be a more important area for cow-calf pairs in mid-summer (July) compared to late summer and fall (August-October). Calves have not been seen in any appreciable numbers in fall perhaps because they migrate out of the area, either south to the southern Chukchi and/or northern Bering Seas or southwestward to the Chukchi peninsula. Surveys flown in the southern Chukchi in September 1987 (as recommended in Ljungblad et al., 1987) resulted in the only grays seen in the area were mostly (75%, n = 21) immatures, further indicating that the area may be relatively important as a nursery or weaning area similar to those seen along the Soviet coast (Krupnik et al., 1983).

The extreme northern extension of their range is somewhat surprising however, since cow-calf pairs appear to leave the breeding lagoons of Baja California after all other adults have left. The coastal Chukchi Sea may present better conditions after all other adults have left. The coastal Chukchi Sea may present better conditions for both cow and calf than the central Bering Sea, which appears to be the most important gray whale feeding ground (Nerini, 1984; Moore et al., 1986b). Although the productivity of the northeastern Chukchi appears to be lower than that of the northern Bering Sea, feeding opportunities specifically in the nearshore coastal zone combined with reduced competition for preferred prey from other adult grays may enable the cow to feed successfully. And Krupnik et al. (1983) indicated that females and young animals remained in shallow coastal areas as an adaptation to the higher respiratory rate of the young.

Table 29. Monthly summary of belukha sightings (number of sightings/number of whales), 1982-87.

Year	September	October	Total
1982	0	20/374	20/374
1983	114/1057	52/513	166/1570
1984	25/204	65/204	90/408
1985	9/119	27/95	36/214
1986	5/14	25/157	30/171
1987	38/214	12/58	50/272
Total	191/1608	201/1401	392/3009

The northeastern Chukchi may also provide protection for both the calf and cow from potential predators, such as killer whales (Orcinus orca) (Braham et al., 1981; Ljungblad and Moore, 1983).

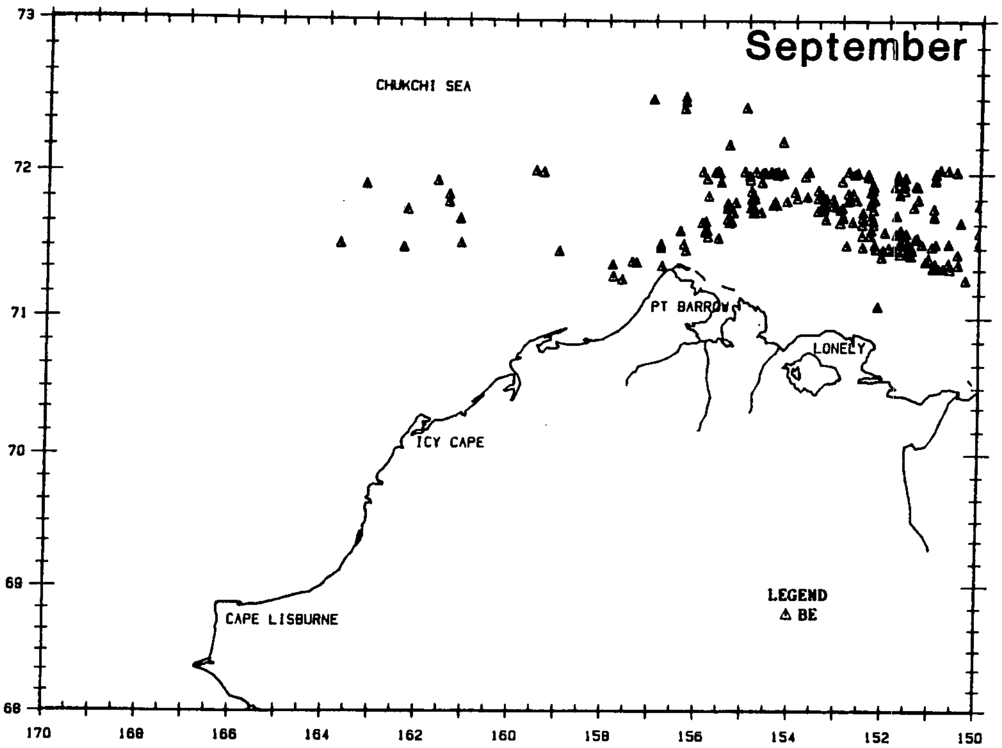
Other Marine Mammals

a. Belukha

Since 1982, 292 sightings of 3009 belukhas have been made in the western Alaskan Beaufort and northeastern Chukchi Seas (figure 26, table 29). The majority (82%, n = 2472) of these were seen in the Beaufort, with 18 percent (n = 537) in the northeastern Chukchi. Over half were seen in 1983 (52%, n = 1570).

Belukhas have been seen from approximately 6 to 175 km from shore (figure 26). The distribution in September was mostly offshore in deeper water east of 154°W, and consistently nearer to shore west of 154°W, apparently following the 50-m contour towards Point Barrow. Belukhas were distributed both nearshore and offshore in the Chukchi Sea. Belukha distribution in October was similar to that in September, although sightings were more widespread in the Chukchi Sea.

Areas of greatest relative abundance (WPUE) in September were block 11 (WPUE = 23.08) and the unblocked area directly north of block 11 (Surveyed only in 1987) (WPUE = 31.85) (table 30). Abundance was also high in blocks 12-N



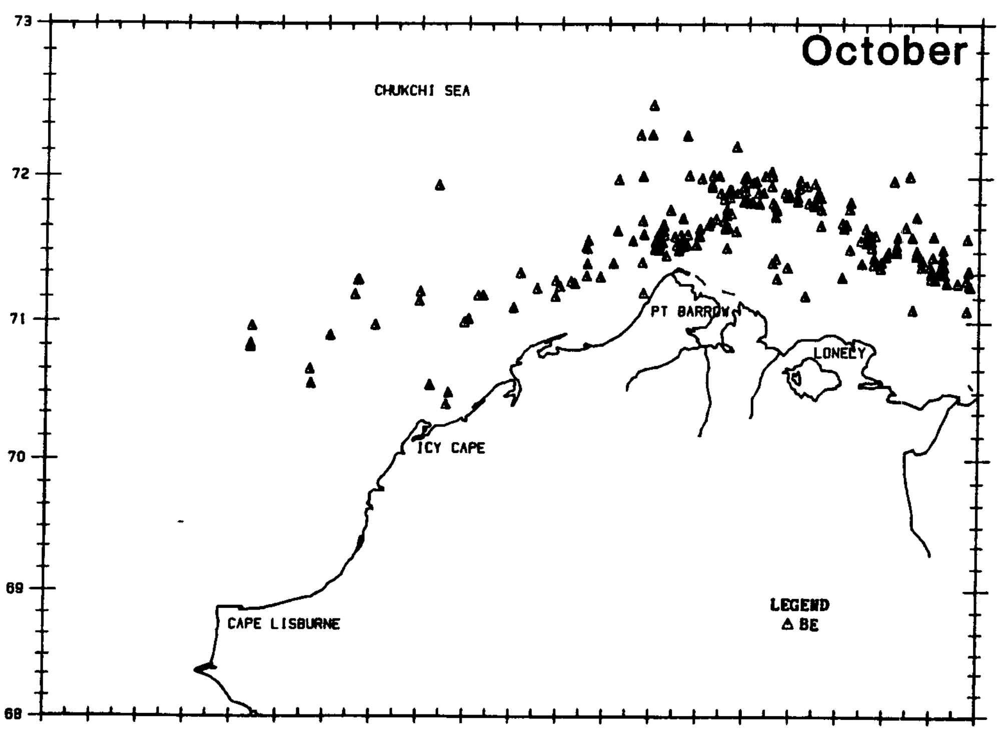


Figure 26. Monthly distribution of belukhas, 1982-87: 191 sightings of 1608 belukhas, September; 201 sightings of 1401 belukhas, October.

Table 30. Monthly belukha abundance (WPUE = no. whales/hours of survey effort) by block, 1982-87.

Month Block	September No.	 WPUE	October No.	 WPUE	TOTAL No.	 WPUE
3	5	0.09	298	5.191	303	2.93
11	**686**	**23.08**	**249**	**9.39**	**935**	**16.63**
12	597	13.37	561	7.49	1158	9.69
12N*	46	15.81	30	3.98	76	7.28
13	199	4.15	138	2.56	337	3.31
13N*	2	1.04	16	4.61	18	3.34
14	28	1.11	65	3.41	93	2.10
15	2	0.19	11	2.10	13	0.81
16	0	-	-	-	0	-
17	0	-	10	0.42	10	0.26
18	0	-	22	1.73	22	1.17
Unblocked*	**43**	**31.85**	1	3.33	**44**	**26.67**
Total	1608	6.73	1401	5.04	3009	5.82

* = data from 1987 only
Bold indicates peak WPUE

(WPUE = 15.81) and 12 (WPUE = 13.37). In October, abundance was highest in blocks 11 (WPUE = 9.39) and 12 (WPUE = 7.49). Overall, block 11 had the highest WPUE for 1982-87 at 16.63.

Mean depth at sightings averaged 481m (range 7-3118m, 702 s.d, n = 392), and decreased from September ($\bar{x}$ = 681m, 839 s.d., n = 391) to October ($\bar{x}$ = 293m, 471 s.d., n = 201). Belukhas were seen in ice cover ranging from 0-99 percent (table 31), although the majority were seen in relatively heavy (61-99%) ice (70%, n = 2111). This may indicate habitat preference, but may also be related to the ice conditions present in the study area during a particular fall season. More than half of all belukhas observed were seen in 1983, a year of exceptionally heavy ice (Ljungblad et al., 1984).

The majority of belukhas (73%, n = 2191) seen were swimming or diving (73%, n = 2204). Other behaviors included milling (6%, n = 185), resting (3%, n = 90) and cow-calf interaction (18%, n = 530). They maintained a significantly westerly heading in the northwestern Beaufort Sea throughout fall (255°T, r = 0.34, z = 27.13, p<0.001). In the northeastern Chukchi Sea, headings were significantly clustered around 254°T (r = 0.32, z = 5.29, p<0.01).

Table 31. Number (No.) and percent (%) of belukhas found in each ice cover class, 1982-87.

Ice Cover (%)	September		October		Total	
	No.	(%)	No.	(%)	No.	(%)
0-10	221	(14)	291	(21)	512	(17)
11-20	65	(4)	43	(3)	108	(4)
21-30	78	(5)	6	(0)	84	(3)
31-40	19	(1)	9	(1)	28	(1)
41-50	72	(4)	25	(2)	97	(3)
51-60	65	(4)	4	(0)	69	(2)
61-70	210	(13)	110	(8)	320	(11)
71-80	266	(17)	387	(28)	653	(22)
81-90	566	(35)	440	(31)	1006	(33)
91-99	46	(3)	86	(6)	132	(4)
Total	1608		1401		3009	

Belukhas seen in the Alaskan Beaufort and northeastern Chukchi Seas in September and October are part of a population estimated at 11,500 (Davis and Evans, 1982) that summers in the Canadian Beaufort and overwinters in the Bering and southern Chukchi Seas. Most of the migration through the Alaskan Beaufort appears to pass through offshore areas (Ljungblad et al., 1987), although sightings have been made in shallow nearshore areas as well. As the whales approach Point Barrow, the migration path has generally followed the 50-m isobath closer to shore. In 1987, an exceptionally light-ice year, belukha distribution was further offshore in the study area (see figure 16) and the migration did not appear to follow the 50-m contour. Although ice conditions appeared similar, the observed distribution in 1986 (Ljungblad et al., 1987) was somewhat different from that seen in 1987. Belukhas were in significantly deeper water in 1987 ($\bar{x}$ = 853m, 1004 s.d., n = 50) than in 1986 ($\bar{x}$ = 421m, 588 s.d., n = 31; t' = 2.44; $p < 0.01$). The apparent variation in observed distribution may have been because transect surveys were flown north of established survey blocks (north of 72°N) for the first time in 1987. However, a comparison of abundance indices in "unblocked areas" north of 72°N between 1986 (1 belukha/5.43 hours survey effort = 0.18) and 1987 (138 belukhas/17.48 hours survey effort = 7.89) supports the idea that the belukha migration in 1987 was farther offshore than in 1986. Notably, belukhas were not recorded at the acoustic monitoring station in Barrow in 1987.

b. Walrus

Since 1982, 5483 walruses have been seen in the western Alaskan Beaufort and northeastern Chukchi Seas in September and October (figure 27). Walruses are usually associated with the pack ice edge (Fay, 1981), and nearly half (46%, n = 2546) of the total were seen in 1983 (table 32), when the ice was exceptionally heavy (Ljungblad et al., 1984). Forty-one percent (n = 2225), however, were seen in 1987, an exceptionally light-ice year when the only ice present during most of the season was occasional broken floe. Between 1982-86, the majority of walruses were seen in October (65%, n = 2124), possibly due to the seasonal increase in ice cover during that month. In 1987, most walruses were seen in September (99%, n = 2195), with few seen in October (1%, n = 30) when very little broken floe ice was available to haul out on and the ice edge was far to the north (see figure 21). Overall, walruses have been found in all ice covers (table 32), with the majority (47%, n = 2530) in moderate cover (31-70%).

The distribution of walruses has been widespread (figure 27), and appears to be dependent on the presence of ice suitable for hauling out as well as the availability of food. The distribution of sightings in 1987 was similar to that in 1986 (Ljungblad et al., 1987), and comprehensive of all other years except 1983, when walruses were found closer to shore. The difference in distribution in 1983 may have been due to the extremely heavy-ice cover that persisted throughout as walruses tended to stay with the ice edge nearshore. Areas of most intense walrus feeding have been identified in the northeastern Chukchi Sea (Nelson and Johnson, 1987; Phillips, 1987) south of Hanna Shoal, located roughly within the northern half of blocks 14 and 15, which is an area where repeated pack ice advancement and retreat have been observed for the last two summers (Phillips, 1987). Walruses were seen there in abundance in 1987 (1680 walruses/19.2 hours survey effort = 87.5 walruses per unit effort), although abundance indices in 1986, when ice conditions were similar, were much lower (88 walruses/23.9 hours survey effort = 3.68 walruses per unit effort). The difference between these two fall seasons may have been the absence of broken floe ice suitable for hauling out in fall 1986, which may have deterred walruses from migrating to the area.

The variability in observed distribution and abundance between years, particularly 1983, 1986, and 1987, illustrates the importance of ground-truthing through field observations, as opposed to analysis by passive means only (i.e., remote sensing/satellite imagery). Brueggeman et al. (1987) recommended the use

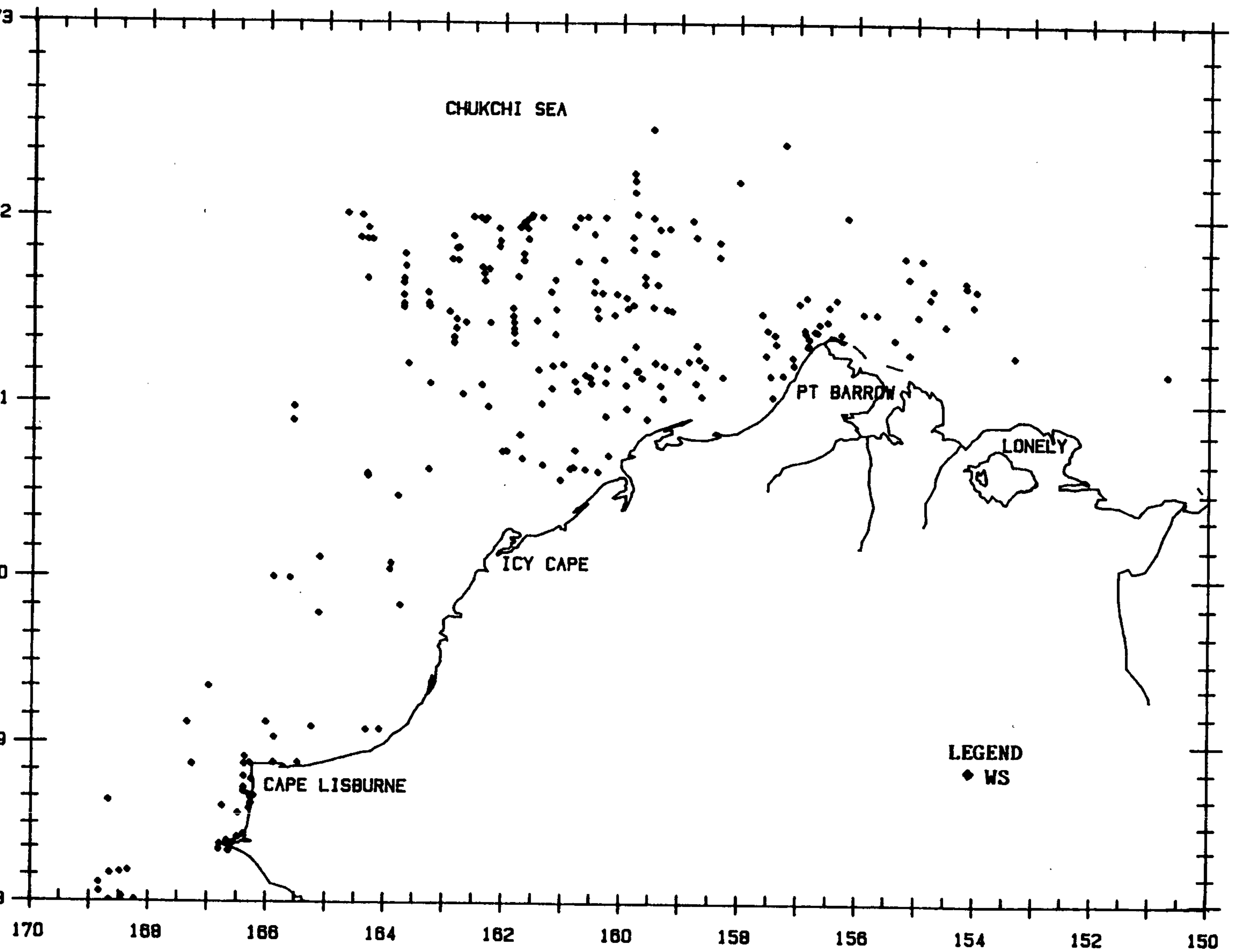


Figure 27. Distribution of 242 sightings of 5483 walrus, 1982-87.

Table 32. Monthly summary of walrus sightings (number of sightings/number of animals), and number (No.) and percent (%) of walruses found in each ice cover class, 1982-87.

Month Year	September	October	Total
1982	1/1	17/457	18/458
1983	42/906	36/1640	78/2546
1984	13/129	3/3	16/132
1985	0	0	0
1986	42/98	8/24	50/122
1987	79/2195	1/30	80/2225
Total	177/3329	65/2154	242/5483

Ice Cover	September		October		Total	
(%)	No.	(%)	No.	(%)	No.	(%)
0-10	270	(8)	240	(11)	510	(9)
11-20	610	(18)	0		610	(11)
21-30	178	(5)	1	(0)	179	(3)
31-40	100	(3)	30	(1)	130	(2)
41-50	77	(2)	1433	(67)	1510	(28)
51-60	367	(11)	2	(0)	369	(7)
61-70	495	(15)	26	(1)	521	(10)
71-80	181	(6)	4	(0)	185	(3)
81-90	261	(8)	411	(19)	672	(12)
91-100	790	(24)	7	(1)	797	(15)
TOTAL	3329		2154		5483	

of a combination of sea-ice monitoring systems, including NOAA and Landsat satellites, to monitor pack ice advancements, but whether these systems are adequate enough to predict annual animal distributions is unclear. In 1983, a heavy-ice year when most of the northeastern Chukchi Sea was covered with ice throughout fall, the distribution of walruses followed closely that of the ice edge and was extremely nearshore. Highest walrus abundance was in block 22 (1491 walruses/3.6 hours survey effort = 414.2 walruses per unit effort), with relatively high abundance in other nearshore blocks (block 17 = 76.0; block 13 = 13.3). In 1986 and 1987, the ice edge was well north of study area survey blocks throughout most of fall. Based on 1983 results, one would except walrus distribution in 1986-87 to be along the ice edge, well north of 72°N. However, few walruses were seen there. Instead, walruses in 1986 were seen swimming in nearly completely ice-free water in small groups (2-25 individuals) throughout the northeastern Chukchi Sea, with relatively low abundance indices (1.04 walruses per unit effort). In 1987, walruses were distributed among the occasional broken floes in predominantly open water throughout the northeastern Chukchi with significantly higher abundance indices, particularly in september (25.99 walruses per unit effort). Remote sensing and satellite imagery may not have detected the subtle differences in ice conditions between 1986 and 1987. Had those techniques been relied on exclusively without the benefit of field observations, inaccurate conclusions may have been drawn with regard to walrus distribution and abundance, including (a) the distribution of walruses in fall 1986 and 1987 was along the pack ice edge (well north of the actual observed distribution) and (b) abundance indices in 1986 and 1987 were similar because of seemingly similar ice conditions (observed abundance indices were significantly different).

CONCLUSIONS AND RECOMMENDATIONS

Aerial surveys for endangered whales have been flown over the western Beaufort Sea OCS planning areas since 1979, with transect surveys over the eastern Chukchi Sea planning area beginning in 1982. Although there are obvious limitations inherent to aerial surveys, flying remains the best means of sampling these large offshore areas over a short time period. An endangered whale sighting data base compiled over several seasons provides an overview to patterns of habitat use and aids in decision making relative to the leasing and development of the Alaskan OCS. In 1986, an acoustic monitoring study was conducted from Barter Island, which provided additional information on bowhead whale temporal occurrence in the eastern Alaskan Beaufort Sea. In 1987, a similar passive acoustic monitoring study was conducted at the Barrow field station on an opportunistic basis. both studies underscored the utility of passive acoustic monitoring for bowheads during the fall migration by significiantly extending data-gathering periods and adding important information as to the temporal occurrence of bowheads within the acoustic study areas. The following is a conclusion summary and recommendations for future field efforts in the western Beaufort and eastern Chukchi Seas.

Endangered Whales in the western Beaufort Sea (1979-87)

Conclusions

1. Bowhead whales inhabit the western Beaufort Sea from mid-September through October. Whales are generally distributed from 15 km to 70 km from shore between Harrison Bay and Lonely, and from 1 km to 70 km from shore from Lonely to Point Barrow.
2. Bowhead whale relative abundance (WPUE) was highest in October for all but 2 years. Years in which relative abundance was higher in September were 1983, when the somewhat earllier timing of migration may have been related to the extremely heavy-ice conditions (Ljungblad et al., 1987); and 1984, when large aggregations of feeding whales were observed just east of Point Barrow in September (Ljungblad et al., 1986a).
3. The bowhead migration route across the western Beaufort Sea was centered about the 29-m median depth isobath. The annual variation in bowhead distribution along the migratory route was not as great as that

described for the eastern Alaskan Beaufort Sea (Ljungblad et al., 1987), nor as great as the annual variation in distribution described for bowheads summering in the Canadian Beaufort Sea (Richardson et al., 1985).

4. There may be some component of the bowhead population that migrates offshore and near the ice edge that go undetected during fall surveys of the western Beaufort Sea. Although some flights were conducted along portions of the ice front in 1987 with no bowheads seen, little survey effort has been expended north of 72°N latitude to determine if bowheads are passing far offshore.

5. As described in Ljungblad et al. (1986, 1987), bowheads swimming through the western Beaufort stop to feed opportunistically, although not with the annual regularity that feeding is observed in the eastern Alaskan Beaufort Sea. Principal areas where bowheads have been seen feeding include waters along the shelf break just north of Harrison Bay, nearshore waters just east of Point Barrow, and coastal waters southwest of Barrow.

6. Bowhead calls recorded during the fall migration from shore-based acoustic monitoring stations were mostly tonal (FM) "moans". These calls have been associated most often with swimming and resting whales, while the more strident (AM) "growl" and "trumpet" calls, which have been recorded during peak-call days at the acoustic stations, are associated with socializing whales (Ljungblad et al., 1986; Würsig et al., 1985).

7. Call rates recorded at the shore-based acoustic stations peaked on days associated with aerial survey sighting rate peaks, indicating that passive acoustic data reflected the passage of migrating whales in a similar fashion to visual sighting rates. Passive acoustic monitoring provided important additional data on bowhead temporal occurrence during the 1986 and 1987 fall migrations.

Recommendations

1. Line transect aerial surveys should be routinely extended to 73°N in the vicinity of Point Barrow (blocks 12-N and 13-N) to further assess the annual variation of bowhead distribution from shore and to determine if there is a component of the fall migration that passes Point Barrow significantly farther offshore than that observed since 1979.

2. In addition to conducting transect surveys in the established survey blocks, transect surveys should be conducted along the ice edge to assess bowhead occurrence there. It has been reported that bowheads are strongly associated with the ice edge as they over-winter in the Bering Sea (Bruggeman et al., 1987; Ljungblad et al., 1986b: appendix E). A similar association may exist during the fall offshore over water deep enough to permit ice-induced upwelling. Upwelling may provide localized areas of productivity leading to bowhead feeding opportunities along the ice edge.

3. Passive acoustics should be used to monitor for bowheads during the fall migration both at Barter Island and Barrow. The utility of the Barrow station would be greatly enhanced if sonobuoys modified for extended service could be moored directly north of the Point Barrow peninsula, thereby eliminating the acoustic shadowing caused by the peninsula in 1987 and extending data acquisition time. The success of acoustic monitoring during 1986 and 1987 recommends this relatively inexpensive technique as a useful tool in determining when bowheads are in a local area.

4. Bowhead relative abundance indices for the Alaskan Beaufort Sea should be calibrated using absolute density estimates by the "double sampling" methods outlined in Eberhardt and Simmons (1987).

Endangered whales in the northeastern Chukchi Sea (1982-87)

Conclusions

1. Gray whales are commonly seen nearshore between Point Barrow and Icy Cape in September and October; most of the grays seen are associated with mud plumes and seem to be feeding.

2. Gray whales were seen feeding approximately 160 km northwest of Barrow in 1986 and 1987. Relative abundance in this area was higher in 1986 than in 1987, indicating that use of this area for feeding varies between years.

3. Gray whale relative abundance has been highest over the years nearshore west of Barrow and near Point Hope; the ratio of calves has also been highest in these areas.

4. Bowheads have been seen in the northeastern Chukchi Sea from late September through October; the swimming direction of whales seen has been

significantly clustered about a southwest direction indicating at least some whales swim around Point Barrow and disperse across the Chukchi Sea crossing roughly over Herald Shoal.

5. Bowhead and gray whales are seen in the northeastern Chukchi Sea in late September and early October, but there is not much overlap in their temporal or spatial occurrence (Moore et al., 1986a).

Recommendations

1. Aerial surveys over the northeastern Chukchi Sea should be continued with effort in established survey blocks stratified by gray whale relative abundance to further quantify feeding and calf weaning habitats.

2. An extension of transect surveys to the offshore ice edge in the northeastern Chukchi Sea could provide additional information on bowhead and (possibly) gray whale use of this area.

3. Resumption of surveys in the southern Chukchi Sea (i.e. blocks 23-25, Ljungblad et al., 1986) inlcuding the coastal areas of Kotzebue Sound could provide additional information on the importance of this area for gray whale calves, and possibly belukha temporal occurrence.

PERSONAL COMMUNICATION LIST

1. Byron Morris, National Marine Fisheries Service, Anchorage, AK, 99513

2. Douglas Chapman, C8S-HR20, University of Washington, Seattle, Washington, 98195

3. Judith Zeh, Department of Statistics, GN-22, University of Washington, Seattle, Washington, 98195

REFERENCES

Bockstoce, J.R. 1986. Whales, Ice and Men. The History of Whaling in the Western Arctic. University of Washington Press, Seattle, WA. 400 pp.

Bockstoce, J.R. and D.B. Botkin. 1983. The historical status and reduction of the western arctic bowhead whale (Balaena mysticetus) population by the pelagic whaling industry, 1948-1914. Rep. int. Whal. Commn. (Sepc. Iss. 5): 107-141.

Bogoslovskaya, L.S., L.M. Votrogov, and T.N. Semenova. 1981. Feeding habits of gray whales off Chukotka. Rep. int. Whal. Commn. 31: 507-510.

Braham, H.W., M.E. Dahlheim, and L.D. Consiglieri. 1981. Killer whales in Alaska from at-sea sightings documented in the U.S. platforms of opportunity program. MS submitted to int. Whal. Commn. SC/JN81/KW2, 10 pp.

Braham, H.W., B.D. Krogman, and G.M. Carroll. 1984. Bowhead and white whale migration, distribution, and abundance in the Bering, Chukchi and Beaufort Sea, 1975-78. NOAA Technical Report NMFS SSRF-778. 39 pp.

Beiwick, J.M., E.D. Mitchell, and D.G. Chapman. 1981. Estimated initial population size of the Bering Sea stock of bowhead whale (Balaena mysticetus): an iterative method. U.S. Fish. Bull. 78(4): 843-853.

Brueggeman, J.J., B. Webster, R. Grotefendt, and D. Chapman. 1987. Monitoring of the winter presence of bowhead whales in the Navarin Basin through association with sea ice. OCS Study, MMS 87-0028. Prepared by Envirosphere Co., prepared for Minerals Management Service. 195 pp.

Caughley G. 1974. Bias in aerial survey. J. Wildl. Manage. 38: 921-933.

Caughley, G. 1977. Analysis of vertebrate populations. John Wiley and Sons, New York, NY. 234 pp.

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

Clark, C.W. 1983. The use of bowhead vocalization to augment visual censusing estimates on the number of whales migrating off Barrow, Alaska in the spring of 1980. Paper SC/35/PS13 to the IWC Scientific Committee, June 1983 (unpublished). 20 pp.

Clark, C.W., W.T. Ellison, and K. Beeman. 1985. Acoustic tracking and distribution of bowhead whales, Balaena mysticetus, off Point Barrow, Alaska in the spring of 1984. Paper SC/37/PS11 to the IWC Scientific Committee. June 1985 (unpublished). 25 pp.

Clark, C.W., W.T. Ellison, and K. Beeman. 1986. A preliminary account of the acoustic study conducted during the 1985 spring bowhead whale Balaena mysticetus migration off Point Barrow, Alaska. Rep. int. Whal. Commn. 36: 311-16.

Clark, C W. and J.H. Johnson. 1984. The sounds of the bowhead whale (Balaena mysticetus) during the spring migrations of 1979 and 1980. Can. J. Zool. 62(7): 1436-1441.

Clarke, J.T., S.E. Moore, and D.K. Ljungblad. 1987a. Observations of bowhead whale (Balaena mysticetus) calves in the Alaskan Beaufort Sea during the autumn migration, 1982-85. Rep. int. Whal. Commn. 37: 287-293.

Clarke, J.T., S.E. Moore, and D.K. Ljungblad. 1987b. Observations on gray whale (Eschrichtius robustus) utilization patterns in the northeastern Chukchi Sea, July-October 1982-86. Paper SC/39/PS3 to the IWC Scientific Committee. June 1987 (unpublished). 23 pp.

Cleator, H., I. Stirling, and T.G. Smith. 1987. Geophysical variation in the repertoire of the bearded seal. Abstract. Seventh Biennial Conference on the Biology of Marine Mammals, Miami, FL, 5-9 December 1987.

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

Courtrage, C.S. and S. Braund, Assoc. 1984. Barrow Arch socioeconomic and sociocultural description. Social and Economics Studies Program, MMS Tech. Rep. 101.

Cummings, W.C. and D.V. Holliday. 1983. Source level of bowhead whale sounds determined by acoustical array localization. J. Acoust. Soc. Am. (Suppl. 1) 74: 555.

Davis, R.A. and C.R. Evans. 1982. Offshore distribution and numbers of white whales in the eastern Beaufort Sea and Amundsen Gulf, Summer 1981. Rep. by LGL Limited, Toronto, Ontario, for Sohio Alaska Petroleum Company, Anch., AK, and Dome Petroleum Limited, Calgary, Alberta. 76 pp.

Durham, F.E. 1979. The catch of bowhead whales (Balaena mysticetus) by Eskimos, with emphasis on the western Arctic. Natural History Museum of Los Angeles County Contributions in Science 314: 1-14.

Eberhardt, L.L. and F. Simmons. 1987. Calibrating population indices by double sampling. J. Wildl. Manage. 51(3): 665-675.

ESL Environmental Sciences Limited. 1986. Beaufort Environmental Monitoring Project 1984-1985 Final Reort, Environmental Studies No. 39, Northern Affairs Program, Catalogue No. R71-19/39-1986E. 162 pp.

Estes, J.A. and J.R. Gilbert. 1978. Evaluation of an aerial survey of Pacific walruses (Odobenus rosmarus divergens). J. Fish. Res. Board. Can. 35: 1130-1140.

Fay, F.H. 1981. Walrus. pp. 1-23, In: Handbook of Marine Mammals, Vol. 1, S.H. Ridgway and R.J. Harrison (eds.). Academic Press, London. 235 pp.

Hayne, D.W. 1949. An examination of the strip census method for estimating animal populations. J. Wildl. Mgt. 13: 145-147.

Houghton, J.P., D.A. Segar, and J.E. Zeh. 1984. Beaufort Sea monitoring program: Proceedings of a Workshop (September 1983) and Sampling Design Recommendations. Prepared for the OCS Assessment Program Juneau, Alaska; Prepared by Dames and Moore, Seattle, Washington. 111 pp.

IWC. 1988. Report of the Sub-Committee on protected species and aboriginal subsistence whaling, Rep. int. Whal. Commn. (Annex H.) 36: xx-xx.

Krupnik, I.I., L.S. Bogoslovskaya, and L.M. Votrogov. 1983. Gray whaling off the Chukotka Peninsula: past and present status. Rep. int. Whal. Commn. 33: 557-562.

LaBell, J.C., J.L. Wise, R.P. Voelker, R.H. Schulze, and G.M. Wohl. 1983. Alaska Marine Ice Atlas. AEIDC, University of Alaska, Anchorage, AK. 302 pp.

Ljungblad, D.K. 1981. Aerial surveys of endangered whales in the Beaufort Sea, Chukchi Sea, and northern Bering Sea. NOSC TD 449, prepared for MMS Alaska OCS OFfice. 302 pp.

Ljungblad, D.K. and S.E. Moore. 1982. Acoustic source level of the bowhead whale (Balaena mysticetus). Unpubl. MS. NOSC 1-82. 8 pp.

Ljungblad, D.K. and S.E. Moore. 1983. Killer whales (Orcinus orca) chasing gray whales (Eschrichtius robustus) in the northern Bering Sea. Arctic 26(4): 361-364.

Ljungblad, D.K., S.E. Moore, J.T. Clarke, and J.C. Bennett. 1987. Distribution, abundance, behavior and bioacoustics of endangered whales in the Alaskan Beaufort and eastern Chukchi Seas, 1979-86. NOSC TR 1177, prepared for MMS Alaska OCS Office. 391 pp.

Ljungblad, D.K., S.E. Moore, and J.T. Clarke. 1986a. Assessment of bowhead whale (Balaena mysticetus) feeding patterns in the Alaskan Beaufort and northeastern Chukchi Seas via aerial surveys, Fall 1979-84. Rep. int. Whal. Commn. 36: 265-272.

Ljungblad, D.K., S.E. Moore, J.T. Clarke, and J.C. Bennett. 1986b. Aerial surveys of endangered whales in the northern Bering, eastern Chukchi and Alaskan Beaufort Seas, 1985: with a seven year review, 1979-85. NOSC TR 1111, prepared for MMS Alaska OCS Office. 409 pp.

Ljungblad, D.K., S.E. Moore, J.T. Clarke, D.R. Van Schoik, and J.C. Bennett. 1985a. Aerial surveys of endangered whales in the northern Bering, eastern Chukchi, and Alaskan Beaufort Seas, 1984: with a six year review, 1979-1984. NOSC TR 1046, prepared for MMS Alaska OCS Office. 301 pp.

Ljungblad, D.K., S.E. Moore, and D.R. Van Schoik. 1984. Aerial surveys of endangered whales in the Northern Bering, eastern Chukchi and Alaskan Beaufort Seas, 1983: with a five year review, 1979-83. NOSC TR 955, prepared for MMS Alaska OCS Office. 356 pp.

Ljungblad, D.K., S.E. Moore, and D.R. Van Schoik. 1983. Aerial surveys of endangered whales in the Beaufort, Chukchi and northern Bering Seas, 1982. NOSC TD 605, prepared for MMS Alaska OCS Office. 382 pp.

Ljungblad, D.K., S.E. Moore, and D.R. Van Schoik. 1986c. Seasonal patterns of distribution, abundance, migration and behavior of the western Arctic stock of bowhead whales, Balaena mysticetus in Alaskan Seas. Rep. int. Whal. Commn. (Spec. Iss. 8): 177-205.

Ljungblad, D.K., S.E. Moore, D.R. Van Schoik, and C.S. Winchell. 1982a. Aerial surveys of endangered whales in the Beaufort, Chukchi and northern Bering Seas. NOSC TD 486, prepared for MMS Alaska OCS Office. 374 pp.

Ljungblad, D.K., M.F. Platter-Rieger, and F.S. Shipp, Jr. 1980. Aerial surveys of bowhead whales, North Slope, AK. NOSC TD 314, prepared for MMS Alaska OCS Office. 188 pp.

Ljungblad, D.K., P.O. Thompson, and S.E. Moore. 1982b. Underwater sounds recorded from migrating bowhead whales, (Balaena mysticetus), in 1979. J. Acoust. Soc. Am. 71(2): 477-482.

Ljungblad, D K., B. Würsig, and S.L. Swartz. 1985b. Observations on the behavior of bowhead whales (Balaena mysticetus) in the presence of operating seismic exploration vessels in the Alaskan Beaufort Sea. Final Report prepared for the Minerals Management Service, prepared by SEACO, Inc. 78 pp.

Miles, P.R., C.I. Malme, and W.J. Richardson. 1987. Prediction of drilling site-specific interaction of industrial acoustic stimuli and endangered whales in the Alaskan Beaufort Sea. OCS Study, MMS 87-0084, prepared by BBN Laboratories Inc. and LGL environmental research assoc., prepared for MMS, Alaska Outer Continental Shelf Region. 341 pp.

Milne, A.R., J.H. Ganton, and D.J. McMillin. 1967. Ambient noise under sea ice and further measurements of wind and temperature dependence. J. Acoust. Soc. Am. 41(2): 525-528.

Moore, S.E., J.T. Clarke, and D.K. Ljungblad. 1986a. A comparison of gray whale (Eschrichtius robustusj) and bowhead whale (Balaena mysticetus) distribution, abundance, habitat preference and behavior in the northeastern Chukchi Sea, 1982-84. Rep. int. Whal. Commn. 36: 273-279.

Moore, S.E., D.K. Ljungblad, and D.R. Van Schoik. 1986b. Annual patterns of gray whale (Eschrichtius robustus) distribution, abundance and behavior in the northern Bering and eastern Chukchi Seas, July 1980-1983. Rep. int. Whal. Commn. (Spec. Iss. 8): 231-242.

Moore, S.E., J.C. Bennett, and D.K. Ljungblad. 1987. Comparisons of observed patterns of bowhead whale (Balaena mysticetus) bathymetric habitat preference to describe the fall migration route across the Alaskan Beaufort Sea, 1979-86. Paper SC/39/PS2 to the IWC Scientific Committee. June 1987 (unpublished). 17 pp.

Naval Hydrographic Office. 1956. Aerial Ice Reconnaissance and Functional Glossary of Ice Terminology. Hydrographic Office Publication Number 609. 14 pp.

Nelson, C.H. and K.R. Johnson. 1987. Whales and walruses as tillers of the sea floor. Sci. Am.

Nerini, M.K. 1984. A review of gray whale (Eschrichtius robustus) feeding ecology. pp. 423-450, In: The Gray Whale, M.L. Jones, S.L. Swartz and J.S. Leatherwood (eds.). Academic Press Inc., San Francisco, CA. 600 pp.

Pease, C. 1987. Ice flow along the coasts. (Oral presentation). MMS Information Transfer Meeting, Anchorage AK 17-20 November, 1987.

Phillips, R.L. 1987. Summary of geology, processes, and potential geohazards in the northeastern Chukchi Sea. OCS Env. Assess. Prog., Chukchi Sea Information Update, June 1987: 21-31.

Pollock, K.H. and W.L. Kendall. 1987. Visibility bias in aerial surveys: a review of estimation procedures. J. Wildl. Manage. 51(2): 502-510.

Porter, W.F. and K.E. Church. 1987. Effects of environmental pattern on habitat preference analysis. J. Wild. Mange. 51(3): 681-685.

Reilly, S.B., D.W. Rice, and A.A. Wolman. 1983. Population assessment of the gray whale, (Eschrichtius robustus), from California shore censuses, 1967-80. Fish. Bull. 81(2): 267-281.

Richardson, W.J., B. Würsig, and C.R. Greene. 1986. Reactions of bowhead whales, Balaena mysticetus, to seismic exploration in the Canadian Beaufort Sea. J. Acoust. Soc. Am. 79(4): 1117-1128.

Samuel, M.D., E.O. Garton, M.W. Schlegel, and R.G. Carson. 1987. Visibility bias during aerial surveys of elk in northcentral Idaho. J. Wildl. Manage. 51(3): 622-630.

Stirling, I., W. Calvert, and H. Cleator. 1983. Underwater vocalizations as a tool for studying the distribution and relative abundance of wintering pinnipeds in the high arctic. Arctic 38(3): 262-274.

Stringer, W.J. and J.E. Groves. 1987. Summertime sea ice intrusions in the Chukchi Sea. OCS Env. Assess. Prog. Chukchi Sea Update, June 1987: 33-41.

Thomas, J.A. and D.P. DeMaster. 1982. An acoustic technique for determining diurnal activities in leopard (Hydrurga leptonyx) and crabeater (Lobodon carcinophagus) seal. Can. J. Zool. 60: 2028-2031.

Thomas J.A., S.R. Fisher, L.M. Ferm, and R.S. Holt. 1986. Acoustic detection of cetaceans using a towed array of hydrophones. Rep. int. Whal. Commn. Spec. Iss. 8: 139-148.

Urick, R.J. 1983. Principles of Underwater Sound, 3rd ed. McGraw-Hill Book Co. New York, New York. 423 pp.

Webster, B.D. 1982. Empirical probabilities of the ice limit and fifty percent ice concentration boundary in the Chukchi and Beaufort seas. National Weather Service, U.S. National Oceanic and Atmospheric Administration, Anchorage, AK NOAA Technical Memorandum NWS AR-34. 9 pp.

Würsig, B., C.W. Clark, E.M. Dorsey, M.A. Fraker, and R.S. Payne. 1985. Normal behavior of bowheads, 1980-84. pp. 13-88, In: Behavior, distrubance responses and distribution of bowhead whales (Balaena mysticetus) in the eastern Beaufort Sea, 1980-84, W.J. Richardson (ed.). Report by LGL Ecol. Res. Assoc., Inc. for U.S. MMS. 306 pp.

Zar, S.H. 1984. Biostatistical Analysis. Prentice Hall, Inc., Englewood Cliffs, N.J. 620 pp.

Zeh, J.E., P. Turet, R. Gentleman, and A.E. Raftery. 1987. Population size estimation for the bowhead whale, Balaena mysticetus, based on 1985 and 1986 visual and acoustic data. Paper SC/39/PS7 to the IWC Scientific Committee. June 1987 (unpublished). 40 pp.