SKRIFTER NR. 184

THOR LARSEN

Population biology of the polar bear *(Ursus maritimus)* in the Svalbard area

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THOR LARSEN:

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Abstract

The following aspects of the population of polar bears were studied in Svalbard and adjacent areas between 1966 and 1983: population composition, migration, distribution, discreteness, range, population size and trends, and biological parameters. Data were collected by observation during ground, ship and aircraft surveys, by capturing, marking and sampling of live animals, by telemetry, and by collecting biological specimens from various sources in Svalbard and other arctic areas. The polar bear population in Svalbard was exposed to extensive hunting prior to 1970, which caused a population decline. After hunting restrictions were implemented in 1970, and total protection in 1973, the population began to increase. Data from two major periods are therefore compared, namely 1966-1970 (decline) and 1976-1983 (growth).

Data collected in winter and summer could not reveal differences in the age and sex composition of polar bears between different areas in Svalbard. Family groups were less abundant in the observations after 1970, probably because of heavy harvest pressure in earlier years. This reduced the number of mature females, and consequently the number of cubs produced. Females must be four years or older before they can breed and produce cubs. There was a shift towards more subadults and adults in the population after 1973. In recent years, fewer litters and relatively high cub mortality in Svalbard may be due to less reproduction, or unfavourable ice conditions. Polar bears in the Svalbard area move seasonally with the changing ice conditions in the Barents Sea. There is also a migration across the Greenland Sea to East Greenland. The Barents Sea is a major summer habitat where bears are particularly common in the active ice south of 80° north. Movements are restricted during summer. Bears in Svalbard, the western Soviet Arctic and East Greenland belong to one common and discrete population. Population size was probably between 1500 and 2500 bears around 1970, and 3000 to 5000 in 1980-1983. Natural adult survival rate is estimated at 0.95. Estimated cub survival rate between birth and weaning was 0.41. Between 77 and 89 per cent of breeding females were estimated to emerge from dens with a litter the following spring. The reproductive rate was estimated to be between 0.51 and 0.59. The polar bear population in the Svalbard area can grow at a maximum rate of 5% per year. Potential harvest levels should not exceed 2%.

Key words: Svalbard, polar bears, live capture, marking, satellite telemetry, set-gun hunting, population composition, denning, migration, range, discreteness, patchiness, densities, population size, survival rate, weaning, breeding interval, reproduction rate, breeding success, modelling, population projection.

1. Introduction

Svalbard and the adjacent ice covered waters (Figs. 1 and 2) are an important habitat for polar bears *(Ursus maritimus)*, which have been hunted in the archipelago and in surrounding waters since 1795. Catch statistics are available from 1824 (Øritsland & Norderhaug 1965; Lønø 1970). The most intensive period was after the second world war. Between 1945 and 1970, a total of 8322 bears, or an average of 320 per year, were killed in Svalbard or adjacent ice covered areas (Lønø 1970; Larsen 1971a). During this period there was also a shift in hunting methods. Between 1945 and 1957, 71% of the bears taken were hunted from icegoing vessels in the Barents Sea. In contrast, between 1958 and 1970, wintering trappers, weather station crew and other land-based hunters took 72% of the total catch. Most of the bears taken by land-based hunters were killed by set-guns.

Little has been known about the relative and absolute abundance of polar bears, and of their migration, population discreteness and other population characteristics. Pedersen (1945) stated that all polar bears in the Arctic undertook long migrations around the Polar Basin, and often between different countries, and that all bears belonged to one common population. Contrary to this, Lønø (1970) stated that Svalbard bears were discrete and different from bears in Greenland and Frans Josef Land.

During the First International Meeting on the Polar Bear in Fairbanks, Alaska, in 1965, delegates from the five arctic nations, USA, Canada, USSR, Denmark, and Norway, agreed that: "...scientific knowledge of the polar bear is far from being sufficient as a foundation for sound management policies", and that: "...each nation should conduct to the best of its ability a research program on the polar bear within its territory or adjacent international waters to obtain adequate

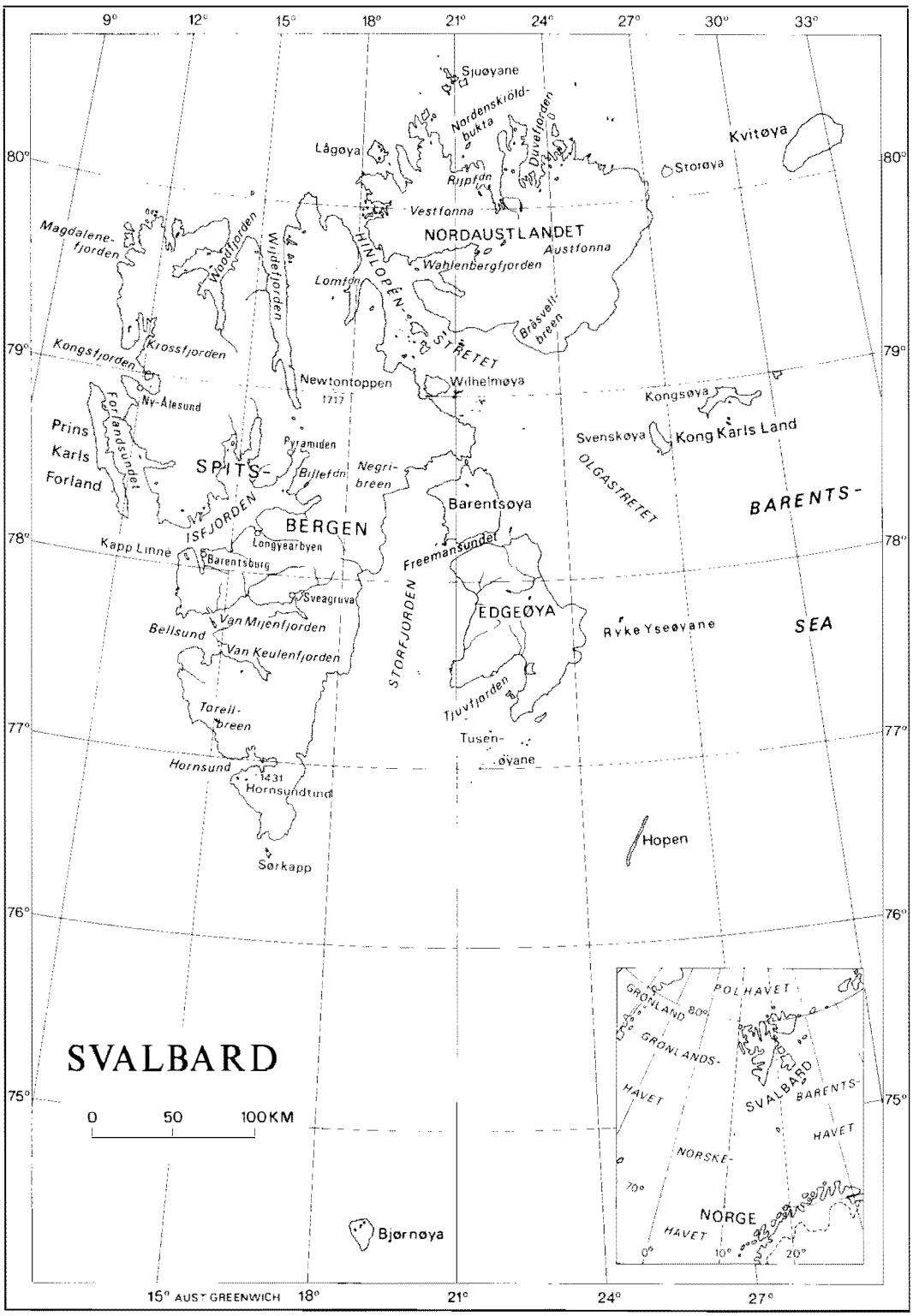

Fig. 1. Map of the Svalbard area.

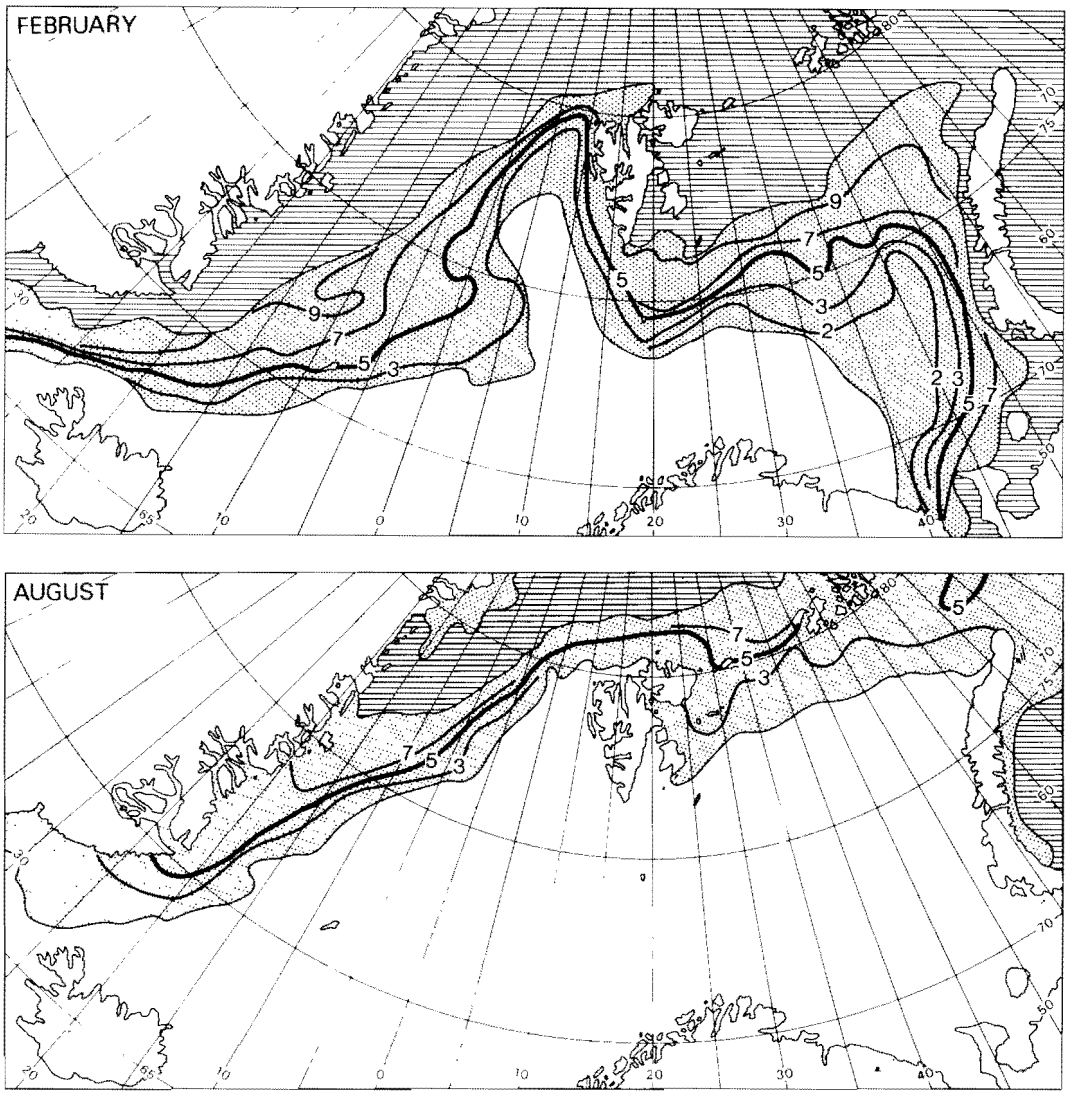

Fig. 2. Average maximum (February) and minimum (August) sea ice frequency distribution in the Barents Sea, 1971-1980. Sea ice concentrations above 2/10 are given in tenths.

scientific information for effective management of the species" (Anon. 1965).

To meet this request, The Norwegian Polar Research Institute and the University of Oslo launched a joint polar bear research program in Svalbard in 1965. The objective was to study polar bear ecology and physiology (Norsk Polarinstitutt 1965). The Norwegian Polar Research Institute was given the responsibility for management oriented polar bear studies in 1972. This paper summarizes research progress and results between 1965 and 1983.

Methods that have been used are: direct observation, live capture for marking and sampling, and telemetry techniques. Additional data and specimens have been obtained from wintering trappers, weather station crew and others. Since polar bear hunting was restricted in 1970, and prohibited since 1973, data distinguish between two major time periods, namely 1966-1970, when hunting was excessive and the population was declining, and 1976-1983, when the population was recovering. The objectives were to study the composition of the population before and after

1970 in different areas and at different times of the year, to define population range and discreteness, to map and describe migratory patterns in Svalbard polar bears, to estimate densities and population sizes before and after 1970, to calculate survival rates of adults and cubs, to estimate recruitment of cubs, and finally to describe and discuss population trends before and after 1970 through modelling and population projections.

2. Methods

2.1. Observations

Polar bear observations were collected from weather station crews on Hopen and Bjørnøya, from wintering trappers, scientific stations and expeditions and from persons in Longyearbyen and Ny-Ålesund. Data include the author's own observations from ships, aircraft and field stations. The many observers who participated in the collecting of data had different experience and background. Some were able to distinguish between the sex and approximate age of bears. Such information is, however, lacking from other sources. The data have therefore been grouped in the following manner to permit comparison:

1.— Adults and subadults are bears not accompanied by offspring. This includes all males and females older than 24 to 27 months, which is when cubs leave their mothers.

2.— Coys are cubs of the year, which are offspring observed between when they emerge from dens in March or April until 31 December at the end of their first year of life.

3.— Yearlings are offspring observed between 1 January and 31 December, in their second year of life.

4.— Two-year olds are offspring observed between 1 January and when they leave their mothers, in their third year of life.

Observations from trappers and weather station crews were obtained on forms distributed before the field season started. Forms contained information on the observer's name, date, location of observation, kind of observation according to categories 1-4 above, number of observations and bear behavior. Some observers submitted additional information as estimated age and sex. Some submitted observation data in letters or through Norsk Polarinstitutt's standard fauna registration forms.

Aircraft observations were made from military fixed-wing airplanes Albatross HU 16 B, from civilian Cessna 185, Piper Navaho, Twin Otter, and from helicopters Bell 206 and Bell 204. Average cruising speeds of the various aicraft varied between 90 and 220 km per hour. Surveys were normally flown at an altitiude of 100 m. One or two observers participated in each flight. When two observers worked together, each viewed opposite sides of the aircraft. Ice coverage and quality, weather and sight conditions, polar bear tracks, and polar bear sightings were continuously recorded against time according to categories 1 to 4. Watches were synchronized with the pilot or aircraft navigator before and after each flight, and observations were plotted on maps according to flight route and positions after the surveys.

Ship observations were made from icegoing vessels. Between 1967 and 1977, commercial sealers were used, often combined with other research activities, which often determined ship routes. The ships were not able to sail in the multiyear pack ice, but had to work in areas with one-year ice. Observations were made from the crow's-nest in the main mast, 15 to 18 m above sea level, with the use of 8× or 10× binoculars. The distances to observed animals and effective transect width were subjectively estimated. Positions of observations made and transect lengths were determined by a combination of navigational position fixes routinely made by the ship's officers, and a subjective estimate of the ship's speed in various ice conditions.

In 1980, observations were made from the Swedish icebreaker YMER and from the Norwegian research vessel NORVARG, from the top of the bridge, 23 and 12 m above sea level, respectively. YMER sailed the one-year old drift ice as well as the multiyear pack ice. Onboard YMER, distances to observed animals were measured with a hand-held laser range-finder (Simrad LP Z, Simrad A/S, Norway), which had an accuracy of ± 10 m up to 10,000 m distances. The angle to each observation was determined according to the "watch method": With the ship's bow at 12, the sighting angles had 30° intervals, corresponding to each hour on the watch between 1 and

12. All observations, as well as data on weather and ice conditions and satellite position fixes, were coded on forms for later transfer to computer systems.

After 1980, observations were made from Norsk Polarinstitutt's research vessel LANCE, from the bridge 12 m above sea level. Miscellaneous ship observations were made from sealers and other expeditions, but without quantitative information on sailing distances, effective observation time, transect width, and weather and ice conditions. Observations from all sources were coded and transferred to Norsk Polarinstitutt's computer system.

New hunting regulations for polar bears in Svalbard prohibited the set-gun and introduced a quota system in 1970 (Anon. 1970). All commercial and sport hunting was prohibited in 1973 (Anon. 1974). Therefore, the data were divided into two major blocks, those which were collected before and after 1970. Observations made between 1970 and 1976 have been deleted in most comparisons, because these years are regarded as an interphase between two different situations.

Bjørnøya is at the southern margin of the polar bear winter range in Svalbard. It is assumed that abnormal distribution patterns, possibly caused by very active ice conditions and unfavourable food supplies, are most pronounced there. Bjørnøya data have therefore been deleted in comparisons of polar bear population composition in Svalbard.

2.2. Live capture, marking and sampling

In summer, bears were chased from ice-going vessels described above, often in combination with small boats with outboard engines or from helicopters operating from the ships (Larsen 1971b, 1983a). Immobilizing drugs used were Sernylan (Parke Davis & Co, England) and Etorphine (M 99) (Reckitt and Sons Ltd, England), delivered by means of powder-loaded syringe guns (Cap Chur, Palmer Chemical Co, U.S.A.). Efforts were made to chase bears onto icefloes and to keep them out of water when they were immobilized. Coys were roped and the immobilizing drugs were delivered by means of hand syringes. Yearling bears were immobilized by means of the syringe gun. Most bears were taken onboard ships for handling and were kept in a steel cage until completely recovered (Fig. 3). Females with cubs were kept together in the cage. In winter, bears were chased from snowmobiles, or restrained by means of foot snares (Aldrich Activated Spring Co. U.S.A.) (Larsen 1970) (Fig. 4).

Zoological length over the curve of the back and girth were measured on each bear captured. Bears which were taken onboard ships were also weighed. Up to 1968, bears were marked with monel metal tags and plastic tags in both ears. Later, only plastic tags, and from 1977, teflon tags were used. Bears were tattooed with the same number as on the tags inside both upper lips, and the two last digits were painted with fur dye (Nyanzol A., Nyanaza Color Co., U.S.A.) on both hips. A blood sample was drawn from the femoral vein and sometimes from the tongue. Blood was spun on a centrifuge, or if centrifuge was not available, left in a cool place for 24 hours for sedimentation of red blood cells. Serum and red blood cell components were separated in vials and frozen at -20° C for later analyses.

Age was subjectively estimated on live captured bears in the field from tooth wear and from the height of the enamel line on the canines. After 1967, a first premolar was pulled from each live captured bear for subsequent sectioning and age determination (Reimers & Nordby 1968). Skulls from bears killed on weather stations or by wintering trappers were aged on the basis of skull size and skull suture closures (Manning 1971) and from tooth sections.

2.3. Satellite telemetry

The migration of polar bears in Svalbard and adjacent areas was studied with the use of two different satellite telemetry systems. In 1979, instruments sent signals through the NIMBUS 6 system, while the ARGOS system was used in 1982. The NIMBUS satellite collar communicated with the satellite for eight hours every four days on 401.2 Mhz. The collar had an additional rf beacon in a self contained circuit operating on 164 Mhz. The instruments were powered by lithium batteries which gave them a life expectancy of one year and 18 months, respectively (Kolz et

Fig. 3. Immobilized bear is hoisted on board research vessel.

Fig. 4. Polar bear restrained by foot snare.

al. 1978). The instruments were packed in a 5 kg plastic collar which was fastened to the bear with a harness of steel cables covered by plastic and rubber tubing. The harness was locked under the chest with a magnesium bolt which was expected to break after one year and cause the harness and collar to fall off the bear. The ARGOS collars communicated with the satellite for 24 hours every ten days on 401.2 Mhz. This instrument's rf beacon operated continuously on 164.4 Mhz. Life expectancy of both instruments was 1.5 years. Temperature sensors were placed on the inside and outside the collar. From this, it was expected that a difference in temperatures, or the lack of them, would indicate if a bear was alive or not. The instruments were powered by lithium batteries. The collar consisted of a steel casing covered by silicone rubber, and it was fastened by a steel chain harness covered with cord and rubber tubing. The position accuracy of both systems was ± 500 m.

2.4. Other sources of information

Weather station crew, trappers and other polar bear hunters collected diaphragma samples for Trichinella studies, blood samples for genetic analyses, and polar bear skulls for age determinations and morphometric studies. Weather station crew on Hopen and wintering trappers submitted journals on the set-gun harvest with information on number of set-guns used and on set-gun efficiency.

3. Results and discussion

3.1. Population composition

3.1.1. General

A total of 4977 polar bear observations (including killed bears prior to 1970) were collected between 1965 and 1983. Observations were grouped according to categories 1-4 (Section 2.1). Of these, 4341 observations, plus 19 observations of polar bear litters with unknown litter size, were systematized according to areas and years. Spring observations (mid March to late April) are from southeastern Svalbard (i.e. Edgeøya, Barentsøya, Halvmåneøya and Ryke Yseøyane), Nordaustlandet, and Kong Karls Land. Summer observations (mid June to early September) are from the Barents Sea, Kong Karls Land and Nordaustlandet. Winter observations are from wintering trappers and expeditions and from weather stations in southeastern Svalbard, Hopen, Bjørnøya, Hornsund and Gråhuken (Fig. 1, Tables 1-7).

3.1.2. Summer observations

There were no significant differences in the population compositions within the same areas from one year to another, i.e. when numbers of adults/subadults were related to numbers of coy, yearling and two-year-old cub litters (Chi-square, P=0.05, d.f.= 1). Therefore, annual summer and winter observations respectively, were pooled within each area before and after 1970. Furthermore, there were no significant differences between the following sets of data:

1.— Summer observations on shorefast ice or on land on Nordaustlandet 1976-1982 versus on Kong Karls Land 1979-1983 (Table 4).

2.— Summer observations on shorefast ice or on land from Nordaustlandet plus Kong Karls Land 1976-1983 versus Barentshavet 1977-1983 (Tables 3 and 4).

The conclusion is therefore that there is nothing in the summer data which indicates that certain population segments prefer one area of summer range to another in eastern Svalbard.

3.1.3. Winter observations

No significant differences in population composition could be found in pooled annual winter data between the following areas:

1.— Halvmåneøya and Tjuvfjorden 1966-1970 versus Ryke Yseøyane 1967-1969 (Table 5).

2.— Pooled observations from Halvmåneøya/ Tjuvfjorden/ Ryke Yseøyane 1966-1970 versus Hopen 1966-69 (Tables 5 and 6).

3.— Hopen 1976-1982 versus Hornsund 1981-1983, and Gråhuken 1974-1980, and Bjørnøya 1976-1983. All winter data from Hopen, Hornsund and Gråhuken have therefore been pooled after 1976 (Tables 5, 6 and 7).

3.1.4. Differences in observations 1966-1970 versus 1976-1983

Significant differences (Chi-square, P=0.05, d.f.= 1) were found between Hopen winter ob-

servations 1966-1969 versus 1976-1982 (Table 6), and between pooled winter observations from all areas 1966-1970 versus 1976-1983 (Tables 5, 6 and 7). The proportions of coy plus yearling litters in relation to adults/subadults in winter fell from 19.3% to 6.6%, or by almost 66%, between the periods 1966-1969 and 1976-1982 (Table 8).

There were also significant differences between pooled summer observations from the Barents Sea and Kong Karls Land 1966-1970 versus 1977-1983. The proportion of cub litters of adults/subadults in summers fell from 22.4% to 14.9%, or by almost 34%, in the Barents Sea summer observations 1967-1968 versus 1977-1983 (Tables 9 and 10). Observations from Kong Karls Land and Nordaustlandet often show a similar pattern. The proportions of cub litters to adult/subadult bears in these areas are comparable to what was found in the Barents Sea (Table 11).

All datasets above show that there was a significant difference in polar bear population composition before and after 1970. There was a higher proportion of family groups in the population before 1970 (Tables 8-11). There are also non-significant differences between Kong Karls Land summer observations 1973 versus 1980 (Table 4), and between the Barents Sea data 1967-68 versus 1977-83 (Tables 9 and 10).

There is no apparent single explanation for the change in the population composition before and after 1970. Sampling biases can be one reason for the differences, because polar bears often are non-randomly distributed at low densities. Some arctic areas, like Alaska, experienced a selective trophy hunt for polar bears over many years, when mainly large male bears were taken (Lentfer 1972). Such harvest regimes may cause changes in the composition of a population over time. But sampling biases cannot be the only explanation, since trends and differences in population composition are consistent in all data sets. Spatial segregation has also been observed in the Hudson Bay area (Latour 1981; Stirling et al. 1977). In Svalbard, 70% of the bears taken after 1957 were killed by set-guns (Table 29). Lønø (1970) stated that this hunting device was non-selective, because all bears visiting the hunting area had the same probability to be exposed to a set-gun and get killed. Larsen & Kjos-Hansen (1983) could not reveal differences in sex and age composition in set-gun harvests versus non-selective summer captures in 1966-1970. Their findings confirm Lønø's statement.

Lowered cub production could result in there being fewer litters in the population after 1970. However, surveys of maternity denning areas between 1972 and 1983 show a significant increase in the number of polar bear maternity dens in traditional denning areas in Svalbard (Larsen 1974, 1983b). New areas are now being used for denning. The total number of litters produced in Svalbard has increased since 1972 (Larsen 1985).

The composition differences observed could also have been caused by more immigration of single or adult bears than of family groups from adjacent areas in recent years. However, there is no logical explanation, nor any biological evidence from other arctic areas which suggest this might occur.

The heavy harvest pressure before 1970 could have resulted in compensatory mechanisms in the population, such as higher cub production due to reduced abundance of adult bears in the Svalbard area. Stringham (1980), Bunnell & Tait (1981), and McCullough (1981) found that the recruitment rate and hence the production of cubs in bears is correlated with the number of males in the area, and that a high number of males would reduce the number of cubs which were produced and which survived until weaning. Reduced age of maturity in female bears due to heavy exploitation can be another factor. Such mechanisms have been demonstrated in exploited seal populations (Benjaminsen & Lett 1976; Capstick & Ronald 1982), and in terrestrial mammals (Markgren 1969; Fowler 1981). Lønø (1970) indicates that female polar bears in Svalbard may reach sexual maturity at 2 1/2 years of age, which is considerably lower than in other high arctic polar bear populations, where females do not mature until they are four or five years old (Stirling et al. 1975; Lentfer et al. 1980). The low age of maturity found by Lønø could have been a compensation for heavy harvest prior to 1970. When hunting ceased in 1973, and the bear population consequently increased, average age of maturity in females may have increased. Simultaneously, cub survival may have decreas-

ed due to higher population density and more conflicts between adult males and cubs (Larsen 1985; Taylor et al. 1986).

A final explanation for the observed differences in the population composition is the direct effects of the harvest upon recruitment to the population. Since females with offspring could be killed, the cubs were actually exposed to an increased possibility of mortality, because of death independent of their mothers (Sections 3.6.2 and 3.6.3), and death caused by the death of their mothers. Orphaned polar bear cubs cannot survive unless they are adopted by other females with cubs, and that does not appear to be common. Consequently, there were relatively few mature females which could produce offspring after hunting was stopped in Svalbard. Any cubs produced would have to mature and have offpring before they could be counted as family groups. That could mean that proportionally more cubs produced after 1973 were registered as adults or subadults between 1976 and 1983.

The conclusion is therefore that the observed differences in polar bear population composition in Svalbard were caused by changes in the age of maturity of adult females, and/or cub survival when hunting ceased in 1973. Alternatively, they could have been a direct result of the high harvest mortalities which resulted in a high proportion of immature animals after 1973, and which were counted as single adults or subadults between 1976 and 1983. Most probably, the observed differences were caused by a combination of these three factors.

3.1.5. Population composition in the denning areas

Data on the relative and absolute occurrence of polar bear coy litters in early spring is an indication of the relative importance of different regions as denning areas. Kong Karls Land has been regarded as particularly important (Ingstad 1948; Lønø 1970), and was therefore protected against polar bear hunting already in 1939. Between 1973 and 1980, there was an increase from 29 to 77 maternity dens found on the islands (Larsen 1983b). Spring observations, i.e. between early March and late April, of population composition in the same years confirm the den observations. The proportion of coy litters ranges between 14.3% in 1973 and 72.3% in 1977 with an average of 57.6% in 1973-82 (Table 12). Air and ground surveys on Nordaustlandet between 1972 and 1978 indicated that about twenty female bears are denning along the northern coast every year, and that the area is less important than Kong Karls Land as a denning area for polar bears (Larsen 1983b). The den observations on Nordaustlandet were confirmed by the observation of the number of litters of coys in the spring in the same area (Table 13).

Data on the composition of the population from southeastern Svalbard 1966-1970 show that coy litters only constituted 8.9% of the adult population, which is not significantly different from winter data from other areas (Table 13). Ground surveys were made on Edgeøya in spring 1969, and six female polar bears were found denning on the island (Larsen 1970). During the 1972 air surveys, six dens were found on Edgeøya, which support the conclusions from the 1969 observations (Larsen 1974). New ground surveys were made in spring 1983. 25 dens were found, and it was estimated that between 30 and 50 dens were located on Edgeøya and Barentsøya that spring (R. Hansson pers. comm.). The proportion of coy litters in relation to the adult/subadult population had increased to 41.7% which is comparable with the Kong Karls Land observations (Table 13).

Although females with coys dominate the population in typical denning areas as Kong Karls Land and Edgeøya in early spring, family groups leave for the drift ice in April and May. During spring and summer they become integrated with the rest of the non-breeding population. Therefore, the population composition on these islands and on the adjacent shorefast ice gradually changes to a situation which is comparable with that which is found in the drift ice and other summer habitat areas. Population composition on Kong Karls Land in summer is not significantly different from the Barents Sea at the same time of year (Tables 3 and 4).

The increased occurrence of polar bear dens on Edgeøya is probably a combined result of the lack of hunting and other human activities after 1970, because the island became part of a larger nature reserve where construction, hunting, and

the use of motorized vehicles is prohibited (Anon. 1973). Polar bear females are probably vulnerable to disturbances in late fall and early spring when they are about to enter or emerge from dens. Denning conditions on Edgeøya may not have been satisfactory until after 1972, when an oil drilling operation on the island was abandoned. The increased denning on Edgeøya may also simply be part of an overall increase in the number of bears in Svalbard in recent years (Larsen 1983a). Consequently, more mature females are in need of den sites. The concentration of maternity dens on Kong Karls Land is already the highest of any arctic area (Hansson & Thomassen 1982; Larsen 1985), and few unoccupied slopes and snowbanks are suitable for denning. A surplus of pregnant females may therefore be forced to seek out other potential denning areas in order to give birth. Climate, topography and snow conditions on Edgeøya and Barentsøya are comparable to those on Kong Karls Land. The islands should consequently offer the same opportunities for denning females. There are no available data, however, which can support that Kong Karls Land is saturated with regard to polar bear den sites or denning opportunities.

3.2. Population range and discreteness

3.2.1. General

Craniometric studies on polar bears (Manning 1971), studies of blood proteins (Larsen et al. 1983b), studies of heavy metals in polar bear tissue (Lentfer 1976), Trichinella parasite infection rates (Larsen & Kjos-Hanssen 1983), mark-recapture programs in many arctic areas (Eriksen 1976; Kistshchinski & Uspensky 1972; Larsen 1971; Lentfer 1968, 1972a, 1976a; Schweinsburg et al. 1981, 1982; Stirling & Smith 1976; Stirling et al. 1975, 1977, 1978, 1980, 1983; Stirling & Kiliaan 1980; Uspensky & Kistshchinski 1972; Uspensky & Belikov 1983; Vibe 1976), and telemetry studies in the North American Arctic (Koltz et al. 1978; Schweinsburg & Lee 1982; Taylor 1982) and in the Greenland and Svalbard area (Larsen et al. 1983a) all show that there are several more or less discrete populations of polar bears throughout the Arctic. Conclusions about the range and discreteness of the Svalbard polar bear population are based on a combination of findings from various studies, such as air and ship surveys, mark-recaptures, telemetry work, and analyses of catch data.

3.2.2. Southern limit

The Barents Sea ice edge forms a natural southern limit for the Svalbard polar bear population. The bears' range and abundance will change with the changing seasonal distribution of the drift ice, between a maximum south of Bjørnøya in winter, and as far north as 82° north in some summers (Fig 2).

3.2.3. Northern limit

Polar bear tracks observed during the 1977 and 1979 air surveys gave an indication of the northern limit of the Svalbard population. Very few tracks were observed north of 82° north (Larsen et al. 1983a). During the 1980 YMER surveys only three of a total of 181 observations were made north of 82° north. The observations between 1977 and 1980 are in agreement with reports from a 1969 transpolar expedition, which travelled over the ice from the North Pole to Svalbard in spring. No bears or tracks were seen between the Pole and 82° north, but were frequently met with further south (W. Herbert pers. comm.). The northern limit of polar bear track observations in Svalbard coincides with where the shallow Barents Sea falls off into the deep Arctic Ocean. It is also a convergence zone between the North Atlantic current which sweeps along the west Spitsbergen coast and the Svalbard north coast, and cold waters from the Polar Basin. The North Atlantic Current is rich in nutrients and plankton, while the cold polar water has very low marine productivity (Zenkevitch 1963; Palosuo 1981a,b). The differences in plankton production determine the availability of seals, and hence polar bears. The shelf area and current convergence zone north of Svalbard at about 82° north is therefore regarded as the northern distribution limit of Svalbard polar bears. It is however recognized that bears occasionally will stray north of this border into the Polar Basin.

3.2.4. Western limit

There are oceanographic differences comparable to those north of Svalbard in the Greenland Sea.

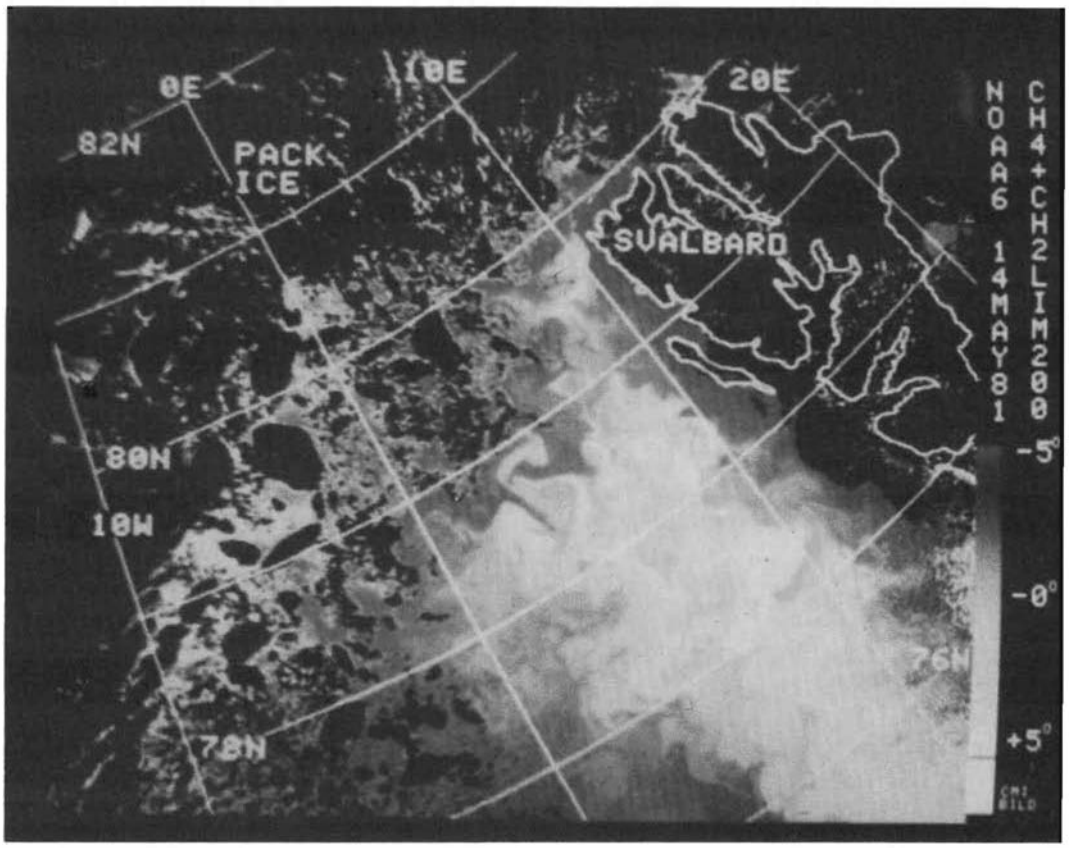

Fig. 5. Satellite photo from the Greenland Sea, showing the influence from the North Atlantic current (light).

While the North Atlantic current flows northwards along the Spitsbergen west coast, the East Greenland current brings ice and cold water from the Arctic Ocean south along the East Greenland coast (Mohn 1887) (Figs. 2 and 5). The two water masses have oceanographic and nutritional differences as described above. There are no quantitative plankton studies which can confirm differences in marine productivity across the Greenland Sea. However, ornithological summer observations made from ships in this area between 1980 and 1983 show that the number of sightings of plankton-feeding birds like little auks *(Alle alle)* and kittiwakes *(Rissa tridactyla)* declines midway across the Greenland Sea from Svalbard or at approximately 5° west (F. Mehlum, pers. comm.). The observations of the distribution of ringed seals between 1980 and 1983 show a similar pattern, although there are fewer data (Ugland & Ree 1983; T. Larsen, unpublished data). Wadhams (1983) showed that this border also distinguishes between ice qualities and properties. The sea ice west of about 5° west is characteristic of the Arctic Ocean interior ice, while the ice east of 5° west is younger. Differences in ice conditions may therefore also explain the observed differences in polar bear abundance in 1977 and 1979. The combination the ice studies, and the bird and seal observations coincides with polar bear observations from air and ships since 1977, and indicates that there are fewer polar bears west of 5° west longitude.

But other data and findings contradict these observations. Manning (1971) found craniometric differences between polar bears from several arctic areas, but not between Svalbard and East Greenland bears. Trichinella infection rates in polar bears from Svalbard and Greenland are

comparable, but different from North American polar bears (Larsen & Kjos-Hanssen 1983). Of 198 bears marked in Svalbard, three have been recovered in southeast or southwest Greenland (Table 22). Satellite telemetry studies in 1979 showed a migration of bears from East Greenland to Svalbard (Larsen et al. 1983a). The combined results of these studies show that there is some exchange of bears across the Greenland Sea. Between 1973 and 1975, 64 polar bears were marked in central east Greenland. Of 24 bears marked in 1973, ten were killed or recaptured in 1973-1974. 29 had been recovered before 1980 in the same general area (Vibe 1983). The mark/recapture data suggest a small and possibly local population of not more than 300 bears in central East Greenland (Vibe 1976,1983; Born 1983). Non-metric studies of polar bear skulls from various arctic areas identify bears from northeast and east Greenland as a local population, significantly different from other populations (T. Sjøvold, pers. comm.). No data show that bears are local or that population sizes are larger south of Scoresbysund, where 70 to 100 bears are killed annually by Greenland hunters (Vibe 1982, 1983; Born 1983). Polar bear denning has been observed south of Scoresbysund (Bay 1896; Pedersen 1931; Vibe 1976; Born 1983) but is assumed to be less than in the Svalbard area. The high harvest levels can only be sustained if there is an immigration of bears from outside areas. Although several hundred polar bears have been marked in the Canadian Arctic or further west, none has ever been recovered in East Greenland. The recoveries of bears from Svalbard as well as the results of the telemetry studies in the Greenland Sea in 1979, suggest that the most probable origin of bears in East Greenland is Svalbard and adjacent areas. Pedersen (1931, 1957) described a northwards polar bear migration along the east Greenland coast in spring and early summer. The 1979 telemetry studies showed that polar bears are able to migrate against the strong East Greenland current (Larsen et al. 1983a). Some bears probably move seasonally between Svalbard and Greenland (Born 1983). The exchange between the two areas must be significant, since the polar bear population in Svalbard and adjacent waters contributes to and helps to maintain a high annual harvest in East Greenland.

3.2.5. Eastern limit

It is difficult to determine a possible eastern limit to the Svalbard polar bear population, because of lack of systematic studies in that area. Lønø (1970, 1972) stated that bears in Svalbard and the western Soviet Arctic belonged to different populations, and that the eastern limit of the Svalbard bear population was around 36° east, or halfway between Svalbard and Frans Josef Land. But Parovshchikov (1967) described what he called "the great bear route" between Frans Josef Land and northern Novaja Zemlja, and between these islands and the Barents Sea ice edge in the Svalbard area. He suggested that bears in this area all belonged to the same population.

Ship observations between 1980 and 1983 across the Barents Sea could not reveal differences in polar bear abundance between Svalbard and Frans Josef Land. There are no significant differences in water mass properties, ice conditions and marine productivity, and no observable differences in seal and bear abundance across the Barents Sea (Hernroth & Edler 1981; Palosuo 1981b; Andersen 1983; Rey & Seglem 1983; Ugland & Ree 1983). One bear instrumented with satellite radio collar in the Greenland Sea in 1979, passed Svalbard and migrated towards Frans Josef Land (Larsen et al. 1983a). One bear marked at Frans Josef Land in 1980 was killed in southeast Greenland in 1982 (Table 22, Fig. 6). These combined observations suggest a regular exchange of bears between these two regions.

An analysis of polar bear catch data from Hopen between 1945 and 1970 is also an indication of connections between bears from Svalbard and the western Soviet Arctic. The short-term fluctuations in the number of bears killed coincided with the ice conditions from one year to another, i.e. number of days with ice around Hopen between 15 October and 15 May (Fig. 7). This confirms that the occurrence of bears on islands and shores is dependent upon the ice situation, as previously shown (Section 3.2.2), and as found in other studies (Vibe 1967). But the ice conditions cannot explain the increase in total harvest each year after 1956. This can have been caused by the occurrence of more bears at Hopen. The Soviet Union introduced a ban on all hunting in 1956. Prior to that year, about one hundred polar bears were killed in the western

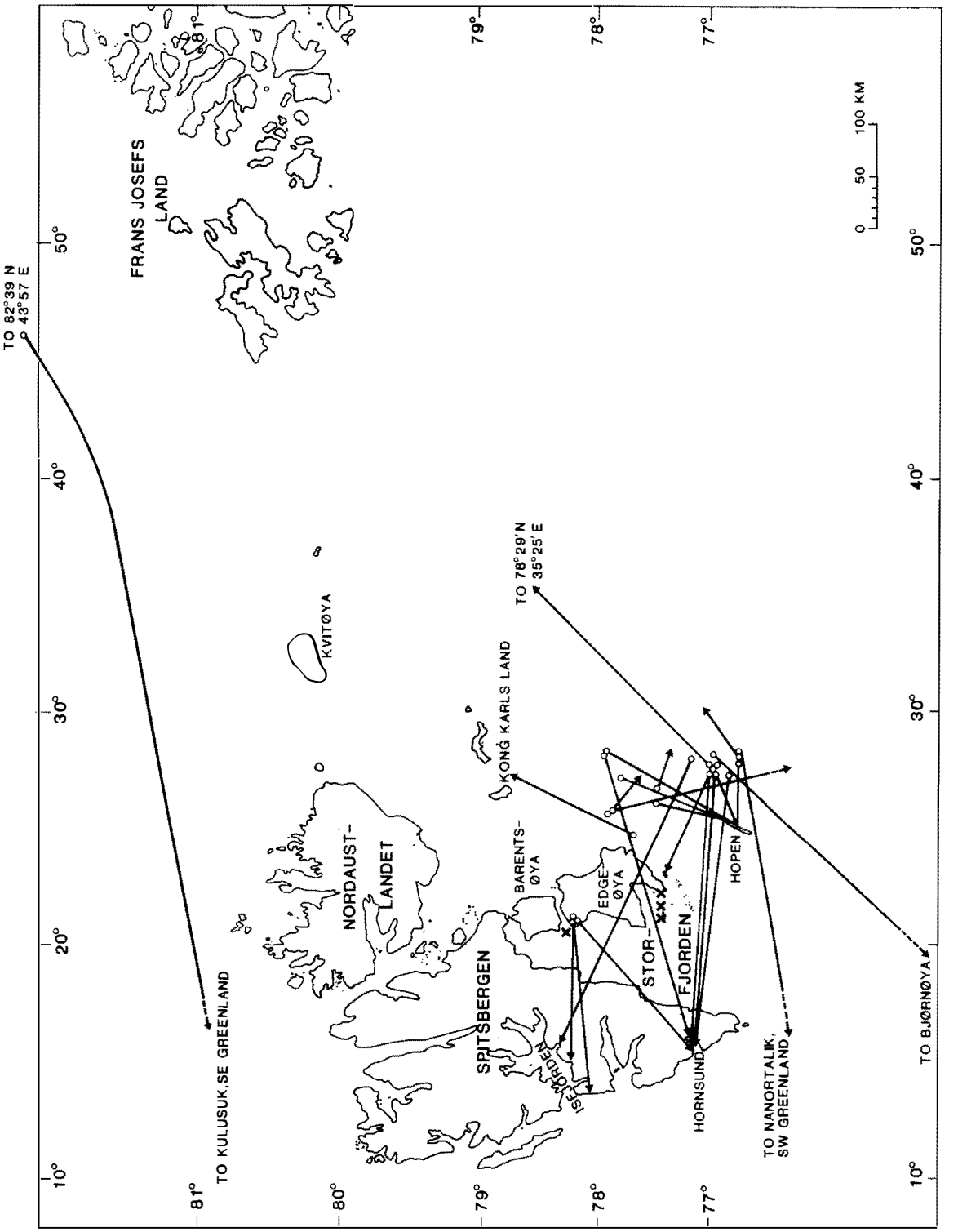

Fig. 6. Recoveries of polar bears marked in Svalbard between 1966 and 1982.
o: locality of marking. Arrow: locality of recovery. X: bears recovered where they were marked.

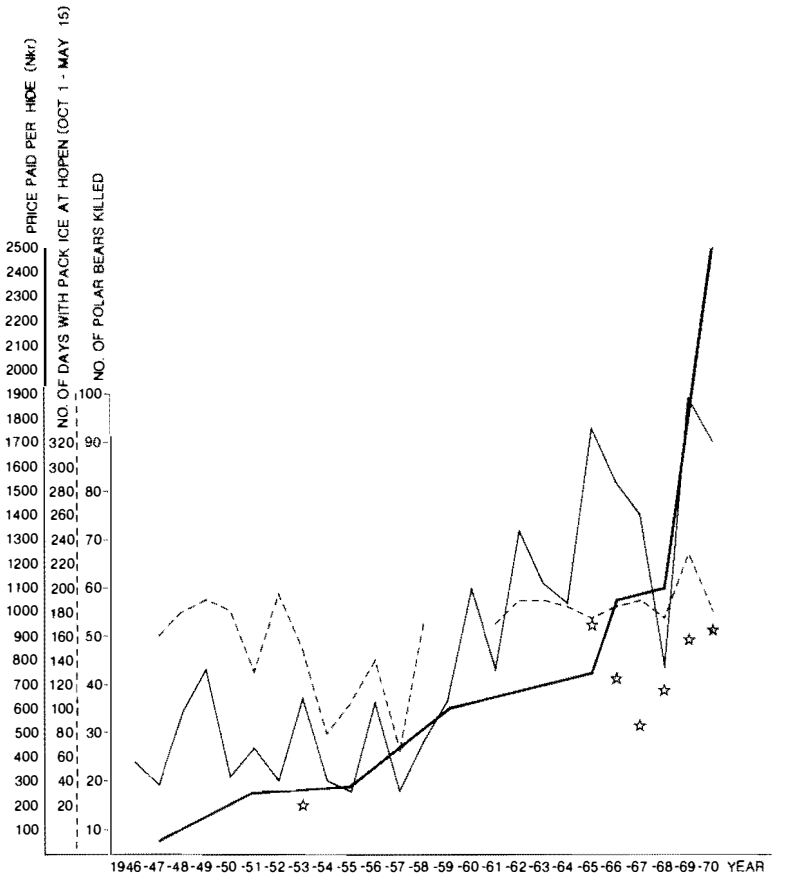

Fig. 7. Catches of polar bears on Hopen station, Svalbard, between 1945/46 and 1969/70. Thin line: number of bears killed. Stipled line: number of days with pack ice between October 1 and May 15. Thick line: average price paid per hide (NOK). *: number of set-guns used.

Soviet Arctic each year (Uspensky 1969). It is probable that the hunting ban in the Soviet Union was the direct reason for increased catches on Hopen, because more bears arrived along the migration routes described by Parovshchikov (1967). The fact that the number of bears observed in the Kara Sea has increased in recent years (Uspensky & Belikov 1983) may be a result of an increasing population in Svalbard and the Barents Sea, and is another indication of connections between the two areas.

The eastern limit of the Svalbard and western Soviet Arctic polar bear population range is not known due to a lack of observations and studies in this area. Uspensky & Belikov (1983) state that there are at least three different populations of polar bears in the Soviet Arctic, and that bears in Frans Josef Land and Novaja Zemlja are different from those in the Servenaja Zemlja area, in the eastern Kara Sea. Parovshchikov (1967) states that the migration of bears from Frans Josef Land and eastwards into the Kara Sea is less frequent. Zenkevitch (1963) shows that the marine productivity in the Kara Sea east of 70° east is less than in the Barents Sea. If marine productivity determines the occurrence and abundance of seals, and hence bears, as it appears to do north of Svalbard, the eastern limit of the Svalbard/western Soviet Arctic polar bear population can therefore be somewhere around 70° east.

3.2.6. Discreteness of the population of polar bears in the Svalbard area

The common result of observations, mark/recaptures, analyses of catch data and harvest data is that the Svalbard polar bear population is relatively discrete, within the Barents Sea southern ice edge and the northern shelf area at approxi-

mately 82° north. There are connections between Svalbard, East Greenland and southwest Greenland. Bears migrate seasonally across the Greenland Sea, probably to Greenland from Svalbard in fall and winter, and northwards back to Svalbard in spring and summer. Bears are able to migrate against the ice drift in the Greenland Sea (Larsen et al. 1983a). Bears in the East Greenland fjords probably belong to a separate population, which is different from the Svalbard/East Greenland drift ice bears. The eastern population range includes Frans Josef Land and probably northern Novaja Zemlja. The eastern limit of the population cannot be determined due to lack of studies and quantitative investigations in the western Soviet Arctic. Tentatively it is assumed to coincide with decreasing marine productivity in the Kara Sea, around 70° east. The extent of migration of bears in and out of this area is not known.

3.3. Migration and local movements

3.3.1. General

The analysis of polar bear local movements and seasonal migration is based on track and bear observations from expeditions and wintering personnel, observations of colour-marked bears, recoveries of marked bears, and telemetry studies.

3.3.2. Observations of bears and tracks

Lønø (1970) stated that the occurrence of polar bears in various areas of Svalbard is largely determined by when the pack ice reaches islands and shores. Bears in the Barents Sea will move south- and westwards with the expanding winter ice in late fall (Parovshchikov 1967). This observation is confirmed by the findings in this study. At Hopen, bears were most abundant between October and April, i.e. between when the ice reaches the island in late fall and disappears in spring (Table 14, Fig. 8). There are slight, but non-significant differences in numbers of bears related to months on Hopen between the period 1966-69 and 1976-82. There was more ice in the Barents Sea prior to 1970 than in recent years (Vinje 1976, 1981, 1984). Bears could therefore reach the island relatively early during the late 1960's (Tables 15 and 16). There is a period of fewer observations in mid winter (December to February) in all Hopen observations. One pos-

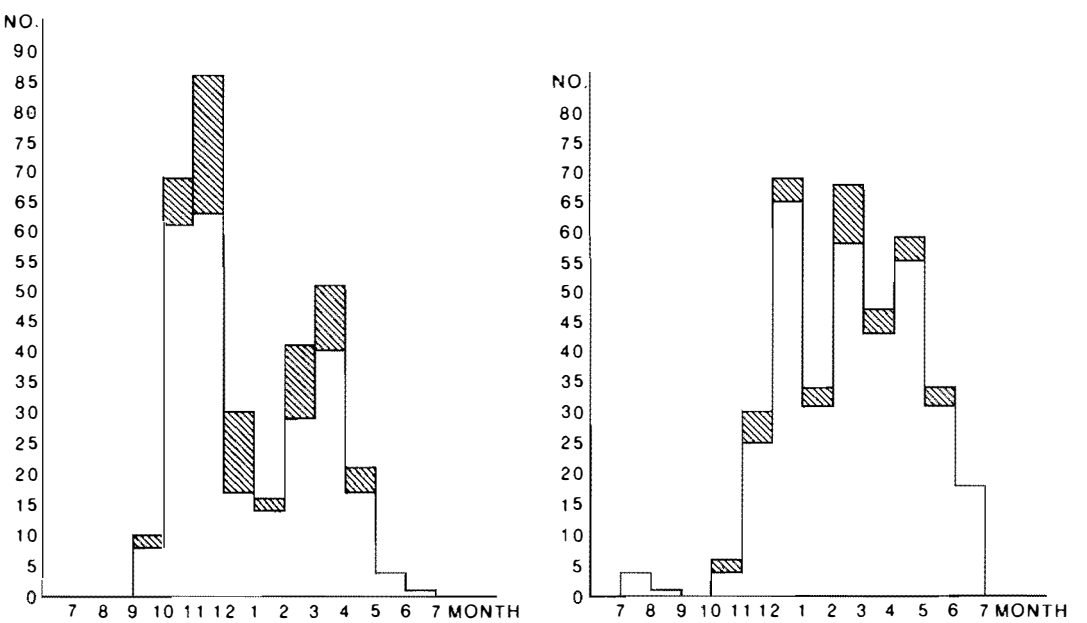

Fig. 8. Number of bears observed at Hopen per month. Left: 1966 to 1970. Right: 1976 to 1982. White columns: single bears (adults or subadults). Hatched columns: family groups.

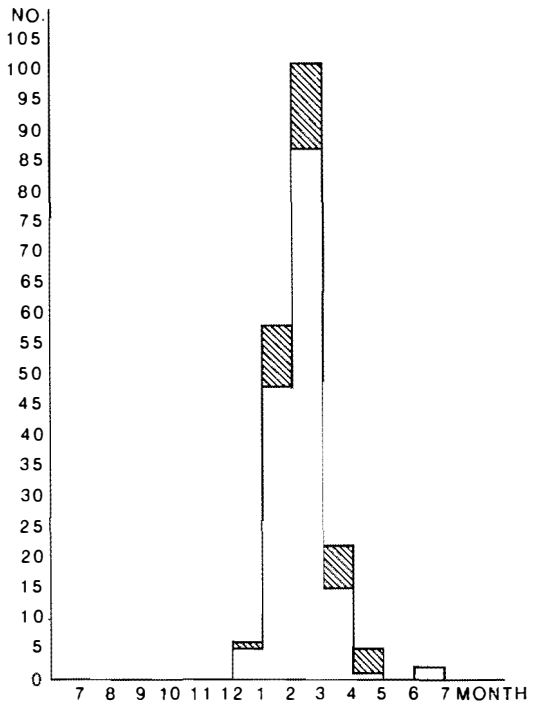

Fig. 9. Number of bears observed at Bjørnøya per month between 1976 and 1983. White columns: single bears (adults or subadults). Hatched columns: family groups.

sible explanation is that bears pass Hopen mainly during their south- and westward migration in late fall and early winter, but will occur again with the breakup of the ice the following spring. Fewer bears will therefore be in the Hopen area during mid-winter.

The Bjørnøya observations show a marked but narrow peak between January and March (Table 17, Fig. 9). Bjørnøya is at the very edge of the Svalbard pack-ice area. The ice, and consequently the bears, will only occur during mid-winter, which is the only time of the year when there normally is ice around the island.

The data from Hornsund show a peak period between January and April (Table 18, Fig. 10). Data from Gråhuken show an even later peak period, between February and June (Table 19, Fig. 11). The late occurrence of bears in these areas can also be explained by the seasonal changes in the distribution of the sea ice. The western and northwestern Svalbard areas are among the latest to receive the drift ice in winter (Vinje 1983). The drift ice which sweeps around Sørkapp in winter will normally not extend further north than the Hornsund area, while Bellsund and Isfjorden remain without drift ice all year round. This explains why not more than 20 to 30 bears are observed annually in outer Bellsund in winter (L. Nielsen, pers. comm.) while more than 200 bears are annually observed in Hornsund only a few kilometres further south (Table 7).

The 1966-70 observations from southeastern Svalbard show increased occurrences after October, with a peak period in March (Table 20, Fig. 12). Bears which move westwards in late fall and winter are normally not able to cross Storfjorden, because it is ice free at that time of the year. But with the freeze-up in January or February, bears may cross Storfjorden back to their summer habitat in the Barents Sea. Track observations in Hornsund in early spring indicate that bears tra-

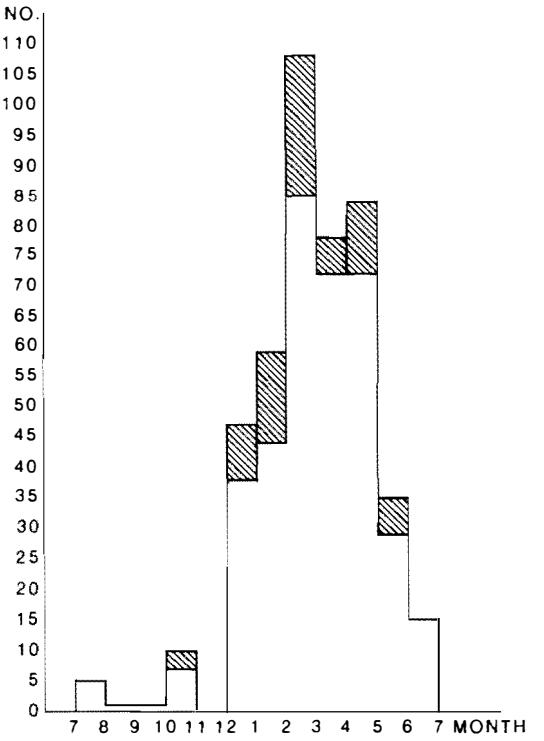

Fig. 10. Number of bears observed in Hornsund per month between 1981 and 1983. White columns: single bears (adults or subadults). Hatched columns: family groups.

vel eastwards and sometimes across land towards Storfjorden (W. Moskal, pers. comm.). Observations from Halvmåneøya by trappers (P. Johnson, A. Strand, pers. comm.) and my own observations in 1968-1969 show that the majority of bears travel eastwards in spring. Their migration route is often limited to a strip only a few kilometres wide between the steep mountains on southern Edgeøya and the active ice with much open water and strong currents further south. This polar bear spring migration has been traditionally known among wintering trappers, who regarded Hornsund in the west and Tjuvfjorden and Halvmåneøya in the east as the best trapping grounds for polar bears in Svalbard (Lønø 1970; Jakobsen 1983). Some bears may head northwards along Storfjorden before they turn into the Barents Sea. There was a migration of bears northwards along the west coast of Edgeøya and east through Freemansundet in March and April 1983 (R. Hansson pers. comm.).

Kong Karls Land is known to be an important summer retreat for polar bears in the Svalbard area (Nathorst 1900; Løvenskiold 1964; Heintz 1964; Gillsæter 1965). The waters around Kong Karls Land are often ice-free in summer, and bears remain stranded on the islands often for weeks. In August 1974, the waters around Kong Karls Land were ice-free. Bears on Kongsøya were observed to swim northwards in late August, towards the ice which was then about halfway between Kvitøya and Kong Karls Land. A field party which was on Kongsøya between May and September 1980 reported a general movement of bears from the island northwards into the drift ice in August and early September (B. Holmgren, pers. comm.). On 3 and 4 September 1983, 97 bears were observed on Kong Karls Land (P. Prestrud, pers. comm., Table 4). On this occasion, surrounding waters were ice-free, and the ice edge was 100 km further to the north (T. Vinje, pers. comm.). A research vessel from Havforskningsinstituttet was working in the drift ice east of Kvitøya in mid September the same year, and the ship drifted with the ice south towards Kong Karls Land. Seals were abundant, but polar bears were not seen until the ship was about 30 km northeast of Kongsøya. Between 15 and 17 September, 57 polar bears were observed in the drift ice (A. Bjørge, pers. comm.). They

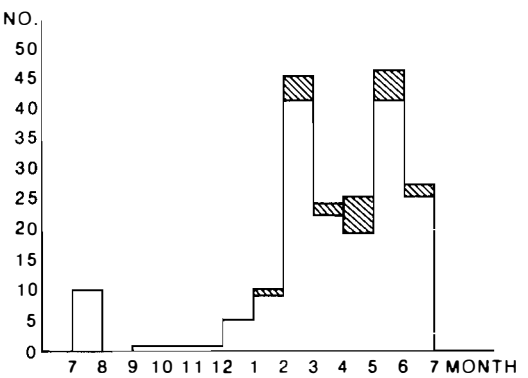

Fig. 11. Number of bears observed at Gråhuken per month between 1974 and 1980. White columns: single bears (adults or subadults). Hatched columns: family groups.

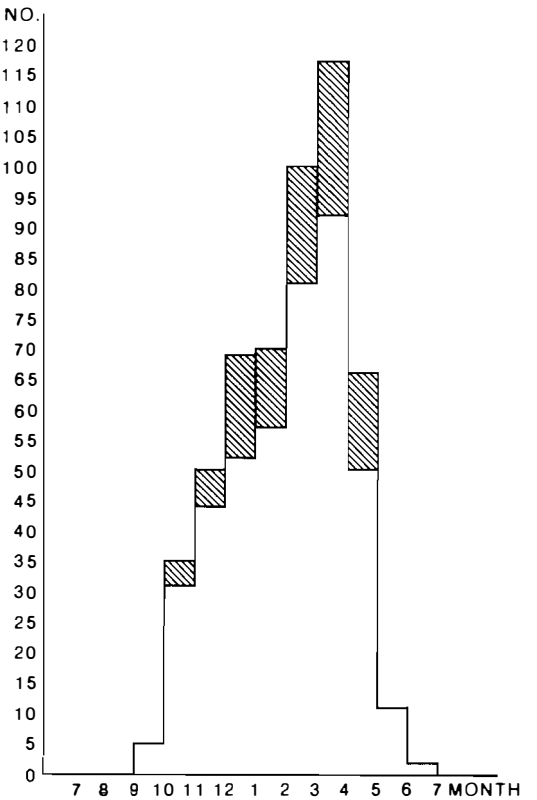

Fig. 12. Number of bears observed in southeast Svalbard per month between 1966 and 1970. White columns: single bears (adults or subadults). Hatched columns: family groups.

were probably the same bears that had been observed on Kong Karls Land two weeks earlier. They left the islands when the ice approached, but before it could be sighted from Kongsøya. It seems possible for polar bears to sense when the ice is approaching even over long distances, and that they make efforts to reach the ice-covered areas even if that involves swimming for several kilometres in open sea.

3.3.3. Observations of colour-marked bears

Eighteen bears colour-marked in the summers 1967, 1968 and 1977 were observed one or several times during the respective expedition periods. But lack of adequate navigational instruments and hence position fixes during the surveys made it difficult to determine directions and lengths of travel between observations. However, movements were small, and all observations were made in the general expedition area south of 80° north. The interpretation was that the summer movements of colour-marked bears were local, and that the bears stayed in the southern ice covered areas of the Barents Sea during summer.

There were eight resightings of seven individual colour-marked bears in Svalbard in 1980 (Table 22). Observations showed that some bears remained on Kong Karls Land throughout the summer, but moved back to the ice in the early fall. Bears marked north of 80° north moved south towards Kong Karls Land in the summer (Fig. 13). The 1980 observations confirmed the 1967-77 observations and that summer movements in the Barents Sea were local and restricted.

3.3.4. Marking and recoveries

A total of 198 polar bears were captured and marked in Svalbard between 1966 and 1982 (Table 21). Between 1967 and 1970, one marked bear was recaptured after one year and released again, and 33 marked bears were killed by hunters (Table 22). Winter kills of marked bears are from Hopen, Halvmåneøya, from the west coast of Spitsbergen, and from Greenland. Summer recoveries are from the Barents Sea (Fig 6). The recoveries show seasonal differences in migration lengths and directions. Twenty-three marked bears were recovered one year or more after they had been marked, showing that bears can remain in, or migrate back to, the Svalbard area in spite of strong ice drift in the Barents Sea. Only three bears have been killed outside Svalbard, one in southeast and two in southwest Greenland (Table 22). The explanation for the low number of recaptures after 1970, is partly the low number of marked bears, but also the fact that polar bear hunting was drastically curtailed in Svalbard in 1970, and stopped after 1973.

3.3.5. Satellite telemetry

Four bears were instrumented with NIMBUS 6 satellite radio collars in the Greenland Sea in the spring of 1979, and five with ARGOS collars in Svalbard in 1982. The 1979 telemetry work showed that bears in the Greenland Sea migrated extensively over large distances towards Svalbard and Frans Josef Land in early spring (Larsen et al. 1983a). Two females with coys were instrumented with ARGOS collars as they emerged from dens on Kongsøya in April 1982. Both moved with their offspring to the sea-ice only a few miles from the north coast of the island, where their local movements could be followed from land over the rf beacon for more than two weeks. One satellite transmitter ceased to function, but the other instrumented bear moved north towards Kvitøya in June. Later, it moved back towards Kong Karls Land again, but the instrument ceased to operate after early July. The last three ARGOS collars were put on single subadult bears in the Barents Sea in July and August. Two of the transmitters functioned for less than one month, but showed local and restricted movements in the drift-ice south of 80° north. Although limited data were collected, the 1982 telemetry studies confirm observations of colour-marked bears and summer recoveries of marked bears, and show that bear movements in the Barents Sea summer habitat are local.

3.3.6. Movement patterns in the Svalbard area

The combined analyses of observations, markings, and telemetry studies show that the ice-covered parts of the Barents Sea and adjacent islands and shores are the main summer habitat for Svalbard polar bears. Bears may remain in the Svalbard area or may move out to adjacent

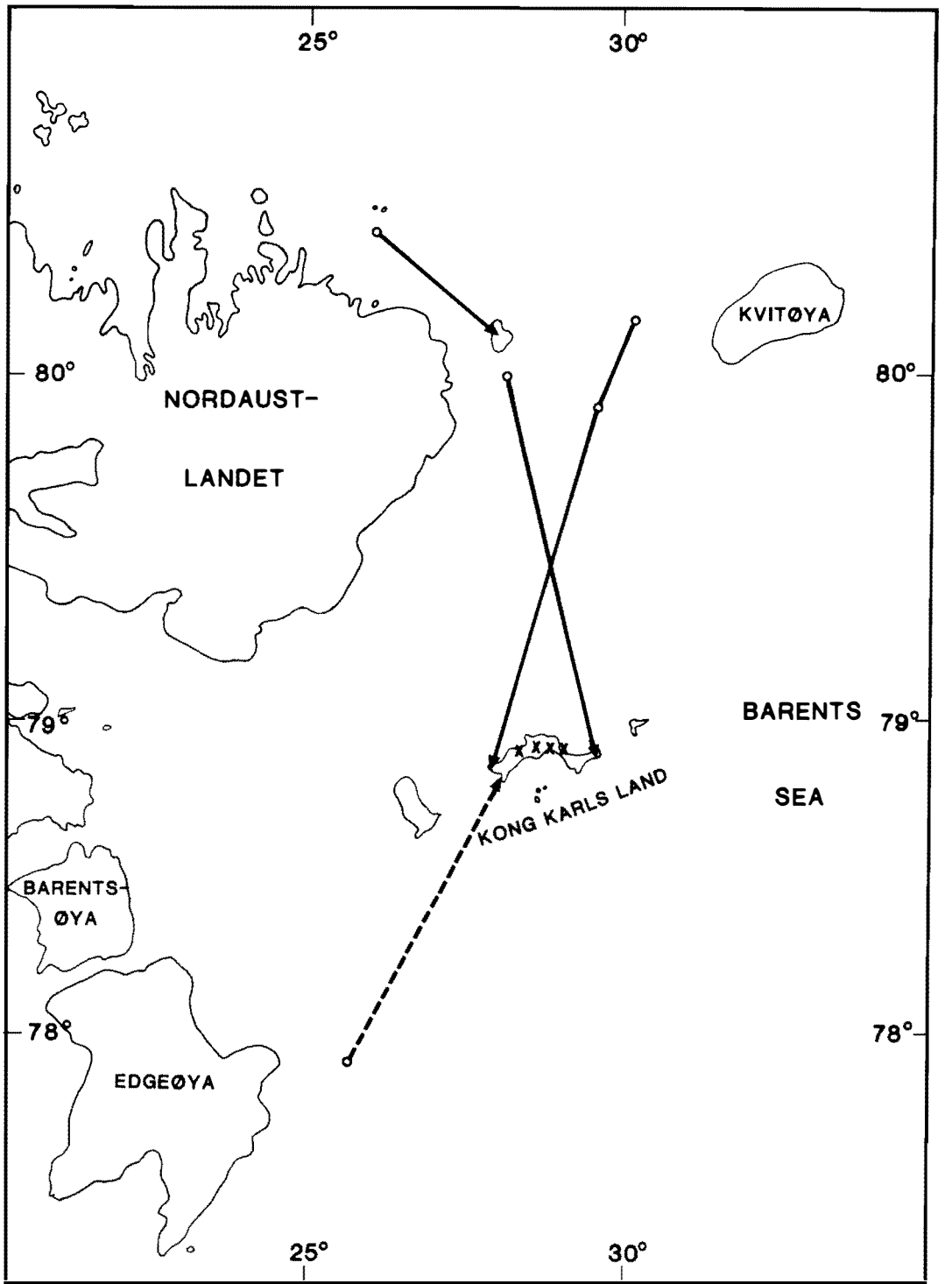

Fig. 13. Observations of colour-marked polar bears in Svalbard in 1969 (stipled line), and in 1980 (whole line). X: observations made where bears were marked.

areas in seasons, but will often reappear in the archipelago and adjacent waters several successive years. Summer movements are limited, and restricted to the ice-covered parts of the Barents Sea and adjacent shores. Observations, recoveries of marked bears and the 1979 telemetry studies suggest that bears often move from far-away areas to the drift ice in the Barents Sea when summer is approaching. Most of the polar bears belonging to the Svalbard population can be found in this area during the summer. Between 50 and 100 bears can be found on Kong Karls Land in normal summers, even if surrounding waters are ice-free. The reason for this phenomenon is not known, but lack of disturbances and many seals on the shorefast ice around the islands could be important factors. In the Hudson Bay and James Bay areas in Canada, bears stay ashore throughout the summer without feeding (I. Stirling pers. comm.) It is possible that bears staying on Kong Karls Land in the summer do not feed either, but scientific information is lacking. In the late summer and early fall, bears on Kong Karls Land and on other islands and shores will return to the drift ice, and may even cross open water in order to reach the ice.

In the late fall, pregnant female bears come ashore to den, mainly on Kong Karls Land, Edgeøya and Barentsøya, and on Nordaustlandet. Adults, subadults and females with cubs follow the ice edge south and westwards, and appear at Hopen, Bjørnøya and the west coast of Spitsbergen during winter. Their appearance is determined by the ice drift and when the ice reaches islands and shores. Few bears occur in central west Spitsbergen because of the lack of winter drift ice. As the ice closes in on the north Spitsbergen coast, bears will also arrive there. In spring, bears follow the retreating ice northwards. Bears on Spitsbergen cross Storfjorden and pass Halvmåneøya or migrate through Freemansundet or further north, eastwards to their summer range. The amount and timing of the bear migration across the Greenland Sea are not known.

3.3.7. Migration between Svalbard and adjacent areas

Reports of bears sighted along the coast of the Norwegian mainland show that bears sometimes go astray from their normal habitat and range and are lost (Larsen 1980). The amount of such emigration from Svalbard and adjacent areas is not known. But bears are also able to cross open water in order to get back to the drift ice and to their normal habitat (Section 3.3.2). Recoveries of bears marked in Svalbard show that they are able to remain in the Barents Sea, where drifting ice sometimes reaches speeds up to 20 km per day, which is comparable to the East Greenland current (Vinje 1982). Vibe (1982) claimed that bears which arrive in Greenland from Svalbard are unable to migrate against heavy ice drift as in the Greenland Sea, and that they will get lost in open sea or come ashore on land which is outside their normal range. But telemetry studies in the Greenland Sea in 1979 show that bears are able to migrate against the ice drift in that area (Larsen et al. 1983a). Pedersen (1931), Degerbøl (1937), and Born (1983) show that there is a northwards migration of bears along the East Greenland coast in the spring and summer. Track observations from the FRAM I drift station in the Fram Strait in April and May 1979 showed that the majority of bears moved from Greenland to the Svalbard area (Larsen et al. 1983a). If there is an exchange of polar bears from Greenland to Svalbard across the Greenland Sea, it must be an active migration. It is unlikely that there is a "one-way traffic" from Svalbard to Greenland, and that bears which follow the East Greenland current are lost.

There are no data which permit quantification of the migration between Svalbard and the western Soviet Arctic. Analyses of observations on Hopen (Section 3.2.5), and findings by Parovshchikov (1967), suggest a seasonal migration between the two areas, but mark and recapture data and telemetry studies from this area are lacking.

3.4. Distribution

3.4.1. General

Polar bears, like many other large mammals, are often unevenly distributed and densities differ between areas. Locations of concentrations of bears may be determined by the ice situation, food supplies, or by other ecological and envi-

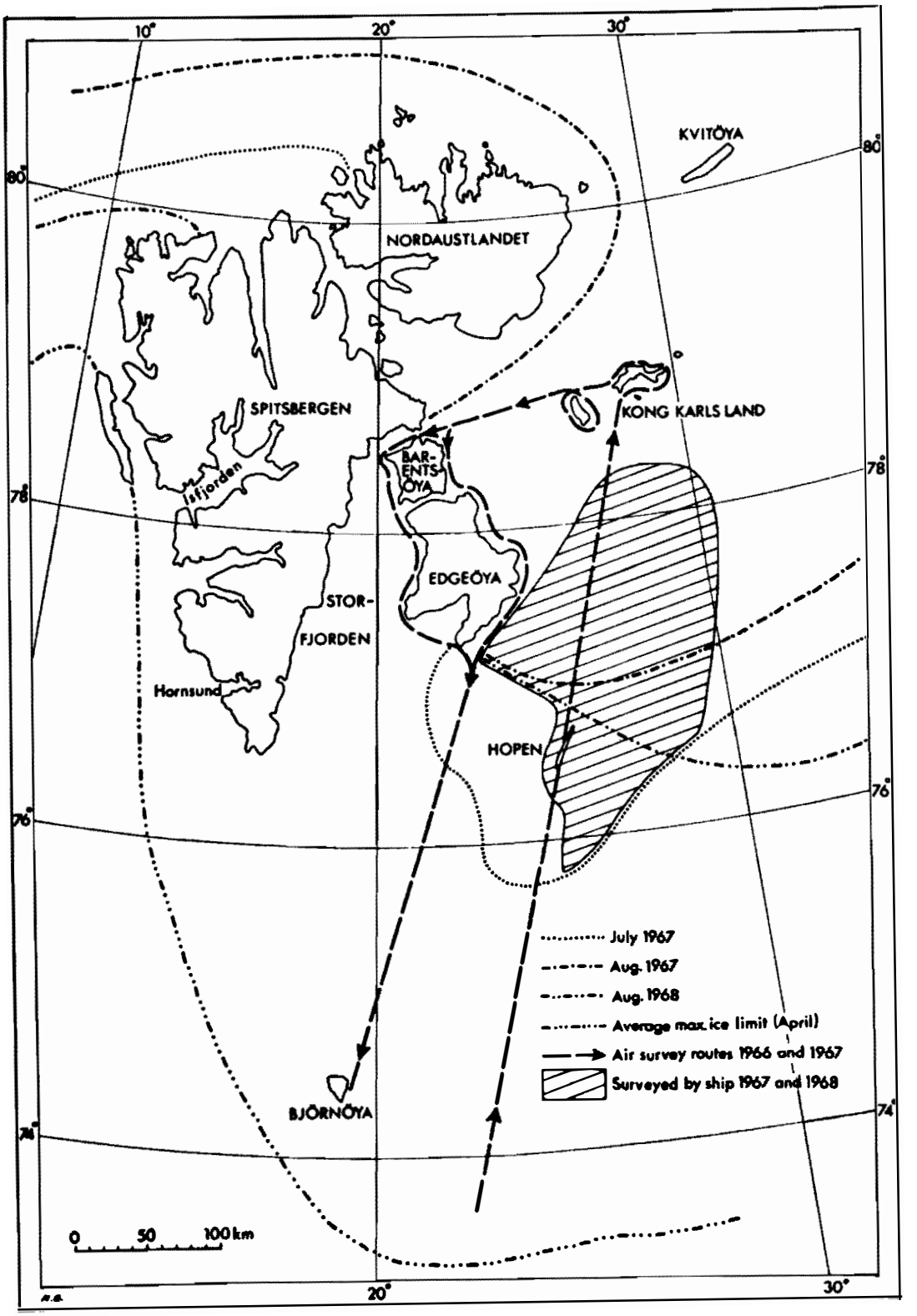

Fig. 14. Areas surveyed fromship and aircraft in Svalbard between 1966 and 1968.

ronmental factors, and may vary with seasons (Vibe 1967). Stirling et al. (1975) stated that the polar bear distribution is largely determined by ice types and seal availability. They found that 47% of all the bears sighted in the Eastern Beaufort Sea were from the active ice zone. Lentfer (1972b) found that bears are more common in the drifting pack ice than in the fast or polar pack ice.

3.4.2. Distribution in the Barents Sea

The aerial surveys in Svalbard in 1966 and 1967 took place once a month between March and October. All surveys were made as two almost parallel flights over the eastern Svalbard waters (Fig. 14). It was estimated that more than 6000 sq. km were effectively surveyed (Table 23). No differences in abundance and distribution in relation to ice coverage and qualities could be found during each survey or between surveys (Larsen 1972).

Nor were any significant differences in distribution and relative abundance of bears in the active ice zone south of 80° north found during ship surveys in the Barents Sea between 1967 and 1977 (Figs. 14 and 15). But observations from YMER in 1980 showed north/south gradients in the Barents Sea between the ice edge in the south and 84° north. There were three to four times more bears south of 80° north than further north in July and August (Table 24). This coincides with differences in ice conditions studied on the same survey. The ice north of 80° north was more consolidated and consisted mainly of multiyear ice, while the area further south was dominated by active, one year old sea ice (Palosuo 1981b). The 1980 findings confirm that sea ice age and quality, and possibly also marine productivity, determine the occurrence and abundance of polar bears in Svalbard. Bears prefer the active ice areas to the consolidated ice in summer.

The air and ship surveys between 1966 and 1983 did not reveal any east-west gradients in polar bear abundance across the Barents Sea. This finding supports the hypothesis that polar bears in Svalbard and the western Soviet Arctic belong to the same population (Sections 3.2.5 and 3.2.6).

3.4.3. Patchiness

Favourable food supplies can sometimes cause abnormal concentrations of bears, as observed by Lønø (1970) and Kulstad (1972). Conflicts between adults and cubs, often resulting in injuries or deaths, have been demonstrated in all bear species (Parovshchikov 1964; Craighead & Craighead 1967; Lønø 1970; Jonkel & Cowan 1971; Kemp 1974; Pearson 1975; Beecham 1980). Female polar bears with offspring avoid large concentrations of bears because of the possible danger of large bears killing the offspring (Taylor et al. 1986). Other studies have shown that abnormal concentrations of polar bears may create non-representative population compositions (Latour 1981). During the 1980 NORVARG survey, a Greenland right whale carcass *(Balaena mysticetus)* was found floating in the drift ice between Kong Karls Land and Nordaustlandet on 2 August. 56 polar bears were counted at the carcass and in its vicinity (Christiansen 1981). The whale carcass may have followed the drifting ice for months (Jonsgård 1983). This carcass may have attracted bears from far away. One bear (No. 492/493) was marked 180 km away only twelve days before it was observed at the carcass (Fig. 16, Table 22). Family groups were observed at the side, but not in the immediate vicinity of the carcass, where eight adult bears were eating, literally shoulder by shoulder.

Such aggregations of polar bears in one site in Svalbard have been deleted in calculations of population compositions, because they may be biased with regard to the representation of females with cubs. But it is unlikely that the congregations will affect the general distribution pattern and average concentrations in the Svalbard drift ice. The average density of bears south of 80° north was 2.14 bears per 100 sq. km in 1980 (Table 24). Consequently, the 56 bears observed at the whale carcass could have been drained from an area with 29 km diameter. Even if bears came from areas further away, they cannot have affected the average density in the drift ice significantly.

3.4.4. Summer retreats

The high concentrations of bears often observed on Kong Karls Land (Sections 3.1.2, 3.3.3, and 3.4.4) can be caused by a large field of shorefast

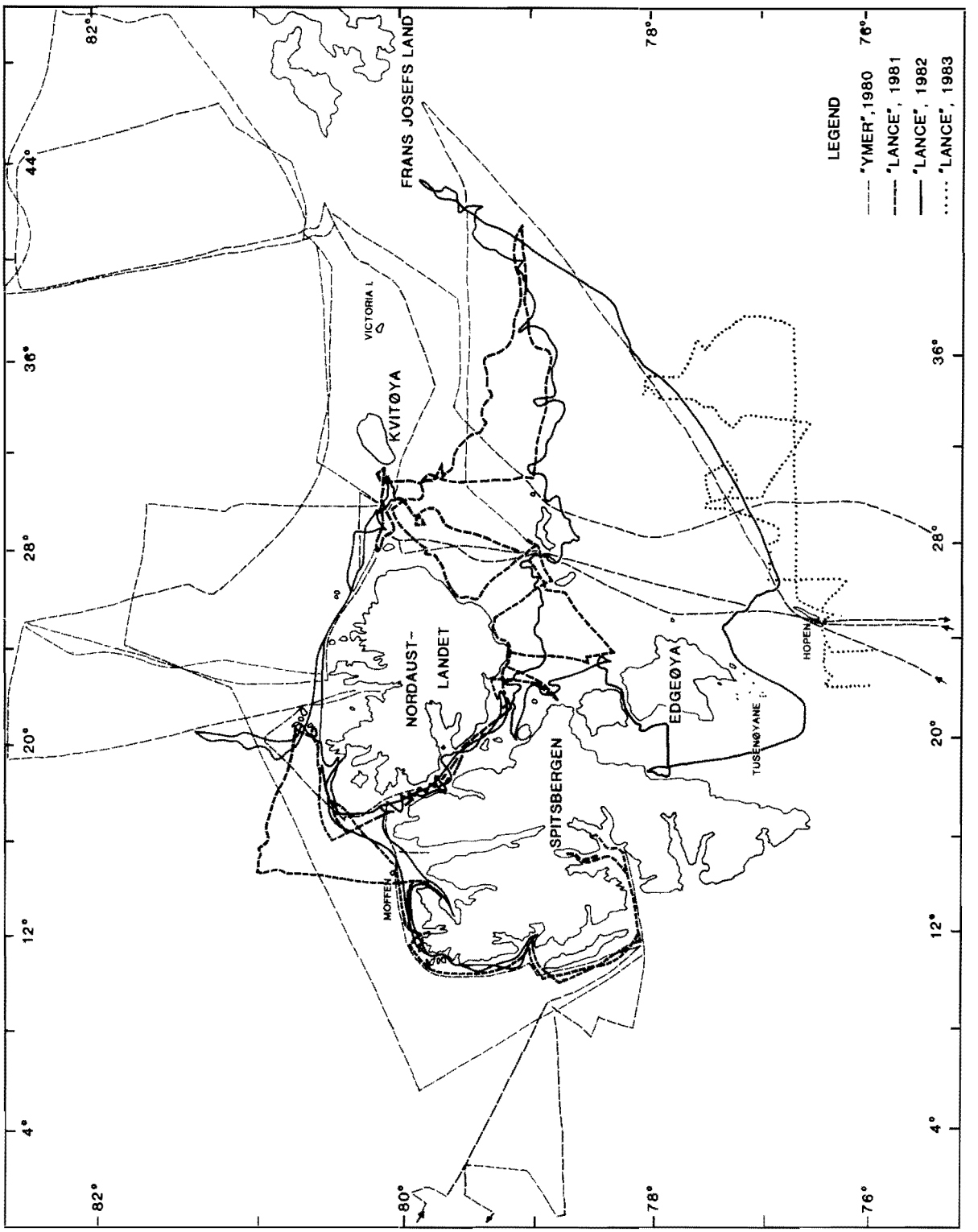

Fig. 15. Areas surveyed from ship in Svalbard between 1980 and 1983.

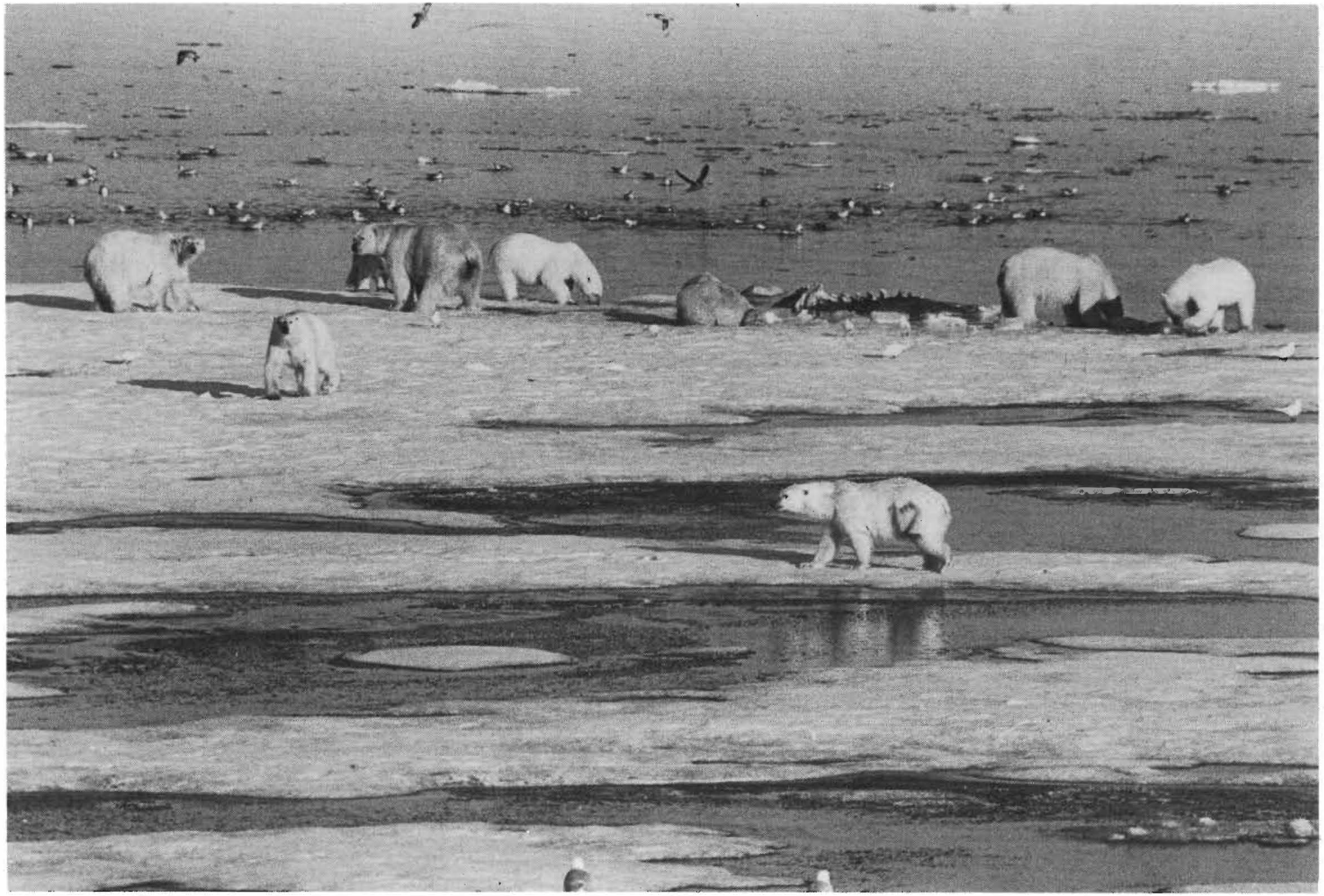

Fig. 16. Polar bears observed at right whale carcass, the Barents Sea, August 1980. Note colour-marked bear in foreground. (Photo: O. Frengen)

ice south of Kongsøya, which remains throughout most of the summer, and where seals are abundant. Similar conditions can be found in the northern fjords of Nordaustlandet. During aerial surveys in 1982, bears were often observed in these fjords, but they were never so abundant as on Kong Karls Land. In 1976, a field party from Norsk Polarinstitutt observed 96 individual polar bears at a camp on southwest Nordaustlandet over a 35-day period (O. Salvigsen, pers. comm.) Simultaneously, ship and helicopter operations along the north coast of Nordaustlandet reported only twelve polar bears in that region. The high concentraton in southwestern Nordaustlandet has not been observed again, and the reason for the occurrence in 1976 is not known.

3.5. Estimates of densities and population size

3.5.1. General

There are several problems involved in the estimation of the size of polar bear populations. The animals are sparsely and unevenly distributed over wide areas, and it is often difficult to obtain sufficiently large samples during surveys to make estimates statistically significant and reliable. Bears distribution and range change with changing seasons. The discreteness of populations are not well enough known, and immigration or emigration affect population size estimates. Population estimates from mark/recapture studies require large samples, which often are prohibitive due to the cost and logistics involved. In this study, different approaches have been used in order to estimate relative and absolute abundances. However, confidence intervals have not been calculated for the results obtained from various approaches, because of the logistic and methodological limitations mentioned above.

All the different approaches have their shortcomings. But weighed against each other, they give the best available density and population estimates for polar bears in Svalbard and adjacent areas. The calculations distinguish between estimates of population sizes before and after 1970. Estimates are based on the Svalbard area, but are intended to include the total population between East Greenland and the western Soviet Arctic.

3.5.2. Air surveys

Observations made from aircraft are affected by such factors as speed, altitude, weather conditions and the observer's experience. Flushing may be a problem during aerial surveys. The reaction of bears to aircraft disturbances can be variable. Some may give no visible reaction while others may run away. Determinations of observation distances, positions and lengths of flights are essential, since such variables will have consequences for estimates of relative and absolute abundance. Air survey results between 1966 and 1967 are shown in Table 23. They are not considered reliable, due to the factors mentioned above, plus the lack of adequate navigational aids and rangefinder instruments onboard the aircraft, and because only a few bears were observed on each survey. Observations and density estimates are presented, however, because they are the only data available from Svalbard prior to 1970, apart from ship survey results (Table 24).

3.5.3. Ship surveys

Ship surveys are considered to be better for estimates of population densities and polar bear abundance in Svalbard. The many factors which limit the efficiency of air surveys are not so pronounced onboard ships. Bears within range are most likely seen, because they remain within observation distance for between 5 and 45 minutes under normal sailing conditions. Studies after 1977 showed that bears could be continually observed 90-95% of the total time after they had been seen for the first time. Flushing does not cause bias. 94% of all bears spotted during ship surveys stood still or walked while observed. Only 2% were hidden behind icebergs or other obstacles, or were swimming so that they were observed by chance. Only 4% ran away from the ship, but could still be seen for long periods. After 1977, transect widths and lengths could be determined accurately by means of new instruments, such as satellite navigational aids and the laser rangefinder. Ninety-five per cent of the observations were made within 3000 m distances (Fig 17). This distance is considered to be effective observation width, and the ship surveys have been truncated accordingly. The most important

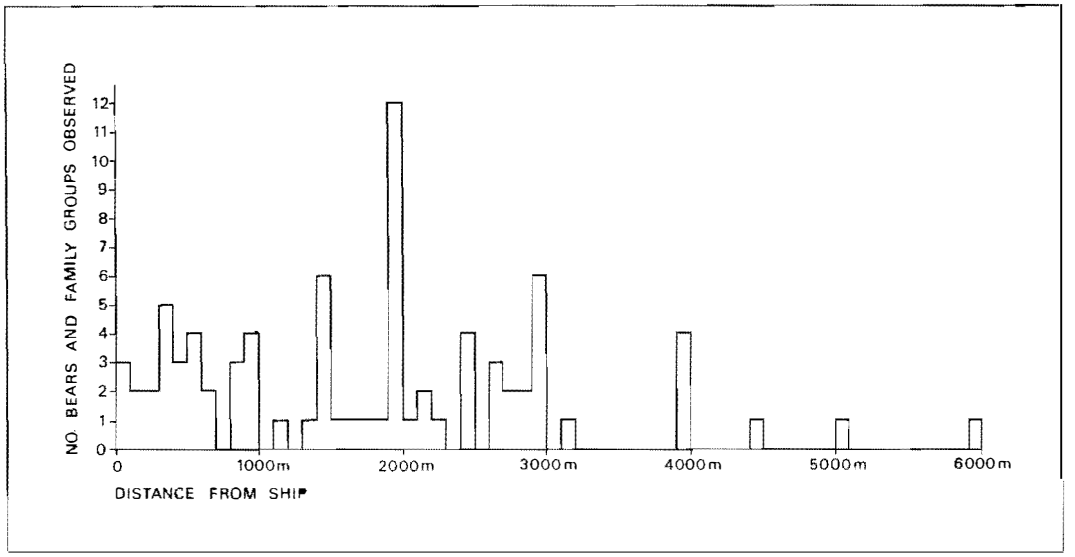

Fig. 17. Distances to polar bears observed from the icebreaker YMER, summer 1980. Measurements with Simrad laser rangefinder.

objection against the use of ship surveys for polar bears is the length of the total transect in relation to total drift-ice area surveyed. Survey tracks could not be selected at random in this study, because polar bear studies were often one of several multi-disciplinary activities onboard. However, track routes covered most of the polar bear summer habitat in the Barents Sea, and are therefore considered representative (Fig. 15). Even if ship routes sometimes crossed previous legs, the time between such crossings related to the bears' own movements made it improbable that individual bears or possible high concentrations of bears were recounted, although a possible bias caused by crossings cannot be ignored.

The ships used in 1967, 1968 and 1977 were small sealing vessels without adequate navigational and rangefinder aids. They were unable to sail in heavy, consolidated drift ice, but were restricted to the active ice area south of 80° north. Transect width was subjectively estimated to 2 km to each side of the vessel (Larsen 1972). A total of 103 bears were observed in 1967 and 48 in 1968. In 1977, only 32 bears were observed. On the basis of the 1967 and 1968 ship surveys, the Svalbard polar bear population was estimated to be between 1500 and 1900 animals in the late 1960's (Larsen 1972). Ship surveys after 1980, where a laser rangefinder was used to measure distances, showed that effective observation range is 3000 m to each side of the vessel. It was also found that densities vary with ice type and coverage. The 1967 and 1968 density figures have therefore been corrected. The revised calculations give a total polar bear population in the Svalbard area in the late 60's of between 810 and 750 animals (Table 24). When corrected for bears probably occurring along shores, in fjords and on Kong Karls Land, an estimate of about 1000 bears in the Svalbard area seems reasonable.

The 1977 ship survey yielded a lower population estimate than those found found in 1967 and 1968 (Table 24). But observations were few, and are not considered reliable for population estimates. It is reasonable to expect higher densities and population estimates in this year, because the polar bear population had recovered after hunting was stopped.

The best ship survey data are from the 1980 YMER expedition. Density calculations based on surveys distinguish between areas south and north of 80° north, because of differences in ice coverage and quality (Palosuo 1981a, b). The densities observed under the first leg of the YMER 80 expedition, from 3 July to 6 August (Fig. 15), show that polar bears were three to four

times more abundant in the active ice areas south of 80° north in the Barents Sea (Larsen 1983a) (Table 24). During YMER's second leg, between 9 August and 24 September (Fig. 15), the ice retreated to about 81° north in late August. The bears followed the retreating ice northwards, and were concentrated along the ice edge. On a helicopter flight on 19 September, where 150 km were flown along a 5 km wide strip, 17 bears were observed, giving an average density of 4.6 bears per 100 sq. km. (Table 24). This must be regarded as extremely high and not directly comparable with other density estimates. The explanation can be that bears which are normally found in the Barents Sea, were concentrated between the ice edge and the unproductive areas at approximately 82° north (Section 3.2.3).

The average density figures yield an estimated total polar bear population of about 1700 to 1900 bears in the Svalbard drift ice the summer of 1980 (Table 24). Adjacent land areas were not effectively surveyed, except for Kong Karls Land. But on the basis of previous summer surveys, it is subjectively estimated that an additional 200 to 300 bears may have been present in fjords, along shores and on Kong Karls Land, at least during the first period of the YMER 80 expedition. This brings the total population estimate up to between 1900 and 2200 bears in the Svalbard area in the summer of 1980.

3.5.4. Markings and recoveries

Another population estimate for the late 1960's can be obtained from markings and recoveries of marked bears, using the Lincoln (1930) index. On the basis of data from between 1966 and 1970, estimates range between 4719 in 1967 and 1905 in 1970 (Larsen 1983a). The great variation in the estimates is caused mainly by the low number of individually marked bears, and recoveries of them, by an unknown immigration and emigration, and by a possible stratification in the population, causing differences in probabilities for captures and recaptures at different times of the year. The variation may also be caused by an unknown mortality of marked animals after handling and by an effect of combined hunting and natural mortality affecting the population in this five-year period. But the Lincoln estimates confirm survey data and the general interpretation of the harvest data and markings, which showed a decline in the Svalbard polar bear population in this period, due to overharvesting.

Mark/recapture data can also be used in a multiple mark/recapture model (DeMaster et al. 1980), which yields population estimates ranging between 446 animals in 1967 and 2341 animals in 1969 (Larsen 1983a). The main reason for this large variation is the low number of marks and recoveries, and the possible biases mentioned above. The multiple mark/recapture method requires that recovered animals are released into the population. But in Svalbard, captures and recoveries are mainly from the harvests, or in other words, represent animals which are removed from the population. Since the polar bear harvest in the late 1960's made a noticeable impact upon the population, the removal of marked animals through harvest also affected the population estimates.

3.5.5. Population estimates from den observations

On the basis of quantitative den studies in Svalbard between 1972 and 1980, it was concluded that between 125 and 135 polar bears den in Svalbard each year (Larsen 1983b). Surveys on Edgeøya and Barentsøya in 1983 showed that there had been an increase in the number of dens on these islands between 1972 and 1983 (Larsen 1974; R. Hansson pers. comm.). Previous estimates of the total number of dens in Svalbard must therefore be corrected. Today, probably between 135 and 165 female polar bears den in Svalbard each spring (Larsen 1984). On the basis of pooled data on the representation of females with family groups of different ages (Table 27, Fig 18), females which emerge from dens constitute between 10% and 11% of the total adult/subadult population. The proportion of females giving birth and emerging from dens can be calculated from an ANURSUS subroutine (Taylor et al. 1984) with population parameters from this study. This gives a proportion of females that give birth of 11.2%. Consequently, the range of the size of the total adult/subadult population from which denning females were recruited can be calculated from the equation:

$$\text{Total population size} = \frac{\text{No. of denning females}}{\text{\% denning females of total population}}$$

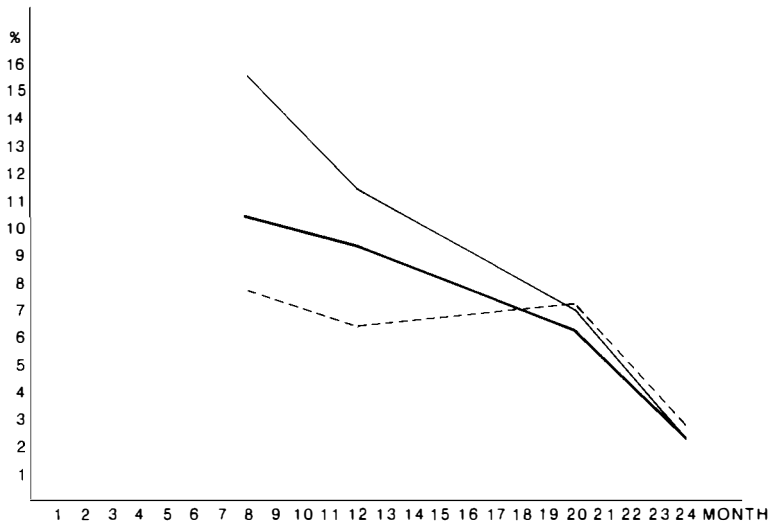

Fig. 18. Observed percentage litters of total adult/subadult polar bear population in Svalbard. Thin line: 1966-70. Stipled line: 1976-83. Thick line: average all years.

which gives total population figures ranging between 1295 and 1750 animals. When cubs and yearlings are added, according to their proportion of the adult/subadult population (Table 27) and average litter sizes (Table 26), the total population size in early spring is between 1680 and 2329 animals.

An estimated 150 polar bear dens are found on Frans Josef Land and about 50 on Novaja Zemlja in the western Soviet Arctic each spring (Parovshchikov 1964, 1967). Few bears which possibly belong to this common population den along the East Greenland coast. If the representation of denning females and population parameters are comparable to what has been found in Svalbard, the total East Greenland/Svalbard/western Soviet Arctic polar bear population must be somewhere in the range between 4000 and 6700 animals after 1980.

3.5.6. Conclusions

Population estimates prior to 1970 can be based on comparisons between ship surveys and estimates from mark/recaptures. The ship surveys in 1967-1968 yielded an estimate for the Svalbard area alone of about 1000 bears. The range of the population embraces the western Soviet Arctic and the Greenland Sea, which were not surveyed in these years. The Svalbard density estimates can be applied to the common East Greenland/Svalbard/western Soviet Arctic population on the basis of estimates of ice cover and ice quality from satellite photos. The Lincoln index and the multiple mark/recapture estimates yielded population estimates for this total area, ranging between 446 and 4719 bears, but with five out of eight different estimates ranging between 1541 and 2351 bears between 1968 and 1970. None of the results are conclusive because of the great variation in the different methods used. But when the 1967-1968 ship surveys, the Lincoln index estimate, and the multiple mark/recapture methods are compared, they indicate together that there were about 1000 bears in the Svalbard area, and at least 1500 to 2500 bears in the East Greenland/Svalbard/western Soviet Arctic area, which is the common range for the whole population, between 1967 and 1970.

Population estimates from between 1980 and 1983 are based on comparisons between ship surveys, and calculations from den counts and estimates of proportions of denning females in the population. An evaluation of the different estimates indicates a population size in the Svalbard area alone of between 1700 and 2000 bears. If the density figures from Svalbard in 1980 are applied to the total ice-covered area between East Greenland and the western Soviet Arctic, where ice coverage is estimated from satellite photos, then there were between 3000 and 5000

Fig. 19. Observed average litter sizes of polar bears in Svalbard. Thin line: before 1970. Stipled line: after 1970. Thick line: average all years.

bears in the common Svalbard/western Soviet Arctic/East Greenland area. If estimates derived from den counts and population parameters are applied to the same total area, the number of animals in the population is between 4000 and 6700. However, all population estimates are probably biased, mainly due to small samples. They can also be affected by an unknown immigration of bears from other areas.

3.6. Age structure and survival rates

3.6.1. Adult survival rate

Teeth from 585 male and female polar bears were collected between 1954 and 1980 (Table 25). Because set-gun hunts were considered to be non-selective (Lønø 1970), and because there was no selectivity involved in the live captures, the teeth samples are regarded as representative for the whole population, except for bears younger than three years. Wintering trappers and other polar bear hunters often did not care to collect skulls from cubs. Coys, yearlings and two-year olds are therefore underrepresented in the samples. Chapman-Robson age analyses could not reveal differences between males and females in the samples, nor between years prior to 1970. Samples have therefore been pooled. The observed average survival rate for Svalbard bears between age three and twenty years was 0.825 (S.D. = 0.021) for the period between 1954 and 1970.

Only 70 male and female polar bear teeth were collected from bears which were live captured between 1977 and 1982, and subsequently aged. Since this material is also considered to be non-selective, males and females have been pooled. Chapman-Robson analyses gave an observed average survival rate for bears between age three and fourteen years of 0.906 (S.D. = 0.05).

3.6.2. Cub survival rate — Changes in average litter size

The average litter size of polar bear cubs of different ages has been calculated from a total of 567 litter observations between 1966 and 1983. There is a decreasing average litter size from when females with coys emerge from their dens in early spring until cubs separate from their mothers in their third year of life (Table 26, Fig. 19). Before 1970, the average litter size for coys about four months of age is lower than what has been observed by Lønø (1970), and much lower than what has been observed after 1970 in this study. This may be due to a small sample size of four months old cubs prior to 1970 (N = 11), or because observations were made on land or on the ice between one and four weeks after den emergence, when some coys may have died. Observed average coy litter size in Svalbard after

1970 is generally higher than what has been observed in other high arctic areas (Parovshchikov 1967; Karpovich 1969; Stirling et al. 1975; Belikov et al. 1977; Lentfer et al. 1980; Stirling et al. 1980; DeMaster & Stirling 1983). All spring observations of coy litters after 1970 were made in the denning areas when family groups emerged from the maternity dens. Observations of litters of coys in other studies are not directly comparable, because they were made in the drift-ice, after females with coys had left the denning areas, and when some cubs may have died. DeMaster & Stirling (1983) estimated the average coy litter size in the North American Arctic to be between 1.70 and 1.98 from coy and yearling survivorship and observed average yearling litter size, and emphasized the difference between calculated and observed values. Their calculated estimates are comparable with average observed coy litter size in Svalbard after 1970 (Table 26) and particularly with data from Edgeøya and Kong Karls Land after 1978 (Tables 1 and 2). Lønø (1970) found an average 2.07 corpora lutea in polar bear ovaries from Svalbard. A combined evaluation of these findings suggests therefore that the observed coy litter sizes in Svalbard denning areas in recent years are representative of polar bear populations in the High Arctic.

The observed average litter size of coys in summer prior to 1970 (age about eight months) is high, but comparable with Lønø's (1970) data. Both samples are small (N = 34 in this study, N = 18 in Lønø's). The observed average litter sizes of yearlings and two-year-olds are lower than in other High Arctic studies (Stirling et al. 1975, 1980; Lentfer et al. 1980; Bunnell & Tait 1981; DeMaster & Stirling 1983), but comparable with Lønø's (1970) data. The decrease in average litter sizes with increasing age of cubs are most pronounced after 1970 (Fig. 19). Eberhardt (1977) shows that the mortalities in marine mammals particularly affect the young. The low average litter size in yearlings and two-year-olds in Svalbard may be caused by high population densities. More adult males in bear populations may result in intraspecific conflicts and higher cub mortality (Bunnell & Tait 1981; McCullough 1981; Fowler 1981). The active ice conditions in the Barents Sea can be another detrimental factor. The ice-drift in the Barents Sea is comparable with the drift in the Greenland Sea, where it may sometimes be 15 n.m. per day or more (Vinje 1982). Observations of polar bears along the Norwegian mainland show that bears often occur far outside their normal range (Larsen 1980). Svalbard polar bear cubs may occasionally be forced to swim for long periods over open leads in order to return to the drift-ice. Small cubs are unable to compensate for the ice-water chill (Blix & Lentfer 1979) and may therefore die. They have also been observed to drown when forced to dive under large floes (C. Vibe, pers. comm.).

The litter size curve based on data prior to 1970 is probably biased, mainly due to small samples for all ages except for twelve months old cubs. Although there seems to be a higher cub mortality in Svalbard bears after 1970, the differences between the two data sets are not significant. Data have therefore been pooled (Table 26, Fig. 19).

Cub survival rates can be calculated from the changes in average litter size (DeMaster & Stirling 1983; Taylor et al. 1984). From ANURSUS (Taylor et al. 1984), we have the following equations:

$$S_{coys} = \frac{(\text{aver. litter size yrls} - 1) \times \text{aver. litter size coys}}{(\text{aver. litter size coys} - 1) \times \text{aver. litter size yrls}}$$

and,

$$S_{yrls} = \frac{(\text{aver. litter size 2yrs} - 1) \times \text{aver. litter size yrls}}{(\text{aver. litter size yrls} - 1) \times \text{aver. litter size 2yrs}}$$

Average values for cubs aged four months and yearlings 20 months, and for cubs/yearlings 12 months and yearlings/two-year-olds aged 24 months in Svalbard from Table 26 give:

$$S_{\text{coys age 4 to 12 months}} = 0.67$$

$$S_{\text{yearlings age 12 to 24 months}} = 0.70$$

Since the survival rates of cubs between age four and 24 months can be expressed as:

$$S_{cubs} = S_{coys} \times S_{yrls}$$

we can now calculate the survival rates for cubs between age four and 24 months, and we get:

$$S_{cubs} = 0.47$$

The coy survival rate between birth and emergence from dens at age 4 months cannot be cal-

culated from changes in average litter size, because observations cannot be made when family groups are in dens. But Lønø (1970) found an average 2.07 corporea lutea in polar bear ovaries from Svalbard. The best and most reliable data of observed average litter size for four months old coys are 1.84 from after 1970 (Table 26). This gives us a coy survival rate between birth and age four months of 0.88, and consequently a total survival rate for cubs between birth and age 24 months of 0.41.

All calculated cub survival rates are conditional, i.e. they provide that the mothers also survive. True cub survival rate between birth and 24 months age, S'_{cubs}, is:

$$S'_{cubs} = S_{cubs} \times S_{adults}^2$$

which gives

$$S'_{cubs} = 0.30 \text{ before } 1970$$

and

$$S'_{cubs} = 0.34 \text{ after } 1976.$$

3.6.3. Loss of whole litters

The proportions of cubs of total adult population have been calculated from 3223 summer and winter observations prior to and after 1970 (Table 27). The representation of family groups in the population undergoes changes with cubs' increasing age. Prior to 1970, the proportion of females with cubs dropped from an average 15.5% at age 8 months to 6.9% one year later. The data suggest a loss of whole litters of 55.5% in this period. The changes in family group representation changed from 7.7% to 7.2% in the period 1976-1983, which gives a litter loss of only 6.5% between cubs' age 8 and 20 months. But samples prior to 1970 are small, and there are no significant differences between the two data sets. They have therefore been pooled (Table 27, Fig. 5).

The loss of litters is also pronounced after the cubs are 20 months old in both data sets. This does probably not reflect a true increase in cub mortality, but is rather the result of a breakup of family groups during late winter and early spring in the cubs' third year of life. One or both cubs may stray farther away from their mother, or one of the cubs may leave the family before the other. It is possible that the loss of whole litters is most pronounced during the cubs first months out of the den, when they are vulnerable to predation by large bears (Bunnell & Tait 1981; McCullough 1981; Taylor et al. 1986), or when severe ice and weather conditions may cause deaths.

There are evidently biases in the 1976-1983 data (Table 27, Fig. 18), because the proportion of cubs of age 20 months cannot be higher than at age 12 months. The proportion of yearling litters is particularly high in the 1980 and the 1982 summer data sets (Table 3). It is probable that the high representation of yearling versus coy litters was caused by different distribution patterns of population groups in the Barents Sea in these years. Likewise, the very high losses of litters observed prior to 1970 seem improbable. Polar bears, like many other large mammals, take many years to reach sexual maturity, and have three or more years between each litter. Recruitment to the population requires that females invest in the survival of their offspring when dependent upon her. It is particularly important that the mortality of young is low in periods of heavy harvest. Studies of other mammals have shown that harvested populations are able to compensate for losses by increased productivity, either because females reach sexual maturity earlier, or because their fertility rate increases, or because their reproductive rate increases (Chapman 1964; Markgren 1969; Benjaminsen & Lett 1976, Bonner 1982; Capstick & Ronald 1982; Kasuya & Miyazaki 1982; Bowen & Sergeant 1983). Lønø (1970) found that polar bear females in Svalbard matured perhaps as early as 2 1/2 years old, which is considerably earlier than in other high arctic polar bear populations. Lønø's samples are from a period with heavy harvest. However, Lønø's tooth samples were re-examined in this study. While Lønø (1970) concluded that two zones were formed in tooth cementum each year in cubs and juveniles, it was found that only one zone was formed each year.

The high litter losses and consequent low coy and yearling survival rates as observed in Svalbard prior to 1970 could not compensate for the high natural and harvest mortalities in that period. Nor is it possible to obtain an increase in the

population as observed after 1970 with such low cub survival rates (Chapter 3.6.2). The observations of coy and yearling litter representations in the population, or the calculated adult and cub survival rates can however be biased. A separation of different age and sex classes of polar bears has been observed in other areas (Lentfer 1972; Stirling et al. 1975; Latour 1977), or by non-representative age samples.

But loss of whole litters cannot be ignored. Loss of whole litters will take place if the females for one reason or another are unable to care for their offspring, and to protect them from dangers, as when family groups are harassed by other bears or by humans. During live capture work in this study, cubs were sometimes separated from their mothers when chased with aircraft or boats, and much effort was involved to bring family groups together again. Observations from Svalbard between 1966 and 1983 include 18 observations of orphaned cubs of ages 12 months or less. Orphanage was not resulting from live captures. The fate of the mothers of these cubs is not known. Cubs are dependent upon their mothers prior to weaning, and will normally not survive if separated from them.

3.7. Age at weaning and breeding intervals

Lønø (1970) stated that polar bear cubs in Svalbard separated from their mothers in the spring or early summer in the cubs' second year of life, and that the normal breeding interval was two years. His findings were partly based on age determinations from tooth sections, which suggested that two layers were deposited per annum during the first years. The age determinations from tooth sections in this study, which include a re-examination of Lønø's material, confirm the findings from other arctic areas, that only one layer is deposited each year (Hensel & Sorensen 1980). Skulls and teeth collected by trappers and weather station personnel prior to 1970 showed that cubs aged two years or more were still with their mothers. Observations by wintering trappers, weather station and scientific station personnel show that females are with two-year old cubs in the winter (Tables 5, 6 and 7). Observations in denning areas in the early spring also show that some cubs older than two years are still with their mothers (Tables 1 and 2). Some of the females captured in summer, when accompanied by cubs between 19 and 21 months of age, were still lactating. The conclusion is therefore that Svalbard polar bears, like other High Arctic polar bear populations, follow their mothers until they are at least 24 months old.

The theoretical breeding interval for Svalbard polar bears is therefore three years, as it is expected that family groups will separate during the breeding season in spring when the cubs are in their third year of life. Females that lose their litters may enter the breeding cycle earlier. There are two observations from Svalbard of females accompanied by coys and yearlings simultaneously. One is from the east coast of Spitsbergen in the spring of 1910, when a trapper found a female with two coys and two yearlings in the same den (Bengtssen 1934). The other is from Kong Karls Land in spring 1977, when tracks showed that a newly opened maternity den had been occupied by a female with two coys and at least one yearling. It is possible that the females have bred when accompanied by coys, but such incidents must be considered rare.

3.8. Recruitment

A commonly used estimator for cub production is productivity rate or reproductive rate, defined as the number of cubs per female per year (Stirling et al. 1980; Bunnell & Tait 1981; Øritsland & Schweinsburg 1983). DeMaster & Stirling (1983) define reproductive rate as the number of female cubs produced per female per year. In this paper, reproductive rate is defined as the number of cubs produced per female per year.

An average litter size of two and a three-year breeding interval for High Arctic polar bear populations give a reproductive rate of 0.67. This must be considered a maximum and theoretical value. Average litter size is normally lower than two (Section 3.6.2). The breeding interval is often longer than three years, because some females forego breeding for one reason or another (Bunnell & Tait 1981). Reproductive rate for wild polar bear populations was found to be between 0.44 and 0.77 by Bunnell & Tait (1981), between 0.53 and 0.60 by DeMaster & Stirling (1983) and

0.39 by Schweinsburg et al. (1981). Bunnell & Tait (1981) calculate polar bear reproductive rates from the data of several authors and investigators from many arctic areas. Their highest calculated reproductive rate of 0.77 is from Lønø's data, with a breeding interval of 2.18 years, which probably is too short (Section 3.7).

If we use an average litter size of 1.84 for four-month old coys as observed in Svalbard in recent years (Table 26), and a breeding interval of 3.12 to 3.6 years (Lentfer et al. 1980; DeMaster & Stirling 1983), we get reproductive rates for Svalbard bears ranging between 0.51 and 0.59.

Observed breeding intervals are determined by factors as fertility rate, or conception rate, rate of abortions, and coy survival in dens, here combined and called Q:

$$Q = \text{Fertility rate} \times \text{rate of abortion} \times \text{coy survival in den}$$

The relationship between theoretical and observed breeding intervals can then be expressed as:

$$Q = \frac{\text{Theoretical breeding interval}}{\text{Observed breeding interval}}$$

Observed breeding intervals between 3.12 and 3.6 years give values for Q between 0.83 and 0.96 if the theoretical breeding interval is three years. What is observed or calculated as fertility rate is often a combination of true fertility rate and rate of abortions. Q is therefore really an expression for observed fertility rate and coy survival in dens. Coy survival rate in dens was estimated to be 0.88 in this study (Section 3.6.2). With the estimates for Q above, we consequently get an observed fertility rate ranging between 0.94 and 1.09. Observed fertility rate must be 1 or less. Consequently, breeding intervals in Svalbard are not shorter than 3.4 years if we accept a coy survival rate in dens of 0.88. An estimated fertility rate of 0.94 is acceptable, because it is comparable with what is often found in other large mammals and carnivores (Chapman 1964; Benjaminsen & Lett 1976; Bonner 1982; Capstick & Ronald 1982; Kasuya & Miyazaki 1982; Bowen & Sergeant 1983).

Taylor et al. (1984a) use the term breeding success in order to calculate recruitment in polar bear populations. Their definition of breeding success is the proportion of the available mature females which actually breed in year i (N_i), and which emerge with cubs from their dens the following spring (N_{i+1}), or:

$$\text{Breeding success} = \frac{N_{i+1}}{N_i}$$

Breeding success is often underestimated, because it is difficult to estimate the number of successful breeders in any year, and because it is difficult to estimate the absolute number of females with coy litters in early spring. If counts are performed in the denning areas, some family groups may be overlooked because they are still in dens. If counts are made in the drift-ice, stratification, i.e. the possibility of segregation by age and sex class, or the fact that some family groups remain in the denning areas for several weeks (Hansson & Thomassen 1982), may cause bias.

N_{i+1} can be expressed as:

$$N_{i+1} = N_i \times \text{adult survival between mating and birth (i.e 9 months)} \times Q.$$

Consequently, from the equations above, breeding success is also:

$$\text{Breeding success} = \text{adult survival rate over 9 months} \times Q$$

An adult annual survival rate of 0.906 (Section 3.6.1) and values for Q of 0.83 (because fertility rate = 0.94) give a breeding success of 0.77.

The conclusion is therefore that 77% of mature and available polar bear females which breed in Svalbard each spring emerge from dens the following spring with a coy litter. The reproductive rate which is calculated from den emergence to weaning, ranges between 0.51 and 0.59. Breeding success and reproductive rates are conditional, i.e. they require that females survive. Low adult survival rate, e.g. caused by hunting, will consequently yield low breeding success and reproductive rate. The recruitment to a hunted population will therefore be low, unless density dependent mechanisms can increase breeding success, reproductive rate and cub production.

3.9. Population trends and projections before and after 1970

Already by the mid 1960's, there was a general concern that polar bears in Svalbard were over-

harvested (Larsen 1971a,b, 1980). An average of 320, and sometimes more than 500, bears were removed each year from a declining total population which was probably around 2000 animals when hunting was curtailed in 1970 (Section 3.5.6). Thirty-two out of a total of 103 marked animals had been killed between 1967 and 1970, confirming a heavy harvest pressure (Larsen 1971b). The catch data from Hopen also show that an overharvest did take place. Hopen is manned by four men all year, and at least one of them had experience from previous winterings, and from polar bear set-gun hunting prior to 1970. Set-guns were mounted in the early autumn, and were checked daily, weather permitting. It is therefore assumed that the crew's polar bear hunting experience and the efficiency in mounting and maintaining set-guns were the same from one year to another. The prohibition of polar bear hunting in the Soviet Arctic had resulted in higher annual takes on Hopen after 1956. But there was no significant increase in the Hopen harvests between 1966 and 1970, in spite of a high increase in prices paid for polar bear hides after 1965 (Fig. 7). The increasing prices encouraged higher hunting efforts, as reflected in the number of set-guns used on Hopen (Fig. 7). Catch per unit of effort can be expressed as the number of bears taken per set-gun hunting day. And set-gun hunting days are the combination of the number of set-guns and the number of days with ice around Hopen in the hunting season between October 1 and May 15. Table 28 shows that catch per unit of effort decreased by 40% from the period 1952-1967 to 1967-1970. The combined results of the mark/recapture data and the analysis of the Hopen catch data show that the Svalbard polar bear population was overharvested in the years prior to 1970.

Population estimates in the late 1960's and in 1980-83 showed that the population had recovered and probably doubled in this period (Section 3.5.6). The population growth rate can be expressed as A, which is less than one for a decreasing population, but more than one for an increasing population (Taylor et al. 1984). Growth rates and survival rates are linked, as expressed in the following equations:

$$S_{\text{observed prior to 1970}} = \frac{S_{\text{natural}} \times S_{\text{harvest}}}{A_{\text{prior to 1970}}} \quad (1)$$

Since there was no polar bear hunting in Svalbard after 1970, it follows that:

$$S_{\text{observed after 1970}} = \frac{S_{\text{natural}}}{A_{\text{after 1970}}} \quad (2)$$

Bunnell & Tait (1981) state that natural survival rates in bears is density dependent. There is no statistical significant evidence for density dependent mechanisms in Svalbard polar bears although the studies of population composition and cub survival rate indicate that this may be the case (Sections 3.1.4, 3.6.2, and 3.5.3.). Fowler (1981) states that adult suvival is inflexible in large mammals, and has not been shown to change in many populations. It is therefore assumed that S natural is constant in the Svalbard polar bear populations before and after 1970 = S. Consequently, it follows that:

$$S_{\text{harvest}} = \frac{S_{\text{observed prior to 1970}} \times A_{\text{prior to 1970}}}{S_{\text{observed after 1970}} \times A_{\text{after 1970}}} \quad (3)$$

In Section 3.6.1 we had S observed before and after 1970, namely:

$$S_{\text{harvest}} = \frac{0.825}{0.906\ A.} \times \frac{A \text{ prior to 1970}}{A \text{ after 1970}}$$

Let us assume a maximum annual population increase in Svalbard polar bears of 5% (i.e. A = 1.05) after 1973, which is the result of ANURSUS and Leslie matrix population projections with optional population parameters (Section 3.5.6), and which is in agreement with the population size estimates before and after 1970. From equation (2) and observed S after 1970 (Section 3.6.1), we consequently get a natural survival rate S = 0.95.

Since A prior to 1970 must be less than 1, equation (3) gives $S_{\text{harvest}} = 0.87$, or less, or in other words, the average harvest mortality was 13% or more.

We have the following equation:

$$\frac{\text{Total bear population}}{\text{Average no. bears killed}} = \frac{1}{\text{Harvest mortality}} \quad (4)$$

which can be used to calculate harvest mortalities. Between 1966 and 1970, a total of 1564 bears, or an annual average of 313 animals were

taken in Svalbard (Table 29). A population size of 2500 animals in this period (Section 3.5.6) gives an average harvest mortality of 12.5%. But a population size of 1500 bears (Section 3.5.6) gives an average harvest mortality of 20.9%. This is probably too high. A comparison of the ANURSUS projection approach and calculations from equation (4) suggest that the true average harvest mortality was around 13% in the late 1960's. Consequently, the population size of the East Greenland/Svalbard/western Soviet Arctic was about 2500 polar bears around 1970. This estimate is the same as the highest estimate from surveys and mark/recaptures (Section 3.5.6).

The size of the population in 1945 can now be calculated on the basis of harvest data and estimated harvest mortality. The average annual harvest between 1945 and 1970 was 320 polar bears (Table 29). We must expect that the impact of the harvest became increasingly pronounced from an initial large population towards a small population of only about 2500 animals prior to 1970. The calculated harvest mortality of 13% is from the period when the impact of the hunting was most pronounced. The population decrease has probably been exponential, but there are no data which permit us to calculate the harvest mortality in different years. The average harvest mortality between 1945 and 1970 is therefore set arbitrarily at 13% : 2 = 6.5%, which can be too low, because there was some polar bear hunting in Svalbard before that (Lønø 1970). But the second world war put an effective stop to all polar bear hunting in Svalbard and adjacent areas, so that the population was effectively protected for five years. If this reasoning is accepted, then equation (4) gives us an initial population size of about 4800 bears in 1945.

The population size in 1945 can be calculated through another approach. If the population size in year i is Ni, the population size the following year is Ni+1, the annual catch is C, and the population growth rate is A, then:

$$(N_i - C)A = N_i + 1$$

or:

$$N_i = \frac{N_i + 1}{A} + C$$

Catch data prior to 1945 are partly unreliable. However, according to Lønø (1970), a total of 11656 bears were taken in Svalbard and adjacant areas between 1909 and 1944, which gives an average of 324 bears taken per year in this period. Consequently, the average annual harvest pressure was comparable to the period 1945-70. It is therefore reasonable to assume that population compensatory mechanisms and population growth rates were comparable before and after 1970. If we accept a population size of 2500 bears in 1970 and with A = 1.05, and if we apply annual total catch data from Table 29, then we get a total population size in 1945 of 5545 bears.

The calculations of population sizes, however, are sensitive to the population growth rate. If we apply an average growth rate of only 1.02, which may seem more realistic, then equation (5) gives us a population size in 1945 of 7842 bears, and unrealistically high population sizes around 1909. But low population growth rates can be accepted under heavy harvest regimes if there is a constant immigration of bears from outside areas. The mark/recaptures and telemetry studies do not suggest this however (Section 3.3).

Let us assume optimal theoretical population parameters with regard to survival rates and breeding success; i.e. adult survival rate = 0.96, coy and yearling survival rates = 0.80, reproduction rates for four-year olds, five-year olds and older = 0.15, 0.35 and 0.70, respectively. Let us also assume a population size of 1000 bears in the Svalbard area in 1968 when we have the best estimates (Section 3.5.6). An ANURSUS population projection (Taylor et al. 1984) yields a growth from 1000 to 1924 bears over twelve years, i.e. from 1968 to 1980. This fits with the estimates of 1700 to 2000 bears in Svalbard between 1980 and 1983. A Leslie matrix population model (Øritsland & Schweinsburg 1983) gives a growth from 1000 to 2525 bears, or a population growth of 8% with the same parameters. This is probably too high. Because of the differences in the projections, ANURSUS (Taylor et al. 1984) and two different Leslie matrix projections (Øritsland & Schweinsburg 1983; DeMaster pers. comm.) were compared. The adult survival rate was 0.95 and coy and yearling survival rates ranged between 0.6 and 0.67. Reproductive rates were 0.35 for four-year olds and 0.6 for bears five

years and older. The choice of parameters is based on field observations and calculations from Svalbard (this study) and other high arctic areas (Bunnell & Tait 1983; DeMaster & Stirling 1983; Øritsland & Schweinsburg 1983).

The population projections suggest that a high arctic polar bear population can grow at a maximum rate of about 5% a year, and that it can be harvested with a maximum of 3% a year if there is an equal proportion between males and females in the harvest, and if coys and yearlings are protected. But true maximum population growth is probably lower, because coy and yearling survival rates can be lower (Section 3.8) and because reproductive rates can be less (DeMaster & Stirling 1983; Øritsland & Schweinsburg 1983). True growth rate is perhaps only 4% a year, with a consequent lower maximum harvest level of 2%. Because of the heavy harvest of reproductive females in Svalbard prior to 1970, and because cubs take several years to reach maturity, there was probably a further decline in the Svalbard polar bear population after 1970-1973, even if all hunting had stopped. Since it is improbable that growths in high arctic polar bear populations can be as high as 5% annually, the population estimates prior to 1970 are either too low, or the estimates in 1980-1983 are too high, or both.

We may question why the rapid population decline which took place in Svalbard in the late 1960's, was not immediately discovered in the last year of hunting. The explanation is probably that wintering trappers and weather stations took their harvest from annual high concentrations or pools of bears as they occurred along the ice edge (Hopen and Hornsund) or along migratory routes (Halvmåneøya). Even if such concentrations or pools became smaller, they were still sufficiently large to sustain annual high takes. A decline due to overharvest would come suddenly, and would be pronounced only a few years prior to a rapid decrease in relative and absolute abundances.

Studies from many arctic regions confirm discreteness of polar bear populations. But the concept of discreteness must be related to time. Markings and recoveries over few years may show limited exchange of bears between populations. But polar bears are occasionally observed in the central Arctic Ocean, far away from their normal range (Lentfer 1972a). Other studies indicate uniformity in morphometry (Manning 1971; Wilson 1974) and in genetics (Allendorf et al. 1979; Larsen et al. 1983b), which indicate that little exchange takes place, or that exchanges between populations may take place over longer periods of time. A better understanding of the Dtekstqualitative and quantitative importance of these factors will have impact upon long term management and conservation policies and practices of polar bears in all arctic countries.

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Table 1: Composition of polar bear spring observations, southeastern Svalbard 1966 to 1970, and from 1983, and from Nordaustlandet 1976 to 1978.

Area	Southeastern Svalbard		Nordaustlandet		
Year	Sum 1966-70	1983	1976	1978	Sum 1976-78
No. adults/subadults	123	60	33	18	51
No. coy litters	11(16)	*15(34)	9(14)	0	9(14)
No. yearling litters	3(4)	3(4)	6(10)	1(1)	7(11)
No. litter 2 year olds	3(3)	1(2)	0	3(5)	3(5)
Aver. litter coys	1.38	2.27	1.56	—	1.56
Aver. litter yearlings	1.33	1.33	1.67	1.00	1.57
Aver. litter 2 yearolds	1.00	2.00	—	1.67	1.67

*: Plus 10 litters with unknown litter size.

No. cubs in parentheses.

Table 2: Composition of polar bear spring observations, Kong Karls Land, 1973 to 1982.

Year	1973	1977	1978	1979	1980	1982	Sum 1977—82
No. adults/subadults	42	47	28	47	63	13	198
No. coy litters	6(9)	*30(50)	12(29)	32(58)	**25(47)	***6(12)	105(191)
No. yearling litters	3(3)	2(2)	2(4)	0	1(1)	0	5(7)
No. litters 2 yearolds	0	0	1(2)	2(3)	0	0	3(5)
Aver. litter coys	1.50	1.67	2.00	1.81	1.88	2.00	1.82
Aver. litter yearlings	1.00	1.00	2.00	—	1.00	—	1.40
Aver. litter 2 year olds	—	—	2.00	1.50	—	—	1.67

*: Plus 4 litters with unknown size

**: Plus 3 litters with unknown size

***: Plus 2 litters with unknown size

No. cubs in parentheses.

Table 3: Composition of polar bear summer observations in the Barents Sea between 1967 and 1983.

Year	1967	1968	Sum 1967-68	1973	1977	1980	1981	1982	1983	Sum 1977-83
No. adults/subadults	67	49	116	63	37	171	51	84	75	418
No. coy litters	11(18)	7(9)	18(27)	6(6)	5(7)	11(18)	5(7)	3(5)	8(13)	32(50)
No. yearling litters	7(10)	1(1)	8(11)	3(5)	1(1)	14(14)	2(2)	9(15)	4(5)	30(37)
Aver. litter coys	1.64	1.29	1.50	1.00	1.40	1.55	1.40	1.67	1.62	1.56
Aver. litter yearlings	1.43	1.37	1.37	1.67	1.00	1.00	1.00	1.67	1.25	1.23

No. cubs in parentheses.

Table 4: Composition of polar bear summer observations, Nordaustlandet and Kong Karls Land, 1976 to 1983.

Area	Norsdaustlandet				Kong Karls Land				
Year	1976	1979	Miscell 1976-82	Sum 1976-82	1969-74	1979	1980	1983	Sum 1979-83
No. adults/subadults	65	40	26	131	61	8	114	86	208
No. coy litters	5(8)	7(13)	5(8)	17(29)	16(29)	0	12(19)	4(5)	16(24)
No. yearling litters	4(5)	1(2)	5(8)	10(15)	4(6)	1(1)	2(2)	5(6)	8(9)
Aver. litter coys	1.60	1.86	1.60	1.71	1.81	—	1.58	1.25	1.50
Aver. litter yearlings	1.25	2.00	1.60	1.50	1.50	1.00	1.00	1.20	1.13

No. cubs in parentheses.

Table 5: Composition of polar bear winter observations (including bears killed), southeastern Svalbard 1966 to 1970.

Area	Halvm.-øya	Ryke Yse øyane	Edgeøya and Halvm. øya	Tjuv-fjorden	Halvm.-øya	Sum all areas
Year	1966-67	1967-69	1968-69	1969-70	1969-70	1966-70
No. adults/subadults	143	118	87	68	91	507
No. coy litters	9(11)	8(9)	10(17)	0	1(1)	28(38)
No. yearling litters	13(20)	17(25)	8(12)	5(6)	8(10)	51(73)
No. litters 2 year olds	2(2)	2(2)	1(2)	4(5)	4(4)	13(15)
Aver. litter coys	1.20	1.11	1.64	—	1.00	1.36
Aver. litter yearlings	1.47	1.47	1.57	1.17	1.22	1.43
Aver. litter 2 year olds	1.00	1.00	2.00	1.25	1.00	1.15

No. cubs in parentheses.

Table 6: Composition of polar bear winter observations (including bears killed) on Hopen 1966 to 1969, and observations 1976-1982.

Year	1966-67	1967-68	1968-69	Sum 1966-69	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	Sum 1976-82
No. adults/subadults	81	45	128	254	41	33	57	61	66	77	335
No. coy litters	6(9)	5(6)	7(13)	18(28)	0	0	1(2)	0	1(1)	1(1)	3(4)
No. yearling litters	11(13)	5(5)	15(21)	31(39)	2(2)	0	2(2)	3(4)	7(12)	5(8)	19(28)
No. litters 2 year olds	0	0	6(8)	6(8)	2(3)	0	0	0	0	0	2(3)
Aver. litter coys	1.50	1.20	1.86	1.56	—	—	2.00	—	1.00	1.00	1.33
Aver. litter yearlings	1.18	1.00	1.40	1.25	1.00	—	1.00	1.33	1.62	1.60	1.45
Aver. litter 2 year olds	—	—	1.33	1.33	1.50	—	—	—	—	—	1.50

No. cubs in parentheses.

Table 7: Composition of polar bear winter observations from Gråhuken 1974-1975 and 1979-1980, from Hornsund 1981-1983, and from Bjørnøya 1976-1983.

Area	Gråhuken			Hornsund			Bjørnøya
Year	1974-75	1979-80	Sum 1974-80	1981-82	1982-83	Sum 1981-83	1976-83
No. adults/subadults	59	113	172	211	158	369	158
No. coy litters	0	3(3)	3(3)	3(3)	7(12)	10(15)	0
No. yearling litters	8(12)	3(3)	11(15)	12(15)	14(23)	26(38)	20(32)
No. litters 2 year olds	1(2)	2(3)	3(5)	14(17)	4(4)	18(21)	1(2)
Aver. litter coys	—	1.00	1.00	1.00	1.71	1.50	—
Aver. litter yearlings	1.44	1.00	1.36	1.25	1.64	1.46	1.57
Aver. litter 2 year olds	2.00	1.50	1.67	1.21	1.00	1.17	2.00

No. cubs in parentheses.

Table 8: Percentage polar bear cub litters of adult/subadult population from various areas in winter 1966 to 1983.

Area and year	SE Svalb. 1966-70	Hopen 1966-1969	Hopen 1976-1982	Gråhuken 1974-80	Hornsund 1981-83	Bjørnøya 1976-82
No. adults/subadults	507	254	335	172	369	127
% coy litters	5.9(n=30)	7.1(n=18)	0.9(n=3)	1.7(n=3)	2.7(n=10)	0
% yearling litters	10.9(n=56)	12.2(n=31)	5.7(n=19)	6.4(n=11)	7.0(n=26)	8.2(n=13)
% 2 year old litters	2.1(n=11)	2.4(n=6)	0.6(n=2)	1.7(n=3)	4.9(n=18)	1.3(n=2)

Table 9: Percentage polar bear cub litters of adult/subadult population from the Barents Sea in summers 1967 and 1968.

Year	1967	1968	Sum 1967-68
No. adults/subadults	67	49	116
% coy litters	16.4(n=11)	14.3(n=7)	15.5(n=18)
% yearling litters	10.4(n=7)	2.0(n=1)	6.9(n=8)

Table 10: Percentage polar bear cub litters of adult/subadult population from the Barents Sea in summers, 1973 to 1983.

Year	1973	1977	1980	1981	1982	1983	Sum 1977-1983
No. adults/subadults	63	37	171	51	84	75	418
% coy litters	9.5(n=6)	13.5(n=5)	6.4(n=11)	9.8(n=5)	3.6(n=3)	10.7(n=8)	7.7(n=32)
% yearling litters	4.8(n=3)	2.7(n=1)	8.2(n=14)	3.9(n=2)	10.7(n=9)	5.3(n=4)	7.2(n=30)

Table 11: Percentage polar bear cub litter of adult/subadult population from Nordaustlandet and Kong Karls Land in summers, 1976 to 1983.

Area	Nordaustlandet		K.K.L.	Nordaustl. and K.K.L.
Year	Miscell. sources 1976-82	1976	Sum 1979-1983	combined 1976-83
No. adults/subadults	131	65	208	404
% coy litters	13.0(n = 17)	7.7(n = 5)	7.7(n = 16)	9.4(n = 38)
% yearling litters	7.6(n = 10)	6.2(n = 4)	3.9(n = 8)	5.2(n = 21)

Table 12: Percentage polar bear cub litters of adult/subadult population from Kong Karls Land in spring, 1973-1982.

Area	Kong Karls Land						Average
Year	1973	1977	1978	1979	1980	1982	1977-82
No. adults/subadults	42	47	28	47	63	13	198
% coy litters	14.3(n = 6)	72.3(n = 34)	42.0(n = 12)	68.1(n = 32)	44.4(n = 28)	61.5(n = 8)	57.6(n = 114)
% yearling litters	7.1(n = 3)	4.3(n = 2)	7.1(n = 2)	—	1.6(n = 1)	—	2.5(n = 5)
% 2 year old litters	—	—	3.6(n = 1)	4.3(n = 2)	—	—	1.5(n = 3)

Table 13: Percentage polar bear cub litters of adult/subadult population from denning areas in southeast Svalbard and Nordaustlandet in spring, 1966-1983.

Area	Southeast Svalbard		Nordaustlandet
Year	1966-70	1983	1976-78
No. adults/subadults	123	60	51
% coy litters	8.9(n = 11)	41.7(n = 25)	17.6(n = 9)
% yearling litters	2.4(n = 3)	5.0(n = 3)	13.7(n = 7)
% 2 year old litters	2.4(n = 3)	1.7(n = 1)	5.9(n = 3)

Table 14: Observations of polar bears related to months, Hopen 1966-1982.

Month	Jan	Febr	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Sum
No. adults/subadults	45	87	83	72	35	19	4	1	8	65	88	82	589
No. single coy litters				1	1						4	4	10
No. twin coy litters				1						2	5	3	11
No. single yearling litters	4	7	8	3					2	2	6	1	33
No. twin yearling litters		3	3	1	1					2	4	3	17
No. single 2 yr. old litters	1	3	1										5
No. twin 2 yr. old litters		3											3

Table 15: Observations of polar bears related to months, Hopen 1966-1969.

Month	Jan	Febr	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Sum
No. adults/subadults	14	29	40	17	4	1			8	61	63	17	254
No. single coy litters											4	4	8
No. twin coy litters										2	5	3	10
No. single yearling litters	2	3	6	2					2	2	5	1	23
No. twin yearling litters		1	2	1						1	2	1	8
No. single 2 yr. old litters		3	1										4
No. twin 2 yr. old litters		2											2

Table 16: Observations of polar bears related to months, Hopen 1976-1982.

Month	Jan	Febr	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Sum
No. adults/subadults	31	58	43	55	31	18	4	1		4	25	65	335
No. single coy litters				1	1								2
No. twin coy litters				1									1
No. single yearling litters	2	4	2	1							1		10
No. single 2 yr. old litters	1												1
No. twin 2 yr. old litters		1											1

Table 17: Observations of polar bears related to months, Bjørnøya 1976-1983.

Month	Jan	Febr	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Sum
No. adults/subadults	48	87	15	1		2						5	158
No. single coy litters													
No. twin coy litters													
No. single yearling litters	2	4	1									1	8
No. twin yearling litters	4	5	2	1									12
No. single 2 yr. old litters													
No. twin 2 yr. old litters			1										1

Table 18: Observations of polar bears related to months, Hornsund, 1981-1983.

Month	Jan	Febr	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Sum
No. adults/subadults	44	85	72	72	29	15	5	1	1	7		38	369
No. single coy litters					1					1		3	5
No. twin coy litters				3	2								5
No. single yearling litters	3	4	2	2	1							2	14
No. twin yearling litters	2	4	1	2						1		2	12
No. single 2 yr. old litters	6	7	2										15
No. twin 2 yr. old litters	1	2											3

Table 19: Observations of polar bears related to months, Gråhuken, 1974-1980.

Month	Jan	Febr	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Sum
No. adults/subadults	9	38	22	19	41	25	10		1	1	1	5	172
No. single coy litters				1		2							3
No. twin coy litters													
No. single yearling litters	1	2	2	1	1								7
No. twin yearling litters				2	2								4
No. single 2 yr. old litters		1											1
No. twin 2 yr. old litters		2											2

Table 20: Observed and killed polar bears related to months, southeast Svalbard, 1966-1970.

Month	Jan	Febr	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Sum
No. adults/subadults	57	81	92	50	11	2			5	31	44	52	425
No. single coy litters			1	5						1	3	7	17
No. twin coy litters				3									3
No. single yearling litters	7	8	8	1						1	3	2	30
No. twin yearling litters		4	7	2						1		4	18
No. single 2 yr. old litters	4	3	2										9
No. twin 2 yr. old litters	1												1

Table 21: Polar bears marked in Svalbard between 1966 and 1982.

Year	No. bears	No. males	No. females	Area and time
1966	4	2	2	Barents Sea 4—5 August
1967	51	30	21	Barents Sea 4 July—21 August
1968	32	14	18	Barents Sea 10—29 August
1968/1969	16	9	7	Edgeøya 15 September -68 — 19 July -69
1974	9	4	5	Kongsøya 2 July—16 August
1976	1		1	Nordaustlandet 2 April
1977	28	12	16	Barents Sea 26 July—25 August
1979	7	4	3	Greenland Sea 26 April—5 May
1980	44	21	23	Barents Sea 7 July—13 September
1982	2		2	Kongsøya 3—12 April
1982	4	1	3	Barents Sea 21—27 August
Sum	198	97	101	

Table 22: Recoveries and observations of polar bears marked in Svalbard between 1966 and 1982.

Tag No.	Sex	Est. age	Location and date Marked	Recovered	Remarks
129	M	—	79°22'N 28°15'E 8-4-66	Berzeliusdalen, Spitsbergen, 4-29-70	Winter sport hunter
303	M	9.7	76°57'N 28°39'E 7-11-67	Bjørnøya, 2-70	Winter sport hunter
304	M	5.7	76°50'N 29°E 7-12-67	Hopen 1-11-70	Weather station crew
311	M	5.7	76°45'N 27°40'E 7-16-67	Eastern Svalbard pack ice, 8-67	Trophy hunter
312	M	5.7	76°36'N 25°55'E 7-17-67	Nanortalik, SW. Greenland, winter 68-69	Local hunter
313	F	4.7	76°40'N 28°55'E 7-18-67	Hopen, 11-14-68	Weather station crew
315	M	15+	77°35'N 28°E 7-25-67	77°30'N 29°E 8-3-67	Trophy hunter
321	M	15+	77°15'N 28°30'E 7-29-67	Kvalpynten, Edgeøya, winter 69-70	Wintering trapper
337	F	1.8	77°50'N 26°30'E 8-17-67	77°40'N 28°E 8-25-68	Released after control
339	M	0.8	77°50'N 26°30'E 8-17-67	77°30'N 29°35'E 6-19-69	Trophy hunter
347	F	1.8	77°50'N 28°30'E 8-28-67	Hopen 10-7-68	Weather station crew
348*	F	9.8	77°55'N 29°30'E 8-21-67	Hopen 10-17-68	Weather station crew
350*	M	0.8	77°55'N 29°30'E 8-21-67	Hopen 10-17-68	Weather station crew
351	M	4.8	77°25'N 29°E 8-21-67	Longyearbyen, Spitsbergen 2-11-68	Sport hunter
355*	F	6.11	Tjuvfj. Edgeøya 11-1-69	Tjuvfj. Edgeøya 1-12-70	Wintering trapper
356*	M	0.11	Tjuvfj. Edgeøya 11-1-69	Tjuvfj. Edgeøya 1-12-70	Wintering trapper
357*	F	0.11	Tjuvfj. Edgeøya 11-1-69	Tjuvfj. Edgeøya 1-12-70	Wintering trapper
362	M	7.8	NE Hopen 8-11-68	Hornsund, Spitsbergen 3-20-70	Wintering trapper

Tag No.	Sex	Est. age	Location and date Marked	Recovered	Remarks
363	F	10+	NE Hopen 8-11-68	Hopen 2-12-70	Weather station crew
366	M	5.8	NE Hopen 8-14-68	Kvalpynten, Edgeøya winter 69-70	Wintering trapper
369	M	5.8	E Edgeøya 8-19-68	Hopen 3-20-70	Weather station crew
371	F	7.8	77°30'N 25°E 8-20-68	Kong Karls Land 7-69	Observed from helicopter
374	F	9.8	76°50'N 27°30'E 8-21-68	Halvmåneøya 11-25-68	Wintering trapper
376	F	0.8	76°50'N 27°30'E 8-21-68	Hornsund, Spitsbergen 2-22-70	Wintering trapper
378	F	3.8	76°50'N 27°30'E 8-21-68	Hornsund, Spitsbergen 10-25-68	Wintering trapper
383	F	3.8	76°55'N 27°30'E 8-25-68	Hopen 3-16-69	Wintering trapper
385	F	4.8	76°55'N 27°30'E 8-25-68	79°29'N 35°25'E 8-31-69	Trophy hunter
390	F	7.8	77°20'N 26°30'E 8-29-68	Hopen 10-5-68	Wintering trapper
251	M	2.9	Kapp Lee, Edgeøya 9-15-68	Isfjord Radio, Spitsbergen 10-16-68	Sport hunter
252	M	4.10	Kapp Lee, Edgeøya 10-5-68	Kvalpynten, Edgeøya winter 69-70	Wintering trapper
253	M	8.3	Kapp Lee, Edgeøya 3-30-69	Kvalpynten, Edgeøya winter 69-70	Wintering trapper
254	M	5.4	Kapp Lee, Edgeøya 4-30-69	Kapp Lee, Edgeøya winter 69-70	Wintering trapper
257	F	1.4	Kapp Lee, Edgeøya 4-30-69	Colesbay, Spitsbergen 3-22-70	Sport hunter
260	M	4.5	Kapp Lee, Edgeøya 5-26-69	Hornsund, Spitsbergen 12-4-69	Wintering trapper
469/470	M	9.5	83°19'N 7°44'W 5-05-79	Sermilikfjord, SW Greenland med. March-83	Local hunter
476/477	M	5.7	80°00'N 28°12'E 7-09-80	Kongsøya, Kong Karls Land 8-27-80	Observed
486/487	M	7.7	82°39'N 43°57'E 7-23-80	Kulusuk, SE Greenland 4-02-82	Local hunter

Tag No.	Sex	Est. age	Location and date Marked	Recovered	Remarks
492/493	F	5.7	80°09'N 30°12'E 7-29-80	79°57'N 29°55'E 8-02-80	Observed at Greenland right whale carcass
492/493	F	5.7	80°09'N 30°12'E 7-29-80	Kongsøya, Kong Karls Land 8-04-+9-12-80	Observed
498/499	F	4.7	80°22'N 26°00'E 7-31-80	Storøya, early August-80	Observed
7520	M	10.8	Kongsøya, Kong Karls Land 8-01-80	Kongsøya, Kong Karls Land 8-12+9-21-80	Observed
7522	F	7.8	Kongsøya, Kong Karls Land 8-01-80	Kongsøya, Kong Karls Land 9-21-80	Observed
205/206	F	3.8	Kongsøya, Kong Karls Land 8-08-80	Kongsøya, Kong Karls Land 7-09-80	Observed
?	F		?	North Nordenskiøldøya, Hinlopen 18-8-80	Observed with one coy

*: Family groups

Table 23: Polar bear observations from aircraft, Svalbard, 1966 and 1967.

Date	Hours	Minutes	Sq. km. surveyed	No. bears observed	Bears per 100sq. km
3-22-66	4	0	440	0	—
4-21-66	5	40	623	7	1.12
5-13-66	4	20	477	6	1.26
6-15-66	3	25	376	5	1.33
7-7-66	2	0	220	0	—
8-2-66	1	0	110	0	—
10-7-66	2	30	275	6	2.18
Total 1966	22	55	2521	24	0.95
4-14-67	2	20	514	7	1.36
5-13-67	4	45	522	7	1.34
6-5-67	4	30	990	10	1.01
7-2-67	4	20	477	4	0.84
7-22-67	2	30	275	1	0.36
8-10-67	2	20	275	0	—
9-20-67	2	0	220	0	—
10-14-67	2	50	312	11	3.53
Total 1967	25	35	3567	40	1.12

Table 24: Average polar bear densities per 100 square km pack ice in different areas and years, and corresponding population estimates.

Year	1966		1967		1968		1977		YMER-80 Leg 1		YMER-80 Leg 2	
	Air	Ship	Air	Ship	Air	Ship	Air	Ship	Air	Ship	Air	Ship
Average density, High. dens. areas (Sq. km in parentheses)	0.95 ?	—	1.12 (70 000)	0.81	— (70 000)	0.75	— (60 000)	0.75	— (60 000)	2.14	4.6 (30 000)	—
Average density, Low dens. areas (Sq. km in parentheses)	— ?	—	— (90 000)	—	— (90 000)	—	— (90 000)	—	— (90 000)	0.45	— (80 000)	0.65
Estimated population High dens. areas	—		*567		*525		*450		1284		1380	
Estimated population Low dens. areas	—		*243		*225		*225		405		520	
Sum	—		*810		*750		*675		1689		1900	

*: Corrected from previous published figures on the basis of calculated transect widths and relative densities observed in 1980.

Table 25: Polar bear age determined from tooth samples from Svalbard between 1954 and 1980.

Age	Area and year								
	SE Svalb. 54-55	Bar.Sea 67-68	SE Svalb. 68-69	Hopen 68-69	Hopen 69-70	Ryke Yse 67-68-69	SE Svalb. 69-70	Bar.Sea 77-79	Bar.Sea 80
1	10	14	—	9	8	7	14	—	—
2	10	9	2	5	13	13	12	1	1
3	9	5	8	4	13	8	18	5	3
4	10	6	7	3	6	6	21	4	3
5	11	9	5	3	5	6	14	3	3
6	10	3	2	3	7	6	9	2	5
7	4	3	—	3	—	4	8	3	5
8	6	6	1	4	3	4	7	1	6
9	5	4	1	1	2	4	6	2	4
10	4	2	—	3	—	3	8	1	3
11	2	2	—	1	1	2	7	1	2
12	2	1	2	1	1	3	4	1	3
13	—	2	1	1	1	4	3	1	2
14	1	2	—	2	1	2	3	2	—
15	—	1	—	3	1	1	3	—	—
16	—	2	—	1	—	1	2	1	—
17	1	2	—	—	—	2	1	—	—
18	1	—	—	—	—	—	—	1	—
19	—	—	—	—	—	—	1	—	—
20	—	—	—	—	—	—	1	—	—
21	—	—	—	—	—	—	—	—	—
22	—	—	—	—	—	—	—	1	—
Sum	86	73	29	47	62	76	142	30	40

Table 26: Average litter size of polar bear cubs in Svalbard between age 4 and 24 months before and after 1970.

	Before 1970	After 1970	Average all years
Coys in spring (age 4 Months)	1.45(n = 11)	1.84(n = 135)	1.78(n = 146)
Coys in summer (age 8 months)	1.65(n = 34)	1.54(n = 71)	1.57(n = 105)
Coys/yearlings in winter (age 12 months)	1.39(n = 128)	1.45(n = 82)	1.42(n = 210)
Yearlings in summer (age 20 months)	1.42(n = 12)	1.29(n = 51)	1.32(n = 63)
Yearlings/2 year olds in winter (age 24 months)	1.21(n = 19)	1.29(n = 24)	1.26(n = 43)
N	294	363	567

Table 27: Pooled percentages of polar bear cub litter of adult/subadult population at various ages. N = 3223.

Years	1966-1970			1976-1983			All observations between 1966 and 1983		
	Win. N	Sum. N	%	Win. N	Sum. N	%	Win. N	Sum. N	%
Adults/subadults	766	116	—	704	418	—	1769	1072	—
Coy litters in summer (8 months)	—	18	15.5	—	33	7.7	—	111	10.4
Coy litters in winter (12 months)	87	—	11.4	45	—	6.4	164	—	9.3
Yearling litters in summer (20 months)	—	8	6.9	—	30	7.2	—	66	6.2
Yearlings/2 year old litters in winter (24 months)	17	—	2.2	20	—	2.8	41	—	2.3

Table 28: Polar bear harvests in relation to effort, Hopen 1952/53 to 1969/70.

Year	No. bears killed	No. set guns	No. days with pack ice at Hopen, Oct. 1 — May 15	Harvest efficiency
1952/53	37	15	150	0.016
1965/66	82	41	185	0.011
1966/67	75	31	190	0.013
1967/68	42	39	175	0.006
1968/69	98	49	227	0.009
1969/70	90	51	180	0.009

Table 29: Catches of polar bears in Svalbard, the Barents Sea, East Greenland and adjacent waters between 1945 and 1970.

Year	Barents Sea Svarbard waters	Wintering trappers	Weather station	East Greenl. + adjacent waters	Others	Sum
1945	195	0	0	0	0	195
1946	366	5	27	1	6	405
1947	190	280	25	16	12	523
1948	167	194	45	30	8	444
1949	203	14	50	22	14	303
1950	443	0	21	63	9	536
1951	265	55	32	12	10	374
1952	96	2	32	7	15	152
1953	284	0	42	13	8	347
1954	172	0	22	11	4	209
1955	356	72	22	10	10	470
1956	255	7	44	25	10	341
1957	277	1	18	5	7	308
1958	92	1	29	35	3	160
1959	152	123	45	7	7	334
1960	26	57	70	7	13	173
1961	56	9	52	5	4	126
1962	45	11	85	22	14	177
1963	149	62	84	10	5	310
1964	195	152	79	5	5	436
1965	29	273	120	7	6	435
1966	52	23	87	0	11	173
1967	51	102	79	2	29	263
1968	47	120	67	2	31	267
1969	41	123	133	0	49	346
1970	87	272	105	0	51	515
1971*	64	21	19	0	12	116
1972*	18	3	13	0	27	61
1973*	3	11	8	0	19	41

*: Quota regulations.