INVESTIGATIONS OF BELUKHA WHALES IN COASTAL WATERS OF WESTERN AND NORTHERN ALASKA

II. BIOLOGY AND ECOLOGY

by

John J. Burns and Glenn A. Seaman

Alaska Department of Fish and Game
1300 College Road
Fairbanks, Alaska 99701

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SUMMARY

Information from 617 belukhas, including fetuses, was obtained during two phases of this study; 1977 to 1979 and 1980 to 1983. The first phase involved harvest monitoring and sampling programs, mainly ancillary to other marine mammal studies, during which data were obtained from 249 belukhas. Preliminary results were reported by Seaman and Burns (1981). The second phase, funded by the NOAA Alaska Office of the Outer Continental Shelf Environmental Assessment Program included monitoring and sampling efforts in which data were acquired from an additional 368 animals, including fetuses. The second phase also included two aerial surveys in 1982, as well as expanded efforts to summarize available information about belukhas.

We consider belukhas in the Bering, Chukchi, Beaufort, and eastern East Siberian seas and Amundsen Gulf to be part of a single population that winters mainly in Bering Sea. We refer to it as the Bering Sea population. Based on samples from northwest Alaska, physical maturity of females is obtained between age 8 and 11 and in males between 10 and 14. Mean standard length of females 11 years and older was 355 cm. Mean length of males 14 years and older was 413 cm. Maximum standard lengths were 414 cm for a female and 457 cm for a male. Length at age in belukhas from Bristol Bay, Alaska and northwest Canada was the same as that in belukhas from northwest Alaska. Length and weight of newborn calves averaged 155 cm and 72 kg. Growth of fetuses from waters of Alaska, eastern Canada, and Greenland appeared similar.

The sex ratio was found to be 1:1. Breeding probably begins in midwinter and extends to June with a presumed peak, yet to be verified, during March. Births occur over a prolonged period from April to late July or early August with a peak in mid-June to mid-July. Gestation is a minimum of 14.5 months and more likely 15 to 16 months. First pregnancy occurs between ages 4 to 7 and first births at 5 to 8 years. Females were reproductively active throughout life, though about 50% of those older than 21 years were nongravid when taken. The oldest whales in our samples were two males at least 38 years and a female at least 35 years. Generation time was about 6 years.

Mature females comprise about 33% of the Bering Sea population and the annual rate of calf production is 0.104. Size of this population is unknown. A minimum of 16,000 to 18,000 belukhas occur in waters adjacent to western North America during summer. The entire population, including whales in waters of the Soviet northeast, northwest North America, and the ice front between, will probably be found to number more than 25,000 animals.

Annual landed harvests are on the order of 415 whales, of which 220 are taken in U.S. waters, 135 in northwest Canada, and 60 in Soviet waters. Instances of unusual availability, such as the occurrence of animals entrapped by ice, may substantially increase the take by hunters and predation by polar bears. Hunting loss in all regions combined is estimated to be about 0.44 and the combined total annual kill is estimated to average 735 animals. The combined total annual kill of 585 belukhas taken in waters of Alaska and northwest Canada is 3.3% to 3.7% of the minimum number of whales occurring in those waters.

Belukhas that occur in ice-free coastal waters of eastern Chukchi Sea during summer first aggregate in Kotzebue Sound. After departing Kotzebue Sound, usually in late June, they move generally northward along the coast, temporarily frequenting Kasegaluk Lagoon in late June to mid-July and arrive near Wainwright in late July to early August. Those whales depart coastal waters in August, presumably to the ice front north of Point Barrow, where they mingle with belukhas migrating from the eastern Beaufort Sea region.

Route of the westward late summer and autumn migration of belukhas that summered in the Amundsen Gulf-eastern Beaufort Sea regions is mainly offshore, along and through the ice front.

Other aspects of the biology of belukhas, as reported in the literature, are reviewed and summarized.

ACKNOWLEDGEMENTS

Any small contribution to knowledge about belukhas that this report may make will have resulted largely from involvement of subsistence whalers, particularly those that hunted near Elephant Point, in Eschscholtz Bay. Their interest and cooperation affected all aspects of our field work there, from transportation of equipment, personnel, supplies, and specimens, to securing the whales that became subjects of study. Our experiences in the field, and hopefully our understanding of the small whale hunting culture, were greatly enhanced by the opportunity to live and work among the whalers and their families. We especially acknowledge the assistance of Beulah Ballot, Lawrence Thomas, Willie Thomas, Nathan Hadley, Lester Hadley, Louis Hadley, Raymond Lee, and Tommy Carter, all of Buckland; Elmer Armstrong, Willie Goodwin, Jr., Bob Uhl, and York Wilson of Kotzebue; the people of Point Lay, particularly Amos Agnasagga; and the hunters at Point Hope, particularly Amos Lane, Joe Frankson, and Henry Attunganna.

Several people assisted us in the acquisition of specimens and measurements in the field. Most of them are appropriately identified in Table 1 in the section on results of biological sampling efforts. Among those colleagues we are especially thankful to Robert Nelson, Kathryn Frost, and Lloyd Lowry, all with the Alaska Department of Fish and Game (ADF&G). Mr. Lowry was also constructively critical of this report. William Marquette of the National Marine Mammal Laboratory (Nat. Mar. Fish. Serv.) made it possible for the junior author to sample belukhas at Point Hope in 1977 and also provided some harvest records from other hunting sites.

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The burden of typing fell on Dawn Hoover and her efforts are appreciated. Jesse Venable willingly assumed many tasks including some of the data entry, all of the computer programming, analyses of data, and preparation of figures in this report. His efforts are greatly appreciated.

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INTRODUCTION

General Description

Belukha whales Delphinapterus leucas (Pallas) are one of two genera of cetaceans belonging to the Family Monodontidae. The other is the narwhal, Monodon monoceros Linnaeus, mainly of the north Atlantic-eastern Canadian Arctic regions.

Belukhas are a northern species that occurs in the seasonally ice-covered seas of temperate, subarctic, and arctic regions. According to Tomilin (1957), during the warmer part of the year, belukhas are in coastal waters. The proportion of various populations that frequent offshore waters during warmer months is not known. In the North Pacific region, belukhas are present in the Sea of Japan, the Okhotsk Sea, Cook Inlet (with sightings reported in adjacent waters of Prince William Sound and the Gulf of Alaska), Bering, Chukchi, and Beaufort seas, the eastern part of the East Siberian Sea, Amundsen Gulf, and adjacent waters of the Arctic Ocean. This report is primarily focused on the population or stocks that occur(s) in the Bering, Chukchi, East Siberian, and Beaufort seas and Amundsen Gulf.

Belukhas of this region have been referred to by various North American authors, including us, as the "Western Arctic" or the "Bering-Chukchi population." On reflection, neither name is appropriate. The name Western Arctic population is incorrect because (1) the whales are adapted to and primarily utilize northern boreal and subarctic marine habitats, escaping arctic conditions through migration, and (2) western Arctic has a different geographic reference in different countries. What a North American refers to as western Arctic is, for a Soviet and most other Europeans and Asians, the eastern Arctic. Therefore, we recommend against further reference to a western Arctic population of belukhas (and for the same reasons, bowhead whales, Balaena mysticetus).

The name Bering-Chukchi population is more acceptable though still misleading and inaccurate. Belukhas of the population we studied have a much larger total range that also includes the East Siberian and Beaufort seas, Amundsen Gulf, and adjacent parts of the Arctic Ocean. It is too cumbersome to designate this population by its total range. Therefore, we propose that the region within which the population normally winters, and most likely breeds, be used to designate it. We recommend the name Bering Sea population and will use it in this report.

As adult animals, belukhas appear white or near white with restricted fringes of grey to black on the posterior edges of flukes and occasionally the flippers. This white, adult coloration is attained after a number of years. Calves are blue-grey at birth, becoming progressively lighter colored with age. The white coloration accounts for this whale's common name in several languages: Marsouin blanc, French-French Canadian; white whale, English; and belukha, from Russian belii meaning white. Mainland Alaskan Eskimo common names include dialectal variants of situaq (Bering Strait Inupiat), sisuaq (north Alaskan Inupiat), and cetuaq (mainland Yupik). On St. Lawrence Island where Siberian Yupik is spoken, these whales are called puugzaq.

In *western* and northern Alaska, coastal people use either the appropriate Eskimo name or the borrowed Russian name. White whale is not a name in common use in this region, reportedly because it is not descriptive or indicative of the color of a significant proportion of the belukhas observed or caught.

A detailed discussion of belukha distribution and seasonal movements in waters adjacent to western and northern Alaska is presented by Seaman et al. (1985). In general, the Bering Sea population winters over a broad area in the drifting ice of Bering Sea. They are found in areas where the ice cover is broken, as for instance in the ice front and in regions of persistent polynyas or ice divergence. Belukhas can surface through relatively thin ice, as in newly refrozen leads and polynyas, but they are definitely limited by ice thickness. Several accounts of entrapment by surrounding heavy ice have been reported and will be discussed later. Numerous sightings of belukhas in thin ice areas indicate that they break the ice *cover* with their back. Excellent photos of belukhas surfacing through thin ice include those published by McVay (1973).

These whales have no dorsal fin, though a prominent well-developed dorsal ridge is present. They are fusiform in shape, have a comparatively small head with a prominent melon, and anteriorly extended jaws which form a short “beak.” The flukes are moderately notched on the midline. Foreflippers are unlike those of other delphinoids, being relatively short, tapered at the proximate and distal ends, and broad across the middle approximately one-third. On older animals, particularly males, they are sometimes curved upward on the distal portion. Also, unlike other cetaceans belukhas have considerable lateral and vertical movement of the head, to the extent that they sometimes appear to be looking almost backward while swimming.

Tomilin (1957) reported that the most common complement of teeth is 34 to 38, with as few as 32 and as many as 40. Kleinenberg et al. (1964) indicate that the first teeth emerge through the gum line at about age one and that there are no deciduous “milk teeth.” Our specimens confirm those reports. Teeth are uniformly simple, peg-like structures that have single roots and are deeply, though rather loosely received in the alveoli of both upper and lower jaws. The crowns are often well-worn with great individual variation in extent of wear and orientation of worn surfaces. Tooth wear results in underestimation of ages of older animals, as will be discussed later.

The homodont-type dentition (little differentiation in shape of teeth) appears well suited for grasping prey, though not for masticating it. Food is swallowed whole and includes a wide array of organisms that, in Alaskan waters, ranges in size from small benthic worms and shrimp to red salmon (Oncorhynchus nerka) and small chinook salmon (O. tshawytscha). In Bristol Bay, where adult red salmon are commonly consumed, average length and weight of these fish are 61 cm and 3.2 kg (6.6 lb.) (ADF&G file data) . Other moderately large species of salmon, including chums (O. keta) and cohos (O. kisutch), are reported, by local residents of the Yukon and Kuskokwim river areas, to be eaten by belukhas. Average weight of adults of these species in the Kuskokwim River is 3.36 kg (7.4 lb.) and 3.45 kg (7.6 lb.) respectively (ADF&G data). About 100 different kinds of prey items have been reported as belukha food (Kleinenberg et al. 1964) though a relatively few species comprise the bulk of diet at a particular time and place. Results of a detailed study of belukha food habits in the eastern Bering and Chukchi seas are reported by Lowry et al. (1985).

These small whales have been, and remain, an important component of the marine mammal resource base available to coastal-dwelling subsistence hunters of northern Alaska. Availability to hunters varies at different locations and is directly related to seasonal movements of the whales. Those whales that move northward through the extensive lead system between Bering Strait and Point Barrow-pass close to the settlements of Wales, Kivalina, Point Hope, Wainwright, and Barrow, mainly in late April and May. Point Hope and Kivalina normally account for the largest spring harvest of these migrants.

An unknown proportion of the belukha population moves into coastal waters of mainland Alaska, from Bristol Bay to Point Barrow, as soon as breakup of nearshore and river ice permits. This, of course, occurs progressively later at higher latitudes. As examples, belukhas enter the Naknek River in Bristol Bay in late March-early April, Kuskokwim Bay in late May-early June, coastal waters of Norton Sound normally in early June, Eschscholtz Bay (southeast Kotzebue Sound) in mid- to late June, and Kasegaluk Lagoon (near Point Lay) in late June to early July. Some whales remain, or return to, coastal waters throughout the open water period, though their presence in late summer-autumn is seemingly not yet predictable. Certain coastal locations appear to constitute preferred habitat as belukhas are present each year.

As can be inferred from the comments above, belukhas can be and are harvested at many different locations. However, the most predictably successful hunting sites during the open water seasons are in eastern Norton Sound (from the villages of Elim, Koyuk, Stebbins, St. Michael, and Shaktoolik), Eschscholtz Bay (mainly by hunters from Buckland and Kotzebue), and in Kasegaluk Lagoon (by hunters from Point Lay). Largest annual harvests are normally taken near Point Hope in April-May and in Eschscholtz Bay in June. The majority of specimens available to us are from these two locations.

Background

A list of early literature that includes mention of belukhas would be long and diverse. Explorers of the higher latitudes, as well as northern missionaries, teachers, entrepreneurs, scientists of various disciplines, and the numerous sojourners to shores of the seasonally ice-covered seas often included mention of these whales in their accounts. Certainly, Europeans that became associated, through commerce or scientific curiosity, with native residents of northern coastal regions were made aware of the importance of this small whale, the times of their availability to local hunters, and some of the more easily observed biological characteristics. The latter included coloration, food habits, local movements (especially occurrence in rivers), aboriginal hunting methods, etc. Some of this early literature is cited in the extensive monograph by Kleinenberg et al. (1964) and the summary paper on belukha distribution by Gurevich (1980).

Collectively, Soviet investigators made the first concerted efforts in the North Pacific region, starting in the 1920's, to obtain information about marine mammal resources of the Soviet north and far east. A number of workers began studies in different regions extending from the White and Kara to the Okhotsk and Bering seas. These initial assessments of resources, including belukhas, were in line with a renewed, post-revolutionary interest in developing and exploiting resources in the "frontier" regions. The 1920's and 1930's were, for instance, decades during which great expenditures of money and manpower were devoted to opening up the Soviet northern sea route from Leningrad and Murmansk to Bering Strait and developing a more vigorous economic base. An interesting account of one such effort, which includes frequent mention of the potential importance of marine mammals, is a narrative of the voyage of the Chelyuskin (Anonymous 1935).

Soviet scientists that significantly contributed to a knowledge of belukhas during the 1920's and 1930's included V. A. Arsen'ev, K. K. Chapskii, S. V. Dorofeev, V. G. Heptner, S. K. Klumov, B. A. Zenkovich, and others. Degerbøl and Nielsen (1930) also provided some of the earliest detailed biological information about belukhas from waters of West Greenland.

Major monographs about the species include those by Vladykov (1944), based on studies he conducted in the Gulf of St. Lawrence (eastern Canada) , and the comprehensive account by Kleinenberg et al. (1964) . The latter is a compendium of virtually all of the available information about belukhas up to that time. Tomilin (1957), in his work on cetaceans of the U.S.S.R. and adjacent countries, also presented an important compilation of available knowledge.

More contemporary studies of belukhas usually have focused less on the economic potential of belukha hunting, though in general, biological material examined has come from commercial or subsistence harvests.

To the extent possible, we have tried to utilize original sources of information about belukhas. However, this was not possible with respect to older works, particularly those in the Russian language that were not available to us. The major secondary sources of earlier writings we utilized included Degerbøl and Nielsen (1930); Vladykov (1944); Tomilin (1957); and Kleinenberg et al. (1964).

Much of the current information about belukhas in western North American waters is contained in "grey literature." Our treatment of that literature may seem overly detailed. However, it includes important data and information that, in our opinion, require integration and broader exposure to persons interested in these whales.

STUDY AREA

The area in which our studies were conducted includes the Bering, Chukchi, and Beaufort seas (Figure 1).

The Bering Sea is a well-defined body of water that is almost completely surrounded by land. Zenkevitch (1963) presents a very useful resume of some major characteristics of this sea, as follows.

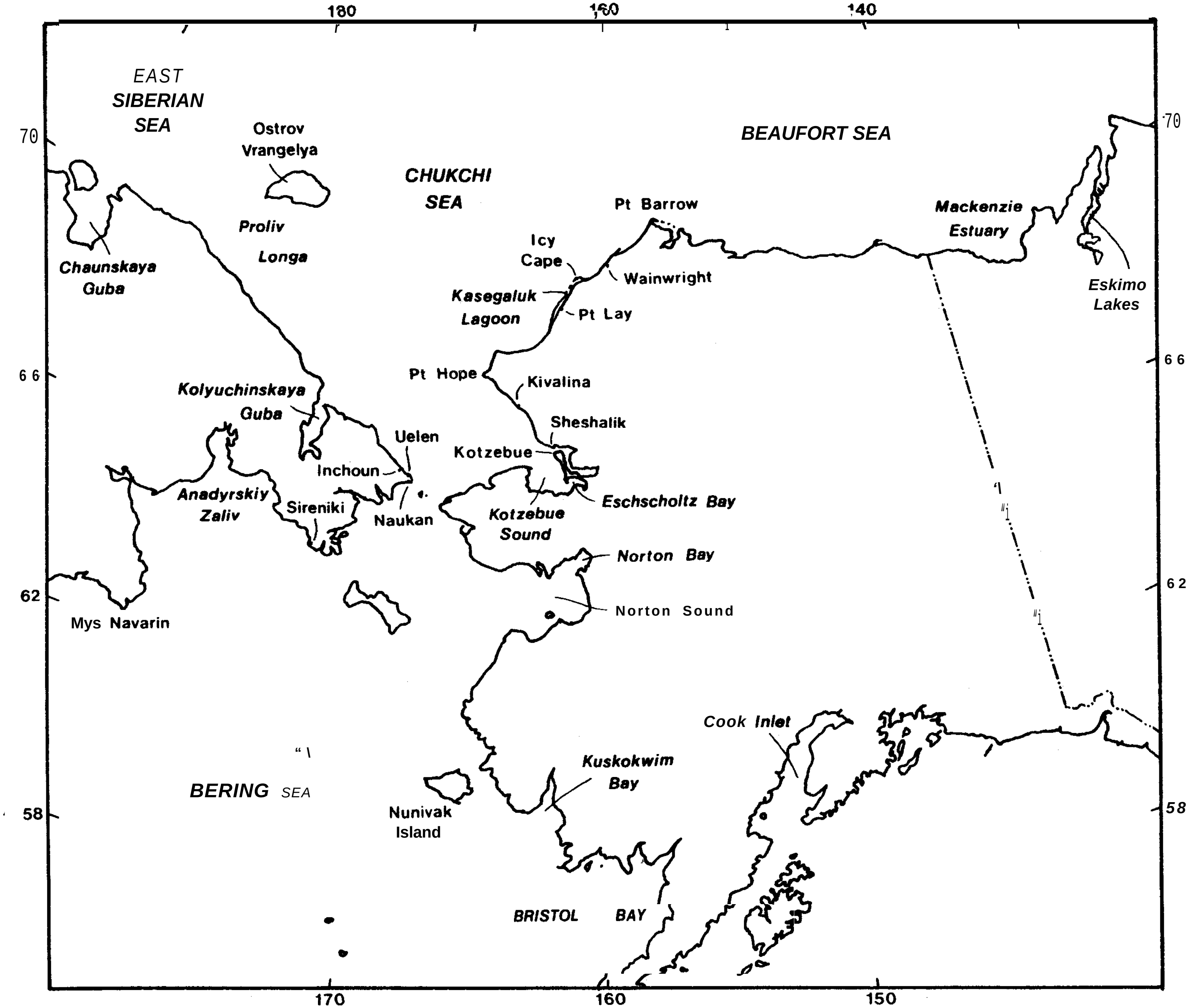

Figure 1. Location map showing the study area and most of the place names referred to in the study area.

The surface approximates 2,304,000 km^2 and its volume approximates 3,683,000 km^3. Greatest depth is in the region of Kamchatka Strait, reaching 4,420 m. Mean depth for the entire sea is 1,598 m. Of great importance, from the standpoint of belukhas, is the fact that the Bering Sea is divided by the 200 m isobath into two approximately equal parts; the southwestern part with depths greater than 3,500 m and the northern and eastern shelf regions of less than 200 m depth. Belukhas mainly occur in the shelf region.

The few soundings available suggest that the continental shelf of the northeastern Bering Sea is a flat plain with gentle slope gradients (Creager and McManus 1966). Minor relief features are present. Major relief features in the Bering Sea are the fjords of the Chukchi Peninsula and the discontinuous trough paralleling the Chukchi Peninsula north of Northwest Cape, St. Lawrence Island (Udintsev et al. 1959).

Of the confined seas, the Bering Sea is exceeded in size only by the Mediterranean Sea. It is connected with the Pacific Ocean by the deep Kamchatka Strait (4,420 m) as well as by numerous, deep passages through the Aleutian Islands.

In the north, Bering Strait connects the Bering and Chukchi seas. This Strait is very shallow (not exceeding 55 m, according to U.S. Coast and Geodetic Survey, chart number 9400) with a width of 85 km and a cross-section of approximately 2.5 km^2 (Zenkevitch 1963) . Throughout most of the year movement of water is north through Bering Strait. Zenkevitch (1963) indicates that about 20,000 km^3 of Bering Sea water passes north through Bering Strait each year. South-setting currents have been recorded (Bloom 1964) and are usually produced by meteorological factors. The magnitude and occurrence of such currents are only poorly known as they occur mainly during the late fall and winter months. South-setting surface currents dominate during November through March and result in a net southward transport of ice during that period.

The Chukchi Sea is somewhat more difficult to delineate as it is not completely surrounded by land. It is frequently considered, especially in the Soviet literature, as an embayment of the Arctic Ocean that is bounded on the south by the Bering Strait, on the west by the Chukchi Peninsula and the eastern shores of Wrangel Island (approximately 176°42'W longitude) , on the north by the edge of the continental shelf, and on the east by the shores of Alaska as far as a line extending north from Point Barrow (approximately 156°13'W longitude). All of this area is underlain by the Chukchi Platform.

According to Zenkevitch (1963), the area of the Chukchi Sea is 582,000 km^2. The continental shelf of the Chukchi Sea is a flat, almost featureless plain having average depths of 45 to 55 m and regional slope gradients ranging from 2 minutes to immeasurably gentle (Creager and McManus 1966) . Local maximum gradients range up to 1055’. Excluding the slope between the land and the sea floor, the major relief features in the Chukchi Sea are Herald Shoal, Hope Sea Valley, and the Cape Prince of Wales Shoal (Udintsev et al. 1959).

The Beaufort Sea is a less discrete body of water than either the Bering or the Chukchi Sea. Generally, it is considered as an integral part of the Arctic Ocean extending from Banks and Prince Patrick islands in northwest Canada to Point Barrow in Alaska. Its southern margin is the shoreline of mainland Canada and Alaska. There is no discrete northern boundary.

Biological and physical features of belukha whale habitat within the three seas are different. The Bering Sea is a northern extension of the North Pacific Ocean. It is a biologically rich and diverse region within which upwelling of nutrient-rich deep water, forced upward by the Aleutian Chain of islands and the continental shelf edge, is a major contributor to the high biological productivity that occurs. Several major rivers, frequented by belukhas, also contribute significantly to the nutrient regime. Climate in the Bering Sea (strongly influenced by the Pacific Ocean) is temperate, grading into subarctic in the northern one-third. Prevailing winds are out the south (mainly southeast) during May through September and from the north (mainly northeast) during November through April. There are great annual differences in climate that result in major annual differences in, for instance, extent and characteristics of the seasonal ice cover. Ice is normally present from late November through June. It includes two major components-- ice that forms during winter in the Bering Sea, and ice that is transported south through the Bering Strait. It appears that most ice is of the former component.

On average, the southern extent of ice, at the time of maximum coverage (March-April), coincides with the edge of the continental shelf. However, annual differences in location of the southern ice margin in the central Bering Sea are as much as 450 nautical miles (rim) (from approximately 60 nm south of St. George Island to about 60 nm south of St. Lawrence Island) . Shifting and movement of the relatively thin ice cover is significant and produces extensive areas where the ice is fragmented and openings are present. This shifting, together with the extensive leeward coastlines of several large islands as well as the coasts of Alaska and Siberia, produce local conditions that may accommodate a relatively high abundance of belukhas during winter.

The Chukchi Sea is mainly subarctic in its characteristics. Much of the North Pacific influence is lost as water flowing north through the narrow constriction of Bering Strait has become altered in the Bering Sea. Biological productivity of the Chukchi Sea is less than that of the Bering Sea.

Ice conditions are more severe due to average lower winter temperatures, a longer freezing period, incursions of multi-year ice during the fall-spring period, constraints of surrounding land masses that are largely exposed to prevailing winter winds (mainly northeast), and the frequent occurrence of persistent “arctic” high pressure systems. Water depths in all parts of the Chukchi Sea are relatively shallow.

The Beaufort Sea is a transition area between the subarctic and arctic provinces. The northward trend of decreasing biological productivity continues and, in comparison to the Chukchi Sea, productivity is significantly lower.

Multi-year ice is a significant feature of the northern part of this sea and the areal coverage of this ice shows extreme annual variations. Seasonal sea ice develops near shore, its extent depending on the amount of multi-year ice that is present. The coastline of the Beaufort Sea north of Alaska has a northeasterly exposure and it is therefore ice-stressed by the shoreward advance of ice during the seasons of freezing. Prevailing winds are northeast and, at least in the eastern part, there are weak cyclonic surface circulations of air and water (Wilson 1974) .

Seasonal and multi-year ice can occur in the Beaufort Sea throughout the year. In most years the nearshore zone is ice-free during August through October but there is great annual variation in the extent of open water. It is mostly ice-covered from late October through mid-July. During the late summer-early fall "open water" period multi-year ice is present at varying distances from shore. Usually it is situated north of the shelf break.

METHODS

Harvest Enumeration

The magnitude of annual harvests of belukhas taken in Alaska from 1977 to 1984 were determined on the basis of many different sources of information. Sampling efforts at major hunting sites provided personnel of ADF&G the opportunity to obtain direct counts of whales harvested during the sampling periods. Public awareness of the belukha investigations was promoted during the course of this and other studies of belukhas, and an extensive network of contacts established. Many of the local contacts reported the seasonal catch of belukhas by hunters in villages where they resided. When a take of whales was reported but the magnitude was unknown, a Department employee stationed close to the hunting site often personally visited that site and determined the take on the basis of direct interview of village residents. At other locations harvests were reported by resident teachers, local pilots, resource managers, or investigators involved with socio-economic studies.

Field personnel of the National Marine Fisheries Service, and later of the Alaska Eskimo Whaling Commission, that were involved in investigations of bowhead whales (Balaena mysticetus) , provided us with records of belukha catches made during the bowhead whaling seasons, mainly at Point Hope and Barrow.

Harvest data were also obtained during routine visits to villages by ADF&G personnel and by interview of village residents during their visits to communities in which Department offices were located.

Biological Sampling

Most biological sampling was accomplished by an ADF&G employee specifically detailed to known productive hunting sites during periods when successful hunting normally occurs. usually a single department employee worked at the sampling sites as a means of minimizing both support requirements and intrusions into the closely knit temporary hunting encampments. Productive sites included Eschscholtz Bay, Point Hope, and Point Lay. Eschscholtz Bay was the major sampling area and produced 68% of all whales we examined.

Conditions existing at the time whales were landed determined procedures used for data acquisition and biological sampling, as well as the thoroughness of sampling efforts. Within Eschscholtz Bay whales are mostly taken by driving pods into shallows and then killing as many as possible. Actual timing of each hunting foray is based on the tide conditions; hunting begins shortly after the tide starts to ebb. If whales are seen and a successful drive takes place within reasonable distance of Elephant Point, where whalers and their families camp, the whales are towed to the Point. Butchering begins immediately and continues until all the whales are cut up or, occasionally, until the next ebbing tide when, weather permitting, the hunters again go out. Very often, a large number of whales are landed at one time. As an example, in June 1982, 75 whales were landed after a single drive and the total catch of 121 whales was secured in three drives during a period of approximately 40 h.

As boats returned with whales, each landed animal was numbered and its sex, color, standard length, and other notations recorded. Standard length is the straight line distance between the notch of the fluke and the anterior tip of the lower jaw with the whale lying on its stomach. The collection of specimens, including mandibles (occasionally complete skulls) , reproductive tracts, and samples of stomach contentst was accomplished as the whales were processed. Whales were landed and butchered along a stretch of beach approximately 0.7 km long. Thus , to initially process whales as they are landed at different points along the beach and to subsequently obtain specimens from them when the butchering process had been sufficiently completed, required continuous movement of the sampler up and down the beach. Traditionally, remains are towed to sea by the hunters prior to initiation of another drive, if possible.

The pace of sampling activity after a successful drive is frenetic, becoming exhausting when successful drives occur during successive tidal cycles. As an accommodation to our sampling effort, the hunters at Elephant Point left unsampled whale remains on the beach until we could examine them and obtain specimens. Reproductive tracts of as many females as possible were obtained. Those of males were obtained only in the first years of this project.

Mandibles and skulls were cleaned and air-dried in the field. Soft parts, including stomach contents, were preserved in 10% formalin. Testes and epididymides from which micro-slides were to be made were sliced for better preservation. Ovaries were usually left attached to the uteri, the latter having been cut off 5-10 cm posterior of the cervix, tied, and the lumen injected with 10% formalin to ensure fixation of the uterus and preservation of a small fetus, if present. Uteri were not obtained from those whales that had a" near-term fetus. Most near-term fetuses were measured in the field. A few were brought to the laboratory.

Lactation was noted at the time whales were landed (either based on the presence of exuding milk or by palpating the teats) or, if not externally obvious, during subsequent inspection of mammary tissue left as part of carcass remains.

Payment of 10-20 dollars (the latter after 1979) was made to each hunter that secured a whale from which we obtained specimens and supporting data.

A similar sampling procedure was utilized at other locations by ADF&G personnel. Non-departmental cooperators, mainly engaged in bowhead whale studies at Point Hope, provided what data and specimens they could secure. Those specimens were frozen and shipped to our laboratory in Fairbanks.

Laboratory Procedures

Male Reproductive Organs

Laboratory procedures varied somewhat over the course of this study. The volume of one intact testicle, with and without the epididymis attached, was determined by water displacement for a small sample. Tissue samples from testicles and epididymides which had been sliced and fixed were sent to a commercial laboratory for preparation of histological slides. Standard histological preparations were made using Hematoxalin-Eosin stain. These slides were examined to determine the state of spermatogenesis in testes and the presence or absence of sperm in tubules of the epididymides.

Female Reproductive Organs

For females, ovaries were separated from uteri. Examination of these two organs was done separately and the subsequent findings regarding appropriate aspects of reproductive status were compared. Length of a "nongravid" uterine horn was measured from the level of the medial, externally recognizable junction of the horns to the anterior end, over the curvature of the preserved horn. General assessment of surficial rugosity and whether or not the whale was parous or nulliparous was noted. Each uterine horn was then opened. Notations were made of general internal appearance, presence of mucus, debris, blood, a cervical plug, and presence or absence of a small fetus. Anomalies were also noted.

Thus, based on examination of uteri, females were categorized with respect to relative age (juvenile, sexually mature and relatively young, or sexually mature and relatively old) and reproductive status (nongravid, gravid, or postpartum).

Ovaries were trimmed of connective tissue, and weighed to the nearest 0.1 g. A two-dimensional diagram of paired ovaries was made on a 5" x 7" index card along with depictions of obvious surficial features. The paired ovaries were then serially sectioned (parallel to the longest axis) by hand. Sections were, on average, about 2 mm thick. Ovarian structures, including follicles larger than 5 mm, corpora lutes, corpora albicantia, calcified bodies, and other noteworthy internal features were drawn based on the serial sections. Several sections of those ovaries that contained multiple structures were drawn. The position of each section was noted on the diagram of the intact ovary from which it was taken. Other notations were included on the diagram cards, including correlations of results of ovarian and uterine examinations.

Age Determinations

Age determinations were based on the number of dentinal layers counted on longitudinal sections of teeth (Laws 1953; Sergeant 1959; Klevezal' and Kleinenberg 1967; Brodie 1971).

Examination of our first collected specimens showed great variation in size and wear of mandibular teeth from an individual and among individuals. Teeth were removed from the mandibles in several different ways depending on the difficulty encountered. Some were rotated in the alveolar socket and pulled using dental pliars, or they were pried out with the aid of a dental elevator. In some instances, the mandibles were boiled or macerated in water until the teeth became loose and could be easily removed with pliars or forceps. The method employed depended on several factors, including size and curvature of the teeth, extent of eruption, or whether the mandibles were stored in water to prevent desiccation and checking of teeth.

Epoxy glue was used to attach the two or three largest mandibular teeth to small wooden blocks which could be clamped on the turntable of a precision lapidary saw. Orientation of glued teeth was important in order to obtain longitudinal sections from the midline portion. Sections from the central portion of one or two teeth were cut to a thickness of 0.001" to 0.012" using a diamond-impregnated blade. Dentinal layers were counted using a microfiche reader or a binocular microscope. In both cases transmitted light was used. When dentinal layers were not sufficiently distinguishable in the tooth sections initially cut, additional teeth were sectioned for examination.

When the neonatal line was evident, the number of dentinal layers was considered to represent the total complement deposited. When absent, an unknown and variable number of layers had been worn away and counts represented some minimum number. In odontacete whales the neonatal line is a distinctive dentinal layer laid down shortly after birth. It separates prenatal from postnatal dentine (Nishiwaki and Yagi 1953; Sergeant 1959). We based the age (or minimum age) of whales on the assumption that two dentinal layers are deposited each year, in accordance with the findings of Brodie (1971).

Aerial Observations

Seasonal distribution and relative abundance of belukhas in the study area are subjects addressed by Seaman et al. (1985) . We report here only an interpretation of late June-August movements of belukhas within or from Kotzebue Sound to Point Barrow, and characteristics of the westward, autumn migration of whales in the northeastern Chukchi and Beaufort Seas.

Most available records of belukha sightings during summer in coastal waters between Kotzebue Sound and Point Barrow have been compiled and summarized by Frost et al. 1983. Those, together with additional sightings, were reviewed to determine possible patterns of movement in that region and the relationship between groups of whales summering in the eastern Chukchi and those in the eastern Beaufort seas.

Additionally, on June 29, 1982 , when belukhas were no longer available to hunters, an extensive aerial reconnaissance of nearshore Kotzebue Sound was made. This reconnaissance was after the period of successful hunting in southeastern Kotzebue Sound (Eschscholtz Bay and near Chamisso Island) that occurred from 22 to 26 June and after the period of successful netting in northeastern Kotzebue Sound which occurred between 17 and 26 June.

Flights were made in a float-equipped Piper Super Cub flown at an altitude of 3,000 ft and an average speed of 90 mph. Time of the flights was such that they occurred during the period 2 h before to 3 h after high tide at Kotzebue. State of the tide was considered a principal factor as the whales usually are in the bays and closest to shore at about high tide. Flight path was maintained by visual reference to the coastline and was 1½ to 2 mi seaward on flights outbound from Kotzebue and about ½ mi seaward on those inbound to Kotzebue. A deviation from this pattern was made to search Eschscholtz Bay and its entrances.

An intensive search of the southern margin of drift ice in the Beaufort Sea was made during 17-21 September 1982. Previous aerial surveys for Pacific walruses (*Odobenus rosmarus divergens*) during this period in the northern Chukchi and western Beaufort seas had suggested that during September belukhas likely were strongly associated with the ice fringe and that the route of the autumn migration may be mainly determined by location of the drift ice margin. Location of the summer-autumn ice margin in relation to the Beaufort Sea coastline is annually quite variable but usually at some considerable distance. Experience during previous years indicated that weather for flying was normally poor along the coast and over open water but was marginal to good over the pack ice. To deal with these conditions a fully instrumented aircraft capable of sustained flight in severe icing conditions was required.

A Conquest (Cessna 441) was selected for our search effort. This aircraft was capable of takeoffs and landings in bad weather, could climb to 30,000 ft through severe icing conditions, and had a high altitude cruising speed of up to 290 knots. Once the pack-ice ice margin was located visually or by on-board radar, descent to desired search altitude was made and the cruising speed reduced to 120-140 knots. Although suitable for a general search for belukhas, the aircraft was less than ideal for making a reliable census because the main observers, located in the passenger cabin, had only limited forward visibility and no capability of taking photographs while the aircraft was in level flight. We made counts and photographed the larger pods and aggregations of whales by closely circling them.

A 500-ft altitude and cruise speed of 120-140 knots were used during search efforts. Occasionally, descents to 200 ft were necessitated by low clouds. A transect width of ½ nm, ¼ nm on either side of the aircraft, was used for counting whales and maintained with the aid of inclinometers. Three observers were utilized: one in the co-pilot's seat and two in the passenger cabin. The pilot and forward observer counted whales within that portion of the transects close to the airplane that were not visible to observers in the passenger cabin. The forward observer also recorded all sightings as well as time, position, other navigational information, ice conditions, and weather. Data were recorded mainly for each l-rein time interval though occasionally the record interval was as long as 3 min.

Survey flights were made on 17, 19, 20, and 21 September. Those on the first three days were along, or north of and parallel to, the ice margin between 141°W and 160°W. On 21 September transects deeply penetrated the pack ice along alternate N-S and S-N lines. Length of transects flown on the 21st was determined by the distance between the open water/ice margin interface and the point at which a solid ice cover was encountered. Total alloted time for all flights, including ferry time from Fairbanks to Prudhoe Bay and Prudhoe Bay to Anchorage was 25 h.

Two concurrent studies in the Beaufort Sea north of Alaska were of particular relevance to our autumn survey effort. Ljungblad et al. (1983) were engaged in extensive aerial reconnaissance over a very broad area of open water, for bowhead whales. S. Johnson (personal communication) repeatedly flew a grid of pre-selected transects from shore, seaward to a distance of 20 nm, in the area between the Alaska/Canadian border and 143°45'W. These surveys were for purposes of recording all marine mammal and bird sightings. Both Ljungblad and Johnson provided us with information about belukha sightings.

Data Management

Data acquired in this study were put into two basic formats (files) suitable for analysis utilizing a "mini" computer (Digital Equipment Corp., VT/78, with associated printer and plotter). The first file was of whale sightings and associated information such as number of animals, time, date, geographic coordinates, ice conditions, begin and end points of survey transects, and pertinent comments about sightings and/or transects.

The second file was of biological data about sampled whales including specimen number, date and location of capture, sex, color, length, weight (mostly of fetuses of neonates), age, and reproductive status.

A variety of programs, prepared by Mr. Jesse Venable, were utilized for data analysis. These included tabulation of harvest data, determination of various biological parameters, tests of statistical significance between or among samples, construction of a life table and age-specific mortality estimates, plots of whale sightings and of transects flown during aerial surveys, and general mapping of the study area.

RESULTS

Biological Sampling

In total, 491 belukhas older than newborn calves, 68 fetuses in the first trimester of development, and 58 term fetuses and newborn calves were sampled in 1977 to 1983 (Table 1). Most were landed by subsistence hunters and were mainly taken in Eschscholtz Bay during June of various years. The Eschscholtz Bay samples amounted to 68% of the whales older than calves and 62% of the fetuses and newborns. Fifteen of the whales, including an abortus and nine neonates, were found beachcast in the Bristol Bay region by L. Lowry and/or K. Frost (personal communication; Frost et al. 1983) .

Subsistence hunting during June-July is during part of the prolonged birth period. At most locations where hunting occurs in these months, belukhas are driven into shallow water where they are relatively easy to follow and kill. Knowledge and observation of hunting techniques employed during whale drives suggest that the younger, smaller whales are under-represented, to an unknown extent, in our samples. Larger whales are preferred because of the higher yield. Their size, lighter color, and more obvious wake make them easier to pursue and hit with rifle fire.

Table 1. Field collection efforts and a summary of belukha whales examined, or from which specimens were obtained and included in this study, 1977 to 1983.

Field location	Dates	No. of belukhas: males	females	undetermined	total	No. of fetuses or newborn calves accounted for: recently implanted	near-term or newborn	total	Field collector
Point Hope	Apr-May 77	19	20	0	39	5	9	14	G. Seaman/ ADF&G
Elim	Jun 77	3	0	0	3	0	0	0	G. Seaman/ ADF&G
Point Hope	Apr 78	11	5	0	16	1	2	3	G. Seaman/ ADF&G
Eschscholtz Bay	Jun 78	38	38	2	78	15	7	22	G. Seaman/ ADF&G
Point Lay	Jul 78	5	4	0	9	0	1	1	G. Seaman/ ADF&G
Wainwright	Jul 78	0	1	0	1	1	0	1	R. Tremaine/ ADF&G
Eschscholtz Bay	Jun 79	2	1	0	3	0	0	0	G. Seaman/ ADF&G
Point Hope	May 79	5	1	0	6	0	1	1	P. Field/ NMFS
Wainwright	Jul 79	28	12	1	41	4	5	9	R. Tremaine & G. Seaman/ ADF&G
Barrow	May 79	1	1	0	2	0	0	0	Unknown collector/ NMFS
Eschscholtz Bay	Jun 80	51	40	2	93	16	5	21	J. Burns & K. Frost/ ADF&G
Point Hope	May 80	4	4	1	9	1	1	2	D. Smullin/ NMFS
Eschscholtz Bay	Jun 81	5	34	0	39	8	6	14	J. Burns/ ADF&G
Nushagak Bay	Jul 82	3	0	0	3	0	2	2	L. Lowry & K. Frost/ ADF&G
Eschscholtz Bay	Jun 82	53	68	0	121	11	9	20	J. Burns/ ADF&G
Point Hope	Apr-May 83	3	5	0	8	2	1	3	R. Clarke/ North Slope Borough
Bristol Bay	May-Jul 83	0	2	0	2	0	8	8	L. Lowry & K. Frost/ ADF&G
Point Lay [a]	Jul 83	8	10	0	18	4	1	5	R. Nelson/ ADF&G
Totals		239	246	6	491	68	58	126	

[a] Only fetuses from this collection are included in results of this report.

Sex Ratio

Of 533 specimens including 47 term fetuses or newborn calves, 265 (49.7%) were females. Although the sex ratio of the entire sample was 1:1, there were great deviations in some subsamples. At Point Hope, 16 whales sampled in April 1978 included 11 males (69%). At Wainwright, in July 1979, 28 (70%) of 40 whales taken were males. In Eschscholtz Bay during June 1981, the entire annual catch, which amounted to 39 belukhas, was taken in a single drive. Thirty-four (87%) of those whales were females.

Differences in sex ratios of these subsamples suggest some degree of segregation among different pods and groups of belukhas, and beg the general questions of sampling biases and the sampling effort required to deal with such biases.

Growth

Age-Body Length Relationship

Age-body length data were obtained from 126 belukhas, not including fetuses. This sample was of 58 males and 68 females. Two other data sets from whales that were taken in, or are known to pass through waters adjacent to Alaska were available for comparison. The first was from 18 belukhas taken in Bristol Bay (Lensink 1961) and the second from 45 animals taken in the Mackenzie estuary (eastern Beaufort Sea) and sampled by Sergeant (1973).

Growth curves for male and female belukhas, based on data obtained during our study, are shown in Figure 2. In Figure 3 the data reported by Lensink (1961) and Sergeant (1973) are plotted in relation to the growth curves for males and females from northwest Alaska.

Age-length relationships of the Bristol Bay and Mackenzie estuary samples appear to be essentially the same as those from whales taken in northwest Alaska. It is noteworthy that the sample from Bristol Bay included a large proportion of belukhas less than 12 years old, based on the assumption of two dentinal layers per year of life.

Maximum standard lengths of belukhas in our sample were of a 30-year-old male 457 cm and a 31-year-old female 414 cm. In comparison, maximum lengths in the smaller samples from Mackenzie estuary were of an approximately 445-cm, 20-year-old male and a 387-cm, 20-year-old female. Maximal lengths in the Bristol Bay samples were 417 cm for a 16-year-old male and 356 cm for a 5-year-old female.

Figure 4 shows growth of belukhas, based on animals from northwest Alaska, ages 0 to 4 years. The increase in SL during the first year of life was found to be 46.3 cm or 26.8%, based on comparison of means of six neonates and four 1-year-olds. This compares to a length increase of 56.4 cm (35.3%) between the same age cohorts, as found by Brodie (1971) for belukhas in Cumberland Sound. Values for annual growth increments are presented in Table 2.

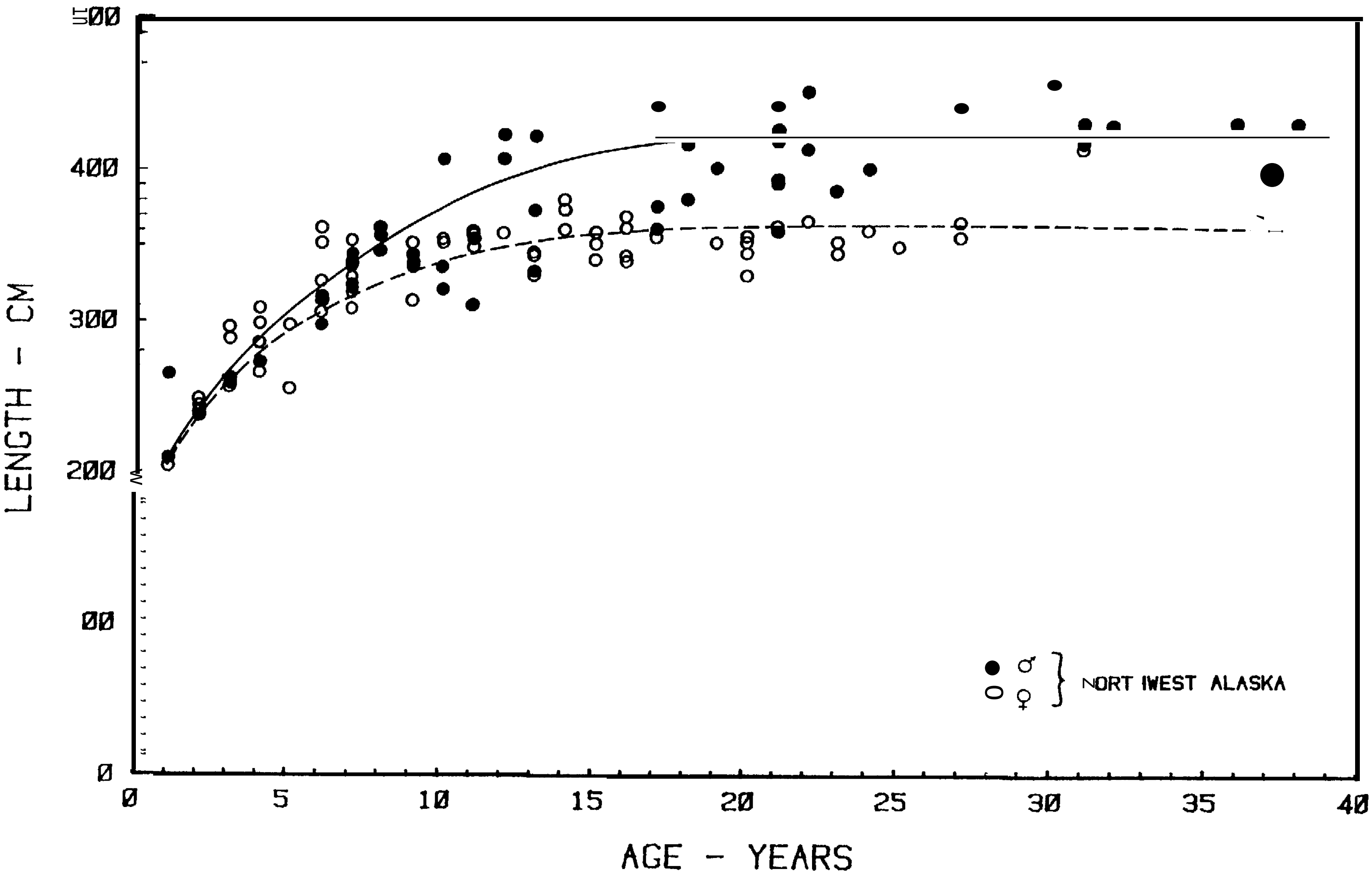

Figure 2. Age-length relationships of 126 belukhas sampled in northwest Alaska, 1977 to 1982 Growth curves were fitted by eye.

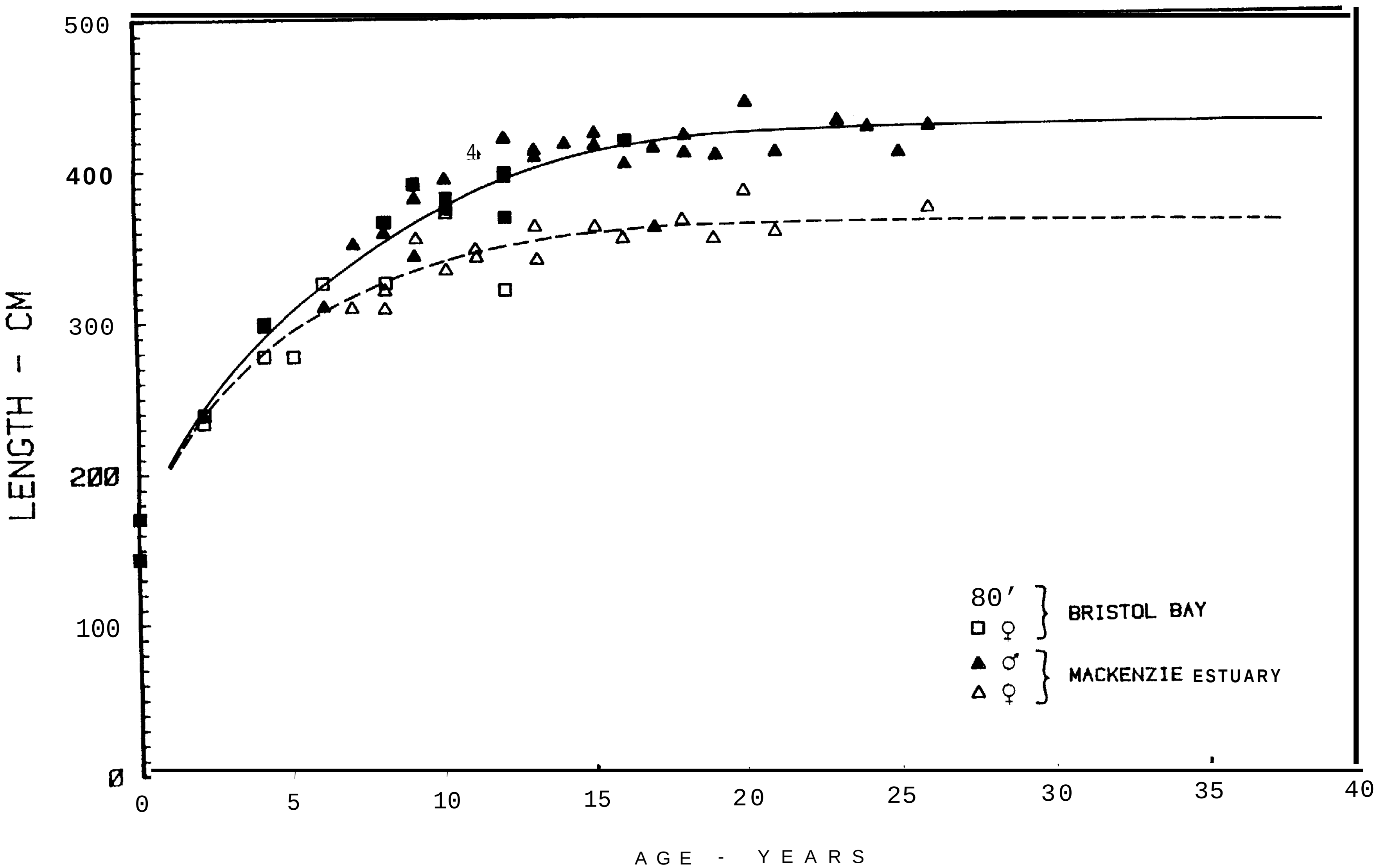

Figure 3. Age-length relationships of 18 belukhas from Bristol Bay, Alaska and 45 from Mackenzie estuary, Canada, plotted on growth curves for whales from northwest Alaska, as shown in Figure 2.

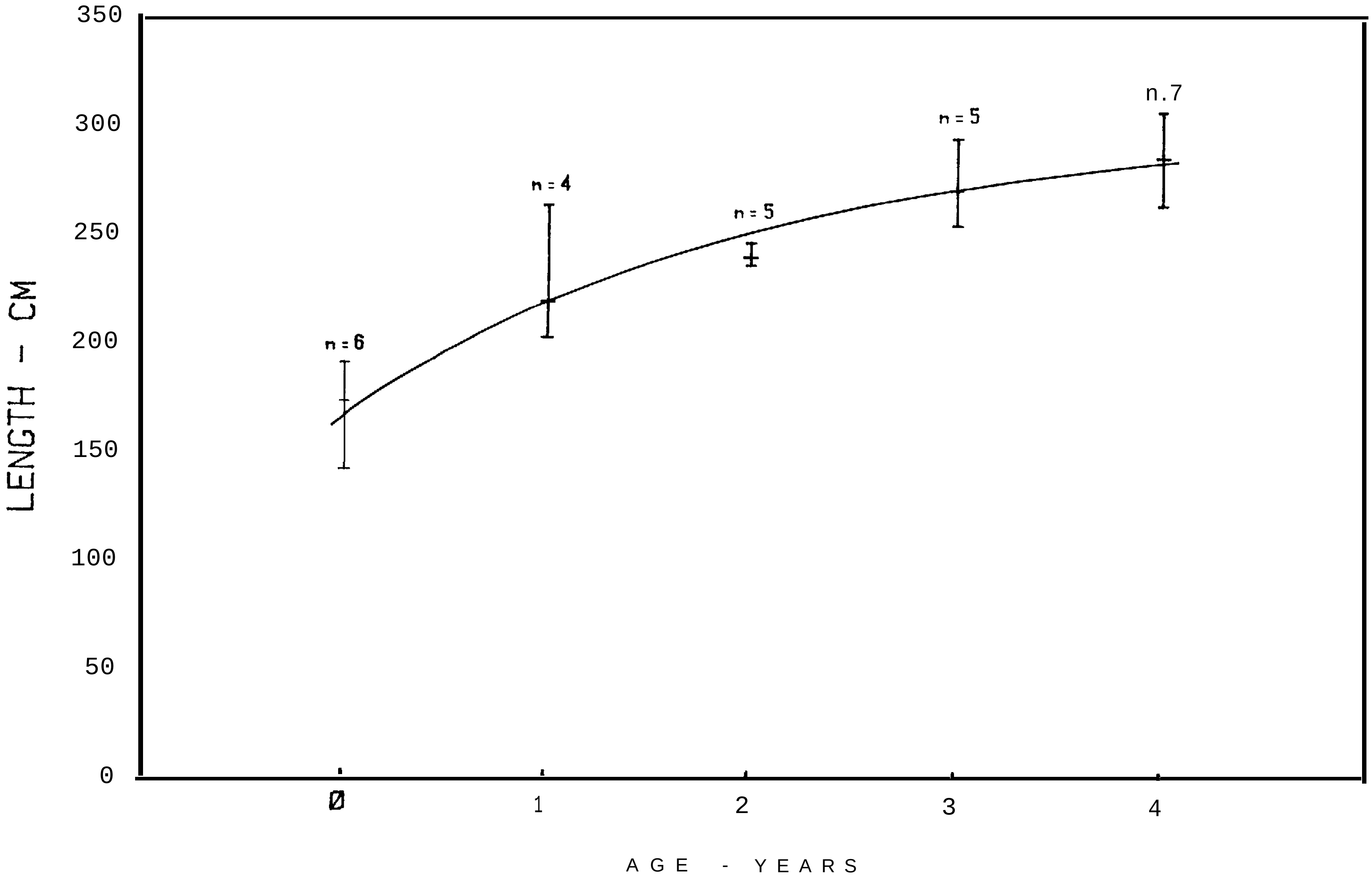

Figure 4. Age-length relationships of belukhas, ages 0 to 4 years, from northwest Alaska.

Table 2. Parameters of age/length relationships for belukhas ages 0 to 4 years, from northwest Alaska; males and females combined.

Parameter	Age (yr) 0	1	2	3	4
Sample size	6	4	5	5	7
Mean length (cm)	173.1	219.4	239.8	270.7	286.1
Minimum length	142.2	202.6	236.2	254.6	264.2
Maximum length	190.5	263.5	246.4	294.6	307.3
Increase from preceding year (cm)		53.3	20.4	30.9	15.4
Percent increase from preceding year		32	9	13	6

Our sample is inadequate to determine the increase in length during the first few months of life, though it is suggested by two calves of the year killed by hunting (as compared to beachcast) in Bristol Bay (Lensink 1961). These included a newborn, 142 cm long, taken in mid-June and an approximately 3-month-old calf, 168 cm long, taken in mid-September. The difference in length was 26 cm or 18.3%. Though such an increase in length in the first three months of life is highly probable, many more specimens would have to be measured and their age determined to adequately estimate growth during early life.

The matter of growth during the first several months of life is important, given the techniques of aerial observation and/or photogrammetry that have been utilized by some investigators to determine the proportion of calves of the year in various aggregations of belukhas. In our opinion, such methods are reasonably accurate during June-July when neonates are small and exhibit little overlap in length when compared with l-year-old animals. However, aerial observation and photogrammetry may be much less useful by late August to October, when some calves of the year are probably as large as some yearlings.

If aerial observation and/or photogrammetry procedures are to be used as a means of determining birth rate or the proportion of calves present at times other than close to the peak birth period, much more data about growth during the first two years of life will be required.

Fetal Growth

Sample size for embryos and fetuses from waters of northern Alaska was 99 and includes 5 from Bristol Bay collected by J. W. Brooks (unpublished) , and 94 obtained during this study. Specimens were collected from April to July and include 59 embryos and small fetuses and 40 near-term and term fetuses. We have no data about fetal growth during the eight-month period, August to March.

Three length measurements were recorded as appropriate for condition of an embryo or fetus. Five embryos were straight and rod-like in appearance. Greatest length of these was used. Forty fetuses were large, near-term or term, and were measurable in a manner similar to larger belukhas. On these, standard length (SL) was measured. On the remaining 54 small fetuses, nose to tail length (NTL), SL, or both were taken, depending on whether the fetus was tightly curled or relatively straight. NTL is a measurement from the anterior end of the jaw to the tip of the developing fluke along the dorsal curvature of the body. A fluke notch is not present on small fetuses in May to July. Of the 54 small fetuses, only NTL was obtainable on 41, and both NTL and SL on 13. NTL is an exaggeration of SL and when used, resulted in a discontinuity when making comparisons with embryos or with larger fetuses. A regression equation was developed, based on the 13 fetuses for which both NTL and SL were recorded. The resulting equation showed that $SL = 0.737 (NTL) - 4.57$, with $r = 0.941$. The derived SL of small fetuses was used to plot progressive increase of fetal length over time (Figure 5) .

Mean length of 26 near-term fetuses collected in June was 155.5 cm (range = 127.3 to 180.3) and is our best indicator of length at birth. The

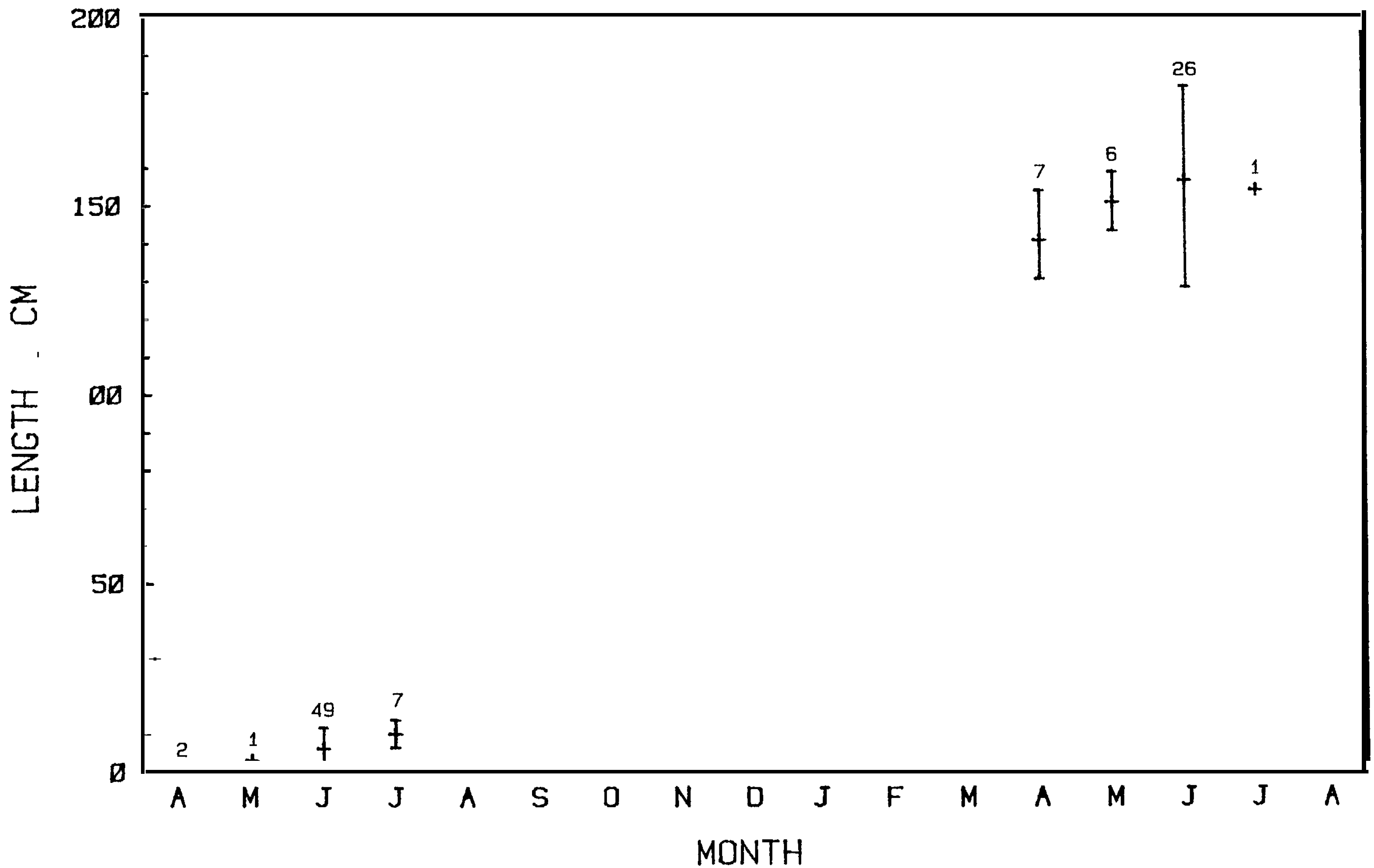

Figure 5. Progressive increase in length of prenatal belukhas from Bristol Bay (N = 5) and northwest Alaska (N = 94). No specimens were available for the period August to March.

increase in weight over time is shown in Figure 6. Average weight of six near-term fetuses taken in mid- to late June was 71.8 kg.

The data from belukhas taken in Alaskan waters show that during late pregnancy from April to June, the increase in fetal length is comparatively small, whereas increase in weight is considerable. Compared to near-term fetuses taken in June, those obtained in April were only 10% shorter, but 45% lighter.

Length of Neonates

Standard length of four newborn calves from northwest Alaska taken in June averaged 164.9 cm with a range of 137 to 175 cm. Nine neonates obtained in Bristol Bay during July included one taken by hunting (J. W. Brooks unpublished) and eight found beachcast. That taken by hunting was 175.3 cm long. Those found beachcast averaged 143.0 cm, with a range of 137 to 152 cm.

Beachcast neonates from Bristol Bay were appreciably smaller than term fetuses from that area. Five term fetuses from Bristol Bay, obtained by Brooks (unpublished), had an average SL of 154.9 cm (range = 134.6 to 170.2); a length approximating the mean of 155.5 cm for other term fetuses from waters of northern Alaska.

Excluding the beachcast neonates from Bristol Bay, average length of four newborn calves obtained in June-July was 174.0 cm.

Reproduction

Interpretation of Female Reproductive Tracts

Extensive examination of female reproductive tracts from ice-associated pinnipeds of Bering Sea indicated the validity of recognizing nulliparous, primaparous, and most multiparous females on the basis of size and external condition of uterine horns (Burns 1981a, b; Burns and Frost 1983) . Exceptions were multiparous females in which successive pregnancies occurred only in the same horn. These could not be discerned from primaparous animals. Differences among the three categories of females were that uterine horns of nulliparous animals were narrow, smooth in external appearance, and relatively thin-walled. When a pregnancy went to late term or birth, the uterine horn became greatly thickened, rugose, and. internally a placental scar was often evident. Correlations of reproductive status based on gross examination of uterine horns and on ovarian analysis were very useful in identifying animals that had ovulated but not given birth, those that were primaparous, and those that had two or more pregnancies alternately involving both horns.

In belukha whales, nulliparous females were easily distinguished from parous animals based on gross external examination of uteri. This, in combination with ovarian features, permitted recognition of young animals that had ovulated but had not supported a fetus. However, primaparous and multiparous animals were indistinguishable. Even when a belukha had supported only one fetus to late term or birth, both uterine horns appeared similar.

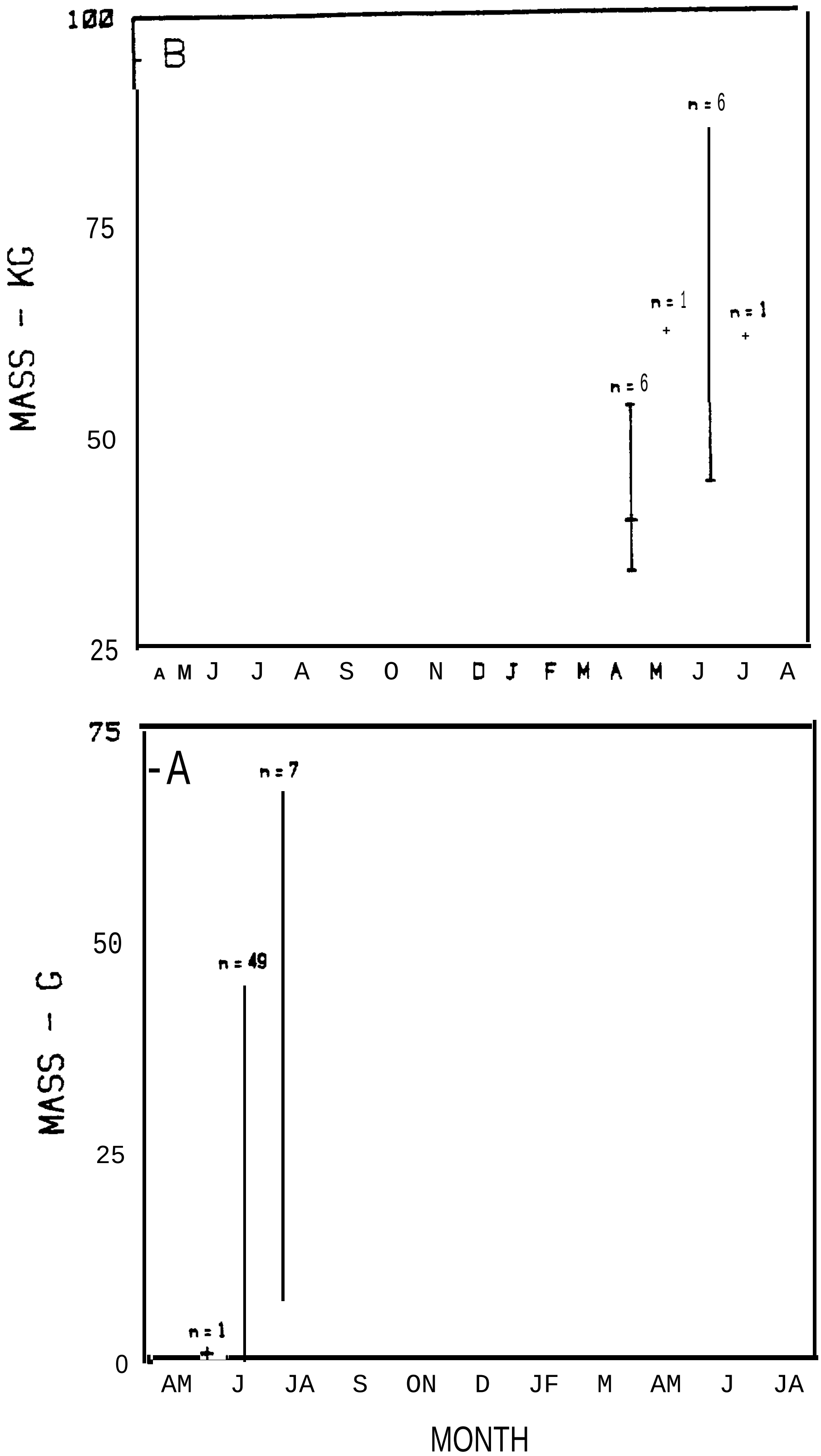

Figure 6. Progressive increase in weight of prenatal belukhas from northwest Alaska; A is of fetuses in the first trimester of development with weight in g, and B is in the third trimester with weight in kg.

We attribute this to involvement of both uterine horns in a pregnancy. Field examination of belukhas with term fetuses, taken in Eschscholtz Bay in 1981 and 1982, showed that in seven of 11 instances the fetus extended into both uterine horns. The head and torso were in the horn where the placenta was and extensive, fluid-filled fetal membranes with the enclosed caudal portion of the fetus extended into the other uterine horn.

In the four instances where a term fetus was within a single horn, the caudal portion was tightly recurved and laid along the ventral surface of the abdomen as described by Doan and Douglas (1953). In one instance, the head was toward the cervix. Caudal presentation was probable in the other three instances. Caudal presentation appeared probable in all instances where the caudal part of a fetus extended into the nongravid uterine horn. In the four instances in which a near-term fetus was completely within one uterine horn, part of the fluid-filled membranes intruded into the other horn.

Perhaps of greater significance was the finding that in seven of 11 early pregnancies noted in our 1982 sample from Eschscholtz Bay, fetal membranes extended into the nongravid uterine horn. Field collections of examined uteri were from 22 to 24 June and the fetuses were small. None exceeded 160 mm in length. Gross appearance of the epithelial tissue in both horns of newly pregnant females appeared similar. No comparisons based on histologic preparations were made.

The apparent frequent involvement of both uterine horns in a single pregnancy is probably facilitated by the broad connection between the horns, the relatively large cavity of the uterus, a single cervical canal, and presence of a mucus plug in the cervical canal during pregnancy. These anatomical features were consistent with findings reported by Kleinenberg et al. (1964), though in our samples there *was* considerable variation in characteristics of the cervical plug. Kleinenberg et al. (1964) indicated that these mucus plugs were, “thick, rubbery, and semitransparent,” and that they were only present in pregnant females, occurring at all stages of pregnancy.

In our samples the mucus plugs varied from gelatinous and amber-colored to rubbery and nontransparent whitish in color. It is not known if the duration of specimen storage in 10% formalin affected appearance of this mucus substance. We found mucus plugs in all pregnant females examined for it and also in a few nongravid adults.

The presence of accessory corpora in the ovaries of belukhas have been noted by several investigators. Brodie (1971) discussed problems of interpretation of ovarian examination resulting from the presence of accessory corpora lutes in pregnant belukhas. Kleinenberg et al. (1964) concluded that such accessory corpora indicated postpartum breeding, an occurrence disproved by Brodie (1oc. cit.) . Multiple corpora lutes from a single pregnancy result in multiple corpora albicantia. Normal interpretation of these structures, as would be done for instance in the walrus or phocid seals, to obtain an indication of the approximate number of ovulations or, less precisely, the number of young born to a female, is not applicable to belukhas. Our earliest samples, obtained in 1977, included females supporting a single fetus (we encountered no multiple pregnancies) but exhibiting more than one corpus luteum. The work of Brodie (1971), combined with our earliest findings, encouraged us to disregard numbers of corpora albicantia as being indicative of the actual number of ovulations or pregnancies. Instead it prompted an effort to obtain a sufficiently large sample of females during the appropriate time of the reproductive cycle to base estimates of productivity on the presence of active corpora lutes in combination with the presence of a fetus. The number and frequency of corpora lutes in our samples of females containing such structures are presented in Table 3.

Our sample of females with at least one corpus luteum was 110. Of those, 87 (79%) had a single corpus luteum, 17 (15.5%) had two luteinized bodies, 5 (4.5%) had three, and 1 (l%) contained five well-developed luteinized bodies.

Subdivisions of this total sample were as follows:

47 females with a near-term fetus or newborn calf
- 34 (72.3%) with one corpus luteum
- 11 (23.4%) with two luteinized bodies
- 2 (4.3%) with three luteinized bodies

63 females with a small fetus
- 53 (84.1%) with one corpus luteum
- 6 (9.5%) with two luteinized bodies
- 3 (4.8%) with three luteinized bodies
- 1 (1.6%) with five luteinized bodies

Brodie (1971) reported that five of 39 (12.8%) term or postpartum females had accessory corpora lutes. In our sample as a whole, 110 pregnancies were associated with 141 corpora lutes, or 1.3 corpora lutes per pregnancy. The 1980 sample of 21 females obtained in Eschscholtz Bay is 19% of the females included in Table 3, though it includes 39% of the females with multiple corpora lutes. We have no explanation for the large annual variation in multiple corpora lutea evident in our samples.

There was a suggestion that more accessory corpora lutes were associated with later stages of pregnancy, though the differences in sample means ($t = 0.5462$, $df = 107$, $P > 0.5$) and distributions (chi-square = 4.57, $df = 3$, $0.5 > p > 0.1$) were not statistically significant. Mean number of corpora lutes in 47 females with a term fetus or newborn calf was 1.32, compared to 1.25 in 63 females supporting a small fetus.

Age at Sexual Maturity in Females

In this discussion, age at sexual maturity is the age at which a female conceives for the first time. Pregnancy may or may not result from the first ovulation. Our sample of known-age females ovulating for the first time includes 24 animals. In only two (8%) of these, ovulations did not result in a pregnancy. This was deduced by the presence of a corpus albicans in an ovary of those females, the uterine horns of which were clearly those of a nulliparous animal.

Table 3. Number of corpora lutes found in ovaries of pregnant and postparturient belukhas from northwest Alaska. Samples are separated into whales supporting a small fetus and those with a near-term fetus or newborn calf.

Sample collection	With near-term fetus or newborn calf					With a small fetus				
		Number of luteinized bodies					Number of luteinized bodies			
	N	1	2	3	>3	N	1	2	3	>3
PHD-77	9	8	1	0	0	5	4	1	0	0
PHD-78	2	2	0	0	0	1	1	0	0	0
PHD-78	7	6	1	0	0	15	15	0	0	0
PLD-78	1	1	0	0	0	0	0	0	0	0
PHD-79	1	1	0	0	0	0	0	0	0	0
WD-79	5	3	1	1	0	4	3	1	0	0
PHD-80	1	0	1	0	0	1	1	0	0	0
EPD-80	5	4	1	0	0	16	8	4	3	1
EPD-81	6	4	2	0	0	8	8	0	0	0
EPD-82	10	5	4	1	0	11	11	0	0	0
PHD-83	0	0	0	0	0	2	2	0	0	0
Totals	47	34	11	2	0	63	53	6	3	1

Determination of reproductive status for sexually immature females is straightforward. However, determination of the age of first pregnancy in the 22 females that had been pregnant only once is slightly confounded by the following considerations:

1. The duration of pregnancy is greater than a year.

2. Those pregnant only once were represented by females of three different conditions commensurate with a basically triennial breeding cycle; recently pregnant (with a small fetus), with a near-term fetus or neonate, or nongravid but having borne a calf prior to the year of capture.

3. Females were taken during the calving period or, stated differently, about the time of their own birthdays.

Thus, a female of age 6, pregnant for the first time and supporting a small fetus, was bred at age 5+ or during its sixth year of life. A female of age 6, pregnant for the first time and supporting a term fetus was bred at age 4+ or during its fifth year of life. The analysis becomes somewhat less accurate for nonpregnant, primiparous females with presumed l-year-old calves. Such females bred for the first time some 26 to 27 (or more) months prior to capture. Our sample includes 10 such known-age primiparous, nongravid females, eight of which were taken near Elephant Point in 1982 again suggesting an interesting sampling bias operative at the particular location and at that time (in this instance, a high proportion of young females of the same reproductive status).

Correlation of age at sexual maturity (= initiation of first pregnancy) for 22 females, based on the considerations stated above showed that 12 females (54%) conceived at age 4+ (fifth year of life), 9 (41%) at age 5+ and 1 (5%) at age 6+.

Table 4 presents a slightly different approach to the question of age at sexual maturity and pregnancy rate for our entire sample of 207 known-age females. Again, it is important to note that we obtained most of the samples at the approximate time of their birth dates. Thus, 4-year-old females were not pregnant when taken during June, though some of them would have become so prior to their fifth birthday. These data show that all animals up to the age of 4 years (N = 28) were sexually immature, 33% of 5-year-olds were sexually mature, as were 94% of 6-year-olds. All animals beyond age 8 were sexually mature.

Pregnancy Rates

Our sample of 207 known-age females included 36 (17%) sexually immature animals. This proportion of immatures is lower than actually occurs in the population as a whole, for reasons which have already been discussed.

Of the entire sample of sexually mature females for which age was determined (N = 171), 35% were nongravid when taken, 35% were newly pregnant, and the remainder were with term fetuses or had recently given

Table 4. Reproductive status of 207 known-age female belukhas from northwest Alaska.

Age	No.	Number Immature	Number Mature: Nongravid	Number Mature: Recent preg.	Number Mature: Near-term
0	1	1	0	0	0
1	4	4	0	0	0
2	6	6	0	0	0
3	6	6	0	0	0
4	11	11	0	0	0
5	9	6	0	3	0
6	16	1	6	4	5
7	11	1	4	4	2
8	7	0	1	2	4
9	7	0	1	4	2
10	5	0	0	3	2
11	9	0	3	3	3
12	4	0	2	1	1
13	8	0	5	0	3
14	8	0	2	5	1
15	9	0	2	4	3
16	8	0	1	3	4
17	8	0	2	3	3
18	6	0	2	3	1
19	5	0	1	2	2
20	8	0	1	4	3
21	5	0	3	0	2
22	9	0	1	5	3
23	10	0	5	2	3
24	5	0	4	1	0
25	3	0	1	0	2
26	5	0	3	0	2
27	5	0	4	1	0
28	1	0	0	1	0
29	3	0	2	1	0
30	1	0	1	0	0
31	1	0	0	1	0
32	1	0	1	0	0
33	1	0	1	0	0
34	0	0	0	0	0
35	1	0	0	0	1

birth (Table 4). These findings further support conclusions of a basically triennial breeding cycle as shown by Brodie (1971) and Seaman and Burns (1981).

Age-specific fecundity was examined in a general way (Table 5). Again, sampling bias and the triennial breeding cycle precluded meaningful comparisons among individual age classes of relatively small sample size. The trend for grouped age classes is evident. Nongravid females comprised 25% of those ages 8 to 20 years and increased to about 50% in animals older than age 20. Thus, the incidence of pregnancy is reduced in older age animals. The analysis by 3-year age groups shows a similar trend though it is confounded by attainment of sexual maturity over several years in young age groups and by the probability of encountering high proportions of females of specific reproductive condition in pods that are hunted in Eschscholtz Bay. As an example, 89% of all females in age group 8 to 10 in our samples were pregnant.

Age-specific birth rates, based on those females with term fetuses or neonates as shown in Table 4, by groups of age classes were: ages O-5, 0.0; ages 6-10, 0.326; ages 11-22, 0.333; ages 23-25, 0.278; ages 26-28, 0.182; and ages 29-38, 0.125. Based on the age frequency of sexually mature females in our sample, as shown in Table 4, birth rate for the population was found to be 0.306. We consider this to be a slight under-estimation because of the inability to recognize those females that may have borne calves during the earliest part of the prolonged birth period in which they had been collected. Age-specific pregnancy rates, based only on inclusion of those females with a small fetus were: ages O-5, 0.055; ages 6-10, 0.414; ages 11-22, 0.363; ages 23-28, 0.267; and ages 29-38, 0.190. Values for age cohorts 6 to 22 indicate that some females become pregnant more frequently than once in three years.

Birth Period

According to residents of coastal northwest Alaska, the time during which most belukha calves are born is from shortly after the middle of June to about mid-July. Our samples indicate an extended birth period beginning at least as early as mid-April and extending through July and possibly later. The peak period, however, is probably mid-June to mid- or late July. Determination of the latter part of the peak may be complicated if selective use of warmer coastal waters by whales about to, or having recently given birth, actually occurs. If, as suggested by Sergeant (1973) and Sergeant and Brodie (1975), such habitat selection does occur, samples would be biased toward females supporting a term fetus or newborn, even after the actual peak period of births.

Our aggregate sample of 195 sexually mature females included 171 for which age was determined and an additional 24 of unknown age. Of the 195, 54 were in the latter stages of pregnancy or were recently postparturient; 14 having been taken in the nearshore lead system of eastern Chukchi Sea during April-May and the remainder by driving them in embayments during June-July.

Postpartum females were determined based on an observed cow/calf pair or on the basis of meeting two or more of the following criteria: (1) presence

Table 5. Age-related fecundity in sexually mature female belukhas from northwest Alaska. Data are presented for, (A) groups comprised of 3-year classes and (B) for larger groups.

A			B		
Age groups (years)	N	Nongravid (%)	Age groups (years]	N	Nongravid (%)
5-7	28	36	8-20*	92	25
8-10	19	11			
11-13	21	48			
14-16	25	20			
17-19	19	26			
20-22	22	23	21-30	47	51
23-25	18	56			
26-28	11	64			
29-31	5	60	31-37	4	50
32-34	2	100			
35-37	1	0	TOTAL :	143	
TOTAL :	171				

* This cohort begins with whales in the age group at which all females were sexually mature.

of one or more corpora lutea/corpora albicantia in the early stages of degeneration; (2) distended uterine horns containing blood or debris; and (3) lactating with evidence of abundant milk production (colostrum in several instances) . The inherent bias in this procedure is that females which may have given birth in April-May would not have shown indications of recent parturition by mid-June-July. They would be classified as supporting a calf because they were lactating, but not necessarily having been pregnant in the year taken. This tends to overestimate the number of nongravid females and underestimate those classified as having near-term fetus/newborn calves. Doan and Douglas (1953) reported that placental scars are not evident in belukhas. We found none, even in females known or judged to be recently postparturient. This may be explained by structure of the placenta, variously referred to as being of the epithelial (Kleinenberg et al. 1964) or indeciduate type (Doan and Douglas, 10C. cit.).

Eight females taken between 25 and 29 April supported a near-term fetus, and one taken on 29 April was postpartum. Four females taken in May had a near-term fetus and none were postpartum. Samples obtained in June include 32 females taken in Eschscholtz Bay between 13 and 24 June, of which 19 supported a near-term fetus and 13 were postparturient. Between 1 and 18 July, eight females were obtained near Point Lay and Wainwright, of which three were recently postparturient and five bore a term fetus.

In Bristol Bay, 68 belukhas were collected between 26 May and 18 August 1954 (ADF&G 1969). These included 4 taken in May, 12 in June, 31 in July, and 24 in August. Three term fetuses were found in the June sample; the last one being on the 23rd. Three calves of the year were taken, the first one on 8 July. In 1961, also in Bristol Bay, Lensink (1961) found a newborn on 14 June and two term fetuses, one each on 11 and 17 June. Lowry et al. (1982) reported finding two beachcast neonates in that region, the first on 7 and the second on 10 July, 1982. Both had been dead for several days. Frost et al. (1983) indicated that in Bristol Bay births occur principally in June and July. During repetitive aerial searches for beach cast whales in 1983, the first belukha was found on 11 May 1983 and the first newborn on 4 July. Five dead newborns were found on 15 July. Additionally, four different masses of drifting afterbirth, identified as being from belukhas, were found and reported by local fishermen on 9 July 1983 (Frost et al., 10C. cit.).

In Kasegaluk Lagoon, near Point Lay, a birth was recorded on 7 July 1978. In this instance an unaccompanied whale was observed for several hours after which a calf suddenly appeared beside it (Seaman, field notes) .

Our findings indicate that in waters adjacent to Alaska, the birth period of belukhas is rather long, extending from April through July and possibly longer. However, most births occur between mid-June and late July.

Breeding Period

Brodie (1971) utilized a straight line method applied to fetal lengths and determined the gestation period to be 14.5 months. For the population of whales he studied near Baffin Island, the known birth period was late July-early August and he concluded that the peak breeding period was therefore in mid-May.

Application of the same procedure used by Brodie (1971) to our data from the Bering-Chukchi population of belukhas would indicate a peak of breeding in April. This is based on a 14.5 month gestation period and a peak of births during a month-long period from mid-June to mid-July.

However, our limited collection of biological samples suggests that breeding may occur earlier and that diapause (delayed implantation) cannot, as yet, be ruled out for belukhas. Our series of 20 early-caught, sexually mature females other than those with a near-term fetus or neonate (these are ruled out as breeders in the year of capture) includes 9 taken in April and 11 in May, as shown below:

Date	No. specimens	Date	No. specimens
April 25	2	May 7	1
26	1	10	1
27	2	17	4
29	4	19	3
		23	1
		24	1

Of the nine females from April, ovaries of four had a large, completely formed corpus luteum, the smallest of which was 39 mm in diameter. One of the females, taken on 27 April, had a 2.8-mm, rod-like, segmented embryo. NO embryos were recovered from the other three, though they were, in all probability, pregnant. Another four females were apparently nonbreeders during the year of capture. They showed no indication of recent or impending ovulation. As is usual for most adult females, the ovaries of these nongravid females contained follicles, in one instance as large as 8 x 5 mm, but mostly less than 2 mm. None of these follicles protruded from the surface of the ovary. One female taken on 29 April 1977, contained a fully mature, ripe follicle, the greatest diameter of which was about 42 mm. The follicle mostly protruded above the surface of the ovary. This female was considered to be nearing ovulation. Thus , of the five females taken in late April that showed signs of breeding activity, four had ovulated enough in advance of collection that the corpora lutes were fully formed. One was approaching ovulation, indicating that some breeding was still occurring.

Of the 11 appropriate females obtained in May, five had ovulated earlier in the year as evidenced by a fully formed corpus luteum, the smallest of which was 41 x 30 mm. An embryo, 8.4 mm, was recovered from the female taken on 7 May. Recent or imminent ovulation was evidenced in one animal taken on 10 May. It had a large (>30 mm) , though collapsed, follicular cavity which protruded above the ovary surface. This follicle may have been naturally ruptured, or burst when the whale was butchered on the ice. The remaining five females were apparently nonbreeders in the year of capture. None of the 112 females taken in June that were potentially capable of breeding during the year of capture showed signs of recent or impending ovulation. Fifty of them were already pregnant and supporting small fetuses and 62 were nongravid. In the July sample of 10 appropriate females, 2 were nongravid and 8 were pregnant. One of the eight had a large, 45-mm, incompletely formed corpus luteum, suggesting ovulation sometime in late June-early July. It was taken on 18 July.

This series of specimens indicates that some breeding occurs in late June-early July but most occurs prior to late April. Kleinenberg et al. (1964) noted the difficulty of finding very small embryos under field conditions. They indicated that some authors had recorded well-developed corpora lutes in belukhas, but were unable to find an embryo. That was the case in our series of newly pregnant females taken in April-May. The two embryos recovered were in uteri from two of three reproductive tracts obtained in 1980 and later, all of which were carefully examined under laboratory conditions. The third of these taken on 19 May, had a fully formed corpus luteum, the largest dimensions of which were 50 x 41 mm. Neither an implantation site nor an embryo was found. We cannot say with certainty that samples obtained prior to 1980 contained a small embryo or not. They did not have obvious implant sites, features which are apparent even with the smallest discernible embryos.

Small to moderate size follicles were found in ovaries of some females, regardless of either the month in which they were taken or their general reproductive condition. As an example, of 68 females taken in June 1982 in Eschscholtz Bay, 24% had one or more obvious follicles. The largest follicle in two recently postpartum females was 12 x 9 mm. In three females with a small fetus the largest follicle was 7 x 6 mm ($\bar{x}$ = 6 x 5.7 mm). Five females with follicles were subadults, being nulliparous and not pregnant. The largest follicle in these was 10 x 8 mm ($\bar{x}$ = 6.6 x 5.2 mm). In six nongravid, parous females, average size of follicles was 11 x 6.3 mm, and the largest was 17 x 12 mm. This large follicle was the only one in the June 1982 sample that might have matured later in the summer. Though it was situated near the surface of the ovary, it did not protrude.

Histological sections of testes and epididymides from 39 males were examined microscopically. This sample included 8 whales taken in late April, 2 in mid-May, 6 in late May, 18 in mid-June, and 5 in early July. Five whales were found to be adolescent. In the 34 sexually mature males, two (5.9%), both taken in mid-June, were judged to have been in breeding condition. In the testes of both, all phases of the maturation of germ cells, from spermatogonia to spermatozoa, were evident. Also, spermatozoa were moderately abundant in tubules of the epididymides of both whales.

In contrast, the other 32 adult males, including the 14 animals obtained in April and May, were in the early to mid part of the retrogression phase of the annual cycle of spermatogenesis. Within epididymides, spermatozoa were mostly absent (22 animals) or present only in trace amounts (10 animals). Contents of tubules mainly consisted of cellular debris. Seminiferous tubules of the testes showed various stages of degeneration of germ cells, presence of giant cells, and extensive debris. Presence of multi-nucleated spermatid giant cells is indicative of the retrogression phase.

These findings show that although a small proportion of males may remain in breeding condition through June and perhaps later, most are in nonbreeding condition by late April-May.

Evidence from reproductive organs of females and males indicate that the breeding season is long but that most breeding occurs during an unknown period prior to mid-April. We suggest that additional study will establish the peak period between late February and early April, when most belukhas are in the Bering Sea or beginning the spring migration.

Color Change

The color of term fetuses and very recently newborn calves seems quite variable. They appear to have a light greyish or silvery sheen that masks much darker pigmentation. Short-term exposure apparently changes or removes this surface coloration and the young calves become a dark brownish-grey or blueish-grey. Belukhas gradually become lighter as they mature and all (or most) are white, with a narrow blackish fringe on the posterior margins of the flukes as adults. Some adults, especially males, also have a narrow dark fringe along the posterior margins of the flippers. Sergeant and Brodie (1969) indicate that the white coloration is obtained when the animals become sexually mature, "but rather later in females than in males."

We classified belukhas into four general categories of color: dark brownish- to blueish-grey, grey, light grey, and white. Since categorization of such a color gradient is subjective, some differences in assigned coloration may have occurred both between the two principal investigators and among different years for the same investigator. The senior author classified 172 of 209 (82%) whales for which color as well as either age, standard length, or both were also determined. The greatest probability for discrepancy may be in classification of light grey- and white-colored animals.

Lengths and ages of males and females of the four color phases are presented in Table 6. For males, dark grey animals were mostly those in their first and second years of life, grey animals were mostly ages 2 through 7, light grey were mostly 6 to 9 years, and white-colored males were 9 years and older. The light grey phase was evident in some males and females by age 5. The mean age of light grey females indicated in Table 6 is misleading. Although the modal age of light grey females was 6 years, this color phase was evident in animals as old as 21, thus skewing the mean to an age significantly higher than either the mode or the median of 7 years. Apparently, in some females the light grey color phase persists well into adulthood while others become white as young as age 6.

Indicated mean ages of white-colored males and females are parameters of little value because of the great range in age of whales in this color cohort.

Reproductive status of females indicated that most reach sexual maturity before they become white. A comparison of coloration and reproductive history showed that none of the dark grey females were sexually mature. Of 29 grey females, three (10%) were sexually mature, having been pregnant once. They were judged to have bred at age 4+ (fifth year of life).

Sexual maturity in females was mainly obtained during the light grey color phase. Of 21 females in this category, 19 (90%) were sexually mature, including 7 (37%) that had been pregnant only once. The older, light grey animals were multiparous.

Table 6. Age (yrs) and standard length (cm) of belukhas from northwest Alaska, classified by color phase.

		Dark grey		Grey		Light grey		White	
Sex	Parameter	Length	Age	Length	Age	Length	Age	Length	Age
Male	N	4	5	8	19	10	17	24	39
	Mean	217.6	1	299.4	5	333.2	7.5	408.3	22.9
	Range	188.0-256.5	0-3	236.2-335.3	2-9	297.0-355.6	5-11	345.4-452.1	9-38
Female	N	5	6	13	23	11	21	35	65
	Mean	214.8	1.2	274.3	3.9	329.7	8.8	350.8	19.3
	Range	190.5-241.3	0-2	238.8-307.3	2-6	304.8-361.3	5-21	312.4-373.4	6-33

Of 71 white-colored females, all were sexually mature and 31 (44%) were pregnant only once; one becoming so at age 4+ years, one at 5+ years, and two at 6+ years. Although they were white when collected, they were probably grey or light grey when they became pregnant.

Of 225 whales in our sample, for which color was recorded, 70% were light grey (whitish) or white.

Age Structure and Mortality Rates

Several sources of bias additional to those inherent in field sampling affect our analysis of population structure. Age determinations were based on counts of dentinal layers and the conclusion by Brodie (1971, 1982) that these layers are deposited at the rate of two per year. Our age determinations for small-sized whales also support Brodie's conclusion. There is great individual and sex-related variation in length and diameter of teeth. On average, those of males are considerably larger, in both dimensions, than those of females. We do not know if there is a general sex-related difference in rate of tooth wear, nor if the growth-to-wear relationships vary at different times of a whale's life. Accurate counts of the total number of dentinal layers actually deposited were possible only when the neonatal line was present. Loss of that important reference line was quite variable. It was worn away in 1 out of 21 (4%) whales 8 years old and all of 15 whales that were determined to be 17 years old (34 to 35 dentinal layers). However, it occasionally persisted in a very few individuals up to the age of 23+ years. For our purposes we used the minimal ages, as determined by the number of remaining dentinal layers, as if they were actual ages. Thus, the true age frequency distribution of older whales in our samples is biased toward younger cohorts and the maximum life span is underestimated.

The derived estimates of birth rate for the population as a whole and age-specific birth rates are also considered to be slightly lower than actual. Birth rates are based on those females that supported a term fetus or had recently given birth. The great majority of whales were sampled in June and July, at which time indications of a birth that may have occurred several weeks to months earlier were no longer obvious. Such whales would have been classified as nongravid. Actual birth rate for our sample was probably closer to 32% for females 6 years and older rather than the derived rate of 30.6%. However, we have used the 30.6% figure.

Age composition of 412 sampled whales from northwest Alaska is shown in Figure 7. Under-representation of age classes 0 to 5 is obvious. This is presumed to result from bias due to three factors: (1) a generally older-age composition of those whales comprising the early spring migrants (those taken in the lead systems near Point Hope in April-May) ; (2) a general hunter preference for larger whales; and (3) the greater ease with which larger, lighter-colored whales can be pursued in shallows. Age composition of our sample indicates that full recruitment into the catch occurs at about age 6. Various aspects of this sort of recruitment into the harvest are discussed, in detail, by Ricker (1958). The age frequency of sampled animals 6 years and older was "smoothed" using the probit regression (Caughley 1977) in order to generate the probable age structure of that

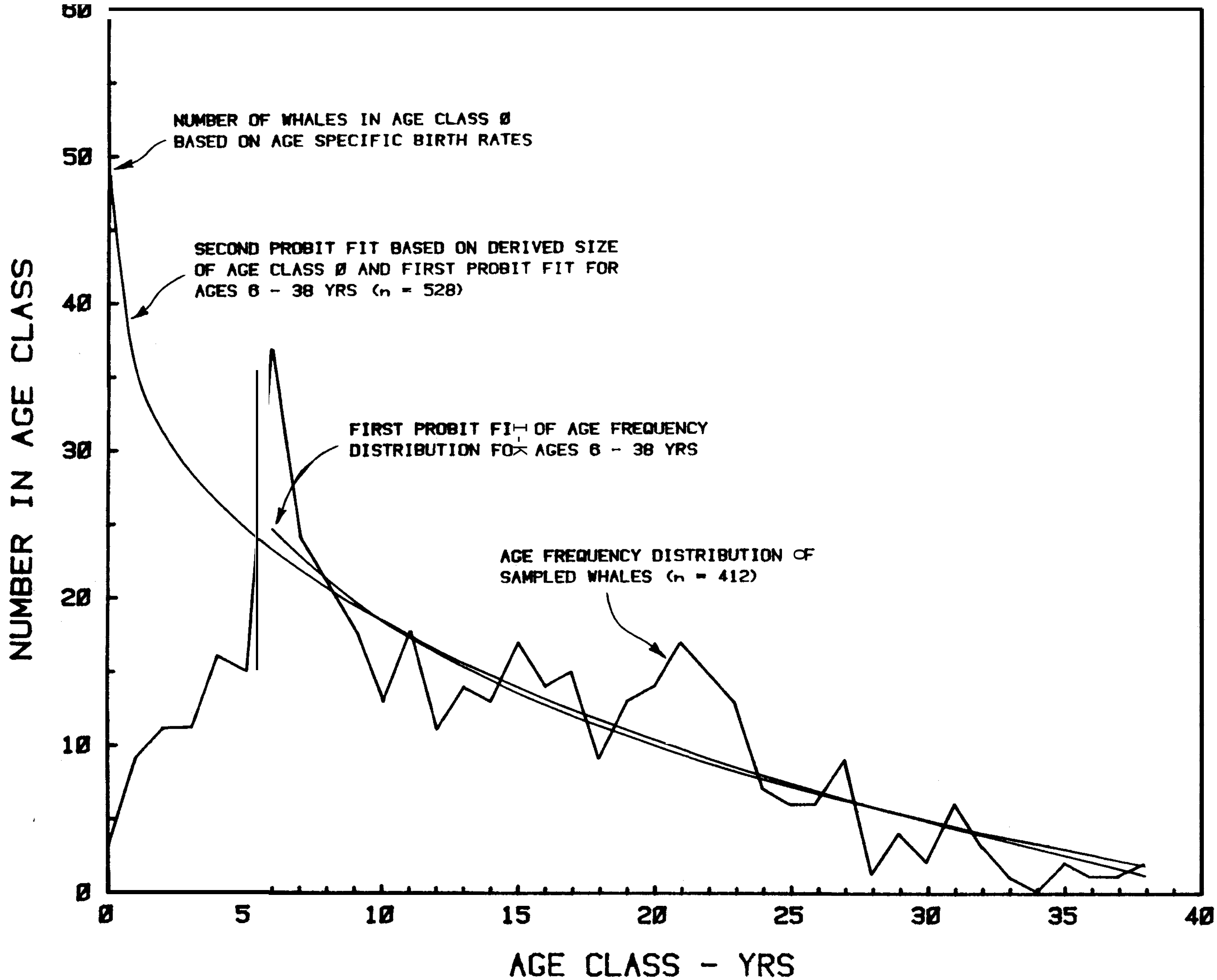

Figure 7. Age-frequency distribution of 412 belukhas sampled in northwest Alaska and the probable age-frequency distribution of model "population."

portion of the population. Then, based on our findings of a 1:1 sex ratio, age-specific birth rates as previously indicated and the fitted age frequency distribution of whales 6 years and older, the number of calves produced by a "population" of our sample size and composition was derived. The 332 belukhas, 6 years and older represented by the probit fit produced 50 calves. Using 50 as the size of age cohort 0, and the values that produced the probit fit for belukhas 6 years and older, another probable age frequency curve was generated. Our assessment is that the derived distribution curve for ages 0 to 38 appears to be a reasonable approximation of population structure.

This statistical exercise indicates that in the derived "population" of 528 belukhas, calves (age 0) represent 9.5%, ages 0 to 5 are 35% to 36%, and those 6 and older are 64% to 65%.

A life table for belukhas in our study area, based on the fitted age distribution is presented in Table 7. Procedures used for deriving that table generally follow those employed by Caughley (1966, 1977) and Smith (1973). Parameters included are age (x), smoothed age frequency distribution (N = 528), number per age class when the population size is 1,000, survivorship (l_x), deaths per age class (d_x), age-specific mortality rates (q_x), and mean life expectancy per age class (e_x). Mean annual mortality rate was found to be 0.0936.

Age-specific mortality (q_x) for a model population of 1,000 belukhas is shown in Figure 8. It suggests that the mortality rate for males, starting about age 4, becomes increasingly greater than for females.

Mortality

We have no data about mortality of belukhas caused by diseases or parasites. Three causes of mortality commonly mentioned in Eskimo lore are entrapment in ice and predation by polar bears and killer whales. Surprisingly, in many years of working with marine mammal hunters of northwestern Alaska, instances of either entrapment or predation by bears were reported from relatively few locations. Entrapment of belukhas by unfavorable ice conditions can certainly facilitate predation by bears and the two phenomena are often linked.

Entrapment

Belukhas normally winter in regions of active drift ice where they have easy access to air. The vast majority of the Bering Sea population apparently winters over a broad area in Bering Sea. Winter distribution is inadequately known. In other parts of the north there are aggregations, groups, and populations that winter in restricted and localized polynya areas in several parts of the Soviet Union (Kleinenberg et al. 1964), in Foxe Basin and James Bay in eastern Canada (Jonkel 1969, Sergeant 1973, Stirling et al. 1981), and in Bering Strait.

Throughout their range, belukhas occasionally become entrapped by extensive ice. Accounts of ice entrapments suggest to us that they most commonly result from two causes--failure of belukhas to migrate prior to or during

Table 7. Life table for belukha whales based on samples obtained in northwest Alaska from 1977 to 1982.

Age class (x)	Number per age class	Number per age class (pop. = 1000)	Survivors per 1000 (lx)	Deaths per 1000 (d_x)	Age specific mort. rate (q_x)	Mean life expectancy (e_x)
0	50	94	1000	294	294	10.18
1	35	66	706	76	107	13.21
2	31	59	630	53	84	13.73
3	29	54	577	42	73	13.95
4	26	50	535	36	66	14.01
5	25	47	500	31	62	13.97
6	23	44	469	28	59	13.86
7	22	41	441	25	57	13.70
8	21	39	416	23	56	13.50
9	19	37	393	21	55	13.26
10	18	35	371	20	54	13.00
11	17	33	351	19	54	12.72
12	16	31	332	18	54	12.42
13	16	29	314	17	54	12.09
14	15	28	297	16	54	11.76
15	14	26	281	15	55	11.40
16	13	25	266	15	56	11.04
17	12	24	251	14	57	10.66
18	12	22	237	14	58	10.28
19	11	21	223	13	60	9.88
20	10	20	210	13	61	9.47
21	10	18	197	12	63	9.06
22	9	17	184	12	65	8.64
23	9	16	172	12	68	8.21
24	8	15	161	11	71	7.77
25	7	14	149	11	74	7.32
26	7	13	138	11	78	6.87
27	6	12	127	11	83	6.41
28	6	11	117	10	88	5.95
29	5	10	106	10	94	5.47
30	5	9	96	10	102	4.99
31	4	8	87	10	111	4.50
32	4	7	77	9	122	4.01
33	3	6	68	9	137	3.50
34	3	5	58	9	155	2.97
35	2	5	49	9	180	2.43
36	2	4	40	9	216	1.85
37	2	3	32	9	271	1.22
38	1	2	23	23	1000	0.50

Mean mortality rate = 0.09362

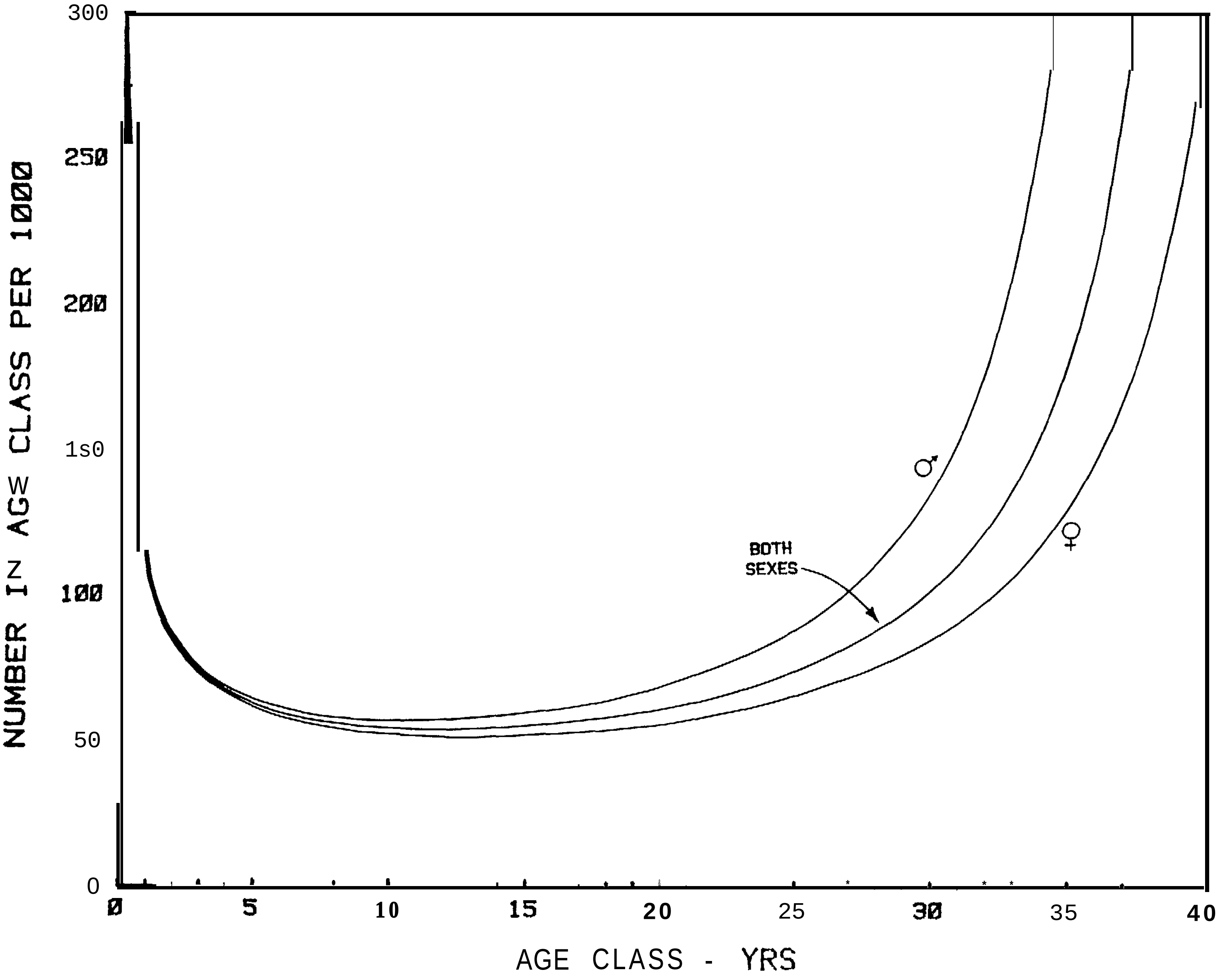

Figure 8. Age-specific mortality (q_x) for a model “population” of 1,000 belukhas, based on samples from northwest Alaska obtained in 1977 to 1982.

autumn freezeup, or deep penetration of the pack ice during spring migration with subsequent cold weather and extensive freezing of openings.

Porsild (1918) described entrapments of animals and introduced the Anglicized Greenland Inuit term savssats into the biological literature. The term savssaq (or its dialectal variants), in its most general sense, means an animal whose way is blocked. In Greenland Inuit, savssaq usually means a single whale or seal locked in a hole in the ice and savssat refers to more than one whale or seal in similar circumstances. The term is less commonly used in reference to sea birds or fishes whose way is blocked by such man-made devices as a weir (Schultz-Lorentzen 1927). In Alaska there are exact equivalents used by coastal Inuit from Bering Strait to Point Hope: sapraq (sing.) and saprat (pi.; Bob Uhl, personal communication) . We will use the more familiar Greenland word in reference to trapped belukhas.

In April 1984, two instances of entrapment were known to have occurred adjacent to Alaska (Lowry et al., in press) . The first was near Fairway Rock, in Bering Strait, at approximately 65°38'N, 168°34'W. An unknown number of whales (savssat) became entrapped around the middle of the month. The opening and numerous dead whales were found by a pilot flying from Nome to Little Diomede Island and the site was subsequently seen, on occasion, for almost a month. Photographs acquired by Mr. Robert Nelson (Alaska Department of Fish and Game, Nome) that were taken on 24 April by Mr. John Fray (pilot, Seward Peninsula Flying Service) showed that a minimum of 40 and perhaps as many as 55 whales had been killed over a period of several days and dragged onto the ice by polar bears. By 6 May the dead whales had drifted to a location approximately two miles north of Little Diomede Island. On that date an estimated 31 polar bears were scavenging belukha remains that were spread over several acres of ice around the opening. Open water was then only several hundred meters away (Sister Joseph Alice, Fraternity of the Little Sisters of Jesus, Diomede Island, Alaska, personal communication, 8 August 1984) . The second entrapment occurred in mid-April in southeast Chukchi Sea at approximately 67°49'N, 165°15'W. Numerous belukhas were seen at two small, closely adjacent holes in extensive refrozen leads. No other openings in the ice were visible. Several polar bears and several dead belukhas *were* seen (David Furber, pilot, Shellabarger Flying Service, Kotzebue, Alaska, personal communication 16 May and 4 September 1984).

Predation

The preceding comments about polar bear predation on savssat add to the existing record of such mortalities as reported by several writers, including Freeman (1973) . Polar bears also take belukhas under different conditions. On 27 April 1984, near Cape Lisburne, Alaska, Lloyd F. Lowry, (biologist, Alaska Department of Fish and Game, Fairbanks, field notes; Lowry et al., in press) examined a kill site at which a polar bear took a young belukha in a narrow though continuous lead system. The first northward migrating belukhas moving through that general area were seen on 25 April. Thousands of whales were seen generally moving northward through the Cape Lisburne area, from 25 April to 13 May, when field study by Alaska Department of Fish and Game personnel was terminated. Dr. F. H. Fay (University of Alaska Fairbanks, personal communication) noted a report by a pilot, of a belukha caught and partially eaten by a polar bear in the southern Chukchi Sea on 27 March 1967. Mitchell and Reeves (1981) show an instance of predation by polar bear(s) in the eastern Beaufort Sea.

Killer whales have been reported as major predators on belukhas. Sleptsov (1952) described a predatory encounter involving those whales that was also recounted in Kleinenberg, et al. (1964) . The latter authors also commented on predation by killer whales published by Kukenthal (1889) and Degerbøl and Nielsen (1930) indicating that belukhas are vulnerable when panicked. Kleinenberg et al. (1964) stated that killer whales do not occur in the Arctic Ocean of Siberia and North America. We are aware of three sightings of killer whales associated with the ice margin in waters north of Alaska. On 10 July 1967, at least five killer whales, in a single pod, closely approached a marine mammal hunting party operating in pack ice near Wainwright (70°39'N). The hunters indicated that game was very "nervous" for several hours after these whales had passed and that the occurrence of these whales was not especially unusual. The two other sightings were in September in western Beaufort Sea; 7 on 17 September 1974 near the ice margin where bowhead whales were present (Burns, field notes) , and one large male in the ice front at 72°28.5'N, 153°06.7'W, on 17 September 1982. The latter sighting was made during our survey of belukhas and the killer whale was in loose ice (2/10) where belukhas were also abundant. Other killer whales may have been present, submerged in the openings, or under the ice.

Dr. F. H. Fay (personal communication) noted a report by an Eskimo hunter of St. Lawrence Island who found a dead adult belukha on 7 November 1967 which was killed by a killer whale(s) . Fay (1982) concluded that killer whales were probably significant predators of walruses in the Bering and Chukchi seas. Predation on belukhas is also a logical occurrence in those seas when the two are present in the same area.

Accounts of harassment or predation by killer whales on belukhas, that have been observed or related to us, have occurred in the Kotzebue Sound area and near Point Lay. Most happened during June-July. During June 1979, belukha hunting success was unusually poor in Eschscholtz Bay and only three were taken. Failure of belukhas to enter the bay from Kotzebue Sound was attributed by local hunters to persistent presence of killer whales near the mouth of the bay (Seaman, field notes) . Other interactions between killer whales and belukhas that have been recounted to us were as follows.

Mr. York Wilson, a hunter from Kotzebue, informed us of an incident that occurred during early July, sometime in the middle 1950's. A pod of belukhas was chased into shallow water near Sheshalik (northeastern Kotzebue Sound) , by a pod of killer whales. The belukhas remained stationary for quite some time while the killer whales cruised back and forth in deeper water. After a time several of the smaller killer whales dashed toward the belukhas, apparently frightening a gray colored one away from the pod. This small belukha was seized by a large male killer and carried away from shore. A brief struggle occurred, the killer whale dove, and considerable blood and oil floated to the surface. The large killer whale swam seaward carrying the limp body of the belukha, with the posterior portion in its mouth. It was not observed to feed on the belukha before disappearing from view.

Two separate accounts were relayed to the senior author by Mr. Willie Goodwin, Jr., also an active belukha hunter from Kotzebue. Several years ago, while camped near Sheshalik in early July, Mr. Goodwin's mother watched a pod of killer whales chase a lone belukha toward shore. In its apparent att.empt to escape, the belukha beached itself. Partial and complete strandings, with animals becoming free on the subsequent rising tide, were reported by Smith (1985) . The second. incident occurred in mid-June 1984, also near Sheshalik. A pod of four to six killer whales chased a much larger pod of belukhas under shorefast ice that was extensive at the time. Reportedly, the killer whales cruised about in the area near where the belukhas went under the ice and did not permit them to come out. These belukhas could have utilized the enlarged access holes of ringed seals to breathe. Basking ringed seals were common in the area at that time. Geptner (1930, cited in Tomilin 1957) indicated that belukhas can utilize seal holes for breathing.

Farther north, in the vicinity of Point Lay, there are three recent records of killer whales in the vicinity of belukhas. On 15 July 1979 the junior author saw at least two killer whales attack and kill a grey, subadult belukha. The event occurred close to the seaward shore of a barrier island and happened within 30 m of the observer. The sea was rough. The first sighting was of a "spyhopping" killer whale. The second was of the belukha, also spyhopping, between the shore and the killer whale. A second killer whale and a young (possibly calf) grey whale (Eschrichtius robustus) then briefly appeared. The next whale seen was the belukha. When it dove it was attacked by one of the killer whales and a bout of violent thrashing occurred, followed by 10 to 15 seconds of relative quiet. Then, the killer whale surfaced with the young belukha in its mouth. None of the whales were seen after that. It was not known if the killer whales were initially pursuing the grey whale or the belukha, nor the eventual fate of the grey whale. On 5 July 1981 a pod of killer whales was seen chasing a pod of belukhas. Outcome of that chase was not known (account by Point Lay hunters to G. Seaman, field notes). On 11 July 1981 a single killer whale was swimming about 50 m offshore (Seaman field notes) .

Sergeant and Brodie (1969) indicated that in Cumberland Sound (eastern Baffin Island, Canada) killer whales have been reported to prey on belukhas. Steltner et al. (1984) report an eyewitness account of how killer whales preyed on narwhals in the eastern Canadian Arctic.

We are not aware of any accounts from the Bering or Chukchi Sea region that suggest predation on belukhas by walruses or sharks, as mentioned by Chapskii (1941) and Sleptsov (1952). Predation on marine mammals by sharks is not unusual (Brodie and Beck 1983). Pacific sleeper sharks, Somniosus pacificus, may be probable predators of belukhas in Alaskan waters. These sharks occur in Bering Sea (Wilimovsky 1958; Bright 1959; Hart 1973) , and are known to prey on pinnipeds (Bright 1959) . Their Atlantic counterpart, the Greenland shark (S. microcephalus) has been known to attack narwhals and belukhas caught in nets (Beck and Mansfield 1969).

Hunting

Seaman and Burns (1981) summarized the recent information about belukha hunting and netting in western Alaska and the harvests of these whales throughout Alaska from the late 1950's through 1979. Information from the late 1950's came from Lensink (1961) who estimated annual average harvests of 400 to 500 whales throughout all of western and northern Alaska; including a known directed take of 165 in Bristol Bay during the five-year period 1954-1958. In the Bristol Bay region the last significant, directed harvest of belukhas was in 1965, when seven whales were known to have been killed (ADF&G 1969). Though belukhas remain abundant in the bay hunting effort was drastically curtailed after 1959 for three reasons: cessation of lethal methods of controlling predation by belukhas on juvenile and adult salmon, greater participation of local residents in the intensifying salmon fishery, and a decrease in the demand and use of belukha whale meat and muktuk in that region. Several factors, mostly related to "modernization" including the virtual demise of working sled dog teams, contributed to that decrease in demand. Use of non-lethal methods of controlling presence of belukhas in major salmon spawning rivers, as reported by Fish and Vania (1971), eliminated that portion of the annual kill actually or subliminally encouraged by a desire to harass these whales and/or reduce their numbers in rivers flowing into Bristol Bay.

In Bristol Bay, the take of belukhas by directed hunting has remained comparatively low since 1961. Four were reported killed by hunting in summer 1983 (Frost et al. 1983). Most belukhas now taken in that region are accidentally entangled in salmon gillnets, with a kill on the order of perhaps 15 to 30 per year depending on characteristics of the salmon fishing season. In 1983, an incidental catch of 23 belukhas was reported (Frost et al. 1983).

Approximate average annual harvests of belukhas from the Bering Sea population, made in Alaska during different time intervals were as follows:

late 1950's	$\bar{x}$ 450/yr - Lensink 1961
mid-1960's	$\bar{x}$ 225/yr - Burns, unpublished
1968-1973	$\bar{x}$ 183/yr - Seaman and Burns 1981
1977-1979	$\bar{x}$ 187/yr - Seaman and Burns 1981
1980-1984	$\bar{x}$ 237/yr - this study

Harvests recorded for specific locations in the years 1977-1979 are reported in Seaman and Burns (1981, p. 571, Table 1). A similar presentation for the years 1980-1984 is included in Tables 8 to 12. In 1984 it was not possible to survey all of the coastal communities. Therefore, only part of the 1984 harvest is known. Based on that known harvest, take in 1984 was estimated to have been about 170 belukhas. This relatively low estimated take was mainly due to a total failure of the important annual hunt in Eschscholtz Bay and the lack of hunting effort near Point Lay, even though whales were present in early July.

It is noteworthy that near Kivalina in 1983 and 1984, harvests of belukhas have been significantly higher than the recent, long-term average take. In spring of 1983 and 1984, residents of Kivalina engaged the assistance of a local pilot to fly over the ice and locate leads through which bowhead whales and belukhas were passing. The hunters then established their ice camps near the most promising leads (R. Quimby, ADF&G, Kotzebue, personal communication; Burch 1984). use of a small airplane to locate suitable openings in the extensive ice cover is a means of ensuring that open water

Table 8. Statewide (Alaska) belukha harvest, 1980, from records compiled by the Alaska Department of Fish and Game.[1]

Village or area	Number known	Number estimated	Source of information
Bristol Bay	8	15-20	Mainly incidental to fishing - K. Taylor - ADF&G and area fisherman
Yukon-Kuskokw im deltas	9	15	J. Burns, Jr. - Fisheries Biologist in region; summer of 1980
St. Michael	unknown	10[2]	estimated
Stebbins	unknown	10[2]	estimated
Shaktoolik	unknown	5[2]	estimated
Koyuk	unknown	15[2]	estimated
Elim	unknown	5[2]	estimated
Nome	0	0	J. Burns - ADF&G, correspondence w/ residents of Nome
Diomede Island	2	2	J. Burns - ADF&G, information from A. Iyahuk and P. Omiak, residents of Little Diomede
S.E. Kotzebue Sound incl. Eschscholtz Bay	101	101	J. Burns and K. Frost - ADF&G, field monitoring and hunter interviews
N.E. Kotzebue Sound incl. Sheshalik	13	13	J. Burns - ADF&G, personal interviews and Elmer Armstrong, resident of Kotzebue
Kivalina	3	3-5	J. Burns - ADF&G, interview of several residents of Kivalina
Point Hope	23	23-25	D. Smullin - biologist at Point Hope during bowhead whaling season
Point Lay	15	15-18	J. Burns - ADF&G, correspondence with residents of Point Lay
Wainwright	0	0	J. Burns - ADF&G, personal interviews with residents of Wainwright
Barrow	0	0	J. Burns - ADF&G, O. Ahkinga and W. Kaleak - residents of Barrow
Kaktovik	11	11	B. Bartels - USFWS, Kaktovik resident W. Marquette - NMFS
Totals	185	243-255	

1 An additional five to seven belukhas were taken in the separate "Cook Inlet" population, most incidental to commercial salmon fishing. K. Schneider - ADF&G, pers. commun.; J. Burns - ADF&G, interview of resident of Tyonek.

2 No unusual harvests of belukhas were reported by local travelers, residents of these villages, or hunters interviewed. Therefore, the average of known annual harvests for the location are used.

Table 9. Statewide (Alaska) belukha harvest, 1981, from records compiled by the Alaska Department of Fish and Game.[1]

Village or area	Number known	Number estimated	Source of information
Bristol Bay	unknown	10-20	K. Taylor - ADF&G, area fisherman
Yukon-Kuskokwim deltas	17	25-28	J. Hanson, Alakanuk, general comments of various village residents and travelers, includes three known taken in salmon nets[2]
St. Michael	11	11	G. Seaman - ADF&G, personal interview
Stebbins	10	10-20	R. Nelson - ADF&G, personal interview
Shaktooklik	7	7-15	R. Nelson - ADF&G, personal interview, L. Schwarz - ADF&G, aerial survey and estimate
Koyuk	21	21-25	R. Nelson - ADF&G, personal interview
Elim	3	3	R. Nelson - ADF&G, personal interview
Nome	1	1	R. Nelson - ADF&G, personal interview
Eschscholtz Bay	39	39	J. Burns - ADF&G, field monitoring
Northern Kotzebue Sound	4	4	J. Burns - ADF&G, personal interview and monitoring
Kivalina	3	10-15	E. Burch - anthropologist, G. Moore - ADF&G, and Kotzebue residents[3]
Point Hope	0	4--I	unverified pilot report
Point Lay	29	29-38	G. Seaman, field interview, and T. Smith - both ADF&G, R. Dronenberg - North Slope Borough
Point Barrow	5	5	O. Ahkinga - Barrow resident, R. Dronenberg - North Slope Borough
Kaktovik	0	0	B. Bartles - USFWS, Kaktovik resident
Totals	150	179-231	

1 An additional three to six belukhas were taken in the separate "Cook Inlet" population, most incidental to commercial salmon fishing (K. Schneider - ADF&G, pers. commun.) .

2 1981 has consistently been reported as a year when all *marine mammals,* including belukhas, were noticeably scarce near the Yukon River mouths during the open-water season.

3 The 1981 harvest in Kivalina was estimated on the basis of an average catch of 10-15 whales as reported by informed village representatives.

Table 10. Statewide (Alaska) belukha harvest, 1982, from records compiled by the Alaska Department of Fish and Game.[1]

Village or area	Number known	Number estimated	Comments and sources of information
Bristol Bay	9	15-20	Mainly incidental to fishing. S. Behnke, K. Taylor, and L. Lowry - ADF&G
Kuskokwim Bay	4	4-10	R. Baxter - ADF&G, J. Hanson - resident of Alukanuk
Hooper Bay	5	5-7	R. Baxter - ADF&G
Yukon River Delta	20	20-30	J. Hanson - resident of Alukanuk
St. Michael	4	4-10	R. Nelson - ADF&G
Stebbins	6	6	F. Pete - resident of Stebbins, R. Nelson - ADF&G
Shaktoolik	16	16	C. Katchatag - resident of Shaktoolik, R. Nelson - ADF&G
Koyuk	13	15-20	K. Dewey - resident of Koyuk, R. Nelson - ADF&G
Elim	14	15-20	C. Sacceous - resident of Elim, R. Nelson - ADF&G
Diomede Island	1	1	P. Omiak - resident of Diomede, R. Nelson - ADF&G
S.E. Kotzebue Sound incl. Eschscholtz Bay	129	129	Harvest recorded directly by J. Burns - ADF&G, take at Choris Peninsula reported by W. Goodwin, Jr. - resident of Kotzebue
N.E. Kotzebue Sound incl. Sheshalik	25	25	Mostly taken in whale nets. B. Uhl and W. Goodwin, Jr. - residents of Kotzebue area, J. Burns - ADF&G
Kivalina	4	4-5	B. Adams and R. Adams - residents of Kivalina, G. Moore - ADF&G
Point Hope	17	17	R. Clark - Ak Eskimo Whaling Comm. field observer, J. Jacobson - resident of Kotzebue
Point Lay	28	28-33	G. Hittson and A. Agnassagga - residents of Point Lay
Wainwright	0	0	Many seen. None taken. B. Patkotak - resident of Wainwright
Barrow	3	3-5	T. Albert - North Slope Borough
Kaktovik	0	0	B. Bartels - USFWS, Kaktovik resident
Totals	298	307-354	

[1] An additional 3 to 6 belukhas were estimated to have been taken from the separate "Cook Inlet" population. Of these, one was reported taken by residents of Tyonek (D. Foster - ADF&G) and others incidental to commercial salmon fishing (K. Schneider - ADF&G).

Table 11. Statewide (Alaska) belukha harvest, 1983, from records compiled by the Alaska Department of Fish and Game.[1]

Village or area	Number known	Number estimated	Source of information
Bristol Bay	22	25-30	L. Lowry, K. Frost, and K. Taylor - ADF&G. Mostly incidental to fishing
Yukon-Kuskokwim deltas	6	15	J. Burns, Jr. - ADF&G Fisheries Biologist in region; summer of 1983
St. Michael	4	4	R. Nelson - ADF&G, interview of village residents
Stebbins	7	7	R. Nelson, same
Unalakleet	2	2	R. Nelson, same
Shaktooklik	7	7	R. Nelson, same
Koyuk	11	11	R. Nelson, same
Elim	10	10	R. Nelson, same
Golovin	2	2	D. Punguk - resident of Golovin
Nome	0	0	J. Burns - ADF&G, interview of Nome residents
Diomede Island	0	0	P. Omiak - resident of Little Diomede
S.E. Kotzebue Sound incl. Eschscholtz Bay	48	48	N. Hadley - belukha hunter from Buckland, W. Goodwin - resident of Kotzebue, pers. commun. with J. Burns
N.E. Kotzebue Sound incl. Sheshalik	19	19-24	J. Burns - ADF&G, personal interviews, B. Uhl - belukha netter and W. Goodwin - Kotzebue
Kivalina	24	24	E. Burch, Jr. - anthropologist working at Kivalina and R. Quimby - ADF&G, Kotzebue
Point Hope	30	31	K. Frost - ADF&G, from several informants R. Clarke - biologist, NMFS, bowhead whale project
Point Lay	18	18	R. Nelson - ADF&G, field monitoring of harvest
Wainwright	0	0	J. Burns - ADF&G, personal interviews with residents of Wainwright
Barrow	0	3	W. Kaleak - resident of Barrow
Kaktovik	0	0	B. Bartels - USFWS, Kaktovik resident
Totals	210	226-236	

[1] An additional three to six belukhas were taken in the separate "Cook Inlet" population, most incidental to commercial salmon fishing (K. Schneider - ADF&G, pers. commun.).

Table 12. Known and estimated harvests of belukha whales taken near selected locations in western and northern Alaska during 1984, from records compiled by the Alaska Department of Fish and Game.[1]

Village or area	Number known	Number estimated	Source of information
Bristol Bay	6	6-15	K. Taylor - ADF&G, Dillingham
Yukon-Kuskokwim deltas	5	20	S. Patten - ADF&G, Bethel, J. Hanson - resident of Alukanuk
Koyuk	38	38	R. Nelson - ADF&G, Nome, K. Dewey - resident of Koyuk
S.E. Kotzebue Sound incl. Ecshscholtz Bay	0	0	J. Burns - ADF&G, Fairbanks, N. Hadley - resident of Buckland
N.E. Kotzebue Sound incl. Sheshalik	31	31	J. Burns - ADF&G, Fairbanks, W. Goodwin - resident of Kotzebue
Kivalina	27	2'?	E. Burch, Jr. - anthropologist working at Kivalina
Point Lay	0	0	J. George - North Slope Borough

[1] On the basis of known and estimated harvests at hunting sites indicated above, the total 1984 harvest of belukhas in western and northern Alaska was estimated to have been about 170.

is found and if openings are numerous, that camps can be established near those that have been frequented by whales. The spring harvests of belukha whales by hunters from Kivalina in 1983 and 1984 were 24 and 27 respectively (R. Quimby, personal communication; Burch, personal communication, 1984). It is anticipated that if aircraft continue to be engaged by hunters from Kivalina for the purpose of choosing the most favorable locations for their whaling activities, catches of belukhas will continue at levels above the long-term annual average.

We did not make a systematic study of the helminth fauna in harvested belukhas. In the course of disarticulating mandibles and cleaning skulls, the senior author examined ear sinuses of 31 whales. Nematodes, identified by Dr. Murray Dailey (California State College, Long Beach, CA) as Otophocaenurus oserskoi, (Skrjabin 1942) were present in all. In their summary of marine mammal parasites, Dailey and Brownell (1972) listed 15 helminths in belukhas, including the nematode indicated above. Those helminths included five species of trematodes representing three genera, one cestode, seven species representing five genera of nematodes, and two species of a single genus of acanthocephalans.

Movements

Summer Movements in Eastern Chukchi Sea

Annual sea ice conditions strongly influence movements of marine mammals (Burns 1970, Fay 1974, Burns et al. 1980, 1981, Braham et al. 1984), including belukhas, throughout their range and especially in the eastern Chukchi Sea during spring and summer. During spring, belukhas often migrate in association with bowheads and may precede the bowheads by one to two weeks (Braham 1984). At Little Diomede Island, which is centrally located in Bering Strait, northward-migrating belukhas are occasionally taken as early as the first part of March. Usually, however, they are not seen by seal hunters there until late March. They generally arrive in association with bowheads near Point Hope in early to mid-April (Johnson et al. 1966) but have been seen as early as mid-March (Seaman et al. 1985). Foote (1960a) reported the first sighting of a bowhead from near shore on 10 April 1960 and the first belukhas on 11 April. Belukhas continued passing Point Hope, close to shore, until late July 1960 (Foote 1960b). Bowheads, and presumably belukhas, have been reported to arrive in the vicinity of Point Hope as early as 19 March (Foote 1960a).

Unusually heavy, close-packed ice conditions have been known to delay whale migrations. In 1980, an extraordinary blockage of Bering Strait by closely packed ice (Johnson et al. 1981, Ljungblad 1981) is reported to have delayed the spring migration of bowheads by approximately one month (Johnson et al. 1981). Presumably belukhas were similarly affected.

The northward migration of belukhas through the flaw zone in eastern Chukchi Sea is quite prolonged. Based on aerial surveys in the region between Wainwright and Barrow in 1976, Braham and Krogman (1977) reported sighting belukhas from 29 April to 19 June. Their surveys were terminated on 20 June. Of note was the finding (Braham and Krogman 1977, P. 20) that, "As many belukhas were seen during the last part of the season as during the first part." An average of 43.3 belukhas were seen per survey day in

May (12 survey days) and 42.0 in June (six survey days) . There is no reason to believe that an end to the migration abruptly coincided with termination of the above-mentioned surveys.

Northward spring migration of belukhas off the northwest coast of Alaska is generally along the same route traversed by bowheads, with two variations. Belukhas are more broadly dispersed during spring migration (Braham et al. 1984), and some of the later migrants enter coastal waters as soon as nearshore ice conditions permit. When they begin to enter the bays, rivers, and estuaries, the directed path of their travels becomes more variable and they spend days or weeks in the same general area.

In March to May or June many belukhas passing northward from Bering Strait to Point Hope move to the west of Kotzebue Sound, beyond the margin of the extensive, unbroken ice cover. It has long been known that some of these early migrants approach land in the region between Kivalina and Point Hope, where a persistent polynyna is present. Kivalina is a settlement from which belukhas are often successfully taken by hunting in leads during April-May. So long as Kotzebue Sound remains icebound, the belukhas apparently continue northward. As ice in the Sound deteriorates, the newly arriving belukhas penetrate it. Annual variation in numbers of belukhas utilizing coastal estuaries is considerable (Anderson 1937; Lensink 1961; Sergeant and Hock 1974; this study). Our studies in Kotzebue Sound support the Eskimo contention that, within the Sound proper, belukhas first occur in the northern part and work their way eastward and southward as seasonal disintegration of ice proceeds. This is graphically shown in Figure 9. They usually arrive in southeastern Kotzebue Sound and Eschscholtz Bay during the second 10 days of June, while other belukhas are still moving up the retreating flaw zone farther north.

The subsequent pattern of movement of those belukhas that enter Kotzebue Sound is suggested by sequential sightings in June to August in and near estuaries along the Chukchi Sea coast (Table 13). On average, after most whales depart Kotzebue Sound, they arrive in the vicinity of Point Lay in late June to early July and near Wainwright in mid- to late July or early August .

Nelson (1969), stated that belukhas may pass within sight of the coast near the village of Wainwright at any time during the summer, and that this may occur whether or not ice is present. Our information may help clarify Nelson's statement a bit more. During summers of severe ice conditions, Icy Cape is the geographic point along the northwest coast, north of which sea ice may persist relatively close to shore. Farther north, there is a higher probability of such an event happening. At Wainwright during years when ice moves far offshore, belukhas are apparently not seen after late July to early August. In years when the ice does not recede far from shore, these whales may appear sporadically in coastal waters throughout August and early September. The greater frequency of sightings in late summer during heavy ice years is thought to involve whales moving back and forth between the pack ice and coastal waters. Summer 1975 was unusual in that the pack ice extended south of Wainwright and was seldom far from land. In late August of that year, Ray and Wartzok (1980) reported sighting both belukhas and bowheads relatively close to shore in the region

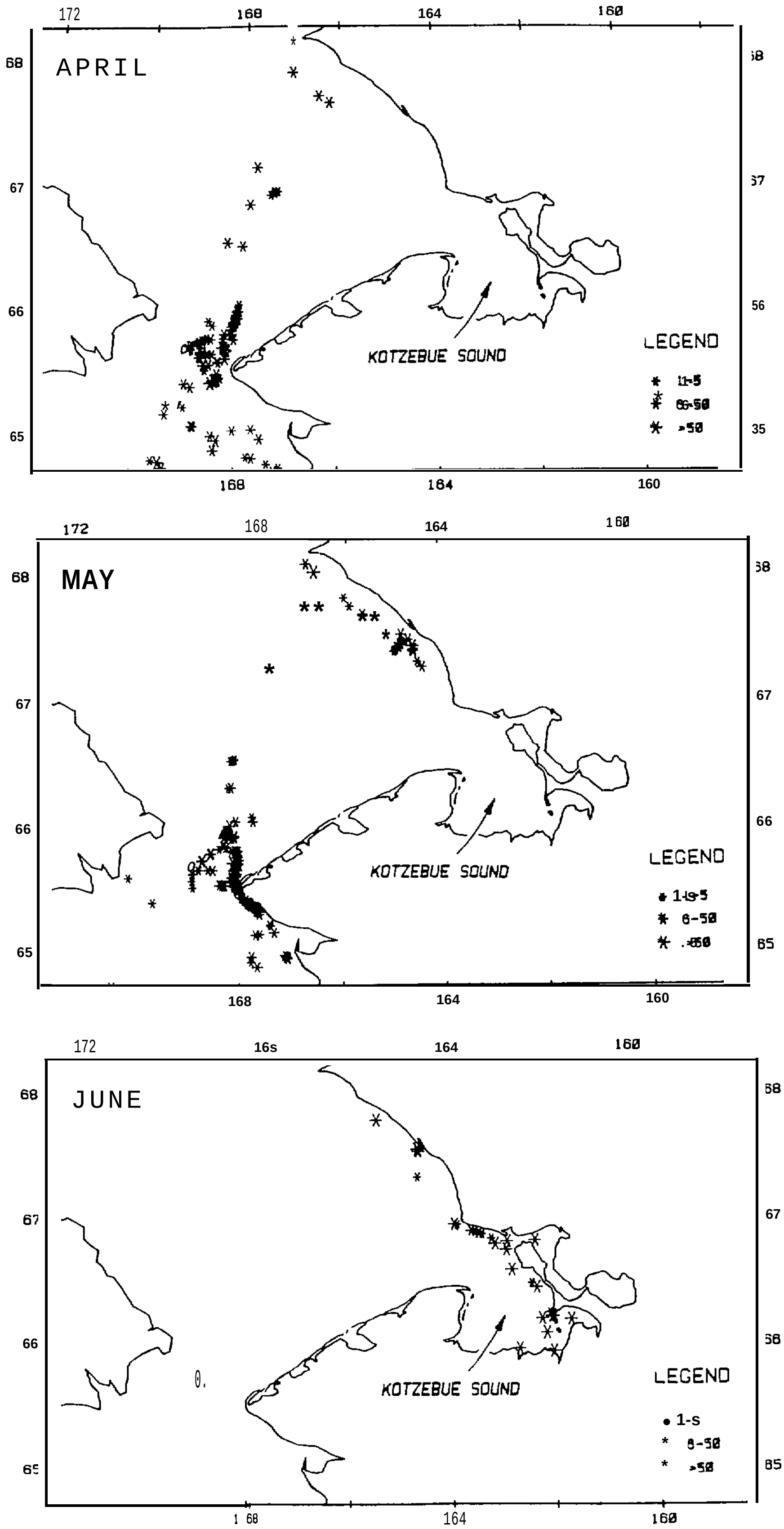

Figure 9. Occurrence of belukhas in or near the Kotzebue Sound region in April to June.

Table 13. Dates when belukhas were known to be present during breakup and ice-free months near selected locations in the eastern Chukchi Sea region.

	Locations				
Year	Kotzebue Sound	Kivalina	Cape Sabine	Point Lay	Wainwright
1958	--	--	24 Jun[1]	--	--
1960	--	1st week Jul[2]	--	--	--
1962	mid- to late Jun	--	--	--	--
1966	--	--	--	--	Early Aug[3]
1976	--	--	--	--	21-28 Jul
1978	11 Jun-9 Jul	21-24 Jun	--	2-10 Jul	15 Jul
1979	8-25 Jun	--	3 Jul	22 Jun-19 Jul	17-20 Jul
1980	13-23 Jun[4]	--	--	11 Jun	20 Jul
1981	12-19 Jun	--	8 Jul	5-15 Jul	--
1982	7-23 Jun	29 Jun	3-6 Jul	5 Jul	--
1984	--	--	4 Jul[5]	4 Jul[6]	--

1 Childs (1969).
2 Saario and Kessel (1966).
3 Nelson (1969).
4 K. Frost, Alaska Dept. of Fish and Game, Fairbanks, Field Notes.
5 J. Coady, Alaska Dept. of Fish and Game, Nome, Personal Communication.
6 Arthur Manning, Fairbanks, Alaska, Personal Communication.

between Icy Cape and Point Franklin. Our studies indicate that belukhas move northward after leaving Kasegaluk Lagoon and presumably, in 1975, they moved to the ice fringe near Wainwright.

The general picture of belukha migrations that emerges from this information is that from March to early June movements of these whales are comparatively rapid and directed; northward toward Point Barrow and thence mostly eastward across the Beaufort Sea. From about mid-June to early August the sustained, directional movement slows, with large numbers of whales entering warmer coastal waters from Kotzebue Sound to Mackenzie Bay and others remaining close to the retreating ice fringe between these points and also probably westward in the northern Chukchi Sea. By early to mid-August most belukhas move away from the coast toward the pack ice.

Those that entered coastal waters, starting in Kotzebue Sound in about mid-June, move slowly northward, some temporarily stopping at other embayments and estuaries enroute and, in August, mostly move off to the ice of the eastern Chukchi and western Beaufort seas.

A generally similar migration pattern is hypothesized as occurring along the coast of Chukhotka (see Discussion) . By early September, belukhas north of Bering Strait are mostly associated with the late summer ice fringe and front over a very broad area extending from Wrangel Island to Amundsen Gulf. Observations in September suggest a late August distribution that includes large numbers of whales north of Chukhotka (Klumov 1936, in Kleinenberg et al. 1964) and from the northeastern Chukchi Sea to Amundsen Gulf. By late August the belukhas slowly begin a return migration that eventually brings most of them back into Bering Sea.

Autumn Migration in Beaufort Sea

Aerial surveys of the ice "front" in extreme northeastern Chukchi Sea and the Beaufort Sea were conducted from 17 to 21 September 1982. The eastern and western limits of this survey area were approximately 141°W and 161°W, respectively. Tracklines were determined during the survey flights and were predicated on location of the ice margin.

This survey was specifically intended to test the hypothesis that in autumn, the westward migration of belukhas across the Beaufort Sea is in close proximity to location of the pack ice margin and front zones. That hypothesis was based mainly on the paucity of reported sightings from shore and in ice-free waters of the Beaufort Sea during autumn, speculations of investigators that had studied summer distribution of belukhas in eastern Beaufort Sea and Amundsen Gulf, and the limited record of sightings for August to October obtained mainly in conjunction with surveys of other marine mammals, including bowhead whales and Pacific walruses. The background for formulation of this hypothesis evolved from results of several studies discussed as follows.

Sergeant and Hock (1974) stated that belukhas depart the eastern Beaufort Sea during September, moving in open water. This conclusion appears to have been based largely on a sighting of 2,000 whales near Demarcation Point on 21 September 1972. These authors did not indicate how far from the pack ice those whales were. Fraker (1977) stated that knowledge of the westward autumn migration from the Mackenzie estuary was a major data gap. He suggested that some belukhas depart the estuary to the north to exploit food resources that may occur along the pack ice margin. Fraker et al. (1978) also indicated that little was known about fall migration in the Beaufort Sea. They suggested that it takes place in late August-September, that movement is toward the west, and that it was not known if migration occurred along the coast or offshore though it was "possibly along the pack ice." Those remarks appear to involve a reassessment of the conclusions previously expressed by Sergeant and Hock (1974). Harrison and Hall (1978) reported results of 6,000 km of aerial survey tracklines flown in the western Beaufort Sea during July 1975 and August 1976. The majority of those survey lines appear to have been over ice-free waters. Only two sightings of belukhas were made in each month in the Beaufort Sea. These four sightings were of 36 belukhas, all of which were within the ice front. Johnson (1979) reported two sightings of belukhas made from islands of the Jones Islands group in southcentral Beaufort Sea. The first was a pod of 75-100, swimming westward within 300 m of the seaward side of Pingok Island on 15 September 1977, and the second was of 35, swimming westward, within 150 m of the seaward side of Thetis Island, on 23 September 1978. The first sighting was of belukhas in ice-free waters 10 to 20 km south of the pack ice. The second sighting was of whales moving along the edge of a small field of scattered ice some 16 to 20 km south of the main pack. Johnson (1oc. cit.) concluded, based on these sightings and previously published records by Fraker et al. (1978), that the autumn migration occurs during the last half of September and is near the coast well south of the pack ice margin. Fraker (1980) again stated that the autumn migration had not been studied, and reiterated the sightings reported in Fraker et al. (1978) and Johnson (1979).

A series of aerial surveys, mainly for walruses and bowhead whales, began to strongly point to the ice front as the habitat through which the autumn migration of belukhas mainly occurred. In September 1974 and 1975, the senior author participated in surveys of Pacific walruses in the northern Chukchi and extreme western Beaufort Sea. Survey lines were over open water and from the ice margin northward until close-packed ice (9/10 to 10/10 cover) was encountered. A few sightings of small groups of belukhas were made, all within the ice front. Distribution of sightings during those September surveys indicated that some belukhas were present in the northern Chukchi as well as in the Beaufort Sea.

An extensive walrus survey in which the senior author also participated was undertaken during 10 to 20 September 1980 (Johnson et al. 1982). Tracklines, location of the pack ice margin, and general position of belukha sightings are shown in Figure 10. The indicated sightings are only of those whales within about 1/8 nm of the survey aircraft. Three important points about the autumn distribution of belukhas emerged from the 1980 walrus survey. These were: 1) belukhas occur well within the ice margin during mid-September, 2) they extended at least as far west as the northcentral Chukchi Sea, and 3) an area of very high abundance occurred north and east of Point Barrow. The last point is not particularly evident from Figure 10. However, on 11 September 1980, during the survey flights north and east of Barrow, several thousand belukhas were present, almost all beyond the pre-selected survey transects. Twenty-three sightings of a total of 124 belukhas occurred on the transects.

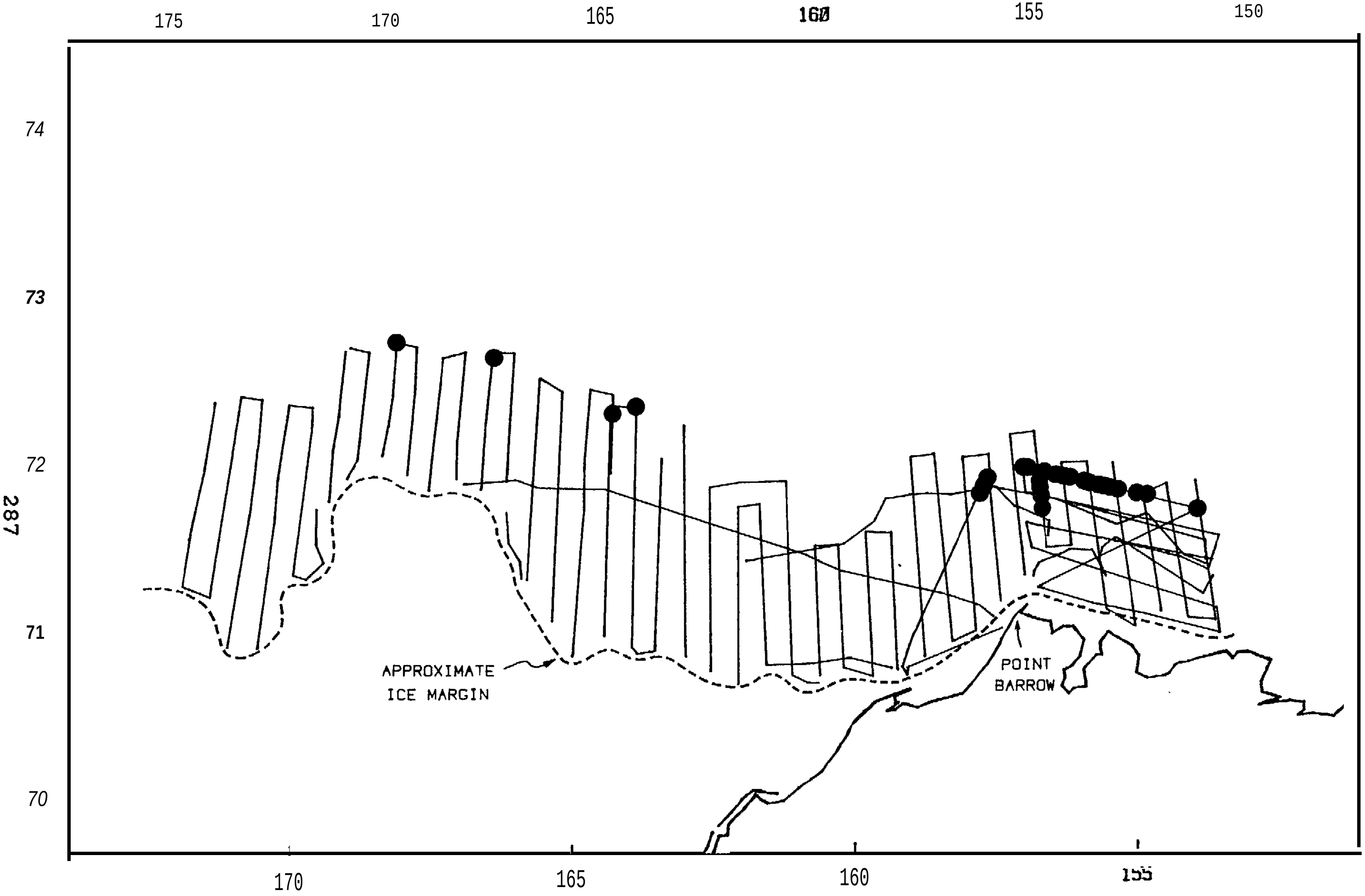

Figure 10. Tracklines flown during a walrus survey, 10 to 20 September 1980, showing locations of the pack ice margin and sightings of belukha whales (after Johnson et al. 1982).

Ray and Wartzok (1980) and Ray et al. (1984) reported sightings of belukhas also made during extensive flights with large aircraft for the purposes of determining the utility and capabilities of remote sensing techniques for study of marine mammals. In September 1974, they sighted belukhas in association with the ice front zone across the western Beaufort Sea and the Chukchi Sea west to approximately 177°W longitude (Ray and Wartzok 1980, Figure 2b). They also found a huge aggregation of belukhas of unknown total size that exceeded several thousand animals. This aggregation was seen on 18 September 1975 about 30 nm south of the pack ice margin in northeast Chukchi Sea. Their sightings led them to suggest the possibility, as had Fraker et al. (1978), that belukhas that summer in the eastern Beaufort Sea-Mackenzie Delta regions may first move north to the ice front, westward across the Beaufort Sea within the front, and then southward from somewhere in the east-central Chukchi. As an alternative possibility, they suggested that belukhas of the front may be a separate subpopulation (from those that supposedly occur near shore?) that may utilize the productivity of that habitat (Ray and Wartzok 1980) .

Ljungblad et al. (1980) reported the results of a very intensive survey effort undertaken during autumn 1979. They reported results of 44 separate flights in the central Beaufort Sea region during September and October of that year. Until the onset of freezeup, most segments of the survey flights were over open water, south of the ice margin that prevailed. Belukhas were seen on only two occasions--on 1 October well into the pack north of Point Barrow and on 19 October in the advancing ice front north of Harrison Bay. The paucity of reported sightings during these extensive surveys over open water indicated that any subsequent searches for belukhas, by us, should be concentrated farther offshore and within the ice front. In autumn 1980, Ljungblad (1981) again conducted extensive surveys for bowhead whales in the Beaufort Sea during September and October. The primary study area during 4 September to 24 October was the near-shore central Beaufort between 146°W and 154°W. Some flights extended to Mackenzie Bay in the east and to Point Barrow in the west. He reported that in autumn 1980 pack ice remained close to the coast, some 8 nm north of the barrier islands that are generally east of the Colville River delta. Additionally, freezeup was underway early, the process being quite apparent by 16 September. No belukhas were reported seen during the 20 separate flights made in September 1980. One sighting of two belukhas was reported during 14 survey flights in October. The sighting was on 6 October and the whales were swimming west (Ljungblad 1981).

Aerial surveys, primarily for bowhead whales, were also undertaken during August-September 1980 in the eastern Beaufort Sea by Renaud and Davis (1981) . These investigators flew extensive, largely replicate transects, mostly north of the Tuktoyaktuk Peninsula, over open water during three periods; 6-7 August, 21-24 August, and 3-4 September 1980. No belukhas were sighted during the September survey. During each of the two surveys in August, 82 belukhas were sighted. The whales were broadly distributed in ice-free waters. Based on the relatively low number of belukhas seen, Renaud and Davis (1981, p. 49) stated simply that, "These results also do not provide much information regarding the whereabouts of the Mackenzie estuary population of white whales in August and September."

The final set of survey data considered in the design of our 1982 search for migrating belukhas were results of surveys undertaken in September-October 1981 by Ljungblad et al. (1982). These investigators flew 134 hours, mainly between 140°W and 154°W and predominately south of the pack ice. The total survey effort included 21 flights in September and 11 in October. No belukhas were sighted on any of these flights, again indicating that if they were migrating westward during this period, they most likely had to be farther north, in or near the ice front.

Our surveys were conducted from 17 to 21 September 1982. Total time on survey transects was 13 hours 29 minutes. An additional eight hours were devoted to transit to and from the survey area and circling over aggregations of whales. We concentrated almost entirely on the ice front zone extending from open water 3 nm south of the margin, northward until the ice cover became complete. Transects paralleled the margin in the survey area east of 148°22'W. West of that longitude some tracks were parallel and others perpendicular to the general ice margin. The only survey effort over water farther than 3 nm south of the ice margin was during transit to or from the primary survey area. In total, 1,768.5 nm of linear tracklines were surveyed on five separate flights as shown in Figure 11. A transect width of ¼ nm on either side of the aircraft was further divided into inner and outer 1/8 nm strips. Boundaries of the transects *were* maintained by use of inclinometers. Sighting conditions were marginal on flight 1 and poor on the four subsequent flights. On 17 September the wind was less than 5 knots, permitting extensive formation of slush ice in openings between ice floes. On the 19th to 21st, winds in excess of 25 knots prevailed producing waves with whitecaps in ice-free waters and in openings north of the ice margin. Additionally, small ice floes and ice rafts were being blown away from the larger masses. The combination of waves, whitecaps, and abundant small floes in openings of water between the larger ice rafts made it difficult to sight and enumerate belukhas. Also, many of the whales we saw were starting to dive beneath or were emerging from under the ice. In spite of these difficulties, our surveys were very useful *for* determining the distribution of belukhas. The combination of poor sighting conditions and an unknown correction factor for whales below the surface and for whales under the ice did not permit any quantitative assessment of the total number that may have been present.

Belukhas were present in the ice front zone from the easternmost to westernmost points surveyed. Within the transects, 103 sightings of 224 belukhas were recorded. Sixty-three percent of the whales counted were within the first 1/8 nm of the transect, indicating a rapid decrease in sightability with distance from the aircraft. From the onset of this survey it was evident to us that the sighting of even a single whale within the transect usually meant that more were present. We temporarily deviated from a transect on 15 occasions to widely circle an area in search of additional whales. During these 15 instances of circling, 731 belukhas additional to those within transects were counted. Mean group size along transects was 2.2 whales (103 sightings of 224 belukhas). Mean size of the few aggregations over which we circled was 48.7 whales (15 aggregations of 731 belukhas). This great difference shows that if the objective of a survey in the front is to obtain a population estimate, a very intensive effort for animals that are mostly underwater, swimming beneath ice, widely distributed, and probably highly clumped would be required.

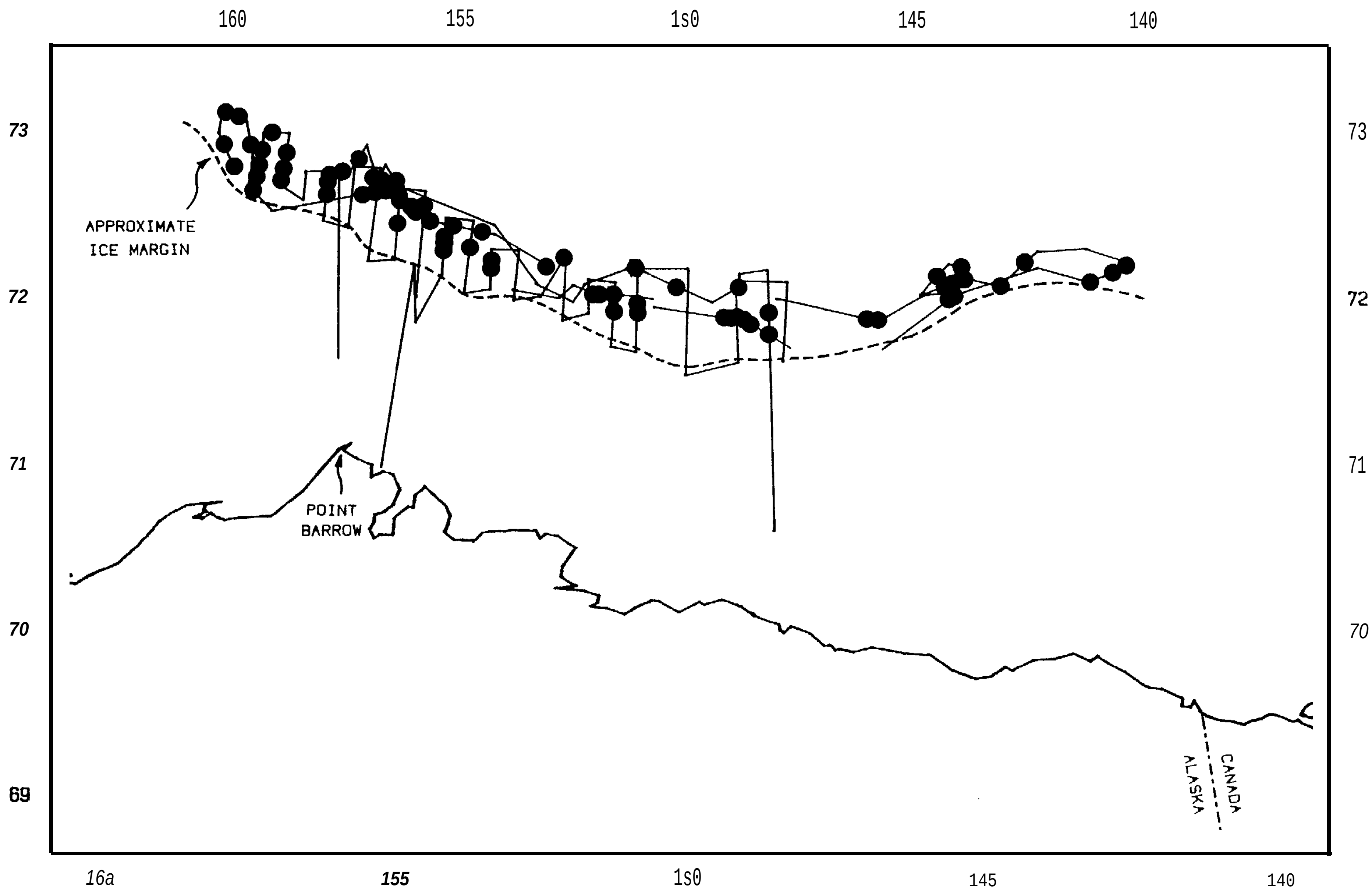

Figure 11. Location of aerial survey tracklines and sightings of belukhas within survey transects during 17 to 21 September 1982.

As was the case for belukhas sighted during the 1980 surveys of walruses (Johnson et al. 1982) and 1981 surveys of bowhead whales (Ljungblad et al. 1982), belukhas were most abundant to the north and northeast of' Point Barrow (see Figures 10 and 11). Directional movement of the whales we saw within transects was basically to the west (98 of 103 sightings) . Two sightings were of four whales swimming east, and three sightings were of six whales swimming south. The latter were on transects in the Chukchi Sea, northwest of Point Barrow. We did not record direction of movement of pods that were beyond the transects.

DISCUSSION AND CONCLUSIONS

Sex Ratios

Our findings show a sex ratio of whales in Alaskan waters to be 1:1 based on a sample size of 533. However, there was great annual variation (cf. annual samples from the same locations, as presented in Table 1, or samples indicated in Table 14. Tomilin (1957) also concluded that the sex ratio was approximately even, based on results of work by Vinogradov (1949, cited in Tomilin 1957) and Klumov and Dorofeev (1936). Though no sample sizes were indicated, Tomilin reported an extreme degree of selection in a sample in which 78.7% of the belukhas taken in the Gulf of Sakhalinskii (Okhotsk Sea) in 1930 were males. Kleinenberg et al. (1964), also citing Vinogradov (1949) as their source, say only that the sex ratio in belukha populations is 1:1.

Causes for the observed differences in sex ratio, even within the same geographic sampling area, are assumed to result from the factors stated by Tomilin (op. cit.) ; specifically, that it results from the differences in composition of pods that are captured. Tarasevich (1958) stated that sexual segregation of belukhas is common. Sergeant (in press) commented on differences in summer distribution of females with young calves and adult males in the St. Lawrence estuary.

According to Eskimos of Little Diomede Island, Alaska, the first groups of whales to pass north during the earliest phases of the annual spring migration are large adult males, based on the sex of those they occasionally kill and the size of those they see. We have not sampled these early migrants. Brodie (1971) indicated a selective bias toward females and neonates in the net capture of belukhas in shallow water. Sergeant and Brodie (1975) -indicate that the long-term catches of whales near Churchill have been on the order of 500 per year, with a strong bias for males, that comprise about 66% of the harvests. Ognetov (1981) found that males were 75% of whales in a sample of 105 animals taken in the Barents Sea in 1973-74. Fraker (1978) similarly indicates a selective bias toward males, which are about 80% of the annual catches made in the Mackenzie estuary.

In Eschscholtz Bay, during the whale drives, the selective bias is toward larger whales that are more often light-colored and leave a larger wake in shallow water. Both characteristics, color and size, more readily focus attention of hunters in pursuit. Thus, hunting bias takes at least two forms: a disproportionate number of older, larger whales from those available, and non-random composition of pods. Notwithstanding, the kinds

Table 14. Sex ratios of belukhas sampled in various studies.

General location	Source of data	Sample size	No. males	No. females	Sex ratio
Bristol Bay Alaska	Brooks 1954 (unpubl.)	66	20	46	
	Lensink 1961	25	15	10	
	Lowry et al. 1982	5	4	1	
	Frost et al. 1983	20	13	7	0.81:1
Northwest Alaska	This study	533	268	265	1.01:1
Mackenzie Estuary, NW Canada	Fraker 1980	129	100	29	
	Hunt 1976	16	8	8	2.92:1
Hudson Bay, NE Canada	Doan and Douglas 1953 3 annual samples				
	1949	180	93	87	
	1950	293	176	117	
	1951	581	383	198	
	Sergeant 1973	590	279	311	
	Finley 1982	60	30	30	1.31:1
Greenland	Degerbøl and Nielsen 1930	190	104	86	1.21:1
White, Barents, and Kara seas	Medvedev 1970	99	66	33	
	Ognetev 1981	385	221	164	1.46:1
		3,172	1,780	1,392	$\bar{x}$ = 1.28:1

of different sampling biases associated with different times, locations, and methods of capture, the sex ratio of various belukha populations is apparently 1:1.

Growth

Age-Body Length Relationships

Increase in length of belukhas during the first few years of life is not well known. Kleinenberg et al. (1964) reported their findings about progressive increase in length of "sucklings" from Tugurskiy Gulf in southwestern Okhotsk Sea in the period from late June to late July. They reported a length increase of 62 cm (27%) between sucklings examined in late June when they averaged 230 cm (N = 6) and those measured on 26 July that had an average length of 262 cm (N = 5). We judged those data as not useful for indicating growth of *calves.* Measurements included in their analysis (Table 54, p. 255) strongly suggest that the broad category of "sucklings" probably included neonates as well as 1- and perhaps 2-year-olds. The numbers of each age cohort cannot be determined on the basis of data they presented. Brodie (1971) also commented on problems of accurately determining growth rate of calves based on the reported findings of Kleinenberg et al. (1964).

Of concern in this discussion are the probable relationships of belukhas that occur in three different geographical regions during summer; Bristol Bay (southwest Alaska), northwest Alaska and the Mackenzie estuary of eastern Beaufort Sea. Belukhas that summer in these three *areas winier* in Bering Sea, though it is not known if or to what extent they may intermingle.

Sergeant and Brodie (1969) examined geographical differences in body size of belukhas from 12 different regions of their range. They concluded that the smallest belukhas come from western Hudson Bay, the White Sea, and Alaska. In both males and females, those from Alaska were ranked fourth and those from Mackenzie Bay, eighth, in order of increasing length in a ranking from 1 (smallest) to 12 (Sergeant and Brodie 1969, Figure 8, p. 2567). Sergeant and Brodie's sources of data about whales from Alaska were those animals obtained in Bristol Bay by Brooks (1954b) and Lensink (1961). As previously indicated, samples of whales taken in Bristol Bay appear to be strongly biased toward younger-age cohorts (smaller-sized individuals) than those taken in other parts of Alaska. Based on an examination of Lensink's data, the modal and mean ages of 21 whales from Bristol Bay, were 5 and 6.2 years respectively. In our sample of 412 animals from northwest Alaska the mode and mean were 12 and 13.6 years respectively.

White-colored belukhas from northwest Alaska were, on average, shorter than those from the Mackenzie estuary (Table 15). This difference was statistically significant only for females ($t = -2.5689$, d.f. = 65; $0.01 < P < 0.02$). This comparison was based on length frequency of harvested "adult" whales and several significant sources of potential bias contributing to samples of different size composition in females are probably operative. These include different conditions in which hunting occurs, hunter selectivity and non-random composition of whale pods. Our

Table 15. Standard lengths (cm) of adult, white-colored belukhas from northwest Alaska and the Mackenzie estuary of northwest Canada.

Statistical parameter	Northwest Alaska		Mackenzie estuary[1]	
	Males	Females	Males	Females
Sample size	23	35	85	32
Mean	402.9	350.7	412.9	359.5
S.D.	33.9	12.3	21.9	15.3
Minimum length	327.8	312.4	377.1	346.5
Maximum length	452.1	373.4	460.0	386.5

[1] Data were interpolated from Sergeant (1969) as follows: samples sizes of white-colored whales were derived from Figure 4, p. 2564 based on the assumption that males longer than 350 cm and females longer than 330 cm are white; means, ranges, and standard deviations are from Figure 8, p. 2567.

samples are almost entirely of whales pursued cooperatively by a large number of boats, driving large pods within enclosed embayments well inshore. The cooperative driving is terminated when the whales are in water shallow enough to be easily followed or can no longer be driven. At that point of a drive, the actual killing begins. In Mackenzie Bay belukhas are hunted in a less confined body of water and each boat (hunting crew) acts as an independent unit usually in pursuit of a single whale (Hunt 1979). According to Fraker (1980), hunters in the Mackenzie estuary select large individuals and avoid taking females with calves. Such selection is evident in the sex composition and length frequencies of harvested whales in that region, reported by Sergeant and Brodie (1969), in which 75% of the examined whales (N = 126) were males and there were no females less than about 310 cm.

We further approached the question of size differences among belukhas from Bristol Bay, northwest Alaska and eastern Beaufort Sea by comparing length at age rather than lengths of white-colored animals, using the growth curves derived from the sample from northwest Alaska. This non-statistical approach indicated that length at age for males and females from all three areas was similar (Figure 12) . As an additional comparison, we used a chi-square test to determine if there was a statistical difference in length at age in females 10 years or older in samples from Mackenzie estuary (N = 12) interpolated from Sergeant (1973, Figure 10, p. 1077) and northwest Alaska (N = 27). No statistically significant difference was evident (x^2 = 6.295, d.f. = 5). Based on those data we conclude that length at age for these aggregations of summering whales is probably the same.

Brodie (1982) compared length at age of a captive male belukha from Alaska, maintained at the Vancouver Public Aquarium (Vancouver, B.C. , Canada) , with his findings from whales sampled near eastern Baffin Island, Canada. The captive whale was measured six times between 1.2 and 14 years of age. Growth of the captive whale closely approximated that of free-ranging animals examined by Brodie (op. cit., p. 446, Figure 1) .

We queried Dr. Newman, Director of the Vancouver Public Aquarium (personal communication, December 27, 1984) about the origin of the whale and verified that it was captured in Bristol Bay. We then compared its growth with that of the male segment of our sample from northwest Alaska (Figure 13). Growth rate of the captive male from Bristol Bay was slightly faster than the average of our sample, though within the range of lengths for appropriate year classes. Its greatest length of 427 cm was 10 cm less than that of the largest male from northwest Alaska.

Fetal Growth

Our data about fetal growth of whales from waters adjacent to Alaska included specimens representing only the early and late stages of gestation. To this we added data from 131 fetuses examined by Degerbøl and Nielsen (1930) from waters of Greenland, 103 from eastern Hudson Bay summarized by Sergeant (1973) , 17 from the St. Lawrence estuary reported by Vladykov (1944) and 9 from waters adjacent to Baffin Island, reported by Brodie (1971). The resulting composite growth curve is shown in Figure 14. It appears that fetal growth in belukhas from Greenland and eastern

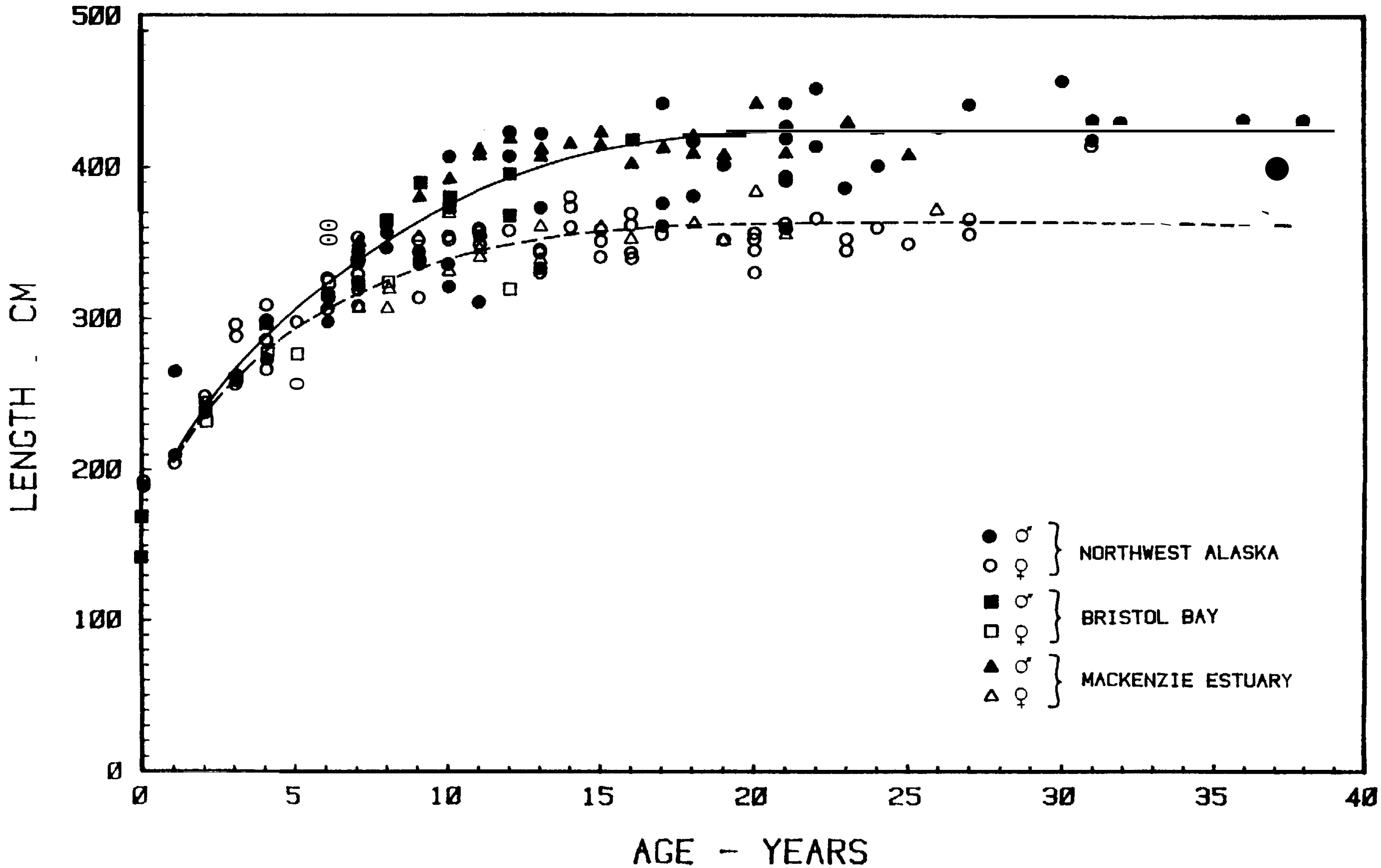

Figure 12. A composite illustration of length at age for belukhas from the three areas indicated and the growth curves for whales from northwest Alaska.

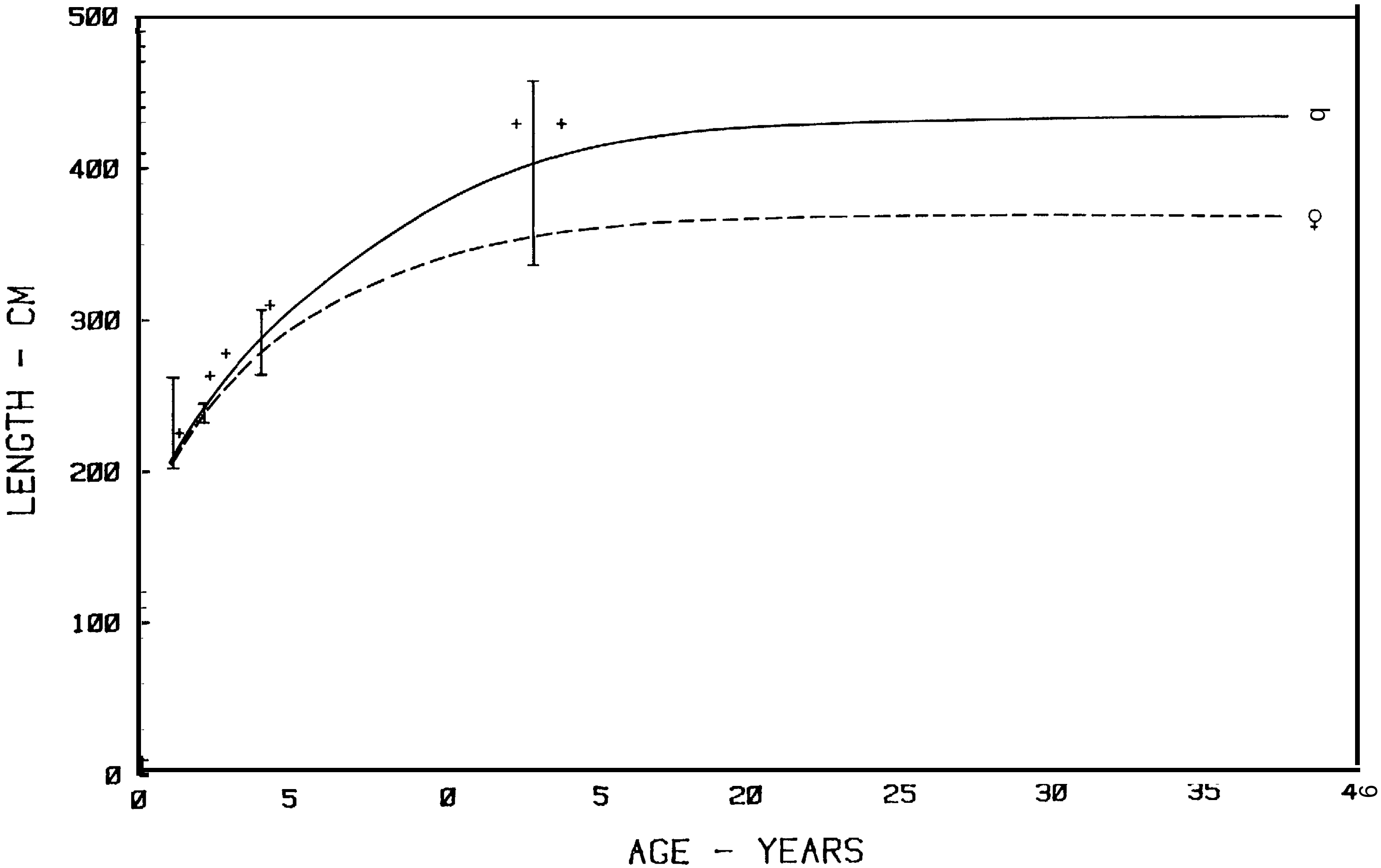

Figure 13. Length at age of a captive male belukha from Bristol Bay, Alaska, maintained at the Vancouver Public Aquarium (+) compared to the range for males and the growth curves for both sexes from northwest Alaska.

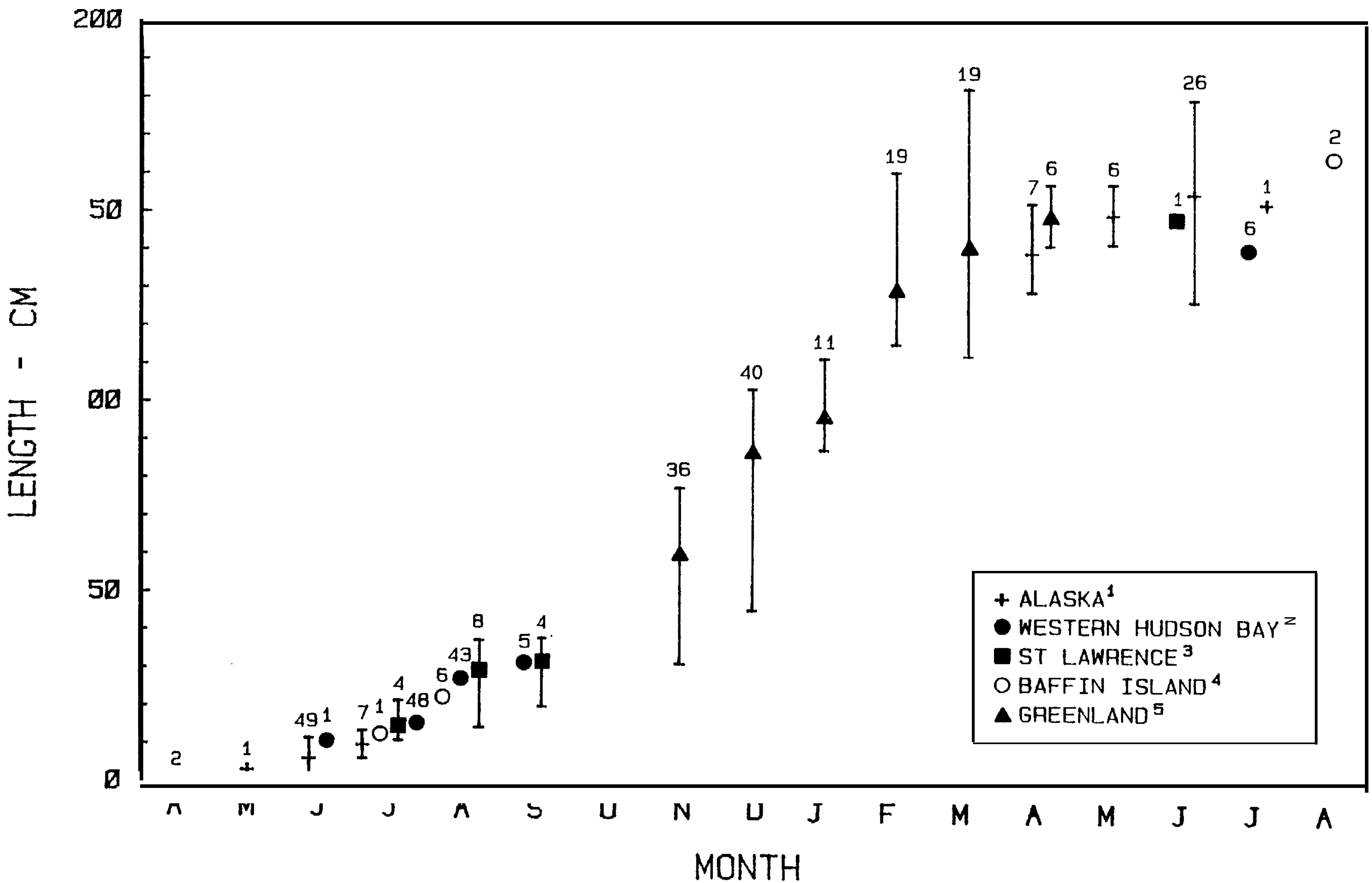

Figure 14. Increase in length of belukha fetuses. Sample size is indicated above symbols. Sources of data are: (1) this study; (2) Sergeant 1973; (3) V. adykov 1944; (4) Brodie 1971; and (5) Degerbøl and Nielsen 1930.

Canadian waters is generally similar to that for whales from Alaskan waters. In most locations, the peak period of births occurs in mid-June to mid-July. However, in Cumberland Sound on eastern Baffin Island, it is in mid-July to mid-August (Brodie 1971). A similarly later peak birth period may also occur in waters adjacent western Greenland, contrary to comments by Degergøl and Nielsen (1930) that most young in that region are probably born in March to May. Their conjecture was based on encountering the first neonates in mid-March and on the observation that fetal length did not increase after April. However, review of their work indicates that no whales were sampled after mid-April. Our findings verify that some early births do occur and that although there is little increase in fetal length after April, there is a considerable increase in weight.

Figure 14 does not include fetuses examined by Soviet scientists. Most of the Soviet data was summarized in graphic form by Kleinenberg, et al. (1964, p. 260, Figure 99). That graphic presentation also included data of Degerbøl and Nielsen (1930) and Vladykov (1944). The combined data plotted by Kleinenberg et al. (1oc. cit.) were not separable by source or geographic location. Nonetheless, their summary showed that growth of fetuses in whale populations adjacent to the U.S.S.R. approximated that of whales from western Greenland and the St. Lawrence estuary, and those values were similar to North American groups illustrated by us. Collett (1911, in Degerbøl and Nielsen 1930) indicated lengths of six small fetuses as follows: one of 14 cm taken on 6 May 1903 near Vardø on the Norwegian coast of the Barents Sea, three taken near Spitzbergen on 14 August 1869 having lengths of 26.0, 27.5, and 29.0 cm, and two taken at an unidentified location in the Svalbard region on 15 August 1881 that were 23.5 and 28.0 cm. Those lengths *are in* line with the growth rate shown in Figure 14, though we have no way of determining how those fetuses were actually measured (SL or NTL) .

Different authors determined probable size at birth in different ways. Our data indicate the average length (N = 26) and weight (N = 6) of term fetuses from Alaskan waters to be 155 cm and 71.8 kg. These values for other populations or groups of belukhas were: Baffin Island (Brodie 1971), 165 cm, 79 kg, N = 2; west Greenland (Degerbøl and Nielsen 1930, average of three fetuses taken on 12 April, 1926) 153 cm; west Hudson Bay (summarized by Sergeant 1973), about 150 cm. Various authors estimated size at birth to approximate an average of the length of the largest fetus and smallest neonate. Using this procedure, size at birth in the Barents Sea (Khuzin 1961, in Kleinenberg et al. 1964) was 158.5 cm; in the Kara Sea (Zaikov 1934, in Kleinenberg et al. 1964, Kleinenberg and Yablokov 1960) 148.5 cm and 149 cm. For the Okhotsk Sea, Sleptsov (1952) reported the smallest neonate and Kleinenberg et al. (1964) reported the largest fetus. Derived mean of these was 152.5 cm. Thus , size of term fetuses from Alaskan waters, 155 cm, is similar to that of other groups or populations of belukhas.

Weight-Gain of Calves

We were not able to weigh belukhas other than fetuses, thus we have no data about the rate of weight-gain. Lensink (1961) reported the weight of a newborn taken in mid-June to have been 45 kg and that of a 3-month-old calf to have been 106 kg. The difference of approximately 61 kg is an increase of 136% in the first three months of life for the two animals from Bristol Bay. Brodie (1971) reported the weight increase from birth to 1 year old for belukhas from Baffin Island based on 17 of the former and three of the latter. Average weight of the neonates was 78.3 kg and that of the yearlings was 187.8 kg; indicating a 140% gain during the first year of life. The average weight of neonates reported by Brodie (1971) was close to that of the six near-term fetuses from late June, obtained in northwest Alaska ($\bar{x}$ = 71.8 kg).

Birth Period

Determinations of the birth period for belukhas are based on two general types of information. The first and most useful is that derived by examination of whales including fetuses and verified newborns, observation of actual births, and rigorously acquired data about short-term changes in the proportion of calves. The second and more confusing type of information includes general comments mostly about such things as finding "large" fetuses (measurements unspecified) or the general sightings of dark-colored calves reported but not verified as newborn.

Sergeant (1973, p. 1080) commented appropriately about the difficulty of determining a peak period of births for belukhas when he stated, "It is strange that the peak could not be narrowed down more closely, since the size frequency of small fetuses . . . shows a very narrow season of matings, with no evidence of variation from year to year over three consecutive seasons . . . ."

Early studies in Alaskan waters indicated, as does our data, that calving occurs mainly in June-July. Nelson (1887) stated that calving occurs in mid-June in the vicinity of St. Michael (southern Norton Sound) and Lensink (1961) indicates a peak of calving in Bristol Bay during mid-June.

Though our data indicate a prolonged birth period extending from April through July and perhaps later, the incidence of births prior to about mid-June is comparatively low. Most seem to occur between mid-June and the second decade of July throughout waters adjacent to Alaska. In northern Alaska, most births that occur prior to about 15 June occur in cold, ice-covered waters. During the open water period (progressively later farther north) any selective utilization of warm, nearshore or estuarine waters by cows about to give birth, or cows accompanied by new calves, would tend to bias samples in such a manner that an apparent peak in the birth period would be suggested even after it actually occurred.

The peak birth period suggested by our data is generally supported by findings elsewhere. As determined by studies conducted in Alaskan waters, some females were still supporting a term fetus as late as mid-July, when our sampling efforts terminated. The first verified postparturient cow was taken on 21 April.

More subjective data, mainly from aerial surveys, suggest a slightly more confused picture. Braham et al. (1984) summarized the results of several years of study in which they were involved from 1975-1978. They reported that young of the year (short-yearlings?) and neonates were seen during the course of aerial surveys in April and May in each of four years. The sighting of neonates in these months is probably based on known births as early as April and the likelihood of being able, at least on occasion, to differentiate between newborns and short-yearlings. These authors (Braham et al. 1984, p. 29) also state that, “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.” Although late summer-early autumn calving is certainly possible, the sighting reported above is inconclusive unless the observers could distinguish with certainty between neonates and calves of 2½ to 4 months age. It is certain that a large proportion of belukhas in the Beaufort Sea during September are returning from Amundsen Gulf and Mackenzie Bay where they calve earlier.

It is general knowledge among Eskimos that in more northern waters the appearance of large numbers of calves coincides with arrival of belukhas in bays and lagoons. Various investigators have also stated this to be the case (Sergeant 1973; Sergeant and Brodie 1975; Finley 1976, 1982; Fraker 1977, 1978). In Alaska, exceptions to this generalization are in Bristol Bay and Cook Inlet, where belukhas usually begin frequenting estuaries *as* early as late March in some years, though neonates have not been seen until June.

Belukhas that summer in eastern Beaufort Sea and Amundsen Gulf are considered by us to be of the same stock as those we sampled in northwest Alaska, and they usually arrive in the Mackenzie estuary in the last week of June (Fraker 1977, 1978). Based on extensive aerial surveys in that region in 1981, Davis and Evans (1982) reported that neonates comprised 13% of 615 belukhas sighted between 18 and 25 July and 12% of 875 whales sighted in the period 5 to 17 August. If neonates were correctly identified from an aircraft, this suggests little calving after late July in that region.

In most other northern areas births also occur mainly in June-July as reported for the Gulf of St. Lawrence (Vladykov 1944) and the White and Kara seas (Bel'kovich 1960). Zaikov (1934, in Tomilin 1957) recorded a catch of 247 whales taken in the Gulf of Ob (White Sea) between 15 July and 3 August 1932. Only one full-term fetus was found, though the catch also included 62 sucklings of which 20 still retained remnants of the umbilical cord. Kleinenberg et al. (1964) concluded that in most Soviet waters the birth period ends between the second half of June and early August. Medvedev (1970) writing about belukhas in southeastern Kara Sea made a general (and confusing) statement that the mating and birth periods end in August-September.

Findings of investigations carried out in the Okhotsk Sea by Arsen’ev (1939) and Nikol'skii (1936) were summarized by Kleinenberg et al. (1964). It was reported that in that region, unlike the situation farther north, belukhas calve in early spring.

In Hudson Bay, Canada, Doan and Douglas (1953) reported the last date of finding a term fetus was in the week ending 14 July. They further stated that the presence of a large fetus is rare in late summer. Brodie (1971) indicates the birth period as occurring in late July to mid-August in Cumberland Sound, near Baffin Island.

Breeding Period

As with several other aspects of reproduction, comments gleaned from the literature about the season of rut or breeding are inconsistent among accounts. Early literature on this subject includes accounts of belukhas in pursuit of each other, or otherwise involved in behaviors interpreted as being or associated with mating. Zhitkov (1904, cited in Kleinenberg et al. 1964) reportedly observed mating in late June-early July in the White Sea. Provorov (1957, in Kleinenberg et al., 10C. cit.) reportedly also observed mating of these whales in the White Sea, on two occasions in mid-July. One of these observations, as recounted, strongly indicates that mating was occurring. That incident was on 10 July 1933.

Vladykov (1944) concluded that the period of mating in the St. Lawrence Estuary extended from early April to early June, with a marked peak at the beginning of May. This was determined on the basis of fetal growth and a presumed gestation period of about a year. In applying similar methodology to data from Greenland (apparently that of Degerbøl and Nielsen, 1930), Vladykov concluded that the period of mating there extended from February to August, with a pronounced peak also around early May. Doan and Douglas (1953) worked with samples of belukhas from the Churchill region of western Hudson Bay. Based on measurements of fetuses and following procedures established by Vladykov (1944), they determined that most conceptions occurred in May though some occurred from March to September.

Tomilin (1957), in his summary of available information, correctly stated that the breeding season is long, though he was in error that its onset is in August. Kleinenberg et al. (1964) recounted much of the reported information and incorporated some additional data. They based their determination of the breeding season on several considerations, though mainly on analysis of fetal growth curves also during an assumed gestation period of 12 months. They concluded that in all seas the mating period seems to be late April to early May, with isolated matings from late February to late August--over a period of six months. Brodie (1971) determined the gestation period to be 14.5 months as compared to all previous findings that it was about a year. This, in combination with a supposed peak birth period for belukhas in Cumberland Sound of late July-early August, placed the peak of breeding for that stock in mid-May.

Sergeant (1973) reported results of his work in western Hudson Bay. He concluded that gestation was most probably around 14 months. Mean date of birth, based on fetal length and length of calves at birth, was not established with certainty and could have been either in the first week of August or closer to mid-July. Thus, he concluded that conception could have been in mid-April or earlier for that stock or population of whales.

Based on the fetal growth curve of belukhas taken in Alaskan waters, the assumption that delayed implantation does not occur, a main birth period of mid-June to mid-July, and the currently assumed gestation period of 14.5 months, as found by Brodie (1971), breeding in belukhas of the Bering population would occur mainly in April. However, this does not in fact, appear to be the case, based on examination of ovaries or of testes.

Examination of ovaries indicated that although some breeding may occur in late April to perhaps mid-June, the peak of breeding is probably appreciably earlier than that. Four of five females taken in late April and judged to have been in breeding condition during the year of capture, had already bred. These four had fully formed corpora lutea and the other was about to ovulate. The time required for complete formation of a corpus luteum in belukhas is unknown. Nonetheless, these specimens indicate that although the peak breeding period cannot be determined, it occurs earlier than mid- to late April.

Examination of histological sections of testes and epididymides indicated, as did ovarian analysis, that the peak breeding period occurs at some unknown time prior to late April. Of 14 adult males taken in late April to late May, all were in the retrogression phase of the annual cycle of spermatogenesis. Retrogressive changes are probably not abrupt and it is assumed that retrogression was initiated significantly earlier than the dates on which those males were collected. Thus, although the peak breeding period cannot be established on the basis of specimens available to us, we suggest that it most likely occurs mainly between late February and early April.

Evidence from females and males suggests that some breeding could occur as late as June. That there is a definite peak is shown by the narrow range of fetal size at age in our sample.

At this time, we cannot rule out the possibility of delayed implantation in belukhas, with attachment occurring mainly in mid- to late April.

Vital Parameters

The sources of data about vital parameters for belukhas of the population we sampled in northwest Alaska are mainly derived from Table 4, which presents information on reproductive status of females and the life table (Table 7). Our presentation is made in the form of a list. There is considerable confusion among different authors with respect to definitions of vital parameters as they are presented in the literature and therefore, when the terms may be ambiguous, we have attempted to explain what we mean and/or provide the values from which an estimate was derived.

Reproductive Parameters

Sex ratio; 1:1.
Breeding season; late February to June with a presumed peak in March.
Birth period; March through July or August with a peak in mid-June to mid-July.
Gestation period; 14.5 mos. at minimum (Brodie 1971); more likely 15 to 16 mos.
First pregnancy; ages 4 to 7.
First birth; age 5 to 8.
Maximum age at last birth; about 35 years (maximum age is not known due to loss of dentinal layers in teeth of old animals).
Generation time; about 6 years.
Duration of dependent nursing period; 6 to 12 mos.

Pregnancy rates;

A. Proportion of sexually mature females age 5 years and older with either a newly implanted fetus, a term fetus, or a newly born calf, 112/179 = 0.626.

B. Proportion of sexually mature females age 5 years and older with a newly implanted fetus, 60/179 = 0.335.

C. Proportion of sexually mature females age 6 years and older with a term fetus *or* a newly born calf, 52/170 = 0.306. In view of bias inherent with interpretation of ovarian analysis, prolonged birth period, and pregnancies at a rate greater than once in three years for younger sexually mature females, a more reasonable estimate is on the order of 0.32 to 0.34. Note in Table 4 that 6 of 16 females, age 6 years, had given birth in a prior year.

Female reproductive life span; this is an ambiguous term. Our samples show that females are reproductively active throughout their adult life though there is a marked decline in pregnancy rates in old-age animals. Potential reproductive life span in our sample is on the order of 31 years, or during the span from age 4 to 35 years. Maximum potential reproductive life span is not known because of loss of dentinal layers in old animals.

Population Parameters

Maximum longevity; due to loss of dentinal layers in teeth, maximum longevity is not known. The oldest animals in our samples included two males 38+ years and a single female, 35+ years.

Proportion of mature females in population; best estimate is 32% to 33%. From the probit age structure, 322/528 (61%) of the whales were age 6 years or older and 357/528 (68%) were 5 years or older. The sex ratio is 1:1. Attainment of sexual maturity occurs when a female becomes pregnant. First pregnancy occurs between ages 4 and 7 years, mainly at ages 5 (33% to 38% of females were pregnant) and 6 (by which age 94% of the females were sexually mature) .

Annual rate of calf production; best estimate is 0.104. This estimate is from the "smoothed" age structure derived through probit, and the resulting life table. The model population of 1,000 whales included 94 calves; 94/906 = 0.104.

Crude birth rate; the same as the rate for females supporting a term fetus or neonate. Best estimate is about 0.33. The range, as indicated by our data, is 0.31 (from probit age structure and age-specific reproductive rates) to 0.34 based on interpretation of ovarian features.

Survival (q_x); 0.094, derived from probit age structure and resulting life table.

There are several sources of comparative data about other stocks or populations of belukhas dealing with one or more of the parameters listed above. We have not included a summary of those data because of the possible ambiguities with respect to definitions and differences in procedures used by other investigators. Primary sources of data that readers can compare with our findings include: Bel'kovich (1960), Brodie (1971), Sergeant (1973, in press) , Heyland (1974) , Finley (1976) , Ognetev

(1981), Seaman and Burns (1981), Brodie et al. (1981), Finley et al. (1982), and Ray et al. (1984). Summary papers of interest are those by Braham (1982, 1984).

Our data indicate that gross annual production of calves per 1,000 belukhas of the composition sampled in northwest Alaska is about 106 (1,000 whales x 0.33 adult females x 0.32 crude birth rate).

Color Change

The change in coloration of belukhas from dark to white, as a function of increasing age and size, has long been known. Nelson's (1887) conclusion about the timing of these color changes was amazingly insightful, considering that he had no quantitative means of accurately determining age of individuals. He wrote (Nelson, op. cit., p. 290), "As already noted these animals are very dark-colored when young. They become lighter each year until the fourth or fifth season, when they are a pale milky bluish, and about the sixth or seventh year they are a uniform, clear milky white."

Various investigators have utilized slightly different categories for describing color phases of belukhas. Kleinenberg, et al. (1964, p. 32, Table 8) indicate the classification schemes used by 13 different researchers of which five used three color categories, six used four, one used five, and one used six. Hay and McClung (1976) refer to 11 color categories though they did not indicate any proportions or numbers within each. We used four categories that were closest to the system utilized by Arsen'ev (1936, in Kleinenberg, et al. , 10C. cit.) . In fact, in the six studies reported in Kleinenberg et al. (1oc. cit.) that utilized four color categories, the color phases were easily relatable to ours. Brodie (1982) reported that a captive male belukha from Bristol Bay, Alaska, maintained in the Vancouver Public Aquarium, obtained its white coloration at about age 6. He compared that to males from eastern Baffin Island that were found to become "noticeably" white at about 7 years. In our sample, males became "whitish" as young as age 5 and white as young as age 9. Considering the ambiguities of different characterizations of color phase, the captive whale, those we sampled, and those sampled by Brodie, indicate that the whitish and white phases are probably obtained at about the same age in whales from Alaska and eastern Baffin Island.

Sergeant (1973) compared the age at which whales from eastern Baffin Island, western Hudson Bay, and eastern Beaufort Sea become white. He found (p. 1072), " . . . that the white color is attained at a fairly constant age in different populations . . . ." He reported the minimum ages of white-colored animals taken in the vicinity of Churchill and Whale Cove, both in western Hudson Bay and in the Mackenzie Delta (animals from the latter area seasonally pass through waters adjacent to Alaska). Assuming two dentinal layers per year of age, minimum ages of white males and females from Churchill were 7 and 8 years respectively; 10 and 8 years respectively for Whale Cove; and 8 and 7 years respectively for whales from Mackenzie estuary. In the Mackenzie estuary, Sergeant (op. cit.) also reported grey-colored females as old as 15 years. Kleinenberg et al. (1964) , similar to all other studies, found that each color phase includes a size range of animals that overlaps markedly, though the sizes of most animals in each color group do not.

White-colored belukhas are sexually mature adults. We found that at least in females, a high proportion of light grey animals (90%, N = 21) are also sexually mature. The proportion of adult belukhas in different populations have been indicated by various writers, on the basis of the proportion of white-colored whales. In our sample of 225 collected whales for which color was recorded, 53% were white and 17% were light grey. Of the light grey females, 19 of 21 (90%) were sexually mature.

The proportion of white and/or whitish-colored whales in samples reported by different investigators is presented in Table 16. Direct comparisons of color composition in samples, based on examination of whales landed and those classified during aerial surveys, may not be entirely appropriate. Landed whales can be more precisely categorized; whereas, there may be a tendency to combine (or an inability to differentiate) light grey and white-colored whales seen during aerial surveys. Our sample of examined belukhas (53% white and 17% grey) would probably be equivalent to 70% white and "whitish", as categorized during an aerial survey. Based on the probable age structure of belukhas sampled in northwest Alaska, the proportion of white and whitish-colored whales would be on the order of 65%.

Movements

Summer Movements in Eastern Chukchi Sea

Until recently, the perspective of summer belukha migrations in eastern Chukchi Sea was that gleaned from compilation of sightings made from shore or the edge of shorefast ice. Those general observations suggested two separate "waves" of migrants (cf. Foote and Williamson 1966, p. 1032); those passing northward through ice-covered waters mainly in March-May and those occurring in ice-free coastal waters and passing northward in a more leisurely manner in June-August.

Available evidence indicates that many or most of the early migrants near Alaska travel eastward after rounding Point Barrow (Braham and Krogman 1977; Fraker 1979; Seaman and Burns 1981; Ljungblad 1981). Perhaps most of these early migrants reach the eastern Beaufort Sea and Amundsen Gulf. Some enter ice-free coastal waters in mid-June through July and begin moving away from the coast in August, returning westward across the Beaufort Sea during August to October (Fraker 1979; Seaman and Burns 1981; Davis and Evans 1982).

Belukhas in the eastern Chukchi Sea also begin to enter ice-free coastal waters during June, first in the region of the northern Seward Peninsula and Kotzebue Sound. The northward movement of these whales is much less directed and more leisurely in that once they begin frequenting rivers, bays, and lagoons they remain in or near these habitats for days and perhaps weeks (as do many of the belukhas that reach eastern Beaufort Sea). Nonetheless, general direction of their movements is northward. In late July-August they leave the coastal zone, also as belukhas in eastern Beaufort Sea do, and by late August-September whales that summered in coastal waters of the eastern Chukchi and the eastern Beaufort seas are mostly associated with the ice front. It is possible, though not probable, that belukhas reaching the vicinity of Point Barrow, from the south, in

Table 16. Proportions of white and "whitish-"colored belukhas in different geographic regions as reported by various authors.

Region	Source	Proportion (%) white-colored animals	Sample size	Sampling method
Kara Sea	Medvedev 1970	61	99	Observation of passing whales from ice
Gulf of St. Lawrence	Vladykov 1944	61	219	Whales examined
White Sea	Provorov 1958	72	32	Whales examined
White and Kara seas	Ognetev 1981	70	385	Whales examined
White Sea	Klumov 1939	54 (white) 73 (white and light)	204	Whales examined
Western Hudson Bay	Doan and Douglas 1953	66	902	Whales examined
Northwest Alaska	Braham et al. 1984	62	507	Observation of passing whales from ice
Northwest Alaska	Braham et al. 1984	93	unknown	Aerial surveys
Northwest Alaska	Braham 1984	71	627	Aerial surveys
Northwest Alaska	This study	70	225	Whales examined

late July-early August move rapidly eastward through Beaufort Sea to the Mackenzie estuary. This probability is considered low in view of the somewhat synchronous departure of most belukhas from northern coastal waters at this time. We suggest that belukhas present in coastal waters of eastern Chukchi Sea during summer eventually reach the ice front generally north and northeast of Point Barrow where they mingle with whales migrating from eastern Beaufort Sea, as schematically shown in Figure 15. Radiotagging efforts in waters of northwest Alaska (a feasible undertaking) are required to verify the hypothesized movements. Kleinenberg et al. (1964) indicate that in Soviet waters, some belukhas are associated with the ice front in summer.

Autumn Migration in the Beaufort Sea

We have already reviewed the survey efforts and other studies that influenced our search for migrating belukhas in Beaufort Sea, west of the Canadian border. Several additional survey efforts are of significance in interpreting our results.

Davis and Evans (1982), reported results of extensive surveys undertaken in the Canadian Beaufort during July-September 1981. Results of these surveys were unavailable at the time of our effort in September 1982. Their survey design included five regions extending eastward from the Alaska-Canada border to and including eastern Amundsen Gulf. Systematic surveys were accomplished during four time periods; 18-25 July, 5-17 August, 19-29 August, and 7-14 September. Several important findings were made. They found that a rather large proportion of belukhas in the Canadian Beaufort did not enter the Mackenzie estuary as was previously thought. The number of belukhas in the Canadian Beaufort was very conservatively estimated to include at least 11,500 animals. Belukhas moved into deeper waters by the first of August and the westward autumn migration was offshore.

Harwood and Ford (1983) conducted more limited surveys during August-September 1982 in part of the region covered by Davis and Evans in 1981. In the 1982 surveys, those authors found that the westward movement of belukhas from the southeastern Canadian Beaufort had probably occurred prior to late August and certainly prior to surveys they conducted from 5-13 September 1982.

Dr. Steven Johnson (LGL Alaska, Ltd., Anchorage, Alaska, personal communication, 16 January 1982) conducted repetitive surveys of transects shown in Figure 16, on 1, 4, and 8 August and on 15, 18, and 22 September 1982. Their transects were 1,600 m wide and extended 20 nm from the near shore starting points. No belukhas were seen on any of those surveys.

Ljungblad et al. (1983) continued a program of very extensive aerial surveys for bowhead whales in the American part of the Beaufort Sea in August-October 1982. Their surveys did not extend appreciably north of 72°N and were mostly south of 71°N. Ice generally persisted in the survey area until mid-August, and then rapidly receded northward. In early August belukhas (numbers unspecified) were widely distributed in association with ice, mainly between 71°N and 72°N latitude (Ljungblad et al., 10C. cit., p. 103). Of significance in relation to our surveys was that during extensive flights in September, they saw no belukhas. Belukhas were again sighted in

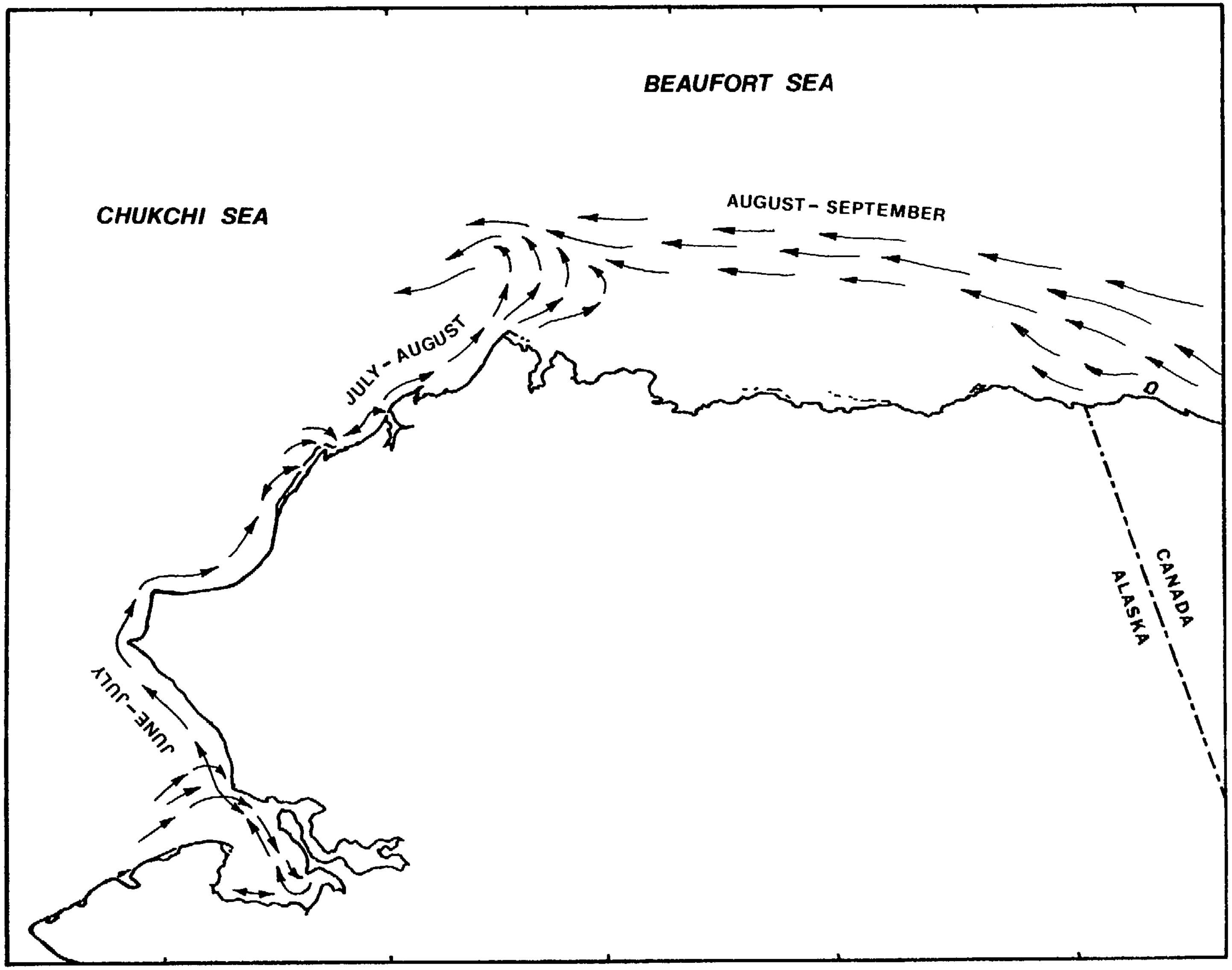

Figure 15. Schematic illustration of hypothesized movements of belukhas that occur in coastal waters of the Chukchi and Beaufort seas during summer.

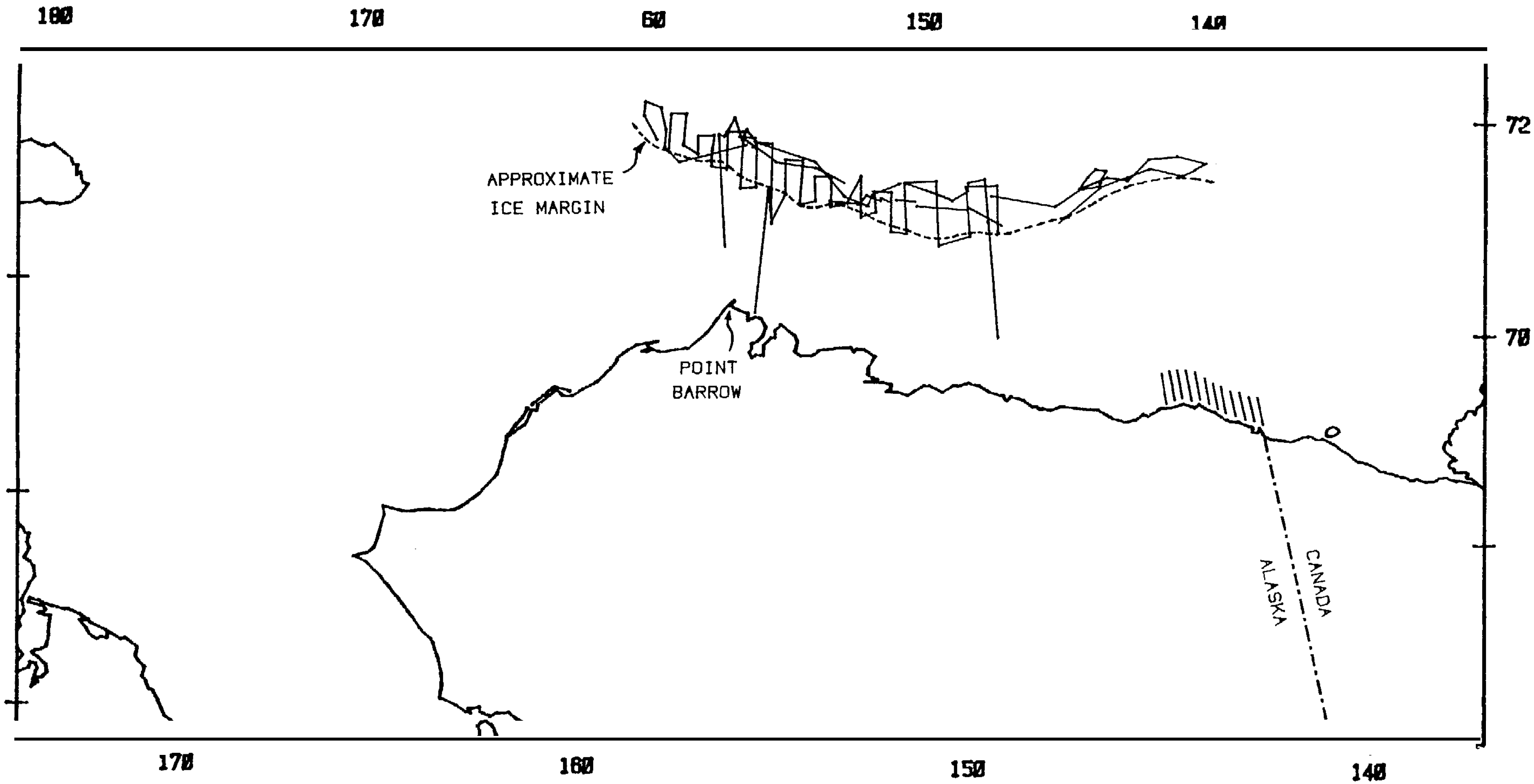

Figure 16 Aerial transect lines flown in mb 1982 during this study and by S Johnson (personal communication).

October during conditions of rapidly advancing and forming ice. A combined total of 485 belukhas were counted in August and October including 250 on 17 October, in the same general area northeast of Point Barrow where they consistently have been observed in September and October. Table 17, compiled from charts of survey transects flown by Ljungblad et al. (loc. cit.) , indicates dates when they saw belukhas.

The most compelling evidence for a westward autumn migration route that is mainly offshore and largely determined by location of the prevailing ice front zone is shown in Figure 17. This figure depicts four things: general position of the ice margin during 17 to 21 September 1982; transect lines flown during this study (mostly near and north of the ice margin); transect lines flown by Ljungblad et al. in September 1982; and the locations of all sightings of belukhas during those two survey efforts.

Figure 18 depicts locations of all sightings of belukhas north of Alaska, based on sources available to us, for which we could determine geographic coordinates. Sources of data for this figure are presented in Table 18. It shows that during August belukhas are widely distributed throughout those areas of the western Beaufort that have been surveyed and occasionally along the Chukchi Sea coast as far as the vicinity of Wainwright. Ice conditions during August are highly variable, though in most years the pack has not yet melted and receded to the minimal annual coverage (Weeks and Weller 1984) . Belukhas are present in the American part of Beaufort Sea during August, at the same time that maximum numbers were counted in the Canadian Beaufort. In our opinion, some of the whales that round Point Barrow do not make the long traverse to eastern Beaufort Sea. There appears to be a progressive movement away from shore in August. Current data are inadequate to describe this movement or to determine numbers of belukhas in western Beaufort Sea during August. The lack of reported sightings in August, west of Point Barrow, is probably an artifact resulting from almost no survey effort in the ice front during that month.

From Figure 18 it is evident that the westward migration is in full swing in September, that a concentration area exists north and northeast of Point Barrow, and that belukhas also occur in the northern Chukchi. The somewhat linear distributions of whale sightings indicate a strong association with the ice front (a linear feature), at least in the Beaufort Sea. Location of the margin and front zone in different years probably accounts for the seemingly great latitudinal distribution of sightings. Latitudinal distribution of sightings in September of different years was rather great and we have not made any correlations of whale distribution and bathymetry. The huge aggregation of belukhas found northwest of Point Barrow on 18 September 1974 by Ray and Wartzok (1980), swimming generally west-southwest, some 30 nm from pack ice, was assumed to have been a migrating assemblage.

In October, most sightings of belukhas were in the western Beaufort. Location of sightings indicates that a linear distribution related to location of the ice front still persists. Frequency and location of sightings suggest that peak migration out of the Beaufort occurs prior to October. However, it should be noted that combined survey efforts in this month have been much less than during September. Sightings in October 1975 by Ray and Wartzok (1980, Figure 26, p. 72) were mostly in central Chukchi

Table 17. Survey dates on which belukhas were sighted in the American sector of the Beaufort Sea in August-September 1982 (from Ljungblad et al. 1983).

August		September		October	
Survey date	Belukhas seen	Survey date	Belukhas seen	Survey date	Belukhas seen
1	no	1	no	2	yes
2	no	2	no	3	no
5	no	4	no	4	no
6	yes	7	no	5	yes
7	yes	8	no	6	no
8	yes	11	no	7	no
11	no	14	no	9	no
12	yes	15	no	10	no
14	yes	16	no	11	no
15	yes	18	no	12	yes
16	yes	21	no	13	no
17	yes	23	no	14	no
18	yes	24	no	15	no
20	no	25	no	16	yes
21	no	27	no	17	yes
22	no	28	no		
23	yes	29	no		
24	yes	30	no		
25	no				
28	no				

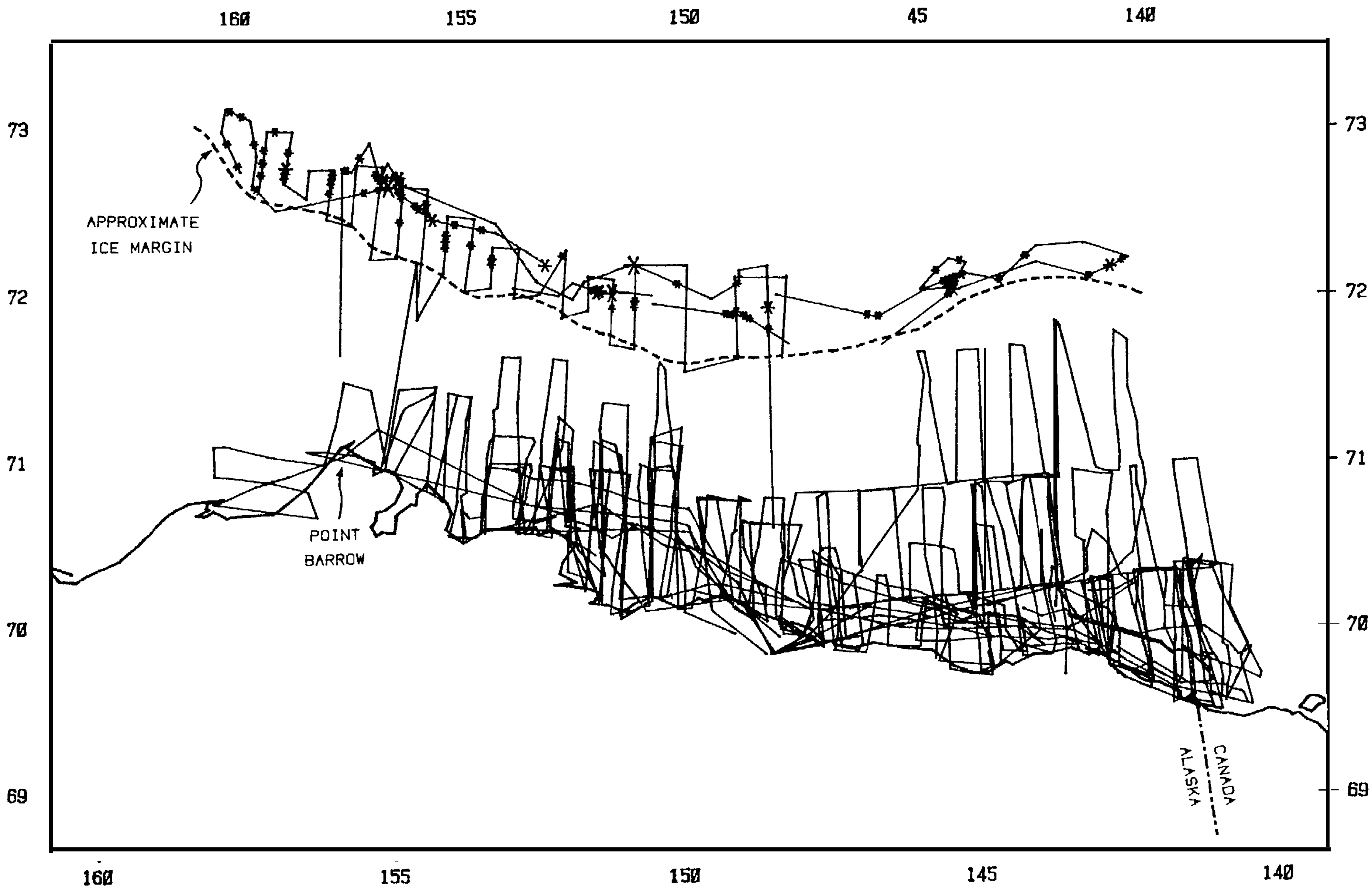

Figure 17. Survey transects flown in September 1982 during this study and by Ljungblad et al. (1983). Location of the ice margin and all belukhas sighted on transects are shown.

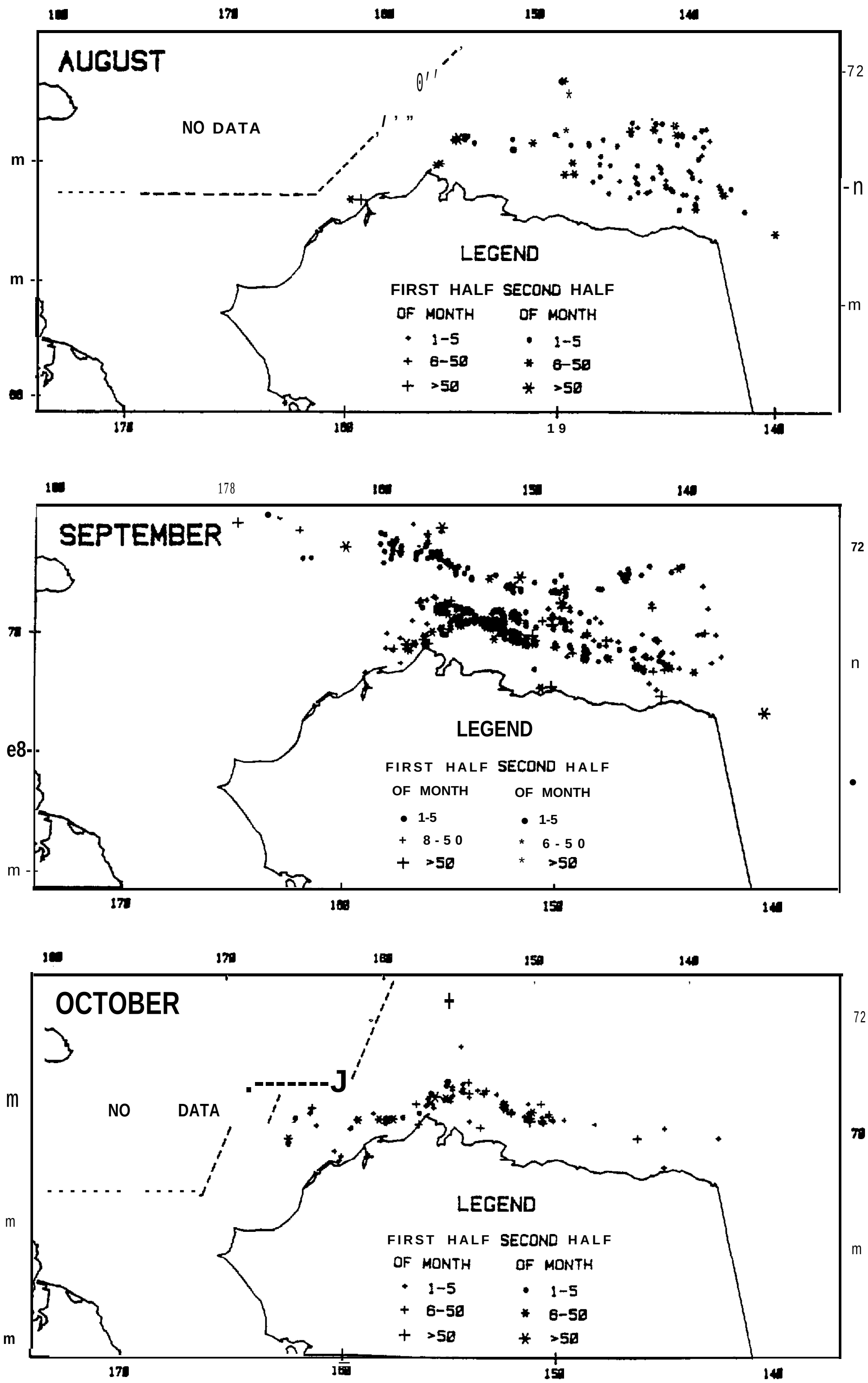

Figure 18. Composite of belukha sightings near northern Alaska in August to October, for which coordinates could be determined. Sources of data are in Table 18.

Table 18. Sources of data on belukha sightings shown in Figure 18. Virtually all sightings were made opportunistically, often during aerial surveys designed primarily for other species (especially bowhead whales and walrus). Only those data appropriate to month and region and for which geographic coordinates were provided, or could be reasonably determined, were utilized.

Source of data	Time of sightings		
	Aug.	Sept.	Oct.
Bitters, J., pers. comm., 1978	X		
Braham and Krogman 1977		X	
Burns, J., field notes, Sept. 1974		X	
Dohl, T., pers. comm., 1979		X	
Fiscus, C., pers. comm., 1974		X	
Fiscus et al. 1976		X	
Fraker et al. 1978		X	
Frost, field notes, 1978	X		
Harrison and Hall 1978	X		
Johnson 1979		X	
Johnson et al. 1981		X	
Johnson et al. 1982		X	
Ljungblad et al. 1980		X	X
Ljungblad 1981	X		
Ljungblad et al. 1982	X		X
Ljungblad et al. 1983	X	X	X
Murdock 1885		X	
Naval Arctic Res. Lab., files, 1978 and 1980	X		X
Nelson 1968	X		
Ray, C. G., pers. comm. in Braham and Krogman 1977		X	
Ray et al. 1984	X	X	
Univ. Rhode Island Lab. for Study of Info. Sci.[1]	X		

[1] Provided a computerized listing of belukha sightings recorded during various projects supported by the Alaska Outer Continental Shelf Environmental Assessment Program and subsequently submitted to the National Oceanic Data Center.

Sea, near and south of 70"N latitude; considerably south of sightings in September. These data are not included in this report as the geographical coordinates were not available to us.

For waters of northern Alaska and northwest Canada, available data indicate a weak association of belukhas with pack ice in July (numbers in coastal areas are greatest), becoming stronger in August when they depart coastal waters, and being very strong by September.

Migration in Soviet Waters

The limited information available about whale migrations and movements in waters of the Soviet far east indicates a "mirror image" pattern to that in Alaskan and western Canadian waters, at least during the first half of this century. Some belukhas remain in coastal waters of Bering Sea throughout the year, though most migrate north through Bering Strait during spring-early summer. Substantial numbers move northwest after passing Mys Dezhneva, summer in the western Chukchi and eastern East Siberian seas, and return to Bering Sea in autumn-early winter. Such a hypothesis is based on the following records.

Kleinenberg et al. (1964) report sightings of belukhas in May from the vicinity of Mys Navarin, the Gulf of Anadyr, and the region from Bukhta Provideniya to Ostrova Arakamchechen and around Chukhotka to Mys Serdtse-Kamen.

Large herds of belukhas occur in the Gulf of Anadyr during the second half of June, migrating along its western and northern shores, some entering Zaliv Kresta and large numbers entering Anadyrskiy Liman where they remain throughout the summer (Vinogradov 1949, in Kleinenberg et al. 1964; Tomilin 1957). The maximum number of belukhas in the Gulf of Anadyr occurs in July (Kleinenberg et al. 1964).

Nikulin (1947, in Kleinenberg et al. 1964) indicated that belukhas appear in the western Chukchi Sea in early summer, though Sverdrup (1930, in Kleinenberg et al. 1964) indicated that they occur in large numbers near Serdtse-Kamen, during April-May and are hunted at that time by the Chukchis. Klumov (1939) indicated that belukhas occur in large numbers near Wrangel Island, in summer. According to Arsen'ev (1939), along the north coast of the Chukchi Peninsula, large numbers of belukhas occur only as far west as Mys Shmidta. However, Tomilin (1957) includes the eastern part of the East Siberian Sea within the range of these whales. Gurevich (1980) states that, "They are common among the ice floes in the Long Strait near Vrangel Island and off the Chukchi coast from Cape Dezhnev westwards as far as Chaunskaya Guba." The latter location indicates a considerable penetration of the East Siberian Sea.

Kleinenberg et al. (1964) state that belukhas pass the settlement of Uelen, near Mys Dezhneva during spring and autumn; a situation similar to that on the Alaskan side of Bering Strait. Fedoseev (personal communication in Kleinenberg et al. 1964) reported seeing two large groups of belukhas. The first, seen on 4 October 1960, north of Wrangel Island, was a huge aggregation that extended over a distance of 15 km. The second group was seen on 17 October 1960, 80 miles from Wrangel Island. It was estimated to include 300-350 whales, swimming in the direction of Bering Strait.

Belikov et al. (1984) reported on opportunistic sightings of marine mammals made during repetitive ice reconnaissance flights from June to September in 1971 to 1979. Relatively few sightings of belukhas were reported. However, they did show that belukhas extended well into the East Siberian Sea as early as June. The majority of their sightings were in the general vicinity of Wrangel Island.

These various reports further support the comments of Kleinenberg et al. (1964) that in the western Chukchi Sea, during summer, belukhas occur, "not only near the coast but also north of Wrangel Island."

Natural Mortality

In his extensive review of information about belukhas, Tomilin (1957) summarized a number of instances of ice entrapment in widely scattered parts of their amphiboreal range. Several of those were noteworthy for the size of aggregations entrapped, as indicated by numbers removed by hunters. An instance in Kolyuchinskaya Guba, a bay on the coast of northwest Chukchi Sea, involved the capture of several hundred belukhas by local inhabitants. Tomilin (1oc. cit.) also noted repetitive instances of entrapment in the same general location and predation by polar bears on trapped belukhas. He suggested that occasional entrapment is evidence for extensive penetration of "dense" (closely packed) ice by belukhas. Citing Geptner (1930), Tomilin (1oc. cit.) indicated that in unbroken ice belukhas utilize seal holes for breathing and, where ice was forming, they used their backs to make and maintain openings.

Kleinenberg et al. (1964) included many of the information sources used by Tomilin (1957) and indicated that instances of ice entrapment have repeatedly been recorded. These authors used the Greenland Inuit term, savssat, apparently in reference to regular occurrences in waters adjacent to Greenland where a specialized hunt of entrapped belukhas sometimes occurs. Kleinenberg et al. (1964) noted that belukhas can survive entrapment without access to food for one-two months. Mitchell and Reeves (1981) list known records of ice entrapment of narwhals and belukhas in the eastern Arctic, extending as far back as 1750. Freeman (1968) presents a detailed account of an entrapment that occurred in Jones Sound, Northwest Territories, Canada.

Including the two instances of entrapment that occurred near Alaska in April 1984 (Lowry et al., in press) , there are five confirmed records and numerous other reports involving belukhas of the Bering population. The five confirmed records are the entrapment of several hundred whales, apparently in autumn, that occurred in Kolyuchinskaya Guba (Tomilin 1957); one of 20+ whales in Eskimo Lakes, Mackenzie Bay in autumn-winter, 1966-67 (Hill 1967, 1968); one of an unknown number from which about 35 were taken by hunters near the northwest coast of the Seward Peninsula, in early March 1976 (Seaman et al. 1985); an unknown number trapped in ice of the central Chukchi Sea in late March (Jack W. Lentfer, formerly a polar bear specialist with the Alaska Department of Fish and Game, personal communication, 29 August 1984); and 2,000 to 3,000 entrapped in Proliv Senyavina (northwestern Bering Sea) in late December 1984.

Entrapment in elongated bays and large lakes during the period of autumn freezeup apparently results when extensive, rapidly forming ice blocks exit of the whales, as was reported for the Eskimo Lakes and Proliv Senyavina events. Hill's account of such an event was interesting in several respects. In August 1966, an estimated 50 belukhas were in the fourth or innermost of the Eskimo Lakes that bound the east shore of the Tuktoyaktuk Peninsula, some 150 miles inland from the Beaufort Sea. A similar number were seen on 20 September. Ice began forming in early October and only three open areas remained in the fourth Eskimo Lake on 1 November. Twenty belukhas were still present on 20 November, apparently utilizing one remaining hole. By 21 January 1967, only one whale remained. The natural hole at which the remaining whale was seen was frozen over when visited on 26 January. No hunting took place at this entrapment. It was presumed that these trapped whales starved. The maximum observed time of dives was 7 min and 25 sec, though a recording crew using hydroacoustic equipment noted that on 21 January, the single remaining whale was away from the hole for about 40 min. During their entrapment whales broke the overhanging ice around the hole with their backs, as has been reported previously by several authors. Records of ice entrapment in the eastern arctic are presented by Mitchell and Reeves (1981).

In April 1984 entrapment during the northward spring migration near Alaska occurred when early migrating whales that deeply penetrated the northern pack were caught by unusually low temperatures and severe freezing conditions. This followed almost a month of warm temperatures. Table 19 shows the average daily temperatures recorded at Nome and Cape Lisburne during March and April 1984. It can be seen that, in comparison to temperatures in March, those recorded in April were unusually cold. Though they are not precise indicators of temperatures that existed in Bering Strait-southern Chukchi Sea region, conditions recorded at Nome reflect the monthly trends and suggest the cause of entrapment in Bering Strait and near Kivalina.

With respect to predation by polar bears and killer whales, records available to us mainly add to the already existing body of information. Some additional insights about the combined impacts of entrapment and predation by bears are suggested by the incidence in April 1984.

Polar bears were exceptionally abundant in northern Bering Sea and eastern Chukchi Sea during winter-spring 1983-84. The largest recorded harvest ever made by coastal-based hunters in those areas were made during that period (292 polar bears; D. Taylor, U.S. Fish and Wildlife Service, Anchorage, AK, undated memorandum) . Thus, any belukhas in the region, whether entrapped or free-ranging, were exposed to a potentially higher than normal probability of predation. Many bears did locate the <u>savssat</u> at entrapments found in April 1984. Additionally, during the course of field work in the Cape Lisburne area during April-May 1984, it was observed that polar bears routinely investigated areas where belukhas had rested under thin ice in newly refrozen leads. Such resting areas are obvious from the air as the whales leave elongate impressions in the thin ice that resemble closely scattered grains of rice. These distinctive impressions have variously been referred to as conical elevations (Kane 1926, in Mitchell and Reeves 1981, p. 675), cupolas (Davis and Finley 1979 Ms), or domes (McVay 1973).

Table 19. Average daily temperatures (°F) at Nome and Cape Lisburne, Alaska, during March-April 1984. Average temperatures are means of the daily highs and lows.

Nome				Cape Lisburne			
March	Temp.	April	Temp.	March	Temp.	April	Temp.
1	8	1	31	1	-27	1	2
2	0	2	24	2	-27	2	8
3	8	3	18	3	-28	3	4
4	-2	4	24	4	-25	4	-8
5	12	5	22	5	-20	5	-17
6	35	6	12	6	-13	6	-17
7	37	7	-4	7	-9	7	-18
8	26	8	-9	8	-6	8	-21
9	37	9	-4	9	-1	9	-19
10	37	10	-2	10	9	10	-17
11	31	11	-1	11	7	11	-13
12	25	12	0	12	16	12	-16
13	35	13	4	13	4	13	-8
14	26	14	5	14	6	14	8
15	15	15	7	15	-3	15	-2
16	13	16	2	16	-9	16	-13
17	32	17	-1	17	-10	17	-11
18	18	18	8	18	-12	18	-7
19	6	19	7	19	-15	19	-8
20	2	20	8	20	-17	20	-9
21	6	21	14	21	-15	21	-9
22	12	22	18	22	-21	22	-9
23	10	23	13	23	-15	23	-9
24	11	24	15	24	-16	24	-8
25	13	25	23	25	-17	25	-9
26	11	26	25	26	-22	26	6
27	11	27	32	27	-17	27	13
28	14	28	24	28	-15	28	6
29	27	29	26	29	-13	29	3
30	22	30	20	30	-10	30	2
31	25			31	-8		

Conditions that prevailed in spring 1984 were atypical. Savssat and predation on them by polar bears in the Bering and eastern Chukchi seas are probably uncommon in most years, as indicated by observations of other biologists that worked in the region over a number of years.

Mr. Jack W. Lentfer (personal communication, 29 August 1984) was engaged in polar bear tagging operations during spring, from 1967 to 1976, in the eastern Chukchi Sea region. This work involved many hundreds of hours of flying to track and capture bears. During his studies he found no instances of bear predation on belukhas and only one entrapment; in which a small number of savssat were present. Mr. James W. Brooks (formerly polar bear specialist for the U.S. Fish and Wildlife Service, personal communications, August 29 and September 6, 1984) was involved in a similar tagging effort during spring seasons, 1968-1972. His field work was all in the eastern Chukchi Sea, off Cape Lisburne. During those five seasons he recorded no instances of entrapment nor of successful predation on belukhas by bears. Mr. Steven Amstrup (currently polar bear specialist for the USFWS) has been tagging and tracking polar bears during spring, from 1981 to 1984. During three of those years he worked in the eastern Chukchi Sea and also reported no instances of belukha entrapment or predation on whales by bears.

Though these polar bear specialists normally started their field work at a time prior to arrival of belukhas in the Chukchi Sea, their field efforts normally included part of the period when migrating whales were present.

The situation in Bering and eastern Chukchi seas is in marked contrast to reports from experienced polar bear hunting guides that operated in western Chukchi Sea until 1972. Sport hunting for polar bears with the aid of small aircraft was common practice from about 1950-1971. General comments of interest were reported by various professional guides over a period of years.

These guides pursued large, trophy class polar bears primarily in the western Chukchi for three stated *reasons: (1)* bears near the Alaska coast, though numerous, tended to be smaller and included a larger proportion of subadults and sows with cubs; (2) pack ice was more fractured and mobile in the eastern part, with a broad active flaw zone (also see Burns 1970); and (3) on average, tracking and landing conditions for aircraft were more favorable in the western Chukchi because of thicker, more extensive ice. The polar bear guides, operating from villages along the eastern Chukchi coast began hunting in the east, though generally, while flying westward. Thus, they were very familiar with conditions in different parts of the Chukchi Sea.

Mr. Robert Curtis (pilot and polar bear guide, personal communication to Dr. F. H. Fay, 27 March 1967) reported finding a belukha in southwestern Chukchi Sea that had been killed and eaten by a polar bear. Mr. Nelson Walker (pilot, big game guide, 30+ year resident of Kotzebue, personal communications during numerous conversations with the senior author) summarized his observations of belukha entrapment and polar bear predation over the period 1952-1971. He recounted no instances of belukha entrapment in the central Chukchi region east of 168°W, and two instances of bear predation. In the western Chukchi the situation was much different. He recounted finding, on average, one or two instances of entrapment involving small numbers of savssat a year, with polar bears present at many of them. The most dead belukhas he reported (presumably killed by polar bears) was seven. Occasionally walruses, mostly single individuals, were also entrapped and successfully preyed upon by bears, according to Mr. Walker.

A *recent* instance of mass entrapment in Soviet coastal waters of northern Bering Sea received worldwide news media attention. It was reported that in late December 1984 several thousand trapped whales (up to 3,000) were found in Proliv Senyavina (Senyavin Strait) that separates Arakamchechen Island from the Chukchi Peninsula. According to newspaper accounts (i.e., Anchorage Daily News, Saturday, 23 February 1985; The New York Times, Tuesday, March 12, 1985) the Soviet icebreaker Moskva, overcoming great difficulties, made a channel through heavy ice, reaching the whales in late February 1985. The belukhas were reportedly reluctant to follow the ship to safety and were eventually coaxed by the sounds of classical music. Some savssat reportedly perished due to crowding in the small open holes.

These newspaper accounts are at some variance with what probably actually happened. According to S. P. Duniushkin, Marine Mammal inspector, Okhotskrybvod, Magadan, U.S.S.R. (personal communications with the senior author in March and April 1985), several thousand belukhas were indeed trapped during late December, in Proliv Senyavina. Repeated attempts of the icebreaker to reach the whales were unsuccessful and some animals began to perish. In view of the grave situation and deteriorating condition of the trapped whales, some 300 to 400 animals were killed for local use by hunters from the nearby Native settlement of Yandrakinot. Eventual fate of the large number of entrapped whales is unknown at the time of this writing. Based on available information about time and location of the event, those whales would have had to survive entrapment until about late May, before ice conditions would have moderated enough to permit their escape.

It is evident that entrapment of belukhas of the Bering population occurs with some frequency. Entrapment in autumn-early winter, as a single factor, probably poses a greater threat of death to belukhas because of intensifying ice conditions and starvation of imprisoned animals over protracted periods of time. Entrapment during late winter-spring, during northward migration, would tend to be of shorter duration and whales would eventually be released by shifting ice before they starved. In either case, entrapment increases the likelihood of predation by polar bears and occasionally by man. Entrapment probably occurs with greater frequency in western rather than eastern Chukchi Sea due to penetration of more severe ice conditions by belukhas. The numbers of savssat involved in spring entrapments are, on average, probably small.

In our opinion, events affecting belukhas that occurred in Bering Strait and eastern Chukchi Sea during spring 1984 were unusual for two reasons; the uncommon abundance of polar bears and the unusually warm temperatures and extent of open water in March, followed by severe cold and extensive re-freezing of leads in April.

Predation by killer whales on belukhas is also of significance in the Bering and Chukchi seas. The extent of such predation is, as yet, not known, though it is probably common in some parts of the belukha's annual range. During the months of minimal ice extent, relatively few of the entire Bering Sea population of belukhas remain in the Bering Sea where killer whales are relatively abundant. Most belukhas are in the northern Chukchi, East Siberian, and Beaufort seas. The number of killer whales in the northern Chukchi is relatively low, based on the infrequency of sightings. There are no reported sightings from the central and eastern Beaufort, and their occurrence in the East Siberian Sea is unknown. Effective use of underwater broadcasting of killer whale sounds to keep belukhas out of major salmon streams in Bristol Bay, Alaska (e.g., Fish and Vania 1971) attests to the strong reaction of belukhas to the acoustical perception of killer whale presence.

Contaminant Levels

Addison and Brodie (1973) reported the occurrence of DDT residues found in samples from 14 adult belukhas taken from the Mackenzie Delta. Whales that summer in that region pass through waters adjacent to Alaska and are hunted by Alaskans. Those authors found that DDT and its metabolizes were present at levels of 0.01 and 0.02 parts per million (ppm) , fresh weight in muscle and liver tissue, respectively, and 2 to 4 ppm fresh weight in blubber. These levels were considered by those authors to be lower than in marine mammals from other regions such as the North Atlantic.

Addison and Brodie (1973) based their comments about sources of these contaminants on the premise that belukhas occurring in Mackenzie Delta do not migrate beyond the Beaufort and Chukchi seas. They concluded that residues of DDT and its metabolizes were thus of local origin, obtained through the food web. However, based on the seasonal migrations of these belukhas it is equally probable that exposure occurs during winter when the belukhas are in the Bering Sea, a region dominated by inflow of North Pacific water.

Sergeant and Brodie (1975) stated that belukha fisheries in the eastern part of the Northwest Territories (Canada) that produced meat and muktuk for human consumption failed because of the discovery of mercury in meat. Mercury in belukha meat exceeded the 0.5 ppm wet weight level that was allowable for human consumption. Heavy metal burdens in belukhas of the Bering population are known only from four females taken in Mackenzie Estuary, the results of which were reported by Hunt (1979). In those four whales mercury in liver tissue ranged from 7.41 to 22.64 ppm ($\bar{x}$ = 13.3). Mean levels in meat and muktuk were 0.91 and 0.14 ppm respectively. Zinc also occurred at high levels, the mean of measurements being 24.1 ppm in liver, 23.8 in meat, and 21.6 in muktuk. Cadmium, copper, lead, and chromium were also reported as present.

Contemporary Harvests and Total Kills

Belukhas of the Bering population historically have been, and continue to be, hunted in coastal waters of three broad regions: far eastern Siberia and Chukhotka; western and northern Alaska and the eastern Beaufort Sea and Amundsen Gulf of Canada. In all three regions the historical aboriginal harvests appear to have been substantially larger than most annual harvests made at the present time (Tomilin 1957; Fraker et al. 1978; Seaman and

Burns 1981). The majority of belukhas taken in earlier times were hunted during open-water seasons by large numbers of men, usually employing kayaks (or similar small craft), harpoons, and spears in highly organized "drives" during which many belukhas were driven into shallows and killed (Pallas 1788, cited in Tomilin 1957; Nelson 1887; Kowta 1963; Meteyer 1966, quoted in Fraker et al. 1978; Foote and Williamson 1966; Ray 1966; Vanstone 1967; McGhee 1974; Fraker et al. 1978; Hunt 1979; Seaman and Burns 1981). During our work in villages of western and northern Alaska, we were frequently told of traditional sites where people formerly gathered to collectively hunt and process the catches.

Review of written records available to us, as well as discussions with Alaskan Natives and other informed individuals, indicates that the complex process of "modernization," has strongly affected belukha hunting. V. A. Arsen'ev, a well-known authority on marine mammals of the Soviet far east, worked in that region during the 1920's and 1930's. He recounted to the senior author, via personal discussions in 1967, that reduced hunting effort and landings in Chukhotka were, in part, due to consolidation of many of the smaller coastal settlements, increasing involvement of potential hunters in activities other than subsistence hunting (especially during summer months) and abandonment of the traditional hunting methods that involved large numbers of hunters. To a great extent, these changes have also occurred in Alaska (Seaman and Burns 1981; Seaman et al. 1985) and probably in northwest Canada. There is a general concensus that the contemporary magnitude of belukha kills, including increased losses associated with the use of rifles as opposed to harpoons and nets, is usually less than in former times for the Bering population of these whales (Arsen'ev, personal communication; Fraker et al. 1978; Seaman and Burns 1981).

Annual harvests of belukhas may fluctuate greatly. The "regular" seasonal harvests are affected by annual differences in abundance and availability of whales, especially in coastal waters during summer. Also, the periodic occurrence of <u>savssat</u> that accord opportunity for unusually large harvests to be secured, further contribute to great annual variations in harvest levels.

Accurate information on magnitude of contemporary kill levels, especially the component that includes numbers of belukhas wounded or killed and lost, is difficult to obtain and interpret. It is our intention to summarize what we consider to be the most reliable information and, from this, to derive an estimate of mortality due to hunting.

Soviet Harvests

Successful hunting for belukhas of the population under discussion, in what are now Soviet waters, formerly occurred over a broad expanse from Kamchatka to Chaunskaya Guba in the western part of the East Siberian Sea (Tomilin 1957). According to Tomilin (1957) and Arsen'ev (personal communciations) in recent times they have mainly been taken in the region of the northern Gulf of Anadyr.

Reported magnitude of landings varied by source. Tomilin (1957) indicates only that they are taken sporadically. Kleinenberg et al. (1964) reported that about 500 are taken in the Laptev, East Siberian, and Chukchi seas combined. It was not possible for us to determine what proportion of that reported level of take may have been from the whale population under discussion. These same authors also indicated a take of 100-300 belukhas in the Bering Sea.

Krupnik (1979, 1980) reported on characteristics of marine mammal harvests, including belukhas, made during the 1920's and 1930's by Asiatic Eskimos. Asiatic Eskimos live along the southern (Anadyr) and eastern (Bering Strait) shores of the Chukchi Peninsula. He indicated that during those years, Siberian Eskimos were 28% of the population of Chukhotka; they took an average of 25 to 30 belukhas a year in the mid-1930's; that catch was 50% to 70% of all whales taken by Native inhabitants of the Chukchi Peninsula and that hunting losses were high, on the order of 100% to 150% of the landed catch (50% to 60% of the whales struck were lost) . Rozanov (1931) reported that formerly, belukhas were taken by shooting only near the settlement of Naukan. Nine belukhas were taken there in 1929 and 42 in 1930.

V. N. Gol'tsev, formerly a fisheries inspector in the Chukotka region during the 1960's (Soviet Ministry of Fisheries, Okhotskrybvod), informed the senior author that few people now normally hunt belukhas and the level of take is low; probably less than 40 whales per year on average, and mainly along the north coast of the Gulf of Anadyr (Gel'tsev, personal communication, August 1973) . Yablokov (1979) indicated that former catches near the Chukchi Peninsula (Bering and Chukchi seas) sometimes reached 100 to 200 animals; that current catches are less than 100 in the Laptev, East Siberian, and Chukchi seas combined; and on the order of 20 to 50 in Bering Sea. Ivashin and Mineev (1981) reported the recent known harvests of belukhas in different parts of the U.S.S.R. In the Chukchi Sea, six were taken during the two-year period 1973-74. Reported harvests in the Bering Sea ranged from 15 to 32 in 1973-1980 with an annual average of 26 during 1976-1980. Harvests in 1981 to 1983, as reported by Mineev (1984), *were* 22, 12, and 18 respectively. Of these, only two were taken in the Chukchi Sea in 1983.

Most recently, A. Somov, Inspector for the Soviet Ministry of Fisheries, stationed in Magadan, informed the senior author that an annual landed catch of about 25 to 30 belukhas is made by workers from the settlement of Sireniki, at the southeastern corner of the Chukchi Peninsula in April and May (Somov, A. G., personal discussion with J.B., December 17, 1985) apparently utilizing the very important, persistent, polynya system referred to as Sirenikovsakaya Polynya by Bogoslovskaya and Votrogov (1981) . Somov further indicated that although belukhas are occasionally hunted at other locations in the Bering and Chukchi seas, the average number taken per year is very low.

On the basis of all the information presented above, we conclude that a reasonable estimate of contemporary Soviet harvests from the Bering Sea population of belukhas is normally on the order of 60 whales per year. The large kill of savssat in Proliv Senyavina in 1985 will greatly increase reported harvest of 1985.

Western Canadian Harvests

Harvests of belukhas from the Bering population, made by Canadians, occur primarily in what is broadly referred to as the Mackenzie estuary of the eastern Beaufort Sea. In addition to kills in that estuary, an estimated 10 whales may be killed (not necessarily landed) in other parts of the western Canadian Arctic (Fraker 1980).

There are several sources of data about landings (retrieved harvest) in the Mackenzie estuary over several years. Those data we have used are presented in Table 20. The average annual landing in the Mackenzie estuary during the n-year period from 1971 to 1981 was 129 belukhas. If it is assumed that six of the 10 belukhas killed per year, on average, in other parts of the western Canadian Arctic are landed, the average level of recent landings is about 135 belukhas per year.

Alaskan Harvests

The landed kill of belukhas in western and northern Alaska, for various years, is presented in Table 21. The most pertinent and reliable data are those for the years 1977 to 1984. During that eight-year period the annual average landed harvest was estimated to have been 220 animals.

The combined estimated annual landed harvest of belukhas from the Bering population, made in Soviet, Canadian, and American waters is 415.

Total Kills

It is extremely difficult to estimate the total annual kill of belukhas based on the landed catch. Losses depend on a great number of variables including the environmental circumstances under which whales are taken, methods of capture, location of hunting activity, attitudes and capabilities of the hunters, and behavior of whales. Loss rates range from zero when whales are taken with nets to very high when they are shot in narrow leads during their northward spring migration or in deep open waters during summer. Some authors have indicated the causes of hunting loss and/or suggestions for reducing it (Hunt 1976, 1977, 1979; Fraker 1980).

Though it may not be precise, a reasonable estimate of total kills, including whales landed and those struck and lost by rifle fire, is necessary in order to estimate the probable impact of harvesting on the population of whales as a whole. As was true for determinations of the landed harvest, the various sources of information are subject to different interpretations.

Estimates of the proportion of belukhas killed but not retrieved in the western Canadian Arctic vary considerably. Hunt (1976, 1979) estimated that 40% of the whales killed were not landed. Fraker (1980) estimated that loss at 33%, while Finley et al. (1983) indirectly indicated that it was about 57%, or an estimated 300 whales killed per year with average annual landings of 130.

We have chosen to use the estimate of 40%. On that basis, the average landing of 135 whales indicates a total kill of 225 in waters of northwestern Canada.

Table 20. Reported landings of belukha whales in the Mackenzie estuary, eastern Beaufort Sea.

Year	Number landed	Source of information	Year	Number landed	Source of information
1960	145	1	1971	82	2
1961	145	1	1972	120	2
1962	96	1	1973	177	2
1963	94	1	1974	122	3
1964	45	2	1975	142	3
1965	70	2	1976	154	3
1966	96	2	1977	140	3
1967	40	1	1978	121	3
1968	14	1	1979	120	4
1969			1980	90	4
1970	105+	2	1981	149	4

[1] Sergeant and Brodie 1975. Data presented by these authors are for the western Canadian Arctic. Lacking clarification, we have assigned them specifically to the Mackenzie estuary.

[2] Fraker et al. 1978.

[3] Fraker 1980.

[4] Fraker and Fraker 1982.

Table 21. Reported or estimated landings of belukhas in western and northern Alaska (Bering, Chukchi, and Beaufort seas) from 1963 to 1984.[1]

Year	Number landed	Source of information	Year	Number landed	Source of information
1963	225	2	1974		
1964	225	2	1975		
1965	225	2	1976		
1966	225	2	1977	247	4
1967	225	2	1978	177	4
1968	150	3	1979	138	4
1969	170	3	1980	249	4
1970	200	3	1981	205	4
1971	250	3	1982	331	4
1972	180	3	1983	231	4
1973	150	3	1984	170	4

[1] When a range in the probable landed kill was indicated in the original data source, the mean of that range has been used in this table.

[2] Burns, J. J., Alaska Dept. of Fish and Game, unpublished.

[3] Seaman and Burns 1981.

[4] Data obtained during this study.

In eastern Canada, Orr and Richard (1985) reported on some aspects of the belukha hunts in Cumberland Sound in 1982 to 1984. Hunting was mainly unorganized in that boats mostly operated independently. Hunting efficiency, as reported by these authors, may have relevance to similarly conducted hunts in other regions. Orr and Richard (ibid.) made one statement that was difficult for us to interpret. They said (p. 3) that, "All the dead whales observed by DFP personnel, were buoyant and it is therefore unlikely that any were lost due to sinking." Their reference apparently was to a hunt on 21 July 1982 when 19 belukhas were landed. However, it was interspersed with more general comments about hunting methods. In our experience, whales that sink before being harpooned or speared, would not be seen unless they were subsequently grappled, or floated to the surface, usually a day or more after death. An assumption that no whales are lost due to sinking is questionable. Though Orr and Richard (op. cit.) reported the number of belukhas landed during each hunt they monitored, ancillary information about whales sunk, or that escaped after being wounded, was only mentioned in relation to five hunting forays made in August 1984. During those hunts (1.6, 18, 21, 23, and 25 August) an estimated 36 to 38 whales were struck by rifle fire. Of those struck, 11 were landed, 1 was known to have been killed and sunk, and 24 to 26 were wounded and escaped. Using values of 37 whales struck and 25 wounded but having escaped, 29.7% of the struck whales were landed, 2.7% were known to have been killed and sunk, and 67.6% were hit but escaped. Fate of belukhas in the latter category was, of course, unknown.
In Alaska, belukhas are mainly taken either in spring, as they migrate northward through the ice, or during the months of open water when they are mostly herded into shallows and killed. We have no additional information that alters our previous conclusions (Seaman and Burns 1981) of loss rates associated with these two types of hunting. The loss rate for hunts conducted at the land-fast ice edge is estimated at about 60% of the animals struck. That, associated with whale drives, is estimated at 20%. The average annual landed harvest of 220 in 1977 to 1984 is considered to have been comprised of 30% taken at the land-fast ice edge and 70% taken in shallow water. Thus , the average annual kill in western and northern Alaska is estimated to approximate about 360 belukhas per year. That estimate is high for years when landings include a significant number of whales caught in nets. In order not to underestimate losses, we have included such whales as being part of the catch taken by driving.

It appears that the Soviet harvest is mainly taken in April-May. We assume that conditions are similar to those in Alaska for hunts at the land-fast ice edge, where losses are estimated to be 60% of the whales killed. If so, an annual average harvest of 60 belukhas represents a kill of 150.

Based on the comments above, we conclude that the estimated total kill of belukhas from the Bering population, made in waters of the U.S.S.R. , Canada, and the U.S.A. is on the order of 735 per year.

It has been obvious to all observers of belukha hunts conducted at the edge of land-fast ice that a considerable reduction of losses can be achieved; particularly by improving hunting methods of the less traditional, inexperienced, younger-aged hunters.

Size of the Bering Population

At present, there are no quantitatively verified estimates of total size of this population of belukhas. Burns (1984) indicated that, at a minimum, it probably included 25,000 to 30,000 animals. That minimum estimate was based primarily on numbers of whales that occur in coastal waters of western North America during months of open water and on information about distribution in other parts of the Bering-Chukchi region during those months.

During summer, in Soviet coastal waters of Bering Sea, belukhas have been reported to occur from south of Karaginskii Island to Mechigmen Gulf in western Bering Strait. The center of summer abundance in Soviet waters of Bering Sea appears to be in the region of the northern Gulf of Anadyr from Kresta Bay to Providenia Bay where they apparently stay or periodically occur throughout the summer (Kleinenberg et al. 1964) .

As far as the Chukchi and East Siberian seas, several informants from Little Diomede Island (U.S.A.) informed the senior author that in former years when they traveled by skin boats to the settlements of Naukan and Uelen, near the northeast tip of the Chukchi Peninsula (up to 1946) , belukhas were seen migrating northward and were occasionally taken in late July-early August. One of the apparent hunting sites was near the estuary between Uelen and Inchoun. According to Arsen'ev (1937, in Tomilin 1957) belukhas are reported to occur in coastal waters of the northern Chukchi Peninsula to a point as far west as Chaunskaya Guba in the East Siberian Sea. They have also been reported at Cape Schmidt in the East Siberian Sea (Arsen'ev 1939, in Kleinenberg et al. 1964). They are apparently numerous in the vicinity of Kolyuchinskaya Guba and Ostrov Vrangelya (Wrangel Island) (Kleinenberg et al. 1964).

Soviet investigators were the first to report that in summer these whales occur offshore as well as nearshore. Kleinenberg et al. (1964, p. 288) stated, "Observations from the air showed that the belukha is also found in summer at the edge of finely broken 4/10-5/10 ice and in polynyas, cracks, and leads in heavier pack ice of 9/10-10/10." The occurrence of belukhas in offshore waters during summer was also found to be the case in western North America (Davis and Evans 1982; this study).

Yablokov (1979) stated that there are no good census data from Soviet waters on which to base estimates of the size of various groups or populations. His approximate estimates of numbers include 1,000 to 2,000 in the East Siberian-Chukchi seas and 2,000 to 3,000 in Bering Sea. It is noteworthy that the 1985 entrapment in Proliv Senyavina, involved up to 3,000 belukhas.

In coastal waters of Alaska and northwest Canada, summer distribution of belukhas extends from Bristol Bay to Amundsen Gulf. The best available estimates of belukha abundance are for these waters and are as follows (see also Seaman et al. 1985).

In Bristol Bay, numbers of belukhas during summer have apparently remained about the same over many years. The estimates are of 1,000-1,500 animals (Brooks 1954b, 1955; Lensink 1961; Frost et al. 1984). At other locations in Alaska the estimates are 1,000-2,000 in the Yukon River Delta to Norton Sound (Seaman et al. 1985; this study) and 2,500-3,000 along the Chukchi Sea coast from Kotzebue Sound to Point Barrow (Seaman et al. 1985; this study). The estimate of 1,000-2,000 for the Yukon River Delta-Norton Sound region is conservative. In mid-June 1956, more than 2,000 belukhas were present in and near the middle mouth of the Yukon River (R. A. Hinman, Alaska Dept. Fish and Game, Juneau, personal communication, 23 Feb. 1985). No assessments have been made in the region between Bristol Bay and the Yukon River Delta, though belukhas are there during summer. Thus, the number of belukhas in coastal waters of western Alaska during summer is minimally estimated at 4,500-6,500 animals.

Several aerial surveys have been undertaken in the eastern Beaufort Sea and Amundsen Gulf. Sergeant and Hock (1974), based on preliminary surveys, estimated that there were 4,000 belukhas present in the Mackenzie Delta region. Subsequent estimates in the Mackenzie estuary were based on more extensive surveys, the results of which were published mainly by Fraker (1977, 1980) and Fraker and Fraker (1982). The more recent of these works placed the number of belukhas in the Mackenzie estuary at about 7,000, not including neonates. Davis and Evans (1982) considerably expanded the survey area beyond the Mackenzie estuary and found that the minimum number of whales in the eastern Beaufort and Amundsen Gulf was 11,500. Their methods of arriving at the estimate were very conservative. Without doubt, future efforts in the eastern Beaufort Sea-Amundsen Gulf region will result in significantly higher numbers of belukhas being accounted for.

Considering these various estimates, the minimum number of belukhas in coastal waters of Alaska, together with those in the eastern Beaufort-Amundsen Gulf region, during summer is on the order of 16,000 to 18,000.

Burns' (1984) estimate of a minimum population on the order of 25,000 to 30,000 belukhas for the Bering *Sea* population as a whole is based on the assumptions of 3,000-4,000 belukhas occurring in offshore waters of the western Beaufort, northern Chukchi, and East Siberian seas; 6,000-8,000 in Soviet coastal waters, including those around Wrangel Island; and 16,000-18,000, as indicated above, for Alaska and Canada. It is highly probable that the Bering-Chukchi population of these whales is larger than 30,000, though at this point such a statement is pure speculation.

The number of whales that summer in waters of North America extending from Bristol Bay to Amundsen Gulf, and from which Alaskan and Canadian hunters kill an annual average of 585, is a minimum of 16,000 to 18,000. Thus, 585 whales *are* removed by hunting (including whales landed as well as those struck and lost) from groups of whales that produce, in aggregate, a minimum of 1,680 to 1,890 calves per year. Size of the Bering population, as a whole, is significantly larger than 16,000 to 18,000 animals.

Population Discreteness

The implicit assumption throughout this report is that belukhas in the Bering, Chukchi, Beaufort, and eastern part of the East Siberian seas and Amundsen Gulf are a single genetic population. This population winters in the ice-covered regions of the Bering Sea and, severity of winter ice conditions permitting, into the southern Chukchi Sea. During summer and early autumn, the seasonal range is greatly expanded, as indicated in several previous sections. The wide summer distribution includes nearshore waters, more distant waters in the Beaufort and western Chukchi seas, as well as the ice fringe and "front" north to (and perhaps into) the consolidated pack.

On an annual basis, there is great variability in numbers of whales and the duration of their occurrence in coastal areas, as indicated by our work in Norton Sound, Kotzebue Sound, and Kasegaluk Lagoon. This was also found to be the case in Bristol Bay (Brooks 1955), the Mackenzie estuary (Slaney 1975, Fraker 1980), and the Kara Sea (Tomilin 1957).

Recently, several authors have urged the recognition of separate summer aggregations of belukhas as constituting different stocks (Fraker 1980; Finley et al. 1982; Braham 1984). However, Yablokov (1979, p. 18) indicated that, "Very possibly, animals from Anadyr Bay (Bering Sea) belong (or are more closely connected) to the northern population." Such a view would be in agreement with reports of northward-migrating belukhas near Naukan and Uelen in July-August, seen in former times by Eskimos from Little Diomede Island. The most significant aspect of stock discreteness is whether or not the summer aggregations of whales that occur in coastal waters comprise different, reproductively isolated groups (populations). For the Bering population, that question will not be definitively answered until the annual movements and interactions among the different aggregations are known.

From our perspective, all of the available information supports the view that belukhas of the Bering, Chukchi, Beaufort, and eastern part of the East Siberian seas are of a single, interbreeding population.

Biological parameters we have examined show similarity in the whales from Bristol Bay to the Mackenzie Delta. It is clear that these whales winter in the Bering Sea. The majority of them pass through the narrow confines of Bering Strait during both the spring and autumn migrations. Extensive intermingling is suggested by the occasional sightings of huge aggregations such as those reported by Fedoseev (in Kleinenberg 1964) and Ray et al. (1984) and our observations in the region generally north of Point Barrow. Breeding probably occurs earlier in spring than was formerly thought, at a time when these belukhas are in the Bering Sea or just beginning the spring migration. There are no natural barriers to prevent intermingling during the breeding period or at other times of the year.

Belukhas are known to also form huge aggregations. Dorofeev and Klumov (1935a) reported the largest of which we are aware, no less than 10,000 animals in the Gulf of Sakhalin (Okhotsk Sea) during mid-June.

Our review of what is known about the seasonal movements, distribution, and biology of belukhas throughout their range suggests to us that different populations, in the traditional sense, are not necessarily represented by geographically separated summer aggregations. Different populations of belukhas are those for which the array of seasonal habitats, particularly those occupied in late winter-early spring, are separate. There can be both large and small, discrete populations. That appears to be the situation in Alaska with respect to the small (300-500 animals) Cook Inlet population and the much larger Bering population.

Physiography of the Bering-Chukchi region, as habitat for belukha whales and some other ice-associated marine mammals of the northern hemisphere, is unique. The region is very large. Extensive heavy ice conditions that preclude overwintering, mostly prevail north of the confines of Bering Strait. Favorable ice conditions occur, to varying degrees, south of the Strait. Species that winter in the seasonally ice-covered regions of Bering Sea have access to extensive summer ranges within the Bering Sea as well as the broader areas including the Chukchi, Beaufort, and part of the East Siberian seas. Species that exhibit seasonal movement patterns somewhat similar to those of belukhas in this region include spotted (Phoca largha) , ribbon (Phoca fasciata) , and bearded (Erignathus barbatus) seals, bowhead whales, and Pacific walruses. Pacific walruses exhibit a high degree of segregation during summer, with disjunct aggregations occurring at several locations along the Soviet and American coasts. Additionally, nearly all females and young summer in the Chukchi Sea and nearly all adult males in the Bering Sea (Fay et al. 1984) .

Behavior

Because of the focus of our study, relatively little information about behavior of belukhas was obtained; thus, this section is mainly a discussion of information in reports and published literature.

Duration and Depth of Dives

As indicated by Ridgway et al. (1984), belukhas are not generally considered to be deep-diving animals, perhaps because of their abundance in relatively shallow coastal waters. Dhindsa et al. (1974) measured the respiratory characteristics of blood from belukhas maintained in captivity. They found a high blood oxygen capacity (25.8 vol.%) though they did not comment on the diving capabilities of belukhas. Ridgway et al. (op. cit.) measured blood characteristics of two active belukhas maintained in excellent physical condition. Blood oxygen capacities (Hb x 1.34) were similar to, but slightly higher than reported by Dhindsa et *al.* (op. cit.); being 28.0 and 27.2 vol.% for a juvenile male and an adult female, respectively. Mean hematocrits were 52.6% and 52.2% for the male and female.

Additionally, Ridgway et al. (1984) provided the most rigorous information about depth of dives, using the two animals for which blood characteristics were determined. The whales were trained to dive in the open ocean. During their experiments, the belukhas remained submerged as long as 15 min 50 s and the adult female dove as deep as 647 m.

Frost et al. (1985) monitored two radio-tagged belukhas in comparatively shallow areas of Bristol Bay, Alaska. A subadult male remained submerged for a maximum of 5 min 56 s and mean duration of its dives was 2.09 min. An adult female dove for a maximum of 2 min 8 s. Percent of time at the surface was found to be 3.8 and 34.7 for the male and female respectively.

Dorofeev and Klumov (1935a) reported that belukhas normally dive for 1 to 1.5 min and up to 3 min when alarmed. Kleinenberg et al. (1964) indicated that these whales can remain under water for 15 to 20 min. Hill (1967; 1968) reported maximum dive time of an entrapped belukha to have been 7 min

25 s though he also indicated that the last surviving whale at an entrapment was absent for up to 40 min. Hay and McClung (1976) reported the duration of dives (presumably all in shallow water) to average only 52 s.

Swimming Speed

Swimming speed of belukhas was reported by Dorofeev and Klumov (1935a) to be 3 to 5 knots (5.6 to 9.3 km/h) when undisturbed and up to 7 knots (13 km/h) when disturbed. Ray et al. (1984) reported that whales with young swam at the rate of 2.3 km/h and traveling groups (without young?) moved at 7 km/h. Kleinenberg et al. (1964) indicated that belukhas swim at 5-6 km/h with a maximum speed of 20 km/h. Ridgway et al. (1984) determined swimming speeds during commanded dives for an immature male and an adult female belukha. The male descended at an average rate of 8.2 km/h and ascended at 8.1 km/h; speeds for the female were 7.2 and 8.2 km/h respectively. Frost et al. (1985) reported a movement of 30 km in 6 h for a juvenile, radio-tagged male, an average of 5 km/h. They also reported regular daily movements by belukhas of 100 to 150 km.

Feeding

Feeding activity of belukhas while they are in estuaries and river mouths has been a point of considerable discussion. Sergeant (1973) suggested that the main advantage of the use of estuarine habitats during summer derives from the thermal advantages of warmer waters to neonates. He indicated that belukhas feed very little while in estuaries. In Alaskan waters, the occurrence of belukhas in rivers and estuaries is usually strongly associated with seasonal concentrations of fish, and the whales prey extensively on them. Bristol Bay is the best-studied location (Brooks 1954a-1957; Lensink 1961; Frost et al. 1983; Lowry et al. 1985). In that region, belukhas enter the estuaries and rivers as early as March and remain through July. They feed intensively on seaward-migrating smelt (Osmerus mordax) in March-to May, on seaward-migrating sockeye salmon smelt in May-June, and on returning adult salmon, mainly sockeye, during June-July.

In the Yukon River and Norton Sound, belukhas arrive as soon as ice conditions permit, usually in late May or early June. Here, according to local residents, they also feed extensively on smelt, on the huge spawning concentrations of herring (Clupea harengus pallasi) , and different species of salmon. Lowry et al. (1985) found that near Norton Bay, in June, belukhas had been feeding on herring, saffron cod (Eleginus gracilis), and various sculpins.

Aspects of belukha food habits, particularly in the Kotzebue Sound area, are discussed in great detail by Lowry et al. (1985) . Of interest here is that the intensity of recent feeding by whales taken in Eschscholtz Bay during June was highly variable among years. Based on our sampling at that location, they were regularly feeding. In most years feeding apparently occurred in Kotzebue Sound, some hours prior to the whales' entering the confines of Eschscholtz Bay. Volumes of food remains in stomachs were relatively small and well digested. However, June 1982 was the exception in that belukhas were observed to be actively feeding within Eschscholtz

Bay and the volume of fresh food remains in stomachs, from which we collected subsamples, was consistently much greater than during previous years. Thus, it appears that the whales actively feed while in coastal waters of Kotzebue Sound and that whether or not they feed while in Eschscholtz Bay is a function of prey abundance (as it probably is at other nearshore locations).

The age at which young belukhas begin to feed independently, is not well known. Kleinenberg et al. (1964) reported the different opinions of various investigators and stated, " . . . we agree with the majority of authors that the lactation period lasts about half a year." The timing of our collections was such that we have no samples of first year animals between the birth period (when neonates are nursing) and about 1 year. A 12-month-old whale taken in Eschscholtz Bay had been feeding on saffron cod and remains of 26 such fishes *were* in its stomach (Lowry, personal communication).

Occurrence in Estuaries and Rivers

Nearshore movements in the lower (tidally influenced) reaches of rivers and confined estuaries are usually closely correlated with the ebb and flow of tides (see discussion of hunting in Eschscholtz Bay). Belukhas normally move into the confined estuaries and river mouths on incoming tides and return seaward during the ebb (Arsen'ev 1939; Vladykov 1944; Brooks 1954a; Lensink 1961; Kleinenberg et al. 1964; Frost et al. 1983; and numerous others).

These whales are known to ascend major rivers to a considerable distance upstream. Numerous occurrences were summarized by Kleinenberg et al. (1964). Yablokov (1979) stated that, at present, small schools of belukhas enter all large Siberian rivers. In the Yukon River of Alaska they were reported as far upstream as Nulato, 729 km by river from the sea (Nelson and True 1887). In mid-June 1982, five belukhas were reported near Tanana, 1,119 km from the mouth of the Yukon (B. Lentsch, personal communication) and a few days later a single whale was seen 18 miles above Rampart, at a location 1,257 km from the sea (P. Wakefield, personal communication). Other past occurrences of these whales in fresh water are indicated by Alaska place names including two different Beluga lakes, Beluga River, and Beluga Slough (Orth 1971).

Disturbance by Noise

Tolerance of non-lethal disturbance by cetaceans has proven very difficult to evaluate if only because of the difficulties of conducting controlled experiments on free-ranging whales. As Reeves et al. (1984) point out, under normal field conditions there are many problems involved in relating behavioral responses to acoustical stimuli.

There are most certainly great differences in potential for harmful effects between short-term, minor modification of behaviors such as group formation, position, swimming speed, dive time, or breathing rates, as compared to displacement from advantageous habitats, disruption of migration and movement routes, significant interruption of feeding opportunities, or other important vital functions.

As has been implied in this report as well as in all studies based on sampling of belukhas at traditional, nearshore hunting locations, the most intensive kind of repetitive disturbance is hunting. In spite of it, belukhas mostly continue to return to favored bays, estuaries, and rivers throughout their range. However, there have been changes in activity patterns, duration of use of favored areas, and tolerance to human-caused sounds.

Several recent reports deal with responses of belukhas to noise. Fraker (1977) observed that belukhas move away from approaching tug and barge traffic. In one instance, he found that a large group of belukhas being observed responded by rapidly swimming away from such vessels at a distance of 2.4 km. Scattering of these whales was still evident 3 h after the incident, but by 30 h they had resumed a normal distribution near their original location. As Mansfield (1983) pointed out, reaction of whales in the incident reported by Fraker (ibid.) was initiated at a distance far less than the estimated maximum perception range of sounds from the tugboat. Fraker (op. cit.) also found that belukhas reacted more to moving, as opposed to stationary, sound sources and that frequent tug and barge traffic impeded the movement of belukhas in that they did not move along their normal travel route until vessel activity temporarily ceased.

With respect to stationary sources of noise, McCarty (1981) reported that in Cook Inlet, Alaska belukhas, including females and calves, passed as close as 10 m to active oil production platforms. Further, belukhas seemed not to be affected by constant noise but showed a temporary avoidance reaction to sudden changes of noise levels.

Stewart et al. (1982, 1983) reported on results of their studies in the Bristol Bay region. They found that responses of belukhas to noise were strongly affected by both the activity of whales and the habitat in which noise occurred. Their work was in the snake River and Nushagak Bay. The strongest reactions of belukhas were to sounds of outboard motors and, regardless of behavior before outboard motor noises began, whales immediately swam downriver. Similar flight responses were elicited by outboard noise in the bay though not to noises emanating from larger inboard-powered fishing and processing vessels. These authors also found that belukhas responded more to sudden noise disturbance than to constant noise. Feeding and traveling activity of whales was not greatly affected by play-back sounds of oil drilling activities and whales passed close to hydrophores while such sounds were being broadcast. Thomas and Kastelein (1983) found that captive belukhas quickly acclimated to sounds of oil drilling activities played at typical sound levels.

Tolerance to disturbance by human activities seems highly variable and it is difficult to make any generalizations, except that in Alaska, displacement of belukhas seems to occur to a greater degree in regions where the variety of man-caused intrusions includes active hunting. This suggests a degree of habituation, or lack thereof, associated with experience. Significant hunting only occurs in western and northern Alaska.

In Cook Inlet, belukhas seasonally occur close to the busy seaport of Anchorage and in the mouths of larger rivers where small boat traffic is heavy.

In the Bristol Bay region the whales likewise frequent rivers where fishing vessel traffic is especially heavy and parts of the bay where actual fishing effort is intense. Entanglement in salmon gillnets occurs and has already been discussed.

The situation north of Bristol Bay is apparently far more complex. Belukhas are hunted by coastal residents whenever the whales are available. In the Kuskokwim Bay region local residents consider the whales to be easily frightened by outboard-powered small boats, low-flying aircraft, and other loud noises. They indicate that whales still frequent Kuskokwim Bay but are far less tractable (in the sense that they can be herded) than during the days prior to the advent of high-powered outboard motors. That same opinion is shared by whalers of the Yukon Delta, Norton Sound, and Kotzebue Sound (Seaman and Burns 1981).

The experiences of whalers that hunt in and near Eschscholtz Bay have led them to conclude that disturbance of belukhas by small boat traffic and low-flying aircraft often keeps the whales from entering the bay. As a result, an agreement among the hunters and with local aircraft operators, in effect when whales are known to be present, restricts such traffic to times that coincide with low tide. The whalers are very aware that belukhas normally enter Eschscholtz Bay a few hours after the tide begins to rise. Sergeant and Brodie (1975) referred to excessive hunting or boat traffic near an Eskimo settlement in eastern Canada as a possible cause for a shift in whale distribution.

Eskimo lore also indicates differences in tolerance levels of belukhas in the pack ice. Whales passing through narrow leads or other small openings in the ice are said to be easily frightened by hunters. Those whales in large openings or wide leads reportedly often move at a more leisurely speed and frequently stop, mill about, or remain at the surface for longer periods of time. It would seem that the more confined openings increase both the risk of whales to predation by polar bears and the "alertness" of older, experienced whales in conditions that place them at high risk.

In western Alaska there is a generally held belief that the modernization of coastal communities, with all of the associated noises (generators, heavy equipment, airplanes, snow machines, outboard motors, etc.) and odors, is presently causing belukha whales and other marine mammals to pass communities at a greater distance from shore and to partially abandon traditionally favored sites now in close proximity to settlements. Sheshalik (= Sesualik and other dialectal variants of Inupiat), adjacent to the large community of Kotzebue is a location where belukhas, though still present, no longer remain in large numbers for long periods of time during summer. This geographic place name means a location where belukhas (sisuaq) congregate. Effects of such displacement are unknown. It seems probable that such avoidance responses are beneficial to the whales in that they are less exposed to hunting. As more information about belukhas has accumulated, it seems likely that such vital functions as successful birth and nurture of calves can occur beyond the coastal zone. Displacement from estuarine waters where whales are intensively hunted may not have an overall, adverse effect on the whale population if suitable habitat in other areas remains available.

Conversely, from a homocentric perspective, such displacement has a negative impact on subsistence users of belukhas and on opportunities for people to observe and study these whales.

ADDITIONAL RESEARCH NEEDS

Some conclusions we have drawn from this study are based either on limited data, or extensions of available information to geographic areas for which adequate data are not available. There are many information needs about belukhas in general and about the Bering Sea population in particular. Those we find to be most pressing are as follows:

1. At present, there is no information about the reproductive biology of belukhas during late winter-early spring. Therefore, duration and peak of the breeding period is not adequately known. Appropriate . biological samples may be difficult to obtain because most belukhas are taken in late spring-early summer. However, it may be possible for investigators that work in waters adjacent to Greenland to sample entrapped whales that are taken by hunters during February to April.

2. The summer distribution of belukhas within and along the ice front zone of the Chukchi, Beaufort, and eastern East Siberian seas should be determined. A substantial portion of the Bering Sea population may occur in that habitat at the same time that whales occur in coastal waters in greatest numbers.

3. The number of belukhas that occur in Soviet coastal waters of the Bering, Chukchi, and East Siberian seas during summer, is unknown and should be studied. In a preliminary way, this could be accomplished through carefully designed aerial survey efforts.

4. The extent of segregation and perhaps habitat partitioning by belukhas, based on age, sex, and reproductive status is not known. These can be studied by sampling whales at different times during the prolonged spring migration or at entrapments that may occur in the same region at different times during winter and spring.

5. Relationships among different summer aggregations of belukhas in waters of northwestern North America and northeastern Asia are not known, though we suggest that they are all part of a single Bering Sea population. The extent of interchange during summer and of intermingling while whales are in Bering Sea during winter-early spring, can be studied with the aid of radiotelemetry techniques. Application of radio tags should be done as soon as possible.

6. Monitoring of annual harvests, at least on an intermittent basis, should be undertaken to determine magnitude and variation as well as extent of hunting loss, composition of harvested animals, and the biological parameters (particularly those relating to productivity) that can be determined by sampling harvested whales.

7. No systematic effort has yet been made to determine the regional distribution and abundance of belukhas in Bering Sea, during winter. It is probable that areas of high whale abundance do occur, perhaps

regularly. The need for information about stock identity and about whale distribution in relation to proposed offshore petroleum development, warrants initiation of efforts to determine winter-early spring distribution and relative abundance.

8. In the Chukchi Sea, incidence of ice entrapment during spring migration appear to be closely correlated with weather during March to mid-May. Assessment of entrapment as a source of direct mortality, and as a factor contributing to increased predation by polar bears should be attempted on an opportunistic basis.

9. Food habits of belukhas in waters beyond the coastal zone are not known and should be studied. It is recognized that such an undertaking would require an ability to respond to opportunistic situations involving belukhas killed by polar bears or at occasional entrapments.

10. Size of the Bering Sea population of belukhas is not known. It is recognized that several preliminary studies must be undertaken before a broad-based aerial census will be feasible. Such preliminary undertakings are indicated as items 2, 3, and 5 (above) .

11. Annual variability and magnitude of the incidental catch of belukhas associated with the Bristol Bay salmon fishery should be determined. Preliminary studies indicate that such mortality may be substantial in some years.

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PERSONAL COMMUNICANTS

Adams, B., marine mammal hunter and lifelong resident of Kivalina, AK.

Adams, R., marine mammal hunter and lifelong resident of Kivalina, AK.

Agnassagga, A., marine mammals hunter and lifelong resident of Point Lay, AK.

Ahkinga, O., marine mammal hunter and lifelong resident of Little Diomede Island, AK.

Albert, T. F., Senior Scientist, North Slope Borough, Barrow, AK.

Alice, J., Fraternity of the Little Sisters of Jesus, Little Diomede Island, AK.

Amstrup, S. C., polar bear project leader, U.S. Fish and Wildl. Serv., Anchorage, AK.

Arsen'ev, V. A., marine mammals specialist, All-Union Research Institute of Marine Fisheries and Oceanography (VNIRO) , Moscow, U.S.S.R.

Bartels, R., formerly the Assistant Refuge Manager, Arctic National Wildlife Refuge, U.S. Fish and Wildl. Serv., Kaktovik, AK.

Baxter, R., formerly a fisheries biologist, Ak. Dept. Fish and Game, Bethel, AK.

Behnke, S. R., formerly a resource specialist, Subsistence Division, Ak. Dept. Fish and Game, Dillingham, AK.

Bitters, J., formerly employed at Naval Arctic Research Laboratory, Barrow, AK.

Brooks, J. W., formerly a belukha whale, pinniped, and polar specialist, resource administrator and expert. Currently with the Nat. Mar. Fish. Serv., Juneau, AK.

Burch, E. S., Jr., anthropologist with many years of experience in northwest Alaska. Harrisburg, PA.

Burns, J. J., Jr., formerly a fisheries technician, Yukon-Kuskokwim area, Ak. Dept. Fish and Game, Bethel, AK.

Clarke, R. G., formerly a field assistant, Nat. Mar. Fish. Serv. bowhead whale monitoring program at Point Hope, AK.

Coady, J. W., Regional Supervisor, Ak. Dept. Fish and Game, Nome, AK.

Curtis, R., former longtime polar bear hunting guide, Anchorage, AK.

Dewey, K., marine mammal hunter and lifelong resident of Koyuk, AK.

Dohl, T. P., cetacean specialist, Univ. Calif., Santa Cruz, CA.

Dronenberg, R., formerly with the Naval Arctic Research Laboratory and the Alaska Eskimo Whaling Commission, Barrow, AK.

Duniushkin, S. P., Marine Mammal Inspector, Okhotskryibvod, Magadan, U.S.S.R.

Fay, F. H., marine mammals specialist, professor, Univ. of Alaska, Fairbanks, AK.

Fedoseev, G. A., marine mammals specialist, Pacific Scientific Research Institute of Fisheries and Oceanography (TINRO) , Magadan, U.S.S.R.

Fiscus, C., marine mammals specialist, formerly with NMFS, Seattle, WA.

Fray, J., pilot, Seward Peninsula Flying Service, Nome, AK.

Frost, K. J., marine mammals biologist, Ak. Dept. Fish and Game, Fairbanks, AK.

Furber, D., pilot, Shellabarger Flying Service, Kotzebue, AK.

George, J. C., North Slope Borough, Dept. Environmental Protection, Barrow, AK.

Gol'tsev, V. N., formerly a marine mammal inspector, Okhotskryibvod and marine mammals specialist, TINRO, Magadan, U.S.S.R.

Goodwin, W., marine mammal hunter and lifelong resident of Kotzebue, AK.

Hadley, N., belukha whale hunter and reindeer herder, lifelong resident of Buckland, AK.

Hanson, J., marine mammal hunter and lifelong resident of Alukanuk, AK.

Hinman, R. A., Deputy Director, Game Division , Ak. Dept. Fish and Game, Juneau, AK.

Hittson, G., Public Safety Officer and resident of Point Lay, AK.

Iyahuk, A., marine mammal hunter and lifelong resident of Little Diomede Island, AK.

Jacobson, J. P., pilot, dentist, entrepreneur, and resident of Kotzebue, AK.

Johnson, S. R., biologist, LGL Ltd., Edmonton, Canada.

Kaleak, W., whaling captain and lifelong resident of Barrow, AK.

Katchatag, C., marine mammal hunter and lifelong resident of Shaktoolik, AK.

Lentfer, J. W., formerly the polar bear specialist for Ak. Dept. Fish and Game and U.S. Fish and Wildl. Serv., Juneau, AK.

Lentsch, W. J., pilot, Tamarack Air Ltd., Fairbanks, AK.

Lowry, L. F., marine mammals biologist, ADF&G, Fairbanks, AK.

Manning, A. E., formerly with the Naval Arctic Research Laboratory. Fairbanks, AK.

Marquette, W. M., marine mammals biologist, Nat. Mar. Fish. Serv. , Nat. Mar. Mammal Lab., Seattle, WA.

Moore, G., formerly a Resource Specialist, Subsistence Division, Ak. Dept. Fish and Game, Kotzebue, AK.

Nelson, R. R., Biologist, Ak. Dept. Fish and Game, Nome, AK.

Newman, M. A., Director, Vancouver Public Aquarium, Vancouver, B.C., Canada.

Omiak, P., marine mammal hunter and lifelong resident of Little Diomede Island, AK.

Patkotak, B., marine mammal hunter and lifelong resident of Wainwright, AK.

Patten, S. M., Jr., Game Biologist, Ak. Dept. Fish and Game, Bethel, AK.

Pete, F., hunter and lifelong resident of Stebbins, AK.

Punguk, D., hunter and lifelong resident of Golovin, AK.

Quimby, R. L., formerly Game Biologist, Ak. Dept. Fish and Game, Kotzebue, AK.

Sacceous, C., hunter and lifelong resident of Elim, AK.

Schneider, K. B., Game Biologist, Ak. Dept. Fish and Game, Anchorage, AK.

Schwarz, L. J., Fisheries Biologist, Ak. Dept. Fish and Game, Nome, AK.

Smith, T. E., Game Biologist, Ak. Dept. Fish and Game, Nome, AK.

Smullen, D., formerly a field assistant, Nat. Mar. Fish. Serv., bowhead whale monitoring program at Point Hope, AK.

Somov, A. G., Marine Mammal Inspector, Okholskryibvod, Magadan, U.S.S.R.

Taylor, K. P., Game Biologist, Ak. Dept. Fish and Game, Dillingham, Ak.

Uhl, B., belukha netter, Sheshalik, AK.

Wakefield, P., pilot and fish buyer on the Yukon River, Fairbanks, AK.

Walker, N., former longtime polar bear hunting guide and commercial pilot, Kotzebue, AK.

Wilson, Y., belukha whale hunter and lifelong resident of the Kotzebue Sound region.