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by Ian Stirling,
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by Ian Stirling[1], Charles Jonkel[2], Pauline Smith[3], Richard Robertson[4], and Dale Cross[4]

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Contents

5 Acknowledgements
6 Abstract
7 Résumé
9 Introduction
9 1. Historical background
13 2. The development of bear–man problems around Churchill
19 Objectives
19 1. Basic research requirements
19 Study area
19 1. Geology
19 2. Topography
20 3. Vegetation
20 4. Climate
21 5. Ice
23 6. Currents
23 7. Other biological life in Hudson Bay
25 Materials and methods
25 1. Tagging programs
26 2. Data collected from polar bears killed accidentally, in control operations (problem bears), and by Inuit and Indians
27 3. Use of aerial and ground surveys
27 3.1. Summer and fall surveys
27 3.2. Winter surveys
27 3.3. Denning–productivity surveys
31 4. Radio tracking
32 5. Age determination
32 6. Other sources of information
32 Results and discussion
32 1. Discreteness of sub-populations
39 2. Seasonal distribution and movements
42 3. Fidelity to the Churchill area
44 4. Maternity denning and productivity
50 5. Age structure and average ages
54 6. Growth rates
57 7. Status of the sub-population
58 Summary and recommendations
59 References

List of tables

13 Table 1. Population of Churchill District
18 Table 2. Recorded information on polar bears in the Churchill area, Manitoba, in falls of 1966–75
20 Table 3. Climate data for Churchill Airport, Manitoba
26 Table 4. Polar bear tagging programs in Manitoba, 1966–75
28 Table 5. Number of polar bears counted in western Hudson Bay (Zone A^1) during ice-free period of year, 1963–75
30 Table 6. Dates of spring polar bear maternity denning surveys in Manitoba, 1970–76
38 Table 7. Number of polar bears tagged in Manitoba and recaptured or resighted (after 6 months), killed, or sent to zoos, 1966–75
38 Table 8. Known numbers of polar bears killed by settlement, zone and year in western Hudson Bay (Zone A^1, Zone A^2, and part of Zone C), 1967–76
38 Table 9. Polar bears tagged in Manitoba and killed outside the province
39 Table 10. Number of bears tagged in three areas of Manitoba and resighted (including recaptures, observations, and kills 6 months or more later)
42 Table 11. Summary of the numbers of different years in which polar bears were re-sighted, recaptured, or killed after tagging

44 Table 12. Number of tagged polar bears released at Kaska by year and number of bears resighted later in the Churchill area

45 Table 13. Number of sightings, tracks, and estimated totals of females and cubs in Manitoba.

45 Table 14. Number and distance inland of possible polar bear maternity den sites in Manitoba, 1970–76

46 Table 15. Number of family groups and litter sizes sighted in Manitoba by year, 1970–76

50 Table 16. The average age by sex of polar bears captured, recaptured, or killed (including found dead) in the western Hudson Bay area (Zone A[1]), 1966–75

51 Table 17. The average age by sex of adult (> 5 years old) polar bears captured, recaptured, or killed in the western Hudson Bay area (Zone A[1]), 1966–75

55 Table 18. Weights (cattle weight tape) in kilograms of polar bears by age and sex, taken in October and November in Manitoba, 1966–75

56 Table 19. Straight-line body lengths in centimetres of polar bears by age and sex, taken in October and November in Manitoba, 1966–75

List of figures

10 Figure 1. Location map of western coast of Hudson Bay

11 Figure 2. Location map of the Churchill–Cape Churchill area

22 Figure 3. Pattern of Hudson Bay ice cover during freeze-up, at maximum development, during early and late break-up (after Canada, Atmospheric Environment 1966–74; Larnder 1968 and Danielson 1971)

26 Figure 4. Relationship between polar bear weights obtained by taking heart girth with a cattle weight tape and weights obtained with spring scales, 1966–68

33 Figure 5. Polar bear tagging locations on the Manitoba coast, Oct. 1966 to Nov. 1975

34 Figure 6. Recorded movements of tagged polar bears recaptured, observed, or killed in Manitoba after more than 6 months, 1966–75

35 Figure 7. Recorded movements of tagged polar bears in western Hudson Bay, recaptured, observed, or killed, within 6 months, 1966–75

36 Figure 8. Recorded movements of radio-tagged bears from tagging location to last radio-location position, 1968–70

37 Figure 9. Recorded movements of tagged bears killed by Inuit outside Manitoba

41 Figure 10. Polar bear track density on the annual ice of Hudson Bay, 26–27 March 1972

43 Figure 11. Recorded movements of tagged polar bears released at Kaska, Manitoba, 1971–75

47 Figure 12. Locations of possible polar bear maternity dens in the Owl River maternity denning area, Manitoba, 1970–76

48 Figure 13. Locations of possible polar bear maternity dens in the Cape Tatnam area, Manitoba, 1971–76

52 Figure 14. Age structure of polar bears captured in western Hudson Bay area (Zone A[1]), 1966–75

53 Figure 15. Age structure of polar bears killed in western Hudson Bay area (Zone A[1]), 1966–75

54 Figure 16. Relationship between polar bear weights obtained by taking heart girth with a cattle weight tape and weights obtained with spring scales, 1966–75

56 Figure 17. Growth rates of four male and seven female polar bears, with three or more years of data, in Manitoba

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Abstract

This report on the ecology of the polar bear (*Ursus maritimus*) along the western coast of Hudson Bay summarizes 10 years of data (fall 1966 to spring 1976) collected mainly by the Canadian Wildlife Service and the Manitoba Department of Renewable Resources and Transportation Services.

A summary of the historical records of polar bears in the Manitoba area, the development of polar bear management in Manitoba, and a documentation of the bear–man problems in the Churchill area are presented. At present, in Manitoba, only Indians can legally hunt polar bears but few are taken. To the north, hunting by NWT Inuit is allowed but is restricted by quotas.

Two hundred and twenty-seven polar bears were ear-tagged in Manitoba, 176 of which were in the Churchill area. Twenty-three bears were also tagged with radio-collars. The recorded movements of the tagged animals suggested the existence of a single sub-population in the western Hudson Bay area, extending from the Ontario–Manitoba border north to between Rankin Inlet and Chesterfield Inlet (Zone A[1]).

The seasonal distribution and movement of polar bears is greatly influenced by the seasonal variation in the ice conditions of Hudson Bay. From radio-tracking data, a limited aerial survey, and tag returns from Inuit-killed polar bears, it appears that the bears move on to the newly formed ice in early November and spend the winter on the ice to the north and east of the Cape Churchill area. The bears return to the southern Manitoba coast in late July–August, when the final ice remnants dissipate in that area. A gradual northward movement to the Churchill – Cape Churchill area has been documented, and is possibly related to the freeze-up which begins to the north of Cape Churchill.

From aerial surveys, some spatial segregation, of family groups into inland areas and groups of large adult males along coastal areas, has been recorded. Land areas are vacated as soon as the ice begins to form.

The influx of bears into the Churchill area each fall was dangerous for the human population. Bears showed a high degree of fidelity to the area over a span of several years and one bear first tagged as a cub with her mother was twice recorded in subsequent years with separate litters of her own cubs. Bears that were judged to be dangerous were either chased away from the settlements, captured and immobilized in culvert traps and then driven east to Bird Cove or Twin Lakes or airlifted to Kaska, 300 km southeast of Churchill, and released. Thirteen of 40 bears that were moved to Kaska returned, some in 14 to 24 days and others in later years. Persistent problem bears were sent to zoos or shot.

From aerial surveys (1970–76), it was estimated that 80 females and 150 newborn cubs leave maternity dens in Manitoba each spring. Denning is concentrated in the Owl River denning area, which is 30–60 km inland in the Fletcher – Sutton lakes – Rupert Creek area, south of the Churchill area. There is another denning area in the vicinity of Cape Tatnam, but the density of dens appears to be much lower. In both areas, mean litter size was high (2.0). The use of earth dens as maternity dens was recorded.

The average ages of male and female polar bears captured, recaptured (after 6 months), or killed, from which teeth were aged, were mainly within the sub-adult range (2 to 4 years inclusive). There were significant differences between the average ages of bears captured or killed in Zone A[1] compared to the James Bay – Belcher Islands area to the south, but the result was biased by the unrepresentative sample of adult

age classes in the total captured sample of the former area. However, the average age of adults alone was still significantly higher in the James Bay – Belcher Islands area compared to Zone A[1] which suggests the difference is real.

The accuracy of the cattle weight tape in estimating the actual weights of polar bears in Manitoba from heart girth measurements was within 92% of the scale weight. Age-specific mean weights and straight-line body measurements of male and female bears in the fall in Manitoba are presented.

A crude estimate of the population size for the Churchill area in 1975, based on a Lincoln Index, was 308 bears. With the data available, it was not possible to estimate the population size for Zone A[1].

The polar bear problem in the Churchill area should be reduced once the garbage problem is resolved. Additional management options for polar bears in Manitoba include the establishment of an annual harvest and the utilization of polar bears as a tourist attraction.

Résumé

Le présent rapport sur l'écologie de l'ours blanc (*Ursus maritimus*) le long de la côte ouest de la baie d'Hudson présente les grandes lignes des données recueillies en 10 ans, soit de l'automne 1966 au printemps 1976. Ces recherches ont été effectuées surtout par le Service canadien de la faune et le ministère manitobain des Ressources renouvelables et des Services de transport.

On y donne un bref historique de la présence de l'ours blanc au Manitoba et de l'évolution de la gestion de cette espèce dans la province ainsi que de la documentation sur les problèmes posés par les rapports de l'ours et de l'homme dans la région de Churchill. A l'heure actuelle au Manitoba, seuls les Indiens ont le droit de chasser l'ours blanc, encore qu'ils n'en prennent guère. Au nord, la chasse en est permise aux Inuit des TNO, mais c'est moyennant contingentement de leurs prises.

Au Manitoba, on a marqué d'étiquettes à l'oreille 227 ours blancs dont 176 dans la région de Churchill. On a aussi assujetti des colliers émetteurs à 23 ours. Il ressort des données ainsi obtenues sur les déplacements des animaux marqués qu'il ne se trouve qu'un seul sous-ensemble démographique de cette espèce dans la région de l'ouest de la baie d'Hudson dite zone A[1], soit dans l'aire délimitée, au sud par la ligne de démarcation de l'Ontario et du Manitoba, au nord par l'intervalle compris entre les baies de Rankin et de Chesterfield.

Les variations saisonnières de l'état des glaces de la baie d'Hudson ont beaucoup d'influence sur la distribution et les déplacements de l'ours blanc. Vu les données recueillies par la radiogoniométrie, un relevé aérien de faible envergure et les retours d'étiquettes par des Inuit qui avaient abattu des ours marqués, il semble que les ours s'en vont sur les glaces nouvelles au début de novembre et passent l'hiver sur la glace, au nord et à l'est de la région du cap Churchill. Ils retournent sur la côte du Manitoba à la fin de juillet et en août, alors que fondent les dernières glaces dans cette région. On a documenté la conclusion comme quoi se produit un déplacement vers le nord, en direction de la région de Churchill et du cap Churchill; il se peut que joue là un rapport avec le fait que c'est au nord du cap Churchill que commence la zone de la glace continue. Des relevés aériens ont permis de constater une certaine ségrégation spatiale des familles à l'intérieur des terres tandis que les groupes de gros mâles adultes restaient dans les régions côtières. Les ours quittent leur habitat terrestre dès que la glace commence à se former.

L'arrivée des ours chaque automne présentait un danger pour la population humaine de la

région de Churchill. Les ours se sont montrés très fidèles à ce secteur au fil de plusieurs années; une ourse, qui avait été marquée pour la première fois alors qu'elle n'était qu'un ourson en compagnie de sa mère, y a été repérée deux fois les années suivantes, accompagnée chaque fois d'une portée différente de ses propres oursons. Les ours jugés dangereux étaient, soit refoulés loin des agglomérations humaines, soit capturés et immobilisés dans des fosses avant de se faire transporter, en camion vers l'est, dans la région de Bird Cove et des lacs Twin, ou bien en avion à Kaska, à 240 km au sud-est de Churchill, où on les lâchait dans la nature. Des 40 ours transportés à Kaska, 13 revinrent dont certains après que de 14 à 24 jours seulement se fussent écoulés et les autres après quelques années. Quant aux ours qui s'entêtaient à se montrer par trop encombrants, on les abattait ou les expédiait à quelque zoo.

À l'aide des relevés aériens effectués de 1970 à 1976, on a estimé qu'à chaque printemps 80 femelles et 150 oursons nouveau-nés quittaient les repaires de mise bas du Manitoba. La mise bas se fait surtout dans le secteur de la rivière Owl, qui est situé à une distance variant de 30 à 60 km à l'intérieur des terres au sud de Churchill, dans la région des lacs Fletcher et Sutton ainsi que du ruisseau Rupert. Il y a une autre aire de mise bas à proximité du cap Tatnam, mais la densité des repaires de mise bas y semble bien moindre. Dans ces deux secteurs, le nombre moyen de petits par portée était élevé, soit 2.00. On a même constaté que des ourses avaient mis bas dans des terriers.

L'âge moyen des ours blancs mâles et femelles capturés, capturés de nouveau six mois plus tard ou abattus, a été calculé d'après l'état de leurs dents; la plupart étaient d'âge pré-adulte, soit de 2 à 4 ans inclusivement. On a constaté un différence significative entre l'âge moyen des ours capturés ou abattus dans la zone A^1 et celui de leurs congénères assujettis à semblable destin plus au sud, dans la région de la baie James et des îles Belcher, mais dans le premier cas, les résultats ont été faussés parce que le sous-échantillon des classes d'âge adulte compris dans l'échantillon total n'était pas lui-même représentatif. Néanmoins, l'âge moyen des ours adultes était à lui seul significativement plus élevé dans la région de la baie James et des îles Belcher que dans la zone A^1, ce qui donne à penser qu'il s'agit d'une différence bien réelle.

L'emploi du ruban à peser utilisé pour déterminer approximativement le poids réel des ours blancs au Manitoba par la mesure du tour de poitrine aboutit à des résultats de l'ordre de 92% du poids-étalon. On présente ici le poids moyen par classe d'âge et la longueur du corps des ours mâles et femelles au Manitoba l'automne.

En se fondant sur un indice de Lincoln, on a évalué approximativement à 308 ours l'effectif de la population dans la région de Churchill en 1975. On n'a pu, vu les données dont on disposait, évaluer la population de la zone A^1.

Les problèmes causés par l'ours blanc dans la région de Churchill s'atténueront lorsqu'on aura résolu le problème des déchets. Parmi les autres possibilités de gestion de l'ours blanc au Manitoba, mentionnons la création d'une saison de chasse annuelle et leur emploi pour attirer le touriste.

Introduction

1. Historical background

Polar bears have been recorded in the Churchill area (Figs. 1 and 2) ever since the first white man set foot there. In the early 1600s when the quest for the Northwest Passage was at a peak, a number of explorers found their way to the western coast of Hudson Bay. In 1619–20, Jens Munk, a Danish explorer, overwintered at the mouth of the Churchill River. He reported the killing of a polar bear in September close to the present-day port facilities at Churchill (Gosch 1897).

In the mid-1600s attention was drawn to the fur-trading potential of the Hudson Bay area. In 1668 the first fur trading expedition, by the company that was later to be known as the Hudson's Bay Company, set out from England for Hudson Bay. Although summer trading was carried out at the mouth of the Nelson River in 1669 and 1672, no permanent trading post was established in what is now Manitoba until 1682. The first permanent post, known later as York Factory, was built at the mouth of the Hayes River. A permanent Hudson's Bay Company post at the mouth of the Churchill River, Prince of Wales Fort, was not built until 1717 and was mainly orientated towards the white whale (*Delphinapterus leucas*) industry.

James Isham, an employee of the Hudson's Bay Company during the 1730s and 1740s, was the first person to record that polar bear maternity denning occurred in Manitoba (Rich 1949). In the late 1760s and early 1770s, Samuel Hearne (Tyrrell 1911), fur trader and explorer, reported that polar bears were common along the sea coast but were not seen in winter except around the Churchill River area. He commented that few winter skins were brought into the trading post. David Thompson (Tyrrell 1916), a fur trader and explorer, described the activities of numerous bears in 1784 and 1785, recounting various incidents from the Churchill and York Factory areas, as well as along the coast. During his journey on foot along the shoreline between Churchill and York Factory in late August and early September 1785, Thompson reported numerous bears lying on the marshy areas, a short distance inland. Thompson also noted that polar bears appeared in the Churchill area in early October and remained there until the ice formation on Hudson Bay was sufficient to allow them to hunt seals. He briefly described the hunting of seals by polar bears. While on land, the bears prowled around and were generally mischievous. He related two incidents, both from the York Factory area, where bears were attracted to camps when food was being cooked.

The Hudson's Bay Company records indicate that 12 hides per year were traded at York Factory between 1854 and 1900 and 3 hides per year at Churchill between 1854 and 1886. These figures at best provide only a minimum estimate of the polar bear harvest in the western Hudson Bay area. No records exist of the numbers of bears killed and abandoned, used for dog food, bait, personal use, or of hides sold through other outlets.

In the late 1800s and early 1900s, the presence of polar bears on land, particularly in the summer and fall, and of maternity denning were documented by Preble (1902) and Tyrrell (1911). However, polar bears did not draw much attention until the military base was established at Fort Churchill, about 10 km east of the Churchill River, in 1942. Churchill, on the east bank of the Churchill River had been little more than a trading post up until that time (Carroll 1968) even though it had been the terminus of the Hudson Bay Railway from Winnipeg since 1929 (Kenney 1932). During the 1950s, when military activity was at its peak, polar bears drew considerable attention as will be described later.

Figure 1

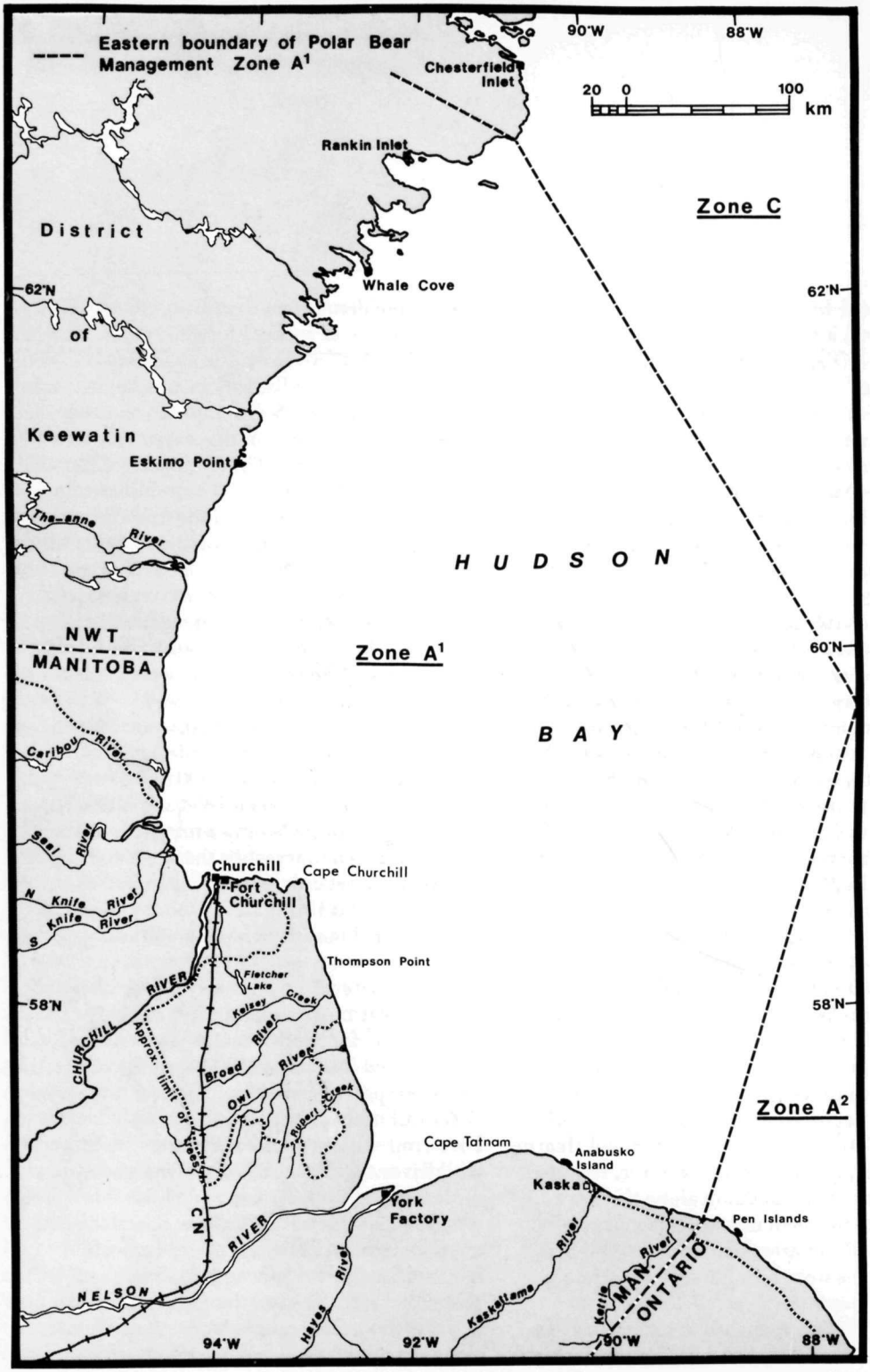
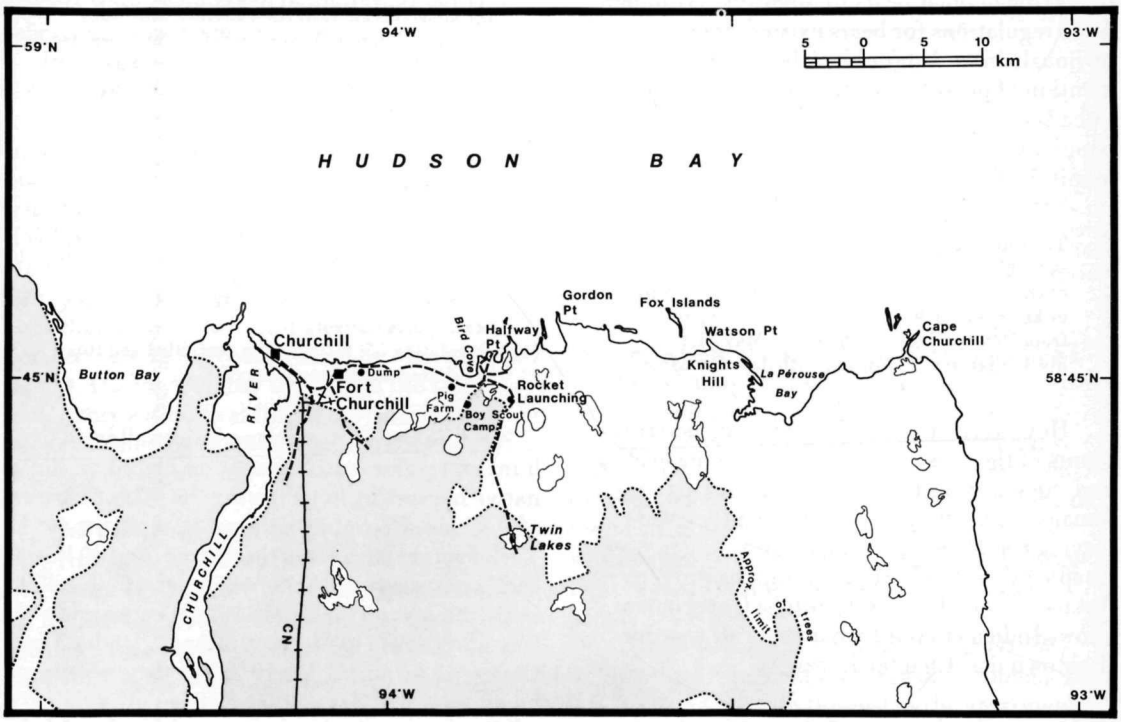

Eastern boundary of Polar Bear Management Zone A¹
90°W
88°W
Chesterfield Inlet
20 0 100 km
Rankin Inlet
Zone C
District
62°N
Whale Cove
62°N
of
Keewatin
Eskimo Point
The-anne River
HUDSON
NWT
MANITOBA
Zone A¹
60°N
BAY
Caribou River
Seal River
Churchill
Cape Churchill
Fort Churchill
N Knife River
S Knife River
Thompson Point
Fletcher Lake
Kelsey Creek
58°N
CHURCHILL RIVER
Approx. limit of tides
Broad River
Owl River
Robert Creek
58°N
Zone A²
Cape Tatnam
Anabusko Island
Kaskadi
York Factory
Pen Islands
CN
RIVER
NELSON
Hayes River
Kaskatamagan River
Kettle
MAN.
ONTARIO
94°W
92°W
90°W
88°W

Figure 1
Location map of western coast of Hudson Bay

Figure 2
Location map of the Churchill – Cape Churchill area

Figure 2



Until 1949 there was no legislation covering the taking of polar bears in Manitoba. Although game regulations for bears existed, they were obviously intended for black bears, and no mention of polar bears was made. In 1949 Manitoba became aware of its vulnerable polar bear population and sought to protect it by passing Manitoba Regulation 55/49 which stated:

> The hunting or killing of Polar or White Bears is prohibited, provided that bona fide residents of the coastal regions of the Province may hunt or kill Polar or White Bears during the period from October 1st in each year to May 31st in the year next following, both days inclusive.

However, what constituted 'bona fide residents of the coastal regions' was not made clear and the season as such allowed the taking of females with young in spring when they were leaving the denning area. However, under Chapter 13 of the Natural Resources Agreement Act passed in 1930, the Manitoba Government allows Indians to hunt polar bears all year for their own use. Chapter 13 reads:

> In order to secure to the Indians of the Province the continuance of the supply of game and fish for their support and subsistence, Canada agrees that the laws respecting game in force in the Province from time to time shall apply to the Indians within the boundaries thereof, provided, however, that the said Indians shall have the right, which the Province hereby assures to them, of hunting, trapping and fishing game and fish for food at all seasons of the year on all unoccupied Crown lands and on any other lands to which the said Indians may have a right of access.

In 1954, the question of who could legally hunt polar bears was clarified with the passing of Manitoba Regulation 21/54:

> (1) The hunting and killing of Polar or White Bears is prohibited, provided that native residents of the coastal regions of the Province may hunt and take Polar or White Bears for their own use during the period from October 1st in each year to May 31st in the year next following, both days inclusive.
> (2) Polar or White Bears or any part of them taken by natives of the coastal regions during the period specified in Section 1 shall not be sold, bartered or otherwise disposed of.
> (3) No person except a native of the coastal regions without lawful excuse, the proof of which shall be upon him, may have in his possession or control at any time Polar or White Bear or any of the parts thereof.
> (4) Regulation 55/49 is hereby rescinded and this regulation substituted therefor.

White residents were no longer allowed to hunt and major restrictions were placed on the native harvest by not allowing the sale or barter of the hide. Up until that time, the Indians at York Factory were thought to take 50–100 bears each year, many of them females and cubs killed in their maternity dens, or as they emerged to travel to the sea in March and April. Under The Game and Fisheries Act 1930, the dens of fur-bearing animals (except for wolves) are protected. However, polar bears are considered as fur-bearing, not big-game animals. This was not clarified until 1963 when Manitoba Bill No. 81, 'An Act respecting the administration and conservation of wildlife in the Province', was passed: no season was listed for polar bears. However, the rights of Indians to hunt polar bears for their own use were still preserved under Chapter 13 of the Natural Resources Agreement Act 1930. Although not specifically stated, in practice the rights of Inuit would also be covered by this legislation. With the passing of the 1963 Act the Manitoba Regulation 21/54 was rescinded.

The organizing of registered trap-lines in the Churchill – York Factory area in the early 1950s

also gave some protection to the polar bears as trappers were encouraged to limit their kill (J. D. Robertson, pers. comm.).

In 1957 the York Factory settlement was closed by government decree and treaty Cree Indians native to the area were moved to York Landing, an Indian settlement inland on the southeastern shore of Split Lake, 260 km southwest of York Factory. A few others (Métis) moved voluntarily to Churchill. From 1952 to 1958 an average of 17 polar bears were known to have been killed by York Factory hunters each year. Since then very little hunting or trapping has been done along the coastal areas by Manitoba Indians. During October 1964, with the Canadian Army withdrawal from Fort Churchill, military manoeuvres and the killing of bears by soldiers came to an end.

2. The development of bear–man problems around Churchill

Apparently because of the decrease in hunting, the numbers of polar bears along the Manitoba coast rose rapidly during the 1960s (J. D. Robertson, pers. comm.). An increasing number of polar bears began to frequent the three garbage dumps at Churchill and Fort Churchill during the fall. During that period the human population of the Churchill area was at its highest (Table 1).

With the increased numbers of bears and people, interactions became common because:

(1) bears fed in the dumps at all periods of the day and night,
(2) people scavenged in the dumps during the daylight hours,
(3) bears were viewed and provoked in the dumps as a popular evening pastime,
(4) bears often wandered around and through the settlements as they became conditioned to the presence of man, and

Table 1
Population of Churchill District

Year	No. of people
1921	207
1926	36
1931	1813
1936	444
1941	406
1946	448
1951	830 (2168)*
1956	1418 (3039)*
1961	2069 (3932)*
1966	2021 (3579)*
1971	1604

*Numbers in parentheses include military establishments at Fort Churchill.

(5) bears were attracted to garbage, stored bait, the whaling station, and food smells in the settlements.

The danger of bear–man conflict was most serious in the garbage dump at the townsite of Churchill. This dump was actually located inside the town, and several residences were located within 30 m of the dumping area. Bears feeding there were in almost constant contact with people.

The Department of Public Works (DPW) dump created the next most serious problem. It was located 1.3 km to the east of the apartment blocks in Fort Churchill and was separated from the apartments by a strip of forest. Bears commonly moved to this forested area during daylight hours to rest in "day beds". Children played and skated within a few hundred metres of the trees, and often used footpaths that led through the trees to the dump.

A third dump was located near the kitchen of the launching area on the Churchill rocket range 15 km to the east of Fort Churchill (Fig. 2). It presented a particular danger to rocket range personnel because it was so near to where people were working.

Incidents between bears and people increased. By 1966, the situation had become almost

alarming. In November 1968, up to 40 polar bears at any one time could be seen in the vicinity of the Fort Churchill dump, and 60 to 80 bears were estimated to be frequenting the settlements. In 1966, 1967 and 1968, people were attacked by bears in the Churchill–Fort Churchill area, resulting in the death of one Inuit boy in 1968 (Jonkel 1969*a* and 1970). Royal Canadian Mounted Police (RCMP) and private citizens killed an increasing number of bears to protect themselves and the community. Minor problems, such as bears breaking into houses, killing dogs, and frightening people, became too numerous to recount. For the most part, the tolerance and restrained behaviour of people resident in the Churchill area were commendable, preventing situations which at times could have turned into chaos. Night workers were driven from doorstep to doorstep when beginning or ending shifts, and the entire Fort Churchill residential area was cleared of bears and ringed with manned vehicles during Halloween activities to protect the children.

Watching, feeding, chasing, and photographing bears did, however, gradually become a popular pastime for many residents and visitors to Churchill during October and November of each year. A small percentage of the public grew to dislike bears, and tormented them or shot them with small calibre rifles as they fed. The RCMP were regularly required to resolve problems between bears and people, but the officers were replaced frequently and therefore gained little experience with such situations. A Conservation Officer of the Manitoba Department of Renewable Resources and Transportation Services (MDRRTS) visited the Churchill area occasionally, but mainly to issue trap-line licences and to enforce the Migratory Birds Convention Act.

The first corrective measures were taken in 1966. In that year the rocket range superintendent agreed to cease dumping food at the range and forbade the feeding of bears by range personnel. Bears were chased from the launch area with helicopters, and one persistent bear was drugged and moved 50 km east to Cape Churchill. She returned overnight, however, and in the following year transferred her attention to the Fort Churchill dump.

In 1967, attempts to educate the public were made by biologists working in the area. As a result of a meeting between federal, provincial, and local government officials, it was recommended that the town dump be discontinued, and that the Fort Churchill dump be moved 15–25 km to the east, away from the settlements, or replaced by an incinerator.

Autumn 1968 brought an even larger than normal influx of bears to the Churchill – Fort Churchill area because ice did not begin to form in the Churchill area of Hudson Bay until 19 November, almost two weeks later than normal (Canada, Atmospheric Environment 1970). No action had yet been taken on either the Fort Churchill or Churchill dumps, but at the beginning of November, DPW officials agreed to place a gate on the road to the Fort Churchill dump to control public access. They also suggested fencing the area, and attempted (rather unsuccessfully) to burn the garbage, but the situation did not improve appreciably.

In the autumn of 1968 discussions were held in Churchill with DPW, local government, and provincial authorities. Subsequent meetings were held in January 1969 in Winnipeg and again in Churchill. General agreement was reached by all persons and agencies present that:

(1) the Churchill and Fort Churchill garbage dumps were the basic cause of the trouble. This was indicated by the annual recapture of tagged bears in the Churchill area, and the boldness of the dump bears;

(2) total slaughter of the bears should be rejected, but certain aggressive or wounded animals should be killed or shipped to zoos;
(3) the Province of Manitoba should consider establishing a quota for Indian hunters to reduce bear numbers;
(4) public information and education should be increased on both federal and provincial levels;
(5) MDRRTS should provide research personnel and continue to provide Conservation Officers to study and control the Churchill problem;
(6) in order to control movements of bears in the area all dumping at the townsites should cease immediately and a new dump or incinerator should be constructed near Bird Cove 20 km east of Fort Churchill (Fig. 2) (federal, provincial, and municipal cooperation was stressed); and
(7) the bears at Churchill should be treated as a resource by allowing the hunting of bears by Indian peoples and/or by encouraging the viewing of bears as a tourist attraction.

DPW and the Local Government District (LGD) agreed to increase the frequency of garbage pick-up and to encourage the use of plastic garbage containers. The following were all agreed to: fencing of the school area, daily burning and burying of garbage, and constant patrols by Conservation Officers during the problem fall period.

By autumn of 1969 DPW had agreed to budget for the construction of an incinerator. The LGD closed the dump in Churchill, and DPW controlled public access to the Fort Churchill dump and attempted to burn and bury garbage as it arrived at the dump. The Province provided culvert traps to ship problem bears from the townsite to zoos, and assigned personnel for a continuous patrol of the townsite to chase bears out of town. Total cost to the Province was estimated at $20,000. Because of the added cost of transportation, DPW and LGD did not keep to their previous agreement to move the dump to Bird Cove. However, DPW began hauling sand from Bird Cove to cover garbage at the dump. The situation improved greatly, but during 1969 ice persisted in southern Hudson Bay until late September, about a month later than average, and many bears may not have come ashore until later than usual. The final steps for solving the problem appeared to be construction of an incinerator, patrols by Conservation Officers each autumn, continued public education, and removal of problem bears by shipment to areas outside the townsite or to zoos, or by killing. The Federal–Provincial Administrative Committee for Polar Bear Research and Management (a co-ordinating committee for jurisdictions within Canada which have polar bears) urged DPW by letter for action on the incinerator.

The autumn of 1970 passed without serious problems in any of the settlements. Manitoba Conservation Officers again provided a 24-hour patrol of the townsites in cooperation with the RCMP, and again they removed problem bears by chasing them away, capturing in culvert traps, or as a last resort, by shooting. Surprisingly, few zoos appeared interested in obtaining live bears. However, six bears were held in the culvert traps during the last 10 days before freeze-up, and were released at Bird Cove when they could go out onto the ice. Cost of the patrol operation was estimated at $35,000 by the Province. From capture–recapture data and aerial surveys by CWS and MDRRTS, 600 bears were estimated to be in the Cape Churchill to Nelson River area, including 50 to 70 bears frequenting the townsites. An abortive attempt by a local resident to raise a small number of pigs near the Boy Scout Camp east of Fort Churchill (Fig. 2), using restaurant and butcher shop waste, drew 10 to 15

bears to that area. The bears caused considerable damage to lakeshore cabins, endangered people, and eventually ate some of the pigs. Live-trapping success in 1970 was very high in the Scout Camp area, compared with little success in this area in previous years or the year following. DPW continued to burn and bury garbage daily at the Fort Churchill dump, but they announced that because of the reduction in staff at the rocket range and its eventual shutdown they could no longer justify construction of an incinerator.

Solution of the Churchill polar bear problem seemed at an impasse in 1971. The Federal–Provincial Technical Committee passed a resolution (accepted by the Administrative Committee) urging DPW to relocate the garbage disposal site immediately to Bird Cove and to continue the practice of burning and burying at the new site. Surveys of the Owl River maternity denning area indicated that 100 to 150 young polar bears were being added to the population annually, and recaptures of tagged animals strongly indicated that the bears along the Manitoba and southern Keewatin coast remained there and on the adjacent sea year-round, and possibly were only being hunted by Eskimo Point, Rankin Inlet and Whale Cove Inuit (total quota of 14 animals in 1970–71) during their annual migrations. The Polar Bear Technical Committee therefore recommended that Manitoba allow up to 50 bears to be taken annually to ensure proper management of the population. Plans were made by MDRRTS to continue 24-hour patrols of the settlements, as it was obvious that an incinerator would not be built or the dump moved to Bird Cove that year. In addition, they were prepared for Conservation Officers to kill up to 50 bears in the Churchill area as an alternate attempt to protect residents. Recent court cases in the United States had held government authorities responsible for attacks by wild grizzly bears (*Ursus arctos horribilis*) on man, and the Provincial Government had no reason to expect a different outcome at Churchill. In conjunction with the control program, MDRRTS became involved in marking bears captured in traps located throughout the Churchill area and prepared an information booklet summarizing what was known about the Manitoba polar bears (Nero 1971).

Concurrent with the control program, a private animal preservation group (International Fund for Animal Welfare) from Fredericton, New Brunswick, became interested in the problem. Their avowed aim was to save the lives of individual bears whenever possible, and to publicize the Churchill problem in such a way as to embarrass the two governments into arranging more efficient garbage pick-up and relocating the dump at Bird Cove, or constructing an incinerator. The Director of the Fund, Brian Davies, in cooperation with provincial authorities, chose to fly problem bears (that would otherwise have been shot) to an abandoned airstrip (Kaska), near the Kaskattama River, 300 km (air) southeast of Churchill, and release them (Fig. 1). Biologists considered this site to be within the normal range of the Churchill bears; therefore no mixing of sub-populations would result. The bears were expected to move north from the Kaskattama River towards Cape Churchill and possibly as far as the Churchill settlements. In the interim, it was hoped that the Bay would freeze so that the relocated bears would return to the sea ice to hunt seals. Twenty-four problem bears (19 of which were eartagged) were successfully moved in this way in cooperation with Manitoba biologists, and the conflict between bears and people around the settlements was greatly reduced.

This method cost the International Fund for Animal Welfare approximately $12,000 and was

considered far too expensive to be considered as more than a stop-gap method.

By the fall of 1972, plans for an incinerator went before the Manitoba Environment Commission and were approved in principle. However, the submission was of undetailed plans which had then to be submitted to a design firm for further refinements. Meanwhile, the garbage disposal system remained the same as in the previous year.

Although 13 bears were destroyed during the fall, the estimated number of problem bears in the Churchill area was much reduced from the preceding year. This was reflected in the decline in the number of calls reporting bears from 184 in 1971 to 63 in 1972. The reduced bear problem was partly attributed to an early freeze-up which permitted the bears to leave around 5 November. Conservation Officers and RCMP maintained a 24-hour patrol during the fall, costing the Manitoba Government approximately the same as in the previous fall. Four problem bears were airlifted to Kaska and three were held in culvert traps and released at Bird Cove when the ice began to form on the Bay.

By the fall of 1973 the incinerator, about 0.5 km north of the Fort Churchill dump site, was built but was not functioning due to the lack of a transformer. Garbage dumping was confined to one area in the dump and was burned but not covered with sand as in previous years. The public education program to make people aware of the potential dangers of polar bears was continued through the local news media, school talks and posters. Patrols by Conservation Officers and RCMP continued as in previous years.

A total of seven bears were killed in the fall of 1973. One problem bear was shipped to the Assiniboine Zoo in Winnipeg and five bears were held in culvert traps and released later at Bird Cove. The reports of bears in the residential area were about the same as in the previous fall. The low number of bear problems was partly explained by the early ice formation on Hudson Bay (Cross 1974*a*). Most of the bears had departed from the mainland by 8 November. However, fewer bears appeared to have been in the Churchill area prior to the ice formation. The reason for this is not known.

A resolution passed in June 1974 by the Polar Bear Administrative Committee shifted the northern boundary of Zone A^1 from the Manitoba–NWT border to between Rankin Inlet and Chesterfield Inlet (Fig. 1) and at the same time suggested an increase in the quota for the three NWT settlements (Eskimo Point, Whale Cove, and Rankin Inlet) now included in Zone A^1. Increasing evidence suggested that a portion of the Manitoba or Zone A^1 sub-population spent part of the winter off the southern Keewatin coast (Anderka *et al.* 1973). The quota for Manitoba was reduced from 50 to 35.

The garbage disposal problem was still not completely solved in 1974 as the incinerator was only functional for a short period during the summer. Due to problems with burst tires on the wheeled vehicle used to load garbage into the incinerator, a tracked replacement was ordered. However, because of unforeseeable delays in delivery of the vehicle, the incinerator was not operational again until late November 1974—after most of the bears had gone. A few bears that were around the dump at that time began frequenting the incinerator. The old garbage dump at Fort Churchill was covered over, leaving little to attract them. During most of the fall, conditions at the dump were much the same as in previous years.

Apart from the dump, two additional problem areas still remained. Bears were attracted by cooking smells to the Poole Construction and the Harbour Board kitchens, even though the gar-

Table 2
Recorded information on polar bears in the Churchill area*, Manitoba, in falls of 1966–75

	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
No. reports	—	—	—	77	200	184	63	65	147	119
Est. no. problem bears	—	—	—	—	75	79	26	15	52	48
Est. no. problem bears in residential area	—	—	20	31	50	57	20	10	42	30
No. problem bears killed	—	—	—	—	4	6	9	4	9	4
No. bears killed	—	—	—	—	7	7	13	7	11	8
No. bears released at Kaska	0	0	0	0	0	24	4	0	11	7
No. bears released at Bird Cove/Twin Lakes	1†	0	1	3	6	0	3	5	6	12
No. bears to zoo	0	0	0	0	0	1	0	1	2	2

*Area between Churchill River and rocket range, including Churchill and Fort Churchill.
†Moved by helicopter to Cape Churchill.

bage storage and disposal had been improved. It was also still apparent that foodstuffs were being placed outside to attract bears for close-up photographs.

One hundred and forty-seven reports of bears in the residential districts were received between 14 September and 30 November 1974. A total of 11 bears, nine of which were classified as problem bears, were killed. One of these was killed by a member of the Canadian Armed Forces between Gordon Point and Knight's Hill, east of Churchill (Fig. 2). An estimated 42 problem bears were in the residential area during the fall. Two problem bears (a female and her yearling cub) were shipped to the Assiniboine Zoo in Winnipeg; another 11 (10 of which were eartagged) were airlifted to Kaska, and six were captured in culvert traps and later released at Bird Cove. One of the bears released at Bird Cove on 21 November returned to the Churchill residential area on 25 November and had to be destroyed. The increase in numbers of bears and problems during October and November was probably due to below average temperatures in September and the late freeze-up (Cross 1975*a*).

In 1975, fewer bears were recorded in the Churchill area, particularly in the vicinity of the dump (Cross 1976). The incinerator was functioning, but only on week days, which necessitated the storing of garbage in a fenced area adjacent to the incinerator. Kitchen wastes and combustible material were usually separated from other garbage and incinerated, but were occasionally left at the old dump site. Bears were still able to reach the garbage, both in the incinerator, through an access hatch, and in the fenced storage area. However, the fact that access to the garbage was somewhat restricted may have accounted for the lower numbers of bears that frequented the dump area. The main problem area was the Poole Construction kitchen which was located only about 100 m from the Hudson Bay coastline, on a route used by bears.

Between 16 September and 16 November, there were 119 reports of bears in residential districts. Thirty problem bears were reported of which 4 were killed and 21 were live-captured in culvert traps. Of the live-captured bears, 7 were air-lifted to Kaska, and 12 were released at Bird Cove or in the Twin Lakes area (Fig. 2). Two orphaned cubs were sent to the Calgary Zoo. As the 1975 fall was relatively mild and the freeze-up was at about the normal time, the effect of the incinerator has yet to be established.

Table 2 summarizes information on the number of polar bears in the Churchill area during the falls of 1966 to 1975.

Objectives

1. Basic research requirements

It was apparent from the outset that a program of protection of polar bears would not be adequate to prevent bear–man interactions. A research program on the population ecology of the bears on the western coast of Hudson Bay was required to develop and evaluate a variety of management alternatives. Data were needed on the following aspects: the numbers of bears involved; the daily and seasonal movements of the population; the seasonal distribution of the various age and sex classes; which bears were causing the problems at Churchill and what was attracting them; fidelity of bears to the Churchill area; status of the bear population; location and productivity of the denning areas; and, essential from a management point of view, determination of whether the bears of the Manitoba coast formed a relatively discrete sub-population.

Initially, polar bear mark and recapture studies and aerial surveys were done in several parts of Hudson and James bays. However, as noted later, it became apparent that the population of polar bears inhabiting the western coast of Hudson Bay was a relatively discrete subpopulation. Thus, this report concentrates on an approximately 160-km wide band of coastline from slightly north of Churchill south to the Manitoba–Ontario border and, within the limits of available data, adjacent areas of sea ice.

Study area

1. Geology

The Hudson Bay area occupies the central, structurally weak, part of the Canadian Shield. Downwarping of the area during the Pleistocene was responsible for the formation of the Tyrrell Sea — a precursor of the present Hudson Bay which was at its maximum extent 7000–8000 years ago (Lee 1968). With the recession of the ice sheets and the resulting isostatic recovery of the land areas, the former sea has shrunk to the present limits of Hudson Bay. Numerous raised beaches now 120–180 m above sea level and marine sediments along the western coast of Hudson Bay indicate former limits of the sea. With the recession of the Tyrrell Sea and the ameliorating effect on ground temperatures, permafrost, surface frost action, extensive bog formation, dune formation, and alluvial deposition around river mouths have occurred.

2. Topography

The western and southern coastal areas of Hudson Bay which were formerly inundated by the Tyrrell Sea form what is known as the Hudson Bay Lowland. In Manitoba it extends 120 km inland south of Churchill to almost 300 km near the Ontario border and comprises most of the study area. As the name suggests, it is a low-lying area, which dips very gradually towards the Bay. The offshore waters are shallow and as a result extensive mudflats are exposed at low tide and bars and spits fringe the coast.

The lack of pronounced relief and the presence of permafrost and impervious silty loams have produced poor drainage resulting in numerous lakes, shallow, meandering streams, and muskeg. Extensive marine beaches, although relatively well-drained themselves, further impede the surface drainage (Zoltai 1973).

3. Vegetation

Two vegetation types characterize the study area, a sub-arctic tundra along most of the cold, wet, wind-swept western coast of the Bay, and a transitional zone which changes from low tundra to typical spruce forest farther inland (Savile 1968). North of the tree-line (transitional zone) trees are replaced by moderately tall willow (*Salix* spp.) and alder (*Alnus* spp.) which give way to lower, widely scattered shrubby willows and dwarf birches (*Betula glandulosa*), and finally tussocks of grass and sedge (*Carex* spp.), arctic flowers, and a number of low heathy shrubs, mosses, lichens, and various herbs.

Within the transitional zone, white spruce (*Picea glauca*), black spruce (*P. mariana*), and balsam poplar (*Populus balsamifera*) are generally small and restricted to the better drained and protected areas on steeper slopes and in valleys. Open areas are often covered with caribou lichens (*Cladonia* etc.), scattered shrubs, or a few small spruce and some herbs. Poorly drained areas have extensive peat bog and fen formations which with the development of permafrost give rise to peat plateaus and palsas (Zoltai 1973).

The depression of the vegetation zones southwards is in response to the ice cover over Hudson Bay which effectively eliminates any moderating influence the water may have during the cold winters. Spring is delayed and there is much fog and cloud cover, associated with the proximity of the cooler open water, during the growing season. It is near the end of summer before the water is finally ice-free and beginning to warm. However, by that time the shortening days and cold nights prevent any significant growth, especially in the coastal zone. As a result, any plants needing a fairly long growing season to produce flowers and seeds are eliminated.

4. Climate

The Hudson Bay area has a typically arctic climate with long, cold winters and short, cool, wet summers (Thompson 1968). Strong, prevailing northwesterly winds bringing in large masses of cold, arctic air are responsible for the long, cold winters. The ice-covered Bay provides no modifying influence and acts as an extension of the broad expanse of the country to the west and north. No major topographical features are present to intercept the flow of cold air. Temperatures are well below zero, wind speeds are strong, and snowfall in winter is light (Table 3). Snowfall is associated with the occasional storm centre that passes through the area, and although not heavy, snow cover lasts about 250 days in the Churchill area. Temperatures drop steadily until February and do not usually climb above freezing before April.

Because warming is delayed by the persistent influence of the sea-ice, winter weather generally prevails into May. As the days become longer and temperatures rise and the ice cover over the Bay breaks up, the frequency of fog and cloud cover increases from the winter low of about 50% to a high of 80%.

Table 3
Climate data for Churchill Airport, Manitoba

Month	Mean t°C	Snow (cm)	Precip. (cm)	Wind (km/h)	Cloud
Jan.	−27.5	12.7	1.27	25.4	0.43
Feb.	−26.4	14.0	1.40	25.1	0.44
Mar.	−19.8	16.5	1.65	23.3	0.51
Apr.	−10.7	25.1	2.64	25.3	0.62
May	−2.3	16.5	3.05	24.3	0.77
June	5.8	1.8	4.14	21.7	0.72
July	12.0	Tr	5.16	20.6	0.64
Aug.	11.6	0	6.10	21.7	0.67
Sept.	5.7	3.6	5.28	26.4	0.82
Oct.	−1.1	24.6	3.81	26.4	0.82
Nov.	−11.7	38.1	3.86	27.2	0.75
Dec.	−21.9	22.6	2.26	24.6	0.54
Year	−7.2	175.5	40.62	24.3	0.64

Summer is short, cool, and cloudy. With the northward movement of the pressure belts, low pressure storm centres frequently cross the area from the west and southwest. The warm air masses preceding these storms are quickly cooled as they pass over the cold waters of Hudson Bay, resulting in considerable amounts of fog, cloud, and precipitation. About a third of the total annual precipitation falls during July and August. Waterlogged ground conditions contribute to the cool summers. A great amount of heat energy, which would otherwise be used to raise air temperature, is consumed during the evaporation process of the surface water. In addition, these conditions lead to high average cloudiness, solar radiation blockage, and delay in spring warming.

Autumn is customarily a short, stormy season. Although Hudson Bay is ice-free during September, the advance of cold, arctic air masses, shortening days, and strengthening northwesterly winds, override any moderating influence of the Bay and temperatures drop relatively quickly. By late October the average daily temperatures are below freezing (Table 3), snow covers the ground, and ice has begun to form in inlets, river mouths, and along the shore-line. The meeting of cold, arctic air with warm, moist air during October and November is responsible for almost half the total snowfall, maximum cloudiness (80% average on the coast), and strong winds. By December, winter has set in and ice covers most of the Bay.

5. Ice

Hudson Bay receives no warming influence from air or ocean currents and consequently is ice-covered for much of the year. There is a great deal of variation in the patterns of formation and breakup of this ice cover, from locality to locality and from year to year (Larnder 1968; Canada, Atmospheric Environment 1966–74). However, a virtually complete ice cover forms every winter and disappears completely each summer (Fig. 3). Maximum development (ice thickness of 1.5 m) occurs in early April. Ice conditions in Hudson Bay may be categorized (Danielson 1971) as follows:

Winter: Jan. to Apr., ice cover nearly 100%
Spring: May to mid-Aug., ice-cover melting
Summer: late Aug. to early Oct., ice-cover nearly zero
Autumn: mid-Oct. to late Dec., ice-cover forming.

Freeze-up of Hudson Bay begins in late October in the northwest near Southampton Island and gradually spreads southward along the western coast. Ice forms along the shorelines first, after the river mouths begin to freeze-up and temperatures drop. The mouths of the Churchill, Nelson and Hayes rivers are usually closed by the second or third week in November. By early November the ice extends about 80 km offshore from Southampton Island south to Churchill, with a narrower band of shore ice from Churchill almost to Winisk, Ontario. Landfast ice has its widest development along the western and southern coasts of Hudson Bay, where coastal waters are relatively shallow. The pack-ice continues to grow most rapidly from the northwest until by the end of December the only significant amounts of open water are in the extreme southeast of Hudson Bay, west of the Belcher Islands.

Ice cover is at its maximum from January through April, but it never reaches 100% because winds, tides, and currents continually produce stresses that fracture the ice, exposing stretches of open water, which may refreeze. The ice pans vary from a few metres to several kilometres in diameter. The leads vary from a few metres to over a kilometre wide and from a few metres to several kilometres long. Most out-

Figure 3

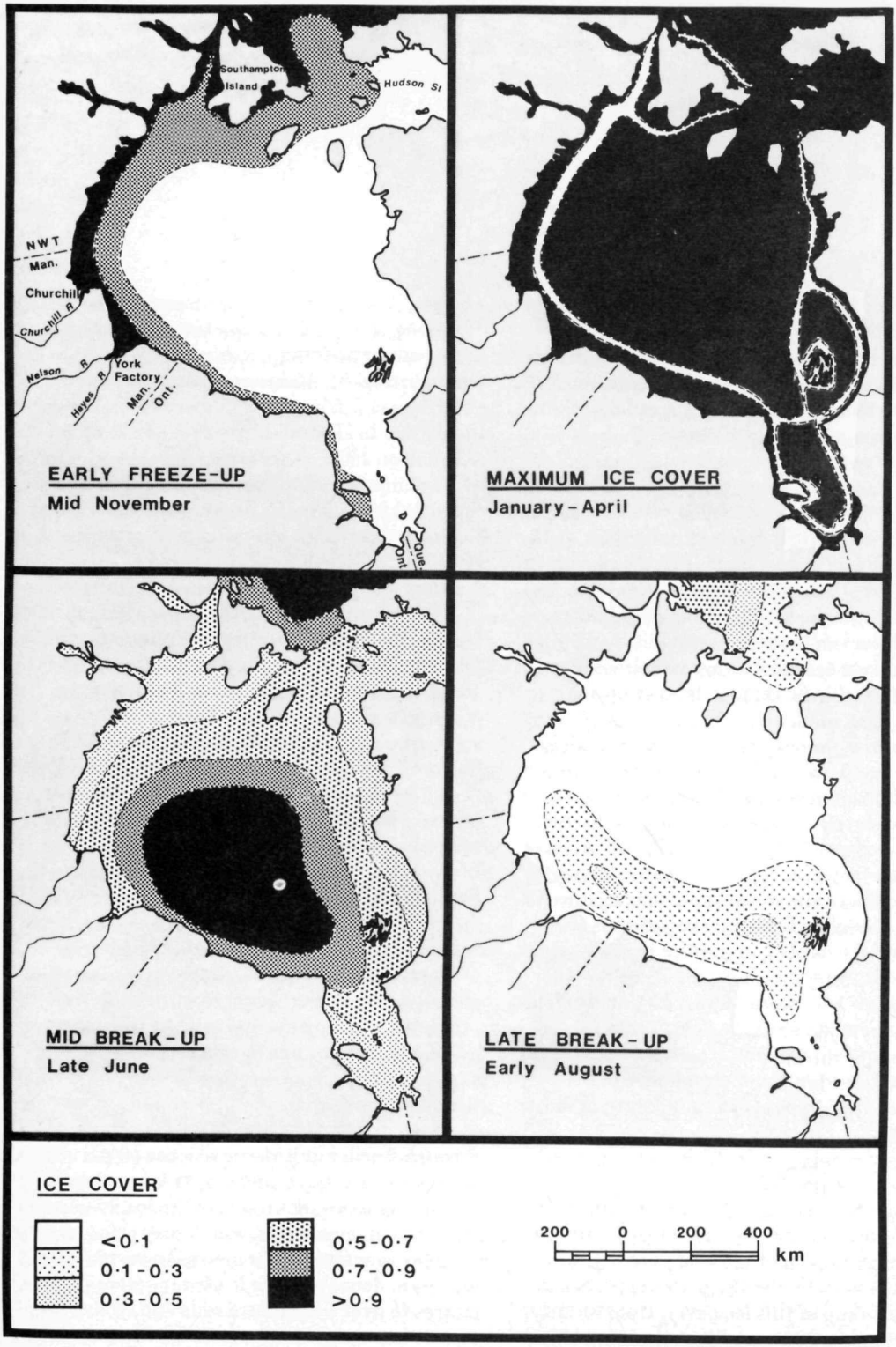

Southampton Island
Hudson St
NWT
Man.
Churchill
Churchill R.
Nelson R.
Hayes R.
York Factory
Man.
Ont.
Que
Ont
EARLY FREEZE-UP
Mid November
MAXIMUM ICE COVER
January - April
MID BREAK-UP
Late June
LATE BREAK-UP
Early August
ICE COVER
<0·1
0·1 - 0·3
0·3 - 0·5
0·5 - 0·7
0·7 - 0·9
>0·9
200 0 200 400
km

Figure 3
Pattern of Hudson Bay ice cover during freeze-up, at maximum development, during early and late break-up (after Canada, Atmospheric Environment 1966–74; Larnder 1968; and Danielson 1971)

standing is the persistent shore lead occurring between shore-fast ice and the main ice cover of the Bay, along the western coast of Hudson Bay between Southampton Island and Churchill. This lead, with an average width of 8 km, is maintained as a result of winds predominantly from the northwest. South to Churchill the shore lead is much less pronounced. Sea fog is common over these open water zones.

Ice along the shallow coastal areas begins to break up in May and June, and is accelerated by the influx of relatively warm flood water from the rivers. The main ice cover melts slowly and finally breaks up and rots through wastage. Only small amounts of ice leave Hudson Bay through Hudson Strait. Winds, tides, and currents influence the movement and distribution of the ice, wind being the dominant factor. The ice generally clears from north to south, with melting beginning in May along the western coast shore lead between Southampton Island and Churchill and progressing southeastward under the influence of the counter-clockwise current pattern and the prevailing northwest winds. It appears that the northward current and the island chain along the eastern coast hasten the breakup in that area. The greatest decrease in ice coverage occurs in July and by early August the only significant cover ($\frac{3}{10}$) remains in the southwestern areas of the Bay. Figure 3 illustrates the general pattern of breakup of the sea-ice in Hudson Bay, showing how the last ice remains off the Manitoba and northern Ontario coasts. Late August, September and October are usually ice-free throughout most of Hudson Bay.

6. Currents

The general water circulation movement of surface currents of Hudson Bay is believed to be an anti-clockwise drift. Fresh water runoff, tidal mixing, and water depth are the most important factors affecting the properties and movement of water in Hudson Bay (Barber 1968). Other factors, including winds, have significant effects on surface layers. However, there is little direct information about the circulation because of the difficulty of acquiring data over much of the year. There is much speculation about the circulation, but it is apparent that the general anti-clockwise movement of water around the periphery of the Bay is disrupted in the Churchill area during the melting period.

Normally the drift, assisted by the prevailing northwesterly winds, carries the ice from the Cape Churchill area southeastward towards James Bay. However, some July ice charts indicate a possible variation. Unexpected movements of the ice pack have been observed over a number of years in the southwestern section of the Bay, east and southeast of Churchill, where high concentrations of ice seem to linger. Thus, it appears that the normal water currents of Hudson Bay are weak and that a northward flow develops, or may develop, in the vicinity of Cape Churchill, at least during the melt period (Canada, Atmospheric Environment 1960, Danielson 1971).

The fresh water inflow from surface streams leads to the stratification of the surface waters of the Bay with the denser more saline waters below. To balance this inflow, there is a net outflow of mainly surface waters from the Bay into Hudson Strait. A sub-surface inflow of saline water counter-balances the surface outflow.

7. Other biological life in Hudson Bay

Hudson Bay appears to be intermediate between the rich North Atlantic and the deficient Arctic Basin in the diversity of animals it supports. The lower productivity of the Bay is believed to result from the lower temperatures, the lack of complete and regular mixing, and the

effect of the long period of ice-cover which inhibits the light supply and shortens the summer period of maximum biological productivity. The production of phytoplankton and zooplankton determines the productivity of fish, seals, whales, and ultimately polar bears.

The greatest concentrations of phytoplankton occur in surface water where the cells float more or less passively, thus the distribution varies with the changing hydrographic conditions. Low salinities in surface waters combined with strong temperature and salinity gradients as a result of fresh water inflow and seasonal melt have allowed many fresh water plankton species as well as the brackish and truly marine organisms to exist. So far, over 235 phytoplankton species have been identified in Hudson Bay, reflecting more favourable conditions than in the Arctic Ocean, where only 63 species have been identified. Larger populations, with an evident preponderance of arctic forms, are thought to occur in the northeastern part of the Bay. The summer phytoplankton bloom occurs at different times in different parts of the Bay, probably depending on ice breakup, and salinity which increases later in summer.

The bottom flora of Hudson Bay have not been well studied. The main part of the Bay has a mud substrate which is unsuitable for algae attachment. Large red and brown seaweeds occupy deeper waters, while the tide pools and protected bays are overgrown with smaller red and brown algae (Bursa 1968). Generally there are few species.

Hudson Bay is primarily arctic in its invertebrate fauna, with a minor Atlantic element reaching into the northeastern parts. Of the 260 invertebrate species known for Hudson Bay, about 210 species are bottom living zoobenthos and about 50 species are floating zooplankton (Grainger 1968). Estimated summer populations in the shallow waters of the southern Manitoba and northern Ontario coasts are quite low.

The fish fauna are typical of arctic regions. Few species are present, their abundance is low, growth rate is slow and their productivity is depressed (Hunter 1968). All the true marine species found in the Bay are small, obscure, bottom-dwelling creatures in low abundance. The anadromous fish have a wide summer distribution, returning to the rivers in the fall. A number of fresh water species venture into shallow brackish water around river mouths.

Ringed seals (*Phoca hispida*), bearded seals (*Erignathus barbatus*), harbour seals (*Phoca vitulina*), harp seals (*Pagophilus groenlandicus*) and hooded seals (*Cystophora cristata*) occur in Hudson Bay. McLaren (1958), using a minimum of information, made population estimates of 205 000 and 84 000 respectively for ringed and bearded seals. From limited aerial surveys in 1974, Smith (1975) estimated the ringed seal population at 455 000. The harbour seal is sparsely distributed, mainly in river estuaries along the southwest coast and in the northwest part of the Bay. Harp and hooded seals are not common.

Walruses (*Odobenus rosmarus*) occur in northeastern Hudson Bay on Coats and Southampton islands, where an estimated population of 3000 is found in the summer. They are also regular summer visitors to the Belcher and Sleeper islands in southeastern Hudson Bay, and small islands northwest of Cape Henrietta Maria in the south. Four species of whales occur in Hudson Bay, the bowhead (*Balaena mysticetus*), white whale, narwhal (*Monodon monoceros*), and killer whale (*Orcinus orca*). Only the white whales are numerous and their population exceeds 5000 (Sergeant 1968). They are most common on the western coast of Hudson Bay, north of Winisk, Ontario.

As was the case with the marine species, the number and diversity of terrestrial species, in general, decrease as one proceeds north. The relative poverty of the northern fauna may be related to the lower plant production in the area. The poorly drained land provides a vast area of ideal breeding habitats for many insect species, particularly mosquitoes, blackflies, and other biting flies (Oliver 1968). North of the tree-line, the number of insect species decreases markedly from about 10000 to about 1000. The herpetofauna of the area consist, at the most, of 15 species (Cook 1968).

The bird fauna are composed of summer visitors, semi-residents, and residents. Possibly of most significance with regard to polar bears are the large colonies of Snow Geese (*Chen caerulescens*) which occur at several points on the flat, coastal tundra of Hudson Bay (Cooch 1968), e.g. La Pérouse Bay (Fig. 2). The geese remain in the colonies from late May to early June throughout the summer. By late October most geese have flown south.

The tundra area of western Hudson Bay is inhabited by sixteen species of mammals, including shrews, microtine rodents, barren-ground caribou (*Rangifer tarandus groenlandicus*), foxes (*Alopex lagopus*), wolves (*Canis lupus*) (Macpherson 1968). The transitional zone is inhabited by about 34 mammal species including woodland caribou (*Rangifer tarandus caribou*), black bears (*Ursus americanus*), marten (*Martes americana*), otter (*Lutra canadensis*), moose (*Alces alces*), beaver (*Castor canadensis*), muskrat (*Ondatra zibethicus*), and porcupine (*Erethizon dorsatum*). The numbers and densities of these species are unknown.

1. Tagging programs

Polar bears were individually marked to determine whether the same bears repeatedly returned to the Churchill area each fall as well as to study seasonal movements and population size and discreteness. In this study, the Churchill area refers to a 5-km wide coastal strip stretching between the rocket launching area and the Churchill River and including the settlements of Churchill and Fort Churchill (Fig. 2). Subsequent information on tagged bears came from resighting or the return of tags from bears killed by hunters. The techniques used to capture and immobilize polar bears have been described by Jonkel (1967 and 1969*b*), Lentfer (1968) and Larsen (1971). Bears were either captured in snares or culvert traps and then immobilized, or were drugged from a helicopter. The drugs Anectine or Sucostrin (succinylcholine chloride, Burroughs Welcome Ltd., Montreal, and Squibb Laboratories, Montreal, respectively) and Sernylan (phencyclidine hydrochloride, Parke Davis and Company, Detroit, Michigan) were used, but the last proved most reliable and, after 1970 was used exclusively. Dosages of Sernylan used were 1 mg/0.5–1.0 kg body weight. The tranquilizer Sparine (promazine hydrochloride, John Wyeth and Brother Ltd., Windsor, Ontario) was used simultaneously with the immobilizing drug Sernylan to reduce stress and hopefully to minimize convulsions.

Most immobilized bears were weighed, had standard measurements taken, and were examined for condition, wounds, and infections. A small premolar tooth was removed for age determination in the laboratory. Some blood samples were collected. Numbered eartags were applied to each ear and a tattoo was put on the inside of both upper lips. The numbers on the tag corresponded to that of the tattoo. Various types of eartags were used: metal stock tags and

Figure 4
Relationship between polar bear weights obtained by taking heart girth with a cattle weight tape and weights obtained with spring scales, 1966–68

Figure 4

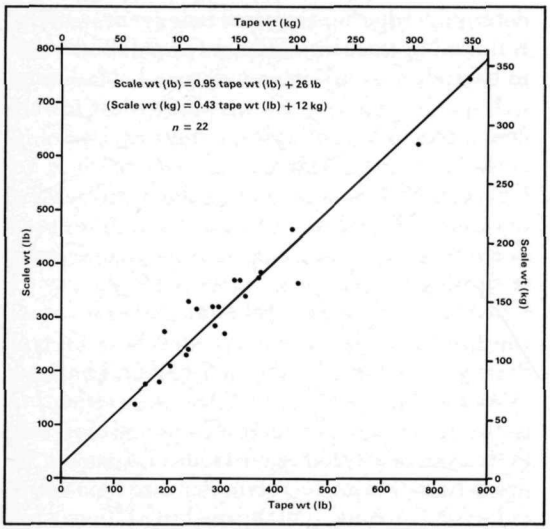


Table 4
Polar bear tagging programs in Manitoba, 1966–75

Year	Date	Means of capture	Area
1966	11–13 Oct.	Snares	Rocket Range – Cape Churchill
1967	4–11 Oct.	Snares	Watson Point
	24–28 Oct.	Snares	Churchill area
1968	12–18 Oct.	Snares	Watson Point
	22–29 Oct.	Snares	Churchill area
1969	7–17 Aug.	Helicopter	Cape Churchill to Ontario border
	10 Oct.–11 Nov.	Snares	Churchill area
1970	23–25 Aug.	Helicopter	Churchill – Broad River area
	1–3 Sept.	Helicopter	Broad – Owl rivers area
	29 Oct.–16 Nov.	Snares	Churchill – Cape Churchill
	10–12 Nov.	Helicopter	Churchill – Cape Churchill
1971	10 Oct.–25 Nov.	Snares and Culvert traps	Churchill – Watson Point
1972	15 March	Helicopter	Denning area
	30 Sept.–11 Nov.	Snares and Culvert traps	Churchill area
1973	4–30 Oct.	Snares and Culvert traps	Churchill area
1974	9 Oct.–25 Nov.	Snares and Culvert traps	Churchill area
1975	15 Oct.–18 Nov.	Snares and Culvert traps	Churchill area

Perma-tags (Ketchum Manufacturing Sales Ltd., Ottawa), plastic Leadertags (Salt Lake Stamp Company, Salt Lake City, Utah), plastic Jumbo Rototags (Dalton Company, Henley, England), and vinyl plastic ribbons (Craighead and Stockstad 1960). Plastic tags, although not as durable, were later used in preference to the metal tags to minimize ear infections. The rumps of some animals were marked using spray enamel, Paint-Stik (Ketchum Manufacturing Sales Ltd., Ottawa), Wound-Kote (Farnam Companies, Omaha, Nebraska), or Nyzanol (Nyanza Inc., Lawrence, Massachusetts).

Polar bears could be accurately weighed by taking a heart girth with a cattle weight tape graduated in both inches and pounds (Ketchum Manufacturing Sales Ltd., Ottawa) (Jonkel 1967). Twenty-two polar bears were weighed with spring scales, a tripod and net, and with the cattle weight tape during 1966–68. Figure 4 shows the relationship between the two weights. A high correlation ($R = 0.97$) was calculated so that subsequently all bears were weighed using the cattle weight tape because of its greater convenience. Some bears handled by MDRRTS were also weighed using spring scales.

Table 4 lists the dates and areas covered during tagging operations carried out by CWS and MDRRTS in Manitoba 1966–75.

Since 1970, the traplines in the Churchill area were operated in the fall as part of the fall depredation survey carried out each year by MDRRTS.

2. Data collected from polar bears killed accidentally, in control operations (problem bears), and by Inuit and Indians

The CWS paid a reward for the return of eartags from bears that were killed by native people in the course of their hunting. Whenever

possible, skulls, reproductive organs, fat, liver, and muscle samples for pesticide and heavy metal analysis (Bowes and Jonkel 1975) were also purchased. Attempts were made to obtain data on the size of the animal, standard measurements, stomach contents, and any other relevant information. Few polar bears are killed by native peoples (mainly Indians) in Manitoba because hunting is allowed only for subsistence purposes. Consequently there were few tag returns from that source. Some tags have been recovered from Inuit living in the southern Keewatin District, NWT, and also from problem bears killed in self-defence or in the interests of public safety. Problem bears are confined mainly to the Churchill area. In the NWT, a native person in each community was paid for collecting and shipping specimens and data to the CWS. In some cases, NWT Fish and Wildlife Officers assisted in the collection and shipping of specimens and data. There was, however, a great deal of variation in the quality of the data actually obtained.

3. Use of aerial and ground surveys

3.1. Summer and fall surveys

Surveys of numbers of bears and their distribution have been conducted by CWS, MDRRTS, and the Ontario Ministry of Natural Resources (OMNR) during the ice-free periods of the year since 1963. Both fixed-wing aircraft and helicopters have been used extensively. One ground survey was carried out on foot in August 1968. Table 5 lists the dates and areas covered during surveys carried out to estimate bear numbers and distribution during the ice-free part of the year. Most surveys followed the coastline close to the high tide line. The coastal surveys were carried out by MDRRTS between Churchill and the Ontario border concurrently with waterfowl enforcement flights. The surveys carried out by OMNR covered the southern coastal area between Anabusko Island and the Ontario border and formed an extension of their annual surveys along the Ontario coast carried out between late August and mid October since 1963 (unpublished reports). Several aerial searches by CWS and MDRRTS using helicopters and fixed-wing aircraft were made inland, in the area between Churchill and the Nelson River. Records of bear numbers in the Churchill area in fall were maintained by MDRRTS as part of the annual fall depredation program.

3.2. Winter surveys

A survey of bear distribution on the sea ice of Hudson Bay was carried out by CWS on 26–27 March 1972. Tracks were counted along two flight lines (32 km apart and heading 70° from Churchill for 450 km over Hudson Bay). A third flight was carried out 32 km to the north and heading in the same direction for 128 km but then turned 35° towards Southampton Island for 320 km. The survey was carried out from fixed-winged aircraft flying at 150 m and 240 km/h. Tracks were totalled every 8 minutes (32 km).

3.3. Denning-productivity surveys

CWS and MDRRTS conducted polar bear maternity denning surveys beginning in 1970, to determine the extent and productivity of these areas in Manitoba (Robertson 1970 and 1971, Cross 1972, 1973, 1974*b*, 1975*b* and 1976*b*; Jonkel *et al.* 1972). The first survey in 1970 was planned to overlap the estimated peak time of emergence, based on available information (Uspenski and Chernyavski 1965, Harington 1968, and reports from local Indians).

Several surveys of the same areas were flown at approximately weekly intervals each spring (Table 6). The actual timing of the surveys was

Table 5
The number of polar bears counted in Zone A[1] during ice-free period of year, 1963–75

				No. of polar bears observed				
				Along coast				Inland
Year	Date	Agency	Type of survey	NWT border – Churchill	Churchill – York Factory	York Factory – Ontario border	Total Manitoba	Churchill – York Factory
1963	25–29 Aug.	OMNR	aerial	—	—	12*e*	—	—
1964	4 Aug.	OMNR	aerial	—	—	10*e*	—	—
1965	25–27 Aug.	OMNR	aerial	—	—	12*e*	—	—
1966	26–27 Sept.	OMNR	aerial	—	—	2*e*	—	—
1967	29–31 Aug.	OMNR	aerial	—	—	3*e*	—	—
	26–28 Sept.	OMNR	aerial	—	—	4*e*	—	—
1968	8 Aug.	CWS	aerial	—	0*a*	—	—	—
	8–18 Aug.	CWS	ground	—	3*a*	—	—	—
	14 Aug.	OMNR	aerial	—	—	34*e*	—	—
	21 Aug.	CWS	aerial	—	23	5	—	—
	27 Aug.	CWS	aerial	—	56	32*f*	—	—
	24 Nov.	MDRRTS	aerial	—	121*b*	—	—	—
1969	7–19 Aug.	CWS	aerial	—	99	82	—	20
	28–29 Aug.	OMNR	aerial	—	—	48*e*	—	—
	1 Sept.	MDRRTS	aerial	—	84	—	—	—
	4 Sept.	MDRRTS	aerial	—	—	23*f*	—	—
	6 Oct.	CWS	aerial	—	34*c*	—	—	—
	6–7 Oct.	OMNR	aerial	—	—	13*e*	—	—
	23 Oct.	CWS	aerial	—	56*b*	—	—	—
	7 Nov.	MDRRTS	aerial	—	93*d*	—	—	—
1970	21 Aug.–5 Sept.	CWS	aerial	—	64	59	—	19
	26–27 Aug.	OMNR	aerial	—	—	8*e*	—	—
	1 Sept.	MDRRTS	aerial	—	39	22	—	—
	24–28 Sept.	OMNR	aerial	—	—	1*e*	—	—
	4 Nov.	CWS	aerial	—	112*d*	—	—	—
	5 Nov.	CWS	aerial	—	150*b*	—	—	—
	7 Nov.	CWS	aerial	—	30*d*	—	—	—
	9 Nov.	CWS	aerial	—	119*a*	—	—	—
	11 Nov.	MDRRTS	aerial	—	92	8*g*	—	—
1971	23–24 Aug.	OMNR	aerial	—	—	23*e*	—	—
	1 Sept.	MDRRTS	aerial	—	103	—	—	—
	12 Sept.	MDRRTS	aerial	—	—	20*f*	—	—
	14 Oct.	MDRRTS	aerial	—	75	—	—	—
	16–17 Oct.	OMNR	aerial	—	—	0*e*	—	—
	26 Oct.	MDRRTS	aerial	—	—	66	—	—
	9 Nov.	MDRRTS	aerial	—	169	37*f*	—	—
	16 Nov.	CWS	aerial	—	96*d*	—	—	—
	17 Nov.	MDRRTS	aerial	—	187	—	—	—
	21 Nov.	CWS	aerial	—	68*i*	1	—	—
1972	9 Aug.	MDRRTS	aerial	—	63	—	—	18
	29–30 Aug.	OMNR	aerial	—	—	15*e*	—	—
	1 Sept.	MDRRTS	aerial	—	69	—	—	—
	4 Sept.	MDRRTS	aerial	—	69	27	—	—
	8 Sept.	MDRRTS	aerial	—	—	22*f*	—	—
	11 Sept.	MDRRTS	aerial	—	—	14*f*	—	—
	14–15 Sept.	MDRRTS	aerial	—	56	20	—	20
	1–3 Oct.	CWS	aerial	—	—	—	—	29
	10–11 Oct.	MDRRTS	aerial	—	39*a*	8	—	3
	27 Oct.	MDRRTS	aerial	—	135	—	—	—
	2 Nov.	MDRRTS	aerial	—	35*b*	—	—	—
1973	14–16 Aug.	MDRRTS	aerial	8	113	34	155	—
	22 Aug.	MDRRTS	aerial	—	104	25*f*	—	—
	31 Aug.–1 Sept.	MDRRTS	aerial	—	130	31	—	—
	8 Sept.	OMNR	aerial	—	—	16*e*	—	—
	13 Sept.	MDRRTS	aerial	—	86	9*f*	—	—
	19 Sept.	MDRRTS	aerial	—	—	6*f*	—	—
	26–27 Sept.	MDRRTS	aerial	—	109	19*f*	—	—
	2 Oct.	MDRRTS	aerial	—	105	—	—	23
	20 Oct.	MDRRTS	aerial	—	126	—	—	—
	8 Nov.	MDRRTS	aerial	—	120	—	—	—

Table 5 continued
The number of polar bears counted in Zone A[1] during ice-free period of year, 1963–75

Year	Date	Agency	Type of survey	No. of polar bears observed				
				Along coast				Inland
				NWT border – Churchill	Churchill – York Factory	York Factory – Ontario border	Total Manitoba	Churchill – York Factory
1974	5 July	MDRRTS	aerial	—	4	—	—	—
	2–3 Aug.	MDRRTS	aerial	—	12	33*f*	—	—
	5 Aug.	MDRRTS	aerial	—	—	42*f*	—	—
	20 Aug.	MDRRTS	aerial	8	119	25	152	—
	30 Aug.	OMNR	aerial	—	—	15*e*	—	—
	12 Sept.	MDRRTS	aerial	—	—	23*f*	—	—
	21 Sept.	MDRRTS	aerial	—	—	19*f*	—	—
	7 Oct.	MDRRTS	aerial	—	94	—	—	—
	23 Oct.	MDRRTS	aerial	—	121*a*	—	—	—
	8 Nov.	MDRRTS	aerial	—	117*h*	—	—	—
1975	5 Aug.	MDRRTS	aerial	—	37	2	—	—
	18 Aug.	MDRRTS	aerial	—	—	31*f*	—	—
	28 Aug.	MDRRTS	aerial	—	23	29	—	—
	31 Aug.	MDRRTS	aerial	—	49	—	—	—
	2 Sept.	MDRRTS	aerial	1*k*	—	—	—	—
	3 Sept.	OMNR	aerial	—	—	19*e*	—	—
	4 Sept.	MDRRTS	aerial	—	—	—	—	0*l*
	8–9 Sept.	MDRRTS	aerial	—	65	31	—	—
	13–14 Sept.	MDRRTS	aerial	1	32	14*f*	—	—
	19 Sept.	MDRRTS	aerial	—	19*j*	—	—	—
	21 Sept.	MDRRTS	aerial	—	—	15*f*	—	—
	13 Nov.	MDRRTS	aerial	—	107*a*	—	—	—

a Churchill – Broad River
b Churchill – Thompson Point
c Churchill – Owl River
d Churchill – Cape Churchill
e Anabusko Island – Ontario border
f York Factory – Kaskattama River
g York Factory – Cape Tatnam
h Churchill – Rupert Creek
i Includes sightings on adjacent newly-formed ice
j York Factory – Broad River
k Churchill – Knife River
l Churchill – Gillam (inland)

Table 6
Dates of spring polar bear maternity denning surveys in Manitoba, 1970–76

	Year						
No. of survey	1970	1971	1972	1973	1974	1975	1976
1	4–6 March	18 February	15–16 February	12 February	19–23 February	18–22 February	24 February
2	16–17 March	25 February	29 February – 1 March	27 February – 1 March	27 February – 1 March	4 March	2–5 March
3	25 March	1–3 March	7–8 March	6 March	7–8 March	10–12 March	9–10 March
4	1 April	11–12 March	13–14 March	13–16 March	11–15 March	18–19 March	24–25 March
5		15–18 March	21–28 March	20–21 March	20–22 March		
6		24–26 March	23–27 March	26 March	27–30 March		
7					4–8 April		
Total no. of surveys	4	6	6	6	7	4	4

dependent on weather conditions. It became apparent on the first survey that some females left their dens earlier than late March. Consequently, after 1970 (except for 1976), the earliest surveys were flown in mid-February. Surveys continued up to the end of March except for 1974 when they continued until 8 April. In 1976 the first survey was flown on 22 February. In October and early November 1970 and 1973, the Owl River area was searched for pregnant females preparing to den.

The 1970 spring surveys were concentrated in the suspected denning area inland between the Broad River and Rupert Creek. This area, particularly north of the tree-line and extending from 5 to 60 km inland, was most thoroughly and most often surveyed in all years. After 1970, the Fletcher – Sutton lakes area, north of the Broad River was also thoroughly searched but less frequently. Surveys of the Cape Tatnam area between the Hayes River and the Ontario border have been flown each year since 1971. The number of surveys each year has varied considerably (five in 1974, one in 1976) and coverage has been limited. Each survey has consisted of one flight close to the tree-line (2 to 10 km inland) and one straight-line flight some distance inland varying from 15 to 85 km, and extending from the Hayes River to the Kaskattama River, the Kettle River, or the Ontario border, depending on the survey. Only cursory surveys of other areas up to about 70 km inland have been made. In 1972 the area west of the Churchill River, southwest of Churchill, was briefly surveyed. In 1973, 1974, and 1975, surveys were conducted northwest of Churchill as far north as the Knife River, north of the Caribou River, and Seal River respectively.

All surveys carried out by MDRRTS were conducted from fixed-wing aircraft flying at 30–120 m and 145–185 km/h depending on the type of aircraft used and weather conditions. One helicopter survey, carried out by CWS from 23 to 27 March 1972, was concentrated in the Fletcher – Sutton lakes area. This flight was at 20–60 m and 90–190 km/h. Most flight paths kept close to the tree-line or along creek and river valleys and lake shores where the snow banks and softer snow on the sheltered and partially treed banks presented more favourable tracking conditions than on the windswept lakes and in other treeless areas. Although general flight paths were planned, many deviations were made to track family groups and because of adverse weather conditions. In some cases, flights were delayed, curtailed or cancelled altogether for a variety of reasons.

Data were recorded on possible maternity dens, females seen with young, tracks of females with young, and litter sizes. When possible,

tracks were followed in both directions to locate the vacated maternity den and the emerged bears. Possible den sites were searched for breakout holes and evidence of bear activity. In 1970, helicopter landings were made at several suspected maternity den sites and den dimensions were taken. Den sites had previously been marked with flare tape tied to nearby trees. Duplication of bear observations was reduced by carefully recording only once the tracks and sightings of each family group. As judgement was subjective, the possibility of duplication remained. In instances where the number of cubs accompanying a female could not be determined from the tracks, these observations were not included in the track records but were allowed for in the estimated totals. No allowance was made for bears which may have emerged before or after the surveys. It is not known to what extent variable weather conditions during a survey (from survey to survey and from year to year) influenced observations and consequently the estimated totals. In March 1973 alternating warm and cold temperatures resulted in melting and refreezing of the snow, which made differentiation between old and new tracks difficult. A more accurate count is possible if a snowfall occurs between surveys, thus erasing previously recorded tracks.

Additional information was obtained from the Indians in the Churchill area, during summer denning surveys, and from historical sources. On 15 March 1972, with the aid of a helicopter, MDRRTS tagged one family group in the maternity denning area.

4. Radio tracking

From 1967 to 1970, 23 individual bears were tagged with radio collars (Anderka *et al.* 1973) to determine when the bears headed out on to the ice or, in the case of pregnant females, when they headed inland to den in the fall. Four of these bears were radio-tagged in two different years. The selection of bears to be radio-tagged was based on information from previous captures and on age and sex. All bears were eartagged.

Searches for radio-marked bears were conducted by truck, fixed-winged aircraft (Aztec), and various types of helicopters. Ground observations were made by truck in the immediate Churchill and Fort Churchill areas, mainly during the first month after the transmitters were placed on bears.

As the bears moved away from Churchill, either to Cape Churchill or onto the sea ice, they were generally re-located from fixed-wing aircraft. Initially, flight paths were random, following the shore, looping inland where bears were known to travel, and covering any new ice surfaces. As the floe edge of the ice moved outwards from shore, and large pans began to form out from the floe edge, flights were concentrated over the ice, especially north of Cape Churchill along the Keewatin coast. By the time Hudson Bay became largely ice-covered, usually by late December, flights followed a box pattern extending to about 250 km north of Churchill – Cape Churchill, and 300 km between lines. Flights were normally at 150 m when visual tracking was possible, and at 30 m if not. Searches by helicopter were usually made in limited areas to locate specific animals. These flights were conducted in a random manner, close to the ground, and in combination with visual observations.

5. Age determination

Preliminary estimates of ages were made in the field by the degree of tooth wear and the size and condition of the bear. Bears with milk canines or very small permanent canines were aged as cubs of the year (i.e. <1 year old) and no tooth was taken.

Ages were further refined by histological sectioning and staining of premolar teeth taken from immobilized bears and from skulls of bears killed by native hunters, in self-defence, or during the fall depredation surveys. The methods of Marks and Erickson (1966), Stoneberg and Jonkel (1966) and Thomas and Bandy (1973), modified by H. P. L. Kiliaan, were followed (Stirling *et al.* 1977).

When skeletal material was available, morphometric data, particularly from the skull (after Manning 1964) were used to aid in the determination of age.

6. Other sources of information

Anecdotal information on polar bears was available from many sources. Additional data were obtained from old reports, historical journals, private diaries, expedition accounts, Hudson's Bay Company fur records, Royal Canadian Mounted Police, pilots and other personnel familiar with the area. The quality and accuracy of such information varied considerably with the type of individual it was collected from, and the period of time that had elapsed between the observation and when it was reported. All data were scrutinized closely and corroborated whenever possible.

1. Discreteness of sub-populations

From 1966 to 1975 a total of 227 polar bears were tagged in Manitoba, 176 of which were in the Churchill area (Fig. 5). During the autumns of 1967 to 1970, radio collars were attached to 23 previously tagged polar bears (Anderka *et al.* 1973). Table 7 summarizes the results of the tagging programs carried out in Manitoba since 1966. Between 1968 and 1973, 29 bears were tagged on the northern Ontario coast including the Cape Henrietta Maria area, and 50 in the James Bay – Belcher Islands area (Jonkel *et al.* 1976). No bears were tagged in Hudson Bay north of a line from Churchill to Port Harrison. Eighteen bears were tagged in Foxe Basin, to the north of Southampton Island, in the summer in 1973. To date none have been recaptured or are known to have been killed in Hudson Bay.

No interchange has been recorded between polar bears tagged on the Manitoba coast and those marked in the southern Hudson Bay and James Bay areas (Figs. 6 and 7). The lack of recorded movement may be partially explained by the fact that mark and recapture programs along the Hudson Bay coast south of the Churchill area were limited. Of an estimated 120 bears killed between 1967 and 1976 by Indian hunters from Fort Severn and Winisk, Ontario (see Table 8), only three tagged bears were reported, and all were from the Ontario coast.

On the basis of no recorded interchange, the Federal–Provincial Technical Committee, in January 1972, designated the polar bears of the Manitoba coast as a separate sub-population (Zone A^1) from those of Ontario (Zone A^2) and the James Bay – Belcher Islands area (Zone A^3) (Figs. 1 and 9). The northern boundary of Zone A^1 sub-population, however, appears to be north of Manitoba. The bears that were radio-tracked out on to Hudson Bay after freeze-up moved north (Fig. 8) and eight bears tagged near

Figure 5
Polar bear tagging locations on the Manitoba coast,
Oct. 1966 to Nov. 1975

Figure 5

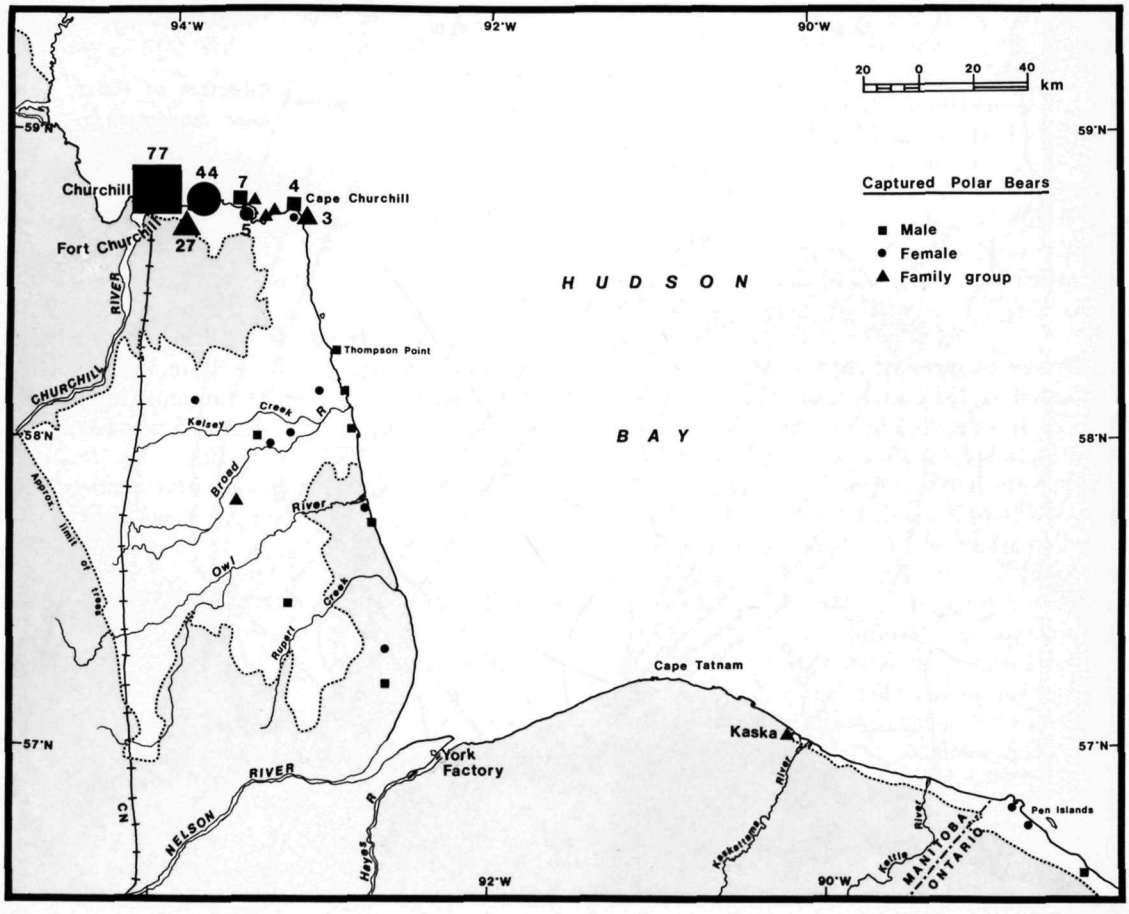


Figure 6
Recorded movements of tagged polar bears recaptured, observed, or killed in Manitoba after more than 6 months, 1966–75. Movements of tagged bears within the Churchill area, released at Kaska, or killed by Inuit are not included

Figure 7
Recorded movements of tagged polar bears in western Hudson Bay, recaptured, observed or killed within 6 months, 1966–75. Radio-tracking movements and movements within the Churchill – Cape Churchill area are not included

Figure 6

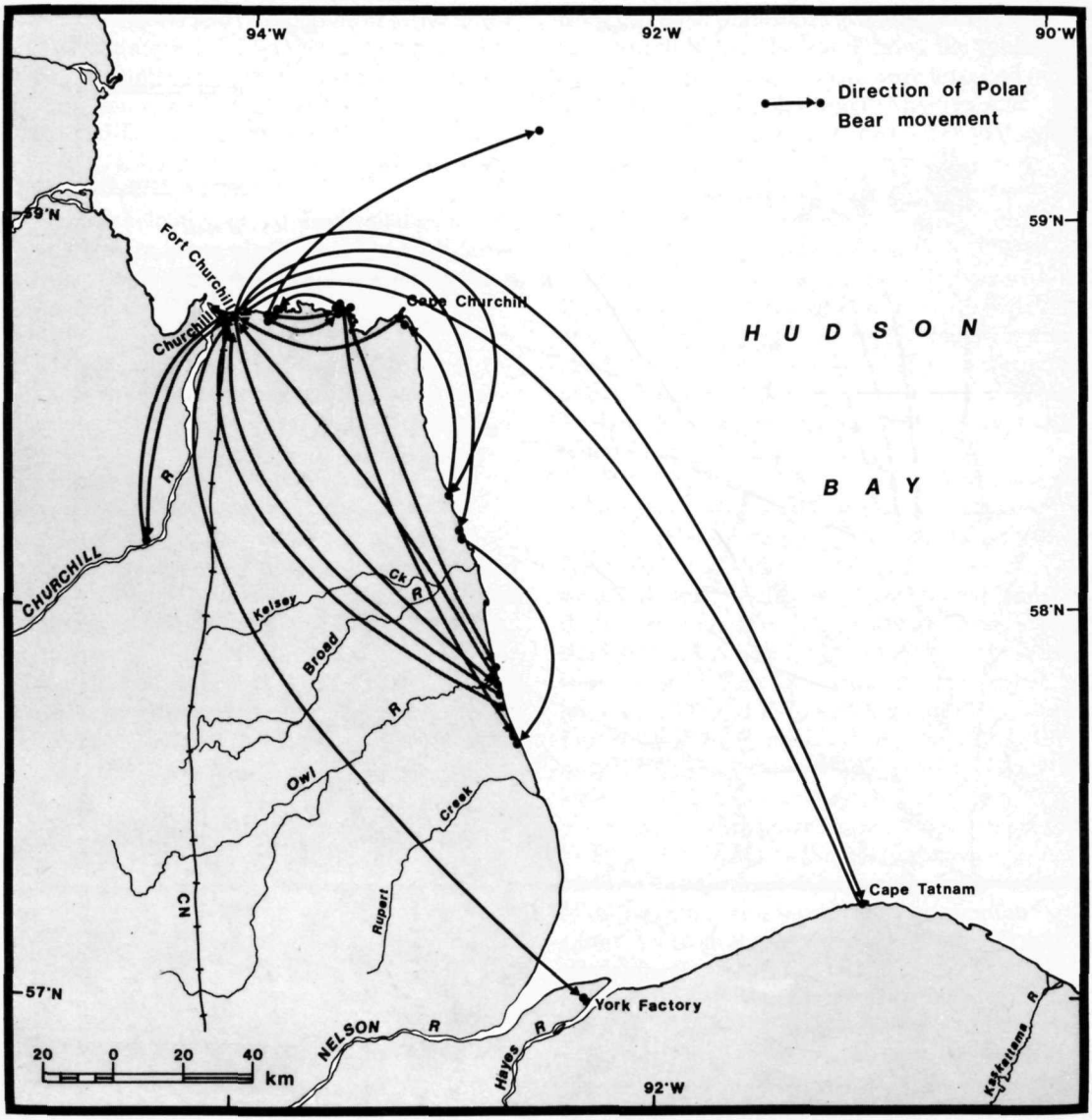


Figure 7

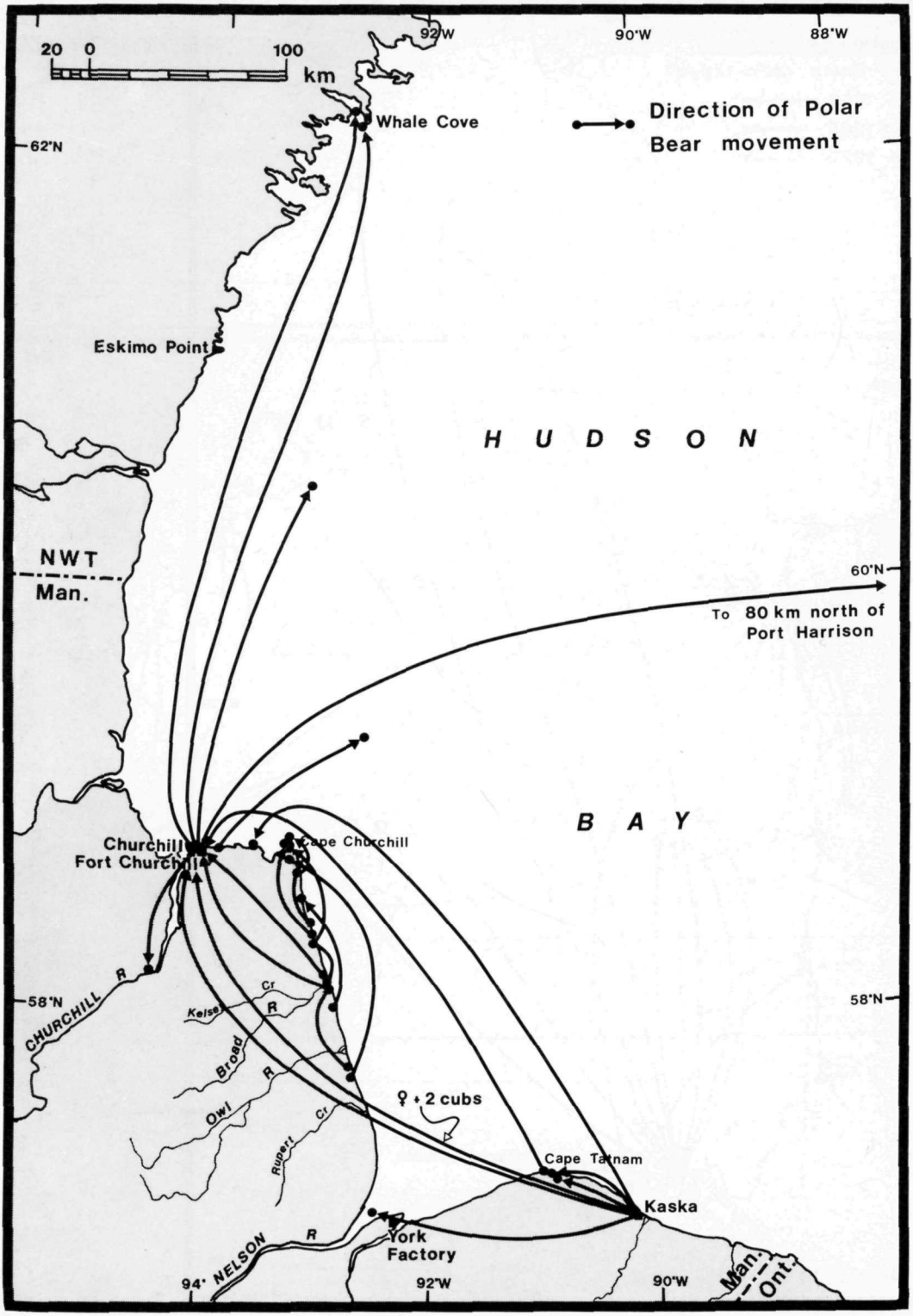

20 0 100
km
92°W
90°W
88°W
Whale Cove
Direction of Polar Bear movement
62°N
Eskimo Point
HUDSON
NWT
Man.
60°N
To 80 km north of Port Harrison
BAY
Churchill
Fort Churchill
Cape Churchill
58°N
CHURCHILL R.
Kelsey Cr.
Broad R.
Owl R.
Rupert Cr.
♀ + 2 cubs
Cape Tatnam
Kaska
York Factory
NELSON R.
94°
92°W
90°W
Man.
Ont.

Figure 8

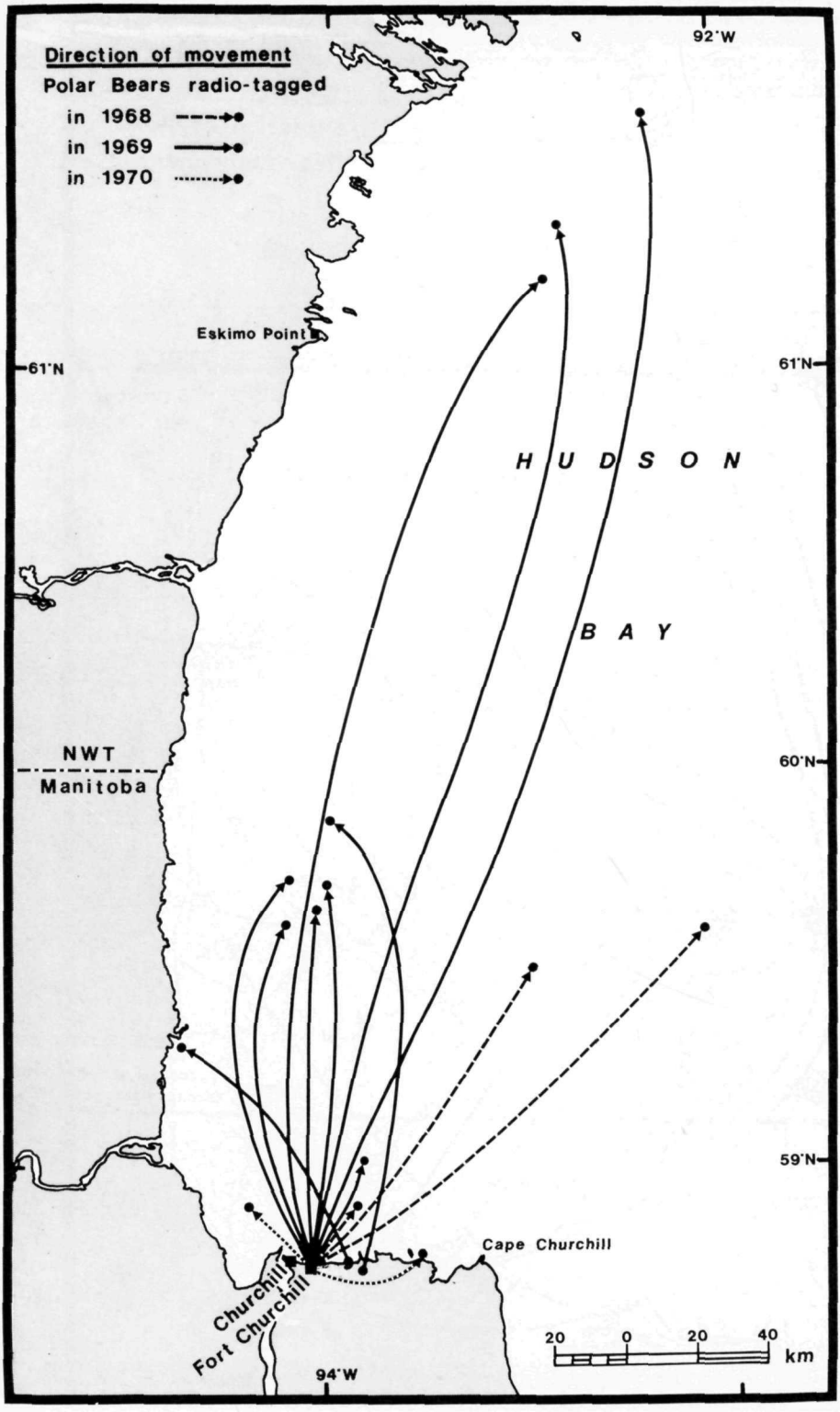

Direction of movement
Polar Bears radio-tagged
in 1968
in 1969
in 1970
92°W
Eskimo Point
61°N
61°N
HUDSON
BAY
NWT
Manitoba
60°N
59°N
Cape Churchill
Churchill
Fort Churchill
94°W
20 0 20 40
km

Figure 8
Recorded movements of radio-tagged bears from tagging location to last radio-location position, 1968–70

Figure 9
Recorded movements of tagged bears killed by Inuit outside Manitoba

Figure 9

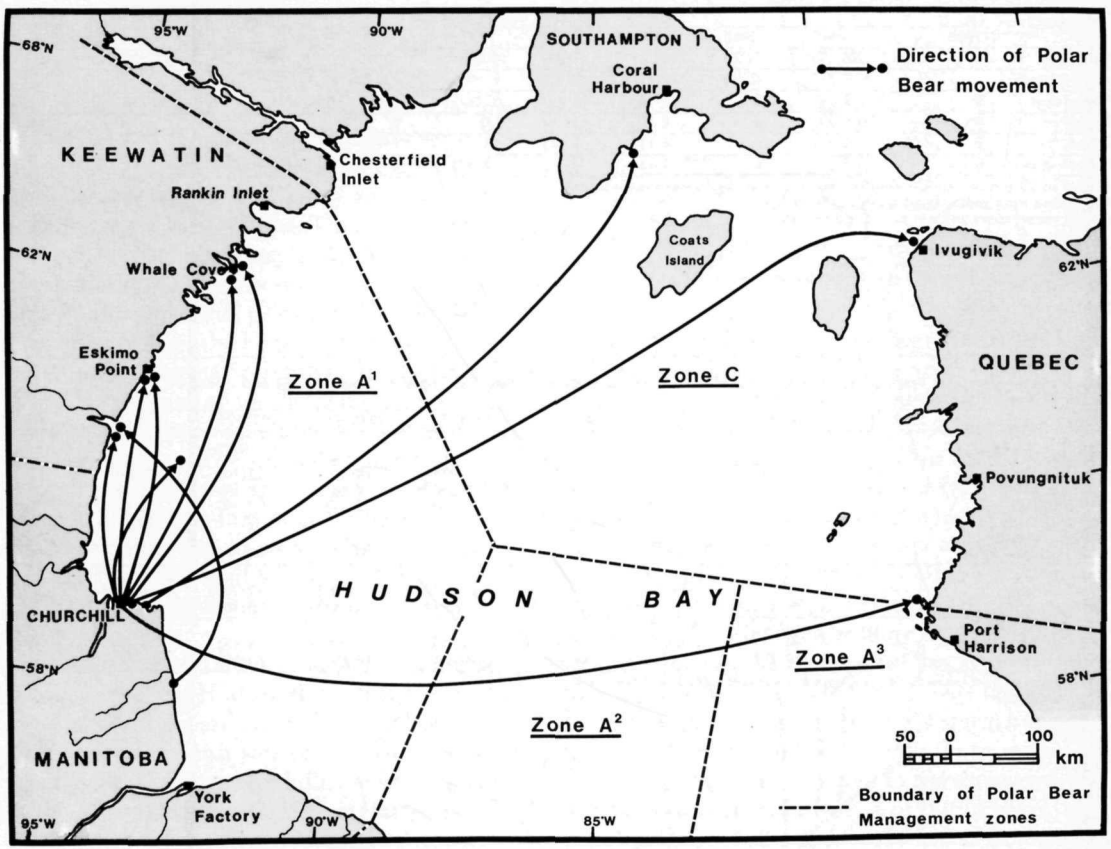


Table 7
Number of polar bears tagged in Manitoba and recaptured or resighted (after 6 months), killed or sent to zoos, 1966–75.
Values in brackets are for the Churchill area

	No. of tagged polar bears									
	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	Total
Ear-tagged	4(1)	15 (7)	15(10)	36(25)	41(22)	40(38)	18(15)	8 (8)	28(28)	22(22)	227(176)
Radio-tagged		1 (1)	6 (6)	12(12)	8 (3)						27(22)*
Recaptured	0	1 (1)	2 (2)	4 (4)	14 (9)	17(15)	14(12)	13(12)	12(12)	18(17)	95(84)†
Resighted	0	0	1	2	0	0	0	0	0	0	3 †
Killed	0	1 (1)	0	4 (1)	5 (3)	1	7 (4)	7 (7)	2 (2)	7 (7)	34(25)
Sent to zoos	0	0	0	1 (1)	0	1 (1)	0	1 (1)	2 (2)	2 (2)	7 (7)

*A total of 23 (18 for the Churchill area) individual bears were radio-tagged.
Four bears were radio-tagged in two different years.
†No. of occurrences and not no. of individuals.

Table 8
Known numbers of polar bears killed by settlement, zone and year in western Hudson Bay (Zone A[1], Zone A[2], and part of Zone C) 1967–76
Values in brackets are quotas

	1967–68	1968–69	1969–70	1970–71	1971–72	1972–73	1973–74	1974–75	1975–76
Zone A[1]									
Keewatin									
Eskimo Point	— (4)	— (4)	— (4)	5 (5)	3 (5)	10(10)	14(10)	8(10)	16(15)
Rankin Inlet	— (5)	— (5)	6 (5)	3 (5)	2 (5)	7 (8)	8 (8)	5 (8)	10(10)
Whale Cove	—	—	5 (4)	7 (4)	2 (4)	9 (7)	7 (9)	7 (7)	6(12)
Churchill Area	4	8	4	6	7	13	7	11	8
Rest of Manitoba	3	—	12	6	—	—	—	—	1
Total for Zone A[1]	7	8	27	27	14	39	36	31	41
Zone A[2]									
Fort Severn	—	—	—	9(10)†	18(10)†	5(10)†	17(10)†	1(10)†	6(10)†
Winisk	—	—	—	1(10)†	—(10)†	1(10)†	8(10)†	7(10)†	6(10)†
Zone C									
Chesterfield Inlet	—	—	6 (5)	2 (5)	5 (5)	5 (5)	5 (5)	5 (5)	4 (8)*
Coral Harbour	74(75)	39(75)	—(75)	66(65)	64(65)	40(65)	65(65)	65(65)	65(65)

*At least three to be taken in NWT Game Management Zone 34 (Zone A[1]).
†Permissible kill.

Table 9
Polar bears tagged in Manitoba and killed outside the Province

No.	Sex	Est. age when tagged	Location tagged	Date tagged		Location killed	Date killed
X549	M	Sub-ad.	Watson Point	18 October	1968	Bear Cove Pt., Southampton I.	10 October 1972
X565	M	Adult	8 km S. Broad R.	11 August	1969	Mouth of Tha-anne R.	2 November 1972
X573	M	Adult	Fort Churchill dump	12 October	1969	5 km SW Eskimo Point	18 October 1970
X732	F	Sub-ad.	Fort Churchill	23 October	1969	Wilson Bay, Whale Cove	17 November 1969
X748	M	Sub-ad.	Fort Churchill	6 October	1971	100 km SSE Eskimo Point	30 April 1973
X2014	M	Yrlg.	Bird Cove	4 November	1971	Ivugivik	August 1972
X2086	M	Sub-ad.	Fort Churchill	7 October	1972	Eskimo Point?	Fall 1973
X2089	M	Cub	Fort Churchill	15 October	1972	10 km NE Whale Cove	2 December 1973
X2263	M	Yrlg.	Fort Churchill dump	13 October	1973	80 km SW Eskimo Point	29 October 1975
X3010	M	Sub-ad.	Fort Churchill	9 October	1974	80 km N Port Harrison	21 March 1975

Churchill are known to have been shot in the NWT (Table 9 and Fig. 9). From 1969 to 1976 at least 140 polar bears were shot by Inuit hunters from Eskimo Point, Whale Cove and Rankin Inlet (Table 8), of which 7 (5%) were known to have been tagged in Manitoba. During the same period at least 397 polar bears were shot by Inuit from Chesterfield Inlet and Coral Harbour (Table 8), of which only one (<0.3%) had been tagged in Manitoba. Thus it appears that the northern boundary of the Manitoba sub-population of polar bears probably lies between Rankin Inlet and Chesterfield Inlet. In recognition of this, the Federal–Provincial Technical Committee, in January 1974, shifted the northern boundary of the Zone A[1] sub-population to that area, so that the best available biological data could be applied to ongoing management practices. The current weakness of this interpretation is that no polar bears were tagged out on the Bay or along the Hudson Bay coast north of Churchill to check on their movements and fidelity in relation to those areas.

The sub-population is probably confined to the western part of Hudson Bay. Only two bears tagged in Manitoba are known to have been taken by hunters on the east side of Hudson Bay (Table 9 and Fig. 9). One bear was killed near Ivugivik and the other 80 km north of Port Harrison, a distance of 875 km from its original capture site. This is the greatest recorded straight-line movement of a bear tagged in Manitoba.

To compare the movements of polar bears on the Manitoba coast, the coast from Churchill to the Ontario border was subdivided into three areas: that immediately surrounding Churchill and east to the rocket range, the La Pérouse Bay area including Knight's Hill, and Cape Churchill to the Ontario border including the inland denning area (Fig. 2). One hundred and seventy-five, 24, and 27 polar bears of all age classes were tagged in the three areas respectively between 1966 and 1975 (Table 10).

Table 10
Number of bears tagged in three areas of Manitoba and resighted (including recaptures, observations, and kills) six months or more late

Area	No. bears tagged	No. bears re-sighted	No. bears re-sighted in area orig. tagged	No. bears re-sighted outside area orig. tagged	No. bears resighted			
					Churchill	La Pérouse Bay	Cape Churchill–Ontario	Elsewhere
Churchill	176	64*	53	13	53	2	5	6
La Pérouse Bay	24	5	1	4	0	1	3	1
Cape Churchill – Ontario	27	5	1	4	3	0	1	1
Total	227	84	55	21	56	3	9	8

*2 bears were resighted both inside and outside Churchill area.

Of the 176 bears tagged in the Churchill area, 63 (36%) were resighted (this includes recaptures, observations, and kills) six months or more later. Resightings were made of 53 bears in the Churchill area and 13 bears outside it (two bears were seen in both places). Of the 24 bears captured in the La Pérouse Bay area, five (21%) were sighted six months or more later. One bear was resighted in the La Pérouse Bay area and four outside that area. Of the 27 bears tagged between Cape Churchill and the Ontario border, five (19%) were resighted six months or more later. One bear was resighted in the same area and four away from it. Only 7 of the 74 bears resighted six months or more later had not been tagged or resighted in the Churchill area. Based on the above information, it is clear that polar bears throughout the Manitoba coastal region belong to the same sub-population.

2. Seasonal distribution and movements

The distribution and movements of polar bears throughout the winter are unknown. It is possible that there is a concentration of bears along the pronounced lead which exists about

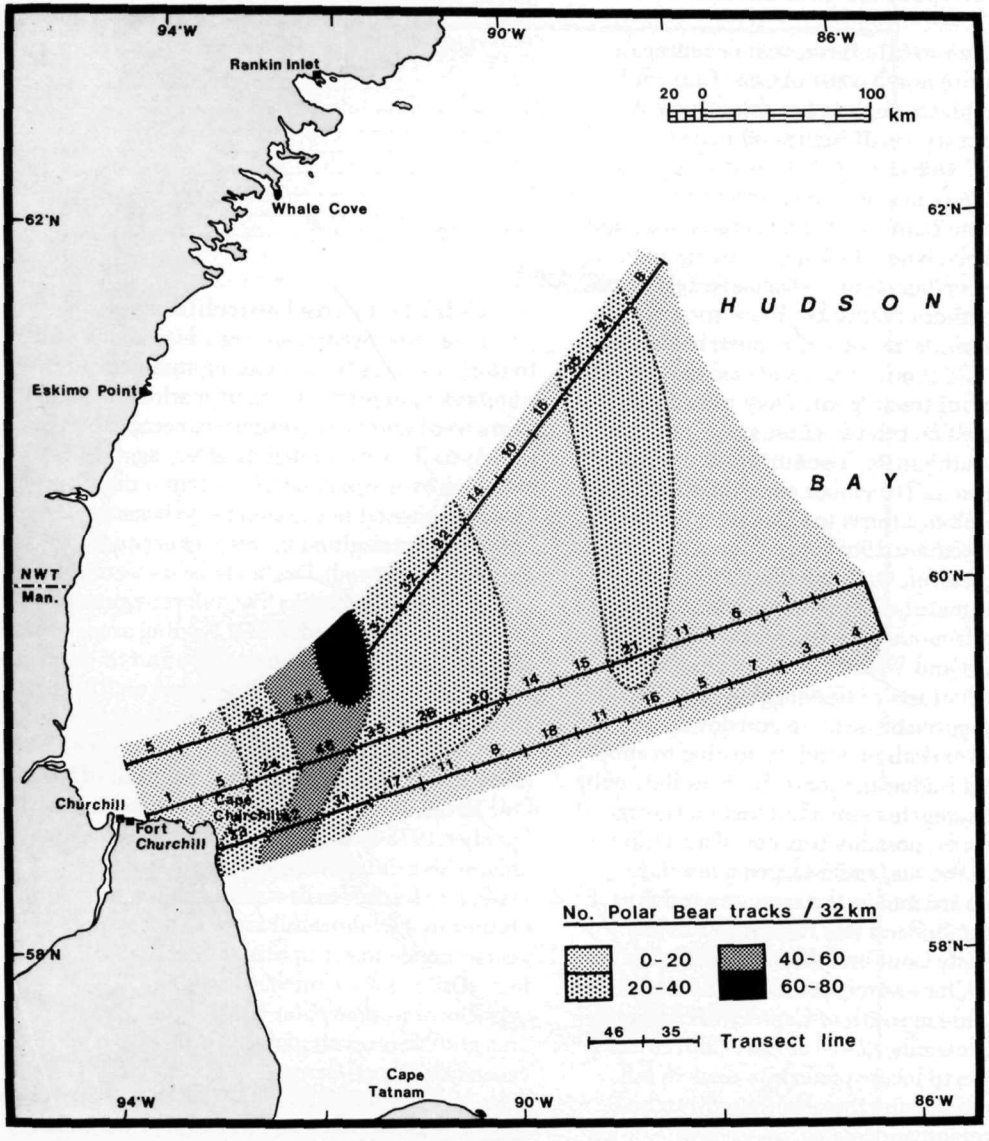
80 km offshore from Southampton Island south to Churchill, similar to that shown in the vicinity of a similar lead system in the Western Arctic (Stirling *et al.* 1975). Movement of bears to this area in the fall after freeze-up has been confirmed through radio-tracking (Fig. 8) and by tag returns from hunter kills off the Keewatin coast (Table 9). The results of the 26–27 March 1972 survey over the sea ice, east and northeast of the Cape Churchill area, also indicate a concentration of bears offshore (Fig. 10). The number of tracks counted on all three transects increased markedly (from <6 tracks/32 km to >40 tracks/32 km) at about 65 km northeast of Churchill and about 16 km east of Cape Churchill. The density of tracks continued to increase (maximum of 80 tracks/32 km) to about 130 km east and northeast of Cape Churchill and then declined gradually towards the centre of the Bay and also towards Southampton Island. Whether this pattern of distribution is the same throughout the winter months and from winter to winter is unknown. During the spring and summer, the last substantial remnants of ice melt and dissipate off the southern Manitoba and Ontario coasts of Hudson Bay (Fig. 3). The polar bears probably stay on the ice as long as they can and when it finally melts they go ashore on the adjacent coast. Once ashore, they tend to congregate along the coast on the capes and headlands, possibly because of a cooling effect from the sea, and slowly move northward. The northward movement may be related to the freeze-up in Hudson Bay, which begins in the area north of Cape Churchill. Thus polar bears would be able to return to the ice to hunt seals earlier if they moved north after coming ashore.

Some movements of marked individuals have been documented. For example, an adult male first observed on 10 August 1969, 10 km north of the Broad River (Fig. 7), was resighted on 22 October 12 km north at Thompson Point where he remained for 2 days, and by 29 October he had moved an additional 50 km north to 5 km south of Cape Churchill. Similarly this same individual was sighted in the following year on 31 August, 15 km south of the Broad River and on 5 November, 115 km further north, 8 km south of Cape Churchill. Personnel stationed at the Decca site near the mouth of the Broad River in 1969 and 1970 also observed a northward movement of bears along the coast, during the ice-free period of the year.

Results of summer coastal surveys show a marked under-representation of females with young, especially considering that an estimated 150 cubs are produced each year in the Manitoba denning areas. This apparent anomaly may be explained by the spatial distribution of polar bears. The proportion of the total number of bears in the coastal areas (i.e. <1 km inland) which were adult males (49/82 or 60%) was much greater than farther inland (27/67 or 40%) in late August to early September 1970. Groups of large adult male bears were observed in the coastal areas but not inland. Family groups appeared to be more prevalent inland, in the denning area. Thirty-one per cent of the bears (21/67) observed inland belonged to family groups ($n = 8$) compared to 6% (5/82) along the coast ($n = 2$). Estimates of the proportion of sub-adults for the two areas are not given because it is difficult to differentiate between sub-adult males and adult females on the basis of sight alone, and we cannot be certain of consistency in the records of different observers.

Once bears reach the Churchill area they appear to remain there until ice forms along the coast. Although tagged individuals were not sighted daily they were recorded sporadically throughout the ice-free period after their arrival. Several bears have been recorded as remaining in

Figure 10
Polar bear track density on the annual ice of Hudson Bay, 26–27 March 1972



the area for 30 to 40 days and in 1970 one adult male was reported in the Churchill area for 74 days.

As the ice starts to form, bears congregate along the entire north coast of Cape Churchill, especially at places such as Fox Islands off Watson Point and the small islands off Cape Churchill (Fig. 2). On 7 October 1974, 13 bears were observed on Cape Churchill. By 23 October and 8 November, the numbers had increased to 47 and 58 respectively. Once the ice is thick enough, the bears move northeastward, approximately parallel to the northern Manitoba–Keewatin coast (Anderka *et al.* 1973). In 1968, three bears were tracked for 1½ months until they moved out onto the Hudson Bay ice (Fig. 8). They were an adult female with 10-month-old cubs, a sub-adult male, and a sub-adult female. The sub-adult male was last located on 12 December over 100 km northeast of Churchill. Efforts to relocate them between 20 December 1968 and 14 January 1969 were unsuccessful. On 1 January 1970, three radio-tagged male bears were relocated about 50 km offshore from the Keewatin coast, between Eskimo Point and Whale Cove, approximately 300 km north of their radio-tagging site (Fig. 8). The bears apparently hunt up and down the coast wherever seals abound, returning to shore the following July as the ice of Hudson Bay melts again. For example, a sub-adult male was originally captured in the dump at Fort Churchill on 12 October 1969 and radio-tagged a few days later. He was tracked in the same general area until 5 November and was relocated 105 km south of Whale Cove on 1 January 1970. On 28 August 1970, he was recaptured in the Broad River area, 60 km south of Cape Churchill, and again on 1 November 1970 at Fort Churchill.

Attempts to locate maternity dens in fall 1970 by radio-tagging females thought to be pregnant were unsuccessful.

Table 11
Summary of the number of different years in which polar bears were resighted, recaptured, or killed after tagging

No. years spanned by resightings	No. different years *after* tagging in which bears were resighted			
	1	2	3	4
1	25	—	—	—
2	1	7	—	—
3	4	6	3	—
4	2	1	1	1
5	1	—	—	—
6	—	—	2	1
7	—	1	—	—
Total no. bears (56)	33	15	6	2

3. Fidelity to the Churchill area

Polar bears showed a high degree of fidelity to the Churchill area. Table 11 summarizes the numbers of different years over which tagged bears were observed (resighted, recaptured, or killed) in the Churchill area after tagging. The duration over which bears return to the Churchill area was biassed to the short side because seven of the bears resighted in years subsequent to tagging were removed. Two male bears were recorded in the Churchill area in five different autumns.

Knowledge of particular feeding areas was also transmitted from one generation to the next. One female, originally tagged on 22 August 1968 as a yearling cub with a female sibling and her mother in the Churchill area, was recaptured alone on 30 August 1970, at the mouth of the Owl River. On 11 October 1971, and again on 15 October 1975 she was recaptured in the Churchill area, with a cub of the year. On 7 November 1969, two female cubs were captured with their mother in the Churchill area. In subsequent years, independent sightings of all three bears were made in the Churchill area.

The arrival of polar bears in the Churchill area and their feeding on the dump each autumn causes an annual danger to the human population. In 1971, MDRRTS decided that if necessary they would destroy as many as 50 problem bears

Figure 11
Recorded movements of tagged polar bears released at Kaska, Manitoba, 1971–75

Figure 11

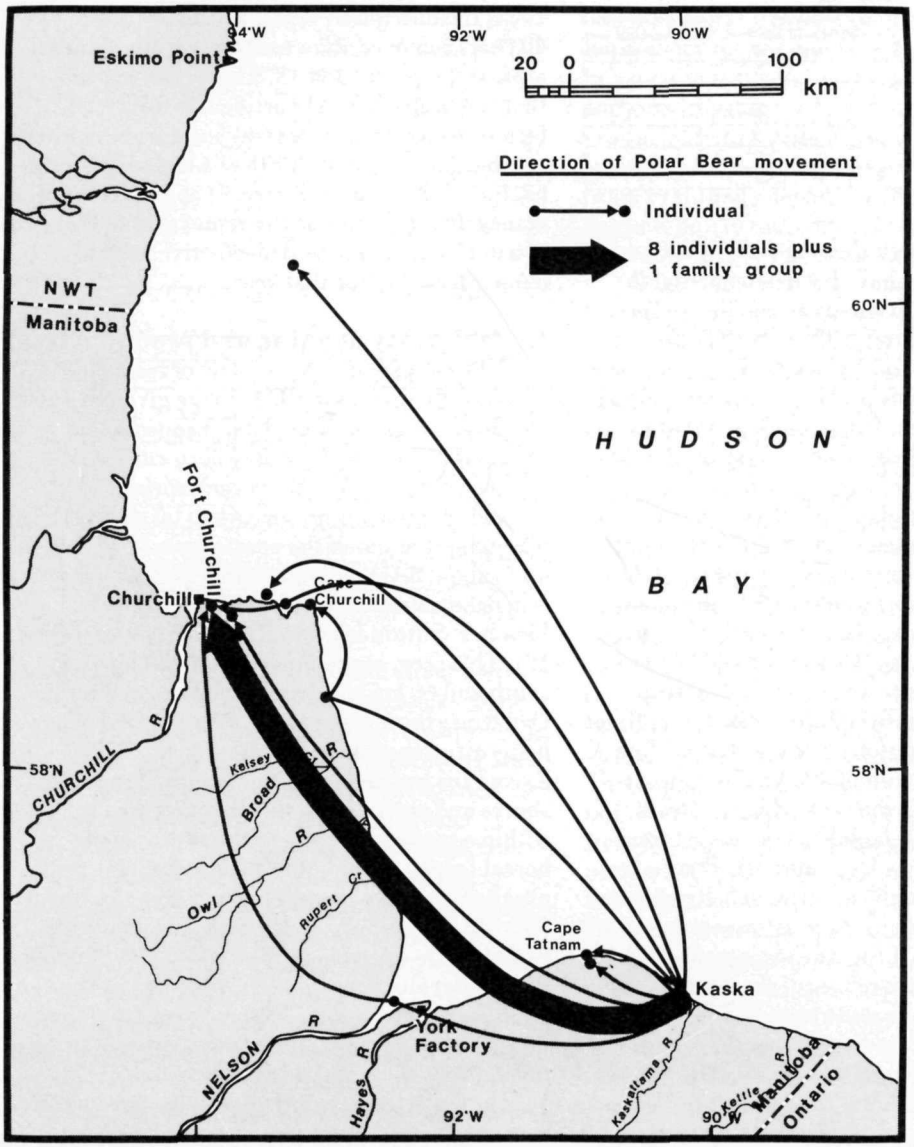


Table 12
Number of tagged polar bears released at Kaska by year, and number of bears resighted later in the Churchill area

Year	No. tagged bears released	No. resighted in Churchill area same year	Total no. resighted in Churchill area in all years
1971	19	3	9
1972	4	0	1
1973	0	0	0
1974	10	3	3
1975	7	0	0
Total	40	6	13

at Churchill. Although the removal of that number of bears may not have been detrimental to the sub-population, it was unacceptable to the conservation community. Thus in 1971 the International Fund for Animal Welfare requested authorization to airlift problem bears and release them in another area. It was suggested that the bears be released on the coast of Ungava Bay or Labrador where polar bear numbers are less numerous (Smith *et al.* 1975). However, this suggestion was rejected because the cost would be too great and the mixing of gene pools of different sub-populations would nullify the possibility of subsequent studies of geographic variation within the species. Thus, it was decided to move problem bears to an abandoned airstrip (Kaska), near the mouth of the Kaskattama River on the southern Manitoba coast, a straight-line distance from Churchill of 300 km, or approximately 480 km along the coast (Fig. 1). Bears were captured and immobilized in culvert traps and then loaded into a DC-3 aircraft. They were released at Kaska on the airstrip, usually without further drugging. Figure 11 illustrates the recorded movements of the bears released at Kaska. Of the 40 tagged bears released, six returned to the Churchill area the same year, before the ice had formed on Hudson Bay (Table 12). Three male polar bears released at Kaska in late October 1971 returned to the Churchill area in 14, 15 and 24 days respectively. An adult female with two female cubs of the year took 18 days to make the same journey in late October–early November 1974. In subsequent years, another seven of the 40 bears removed were resighted in the Churchill area, making a total of 13. These data indicate that the bears that were artificially displaced farther south on the coast during autumn moved north again, and that they had a high degree of fidelity to the Churchill area. It appeared that as a management technique the removal of polar bears to a different area provided effective but only temporary relief for that year.

4. Maternity denning and productivity

The estimated annual totals of females and cubs for Manitoba for 1970–76 are given in Table 13. On the basis of these data, it appears that about 80 females and 150 newborn cubs leave maternity dens in Manitoba each spring.

Although denning appears to take place throughout much of the coastal area of Manitoba, up to about 80 km inland south of Churchill, most is concentrated 30 to 60 km inland in the Fletcher–Sutton lakes to Rupert Creek area (Fig. 12). This area, approximately 100 km north to south and 60 km east to west and centred on the Owl River Basin, is referred to as the Owl River maternity denning area (Jonkel *et al.* 1972). Except for isolated open tree stands along lake shores and river banks, this denning area is within a treeless enclave in the surrounding boreal forest. In mid-March 1969, Indians trapping beaver in this area reported seeing tracks of 30 to 40 female polar bears each with two cubs, except for two females which had three. Six possible maternity dens have been located in the Cape Tatnam area (Fig. 13) but, even from the limited data available, the density appears to be much lower than in the Owl River area (Table 14). In Ontario, maternity denning appears to be widely scattered up to 120 km inland with a slight

Table 13
Number of sightings, tracks, and estimated totals of females and cubs in Manitoba. Data from spring surveys 1970–76

Year	♀ + cub sightings	No. single bears sightings	♀ + cub tracks	No. single bears tracks	♀ + cub est. total	Single bears est. total
1970	23 + 49	0	22 + 42	0	45 + 91	0
1971	16 + 30	0	58 + 107	2	74 + 137	2
1972	13 + 25	0	73 + 135	3	86 + 160	3
1973	17 + 33	2	107 + 212	0	135 + 255	2
1974	27 + 54	1	45 + 82	5	89 + 168	6
1975	17 + 32	2	63 + 122	0	84 + 163	2
1976	11 + 20	0	35 + 66	2	63 + 117	2
Ave.	18 + 35	0.7	58 + 109	1.7	82 + 156	2
Ave. litter size	2.0		1.9		1.9	

Table 14
Number and distance inland of possible polar bear maternity den sites in Manitoba, 1970–76

Year	No. dens Manitoba	No. dens Owl River	No. dens Cape Tatnam	Ave. distance (with range) inland in km
1970	20	20	—	48 (19– 73)
1971	27	27	0	47 (28– 61)
1972	24	24	0	46 (18– 60)
1973	24	21	3	41 (8– 65)
1974	11	10	1	52 (7–150)
1975	9	8	1	48 (32– 75)
1976	14	13	1	49 (19– 75)
Total	129	123	6	47 (7–150)

concentration between the Shagamu River and Ministik Creek, west of Winisk (Kolenosky 1974, 1975 and 1976; Jonkel *et al.* 1976). The Cape Tatnam area may not form a discrete denning area but may be continuous with the areas reported to the east in the Hudson Bay coastal area of Ontario. Unlike parts of the Owl River area, the Cape Tatnam and Ontario denning areas are more densely treed. Tracks of females with young have been observed to the west of the railroad and the Churchill River but as yet no maternity dens have been located.

Female polar bears are thought to give birth to their young (weighing about 0.5 kg) in late December to early January and then remain within the maternity den for several weeks. After breaking out of the maternity den, some time between early February and early April, the family group may remain in the vicinity of the den for several days and then return to it, or the female may dig a temporary den (or dens) nearby, in which to rest and suckle the young. Playing and some digging for food (vegetation, e.g. crowns of bunch grass *Elymus* spp.) often occur around the den during this period before the bears eventually depart for the ice cover of Hudson Bay to hunt seals. Frequent stops and several temporary dens may be made en route.

Some bears may have emerged prior to the first surveys in mid-February. It is unlikely that many emerged after the final surveys in early April because by then warmer temperatures caused deterioration of snow conditions. Only one family group was sighted in the denning area after 25 March, even though surveys continued later (Table 6). Based on observations of family groups, the peak time of emergence was 1–15 March. Sixty-one per cent (76/124) of the sightings of family groups was made during this time. The age of the tracks is often difficult to determine from fixed-wing aircraft, so that actual sightings of family groups present a more accurate temporal picture of the pattern of emergence.

The number of family groups observed each year since 1970 has varied markedly (Table 13). This is partially explained by the sampling techniques (see p. 27). In 1974 when most surveys were flown, there was a marked reduction in the number of tracks observed and consequently in the estimated total number of denning females. However, the number of family groups sighted, the highest number for all years, indicates that poor tracking conditions may have biased the count of tracks in 1974. The degree to which weather conditions influenced the tracking and sighting of bears, or their movements, is unknown. It is unlikely that the same number of females go into maternity dens each year because

Figure 12
Locations of possible polar bear maternity dens in the Owl River maternity denning area, Manitoba, 1970–76

of a variety of natural factors (e.g. the number of adult females available to breed, the number that bred successfully, the state of the population, food availability, etc.). Rogers (1976) has shown that female black bears fail to produce young if fat reserves are insufficient.

It is interesting to note that few single bears were observed or tracked on the surveys. There was, however, a significant increase in the proportion of single bears recorded in 1974 (7.7%) compared to the other years (2.2%) ($\chi^2 = 7.36$, $p > 0.01$). Whether these were females which had not bred successfully or were male bears which had denned in the area is not known. On 23 January a single female bear was sighted near her den site on the north bank of the Churchill River, 75 km southwest of Churchill. No cubs were observed. Although only pregnant females are thought to den for any extended period, other bears (non-pregnant females and males) have been reported elsewhere in winter dens (Van de Velde 1957 and 1971, Harington 1968). The extent to which this occurs is not known. Only once was a female with yearlings observed leaving denning areas in Manitoba. It was not possible to confirm whether they had denned.

The average litter size of cubs produced in Manitoba based on the spring surveys was 1.9 ($n = 576$). Litter sizes of 2.0 for sightings ($n = 124$) and of 1.9 for tracks ($n = 403$) of family groups were calculated. These calculations may be slightly high as they are based on records of family groups and do not include observations of females which may have lost their cubs prior to the surveys. However, few single bears were observed (5 bears) or tracked (12 bears) in the denning area. When these were included in the calculations, litter sizes of 1.9 for sightings, 1.8 for tracks, and 1.8 for the total estimate were obtained. Mean litter sizes of 2.0 for observed family groups were calculated for

Table 15
Number of family groups and litter sizes sighted in Manitoba by year, 1970–1976. Data from spring surveys 1970–76

Year	No. family groups	No. females			Ave. litter size	σ
		1 cub	2 cubs	3 cubs		
1970	23	1	18	4	2.1	0.4
1971	16	5	8	3	1.9	0.7
1972	13	2	10	1	1.9	0.5
1973	17	3	12	2	1.9	0.5
1974	27	3	21	3	2.0	0.5
1975	17	2	15	0	1.9	0.3
1976	11	3	7	1	1.8	0.6
Total	124	19	91	14	2.0	0.5

the Owl River area ($\sigma = 0.5, n = 116$) and the Cape Tatnam area ($\sigma = 0.5, n = 8$). No significant variation in litter size (Table 15) was recorded from year to year in Manitoba. However, significant variation in litter size was recorded from sightings between the period before 1 March (litter size $= 1.7 \pm 0.5, n = 33$) and after 1 March (litter size $= 2.1 \pm 0.5, n = 91$) ($t = 3.38, p = <0.01$). Although based on a fairly small sample, the litter sizes of observed family groups recorded in Manitoba and Ontario (litter size $= 2.1, n = 20$) (Kolenosky 1974, 1975 and 1976; Jonkel *et al.* 1976) are the highest known, for all the polar bear range.

Since the denning surveys began in 1970, 129 possible maternity den sites have been located (Table 14). Of these dens, 95% (123) were in the Owl River denning area (Fig. 12). The other six dens were recorded in the Cape Tatnam area (Fig. 13). No maternity dens have been recorded in Manitoba north of the Churchill area. Because few of the suspected maternity den sites were checked on the ground, it is possible that some may have only been temporary dens.

All dens were located inland, an average straight-line distance of 47 km from the Hudson Bay coast. All dens but one were located between 7 and 75 km inland. One den in the Cape Tatnam area was recorded 150 km inland up the Hayes River. These inland locations provide a marked

Figure 12

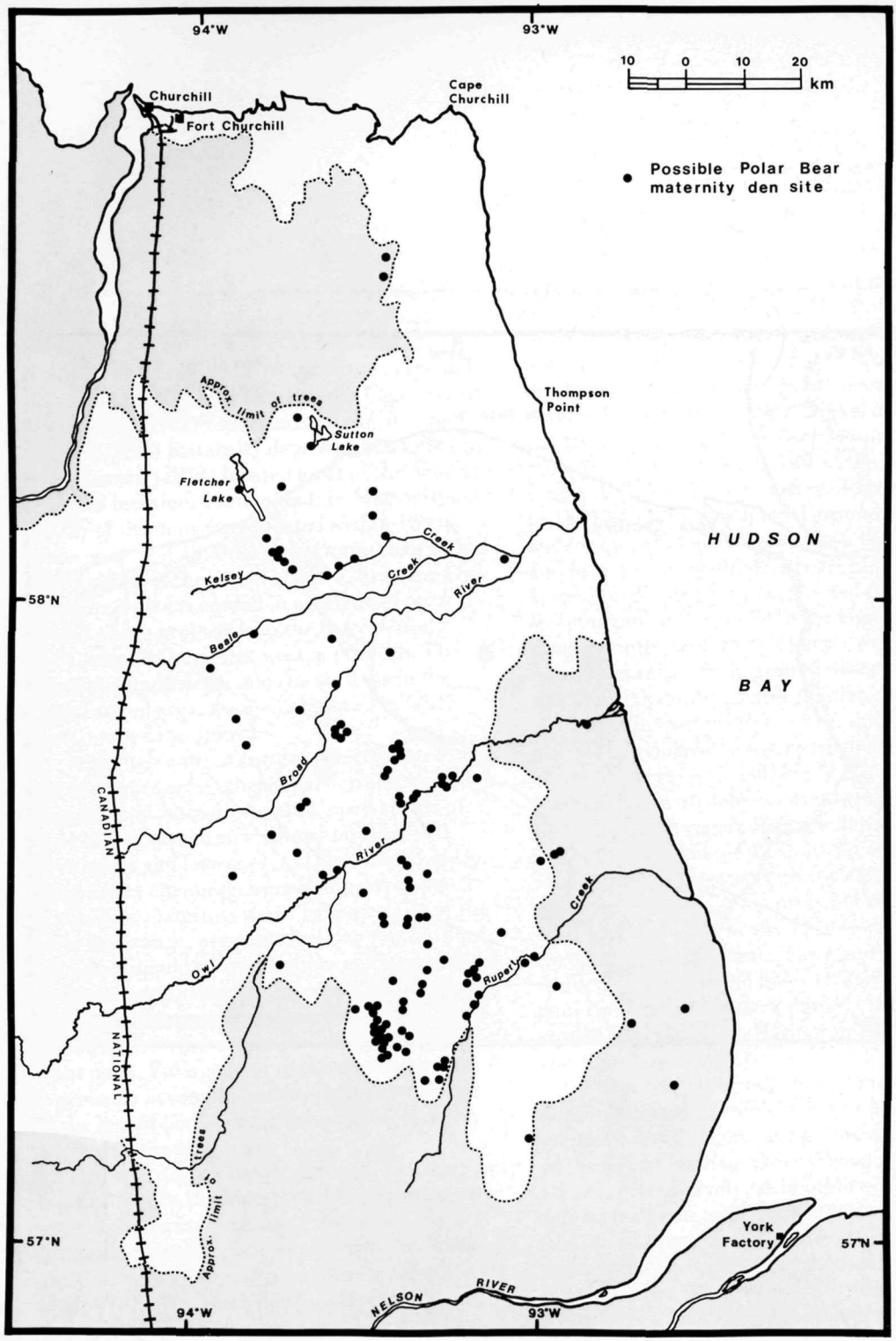
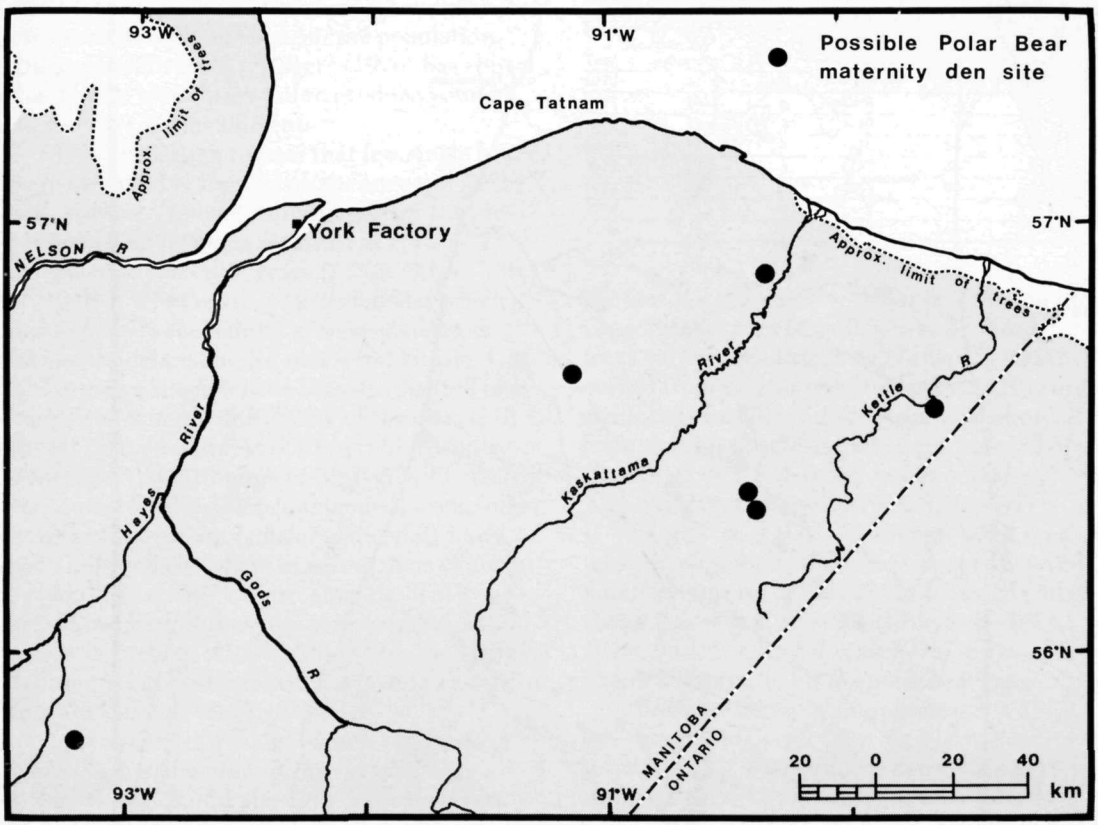

94°W
93°W
10 0 10 20
km
Churchill
Fort Churchill
Cape Churchill
Possible Polar Bear maternity den site
Approx. limit of trees
Sutton Lake
Fletcher Lake
Thompson Point
HUDSON
BAY
Kelsey Creek
Beele River
Broad Creek
Owl River
Rupert Creek
CANADIAN NATIONAL RAILWAY
58°N
57°N
Approx. limit of trees
York Factory
NELSON RIVER

Figure 13
Locations of possible polar bear maternity dens in the Cape Tatnam area, Manitoba, 1971–76

Figure 13



contrast to the more coastal den locations recorded in other areas of the Arctic. Harington (1968) found that 81% (91) of the den sites he investigated were within 16 km of the coast and none were more than 48 km inland. Uspenski and Kistchinski (1972) found most of the Wrangel Island (USSR) maternity dens within 8 km of the coast. Larsen (1974) located most of the dens on Svalbard less than 1 km inland. In Manitoba only 2% (3) of the dens were located within 16 km of the coast and 48% (61) were more than 48 km inland. Most of the dens (115 of 123) in the Owl River area were recorded in a tongue of open tundra which projects into the more densely treed areas to the north, west, and south. The remaining eight dens, and the six dens in the Cape Tatnam area, were all observed in fairly heavily treed locations.

Although most of the dens were located within tundra areas, the actual den site was often associated with small, isolated, open stands of trees (black spruce and willow) on sheltered river banks and lake shores. These locally steep, treed slopes encourage snow bank development suitable for maternity dens. In most parts of the polar bear range, pregnant females come ashore sometime in mid to late October and head inland to the maternity denning areas. At this time, if snow bank development is adequate, dens may be dug in the wind-compacted snow using the front paws. Enlargement of the maternity den is probably accomplished through thawing due to the loss of body heat, consumption of snow, digging and compaction.

However, snow depth and snow type may not be as critical in the Manitoba denning areas as in other areas because many of the dens have a unique form and structure. The dens are excavated in both snow and ground materials (Jonkel *et al.* 1972). The earth dens were probably dug during the summer by bears of all ages, to keep cool and to escape from insects. For more information on summer dens in Manitoba see Jonkel *et al.* (1972). Earth dens have been reported farther south in northern Ontario and on the Twin islands in James Bay (Kolenosky and Standfield 1966, Doutt 1967, Jonkel *et al.* 1976) but their use as maternity dens has not been recorded. Throughout the rest of the polar bear range, the development of earth dens is precluded by the lack of unconsolidated ground materials and/or more extensive permafrost development and may not be required by bears as places to keep cool. Stirling (1974) reported the use of sleeping pits in the gravel in the High Arctic. Consequently, maternity dens are excavated entirely in snow. From ground observations it was found that of six maternity den sites investigated in the Owl River area, the female had utilized a previously existing earth den. Whether or not all pregnant females in Manitoba utilize pre-existing earth dens is unknown. In four cases, the earth den formed the major part of the maternity den and only a short (<1 m long) snow tunnel connected with the exterior. The dens consisted of a snow tunnel or entrance (or exit) leading to one or two chambers, in snow, earth, or snow and earth. The general shape of the dens corresponded fairly closely to the maternity dens excavated entirely in snow, recorded in other areas (Harington 1968, Uspenski and Kistchinski 1972).

The pattern of occupation of maternity dens in Manitoba is not clear. It is possible that pregnant females may occupy summer dens late in the fall and remain there throughout the winter. Alternatively, as in other areas, the female may wait until there is some snow accumulation and then commence excavation in the snow bank, through to a pre-existing earth den. The latter procedure seems a little precarious as knowledge of the exact location of the entrance

Table 16
The average age by sex of polar bears captured, recaptured, or killed (including found dead) in the western Hudson Bay area (Zone A[1]), 1966–75

	Males			Females			Unsexed			Total		
	Av. age in yrs.	σ	No. of bears	Av. age in yrs.	σ	No. of bears	Av. age in yrs.	σ	No. of bears	Av. age in yrs.	σ	No. of bears
Zone A[1]												
Captured	2.0	2.5	81	3.0	3.6	89	2.3	1.7	3	2.6	3.1	173
Recaptured	4.1	2.1	42	4.5	3.2	42	3.0	—	1	4.3	2.8	8
Killed	3.5	3.3	75	4.3	4.2	40	2.4	1.9	10	3.7	3.5	125
Pooled	3.0	2.9	198	3.7	3.7	171	2.4	1.8	14	3.3	3.3	38
Churchill area												
Captured	2.3	2.6	69	2.5	3.0	70	2.3	1.7	3	2.4	2.8	142
Recaptured	3.6	1.8	36	4.3	3.2	40	3.0	—	1	4.0	2.6	7
Killed	2.9	2.1	24	4.8	4.0	17	3.3	2.5	4	3.6	3.2	45
Pooled	2.7	2.4	129	3.4	3.4	127	2.9	2.1	8	3.1	2.9	26
Zone A[1] excluding Churchill area												
Captured	0.8	1.3	12	5.1	4.9	19	—	—	0	3.4	4.4	31
Recaptured	6.2	2.5	6	6.0	3.0	2	—	—	0	6.1	2.6	8
Killed	3.8	3.7	51	3.8	4.2	23	1.8	1.3	6	3.7	3.8	80
Pooled	3.5	3.6	69	4.5	4.5	44	1.8	1.3	6	3.8	3.5	119
Killed by Inuit hunters	4.1	3.8	44	2.3	1.5	16	1.5	0.5	2	3.5	3.4	62

to an earth den is necessary. It seems unlikely that this is the case, even though there is a high incidence of earth dens in some areas. Thirty earth dens of various ages have been recorded along the shore of one small lake in the Manitoba denning area. Although bears, possibly pregnant females, were observed in the denning area and in dens in October and early November 1970, it is not known whether any of these bears remained in the same earth den and used it as a maternity den.

The degree of fidelity that females may show to their birth place or to previous maternity denning sites is unknown.

5. Age structure and average ages

The average ages of male and female polar bears captured, recaptured, or killed (from which teeth were aged), in the western Hudson Bay area are given in Table 16. The age structures of male and female polar bears captured or killed in the western Hudson Bay area are given in Figures 14 and 15. Most of the averages fall within the sub-adult range (2 to 4 years inclusive). The only exceptions were for recaptured bears outside the Churchill area and these may partly reflect the small sample size (total of 8 bears). The averages are slightly under-estimated as part years were dropped from the calculations. In most cases ages were assessed in the fall, consequently cubs of the year were recorded as 0 years when in fact they were 0.75 years old; yearlings as 1 when 1.75 years old and so on. Inclusion of part years in the calculations would only raise the average age by 0.75 years at most, and the resulting averages would still be low.

Another factor contributing to the low averages is the lack of specific age data for 34 (19%) of the bears captured in the Churchill area and for 20 (39%) captured in the rest of Manitoba. Cubs of the year and yearlings, the ages of which could be determined without tooth-sectioning, were included in the calculations. They are not included in the total of 54 bears mentioned above. In other words, half the adult bears captured (60 bears) could not be aged accurately. Judging from their weight, condition and tooth wear, 30 of the un-aged bears could have been adults. If ages were available for these bears, then the averages would be increased but

Table 17
The average age by sex of adult (≥ 5+ years old) polar bears captured, recaptured, or killed (including found dead) in the western Hudson Bay area (Zone A[1]), 1966–75

	Males			Females			Unsexed			Total		
	Av. age in yrs.	σ	No. of bears	Av. age in yrs.	σ	No. of bears	Av. age in yrs.	σ	No. of bears	Av. age in yrs.	σ	No. of bears
Zone A[1]												
Captured	7.2	3.6	9	8.9	2.8	21	—	—	0	8.4	3.1	30
Recaptured	6.9	1.6	13	7.7	2.9	15	—	—	0	7.4	2.5	28
Killed	7.5	4.2	19	9.4	3.4	13	7.0	—	1	8.2	3.8	33
Pooled	7.3	3.4	41	8.7	3.1	49	7.0	—	1	8.0	3.3	91
Churchill area												
Captured	7.2	3.6	9	8.2	2.0	13	—	—	0	7.8	2.8	22
Recaptured	6.0	1.1	9	7.6	3.0	14	—	—	0	7.0	2.6	23
Killed	6.4	1.0	5	9.1	2.5	7	7.0	—	1	7.9	2.3	13
Pooled	6.6	2.4	23	8.2	2.6	34	7.0	—	1	7.5	2.6	58
Zone A[1] excluding Churchill area												
Captured	—	—	0	10.0	3.4	8	—	—	0	10.0	3.4	8
Recaptured	7.8	1.3	4	9.0	—	1	—	—	0	8.0	1.1	5
Killed	7.9	4.8	14	9.7	4.2	6	—	—	0	8.5	4.3	20
Pooled	7.9	4.2	18	9.8	3.1	15	—	—	0	8.8	4.1	33
Killed by Inuit hunters	8.4	5.0	12	5.5	0.5	2	—	—	0	8.0	4.7	14

the degree is unknown. The average ages for adult bears captured, recaptured, or killed in the western Hudson Bay are given in Table 17.

On the basis of the age data that were available, there were no significant differences in the average ages of bears captured or killed in the Churchill area compared to the rest of Zone A[1]. However, there were highly significant differences between the average ages of bears captured or killed in Zone A[1] and those in the James Bay – Belcher Islands area (Zone A[3]) to the south (captured, $t = 5.85$, d.f. $= 2.11$; killed, $t = 5.09$, d.f. $= 197$, $p < 0.001$). A more realistic comparison was made between the adult bears captured and killed in Zone A[1], which it was possible to age, and those of Zone A[3]. There were still highly significant differences between the two sub-populations (captured, $t = 3.3$, d.f. $= 53$, $p < 0.01$; killed, $t = 3.7$, d.f. $= 74$, $p < 0.001$). It would appear that adult bears constituted a higher proportion (63%) of the Zone A[3] sub-population than adults captured in the Zone A[1] sub-population (17% aged by tooth sectioning or 26% aged by tooth sectioning or by weight condition and toothwear).

The age structures of the Inuit-killed and captured bears in Zone A[1] are fairly similar in that adults constituted a relatively small proportion, *cf.* 17% adults for captured and 23% adults for Inuit-killed bears (Figs. 14 and 15). However, no direct comparison of these ages can be made as cubs of the year are not included in the Inuit-killed statistics (in NWT it is illegal to hunt bears less than 137 cm in length — a length which is thought to be attained in the western Hudson Bay area at 1½ years of age), whereas cubs are included in the capture figures, and the under-estimation of the ages of captured bears as a result of incomplete aging. Compensation can be made for the first factor by removing cubs of the year from the average capture statistics. By so doing, the average age of captured bears is raised from 2.6 to 3.3 years of age. It is difficult to compensate for the second factor which would undoubtedly raise the average age considerably above the average age of the Inuit-killed sample. In the western Arctic (Stirling *et al.* 1975) and in the Belcher Islands (Jonkel *et al.* 1976) the under-representation of adult bears in the kill has been documented, indicating that the Inuit

Figure 14
Age structure of polar bears captured in western Hudson Bay area (Zone A[1]), 1966–75

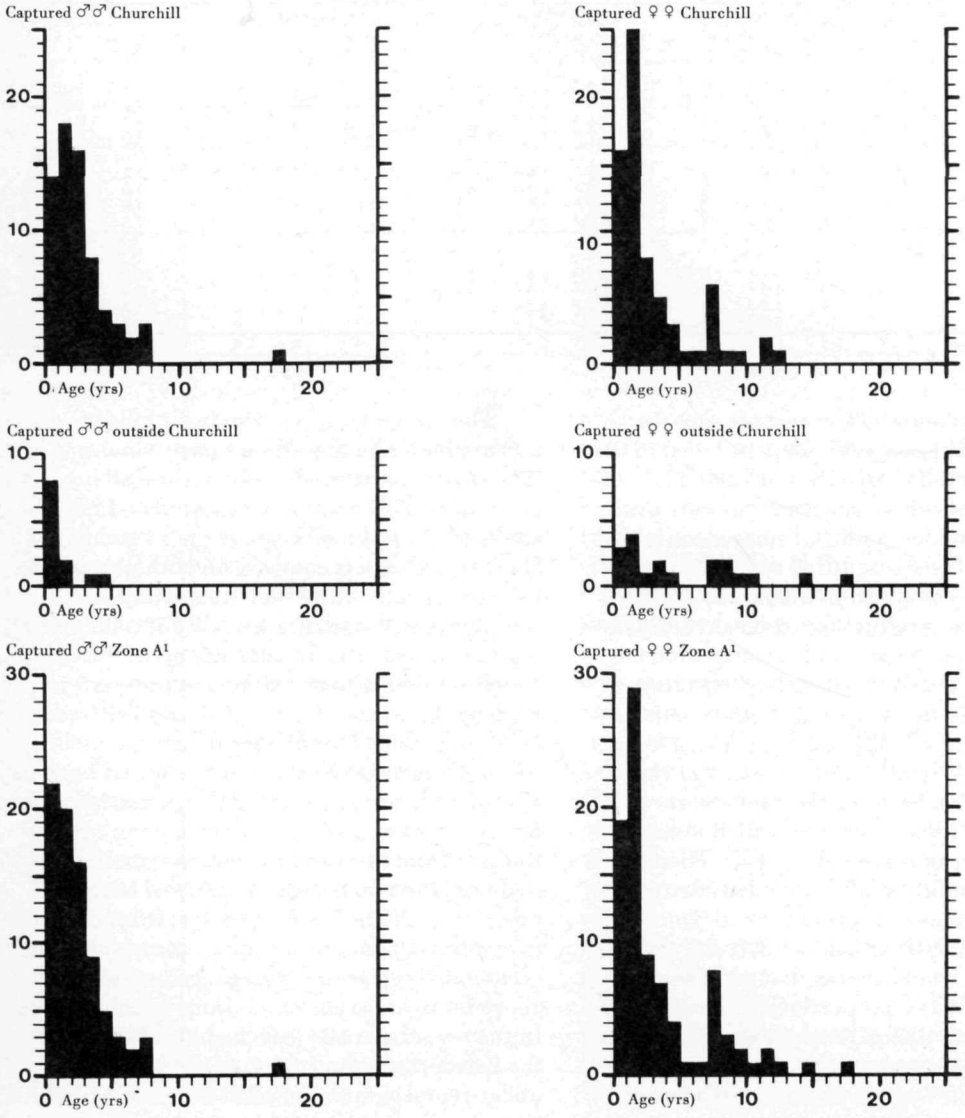


Figure 15
Age structure of polar bears killed in western Hudson Bay area (Zone A[1]), 1966–75

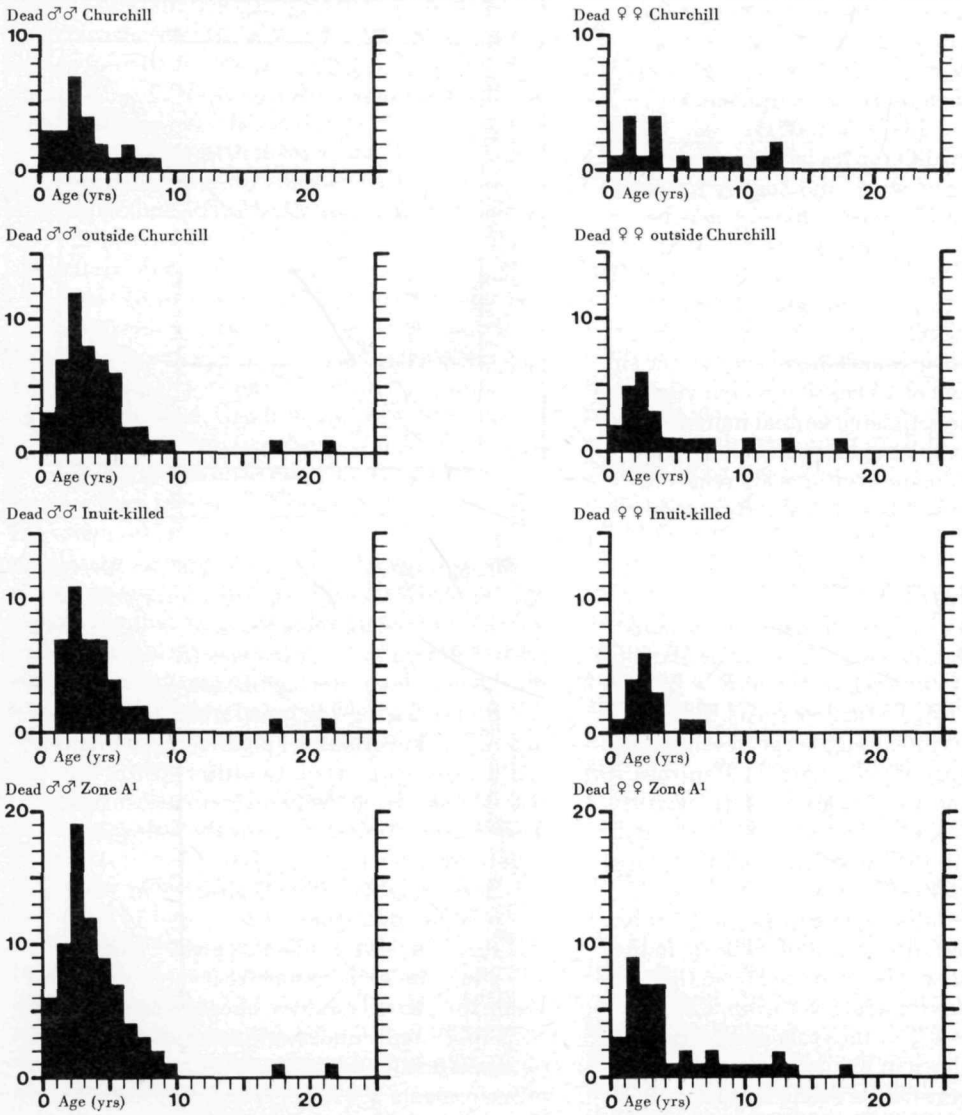


Figure 16
Relationship between polar bear weights obtained by taking heart girth with a cattle weight tape and weights obtained with spring scales, 1966–75

hunting pattern has resulted in the taking of younger bears. In those areas, the average age of the bears killed was younger than that of the overall populations. The average age of bears killed by native peoples in Zone A^1 was significantly lower than those taken in Zone A^3 ($t = 5.05$, d.f. $= 134$, $p < 0.001$).

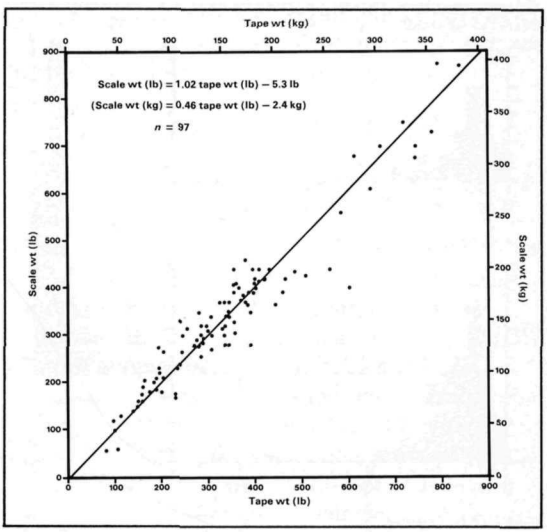
The marked differences between the two sub-populations (Zone A^1 and Zone A^3), which are so close together geographically, may be partially explained by the different hunting pressures on the sub-populations. In Zone A^1 the known harvest by Inuit along the Keewatin coast and the killing, and removing (to zoos), of problem bears in Manitoba accounted for an annual maximum of 40 bears in recent years (Table 8). If the estimated annual increment of 150 cubs to this sub-population is reasonably accurate, then the number of bears removed each year could still be below the sustainable yield.

6. Growth rates

Preliminary analysis of scale weights and chest girth measurements taken during 1966–68 indicated a very close relationship: $R = 0.97$, $n = 22$ (see p. 26). To further verify the accuracy of the cattle weight-tape in estimating the actual weights of polar bears in Manitoba, an analysis of the actual weights and tape measurements of an additional 75 bears taken during the fall from 1973 to 1975 in the Churchill area was carried out. The weights were taken from 22 adults, 44 sub-adults, 21 yearlings and 10 cubs. It was found that the weights of all bears in the Churchill area could be predicted from the weight-tape measurements to within 92% ($R = 0.96$, $n = 97$) of the scale weight, using the equation shown in Figure 16.

A similar correlation coefficient ($R = 0.96$, $n = 16$) was calculated for polar bears measured

Figure 16



during spring and summer 1974 in the Western Arctic. A slightly higher correlation coefficient was determined for male bears ($R = 0.96$) in the Churchill area than for females ($R = 0.95$) but the difference was not significant.

By using a log–log transformation, the weight in pounds (kilograms) of polar bears in Manitoba could also be predicted, to within 90% of the scale weight, from the chest girth measurement in inches (centimetres) using the following equation:

Scale weight $= 0.0083$ girth $^{2.75}$ in pounds and inches

(Scale weight $= 0.00028$ girth $^{2.75}$ in kilograms and centimetres)

Using the above equation, chest measurements <39 in. (99 cm) under-estimated the weights obtained from the cattle weight-tape, while measurements <39 in. (99 cm) over-estimated those from the tape.

These results are comparable to those of Payne (1976) and Cherry and Pelton (1976). Payne found that he could predict from the chest girth measurements the weights for black bears in Newfoundland to within about 95% of the true value ($R^2 = 0.944, n = 173$). Cherry and Pelton also found a close relationship between the actual weight and chest girth measurement at the 95% level of significance for black bears weighing <50 kg in the Great Smoky Mountains, Tennessee. For heavier bears (>70 kg) they could not accurately predict the weight.

Table 18 summarizes the mean live weights (in kilograms) by age and sex for polar bears in Manitoba from 1966 to 1975. All weights were taken during October and November, using a cattle-weight tape. Generally males were significantly heavier than females ($t = 6.37$, d.f = 207, $p = <0.001$) and on average were 1.27 times heavier than females of the same age. However, the weight differences, both relatively and absolutely, increased with age. Adult male bears were 1.57 times the weight of adult females. Figure 17 illustrates the growth rates of four male and seven female polar bears for which there are three or more years of weight data. All measurements except one were taken during the fall (late September to November) using a cattle weight-tape.

Lack of data for other periods of the year preclude evaluation of the annual weight cycle. However, it seems unlikely that polar bears follow the same cycle of weight gain and loss displayed by black bears (Jonkel and Cowan 1971, Sauer 1975) or grizzly bears (Pearson 1976). The food habits of polar bears have long been known to vary seasonally. The main food source is the ringed seal which is available to the polar bears on Hudson Bay from freeze-up to break-up. All age classes of bears are suspected to gain weight from mid-winter through spring. During the ice-free part of the year, the diet changes to marine algae, grasses and small mammals (Russell 1975). In contrast to the protein – and fat-rich winter diet, the summer foods have a low energy content (Koettlitz 1898, Best 1976). Consequently, the bears probably lose weight or remain relatively stable during the summer. Two subadult males showed small weight losses (from 242 to 241 kg and 222 to 220 kg) during a two-month period in late summer to early fall 1969. In the autumn the bears return to hunting seals as soon as the ice forms on the Bay. However, pregnant females are thought to remain inland and not hunt seals on the ice until the following spring. Therefore, breeding females must have sufficient energy reserves to survive the winter, and produce and suckle an average of two cubs up to about 11 kg (25 lb) in weight. Whether the energy reserves are accumulated during the preceding winter and spring, or through summer feeding is unknown. The summer and autumn food habits of polar bears along the coastal areas of Manitoba have been studied (Russell 1971 and 1975), but neither the degree of utilization nor the nutritional importance of these alternate foods are known.

On land, the polar bear range overlaps those of other mammal species. However, the importance of interspecific relationships is unknown. An encounter with a porcupine (Jonkel 1968), the remains of muskrats, microtine rodents, and

Table 18
Weights (cattle weight-tape) in kilograms of polar bears by age and sex, taken in October and November in Manitoba, 1966–75

	Males				Females			
Age	n	$\bar{x}$	Range	σ	n	$\bar{x}$	Range	σ
0+	21	54	31–104	22.49	12	47	32– 86	15.68
1+	23	114	54–209	33.65	31	98	59–138	21.89
2+	21	176	89–272	45.85	14	130	84–200	29.97
3+	14	184	98–253	39.29	14	179	102–279	58.57
4+	10	262	181–339	48.35	7	117	120–236	31.94
≥5+	19	276	143–367	66.75	23	176	139–284	39.93
All ages	08	166	31–367	44.14	101	131	32–284	34.79

Figure 17
Growth rates of four male and seven female polar bears, with three or more years of data, in Manitoba

Figure 17

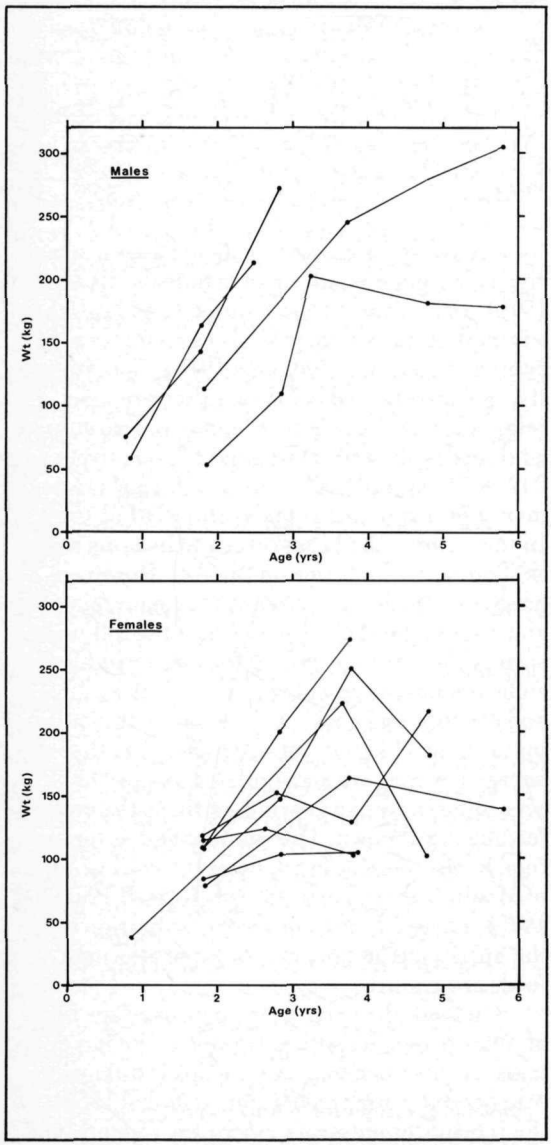


Table 19
Straight-line body lengths in centimetres of polar bears by age and sex, taken in October and November in Manitoba, 1966–75

	Males				Females			
Age	n	$\bar{x}$	Range	σ	n	$\bar{x}$	Range	σ
0+	9	131	115–142	8.63	13	131	107–171	15.73
1+	14	174	157–191	9.77	20	166	155–183	8.11
2+	13	190	175–208	8.85	5	180	170–193	7.83
3+	7	201	192–213	6.82	9	195	184–206	7.27
4+	5	209	202–220	7.08	5	204	199–221	8.45
≥5+	12	241	203–269	16.03	15	206	191–221	7.99
All ages	60	190	115–269	10.56	67	176	107–221	9.95

birds in polar bear scats (Russell 1975), and predation on flightless Canada Geese (*Branta canadensis interior*) have been documented for the area. Certain single female bears and also family groups and sub-adults spend the summer inland where different food sources may be available. A few animals have been seen feeding in areas of dense blueberry (*Vaccinium* spp.). This may give rise to some competition with black bears.

Table 19 summarizes the straight-line body lengths in centimetres of polar bears by age and sex in Manitoba from 1966 to 1975. All measurements were taken during October and November: overall, males were significantly longer than females ($t = 7.99$, d.f. $= 125$, $p < 0.1\%$), and on average were 1.08 times longer than the females. Average lengths of both male and female cubs of the year were similar. The greatest differences were recorded for adult bears where males were 1.17 times longer than the females.

A close relationship between the straight-line body length and weight (using the weight-tape) was determined for male polar bears in Manitoba ($R = 0.90$, $n = 57$). Female bears did not display as close a relationship ($R = 0.75$, $n = 66$), indicating a proportionately slightly lighter build compared to males.

7. Status of the sub-population

Table 5 summarized the results of population surveys carried out in the western Hudson Bay area between 1963 and 1975. Based solely on those surveys it is difficult to make population estimates of the sub-population of polar bears in the western Hudson Bay area. Perhaps 200 polar bears are confined to a narrow (<1 km wide) coastal strip of Manitoba from Churchill to the Ontario border during the ice-free months of the year. From brief surveys inland between Churchill and the Broad – Owl River area, it is known that there are a number of bears inland, often utilizing earth dens and pits, many of them excavated in treed areas (Jonkel *et al.* 1972) which compounds the problem of sighting and counting bears.

As no capture–recapture program has operated outside the Churchill area since the spring of 1972, a total estimate of the size of the sub-population could not be calculated. From the recapture and observation data (Table 11), it is apparent that there is a high degree of fidelity to the Churchill area. A crude estimate of the number of bears in the Churchill area before freeze-up in 1975 was calculated using a simple Lincoln Index[5]. Bears marked outside the Churchill area and also bears marked outside but later recaptured in the Churchill area were not included in the calculation (Table 7).

As the Lincoln index* does not allow for natural mortality, the estimate of 308 bears calculated for the Churchill area is probably too high. What proportion of the total sub-population this estimate represents is unknown. However, we do know for example that few of the large males in the Cape Churchill area move to the Churchill area.

* For Churchill area

$$\frac{\text{No. bears recaptured in 1975}}{\text{Total no. bears captured in 1975}} = \frac{\text{Total no. marked bears available for recapture in 1975}}{\text{Total population of Churchill area in 1975}}$$

$$\frac{17}{40} = \frac{131}{\text{Total pop. in 1975}}$$

$$\text{Total pop. of Churchill area in 1975} = 308$$

Summary and recommendations

The entire Churchill experience illustrates the inevitability of problems when human settlements are located in areas containing high densities of polar bears and how those problems are aggravated when garbage is not dealt with properly. Similar problems, although on a smaller scale, have been reported elsewhere by oil exploration and geological field camps. Inuit settlements in the NWT generally have been free of continued danger or damage from problem bears because those which do wander into the villages can be shot as part of the annual hunting quota.

The pattern of behavioural interactions between polar bears and man is similar to that between man and other species of bears in national parks (Mundy and Flook 1972), and can be predicted. Poor camp practices and garbage dumps rich in food usually initiate the cycle. When bears first approach a camp, much excitement and interest is generated among the personnel. Cameras are brought out and food is tossed to the animals to lure them closer for better pictures. Eventually the bears become commonplace, someone gets injured or the bear gets shot, or both.

Data from recaptured bears have shown that many bears return each year to the garbage dumps and that the habit may be passed on to their young. New animals, if allowed to eat regularly in the dump, soon become habituated. The attempt to raise a small number of pigs which involved considerable careless handling of stored food in an area normally not frequented by polar bears (Fig. 2) quickly drew a large number of bears to the area. They could be seen feeding or resting in the area during the day or night. Damage to buildings and encounters with people increased sharply in the area where the pigs were kept. Likewise, those residents in the Churchill settlements who keep large quantities of food stored for dogs and traplines repeatedly have problems with passing bears, whereas other homes are seldom or never visited.

The preservation of a large carnivore is not simply a matter of protection. Such species compete with man for space, and the preservation of certain stocks must be based on careful management, which may include restrictions on the activities of people, as well as the removal of some surplus or problem animals.

Once the garbage problem is resolved, the number of new problem bears in the Churchill area should be reduced. Hopefully, the number of habituated bears returning each fall will decline when they no longer receive positive reinforcement in the way of food. However, there will probably always be some problem polar bears at Churchill if only because of its proximity to such large concentrations of bears. Consequently, there will probably be a continued need for some level of patrolling and monitoring in the fall, as well as the removal of some bears each year.

Two other options in the management of polar bears in Manitoba are the establishment of an annual harvest and the utilization of the bears as a tourist attraction. A harvest could be realized by: having Conservation Officers shoot some surplus and problem bears; establishing a quota for local native residents; or introducing sport hunting under special licence. Each plan would, of necessity, be based on carefully regulated hunts in the Churchill area and possibly near Cape Churchill. These practices would probably reduce the occurrence of problem bears. Precedents for hunting polar bears currently exist elsewhere in Canada, and in Alaska and Greenland. However, it is possible that public sentiment in Manitoba and the rest of Canada would not welcome the introduction of more liberal harvest regulations. However, before introducing a harvest in Manitoba, the survival rate of young

bears produced in Manitoba as well as fidelity of individual females to summer retreats and maternity den sites should be determined.

The potential in Manitoba for polar bear viewing as a tourist attraction is almost unparalleled. Such a program could be developed in the immediate vicinity of Churchill and it could possibly be based on undisturbed groups. The plan would require the imposition of strict regulations on all users of Manitoba coastal areas to ensure the safety of both the people and the bears. A zone favouring polar bears would probably have to be established, with partial exclusion of man. An evaluation should be made of the effects on bears of viewing summer dens and the effects of increased human activity on tundra vegetation and other wildlife, such as Snow Geese, Canada Geese, and woodland caribou.

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