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The ecological significance of supplemental food to polar bears on land during the ice-free period in western Hudson Bay

by

Nicholas John Lunn

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF Master of Science

Department of Zoology

EDMONTON, ALBERTA

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled The ecological significance of supplemental food to polar bears on land during the ice-free period in western Hudson Bay submitted by Nicholas John Lunn in partial fulfilment of the requirements for the degree of Master of Science.

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Supervisor

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Date 20 December 1984

Abstract

During the summers and falls from 1981 to 1983 polar bears were studied in the Churchill, Manitoba area to examine how bears have evolved to deal with extended periods of time away from their primary food source and also to determine if supplemental food sources were important. Once ashore, bears segregated by age and sex class; females with cubs and pregnant females moved inland into a denning area, while single bears, especially adult males, remained along the coast. Bears along the coast were observed engaged in 870 hours of activity. Bears were inactive and ate very little. Evidence from analysis of blood samples taken from bears in the denning area suggested that they were also not feeding. By remaining inactive, polar bears are able to minimize energetic demands and also minimize the chance of hyperthermia.

After approximately two months ashore, a small proportion of the bear population arrived in the Churchill dump and began to feed. Bears were observed engaged in 1215 hours of activity. The dump was used mainly by females with cubs and by subadults. The data indicated that individual need and the learning of its location were major factors determining which bears used the dump. However, adult male bears did not use the dump even though they may have used ~~it~~ as a cub or subadult.

Those bears that fed in the dump were significantly heavier than their counterparts that did not feed while

ashore. There was no evidence that bears that fed in the dump had either reproductive or survival advantages over bears that were not feeding. My conclusion is that polar bears will use supplemental food sources if they are readily available or if they have learned its location; however, most polar bears do not need to.

Acknowledgements

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I. INTRODUCTION

Polar bears (*Ursus maritimus*) have a circumpolar distribution on the Arctic sea ice. However, they do not occur as one large population throughout the Arctic, but rather as smaller discrete populations (e.g. Larsen 1972; Lentfer 1972; Stirling 1976; Stirling *et al.* 1980). There is apparently some variation in the size of polar bears from different geographic areas (Manning 1971).

Ringed seals (*Phoca hispida*) and the larger but less abundant bearded seals (*Erignathus barbatus*) are the main prey of polar bears (Stirling and Archibald 1977; Smith 1980; Stirling *et al.* 1981), although they may occasionally kill walrus (*Odobenus rosmarus*) and hooded seals (*Cystophora cristata*) (Stirling and Archibald 1977; Kiliaan and Stirling 1978). Polar bears are opportunistic feeders and will scavenge on the carcasses of walrus, beluga whales (*Delphinapterus leucas*), and bowhead whales (*Balaena mysticetus*) (Lentfer 1972; Uspenski and Kistchinski 1972; Christiansen 1981).

On the sea ice, polar bears hunt by stalking basking seals, by breaking into seal birth lairs, and by lying at seal breathing holes and along lead systems (Lentfer 1972; Stirling 1974; Stirling and Latour 1978; Smith 1980; Stirling *et al.* 1981). Seals are not caught often (Stirling 1974; Stirling and Latour 1978); however, once caught, they have a large caloric content (Stirling and McEwan 1975). Larger, more dominant bears may sometimes displace family groups and smaller bears from their kills. Therefore, scavenging on seal carcasses may be important to the survival of smaller bears and/or family groups (Stirling 1974). Polar bears feed on high-energy foods in order to meet the metabolic requirements of thermoregulation and the higher energetic costs associated with walking and hunting (Stirling and McEwan 1975; Øritsland *et al.* 1976; Hurst *et al.* 1982). Typically, polar bears feed mainly on seal fat (Stirling and McEwan 1975). As a food source, fat yields more than twice the energy per gram oxidized than either carbohydrate or protein (Schmidt-Nielsen 1975; Young 1976). Fat metabolism also produces more water per gram metabolized than other nutrients (Nelson 1973; Young 1976). By using metabolic water for body requirements, polar bears may minimize their external water requirements, mainly snow and ice, and therefore minimize the amount of energy required to raise exogenous water sources to body temperature. Nelson *et al.* (1973) noted that denning black bears (*Ursus americanus*) use only internal water sources throughout the winter and it has been suggested that polar bears that feed on seal blubber probably do not require any external water sources (Nelson *et al.* 1983).

Seal availability varies both regionally and seasonally (McLaren 1958; Smith 1973; Stirling and McEwan 1975; Stirling *et al.* 1977a; Smith and Stirling 1978; Stirling *et al.* 1982). During spring and summer, as temperatures increase, the annual ice in the Arctic breaks up (Lentfer

1972; Lindsay 1975, 1977, 1982; Stirling *et al.* 1982). In these regions, polar bears must either move with the remaining sea ice or go ashore and wait for the sea ice to reform (Stirling *et al.* 1980). The extent to which the sea ice breaks up and the geographical location of the population will determine which of the two options polar bears choose (Uspenski and Kistchinski 1972; Stirling *et al.* 1977b; Lutzyuk 1978; Stirling and Kiliaan 1980; Stirling *et al.* 1981). It is important to those bears that go ashore, and do not find alternative food sources, to accumulate adequate fat reserves for the entire period they spend on land.

Polar bears mate on the sea ice during April and May. Pregnant females construct maternity dens in drifted snow during October and give birth to one or, usually, two cubs in December or January (Harington 1968; Jonkel *et al.* 1972; Lentfer and Hensel 1980; Ramsay and Stirling 1982). Family groups emerge from their dens from late February through April, depending on latitude, and move onto the sea ice to hunt seals (Harington 1968; Ramsay and Stirling 1982; Kolenosky and Prevett 1983). In most areas cubs remain with their mothers until they are about two to two and one half years of age, except in southern Hudson Bay where up to half of them may be weaned at one to one and one half years of age (Stirling *et al.* 1975, 1977b; Stirling and Latour 1978; Lentfer *et al.* 1980; Ramsay and Stirling 1982).

The sub-population of polar bears resident in southwestern Hudson Bay spends several months ashore each year (Stirling *et al.* 1977b). From mid-November to late July, all polar bears except denning females are out on the sea ice hunting seals. Family groups emerge from dens and move onto the sea ice in late February and March. From late July to mid-November, Hudson Bay is ice-free. Polar bears cannot move to areas still covered by ice and come ashore along the coasts of Manitoba and Ontario (Nero 1971; Russell 1975; Jonkel *et al.* 1976; Stirling *et al.* 1977b; Latour 1981a,b; Prevett and Kolenosky 1982). In order to meet their metabolic demands while ashore for the next three and one half to four months, polar bears must lower their activity rate, use stored fat reserves built up during the on-ice period, find alternative sources of food, or some combination of the three. Russell (1975) documented food habits of polar bears during summer and autumn but was unable to determine how often polar bears fed. Previous research in Churchill indicated that while ashore, adult male, subadult male, and subadult female polar bears remained inactive and fed very little, 70.8 percent and 1.25 percent of the total time budget respectively (Latour 1981a). Knudsen (1978) found that, on the islands in James Bay, polar bears were inactive 86.8 percent of the observed time and fed for 3.2 percent of the time.

From these preliminary data, it appeared that most polar bears fed little while ashore. During the period spent on land, there is one reliable source of food, although variable in quality and quantity, available to polar bears in northeastern Manitoba: the Churchill dump. However, this food source is used only by approximately one percent of the total population in the area, and primarily from October to November. As a seasonal food supply, used only by some individuals, the Churchill dump can be considered ecologically similar to some natural food sources that are also used only seasonally. For example each summer, some black bears (Frame 1974) and brown bears (*Ursus arctos*) (Gard 1971; Stonorov and Stokes 1972; Martinka 1974; Egbert and Stokes 1976; Luque and Stokes 1976) congregate to feed at salmon (*Oncorhynchus* spp.) spawning streams. Salmon return to Alaskan streams to spawn from July through October (Gard 1971). Brown bears in Alaska feed on salmon only from mid-July to the end of August, a period of about 40 days (Stonorov and Stokes 1972; Egbert and Stokes 1976; Luque and Stokes 1976). Like polar bears, only some individuals feed at these seasonally reliable food sources, with maximum numbers each year at some locations, ranging between 30 and 40 individuals (Egbert and Stokes 1976). Use of dumps as food sources by both black bears (Rogers *et al.* 1976; Rogers 1977; Beeman and Pelton 1980; Young and Ruff 1982; Herrero 1983) and brown bears (Cole 1971; Craighead and Craighead 1971; Mundy and Flook 1973; McCullough 1982) has been well documented in the literature. However, there are differences between the use of salmon streams and the use of garbage dumps: 1) the use of salmon streams by bears has had a longer time to evolve, and 2) there is no major human activity at these streams.

Both Kihlman and Larsson (1974) and Horton *et al.* (1983) investigated the importance of garbage dumps to populations of gulls (*Larus* spp.). Both studies found that when natural foods were abundant, use of dumps was low. However, in times of low natural food availability, the numbers of gulls feeding in dumps increased. Hubert *et al.* (1980) had similar observations of a captive herd of white-tailed deer (*Odocoileus virginianus*); they used supplemental foods only when natural foods were scarce. Bears also prefer natural foods, but will use garbage dumps when mast and berry crops fail (Rogers 1976; Grenfell and Brody 1983). Although Rogers (1976) and Rogers *et al.* (1976) suggested that bears using dumps produced larger litters and may have increased cub survivorship, most studies of the use of garbage dumps have not related the use of dumps to reproduction or survival.

A comparison of polar bears that used supplemental food, in this case, the Churchill dump, with those that did not, was conducted in order to acquire a better understanding of the nutritional and behavioral strategies that polar bears have evolved to be able to spend an extended period of time away from their primary food source. Since the early 1960's, bears that used the dump have received much attention, to the point that now popular myth has labelled them as 'garbage' bears, using and depending upon the dump each year. Is this valid? Have bears used the dump through necessity or preference? A natural experiment was conducted with those bears that fed in the Churchill dump as the experimental group and bears that did not feed there as the control group. An evaluation of the importance of supplemental food sources for polar bears, while ashore, may be used to aid in the management of the species. The specific objectives of this study were to:

1) Document the numbers of polar bears of each age and sex class that use the Churchill dump as a supplemental food source and those that do not.

2) Construct activity budgets for bears of each age and sex class that use the Churchill dump and those that do not.

3) Look at possible factors that may determine which bears use the dump as a food source.

4) Try to assess any benefits or costs, in terms of survival and reproduction, to polar bears that use the dump compared to those bears that do not.

II. MATERIALS and METHODS

A. Study Area

Research was conducted in the province of Manitoba, in the southwestern region of Hudson Bay, bounded by latitudes 57° 30' N and 58° 50' N and by longitudes 92° 30' W and 94° 10' W (Figure 1). The study area lies within the Hudson Bay Lowlands (Ritchie 1962; Robinson 1968), a region where the topography has been greatly influenced by past glaciations. With the break-up of the Wisconsin Laurentide ice-sheet, approximately 8,000 years ago, the entire study area became submerged beneath the Tyrrell Sea (Lee 1968). Following the melting of the Wisconsin Laurentide ice-sheet, the Tyrrell Sea began to retreat (Lee 1968), resulting in the formation of raised beaches. These raised beaches are prominent along the coast of Hudson Bay. Eskers formed by the last deglaciation are found throughout the study area, but are more common near the coast. Poor drainage throughout most of the study area has resulted from recent uplifting, from low gradient of relief, and from the underlying permafrost (Lee 1968). Numerous lakes, ponds, small rivers, streams, and expanses of fen dominate the inland region of the study area.

Ice formation and break-up on Hudson Bay varies annually and geographically; however, except for shore leads, the Bay is usually completely ice covered from January to April (Larnder 1968; Danielson 1971). Shore leads

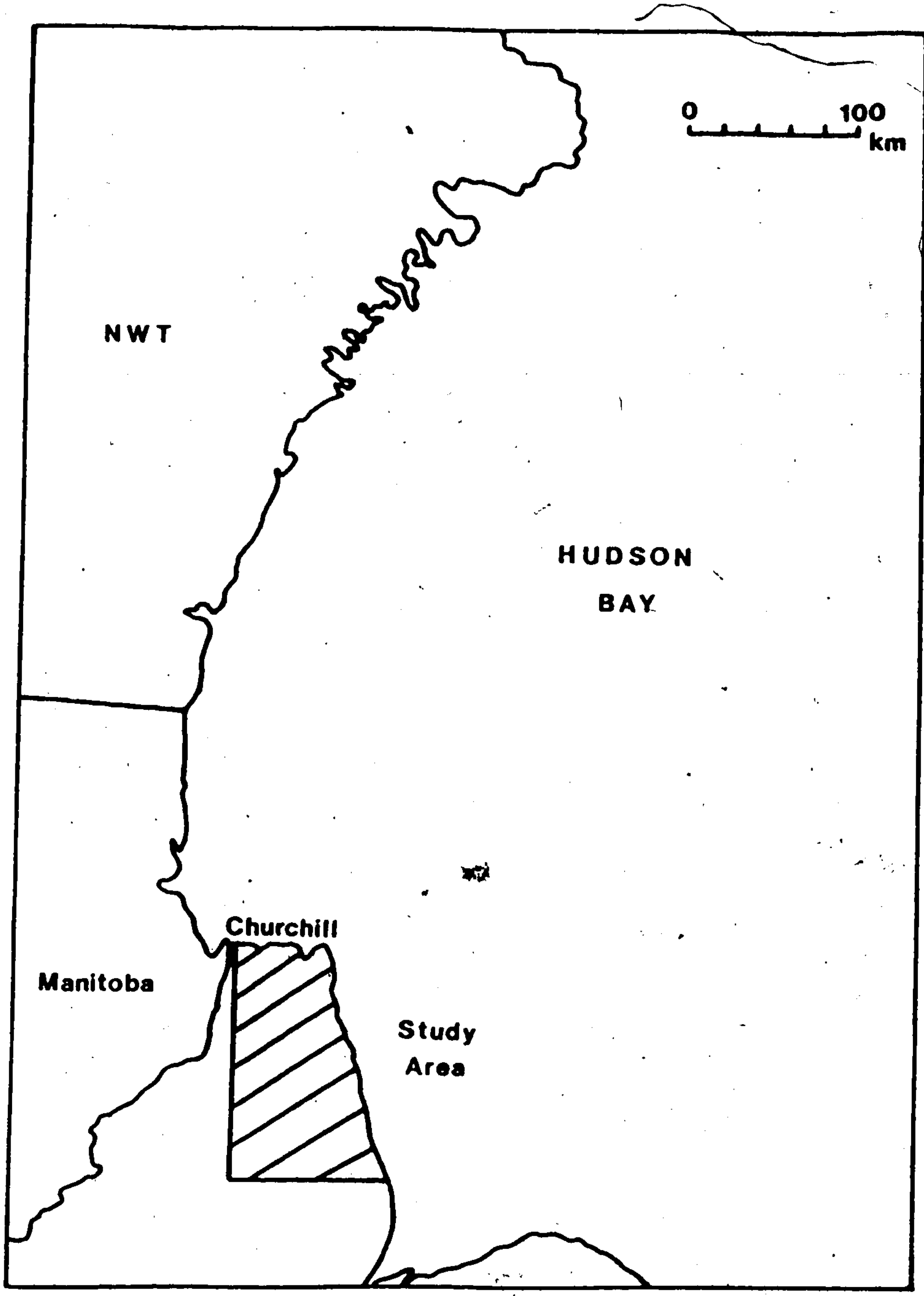

Figure 1. Location of the study area along the southwestern coast of Hudson Bay (after Stirling *et al.* 1977b).

are areas of open water that form between fast ice anchored to the coast and free-floating ice of deeper waters (Larnder 1968). The widest and most persistent shore lead in Hudson Bay occurs along the west coast and is maintained by winds blowing from the north, northwest, and west (Larnder 1968; Danielson 1971). Break-up begins in May, and in general proceeds from north to south (Larnder 1968). As the ice breaks up, the wind and the general counter-clockwise circulation in Hudson Bay cause the unmelted ice to move gradually southward (Barber 1968; Larnder 1968). By the end of July, the Bay is almost completely ice-free except for an accumulation of ice off the coasts of Manitoba and Ontario (Danielson 1971). In general, the Bay remains ice-free from the end of August to about the end of October, when freeze-up begins along the southwest coast (Danielson 1971). Usually two to three weeks elapse between the appearance of coastal ice and the time it becomes firm (Larnder 1968). Shorefast ice is well established along most coasts by the end of November, but is widest off the west and south coasts of Hudson Bay (Larnder 1968). Freeze-up is nearly complete by the end of December (Larnder 1968; Danielson 1971).

The climate of the Hudson Bay Lowlands, which has been described as subarctic (Scoggan 1959; Thompson 1968), is greatly influenced by the close proximity of Hudson Bay. Spring is delayed by the persistent influence of the sea ice (Thompson 1968). Mean daily temperatures recorded at the Churchill airport for May and June are -2.3° C and 6.1° C, respectively. During these two months, 17 percent (6.8 cm/39.6 cm) of the total mean annual precipitation falls (Canada Atmospheric Environment Service 1973). Low-lying clouds increase in frequency which cause a large percentage of the sun's radiation to be reflected, further delaying spring warming (Thompson 1968). Summers tend to be short and cool as the cold waters of the Bay affect air temperature (Thompson 1968). Mean daily temperatures reach 12.0° C in July and August but drop to 5.7° C in September. Summer is the wettest season as 40 percent (15.9 cm/39.6 cm) of the total mean annual precipitation falls during this period. During autumn, cold Arctic air masses move south over the Bay more frequently (Thompson 1968) resulting in mean daily temperatures dropping 20° to 25° C below summer means. Nearly one half of the total mean snowfall (88.7 cm/183.8 cm) falls from October through December. Winters tend to be long and cold as mean daily temperatures for January, February, March, and April are -27.6° C, -26.7° C, -20.3° C, and -11.0° C, respectively.

The study area was divided into five main regions: Denning Area, Coast 1, Coast 2, Intermediate Area and Dump (Figure 2). The Denning Area, by far the largest of the regions, was defined by latitudes 57° 30' N and 58° 15' N and by longitudes 93° 10' W and 94° 10' W. Numerous lakes and ponds occur in this region as well as several rivers and creeks. Mosses and lichens dominate the area between water bodies except along the river systems. Here, black spruce

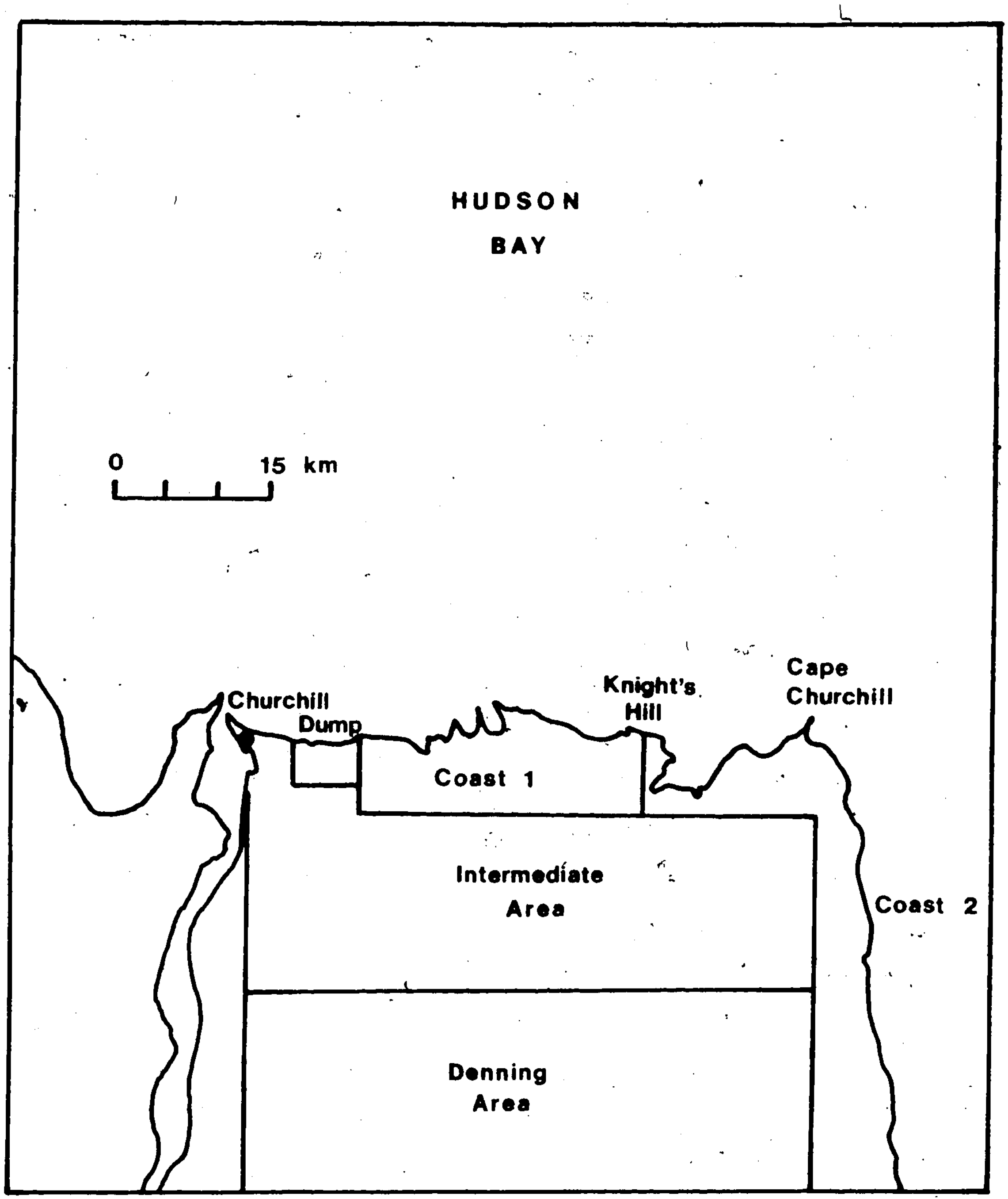

Figure 2. Locations of the major regions within the study area (after Stirling *et al.* 1977b).

(*Picea mariana*), tamarack (*Larix* sp.), willow (*Salix* sp.), bearberry (*Arctostaphylos uva-ursi*), crowberry (*Empetrum nigrum*), and cloudberry (*Rubus chamaemorus*) are abundant. Arctic foxes (*Alopex lagopus*), red foxes (*Vulpes vulpes*), wolves (*Canis lupus*), and caribou (*Rangifer tarandus*) occur in the Denning Area.

The coastal regions encompassed the entire coastline within the study area except for the small section of coast immediately north of the dump (Figure 2). The width of the coastal strip was arbitrarily set at five kilometres. There is limited access to the coastal region, by track vehicles and all terrain vehicles, from the eastern edge of the dump as far east as Knight's Hill. As the effect that limited human activity may have on polar bears was unknown and there were few observations of bears in the area, the coastal region was divided into two parts: Coast 1, the area east of the dump to Knight's Hill; and Coast 2, the rest of the coastal region (Figure 2). The vegetation along the coastal beach ridges consists mainly of coarse grasses (*Elymus* sp.); one km further inland, mosses and lichens are dominant. In the wetter depressed areas, salt meadow grass (*Puccinellia nuttalliana*) and sedges (*Carex* sp.) are present. Willow and alder (*Alnus* sp.) patches occur throughout the coastal regions. Willow ptarmigan (*Lagopus lagopus*) are common both in Coast 1 and Coast 2. From the end of May to the beginning of October, large colonies of lesser snow geese (*Anser caerulescens*) and smaller colonies of Canada geese (*Branta *canadensis*) are found, predominantly in the Coast 2 region. Arctic and red foxes are present in both coastal areas, while wolves and caribou occur mainly in the Coast 2 region.

The Dump region (Figure 3) was arbitrarily defined to encompass the area within a three km radius of the town garbage dump. The town of Churchill is approximately eight km from the dump and is therefore not included in this region. The dump was created in the 1960's and is now approximately 150 m long, 75 m wide, and 20 m high. Access to both the top and bottom of the dump is maintained by narrow gravel roads. A small creek flows north through this region and empties into Hudson Bay, which is about 600 m from the garbage dump. Exposed bedrock lies to the west, northwest, and northeast of the dump. The main vegetation consists of grasses and sedges, although immediately south of the dump lichens and mosses are dominant. Clumps of white spruce (*Picea glauca*), willow, and alder are found to the west, south and east. Gulls, ravens (*Corvus corax*), red squirrels (*Tamiasciurus hudsonicus*), short-tailed weasels (*Mustela erminea*), arctic foxes, and wolves have also been seen at the dump.

The area between the northern boundary of the Denning Area and the southern boundaries of the Dump and Coast 1 regions was called the Intermediate Area (Figure 2). As this area was not representative of any of the other regions, I made it a separate region. Although the vegetation was similar, the Intermediate Area lacked the numbers of lakes,

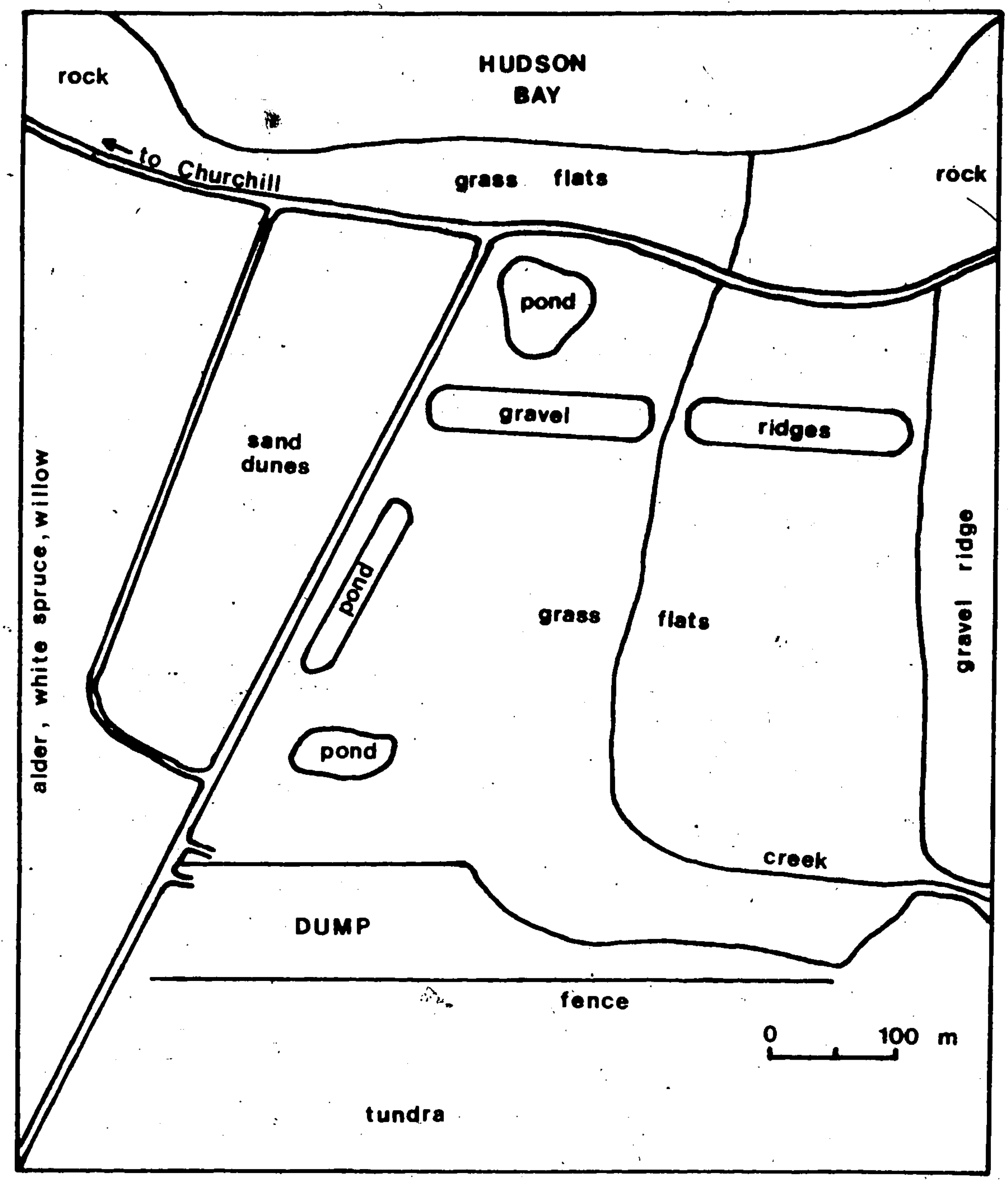

Figure 3. Major features of the Churchill dump and the surrounding area.

ponds, creeks, and rivers found in the Denning Area.

B. Methods

Since 1966, both the Canadian Wildlife Service and the Wildlife Branch of the Manitoba Department of Natural Resources have been involved in ecological studies of polar bears in Manitoba (Stirling *et al.* 1977b). Many polar bears have been handled and the resultant data are in the national computerized data base stored by the Canadian Wildlife Service in the University of Alberta computer. Through the use of pre-existing computer programs, information pertaining to the age and sex classes of polar bears, previous histories of individual bears, weights, and other information on all polar bears captured by researchers, killed as problem bears, or taken by Inuit hunters could be extracted. To simplify extraction, each region was defined by latitudes and longitudes. As polar bears typically do not begin feeding in the Churchill dump until October (Stirling *et al.* 1977b), two seasons, summer and fall, were used both for computer extractions and for field observations. The months of July, August, and September comprised the summer season, while October, November, and December comprised the fall season. The extracted data were analyzed using the Michigan Interactive Data Analysis System (Fox and Guire 1976).

In the field, polar bears were immobilized using methods described by Lentfer (1968) and by Stirling *et al.*

(1977b, 1980). The straight-line length and the axillary girth were measured and recorded. A fairly accurate estimate of weight could be derived from the axillary girth using a cattle weigh tape, as a high correlation (r=0.97) exists between the derived tape weight and the scale weight (Stirling *et al.* 1977b). All weights reported are derived from cattle weigh tapes unless otherwise mentioned. Bears captured for the first time had unique identifying numbers tattooed on the inside of both upper lips. Identically numbered plastic Delrin tags were placed in each ear. A large number was painted on the animal with hair dye to facilitate identification throughout the field season. Blood samples were collected from some individuals and analyzed for various blood parameters by Dr. R. Nelson at the Carle Foundation Hospital, Univ. of Illinois, Urbana. A small first premolar was extracted from each bear for age determination using methods similar to Thomas and Bandy (1973). Based on this age, each bear was placed in one of the following classes:

1) cub of the year (COY) - less than one year of age
2) yearling - between the ages of one and two years
3) subadult - from age two to four years
4) adult - five years of age or older

Adult females that were not accompanied by cubs of any age were classified as solitary, whereas adult females and accompanying offspring were classified as family groups. Up to about one half of the adult female polar bears in Manitoba show a two-year breeding cycle as opposed to the more usual three-year cycle in more northerly populations (Ramsay and Stirling 1982), so a number of yearling bears may be on their own. These bears were classified as independent yearlings. Any bear without cubs that had no known age or was not captured was placed in the category "unknown". Activities of bears that were handled were not recorded until three days after capture in order to minimize the chance that the behavior observed could have been influenced by the drugs used in immobilizing bears.

Field research began in the fall of 1981 and concluded in the fall of 1983. Direct observations of polar bears were conducted during each of five field seasons. Since there were few, if any, bears in the vicinity of the Churchill dump until fall, both summer seasons, 11 July to 8 August 1982, and 27 July to 24 August 1983, were spent in the Coast 2 region. During the fall of 1983, 26 days (24 September to 19 October) were spent in the Coast 2 region to determine if the activities of polar bears varied between the summer and fall. Bears were also observed at the Churchill dump for three successive fall periods: 5 October to 11 November 1981, 24 September to 14 November 1982, and 12 September to 23 September and 20 October to 4 November 1983. Except for identifying which bears were foraging in the dump, no observations of their activity were recorded while I was in the Coast 2 region during part of the fall of 1983.

In the Coast 2 region, most polar bears were observed either from a 13.5 m tower located at Cape Churchill or from a 6 m tower, 12 km south of Cape Churchill. Polar bears were also observed from the ground after being located by travelling along gravel beach ridges on Honda Model 110 and 200 All Terrain Cycles. All bears were observed through Leitz Trinovid 10 X 40 binoculars or Bausch and Lomb 15-60 X Zoom spotting scopes. In the Dump region, polar bears were observed from a parked vehicle 200 m northwest of the dump site. As all observations were made between 0700 h and 1930 h, the data were biased towards daylight hours.

Observed activities were placed into one of the following categories:

1) **Foraging** - characterized by feeding; head down investigation of potential food sources; digging; or moving within a 100 m area, but still investigating potential food sources.

2) **Travelling** - characterized by walking or running through an area without stopping, except for short (less than one minute) rests; or swimming over 10 m in one direction.

3) **Resting** - characterized by lying; standing; sitting; moving less than 10 m and then lying; or swimming less than 10 m in one direction.

4) **Aggressive Interactions** - characterized by hissing; charging; locking of jaws; or swiping with front paws with or without contact. Less overt aggression was not

detectable, as a result, aggression may be under-represented in the time budgets.

5) **Non-aggressive Interactions** - characterized by social play, such as described by Latour (1981b), between two or more bears.

The duration of each activity was recorded to the nearest minute and a time budget was constructed, using the percentage of the total observed time accounted for by each of the five activities. To make comparisons between time budgets, an arcsine transformation was used in order that the data approximated a normal distribution (Sokal and Rohlf 1981).

In order to assess night movements, twelve bears, four in the Coast 2 region and eight in the Dump region, had small radio transmitters attached to their ears. Four individuals in the Dump region had these transmitters attached in the fall of 1982, while four bears in the Coast 2 region and four more bears in the Dump region, had them attached in the summer and fall of 1983. These individuals represented, as best possible, the spectrum of age and sex classes present in each area. Before leaving each night, visual fixes or triangulation were used to determine the location of as many of the instrumented bears as possible. The next morning, the bears were relocated; if they had not moved more than one km, I assumed that they had not travelled far during the night. In the dump, but not in the Coast 2 region, locations of instrumented bears were determined, by triangulation once almost every other night, between 2000 h and 0100 h as a further gauge of night movement. Approximately three weeks after being attached, some transmitters were observed with their antennae broken off. Therefore, it was uncertain whether a lack of signal reception was due to movements of polar bears, or to broken transmitters. However, because of the road system, I was able to get closer to bears in the Dump region and therefore managed to pick up faint signals and record the bears' locations when radioed bears were checked in the night.

In order to determine whether polar bears were deriving measurable nutritional benefit from the Churchill dump, it was necessary to compare weight changes of individual bears, handled twice in one year, that had fed in the dump with those that had not fed there. However, from 1966 to 1980, the sample size of bears feeding in the dump, and caught twice during the same fall, was one, while the sample size of bears not feeding there was eleven. Therefore, from 1981 to 1983, forty more bears were handled twice in order to increase sample sizes. Of these forty bears, twelve were bears that were not using the dump (nine from the Coast 2 region and three from the Denning Area region) and the remaining twenty-eight bears were using the dump.

III. RESULTS

A. Segregation of polar bears

To assess the value of the Churchill dump to polar bears, I determined the frequency of occurrence of bears of different age and sex classes in the different regions of the study area. The records of polar bears handled in the past were analyzed to look at the extent that bears of each age and sex class segregated. In the past there may have been some capture bias towards family groups in the Denning Area region and single bears in the Coast 2 region. Although I spent little time in the Denning Area region, when I was there I saw mainly family groups; I also observed mainly single bears in the Coast 2 region. Therefore, I felt that the capture records were a good representation of the age and sex classes of bears present in each region.

Since 1966, a total of only 27 polar bears have been captured in the Intermediate Area region. Since few bears have been seen in this region, and I did not observe the activities of any bears there, I did not include the Intermediate Area region in any analyses.

Although the sample sizes of bears of most age and sex classes captured in the summer were admittedly small, the data available indicate that polar bears segregated by age and sex class once they came ashore (Table 1). Adult males tended to remain in the Coast 2 region, whereas most family groups and solitary adult females moved inland to the

Table 1. Numbers of polar bears captured during the summer, from 1966 to 1983, in each region by age and sex class.

	Coast 1	Coast 2	Dump	Denning Area
Family Groups	3	8	7	23
Independent Yearling Males	1	3	0	1
Independent Yearling Females	0	1	0	0
Subadult Males	3	12	9	5
Subadult Females	2	6	4	6
Adult Males	2	17	3	3
Solitary Adult Females	0	2	1	7
Total	11	49	24	45

Denning Area. Subadult females appeared to be more evenly distributed, and subadult males tended to be found mainly in the Coast 2 and Dump regions. Although 9 of 29 subadult males were captured in the Dump region, overall, the Dump and Coast 1 regions did not appear to be major areas used by polar bears during the summer. These two regions only accounted for 27 percent (35/129) of the total bears captured. Records of the Manitoba Wildlife Branch Bear Patrol and the observations of local Churchill residents also indicated that bears were uncommon in the Coast 1 or Dump regions during the summer.

During the fall, bears began to move back towards the coast. During the fall, polar bears also segregated by age and sex class (Table 2, G test, $p<0.001$). Adult males tended to remain in the Coast 2 region and solitary adult females were most abundant in the Denning Area. Both the Denning Area and Dump were regions used by family groups; however, the Dump was used much more in the fall than in the summer. During the summer, only 17 percent (7/41) of family groups caught were in the dump, whereas during the fall 33 percent (42/127) of family groups were caught there. Subadult males were more abundant in both the Dump and Coast 2 regions. Independent yearlings, both males and females, and subadult females were most abundant in the Dump region. Younger bears (independent yearlings and subadults) used the Coast 1 region more than family groups or adult bears, but overall it did not appear to be a major area of use.

Table 2. Numbers of polar bears captured during the fall, from 1966 to 1983, in each region by age and sex class.

	Coast 1	Coast 2	Dump	Denning Area
Family Groups	19	15	42	51
Independent Yearling Males	11	5	24	0
Independent Yearling Females	13	8	21	2
Subadult Males	37	59	75	6
Subadult Females	25	26	45	11
Adult Males	12	83	32	21
Solitary Adult Females	6	5	10	33
Total	123	201	249	124

B. Age structure of polar bears in the study area

As a result of polar bear research conducted along the western coast of Hudson Bay since 1966, the age structure of bears in the study area has been fairly well recorded over the past eighteen years. Female bears in the Denning Area were significantly older (ANOVA, $p<0.001$) than females in any of the other three regions of the study area (Table 3). The difference between the mean age of females in the Denning Area and their mean ages in the other three areas was due to an over-representation of older females and an under-representation of independent yearlings and subadults in the Denning Area. Although 63 percent (64/102) of female bears handled in the Dump region were subadults or independent yearlings, all ages of females were represented there. Male bears were significantly older (ANOVA, $p<0.001$) in the Coast 2 and Denning Area regions, than in the Dump and Coast 1 regions (Table 4). However, only 7 percent (8/118) of all males handled in the Dump region were older than 6 years. It appeared that age or some age-related factor was more important in determining which male bears used the dump than which female bears used it.

C. Behavior of polar bears in the Coast 2 region

In order to determine strategies used by polar bears to deal with an extended period of time away from primary food sources, I documented their activities while ashore. Table 5 shows the percentage of observed time that polar bears spent

Table 3. Numbers of female polar bears, not including offspring, handled by age, in each region of the study area, from 1966-1983.

Age (in years)	Coast 1	Coast 2	Denning Area	Dump
1	13	9	2	21
2	14	11	5	23
3	7	16	2	12
4	4	4	9	8
5	4	0	6	4
6	1	2	9	3
7	4	4	11	4
8	3	6	5	3
9	4	2	2	3
10-14	5	7	35	12
≥15	1	3	27	9
Total	60	64	113	102
Mean Age	4.5	5.4	10.4	5.4
SD	3.9	5.0	5.5	5.1

Table 4. Numbers of male polar bears, not including offspring, handled by age, in each region of the study area, from 1966-1983.

Age (in years)	Coast 1	Coast 2	Denning Area	Dump
1	12	8	1	24
2	16	21	8	29
3	16	25	1	26
4	6	22	2	15
5	4	11	2	7
6	1	10	2	9
7	2	6	2	0
8	1	9	2	2
9	2	9	1	2
10-14	1	22	8	2
≥15	2	22	4	2
Total	63	165	33	118
Mean Age	3.6	7.2	7.5	3.4
SD	3.3	5.5	5.1	2.9

engaged in each activity during the summers of 1982 and 1983. Because there was no significant difference between the percentage of time accounted for by each activity by bears of each age and sex class between summers, the data for both years were pooled. A total of 299.7 hours of activity were observed on 100 polar bears in the Coast 2 region. As the 91 bears of unknown age and sex were not captured and marked, I could not be certain what age and sex classes were represented or how many different individuals there were. However, for the most part, they were probably adult and subadult males.

Resting was the dominant activity, as it accounted for between 77 percent and 97 percent of the total observed activity. When resting, most of the bears lay in day-beds in the grass along the coast. A day-bed was an area of flattened grass, approximately 2 m by 1 m, formed by the weight of a lying polar bear. Polar bears would sometimes lie in similar sized pits dug in the sand along the coast. Family groups did the greatest amount of travelling, 21 percent of their total observed activity. Two factors probably contributed to the amount of observed time family groups travelled. Firstly, after about one week ashore, they tended to move inland, and secondly, because cubs were usually active and stimulated their mothers to move, family groups moved around more often than single bears. Only one solitary adult female was observed during the summer, and for only one day. This sample size was too small for

Table 5. Percentage of observed time different age and sex classes of polar bears spent engaged in each activity, during the summers of 1982 and 1983 in the Coast 2 region.

	Forage	Travel	Rest	Ag	Nag	Total(min)
Family Groups (7)	2	21	77	0	0	3085
Independent Yearling Males	-	-	-	-	-	-
Independent Yearling Females	-	-	-	-	-	-
Subadult Males	-	-	-	-	-	-
Subadult Females	-	-	-	-	-	-
Adult Males (1)	0	3	97	0	0	225
Solitary Adult Females (1)	0	9	91	0	0	402
Unknown Bears (91)	0	9	91	0	0	14268

Ag = aggressive interactions
Nag = non-aggressive interactions

comparison of activities between females with and without cubs. Most of the other bears made short movements between day-beds once or twice each day. Family groups were the only bears observed feeding. Both cubs and mothers were seen consuming moss and the seed heads of grasses. Even so, feeding accounted for only 2 percent of their total activity. Although numerous flocks of flightless geese were present in the Coast 2 region throughout the summer, no polar bears were observed attempting to capture them. No bears were observed interacting, either aggressively or non-aggressively.

By the beginning of October, temperatures decrease, daylength shortens, and polar bears have been ashore for at least two months with little or no access to food. As it was unknown whether any of these factors might alter the behavior of polar bears in the Coast 2 region, I observed bears in this region from 24 September to 19 October, 1983. A total of 570.6 hours of observations were made on 91 bears (Table 6). Although sample sizes for most age and sex classes in both summer and fall were too small for rigorous comparison, the data in Tables 5 and 6 indicated that the activity patterns of polar bears were similar during the summer and fall in the Coast 2 region. Resting was the predominant activity, accounting for over 85 percent of the activity of bears of most age and sex classes. For both independent yearling females and subadult females, the periods of observation were probably not long enough to be

Table 6. Percentage of observed time different age and sex classes of polar bears spent engaged in each activity, during the fall of 1983 in the Coast 2 region.

	Forage	Travel	Rest	Ag	Nag	Total(min)
Family Groups	-	-	-	-	-	-
Independent Yearling Males	-	-	-	-	-	-
Independent Yearling Females (1)	<1	22	78	0	0	832
Subadult Males (2)	1	10	88	0	0	1392
Subadult Females (1)	0	43	57	0	0	218
Adult Males (3)	1	5	90	0	4	5760
Solitary Adult Females	-	-	-	-	-	-
Unknown Bears (84)	<1	3	97	0	<1	26020

Ag = aggressive interactions
Nag = non-aggressive interactions

representative. Except for the above two age and sex classes of bears, travelling accounted for ten percent or less of observed activity. Foraging on fresh kelp, grasses, and mosses was observed, but occurred less than one percent of the time. No aggressive interactions between any bears were seen. Non-aggressive interactions were not observed until the middle of October, and made up from <1 percent to 4 percent of the time budgets. The numbers of bears in the Coast 2 region, in the vicinity of the Cape Churchill tower, appeared to increase at this time and probably contributed to my observations of interactions at this time.

I was only able to relocate 3 of the 4 bears that had radio transmitters. Out of 15 days that I tried to locate these bears, one was located 4 times and two were each located 3 times. When located, they were always near where they were last seen. The raised beach ridges may have hidden these bears from my view and also prevented my reception of the radio signals. However, as I could not tell if these bears had moved out of the area, had malfunctioning transmitters, or were hidden from view, I was unable to determine the extent of night movements by bears in the Coast 2 region.

D. Behavior of polar bears in the Denning Area

It was not possible to observe the behavior of polar bears in the Denning Area during any season. However, it was possible to determine to what extent polar bears were feeding in the Denning Area by the analysis of samples of blood collected from bears captured in this region and comparing those results with those from bears in regions where the activities of bears have been recorded.

Metabolism of both carbohydrates and fats results in the formation of carbon dioxide and water as the ultimate end-products of oxidation. However, when proteins and nucleic acids are metabolized, carbon dioxide, water, and ammonia, a highly toxic and highly soluble compound, are formed (Schmidt-Nielsen 1975; Eckert and Randall 1978). In mammals, ammonia is converted to urea and subsequently excreted. Other nitrogen-containing products are also formed and must be removed. Creatinine is an end product of muscle metabolism; its production is relatively constant for an individual and is proportional to muscle mass (Morgan-Hughes 1974).

Blood urea concentration depends upon the degree of protein intake and catabolism (Britton 1974). Bears that feed at a source of protein should have higher blood urea concentrations than those that do not feed. However, to be able to pool blood urea concentrations of all bears from one region for comparisons between regions, urea-creatinine ratios were calculated for all bears. Nelson *et al.* (1973, 1983) found that mean urea-creatinine ratios of non-feeding black bears, during winter sleep, were below ten, while for feeding black bears, mean urea-creatinine ratios were above ten. Therefore for the purposes of determining the extent of feeding by polar bears, ten was used as the critical value. During the summer, mean urea-creatinine ratios suggested that bears in the Coast 2 and Dump regions were feeding while those in the Denning Area were not (Table 7). As bears in summer had recently come ashore from the sea ice, the mean urea-creatinine ratio of bears in the Coast 2 and Dump regions may merely indicate that these bears fed recently. However, bears in the Denning Area had also come ashore recently, yet their urea-creatinine ratio indicated they were not feeding. However, these bears also moved inland to the Denning Area, which suggests that activity may lower blood urea levels. Bears in the dump were also active in getting to this region, however they were able to feed upon arrival.

After being ashore for two to three months, the blood urea concentrations of non-feeding polar bears should have decreased from summer levels, resulting in lower urea-creatinine ratios. In the Dump region, this ratio was well above a ratio of ten, indicating that these bears were still feeding. In the Coast 2 region the ratio decreased and in the Denning Area the ratio remained unchanged. However, on one flight through the Denning Area, one family group was observed feeding on a caribou carcass. When subsequently captured three days later, they were still at the carcass. A blood sample was taken only from the adult female and later analysis showed the urea concentration and the urea-creatinine ratio to be the highest values in any

Table 7. Mean concentrations, plus one standard deviation, of urea (mg/dl) and creatinine (mg/dl) in the blood of polar bears, during the summer and fall, at different locations in the study area, sample size in parenthesis.

Location	Urea	Creatinine	Urea/Creatinine
Dump			
AUG-SEP (4)	24.7 ± 8.3	1.1 ± 0.3	22.9 ± 8.4
OCT-NOV (16)	24.3 ± 13.0	1.2 ± 0.5	22.0 ± 12.9
Coast 2			
AUG-SEP (19)	21.8 ± 7.7	1.5 ± 0.4	16.9 ± 9.9
OCT-NOV (75)	14.0 ± 7.8	1.8 ± 0.4	7.9 ± 4.5
Denning Area			
AUG-SEP (7)	18.4 ± 3.7	1.9 ± 0.4	10.1 ± 2.4
OCT-NOV (61)	18.3 ± 15.7	1.9 ± 0.4	10.4 ± 11.8
OCT-NOV (60)[1]	16.6 ± 7.5	1.9 ± 0.4	9.0 ± 5.3

[1] - adult female feeding on caribou carcass not included

region. When this single record was removed and the urea-creatinine ratio redetermined, a value of 9.0 ± 5.3 was calculated. As direct observations of polar bear foraging activities in the Dump and Coast 2 regions supported the conclusions drawn from the blood analysis, I concluded by inference that polar bears in the Denning Area did not feed to any significant extent. It appeared that bears in the Denning Area and Coast 2 regions were not ordinarily feeding, yet those in the Dump region were.

E. Behavior of polar bears in the Dump region

The activities of polar bears in the Churchill dump were also observed and recorded. The effect that a food source may have on the activities of bears, while ashore, was examined by comparing time budgets of bears that foraged in the Churchill dump with those of bears that did not. As there was no significant difference in the percentage of time engaged in each activity by polar bears of each age and sex class, between 1981 and 1982, the data for both years were pooled. During the falls of 1981 and 1982, a total 683.2 hours of observations were made on 82 polar bears (Table 8). By the first week and a half of each fall field season, most of the bears using the dump had been captured and marked. By the end of October and beginning of November more unmarked bears arrived. The maximum number of unmarked bears observed at any one time was six. Most were caught within a day or so after their arrival in the dump and were

Table 8. Percentage of observed time different age and sex classes of polar bears spent engaged in each activity, during the falls of 1981 and 1982 at the Churchill dump.

	Forage	Travel	Rest	Ag	Nag	Total(min)
Family Groups (7)	48	14	38	<1	0	25473
Independent Yearling Males (3)	49	21	24	6	0	191
Independent Yearling Females	-	-	-	-	-	-
Subadult Males (4)	62	14	13	<1	10	4800
Subadult Females (2)	17	9	70	0	4	2728
Adult Males (2)	21	16	52	<1	11	3049
Solitary Adult Females	-	-	-	-	-	-
Unknown Bears (44)	30	19	44	<1	6	4752

Ag = aggressive interactions
Nag = non-aggressive interactions

subadult males and females. I estimated that no more than seven or eight different unmarked individuals used the dump briefly before being captured, observations of which amounted to only 12 percent of the total time (4752 min/40993 min).

The activity budgets of bears of each age and sex class in the Dump region were different from their counterparts in the Coast 2 region. Resting, which was the most dominant activity in terms of time allocation in the Coast 2 region, was not as common in the Dump region. Except for subadult females and adult males, all bears of each age and sex class in the dump rested for less than 50 percent of the observed time. This may reflect a tendency for polar bears not to rest in the same areas where they feed. As expected, foraging accounted for a much greater percentage of the observed activities of bears in the Dump region than in the Coast 2 region. Garbage was delivered twice a day, four days a week. The two loads were dumped around 1100 h and 1500 h. Most bears that foraged in the dump arrived between 0800 h and 1000 h and left between 1700 h and 1900 h. When they left each afternoon, individual bears tended to select specific sites, within a two km radius of the dump, and used them for resting throughout the fall. Movements to these specific sites from the dump in late afternoon and movements back to the dump the following morning accounted for most of the observed travelling by bears in this region.

Except for family groups and independent yearling males, bears of each age and sex class engaged in non-aggressive interactions, such as described by Latour (1981b) between adult males at Cape Churchill. These interactions usually involved only two bears, although on two separate occasions, three bears were involved. Mean duration of all non-aggressive encounters was 19 minutes (n=32) and varied in length between 2 and 66 minutes. These interactions usually occurred in the grassy areas adjacent to the dump.

Unlike in the Coast 2 region, aggressive interactions did occur in the dump, although they accounted for less than one percent of the activity budget for all groups except independent yearling males. However the period of observation of independent yearling males may not have been long enough to be representative. Typically, aggressive interactions (n=52) were brief; the mean duration was 1.2 minutes, and ranged from 1 to 3 minutes. All but one aggressive encounter, were initiated by adult females with cubs (Table 9). Initiation of aggression among bears resulted from contact between a female's cubs and other bears. Family groups won all but one of the 51 bouts they initiated, and appeared to be the most dominant bears in the Dump region. I considered a bear to have won an interaction when the other bear ceased interacting and moved away. Family group - family group interactions were the most common, accounting for 45 percent (23/52) of all observed

Table 9. Numbers of aggressive encounters initiated by each age and sex class of polar bears, and the outcomes of these bouts, observed in the Churchill dump during the falls of 1981 and 1982.

		INITIATORS			
		Family Groups	Subadult Males	Total Bouts Defended	Total Bouts Won
DEFENDERS	Family Groups	23	0	23	1
	Adult Males	4	1	5	1
	Subadult Males	11	0	11	0
	Independent Yearling Males	4	0	4	0
	Unknown Bears	9	0	9	0
	Total Bouts Initiated	51	1		
	Total Bouts Won	50	0		

aggressive encounters. One subadult male initiated a bout with an adult male, but lost. The adult male was feeding on what appeared to be meat scraps. Except for this one case, no other aggression between bears of the other age and sex classes were observed.

During the fall of 1982, three of the four bears with radio transmitters chose specific sites near the dump and returned to these sites each night. Although the dump was not monitored continuously, of 24 trips to the dump at night, on only 4 occasions were one or two small bears observed foraging there. This indicated that for the most part, the dump was not an important feeding site for bears at night. Three of the four bears with transmitters were found in the vicinity of their selected sites from 20 to 22 of the 24 nights, suggesting that bears that used the dump during the day moved little during the night. I was unable to locate these bears on the nights they were not near their selected sites. In the morning, these same bears were observed lying in the same site where they were seen the day before and located the previous night. One subadult male with a transmitter left the dump region for seven days, returned for six days, and then left for another six days. I was unable to locate this individual while it was away from the dump, although several local tour operators occasionally saw this bear 25 to 30 km east of the dump. During the six days in the Dump region, I located this bear in three separate areas on five nights.

In 1983, bears came into the dump more than a month earlier (late August compared to early October) and there were about twice as many (20 vs 10-11) as in the previous two falls. A total of 532.1 hours of observations were made on 27 bears (Table 10). There was a significant difference (G test, $p<0.05$) between the time budgets in 1981/1982 and 1983 for bears of each age and sex class observed in the Dump region, except for subadult males and females. Family groups and unknown bears foraged less and rested more during 1983 than in 1981/1982. Adult males foraged more in 1983 than in 1981/1982. All groups of bears travelled less in 1983 than in the previous two falls. Except for family groups, the percentage of activity accounted for by non-aggressive interactions remained the same or decreased from 1981/1982. Mean duration of all non-aggressive encounters (n=44) was 18 minutes, and varied between 2 and 50 minutes. Family groups did not engage in non-aggressive interactions in 1981/1982, yet in 1983, this activity accounted for 6 percent of their time budgets. Two family groups always left the dump and arrived at the dump together every day. While away from the dump, both family groups stayed within 50 m of each other. Although one set of cubs were COYs and the other set were yearlings, both adult females tolerated each other's offspring. This association accounted for most of the observed non-aggressive activity of family groups. The percentage of activity accounted for by aggressive interactions decreased in 1983. The mean

Table 10. Percentage of observed time different age and sex classes of polar bears spent engaged in each activity, during the fall of 1983 at the Churchill dump.

	Forage	Travel	Rest	Ag	Nag	Total(min)
Family Groups (4)	35	11	48	<1	6	13812
Independent Yearling Males	-	-	-	-	-	-
Independent Yearling Females (2)	61	9	29	0	<1	1821
Subadult Males (6)	45	11	36	<1	8	6337
Subadult Females (4)	40	9	49	0	1	4063
Adult Males (2)	39	9	48	0	3	4088
Solitary Adult Females	-	-	-	-	-	-
Unknown Bears (9)	10	9	74	<1	7	1806

Ag = aggressive interactions
Nag = non-aggressive interactions

duration of these encounters (n=11) was 1 minute, and ranged between 1 and 2 minutes. All except one encounter were initiated by family groups (Table 11). As in the previous two falls, family groups that initiated encounters were the dominant bears, as they won all 10 bouts. Of the total of eleven observed aggressive encounters, only one was an intraclass confrontation between family groups.

Although the sample size was small, it appeared that bears did not use the dump during the night. They were observed there only on one out of the ten trips made during the night. As before, individuals selected specific sites for resting during the evening when away from the dump. Three of four bears with radio transmitters were found near their selected sites, ranging from 8 to 10 out of the 10 trips made at night. Only one bear was found in another location at night. In the morning, I found these bears still in their selected areas, suggesting as before that they moved little during the night. One old adult male (15 yrs) was caught in the Coast 1 region, held near town and released with a transmitter. Although I never located this bear again, it was seen several weeks later in the Northwest Territories. Individual bears that were in the dump both in 1982 and 1983 selected different specific sites each year; however, the sites used in 1983 had been used by other bears in 1982.

Table 11. Numbers of aggressive encounters initiated by each age and sex class of polar bears, and the outcomes of these bouts, observed in the Churchill dump during the fall of 1983.

		INITIATORS			
		Family Groups	Subadult Males	Total Bouts Defended	Total Bouts Won
DEFENDERS	Family Groups	1	0	1	0
	Subadult Females	2	0	2	0
	Subadult Males	5	0	5	0
	Adult Males	1	1	2	1
	Unknown Bears	1	0	1	0
	Total Bouts Initiated	10	1		
	Total Bouts Won	10	0		

F. **Annual fidelity of polar bears to the Churchill dump**

Since 1966, 33 individual adult females, handled in the Churchill dump, have brought 57 litters and 101 offspring there. Thirty-nine percent (13/33) of these adult females have returned to the dump in subsequent years with different litters. One female has returned with four different litters and one female has returned with five different litters. The mean litter size and one standard deviation was 1.8 ± 0.7. Once weaned, 21 percent (15/72) of the offspring were known to have returned to the dump. One female cub that came to the dump with her mother, subsequently returned there with two different litters of her own.

Since 1966, 207 individual polar bears have been captured at the Churchill dump; of these, 67 (32 percent) have been recaptured there in years subsequent to their first capture. One female caught in the Churchill dump in 1967, at the age of two, has returned there almost every other year over the past sixteen years. Three females have each returned to the dump over an eleven year time span, while two females have been returning over a ten year period. Male polar bears did not return as often as females even if they were in the dump as cubs. Since 1966, a total of 23 cubs and subadults that were originally caught in the dump have not returned there but have been recaught elsewhere as adults. Of this total, 2 males (9 percent) and 2 females (9 percent) were recaught in the Denning Area. By contrast, 17 males (74 percent) and 2 females (9 percent) were recaught along the coast. Although the sample size is admittedly small, the data available indicated that once male bears reached the age of six they no longer returned to the dump.

G. **Benefits and costs of a large supplemental food source**

In order to see if there were any benefits gained by using the Churchill dump, I determined if bears of the same age and sex class came ashore in comparable condition. Weights of bears that both fed and did not feed in the dump during the summer were used to compare overall condition. Sample sizes of bears handled in the dump during the summer were small. Except for COY females, there were no significant differences between the weights of bears in the dump and bears not in the dump (Table 12). This suggested that polar bears of each age and sex class came ashore in comparable nutritional condition.

By comparing the mean weights of bears in the summer with those in the fall, it should be possible to determine if bears gained any nutritional benefit by feeding in the Churchill dump. Bears from six age and sex classes that were not feeding in the Churchill dump were significantly lighter in the fall than they were in the summer, while bears from four age and sex classes were not significantly lighter (Table 13). By contrast, there were no significant differences between summer and fall weights of bears feeding in the Churchill dump (Table 14). As the sample size of

Table 12. Mean summer weight (kg) of bears captured in the dump and not captured in the dump from 1966 to 1983, sample size in parenthesis.

	Non-dump	Dump	*t*	*p*
Adult Females	193 ± 31 (29)	217 ± 52 (5)	-1.403	NS
COY Females	54 ± 13 (18)	74 ± 22 (4)	-2.616	S
COY Males	57 ± 7 (11)	54 (1)	-	
Yearling Females	116 ± 21 (6)	102 ± 1 (2)	0.899	NS
Yearling Males	110 ± 25 (5)	143 (1)	-	
Independent Yearling Females	112 (1)	-	-	
Independent Yearling Males	118 ± 22 (1)	-	-	
Subadult Females	171 ± 46 (12)	163 ± 44 (5)	0.341	NS
Subadult Males	224 ± 46 (18)	221 ± 49 (6)	0.141	NS
Solitary Adult Females	226 ± 20 (4)	-	-	
Adult Males	323 ± 72 (15)	266 ± 57 (3)	1.281	NS

Table 13. Mean summer and fall weights (kg) of polar bears captured in areas other than the dump from 1966 to 1983.

	Summer	Fall	*t*	*p*
Adult Females	193 ± 31 (29)	159 ± 28 (61)	5.197	S
COY Females	54 ± 13 (1[illegible]	41 ± 10 (36)	3.803	S
COY Males	57 ± 7 (11)	44 ± 13 (27)	3.238	S
Yearling Females	116 ± 21 (6)	93 ± 20 (13)	2.337	S
Yearling Males	110 ± 25 (5)	112 ± 15 (21)	-0.237	NS
Independent Yearling Females	112 (1)	85 ± 34 (22)	-	
Independent Yearling Males	118 ± 22 (4)	107 ± 26 (14)	0.800	NS
Subadult Females	171 ± 46 (12)	144 ± 33 (51)	2.356	S
Subadult Males	224 ± 46 (18)	178 ± 43 (88)	4.136	S
Solitary Adult Females	226 ± 20 (4)	227 ± 57 (33)	-0.031	NS
Adult Males	323 ± 72 (15)	310 ± 70 (102)	0.668	NS

Table 14. Mean summer and fall weights (kg) of polar bears captured in the Churchill dump from 1966 to 1983.

	Summer	Fall	*t*	*p*
Adult Females	217 ± 52 (5)	197 ± 56 (31)	0.745	NS
COY Females	74 ± 22 (4)	64 ± 24 (28)	0.808	NS
COY Males	54 (1)	46 ± 11 (19)	-	
Yearling Females	102 ± 1 (2)	141 ± 32 (8)	-1.656	NS
Yearling Males	143 (1)	121 ± 27 (4)	-	
Independent Yearling Females	-	105 ± 24 (16)	-	
Independent Yearling Males	-	128 ± 42 (22)	-	
Subadult Females	163 ± 44 (5)	150 ± 40 (39)	0.655	NS
Subadult Males	221 ± 49 (6)	198 ± 60 (58)	0.902	NS
Solitary Adult Females	-	196 ± 41 (5)	-	
Adult Males	266 ± 57 (3)	293 ± 61 (22)	-0.739	NS

bears in the dump during the summer was small, I also compared the mean weights of bears in the dump in the fall with the mean weights of non-feeding bears in the summer. Except for COY females, there were no significant differences between the mean weights of bears feeding in the dump in the fall and the mean weights of bears in the other areas in the summer. From these data, it was clear that by foraging in the dump, polar bears had a nutritional benefit over non-feeding bears in that their fall weights, prior to going onto the sea ice, were similar to their summer weights when they came ashore.

In order to determine whether individual bears lost weight between coming ashore and the onset of feeding in the dump, and also to determine benefits to individuals, some bears were captured twice in one year. Except for one subadult female, all bears in the Coast 1 and Coast 2 regions lost between 0.3 percent and 0.4 percent of their total initial body weight per day (Table 15). The single subadult female gained 37 kg in 13 days, or 2.5 percent of total initial body weight per day. In order to gain so much weight in such a short time, this bear must have found a carcass to scavenge upon. Bears in the Denning Area either lost no weight or lost between 0.1 percent and 0.8 percent of their total initial body weight per day. In contrast, individual bears foraging in the dump either gained between 0.1 percent and 0.6 percent of total initial body weight per day or showed no weight loss. The greatest increase was 2.8

Table 15. Weight changes of polar bears that have been handled twice in one year from 1966 to 1983, sample size in parenthesis.

Region	Age/sex Class	Mean Days	Mean Wt. 1 (kg)	Mean Wt. 2 (kg)	% Wt. change /day
COAST	Adult Females (1)	105	164	115	-0.3
	COY Females (1)	105	54	35	-0.3
	Independent Yearling Males (2)	84±18	118±13	83± 6	-0.4
	Subadult Females (1)	13	115	152	2.5
	Subadult Males (6)	42±43	234±59	206±50	-0.3
	Solitary Adult Females (1)	108	188	115	-0.4
	Adult Males (5)	64±27	243±57	197±45	-0.3
DENS	Adult Females (1)	24	157	127	-0.8
	COY Females (2)	24± 0	52± 3	44± 2	-0.6
	Subadult Males (2)	70± 7	232±14	231±15	0.0
	Solitary Adult Females (1)	89	201	185	-0.1

Table 15. Continued.

Region	Age/sex Class	Mean Days	Mean Wt. 1 (kg)	Mean Wt. 2 (kg)	% Wt. change /day
DUMP[1]	Adult Females (5)	46±25	228±83	239±27	0.1
	COY Females (6)	38±32	71±29	80±19	0.3
	COY Males (1)	27	37	65	2.8
	Yearling Females (2)	57± 0	102± 1	140±23	0.6
	Yearling Males (1)	53	143	147	0.1
	Independent Yearling Females (2)	24± 2	73±20	73± 1	0.0
	Independent Yearling Males (1)	98	109	112	0.0
	Subadult Females (2)	34± 1	134± 6	159±29	0.6
	Subadult Males (6)	33±14	206±79	220±89	0.2
	Solitary Adult Females (1)	7	180	210	2.4
	Adult Males (2)	55±13	255±77	264±51	0.1

[1] includes one female and her 3 female COYs that all lost weight while in the dump.

percent per day for one COY male. The only bears to lose weight in the Dump region were all members of the same family group. Three COY females lost up to 11 kg in fifteen days, while their mother lost 88 kg in the same time period. It was unknown why they lost weight; however, when their weights were removed from the analysis, the weight change of adult females in the dump increased from 0.1 percent to 0.4 percent of total initial body weight while the weight change of COY females increased from 0.3 percent to 0.7 percent.

It appears that, once ashore, all bears lost weight. Those bears that foraged in the dump were able to replace the lost weight, going back onto the sea ice weighing about the same as they did when they came ashore. However, this nutritional benefit did not appear to translate into a reproductive benefit. There was no significant difference (*t*-test, $0.5<p<0.9$) between the mean litter size of bears that foraged in the dump (mean=1.8±0.7, n=58) and those that did not forage there (mean=1.7±0.6, n=152).

Another consideration in determining benefits of supplemental food sources is the effect on survivorship. It was not possible to get an accurate estimation of survivorship; however, a crude value, based on recapture, was determined. Of the total number of polar bears that have fed in the dump and could have been recaptured, 49 percent (89/183) were recaptured throughout the study area in subsequent years. By comparison, only 24 percent (99/410) of bears not feeding in the dump have been recaptured. However, these results are biased as bears returning to the dump are much more easily recaught. Therefore, the recapture rates need to be weighted differently to attempt to make any comparisons. Essentially 100 percent of bears in the dump are captured each year; however, in the other areas this is not the case. The total number of bears tagged, therefore potentially recapturable, increases each year. In 1983 the recapture rate was approximately 40 percent. In past years the recapture rate was not this high. Therefore I used a conservative estimate of a 30 percent recapture rate in the other areas. Of the bears in the dump, approximate 1/3 were recaught there. As an individual bear had a 3 1/3 times greater chance of being caught in the dump than in the other areas (100 percent vs 30 percent), I weighted 1/3 of those bears that were recaught but had never been in the dump, by a factor of 3 1/3. The weighted recapture rate of bears never feeding in the dump increased to 43 percent (176/410). Therefore, although the method is admittedly subjective, in general it appeared that there was no advantage or disadvantage, in terms of survivorship, to those bears that fed in the dump.

Although there were nutritional benefits to bears feeding in the dump, there were costs as well. One bear was found dead 200 m from the dump, with no visible signs to suggest cause of death. During our field autopsy, two pieces of lead batteries were found in the stomach. We concluded that this bear probably poisoned itself. Although there was no way to determine how many bears poisoned themselves while feeding in the dump, the large number of tagged bears that have returned in subsequent years suggested that accidental poisonings were rare.

Another cost of feeding in the dump was the effect that the acclimation of polar bears to humans may have. Each fall, some polar bears walk into the town of Churchill, become problems, and have to be destroyed. A significantly higher number of tagged bears that have used the dump, than have not, have been destroyed as problem bears (G-test, $p<0.001$). Of 207 tagged bears that have fed in the dump, 12 percent (24) have been destroyed as problem bears compared to only 2 percent (11/496) of tagged bears that have not fed there. Of the 24 "dump" bears destroyed, 19 were subadult males.

When Hudson Bay freezes, polar bears move north along the Keewatin coast, where they are hunted by natives from several Inuit communities. A significantly higher number of tagged polar bears that have fed in the dump than have not, were harvested by the Inuit (G-test, $p<0.001$). Of 496 tagged bears not feeding in the dump, 4 percent (19) have been killed by Inuit hunters, while 8 percent (17/207) of tagged bears that have fed in the dump have been killed.

IV. DISCUSSION

A. Segregation of polar bears

Segregation did not appear to result from competition for resources. In two summers spent in the Coast 2 region, no interactions over any discernable resource were observed between any bears. As far as could be determined, there was abundant unoccupied space available to family groups in the Coast 2 region, or to adult males in the Denning Area. Family groups tended to come ashore at the same time as adult males, but were not seen in the Coast 2 region after one week, suggesting that they had moved into the Denning Area. Although I observed no adult males moving inland, some had as they have been caught in the Denning Area.

Segregation may be based on the avoidance of males by family groups. Intraspecific mortality of polar bears has been reported. Claws of cubs were found in two polar bear scats collected from the Hudson Bay coast and the islands in James Bay (Russell 1975). Adult males have occasionally killed entire family groups (Russell 1971). On two separate occasions during the summer of 1983, carcasses of cubs were found; an adult male was feeding on one carcass (M. Ramsay pers. comm.). It was unclear if this male had actually killed the cub or if he was scavenging. Although over shorter distances females with cubs are probably able to out run adult males, over longer distances cubs will tire. As a result, those cubs that tire may become easier prey for adult males. Even though adult females will defend their cubs it is probably a better reproductive strategy, in terms of cub survival, for family groups to move inland to the Denning Area soon after coming ashore and thereby minimize potential encounters with adult males.

Intraspecific mortality caused by adult male black bears (Kemp 1976; Rogers 1977; Beecham 1980; Bunnell and Tait 1981) and brown bears (Troyer and Hensel 1962; Stringham 1980; Bunnell and Tait 1981; McCullough 1981; Stringham 1983) has been reported, but some of the cases involved trapped animals. Therefore the extent to which it occurs in these species, under natural conditions, is still uncertain. Both adult male lions (*Panthera leo*) (Schaller 1972) and langurs (*Presbytis* sp.) (Mohnot 1971; Rudran 1973; Hrdy 1974) are known to kill offspring of other males, but this occurs after the displacement of previous dominant males from social groups.

During the fall, bears of each age and sex class have used the Dump region. This suggests that around a food source, the degree of segregation decreased. However, bears were not completely tolerant of each other and some aggressive behavior was observed. Polar bears used this region more in the fall than in the summer. The increase in the relative use of the Churchill dump was most evident in family groups. For most bears in the study area in the fall, the shortest route back to Hudson Bay is to the east or northeast instead of north toward the dump. Therefore, the use of the Dump region was not due to bears taking the shortest route back to the coast but rather, to some other factor intrinsic to the Churchill dump.

B. Behavior of polar bears in the Coast 2 region

Knudsen (1978) constructed time budgets of polar bears during the summer on North Twin Island in James Bay. His results, based on 111 hours of activity on a minimum of five family groups and nine lone bears, were similar to mine in that resting was the dominant activity. Lone bears and family groups rested 86.4 percent and 87.7 percent of the total observed time, respectively. The percentage of activity accounted for by foraging was similar in the two studies. Knudsen found that feeding accounted for 2.4 percent of the activity of lone bears and 4.9 percent of the activity of family groups. On North Twin Island, bears fed mainly upon crowberries and Canada geese. Russell (1975) found that birds comprised a larger part of the diet of polar bears on the islands in James Bay than along the Manitoba and Ontario coasts. He suggested that the abundance of ducks and water turbidity around the islands may have created a situation where capture of birds was relatively easy. The general lack of observations of bears attempting to capture flightless geese in the Coast 2 region suggested that 1) the success rate may be lower than for seabirds on water, 2) that net energy returned per captured bird makes hunting on land energetically inefficient, 3) that bears on the mainland may not have associated birds as potential prey, or 4) a combination of the three. Over the past 20 years, scientists from two field camps have conducted research on geese in the Coast 2 region. M. Gillespie (pers. comm.) indicated that although bears had been observed walking through flocks of geese, no attempts were made to capture them.

Latour (1981a) documented activities of polar bears at Cape Churchill during two successive fall periods. He also found that resting was a major activity, as adult and subadult males rested 78.6 percent and 73.2 percent of the total observed time, respectively. His results also indicated that polar bears along the coast remained inactive most of the time. He found that subadult females rested the least, 56.3 percent of the time. My sample for this age and sex class was small, but the similarity suggests that it may not have been unrepresentative. Foraging accounted for approximately 1 percent in both studies. Travelling was not a separate category in Latour's study; however, active behavior ranged between 18 percent and 36.5 percent. Adult males were the least active while subadult females were the most active. I found a similar trend, with travelling accounting for 5 percent of the adult male time budgets and 43 percent of subadult female time budgets. However, I attribute the variation between studies to a seasonal difference in when the observations were made. I finished observing bears in the Coast 2 region approximately one month earlier than Latour. Although the numbers of bears increased at Cape Churchill and non-aggressive interactions occurred, the bears did not appear to move around more. Latour also noted that the numbers of bears began to increase in his study area in October, but he did not report an increase in non-aggressive interactions. He found that non-aggressive behavior accounted for between 3.1 percent and 7.6 percent of the time budget, similar to my results which ranged between 0 and 4 percent. In both studies bears were observed during daylight hours. However, most of Latour's observations were made at a later date than mine. As the numbers of bears along the coast continues to increase throughout the fall, the opportunity for interactions should also increase. Therefore, interactions between bears may have increased later in the fall when I was not there.

While ashore, most polar bears remained inactive. As a result, polar bears could minimize their metabolic demands by minimizing their energetic costs. As polar bears are energetically inefficient walkers (Øritsland *et al.* 1976; Best 1982; Hurst *et al.* 1982), being active would be a particularily poor strategy, in terms of energetic costs, especially when there is little or no access to food sources. The high energetic cost of walking, to polar bears, may also explain why they do not attempt to capture flightless geese.

Ankney and MacInnes (1978) determined the body composition of nesting female lesser snow geese at the McConnell River in the Northwest Territories. They weighed the gizzard, sternal muscles, and leg muscles as an index of protein reserves and also weighed subcutaneous, mesenteric, and abdominal fat as an index of fat reserves from female geese during the post hatch period (6 July to 13 July). They found that in these females (*n*=35) mean protein reserves accounted for [illegible] percent (163 g) of total body weight while fat reserves were negligible.

Hurst *et al.* (1982) studied polar bear locomotion and derived the following equation to measure oxygen consumption:

$$VO_2 = 0.62e^{0.06V^{1.5}}$$

where VO_2 = oxygen consumption in ml O_2 per gram per hour, e = natural log = 2.718, and V = walking speed in km/h. Using this equation and the data of Ankney and MacInnes, an estimate was calculated to determine how quickly a bear must catch a goose in order for it to be an energetic benefit. The following assumptions were made: 1) bears only used fat as an energy source while catching geese, 2) body composition of lesser snow geese in Churchill was similar to that of geese at the McConnell River, and 3) bears only fed on the protein and fat reserves of geese. When only fat is metabolized, 4.7 kcal of heat are produced for each litre of O_2 used (Schmidt-Nielsen 1975). Therefore, using the above equation, a 320 kg bear (average weight of adult males) running at 20 km/h would use 55 kcal/second. The energy returned by consuming female lesser snow geese would be 701 kcal. In order to get a net energy gain, a polar bear must catch a goose in approximately twelve seconds. It does not appear that it is energetically efficient for polar bears to feed on flightless geese while ashore. Bears scavenging on geese carcasses in the dump did not consume the entire carcass, but only ate the remaining flesh. Grizzly bears would appear to expend more energy than returned when digging out and trying to catch ground squirrels. This may suggest that energy efficiency may not be the only reason that polar bears do not hunt geese, but that they may also have little interest.

By remaining inactive, polar bears may also be able to cope with another potential problem, high temperature. Fur, blubber, and peripheral tissues provide significant insulation in and out of the water (Øritsland 1970). However, under warm weather conditions, mechanisms for heat dissipation may be insufficient to prevent increases in body temperature (Øritsland 1970). As the ambient temperature increases, the amount of heat dissipated decreases and hyperthermia may occur (Best 1982; Hurst *et al.* 1982). Best (1982) concluded that the pelage of an active polar bear may be an adequate insulator for ambient conditions ranging up to 7.0° C. Mean summer temperatures of 12° C may be near the upper limit at which polar bears can maintain their body temperature at a relatively constant level. Activity increases the amount of metabolic heat that must be dissipated. Therefore, heat load during hunting may be another reason for the lack of interest in geese. However, inactive polar bears can reduce the chance of hyperthermia by minimizing the amount of metabolic heat produced.

Wind can increase the thermal gradient between the body and the air by decreasing skin temperature (Øritsland 1970; Best 1982). Bears in the Coast 2 region, were mainly found on the seaward sides of beach ridges and eskers, and along the edge of the coast, where they were exposed to the cool winds blowing off the Bay. Bears were also observed lying in the waters of Hudson Bay, presumably to keep cool. In the Denning Area, polar bears sometimes lie at the edge of large lakes where they can take advantage of breezes coming off them, or dig dens down to the permafrost in order to keep cool (Jonkel *et al.* 1972, 1976; Stirling *et al.* 1977b).

C. Behavior of polar bears in the Dump region

Studies of black bears feeding at dumps (Herrero 1983) and brown bears feeding at salmon streams (Stonorov and Stokes 1972; Egbert and Stokes 1976) found that most individuals fed late in the afternoon and early evening. According to my results, polar bears fed much earlier, arriving in the morning and leaving in the late afternoon or early evening. Animals that make use of concentrated food sources should forage when they can maximize their chance of successfully obtaining food. Large quantities of garbage were brought into the Churchill dump once in the morning and once in the middle of the afternoon. By late afternoon, most of the edible garbage had been consumed. Therefore, foraging success is greatest during the morning and afternoon. In the Canadian Arctic, Stirling (1974) observed that polar bears were hunting most often during the early morning, when the probability of seals surfacing at any particular location was greatest. Egbert and Stokes (1976) also observed that the greatest success of fishing by brown bears occurred during the late afternoon and early evening, the same time that most bears were observed feeding.

Typically, polar bears, like black and brown bears, are asocial. Family groups and mating bears are usually the only extended associations out on the sea ice. Concentrations of polar bears at the Churchill dump and along the coast as well as the more individually spaced bears inland, illustrate the flexibility of their social organization while on the land during summer.

At concentrated food sources, social systems amongst black and brown bears are built and maintained through a dominance hierarchy. Adult males are typically the most dominant, because of their larger size (Stonorov and Stokes 1972; Egbert and Stokes 1976; Rogers 1977; Herrero 1983). Stonorov and Stokes (1972) observed about 600 aggressive encounters between brown bears fishing at a salmon stream over a 6 week period, while Herrero (1983) observed 131 aggressive encounters between black bears feeding in a dump, over a 20 week period. In a total of 16 weeks, spanning three successive fall field seasons, I observed only 63 aggressive encounters. Family groups initiated 61 aggressive encounters and won 60 of them. Single bears usually remained outside of the dump or foraged at the periphery when two or more family groups foraged there. In the three years that I observed bears in the Churchill dump, only family groups were ever avoided by bears of other age and sex classes. Polar bears appeared to assess dominance without engaging in aggressive encounters. Family groups appeared to be dominant in the Dump region.

This result differs from studies of black bears at dumps (Rogers 1977) and brown bears (Egbert and Stokes 1976) at salmon streams where adult males are dominant. This difference probably occurs because few adult males use the Churchill dump and polar bears have different energetic requirements than do other bear species at this time of year. Both black and brown bears den in the fall (Rogers 1977; Pelton *et al.* 1980; Vroom *et al.* 1980; Beecham *et al.* 1983; Servheen and Klaver 1983). It is important that these bears build up adequate fat reserves for use during the winter denning period (Rogers 1976; Beeman and Pelton 1980; Garshelis and Pelton 1980; Nelson *et al.* 1983). Both black and brown bears may be more aggressive at concentrated food sources in an effort to maximize the amount of stored fat reserves that they build up before they den. Polar bears, on the other hand, move back onto the sea ice and begin hunting seals by the end of November and beginning of December, except for pregnant females which are already in the denning area and do not feed in the dump anyway. Therefore, it is not necessary for polar bears to build up fat reserves prior to going on the sea ice.

Latour (1981a, b) observed non-aggressive interactions between polar bears at Cape Churchill. The mean duration of those bouts was 3.7 minutes. The difference between the duration of bouts in his study and mine may have been related to the number of family groups foraging in the dump, as their presence affected the behavior of single bears in the Dump region. Single bears avoided contact with family groups as much as possible. Therefore, while family groups fed in the dump, single bears would stay at the edge of the dump, thereby increasing the opportunity for encounters between single bears. When family groups left the dump or moved to other areas within the dump, single bears usually moved into the vacated locations and began to forage. As a result, the length of time that two or more family groups spent in the dump may have limited other bears from using it and thereby increased the opportunity for interactions between single bears.

D. Age structure and annual fidelity of polar bears in the Churchill dump

As a large and reliable food source, the Churchill dump has existed since the early 1960's (Stirling *et al.* 1977b).

In this relatively short period of time, some individual polar bears have learned the location of the Churchill dump and have shown a high degree of seasonal fidelity. Two ways in which animals may learn the location of a particular resource are by imitating the experiences of others and by positive reinforcement of investigative behaviors (Mackintosh 1974; McCullough 1982). Young bears typically learn from their mothers, although they also learn from association with other bears (McCullough 1982). Weaned offspring have returned to the dump which suggests that these bears have learned the location of the Churchill dump from their mothers. How many of the adult females that have used the dump learned this association from their mothers is unknown because the tagging record is incomplete.

Bears on the islands in Hudson and James Bay prey more on birds than their mainland counterparts (Russell 1975). Russell speculated that cubs may have learned to catch birds by imitating their mothers. Why the first bears began to prey on birds is unknown; it may have occurred as a result of positive reinforcement.

By associating with unrelated bears in the vicinity of the dump, individual bears may learn of its location by following others. In 1983, I observed a group of three unrelated subadult bears enter the dump, feed there, and leave together. This occurred on ten days over a two week period. One of the three bears had never been captured in the dump before whereas the other two had. Social interactions between unrelated individuals are not only important in the determination of dominance hierarchies and assessment of opponents (Geist 1971; Stonorov and Stokes 1972; Egbert and Stokes 1976; Rogers 1977; Alcock 1979; Latour 1981b), but may also be important in learning the locations of food sources.

Polar bears may also learn of the Churchill dump by positive reinforcement of investigative behavior. Any behavior or behaviors used by an animal that are rewarded, for example by food, may become positively reinforced (Mackintosh 1974; Gould 1982; McCullough 1982). If the behavior is continually rewarded, the animal soon associates the reward with the behavior and may ultimately learn the location of the source of the reward. Bears, in general, are opportunistic feeders and are adept at locating food sources by smell. As polar bears move back toward the coast in the fall, individuals that smell the dump and investigate will be rewarded by finding food there. By continuing to feed in the dump each day, investigation of dump smells becomes positively reinforced. From repeated exposure and reward, the location of the dump is learned. In subsequent years, dump smells may cause the same investigative behavior to occur and the bear returns to the dump, or the location may be sufficiently learned that no stimuli are needed. Similarily, other studies have shown that black and brown bears learn locations of food sources and return in subsequent years to feed there (Craighead and Craighead

1971; Luque and Stokes 1972; Rogers *et al.* 1976; Rogers 1977; McCullough 1982).

On the sea ice, independent yearling and subadult polar bears may be displaced from their kills by larger, more dominant bears. Consequently, smaller bears may have more difficulty maintaining adequate fat reserves. In addition to basal metabolic needs they also have energetic costs associated with growth. Therefore, when these bears come ashore, they are more likely to be nutritionally stressed than older bears that do not have these added costs. Any nutritionally stressed bear that is able to use a food source, such as a dump, would be expected to have a nutritional advantage over similarly nutritionally stressed bears that do not have the same opportunities to feed. Adult females with cubs may also have additional needs for energy because of milk production. I had a total of six observations of mothers suckling their cubs. Like younger bears, there may be a nutritional advantage to those adult females with cubs that feed in the dump.

However, once male bears reach the age of five or six, they approach adult size, so that it would be expected that they should have less energetic demands due to growth. Not only are older bears larger and more capable of defending their kills, but they are probably more experienced and competent hunters than younger bears and may therefore feed more often. Once ashore, older bears may have sufficient fat reserves to draw upon throughout the summer, and therefore may not become nutritionally stressed.

This result differs from what has been observed for both black bears (Rogers *et al.* 1976; Rogers 1977) and brown bears (Craighead and Craighead 1971; Stonorov and Stokes 1972; Luque and Stokes 1976), in which males continued to use supplemental food sources, whether natural or artificial, regardless of their age.

The negative reinforcement of human activity may be an alternative or additive explanation. Just as a behavioral response to a stimuli may be rewarded, it may also be punished. If continually punished, that behavior becomes negatively reinforced and the animal may soon learn to avoid areas where it has been punished (Mackintosh 1974). The Manitoba population of polar bears is hunted by Inuit living along the Keewatin coast. In the Northwest Territories it is illegal to hunt bears that are less than 150 cm in length (Stirling *et al.* 1976,1977b), a length attained by one and one half years of age. Polar bear hides have an economic value to the Inuit, the larger the bear the greater the monetary return. Therefore there would be an incentive for Inuit to hunt larger bears. As a result, the greatest hunting pressure would be expected to be on adult and subadult males, as these bears are typically the largest. Throughout the hunting season, being shot at and chased by dogs and Inuit might be expected to negatively reinforce polar bears and they may learn to avoid areas where Inuit hunters are. Stirling *et al.* (1975, 1977b) found that older bears were under-represented in the harvest and suggested that the larger, older bears may have frequented areas less accessible to Inuit hunters and thereby have avoided being shot. Through the process of generalization (Mackintosh 1974), adult males ashore in Manitoba, may learn to avoid areas where they receive stimuli similar to those of Inuit hunters. As I travelled from base camp to the observation towers in the Coast 2 region, all bears along the coast moved away as I approached.

In and around Churchill, bears have been chased by the Manitoba Wildlife Branch Bear Patrol, and shot at with modified shotgun shells that produce both loud sounds and bright flashes. Some bears have also been caught in culvert traps, held in holding facilities and drugged by scientists. All these various forms of bear control may act as negative reinforcements to polar bears. However, as some bears have returned to the Churchill area, aversive conditioning is not completely effective.

E. Benefits and costs of a large supplemental food source

Once polar bears came ashore most had little or no access to food. However, some bears used the Churchill dump as a supplemental food source. What were the possible advantages of feeding when most individuals were fasting? The most obvious advantage would be in minimizing weight loss. Bears not using a supplemental food source should continue to lose weight throughout the fasting period.

Depending on the quality of the supplemental food and also on when the food source is used, individuals that do feed should be able to limit overall weight loss. Therefore, feeding bears should be expected to be heavier than their non-feeding counterparts. My results supported what was expected. By feeding in the dump, polar bears were able to put back on the weight that they had lost since coming ashore.

Other studies of supplemental feeding have given similar results. For example, Rogers *et al.* (1976) reported that black bears feeding in garbage dumps, in northern Michigan, were significantly heavier than their counterparts not feeding in dumps. Populations of white-tailed deer (Ozoga and Verme 1982), Japanese monkeys (*Macaca fuscata*) (Sugiyama and Ohsawa 1982), and Townsend's chipmunk (*Eutamias townsendii*) (Sullivan *et al.* 1983) that received supplemental feed were all significantly heavier than populations that did not.

A second potential advantage of a supplemental food source is the increased survival of nutritionally stressed individuals that use it. After four months of fasting, bears with the greatest energetic demands above basal metabolic needs, such as those associated with growth or milk production, should be the most likely to be nutritionally stressed. Therefore, by feeding in the dump, bears may have increased their chance of survival. Although my method for determining survivorship was subjective, it appeared that in general there was no advantage, in terms of survival, to bears that fed in the Churchill dump.

A third potential advantage may be that bears that feed may produce more offspring per litter than bears that do not feed. By feeding, adult females should be able to maintain higher levels of stored fat. These fat reserves can then be used later to meet the energy needs of both offspring and mother. If the female has insufficient fat reserves, both she and her offspring may suffer. Therefore, female bears with larger fat reserves may be more successful in raising more offspring per litter. However, by feeding in the Churchill dump, there was no apparent reproductive advantage as measured by litter size.

Black bears that fed in dumps had significantly higher mean litter sizes than non-dump bears (Rogers *et al.* 1976). However, these data need to be put into perspective. Female black bears in dumps, den and give birth to cubs within three months of feeding there. Rogers (1976) reported that females that did not gain sufficient weight prior to denning usually failed to produce cubs. Any reproductive advantage, is realized within three months. Pregnant female polar bears do not forage in the dump as they begin to den in late October. Female polar bears in the dump go out onto the sea ice during the winter and at the earliest would den the following fall. Therefore the earliest that females in the dump could produce a litter would be about fourteen months after feeding there. In that time span, all pregnant females, regardless of whether they fed or not while ashore, have had the opportunity to feed on seals and build up fat reserves prior to entering dens and giving birth. Although females that fed in the dump were heavier when they went onto the sea ice, it did not appear to be enough of an advantage to increase litter size.

Polar bears that foraged in the Churchill dump had a nutritional advantage over their counterparts that did not feed. Although all bears came ashore at the end of July, bears did not typically arrive in the dump until the beginning of October. Why do polar bears that know the location of the dump wait two months before going there?

Individual need is probably the main reason that determines when bears use the dump. All bears of each age and sex class were of similar weight when they came ashore. Naturally, those bears with higher energetic demands would use up their reserves faster and may become nutritionally stressed. Although it was not possible to determine when or if bears became nutritionally stressed, it may have occurred around the onset of their use of the dump. Major movements of bears back towards the coast do not begin until the end of October. Therefore, most of the bears that fed in the dump did not do so as a result of their overall movement back towards the coast. The lack of adult male bears in the dump, a group that should be the least nutritionally stressed, further suggested that nutritional condition of individual bears may be important in determining if they use the dump.

As some bears do benefit by feeding in the Churchill dump, why do some not remain ashore all year and feed there? As polar bears are adapted for the cold, they require a high energy diet, which they get by preying upon seals. It is unknown whether a steady twelve month diet of garbage could supply all the nutrients and energy required by polar bears. Certainly during the winter, the amount of garbage decreases as all the tourists have left. Bears may also prefer seals and sea ice to garbage. They do not arrive in the dump as soon as they come ashore but wait several months, which may suggest that they do not want to be there and take the first opportunity to leave. Remaining in the dump all year is also a poor reproductive strategy. Except for those bears remaining in the dump, all reproductively active bears, both males and females, are on the sea ice. By staying all year in the dump, bears might have difficulty finding mates. However, there are no records of bears remaining in the dump all year.

Because of repeated rewards obtained at the dump, polar bears may learn to associate certain human stimuli with food. Through generalization, bears may soon learn that any areas that have human stimuli will reward them with food. Younger bears are probably less experienced than the older bears and therefore may be more prone to investigate a more diverse array of stimuli. This suggested that acclimation to people in the Churchill dump, was a cost to young male bears that fed there. By feeding in the dump and becoming habituated to man, the sights and sounds of Inuit hunters may evoke less avoidance behavior in some bears.

V. CONCLUSIONS

The population of polar bears resident in Hudson Bay comes ashore and spends three and a half to four months each year along the coast of Manitoba. While on land, most individuals do not ordinarily feed, yet a small portion of this population feed in the Churchill dump. Both groups of bears have adopted different strategies to cope with the period of time that they spend ashore.

The strategy of most polar bears that spend the summer on land appears to be to come ashore with ample fat reserves and remain inactive. Inactive bears can minimize metabolic demands and minimize the chance of hyperthermia. Staying in areas where cool winds help to lower skin temperature and thereby increasing the thermal gradient between body core temperature and ambient temperature, aids in minimizing the chance of hyperthermia. These polar bears are in a biochemical state similar to that of hibernation, in which they are capable of going without food and water. Lean body mass is conserved by using only fat as an energy source, which produces enough metabolic water to meet all body requirements.

Younger bears and family groups are the main users of the dump. Individual nutritional condition and the learning of its location appear to be important factors in determining which bears use the dump. By foraging there, polar bears do not appear to gain a reproductive advantage, in terms of increased litter size, over those bears that do not feed while ashore. Young male bears feeding in the dump may have a lower survivorship than their non-feeding counterparts. However, bears using the dump are heavier than those non-feeding bears when they return to the sea ice.

As most bears probably catch seals within a few days of returning to the sea ice, the nutritional advantage that feeding polar bears have over non-feeding bears may not be a critical factor. After all, they have had to deal with this period on land long before the Churchill dump was there. Polar bears will use supplemental food sources if they are readily available, or if they have learned their locations, but most bears have no need to. It appears that polar bears are able to deal with a three or four month period of little or no access to food.

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