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Bowhead and White Whale Migration, Distribution, and Abundance in the Bering, Chukchi, and Beaufort Seas, 1975-78

Howard W. Braham, Bruce D. Krogman, and
Geoffrey M. Carroll

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

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741. Distribution of gammaridean Amphipoda (Crustacea) in the Middle Atlantic Bight region. By John J. Dickinson, Roland L. Wigley, Richard D. Brodeur, and Susan Brown-Leger. October 1980, iv + 46 p., 26 figs., 52 tables.

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John V. Byrne, Administrator
National Marine Fisheries Service
William G. Gordon, Assistant Administrator for Fisheries

PREFACE

This is a final report from Outer Continental Shelf Environmental Assessment Program (OCSEAP) Research Unit 69/70 supported by the U.S. Bureau of Land Management (BLM) and is for the period September 1975 to March 1978. Because a great deal of additional research has been conducted since 1978, as part of an expanded National Marine Fisheries Service (NMFS) program, we felt it important to update our original unpublished final report submitted to OCSEAP in September 1979 in order to reflect some new data, clarify past statements, and in general provide more timely information for managers. The title of the first edition 1979 report was "Population biology of the bowhead whale (*Balaena mysticetus*) II: Migration, distribution, and abundance in the Bering, Chukchi, and Beaufort Seas, with notes on the distribution and life history of white whales (*Delphinapterus leucas*)."

This report is not comprehensive because our OCSEAP research was general in scope and the entire study area could not be covered completely. Some of the new information added to this report came from other programs supported by the NMFS from 1978 to 1981.

Some of the recommended research we propose in this report, dating back to 1978, have been undertaken through BLM. This report, however, does not reflect recent research directly supported by them. Again, we do not claim to have covered the breadth and depth of bowhead whale research, and recognize that much more work is needed on both species.

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HOWARD W. BRAHAM, BRUCE D. KROGMAN, and GEOFFREY M. CARROLL[1]

ABSTRACT

From September 1975 to September 1977 we conducted field research on bowhead, *Balaena mysticetus*, and white, *Delphinapterus leucas*, whales in the U.S. Bering, Chukchi, and Beaufort Seas. The objectives were to determine the general distribution and migration of these whales in spring and autumn and to estimate abundance. We also surveyed the literature beginning in June 1975 through March 1978 to augment our empirical results.

Bowhead and white whales spend the winter months among the pack ice and open water of the central and western Bering Sea. They migrate into the eastern Chukchi Sea and across the southern and central Beaufort Sea from April through June. Their route takes them along the west side of the northern Bering Sea through Bering Strait, along the northwest coast of Alaska between Point Hope to Point Barrow, generally within 50 km of shore (closer to Point Barrow than off Point Hope and Cape Lisburne), and offshore in the Beaufort Sea generally to within 60 km of the coast. Exceptions exist, and these are pointed out in the text.

It appears that virtually the entire bowhead migration follows this pattern; however, white whales may be divided into groups (or stocks) of varying sizes, some occurring in Bristol Bay, Norton Sound, Kotzebue Sound, and along the northwest coast of Alaska during summer. The largest component of the white whale population migrates into the Canadian Beaufort Sea in spring at roughly the same time as the bowheads. Autumn migration results were not obtained, generally, for either species.

The 1978 minimum estimate of the size of the bowhead population was 1,800 to 2,900 individuals, and for the white whales occurring in Alaskan waters between 9,000 and 16,000 individuals.

INTRODUCTION

In 1975 the Outer Continental Shelf Environmental Assessment Program (OCSEAP) Office awarded a contract to the Marine Mammal Division (now the National Marine Mammal Laboratory) of the Northwest and Alaska Fisheries Center, NMFS, to study the bowhead whale, *Balaena mysticetus*, and white whale, *Delphinapterus leucas*, in the Bering, Chukchi, and Beaufort Seas. The objectives were to summarize the current state of knowledge on each population, define migration routes and timing, and make an estimate of population size from original field research and a review of the literature. Field research was funded from September 1975 to September 1977.

This report is the final of two reports written under OCSEAP contract number R7120807, research unit 69/70. Braham and Krogman (1977)[2] covered our first full year's research, 1976. All significant research findings, including those already reported on in our other OCSEAP reports, are incorporated into this report. This document is an update of the final report submitted to OCSEAP in September 1979.

During the course of our field research, information was acquired on spring movements of whales from St. Lawrence Island to Point Barrow. Research on bowhead and white whale distribution south of St. Lawrence Island was not extensive, nor was much information found in the literature. Also, our understanding of distribution in the Beaufort Sea was fragmentary, coming from scant data from our research, from Eskimo informants, and from early commercial whaling accounts. At the time this contract was active, specific oil lease sites were not known. Therefore, our research was directed only at a general understanding of these species.

In 1978, the National Marine Fisheries Service expanded its research on bowhead whales, with the principal objectives of determining population size and obtaining information on life history parameters. Data acquired during the 1978 and 1979 field seasons are reported in Braham et al. (1979, 1980c, d, e). Further analyses, and reports, are continuing. Where applicable, information from these papers is presented here.

The bowhead whale is the most depleted marine mammal occurring in Arctic and sub-Arctic waters of the Northern Hemisphere. Under the Endangered Species Act of 1973, no human activities of any kind can take place which are likely to jeopardize the continuing existence of a species or population. Proposed OCS development for oil and gas in the Beaufort, Chukchi, and Bering Seas includes habitat essential for the survival of this population.

Results presented in this report represent the first research funded by a U.S. Federal agency to provide baseline information on the endangered bowhead whale in relation to proposed OCS development.

STUDY AREA AND DATA SOURCES

Study Area

The study area included the eastern Bering Sea, the Chukchi Sea east of the USA-USSR 1867 Convention Line, and

[1]National Marine Mammal Laboratory, National Marine Fisheries Service, NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.

[2]Braham, H. W., and B. D. Krogman. 1977. Population biology of the bowhead (*Balaena mysticetus*) and beluga (*Delphinapterus leucas*) whales in the Bering, Chukchi and Beaufort Seas. Processed rep., 29 p. Natl. Mar. Mammal Lab., Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.

the Beaufort Sea to the United States-Canadian border at long. 141°W.

Sea ice covering the Chukchi Sea begins to advance south in early October from its most northerly limit near lat. 72°-74°N and extends well into the Bering Sea through June during average ice years (Shapiro and Burns 1975). Sea ice is present winter and spring over most of the intercontinental shelf of the northern and eastern Bering Sea and occurs infrequently in the southwestern Bering Sea. With the progression of winter, landfast ice develops most extensively in bays and inlets that are protected from the shearing forces of mobile drift (sea) ice. Landfast ice increases outward from shore to the 12-30 m depth contour. Along the northwest coast of Alaska from Point Hope to Point Barrow in spring, a persistent flaw or transition zone occurs between the landfast ice and pack ice where open water often is found. These open water pathways are called leads when they are long and thin; when the openings are persistent and lake-like, they are called polynyas. The importance of polynyas has recently been summarized by Stirling (1980). It is this transition zone which is used by migrating bowhead and white whales. The transition zone may exceed 50 km in width near Cape Lisburne and Point Hope during some years (pers. obs.; Burns et al. 1977[3]); east of Point Barrow into the Beaufort Sea the zone occurs farther offshore (Marko 1975).

Shelf waters of the Beaufort Sea are typically ice-free from late July to September or early October, but northernly winds may keep or blow the pack ice near or against the coastline at any time (Blood 1977[4]).

Data Sources

Aerial surveys were used to study the spatial distribution of bowhead and white whales throughout the Bering, Chukchi, and Beaufort Seas. Data collected during these surveys have been digitized, stored in the National Marine Mammal Laboratory computer file library (Appendix I), and submitted to the Environmental Data Service (EDS), NOAA.

Spring migration and temporal distribution of bowhead and white whales along the northwest coast of Alaska were studied from ice and land stations near Point Barrow, Cape Lisburne, and Point Hope. Since data collected at these field sites during 1976 and 1977 were analyzed by hand (not digitized for computer analysis), they were not submitted to EDS.

METHODS AND MATERIALS

Ice and Land Camps

During the spring migration, counts of bowhead and white whales were maintained on a 24-h basis as conditions allowed at the following localities: Fast ice edge near Point Barrow (25 April-2 June 1976 and 19 April-3 June 1977); cliffs at Cape Lisburne (6-15 May 1977); and fast-ice edge off Point Hope (18 April-28 May 1977). One or two observers stood 4-h watches.

As whales moved past observers, the following information was scored: Number of animals; direction of travel; general behavior; weather conditions; time of day; and, when possible, length of time animal(s) spent at the surface and duration of dive.

In 1978, an upgraded counting effort was conducted at Point Barrow, Alaska, using two counting stations (Braham et al. 1979). The camps, called South Camp and North Camp, worked with each other, 15 April-5 June. South Camp observers made the primary counts and, through radio communication to North Camp, North Camp observers evaluated South Camp's results. The watch schedule during 1978 was two observers per shift rotating each 3 h. Documentation of current ice camp counting procedures and theory is reported in Krogman et al. (1979)[5] and Krogman (1980). In addition to the Barrow counts, counting was conducted at Cape Lisburne 2 April-7 June 1978.

Aerial Survey

Aerial survey procedures were designed to delineate nearshore and offshore distribution of whales, frequently over pack ice conditions. We flew the aircraft over open water—the leads or polynya—at elevations of 70-300 m depending upon cloud cover. Data collected on bowheads and white whales during OCSEAP studies RU 14 (Krogman et al. 1979[6]) and RU 67 (Braham et al.[7]) are included in this report. Aerial survey methodology for RU's 14 and 67 differed in the placement of flight tracks in that for those studies (walruses and seals) tracks were flown as straight lines irrespective of sea ice coverage. Because this report presents aerial survey results by showing only tracklines and geographic positions of sightings, the two methodologies of aerial survey (systematic flying over open water versus straight tracklines) are analytically equivalent although no estimate of abundance is generated from either method. Aerial surveys were not flown to make estimates of bowhead abundance. This method was determined to be impractical (experimentally) and too costly.

Four aircraft types were used during the surveys for whale distribution: A single engine Cessna from Cape Smythe Air Service, Barrow, Alaska; a twin-engine Grumman Otter chartered from the Naval Arctic Research Laboratory, Barrow, or Cape Smythe Air Service; a twin-engine Grumman Goose and a Lockheed P-2V both chartered from the Office of Aircraft Services, U.S. Fish and Wildlife Service, Anchorage, Alaska. Depending on the aircraft used, one to five observers

[3]Burns, J. J., L. H. Shapiro, and F. H. Fay. 1977. The relationships of marine mammal distributions, densities, and activities to sea ice conditions. *In* Environmental assessment of the Alaskan continental shelf, annual reports of principal investigators for the year ending March 1977, Vol. 1, Receptors mammals. Unpubl. rep., p. 503-554. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Environ. Res. Lab., Boulder, Colo.

[4]Blood, D. A. 1977. Birds and marine mammals: the Beaufort Sea and the search for oil. Unpubl. rep., 12 p. Beaufort Sea Project, Dep. Fish. Environ., Can.

[5]Krogman, B. D., R. M. Sonntag, H. W. Braham, S. Savage, and G. W. Priebe. 1979. Arctic Whale Task ice camp survey format 1979 version. Unpubl. manuscr., 60 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.

[6]Krogman, B. D., H. W. Braham, R. M. Sonntag, and R. G. Punsly. 1979. Early spring distribution, density and abundance of the Pacific walrus (*Odobenus rosmarus*) in 1976. Unpubl. rep., 47 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.

[7]Braham, H. W., R. D. Everitt, B. D. Krogman, D. J. Rugh, and D. E. Withrow. 1977. Marine mammals of the Bering Sea: Preliminary analysis of distribution and abundance, 1975-76. Processed rep., 90 p. Natl. Mar. Mammal Lab., Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.

were used; the usual crew of two observers, one recorder, and one person resting aft rotated hourly to reduce observer fatigue. For the study period 1976-78, the Grumman Goose was by far the more frequently used aircraft.

Information recorded included species identification; number of adults and/or calves; local time of sightings; geographic position to 1 square nmi obtained from an onboard Global Navigation System-500; perpendicular angular distance from aircraft to animal(s) taken with an optical reading clinometer (Model PM-5/360 PC, by Suunto Oy of Finland); animal activity; and environmental data on weather, visibility, and ice. Complete documentation of aerial survey methodology used for this research is reported in Krogman et al. (1979)[8].

Laboratory Activities

Ice and land camp results are presented by locality by year. Length of season, total number of hours watched, percent of total hours watched, total number of whales counted, and indices to total number of whales passing by the counting camps are presented. Bowhead abundance indices for spring seasons 1976 and 1977 were computed as the sum of the products of rates per day for each day times 24 h. Histograms showing the daily index are used to illustrate temporal distribution that occurred during each field study. Indices are presented for bowheads only. The temporal distribution of white whales was too clumped to calculate a meaningful index.

Aerial survey results are presented in computer plots showing effort and sighting data. Numerical results accompanying the figures include the total number of adults and immatures observed, average group size, and standard deviation (SD) of average group size. A plot of all tracklines flown in 1976 and 1977 is displayed in Appendix II.

REVIEW OF BOWHEAD STOCKS

Rice (1977) recognized four bowhead whale populations or stocks worldwide: 1) From Spitsbergen west to east Greenland, called the Spitsbergen stock by Tomilin (1957) or Spitsbergen-Barents Sea stock by Jonsgard[9]; 2) in Hudson Bay, Davis Strait, Baffin Bay, and James Bay, called the West Greenland stock by Tomilin (1957) or Davis Strait stock by the International Whaling Commission (IWC) Committee of Scientific Advisors (IWC 1978); 3) Bering, Chukchi, and Beaufort Seas, called the Bering-Chukchi stock by Tomilin (1957), Bering Sea stock by the IWC (1978), or the western Arctic population by Durham (1972)[10] and Bockstoce (1977); and 4) in the Sea of Okhotsk. Mitchell (1975) recognized five stocks, treating a Hudson Bay stock as isolated from the West Greenland stock. Figure 1 is an overview of the species distribution prior to commercial exploitation.

Commercial whaling severly reduced the Spitsbergen stock during the 17th century, the West Greenland stock during the 18th century, and the western Arctic-Bering Sea and Okhotsk Sea stocks during the 19th century (Tomilin 1957; Braham and Krogman footnote 2; Bockstoce 1978[11]).

Spitsbergen-Barents Sea Stock

Bowheads from this stock apparently wintered south of the area bounded by the eastern coast of Greenland, Iceland, and Jan Mayen Island, to Spitsbergen (Tomilin 1957). Their northeasterly spring movement was associated with the recession of the ice front, with some whales arriving at Spitsbergen in April (Clark 1943). By early summer, most of the population was found between Greenland, Spitsbergen, and the Barents Sea, with some animals occurring south along the coast of Greenland when sea ice coverage was extensive (Vibe 1967). A southerly migration was made during autumn along the Greenland coast and open winter areas of the coast. From an initial population estimated at 25,000 (IWC 1978), the Spitsbergen-Barents Sea stock underwent a gross reduction in size as a result of intensive commercial whaling (Vibe 1967). This stock is now considered to be nearing extinction (Jonsgard 1981, footnote 9). Reeves (1980) recently completed a review of the stock.

West Greenland or Davis Strait Stock

Recent information on the seasonal distribution of bowheads in this stock is lacking. However they apparently winter in southern Davis Strait from Godhaven southwest to approximately lat. 60°00'N. Migration to summering grounds is closely associated with the northerly retreat of the ice front. The summering area and migration routes include northeast Baffin Bay as far north as Smith Sound (Clark 1943), the waters between the islands of the Canadian Arctic Islands and as far west as Barrow Strait (Gilmore 1951), Lancaster Sound, and Prince Regent Inlet (Lubbock 1937). Animals apparently winter also in Hudson Strait and southcentral and western Hudson Bay. In summer, animals move to the northwestern part of Hudson Bay and Foxe Basin (Gilmore 1951; Ross 1974). Sex and age segregation within the population was reported by Southwell (1898) to be that older males occurred more often in open water than females and young who were associated with the pack ice front. The initial stock size was estimated at 6,000 and the current level is believed to be 10% of that (IWC 1978). However, since so few animals have been seen in this century, it seems likely that the present population size is smaller than the 10% estimated.[12] Mansfield (1971) believed the stock was recovering; recent studies have not confirmed this (Davis and Koski 1980).

Western Arctic-Bering Sea Stock

The distribution of bowheads in the western Arctic-Bering Sea stock prior to commercial exploitation (1848) can be in-

[8]Krogman, B. D., R. M. Sonntag, and H. W. Braham. 1979. Arctic Whale Task aerial survey format 1979 version. Unpubl. manuscr., 30 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.

[9]A. Jonsgård, University of Oslo, Oslo, Norway, pers. commun. 7 February 1979.

[10]Durham, F. E. 1972. Biology of the bowhead whale (*Balaena mysticetus* L.) in the western Arctic. Unpubl. manuscr., 93 p. Univ. Southern Calif., Dep. Biol., Los Angeles, CA 90500.

[11]Bockstoce, J. R. 1978. A preliminary estimate of the reduction of the western Arctic bowhead whale (*Balaena mysticetus*) population by the pelagic whaling industry: 1848-1915. Unpubl. rep., 33 p. U.S. Mar. Mammal Comm., 1625 I St. N.W., Wash., DC 20006.

[12]R. Davis, LGL Ltd., Toronto, Can., pers. commun. 30 June 1979.

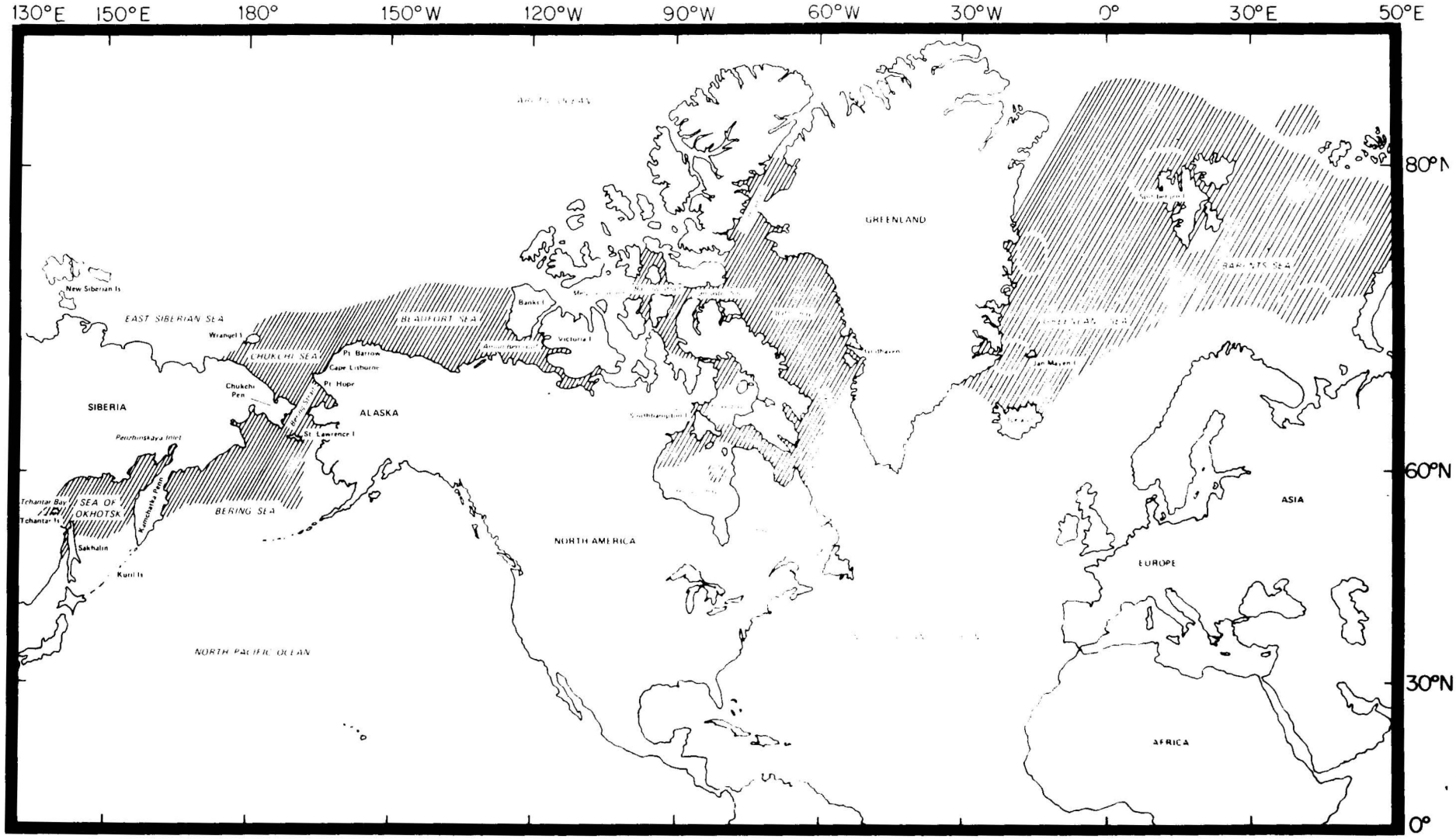


Figure 1.—Approximate world distribution of bowhead whales prior to commercial exploitation.

ferred from Townsend's (1935) charts which locate by month bowhead whales taken by Yankee whalers (Fig. 2). The whaling grounds were within lat. 53° to 73°N and long. 120°W to 175°E. Whaling occurred in the Bering Sea from April to July and, in the Chukchi and Beaufort Seas, generally from August to October. The lack of harvest records north of the Bering Strait during April and May is explained by the avoidance of heavy ice by whalers. Very few whales were taken in the eastern Bering Sea, suggesting that the species was formerly distributed off the continental shelf in the southwest Bering Sea and over the shelf in the west central and northern Bering Sea during the winter, spring, and early summer months.

Initial stock size estimates range from 9,000 to 40,000 (IWC 1978; Bockstoce and Botkin 1980[13]), with a best estimate of about 18-20,000 (IWC 1978; Breiwick et al. 1980; Bockstoce footnote 11). The stock was exploited commercially from 1848 to approximately 1921. An estimate of the population size in the early 1900's is 600-2,000 (Eberhardt and Breiwick 1980). For further details of commercial exploitation

[13]Bockstoce, J. R., and D. B. Botkin. 1980. The historical status and reduction of the western arctic bowhead whale (*Balaena mysticetus*) population by the pelagic whaling industry, 1848-1914. Unpubl. rep., 120 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.

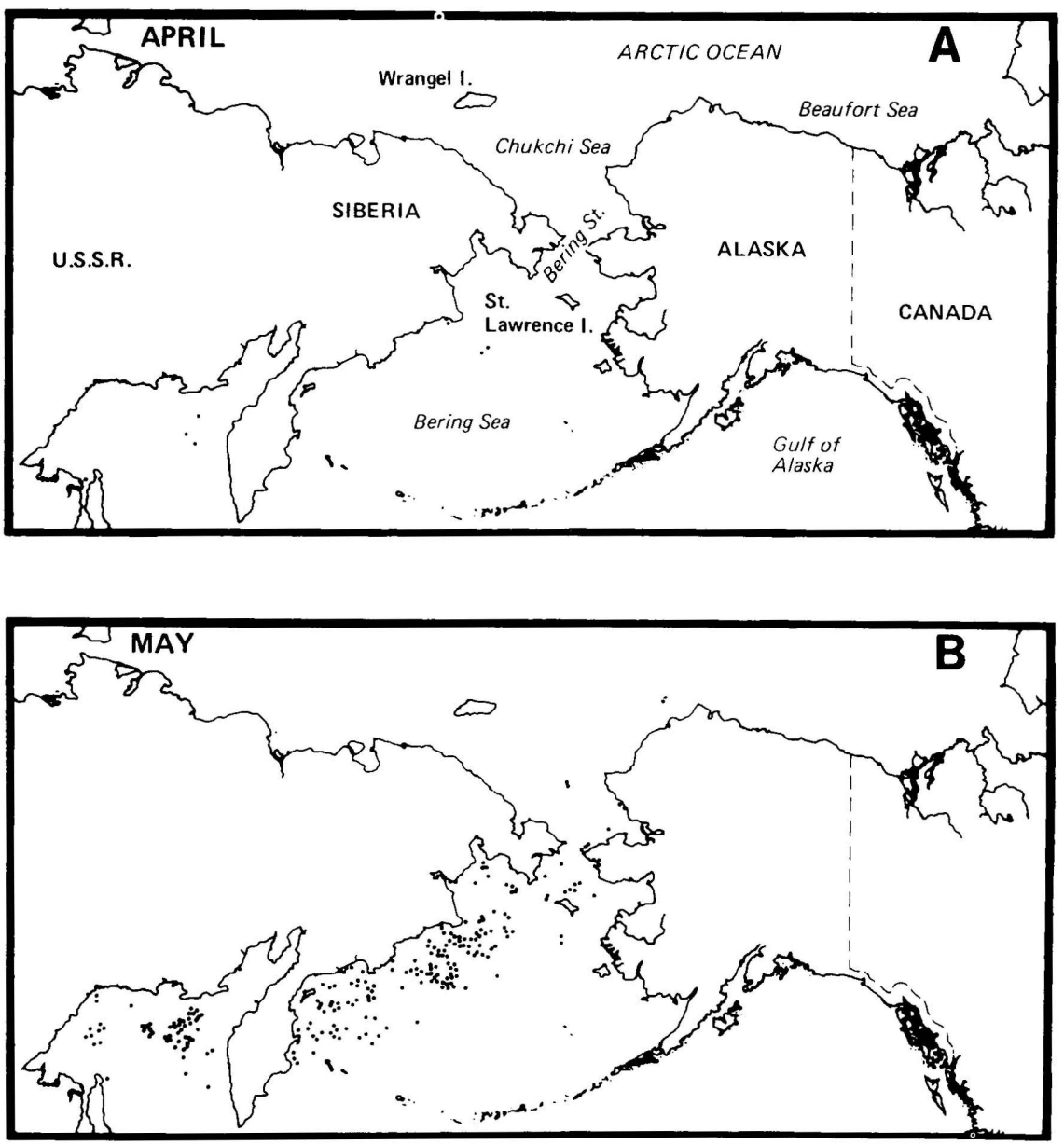


Figure 2.—Locations where bowhead whales were harvested by Yankee whalers in A,B) April and May 1848-1919; C,D) June and July 1848-1919; and E-G) August, September, and October 1849-1919. Each black dot represents a single harvested whale. Data redrafted by month from Townsend (1935).

and whaling activities refer to Marquette (1976, 1977[14]), Bockstoce (footnote 11), and Marquette and Bockstoce (1980).

Okhotsk Sea Stock

Bowheads were generally found in the northern and western Okhotsk Sea in spring and summer. They once occurred as far north as Penzhinskaya Inlet and as far west as Tchantar Bay (Townsend 1935). During spring, they were also taken as far south as Korea and Japan (Townsend 1935; Nishiwaki and Kasuya 1970). Today, their seasonal movements are unknown. During the late 1850's, as it became more difficult to find bowheads in the Bering Sea, whalers turned their attention to the Okhotsk Sea, and soon depleted this stock. Initial stock size has been estimated at 6,500 (IWC 1978). Although inconclusive, recent results of Bockstoce and Botkin (footnote 13) leads us to conclude that intermixing between the Okhotsk Sea and the Bering Sea stocks may have taken place in the past, but probably not since the late 19th century. Sighting records supplied by A. A. Berzin[15] indicate that bowheads still occur in the Okhotsk Sea: 16 bowheads were sighted during surveys in 1973-74. Fifty-five bowheads were seen in the south-southwest Okhotsk Sea during an August aerial survey in 1979 (Berzin and Doroshenko 1981).

[14]Marquette, W. 1977. The 1976 catch of bowhead whales (*Balaena mysticetus*) by Alaskan Eskimos, with a review of the fishery, 1973 - 1976, and a biological summary of the species. Processed rep., 80 p. Natl. Mar. Mammal Lab., Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.

[15]A. A. Berzin, Pacific Scientific Research Institute of Fisheries Oceanography (TINRO), 20 Lenin St., Vladivostok, U.S.S.R., pers. commun. 7 January 1976.

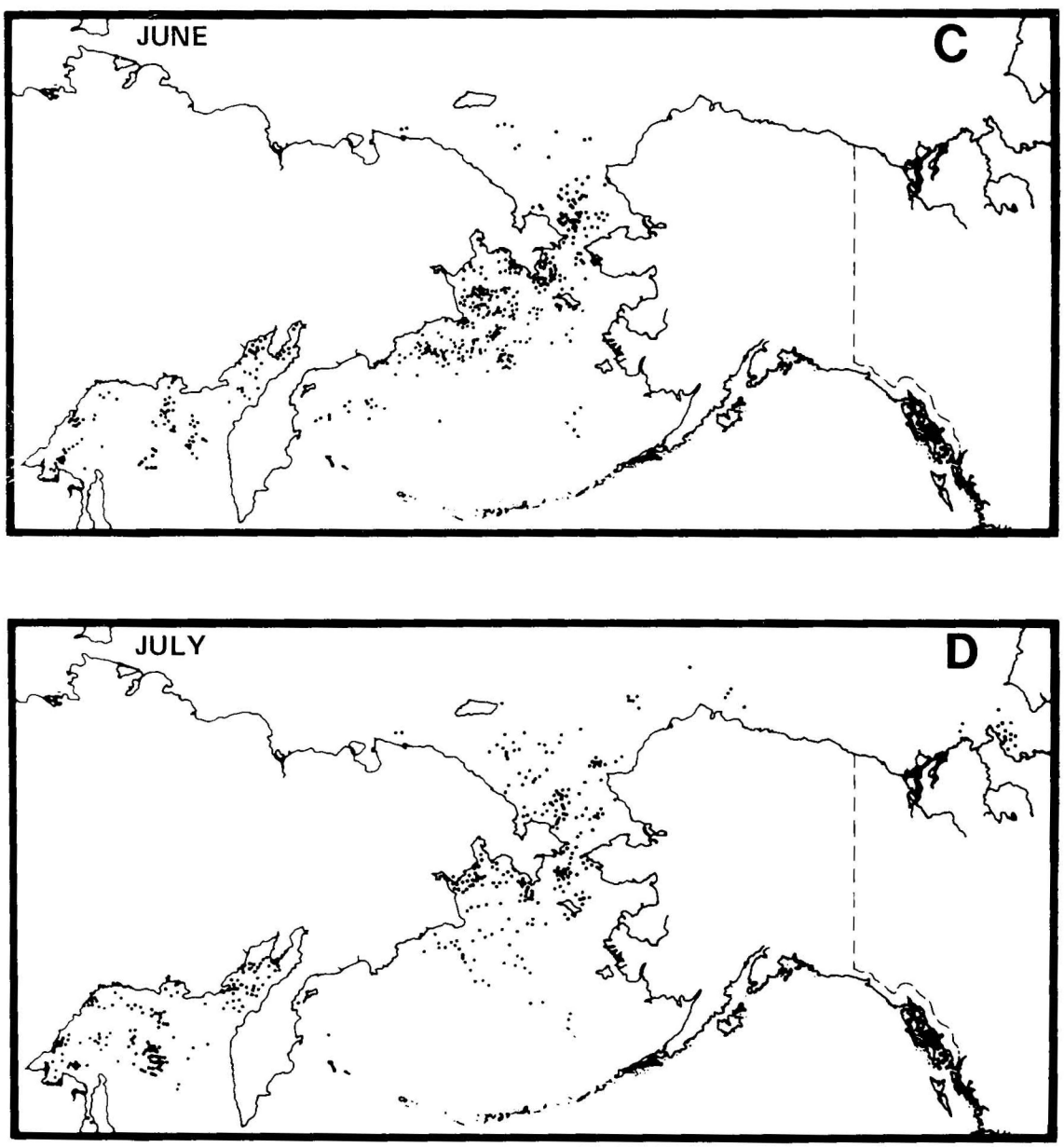
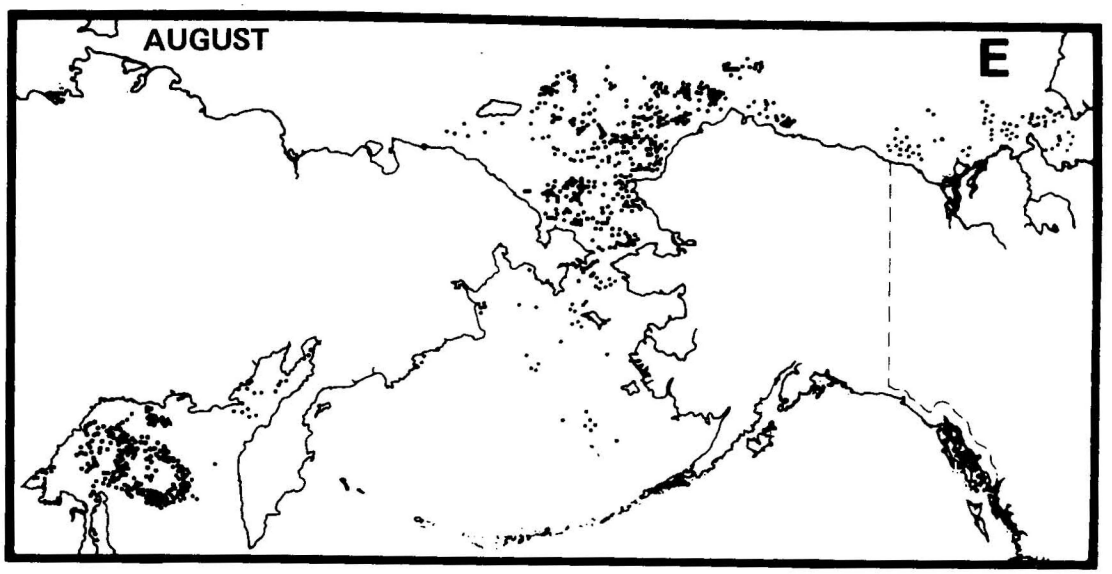
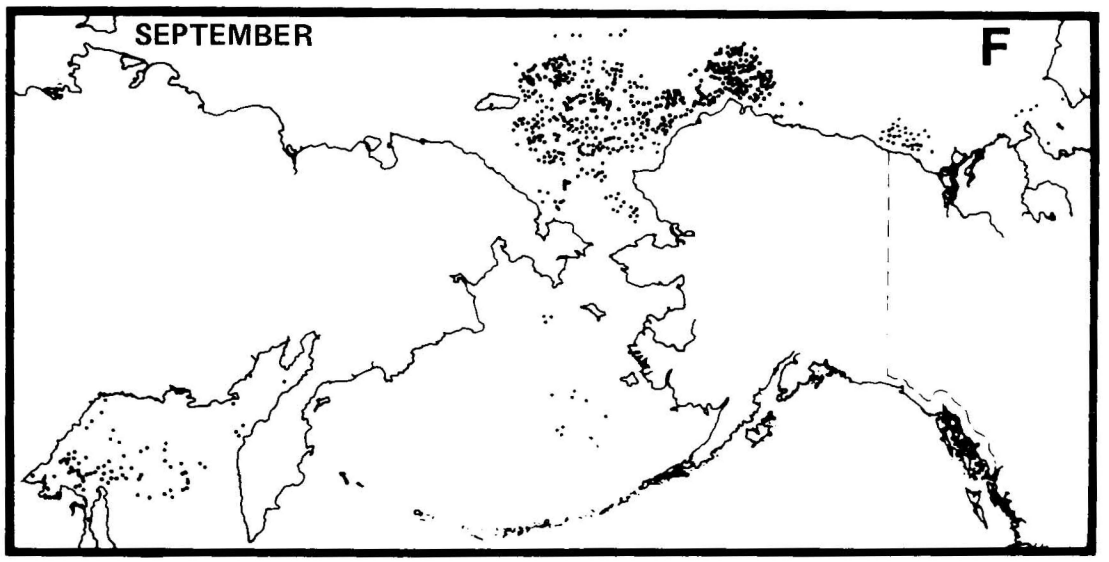


Figure 2.—*Continued.*





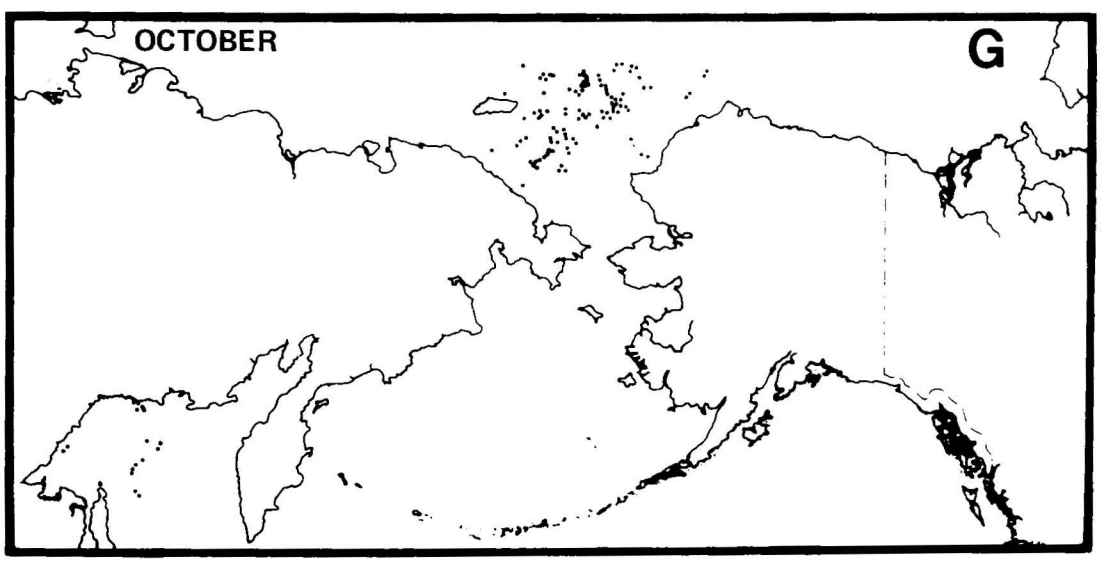


Figure 2.—*Continued.*

FIELD RESEARCH RESULTS

Spring Counts of Migrating Bowhead Whales: Ice and Land Camps

Barrow

Counts of bowhead whales were made 25 April-2 June 1976, 19 April-3 June 1977, and 15 April-5 June 1978 at the nearshore lead northwest of Point Barrow. These periods coincided with the annual northeasterly spring migration of bowhead whales from their winter grounds in the Bering Sea to summer feeding grounds in the Arctic Ocean. Summary data for these three census years are presented in Table 1. The estimate of the number of whales passing the camps during the census periods was not, for 1976 to 1978, considered to be a total population estimate. A more detailed comparison of indices among years for the period 15 April-30 May is reported in Braham et al. (1979, 1980c) and Krogman (1980).

Table 1.—Summary of spring counts of bowhead whales during their annual spring migration through the flaw zone near Barrow, Alaska. Indices of abundance ("Index") were computed as the sums of the products of daily rates times 24 h (see Krogman 1980 and Fig. 3).

Year	Counting period	Total hours in period	Total hours watched	Percent period watched	Bowheads counted	Index
1976	25 Apr.-2 June	936	392:25	42	330	762
1977	19 Apr.-3 June	1,104	395:12	36	327	715
1978	15 Apr.-5 June	1,248	1,108:44	89	1,389	[1]2,276

[1]In Braham et al. (1979) an estimate of 2,264 was given for the period from 15 April to 30 May. The value of 2,276 has a range of uncertainty of approximately (−481 to +601) around the value, and will be further adjusted as results of bias analysis dictate.

The 1978 estimate of 2,276 was higher than indices of 762 achieved in 1976 (revised from 796, originally quoted in Braham and Krogman footnote 2), and 715 in 1977 (Fig. 3). The increase in counts is attributable to several factors: 1) Increase in survey effort (period of watch); 2) better survey location; 3) environmental conditions; and 4) increase in observer effort.

Figure 4 partially illustrates the increase in survey effort by comparing the number of hours watched per day during the same time frame among years. These histograms illustrate the variation in watch effort among years. For all years the strategy was to maintain an unbroken 24-h watch schedule. In 1976 and 1977, the period of OCSEAP funding, this watch-effort strategy was undermined by fog, closed leads, unstable ice conditions, and a limited number of observers. This was not so during 1978, the first year of the NOAA, NMFS expanded bowhead research program.

In addition to the outstanding environmental conditions in 1978, another factor contributing to the increase in the estimate was a change in location of the ice camps. During 1976 and 1977 the primary location for counting was 10-20 km to the southwest of Point Barrow, where our observers stationed themselves near Eskimo whalers. In that vicinity, the lead is generally 11-32 km in width, whereas immediately northwest of Point Barrow, where the 1978 camps were located, the lead width is generally 1-11 km wide. During 1978 the lead

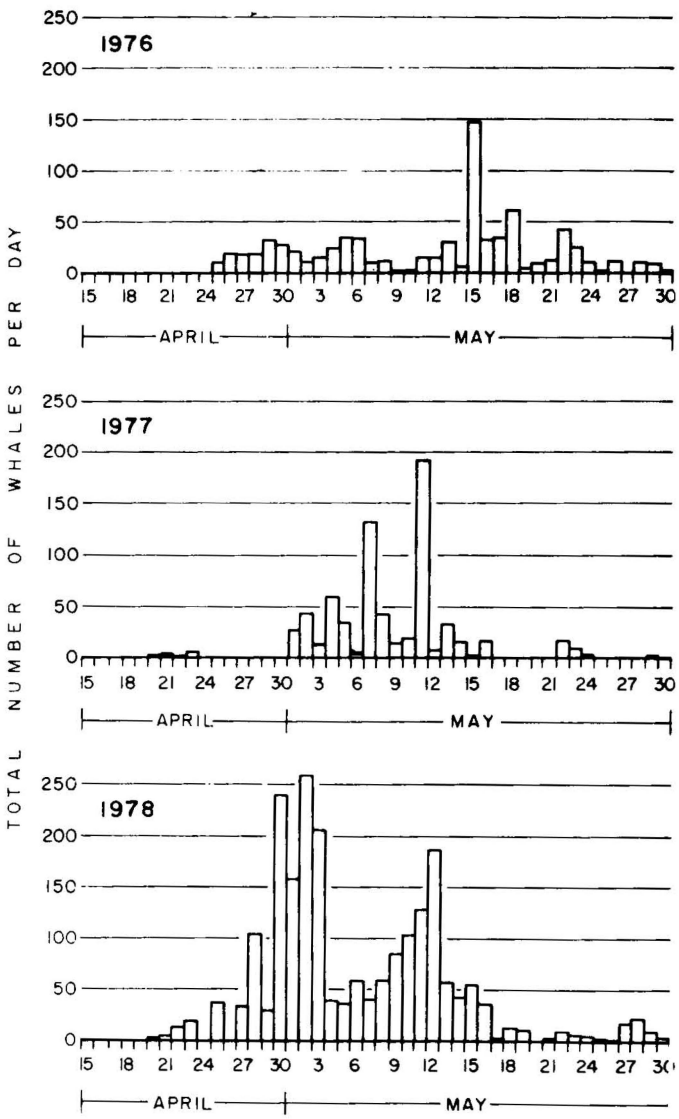


Figure 3.—Comparison among years (1976-78) of estimated total number o bowhead whales migrating northwardly past Pt. Barrow, Alaska, from 15 Apri to 30 May. For purposes of comparison, totals are based on hourly rates per da times 24 h.

was open wider than 0.5 km approximately 94% of the time providing us with an unusually long time period to watch for whales. The median as well as mean (of means) lead width, 23 April to 1 June 1978, at Barrow as 3.70 km (SD = 2.94. n = 38) as calculated from data in Brueggeman (1980). A lead width of 5 km or less is considered ideal for viewing bowheads.

Another important factor contributing to a higher count during 1978 was the increase in observer effort. The 1978 observer schedule called for two observers per 3-h rotating watch; in previous years single observers rotated every 4 h.

Observers at South Camp conducted all watches from an unusually high perch (ice ridge) in 1978. Height of the eye at South Camp was approximately 11.8 m above sea level yielding a view to the horizon of 10 km. Observers in 1976 and 1977 were located on young ice with eye height of 2-4 m, yielding a view to the horizon of 4-6 km.

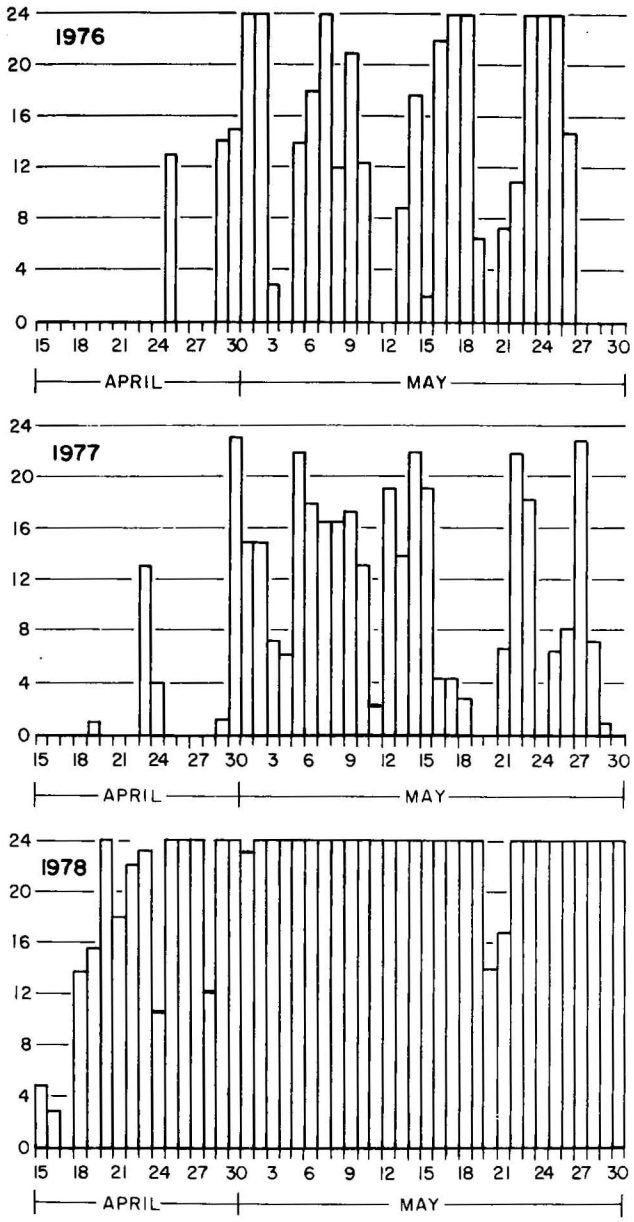


Figure 4.—Comparison among years (1976-78) of observer effort (total hours of watch/hour) expended from 15 April to 30 May. The schedule for 1976 and 1977 called for rotating single observers every 4 h, whereas the 1978 schedule called for two teams of two observers each (four total) to rotate every 3 h. Percent of total survey hours watched were: 1976 = 37.0%; 1977 = 35.8%; 1978 = 86.7%.

Cape Lisburne-Point Hope

Counts of bowhead whales were made 6-16 May 1977 at Cape Lisburne, Alaska. This was a feasibility study which resulted in 54 bowhead whales counted during 72 h of watch. Based upon results of the 1977 study, a full scale counting study was conducted 2 April-7 June 1978 (Rugh and Cubbage 1980). Results of that study indicated that: 1) Spring migration of bowhead whales past Cape Lisburne commenced during the latter half of April; 2) bowheads generally pass Cape Lisburne on a northeasterly course; 3) bowheads usually require 3-5 d to traverse the corridor from Cape Lisburne to Point Barrow; 4) our counting camps at Point Barrow were established before whales passed Cape Lisburne; and 5) few if any whales moved past Point Barrow beyond 1 June. These results, and those from aerial surveys, indicated that the 1978 counts made at Point Barrow probably can be used to estimate abundance.

Counts of bowhead whales were made at Point Hope from 18 April to 28 May 1977. A total of 185 bowhead whales was observed during 546 h of watch. Two waves of movement apparently occurred that year, the first during late April and early May and the second during the latter half of May.

Aerial Surveys for Bowhead and White Whales

Approximately 75,000 km of tracklines were flown during 96 flights over the 1975-77 study period. For ease of analysis and reporting, these surveys have been chronologically and geographically ordered into 16 sets (Appendix I). Survey results are reported by month; no surveys were flown during November-February.

Statistics presented in figure captions associated with aerial surveys are total number of whales counted, mean group size, and standard deviation of group size. Whale counts from the air were used as a relative indicator of how many whales were present in any given area. Group size described the number of whales observed in "close association" which were counted at any one moment. When more whales surfaced, they were tallied as new sightings. Thus, mean group size is downward biased since only a subset of the total group was visible near the surface at any given time.

March and April

1976

From 15 to 21 March 1976, four surveys were flown in the vicinity of St. Lawrence Island. South of St. Lawrence Island

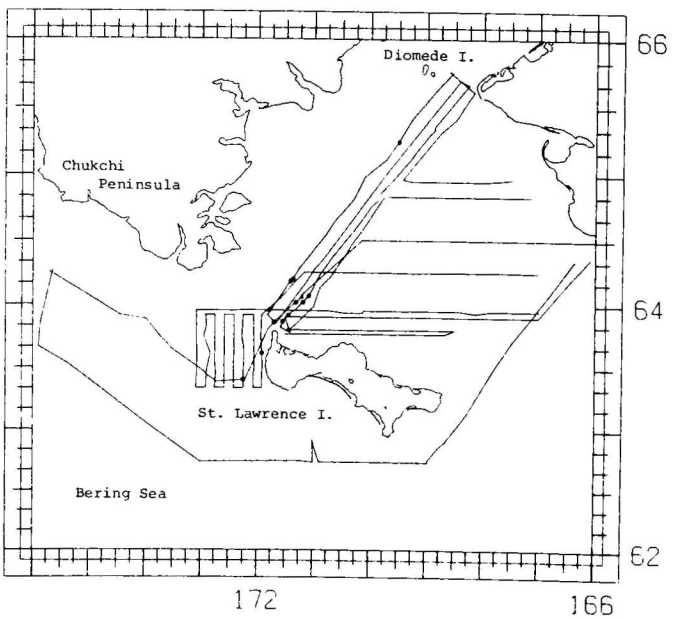


Figure 5.—Aerial survey tracklines flown in the northern Bering Sea on 15, 18, 19, and 21 March 1976. No bowheads were observed. Dots depict the presence of white whales: a total of 39 were counted with a mean group size of 2.8 and a standard deviation (SD) of 2.3. Note: tracklines are not continuous because effort was periodically broken in time; plots were drawn by computer and thus reflect the actual route taken by the aircraft.

thin ice coverage was extensive. North of the island there was nearly 90% ice coverage and pack ice was thick. No bowhead whales were observed. White whales were most common just northwest of St. Lawrence Island (Fig. 5).

During the 6-23 April 1976 survey pack ice was thick between lat. 64° and 65°N in the vincinity of St. Lawrence Island. South of lat. 64°N pack ice was of medium thickness. Ice coverage at this time of year was still extensive: 70-100%; 80% coverage was most common. Large expanses of 100% coverage occurred northwest of St. Matthew Island. Southeast of St. Matthew Island, and in Bristol Bay, sea ice was extensive to the southern limit indicated by aerial survey tracklines (Fig. 6).

No bowheads were seen during the 6-23 April 1976 survey in Bristol Bay (Fig. 6)[16]. Three bowheads were observed in the northern Bering Sea, one on 19 April about 20 km south of Little Diomede Island (Bering Strait), migrating northeasterly in a lead.

White whales were observed most often in the region from northwest of St. Lawrence Island to the Bering Strait during the 6-23 April 1976 survey (Fig. 7). Twenty-five white whales, 18 adults with 7 presumed immatures (grey skin) were seen on 9 April in Bristol Bay (Fig. 7).

1977

In the region near St. Lawrence Island, aerial surveys were flown 31 March-3 April 1977 (Fig. 8). No bowheads were observed in Norton Sound, but a pair was observed southwest of St. Lawrence Island and another, or one of a pair, observed later in the same area. Two more were observed in the lead just southeast of the Bering Strait.

During the 31 March-3 April 1977 surveys white whales were most common north and west of the west end of St. Lawrence Island, and in a large polynya off the coast of the Seward Peninsula (Fig. 9).

May

1976

Results from the 30 April to 14 May 1976 (Fig. 10) and the 15 to 31 May 1976 (Fig. 11) aerial surveys indicate that the

[16]One bowhead was observed on 9 April 1976 west of the Pribilof Islands by Patrick McGuire, National Marine Mammal Laboratory, from the NOAA ship *Survevor*.

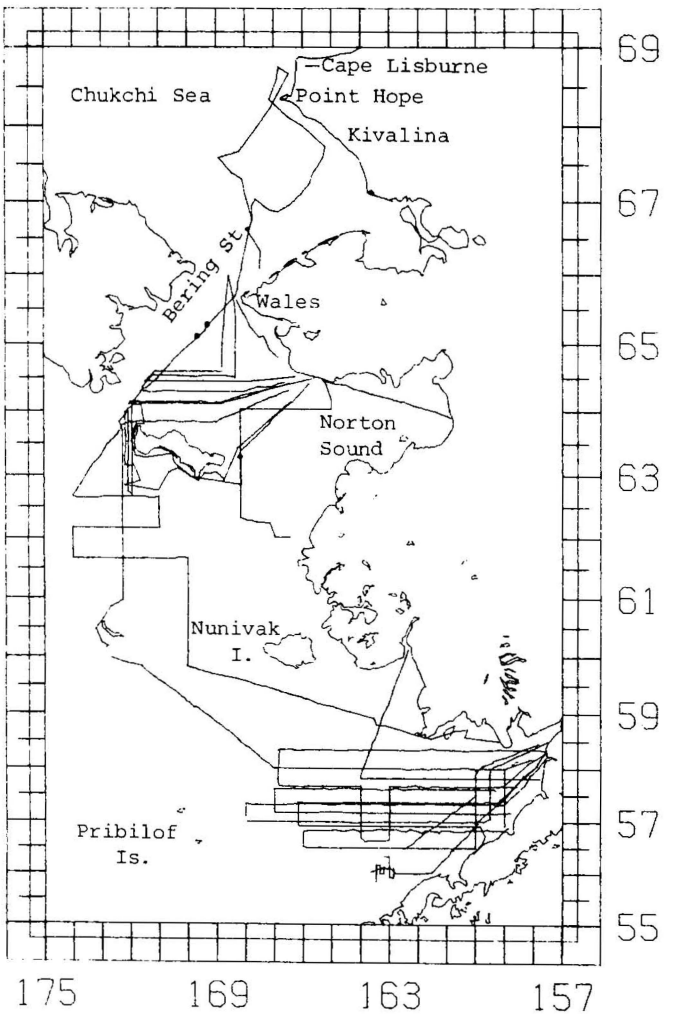


Figure 6.—Aerial survey tracklines flown on 6, 8, 9, 12, 13, 15, 17, 18, 19, 20, 21, 22, and 23 April 1976. Each of the three dots represent a sighting of a bowhead whale. No bowheads were observed below lat. 63° N.

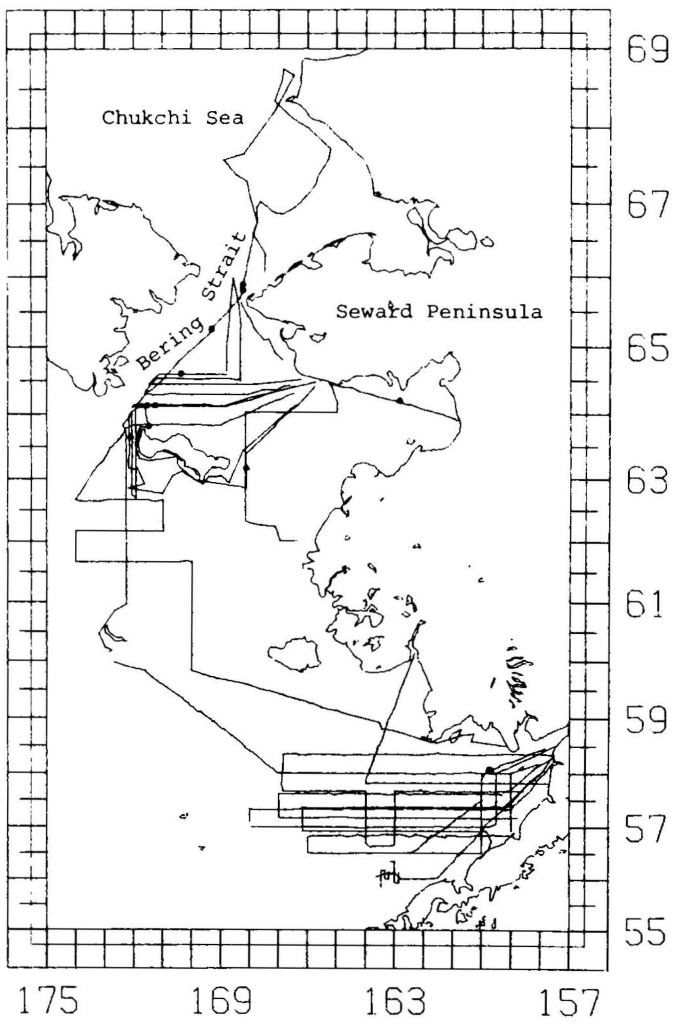


Figure 7.—Aerial survey tracklines flown in the Bering Sea on 6, 8, 9, 12, 13, 15, 17, 18, 19, 20, 21, 22, and 23 April 1976. Dots depict presence of white whales: a total of 135 were counted with a mean group size of 5.4 (SD 6.2).

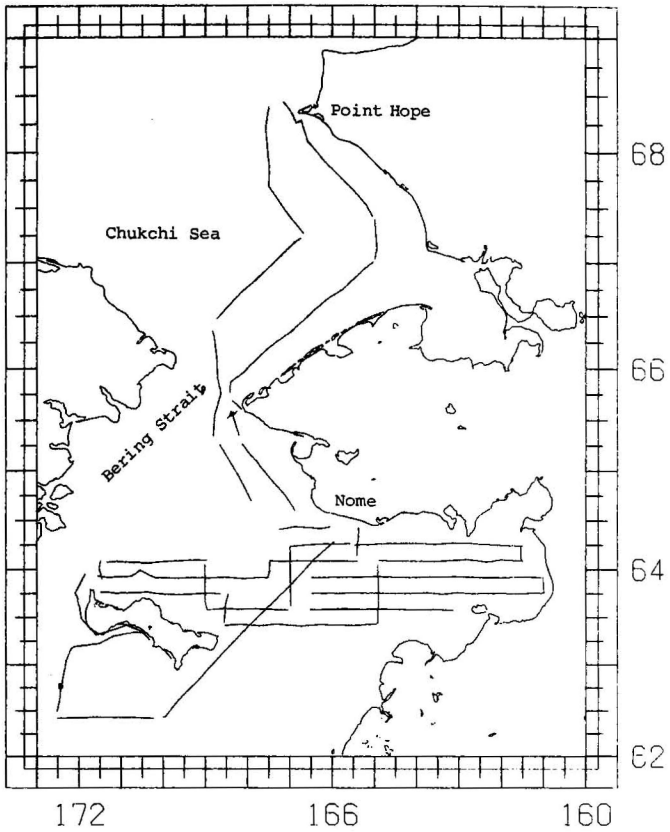


Figure 8.—Aerial survey tracklines flown in the northern Bering and southern Chukchi Seas 31 March and 1-3 April 1977. The two dots represent presence of bowhead whales: a total of 5 whales were sighted with a mean group size of 1.7 (SD 0.6).

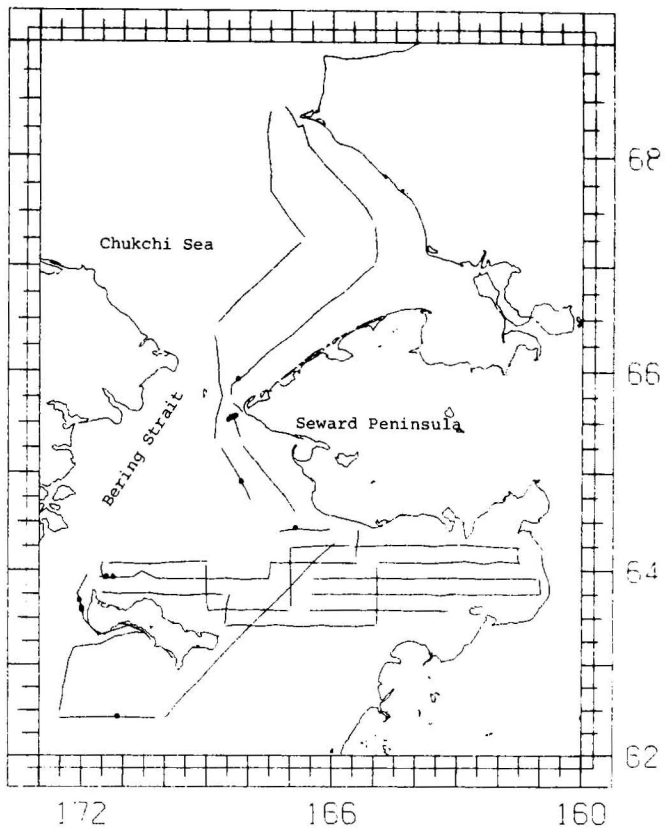


Figure 9.—Aerial survey tracklines flown in the northern Bering and southern Chukchi Seas 31 March and 1-3 April 1977. Dots represent presence of white whales: a total of 370 whales were counted with a mean group size of 4.6 (SD 4.5).

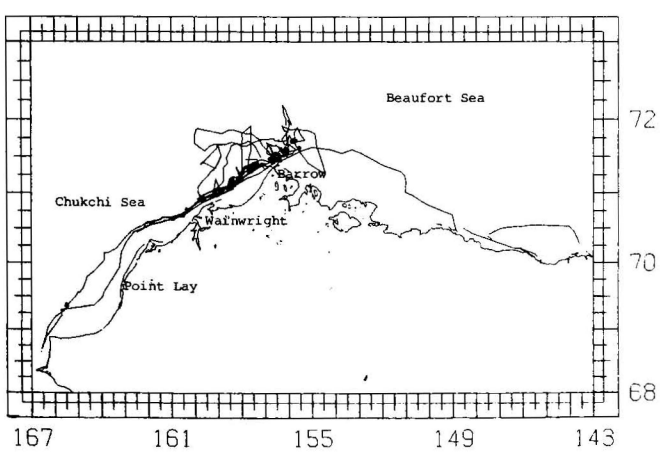


Figure 10.—Aerial survey tracklines flown in the eastern Chukchi and southern Beaufort Seas on 30 April and 1, 3, 8, 9, 12, and 14 May 1976. Dots represent presence of bowhead whales: a total of 68 whales were counted with a mean group size of 1.3 (SD 0.86). Whales were observed in the nearshore lead only in the Chukchi Sea.

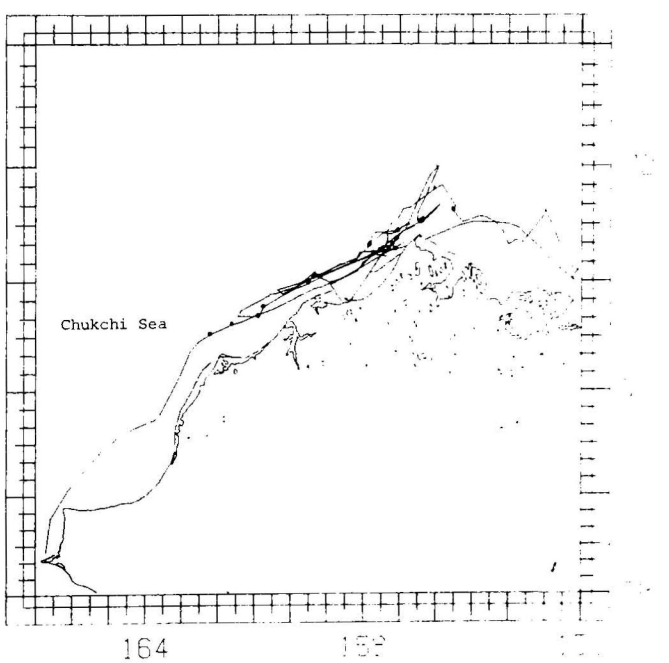


Figure 11.—Aerial survey tracklines flown in the eastern Chukchi and western Beaufort Seas on 15, 19, 20, 22, 24, 28, and 31 May 1976. Dots represent presence of bowhead whales: a total of 30 whales were counted with a mean group size equal to 1.2 (SD 0.82). Whales were observed in the nearshore lead only in the Chukchi Sea.

northeast migration of bowhead whales along the northwest coast of Alaska (Chukchi Sea) occurred in the nearshore lead. No bowheads were seen nearshore in the Beaufort Sea.

From Figures 12 and 13 it is apparent that white whales were more widely distributed in the Chukchi Sea than bowheads. They were observed to the northerly limits of most aerial surveys offshore to approximately 60 km, indicating that they penetrate the pack ice even farther north than bowheads. White whales were also common in the nearshore lead.

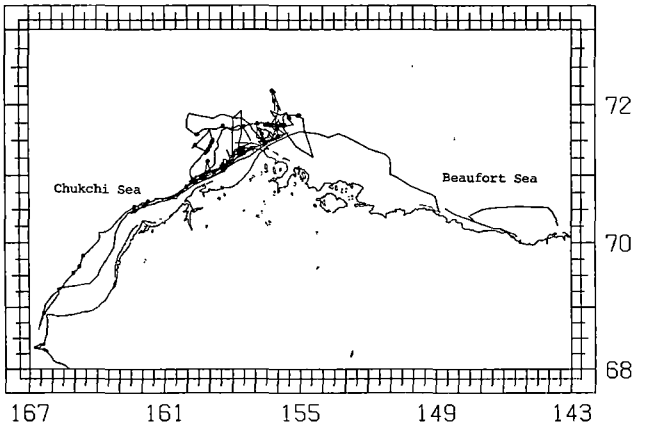


Figure 12.—Aerial survey tracklines flown in the eastern Chukchi and Beaufort Seas on 30 April and 1, 3, 8, 9, 12, and 14 May 1976. Dots represent presence of white whales: a total of 485 whales were counted with a mean group size of 3.9 (SD 5.5).

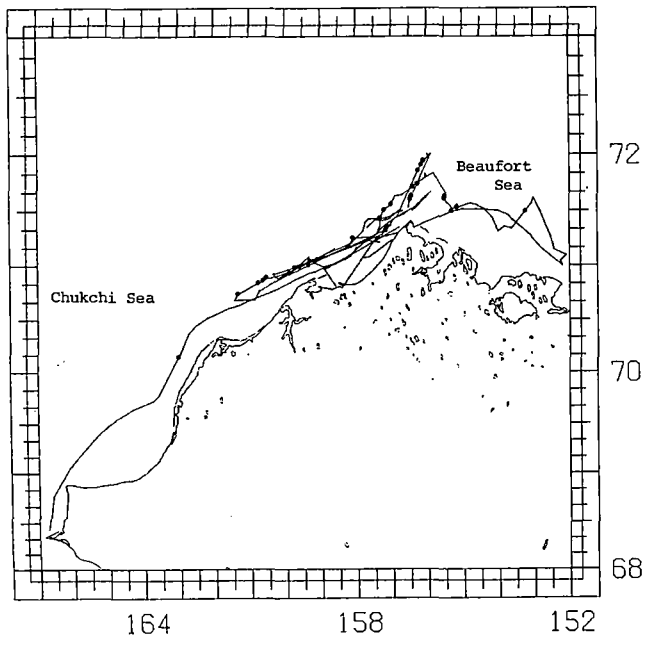


Figure 13.—Aerial survey tracklines flown in the eastern Chukchi and western Beaufort Seas 15, 19, 20, 22, 24, 28, and 31 May 1976. Dots represent presence of white whales: a total of 289 whales were counted with a mean group size of 6.0 (SD 7.4).

1977

Aerial surveys flown from 11 to 14 May 1977 (Fig. 14) in the southeastern Chukchi and eastern Bering Seas revealed no bowhead whales. It was not expected that bowheads would be observed in the area surveyed from Norton Sound south.

A herd of white whales was encountered on the 11-14 May survey in Kotzebue Sound (Fig. 14). Six adult white whales were observed in Norton Sound; eight, including one immature, were observed south of Norton Sound. The trackline leading south from Norton Sound followed near the fast ice edge to Nunivak Island. No white whales were observed in the open water south of Nunivak Island.

The hypothesis we proposed, that spring migrating white whales use leads offshore in the Beaufort Sea (Braham and Krogman footnote 2), is further substantiated when white whales were observed as far as 150 km north of Point Barrow but not nearshore along the north coast of Alaska in the Beaufort Sea (Fig. 15). The fact that no bowheads were seen is probably a reflection of fewer animals present nearing the end of their spring migration (Fig. 3).

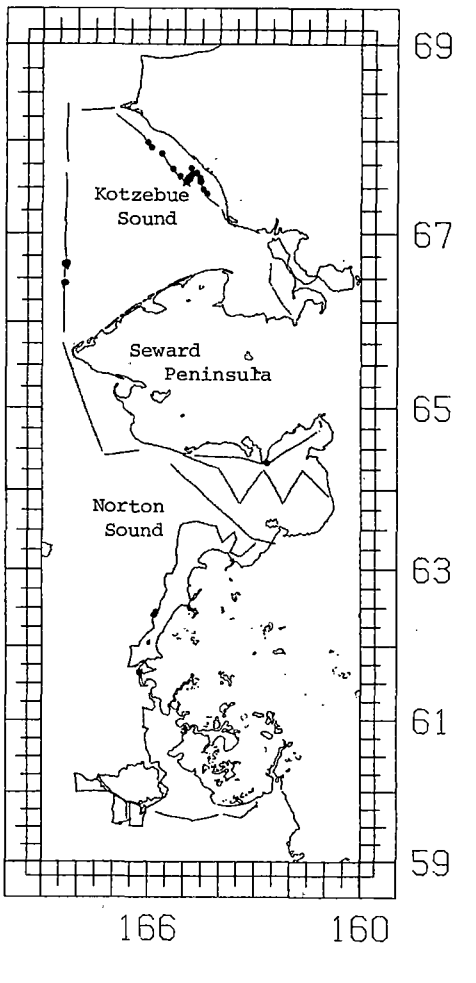


Figure 14.—Aerial survey tracklines flown in the eastern Bering and southeastern Chukchi Seas on 11, 12, and 14 May 1977. No bowhead whales were seen. Dots represent presence of white whales: a total of 272 whales were counted with a mean group size of 4.5 (SD 7.6).

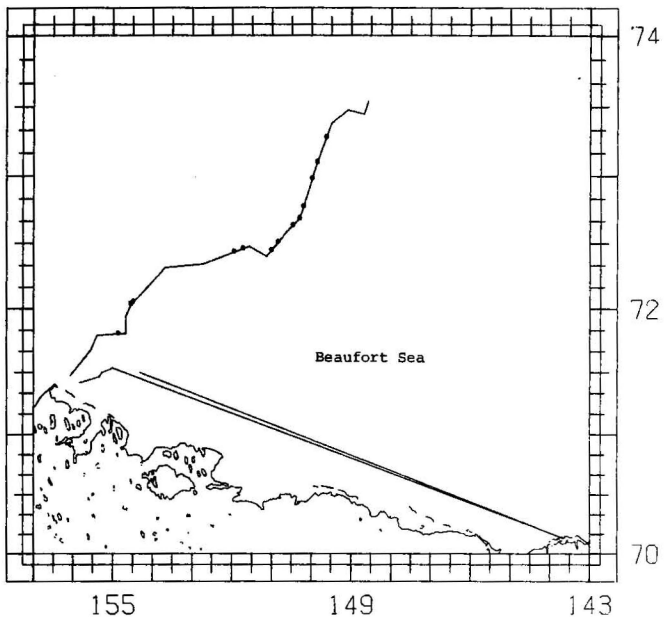


Figure 15.—Aerial survey tracklines flown in the western Beaufort Sea on 21 and 30 May 1977. No bowhead whales were seen. Dots represent presence of white whales: a total of 26 whales were counted with a mean group size of 1.5 (SD 2.5).

June

1976

In early June 1976 the bowhead whale migration along the northwest coast of Alaska (Chukchi Sea) was still confined to the nearshore lead. From Figure 16, however, it is evident that few bowheads were present in the study area. During the 8-14 June (Fig. 17) aerial surveys in the southern Chukchi and northern Bering Seas, two bowheads were observed just south of the southern limit of the pack ice edge. They may have been waiting for a lead to open, since the pack ice appeared solid

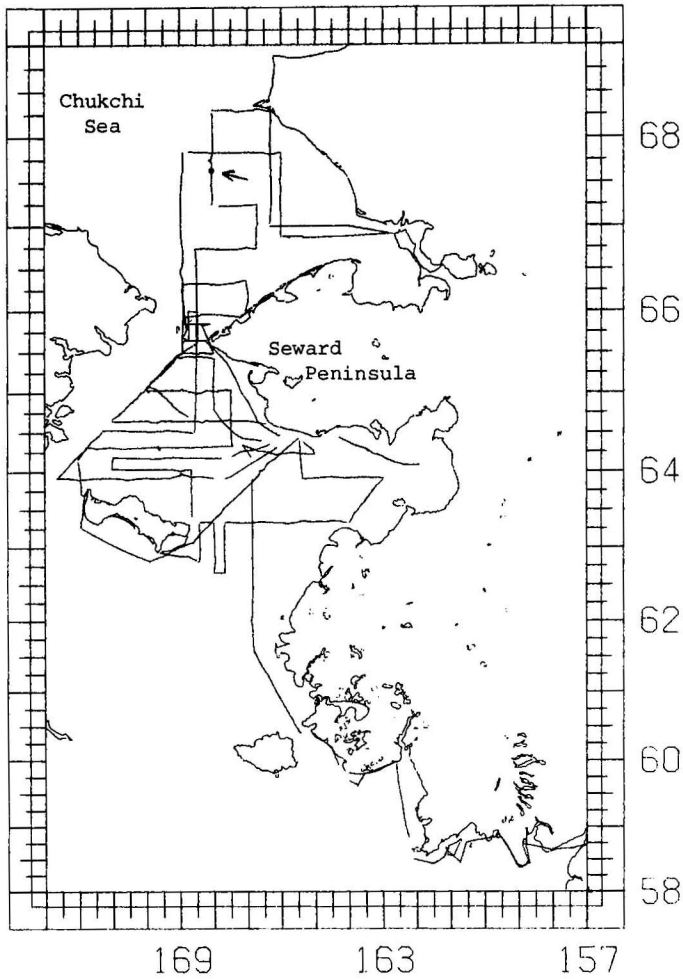


Figure 17.—Aerial survey tracklines in the northern Bering and southern Chukchi Seas flown on 8, 9, 10, 11, 12, 13, and 14 June 1976. The dot (highlighted by an arrow) represents two bowhead whales seen just south of the ice front. One whale, a large adult, remained stationary at the surface for the 5-10 min period we surveyed the area.

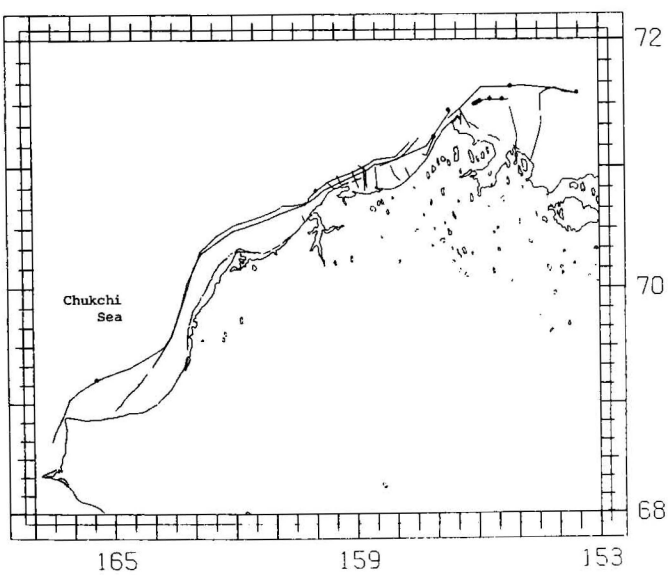


Figure 16.—Aerial survey tracklines flown in the eastern Chukchi and western Beaufort Seas on 1, 4, and 5 June 1976. Dots represent presence of bowhead whales: a total of 20 whales were counted with a mean group size of 1.8 (SD 1.1).

north of their location. By 18-20 June 1976 the bowhead migration along the northwest coast of Alaska was essentially over; during aerial surveys flown in the nearshore leads only one animal was observed (Fig. 18).

The 1-5 June 1976 survey along the northwest coast of Alaska verified that white whales were still present in the Chukchi Sea (Fig. 19). On 1 June, 153 white whales were observed at lat. 70°59′N, long. 158°41′W. All other sightings were of 12 or fewer whales.

Eighteen adult white whales were sighted near the mouth of the Yukon River on 14 June 1976 (Fig. 20). White whales were not encountered elsewhere during the survey, which suggests that most had left the north Bering Sea by June and that the Yukon Delta sightings were of a group which summers in Norton Sound.

The Chukchi and Beaufort Seas were again surveyed 18-20 June 1976 (Fig. 21). Only two sightings of white whales were made: 12 adults were observed at lat. 70°39′N, long. 161°47′W on 19 June, and 49 adults with 12 immatures were observed at lat. 69°28′N, long. 164°10′W on 20 June.

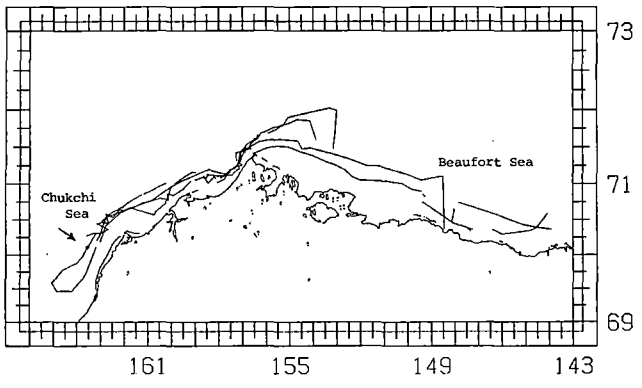


Figure 18.—Aerial survey tracklines flown in the eastern Chukchi and western Beaufort Seas on 18-20 June 1976. The dot (highlighted by an arrow) represents one bowhead whale seen.

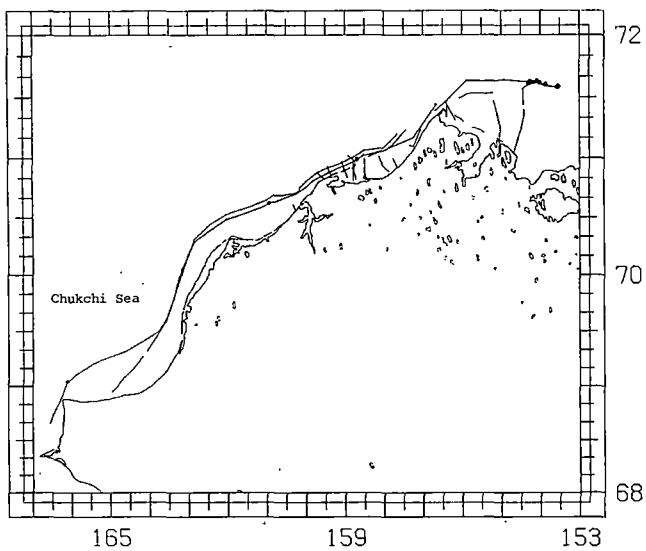


Figure 19.—Aerial survey tracklines flown in the eastern Chukchi and western Beaufort Seas on 1, 4, and 5 June 1976. Dots represent presence of white whales: a total of 177 whales were counted with a mean group size of 11.1 (SD 32.0).

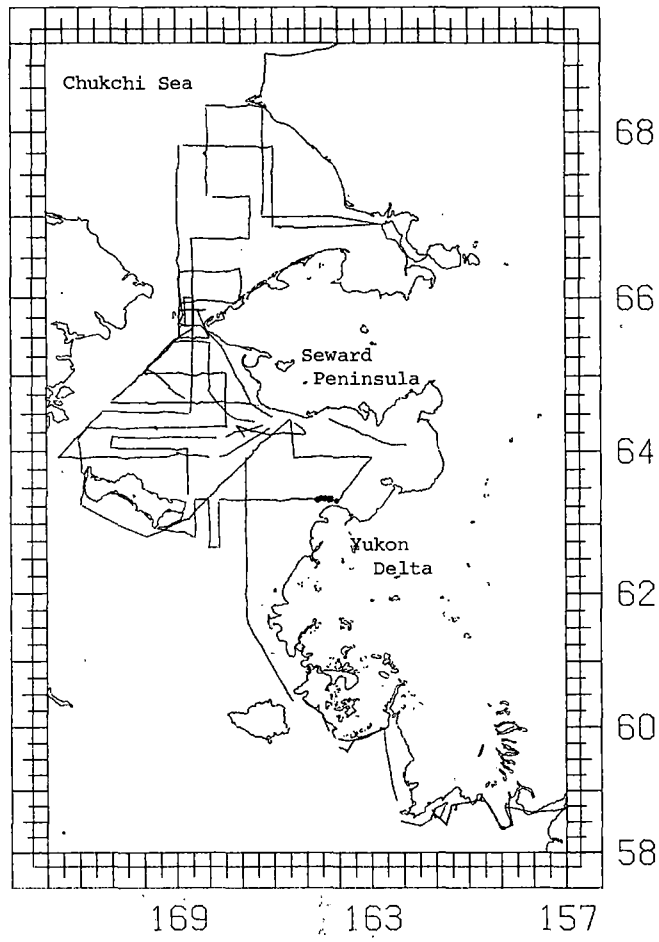


Figure 20.—Aerial survey tracklines flown in the northern Bering and southern Chukchi Seas on 8, 9, 10, 11, 12, 13, and 14 June 1976. Dots represent presence of white whales: a total of 18 whales were counted with a mean group size of 1.6 (SD 1.4).

July

No aerial surveys were flown in July 1976, 1977, or 1978.

August

Aerial surveys were flown on 17-26 August 1976 over open water (Fig. 22). Four bowhead whales were observed together on 19 August east of Point Barrow.

Sighting records of bowhead whales from other OCSEAP contractors have been sent to us. In August 1975 Carleton Ray[17] sighted 74 bowheads northeast of Icy Cape (about lat. 70°34′N, long. 161°00′W). Ray's data and ours from 1975 suggest that at least some bowheads may not have been able to complete their migration into the Beaufort Sea that year because of the heavy pack ice. Ice did not restrict their migration, however, from 1976 to 1978.

[17]C. Ray, Johns Hopkins University, Baltimore, Md., pers. commun. 21 January 1978.

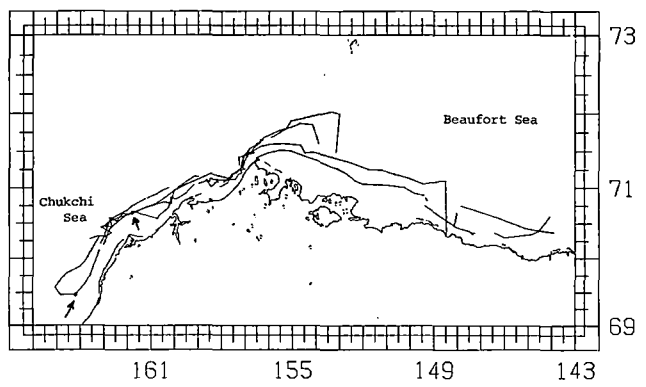


Figure 21.—Aerial survey tracklines flown in the eastern Chukchi and western Beaufort Seas on 18, 19, and 20 June 1976. Dots (highlighted by arrows) represent presence of white whales: a total of 73 whales were counted with a mean group size of 36.5 (SD 34.6).

Seven white whales were observed during the 17-26 August 1976 survey (Fig. 23). Five were observed in Norton Sound, none were seen in the Chukchi Sea, and two were seen in the north central Beaufort Sea.

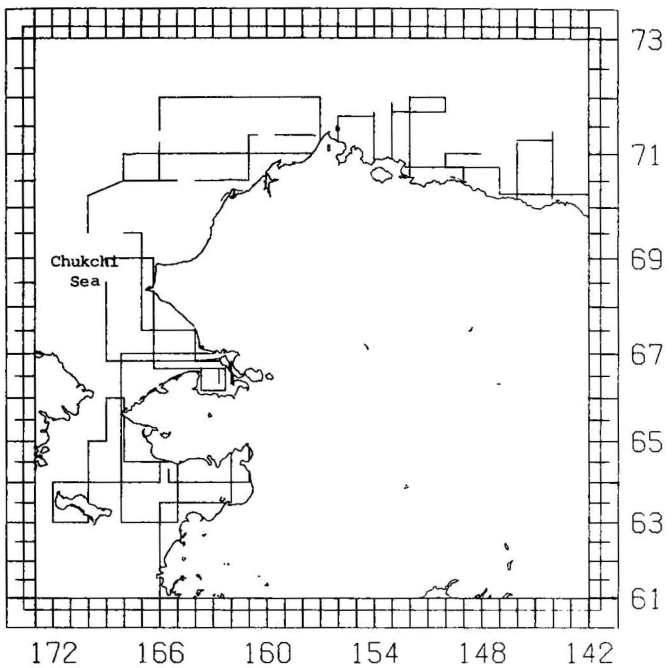


Figure 22.—Aerial survey tracklines flown in the northern Bering, eastern Chukchi, and western Beaufort Seas on 17, 18, 19, 20, 21, 22, 23, 24, 25, and 26 August 1976 during bird surveys conducted by the U.S. Fish and Wildlife Service. The dot represents 4 bowhead whales seen just east of Pt. Barrow in open water.

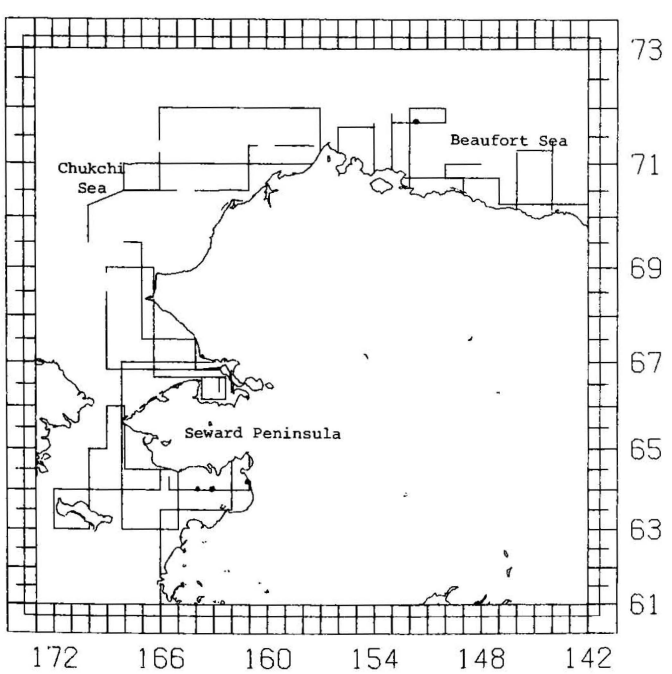


Figure 23.—Aerial survey tracklines flown in the northern Bering, Chukchi, and western Beaufort Seas during bird surveys conducted by the U.S. Fish and Wildlife Service on 17, 18, 19, 20, 21, 22, 23, 24, 25, and 26 August 1976. Dots represent presence of white whales: a total of 7 whales were counted with a mean group size of 1.2 (SD 0.4).

September and October

During the 20-26 September 1976 survey an aggregration of bowhead whales was observed nearshore from Smith Bay to Point Barrow (Fig. 24). The highest count was 47 on 21 September. Several animals were observed to be stationary at the surface with their mouths open; they appeared to be feeding. The area between Smith Bay and Point Barrow may be a staging area for migrating whales and/or an important feeding location during years of high invertebrate production. It is likely these animals, and perhaps more, summered in this region in 1976. A few Eskimo whalers from Barrow have told us that this is not an uncommon occurrence. Tracklines were flown offshore during this period in 1976 but no bowheads were observed.

Results were inconclusive as to whether or not bowheads congregate every year nearshore east of Point Barrow. During a 12-22 September 1974 aerial survey by Fiscus and Marquette[18] many bowheads were observed near Cape Simpson; the highest count, 57, was made on 18 September 1974. During the 26 August-13 October 1977 survey, however, only seven bowheads were observed in the area (Fig. 25). Of significance, though, was that most of the 1977 sightings were made offshore, probably of whales on their return migration from the Beaufort Sea into the Chukchi Sea.

Although the data are sparse, they indicate that bowheads move west and south in September. We have, as does C. Ray, sightings that place bowheads at three locations during September: 1) East along the northern coast of Alaska to within

[18]Fiscus, C. H., and W. M. Marquette. 1975. National Marine Fisheries Service field studies relating to the bowhead whale harvest in Alaska, 1974. Processed rep., 23 p. Natl. Mar. Mammal Lab., Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.

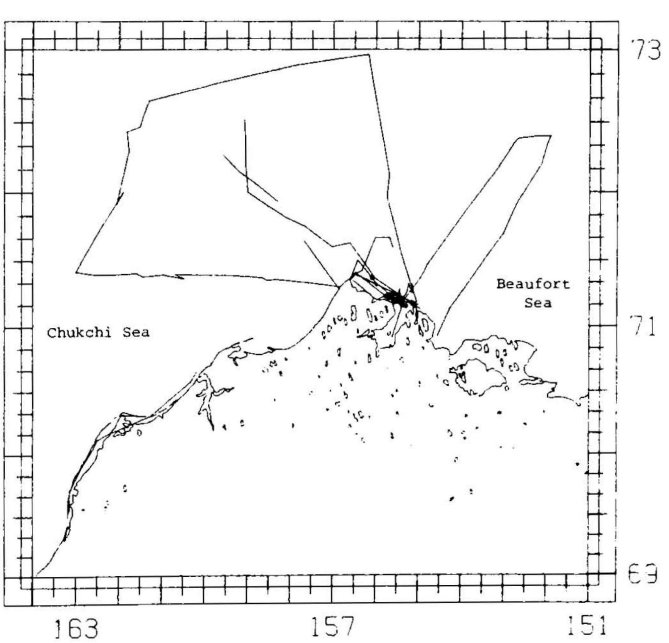


Figure 24.—Aerial survey tracklines flown in the eastern Chukchi and western Beaufort Seas on 20, 21, 22, 24, and 26 September 1976. Dots represent presence of bowhead whales: a total of 102 whales were counted with a mean group size of 2.7 (SD 3.5).

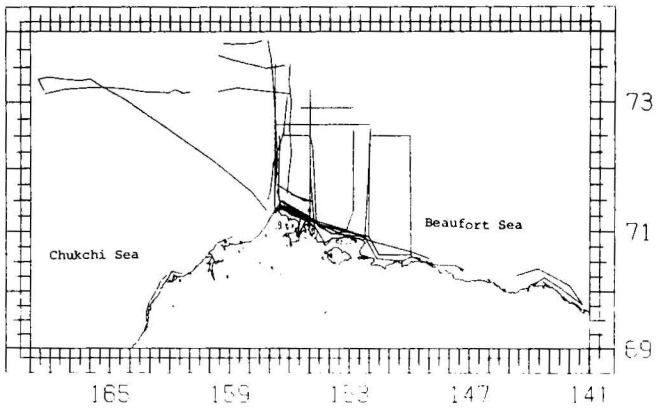


Figure 25.—Aerial survey tracklines flown in the eastern Chukchi and western Beaufort Seas on 26 and 29 August 1977; 1, 5, 8, 10, and 14 September 1977; and 3, 6, and 13 October 1977. Dots represent presence of bowhead whales: a total of 7 whales were counted in September and October with a mean group size of 1.2 (SD 0.4). No whales were observed in August 1977.

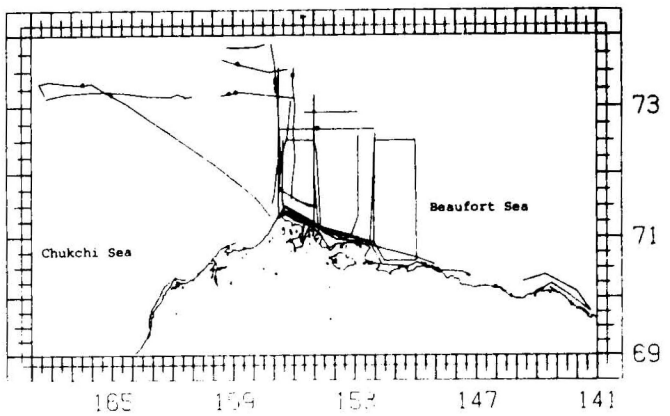


Figure 27.—Aerial survey tracklines flown in the eastern Chukchi and western Beaufort Seas on 26 and 29 August 1977; 1, 5, 8, 10, and 14 September 1977; and 3, 6, and 13 October 1977. Dots represent presence of white whales: a total of 89 whales were counted with a mean group size of 4.0 (SD 3.5). All but 3 of the 89 whales were observed on 10 and 14 September.

100 km of Point Barrow; 2) south of Barrow along the coast to Peard Bay, lat. 70°50′N, long. 158°30′W; and 3) west of Point Barrow some 100 km into the Chukchi Sea.

One white whale was observed during the 20-26 September 1976 survey (Fig. 26). Eighty-nine white whales were observed on the 26 August-13 October 1977 survey (Fig. 27). The westward migration of white whales past Point Barrow appears to be predominantly offshore.

No bowheads were seen on the 9-14 October 1975 survey conducted over the southern Chukchi and northern Bering Seas (Fig. 28). A. Berzin[19] reported seeing bowhead whales near the Soviet coast of the Chukotka Peninsula during surveys conducted in October 1974 and 1975 (Fig. 29). His sighting (in Fig. 29), commercial whaling records (Fig. 2), and our results reported in Johnson et al. (1981) indicate that at least some, and perhaps most, bowheads migrate to the northern coast of Siberia in the autumn before moving south through the Bering Strait and into the Bering Sea to their wintering grounds.

[19]A. A. Berzin, TINRO, Magadan, U.S.S.R., pers. commun. 14 February 1979.

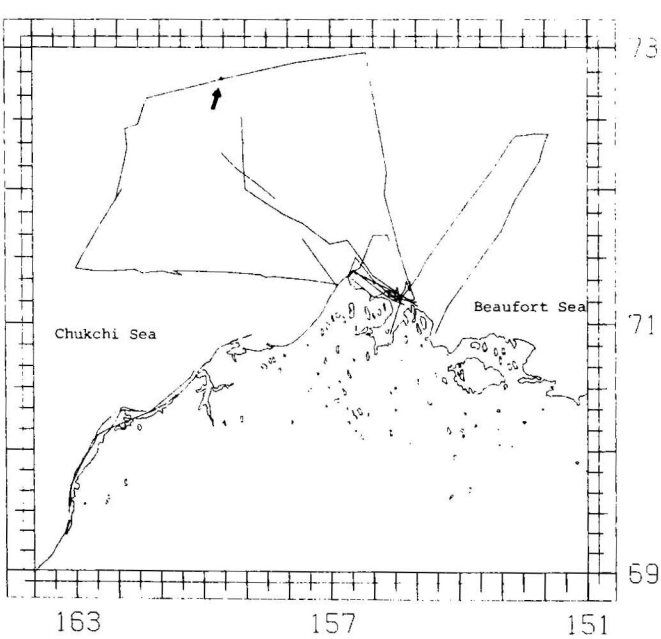


Figure 26.—Aerial survey tracklines flown in the eastern Chukchi and western Beaufort Seas on 20, 21, 22, 24, and 26 September 1976. The dot (highlighted by an arrow) represents one white whale seen.

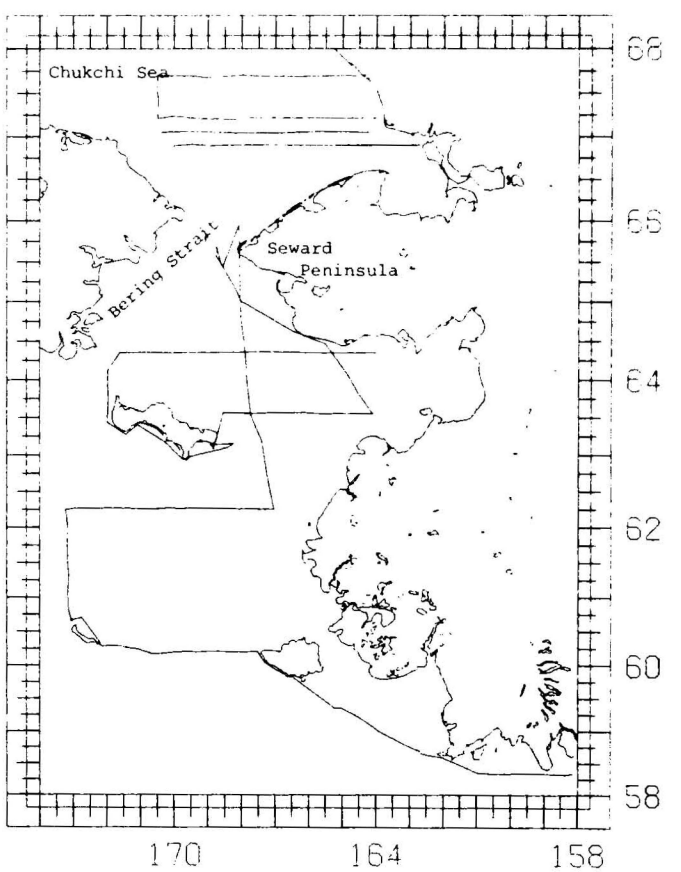


Figure 28.—Aerial survey tracklines flown in the northern Bering and southern Chukchi Seas on 9, 12, and 14 October 1975. No bowhead or white whales were observed.

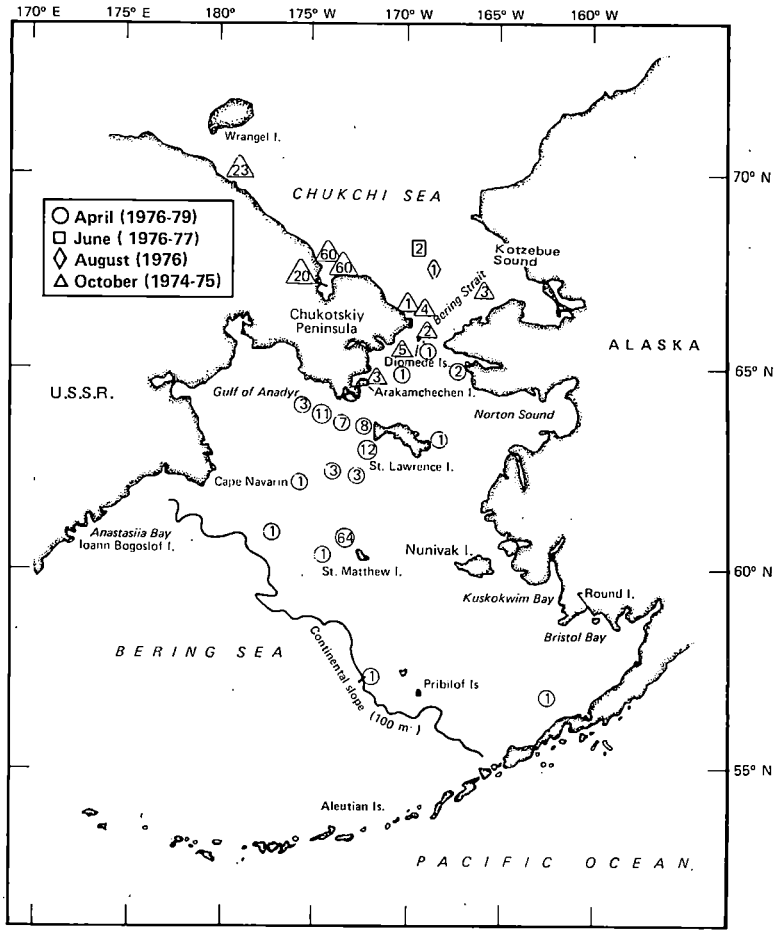


Figure 29.—Bowhead whale sightings in the Bering and southern Chukchi Seas, 1974-79, from aerial and vessel surveys. October sightings were provided by A. Berzin, pers. commun. For greater detail see Braham et al. (1980b).

Twenty large, apparently adult bowheads were observed north of Point Barrow at lat. 71°N between long. 156° and 157°W on 22 October 1978 (Savage 1978[20]). The animals were following a large, slow moving ice floe and appeared to be feeding. As ice appeared to cover the Beaufort Sea east of long. 152°W on this date, Savage felt that these sightings were made near the end of the autumn westward migration. Details of the few other sightings made in October 1978 and the unsuccessful aerial survey effort of the area around Prudhoe Bay in September 1978 are reported in Braham et al. (1980d).

DISCUSSION AND REVIEW

Western Arctic-Bering Sea Population of Bowhead Whales

Distribution and Migration

Bowhead whales of the western Arctic-Bering Sea stocks occur seasonally from the west central Bering Sea northward along the coast of Siberia and around St. Lawrence Island in the northern Bering Sea, throughout the Chukchi Sea, and in fewer numbers in the eastern East Siberian Sea, and eastward throughout the U.S. Beaufort Sea to Banks Island and Amundsen Gulf, Northwest Territories, Canada (Fig. 1).

The exact location of the wintering area for bowheads is not known, but the western and central Bering Sea appear to be the most probable location (Sleptsov 1961; Durham footnote 10; Braham and Krogman footnote 2; Braham et al. 1980b, c; Brueggeman 1982). Results from our icebreaker survey in March and April 1979 indicated that bowheads winter in the west central Bering Sea pack ice (Braham et al. 1980c). Comments made to Braham by A. Berzin (footnote 19) indicate that in some years a few bowheads may winter in open water in the Gulf of Anadyr. The waters around St. Lawrence Island are occupied intermittently by bowheads, dependent upon open water, from approximately December to April (Braham et al. 1980c, d). Past whaling records and reported observations by Alaskan Eskimos support the hypothesis that bowhead winter distribution is south and west of St. Lawrence Island to the pack ice front and perhaps farther south into open water. Townsend's (1935) records of bowhead whale catches and recent data from Bockstoce and Botkin (footnote 13) show that large numbers of whales were taken from Cape Olyutorskiy north to the Gulf of Anadyr, U.S.S.R., and adjoining waters during early spring and summer during commercial whaling when bowheads were more abundant than now. Few whales were taken or have been observed in the eastern Bering Sea, despite extensive aerial and shipboard surveys. Of those sightings in the eastern Bering Sea over the Continen-

[20]Savage, S. 1978. Distribution of *B. mysticetus* and *D. leucas* in the Beaufort Sea, October 1978. Unpubl. manuscr., 11 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.

tal Shelf, most were in the vicinity of the Pribilof Islands (Townsend 1935) and St. Matthew Island (Hanna 1920; Braham et al. 1980c). In April 1976, at least two bowheads were seen in outer and southern Bristol Bay representing the most southeastwardly sighting of the species (Fig. 29).

The northward spring migration of the bowhead whale from the Bering Sea is timed with the breakup of the pack ice (Bailey and Hendee 1926; Foote 1964[21]; Nishiwaki 1967; Durham footnote 11). This generally occurs in April (Sleptsov 1961; McVay 1973) or earlier in a mild ice year (as in 1979). At that time, most whales travel north through the Strait of Anadyr, between St. Lawrence Island and the Chukchi Peninsula, continuing north by northeast through the Bering Strait probably on the Soviet side, west of Big Diomede Island (Braham et al. 1979). During an "average" ice year, apparently few animals migrate through the eastern half of the northern Bering Sea—heavier ice usually occurs there than to the west. Even so, Eskimo whalers at Wales periodically take bowheads along the Alaska coast near the Bering Strait (Marquette footnote 14; Johnson et al. 1981). Most of the migrating animals have passed through this corridor between St. Lawrence Island and the coast of the Chukotka Peninsula by mid-May (Bailey and Hendee 1926; Foote footnote 21; Durham footnote 10; Burgess 1973; Braham and Krogman footnote 2; Braham et al. 1979, 1980c).

Upon entering the Chukchi Sea the migration is northeasterly across outer Kotzebue Sound in leads occurring in the flaw zone. A few whales move into a polynya that characteristically forms between Kivalina and Point Hope, but most whales move past Point Hope, some offshore to 45-90 km (Braham et al. 1980b). A few whales might migrate into the western Chukchi Sea in spring; however, this is unlikely since pack ice is extensive with few leads north of the Chukotka Peninsula (Braham et al. 1979; G. Fedoseev[22]). Apparently, Siberian Eskimos living along the north side of the Chukotka Peninsula did not hunt bowheads in the spring as did their counterparts along the east side of the Peninsula (A. Berzin, footnote 19).

Proceeding northerly on a heading of 10°-20° magnetic (Braham et al. 1980d) bowheads follow open leads north past Cape Thompson and Point Hope and then northeasterly to Cape Lisburne and Point Barrow. The migration past Cape Lisburne seems to follow two or more corridors, depending on the number of leads, 2-10 km offshore; sightings have been made to 15 km offshore (Rugh and Cubbage 1980). No bowheads have been observed in offshore leads between Point Lay and Point Barrow during 4 yr of aerial surveys, even though aerial survey time has been split equally between offshore (to 100 km) and nearshore coverage (Braham and Krogman footnote 2; Braham et al. 1979, 1980c, d). The majority of bowheads have usually passed Point Hope by mid-May (Foote footnote 21; Johnson et al. 1966) and occur in peak numbers at this time at Point Barrow (Maher and Wilimovsky 1963; Fiscus and Marquette footnote 18; Braham and Krogman footnote 2; Braham et al. 1979, 1980c). The migration along the northwest coast (Bering Strait to Point Barrow) essentially covers the period mid-April to early June, with a few whales migrating by thereafter, according to our work to date.

Previous authors and numerous Eskimo whalers describe the bowhead migration as occurring in three waves or pulses of whales that pass by the northwest coast each spring (Foote footnote 21; Marquette footnote 14). Examination of Figure 3 confirms that at least two pulses of whales migrated past Point Barrow in 1976, 1977, and 1978. These pulses appeared to occur in late April-early May and again near mid-May. A third pulse may occur in late May or early June; but our data either do not support this or the peak is small. The significance of this bimodal, or trimodal, distribution is not clear, but Eskimo whalers associate it with age, sex, and/or segregation of cow-calf pairs from other adults in the population. This cannot be confirmed from sightings and harvest data collected between 1975 and 1980.

From Point Barrow the whales travel northeasterly into the Beaufort Sea to Banks Island and Amundsen Gulf, Canada, some by early May (Braham and Krogman footnote 2; Fraker et al. 1978; Braham et al. 1979). Leads do occur closer to shore, but no whales were seen in them (Figs. 10, 15, 18), nor are the nearshore leads extensive. Further evidence in support of the hypothesis that bowhead and white whales migrate offshore in the Beaufort Sea in the spring independently proposed by Braham and Krogman (footnote 2) and Fraker (1977)[23] is reported in Braham et al. (1979, 1980d). The portion of the population which enters Canadian waters compared with the number passing Point Barrow is unknown. In the Canadian Beaufort Sea bowheads remain from May until late August or September (Cook 1926; Townsend 1935; Foote footnote 21; Sergeant and Hoek 1974; Fraker et al. 1978) before beginning the return autumn migration west. From June to September bowheads are reported to frequent Amundsen Gulf, Franklin Bay, Coronation Gulf, the east side of the Mackenzie Delta, and various areas south of Banks Island (Cook 1926; Townsend 1935; Anderson 1946; Porsild 1950; Manning and MacPherson 1958; Sergeant and Hoek 1974; Allen 1978; Fraker et al. 1978).

In August and September bowheads begin to leave the eastern Beaufort Sea on their autumn migration back to the Bering Sea (Cook 1926). The whales travel west in the southern Beaufort Sea, where they are hunted during September and October by Alaskan Eskimos from Kaktovik, Nuiqsut, and Barrow (Brower 1942; Maher and Wilimovsky 1963; Marquette footnote 14). Whales traveling this route have been sighted or harvested near Herschel Island (Cook 1926; Townsend 1935); Barter Island (Marquette footnote 14), Cross Island[24]; Colville River and Harrison Bay (Brower 1942); and Cape Simpson and Plover Islands (Braham and Krogman footnote 2; A. Brower[25]). Their spatial distribution from the shore to the pack ice during the autumn migration is not known, but it is likely to be dependent on ice conditions, food availability, and water depths. Sightings made in

[21]Foote, D. C. 1964. Observations of the bowhead whale at Pt. Hope, Alaska. Unpubl. manuscr., 73 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.

[22]G. Fedoseev, Pacific Scientific Research Institute of Fisheries Oceanography, Magadan, Nagaevskaya, 51, 685013, U.S.S.R., pers. commun. 28 February 1979.

[23]Fraker, M. A. 1977. The 1976 white whale monitoring program, Mackenzie Estuary, N.W.T. Imperial Oil Ltd. Unpubl. rep., 73 p. F. F. Slancy & Co., Ltd., Vancouver, B.C., Can.

[24]T. Brower, Barrow, Alaska, pers. commun. 4 October 1977.

[25]A. Brower, Barrow, Alaska, pers. commun. 19 May 1978.

the Beaufort Sea since 1974 (Figs. 24-27, 30, 31) indicate that bowheads are distributed from shallow coastal waters to the pack ice and perhaps into the pack ice. The numerous sightings in shallow water from Point Barrow to Smith Bay (Fig. 30) seem to confirm the importance of the nearshore areas to this species in the western Beaufort Sea.

From Point Barrow the animals appear to move westerly to Herald Shoal and Herald and Wrangel Islands (Cook 1926; Townsend 1935; Bockstoce 1977), then south through the Chukchi Sea into the Bering Sea. There is speculation by Soviet scientists that bowheads pass to the Bering Sea by traveling the western Chukchi Sea. Some animals appear to move southwest along the northwest coast of Alaska past Point Barrow to the Bering Strait, but this probably varies with weather and ice conditions. Most in the population migrate to the north side of the Chukotka Peninsula before entering the Bering Sea (Fig. 2; Townsend 1935; Johnson et al. 1981). Johnson et al. (1966) and F. Durham[26] believed that the fall migration through the Chukchi Sea followed an offshore passage, since bowheads were not seen at Wainwright, Cape Thompson, Point Hope, or Kivalina in the autumn during their studies. Simultaneous sightings of bowheads in the eastern Beaufort and western Chukchi Seas suggest that 1) there is a division in the autumn migration, with some whales leaving the Beaufort Sea perhaps as early as July and/or August; and/or 2) there are two subpopulations (i.e., that a later component of the spring migration moves into the Chukchi Sea and remains there in summer not completing the migration into the Beaufort Sea). Preliminary data presented earlier and in Braham et al. (1980b) suggest the first hypothesis is the more likely one.

Bowheads generally enter the northern Bering Sea in November and December, although sometimes they are seen in late September, arriving in central Bering Sea wintering areas in December-February.[27]

Life History and Associated Information

Reproduction

Facts about the reproductive biology of the bowhead whale are scant, though information gathered on animals harvested by Alaskan Eskimos has provided opportunities to study this species' reproductive cycle. A summary of some estimated reproductive life history data is reported in Table 2.

Sexual maturity is reached when animals attain lengths exceeding 1,100 cm. Durham (1979, footnote 10) reported that males attain sexual maturity at 1,158 cm (38 ft) and females at 1,220 cm (40 ft) at 4 yr of age. Marquette (footnote 14) noted that two female whales taken at Barrow, one accompanied by a newborn calf and the other containing a fetus, measured 1,525 cm (50 ft) and 1,730 cm (56 ft 6 in) long, respectively. From the presence of corpora albicantia in ovaries of 12 whales harvested in 1978 and 1979, sexual maturity in females may be reached at about 1,200 cm (preliminary findings); and adult females are larger than males (Johnson et al. 1981). Age, and length at first pregnancy, however, are unknown.

The mating period of the bowhead whale is not well known. Durham (footnote 10) maintained that mating occurs in early April before the whales reach Point Hope. Foote (footnote 21), however, observed what appeared to be copulatory be-

[26]F. Durham, University of California, Los Angeles, Calif., pers. commun. 21 September 1978.

[27]D. Harry and C. Oozeva, Gambell, Alaska, pers. commun. 25 July 1978 and 25 February 1979, respectively.

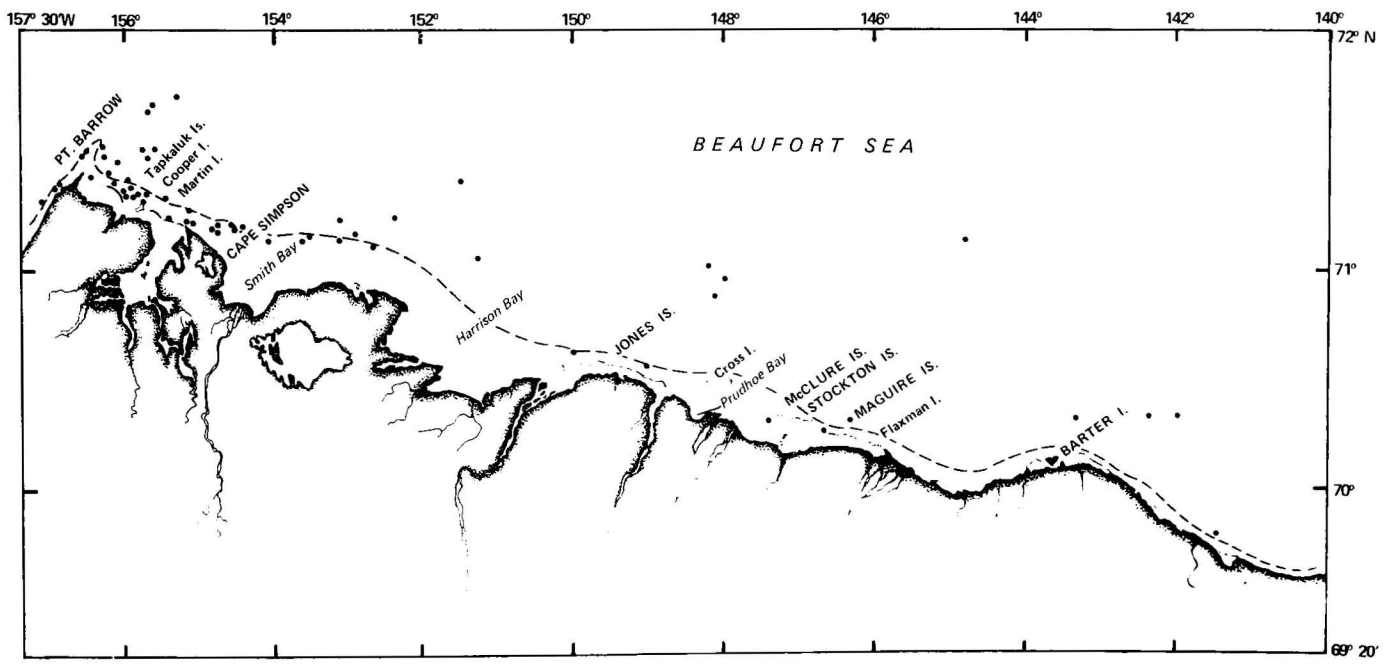


Figure 30.—Bowhead whale sightings in the Beaufort Sea, August through November 1974-78. Only sightings with a verified position were used. Most sightings occurred in the last half of September. The dash line represents the 12 m depth contour.

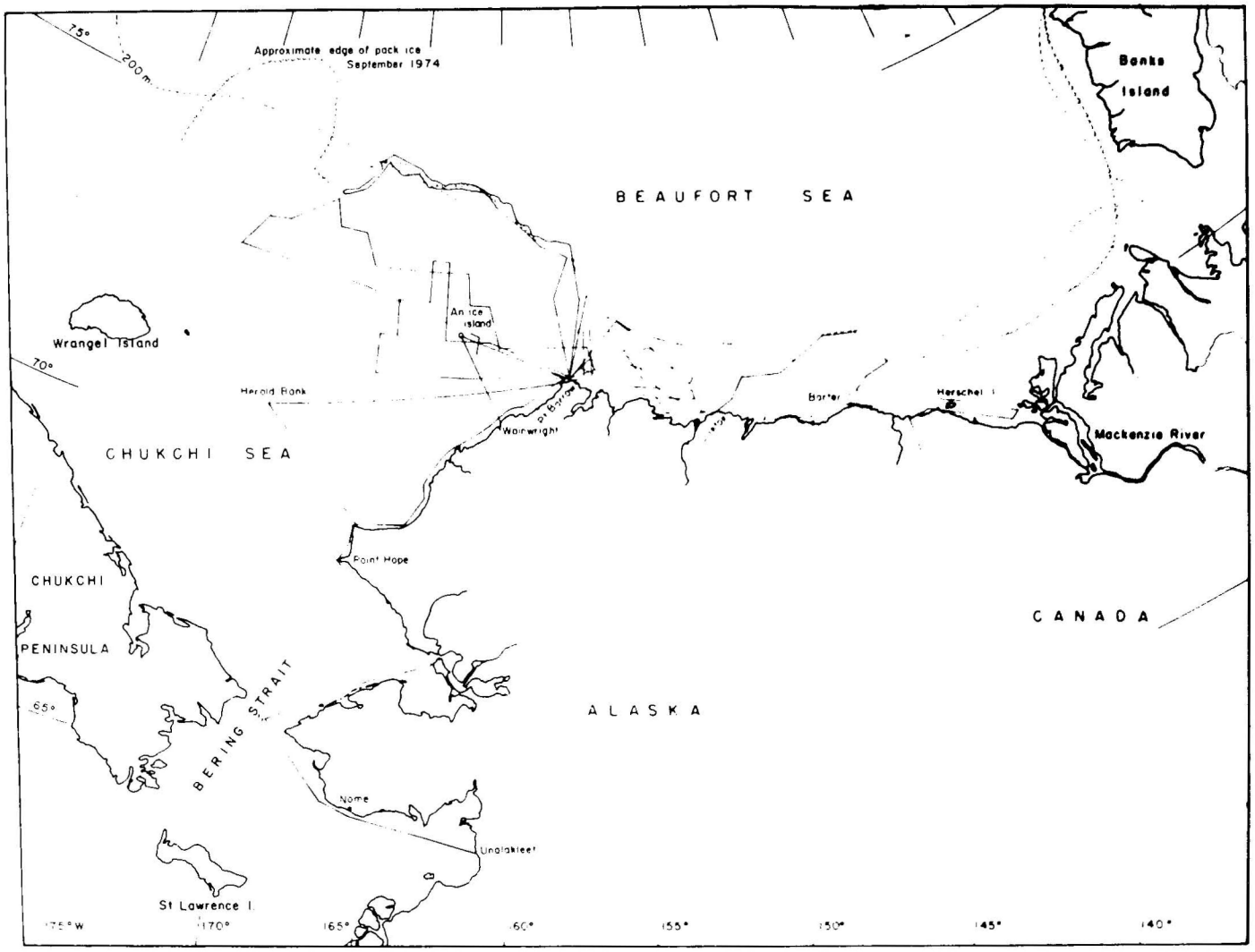


Figure 31.—Aerial survey tracklines flown by NMFS scientists, September 1974. Bowhead whale sightings in the Beaufort Sea are incorporated into Figure 30. (From Fiscus and Marquette text footnote 15.)

havior in May, as whales passed Point Hope. Copulatory behavior was also reported by Krogman (1977) and Everitt and Krogman (1979) in May north of Point Barrow. Mating behavior of Atlantic bowheads was reported in late summer (Scoresby 1820). Possible copulation was witnessed on 16 March 1979 west of St. Matthew Island (Braham et al. 1980c). Mating may therefore occur from late winter to summer, with spring (April-June) being the more probable peak period.

Gestation is estimated to last 1 yr Scoresby (1820) believed that bowheads have a 9-10 mo gestation period, while Eschricht and Reinhardt (1866) believed it to be 13-14 mo. Durham (1980, footnote 10) reported from observations of harvested bowheads taken at Point Hope and Barrow that the gestation period is 12 mo. The actual length, however, is still unknown. Minimum gross annual reproductive rate (calves per total population) has been estimated at 1-5.6% (Davis and Koski 1980; Cubbage and Rugh 1982; Marquette et al. 1982).

The calving period is reported to correspond with the time of mating—early spring to early summer. Cows with calves pass Point Hope and Point Barrow from mid-April to early-June (Maher and Wilimovsky 1963; Marquette 1976; Braham et al. 1979). Whalers in the eastern Arctic reported seeing apparent cows with calves from early May to July (Gray 1886). Durham (footnote 10) believed that bowhead whales in the western Arctic calve in early April. Eschricht and Reinhardt (1866) in the eastern Arctic Canada reported calving occurring from late March to early May. Most researchers agree that a single calf is born.

Although recognizing that parturition has never been observed, our scant sightings of calves indicate that bowheads probably give birth in spring, perhaps a few before (February-March) but most during migration (April-June). Marquette (footnote 14), summarizing the known data on calving, provided information that bowheads may calve from April through August. Observations of calves in the spring (Braham et al. 1979, 1980b) and apparent copulatory behavior in the late winter (Braham et al. 1980c) and spring (Everitt and Krogman 1979) with no sightings reported for the autumn, also indicate that the peak period of mating and calving is March-June, with few calves being born in summer or autumn.

The length of newborn calves has been measured at 305-460 cm (10-15 ft) (Scoresby 1820; Durham 1980). Bodfish

Table 2.—Summary of some estimated reproductive life history data for bowhead whales.

Life history parameter	Parameter value	Area data collected	Reference
Sexual maturity			
Males	> 11m	Chukchi Sea	Durham (text footnote 11)
Females	> 12m	Chukchi Sea	Durham (text footnote 11); Johnson et al. (1981)
Calving and mating period	Mar.-May	No. Atlantic	Eschricht and Reinhardt (1866)
	Mar.-June	Bering to Beaufort Seas	Braham and Krogman (text footnote 2); Braham et al. (1979, 1980c); Everitt and Krogman (1979)
	April	Chukchi Sea	Durham (text footnote 11)
	Apr.-June	Chukchi Sea	Maher and Wilimovsky (1963); Marquette (1976)
	Apr.-Aug.	Western and eastern Arctic	Summarized in Marquette (text footnote 15)
	May	Chukchi Sea	Foote (text footnote 23)
	May-July	No. Atlantic	Gray (1886)
Gestation	9-10 mo	No. Atlantic	Scoresby (1820)
	12 mo	Chukchi Sea	Durham (1980)
	13-14 mo	No. Atlantic	Eschricht and Reinhardt (1866)
Lactation	5-6 mo	Beaufort Sea	Marquette (text footnote 15)
	12 mo	No. Atlantic	Slijper (1962)
	711-851 cm (calf length)	—	Tomilin (1957)
Gross annual reproductive rate (GARR)	[1]1-5.6%	Chukchi and Beaufort Seas, and eastern Canadian High Arctic	Davis and Koski (1980); Cubbage and Rugh (1982); Marquette et al. (1982)

[1]Considered a minimum estimate when compared with estimates for other large baleen whales.

(1936) estimated the length of newborns at 305-366 cm (10-12 ft); Eschricht and Reinhardt (1866) reported lengths of 366 to 396 cm (13-14 ft). An apparent newborn calf taken at Barrow 20 May 1954 was measured by Eskimos at 300-350 cm (10-12 ft) (Marquette footnote 14). According to these findings the average length of a newborn bowhead whale is about 360 cm (12 ft). One bowhead calf with attached umbilicus taken at Barrow in 1971 or 1972, was estimated (no measurements made) by resident Eskimo whalers to be about "20 ft" long, or 615 cm.[28] This is unusually large for a newborn, if the estimate was accurate.

Information on the duration of the lactation period in bowheads is scant and variable. Slijper (1962) reported the lactation period to be 12 mo. Marquette (footnote 14) stated that since lactating females have not been recorded in the autumn take near Barrow, lactation may last only 5 or 6 mo. Tomilin (1957) reported that lactation ends and calves are weaned at a length of 711-851 cm (23-28 ft). Although inconclusive, it appears that bowheads have a 6-12 mo lactation period. Since yearlings are not seen in very close association with adults in spring, it seems unlikely that lactation lasts 1 yr. Lactation in gray whales last approximately 4 mo (Rice and Wolman 1971).

Based on the estimated lactation and gestation periods, the calculated calving interval for female bowhead whales is at least 2 yr and is likely to be longer. Large, long-lived mammals are characterized in having calving intervals of more than 2 yr (Fowler and Smith 1973; Goodman 1978).

[28]O. Leavitt and J. Adams, Alaska Eskimo Whaling Commission, Barrow, Alaska, pers. commun. 15 May 1978.

Food Habits

Nemoto (1976) classified the bowhead whale as a bottom skimmer, and although individuals have been observed feeding in shallow waters, bowhead probably feed throughout the water column. A comprehensive study of bowhead feeding has not been conducted; however, the small data base from the available literature indicated that pelagic arthropods (euphausiids, mysids, pteropods, copepods, and amphipods) are the prey species mostly taken, and, to a lesser extent, annelids, molluscs, and echinoderms (Mitchell 1975; Marquette footnote 14; Lowry et al. 1978). Johnson et al. (1966) examined the stomach contents of three bowhead whales taken by Point Hope Eskimos in the spring. The stomachs were empty and the third contained fragmentary remains of polychaetes, reptantia, gastropods, crustaceans, echinoids, and sand and gravel. Lowry et al. (1978) analyzed the stomach contents of two bowhead whales taken at Point Barrow in the fall of 1977 and found that together they contained (by volume) 90.3% euphausiids (*Thysanoessa raschii*), 6.9% gammarid amphipods (*Gammarus zaddachi*, *Acanthostepheia behringiensis*, *Monculoides zernovi*, and *Rozinante fragilis*), and 2.7% hyperiid amphipods (*Parathemisto libellula*). Five bowheads taken by Kaktovik whalers off Barter Island in autumn 1979 had primarily euphausiids and copepods (*Calanus* spp.) in their stomachs (Lowry and Burns 1980). A 1-yr study of bowhead feeding contracted by us to the Alaska Department of Fish and Game, Fairbanks, determined that competition for food with Arctic cod may be important in some years if food is limiting (Frost and Lowry

1981)[29]. Of the 17 bowhead whale stomachs and intestinal tracts examined to date from whales landed at Barrow and Kaktovik with discernable prey items present, the following proportions in the bowhead diet were: Euphausiids 65%; copepods 30%; hyperiid amphipods 1%; and all others, primarily including amphipods, 4% (see Marquette et al. 1982 for a summary of Frost and Lowry footnote 29).

Behavior

Essentially all bowheads progress steadily through the nearshore lead during the spring migration along the northwest coast of Alaska, following a fairly straight course towards the northeast (20°-30° magnetic north). Since the NMFS ice camp studies were initiated in 1976, < 1% of all bowheads were seen going southwest in the spring (Carroll and Smithhisler 1980). The rare exceptions occurred when the lead was obstructed by ice, or when the whales were resting, feeding (presumably), courting, mating, or breaching. Most whales progressed past the ice camp at a rate of 1.9-7.5 km/h (1.0-4.0 nmi/h) depending on the direction of the current; this rate of travel was confirmed by studies at Cape Lisburne (Rugh and Cubbage 1980).

Bowheads do not travel in close association with one another. Of 2,406 bowhead observations recorded between 1976 and 1978, 1,815 (75.4%) were singles, 470 (19.5%) were in pairs, 105 (4.4%) were in groups of three, and 16 (0.7%) were in groups of 4. There were noticeable peaks during the course of the migration, sometimes related to ice conditions, but also at times when the whales had free movement in the lead.

When bowheads come to the surface to breathe, they usually break the water surface from 1 to 14 times, with each surfacing (roll) interrupted by a short shallow dive. Exhalation is not always observed during each roll. A completed series of rolls is termed a rise (= total number of rolls visible during a passage of one whale in front of an observer). The mean number of rolls per rise recorded from 1975 to 1977 was 6.57 (SD = 3.08; n = 63), while the mean in 1978 was 6.53 (SD = 2.84; n = 41) (Carroll and Smithhisler 1980).

Each time a bowhead rolled it was on the surface for a mean of 4.7 s (SD = 2.0). The average time below the surface between blows (= rolls) was 10.8 s (SD = 5.2). From this we calculated that the average amount of time a bowhead was above the surface per rise was about 31 s. The average duration of a rise between the first roll and the sounding dive was 1.5 min.

The duration of sounding dives varied from 3.0 to 26.7 min. The mean dive time recorded during the 1975-77 spring seasons was 15.2 min (SD = 4.4). Of 51 dives times in 1978 the mean was 15.6 min (SD = 5.2). Combining these with the 1.5 min mean rise time, a time of 17.1 min was calculated for the complete cycle. On the basis of these data, we estimate that during their migration near Barrow, bowhead whales were visible above the water surface 3.1% of the time within the field of view of our ice camp observer(s). Using the same basic calculations, bowheads were visible to aircraft observers for approximately 8.4% of the time they were under observation.

The surfacing pattern of a cow and calf pair seems to be related to the calf's activity. Of three cow and calf pairs timed, mean dive time was 6.6 min (range 5.9-7.0 min). Calves often blew two times during each roll. Very small calves were seen during the migration, usually traveling very close to the accompanying adult. We judged these calves to be recently born.

Bowheads move steadily through partially closed leads by adjusting their diving and surfacing sequences to the size and location of open water in the pack ice. They take fewer breaths per rise and make shorter dives. A whale coming to a small polynya will roll as many times as it has time, while traveling at a normal speed, then dive when it comes to the distant edge.

Occasionally, the ice cover was so complete that the whales' progress was hindered and they were seen milling in polynyas. It appears that the whales dive, search, and, if they do not find another polynya close enough, return to the original hole. Sea ice is more flexible than freshwater ice and both bowheads and white whales push up on the ice to breathe, forming hummocks. Bowheads have been heard exhaling under the ice when no apparent open water is available.[30]

Apparently bowheads are not always successful in finding open water or in being able to lift pack ice to breathe. Tomilin (1957) and Southwell (1898) both cited instances of bowheads perishing in the ice, and Sleptsov (1961) stated that there was a mass mortality of several dozen bowheads in Karaginsky Bay in 1932. Cook (1926) also reported bowheads perishing under ice during the autumn in the Beaufort Sea. Unfortunately, the details of these events were not reported.

Bowheads do not seem habituated to small boats. The sound of an outboard motor will cause a bowhead to vacate an area. The normal reaction to being pursued is escape. If a bowhead is injured, it will often dive under the ice. Reaction to airplanes flying overhead seems mixed. Few whales have reacted vigorously to our presence when we fly between 130 and 300 m. On a few occasions we have flown above whales at 65 m without obvious disturbance (c.f. photos in Everitt and Krogman 1979 where altitudes were down to 65 m). In 160 encounters using a Coast Guard helicopter and flying at elevations below 300 m only 17 (11%) bowheads appeared to react noticeably to the aircraft noise. The same results occurred at altitudes down to 130 m (Braham et al. 1980c). It appears then that fright reaction to noise varies greatly, depending upon the source, time of year, environmental conditions, and activity of the animals. Surface noises in water appear to cause more frequent fright reactions by bowheads than noises originating above them in the air.

Occasionally bowheads show considerable exuberance. We have observed them breaching, tail lobbing, flipper slapping, swimming on their backs and sides, and demonstrating other behavior. Along with numerous tail lobs and flipper slaps, a whale seen off Point Hope in 1977 breached 57 times in 96 min. We do not know the significance of these kinds of

[29]Frost, K., and L. Lowry. 1981. Feeding and trophic relationships of bowhead whales and other vertebrate consumers in the Beaufort Sea. Final report to Natl. Mar. Mammal Lab., Contract No. 80-ABC-00160, 106 p. Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA. Unpubl. manuscr., Alaska Dep. Fish Game, 1300 College Road, Fairbanks, AK 99701.

[30]Eskimo whalers, pers. commun. 1976-79.

activities, but they may indicate communication (Rugh and Cubbage 1980).

During the autumn migration bowheads may travel in larger groups than in spring. Groups of 2-30 animals have been recorded in the Canadian Beaufort Sea (Sergeant and Hoek 1974), and several groups up to 20 animals each were seen in September of 1974 and 1976 east of Point Barrow. Unfortunately, the composition of these groups or their specific activities during the fall migration are not known.

Occurrence of Bowheads in Outer Continental Shelf Lease Areas

Outer Bristol Bay-St. George Basin

Bowhead whales probably occur in the southeastern Bering Sea only during the late winter and early spring months when the seasonal pack ice front extends south of lat. 60°N, and then in low numbers. Only three sightings have been made in this area between 1976 and 1980, with one of those in 1976 undoubtedly being a duplicate west of St. Paul Island (Fig. 29). During the height of commercial whaling very few bowheads were taken in the southeastern Bering Sea even at a time when the population was at its apparent maximum size (Fig. 2, Bockstoce and Botkin footnote 13). It seems unlikely that animals would have been missed during commercial whaling operations as many ships traveled there enroute to Alaskan and Siberian ports to the north. The St. George Basin-Outer Bristol Bay area is beyond the central range of the bowhead.

Given our present state of knowledge, the Outer Bristol Bay-St. George Basin OCS areas east of long. 170°W and south of lat. 59°N do not include important or traditional habitat for the bowhead whale. If during those years when ice extends to its maximum southern limit (similar to 1976) and if unusual ice or storm conditions force the whales to move farther southeast than normal, then some whales are likely to occur here.

Navarin Basin

Townsend's (1935) review of bowheads taken in the Bering Sea clearly indicated that they formerly frequented the Navarin Basin (St. Matthew Island to Cape Navarin along the continental shelf break) from April to July (Fig. 2). Under NOAA's Platforms of Opportunity Project we have received a few observations of bowheads throughout the Bering Sea and, although some effort has been expended near the Navarin Basin, we have received no bowhead sightings from the area. Several U.S. and Soviet aerial surveys have been conducted during the spring in or near the area but no bowheads were reported (Fedoseev 1966; Kenyon 1972[31]; G. Fedoseev and V. Golt'sev[32]).

A recent icebreaker survey of bowhead winter distribution (Braham et al. 1980c), indicated that bowheads spend the late winter and early spring months in and adjacent to the Navarin Basin. We made a systematic survey of the ice front in March 1979 from approximately 50 km east of Cape Navarin to south of St. Matthew Island. Bowheads were observed in highest densities on the west side of St. Matthew, as well as farther north of St. Matthew Island, and west and southwest of St. Lawrence Island (Fig. 29). Weather prohibited extensive coverage of the Navarin Basin.

No bowheads were seen between St. Lawrence and St. Matthew Islands in 1976 and 1977 but 109 animals were seen in 1979. During years of more extensive ice coverage bowheads presumably occur farther south. Under these circumstances they are likely to occur in and adjacent to the Navarin Basin in greater numbers than we have seen. (Note: The Navarin Basin was not surveyed in 1976 and 1977.) The frequency of occurrence and time spent by bowheads near Navarin, then, is probably related to ice conditions.

Norton Sound-Northern Bering Sea

The Norton Sound-northern Bering Sea (NBS) OCS lease area, as it is presently designated to include St. Lawrence Island and the eastern half of the northern Bering Sea from the USA-USSR 1867 Convention Line to the Bering Strait at Cape Prince of Wales, includes both important habitat for bowheads and areas where they do not normally occur. Bowheads have not, prior to spring 1980, been reported east of long. 166°W into Norton Sound. West of long. 166°W bowheads occur seasonally (Table 3).

The best available data indicate that the bowhead population is found in the NBS during the spring, from late March through May, and in the fall from November through January. They might be present in low numbers near the Bering Strait from July to October, especially in September and October; however, Eskimo informants at Little Diomede and St. Lawrence Islands have told us (Braham et al. 1980d) that bowheads are essentially absent in the NBS during the summer (late June-October). An adult with calf was seen in July several years ago, and two adult bowheads were reported near Punuk Island (southeast of Northeast Point, St. Lawrence Island) in June or July 1978, however this is an unusual occurrence.[33]

The bowhead whale spring migration around St. Lawrence Island may be more complex than reported by us earlier (footnote 2). Bowheads apparently converge on the island from the south exhibiting three general patterns: Two routes around the west end of the island and one around the east end. Many Eskimos at Gambell and Savoonga report that whales that reach the island near Southeast Cape move west along the south coast and then north past the west end of the island near Gambell. Whales that arrive at the island at Southwest Cape are said to migrate west away from the island across the Anadyr Strait to the Siberian coast at Cape Chukotskii (lat. 64°15'N, long. 173°W) and the village of Siriniki before continuing north on migration. This suggests that there are two migration routes around the west end of St. Lawrence Island. Data collected since 1976 on the occurrence and movements of bowheads adjacent to St. Lawrence Island did not confirm this hypothesis, primarily because few sightings were made. In 1979 bowheads were seen all across the Strait of Anadyr (Braham et al. 1980c); however, mild ice conditions may have altered the migration pattern as described above.

[31]Kenyon, K. 1972. Aerial surveys of marine mammals in the Bering Sea, 6-16 April 1972. Unpubl. rep., 79 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115.

[32]G. Fedoseev and V. Golt'sev, TINRO, Magadan, U.S.S.R., pers. commun. 12 September 1977.

[33]R. Silook, Gambell, Alaska, pers. commun. from another, unidentified Eskimo from Savoonga, 16 August 1979.

Table 3.—Area use and timetable for the majority of the bowhead whale population in or adjacent to proposed Outer Continental Shelf (OCS) lease areas of the Bering, Chukchi, and Beaufort Seas. Some exceptions exist, of course.

OCS lease areas	Temporal use		Spatial use	
	Present	Absent	Present	Absent
St. George Basin-outer Bristol Bay	Essentially absent, a few may occur irregularly in the spring in the western side		west-central[1] St. George Basin	Remaining?
Navarin Basin	Feb.-Apr.	May-Jan.	Unknown	Unknown
Norton Sound-No. Bering Sea	Mar.-June, Oct.-Jan.	Feb., July-Sept.	Western half	Norton Sound[2]
Hope Basin (Chukchi Sea)	Apr.-June, Sept.-Dec.	Jan.-Mar., July-Aug.	West of long. 164°W	Kotzebue Sound[3]
Beaufort Sea	Apr.-June, Aug.-Nov.	Dec.-Mar. July?	Nearshore and offshore	

[1]If and when present.
[2]During most years.
[3]East of long. 164°W.

The migration route along the west side of St. Lawrence Island then takes the whales through the western portion of the NBS OCS lease area west of an imaginary line from Savoonga to Cape Prince of Wales. Whales in spring are on occasion seen in open water east of Gambell to west of Savoonga (closer to Gambell). Open water increases from east to west towards the Chukotka Peninsula. We conclude that most bowheads migrate through the western half of the NBS OCS lease area in the spring, during average ice years. Eskimos also report that some bowheads migrate around the east end of St. Lawrence Island in the spring. We have only two sightings at the east end of the island since 1976. We do not believe that the east end of the island is an important migration corridor. A more detailed description of the spring migration is covered in Braham et al. (1980b).

No records were found nor sightings made by us prior to 1980 of bowheads in the eastern portion (east of long. 166°W) of the NBS OCS lease area (i.e., Norton Sound). More than 10 bowheads were observed in Norton Sound in May 1980; at least 5 were seen near Norton Bay. These animals occurred here as a result of an ice blockage in the Bering Strait which halted their spring migration. Although a complete account of the number and location of bowheads in Norton Sound during the spring of 1980 was not available for this revised report, Johnson et al. (1981) summarized the causes for the delayed migration. The important point here is that, given the proper conditions, bowheads can be found throughout the NBS OCS lease area but in low numbers in Norton Sound.

The autumn migration pattern in the NBS is less clear than for the spring, but apparently bowheads can be seen across the north side of St. Lawrence Island, suggesting that the migration path in autumn may be more diffuse than in spring. Several Eskimos at St. Lawrence Island have told us that bowheads do not migrate around the east end of the island in the autumn but rather move by the west end.

The waters adjacent to St. Lawrence Island are important to the survival of this population. The Bering Strait is also important because the entire bowhead population passes through it twice annually. The autumn period in the Bering Strait may be more important than the spring because if bowheads were limited or restricted from entering the Chukchi and Beaufort Seas in the spring, they would still be able to feed throughout the summer in the ice-free waters of the northern Bering Sea. Townsend (1935) clearly showed that bowheads once occurred in the NBS in the summer, a period thought to be a traditional feeding time for the species. However, if restricted from moving into the Bering Sea in autumn, some, if not many bowheads might be trapped by winter freezeup.

In conclusion the following points can be made from our investigations: 1) In spring, bowheads are more likely to migrate through the western portion of the NBS OCS lease area than to the east. 2) The autumn-winter migration in the NBS probably occurs throughout most of the western NBS, but no information exists to help us predict how far east into outer Norton Sound they occur. 3) Inner Norton Sound (east of long. 166°W) is seldom used by bowhead whales, and does not include important habitat. 4) Waters adjacent to St. Lawrence Island and the Bering Strait may be critical habitat areas for the stability and survival of this population.

Hope Basin and Northeastern Chukchi Sea

Very little is known of the specific movements of bowheads in the Hope Basin (south of lat. 69°N, east of long. 169°W) and northeastern Chukchi Sea (north of lat. 69°N, east of long. 160°W). From April to June, bowheads migrate north in leads through the pack ice flaw zone from the Bering Strait to an area stretching from Kivalina out to, on some occasions, 90 km offshore Point Hope. For additional specific details, see Braham et al. (1980b) and Johnson et al. (1981).

The autumn migration through the northern Chukchi Sea and Hope Basin to the Bering Sea appears to be farther offshore than during the spring. Bowheads are not known to frequent Kotzebue Sound (east of long. 164°W) with any regularity. Townsend's (1935) plots of harvested whales (Fig. 2) indicated that the western portion of the Hope Basin was more heavily exploited, presumably a reflection of bowhead distribution. We believe that bowheads are generally found west of this lease area during autumn (September-November) (Braham et al. 1980c; Dahlheim et al. 1980; Johnson et al. 1981).

In conclusion, bowheads frequent the Hope Basin and northeastern Chukchi Sea during the spring and autumn migration but do not appear to spend a significant portion of time there for purposes of reproduction, growth, or feeding.

The entire population migrates through the lease area from April to June and are found primarily west of the lease area from September to December.

The northeastern Chukchi Sea is important for both spring and autumn migration, nearshore in the spring, and less so during autumn. Bowheads probably feed in the northeastern Chukchi Sea during autumn, most likely from September to December. If some bowheads do not migrate into the Beaufort Sea during the spring, then it seems likely that some whales occur west and perhaps southwest of Point Barrow from late summer on, especially during years of heavy ice.

Beaufort Sea

For an assessment of the occurrence of bowheads in or adjacent to existing or anticipated OCS lease areas in the Beaufort Sea, we consider the Beaufort Sea east of long. 150°W first, then west to approximately Point Barrow. This was done because 1) of the high probability that the western Beaufort Sea will soon be considered for OCS leasing, and 2) we have more site specific information on bowheads west of long. 150°W than east.

East of Longitude 150°W

The fact that few sightings (5) were made of bowheads within or adjacent to the existing OCS lease area (approximately between Colville River and Flaxman Island) between 1974 and 1978 makes it extremely difficult to determine what effects oil and gas development may have on the population (Table 4). Since 1974 we have made, or obtained, 53 fall sightings totaling approximately 323 animals for the entire Beaufort Sea (Fig. 30). Only about 23% (a total of 15 animals) were made east of long. 150°W. The paucity of sightings is directly proportional to effort: We were not able to conduct extensive surveys east of long. 150°W because of poor flying weather.

Table 4.—Sightings of bowhead whales within and adjacent to the existing Beaufort Sea Outer Continental Shelf lease area between long. 150° and 145°W within the 12 m depth contour. Data compiled from aerial surveys conducted between 1974 and 1978. Positions are approximate.

Date	Time	No. of animals	Latitude (N)	Longitude (W)	Information source
21 Sept. 1974	1528	1(t)[1]	70°13′	146°39′	NMFS
12 Sept. 1975	1130	1	70°16′	147°21′	NMFS
2 Aug. 1977	2300	1(t)[1]	70°35′	150°00′	S. R. Johnson[2]
21 Sept. 1977	1243	1	70°30′	149°00′	NMFS
21 Sept. 1977	1442	1	70°20′	146°20′	NMFS

[1](t) = tentative.

[2]LGL, Edmonton, Alberta, Canada, pers. commun. 20 September 1977.

Results nevertheless indicate that bowheads do visit the OCS lease area, as 38% of our sightings east of long. 150°W were within or adjacent to the barrier islands between long. 145° and 150°W (Fig. 30). Other evidence exists for the occurrence of bowheads in the OCS lease area. In autumn 1921 Sara Kunaknana's (Kaktovik, Barter Island, Alaska) family took a whale on Cross Island; and in 1935 they took another whale in the "Prudhoe Bay area."[34] A whale was also taken near the east fork of the Canning River (east edge of OCS lease area) in the fall of 1973.

Commercial whalers frequently followed bowheads during the late summer and autumn months from the western Canadian Beaufort Sea to the Chukchi Sea, yet few whales were taken near the OCS lease area (Fig. 2). This may have been because 1) few whales were present, 2) whales occurred in areas where the whalers could not go (e.g., in shallow waters), 3) the whales moved swiftly through the area and thus were difficult for the whalers to catch, and/or 4) whales occurred farther offshore near or in the pack ice. The net result is that we simply do not know how important the Beaufort Sea OCS lease area is to the bowhead whale. However, if they are present in any significant numbers, then they probably occur from late August to mid-October. Unfortunately, we have very little data to verify the precise timing and magnitude of their movements. Recent sightings of bowheads in and adjacent to this lease site by Ljungblad (1981) confirm that at least some bowheads frequent the nearshore environs in the eastern and central Beaufort Sea in autumn. We do know a few bowheads have been sighted or taken by Eskimos in the OCS area in the past 50 yr.

Eskimo whalers at Kaktovik, Barter Island, hunt bowheads as the whales head west on their autumn migration. They inform us that the autumn migration is segregated roughly into age classes. Smaller whales pass by early in the autumn and larger whales, including cow-calf pairs, pass by later. Whales are often first seen by late August, and later are seen near the pack ice as the ice moves closer to shore in September and October. The earliest whale taken in memory by Kaktovik Eskimos was 21 August 1972. Bowheads are still going by Barter Island as late as the whalers can get out in their boats and are seen even when the sea is covered with slush ice as late as mid-October.

West of Longitude 150°W

Bowheads apparently frequent the inshore waters of the Beaufort Sea between Point Barrow and Smith Bay on an annual basis (Figs. 24, 25, 30). Though we have spent more time flying offshore (out to 225 km) than nearshore west of long. 150°W, most animals were sighted within only a few kilometers of the coast. Most were seen in September (over 90%), but sightings made in August (Fig. 22; A. Brower, Sr.[35]), and one in November[36] point out that the time of occurrence here, as well as east of long. 150°W, covers a longer period than we previously thought (Table 2). Again, the timing of migration and occurrence undoubtedly varies somewhat among years.

We observed bowheads feeding east of Point Barrow to Smith Bay during September 1976. The whales were observed in shallow water, adjacent to the Plover Islands (Fig. 24). The same occurrence and behavior was observed in 1974,[37] 1975 (Ray in Braham and Krogman footnote 2), and 1978 (Braham et al. 1980d) (Fig. 30). On 21 September 1976, R.

[34]G. Jarrell, National Marine Fisheries Service, NOAA, pers. commun. 15 October 1978.

[35]A. Brower, Sr., Barrow, Alaska, pers. commun. 20 December 1977.

[36]J. Burns, Alaska Department of Fish and Game, Fairbanks, Alaska, pers. commun. 20 December 1977.

[37]C. Fiscus, Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Bldg. 32, Seattle, WA 98115, pers. commun. 28 September 1976.

Everitt (NMML, Seattle) photographed three whales lying at the surface with their mouths wide open at right angles to the wind and tide. If they were feeding, and we believe they were as this incident coincided with a large bloom and onshore movement of euphausiids, then this is the first known case of a whale passively feeding.

Eskimo whalers hunt for whales west of long. 150°W. Four whales were taken in the channel between Tapkaluk and Cooper Islands (lat. 71°51'N, long. 155°40'W) 29 September-8 October 1974. Whether the nearshore waters west of long. 150°W are more important to this population than east of long. 150°W has not been determined, but we believe that they are.

Bowheads have been seen in the autumn in shallow water of 3-12 m deep in the U.S. Beaufort Sea (Fig. 30, and Fraker and Bockstoce 1980). Bodfish (1936) found bowheads consistently at water depths < 40 m, but not deeper. Between August and November 1974-78, we have scored 234 sightings of bowheads in the Beaufort and eastern Chukchi Seas near Point Barrow: 172 were in water < 12 m deep, and 62 in water > 12 m (Fig. 30). The 12 m contour east of Point Barrow averages < 5 km offshore and 2 km off the Plover Islands. More of our aerial survey effort was conducted offshore near the 12 m contour rather than nearer to shore. The nearshore waters here appear to be more important for feeding whales than are waters further offshore.

A Question of Species Identity: Bowhead, *Ingutuk*, Right Whale?

During spring 1978 a controversy developed over whether two species of right whale (of the genus *Balaena* = *Eubalaena*) were present during the bowhead whale migration along the northwest coast of Alaska. Discussion at that time centered around the belief that a small, early spring "Arctic ice whale," called *ingutuk*, was the Pacific right whale, *Balaena glacialis*, rather than the bowhead whale, *Balaena mysticetus*. This led to the further concern that two endangered right whales, as well as the California stock of gray whales, *Eschrichtius robustus*, seasonally frequent the Beaufort Sea OCS lease area. The following evidence may resolve the issue (discussed in detail in Braham et al. 1980a).

Historical Evidence

Nomenclature

The question of taxonomic placement of the *ingutuk* is not new: Hadley (1915), Brower (1942), and Jim Allen in Bailey and Hendee (1926) thought *ingutuks* were not the same species as bowheads. The term *ingutuk*, an Eskimo word thought to refer specifically to young, fat, perhaps female, bowheads, is one of several terms commonly used to describe differing age and/or size categories of *agvik*—the bowhead whale. The term *ingutuvuk* ("one who carries a calf") describes a large female; *usingwachaek* is a full-sized bowhead; *kairalik*, *kiyralivuk*, and *kiyralivoak* refer to different sizes of male bowheads[38] (Durham footnote 10; Rice 1977; A. Brower, Sr. footnote 25). The profusion of terms describing these whales appears to be based upon historic and cultural usage.

Geographic Isolation

Bowheads now in the western Arctic-Bering Sea stock may be isolated from the Atlantic and/or Okhotsk stocks, and morphologically differences among stocks may explain the existence of the *ingutuk*. Townsend's (1935) and Bockstoce and Botkin's (footnote 13) harvest records indicate that while the Okhotsk and western Arctic-Bering Sea stocks are now isolated, this may not have been so > 100 yr ago. This would not seem enough time for genetic-morphological changes to occur. No diagnostic differences have been described between Atlantic and Pacific stocks (Scoresby 1820; Eschricht and Reinhardt 1866; Scammon 1874), and although detailed recent morphological data are not available for comparison among stocks, geographic isolation leading to new morphological types reentering the population cannot be ruled out.

Biological Evidence

Morphological Features

Some 22 morphological and behavioral features have been used to describe the differences between bowheads and *ingutuks*. After evaluating these characters with results of our research since 1973, and using information compiled by Durham (footnote 10) and Foote (footnote 21), we found that 14 (61%) of the characters were not unique to *ingutuks*, and that 4 (18%) of the characters could not be classified to either. Only 4 (18%) seemed to be positive *ingutuk* characteristics. These data do not exclude the possibility that the *ingutuk* represents one extreme of normal variation. An occasional whale with features usually attributed only to *ingutuk*, *usingwachaek*, or *kyralik* have been reported (Durham footnote 10), suggesting that a range of features may occur within individuals as well as within the (bowhead) population.

Sex and Size Categorization

There is belief by some Alaskan Eskimos that *ingutuks* are young female bowheads. Prior to 1978 only one of many *ingutuks* taken since 1962 was reported to be a male; all others were females. Since 1978, three males have been reported. Since 1973 we have identified 14 *ingutuks* out of 112 bowheads taken at Point Hope and Barrow. Ten of the *ingutuks* were female, 3 were males, and 1 was not satisfactorily sexed. The sex ratio of non-*ingutuk* bowheads from 1973 to 1978 was 46 females to 53 males. Significantly fewer male than female *ingutuks* have been taken, suggesting that "*ingutuk*" may be a female sex-related trait or term. *Ingutuks* have been reported to be smaller than bowheads; however, we found no significant difference. This test included all size classes of *usingwachaek* (= *kiyralik*), *ingutuk*, and *ingutuvuk* (= large *ingutuk*?).

[38] "Eskimo whaling at Barrow," an anonymously authored manuscript dated 12 December 1972, "compiled by the Naval Arctic Research Laboratory, Barrow, Alaska, for use by Dr. Floyd Durham."

Genetic-Biochemical Studies

We conducted biochemical and genetic studies on bowheads taken from 1977 to 1979 to help clarify stock discreteness. Electrophoretic analyses of liver tissues (nine whales) and blood proteins (three whales), including one *ingutuk* in each analysis, showed that much variability occurs within the population and within at least one individual analyzed. The biochemically variant animal, however, did not possess morphological characteristics attributed to *ingutuk*. Conversely, the *ingutuk* samples were not distinguishable from the other bowheads.

Conclusion

It is apparent that some bowhead whales look different from others, even though it often takes an experienced observer to make the distinction. The most apparent differences seem to occur with the variant called *ingutuk*. The preponderance of direct and circumstantial evidence suggests, however, that a clear distinction between *ingutuk* and bowhead cannot always be made when considering all morphological features over a range of whale sizes.

Although detailed morphometric and genetic-biochemical analyses of bowhead whales are far from complete, our research to date leads us to conclude that the *ingutuk* is not a species separate from the bowhead. The *ingutuk* is likely an age and/or sex related trait with the most compelling explanation that it is a yearling.

White Whales in Alaska

Abundance and Distribution

White whales of the northeastern North Pacific Ocean occur from the Gulf of Alaska westward to the Bering Sea, northward through the Chukchi Sea, eastward into the Beaufort Sea (Klinkhart 1966; Scheffer 1972), and west into the East Siberian Sea (Kleinenberg et al. 1964).

The Gulf of Alaska population of stock,[39] an estimated 300-500 animals, appears to remain in or near Cook Inlet yearround (Brooks 1963; Klinkhart 1966; Scheffer 1972; Alaska Department of Fish and Game 1975[40]; Harrison and Hall 1978). Murray and Fay (1979)[41] found few animals present during the winter months.

White whale sightings have been made, however, in the Gulf of Alaska beyond the boundaries of Cook Inlet. Harrison and Hall (1978) document the sighting of a single animal in Prince William Sound in March, and near Kodiak Island in March and July. Calkins and Pitcher (1977)[42] reported a late May sighting of 21 white whales in Yakutat Bay. They have been sighted as far south as Washington State (Scheffer and Slipp 1948), although this is certainly beyond their normal range. The population in Cook Inlet and the Gulf of Alaska is believed to be local and separate from Bristol Bay and Bering Sea population(s). Even though the Alaska Peninsula is evidently a barrier to the movement of these animals from the Gulf of Alaska into the Bering Sea, it seems plausible that interbreeding occurred in the recent past.

White whales occurring in the Bering Sea compose resident (or at least local to a defined area) and migratory groups. A minimum of 1,000-1,500 has been estimated to occur in the Bristol Bay-Kuskokwim Bay area throughout the year (Alaska Department of Fish and Game 1957 footnote 40; Klinkhart 1966). An additional, but unknown, number are thought to winter in the Bering Sea north of Bristol Bay. These animals apparently migrate into eastern Siberian and western Canadian waters in late spring and summer (Alaska Department of Fisheries 1955, 1956; Kleinenberg et al. 1964; Sergeant and Hoek 1974; Braham and Krogman footnote 2; Fraker footnote 23). An unknown portion of these migratory animals summer in the Norton Sound-Yukon Delta area (Figs. 20, 32), while others continue north through the Bering Strait (Scheffer 1972; Fay 1974).

White whales in the Chukchi Sea seem to be largely transients. Most migrate between the Bering and Chukchi Seas. An unknown number summer in Kotzebue Sound, particu-

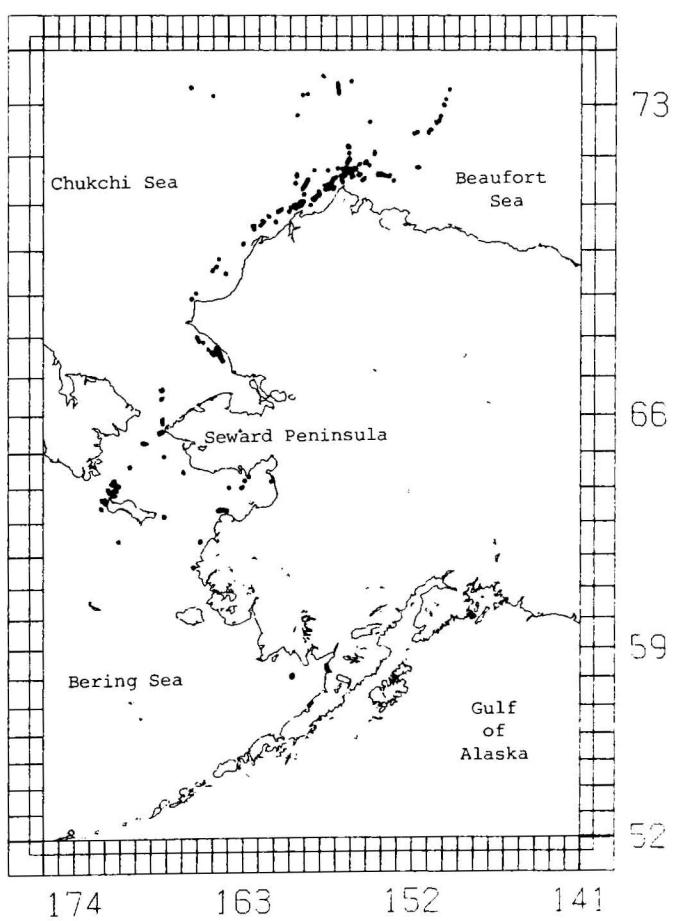


Figure 32.—Sightings of white whales during aerial surveys conducted between the months of March and September 1975-77. Over 400 sightings were made of approximately 2,000 whales.

[39]"Stock," as defined here, is a geographic subunit of a larger interbreeding population.

[40]Alaska Department of Fish and Game. 1975. [Untitled.] Unpubl. manuscr., 8 p. Alaska Dep. Fish Game, Juneau, Alaska.

[41]Murray, N. K., and F. H. Fay. 1979. The white whales or belukhas, *Delphinapterus leucas*, of Cook Inlet, Alaska. Unpubl. manuscr., 6 p. Coll. Environ. Sci., Univ. Alaska, Fairbanks, AK 99701.

[42]Calkins, D., and K. Pitcher. 1977. Unusual sightings of marine mammals in the Gulf of Alaska. [Abstr.] *In* Proc. Second Conf. Biol. Mar. Mammals, San Diego, Calif., 12-15 Dec., 1977, p. 53.

larly in Eschscholtz and Spafarief Bays, and others along the northwest coast. White whales have been reported in the southern Chukchi Sea in February,[43] which may mean that some overwinter in the Chukchi Sea as well as the Bering Sea.

The Beaufort Sea probably serves mainly as a summer feeding area for white whales migrating from the Bering and Chukchi Seas. Overwintering in the Beaufort and Chukchi Seas, should it occur (Bailey and Hendee 1926), would most likely be associated with the occurrence of some open water during mild ice years.

The Bering Sea population of white whales in 1976 exceeded 9,000. Some 6,000 migrants from U.S. waters were estimated in the Canadian Beaufort Sea (Fraker footnote 23; Fraker et al. 1978) at the same time that perhaps 3,000 animals were estimated in U.S. waters along the northwest coast of Alaska (Point Lay to Wainwright), Kotzebue Sound, Norton Sound, and Bristol Bay.[44] J. Burns (footnote 44) estimated the Alaska population size of white whales to be near 16,000 individuals.

Migration

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Calving and mating apparently occur simultaneously from May through August in eastern Siberian and Canadian waters (Vladykov 1944; Laws 1959; Sergeant 1962, 1973; Kleinenberg et al. 1964; Brodie 1971; Nishiwaki 1972). Similarly, Belkovich (1960) found that in the Soviet Arctic (White to Kara Seas) calving occurred from mid-June to mid-July, later to the east. Calving in Alaska is believed to commence in May or June (Klinkhart 1966); however, young calves are commonly seen by coastal Eskimo residents as early as March. Young of the year and neonatal calves have been seen in April and May each of the 4 yr we have been studying bowheads along the northwest coast of Alaska (Braham et al. 1979, 1980c). Small young of the year calves were observed by the senior author 100 km north of Barrow on 28 September 1979. Calving may therefore occur into late summer or early autumn. Mating locations in the eastern Bering Sea are southeast Kotzebue Sound, Bristol Bay, Yukon Delta-Norton Sound, and along the northwest coast of Alaska, particularly near Peard Bay.

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Cows are believed to nurse calves for approximately 24 mo. Brodie (1971) and Sergeant (1973) estimated lactation periods of 24 mo and 21 mo, respectively, for white whales in eastern Canadian Arctic waters. Kleinenberg et al. (1964) estimated the lactation period in Siberian Arctic waters to be 5-6 mo.

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larly in Eschscholtz and Spafarief Bays, and others along the northwest coast. White whales have been reported in the southern Chukchi Sea in February,[43] which may mean that some overwinter in the Chukchi Sea as well as the Bering Sea.

The Beaufort Sea probably serves mainly as a summer feeding area for white whales migrating from the Bering and Chukchi Seas. Overwintering in the Beaufort and Chukchi Seas, should it occur (Bailey and Hendee 1926), would most likely be associated with the occurrence of some open water during mild ice years.

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ductive activities (Sergeant and Hoek 1974). Later on, due to the gradual dispersal of food (primary fish), Klumov (1939) reported the whales divide into smaller groups and eventually move toward the wintering grounds.

From a sample size of 2,002 white whales observed during surveys since 1976, we calculated that mean group size was 4.8 (SD 0.43, $n = 419$). The preponderance of sightings occurred in April and May. The mean group size estimated is believed to be biased downwards because of a tendency to split larger "groups" when counting from an airplane. Group size estimates made from our ice camps at Point Barrow varied from 4.8 to 12.4 (no variance estimate) depending on lead width (extent of water). As open water increased, group size decreased.

Kleinenberg et al. (1964) further detailed the composition of groups with size variation (i.e., 10's or 100's of individuals). In groups of 10, the animals were normally traveling by two's and three's, some 10-30 m apart. Within these groups of 10 they found that 1) adults always kept apart; 2) adults often formed the majority of the herd; and 3) the few young that were present remained in the middle of the larger group structure. In groups of 100's, large adult males, forming 51.2% of the herd, were followed by females with calves (Dorofeev and Klumov 1936; Arsenyev 1939). Kleinenberg et al. (1964) reported that females were often accompanied by one to three "young" (presumably gray-colored subadults).

White whales are dark brown to gray in color up to about 6 yr old. Sexual maturity occurs at approximately 5 yr for females and 8 yr for males (Sergeant 1973). Color change can thus be used to estimate the minimum size of the subadult population. In 1977, we scored 1,699 white whales (including 7 newborn calves) as to color phase during their annual spring migration past Point Hope, Alaska. It was possible to make a classified count of 507 animals: 316 (62.3%) were white; 166 (32.7%) were gray; and 25 (4.9%) were transitional between gray and white. This resulted in an approximate adult to subadult ratio of 2:1. From aerial surveys in 1976 and 1977, a ratio of 14:1 (white:gray phase) was estimated. We believe the aerial results to be an overestimate because of the short amount of time to count and confirm the color of an animal from the air (for these data years only), and the ice counts to be an underestimate because of the light reflection off gray ice or dark water onto a light object making the object appear darker than actual. Also, we assume that both methods were an unbiased estimate of the population(s).

RECOMMENDATIONS

Actions Based on Existing Knowledge

Based on our present state of knowledge of the distribution and biology of the bowhead whale in the Bering, Chukchi, and Beaufort Seas, we recommend that serious consideration be given to removing or drastically limiting oil and gas development in four important (perhaps critical) habitat areas: 1) The northern Bering Sea around St. Lawrence Island. 2) The Bering Strait. 3) Northwest coast of Alaska, Cape Lisburne to Point Barrow. 4) The western U.S. Beaufort Sea from long. 150°W to Point Barrow.

Designation of these areas as of primary importance to the species is partly based on the fact that we have better information for these areas than for others. Unfortunately, we have less good information for areas which might prove to be of particular importance, e.g., the eastern Beaufort Sea (including the present OCS lease site), Hope Basin, and the Navarin Basin. However, the eastern Beaufort Sea and the Hope Basin appear to be transition zones for the whales during their annual migration rather than vital places where they would be most vulnerable. Additional research, particularly in the Beaufort Sea, is needed to verify this point.

Without precedents regarding effects on whales of oil-related development activities, it is difficult to assess jeopardy to this population, as required by Section 7 of the U.S. Endangered Species Act of 1972. However, we can predict the times and locations where the population, or at least individuals, would be vulnerable to an oil spill or other possible disturbing activities. The times are outlined by OCS lease area in Table 3. Specifically the above described areas are of greatest significance because we believe bowheads engage in two critical life history phases there—reproduction and feeding. They also migrate directly through these areas twice annually.

Our conclusions are based on 2 yr of OCSEAP research, and two additional years of NMFS studies where, in both cases, we were limited by weather, time, and budget to completely cover all areas visited by bowheads. It is, of course, difficult to draw conclusions on the importance of areas and times within their range where few data exist.

We are less certain about the times and areas where white whales might be vulnerable. Certainly inner Kotzebue Sound appears to be an important summering area for reproduction and feeding. The northwest coastal waters from Point Lay to Point Barrow appear also to be an important area for white whales, although this may vary among years. But again, because we do not know how many stocks of white whales we are dealing with, site specific vulnerability is particularly difficult to assess.

White whales appear to occur farther offshore in the U.S. Arctic Ocean than bowheads; perhaps they are less vulnerable to nearshore development. Some do, however, occur very near shore in the eastern Bering and Chukchi Seas during the spring and summer. Because some Eskimo subsistence depends upon both species, we urge that site specific studies related to interaction between whale, subsistence activities (hunting requirements), and oil development activities be undertaken or continued.[48] We further urge that ecological studies be conducted, placing greater value on both species habitat requirements and environmental (physical and biological) interaction than previously suggested or conducted.

[48]Since this paper was written two important studies were conducted on behavior and distribution of bowheads which we recommend to the reader. 1) Wursig, B., C. Clark, E. Dorsey, M. Fraker, and R. Payne. 1981. Normal behavior of bowheads. *In* W. J. Richardson (editor), Behavior, disturbance responses and feeding of bowhead whales in the Beaufort Sea, 1980, p. 21-90. Chapter in unpublished report from LGL Ecol. Res. Assoc., Inc., Bryan, Tex., for U.S. Bureau of Land Management, Wash., D.C. 2) Fraker, M., C. Greene, and B. Wursig. 1981. Disturbance responses of bowheads and characteristics of waterborne noise. *In* W. J. Richardson (editor), Behavior, disturbance responses and feeding of bowhead whales in the Beaufort Sea, 1980, p. 91-195. Chapter in unpublished report from LGL Ecol. Res. Assoc., Inc., Bryan, Tex., for U.S. Bureau of Land Management, Wash., D.C.

Proposed Research Needs

With regards to potential problems or questions of concern to the BLM, future bowhead whale research needs include consideration of direct and indirect effects of oil pollution and developmental activities with potential first-order effects, such as: 1) Intestinal disturbances resulting from oil ingestion; 2) irritation and deterioration of skin and eye tissues; 3) impairment of thermal regulation; 4) fouling of baleen plates; 5) inhalation of oil and congestion of the lungs; 6) noise interference with intraspecific communications; and 7) threat to traditional migration routes, calving areas, and/or feeding grounds. The most critical second order effects would be destruction of food supplies through contamination or alteration of the marine habitat, should it occur.

The objectives of any research in and near OCS lease areas should be to determine 1) the frequency of occurrence in and adjacent to specific lease sites; 2) the magnitude of, or compoment of, the population (including sex and/or age class segregation) frequenting the lease areas; 3) the reasons why whales occur in certain areas (e.g., apparent annual feeding nearshore east of Point Barrow in September); and 4) the studies (direct and indirect) that could best address potential noise, oil, and traffic interference problems. Because destruction of preferred wildlife habitat is a common result of man's activities, general studies of the marine environment as it now exists in Alaska would be of primary importance. Presumably these kinds of studies will continue on a lease site basis as lease sale scheduling proceeds from site to site.

The following is a list of proposed research topics with regard to bowheads and white whales. Results from these studies should provide at least the minimum information needed to make management decisions, especially where related to the requirements of the Endangered Species Act. These studies admittedly relate primarily to occurrence and direct effects because, we believe, these are the most obvious studies for which answers might be readily obtained. Most have been recommended previously in various meetings and documents since June 1978.

Bering Sea

1) Study whale movements and habits of whales associated with the movement of ice during breakup in spring and formation in autumn around St. Lawrence Island.

2) Study calving and feeding near St. Lawrence Island in the spring and feeding in the autumn, especially north of the island.

3) Study habitat use patterns in the Navarin Basin during late winter.

Chukchi Sea

1) Determine if bowhead and white whales migrate directly into the western Chukchi Sea during the late spring or summer from the NBS, and if they migrate from the Beaufort Sea into the Chukchi Sea between June and September. This information is necessary to determine if the entire population enters the Beaufort Sea and, thus, might be vulnerable to oil development related activities along the North Slope.

2) Ascertain whether the Hope Basin area supports bowheads for feeding in late autumn.

3) Study presence of white whales in Kotzebue Sound and adjacent bays (e.g., Escholtz Bay) and the northwest coast to relate habitat use and seasonal dependency. Population segregation or stock identification might be studied using electrophoretic analyses. Life history information is essential.

4) Determine which areas of the northeast Chukchi Sea that bowhead whales are most likely to feed in and migrate through in the autumn.

Beaufort Sea

1) Determine the frequency distribution of whales from the shore to the pack ice in the summer and autumn. It is essential that we know what component of the migrating population will be in or near the OCS area. For example, do all whales move offshore (i.e., near the ice edge), or nearshore through the lease area? A knowledge of the spatial distribution is necessary to determine how many individuals in the population might be vulnerable. Changes in ice conditions and relative movement of whales to ice is an important corollary study.

2) Conduct aircraft and/or vessel surveys in the western Canadian Beaufort Sea during the summer, principally in Amundsen Gulf, to further determine if the relative magnitude of the bowhead population here is similar to that estimated at Point Barrow in the spring. Again, this is important in order to assess what portion of the population might be vulnerable. Related behavior and feeding studies are also recommended.

3) Define the importance of the U.S. Beaufort Sea for bowhead feeding. Food habit studies and sample collecting of zooplankton should be done over a wide area of the Beaufort Sea. General trophic interaction studies are important too. This is important baseline information because we have no idea how, or if, animals respond to changing resource (prey density) patterns between the shore and pack ice, or even east to west in the Beaufort Sea. General biological oceanographic information is paramount to understand the Beaufort Sea ecosystem; such information is presently lacking.

Non-site Specific Studies

Noise effect studies should be conducted. Additional detailed studies on behavior and response vocalizations might also help determine the whales' sensitivity to man's activities. Further analysis of historical Eskimo and Yankee shore-based whaling records should be made to establish and to evaluate total mortality. Since the euphasiids (e.g., *Thysanoessa raschii*) and copepods (*Calanus* spp.) are the principal prey taken by bowheads, a detailed study of the life cycle and quantitative occurrence of these species should be made in the Arctic, especially in the Beaufort Sea nearshore from Barter Island to Point Barrow, Amundsen Gulf, and eastern Chukchi Sea. Naturally, the life histories and quantitative determination of other prey species and competing predators should be made as other important bowhead food items are discovered. Concurrent biological oceanographic studies should support the laboratory work. Oil effects studies, after life cycle studies, should follow.

The aforementioned proposed studies are only generally discussed here. Specific studies should be thoroughly re-

viewed for scientific relevance and management alternatives considered. Results from these, or similar studies, will provide a preliminary basis for making timely decisions concerning further research and possible implications of OCS development. Additional much needed research on life history parameters should also be vigorously pursued.

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APPENDIX I

Aerial surveys flown during 1975-77 as part of OCSEAP Research Unit 69. File identifiers are those used on both Environmental Data Service OCSEAP 027 format and National Marine Mammal Laboratory format. Mileage (approximate) is in kilometers. Wnt-Wainwright; RE-return.

File identifier	Survey date	Description (survey origin/area surveyed)
1. Sep 6-Sep 29,'75 Total miles surveyed: 10,945. Total hours flown: 47:10.		
175249	6 Sep	Barrow, Wnt., RE / C. Simpson / coast
175252	9 Sep	Barrow, RE / C. Simpson / coast
175255	12 Sep	Barrow, Deadhorse, RE / coast
175257	14 Sep	Barrow, Barter I., Deadhorse, RE / coast
175258	15 Sep	Barrow, Prudoe Bay, Lonely / coast
175259	16 Sep	Lonely, Barrow / coast
175263	20 Sep	Barrow, Barter I., RE / coast
175266	23 Sep	Barrow, Pt. Lay., Icy Cape, RE / coast
175267	24 Sep	Barrow, RE / C. Simpson
175269	26 Sep	Barrow, Pt. Lay, RE / coast
175270	27 Sep	Barrow, RE / coast
175272	29 Sep	Barrow, Barter I., Barter I., RE / Herschel I.
2. Oct 9-Oct 14,'75 Total miles surveyed: 4,695. Total hours flown: 18:25.		
175282	9 Oct	Nome, RE / S. Chukchi Sea
175285	12 Oct	Nome, RE / N. Bering Sea, St. Lawrence I.
175287	14 Oct	Nome, Anch. / St. Lawrence I., St. Matthew I., Nunivak I.
3. Mar 15-Mar 21,'76 Total miles surveyed: 4,380. Total hours flown: 19:52.		
176075	15 Mar	Nome, RE / St. Lawrence I., Gulf of Anadyr
176078	17 Mar	Nome, RE / St. Lawrence I., Bering St.
176079	19 Mar	Nome, RE / N. St. Lawrence I., SW. St. Lawrence I.
176081	21 Mar	Nome, RE / N. St. Lawrence I.
4. Apr 6-Apr 23,'76 Approx. total miles surveyed: 17,140. Total hours flown: 72:07.		
176097	6 Apr	King S., RE / Bristol Bay, ice front, Cold Bay
176099	8 Apr	King S., RE / Central Bristol Bay
176100	9 Apr	King S., RE / Bristol Bay
176103	12 Apr	King S., RE / Central Bristol Bay
176104	13 Apr	King S., Nome/Bristol Bay, St. Lawrence I.
176106	15 Apr	Nome, King S. / St. Lawrence I., St. Matthew I. Bristol Bay
176108	17 Apr	King S., RE / Central Bristol Bay
176109	18 Apr	King S., RE / Central Bristol Bay
176110	19 Apr	King S., Bethel, Nome / Bristol Bay, St. Lawrence I.

File identifier	Survey date	Description (survey origin / area surveyed)
176111	20 Apr	Nome, RE / St. Lawrence Island, Bering St.
176112	21 Apr	Nome, RE / St. Lawrence I., Bering St., Pt.Hope
176113	22 Apr	Nome, RE / St. Lawrence I.
176114	23 Apr	Nome, Anch / Norton Sound
5. Apr 30-May 14,'76 Total miles surveyed: 4,600. Total hours flown: 25:17.		
176121	30 Apr	Barrow, RE / coast, Pt. Hope
176122	1 May	Barrow, RE / Wainwright, offshore
176124	3 May	Barrow, RE / Icy Cape
176129	8 May	Barrow, RE / Shorelead
176130	9 May	Barrow, RE / N.E. offshore
176133	12 May	Barrow, Barter I., Deadhorse, RE / Leads, fast
176135	14 May	Barrow, RE / N.E. offshore
6. May 15-May 31,'76 Total miles surveyed: 2,605. Total hours flown: 14:43.		
176136	15 May	Barrow, RE / Shorelead W.
176140	19 May	Barrow, Pt. Hope, RE / coast
176141	20 May	Barrow, RE / N.E. lead system
176143	22 May	Barrow, RE / lead W., N.E. pack ice
176145	24 May	Barrow, RE / shorelead W.
176149	28 May	Barrow, Peard Bay, RE/shorelead, fast ice
176152	31 May	Barrow, RE / shorelead W.
7. Jun 1-Jun 5,'76 Total miles surveyed: 1,575. Total hours flown: 7:21.		
176153	1 Jun	Barrow, Pt. Hope, RE / coast
176156	4 Jun	Barrow, RE / C. Simpson and N.E.
176157	5 Jun	Barrow, RE / coast W.
8. Jun 8-Jun 14,'76 Total miles surveyed: 8,025. Total hours flown: 34:30.		
176160	8 Jun	Anch., Nome/Norton Sd.
176161	9 Jun	Nome, RE / St. Lawrence I., Bering St.
176162	10 Jun	Nome, RE / N. Bering Sea, S. Chukchi Sea
176163	11 Jun	Nome, Kotz. / N. Bering Sea, S. Chukchi Sea
176164	12 Jun	Kotz., Nome / Bering St., N. St. Lawrence I.
176165	13 Jun	Nome, RE / Norton Sd., St. Lawrence I.
176166	14 Jun	Nome, King S. / Bering St., E. Bering Sea
9. Jun 18-Jun 20,'76 Total miles surveyed: 2,930. Total hours flown: 15:26.		
176170	18 Jun	Barrow, RE / offshore
176171	19 Jun	Barrow, RE / nearshore leads
276172	20 Jun	Barrow, Barter I. Prudoe Bay, RE / offshore, fast ice

File identifier	Survey date	Description (survey origin / area surveyed)
10. Aug 17-Aug 26,'76 Total miles surveyed: 8,830. Total hours flown: 39:22.		
176230	17 Aug	Deadhorse, RE / S. Beaufort Sea
176231	18 Aug	Deadhorse, RE / S. Beaufort Sea
176232	19 Aug	Deadhorse, Barrow / S. Beaufort Sea
276233	20 Aug	Barrow, RE / S. Chukchi Sea
276234	21 Aug	Barrow, Kotz. / S. Chukchi Sea
176235	22 Aug	Kotz., RE / Kotz. Sd.
176236	23 Aug	Kotz., RE / Kotz. Sd.
176237	24 Aug	Kotz., Nome / Bering Sea
176238	25 Aug	Nome, RE / St. Lawrence I.
176239	26 Aug	Nome, Bethel / Norton Sd.
11. Sep 20-Sep 26,'76 Total miles surveyed: 2,183. Total hours flown: 9:49.		
176264	20 Sep	Barrow, C. Lis., RE / coast, bird survey
176265	21 Sep	Barrow, RE / C. Simpson, N. pack ice
176266	22 Sep	Barrow, RE / C. Simpson, N.W. pack ice
176268	24 Sep	Barrow, RE / C. Simpson, N.E. pack ice
176270	26 Sep	Barrow, RE / C. Simpson
12. March 31-Apr 3,'77 Total miles surveyed: 4,540. Total hours flown: 18:18.		
177090	31 Mar	Anch., Nome / S. Norton Sd.
177091	1 Apr	Nome, RE / Pt. Hope, Kotz. Sd.
177092	2 Apr	Nome, RE / St. Lawrence I.
177093	3 Apr	Nome, RE / N. Norton Sd., N. St. Lawrence I.
13. Apr 19-Apr 26,'77 Total miles surveyed: 325. Total hours flown: 1:17.		
177109	19 Apr	Barrow, RE / Pt. Hope
177113	23 Apr	Barrow, Pt. Hope / coast, fast ice
177116	26 Apr	C. Lis., Barrow / coast
14. May 11-May 14,'77 Total miles surveyed: 3,875. Total hours flown: 12:14.		
177131	11 May	Anch., Nome / N. Norton Sd.
177132	12 May	Nome, RE / Pt. Hope, Kotz. Sd.
177134	14 May	Nome, Bethel / Norton Sd., Nunivak I.
15. May 21-May 30,'77 Total miles surveyed: 1,317. Total hours flown: 5:45.		
177141	21 May	Barrow, RE / Barter I.
177150	30 May	Barrow, RE / Northeast leads

File identifier	Survey date	Description (survey origin / area surveyed)
16. Aug 26-Oct 13,'77 Total miles surveyed: 6,500. Total hours flown: 27:17.		
177238	26 Aug	Barrow, C. Simpson, RE / coast, Oarlock Isl.
177241	29 Aug	Barrow, RE / coastal to Lonely, Mid-Oarlock I.
177244	1 Sep	Barrow, C. Simpson, RE / coast, Oarlock I.
177248	5 Sep	Barrow, RE / N. to ice, E. to Lonely, coastal
177251	8 Sep	Barrow, Barter Isl., RE / offshore E. to Bord
177253	10 Sep	Barrow, RE / N.W. Chukchi Sea
177257	14 Sep	Barrow, RE / N.W. Chukchi Sea
177276	3 Oct	Barrow, RE / N. to ice, E., coastal
177279	6 Oct	Barrow, RE / N.E. and coastal
177286	13 Oct	Barrow, C. Simpson, RE / coast.

APPENDIX II

Aerial survey tracklines flown September 1975-October 1977