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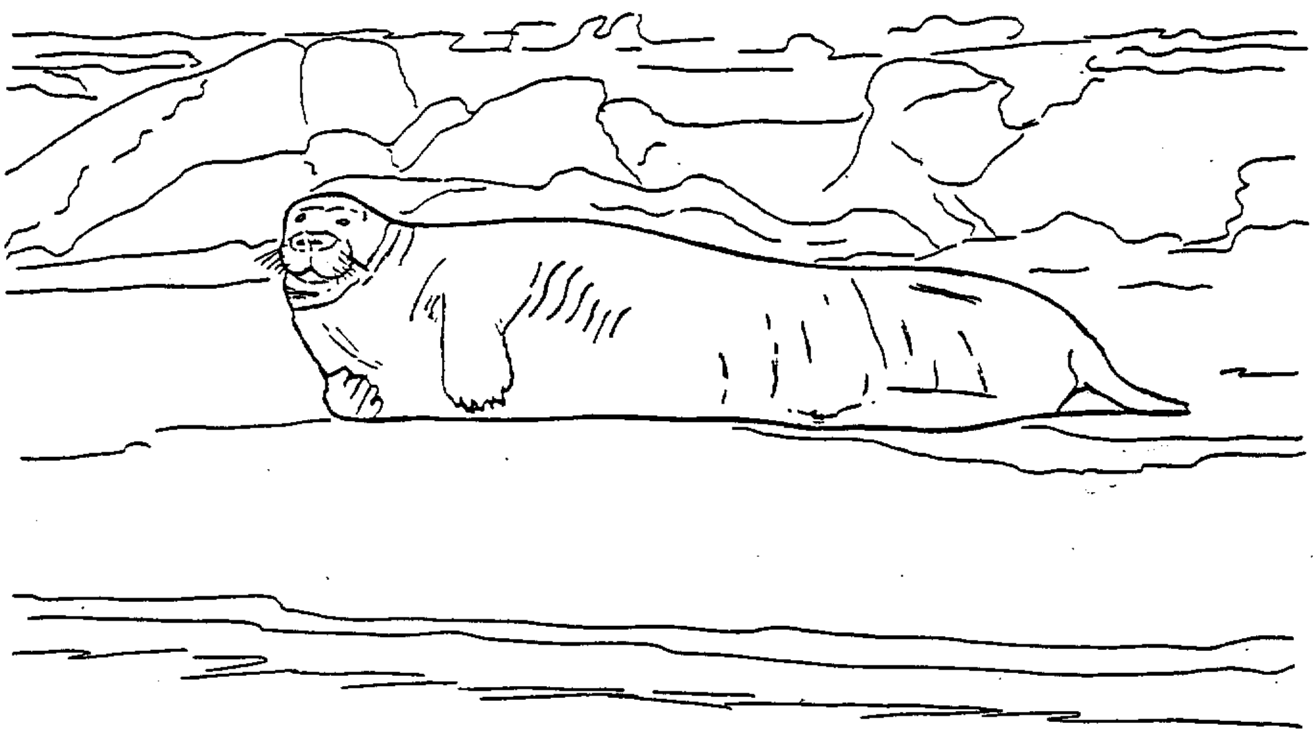
The Natural History and Ecology of the Bearded Seal, *Erignathus barbatus*



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Some of the specimen material and data included in this report was collected prior to initiation of the OCSEAP projects. These were obtained by personnel of the Alaska Department of Fish and Game and were acquired as part of projects funded by Federal Aid in Wildlife Restoration, mainly project W-17.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. Summary

A study of the natural history and ecology of bearded seals (Erignathus barbatus) was undertaken from June 1975 through April 1979. Of the proposed OCS lease areas which are north of the Alaska Peninsula, the Bristol, Norton and Hope Basins seasonally support the greatest numbers of bearded seals. The Beaufort Basin supports relatively low numbers of these seals but on an almost year round basis. St. George Basin and Bristol Bay are important for the direct support of these seals during years of extensive ice cover and the Navarin Basin is beyond the normal limit of bearded seal distribution. The continental shelf underlying the Bering and Chukchi Seas provides the largest continuous area of favorable bearded seal habitat in the world.

For the most part bearded seals maintain an association with drifting, relatively disturbed, sea ice during all months. As a result, these seals move extensively, being most numerous in Bering Sea during winter-spring and in the northern Chukchi Sea during summer-fall. It appears that seasonal movement into and out of the Beaufort Sea occurs but is not great except in the western part. The seasonal extremes of range vary considerably depending on annual variation in ice conditions.

Age composition of harvested seals was strongly biased toward pups. Thus, direct evaluation of harvest characteristics was not possible. After evaluation of biases influencing composition of the harvest, it was concluded that during early summer pups comprise 22-25 percent of the population, subadults (ages 0 through 3) 40-45 percent and animals 4 years and older 55-60 percent. The sex ratio was close to unity in pups and favored females in older age classes. Analysis of harvest data for individual collection years indicated variation in survival of pups born in different years. Age structure of the harvest was fitted into a "smoothed" age frequency distribution for the populations. This fitted age structure indicated that in early summer the population included 22 percent pups, 44 percent juveniles (ages 0 through 3) and 56 percent 4 years or older. These findings were in agreement with those derived through our understanding of factors which biased age composition of harvests.

A preliminary life table was developed and presented. Mean mortality rate for all ages (0-27) was found to be 219/1000 individuals. It was 96/100 individuals for age classes 6-27. The mean mortality rate for males was higher than for females and may account for the greater proportion of females in older, harvested animals.

Recent harvests are reported. In 1976 the American catch of bearded seals was 2,125 and 4,750 were taken in 1977. The contribution of bearded seals to village economies was estimated based on a reported harvest of 6,308 bearded seals landed between January 1977 and June 1978. The model age of a seal in that harvest was 5.1 years. Weight was 156.9 kg and its "equivalent monetary contribution" to a village was $285.62. The equivalent monetary contribution of this resource to Alaskans during the 18 months indicated above was $1,801,682. Bearded seals are an important resource to residents of northern Alaska.

Parameters of growth in these seals are presented. At birth pups averaged 131.3 cm long and weighed 33.6 kg. Mean length of all seals 9 years or older was 219.7 cm. Weights varied seasonally. Weight of adult females averaged 250.3 kg in spring and 228.6 kg in midsummer. The average weight of two adult males taken in winter was 390.0 kg. It was 244.4 kg in males taken during summer. These seals are heaviest during fall through early spring. Girth of bearded seals varies seasonally and is between 71 and 83 percent of the standard length. Thickness of the skin and blubber layer also varies with season between an average of 7.2 cm in winter and 4.4 cm in summer. Hide and blubber account for between 29 and 39 percent of total body weight.

Males attain sexual maturity at 6 or 7 years of age, females at 4 to 7 years (average age was 6 years). Breeding is mainly in May and implantation is mainly in July. The pregnancy rate for all females in our samples, ages 4 and older, was 77 percent. It was 83 percent in females 6 years and older. The latter value was the same as that derived in the same manner for females examined between 1962 and 1966. We found no evidence of reproductive senility in females.

Some behavioral characteristics of bearded seals are reported. These seals occupy areas of drifting ice. Pups are born on the ice floes with little shelter. The mother-pup bond is strong, pups can swim shortly after birth and lactation lasts for 12 to 18 days. Some pups probably begin independent feeding during the late stages of nursing. They feed as soon as they are weaned and therefore do not undergo a fasting period immediately after weaning occurs.

Bearded seals are relatively tolerant of aircraft and boats. Their tolerance to noise is unknown. They are highly vocal.

Major foods of these seals include crabs, shrimps, mollusks (including clams during summer) and some fishes (mainly cods and sculpins) on a year round basis. Shrimps were important to bearded seals in their first year of life. The specific prey species utilized varied with time and location.

Information on pathology and contaminant burdens was summarized from available literature. Pesticides found in bearded seal tissues included DDT, DDD, DDE, dieldrin and PCB's. Bearded seals had the highest levels of DDT of the Bering Sea phocids examined. Mercury, selenium, cadmium, nickel, copper and zinc were also present in bearded seal tissues. Mercury and cadmium were concentrated in the liver.

Direct effects of OCS development, excluding major accidents such as spills, will probably not be significant to bearded seals and will mainly involve short-term dislocation of animals in areas of exploration and production activity. Indirect effects of OCS development will be much more significant. Accumulations of petrochemical pollutants, under normal conditions of operation, will increase and the possibility of major introductions of contaminants is real.

Organisms eaten by bearded seals (or similar species to those utilized) have been shown to be sensitive to and significantly disadvantaged by petrochemical contamination. Extensive OCS development, in itself, will reduce the carrying capacity of habitats for bearded seals, especially if major accidental releases of fuel, crude oil or other pollutants occur.

II. Introduction

The distribution of bearded seals, Erignathus barbatus, Gill 1866, is circumpolar. These seals are boreoarctic and their effective range is restricted to regions within which seasonal sea ice occurs over relatively shallow waters, less than 200 m (Fig. 1). They are bottom feeders.

Two subspecies have been recognized: E. b. barbatus (Erxleben 1777) in the region extending from the Laptev Sea westward to about Hudson Bay, and E. b. nauticus (Pallas 1811) in the remaining range from central Canada westward to the Laptev Sea (King 1964). Boundaries of these supposedly different forms are unknown and, in view of the ecological strategy of this animal, probably do not exist. Manning (1974) examined 260 skulls from both forms and concluded that recognition of the two subspecies is justified. Conversely, Kosygin and Potelov (1971) concluded, based on examination of 416 skulls, that the subspecific differentiation is not warranted. Their findings suggest a single, wholearctic species.

Since we are not in a position to draw a definitive conclusion in this matter, we use the traditional concept of two subspecies--nauticus being the subject of this report.

In the North Pacific region bearded seals occur in the Japan (Tartar Strait), Okhotsk, Bering, Chukchi, Beaufort and East Siberian Seas. The Bering-Chukchi population, which extends into the Beaufort Sea, is the subject of this report. In the Bering and Chukchi Seas these seals are extensively hunted for human food and byproducts by Alaskan and Siberian Natives. Commercial Soviet sealers, operating from large ships, also hunt them in the Bering and Chukchi Seas.

Of the six proposed OCS lease areas in waters of western and northern Alaska (Fig. 2), the St. George and Navarin Basins are on the southern fringes of the winter range of bearded seals. The remaining four (Bristol Bay, Norton, Hope and Beaufort Basins) are all within the range of these seals.

Common Names of the Seal

Some common names of E. barbatus used in the Bering-Chukchi Sea region include: bearded seal (English), morski zaits (Russian, meaning sea hare, commonly used in the western portion of the USSR), laktak (from the Kamtschatdal term, now generally used throughout the Soviet far east), mukluk (Upik Eskimo term used in southwest Alaska, St. Lawrence

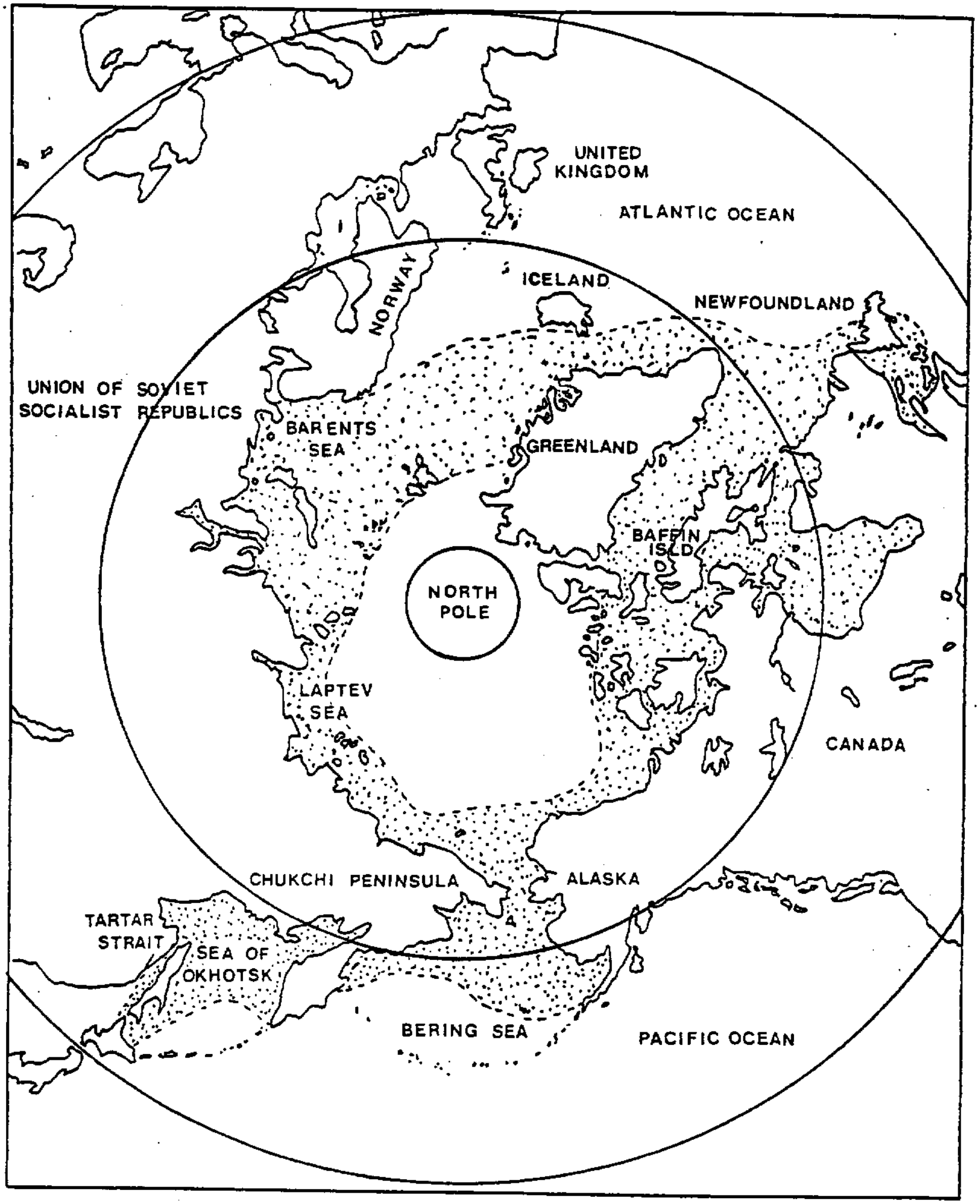


Figure 1. World distribution of the bearded seal, _Erignathus_ _barbatus_.

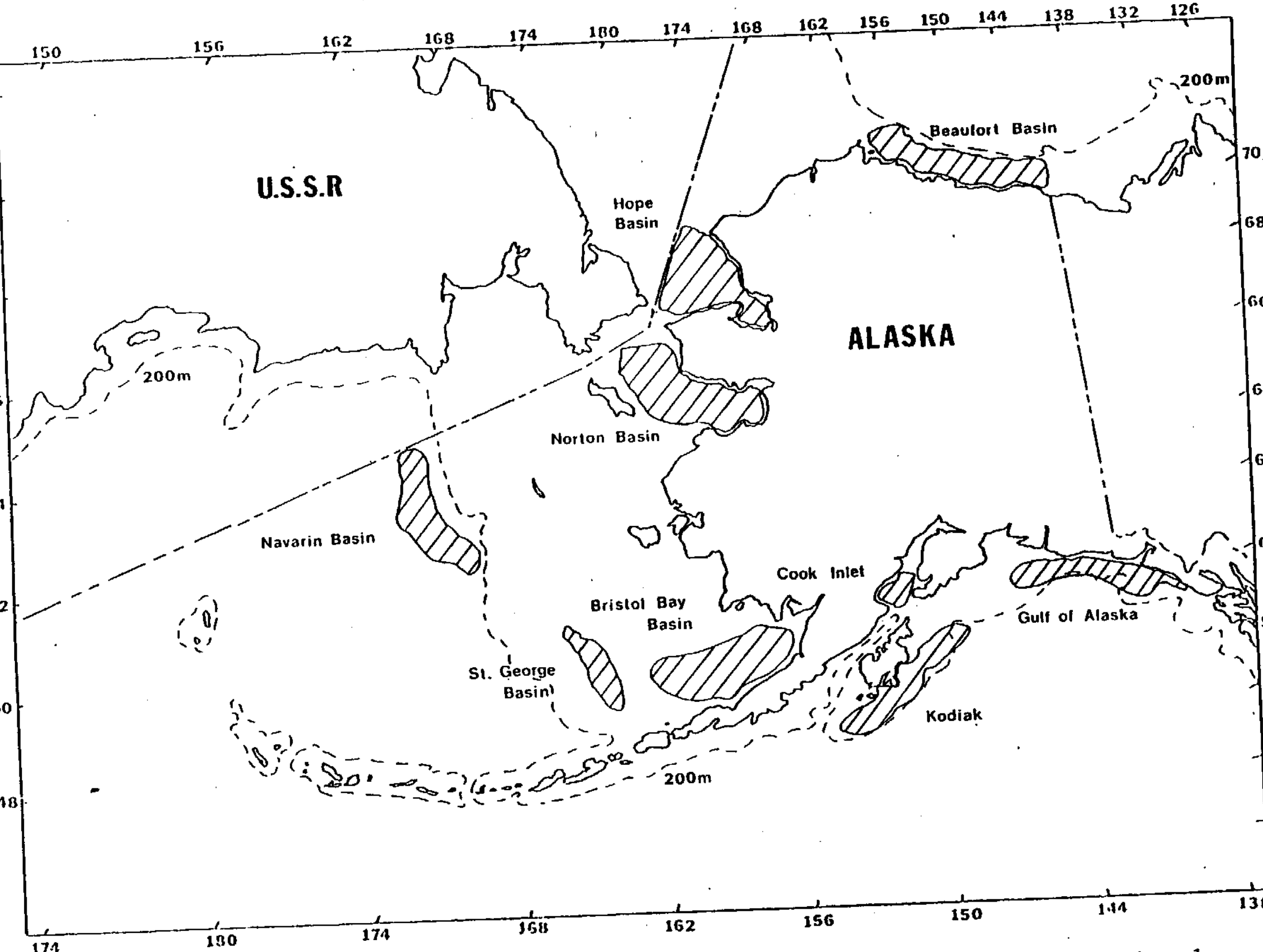


Figure 2. Map of Alaska showing proposed OCS lease areas. In this figure the range of bearded seals roughly coincides with location of the 200 m isobaths.

Island and southern Chukchi Peninsula) and oogruk (Inupiat Eskimo term, a close approximation of which is used by these Eskimos from the Chukchi Peninsula east to Greenland).

External Characteristics and Morphology

The scientific name is descriptive of two prominent features of bearded seals. As indicated by King (1964), the generic name, *Erignathus*, is from Greek and refers to the deep jaw. The specific name, *barbatus*, is derived from Latin and refers to the relatively long and numerous moustachial vibrissae. Obviously, the English common name, bearded seal, is aptly applied. The Norwegian sealer's term, square flipper, is in reference to the shape of the distal portion of the foreflippers, on which the third digit is slightly longer than the others, giving the appendage a blunt, squared appearance. This is in marked contrast to the other northern phocids in which the first digit is the longest.

Bearded seals are the largest of the northern phocids. However, they have a disproportionately small head. This characteristic was noted by Allen (1880) who wrote, "I find that the lower jaw of a very old male *P. vitulina* just fits an adult skull of *Erignathus barbatus*, except that the latter is slightly longer."

These seals have four retractable teats (the other northern phocids have two) which are evenly spaced, two on each side of the midline near the navel.

Coloration

Color of bearded seals is variable. Most adults are basically light to dark gray, slightly darker down the middle of the back. Other individuals vary from tawny-brown to dark brown, also being darkest on the dorsal surface. The sexes are similarly colored. Some younger animals, especially weaned pups, have faint irregularly shaped blotches which are unevenly distributed on the entire body. In general, however, these seals have none of the distinct and diagnostic color patterns such as the spots, rings or bands found in other species. The hair is relatively short and straight. On many animals the face and foreflippers have a rust or reddish brown color.

Term fetuses and newborn pups have dark (usually brown), dense, slightly wavy hair with light coloration on the facial region and one to four broad, transverse light bands on the crown and back. By the time these pups are weaned the pelage resembles that of older seals. Prior to Chapskii's (1938) excellent study of this species, there was considerable confusion in the literature about the pelage coloration of fetal and newborn bearded seals. It was thought that they, like other ice-associated phocids of the north, were white.

General Anatomical Characteristics

The following resumé of some anatomical characteristics of bearded seals was adapted from Burns (in press).

The skull of these seals is wide, comparatively short and more massive than those of other ice-associated phocids of the North Pacific region. Bearded seals commonly break through thin ice with their heads. There is no saggital crest. Teeth are comparatively large, and, except for the upper canines, are weakly rooted. The dental formula is typical of phocids: I $\frac{1\text{-}2\text{-}3}{0\text{-}2\text{-}3}$, C $\frac{1}{1}$, PC $\frac{1\text{-}2\text{-}3\text{-}4\text{-}5}{1\text{-}2\text{-}3\text{-}4\text{-}5}$, on each side for a complete complement of 34. Anomalies are not uncommon and usually involve lack of an incisor or presence of supernumerary postcanines. Teeth are mostly worn down or missing in adults.

The palate is more arched and higher than in other phocids and the mandibles are deep. These features result in a comparatively large buccal cavity, an adaptation for a modified type of suction feeding (presumed).

Mean condylobasal length for 63 adult Pacific bearded seals was 222.8 mm and zygomatic breadth was 130.3 mm (Manning 1974).

The rostrum is broad and rounded, supporting fleshy nasal pads with a large number of vibrissae, the feature on which the English common name of this seal is based.

Fay (1967) reported that a bearded seal he examined had 15 thoracic vertebrae and pairs of ribs, typical of the order Pinnipedia.

The trachea of bearded seals is different from that of other North Pacific phocids in that most of the rings are incomplete. On the average there are 69 rings (64-81) of which only the first 6 to 12 are complete. In the remainder there is a broad elastic membrane between the ends of the flattened rings. Ends of the rings are most widely separated in the central portion of the trachea (Sokolov et al. 1968, Burns unpubl.). The function or functions of this type of trachea are unknown but may be related to production of the unique vocalizations in this animal. The hyoid arch is complete.

Lungs in the bearded seal are multilobular and generally resemble those of ringed seals, having apical, cardiac, diaphragmatic and post-cardiac lobes on the right lung and lacking the postcardiac on the left. These are different from the unlobulated lungs of ribbon seals (Sokolov et al. 1968).

In five large bearded seals average length of the intestine was 2,502 cm. The duodenum averaged 33.6 cm, small intestine 2,164.6 cm and large intestine 303.8 cm.

Average heart weight in adults was found to be about 1,110 g.

III. Objectives

The objectives of this study were as follows:

1. To summarize and evaluate existing literature about bearded seals, particularly that population which occurs in the study area and in the six proposed lease areas within the range of these seals.

2. To determine population structure, dynamics and productivity of these seals as indicated mainly by specimens obtained from Eskimo subsistence hunters.

3. To compare current parameters of species productivity with similar measures determined in the recent past.

4. To determine important aspects of bearded seal natural history including prenatal and postnatal growth, condition, timing of major biological events, habitat requirements and behavior.

5. To determine the magnitude and distribution of annual harvests of these seals by residents of coastal Alaska villages and estimate the contribution of these harvests to village economies.

6. To acquire specimen material, mainly from subsistence harvests, necessary for the successful completion of related studies, particularly that of food habits and trophic relationships.

7. To predict, if possible, the potential effects of various stages of petroleum development on bearded seals.

Collectively, the objectives stated above were intended to provide information required for an assessment of the susceptibility of bearded seals to proposed OCS development, to acquire base line information about these seals against which future findings can be compared, and to provide a species account of use to the general public.

IV. Current State of Knowledge

The bearded seal has been important to man since he first occupied the Arctic and Subarctic regions. Every culture that utilized these large seals developed a body of knowledge about them that was based on observation during generations of hunting, examination of killed animals and a first-hand exposure to part of the environment in which the seals live and interact. Some of this knowledge has found its way into scientific literature, mostly through investigators who recorded the opinions and facts reported to them by Native peoples. Unfortunately, a large body of the information known to local residents of the North has not been recorded and much of it may be lost.

There are numerous references to bearded seals in a large number of publications dealing with various aspects of the Far North. Earliest accounts of northern explorers often indicate the importance of bearded seals to local peoples encountered during expeditions, and occasionally describe details of the natural history of the seals. Many of these accounts are in Russian and stem from an early interest in the Far North by the Russian Empire.

There have been relatively few scientific studies directed specifically toward bearded seals. Most scientific information about them has been obtained as an adjunct to work on other marine mammals such as the more abundant ringed (Phoca hispida) and harp (Phoca groenlandica) seals.

The following references are those which include significant contributions to our knowledge of bearded seals. An interested reader could obtain a general understanding of the species from them, although they are by no means the only sources of information. As an example, a listing of publications on regional faunas, which included references to bearded seals, would, in itself, be very long.

Accounts of the natural history of bearded seals include the pioneering work of Chapskii (1938), based on studies in the Kara and Barents Seas; Vibe (1950) who worked in northwest Greenland; Johnson et al. (1966) from the eastern Chukchi Sea; and Burns (1967) from the Bering and Chukchi Seas.

Plekhanov (1933) described a method for determining the age of seals based on examination of claws. Sleptsov (1943), McLaren (1958), Tikhomirov (1966) and Potelov (1975) studied growth and/or reproduction in bearded seals, relying mainly on Plekhanov's method for determining age of seals in their samples. Benjaminsen (1973) found that although the teeth of bearded seals are largely lost or reduced in adults, the root of upper canine teeth could be used for more precise determination of age in adult seals. His paper describes age and growth in these seals from the North Atlantic and Barents Seas. Benjaminsen's method was utilized in this study.

Feeding of bearded seals was studied by Pikharev (1940) and Fedoseev and Bukhtiyarov (1972) in the Okhotsk Sea; Dunbar (1941) in the eastern Canadian Arctic; Kosygin (1966a) in the Bering Sea; Kenyon (1962) in the Bering Strait; and Lowry et al. (1977, 1978, 1979a&b) in the Bering, Chukchi and Beaufort Seas. Delyamure (1955) reported on the helminth parasites of seals, including bearded seals. Fay et al. (1977, 1978, 1979) reported results of their studies on various aspects of morbidity and mortality in Alaskan marine mammals including bearded seals.

The taxonomy and/or systematics of bearded seals are included in papers by Chapskii (1955), Burns and Fay (1970), Kosygin and Potelov (1971) and Manning (1974).

Distribution of bearded seals in the study area was reported by Tikhomirov (1961), Kosygin (1966b&c), Burns (1970), Stirling et al. (1977) and Braham et al. (in press).

Relationships of marine mammals, including bearded seals, to sea ice in the study area were described by Burns (1970) and Fay (1974).

V. The Study Area

The study area includes the Bering, Chukchi and Beaufort Seas (Fig. 3). Although almost all of the data and samples were obtained in the

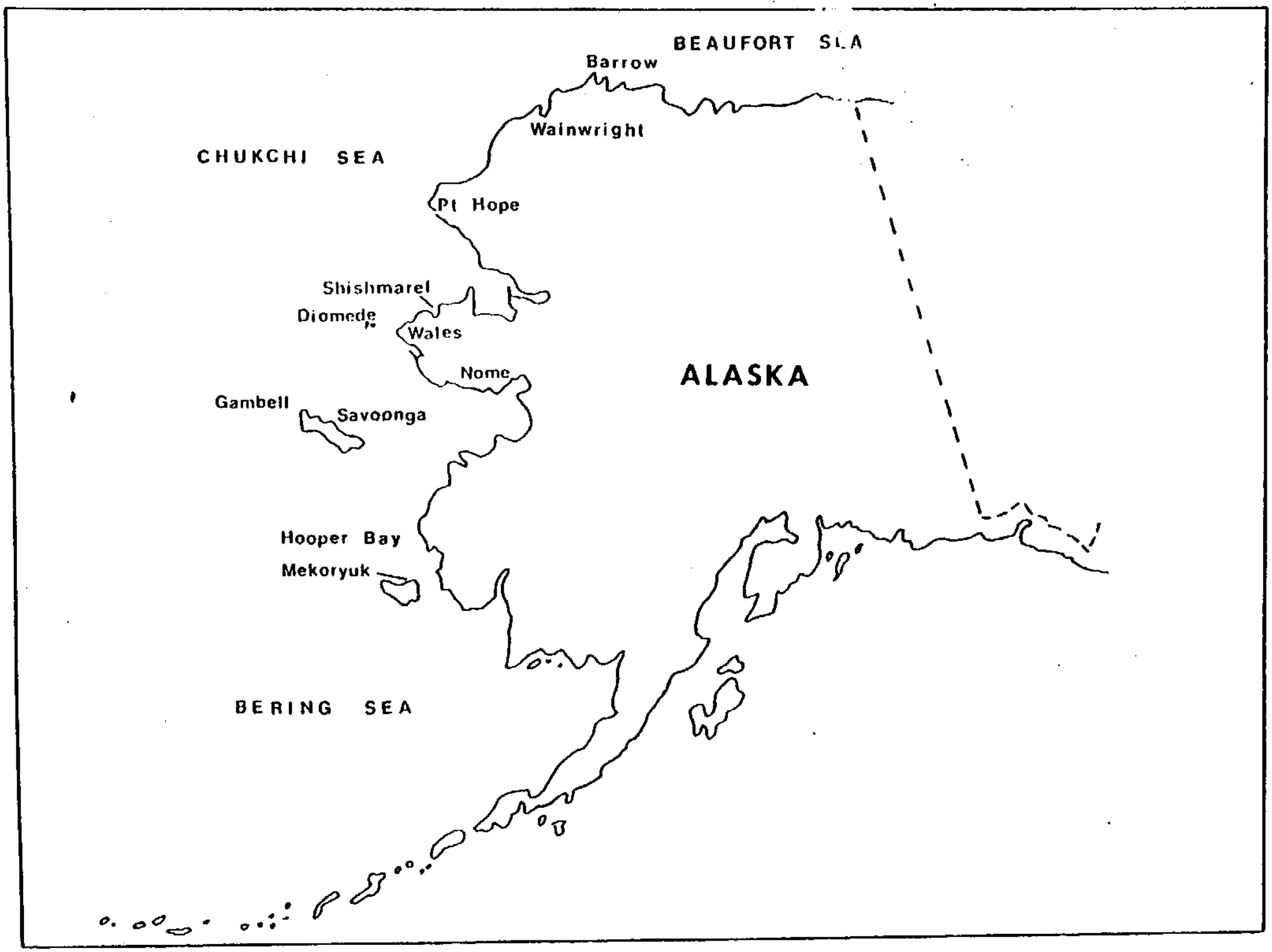


Figure 3. Locations where the major collections of specimen material and data were obtained during this investigation.

American "sector" of these seas, they were derived from what appears to be a single population whose range and seasonal movements occur mainly within (and between) these seas. The eastern part of the Beaufort Sea may be an exception in that nothing is presently known about movements of bearded seals between that region and the areas west and south.

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

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 bearded seals, 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. Bearded seals 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 (Zenkevich 1963). Throughout most of the year movement of water is north through Bering Strait. Zenkevich (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, pers. comm.) 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 which is bounded on the south by the Bering Strait; on the west by the Chukchi Peninsula and the eastern shores of Wrangell 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 Zenkevich (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 slopes (Creager and McManus 1966). Local maximum gradients range up to 1°55'. 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 Bering-Chukchi Platform underlying the northern and eastern half of the Bering Sea and all of the Chukchi Sea comprises the largest continuous area of bearded seal habitat in the world.

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. The portion of the Beaufort Sea presently under discussion extends from Point Barrow to Demarcation Point and from the Alaska Coast north to the 200 m isobath (i.e. the continental shelf). This is a narrow region which falls mostly within about 45 nautical miles of shore. The shelf break in the Beaufort Sea is abrupt.

The study area is shown in Figure 2. In this figure distribution of bearded seals can be considered to coincide with location of the 200 m isobaths.

Biological and physical features of bearded seal 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 which occurs. Several major rivers 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 of 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 which 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 which forms during winter in the Bering Sea, and ice which is transported south through the Bering Strait. It appears that most ice is of the former component.

On the 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 (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 conditions which accommodate a relatively high abundance of bearded seals during winter. A high biomass of food species, which is present, supports these seals.

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 which 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 suitable for bearded seals feeding. These seals occur throughout this sea in winter. However, ice conditions are such that highest densities occur in the limited regions of persistent shear and flaw zones such as occur immediately north of Bering Strait and parallel to the Alaska and Siberian coasts. The abundance of bearded seals in the Chukchi Sea during winter is much less than in the Bering Sea.

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 which is present. The coastline of the Beaufort Sea north of Alaska has a northeasterly exposure and is therefore ice stressed. 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 and therefore beyond depths suitable for bearded seals. These seals occur in open water overlying the continental shelf or in association with nearshore ice remnants which sometimes persist through late summer. In winter ice conditions are such that bearded seals, in low numbers, are restricted to the narrow flaw zone which roughly parallels the coast. Compared to the Bering and Chukchi Seas, the Beaufort Sea is marginal winter habitat for bearded seals. They are restricted in distribution to a rather narrow zone and occur in low densities.

The requirements of bearded seals for suitable ice conditions over waters shallow enough to permit feeding on the sea floor result in an annual cycle of movements in which the majority of these seals move south into the Bering Sea with the buildup and advance of seasonal ice, and north with the retreat and disintegration of this ice cover. Many areas, especially in the Chukchi and Beaufort Seas, which do not support high densities of bearded seals during the winter or summer are important during the transition periods.

VI. Sources, Methods and Rationale of Data Collection

A. Field Processing of Seals

Data and specimens were obtained mainly from two sources: 1) a program to assess species, age and sex composition of the seal harvest in northern Alaska (funded by the Alaska Department of Fish and Game) and 2) the OCSEAP programs undertaken to investigate the ecology of bearded and ringed seals (RU #230) and the trophic relationships among ice-associated phocid seals (RU #232). Most of our data and specimens were obtained from bearded seals taken by Eskimo subsistence hunters. Locations of major hunting villages at which specimens were collected are shown in Figure 3. Some bearded seals were collected in the course of OCSEAP studies, mainly during research cruises of the NOAA ship SURVEYOR. Collections by project personnel were undertaken in regions or during times of the year when these seals were not available to coastal-based subsistence hunters.

Sampling procedures varied depending upon facilities available when bearded seals were examined, objectives of the program being conducted and on the number of seals being landed when investigators were present.

During sampling programs in villages, undertaken by ADF&G, notation of date, location, species and sex of the seal was always obtained. Minimum specimen requirements included upper jaws and claws of the foreflipper. When possible, seals were measured (see below) and reproductive tracts (mainly from female seals) and stomachs were obtained. Bearded seals were usually not weighed because of their size and the difficulty of moving them on the beaches.

During OCSEAP funded programs undertaken in the villages, specific effort was devoted to bearded seals. These seals were processed as completely as possible. Specimen material obtained included jaws, claws, female reproductive tracts and stomachs. Supporting data from each seal, including measurements, were obtained.

Seals collected by OCSEAP investigators, mainly with the support of ships, were photographed, weighed, measured and necropsied. A variety of organs and tissues were saved including skulls or jaws, claws, reproductive tracts, digestive tracts and samples of heart, liver, kidney, muscle and blubber. Blood samples were obtained when feasible. Weights obtained included that of the whole seal (no estimate of blood loss), the hide and blubber and a limited series of organ weights.

A series of 12 measurements were taken. Those utilized in this report include:

Standard length - the straight line distance measured from the tip of the nose to the tip of the tail with the head and neck in a natural position. Seals were placed on a flat surface (back down), the appropriate points marked, the seal moved aside and the distance between points measured.

Girth immediately behind foreflippers - measured with a flexible tape around the body, under the foreflippers, at the level of the axillae.

Skin and blubber thickness - the thickness of skin and blubber immediately overlying the sternum at the level of the xiphoid process. An incision was made and a knife inserted down to the bone. The skin and blubber thickness was marked on the knife blade and measured.

Occasionally dead seals were found. These were processed as indicated above and, if possible, cause of death was determined.

B. <u>Laboratory Examination of Specimens</u>

Age determinations were based on examination of claws and/or upper canine teeth. Tooth wear in bearded seals is rapid and in the majority of animals older than about 8 years teeth are missing or worn down to the gum line. Therefore, in several previous studies teeth were not examined to determine age (i.e. Chapskii 1938, McLaren 1958, Johnson et al. 1966, Burns 1967). In most of these earlier studies growth ridges on claws of the foreflippers were used, as described by Plekhanov (1933). However, Benjaminsen (1973) found that the roots of the upper canine teeth remained throughout life in most bearded seals. The remaining portions of these teeth could be sectioned and the age determined on the basis of annuli in the cementum layer. In our continuing studies of bearded seals we adopted a combination of the two methods. Initial determination of age was based on claw annuli. If the determined age was doubtful because annuli extended out to the tip of the claw, the roots of the upper canine teeth were sectioned. In most animals age 0 to 8 years results of both methods were in close agreement. The change in procedure has resulted in minor difficulties when comparing, for instance, growth curves from studies conducted prior to 1973.

Female reproductive tracts were preserved in 10 percent formalin for later study. In the laboratory the uterine horns were externally examined for signs of current or previous pregnancy, indicated by external size, conformation and degree of rugosity.

Uterine horns were then opened and examined for placental scars, fetuses, or other indications of recent pregnancy. These indications included shape and size of each horn, condition of the uterine walls, presence of hemorrhagic tissue, and the kinds and amount of debris in the lumen.

Ovaries were weighed and serially sectioned with a scalpel, parallel to the longest axis. Sections were 1-2 mm thick. Each section was examined macroscopically for follicles, corpora lutea or corpora albicantia. On these bases females were classified as nulliparous, primaparous or multiparous. Drawings were made of each ovary for later reference. The presence or absence of a fetus was noted at necropsy.

Testes were weighed to the nearest 0.1 g with and without epididymides. Length and width at the middle of the testes were measured to the nearest millimeter. Testes volume (nearest cc) was determined by water displacement. Bacula were cleaned by boiling, air dried and then measured (nearest mm) and weighed (nearest 0.1 g).

Samples (about 125 cm^3) of heart, liver, kidney, skeletal muscle and skin and blubber were wrapped in aluminum foil, labeled and frozen. These tissue samples were stored and/or provided to other investigators for microbiological, hydrocarbon, pesticide and heavy metal analyses.

C. Surveys and Observation of Seals

Seasonal migration patterns were determined through observations at coastal hunting sites and from surveys. Aerial and small boat surveys were used to determine the distribution and densities of pinnipeds in the ice-covered Bering, Chukchi and Beaufort Seas.

Aerial surveys were flown in fixed-wing aircraft and in helicopters. Aircraft used for surveys were a Cessna 180, Cessna 185, DeHavilland Twin-Otter and Lockeed P2V (all fixed-wing aircraft) and a Bell 206B helicopter. Strip transects were flown. Transect width varied, depending upon conditions, from 0.05 to 0.5 nm on one or both sides of the aircraft. Reported densities of seals were expressed as animals per nm^2. Transect width was maintained with fixed reference points on the aircraft windows and wing struts or floats. Surveys were usually flown at altitudes of 91.5 m (300 feet). All seals (by species) and polar bears observed on these flights were enumerated.

Locations and distances traveled along flight tracts were determined by standard aerial navigation techniques, by radar fixes from various DEW-Line stations, or with the aid of a GNS-500 system (very low frequency, Omega navigation system).

Some surveys were conducted from small boats. In these surveys general locations and numbers of seals seen per boat hour were recorded. It was not possible to reduce these data to densities per nm^2. However, these surveys did indicate relative abundance of seals in the different areas studied.

Natural history and behavioral observations were obtained from several sources: 1) field observations by the principal investigators, 2) unpublished field observations of other investigators and 3) reports from Eskimos. The bulk of the natural history and behavioral observations were recorded by the principal investigators while they were on the sea ice, or aboard ships, skin boats or aircraft. These observations are usually made with the aid of field glasses or spotting scopes and are recorded as field notes with appropriate ecological and behavioral notations.

Because of the amount of time they spend on the ice pursuing marine mammals, Eskimo hunters are able to provide a wealth of information concerning behavior and natural history. Their observations were recorded and, as appropriate, are presented.

D. Data Management

Data obtained in the course of OCSEAP funded programs were entered, as contractually required, into standardized data management programs. Two data sets were prepared--one being submitted to the National Oceanic Data Center and the second retained and used for analysis. We utilized a VT/78 micro-computer (Digital Equipment Corporation) for data entry and analysis.

The age structure of bearded seal harvests for the years 1971 through 1974 and 1975 through 1978 each consisted of two components: 1) those seals for which age determinations based on claws (young animals) and teeth were acceptable and 2) older aged seals for which only a minimum age, based on examination of claws, was known. The sample size in each category was:

Sample Series	No. for which age determinations were acceptable	No. for which only minimum age was known (claws)	Range of minimum known ages
1971-1974	306	55	6-16
1975-1978	1160	151	5-18

We combined the two components for each series by redistributing the seals of known minimum age in accordance with the age distribution of the larger sample for which age determinations were acceptable. In the minimum age component seals were not younger than the minimum age assigned to them. However, they were either of the minimum assigned age or of some older age class.

The mathematical procedure for incorporating the minimum age component into the larger series was based on the following calculations:

$$N_A \text{ total} = N_A \left[1 + \sum_{j=0}^{A} \left(\frac{M_j}{\sum_{i=j}^{26} N_i} \right) \right]$$

where

N_A total = number in age class A (exact + minimum)
N_A = number in age class A (exact only)
A = age class being analyzed
M_j = numbers that are at least j years old
N_i = numbers that are exactly i years old
26 = oldest age class in known distribution

VII. & VIII. Results and Discussion

A. Distribution and Movements

The shelf regions of the study area are mostly covered by sea ice during late winter and spring and are mostly ice free by late summer and fall. The southern margin of multi-year ice which persists through the melting period is usually south of the northern limit of the Chukchi platform and extends completely across it. In most years multi-year ice is situated north of the Beaufort Sea shelf in August through October.

Bearded seals can and do make and maintain breathing holes in relatively thin ice. They avoid regions of continuous, thick shorefast ice (unlike ringed seals, Phoca hispida) and are not common in regions of unbroken, heavy, drifting ice. These seals mainly utilize areas of shallow water where the ice is in constant motion, producing leads, polynya and other openings. In the Chukchi Sea during winter and spring such conditions occur as extensive "flaw zones" which occur where heavy drifting ice, influenced by winds and currents, interacts with coastal features. The extent of such favorable winter habitat in the Chukchi Sea is relatively limited. It is most restricted in the Beaufort Sea. In comparison, this combination of suitable ice conditions and water depths occurs over a much broader area in the more temperate Bering Sea. Most of the population moves south through Bering Strait in late fall-early winter and "winters" in the Bering Sea. During the winter and early spring bearded seals are widely, though not uniformly, distributed throughout the drifting ice of the Bering Sea. Highest densities occur in the northern part of the ice-covered Bering Sea shelf. Relationships of marine mammals to sea ice in the region under discussion are described by Burns (1970) and Fay (1974).

As implied by the remarks above, most bearded seals move great distances during the year, mostly maintaining an association with ice. These movements are directly related to the seasonal advance and retreat (as well as the growth and degeneration) of the ice cover. During winter most of them are in the Bering Sea; in summer they are near the wide, fragmented margin of multi-year ice in the Chukchi Sea. The northward spring migration through Bering Strait, occurring from mid-April through June, is more marked and noticeable than the southward movements in late fall through winter. Spring migration past St. Lawrence Island, as indicated by hunting success, is shown in Figure 4.

Bearded seals do not resort to coastal hauling areas in the Bering-Chukchi region. This is probably because they are able to maintain their association with ice on a year-round basis, in water depths suitable for bottom feeding.

In other parts of their circumpolar range they regularly come ashore during summer. This has been reported to occur in the Okhotsk Sea (Tikhomirov 1961; Fedoseev, pers. comm.), the White Sea (Heptner 1976) and the Laptev Sea (Tavrovskii 1971). In these regions ice either melts in summer or recedes beyond limits of suitably shallow water.

Some bearded seals, perhaps a significant proportion of juveniles, occur in the open sea during summer. They also enter small bays and ascend some rivers. In Imuruk Basin on the south coast of the Seward Peninsula pups were occasionally taken in nets at the time of fall freeze-up. This basin is separated from a larger bay by a long, narrow channel. There are several reports of seals becoming trapped by freeze-up of this brackish body of water and seeking escape by traveling over ice or land. In two reported instances pups were tracked down in the snow and were dead when found (Kugzruk, pers. comm.). A similar occurrence in the Canadian Arctic was noted by Smith and Memogana (1977).

The seasonal occurrence of bearded seals in the proposed lease areas and the vital biological functions which occur while they are there vary with location.

Bristol Bay is normally occupied by ice to some extent from December through April. The annual extent of coverage is variable, from virtually complete (almost reaching the Alaska Peninsula) to ice free. Except for the extreme eastern part, seals occur throughout the drifting ice. This lease area supports a moderate but unknown number of wintering bearded seals in most years. The number of seals is directly related to extent and duration of the ice cover. In April 1971 and 1976, as examples, Bristol Bay was completely ice covered. In April 1979 it was ice free. Bearded seals begin migrating north in early April.

In heavy ice years pups are born, nursed, weaned and deserted within this lease area. Newly independent pups are less migratory than older seals and remain with the disintegrating ice until it is gone. Some probably remain in the bay during summer but, based on the abundance of pups in the Yukon-Kuksokwim Delta area during May and early June, most move north with the receding ice.

St. George Basin, like Bristol Bay, is on the southern boundary of bearded seal range. Importance of this lease area to the seals is directly related to annual ice conditions. In "average" years sea ice reaches the northern part while in heavy ice years much of this lease area is covered during late January through early May. When ice is present, bearded seals are moderately abundant through late March and begin to migrate northward in April. This lease area is particularly

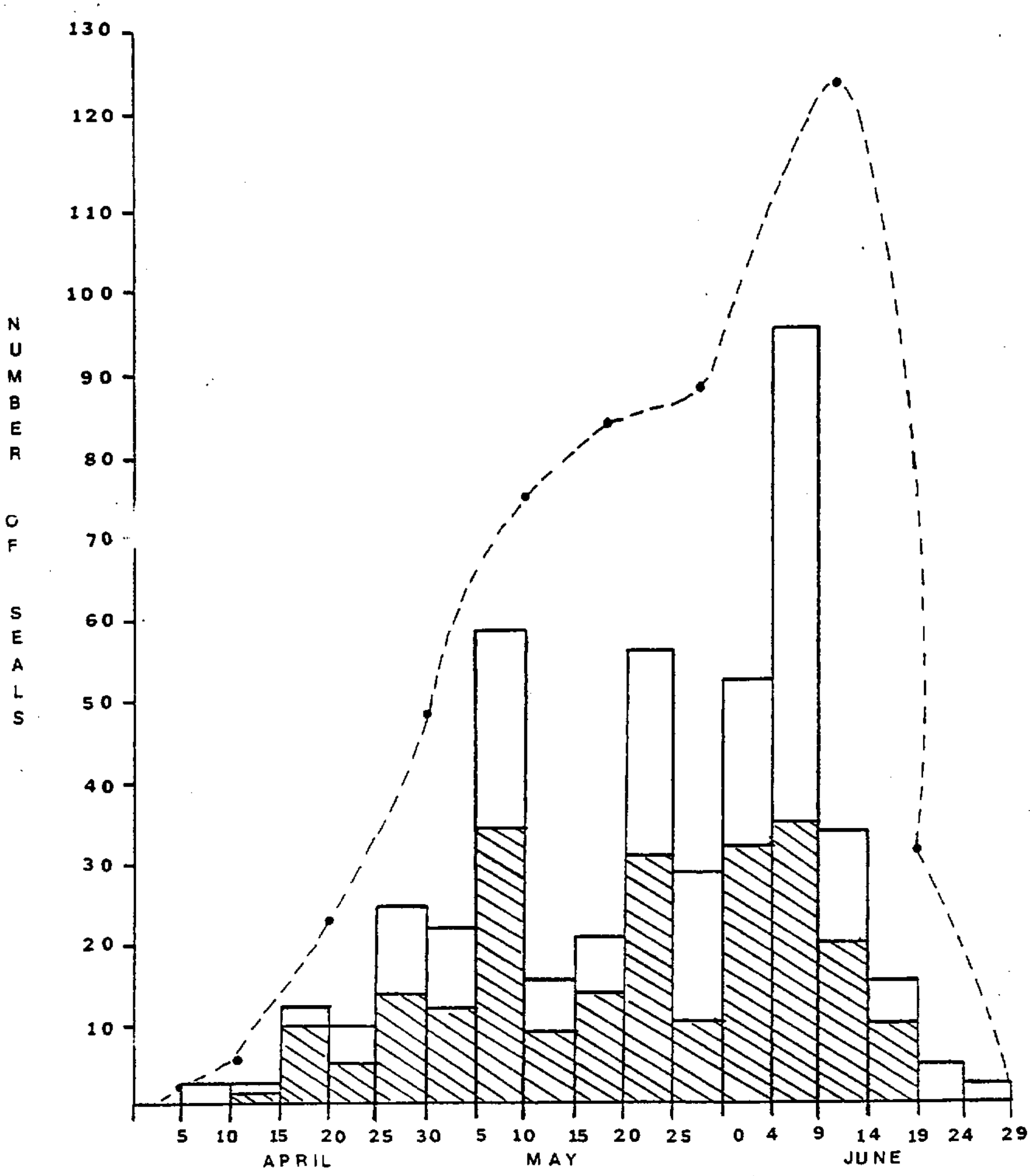


Figure 4. Spring migration timing of bearded seals past St. Lawrence Island as indicated by recorded hunting success from 1963-1966. The bars indicate harvest by five day intervals, with the female component indicated by stippling. The dots connected by a broken line indicate the harvest by ten day intervals, starting with the period from April 5 to 15. Total sample was 471 seals.

favorable habitat during late winter because of the high abundance of potential food (crabs and shrimps). As in Bristol Bay, birth, nursing and weaning of pups occurs in this proposed lease area. If ice persists into May, breeding adult seals are also present.

Navarin Basin is south of the limit of seasonal sea ice and probably does not support significant numbers of bearded seals.

Norton Basin is important bearded seal habitat. Shorefast ice is limited in extent while drifting ice of suitable characteristics for seals occurs throughout this lease area from late November through about 20 to 25 June. It is a region through which large numbers of seals migrate during spring and fall and in which they are abundant residents whenever ice is present. This lease area is one of seasonally high seal densities. Major biological events which occur in this lease area include birth, nursing, weaning, breeding and molting. Large numbers of newly independent pups are present in the area during May through June and some pups and subadults remain throughout the open water season. However, most seals pass north, through Bering Strait, by late June.

Hope Basin, like Norton Basin, is a very important area for bearded seals. They are present for a longer period of time because ice is present a little earlier and persists significantly longer. Ice is usually present from mid-November through mid- to late July. Bearded seals migrate through the Hope Basin in spring and fall. These seals are also abundant in suitable areas of drifting ice from late fall to summer. Extensive landfast ice occurs along the northern coast of the Seward Peninsula and in Kotzebue Sound. The fast ice zone is not utilized by bearded seals until it begins to disintegrate.

Hope Basin has several important features which contribute to its great importance for bearded seals. During winter prevailing winds are northeast. Thus, the northeastern part of this lease area (except Kotzebue Sound) is leeward of the coast. Polynya and lead systems occur throughout winter and spring. Similarly, disturbed ice conditions predominate in the vicinity of Bering Strait, caused by strong currents in that region. The conditions in Hope Basin, which maintain numerous openings in the winter ice cover, are favorable for bearded seals.

A shoal extending more than 100 km north of Cape Prince of Wales produces a gyre which, during the process of ice disintegration, entrains floes producing a large remnant. This ice remnant, consisting mainly of thick floes from the former shorefast zone, persists along the northwestern coast of the Seward Peninsula, as late as the end of July. Kotzebue Sound, on occasion, also traps drifting ice. Bearded seals congregate in these ice remnants for as long as they persist. Some subadults, mainly pups, remain in Hope Basin during the open water season.

From the standpoint of the bearded seals, major biological events which occur in the Hope Basin include all of those indicated for Norton Sound. Additionally, large numbers of seals are in the ice remnants of this lease area when implantation and early prenatal growth occur (i.e. mainly during July). It is noteworthy that two of the more successful seal hunting villages, Shishmaref and Point Hope, border the Hope Basin.

The Beaufort Basin has a relatively narrow shelf and is influenced by more severe ice conditions than the Chukchi or Bering Seas. The ice cover is more complete in winter through late spring and movement of the drifting ice is significantly less. A schematic representation of ice zonation and interaction with the shelf is shown in Figure 5.

A narrow flaw zone of varying width occurs where drifting ice interacts with fast ice, creating leads and other openings distributed generally parallel to the coast. The location of this broken ice zone changes in relation to meteorological conditions, usually being farther off shore as the freezing process continues. In the Beaufort Sea the late winter flaw zone is comparatively narrow and located near the northern edge of the shelf. Bearded seals are most numerous in the flaw zone but their density in most of the Beaufort Sea during winter is low. We have seldom seen bearded seals in open water areas north of Prudhoe Bay during February and March. Conversely, ringed seals were numerous.

The density of bearded seals increases in the extreme western Beaufort Sea. This is directly correlated with greater instability of ice and a wider shelf in the vicinity of Point Barrow.

Extent of open water during the ice-free period of the year is highly variable (Fig. 6). In most years the southern margin of multi-year ice (seasonal ice disappears) is over or slightly north of the shelf and therefore available to bearded seals. These seals are not associated with the ice margin when it occurs over deep water. Highest densities of bearded seals during summer occur in the western Beaufort Sea and in ice remnants which persist close to shore. The summering population is augmented by seals moving into the western Beaufort Sea from the Chukchi Sea. Density of bearded seals in the eastern Beaufort Sea seems to remain relatively low, suggesting that eastward movement from the Chukchi Sea is not great. A similar situation prevails with another benthic feeder, the Pacific walrus. There are more sightings of bearded seals in ice-free waters of the Beaufort Sea shelf during summer than in ice-free areas of either the Chukchi or Bering Seas (Burns, unpubl. data).

Annual differences in ice conditions influence the number of bearded seals in the Beaufort Basin and the region approaches being marginal habitat for these seals. Some are present at all times, thus all events in the annual and life cycles take place there. Nearshore ice remnants support the highest densities. These remnants occur and are utilized at the time when seals are completing the molt, resuming intensive feeding and when implantation and early fetal growth are occurring.

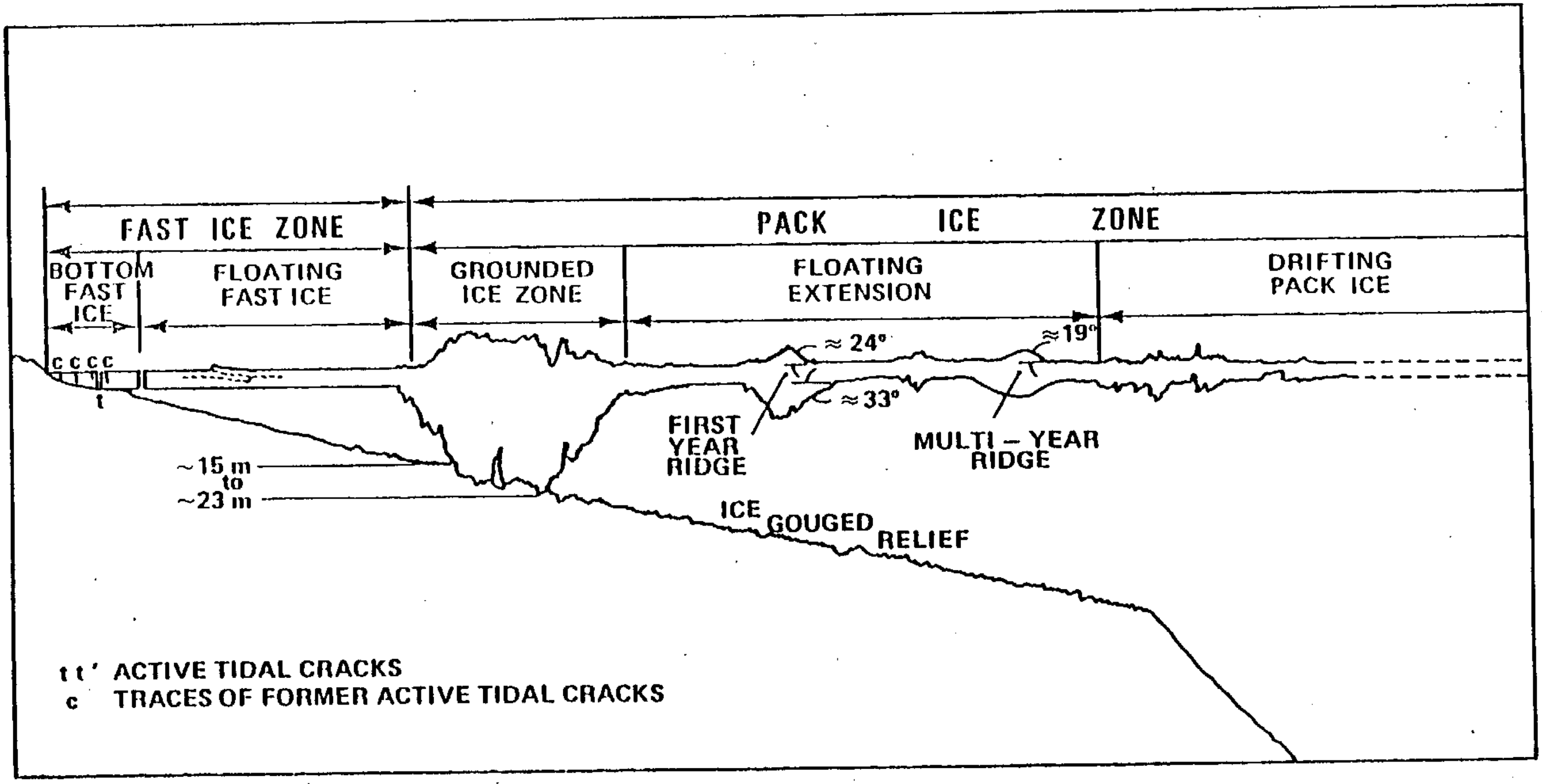
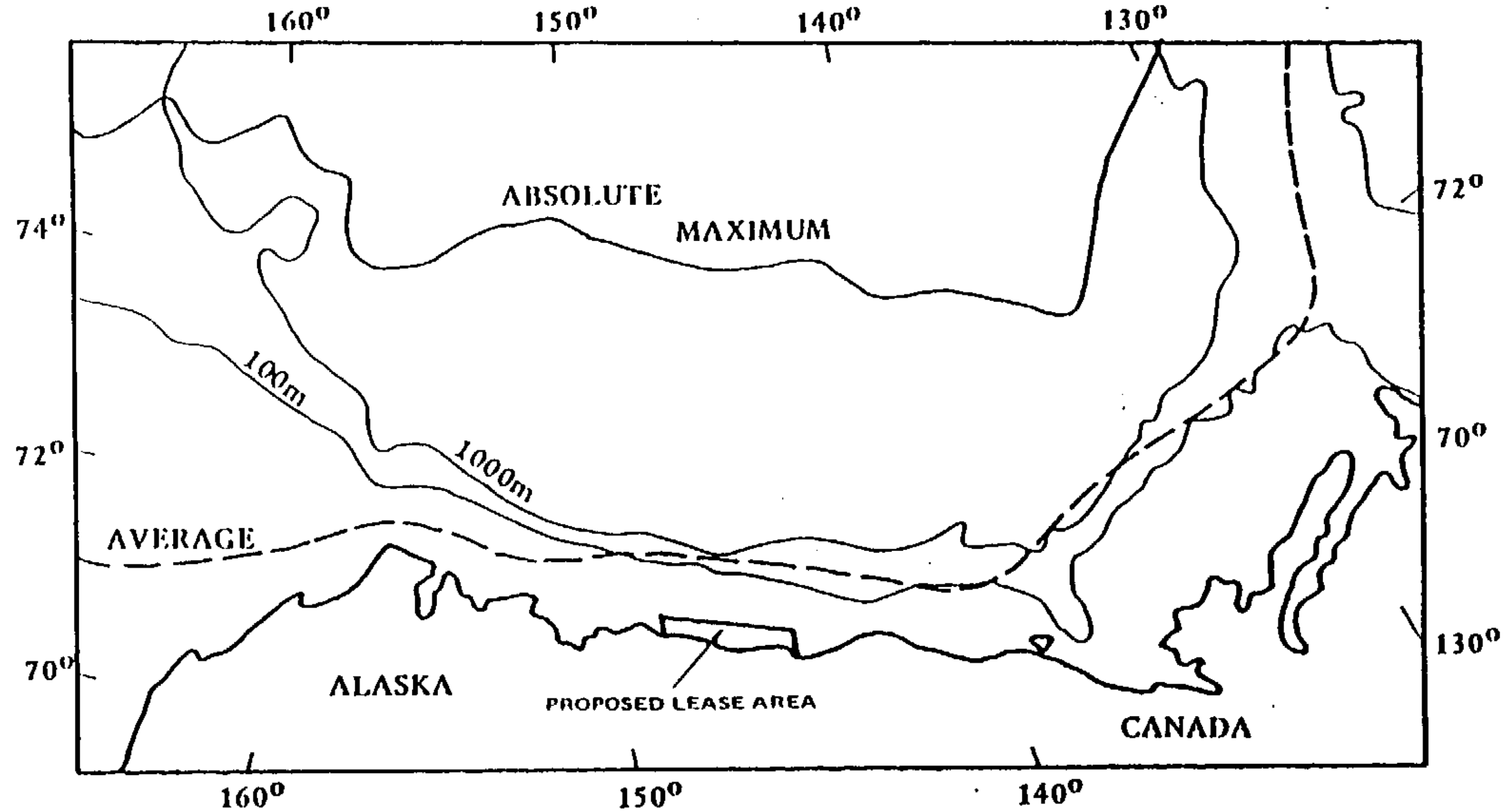


Figure 5. Schematic illustration of ice features in the coastal zone of the Beaufort Sea. The interaction of ice, shallow water and the coast are apparent. Similar features develop in the Bering and Chukchi Seas although their extent varies. (From Shapiro and Barry 1978.)



SOURCE: MODIFIED FROM AMERICAN GEOGRAPHICAL SOCIETY MAP OF THE ARCTIC REGION, 1975.

Figure 6. Average and absolute maximum retreat of multi-year ice during summer-early fall in the Beaufort Sea.

B. Regional Abundance

Many aerial and ship surveys for marine mammals have been undertaken in the study area. None of these have been specifically designed to assess bearded seal numbers and most have been conducted in the Bering Sea during spring, mainly April and May. Although these surveys could not be used as a basis for estimating the total number of seals present in areas surveyed, they did provide information on the relative abundance of seals in various parts of the study area and in different seasons.

Kosygin (1966b) graphically illustrated the relative abundance of ice-associated pinnipeds in those areas of the ice front where sealing by the Soviets was undertaken in March through June 1962 and April through June 1963. The front disintegrated and receded northward during these time periods. In general, highest densities of bearded seals in the front during April were: 1) near the Pribilof Islands, 2) southwest of St. Matthew Island and 3) in the southern Gulf of Anadyr. Movements were northward during May and June, commensurate with retreat of ice.

Extensive aerial surveys of marine mammals were conducted in the Bering Sea during April 1976 (Braham et al., in prep.). This effort involved three independent but coordinated programs; one was in the western and northern Bering Sea by Soviet investigators and two were in the eastern Bering Sea conducted by American scientists. Relative abundance of bearded seals in different regions is shown in Figures 7 and 8.

These extensive surveys confirmed previous findings (Burns 1970) that bearded seals are the most widely distributed species occurring in the drifting seasonal ice of the Bering Sea. In April 1976 highest numbers were seen in the northern Bering Sea, near St. Lawrence Island; in ice 60-100 km north of the front zone; west of St. Matthew Island; and in the southern Gulf of Anadyr (Braham et al., in prep.).

In March 1970, during a cruise of the icebreaker NORTHWIND, bearded seals were found to be abundant in northwestern Bristol Bay (Muktoyuk, pers. comm.).

Surveys by helicopter from the research vessel SURVEYOR were conducted in the eastern Bering Sea during spring 1977, 1978 and 1979. In 1977 these surveys were in the ice front. In 1978 and 1979 they were farther north in the receding and disintegrating ice. Results of these surveys are presented in Table 1. Location of the surveys and observed density of seals are shown in Figure 9.

An aerial survey from a single-engine fixed-wing aircraft (Cessna 180) was conducted in Norton Basin on 20 April 1967. The winter of 1966-1967 was unusually mild with frequent strong winds from the south. Ice was restricted mainly to the northern Bering Sea and the southern terminus was slightly south of St. Lawrence Island. Thus, the various ice-associated pinnipeds were more concentrated. The survey was undertaken to determine the relative abundance of marine mammals in western Norton Sound under the conditions existing at that time.

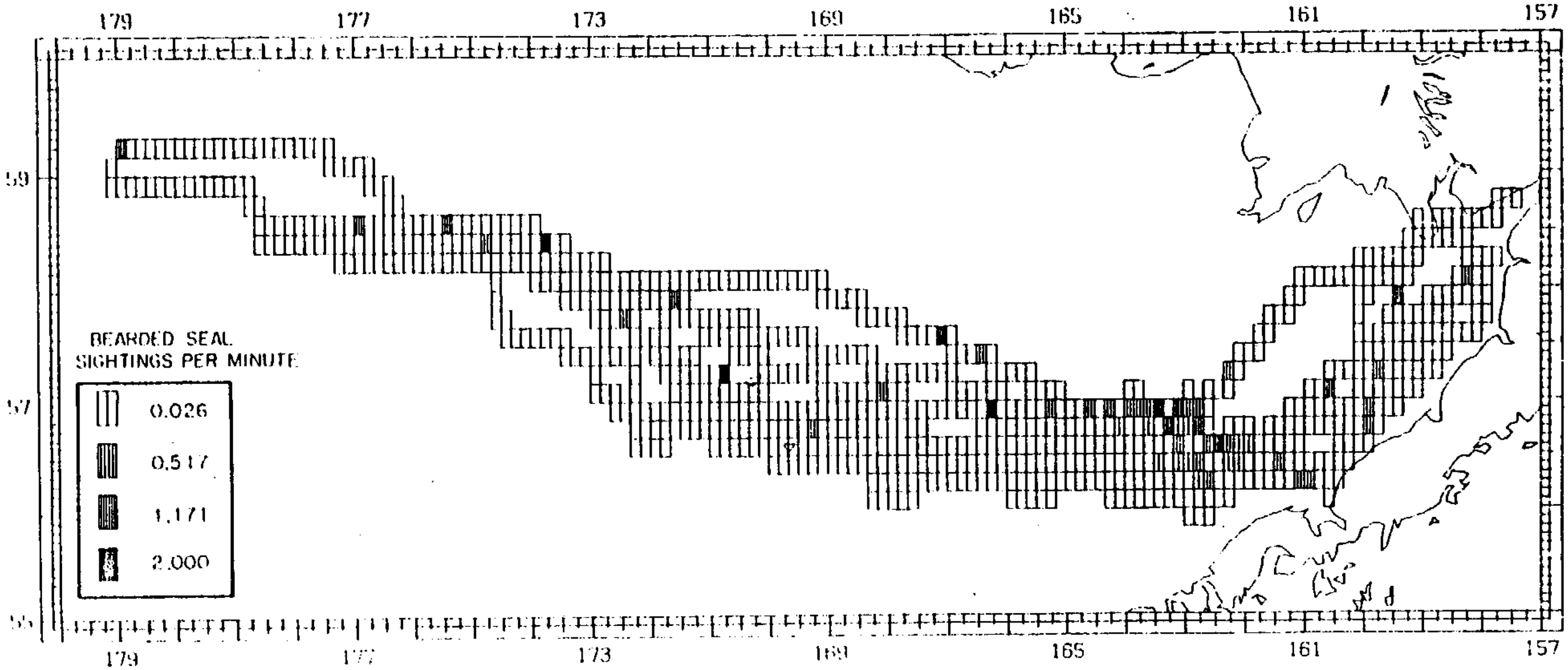


Figure 7. Density of bearded seals in the Bering Sea ice front during April 8-23, 1976. (Figure prepared by B. Krogman, NMFS, Seattle, from data obtained by Burns and Harbo, 1977.)

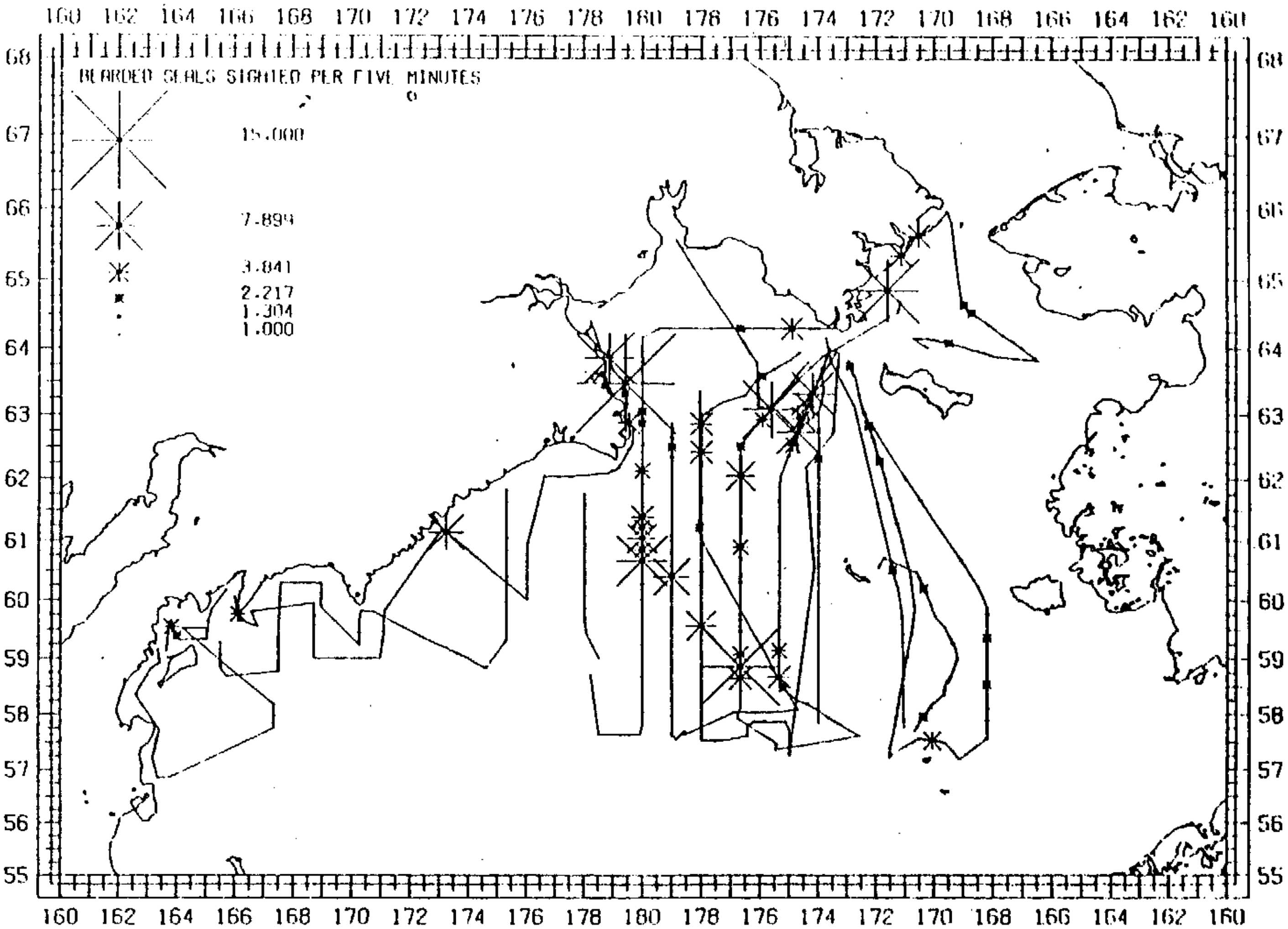


Figure 8. Density of bearded seals in western Bering Sea during April 1976. (Figure prepared by B. Krogman, NMFS, Seattle, from data provided by G. Fedoseev and included in Braham et al., in press).

Table 1. Results of aerial surveys conducted in spring 1977 and 1978 in eastern Bering Sea. Surveys were made using a Bell 206 helicopter operating from the research vessel SURVEYOR.

Date	Survey Number	General Position	Area Surveyed (nm^2)	Bearded Seals Seen	Density Seals /nm^2
March 1977					
27	1	55°49' 164°25'	82.7	0	0.00
28	2	59°08' 169°35'	103.3	68	0.66
30	3	58°20' 164°50'	81.2	16	0.20
April 1977					
21	4	57°40' 164°55'	40.6	9	0.22
23-25	5	58°45' 169°30'	289.3	11	0.04
27	6	59°40' 174°20'	55.9	0	0.00
May 1978					
5-6	7	61°40' 176°00'	94.5	0	0.00
7-9	8	61°45' 172°00'	211.0	26	0.12
10-13	9	61°35' 168°00'	180.0	70	0.39
29-31	10	64°45' 170°00'	218.7	293	1.34
June 1978					
1-3	11	62°45' 169°30'	51.5	16	0.31
4-6	12	63°15' 167°00'	51.1	0	0.00
7-9	13	64°45' 167°00'	75.6	66	0.87
May 1979					
15	14	61°46' 168°10'	67.0	15	0.22
18	15	63°58' 166°32'	51.0	8	0.16
20	16	62°10' 170°16'	60.0	60	1.00
21	17	62°16' 171°02'	59.0	51	0.86
22	18	62°16' 171°05'	44.0	17	0.39
24	19	62°50' 173°10'	49.0	79	1.61
25	20	62°50' 173°20'	49.0	108	2.20
27	21	62°50' 174°30'	48.0	65	1.35

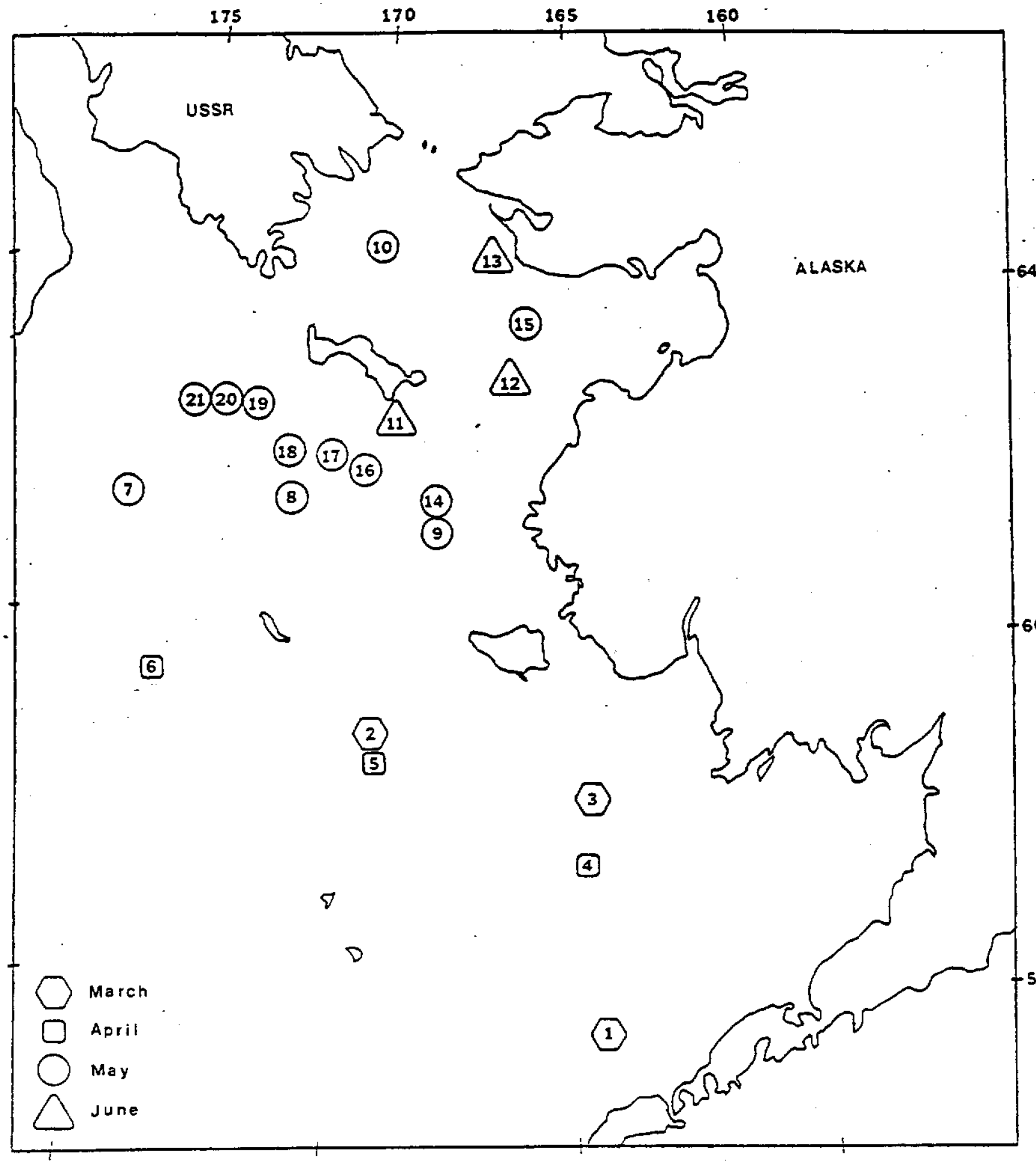


Figure 9. Locations where aerial surveys of seals were made in the spring seasons of 1977-1979.

The area surveyed was 314 nm^2 along a flight line generally from Nome to King Island to Diomede Island and return to Nome. Bearded seals were the most numerous marine mammals seen and the observed density of these seals was 0.72 per nm^2. Walruses were the next most abundant and the observed density was 0.52 per nm^2. Walruses were mainly in the vicinity of Bering Strait while bearded seals were rather evenly distributed throughout the area surveyed.

Johnson et al. (1966, Fig. 1, p. 885) conducted aerial surveys in parts of the Hope Basin between 19 April and 28 June 1963. They did not derive estimates of density. However, bearded seals were regularly observed in association with the flaw ice zone from Point Hope southeast toward Kotzebue Sound.

We conducted surveys in the northeastern Chukchi and Beaufort Seas during August and September 1977. A small boat working from the icebreaker GLACIER was employed. Weather conditions were generally marginal because of persistent fog. We recorded the number of seals seen per hour of travel by small boat at each of the stations occupied during the cruise. Results of those surveys are presented in Table 2. The stations occupied are shown in Figure 10. Bearded seals were most numerous in the Chukchi Sea and in the ice remnants of the Beaufort Sea. Some animals were seen in the offshore pack ice in the Beaufort Sea well north of the continental shelf.

Stirling et al. (1975) conducted systematic aerial surveys of marine mammals in the eastern Beaufort Sea and Amundsen Gulf during the peak period of molt (mid- to late June) during 1974 and 1975. The study area was divided into four strata based on depth, ice conditions and water characteristics. Bearded seals were strongly associated with the shallow water areas although they also occurred over deep water. The densities of bearded seals in the stratum over shallow areas with annually occurring lead systems was 0.091 per mi^2 in 1974 and 0.040 in 1975. Total population estimates in their study area, based only on seals sighted, were 2,759 $\pm$ 729 in 1974 and 1,197 $\pm$ 235 in 1975. The decline between years was significant.

C. Population Structure and Dynamics

Parameters of population structure and dynamics were investigated on the basis of harvest composition. The harvests are probably not representative of the population. Two approaches were taken in our analyses: 1) determination of population structure based on our perceptions of factors which bias the data base and 2) mathematical procedures of fitting or "smoothing" the available data. Each of these will be discussed separately.

The sex ratio in the population, as indicated by harvests, appears to change with age. At birth males may predominate, although the ratio is close to unity. It was 50 percent males in the sample of pups obtained between 1962 and 1966 (N=185), 49 percent males in 1971-1974 (N=172) and 55 percent males in 1975-1978 (N=434). In harvested animals older than

Table 2. Stations where small boat operations were conducted during the August-September 1977 cruise of the GLACIER, and the observed densities of bearded and ringed seals seen from the small boats.

Station No.	Position	Small Boat Hours	Bearded Seals /Boat Hour	Ringed Seals /Boat Hour	Total Seals /Boat Hour
1	71°18' 157°48'	2.0	4.5	0.5	5.0
2	71°19' 160°01'	5.0	0.6	0.2	0.8
3	71°28' 163°47'	3.7	1.1	0.5	1.6
4	71°17' 161°10'	2.5	1.2	0.4	1.6
5	71°12' 158°45'	4.0	0.0	0.0	0.0
6	71°45' 155°43'	6.3	0.2	0.9	1.1
7	72°24' 154°37'	7.2	0.0	0.3	0.3
8	71°13' 151°23'	2.3	0.0	0.9	0.9
9	71°47' 150°49'	3.9	0.0	0.8	0.8
10	71°09' 150°09'	7.5	0.4	1.2	1.6
11	71°00' 150°45'	3.0	0.3	2.3	2.6
12	70°40' 147°46'	6.5	0.6	1.1	1.7
13	72°48' 146°28'	2.0	0.0	0.0	0.0
14	72°46' 146°15'	4.0	0.0	0.2	0.2
15	72°58' 143°30'	5.9	0.0	0.0	0.0
16	70°11' 145°38'	2.0	0.0	0.0	0.0
17	70°22' 146°26'	2.2	0.0	0.9	0.9
18	70°32' 147°42'	2.0	3.0	8.5	11.5
19	70°47' 149°03'	8.1	0.5	2.8	3.3
20	70°45' 148°58'	10.8	0.3	4.2	4.5

Chukchi

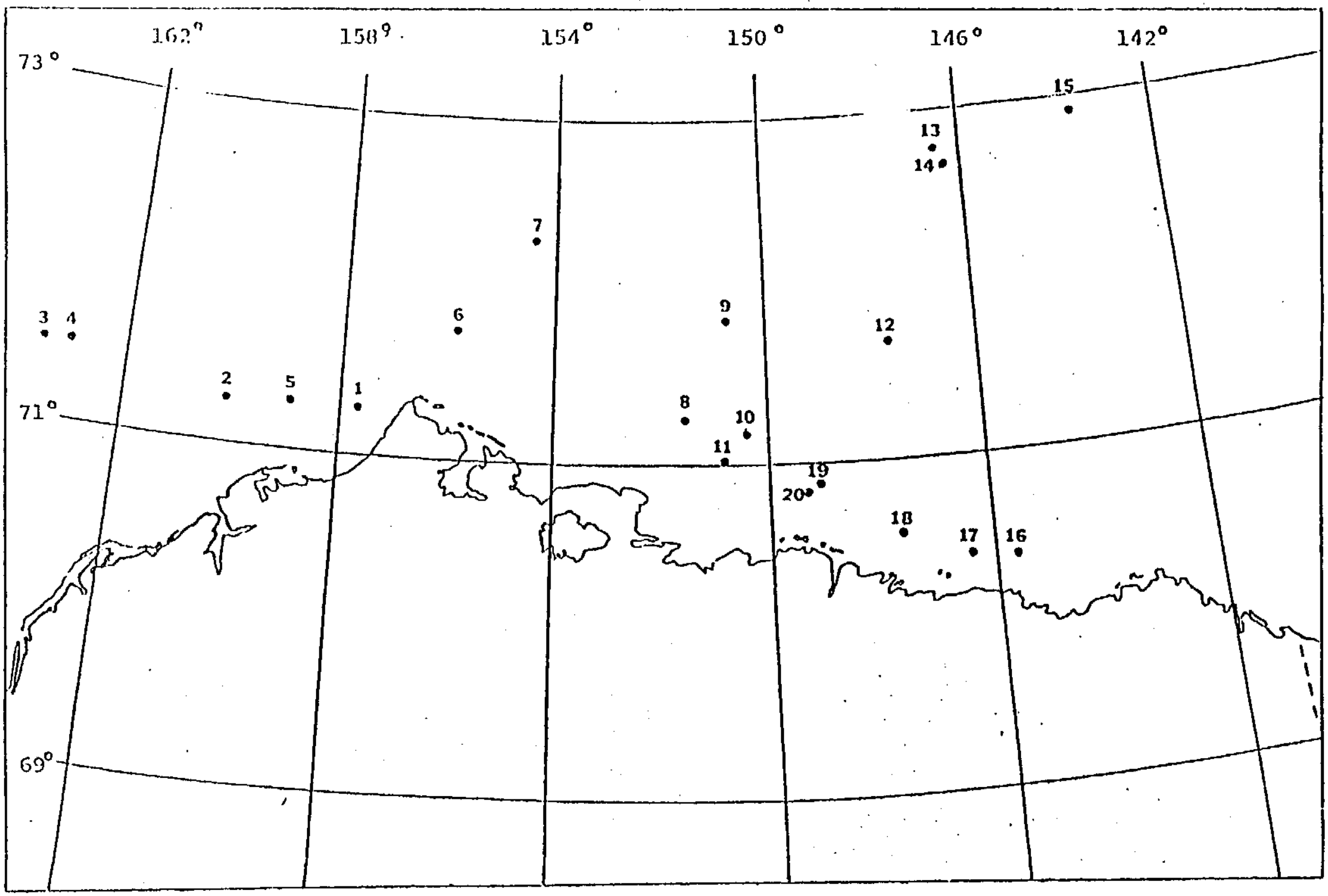


Figure 10. General locations of stations at which small boats were used to observe and collect seals during the August-September 1977 cruise of the GLACIER. Information for each station is presented in Table 2.

pups, females comprised 53 percent in 1962-1966 (N=205) and 55 percent in 1975-1978 (N=727). This change may be indicative of higher mortality in older males--a suggestion supported by calculated mortality rates (discussed below).

Data on age composition of harvests have been obtained over many years. They were grouped into three data sets, based on chronology, as follows: 1) for years 1962-1966, from seals taken mainly in Bering Strait (N=390); 2) for years 1971-1974 (N=361), from seals taken primarily during June near the villages of Hooper Bay (N=109), Shishmaref (N=103) and Savoonga (N=85); and 3) for the years 1975-1978 (N=1311), from seals mainly taken during May through July near the villages of Hooper Bay (N=382), Shishmaref (N=357), Gambell (N=122), Savoonga (N=91) and Wainwright (N=50).

Claws were used for determining age of seals in data set 1, while both claws and teeth were used to determine age of seals in data sets 2 and 3. In data sets 2 and 3 those seals for which only a minimum age was determined (i.e. claws but not teeth collected) were redistributed among age classes by the mathematical procedure previously indicated. Fifty-five reassignments were made in data set number 2 (minimum determined ages were 6 to 16 years) and 151 reassignments in data set 3 (minimum determined ages ranged from 5 to 18 years). The age frequency distribution as determined from harvests is illustrated in Figure 11. Data from 1971-1974 were considered poor as hunting conditions produced harvests of primarily pups. Table 3 indicates composition of the harvest for 1975-1978.

Differences in the proportion of pups taken in the major sampling areas are large and indicate a significant bias which may result from age segregation in the population due to differences in movement patterns and perhaps due to high mortality in pups. The proportion of pups was significantly lower at more northerly hunting sites. Table 4 shows this difference based on samples from Hooper Bay (southeastern Bering Sea), Shishmaref (southeastern Chukchi Sea) and Wainwright (northeastern Chukchi Sea). This bias must be considered in any effort to determine age structure of the population.

The proportions of pups in harvests as a whole were 27.4 percent for 1962-1966 and 36.9 percent for 1975-1978. The sample from 1962-1966, obtained from the island villages in and near Bering Strait, is probably more representative of the actual population.

In our samples seals of age classes 0 through 3 (those younger than the youngest breeding females) comprised 47 percent of the seals examined in 1962-1966 and 56 percent of those examined in 1975-1978. Again, disproportionate representation of pups in the harvest results in a higher than actual proportion of pre-breeding age animals in our samples.

Based on available data from harvested animals and our perceived understanding of biases which affect these harvests, we suggest that the proportion of pups in the population during summer is 22 to 25 percent,

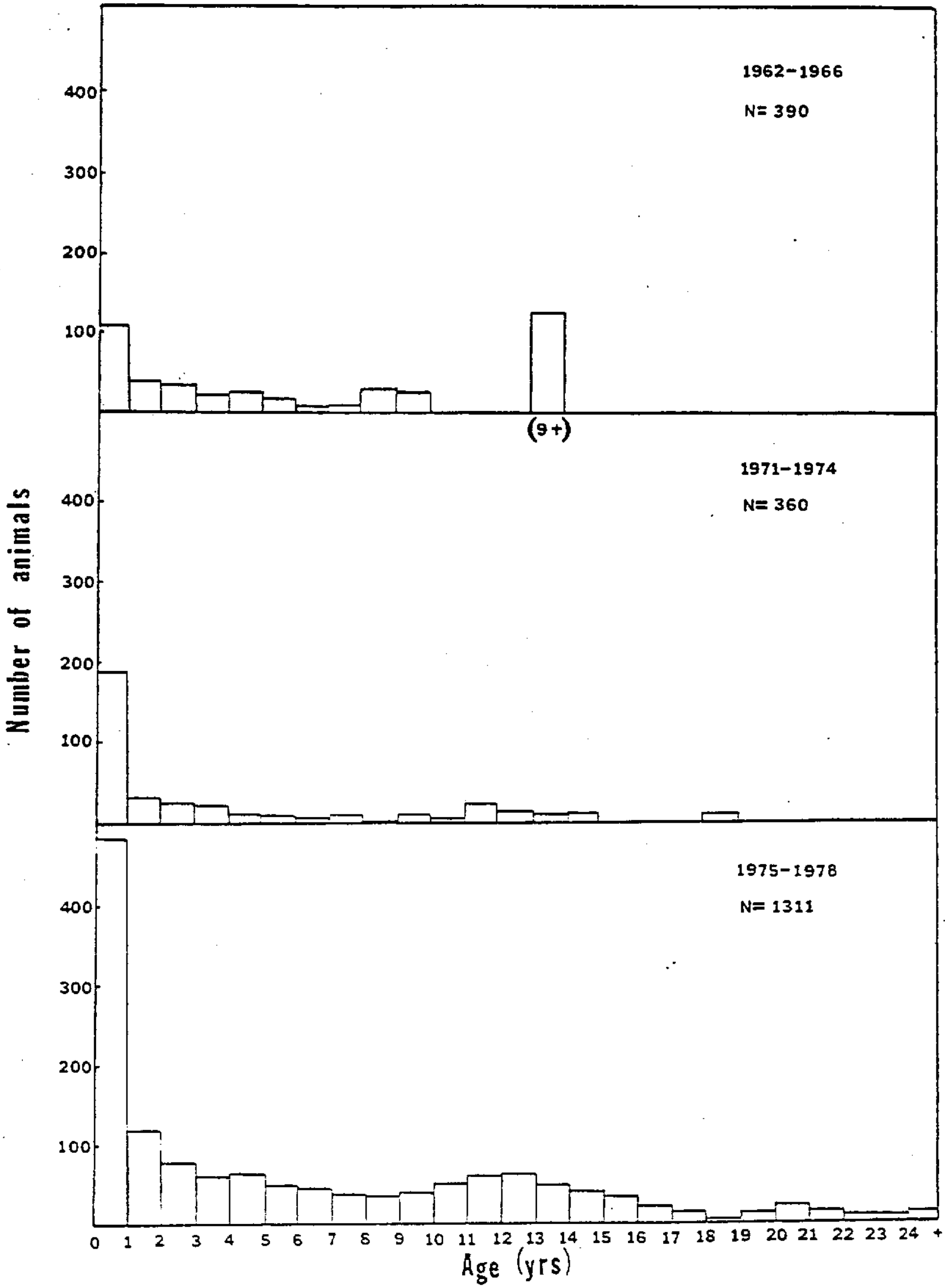


Figure 11. Age frequency distributions of sampled harvests of bearded seals taken in Alaska during 1962-1966, 1971-1974 and 1975-1978.

Table 3. Age and sex composition of the sampled bearded seal harvest, 1975-1978.

Age (yrs)	Sex Undetermined #	%	Males #	%	Females #	%	Total #	%
0	50	34.7	237	45.1	197	31.0	484	36.9
1	10	6.9	49	9.3	56	8.8	115	8.8
2	10	6.9	32	6.1	33	5.2	75	5.7
3	5	3.5	25	4.8	24	3.8	54	4.1
4	12	8.3	21	4.0	24	3.8	57	4.3
5	2	1.4	17	3.2	28	4.4	47	3.6
6	3	2.1	17	3.2	20	3.1	40	3.1
7	5	3.5	7	1.3	17	2.7	30	2.3
8	6	4.2	6	1.1	16	2.5	28	2.1
9	2	1.4	10	1.9	21	3.3	33	2.5
10	6	4.2	12	2.3	21	3.3	40	3.1
11	10	6.9	18	3.4	30	4.7	58	4.4
12	6	4.2	20	3.8	34	5.4	60	4.6
13	7	4.9	7	1.3	33	5.2	48	3.7
14	1	0.7	13	2.5	19	3.0	33	2.5
15	3	2.1	11	2.1	14	2.2	28	2.1
16	1	0.7	2	0.4	12	1.9	15	1.1
17	1	0.7	4	0.8	6	0.9	12	0.9
18	0	0.0	0	0.0	2	0.3	2	0.2
19	0	0.0	2	0.4	8	1.3	10	0.8
20	3	2.1	0	0.0	12	1.9	16	1.2
21	1	0.7	4	0.8	6	0.9	12	0.9
22	0	0.0	4	0.8	0	0.0	4	0.3
23	0	0.0	2	0.4	2	0.3	4	0.3
24	0	0.0	2	0.4	0	0.0	2	0.2
25	0	0.0	2	0.4	0	0.0	2	0.2
26	0	0.0	2	0.4	0	0.0	2	0.2
27	0	0.0	0	0.0	0	0.0	0	0.0
Totals	144		526		635		1311	

animals 3 years or younger (including pups) comprise 40 to 45 percent and those 4 years or older 55 to 60 percent. These values are similar to those reported by Burns (1967).

Mathematical procedures were applied to the harvest data obtained from 1975-1978 by Mr. Lloyd Lowry (ADF&G).

Age composition of annual samples, excluding pups, obtained during this time period are shown in Figure 12. These data suggest the occurrence of differential survival of year classes. For example, in the 1975 harvest, age classes 3, 11 and 20 are strongly represented. In 1976, the 4, 12 and 21-year-olds are strongly represented, as are the 6, 15 and 23-year-olds in 1978. Presuming that mortality is greatest during the first year of life, there was good survival (and perhaps production) of pups in 1955, 1964 and 1972.

Conversely, poor survival of pups is suggested in 1968 and 1973. Age class 2 was poorly represented in our 1975 sample. As 3, 4 and 5-year-olds this cohort continued to be poorly represented in the subsequent harvests. Similarly, 7-year-olds which occurred in low numbers in the 1975 harvest continue to be underrepresented in successive years through 1977.

The age frequency of sampled animals older than pups was "smoothed," using the probit regression (Caughley 1977) in order to generate a probable age structure of the population. The fitted age distribution was used to construct a life table and examine age specific mortality. Figure 13 shows the age frequency distribution of animals in the harvest and the age frequency distribution of the fitted data.

The probit curve results in a sample size of 804 animals older than pups. The number of pups in the population was calculated based on age specific reproductive rates (see section on Reproduction) and the fitted age frequency distribution. This produced an estimated 225 pups and gives a total sample size in the hypothetical population of 1,029 individuals.

Thus 22 percent of the hypothetical population was pups, 451 (44%) were in age classes 0 through 3 and 578 (56%) were 4 years or older. The probit curve generated estimates very similar to those derived from intuitive evaluation of biases affecting age composition of the harvest. We consider these values to be realistic.

A life table for bearded seals in the study area, based on the fitted age distribution of the 1975-1978 sample, is presented in Table 5. Procedures employed follow those as presented by Caughley (1966, 1977) and Smith (1973). Parameters included are age, smoothed age frequency, survivorship (l_x), mortality rate (q_x) and mean life expectancy (e_x). Age specific mortality rates (q_x) for males, females and for the sample as a whole are shown in Figure 14. The mortality rate for males is higher than for females. This is significant and may account for the higher proportion of adult females in the harvest (see below). For the

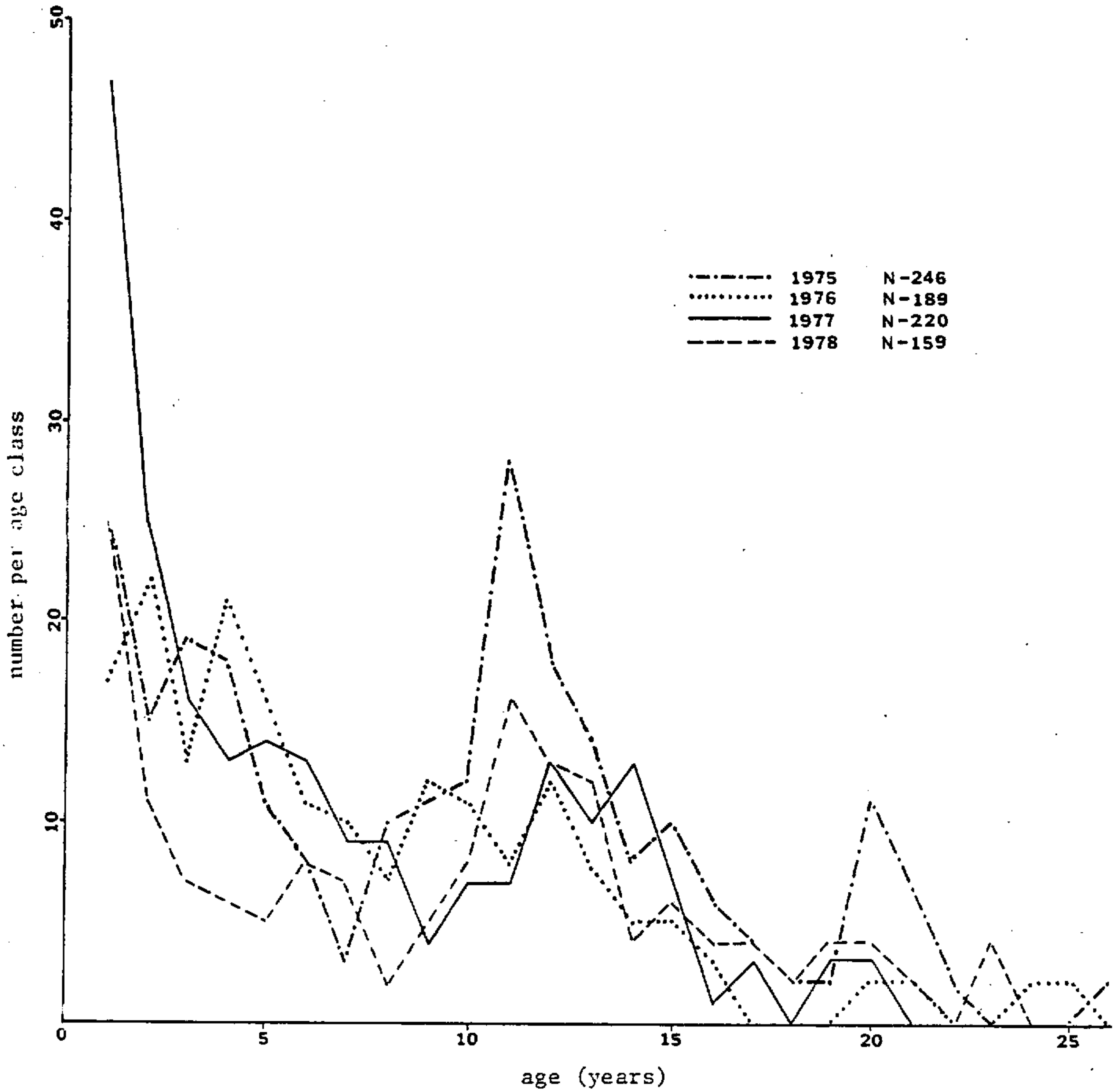


Figure 12. Age distributions of sampled bearded seal harvests, excluding pups, taken in Alaska during each year from 1975 through 1978.

Table 5. Life table for bearded seals based on specimens obtained in the Bering, Chukchi and Beaufort Seas, 1975-1978.

Age in Years	Fitted Age Frequency	Number per 1000 per Age Class	1000 l_x	$1000q_x$	$1000e_x$
0	225	219	1000	599	4.06
1	90	88	401	190	8.38
2	73	71	325	139	9.23
3	63	61	280	115	9.63
4	56	54	248	101	9.82
5	50	49	223	92	9.87
6	46	44	202	86	9.82
7	42	40	185	82	9.71
8	38	37	170	79	9.53
9	35	34	156	77	9.31
10	32	32	144	76	9.05
11	30	29	133	75	8.75
12	28	27	123	75	8.42
13	26	25	114	75	8.05
14	24	23	105	75	7.67
15	22	21	97	76	7.25
16	20	20	90	78	6.81
17	19	18	83	80	6.34
18	17	17	76	82	5.85
19	16	15	70	85	5.33
20	14	14	64	88	4.77
21	13	13	59	92	4.19
22	12	12	53	97	3.56
23	11	10	48	103	2.89
24	10	9	43	110	2.17
25	9	8	38	119	1.38
26	8	7	34	1000	0.50
27	0	0	0	0	0.00

entire sample the mean annual mortality rate for all age classes (0 to 27) was 219/1000 individuals. The mean annual mortality rate for age classes 6 to 27 was 96/1000 individuals.

D. Harvest Levels and Utilization

Bearded seals have been hunted in the Bering, Chukchi and Beaufort Seas since the earliest occupation of these regions by man. At present they are still hunted wherever they occur and are accessible. They are taken by shore-based subsistence hunters of Alaska and Siberia and by Soviet commercial sealers employing modern ships. Harvests during recent years are indicated below:

Year	American Harvest	Soviet Harvest	Total Annual Harvest
1966	1,242	6,230	7,472
1967	1,300	7,009	8,309
1968	1,050	4,577	5,627
1969	1,772	1,986	3,758
1970	1,759	2,533	4,292
1971	1,754	1,490	3,244
1972	1,353	1,428	2,781
1973	1,500	1,293	2,793
1974	1,600	1,256	2,856
1975	1,200	1,220	2,420
1976	2,125	1,644	3,769
1977	4,750	1,204	5,954

This seal is of great importance to coastal residents of Alaska as a dependable and significant source of food and necessary byproducts. Foot gear, boat covers (skin boats), lines, harnesses and other items are made from their very durable skins. Formerly, implements were made from their bones, rain gear and translucent windows from their intestines, fuel from their blubber, and waterproofing compounds and dyes from their blood. Although the methods used by coastal residents to hunt these seals and some of the traditional uses of byproducts have changed, the major uses of meat and hides remain the same.

Coastal-based hunters of Alaska use small, outboard motor-powered boats to hunt in open leads and among the scattered ice floes relatively near shore. Most bearded seals are taken in late spring-early summer as they migrate north and are basking on the ice. During spring they are specifically sought. Other species of seals are often passed up at this time of year as the large bearded seals require a great deal of effort and time to process. A small proportion of the annual catch is taken during winter-early spring. At the island villages, use of small boats during these seasons is sometimes possible. Also, bearded seals are occasionally taken in leads which occur at the fast ice boundary during winter. In these instances the seals are returned to shore with the aid of dog teams or snow machines, or dragged by men.

Hunting success varies with annual differences in ice conditions. Extensive ice cover usually results in availability of more seals for a longer period of time in the Yukon-Kuskokwim Delta area. A rapid spring "break-up" in which ice quickly leaves the coastal zone results in a truncated season. Frequent storms may eliminate a significant number of potential hunting days, etc. Loss is relatively low during the main (spring) hunting season, averaging about 25 percent (1 animal lost out of each 4 killed). It occasionally exceeds 50 percent during seasons when most animals are shot in the water.

The harvest of bearded seals in Alaska was determined for the periods 1 January to 31 December 1977 and 1 January to 30 June 1978 (Matthews 1978). These harvests were recorded by Alaska Game Management Units (GMU). Those units in which bearded seals are taken include GMU's 18, 22, 23 and 26. Coastal settlements in these units from which bearded seals are taken are as follows: 1) GMU 18, Kinegnak, Platinum, Goodnews Bay, Quinhagak, Eek, Akulrak, Tuntululiak, Kwigillingok, Kipnuk, Nightmute, Toksook Bay, Tanunak, Mekoryuk, Chevak, Hooper Bay, Scammon Bay, Akulurak, Sheldon Point, Alakanuk, Emmonak, Emanguk and Kotlik (22 villages); 2) GMU 22, Stebbins, St. Michael, Unalakleet, Shaktolik, Koyuk, Elim, Golovin, Solomon, Nome, Savoonga, Gambell, Teller, Brevig Mission, Wales, Diomede and Shishmaref (16 villages); 3) GMU 23, Deering, Candle, Buckland, Kotzebue, Kivalina and Point Hope (6 villages); and 4) GMU 26, Point Lay, Wainwright, Barrow, Nuiqsut and Kaktovik (5 villages).

We have estimated the yield of meat, hides and oil from the reported harvests and the dollar equivalent of that yield to the local economies in each of the Game Management Units. Assumptions made and procedures used in our determination of the yield derived from harvests of bearded seals were:

1. Age structure of the sample harvest approximated that indicated in Table 3.

2. Mean weight of seals in each age group through 6 years was derived from the growth curve and all seals older than 7 years were considered to weigh 242 kg.

3. Weight of hide and blubber was estimated to be 29 percent of whole weight.

4. 70 percent of the carcass (not including hide and blubber) was usable meat.

5. 80 percent of the combined weight of hide and blubber was oil.

Harvests of bearded seals in Alaska are almost entirely for human food, oil and hides which are consumed or utilized in rural villages. It is therefore difficult to place a monetary value on the harvest. However, the cost of purchasing bearded seal meat, oil and hides, or in some cases the cost of purchasing substitute items (i.e. beef), can be used as a basis for determining monetary value (= equivalent cash contribution) of the harvest. This dollar value was estimated based on the following, very conservative prices.

1. Oil valued at $.22 per kg ($.10 per lb).
2. Meat valued at $3.30 per kg (1.50 per lb).
3. Hides valued at $20.00 each.

From 1 January 1977 through 30 June 1978, 6,308 bearded seals were estimated to have been taken by Alaska residents (Matthews 1978). The derived yield and value of that harvest are given in Table 6. Based on the calculations included in that table, the average weight of a seal in that harvest was 156.9 kg and the equivalent monetary value of that "average" seal was $285.62. The total "equivalent" monetary contribution of the sample harvest was $1,801,682.

Geographic distribution of the sample harvest, as well as yield and equivalent monetary contribution to the regions, are presented in Table 7. The average harvest of bearded seals per village in the four Game Management Units was 89 in Unit 18, 169 in Unit 22, 161 in Unit 23 and 135 in Unit 26.

Clearly, the bearded seal is a very important resource to residents of the Bering, Chukchi and Beaufort Sea coasts. Largest catches are made from villages situated in the northern Bering and southern Chukchi Seas.

E. Age and Growth

In describing age and growth of bearded seals in the Bering-Chukchi population, mean birth date is considered to be 20 April. Standard length and weight of seals at birth, determined from 13 full-term fetuses, was 131.3 cm and 33.6 kg (Burns 1967, in press). However, the mean standard length and weight of newborn pups obtained during this study was slightly less. This may be due to small sample size. The nursing period was found to be short and was estimated to last 12 to 18 days (Burns 1967). Growth during the first few months of life is rapid. By 11 months of age maximum standard length was 165 cm. Increase in standard length and weight of pups is indicated in Table 8.

Growth of bearded seals throughout life is shown in Table 9. The average standard length of all seals 9 years and older was 219.7 cm. Using this mean value as the length of physically mature adults, the proportional length of younger year classes was as follows: pups, 66 percent of adult length; 1-year-olds, 73 percent; 2-year-olds, 83 percent; 3-year-olds, 88 percent; 4-year-olds, 94 percent; 5-year-olds, 96 percent and 9-year-olds, 100 percent.

Maximum recorded standard lengths of bearded seals from the Bering-Chukchi region were 243 cm for a female (Burns 1967) and 233 cm for a male (Johnson et al. 1966). In this study mean standard length of adult females was found to be 221.3 cm (N=20). In males it was 216.8 cm (N=11). These maximum values from the Bering Sea compare with a maximum standard length of 252 cm (sex of animal unknown) reported for the eastern North Atlantic (Benjaminsen 1973) and 253 cm for a female from the eastern Canadian Arctic (McLaren 1958). Maximum and mean standard lengths for mature seals from the Kara and Barents Seas were 238 cm ($\bar{X}$ = 215.4 cm) for males and 232 cm ($\bar{X}$ = 209.3 cm) for females (Chapskii 1938).

Table 6. Estimated yield from and "equivalent monetary value" of 6,308 bearded seals taken in Alaska from 1 January 1977 through 30 June 1978*.

Age Group	No. in Group	Mean Wt.	Collective Wt. All Seals in Age Group (kg)	Collective Wt. of Hide and Blubber (29% whole wt. kg)
0	2,337	68.2	159,383	46,221
1	555	112.4	62,382	18,091
2	359	155.6	55,860	16,199
3	259	196.9	50,997	14,789
4	261	210.0	54,810	15,895
5	227	230.0	52,210	15,141
6	195	242.2	47,229	13,696
7	145	242.0	30,090	8,726
8	132	242.0	31,944	9,264
9	158	242.0	38,236	11,088
10	195	242.0	47,190	13,685
11	277	242.0	67,034	19,440
12	290	242.0	70,180	20,352
13	233	242.0	56,386	16,352
14	158	242.0	38,236	11,088
15	132	242.0	31,944	9,264
16	69	242.0	16,698	4,842
17	57	242.0	13,794	4,000
18	12	242.0	2,904	842
19	50	242.0	12,100	3,509
20	76	242.0	18,392	5,334
21	57	242.0	13,794	4,000
22	19	242.0	4,598	1,333
23	19	242.0	4,598	1,333
24	12	242.0	2,904	842
25	12	242.0	2,904	842
26	12	242.0	2,904	842
Totals	6,308		989,701	287,010

* The number of bearded seals harvested is from Matthews (1978). Age structure of the harvest, yield and equivalent monetary value were derived as indicated in the text.

Table 6. Continued.

Age Group	Collective Weight Carcass Less Hide and Blubber (kg)	Collective Weight Usable Meat (70% carcass, kg)	Collective Weight Oil (80% hide and and blubber, kg)
0	113,162	79,213	36,977
1	44,291	31,004	14,473
2	39,661	27,763	12,959
3	36,208	25,346	11,831
4	38,915	27,241	12,716
5	37,069	25,948	12,113
6	33,533	23,473	10,957
7	21,364	14,955	6,981
8	22,680	15,876	7,411
	27,146	19,002	8,870
10	33,505	23,454	10,948
11	47,594	33,316	15,552
12	49,828	34,880	16,282
13	40,034	28,024	13,082
14	27,148	19,004	8,870
15	22,680	15,876	7,411
16	11,856	8,299	3,874
17	9,794	6,856	3,200
18	2,062	1,443	674
19	8,591	6,014	2,807
20	13,058	9,141	4,267
21	9,794	6,856	3,200
22	3,265	2,286	1,066
23	3,265	2,286	1,066
24	2,062	1,443	674
25	2,062	1,443	674
26	2,062	1,443	674
Totals	702,689	491,885	229,609

Table 6. Continued.

Age Group	Value of Usable Meat ($3.30/kg)	Value of Oil ($.22/kg)	Value of Hides ($20 ea)
0	$261,402	$8,135	$46,740
1	102,312	3,184	11,100
2	91,617	2,851	7,180
3	83,641	2,603	5,180
4	89,894	2,798	5,220
5	85,629	2,665	4,540
6	77,461	2,410	3,900
7	49,351	1,536	2,900
8	52,391	1,630	2,640
9	62,707	1,951	3,160
10	77,397	2,409	3,900
11	109,942	3,421	5,540
12	115,103	3,582	5,800
13	92,479	2,878	4,660
14	62,712	1,951	3,160
15	52,391	1,630	2,640
16	27,387	852	3,180
17	22,624	704	1,140
18	4,763	148	240
19	19,845	618	1,000
20	30,164	939	1,520
21	22,624	704	1,140
22	7,542	235	380
23	7,542	235	380
24	4,763	148	240
25	4,763	148	240
26	4,763	148	240
Totals	1,623,209	50,513	127,960

Table 7. Geographic distribution of the bearded seal harvest taken in Alaska from 1 January 1977 through 30 June 1978: the estimated yield and the "equivalent monetary contribution" of this harvest to each of the four Alaska Game Management Units involved.*

GMU No.	No. of Coastal Villages in GMU	Seals Harvested	Yield of Usable Meat (kg)	Yield of Oil (kg)	Value of Meat ($3.30/kg)	Value of Oil ($.22/kg)	Value of Hides ($20.00/ea)	Dollar Value to GMU
18	22	1963	153,075	71,453	505,147	15,720	39,260	560,127
22	16	2706	211,014	98,498	696,346	21,670	54,120	772,136
23	6	964	75,172	35,090	248,068	7,720	19,280	275,068
26	5	675	52,636	24,570	173,698	5,405	13,500	192,603

* The number of bearded seals taken and the geographic distribution of this harvest are from Matthews (1978). Yield and value were derived from Table 6.

Table 8. Growth in bearded seal pups from the Bering and Chukchi Seas during their first year of life. Specimens were obtained during the period 1975-1979.

Month of life	Standard Length (cm) N	Mean	Range	Std. Dev.	Weight (kg) N	Mean	Range	Std. Dev.
1	1	120.0	-	-	2	28.6	27.2-30.0	2.0
2	8	137.8	123.0-145.0	7.7	5	76.5	57.7-90.9	12.8
3	30	144.4	129.0-173.0	12.0	4	69.8	56.3-79.5	9.7
4	6	163.6	148.0-179.0	12.1	0	-	-	-
5	3	153.1	147.0-160.1	6.6	0	-	-	-
6	0	-	-	-	0	-	-	-
7	1	156.2	-	-	0	-	-	-
8	2	147.7	146.2-149.2	2.1	2	84.0	76.3-91.6	10.8
9	0	-	-	-	0	-	-	-
10	0	-	-	-	0	-	-	-
11	1	165.0	-	-	0	-	-	-
Totals	52				13			

Table 9. Age, standard length and weight of bearded seals from the Bering and Chukchi Seas. Specimens were obtained during the period 1975-1979.

Age (yrs)	Standard Length (cm)				Weight			
	N	Mean	Range	Std. Dev.	N	Mean	Range	Std. Dev.
0	52	146.4	120.0-179.0	13.4	13	68.2	27.2- 91.6	20.5
1	17	159.0	127.5-188.0	17.0	5	112.5	64.0-152.2	31.6
2	10	182.8	164.7-199.0	10.0	4	155.7	86.2-204.5	50.6
3	7	193.8	158.8-215.7	20.3	4	197.0	160.9-243.1	35.6
4	7	207.2	180.0-233.0	17.1	0	--	--	--
5	4	210.1	200.0-226.0	12.1	0	--	--	--
6	5	208.3	197.0-221.0	9.1	2	242.3	222.7-261.8	27.6
7	3	211.9	204.5-222.3	9.3	1	215.7	--	--
8	3	213.0	200.0-220.0	11.2	1	244.5	--	--
9	8	219.7	205.8-235.1	8.2	2	242.0	222.7-261.3	27.3
10	2	229.5	227.0-232.0	3.5	0	--	--	--
11	6	224.4	215.0-240.0	10.5	1	240.9	--	--
12	9	214.5	204.0-222.0	6.3	2	261.4	206.8-315.9	77.2
13	4	219.9	215.0-231.0	7.5	0	--	--	--
14	1	227.0	--	--	0	--	--	--
15	2	218.2	217.2-219.1	1.3	1	220.2	--	--
16	1	233.0	--	--	0	--	--	--
17	0	0	--	--	0	--	--	--
18	0	0	--	--	0	--	--	--
19	0	0	--	--	0	--	--	--
20	1	224.3	--	--	1	268.2	--	--
20+	7	214.1	202.0-232.0	9.7	0	--	--	--
Total	149				37			

In the Bering-Chukchi population females were, on the average, 2 percent longer than males. In other studies females were also found to be slightly longer than males (Johnson et al. 1966, Burns 1967, Benjaminsen 1973). Maximum recorded weights of seals from the study area were 318 kg for a male (this study) and 360.5 kg for a female (Johnson et al. 1966). The heaviest female examined in this study was a 316 kg pregnant female. She had a 32.3 kg fetus (10.2% of her total weight) and was taken on 29 March 1977. The mean weight of five adult females, all taken during late winter-spring, was 250.3 kg. This compares with a weight in summer of 228.6 kg (N=14, Burns 1967). Only two adult males, taken during late winter, were weighed during this study. Their average weight was 390.0 kg. Average weight of 11 adult males taken during summer was 244.4 kg (Burns 1967).

Bearded seals are heaviest in fall through spring. On the average, adult females are heavier than males during this period, especially in early spring when they are supporting a large fetus. Females lose considerable weight during lactation and both sexes undergo weight losses during the molt. By summer the average weight of adult females is less than that of males.

The robust body form of bearded seals is indicated by comparison of standard length and girth immediately behind the foreflippers. In a series of 40 seals 4 years and older, girth was between 71 and 83 percent of standard length. This relationship changes seasonally, lowest values occurring during summer and highest values during late fall through early spring. Seasonal changes in thickness of the blubber layer which account for the changes in girth are marked. Thickness of the blubber layer varies from an average of about 7.2 cm in late fall through early spring to about 4.4 cm during summer. Similarly, the hide and blubber layer account for an average of about 39 percent of total body weight when these seals are fattest and about 29 percent when they are lean.

F. Reproduction

Our investigation of the various aspects of reproduction in bearded seals was directed mainly toward females as it is this group which determines the various aspects of productivity. Most of our samples (about 90%) were obtained between mid-May and late July.

Reproduction in males has previously been investigated. A general resumé of findings is as follows.

McLaren (1958) examined growth in baculum size, seasonal changes in size of testes and in diameter of testis tubules. He concluded that in seals of the eastern Canadian Arctic sexual maturity is obtained at age 7 and that the peak breeding period is during mid-May. Based on his data, males appear to be in breeding condition through early June. Tikhomirov (1966) investigated reproduction in North Pacific bearded seals. He recorded presence of sperm in tubules of the testis and epididymis and changes in testis weight. His findings indicated that sexual maturity in males was obtained between ages 5 and 7 with 50 percent of the 5-year-olds, 66 percent of the 6-year-olds and 100 percent of the 7-year-olds being mature. The main period of breeding was indicated as 20 April to 20 May. Burns (1967) investigated baculum growth, growth and annual variation in size of testes and seasonal presence of sperm in tubules of the epididymis. He concluded that males from the northern Bering and Chukchi Seas attained sexual maturity at ages 6 and 7 and that males were capable of breeding from early April through early June. The peak breeding period was found to be during May.

In the present study we found that baculum length of 8-year-olds approximated the mean for all males older than 8 and that the mean weight of testes for 7-year-olds was within the range of weights for older age animals.

Investigation of reproduction in females has been based mainly on examination of ovaries. Both McLaren (1958) and Tikhomirov (1966) considered the presence of a corpus luteum to indicate ovulation (which it does) and pregnancy (which it may). These authors considered the age at which initial ovulation occurs to be the age at which sexual maturity is obtained.

McLaren (1958) suggested that in the eastern Canadian Arctic females attain sexual maturity, on the average, at 6 years of age. This conclusion was based on findings of follicles up to 10 mm in maximum diameter in a 6-year-old and a 7-year-old. An animal in her eighth year had been pregnant in her seventh year.

Tikhomirov (1966) working in the North Pacific region found that ovulation occurred in 8 percent of 3-year-olds, 21 percent of 4-year-olds, 83 percent of 5-year-olds and 100 percent of 6-year-olds. Ovulation was equated with sexual maturity.

In this study we obtained uteri and ovaries from 260 seals. Examinations of both were employed to correlate presence of a corpus luteum with pregnancy. A corpus albicans and characteristics of the uterus, including placental scars, indicated pregnancy during the reproductive cycle preceding collection. We considered sexual maturity to be obtained at the age of first pregnancy, not the age of first ovulation. As will be seen, this difference in interpretation is significant in estimating population productivity.

Our findings are summarized in Table 10. Interpretation of several important aspects of reproduction is possible from this table. Presence of a corpus luteum was indicative of ovulation and possible pregnancy. A corpus albicans indicated previous ovulation and possible previous pregnancy. These ovarian structures were correlated with characteristics of the uterus including placental scars.

Ovulation occurred in 67 percent of our sample of 3-year-olds. The frequency increased to about 93 percent in 4- and 5-year-olds and 100 percent in 7-year-olds. In order to determine incidence of pregnancy compared to ovulation, we examined the age distribution of animals which had definitely been pregnant during the reproductive cycle prior to

Table 10. Reproductive activity in 260 female bearded seals from the Bering and Chukchi Seas. Eleven seals were taken in 1969 through 1973 and 249 from 1975 through 1978.

Age (yrs)	N	Ovulated and perhaps pregnant in reproductive cycle when taken (corpus luteum) N	%	Pregnant in reproductive cycle preceding collection (large C.A.&Plac. Scar)[1] N	%	Pregnant in any preceding year (uterus & C.A.'s)	Previously ovulated (corpora albicantia)
0	61	0	0	0	0	0	0
1	23	0	0	0	0	0	0
2	13	0	0	0	0	0	0
3	9	6	67	0	0	0	0
4	15	14	93	0	0	0	7
5	12	11	92	2	17	2	6
6	10	9	90	5	50	6	8
7	10	10	100	8	80	8	10
8	16	16	100	13	81	15	16
9	9	9	100	9	100	9	9
10	10	10	100	9	90	10	10
11	18	16	89	15	83	17	18
12	16	15	94	16	100	16	16
13	10	10	100	8	80	10	10
14	4	4	100	2	50	4	4
15	8	7	88	6	75	8	8
16	3	3	100	2	67	3	3
17	2	2	100	2	100	2	2
18	1	1	100	1	100	1	1
19	1	1	100	1	100	1	1
20	2	2	100	2	100	2	2
21	2	2	100	2	100	2	2
22	1	1	100	1	100	1	1
adult	4	4	100	3	75	4	4
Totals	260	153					

[1] C.A. means corpus albicans and Plac. Scar means placental scar.

collection. Pregnancy was indicated by a recent placental scar and a large corpus albicans in the associated ovary. The youngest pregnant animals were 4-year-olds (in their fifth year of life), based on the finding of 2 out of 12 (17%) 5-year-olds that had apparently given birth during the reproductive cycle preceding collection. Thus, in our sample, first pregnancy occurred 1 year after first ovulation. The incidence of pregnancy steadily increased to 50 percent in 5-year-olds, 80 percent at age 6 and 100 percent at age 8. Most females apparently become sexually mature at age 6.

The average age at attainment of sexual maturity was also estimated according to procedures described by DeMaster (1978). In these, ovulation and pregnancy rates increase with each succeeding age class, to a maximum rate. In our calculations we used the ovulation rates indicated in Table 10 for ages 0 to 3 and the mean ovulation rate of 96 percent for ages 6 and older. Rates for age classes 4 and 5 were determined by linear interpolation, between the rates for 3- and 6-year-olds. The interpolated ovulation rate for 4-year-olds was 77 percent and for 5-year-olds 86 percent. For pregnancy rates the values indicated in Table 10 for seals which were pregnant in any preceding year were used for age classes 0 to 6. In age classes older than 6 the mean pregnancy rate of 83 percent was used. Sample sizes in the calculations were the number of animals in each age class from the "fitted" age distribution (see section on Population Structure and Dynamics). If attainment of sexual maturity was based solely on ovulation (indicated by the presence of a corpus luteum) the average mathematically derived age of sexual maturity was found to be 3.4 years ($N=753$, $S^2 = 0.137$). When the attainment of sexual maturity was based on successful pregnancy the average age of sexual maturity was found to be 5.6 years ($N=753$, $S^2 = 0.478$). We found that sample sizes and variances had little apparent meaning when fitted data were used, as both changed depending on the number of age classes included. We consider 5.6 years to be the best derived estimate of the average age of sexual maturity in bearded seals.

Once females begin to ovulate, they do so almost every year. In 127 seals 6 years and older, 122 (96%) contained a corpus luteum. The number which were pregnant could not be determined. However, 105 of these 127 seals (83%) had supported a fetus in the year preceding collection. Also, of 17 sexually mature females taken in 1975-1978 between mid-August and early April, when fetuses are present, 14 (82%) were pregnant. Since earlier estimates of the pregnancy rate were derived in this manner (i.e. Burns 1967), we have continued to use this procedure in order to have a basis for comparison.

Similar pregnancy rates in the Bering-Chukchi population have prevailed for some time. Johnson et al. (1966) studied these seals in 1959-1961. Five of six adult females (83%) taken between January and April were pregnant. Burns (1967) examined 133 sexually mature females between 1962 and 1966. In that study the pregnancy rate, based on examination of uteri and ovaries, was 83 percent. In 20 sexually mature females taken between mid-August and early April, 17 (85%) supported a fetus.

The incidence of pregnancy can also be calculated by determining the reproductive performance of all age classes which included any pregnant animals. In our sample all females 4 years and older would be included. On this basis the pregnancy rate in 139 females was 77 percent.

We determined the breeding period of bearded seals based on the time of ovulation in females. Approximate time of ovulation can be inferred from the presence of large follicles or the presence of corpora lutea in the early stages of development. A large follicle was one greater than 17 mm in diameter and an early stage corpus luteum was one less than one-fourth developed. Based on the 1975-1978 sample the breeding period was approximately 25 April to 30 May with the peak from 5 to 25 May. Females with large follicles (considered gravid) were taken between 29 April and 28 May (N=8). Presence of gravid follicles indicates imminent ovulation. Females containing corpora lutea in the earliest stages of development (only the periphery of the follicular cavity luteinized) were taken between 8 and 30 May (N=11). May 29 was the earliest date on which a female with a completely formed corpus luteum was taken. Fully mature follicles exceed 22 mm on the longest axis before erupting. We found two cases which suggest that ovulation may occur while the female is still nursing a pup. One seal taken on 12 April was supporting a full-term fetus and the ovary of the nongravid uterine horn contained a follicle 16 x 13 mm. The other seal, taken on 14 May, was lactating and accompanied by a pup. She had a follicle which was 22 x 18 mm. However, it appears that in most instances ovulation occurs after lactation has ceased and the females have left their pups. According to Tikhomirov (1966) ovulation is spontaneous.

Implantation was found to occur mainly in July, but apparently extended from early June through about 8 August. The delay between breeding and implantation is 2 months. The implantation site begins to swell and is obvious prior to presence of an embryo which was recoverable by us under existing field conditions. Figure 15 shows the time during which implantation occurred and early prenatal growth. Fetal growth from implantation to birth is illustrated in Figure 16. The duration of implanted fetal growth is 9 months. Total gestation is 11 months.

We found no evidence of reproductive senility in our samples, nor has evidence for such been reported in other studies.

G. Behavior

The following comments are from Burns and Harbo (1977) and Burns (in press).

Behavior including escape response is often important in the identification of seals from aircraft, as during surveys. Bearded seals usually react mildly to an airplane, even at close range. They almost always raise their heads, frequently look up at the plane and usually remain on the ice unless the plane passes directly over them. They do not form herds nor, with the exception of females with pups, do they rest next to each other with bodies touching. Pups in association with

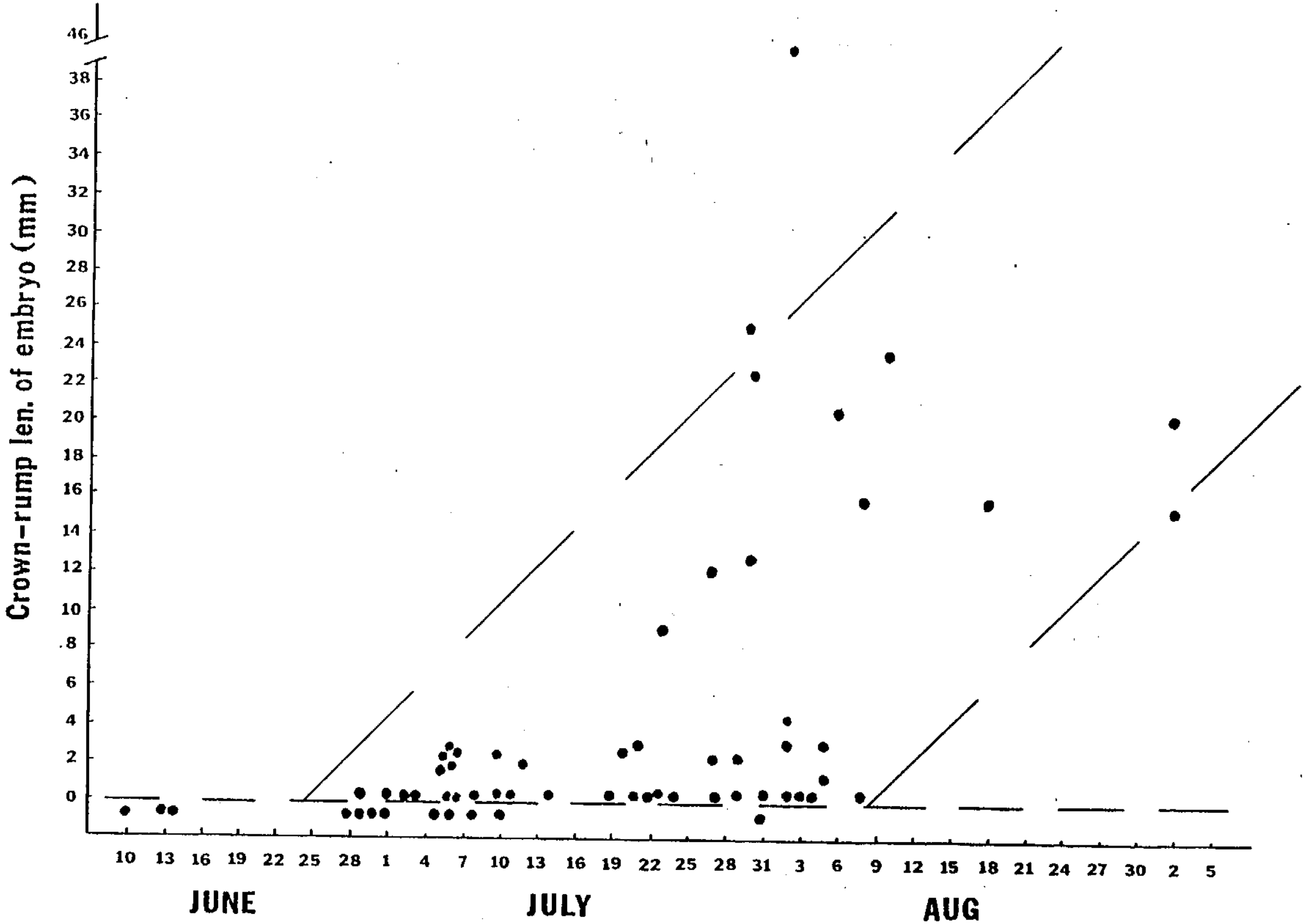


Figure 15. Time of implantation and early growth of embryos in bearded seals taken in the Chukchi Sea between 1964 and 1978 (N=62). Points below the 0 line indicate preimplantation sites, recognized by an obvious swelling in the uterus wall.

adult females (mainly in April) appear dark. Bearded seals are encountered mostly as single animals, although several may rest on a single floe. They lie on their bellies and, almost without exception, their heads are within a few feet of water. When several bearded seals are lying on a single ice floe they position themselves around the edge and appear as if facing away from each other. If animals are resting on both sides of a narrow lead they also face the water and orient themselves perpendicular to the axis of the lead. They rarely rest farther than a few feet from water and, when alarmed, move toward it in a wriggling gait using both foreflippers in unison. They slide head first into the water, frequently raising their hind end high in the air as they dive. The hindflippers do not rotate forward and are not used for locomotion over the ice. Fore- and hindflippers are not obvious except at close range. When sufficiently alarmed they bolt into the water raising and propelling their bodies by the simultaneous movement of both foreflippers. This leaping, forward movement of alarmed animals escaping from the ice is the behavioral basis for the Russian common name of sea hare (Kaitkulov, pers. comm.). Bearded seals rarely move away from water when disturbed, as will spotted and ribbon seals.

The capability of pups to swim shortly after birth, the habit of resting on the ice immediately adjacent to a route of escape and the explosive escape response of alarmed animals are thought to be adaptations which have evolved in the face of continuous predation by bears over a significant portion of their range.

The senses of sight, hearing and smell are difficult to evaluate as the responses of these seals to disturbance are so varied. On a warm, calm spring day when they are basking they often show little concern for a low-flying aircraft, or the close presence of men or boats. With care it is sometimes possible to crawl across the ice and touch one. This is in marked contrast to responses of these seals in winter when the slightest sound-producing movement of a man on the ice will cause a basking seal to flee, or entice a swimming seal to surface several hundred yards from the sound source. An undisturbed bearded seal will characteristically swim with its head and back above the water. One would conclude that when alert they have good senses of sight and hearing and a fair sense of smell.

The mother-pup bond is strong during the early nursing period. Females often remained near pups which were being marked, occasionally coming out on the ice in an attempt to frighten the intruder or defend the pup. Similarly, they will remain in the water near a pup killed by hunters on the ice, or assist a wounded pup in its attempts to escape.

Young animals have been observed engaged in what appeared to be play. In one instance two small bearded seals kept up a constant chase which involved a repetition of riding swells into the beach, active rolling, mock fighting with the foreflippers and tail-chasing back out through the surf. This activity continued for 37 minutes. In another situation two small seals moved along with a small outboard-powered boat and engaged in active tail-chasing, rolling, jumping partially clear of the water, slapping the water surface with their foreflippers and swimming from one side to the other immediately beneath the boat.

Formerly, hunters using kayaks in the open sea were especially successful in harpooning these seals during fall. On moderately windy days the seals could be approached very closely. It is thought that seals remaining at the surface for long periods of time were sleeping and could not hear an approaching kayak over the noises of wind and waves. Unlike swimming seals which expose both head and back, these "sleeping" seals are vertical in the water (Koezuna, pers. demonstration).

Mothers and pups frequently nose and gently scratch each other. Mutual nosing was part of every encounter observed in which a female rejoined her pup on the ice. It was similar to that reported by Burns et al. (1972) for spotted seals.

Use of foreflippers is probably important in social interactions among adults. Adults often bear deep, parallel scratch marks or scars on the posterior third of the body, particularly the abdomen. These marks are usually attributed to polar bears. However, although the distance between the parallel marks is about the same as that between the claws of a small to medium-sized bear, it is also similar to that between the claws of a flexed foreflipper. Additionally, it is difficult to imagine that a significant number of bearded seals struck on the abdomen by bears could escape the strong curved claws relatively unscathed.

In the only killing of a bearded seal by a bear which was observed, the seal's head was crushed by a single blow as it lay on the ice. The bear then grasped the seal's neck in its mouth and pulled it away from the edge of the ice floe. Tooth marks have not been found on seals we examined which had scratch marks.

Bearded seals are very vocal and produce a distinctive song. The long, musical underwater sounds are well known to Eskimo hunters who, in the days when kayaks were extensively used for spring hunting, tried to locate animals by listening for them. Although parts of the song are audible at close range in air, it can easily be heard by placing a paddle in the water and pressing an ear against the butt of the handle. The Alaskan Eskimo terms aveloouk (Upik Eskimo) and ayuktuk (Inupik Eskimo) specifically refer to bearded seals singing in the water.

The production of sounds by these seals has been referred to by several earlier workers. Chapskii (1938) summarized the available information up to the time of his studies. He and others, notably Dubrovskii (1937), associated these sounds with the mating period (Dubrovskii referred to the nuptial whistle) and stated that, "it cannot be explained otherwise than being a sound expression of sexual excitement." Some of Chapskii's informants apparently indicated that both males and females made these sounds.

In the Bering Sea the bearded seal song can be heard from March through July. There is definitely a marked peak in "singing" during April and May.

Analysis of these songs showed them to be complex, long, oscillating frequency-modulated warbles that may be longer than a minute in duration, followed by a short unmodulated low-frequency moan. These sounds are stereotyped and repetitive (Ray et al. 1969). Once located, the singing animals are easy to approach, apparently being inattentive to minor disturbances. They dive slowly, apparently in a loose spiral (judged by the rhythmic changes in strength of the sounds), release bubbles (which signal their general location to the seal hunters) and surface in the center of their area of activity. This behavior is repeated many times.

All of the "singing" bearded seals taken by Eskimo hunters, which we subsequently examined, were adult males. It was suggested that the song is produced by mature males during the spring breeding season and that it is a proclamation of territory or of breeding condition or both (Ray et al. 1969). Future studies will probably show that females also produce these songs. This is suggested by the number of songs that have been heard simultaneously at some locations. It seems that most of the seals observed had to be participating in the singing and it does not seem probable that they would all be males (Burns, in press).

H. Food Habits

Bearded seals are primarily benthic feeders. As a result their distribution is largely restricted to the shallow continental shelf waters which are seasonally covered by sea ice. Their diet is diverse. Epifaunal animals comprise most of the food; however, infaunal organisms and demersal fishes are also consumed. Feeding depths of up to 200 m are reported by Kosygin (1971). Chapskii (1938) indicates feeding depths of up to 50 m. Vibe (1950) found that at depths greater than 100 m bearded seals had not eaten benthic organisms, but instead bentho-pelagic fishes. Based on observed distribution of these seals in the southeastern Bering Sea, they are restricted to waters of 130 m or less.

Although the total array of food items consumed by bearded seals is quite large, relatively few types of organisms comprise the bulk of the food. These are bivalve molluscs, crabs, shrimps, sculpins and sometimes arctic or saffron cod. Geographical variation in diet is largely a reflection of local faunal differences. Major prey types remain the same among areas, however the species eaten may change.

Prior to OCSEAP studies initiated in 1975 (Trophic relationships of ice-inhabiting seals, OCSEAP RU #232) there were only five published accounts of the food habits of bearded seals in the Alaskan sectors of the Bering, Chukchi and Beaufort Seas. Kosygin (1966a, 1971) reported on the foods of bearded seals in the Bering Sea collected in spring and early summer 1963-1965. In 152 stomachs containing food, tanner crab (*Chionocetes* spp.) made up from 53 to 76 percent of the food. Shrimp (particularly *Argis lar*) were the second most important food. Snails, octopus, priapulids and fishes (particularly pricklebacks and flatfishes) were eaten regularly.

Kenyon (1962) examined 17 specimens from Little Diomede Island collected in May-June 1958. Shrimps, crabs and clams comprised most of stomach contents. Other benthic invertebrates (sponges, annelid worms and snails) and several species of fishes were found in small amounts.

Johnson et al. (1966) examined the stomach contents of 164 bearded seals taken at Point Hope and Kivalina in the Chukchi Sea. The only month in which a large sample (129) was obtained was June. Shrimp, crabs and clams were the most common food items with other benthic invertebrates found in small quantities, and fishes (sculpins and arctic cod (*Boreogadus saida*)) usually comprising less than 10 percent of the total volume.

In his summary of the biology of the bearded seal, Burns (1967) reported on stomachs from seals collected at Nome, Gambell and Wainwright. In May he found that crabs accounted for 57 percent of the contents with shrimp, fishes (saffron cod (*Eleginus gracilus*), arctic cod and sculpins) and sponges comprising most of the remainder. In July and August clams were the most abundant food item, with shrimp, crabs and isopods also quite common.

Prior to the OCSEAP program there were no published accounts of feeding in bearded seals of the Beaufort Sea north of Alaska.

The following discussion of bearded seal food habits, by lease area, is summarized from Lowry et al. (1978, 1979a&b).

Bristol Bay and the St. George Basin are at the southern limit of normal bearded seal range. As stated previously, importance of these lease areas to the seals is directly related to ice conditions, and may vary from one year to the next. In general, seals in the southeastern Bering Sea appear to rely on tanner crabs, *Chionocetes* spp., as their primary food source. Gravid female tanner crabs (those with eggs) were eaten more frequently than males. Spider crabs (*Hyas coarctatus*), crangonid shrimps (*Argis* spp. and *Crangon* spp.) and sculpins were important food items in some areas. Differences in consumption of food species probably reflect the patchy distribution of concentrations of tanner crabs. The importance of tanner crabs to bearded seals is indicated by the large volumes found in stomachs of seals which had eaten primarily that species ($\bar{X}$ = 1000 ml), as opposed to much smaller volumes found in seals eating spider crabs, shrimp and sculpins ($\bar{X}$ = 150 ml). Tanner crabs are the most abundant epifaunal invertebrate in the offshore waters of the southeastern Bering Sea (Feder 1978, Lowry and Frost unpubl.).

In Norton Basin and the northern Bering Sea shrimps, crabs (*Chionocetes* and *Hyas*) and clams (mostly *Serripes groenlandicus*) were the most important food items. They made up from 59 to 93 percent of the stomach contents at various locations. Clams were of particular importance in the diet of bearded seals taken at Nome where they accounted for 69 percent of the total stomach contents of seals taken in June. Fishes were usually of minor importance in the diet. Sculpins, saffron cod and arctic cod were the fishes most commonly eaten.

Seasonal variations in diet were found at Gambell and Nome. At Gambell sculpins were of major importance in the diet in March and were much less common in stomachs of seals taken in May and June. At Nome shrimps (mostly Pandalus hypsinotus) were the main food in January-April. In May-June shrimps were of lesser importance in the diet and consisted mostly of Argis lar. A major seasonal difference at both Gambell and Nome was in the importance of clams in the diet. They were rarely found in the stomachs of seals collected during winter months. In stomachs collected during spring-summer they were frequently present in large quantities. A similar lack of clams in the winter diet of bearded seals was noted by Burns (1967).

The Hope Basin lease sale area occupies a large portion of the southern Chukchi Sea. Large numbers of bearded seals feed in this area during much of the year. Most of the information on feeding in this area was from seals collected at Shishmaref. Foods of bearded seals taken near that locality in June-July were similar in 1976, 1977 and 1978. Shrimps (Crangon septemspinosa and some Argis lar), crabs (Telmessus cheiragonus) and clams (Serripes groenlandicus) made up 65-76 percent of the total stomach contents in all years. The predominance of the crab Telmessus, rather than Hyas or Chionocetes, at Shishmaref, and its infrequent occurrence in other samples, is due to the fact that these crabs are generally restricted to waters less than 10 m deep. Such shallow waters extend much farther off shore at Shishmaref than they do at other coastal hunting villages.

In October at Shishmaref shrimps and fishes (flatfish and sculpins) were the only foods eaten. The absence of clams in the fall diet is consistent with observations in the northern Bering Sea.

Point Hope is at the northern edge of the Hope Basin. Johnson et al. (1966) present the most complete account of feeding in bearded seals from this area. As at Shishmaref, crabs (Hyas and Telmessus), shrimp, clams and fishes (saffron cod, arctic cod and sculpins) were the major foods. In May crabs were the major food item whereas in July and August clams predominated.

Bearded seals collected at Wainwright ate clams, shrimp and lesser quantities of sculpins and crabs. Clams were eaten in large quantities, probably reflecting the presence of large clam beds in the Wainwright area.

The Beaufort Sea is an area of relatively low bearded seal abundance. Unlike the Chukchi and northern Bering Seas, it has a relatively narrow continental shelf. The 100 m contour is mostly within 40 km of shore. Since this depth is probably close to the maximum feeding depth for bottom foraging bearded seals, the Beaufort Sea does not include a very large area of favorable habitat for these seals. This is true in winter when landfast ice extends 20-40 km from shore (resulting in a very narrow band in which appropriate ice and water depths occur) and in summer when ice is mostly over deep water.

Data from stomach contents are available for 20 bearded seals taken in the Beaufort Sea. Sixteen of those seals were collected in the Barrow region. As at other locations along the coast of Alaska, crabs and shrimps were primary prey items. Clams, hermit crabs, octopus, gammarid amphipods, isopods and fish were also eaten.

During spring and summer invertebrates comprised over 95 percent of the stomach contents. Clams were an important component near Barrow in August. Large clam beds are known to occur off shore in that region (Carey 1978). In samples from Barrow, taken during November and February, fish were of greater importance than at other times of year. Although shrimps and crabs were still eaten, arctic cod were taken in substantial quantities. The importance of arctic cod is probably a result of the abundance of this fish in the Beaufort Sea, and its appearance in the winter diet may coincide with an onshore spawning migration during early winter.

The overall most important food species at Barrow were tanner crabs, spider crabs and the shrimp Sclerocrangon boreas. In the Prudhoe Bay area spider crabs and the shrimp Sabinea septemcarinata were the most important components of the diet. The absence of tanner crabs and the change in shrimp species reflect faunal differences between the areas. East of Barrow tanner crabs occur only rarely and Sabinea is more abundant than Sclerocrangon (Lowry et al. 1978).

Age-related differences in diet were found in bearded seals from both the Bering and Chukchi Seas. Table 11 presents data from all our Bering Sea samples combined and from June-July 1976-1978 at Shishmaref. Whereas the prey types were similar in all age classes, there were significant differences in the proportions of those types in pups, yearlings and older animals. The proportion of shrimps in the diet decreased with age while the proportion of crabs and clams increased. Capture of these last two prey types may depend on learned behavior acquired by the seal in the first few years of life. The species composition of fish included in the diet also changes with age. Saffron cod was most important as a food for pups, whereas flatfish and sculpins were most utilized by yearlings and adults. Sculpins, in both the Bering Sea and Shishmaref samples, were eaten in greatest number by yearlings. It may be that saffron cod are slow swimming and aggregated and are thus easy prey for pups.

Table 12 presents a summary of major prey species of bearded seals in each of the proposed Alaskan OCS lease sale areas in which the seals occur. This table makes it readily apparent that a very few species are extremely important to seals throughout Alaskan waters. In all five lease areas crabs are the primary food item. Crangonid shrimps were also of major importance in every area. Geographical distribution and abundance of the different species in these two groups determines which particular species will predominate as bearded seal food. Tanner crabs are most abundant in the Bering Sea and are most common in bearded seals from that area, whereas spider crabs (Hyas) are most numerous in both the fauna and in bearded seal diets in the Chukchi and Beaufort Sea. Shrimps show a similar pattern.

Table 11. Major foods of bearded seals collected in 1975-1978 in the Bering Sea and at Shishmaref. Results are reported by age group of seals. Numbers are the percent of total volume for invertebrates, and total fish. For species of fishes, numbers are the percent of the total number of identified fishes.

Food Item	Bering Sea Pups N=52	Bering Sea Yearlings N=23	Bering Sea ≥2 yrs old N=58	Shishmaref Pups N=38	Shishmaref Yearlings N=14	Shishmaref ≥2 yrs old N=87
Shrimp	45	23	28	58	36	31
Isopod	*	-	*	18	17	8
Clam	2	4	22	4	16	18
Brachyuran crab	28	42	27	6	12	23
Echuiroid worm	*	*	*	*	*	11
Total Fish (% volume)	13	27	11	7	17	6
Identified Fish (% number)						
Saffron cod	41	4	5	51	15	36
Sculpin	47	90	78	28	60	27
Flatfish	*	*	2	22	21	35
Mean Volume Contents (ml)	213	589	653	325	346	526

* Trace amounts present (less than 1 percent).

Table 12. Major prey species of bearded seals in 5 proposed OCS lease areas in the Bering, Chukchi and Beaufort Seas.

Area	Relative Ranking of Importance*			
	1	2	3	4
St. George Basin	*Chionocetes opilio*	*Hyas coarctatus*	*Argis lar*	*Crangon dalli*
Bristol Bay	*Chionocetes opilio*	*Hyas coarctatus*	*Argis lar*	*Crangon dalli*
Norton Basin	*Chionocetes opilio*	*Hyas coarctatus*	*Serripes groenlandicus*	*Argis lar*
Hope Basin	*Hyas coarctatus*	*Serripes groenlandicus*	*Crangon septemspinosa*	*Argis lar*
Beaufort Basin	*Hyas coarctatus*	*Sabinea septemcarinata*	*Boreogadus saida*	

* Decreasing importance (1 to 4).

I. Pathology

Pathology was not investigated by us. Readers are referred to reports of Fay et al. (OCSEAP project #194) for information on specimens jointly available to our respective studies. The following account is mainly summarized from Burns (in press).

An exhaustive list of the helminth parasites in bearded seals is beyond the scope of this report. Interested readers can refer to the various writings of K. I. Skriabin, S. L. Delyamure (1955) and King (1964). Current studies of the helminth parasites and other pathologies in bearded seals in the Bering-Chukchi region are being conducted by American and Soviet investigators.

Fay et al. (1978, 1979) reported that the causes of natural mortality in these seals, other than predation by polar bears, are essentially unknown. Lowry (pers. comm.) reported two cases of apparent predation on pups by Pacific walruses found during April 1979. The only major pathological findings in samples from the living population included helminthiasis of the liver and associated secondary bacterial invasion. This occurred in 5 of 96 specimens examined. They reported other conditions including acute dermato-mycosis, focal necrosis of the liver, trauma from unknown causes, biliary fibrosis, hepatitis and gastro-duodenal ulcers.

The most commonly occurring helminth parasites in eight seals from the Bering-Chukchi region examined by Fay et al. (1978) included Diphyllobothrium cordatum, D. lanceolatum, Pyramicocephalus phocarum and Corynosoma validum which occurred in all; Diphyllobothrium sp. and Phocanema dicipiens which occurred in five; Orthosplanchnus fraterculus in four; and Contracaecum osculatum in two. San Miguel sea lion virus/VESV was not found in 1 tested bearded seal and 11 seals were negative in tests for Leptospira.

A total of three bearded seal pups, one stillborn and two newborn, with injuries resulting in death from internal hemorrhage were reported by Fay et al. (1978). Between 1962 and 1969 we found four dead pups, three stillborn and one newborn, which had apparently died of similar causes. The incidence of death from trauma in term fetuses (during birth?) and shortly after birth seems high in relation to the limited opportunities we have had to detect this type of natural mortality.

Pesticides and heavy metals are present in tissues of bearded seals. Galster and Burns (1972) reported DDT, DDD, DDE, dieldrin and PCB's in adipose tissues of polar bear, ringed seal, spotted seal, walrus, bearded seal and Stellar sea lion (Eumetopias jubata) from the Bering-Chukchi region. Small concentrations of pesticides were present in nearly all samples and only PCB's occurred in what were thought to be high concentrations. The contaminant burden of the different species was greater than differences between areas. Of the pinnipeds, bearded seals had the highest concentrations of DDT residues (0.330 μ g/g) and sea lions the lowest (0.026 μ g/g). Levels of dieldrin were low and varied from one-half to one-tenth the levels of DDT. Concentrations of PCB's were similar in all the pinnipeds and averaged 1.78 ± 0.52 μg/g.

Accumulations of mercury were present in samples of liver, muscle and fat of the Bering Sea pinnipeds. The average concentration of mercury in the examined tissues from bearded seals was 0.95 μg/g. It was four times more concentrated in the liver than in muscle or adipose tissue (Galster 1971). Mercury and selenium were present in bearded seals from the Canadian Arctic (Smith and Armstrong 1978).

Cadmium, nickel, copper and zinc were present in tissues of four bearded seals from Bering Sea analyzed by Burrell (1978). Concentrations of cadmium were mainly in the liver and kidney. On the average, highest concentrations in the various tissues were as follows: nickel in muscle, copper in the kidney and liver, and zinc in the liver and kidney. Bearded seals had the highest metal loads of the marine mammals examined (walrus, spotted seal, ribbon seal and bearded seal), perhaps because of their food habits. It was advised that in light of the high concentrations of cadmium found in liver and kidney, these organs not be used as human food.

Petrochemical contaminant levels in seals from the Bering-Chukchi region have, as yet, not been determined.

J. Potential Effects of Development

The effects of petrochemical development on bearded seals will be of two general kinds, direct and indirect. Direct effects include such things as disturbance which may result in displacement of seals (short-term abandonment of formerly favorable habitat), the direct physical effects of exposure to fuel and crude oil spills, and the occasional death of seals struck by vessels.

Bearded seals live in the regions of drifting ice. The pup can swim shortly after birth (it can remain with the mother if she is disturbed), they can leave areas of intolerable disturbance (tolerance levels are unknown) and can probably avoid areas of chronic low-level fuel or crude oil spills.

It is anticipated that drilling rigs and production installations will be serviced by vessels and aircraft. Based on our experiences aboard icebreakers, some seals would be struck and killed by large ships, mainly during April-June. The magnitude of this kind of mortality will probably be small and obviously in proportion to the extent of vessel support required. Low flying aircraft, especially helicopters, frighten seals resting on the ice. This kind of disturbance can be minimized by requiring normal flight altitudes higher than 2,000 feet, by short climbs and descents from installations in bearded seal habitat, and by use of the shortest, most direct flight routes.

Disturbance caused by noises transmitted through the water may affect bearded seals. This possibility is based on the proven importance of vocalization in this species. However, there are no data which indicate the effects of noise on these seals. Based on their occurrence near large settlements such as Nome and Barrow, it appears that constant background noise levels from exploration or production installations will probably not cause significant dislocation of seals. However, periodically recurring loud noises such as explosions probably would.

It is not known whether bearded seals will avoid the small spills of fuel or crude oil which are inevitable. Observations of Eskimo hunters suggest that they, as well as ringed seals and walruses, will. A chronic fuel spill at Wainwright, Alaska, which produced a slick more than 3 miles long, was reported to have resulted in low numbers of seals and very poor hunting near that village, until the fuel leak was stopped. Hunters from Diomede Island, Alaska pour gasoline in the water if they think a skin boat may be imperiled by milling walruses. We have no data on which to evaluate avoidance of limited spills by bearded seals.

One can expect year round vessel and aircraft support of OCS development in Bristol Bay. This lease area has annual variations from being essentially ice free to having extensive thin ice during December through May. Helicopter support of installations in Bristol Bay will also be extensive, as the lease area is within range of shore.

St. George and Navarin Basins will, if developed, be serviced almost entirely by ships. As indicated previously, the occurrence of bearded seals in the St. George Basin lease area is irregular depending on extensiveness of ice. These seals can be considered as not normally present in the Navarin Basin.

Norton and Hope Basins are in areas where bearded seals are abundant for a major part of the year. It is anticipated that year round vessel traffic will be practical in Norton Sound and feasible in Hope Basin from May through December. Helicopter support will be extensive in these areas as development will be mostly within the range of shore bases. Shorefast ice is neither extensive nor thick enough to provide reliable access to nearshore installations except under unusual conditions. The effects of human presence and activities in these two lease areas has potential for the largest number of encounters with bearded seals.

The Beaufort Basin is marginal bearded seal habitat. It is extensively covered by fast ice in winter and the open water season is relatively short. It can be expected that vessel traffic will be limited and most access to development sites will be by fixed-wing aircraft landing on prepared ice strips, by helicopters and by surface travel over ice roads. The region occupied by bearded seals in winter is beyond the limits where petroleum development is now technologically practical (although it is feasible). Development of the Beaufort Basin, free of major accident, will probably have little direct impact on bearded seals.

Some direct impact of seals will occur if a major release of fuel or crude oil were to occur in any area when seals were present. The significance will vary with time, location and volume of the release. Seals swimming in slicks can be expected to suffer from eye irritation which is probably reversible (Geraci and Smith 1976). All seals hauling out on the ice through surface water containing fuel or crude oil would be completely covered. This would disadvantage newborn pups with an insufficient layer of blubber for insulation, and would also result in the ingestion of oil by nursing pups. In grey seals, growth of oiled pups was slower than growth of unoiled pups (Davis and Anderson 1976).

Indirect effects of petroleum development on bearded seals are of much greater concern than are the probable direct effects. They also have the greatest potential for adversely affecting marine systems. Indirect effects will derive mainly from introduction of toxic compounds into the system on a continuous, low volume basis or as the result of a major accident. The former is likely to occur in conjunction with any development while occurrence of the latter cannot be predicted.

Carrying capacity of bearded seal habitat is likely to be reduced as a result of large or long-term releases of toxic compounds. This reduction in carrying capacity is likely to be caused by decreased survival of important components in the food web as discussed by Lowry et al. (1979a).

Hydrocarbon pollution was found to result in mortality of saffron cod (DeVries 1976), eggs of the cod Gadus morhua (Kuhnhold 1970) and eggs of other cods (Mironov 1967). For a closely related fish, the Atlantic pollock (Pollachius virens), 70 percent of the eggs within a slick from the "Argo Merchant" spill were moribund. There was a high incidence of abnormal egg development in areas adjacent to this spill (Grose 1977 in Clark and Finley 1977).

Crabs are important to bearded seals and may be highly susceptible to oil pollution as suggested by Karinen and Rice (1974), Parker and Menzel (1974), Smith (1976), Rice et al. (1976) and Mironov (1970). These investigators demonstrated a variety of effects including sensitivity of larvae, abnormal growth, delayed and unsuccessful molting, retarded growth and morbidity.

Bivalve mollusks, another important food item of bearded seals, were reported to assimilate hydrocarbons (Scarratt and Zitko 1972), and still retained 40 percent of the initially introduced concentrations after 75 days (Vandermeulen and Penrose 1978). Effects of oil on mollusks included reduced breeding success, reduced survival of gametes and abnormal embryos and larvae (Renzoni 1975). Significant reductions in populations have been reported. Dow (1975) indicated a 20-percent decline on oil-contaminated mud flats. Gilfillan and Vandermeulen (1978) recorded a 60-percent reduction in clam stocks 6 years after the "Arrow" spill. Other moderately long-term reductions in clam stocks after oil spills have been documented.

Some shrimps ingest oil and apparently suffer behavioral or physiological changes making them more susceptible to predation by fishes (Blackman 1974, in Johnson 1977). Other effects similar to those found in crabs can also be expected.

It is probable that organisms comprising the food web of bearded seals would be significantly impacted by large spills and, as a result, the bearded seal population would be disadvantaged.

It is noteworthy that in the Baltic Sea, where every effort has been made to protect ringed seals from direct killing by man, the population of these animals continues to decline and is now at a dangerously low level. The continuing decline is ascribed to pollution (Popov, pers. comm.). Likewise, in Puget Sound harbor seals seem unable to increase in numbers in spite of complete protection from hunting.

IX. Conclusions

1. Bearded seals occur throughout the seasonally ice-covered regions of the Bering, Chukchi and Beaufort Seas. They mostly maintain a year round association with drifting ice undertaking major seasonal movements.

2. The oldest seal in our samples was 26 years. Age composition of the harvest is strongly biased toward pups. The proportion of pups in the population during early summer approximates 22-25 percent and the proportion of seals 4 years or older (those classes in which pregnancy occurs) was estimated at 55 to 60 percent, based on consideration of biases affecting the harvest.

3. In harvested animals the sex ratio of pups was approximately even. In older age classes there were more females taken than males.

4. A preliminary life table for bearded seals in the Bering and Chukchi Seas indicated an age frequency distribution in the population which included 22 percent pups, 44 percent juveniles (ages 0 through 3) and 56 percent animals 4 years and older. Mortality was higher for males than for females and may account for the discrepancy observed in harvests. Mean mortality rate for all ages (027) was 219/1000 individuals. For age classes 6-27 the mean mortality rate was found to be 96/100 individuals.

5. The harvest of bearded seals in Alaska between January 1977 and June 1978 was 6,308. Yield of products and the equivalent cash value of this harvest were estimated. A seal in this harvest was the equivalent of 5.1 years old, weighed 156.9 kg and had an equivalent cash value of $285.62. The total estimated value of this harvest was $1,801,682.

6. The mean date of birth for bearded seals was 20 April. At birth pups average 131.3 cm long and weigh 33.6 kg. During the 12-18 day nursing period they increase in weight to between 72 and 95 kg. Average length of seals 9 years or older was 219.7 cm. Weights varied seasonally. Weight of adult males in winter and early spring averaged 290.0 kg. In summer it was 244.4 kg. Adult females averaged 250.3 kg in late winter and early spring and 228.6 kg in summer. There were commensurate changes in girth, thickness of blubber and proportional weight of the hide and blubber layer.

7. Sexual maturity was attained at 6 to 7 years in males and at 4 to 7 years in females. The average age of sexual maturity in females was 6 years. Sexual maturity was based on pregnancy rather than ovulation.

Pregnancy rates were 77 percent for age classes 4 and older and 83 percent for females 6 years and older. The latter value was the same as that found in 1962-1966. Breeding occurs mainly in May and implantation mainly in June. The complete reproductive cycle in females is slightly more than 11 months.

8. Bearded seals may be less sensitive to disturbance by aircraft and vessels than other marine mammal species. The mother-pup bond is initially strong and pups can swim from shortly after birth. Thus, separation of mothers and pups may not be a significant problem.

9. Some pups apparently begin to feed while still nursing. In pups there is no indication of a post-weaning fasting period as in several other seals. The main food of newly independent pups are shrimps. Foods of bearded seals include mainly crabs, shrimps, mollusks (including clams during summer) and some fishes (mainly cods and sculpins).

10. These seals were shown to have a variety of pesticide and heavy metal residues in their tissues. Mercury and cadmium are concentrated in the liver to the extent that this organ should probably not be consumed for human food.

11. Predators of bearded seals include man, polar bears and, in some instances, walruses.

12. Bearded seals regularly occur in the Bristol, Norton, Hope and Beaufort Basins. Of these the Norton and Hope Basins support the largest numbers in most years. Bristol Bay is important during "average" and severe ice years. Beaufort Basin supports relatively low numbers of bearded seals on a year round basis. St. George Basin is utilized by these seals during occasional years of extensive ice while the Navarin Basin is south of the normal range of bearded seals.

13. Development, particularly for petroleum, will have an impact on bearded seals. The impact will range from minor to significant depending on occurrences during petroleum exploration and production phases. Direct effects on bearded seals are expected to be relatively minor. Indirect effects, mainly resulting from reduced productivity and survival of prey species could be significant if routine operating procedures are poor or if large accidental spills of fuel or crude oil occur.

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