Distribution and Abundance of Polar Bears in the Eastern Beaufort Sea

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Beaufort Sea Project

THE DISTRIBUTION AND ABUNDANCE OF POLAR BEARS IN THE EASTERN BEAUFORT SEA

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1. SUMMARY

This report presents baseline information on the biology, distribution, and abundance of polar bears in the Beaufort Sea; identifies critical feeding and denning areas; and makes recommendations relative to projected industrial activity and future research requirements.

From October 1970 through July 1975, 425 polar bears were tagged in the western Arctic. Subsequent to tagging, 25 polar bears were shot, 51 were recaptured, and 117 sightings were made of tagged bears (with numbers painted on them, up to two months after tagging). Seven polar bears, originally tagged in Alaska were recaptured in Canada and six bears tagged in Canada were recaptured in Alaska, demonstrating that a limited amount of exchange takes place between the two areas. In general however, polar bears tagged within the study area showed a high degree of fidelity to it.

Seasonal movements in the population were largely determined by ice conditions. From freeze-up in the fall through to break-up in the spring, most of the polar bears moved throughout the southeastern Beaufort Sea and Amundsen Gulf. As break-up proceeded, the bears moved north so as to be able to remain with the ice and continue to hunt seals.

Five sea-ice habitat types for polar bears were described. Eighty-seven percent of the sightings of bears were made in two similar types of habitat which occurred in a relatively narrow band parallel to the mainland coast to Cape Parry and off the west coast of Banks Island. This zone of critical feeding habitat overlies much of the offshore acreage currently under lease for future petroleum exploration activities.

The distribution of polar bears varied between years with changes in the abundance and accessibility of the seals they preyed upon. Heavy ice conditions in 1974 stimulated marked changes in seal productivity, distribution and availability which were reflected in lower survival of polar bear cubs and changes in polar bear distribution.

Most maternity denning of polar bears in the western Arctic occurred along the west and south coasts of Banks Island and, to a lesser degree on the western peninsulas of Victoria Island. Little maternity denning occurred along the mainland coast.

Although a small proportion of three and four-year-old female polar bears conceived (≃10%), the onset of sexual maturity appeared to be at five. Theoretically, adult females breed every three years for an annual conception rate of 33.3%. The fact that an annual conception rate of 39.1% was calculated indicated that some females were losing their cubs or suffering intrauterine mortality and consequently were breeding more often than every three years. The mean litter size of the three and four-year-old females (1.16 and 1.33) was also lower than that of the older females (1.66).

The average age of male polar bears killed by Inuit hunters was lower than the average age of male polar bears captured by us. There was no significant difference between the average ages of female polar bears killed by Inuit hunters and those captured by us. The reason that adult females and cubs one year of age and older were so highly represented in the age structure of polar bears

killed by Inuit hunters was that the family groups of bears constituted a high proportion of bears present in the most accessible hunting areas and the Inuit harvested the bears non-selectively.

The mortality rates of male and female polar bears three years of age and older, calculated from the age structure of bears captured by us, were 22.5% and 21.5% respectively. The mortality of cubs less than one year of age appeared to be higher in 1974 and 1975 than in previous years. Recorded emigration from the study area was higher in 1975 than in previous years. These latter two results were probably stimulated by a marked reduction in the abundance and accessibility of the seal species preyed upon by the polar bears.

The population of polar bears in the study area in 1974 was estimated as 1,521. Crude estimates of the population size in 1975 indicated that the total could be as low as 1,000 individuals.

Recommendations for the protection of the critical feeding and maternity denning areas were made as were recommendations for future monitoring and research needs.

2. INTRODUCTION

2.1 Nature, Scope and Objectives of the Study

Research on the polar bears (*Ursus maritimus*) in the western Canadian Arctic (hereinafter referred to as the western Arctic) was initiated by the Canadian Wildlife Service in 1970 to resolve questions involved with management of that species. Although about 60 polar bears were being killed each year by Inuit, there were no data to determine if the population could withstand that level of utilization. Data were required on the distribution and productivity of denning areas in relation to the number of bears being harvested annually from the population. Polar bears had been tagged in Alaska for three years but none had been killed in Canada. Thus, data were required on the relative discreteness of the two populations and in particular, on whether polar bears produced in Canada were supporting the Alaskan sport hunting of the species. Finally, non-resident sport hunting of polar bears in the western Arctic began in the spring of 1970, making it essential to obtain population data in order to respond to queries about the survival of polar bears in Canada.

To answer these questions, data were required on population dynamics, movements, distribution, abundance, and denning areas in the western Arctic, in relation to the distribution and abundance of prey species and variations in sea ice conditions.

Since the initiation of this project, two additional but interrelated aspects have developed. In November 1973, Canada, Denmark, Norway, the United States, and the Soviet Union signed an international agreement on the conservation of polar bears (Appendix I) which stated in part: "Each contracting party shall take appropriate action to protect the ecosystems of which polar bears are a part..." and "They [contracting parties] shall... consult with other parties on the management of migrating polar bear populations, and exchange information on research and management programmes...." The second major development is the potential for environmental damage created by offshore oil drilling.

Recovery of tagged bears has demonstrated movements between western Canada and Alaska and that the Inuit of both areas hunt this migratory population. Because of the international agreement, possible detrimental effects to polar bears resulting from offshore drilling must be minimized (as will be detailed later in the report, the area in which the drilling will take place is one of the most important feeding areas for polar bears in the western Arctic).

Thus, research on polar bears in the western Canadian Arctic must meet the needs of a developing bear management program, ensure the conservation of an interjurisdictional population of polar bears and its habitat as stated by the international agreement, and provide information to minimize damaging interactions between bears and people in the exploration area.

2.2 Relationship of the Project to Offshore Drilling

Current plans for offshore oil exploration in the eastern Beaufort Sea call for the initiation of drilling activity in the summer of 1976. If the exploratory phase is successful, much more drilling activity will ensue, followed naturally by production for several years thereafter.

In any offshore drilling program, there is a possibility of a blowout and such accidents have been well documented from other parts of the world. In the eastern Beaufort Sea, which is ice covered for most of the year and where drifting ice may be present at any time, the normal hazards to an offshore drilling program appear to be aggravated.

The possibility of a large scale oil spill or blowout resulting from drilling or production activities in the eastern Beaufort Sea respresents a considerable threat to the species of marine wildlife inhabiting the area, including the polar bear. Clearly, in this circumstance, quantitative baseline data are required on the present status of all the species that might be affected. Hopefully with these data, we could do a quantitative assessment of the effect on the wildlife species of events such as an oil spill, or the large scale disturbance that is inevitable. Without baseline data, post-impact assessment is of considerably less value.

Rather than present a broad treatise on the general biology of the polar bear, this report will concentrate on two specific objectives which we believe will more realistically meet the needs of the Beaufort Sea Project. These two objectives are:

a. To provide baseline information on the biology, distribution, and abundance of polar bears in the eastern Beaufort Sea; and

b. To identify critical areas or times in the annual cycle of the polar bear that might warrant protection from, or modifications of, exploration and production activities.

The quantity of data required for a useful report of the nature of the one requested for this Project takes several years, not 18 months, to collect. In the polar bear project, we were extremely fortunate to already have three years of management oriented baseline research in the area. Thus, the methodology and biology were well enough known that the more specific requirements of the Beaufort Sea Project could be pursued more effectively with the funds available. Even more important, this headstart was absolutely critical to being able to interpret the data collected in the heavy ice year of 1974 and its subsequent effects. Without the information collected in 1971 through 1973, we could not have submitted a useful and responsible report.

Besides its obvious esthetic value, the polar bear represents a substantial component of the cultural and economic base of the Inuit of the western Arctic. At one time, polar bear meat was used for food for both people and dogs, and the hides were utilized to a lesser degree for trade or the making of clothing. In more recent times however, the principal motivation for polar bear hunting has been the sale of the hides, several of which sold for prices in excess of $3000 in 1973 (Smith and Jonkel, 1975). A limited amount of meat is still utilized for food, both by humans and dogs. As such, there is a direct economic value in the polar bear resource plus the sociological and cultural values of a self-supporting existence for the hunters and trappers involved.

Polar bears live primarily on ringed seals (*Phoca hispida*) and to a lesser degree on bearded seals (*Erignathus barbatus*). However, when a polar bear kills a seal, it often leaves a large portion of the meat and entrails, and sometimes fat as well, uneaten on the sea ice (Stirling, 1974a; Stirling and McEwan, 1975) although hungry bears or family groups may eat the whole seal, particularly if it is small. Thus, in the western Arctic, from freeze-up in the fall to break-up in the early summer, there is an abundant, high-quality, alternate food source in the form of seal carrion. Consequently, large numbers of arctic foxes go out onto the ice to follow the polar bears and survive by scavenging throughout the winter. This relatively little known aspect of polar bear ecology is probably highly significant to the white fox trapping industry of the western Arctic so that anything that detrimentally affected the distribution and abundance of polar bears and seals could have a significant effect on the land based trapping economy as well.

3. CURRENT STATE OF KNOWLEDGE

3.1 Life History of the Polar Bear

The polar bear is circumpolar in distribution. In Canada, its range extends from the permanent pack ice of the Arctic Ocean and high arctic islands to southern James Bay.

Although any polar bear may dig a den and use it for a few days during a winter storm, only pregnant females regularly den for an extended period, usually from about early November to late March or April.

The maternity dens are often dug in deep snowdrifts on steep slopes, riverbanks, or stream banks located near the sea. The entrance may be several feet long and usually slopes upward into the main chamber. Most dens have one or sometimes two rooms, often with alcoves dug into the walls, and a ventilation hole through the roof. An average den size is seven feet long, by five feet wide, by three feet high (Harington, 1968). Lentfer (1975) has documented that some maternal denning takes place on the drifting pack ice of the Beaufort Sea but the extent to which this occurs is not known.

Polar bears, like several other mammal groups have delayed implantation. This means that the fertilized egg does not begin to grow immediately but remains in the uterus in a dormant state. Thus, although the polar bear mates in May, the fertilized egg does not implant and begin to grow until about September.

In captivity, the young, normally two, are born anywhere from late November to January. In the wild there is likely as much or more variation in birth dates because of latitudinal differences in the Arctic seasons. Baby polar bears are hairless, blind, and weigh only about 1½ pounds at birth. By the time they leave the den in March or April the cubs weigh approximately 20 pounds. The females lose weight while suckling the cubs and are hungry when they leave the den.

For the first few days after breaking out of the den the female and cubs appear to just play near the den and return to it often. The den entrance is surrounded with the tracks of young cubs digging, climbing bushes, and sliding down banks. In the meantime, most females seem to dig out and eat ground vegetation. This process may last as long as two weeks before the family heads for the sea to begin hunting seals. Young polar bears stay with their mothers until they are 1½ or 2½ years old, although some may remain with the female into their third or fourth year.

Once back on the sea ice the diet of the polar bear consists mainly of ringed and bearded seals. However, observations have been made of bears catching sea birds by diving and coming up beneath them and of bears diving for and eating kelp. Seals are mainly captured by stalking, waiting for the animal to surface at a breathing hole (Stirling, 1974a), or, in the spring, digging out seal pups and sometimes adults from the birth lairs beneath the snow. Few seals captured are wholly eaten by the bears that catch them (Stirling, 1974a; Stirling and McEwan, 1975).

When full grown, adult males in Canada range from about 1,000 to 1,200 lb (450-550 kg) while adult females weigh from about 400 to 600 lb (180-270 kg).

At one time the theory was that the world population of polar bears was a unit and individuals lived a nomadic existence wandering about the whole circumpolar range. However, recent tagging and recapture programs, particularly in Canada, Norway, and Alaska, have shown this is not the case. Instead, it appears that most populations are fairly local. In Canada, there may be as many as 15 such relatively discrete subpopulations.

3.2 Previous Knowledge of Polar Bears in the Beaufort Sea

In the Canadian sector of the Beaufort Sea, knowledge of the polar bear prior to the initiation of this project was scanty. Stefansson (1913 and 1921) documented a number of general observations of polar bears made in the course of his extensive travels in the western Arctic. Manning and Macpherson (1958) summarized available observations from Banks Island and Harington (1964) did a preliminary denning survey. Biologists from the Alaska Department of Fish and Game and the U.S. Fish and Wildlife Service had been studying polar bears in the Barrow area since 1967, to the north and west of Alaska. Some of the results of this research have been published by Lentfer (1968, 1972 and 1974). Frame (1972) reported some offshore sightings of polar bears during the summer of 1969. As referred to earlier, Lentfer (1975) documented maternal denning in the pack ice although the extent to which it occurs remains unknown.

4. STUDY AREA

4.1 Outline of the Area

The study area was broadly defined as the Beaufort Sea east of 140° W and south of 78° N, including Amundsen Gulf, M'Clure Strait, Banks Island, and western Victoria Island (Fig. 1). The reason for considering such a large study area relative to the small zone in which the first offshore drilling

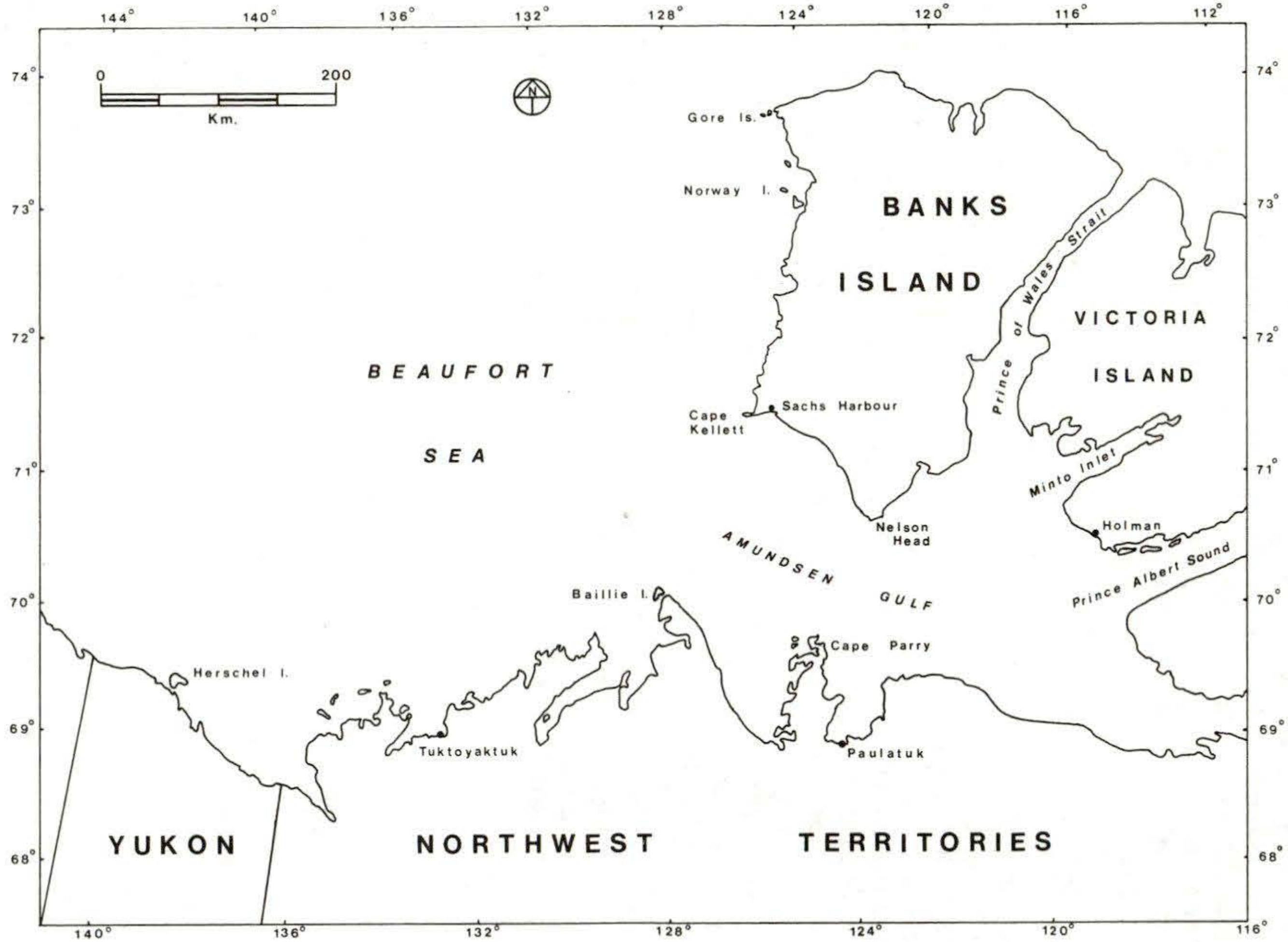

Figure 1. Map of the study area.

was proposed was twofold: besides the area north of the Tuktoyaktuk Peninsula, the offshore areas have already been leased all the way up the west coast of Banks Island, and, our initial mark and recapture studies indicated that the polar bears of the western Arctic population could travel throughout the study area in the course of their annual movements. Within that broad area however, field work was still more concentrated near settlements for logistic reasons.

4.2 Physical Parameters

Knowledge of the physical and biological characteristics of the Beaufort Sea, as known to date, is summarized in Reed and Sater (1974) and in the 1974 Interim Reports to the Beaufort Sea Project. Only a brief summary of the most relevant aspects will be included here. From break-up in the late spring to freeze-up in the fall, the area has an arctic maritime climate with coastal temperatures in the range of 5-15°C. Along the mainland coast, the sea may be ice free for up to 250 to 350 km offshore in late summer, or, in some years, as little as a few kilometres. Details of ice distribution and type through each year are given in the weekly summaries of the Ice Forecasting Central, Department of Environment. The sea is completely ice covered during the winter months with the exception of a few leads which periodically open and refreeze, depending on the wind and temperature. Winter minimum temperature may exceed -40°C. The wind causes snow to form compacted drifts around pressure ridges and on the various land masses. There is 24 hour daylight during the summer months and a corresponding absence of sun during the winter, although some light may still be provided by the moon and stars on clear nights.

5. METHODS

5.1 Field Techniques

5.1.1 Tagging and Recapture of Individual Polar Bears

The most important single task in a study of this nature is to individually tag a large sample of polar bears and to obtain subsequent observations through recapture of the animals themselves or return of their tags from Inuit hunters. If a sufficient number of observations are made, quantitative assessments can be made of population size, seasonal movements, and the discreteness of the subpopulation resident in the area. The techniques of immobilizing and tagging polar bears were described by Lentfer (1968) and Larsen (1971). When the polar bears were immobilized, they were tagged on the ears, weighed, measured, examined for general condition, tatooed on the inside of the upper lip on each side with the same number as was on the ear tag, and a premolar tooth was extracted for age determination. In some instances, numbers were painted on the animals (Fig. 2) to facilitate easy recognition of individuals from the air and consequently, resighting data for periods of up to a few months.

5.1.2 Recording of Tracks

During the spring, when tracks are visible in the snow, notes are kept on the numbers of tracks seen, the direction of travel if discernable, and

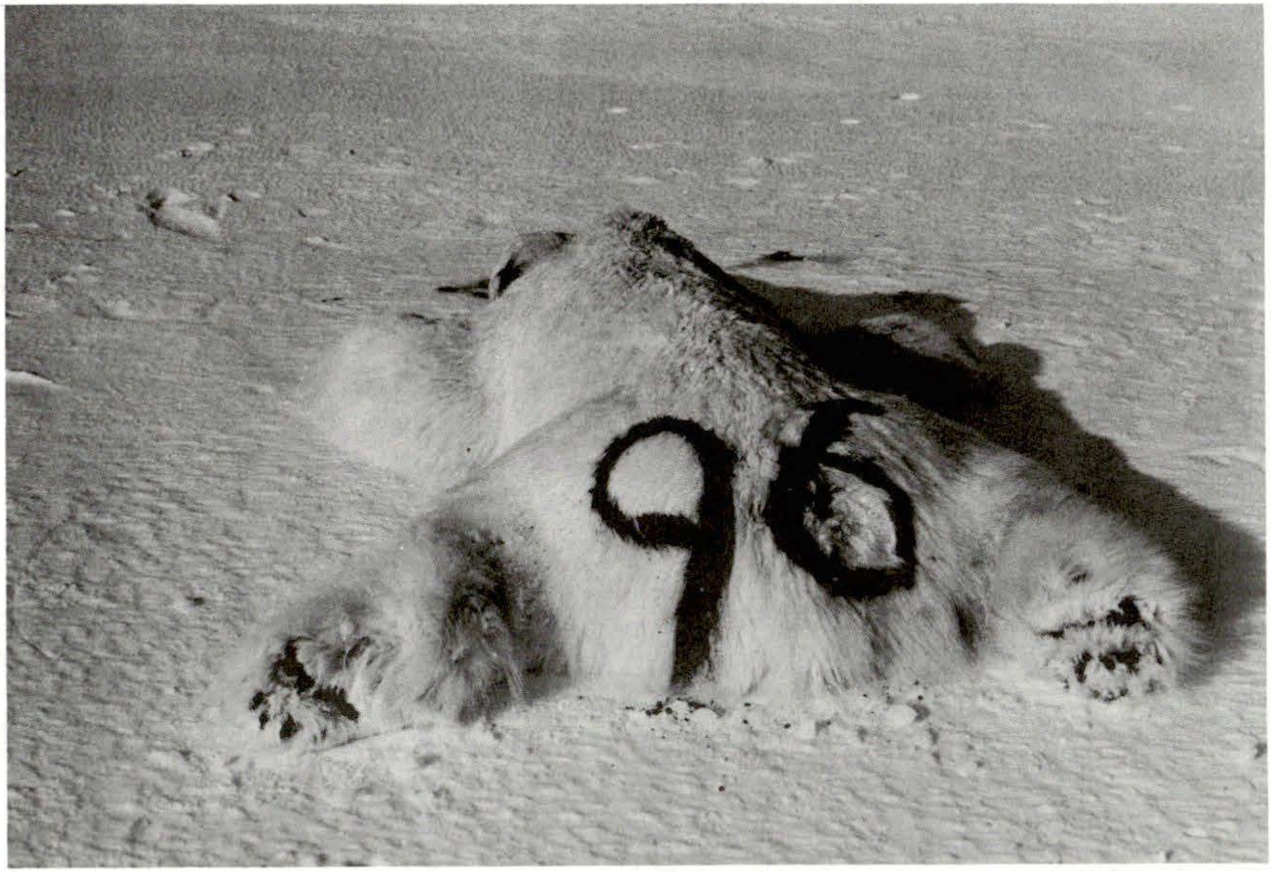

Figure 2. Number painted on a drugged polar bear to facilitate easy recognition when resighted.

the number of kilometres of available habitat flown over. Although these data do not relate to absolute numbers of polar bears, they give a comparative measure of relative abundance between areas and years.

5.1.3 Denning Information

Systematic aerial or ground searches for polar bear dens were not made because of the paucity of data collected for the amount of money and manpower expended. However, all dens found by us or reported by reliable observers were recorded. Tracks of females with cubs of the year leaving their dens on the land for the sea or sightings of the bears themselves in the early spring were plotted to aid identification of areas important for maternity denning. Although slow, and lacking in precision, the accumulation of data in this fashion provided most of the basic information actually required.

5.1.4 Location of Important Feeding Areas

Important feeding areas were documented by simply recording the locations of bears sighted and captured at each season of the year, noting where and how seals were killed, whenever possible determining the age, sex, and species of seal killed, and the degree of utilization of the carcasses.

Data on the biology, distribution, and abundance of the seals available to the bears in the offshore ice will be reported on by Stirling, Archibald, and DeMaster (1975) but some of their results will be incorporated into the discussion section of this report as applicable.

5.1.5 Specimens from Inuit Hunters

Rewards were paid for the skulls of polar bears killed by Inuit hunters and for the return of ear tags or lip tatoos. From these specimens we obtained additional information on the movements and survival of tagged polar bears and enlarged our sample of teeth for age determination.

5.2 Laboratory Techniques

5.2.1 Age Determination

Preliminary estimates of ages were made from skulls when available on the degree of fusion of the basisphenoid-basioccipital, maxillal-premaxillal, and nasal sutures; condylobasal length; coronoid height; interorbital breadth; and sagittal crest development after Manning (1971).

Ages were further refined by histological sectioning and staining of teeth, using a modification of the methods of Stoneberg and Jonkel (1966) and Marks and Erickson (1966), based on cementum annulations.

Crowns were removed with a diamond saw. Roots thicker than 4 mm were ground down to this thickness with a rough grinding stone. Root sections were then placed in a 30% formic acid solution for decalcification (decalcification in formic acid progresses gently and can be easily controlled). Sections 3 mm thick were decalcified 1-3 days, teeth that had been previously preserved in 10% formaldehyde took 3-7 days. Decalcification point was determined by flexibility of sections and by prodding with a needle for calcium deposits.

Decalcified sections were washed for 12-15 hours in running tap water. If sections needed to be stored to await sectioning, they were placed in 70% ethanol. Sections to be cut were imbedded in Lab-tech compound, and cut on a cryostat at -20 to 30°C to 10μ longitudinal sections. Sections stored in alcohol were soaked in slightly alkaline water for about 1-2 hours for hydration before cutting on the cryostat.

Cut sections were placed in water pH 8-9 for at least 20 minutes before being affixed to a glass slide with egg albumen. Drying occured in 30-45 minutes at room temperature.

Sections were stained in a 0.032% aqueous solution of Toluylene Blue (Allied Chemical, Morristown, N.J.) - solution filtered before use. A more intense stain was obtained when the Toluylene blue crystals were dissolved in alkaline water (pH 8-9).

Staining was watched closely (checked every 30-45 seconds, one slide at a time), taking from 1-5 minutes. Sections were covered with a glass cover slip before being photographed. Results were sometimes improved by overstaining and then destaining in water. Stained sections were dried and stored with cover slips on. If necessary, sections in this form were re-stained or, if less than 1 month old, simply wetted in water to restore brilliance, although they never obtained original brightness.

Figure 3 illustrates a thin section of a 5-year-old polar bear showing the annuli in the cementum.

Teeth collected from seals killed by polar bears were aged in the same way. In some instances only the claws of seals killed by polar bears could be located. These were cleaned in the laboratory, moistened on the surface, and the annual laminae counted (McLaren, 1958). This technique was adequate for young seals but only gave a minimum age for older animals.

5.2.2 Basic Data Reduction

All data were recorded in the same manner on both standardized observation forms and in written field notes. Thus, data were simply tabulated as required directly from the field notes in whatever format was required for the various analyses.

5.2.3 Estimation of Population Size

The greatest problem in attempting to estimate the size of a population of wild animals is to obtain an adequate sample of representative observations. It is considerably more difficult, as well as expensive, when there is a relatively small number of individuals spread out over a vast area. In addition, polar bears are often difficult to see and may even hide or leave the transect area when an approaching aircraft is heard. For these reasons, it is not practical to obtain a reliable estimate of the size

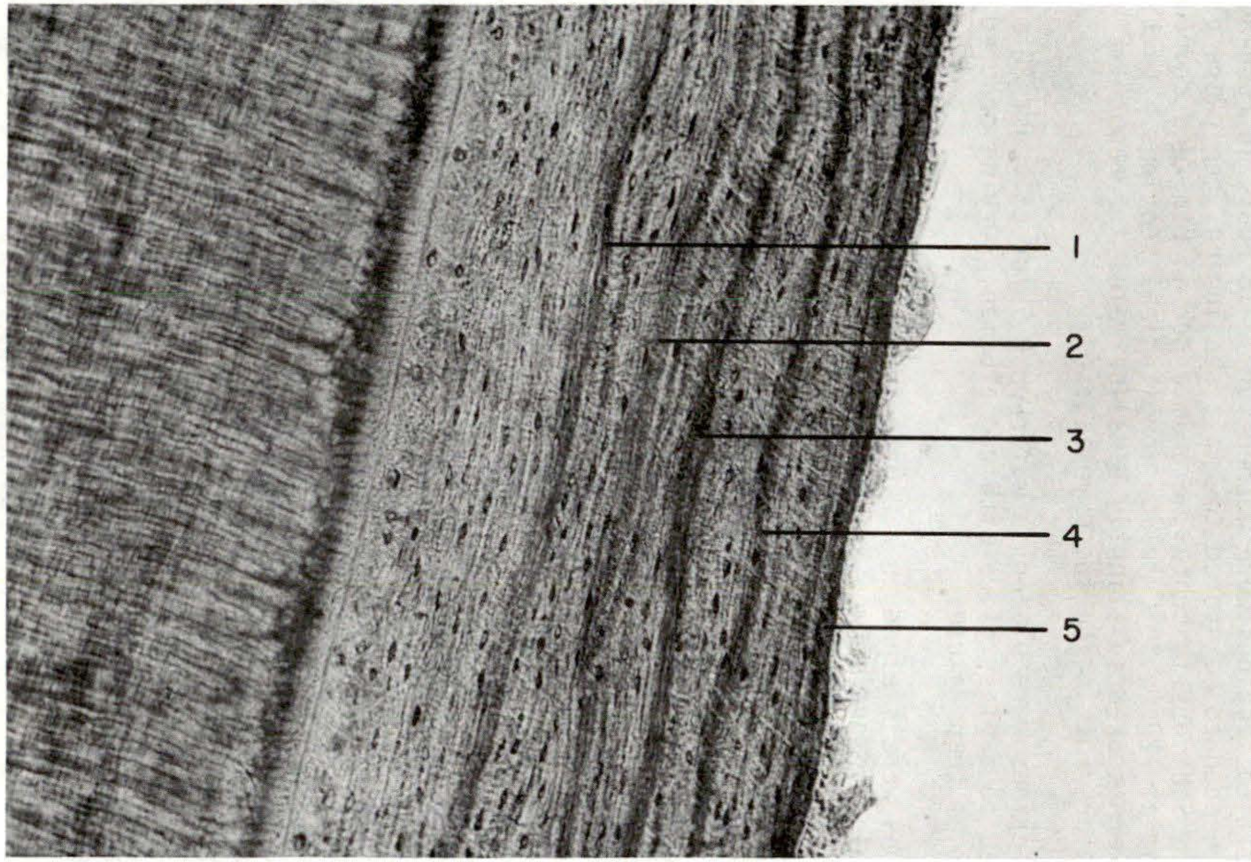

Figure 3. Thin section of the tooth of a 5-year-old polar bear showing the annuli in the cementum.

of a polar bear population by aerial surveying.

In this study, we have applied the technique of mark and recapture over a period of years to estimate numbers. Again, the problem of reduced sample size is experienced in attempting to calculate population size. However, each individual recapture provided a great deal of additional information on movements, growth, survival, and age so that in terms of data collected per dollar expended, this approach was the most desirable.

Basically, the technique of marking and recapturing individual animals depends for its reliability on a number of assumptions:

1) that the probability of capturing a marked animal is equal to the probability of capturing an unmarked animal;

2) that the individual markings or tags are present and recognizable when a marked animal is recaptured; and

3) that the ratio of marked to unmarked animals is the same throughout the population when it is being resampled.

The last assumption requires that the population becomes evenly mixed between sampling periods so that the marked portion of the population is distributed evenly throughout the area in which it will be resampled. In the Beaufort Sea, the mixing of the population is accomplished by the seasonal movements caused by the annual break-up of the sea ice during the summer which causes the population to go north with the permanent ice (Section 6.2). Thus, all bears captured after freeze-up and before break-up, were considered as one sample. The samples from successive seasons were pooled to make up the sample of tagged bears available for recapture in each subsequent season.

The problem of calculating the size of the population in the Beaufort Sea is also confounded by a number of factors:

1) small sample sizes collected over a large area;

2) the fact that the population appears to be partially separated into two segments associated with the west coast of Banks Island and the mainland coast respectively (Section 6.1); and

3) the environmental conditions that prevailed in 1974 and 1975 appear to have greatly reduced the seal population (Stirling, Archibald and DeMaster, 1975) and stimulated abnormally high cub mortality and some adult emigration (Section 6.7).

However, it is essential to attempt to estimate the size of the population for management purposes and to provide some baseline information with which to assess subsequent change that might be caused by natural or unnatural causes.

Table 1. Age and sex class of polar bears tagged in the western Arctic, October, 1970 to July, 1975. (Single bears 2½ years of age to 4 years inclusive were called subadults; bears 5 years of age and older were called adults.)

Age and Sex Class	YEAR 1970	1971	1972	1973	1974	1975	TOTAL
Adult male	-	5	14	19	20	45	103
Adult female (alone)	-	-	2	9	6	20	37
Subadult male	1	8	8	13	16	18	64
Subadult female	-	2	9	13	20	17	61
Adult females with cubs	1	5	13	17	12	13	61
Cubs of year							
male	-	-	2	7	7	4	20
female	-	-	1	1	4	6	12
Yearling cubs							
male	-	3	1	6	3	2	15
female	1	3	5	10	1	3	23
Two-year-old cubs							
male	-	1	3	2	6	-	12
female	-	2	3	4	4	4	17
Three-year-old cubs							
male	-	-	-	1	-	1	2
Yearling females (alone)	-	-	1	1	-	-	2
TOTAL	3	29	62	103	99	133	429

6. RESULTS AND DISCUSSION

6.1 Discreteness of the western Arctic Polar Bear Population

From October 1970 through July 1975, 429 polar bears were tagged in the western Arctic (Table 1). Figure 4 shows the locations at which bears were tagged. Subsequent to tagging, 25 polar bears were shot and 51 were recaptured. An additional 117 resightings were made of tagged polar bears (with numbers painted on them) up to two months after tagging.

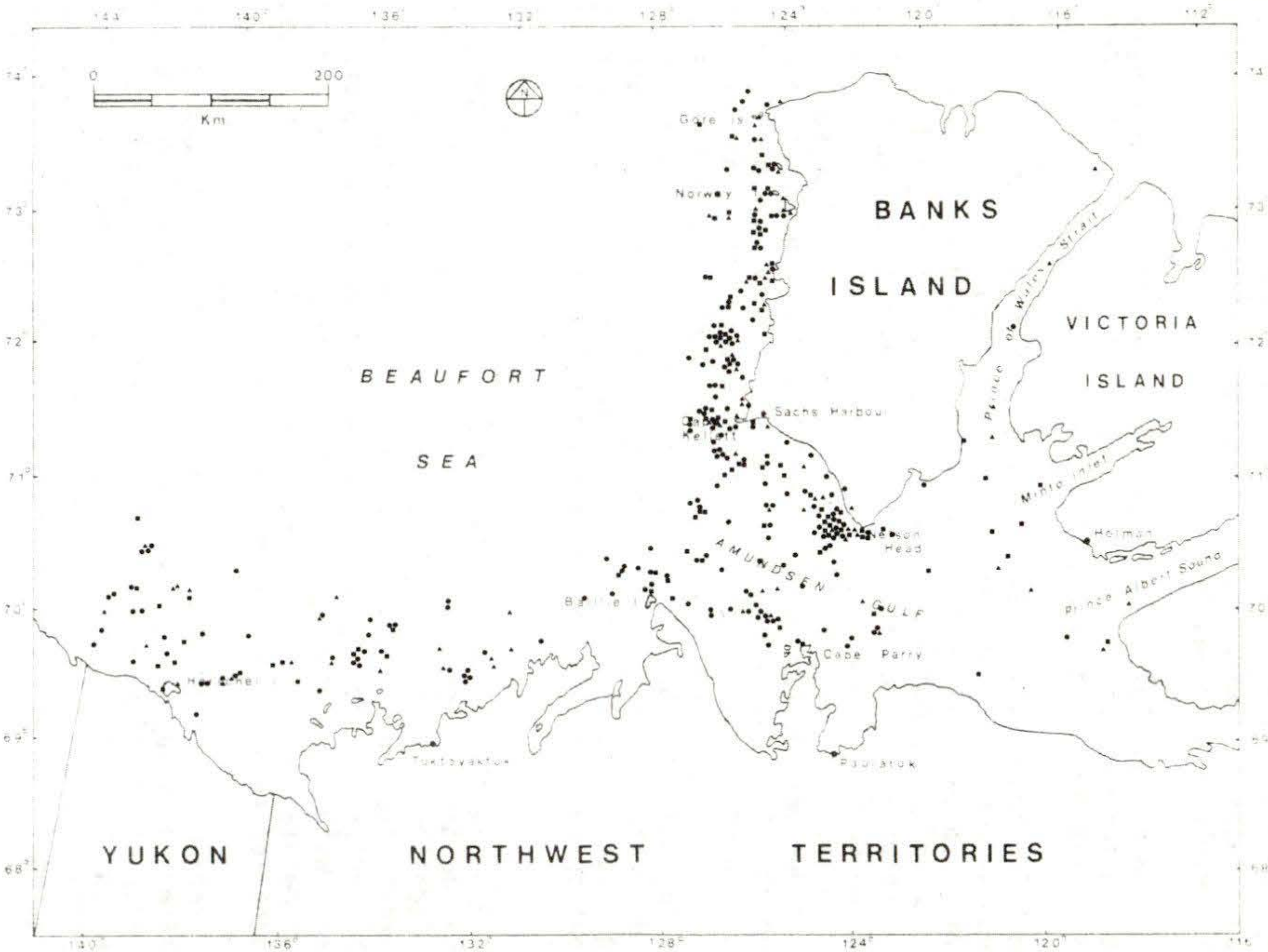

Figure 4. Locations at which polar bears were tagged in the western Arctic from October 1970 to July 1975. Dots represent males; squares represent females; triangles represent family groups.

Figures 5, 6, and 7 illustrate the recorded movements of polar bears tagged between the west coast of Banks Island, Amundsen Gulf, and the mainland coast from the Alaska border to Cape Parry, and recaptured or shot one or more years later. Figure 8 illustrates the recorded movements of tagged polar bears between Alaska and Canada.

From 1968 to June 1975, 888 polar bears were known to have been killed or captured in the western Arctic, of which seven (0.8%) were tagged in Alaska. None was recovered east of Baillie Island.

From 1970 through 1972, 261 polar bears were captured or shot in the Point Barrow area but only one (0.4%) had been tagged in Canada (Lentfer, 1972 & 1974). In 1974, 142 polar bears were captured near Barrow, including 20 Alaskan-tagged bears but none that had been tagged in Canada. In 1975, 50 polar bears were captured at Barrow, including nine tagged in Alaska and three from Canada (6.0%) and 43 were captured near Barter Island, including one tagged in Alaska and two (4.6%) from Canada. These data suggest virtually no exchange between Alaska and Canada but they are biassed because there is no way of knowing where an untagged bear may have been prior to capture or tagging. A more realistic assessment may be gained by examining the recorded exchange in recapture data. Seventy-six polar bears tagged in the study area have been shot or recaptured, eight (10.5%) of which were recovered elsewhere and six (7.9%) of which were recovered in Alaska. Thirty-eight tagged polar bears were recaptured in the Barrow and Barter Island areas in 1974 and 1975 of which six (15.8%) were originally tagged in Canada.

On the basis of the above data, and Figures 5 to 8, a number of conclusions may be drawn. Polar bears tagged within the study area show a high degree of fidelity to that area. Furthermore, in subsequent years, they often return to feed in areas close to where they were originally captured despite the fact that they may have moved several hundred kilometres between years. Within the population there is a tendency for less exchange between the mainland coast and the west coast of Banks Island than there is between either of those areas and Amundsen Gulf.

The exchange of polar bears between Alaska and Canada appears to be limited, although it may vary with changes in environmental conditions. For example, seven of the eight polar bears recaptured outside the study area were caught in 1975. This aspect will be discussed in more detail later. Lentfer (1974) reported a similar degree of discreteness between the polar bear population in the Barrow area and that off the west coast of Alaska.

6.2 Seasonal Movements

Figure 9 shows the directions of movements of polar bears captured in the western Arctic during the spring, from 1971 through 1975, and resighted 10 days or more later in the same spring or early summer. Figure 10 shows the direction of movements of polar bears captured in the western Arctic during the fall and resighted or shot up to six months later.

These data further confirm the general description of seasonal movements given in Stirling (1974b). From freeze-up in the fall to break-up in

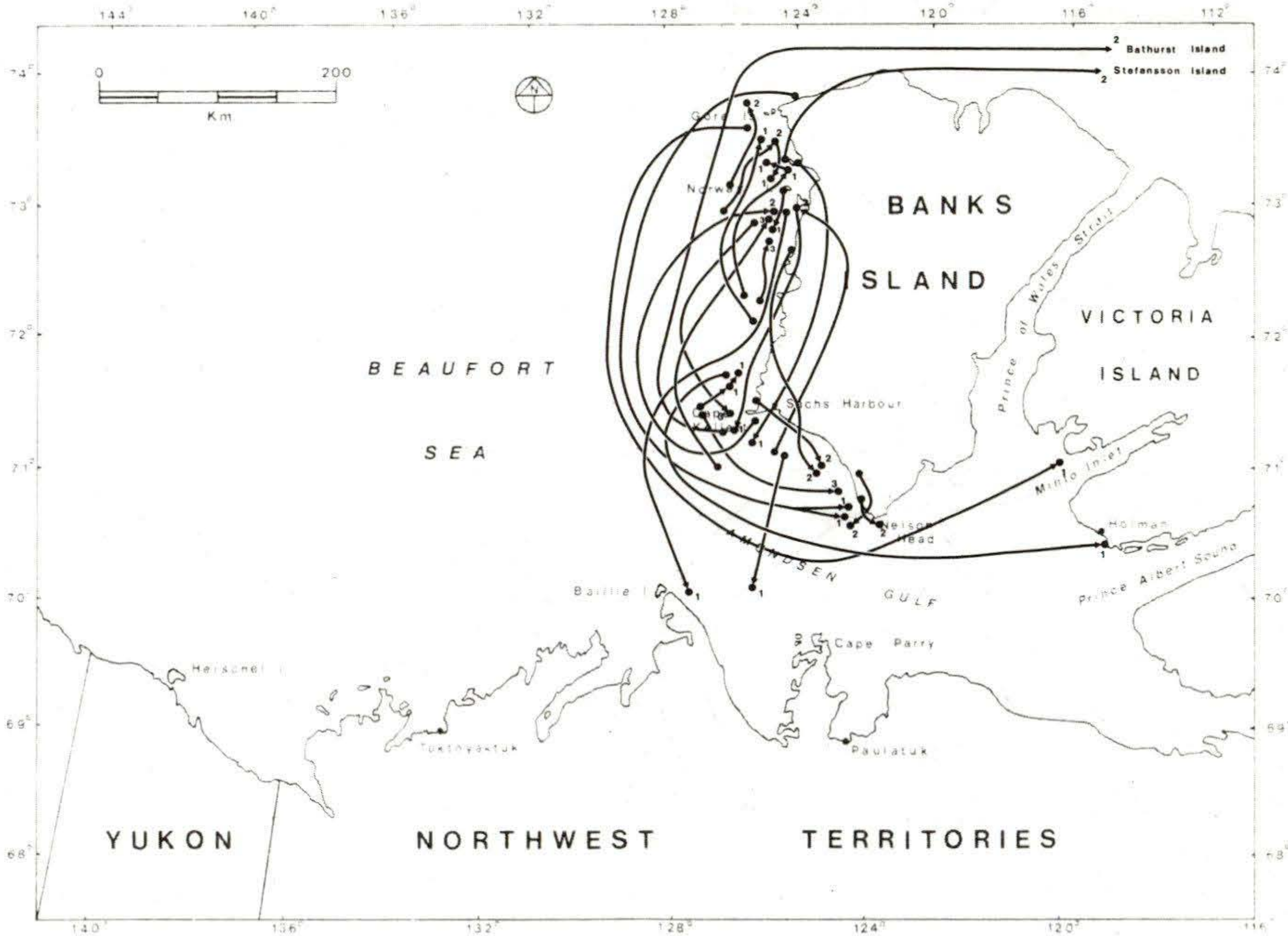

Figure 5. Recorded movements of polar bears tagged on the west coast of Banks Island and recaptured one or more years later. Number beside arrow indicates how many years later the bear was recaptured.

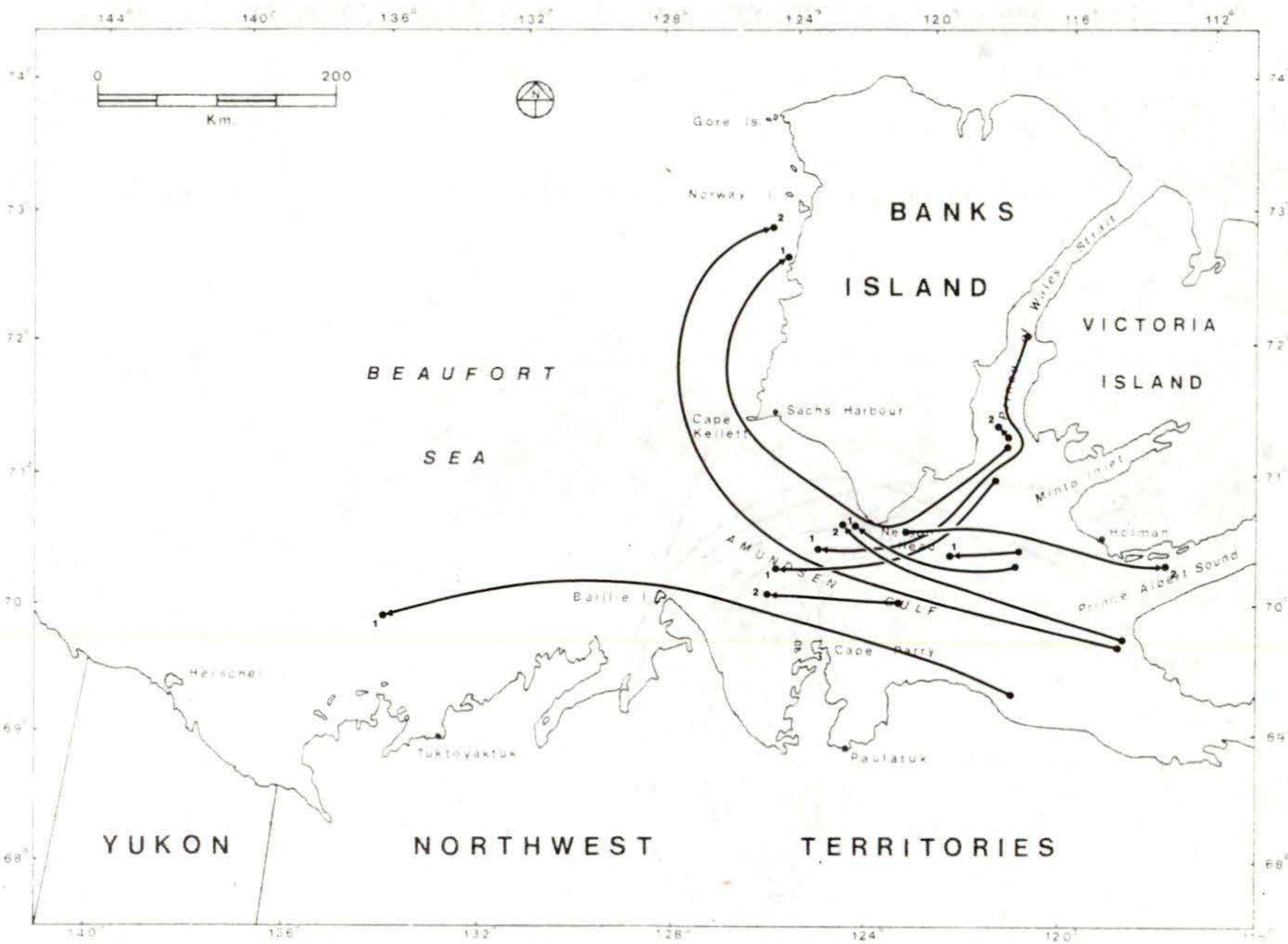

Figure 6. Recorded movements of polar bears tagged in Amundsen Gulf and recaptured one or more years later. Number beside arrow indicates how many years later the bear was recaptured.

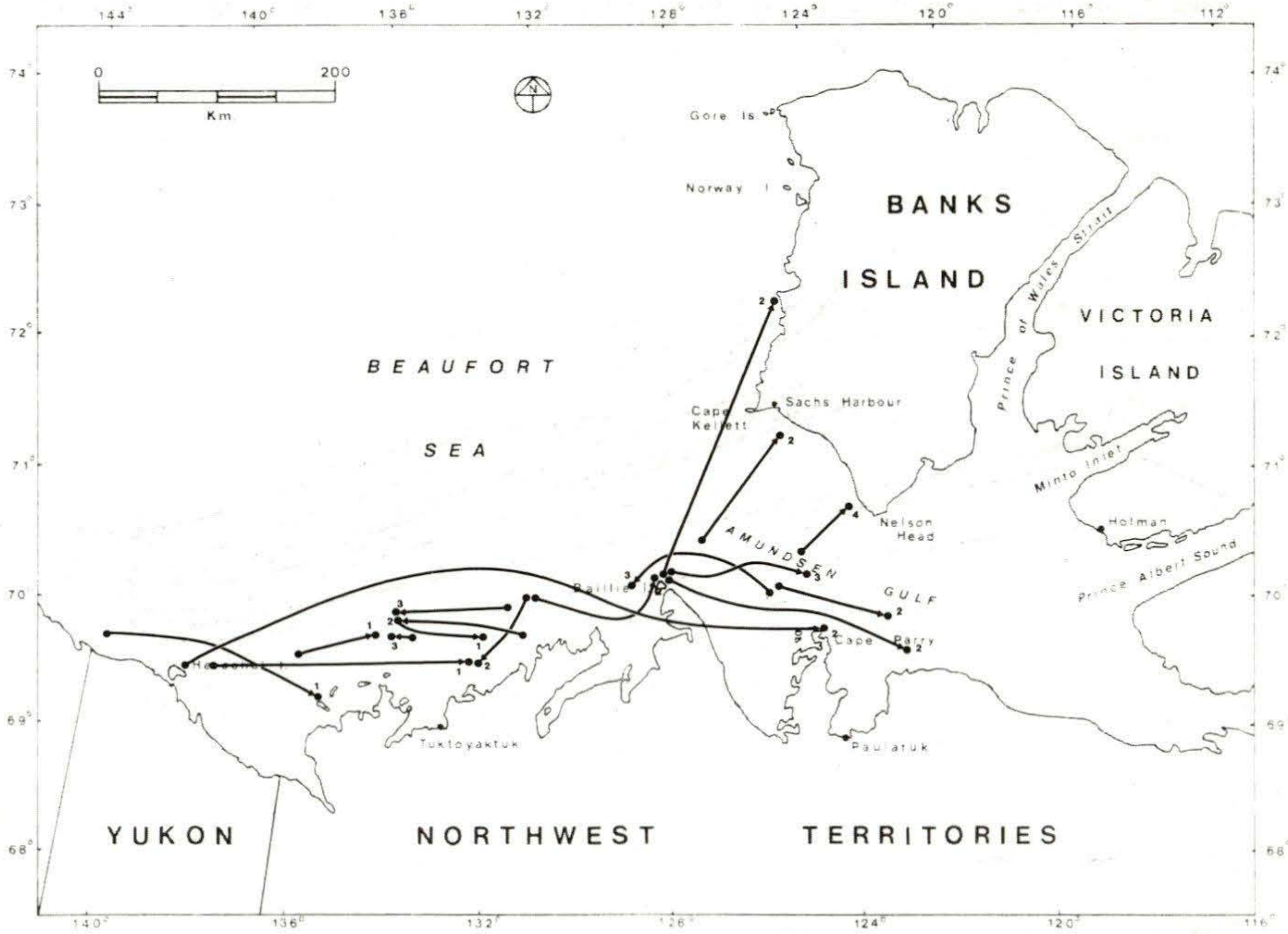

Figure 7. Recorded movements of polar bears tagged on the mainland coast from the Alaskan border to Cape Parry and recaptured one or more years later. Number beside arrow indicates how many years later the bear was recaptured.

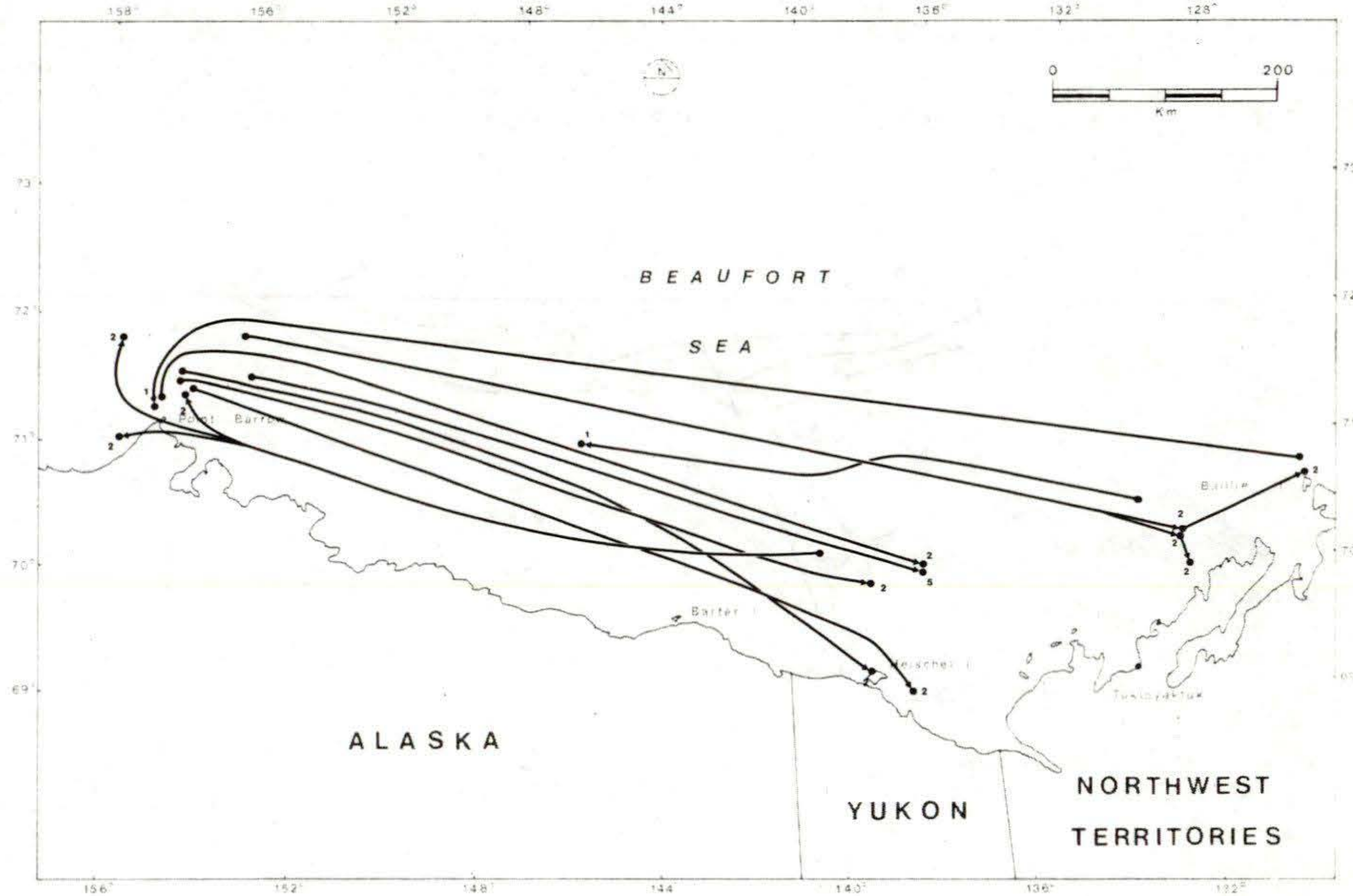

Figure 8. Recorded movements of tagged polar bears between Alaska and Canada. Number beside arrow indicates how many years later the bear was captured.

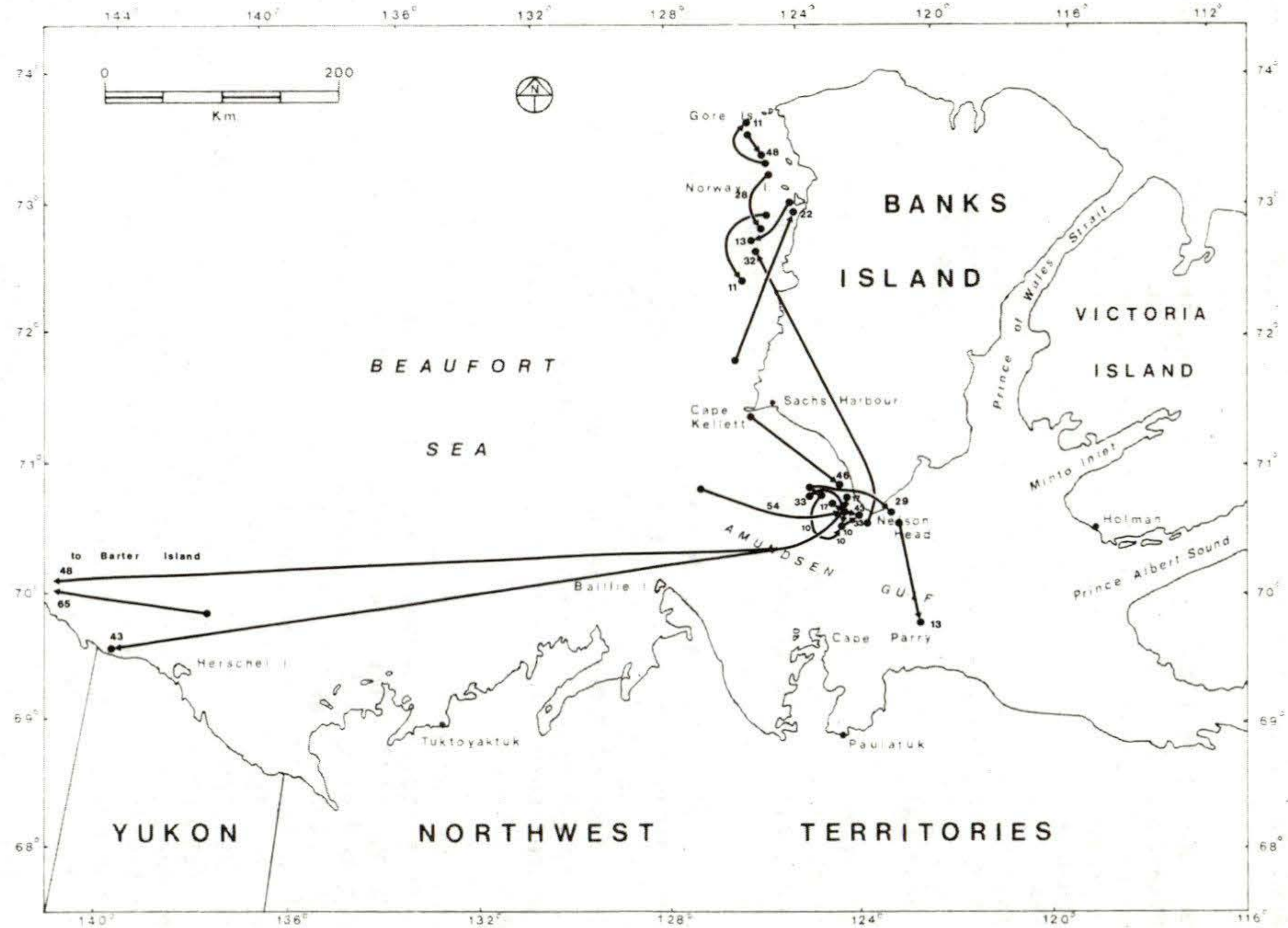

Figure 9. Movements of polar bears captured during the spring in the western Arctic from 1971 through 1975 and resighted 10 or more days later in the same spring or early summer. Number beside arrow represents how many days later the bear was sighted.

the late spring, polar bears are distributed throughout the southeastern Beaufort Sea and Amundsen Gulf. The factors affecting their distribution within the area during and between seasons are discussed in Sections 6.3 and 6.4.

As break-up proceeds through the late spring and early summer, the annual ice disappears from the mainland coast and Amundsen Gulf, and the southern edge of the permanent pack ice retreats to the north. Most bears apparently migrate north to stay with the ice although they may move back and forth within a local area for as long as the ice remains intact (Fig. 9). Presumably they do this so as to be able to continue to hunt seals since they are unable to capture seals in the open water and the seals very rarely haul out on land. Occasionally some bears spend the summer on land on the south end of Banks Island (Manning and Macpherson, 1958; this study), probably by accident rather than by design.

In years such as 1974, when break-up was much more limited and a large proportion of the ice did not move north, sightings of bears off the mainland coast and Baillie Islands were common during the summer, suggesting that the northward migration in summer is more facultative than obligatory.

During October or November, depending on when freeze-up takes place, the bears immediately migrate south (Fig. 10). This movement was first documented by Stefansson (1921) but movements of large numbers of bears south along the west coast of Banks Island have been well known to the Inuit of that region for many years. Presumably the stimulus for this movement is to reach areas where there are either more seals or better hunting conditions, or both (see Section 6.3).

Inclement weather, variable ice conditions and short days during autumn confound systematic surveys and tagging studies in the western Arctic. However, in October 1973, there was a rare period of six consecutive days of good weather immediately after the annual ice first froze between the southern edge of the pack ice and the mainland. During that period, field work was conducted in the eastern Beaufort Sea from Norway Island to 145 km south of Sachs Harbour. The direction of travel was determined for 51 sets of polar bear tracks (family groups were considered as one unit because each adult female presumably determined the direction of travel of her cubs). Eighty-six percent (44 of 51) of these tracks were headed south (Stirling, 1974b). The motivation for these bears to move south was apparently so strong that many of the bears were many kilometres out onto young sea ice that was barely thick enough to support them.

Lentfer (1972) reported that in Alaska, polar bears are much more abundant during years in which a large amount of the permanent pack ice is blown south to the mainland coast than when it is sparse. Similarly, at Herschel Island, in 1970 and 1975, when heavy pack ice moved south in early October and remained there, numerous polar bear sightings were reported.

However, should the ice suddenly be blown offshore from the mainland by SE winds after freeze-up, the bears move back out with it rather than remain on the coast. For example, Stirling (1974b) reported that sometime between 8 and 15 October 1971, young ice united the pack ice

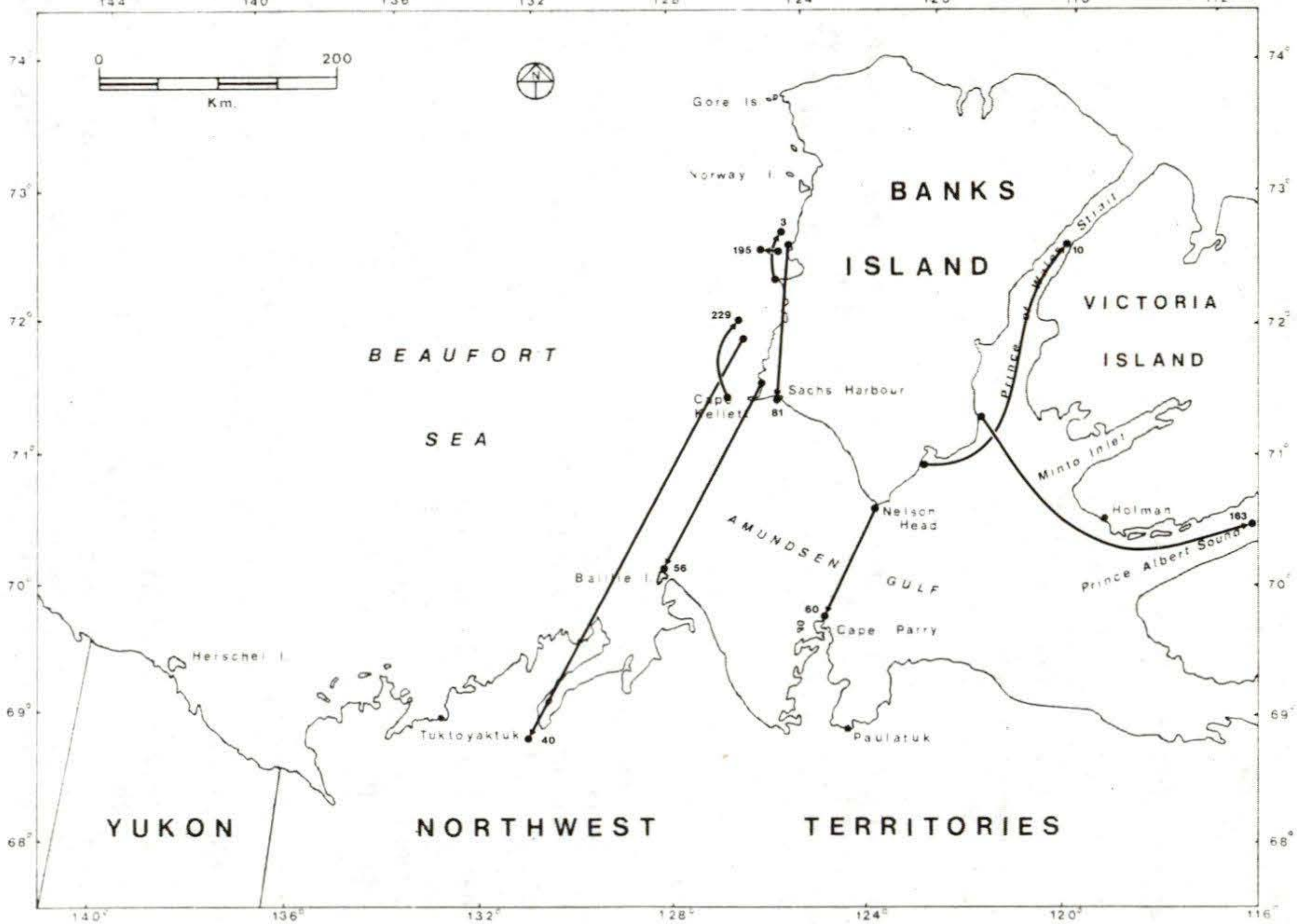

Figure 10. Movements of polar bears captured in the western Arctic during the fall and resighted or shot up to six months later. Number beside arrow represents how many days later the bear was sighted.

with the Yukon Coast. In the week or so that followed, 10 polar bears were sighted at Herschel Island. A survey conducted after two days of SE winds had removed the ice, showed that the bears were absent, having departed with the ice as rapidly as they had arrived, demonstrating clearly their close relationship to it.

6.3 Polar Bear Distribution in Relation to Ice Types

Polar bears are not distributed evenly over the ice-covered surface of the sea, but are clumped on specific ice types, presumably in relation to the abundance and availability of seals. For the purposes of this analysis, the sea ice, between the late fall and late spring, may be divided into a series of broad habitat types in terms of its usage by polar bears as follows:

1) stable flat ice areas interspersed with pressure ridges that have not moved for a long time; are drifted with snow and suitable for seal lairs (Fig. 11) (for more descriptive detail on seal lair habitat see Smith and Stirling, 1975);

2) as above but without suitable drifts for seal lair construction (Fig. 12);

3) the floe edge where leads are wide (>1 km), usually with small open or refrozen leads parallel to floe edge or emanating from it, some pressure ridges, occasionally fresh but usually not heavily drifted (Fig. 13);

4) areas of 9/10 or 10/10 ice cover but in "active zones", such as around Baillie Island, where wind and sea currents cause much movement of ice, followed by refreezing, creating intermittent lanes or patches of refrozen young ice, bare or only slightly drifted (Fig. 14);

5) areas of continuous heavy pressure ice that have not moved for a long time, relatively uncommon though present in extensive areas in 1974 (Fig. 15).

Table 2 summarizes the sightings of polar bears of different age and sex categories in the five ice types between late March and mid-May from 1971 through 1975. Type 4, the active ice habitat, was the most important and 47% (181/385) of the sightings were made there. Type 3, the floe edge was the next most important area with 40% of the sightings. This latter figure may be biassed to the high side because the bears are concentrated right along the floe edge where they are easy to see and little time-consuming tracking is required. In comparison, most sightings in Type 4 habitat are made after tracking the bears. The number of sightings recorded from habitat Types 1, 2, and 5 may be biassed to the low side because almost all bears have to be located by tracking and conditions are often very difficult. Nevertheless, of the latter three habitat types, only Type 1, with birth lair habitat for ringed seals, attracts a significant proportion of the polar bears.

Figure 11. Type 1 sea ice habitat (note the long deep snow drifts around the pressure ridges).

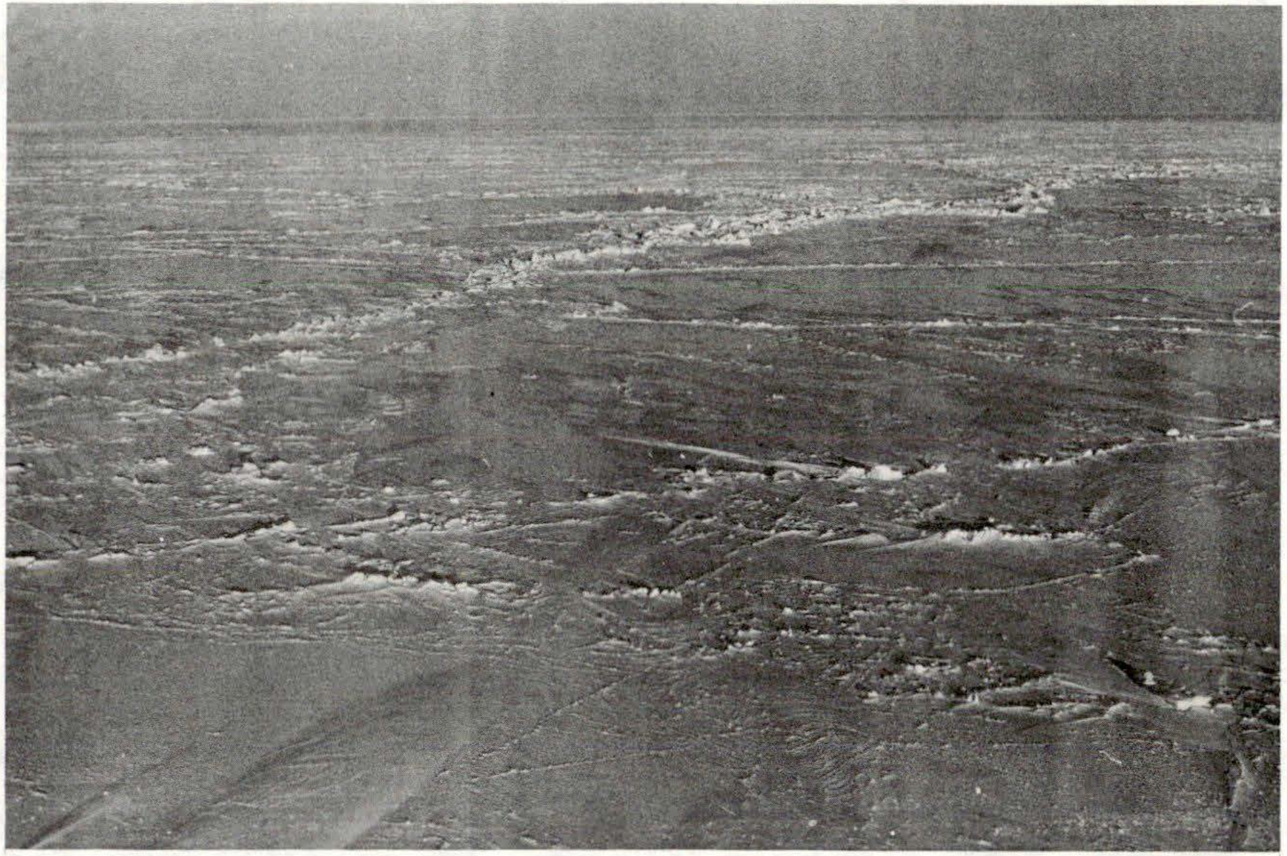

Figure 12. Type 2 sea ice habitat (note the bare ice and small snow drifts around the pressure ridges).

Figure 13. Type 3 sea ice habitat.

Figure 14. Type 4 sea ice habitat (note the abundance of polar bear tracks).

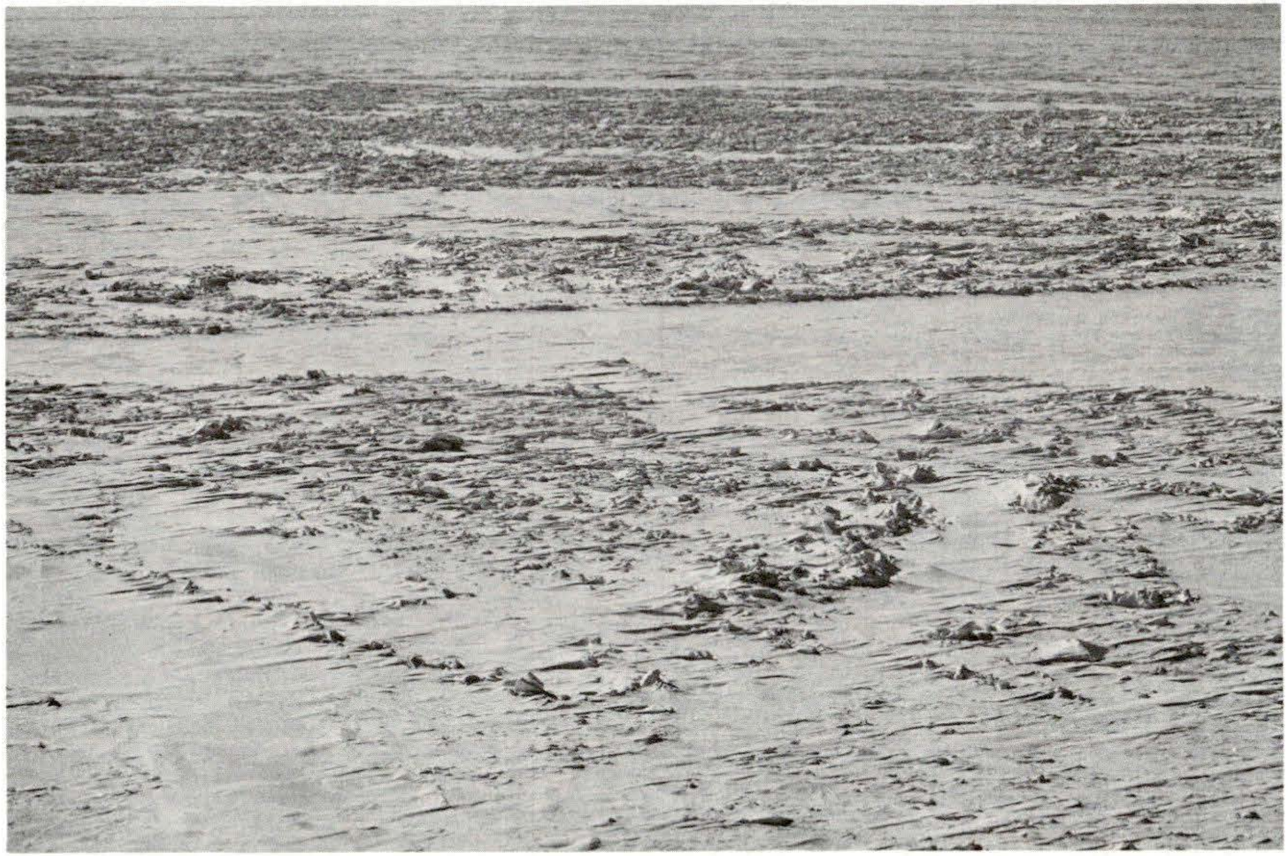

Figure 15. Type 5 sea ice habitat.

Although the numbers of bears recorded in the various habitat types may have some biasses, the proportions of bears of different age and sex classes within the sample from each habitat should be representative.

Adult females with cubs of the year were underrepresented in our surveys. From Table 2, it appeared that during the spring, these females spatially segregated themselves from the majority of the polar bear population into a habitat type in which there were fewer bears and in which they were more difficult to locate. When the cubs were older, the family groups mixed with the rest of the population although they were still twice as abundant in Type 4 habitat than in Type 3. Family groups of polar bears will avoid adult males when possible, presumably because of the threat of predation on the cubs. This probably explains the segregation of adult females with cubs of the year into Type 1 habitat where there were seals to prey upon but the lowest concentration of adult males. Similarly, the fact that the abundance of adult females with older cubs was double in Type 4 habitat than it was in Type 3 is probably also inversely related to the abundance of adult males.

Table 2. Sightings of polar bears of different age and sex classes in the five ice types between late March and mid-May, 1971-1975 (family groups were considered as one sighting).

Age and Sex Class	ICE TYPE 1	2	3	4	5	TOTAL
Adult male	9	2	68	64	0	143
Adult female (alone)	3	0	12	16	0	31
Adult female with cubs of year	13	1	4	3	0	21
Adult female with cubs one year and older	3	1	15	35	0	54
Subadult male	3	0	26	26	0	55
Subadult female	9	3	16	23	0	51
Adult unclassified	2	0	14	14	0	30
TOTAL	42	7	155	181	0	385

The distribution of polar bears over the sea ice is probably determined by the influence of the ice type on the abundance and accessibility of the seals.

Ringed and bearded seals are concentrated along the last open leads prior to freeze-up. At freeze-up, they maintain their own breathing holes in refrozen leads on pressure ridges by abrading the ice with the heavy claws of their foreflippers. Drifting snow covers the breathing holes, providing a degree of protection from predators. In stable ice areas (Type 1 habitat) where the drifts become deep enough, the pregnant female ringed seals scoop out subnivean birth lairs in which to give birth to their single pups (McLaren, 1958; Smith and Stirling, 1975). Ringed and bearded seals also concentrate in areas where the combination of currents and winds periodically form open patches of water, because of easy access to the air, and subsequently along those when they refreeze (Type 4 habitat).

Recent studies of the behavior of wild polar bears (Stirling, 1974 and unpublished) have shown that the most common method of hunting seals is to wait beside an open, or snow-covered, breathing hole and wait for the seal to surface to breathe. This is especially true during cold or windy weather when few seals haul out on the ice. Thus, it is obvious that seals are much more accessible to bears through their relatively exposed breathing holes on refrozen leads than they are under heavy snow drifts under pressure ridges. Similarly, we suspect that the most beneficial aspect of the floe edge to a polar bear is hunting along the narrow band of small open and refrozen leads that emanate from the ice edge itself.

The importance of the habitat Types 3 and 4 is clear from the above discussion. The value of those habitat types is greatly magnified by the fact that they are relatively limited in distribution and that they overlie a large proportion of the offshore acreage currently under lease for present or future offshore exploration and potential production (Fig. 16). Furthermore, from Figures 5 to 7, it is clear that industrial activity anywhere in the Type 3 or 4 habitat areas has a potential influence on a large proportion of the entire population of polar bears in the eastern Beaufort Sea and Amundsen Gulf, not simply those present in the immediate vicinity at the time. In addition, from Figure 8 it is clear that industrial activity offshore from the mainland coast could influence part of the polar bear population shared between Alaska and Canada.

6.4 Tracks and Sightings of Polar Bears as Indicators of Abundance

The numbers of tracks and bears recorded per 100 km travelled over potential habitat give comparative estimates of distribution and abundance between years even though they are not indicative of absolute numbers. For this comparison, the study area was divided into three areas: Amundsen Gulf west to an arbitrary line from Nelson Head to Cape Parry, the west coast of Banks Island, and the mainland coast from the Alaskan border to Cape Parry.

The best data are available from the spring surveys, done between late March and mid-May, because the tracking conditions are best then, the weather is relatively stable and the long days permit extensive field work.

Table 3 summarizes and Figure 17 illustrates the data on number of polar bears and tracks seen per 100 km travelled between late March and mid-May from 1971 through 1975. These data may be interpreted in general terms,

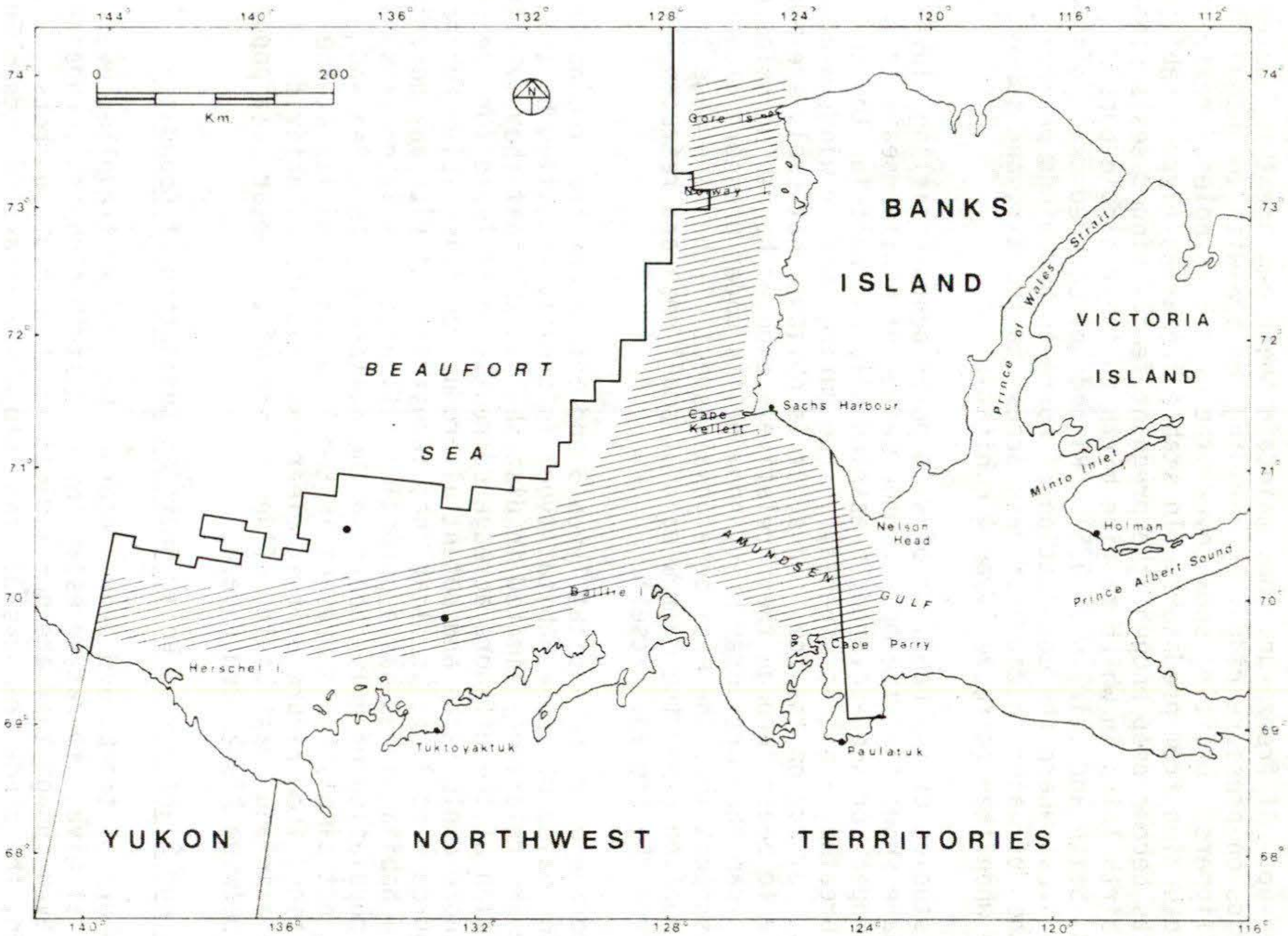

Figure 16. Distribution of Type 3 and Type 4 sea ice habitat between freeze-up and break-up in relation to offshore acreage currently under lease for current and future offshore drilling activity. The solid dots indicate the locations of the two drilling sites proposed for the summer of 1976.

Table 3. Comparison by geographic area of the number of bears and tracks seen per 100 km travelled over sea ice habitat between late March and mid-May from 1971 to 1975.

	Mainland coast to Cape Parry			West coast of Banks Island			Amundsen Gulf		
Year	Kilometers travelled	Bears seen per 100 km	Tracks seen per 100 km	Kilometers travelled	Bears seen per 100 km	Tracks seen per 100 km	Kilometers travelled	Bears seen per 100 km	Tracks seen per 100 km
1971	2,510	1.24	9.52	3,379	0.15	3.87	1,319	-	1.63
1972	3,218	0.93	6.33	3,097	0.67	6.33	2,430	0.37	4.00
1973	2,662	0.86	12.04	2,590	1.77	11.11	4,666	0.53	3.93
1974	3,958	1.41	19.08	3,737	1.07	9.59	3,701	0.14	2.29
1975	3,327	1.47	7.75	7,919	2.12	9.74	2,747	0.11	1.38

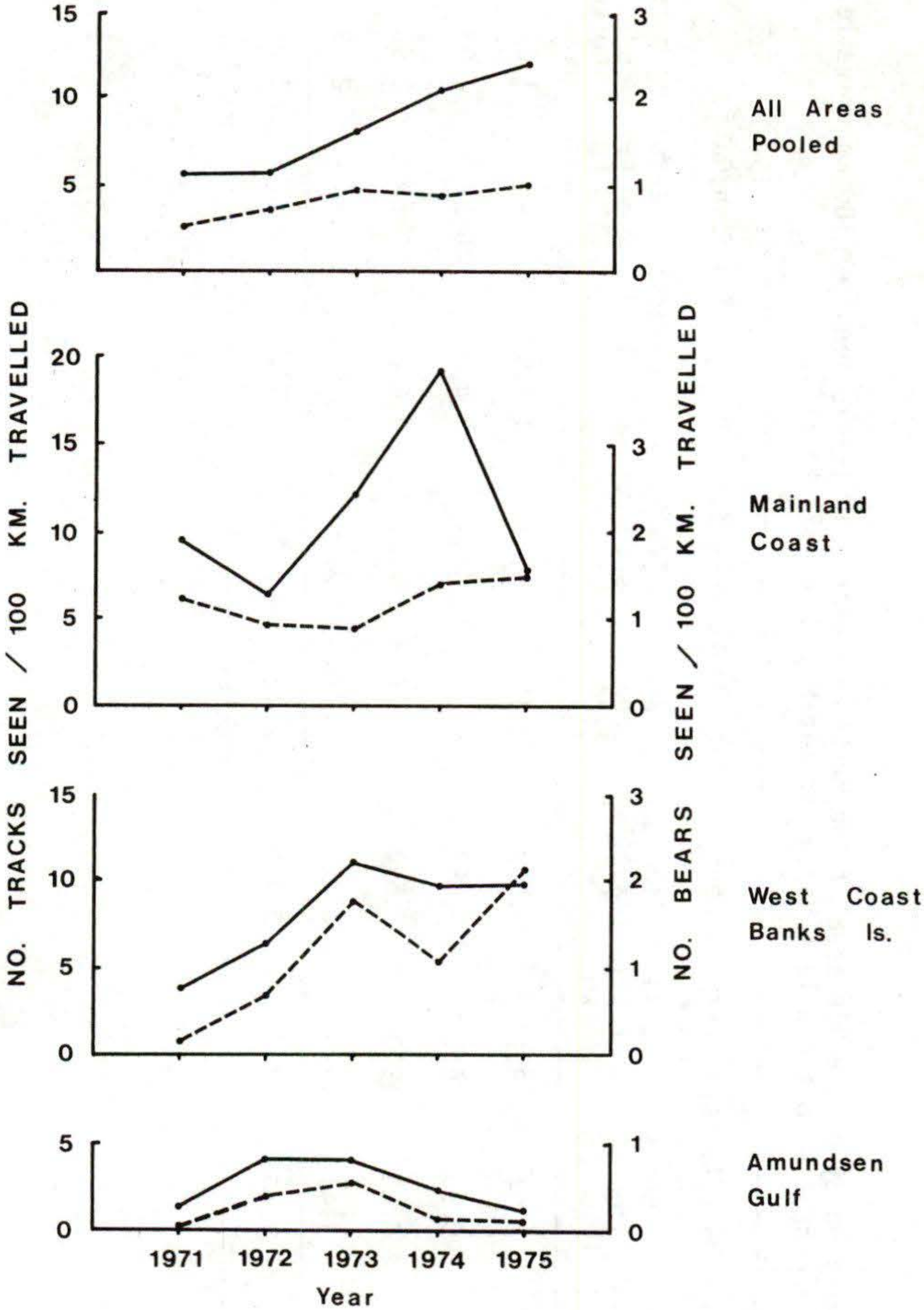

Figure 17. Relative abundance of polar bears and polar bear tracks recorded in study area from late March through mid-May, 1971 to 1975.

in conjunction with overall trends in ice conditions.

As discussed in Section 6.3, the preferred habitat for hunting seals is where the ice periodically breaks and refreezes. Hunting at the birth lairs is done when the habitat is suitable for seals to utilize it but the availability is quite variable (Smith and Stirling, 1975 and unpublished data).

In the winter of 1970-71, there was little ice movement and the sea ice was relatively unbroken for at least 240 km west of Banks Island until about mid-April. From the track data, relatively few bears remained on the west coast of Banks Island compared to the mainland coast area where there had been a certain amount of ice movement. In that year, the Inuit of Sachs Harbour killed only five of their quota of 18 bears. We have no data on seal productivity from Amundsen Gulf in 1971 but from Figure 17, there were relatively few bears in that area during the spring.

In 1972 and 1973 conditions were good for seals everywhere in the study area so that the polar bear population was widely dispersed. Note from Figure 17 that the numbers of bears were greater in Amundsen Gulf in 1972 and 1973 and that there was also some suggestion from the number of bears seen/100 km that there were probably more bears present.

1974 was one of the heaviest ice years on record. During the winter of 1973-74, the winds consistently came from the northwest, resulting in heavy compaction of the ice throughout the study area. Through that winter, there were few or no periods during which there were areas of open and freshly refrozen leads. As a result, a large proportion of the seals present probably had breathing holes that were not nearly as accessible to polar bears as they are on refrozen leads. In addition, there was a relatively low snowfall so that the extensive snow drifts in which seals make their lairs did not form. The result of this lowered accessibility of seals throughout the whole study area meant that bears had to travel extensively in search of seals because there were few areas in which the bears could concentrate their efforts. Wherever such local areas existed, such as in the vicinity of the Baillie Islands, there were great concentrations of tracks. However, to generalize, the pattern was one of more extensive travelling in search of local areas of greater seal abundance and accessibility.

In 1975, there was an interesting variation on the ice conditions that prevailed in 1974. The ice in Amundsen Gulf was again relatively snow-free and unproductive for seals (Smith and Stirling, 1975 and unpublished) but the offshore leads along the mainland and Banks Island coast opened and refroze periodically, providing good hunting conditions. The numbers of seals appeared to be low everywhere (Stirling, Archibald, and DeMaster, 1975) which made the areas in which they were concentrated and accessible to polar bears even more important. The number of tracks seen in Amundsen Gulf were again very low compared to the other two areas. In the area of active offshore leads, the number of tracks seen per 100 km travelled was lower than in 1974 but the number of bears seen was almost double the highest value previously recorded (Fig. 17). On inspection, this might indicate an increase in the numbers of bears present. However, Figures 18 and 19 compare the distribution of bears sighted in 1973 in which seals were abundant and accessible

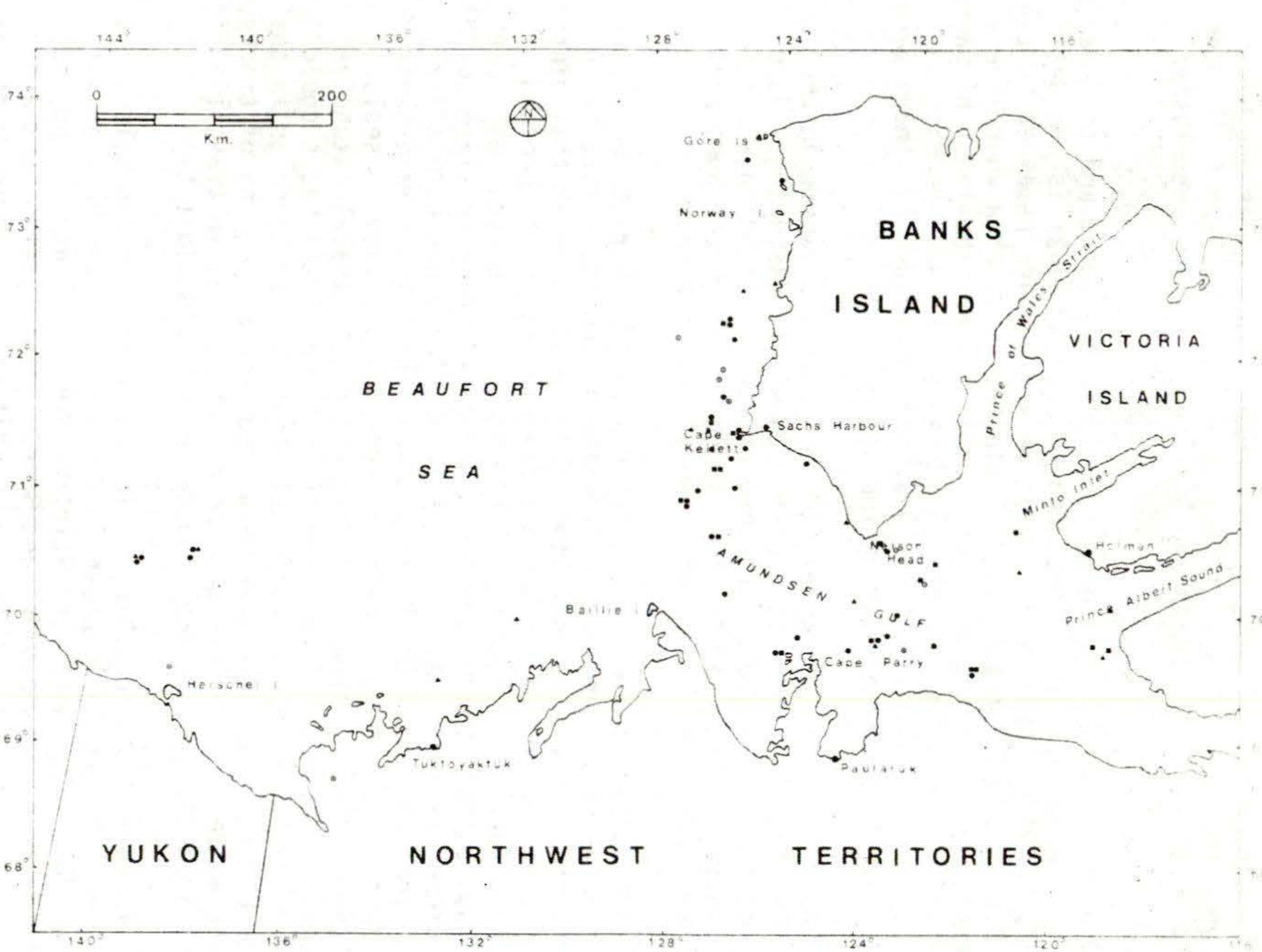

Figure 18. Distribution of sightings of polar bears in the study area between late March and mid-May, 1973. Dots represent males; squares respresent females; triangles represent family groups; open circles represent unclassified bears.

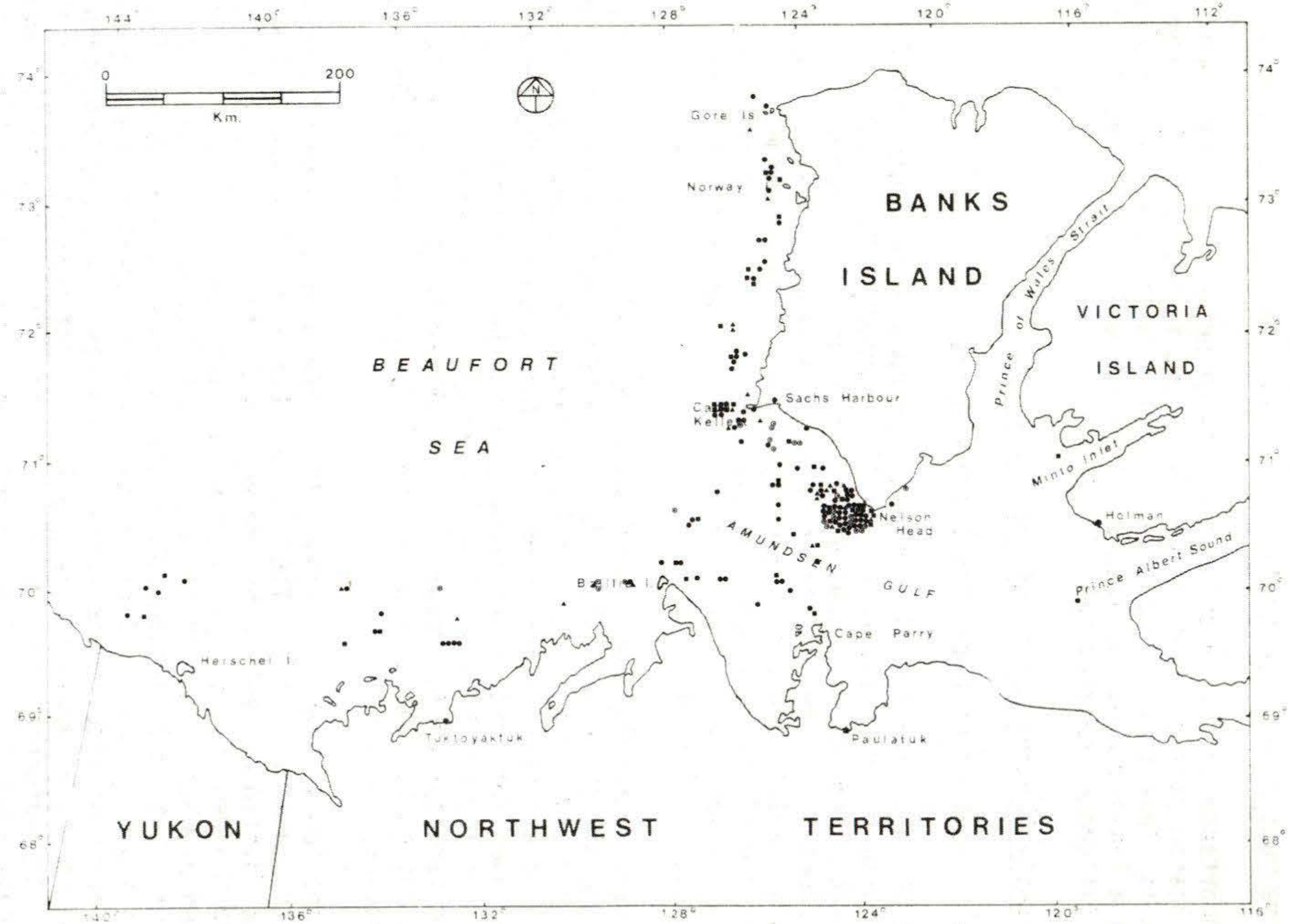

Figure 19. Distribution of sightings of polar bears in the study area between late March and mid-May, 1975. Dots represent males; squares represent females; triangles represent family groups; open circles represent unclassified bears.

over a wide area, and 1975, when seals were not abundant and were accessible in a much more restricted zone. From these figures, it is clear that the main reason that more bears were sighted per 100 km travelled in 1975, was that they were much more concentrated in a single habitat type (Type 3).

The importance of the relationship between prime polar bear feeding habitat and leased offshore acreage was discussed in Section 6.3. From Figure 19 it is clear that in years such as 1975, when polar bears are more dependent on a limited area for feeding, they are even more vulnerable to detrimental influences on that habitat.

6.5 Maternity Denning Areas and Productivity

6.5.1 Location of Maternity Denning Areas

Figure 20 shows the location of dens recorded by Harington (1964) and during the course of our field work from 1971 through 1975. Sightings made in April of adult females with cubs of the year were also plotted because they were indicative of the location of maternity denning areas. Figure 20 is by no means complete because of the size of the area concerned and the incomplete nature of the searches. However, it is clear that most maternity denning in the western Arctic occurs along the coastal areas of Banks Island and western Victoria Island.

Apparently, maternity denning of polar bears along the mainland coast occurs infrequently since only three dens have been reported by Inuit hunters in the last 10 years and only one was found during this study. Lentfer (1973) reported finding a number of dens along the Alaskan coast but the total was insignificant when compared to the large size of the population of polar bears on the sea ice north of Alaska. Subsequently, Lentfer (1975) has confirmed that maternity denning occurs in the multi-year pack ice of the Beaufort Sea but as yet there is no further information on the extent to which this occurs.

On inspection it seems surprising that more maternal denning does not occur along the mainland coast. There is an abundance of suitable snowbanks and only short distances need to be crossed by the females to hunt seals after leaving the den in the spring. However, the mainland coastal area has been inhabited by whalers and Inuit supplied with firearms for over 80 years. It seems likely that adult female polar bears which utilized the mainland coast for denning were shot. Since in most mammals, adult females show a fairly high degree of fidelity to parturition sites, there may have been a proportion of the total adult female population that returned to the mainland coast to dig maternity dens so that over the course of time they were simply eliminated when the use of firearms became widespread. Continued hunting and extensive travelling along the coast would maintain a strong negative selection pressure against re-establishment of this habitat by new adult females. This conclusion would appear to be supported by Leffingwell's (1919) report that, "The natives in the vicinity [Canning River] shot perhaps a dozen [polar bears] each year, mostly females that were giving birth to young in snow caves under high banks on the land." Lentfer (pers. comm.) has found few dens in that area in recent years.

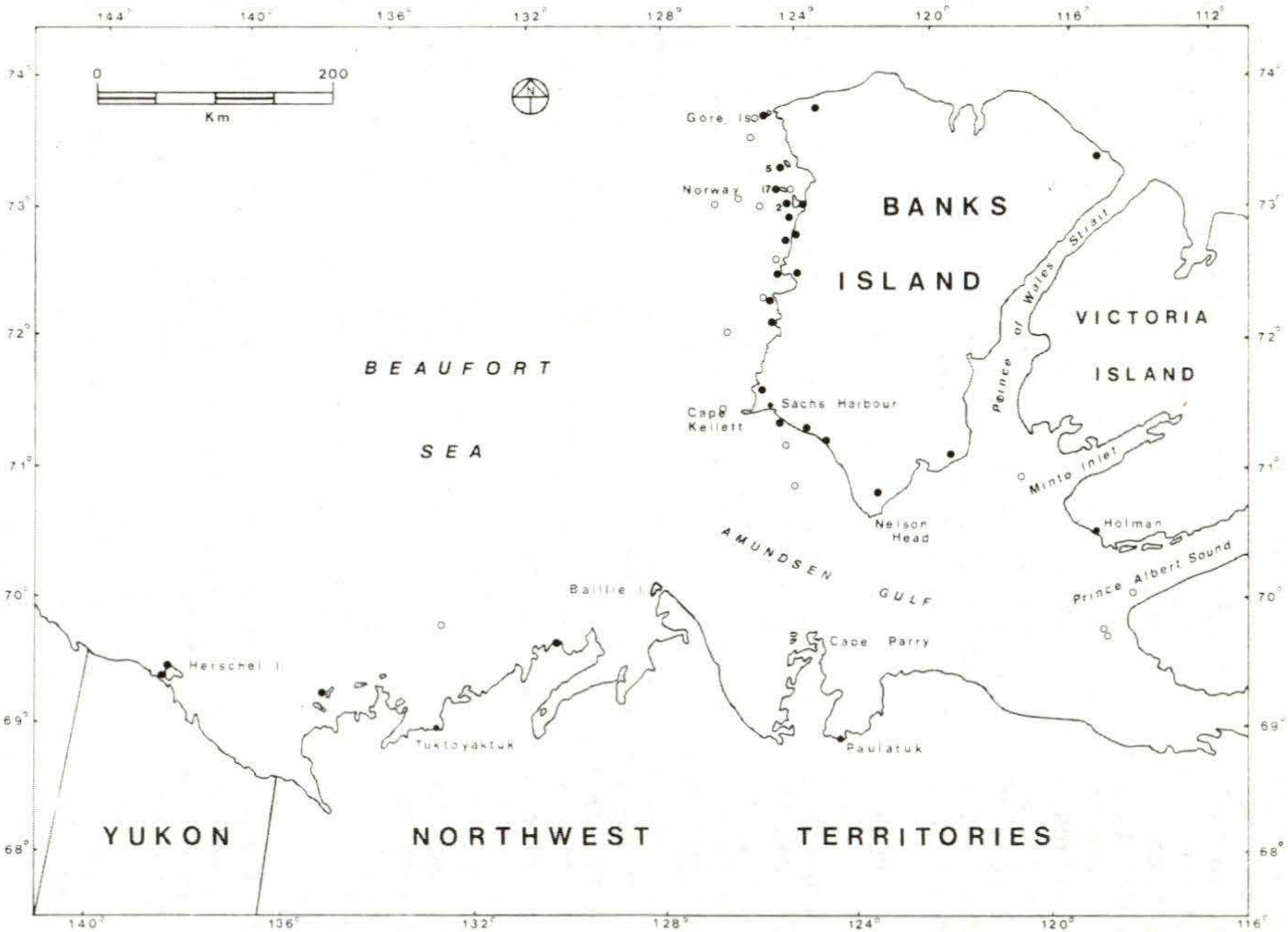

Figure 20. Location of dens and early spring sightings of female polar bears with newborn cubs. Dots represent dens and circles represent sightings. Data are from Harington (1964) and this study.

6.5.2 Productivity of Maternity Denning Areas

It is not practical to attempt to determine total number of cubs born each year in the western Arctic as can sometimes be done on the Manitoba coast of Hudson Bay (eg. Cross, 1975). In Manitoba the denning area is very concentrated and the bears have to walk through deep snow in the forest to reach the sea so that their tracks are easy to see and count. By surveying after each of the intermittent snow storms during the emergence period, and counting fresh tracks, a reasonably accurate estimate of productivity can be made. In contrast, maternity dens in the western Arctic are widely scattered although there are sometimes local concentrations in areas such as Nelson Head and the islands along the west coast of Banks Island. The snow is packed hard by the wind, making tracks difficult to locate, and the den themselves may be covered over with drifted snow within a few hours of being deserted. Thus, it was not worthwhile to spend large amounts of time or funds to attempt to assess productivity accurately.

6.5.3 Productivity of Adult Females

Table 4 gives the number of females of various ages, captured between 1970 amd 1975, and the litter size and ages of the cubs that accompanied them. Based on Table 4, Table 5 gives the age specific conception rate and litter size of female polar bears in the western Arctic from October 1970 through July 1975. For the calculations in Table 5, we assumed no mortality of cubs between conception and weaning. We recognize that assumption is incorrect but, at present, there is no reliable way of calculating a correction factor. However, data on size of the litters of cubs of different ages in the western Arctic (Stirling, 1974b) suggest that under normal conditions, cub mortality prior to weaning is low.

The low conception rate and litter size of three and four-year-old females suggested that the onset of sexual maturity of most female polar bears in the western Arctic occurred at five years of age. Even at five, the conception rate (21.4%) was lower than that for 6-18 year old females (39.15%) although the litter size of 1.66 was the same as the mean litter size of the older females.

Most female polar bears wean their cubs at 2½ years of age and thus, theoretically, are capable of breeding every three years. If so, then the conception rate of the adult female population should be 33.3% per year. The fact that the conception rate of 39.1% (47/120) for females 6-18 years of age was 6% higher than the theoretical mean could have been caused by some females losing their cubs or suffering intrauterine mortality and consequently breeding more often than every three years.

6.6 <u>Mortality of Rates and Numbers</u>

6.6.1 Mortality

Table 6 and Figures 21 and 22 give the number of male and female polar bears of each age class captured or killed in the western Arctic from 1970-71, through 1974-75. From inspection, it is apparent that the age of male polar bears killed was lower than the mean age of those captured. In comparisons of the mean ages captured and killed male polar bears one year of age plus,

Table 4. Number of females of each age class captured between 1970 and 1975 and the litter size and age of cubs that accompanied them.

Age	Total Number Females	Number Females Alone	Age and Litter Size of Cubs Accompanying Females: Cubs of Year 1	Cubs of Year 2	Yearlings 1	Yearlings 2	2-Year-Olds 1	2-Year-Olds 2	3-Year-Olds 1	3-Year-Olds 2
3	34	34	-	-	-	-	-	-	-	-
4	30	29	1	-	-	-	-	-	-	-
5	11	11	-	-	-	-	-	-	-	-
6	18	8	1	2	1	1	4	1	-	-
7	10	5	-	1	1	2	1	-	-	-
8	8	3	1	1	1	2	-	-	-	-
9	12	1	1	1	3	3	3	-	-	-
10	3	0	-	-	-	3	-	-	-	-
11	7	1	-	-	1	1	-	4	-	-
12	9	3	1	1	-	2	-	1	1	-
13	4	0	1	2	-	-	1	-	-	-
14	3	0	-	1	1	1	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-
16	4	0	-	1	-	-	-	3	-	-
17	2	0	-	2	-	-	-	-	-	-
18	1	0	-	-	-	-	-	-	1	-
19	1	0	-	1	-	-	-	-	-	-
25	1	1	-	-	-	-	-	-	-	-
		TOTAL	6	13	8	15	9	9	2	-

Table 5. Age specific, conception rate and litter size of female polar bears in the western Arctic, 1970-1975, calculated from Table 4, assuming no mortality from conception to weaning.

Age	Conception Rate		Litter Size	
	N	%	N	$\bar{X}$
2	0/75	0.0	-	-
3	6/59	10.1	7/6	1.16
4	3/34	8.8	4/3	1.33
5	6/28	21.4	10/6	1.66
6	7/26	26.9	10/7	1.42
7	8/17	47.0	12/8	1.50
8	10/22	45.4	18/10	1.80
9	3/11	27.2	5/3	1.66
10	3/12	25.0	5/3	1.66
11	2/11	18.1	3/2	1.50
12	5/6	83.3	8/5	1.60
13	4/5	80.0	8/4	2.00
14	1/3	33.3	1/1	1.00
15	1/3	33.3	2/1	2.00
16	2/3	66.7	4/2	2.00
17	-	-	-	-
18	1/1	100.0	2/1	2.00

and three years of age plus, T values of 4.72 (df=62) and 2.86 (df=37) respectively were calculated, both of which were highly significant. Similar comparisons of the mean ages of captured and killed female polar bears showed no significant difference.

Table 6. Number of polar bears of each age class captured and killed. (The age structure of the kill sample is not complete because specimens were not turned in from all the bears shot and some of those turned in lacked adequate data.)

Age	NUMBER IN SAMPLE			
	Killed Bears		Captured Bears	
	♂	♀	♂	♀
0	-	-	21	17
1	8	5	11	23
2	17	8	24	21
3	4	10	31	36
4	6	10	32	27
5	4	5	25	17
6	3	4	19	17
7	4	2	8	12
8	4	1	16	11
9	1	3	6	12
10	-	3	11	4
11	-	1	5	8
12	-	1	8	9
13	1	-	5	4
14	-	-	3	4
15	-	-	2	0
16	1	-	1	4
17	-	-	-	1
18	-	-	-	1
19	-	1	-	-
25	-	-	-	1

In the Northwest Territories, cubs are only protected until they are 54 inches long, a length which is obtained shortly after one year of age. Thus, family groups are legally vulnerable to hunting for about a year prior to the cubs being weaned at 2½ years of age.

Polar bear hunting by Inuit is done from bases along the shoreline, either in single or several-day trips, depending on the area and the stability of the ice. Figure 23 shows the locations where 226 polar bears were killed by Inuit hunters between 1969-70 and 1974-75. Note the close proximity of most kill sites to the shoreline. The outer limit of polar bear habitat that is accessible to Inuit hunters is the floe edge. In most of the heavily hunted areas there is a variable amount of Type 4 habitat (Fig. 14) between the shoreline and the floe edge. From Table 2, adult female bears with cubs one year of age and older were twice as abundant in Type 4 habitat as any-

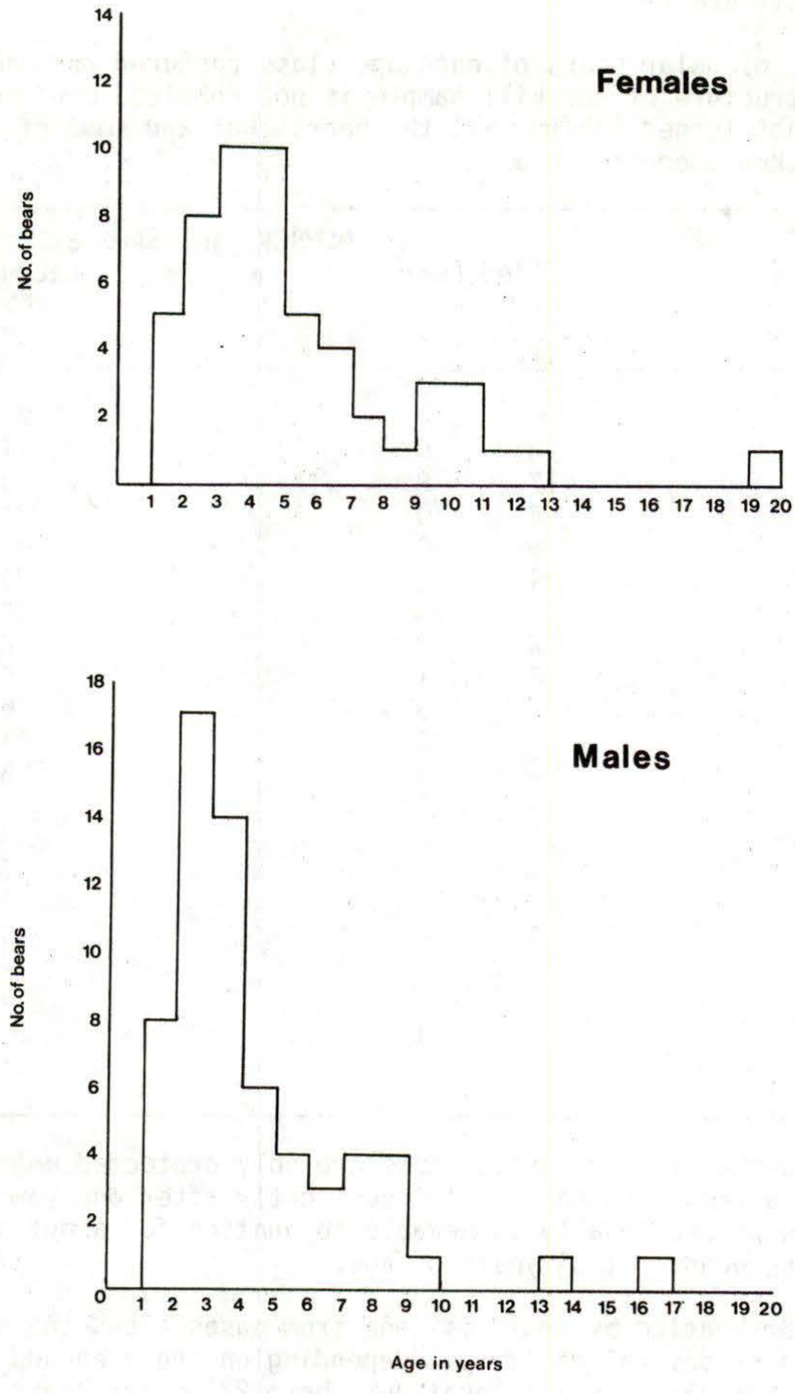

Figure 21. Age structure of polar bears killed in the western Arctic from 1971 to 1975, from which specimens with adequate data were collected.

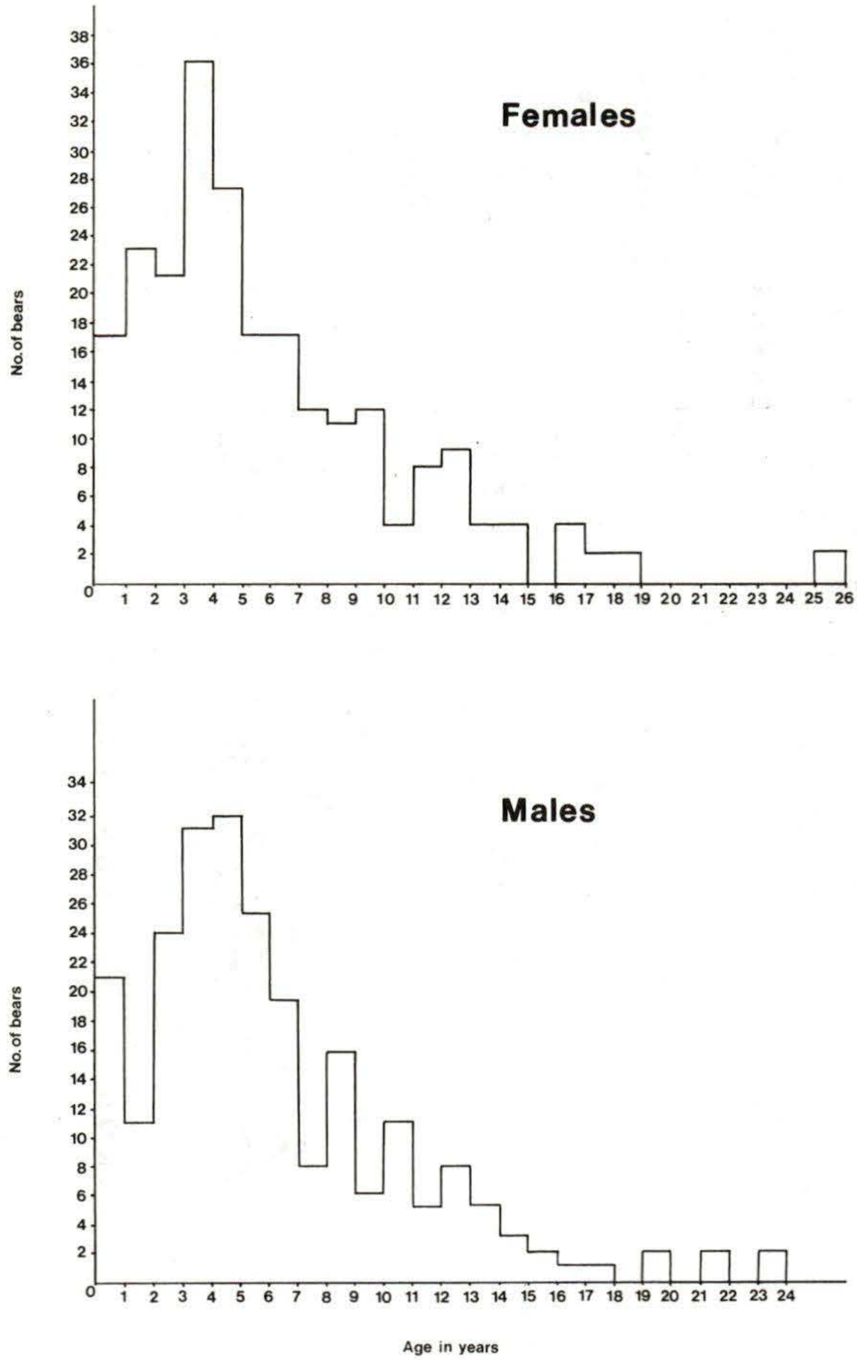

Figure 22. Age structure of polar bears captured in the western Arctic from 1971 to 1975. (The ages of recaptured bears were included.)

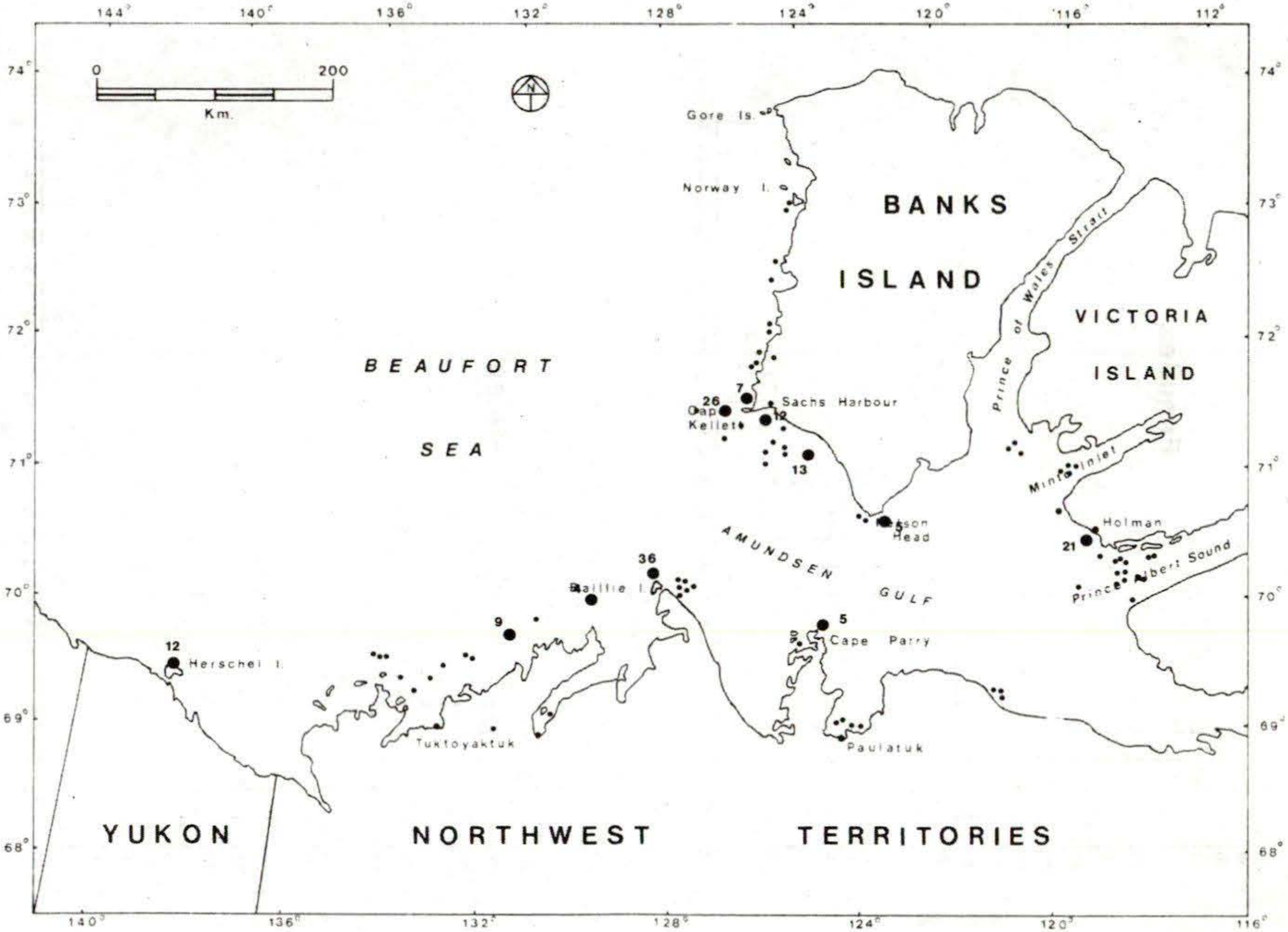

Figure 23. The locations where 226 polar bears were killed by Inuit hunters between 1969-70 and 1974-75. Single dots represent single kills; larger dots with a number indicate the number of bears killed there.

where else. Thus, it is clear that the reason that yearlings and two-year-olds were so well represented in the age structure of killed bears was that the hunters were killing non-selectively in the habitat type in which family groups were most abundant.

The most marked difference between the ages of the kill and capture samples was in the adult males. This probably occurred because adult males were more abundant along the floe edge and therefore less likely to be encountered, either because of the greater distance from the shoreline, or because of the possibility of a hunter encountering a subadult or family group before reaching the floe edge, if indeed he intended to travel that far. In contrast, the distribution of the older females with cubs made them more vulnerable to being killed by hunters so that their age structure was more accurately represented in the kill sample than the adult males.

Because of the biasses in the hunter samples discussed above, only the age structures of captured bears were used to calculate mortality rates. The age classes from 0 to 2 were underrepresented in the samples so that the peak in the frequency of occurrence by age occurred at three (Table 6). The mortality rate after 3 years of age may be calculated using the formula, $\hat{a} = 1 - \bar{x}(1 + \bar{x} + 1/n)^{-1}$ (Chapman and Robson, 1960), where $\hat{a}$ is annual mortality rate, n is the number in the sample, and $\bar{x}$ is the mean age, with ages coded beginning at zero. This formula gives annual mortality rates of 22.5% and 21.7% respectively for males and females after 3 years of age. The formula (which was developed for use or similar data from northern fur seals) assumes a constant annual mortality, which is not necessarily valid, but it gives a useful result provided the bias is realized.

The marked reduction in either numbers or accessibility of seals, or probably both, in 1974 and 1975 appears to have had a marked affect on the survival of polar bear cubs. For example, in April 1974, we found two adult females which had lost their newborn cubs and were extremely thin themselves, and a third emaciated adult female with two thin cubs, one of which could hardly walk. Two additional females, each of which were captured in 1974 with two newborn cubs were recaptured in April 1975. One female had no cubs and had not lactated recently while the second had only one cub remaining. Table 7 shows what percentage of the polar bears captured each year from 1971 through 1975 were yearlings. The marked reduction in yearlings in 1974 and 1975 is probably indicative of a high level of cub mortality prior to one year of age.

Extensive marking and recapture programs have been conducted off the north coast of Alaska and in the Canadian High Arctic during the last few years. However, of the eight recorded long distance movements of bears right out of the study area, six were full grown adults and two were 4½ years old. It is possible that the reduction in the seal population in the study area was a factor in stimulating this emigration.

6.6.2 Estimation of Population Size

Table 8 summarizes the capture-recapture data in the format required for a Jolly-Seber estimate (after Krebs, 1972). The sample sizes over the intervals were too small to attempt to calculate the size of each age and sex class (eg. adult males, etc.). Thus, the analysis was applied to all polar bears tagged and recaptured during the study.

Table 7. The percentage of polar bears captured each year from 1971 through 1975 that were yearlings.

Year	Total No. Polar Bears Captured	Total No. Yearlings	% Yearlings
1971	29	6	20.6
1972	63	6	9.5
1973	107	16	14.9
1974	111	4	3.6
1975	167	6	3.6

The number of marked animals ($\hat{M}_i$) in the population in 1974 (= $\hat{M}_4$), prior to the onset of tagging may be calculated using the formula

$$\hat{M}_i = \frac{r_i}{s_i} = \frac{z_i}{\hat{M}_i - m_i}$$ where:

r_i = number of marked animals that were marked and released in period i that are recaptured sometime later

m_i = marked animals recaptured in period i that were marked prior to period i

z_i = number of marked animals that were marked and recaptured prior to period i, not recaptured during period i, but were recaptured sometime after period i

s_i = total number that were marked and released in period i (new and old)

The estimated number of marked polar bears in 1974, using the above calculation, was 155. Thus, the size of total population in 1974 ($\hat{N}$), as estimated by using the Lincoln-Peterson Index formula $\hat{N} = \frac{(s_i)(\hat{M}_i)}{m_i}$, was 1521.8.

Various data discussed earlier suggest that the number of polar bears in the western Arctic may have decreased between 1974 and 1975. Again, using the Jolly-Seber format, the loss rate (emigration plus death) between periods (1973-74) and 5 (1974-75) equals 1 - ø (ø = survivorship) where:

$$ø = \frac{\hat{M}_i + 1}{\hat{M}_i - m_i + s_i} = 0.62$$

This gives a loss rate of 0.38 (which includes the bears killed by Inuit hunters). Although this estimate is likely too high, it supports the suggestion that the size of the polar bear population in the western Arctic has decreased markedly in the last year.

Using the Jolly-Seber method, we cannot calculate a population estimate for 1975 without capture-recapture data from the following season. We can, however, make two crude estimates using the simple Lincoln Index, as follows:

$$\frac{\text{Number of recaptures}}{\text{Total number of captures}} = \frac{\text{Total number tagged animals available for recapture}}{\text{Total size of the population}}$$

After deducting the number of polar bears killed by hunters, if none of the remaining bears tagged from 1970 through 1974 dies of natural causes (which we know could not be true) then theoretically 261 polar bears were available for recapture in the 1974-75 capture period. Of 187 polar bears captured, 34 (18.2%) were marked which, using the above formula, gives a population estimate of 1394. If we use the Jolly-Seber estimate of 155 tagged polar bears available for recapture at the end of the 1973-74 season, in the Lincoln Index formula, we get a population estimate of 828.

Even from these crude estimates it is clear that the total population probably does not exceed 1500 and may be as low as 1000 individuals.

6.7 Inuit Harvest of Polar Bears

Polar bears in the western Arctic are harvested on the basis of quotas which are set for each community. The issuing of polar bear tags within each community is determined by the local Trappers Association. At present, the quotas for the western Arctic are: Tuktoyaktuk, 22; Paulatuk, 13; Holman, 16; Sachs Harbour, 18; and Yukon, 6; for a total of 75.

The prices of hides have been quite variable in recent years. The highest prices were realized at the end of the 1972-73 season when the average price of a hide was $1800 and several hides brought over $3000 (Smith and Jonkel, 1975a & b). More recently there has been a reduced demand and many hides are selling for only $300-400 (Pauline A. Smith, pers. comm.). Despite the fluctuations in prices, polar bear hides remain an important part of the local economy and of the culture generally.

As discussed in Section 6.6.1, polar bear hunting is done from bases along the shoreline, either in one day or several-day long trips, depending on the area and the stability of the ice. Since polar bears concentrate in areas of habitat Types 3 and 4 (Table 2), the most important hunting areas are those which are closest to land and settlements. From Figure 3, note that the important hunting areas such as Cape Parry, Baillie Island, north of the Tuk Peninsula, and the area west and SE of Sachs Harbour, are all under lease for future offshore exploration.

Table 8. Capture and recapture data for polar bears in the western Arctic from 1970-71 to 1974-75 in format for Jolly-Seber estimate (after Krebs, 1972).

	CAPTURE AND RECAPTURE DATA (Capture Periods)				
	1	2	3	4	5
	1970-71	1971-72	1972-73	1973-74	1974-75
Total Number of Bears Caught	32	48	109	109	189
Total Number of Unmarked Bears Caught	32	47	105	100	152
Total Number of Marked Bears Caught	0	1	4	9	35
Total Number of Marked Bears (Old and New) Released	32	46	107	108	187
	RECAPTURE DATA ONLY (Periods of Recapture)				
	1	2	3	4	5
Trapping period in which these animals were last recaptured 1	-	1	1	3	1
2	-	-	3	2	8
3	-	-	-	4	11
4	-	-	-	-	15
5	-	-	-	-	-

7. RECOMMENDATIONS

7.1 The Concept of Critical Areas

In the simplest of terms, the survival of any species is dependent on its ability to feed and reproduce successfully. Thus, the most important aspect of the conservation and management of a species is the protection of the most important areas of feeding and breeding habitat. If that condition is met, a population can recover, in time, from a large scale reduction in numbers, be it caused by accident or by design. Attempts to preserve, in this instance the maximum number of individual polar bears, would be of little value if the key feeding and denning areas were destroyed. Therefore, we have restricted our recommendations to these two key aspects.

Figure 16 illustrated the distribution of the most important sea ice habitat for polar bear feeding between freeze-up in the fall and break-up in the spring. Because seals are more concentrated there or simply more accessible to the bears, or both, that area is critical to the maintenance of a viable polar bear population in the western Arctic, especially in years such as 1974 and 1975 when seal numbers and productivity in the fast ice areas was low. During the open water period, the polar bears are absent in the more northerly areas so that industrial activities which took place then would have no effect on the bears provided there were no detrimental effects on the seal stocks.

Unpublished behavioural data suggest that polar bear hunting efficiency is lower in the summer when the ice is perforated with melt pools, leads, and large areas of open water because the seals have an almost unlimited number of alternate holes in the ice in which to breathe, and in many of these they are simply not vulnerable to predation. Thus, less caloric benefit is gained per unit of energy expended during hunting activities between break-up and freeze-up and hunting success is more variable. Stirling and McEwan (1975) also noted that the caloric value of the seals to the bears is lowest during the summer period and furthermore that polar bears in areas such as Hudson Bay are able to utilize surplus fat stored during the winter and spring to survive several months on land with no seals to feed upon at all. It is clear that polar bears have adapted to seasonal and local variations in food supplies by making the maximum use of the seals when they are most accessible. The speed with which the southern migration of the polar bears in the western Arctic occurs after freeze-up illustrates their dependence on the winter and spring feeding areas.

Denning areas are only used by pregnant female polar bears between about late October and mid-April. Of 113 dens reported by Harington (1968), 61% (69/113) and 80.5% (91/113) were found within five and ten miles respectively of the coastline. Figure 20 illustrated the distribution of known denning areas in the western Arctic and confirmed the importance of coastal areas, particularly on Banks Island. Because of the critical nature of polar bear cubs at birth it seems likely that disruption of dens, prior to the time they would normally be deserted, would result in a high degree of mortality of newborn cubs.

7.2 Specific Recommendations Related to Industrial Activities

a) With respect to the key feeding areas, the most obvious recommendations that we could make would be, ideally, to permit no industrial activity between about mid-October and mid-May or at best to keep it at a minimal level at highly specific sites. Areas in which Inuit hunting occurs should be avoided during the period which the sea is frozen. It is not yet clear what the reaction of both the polar bears and the seals would be to extensive industrial activity and aircraft noise but until we know more about this aspect, a circumspect approach seems advisable.

b) With respect to denning areas, we recommend that surface activities such as seismic operations not be permitted, certainly within five miles (8 km) and preferably not within 10 miles (16 km) of the coastline of Banks Island, between 1 October and 30 April.

7.3 Recommendations for Future Research

a) It will be very important to continue to monitor the basic biological parameters of the polar bear population in the western Arctic to know the total effect of the natural population trends that are taking place at present. There are two reasons why this is important; firstly, management of the polar bear and the setting of quotas should be responsive to major changes in the status of the population, and secondly, to ensure that industrial activities are not unfairly blamed for changes in polar bear numbers and distribution that may be occurring because of natural factors.

The field work could probably be limited to spring tagging and recapture in two representative and important areas, Tuktoyaktuk and Sachs Harbour. The critical data to be obtained would be on survival and reproductive rates of marked bears, age structure of the population, fidelity to feeding areas, and the marking of a larger sample of bears which might be recovered in continuing polar bear research programs in either Alaska or the High Arctic, thereby giving an additional measure of the extent to which emigration may be taking place.

b) It will be essential to have the lower jaws and ear tags returned from all polar bears killed by Inuit hunters each year to monitor the age structure of the harvested population and the survival and movements of tagged bears. However, as noted in Section 6.6.1, there are limitations to the degree to which data from the Inuit kill can be interpreted so that these collections would not be adequate to completely monitor possible population changes.

c) An in-depth study should be conducted on the effect of man, machines, and industrial activity on polar bear behaviour and distribution. This research should encompass a variety of areas including the western Arctic, High Arctic, and Western Hudson Bay. The purpose would be to obtain quantitative measures of the importance of disturbance, the degree to which acclimation occurs, and forms of deterrents that might be valuable. The benefits would apply to human activities throughout the arctic but could be especially valuable to offshore activities in ice-covered waters.

d) A mammal which is of great economic importance to the Inuit of the western Arctic, but has received little consideration to date in relation to the sea ice habitat, is the arctic fox *(Alopex lagopus)*. Stirling and Smith (1975) summarized some of the interspecific relationships of mammals in the pack ice ecosystem. They specifically noted the value of carrion left from seals killed by polar bears to the maintenance of large numbers of arctic foxes in the western Arctic. It would be of great value to undertake an in-depth baseline study of the population dynamics of the arctic fox and assess the relative importance of its different food sources in different seasons and years. The benefit of such a study would be to determine the importance of the sea ice habitat to the arctic fox population, and consequently to the fur-based economy of the region. This would provide further understanding of possible detrimental effects, natural or otherwise, on the wildlife component of the total economic base of the Inuit of the area.

e) To date, there is only a limited amount of baseline data on heavy metal and PCB contamination from polar bears and seals in the western Arctic (Smith and Armstrong, 1975; Bowes and Jonkel, 1975). Because these mammals are at the top of the food chain, they can serve as indicators of the degree of contamination present in the ecosystem. Therefore, it would be valuable to collect more specimens to establish a firm baseline on the present contamination level against which change, if it occurred could be measured.

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APPENDIX I

AGREEMENT

ON

THE CONSERVATION OF POLAR BEARS

THE GOVERNMENTS of Canada, Denmark, Norway, the Union of Soviet Socialist Republics, and the United States of America,

RECOGNIZING the special responsibilities and special interests of the States of the Arctic Region in relation to the protection of the fauna and flora of the Arctic Region;

RECOGNIZING that the polar bear is a significant resource of the Arctic Region which requires additional protection;

HAVING DECIDED that such protection should be achieved through co-ordinated national measures taken by the States of the Arctic Region;

DESIRING to take immediate action to bring further conservation and management measures into effect;

HAVE AGREED AS FOLLOWS:

ARTICLE I

1. The taking of polar bears shall be prohibited except as provided in Article III.

2. For the purpose of this Agreement, the term "taking" includes hunting, killing and capturing.

ARTICLE II

Each Contracting Party shall take appropriate action to protect the ecosystems of which polar bears are a part, with special attention to habitat components such as denning and feeding sites and migration patterns, and shall manage polar bear populations in accordance with sound conservation practices based on the best available scientific data.

ARTICLE III

1. Subject to the provisions of Articles II and IV, any Contracting Party may allow the taking of polar bears when such taking is carried out:

   (a) for *bona fide* scientific purposes; or

   (b) by that Party for conservation purposes; or

   (c) to prevent serious disturbance of the management of other living resources, subject to forfeiture to that Party of the skins and other items of value resulting from such taking; or

   (d) by local people using traditional methods in the exercise of their traditional rights and in accordance with the laws of that Party; or

   (e) wherever polar bears have or might have been subject to taking by traditional means by its nationals.

2. The skins and other items of value resulting from taking under sub-paragraphs (b) and (c) of paragraph 1 of this Article shall not be available for commercial purposes.

ARTICLE IV

The use of aircraft and large motorized vessels for the purpose of taking polar bears shall be prohibited, except where the application of such prohibitions would be inconsistent with domestic laws.

ARTICLE V

A Contracting Party shall prohibit the exportation from, the importation and delivery into, and traffic within, its territory of polar bears or any part or product thereof taken in violation of this Agreement.

ARTICLE VI

1. Each Contracting Party shall enact and enforce such legislation and other measures as may be necessary for the purpose of giving effect to this Agreement.

2. Nothing in this Agreement shall prevent a Contracting Party from maintaining or amending existing legislation or other measures or establishing new measures on the taking of polar bears so as to provide more stringent controls than those required under the provisions of this Agreement.

ARTICLE VII

The Contracting Parties shall conduct national research programmes on polar bears, particularly research relating to the conservation and management of the species. They shall as appropriate coordinate such research with research carried out by other Parties, consult with other Parties on the management of migrating polar bear populations, and exchange information on research and management programmes, research results and data on bears taken.

ARTICLE VIII

Each Contracting Party shall take actions as appropriate to promote compliance with the provisions of this Agreement by nationals of States not party to this Agreement.

ARTICLE IX

The Contracting Parties shall continue to consult with one another with the object of giving further protection to polar bears.

ARTICLE X

1. This Agreement shall be open for signature at Oslo by the Governments of Canada, Denmark, Norway, the Union of Soviet Socialist Republics and the United States of America until 31st March 1974.

2. This Agreement shall be subject to ratification or approval by the signatory Governments. Instruments of ratification or approval shall be deposited with the Government of Norway as soon as possible.

3. This agreement shall be open for accesssion by the Governments referred to in paragraph 1 of this Article. Instruments of accession shall be deposited with the Depositary Government.

4. This Agreement shall enter into force ninety days after the deposit of the third instrument of ratification, approval or accession. Thereafter, it shall enter into force for a signatory or acceding Government on the date of deposit of its instrument of ratification, approval or accession.

5. This Agreement shall remain in force initially for a period of five years from its date of entry into force, and unless any Contracting Party during that period requests the termination of the Agreement at the end of that period, it shall continue in force thereafter.

6. On the request addressed to the Depositary Government by any of the Governments referred to in paragraph 1 of this Article, consultations shall be conducted with a view to convening a meeting of representatives of the five Governments to consider the revision or amendment of this Agreement.

7. Any Party may denounce this Agreement by written notification to the Depositary Government at any time after five years from the date of entry into force of this Agreement. The denunciation shall take effect twelve months after the Depositary Government has received the notification.

8. The Depositary Government shall notify the Governments referred to in paragraph 1 of this Article of the deposit of instruments of ratification, approval or accession, of the entry into force of this Agreement and of the receipt of notifications of denunciation and any other communications from a Contracting Party specially provided for in this Agreement.

9. The original of this Agreement shall be deposited with the Government of Norway which shall deliver certified copies thereof to each of the Governments referred to in paragraph 1 of this article.

10. The Depositary Government shall transmit certified copies of this Agreement to the Secretary-General of the United Nations for registration and publication in accordance with Article 102 of the Charter of the United Nations.