1980

Environmental factors affecting high arctic sea ice habitat of polar bears

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ENVIRONMENTAL FACTORS AFFECTING HIGH ARCTIC SEA ICE HABITAT OF POLAR BEARS

By

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B.S., University of California at Berkeley, 1977

Presented in partial fulfillment of the requirements for the degree of

Master of Science

UNIVERSITY OF MONTANA

1980

Approved by:

Chairman, Board of Examiners

Dean, Graduate School

4/10/80
Date

ABSTRACT

Martin, Sandra K., M.S., Spring 1980 Wildlife Biology

Environmental Factors Affecting High Arctic Sea Ice Habitat of Polar Bears (127 pp.)

Director: Charles J. Jonkel

Habitat of polar bears (Ursus maritimus) on coastal sea ice was investigated through observation of undisturbed polar bears and their environment. Approximately 40 sq km of nearshore sea ice were kept under 24-hour surveillance from 4 field camps established successively from 20 May to 18 July 1979 on island coasts bordering Barrow Strait and Lancaster Sound, Northwest Territories, Canada. Results of recent field work were used to choose 2 areas heavily used by polar bears and 2 lightly used areas for study. Several biological and physical parameters of the coastal sea ice ecosystems were compared between study areas. Data analysis indicated that the observed polar bears exhibited habitat selection on the sea ice. Recorded activities of the bears included travel, play, sleep, and several hunting methods. The heavily used study areas harbored higher numbers of seals than the lightly used areas. Bird densities were higher in areas heavily used by bears and plant cover was greater on beaches bordering the sea ice in these areas. Coastal ice areas receiving the greatest polar bear use had the greatest amounts of smooth ice, indicating greater stability. The bay receiving most use by polar bears had more diversity in ice types than the unused bays. Examination of data on habitat selection by polar bears in offshore areas, collected in 1978, indicated that most levels of use of ice types were similar to patterns of use detected in coastal areas.

ACKNOWLEDGEMENTS

I thank the agencies and organizations that supported this project with financial and logistic assistance. These were: Polar Continental Shelf project of Energy, Mines and Resources Canada; the National Wildlife Federation; the New York Zoological Society; PetroCanada; and the U.S. National Science Foundation through grant No. 7617644 given to Drs. Charles Jonkel and Bart O'Gara. I would like to thank the Government of the Northwest Territories, the Canadian Wildlife Service, the (Canadian) Department of Indian and Northern Affairs, and the Fisheries and Marine Service of Environment Canada. These agencies all gave me permission to carry out various aspects of my project.

Jim Morrison provided assistance in the field in 1978. Special thanks go to my field assistnats in 1979, Barbara Taylor and Pierre Dawson, for their dedication, enthusiasm, and optimism. I also thank the personnel of Polar Continental Shelf Project's Resolute Bay base camp for their cheerful and thorough assistance.

Thanks go to Drs. Bart O'Gara, John Tibbs, and Robert Curry for participating on my committee and for reviewing this manuscript. I would especially like to thank Dr. Charles Jonkel, my major adviser, for initial direction, guidance throughout the project, and most of all for giving me the opportunity to conduct this investigation.

TABLE OF CONTENTS

LIST OF TABLES

Table		Page

LIST OF FIGURES

Figure | Page

CHAPTER I

INTRODUCTION

Polar bears (*Ursus maritimus*) were once thought to comprise 1 interbreeding population throughout the species' holarctic range (Schweinsburg et al. 1977). A large amount of the research conducted in the 1960's and early 1970's on polar bears tested this hypothesis. Polar bears belong to many separate populations with restricted ranges according to data accumulated during mark-recapture studies (Jonkel 1976, Stirling et al. 1975, 1977a). In Canada, the polar bear is found from the high arctic islands of the Canadian Archipelago to the southwest coast of Hudson Bay, James Bay, and easternmost Newfoundland. At least 15 subpopulations exist in Canada alone (Schweinsburg et al. 1977).

The identification of maternity denning areas has received priority in polar bear research (Jonkel et al. 1976, Kiliaan et al. 1978, Stirling et al. 1975, 1977a). The same sites are used during consecutive years by the same bears. Dens are occupied predominantly by pregnant females (Harington 1968). Denning was believed to occur exclusively on land, but dens were recently found on drifting sea ice north of Alaska (Lentfer 1975). Maternity denning areas are considered critical habitat for the continuance of the populations. Management based on protection of denning areas is dependent on their delineation.

Polar bear research is now beginning to focus on other parts of the animals' habitat. Throughout the world, sea ice provides the primary habitat during most of the year. The sea ice acts as a physical extension of land, serving as a platform for travel, hunting, breeding, and other activities. The ice harbors the primary prey of the polar bear, the ringed seal (Phoca hispida; Stirling and McEwan 1975).

The polar bears' distribution and movements within the geographic range of a population are affected by variation in the sea ice (Jonkel 1976). Three major categories are used to classify arctic sea ice: land fast ice is anchored to the shore; polar pack ice permanently covers the central area of the polar basin; and the drifting pack ice extends as a belt between the landfast ice and the polar pack ice (Lentfer 1972). The channels of the Canadian Archipelago are filled with landfast and drifting pack ice.

Factors that affect configuration of the sea ice include thickness of the ice, winds, ocean currents, snow depth, air temperature, and salinity of the ice (Kovacs and Mellor 1974). These factors influence the formation of the sea ice, drift, deformation, and the ratio of ice to open water.

Female polar bears and their cubs emerge from maternity dens during early spring. The family remains close to the den for several days or weeks and then moves onto the sea ice to hunt (Jonkel et al. 1970, Stirling et al. 1975). The ice begins to break up in early summer and recedes from the areas of earliest disintegration. Many bears and seals concentrate along the ice edge at this time (Jonkel 1976).

The bears move toward land as more ice disappears, and ocean currents and winds move the remaining ice floes. The ice remnants often collect in coastal inlets and may remain partially intact throughout the summer. Polar bears are found on the remnant ice in some bays and inlets. Tagging programs conducted by Schweinsburg et al. (1977) in the Canadian High Arctic documented use of these summer retreats by all age-sex classes of polar bears except adult males. Summer habitat for males includes ice floes away from the coast and inland ice caps (Jonkel 1976).

Ice cover begins to re-form over the ocean in early fall and the polar bears can move offshore again. Denning females retreat to traditional denning areas in November and do not emerge until March. Some females and most males range over the ice throughout the winter. Temporary dens may be used by these bears in extreme weather (Harington 1968).

During the summers of 1978 and 1979, an investigation of polar bear habitat on the sea ice was conducted in Barrow Strait and adjacent channels of the Queen Elizabeth Islands, Northwest Territories, Canada. Selection of specific ice features by polar bears was examined in offshore areas in 1978. During 1979, several biological and physical components of 4 specific coastal ecosystems were examined. Two coastal areas habitually frequented by polar bears and 2 areas lightly utilized by bears were studied and compared.

Two hypotheses were tested: that coastal areas heavily utilized by polar bears during late spring and summer harbored more productive ecosystems than lightly used areas; and heavily utilized areas contained an optimum percentage of ice cover in structural categories attractive to polar bears and their primary prey, the ringed seal.

CHAPTER II

THE SEA ICE ENVIRONMENT

The timing of ice cover formation is highly variable and is dependent upon the amount of heat accumulated in the water during summer and the rate of cooling in the fall (Volkov 1972). The amount of heat stored is a function of the length of time the water surface was exposed to the sun and so is strongly dependent on the timing of ice break-up in the spring. Cooling rate is a function of eddy heat exchange, evaporation, and the amount of incoming radiation. Cooling rate is proportional to the water-to-air temperature gradient. Atmospheric conditions that affect ice growth are air temperature, cloud cover, and wind speed (Kovacs and Mellor 1974). Marine conditions that affect the growth rate are roughness of the sea, currents, water depth, and salinity. Snow cover can retard ice growth (Jacobs et al. 1975).

Sea ice first forms as dendritic platelets in the upper few centimeters of the water (Weeks and Lee 1958). Movement of the water causes this crystal layer to turn into "mush", which freezes into platters a few meters in diameter or smaller. These "pancakes" become cemented together in a matrix as the freezing process continues. When the water surface is very calm, smooth sheet ice will form directly as the ice crystals that first appear grow larger and more numerous. First-year ice will usually reach a thickness of 1 to 2 m by early spring (Jacobs et al. 1975).

The intensity of ice disintegration is determined in large part by the thickness of the ice and its concentration (ice to open water; Volkov 1972). Heat influx from the atmosphere is important in defining the time of break-up. Changing albedo of the ice surface as the ablation process proceeds has a major effect on the rate of ice melt.

As air temperatures begin to rise, the snow on the sea ice surface begins to melt, free water becomes available within the snow layer, and puddles form at the snow-ice interface (Jacobs et al. 1975). As thaw continues, the snow layer disappears intermittently and fresh water puddles are formed on the ice surface, increasing the heat absorption of the sea ice. Thaw holes develop where these puddles are found and fresh water drains through the ice to form a layer directly beneath the ice. Many cracks begin to form and the ice floes break up further. The minimum concentration of ice in a particular area is therefore dependent on air temperatures, incident radiation, winds, and currents.

The drift and deformation of sea ice are primarily determined by the vertical and horizontal transfers of momentum (Sater 1969). Forces that cause the drift of ice include wind stress, water stress, the Coriolis force (the influence of the rotation of the earth), the pressure-gradient force, and internal ice resistance. Theoretically, the ice canopy can attain velocities that are 3% of wind speed. Coastal configuration, particularly geographic blocks that occur in the path of a current- or wind-driven stream of moving ice, have major effects on sea ice distribution. Tidal phenomena can play an important role in ice drift near shore (Dunbar and Wittman 1963). The overall effect of ice drift is a continuously changing ice cover, with convergence in some areas, divergence in others, and the separation of the ice surface into floes of different shapes and sizes (Kovacs and Mellor 1974).

On scales as broad as the entire Arctic Ocean, and over a year or several years, the ice canopy is no different from an open water surface as the interface between atmosphere and ocean which transfers momentum from the winds to drive ocean currents, which in turn play a part in moving the ice (Coachman and Aagard 1974). However, on smaller scales the presence of sea ice and the structure of the ice affect its motion. Satellite tracking studies of ice islands have shown movement patterns with large loops.

The motion of the ice canopy is the force behind its physical structure. When sheets of ice converge, pressure ridges or ice hummock fields are often formed. Pressure ridges are linear accumulations of ice blocks that extend both above and below the abutting floes (Kovacs and Mellor 1974). With only compression acting on the floes, the ice blocks in a ridge tend to be large and the ridge structure is loose. When shear components are involved, the ice blocks are slid, broken, and pushed into tighter packing. The ice blocks below the water surface are referred to as the keel of the ridge. The ridge height to keel depth ratio is generally 1 to 4. Ice blocks on multi-year ridges are rounded, due to melting part of the upper surface in spring and refreezing in the fall. Ice hummock fields are similar deformations of the sea ice, but are greater in areal extent than the linear pressure ridges.

The divergence of ice floes is also caused by differential movement of the ice canopy. Cracks, leads, and areas of open water appear at points of divergence. High pressure systems in the atmosphere can cause openings in the sea ice to appear, as well as diverging winds (Ackley and Hibler 1977).

Throughout most of the year ice will re-form in cracks and leads. This will not occur during late spring and summer when air temperatures are high enough to reduce the thermal gradient between ocean and atmosphere to a negligible figure. Refrozen cracks and leads are the first areas to fail under pressure of impinging ice floes and pressure ridges are often located along these refrozen boundaries between ice floes (Kovacs and Mellor 1974).

Ice conditions in the fast-ice zone are highly variable (Kovacs and Mellor 1974). The seaward extent of this zone varies with the protection given by the coastal configuration, water depth, time of year, and the magnitude of the forces of the drifting pack ice. As the fast ice thickens, it becomes less susceptible to deformation caused by stress imposed by the pack ice. The multi-year ice of the polar pack is generally 2 to 4 m thick. Relatively few cracks and leads occur in this zone, and several seasons of partial melting followed by refreezing leave the pressure ridges eroded, lending a relative uniformity to the surface of the ice in this zone (Lentfer 1972). The ice in the drifting pack zone is subjected to the highest stresses (Kovacs and Mellor 1974). Studies in the Beaufort Sea found that 26% of this zone was ridged or hummocked in winter.

As ice crystals form from sea water, salts are rejected during the freezing process as only molecules of pure water can occupy lattice sites in the ice crystal (Sater 1969). Any salt present in sea ice is found in pockets within the crystal structure. The quantity of salt initially trapped depends on the rate of freezing; a fast rate would result in a larger amount of salt present. Brine pockets tend to be vertical cylinders. The salinity of an ice sheet decreases rapidly with time; brine drains out of the ice and into the water column below (Weeks and Lee 1958). The 2 components of sea ice, freshwater crystals and brine pockets, are never at equilibrium (Kovacs 1972). As a result, the sea ice is dynamic on a micro-scale as well as on the macro-scale, and the physical properties of sea ice are not constant.

A portion of the food web of the high arctic marine environment leads directly to the polar bear as the top trophic level consumer, excluding man. The predominant prey item of the polar bear throughout the Arctic is the ringed seal (Stirling and McEwan 1975). The bearded seal (Erignathus barbatus) is a regular prey item of the polar bear, also, but is taken less frequently than ringed seals, most likely due to its lower relative abundance (Stirling and Smith 1975). Because access to seals is limited by the presence of extended open water, the diet of local polar bear populations can vary seasonally depending on ice conditions (Stirling and McEwan 1975). Beluga or white whales (Delphinapterus leucas) and walrus (Odobenus rosmarus) occasionally turn up in the polar bear diet (Schweinsburg et al. 1977). Other infrequent items taken by polar bears in the High Arctic include sea birds and their eggs, fish, marine invertebrates, arctic fox (Alopex lagopus), caribou (Rangifer tarandus), and rodents (Stroganov 1962).

The ringed seal is an opportunistic feeder and its diet includes zooplankton, crustaceans, and fish (Stirling et al. 1975). Zooplankton conspicuous in the ringed seal's diet are Thermisto spp. and commonly taken crustaceans are Mysis spp.. Cryopelagic fish species in the seals' diet include arctic char (Salvelinus alpinus) and arctic cod (Boreogadus saida; Mansfield 1975). Bearded seals feed almost exclusively on benthic organisms and may be limited to an effective feeding depth of 100 m (Stirling et al. 1975).

The invertebrate fauna of the Arctic Ocean is low in diversity when compared to that of lower latitudes (Grainger 1959). Carnivorous zooplankton species include decapod larvae, the amphipod Hyperia, and the ctenophores. Herbivorous species include copepods, pteropods, and cirriped nauplii. Carey and Ruff (1977) found a benthic organism distribution in the western Beaufort Sea characterized by low densities at the shallowest stations on the continental shelf, increasing densities towards a maximum over the shelf break, and a decrease to low densities at the deepest stations down the continental slope.

The entire food web rests on the base trophic level provided by the primary producers, the phytoplankton. The dominant species in the Arctic Ocean flora are diatoms throughout most of the year (Allen 1971). Green flagellates and other green algae have been observed to develop extensively in the low salinity melt-water from ice during the summer. Polar seas apparently lack blue-green algae.

Algal organisms also grow directly in the sea ice. The ice-inhabiting community in the Beaufort Sea includes dinoflagellates, cryptomonads, and larger flagellates (Alexander 1974). Apollonio (1961) described a brown layer on the undersurface of sea ice near Devon Island in the Canadian Archipelago which faded out 1.5 inches (3.8 cm) into the ice from the bottom surface.

Currently, controversy and confusion exists concerning the relationships between the ice algae and phytoplankton in the water column and their relative contributions to primary production. Meguro et al. (1967) concluded that the diatoms liberated from sea ice during the ice break-up "seeded" the water columns below and were the cause of the annual phytoplankton bloom. However, analysis indicated that the population composition of the ice algae and phytoplankton in the water are different and that a time lag between ice algae liberation and phytoplankton bloom occurs, indicating that the former is not the cause of the latter (Horner 1977).

From 2 seasons of data, Alexander (1974) computed a photosynthetic carbon uptake for the ice algae community of 5 g $C/m^2/yr$. Annual production for the nearshore Beaufort Sea was found to be in excess of 10 to 15 g $C/m^2/yr$. Ice algae are not only important as the contributors of 25 to 30% of total annual primary production, but also because their bloom precedes the planktonic bloom, these organisms effectively extend the productive period.

Factors that affect the phytoplankton of the Arctic Ocean include the seasonal variation in light, nutrient supply, and the ice cover (Mansfield 1975). The combined effect of these factors is a greatly restricted season of plant production. Characteristic seasonal successions of phytoplankton species have been noted throughout the Arctic, largely dependent on the light regime (Allen 1971). End of production is linked to light depletion as the ice re-forms in early fall (Mansfield 1975). A decrease in production can also be caused by nutrient depletion. Nutrient replenishment from upwelling does not generally occur because of the highly stratified nature of arctic waters.

The ice algae may provide a food source for herbivorous zooplankton. Numerous workers have noted the association between several zooplankton species and the ice bottom surface (Apollonio 1961, Mohr and Tibbs 1963). Mohr and Tibbs found no evidence for amphipod browsing on the ice algae, but other authors consider the ice algae a source of food for the grazing zooplankton (Horner 1977, Mansfield 1975). The significance of the ice algae is that the timing of its bloom, prior to the planktonic bloom, extends the period of plant availability to the grazing populations. The ice undersurface environment is found to be analogous to shallow water benthic communities, on the basis of the organisms present.

The standing crop of zooplankton in the High Arctic is relatively small, due primarily to the low, seasonal primary production of the region and the relative absence of meroplankton (Johnson 1963). Zooplankton populations are enhanced in coastal areas where seasonal ice-free waters and shallower depths provide a richer environment for phytoplankton production. Benthic larvae are to be found in coastal waters, also. Herbivorous zooplankton exhibit extreme seasonal oscillations in abundance, keyed by the bloom of the phytoplankton and its subsequent decline in autumn (Mansfield 1975). Carnivorous zooplankton show little change in numbers throughout the annual cycle, as they find adequate amounts of herbivorous zooplankton to feed on during a longer period of the year.

Little is known or reported in the literature concerning the abundance and distribution of the few cryopelagic fish species that inhabit the Arctic Ocean. Mansfield (1975) states that the ice algae form a series of close trophic links with these fish species, which are in turn important to pinnipeds.

Food is apparently available to ringed seals throughout the year in the High Arctic. Ringed seals are not migratory, though seasonal shifts in distribution may occur (Stirling 1977). These seals utilize sea ice for rest and for the birth of their young. Ringed seals locate their breathing holes on the last, naturally-occurring openings in the ice as they freeze over in the fall, or in areas where wind- and tide-caused movement of the ice creates leads. In areas with ice hummocks and pressure ridges, lairs are dug by ringed seals above old breathing holes in the accumulated snow on the leeward side of the hummock or ridge (Smith and Stirling 1975). Single-chambered lairs may be used by 1 or several seals for hauling out. Birth lairs are larger and may have extensive tunneling associated with them. The young are suckled in the birth lair for 4 to 6 weeks from mid-March to mid-May, when the sea ice begins to break up. Both types of lairs provide protection for ringed seals from predators and from the cold. The ringed seal is the smallest of the arctic pinnipeds. This small size has probably evolved to permit the use of subnivean lairs (Stirling 1977).

The preferred habitat of the ringed seal is found on stable, landfast ice (McLaren 1958). The growth and survival of the pup are positively correlated with stability of the ice and depth of snow (Fay 1974). Prime ringed seal habitat is found in the sheltered bays and fiords along the coasts of arctic land masses. Intraspecific competition for this prime habitat results in partial segregation of the age classes (Stirling 1977). During winter and spring, sub-adult seals are largely excluded from these areas and are found farther from shore on less stable ice.

Polar bears appear to show differential selection of seal age classes. The bears hunt on the offshore ice extensively in the spring, and possibly in fall and winter, and seldom move into the bays and fiords occupied by adult ringed seals (Stiriling and McEwan 1975). The higher percentage of sub-adult seals on the offshore ice, that present caloric value equivalent to that of adult seals but which are less experienced and easier to hunt, may be the attraction to the bears. When new-born pups are dug out by polar bears, they are usually totally consumed.

While polar bear predation on ringed seal pups born in the prime habitat of bays and fiords may not be great, arctic fox predation is. Fox predation appears to be the most important mortality factor for ringed seals in the first year of life in the landfast ice habitat (Smith 1976). According to Smith, arctic foxes can exert significant population control on ringed seals.

A prime adaption of the ringed seal that allows it to reside in areas where ice completely covers the water surface for at least part of the year is its ability to form breathing holes by abrading the ice with the claws on its flippers. It was previously thought that bearded seals did not share this ability and were restricted to areas with open water present (Stirling and Smith 1975). Recently it has been determined that bearded seals also can maintain breathing holes. The range of the bearded seal broadly overlaps those of all other northern, ice-inhabiting pinnipeds (Fay 1974).

A final component of the food web is the avian group. As noted above, polar bears may occasionally prey on sea birds. More importantly, the millions of sea birds that breed in the Arctic every summer obtain the major share of their food from the marine environment (Schweinsburg et al. 1977). Their use of fishes and marine invertebrates places them in direct competition with the other members of the polar bear food web who rely on these food resources. Birds may also have an ultimate effect on the entire food web by providing increased nutrient sources in areas where their guano is concentrated.

In summary, sea ice affects the base trophic level by restricting light, reducing surface salinities in melt, and providing habitat for a significant portion of the autotrophic population, the ice algae. The ice algae not only increase total primary production of an area, but extend the production period by reaching high concentrations prior to ice break-up, and the planktonic bloom. The highly cyclic nature of phyotplankton concentrations in the Arctic, in part a result of ice cover but also very dependent on nutrient depletion and the severe light regime of the high latitudes, is reflected in the populations cycles of herbivorous zooplankton. However, this phenomenon does not appear to be transferred appreciably to higher trophic levels. The sea ice provides an inverted substrate to some benthic invertebrates.

The sea ice is the primary habitat of arctic pinnipeds, and variations in the structure and stability of the ice have been shown to affect distribution of ringed seals and bearded seals. Also, age class segregation occurs when competition for quality breeding habitat forces subordinant individuals away from choice landfast areas and into more hazardous, less stable locations. Polar bears utilize the sea ice as their primary habitat.

The dependence of the abundance and distribution of the highest trophic level consumers in this food web, the polar bears and the pinnipeds, on the base trophic level is well defined in the often-noted phenomenon of animal concentration at the ice floe edge (Jonkel 1976, McRoy and Goering 1974). High levels of phytoplankton production occur in this region, due to the structure of the stratified water column induced by melt water from the ice. The abundance of seals along the ice floe edge indicates the presence of concentrations of intermediate trophic level organisms; invertebrates and fish. The ice floe edge is a preferred hunting habitat in many areas of the Arctic for polar bears (Jonkel 1976, Stirling et al. 1975).

CHAPTER III

THE STUDY AREA

Barrow Strait and Lancaster Sound are the eastern sections of Parry Channel. The Channel lies east-west at 74^0 north latitude south of the Queen Elizabeth Islands in Canada's Northwest Territories (Figs. 1 and 2). Barrow Strait is bounded on the south by Prince of Wales and Somerset islands, and by Cornwallis and Bathurst islands to the north. Lancaster Sound is limited by Devon Island along its north boundary, and by Somerset Island and the Brodeur and Borden penninsulas of Baffin Island to the south.

Barrow Strait and Lancaster Sound span 60 miles (97 km) from north to south and together are 450 miles (725 km) long. The channels comprise the home range core of 1 subpopulation of polar bears (Schweinsburg et al. 1977). The bears also utilize parts of adjacent channels, inlcuding Prince Regent Inlet, Peel Sound, and Wellington Channel.

Outflow of waters from the Arctic Basin through the Canadian Archipelago (Queen Elizabeth Islands) is a significant component of the Arctic Ocean water balance (Aagard and Coachman 1977). One of 3 important passages in the Archipelago is Lancaster Sound. The outflowing current flows west to east through Barrow Strait and then east through Lancaster Sound in the southern half of the channel. Surface waters flow west in the northern half along the coast of Devon Island.

Fig. 1. Study areas. Area enclosed in box enlarged in Fig. 2.

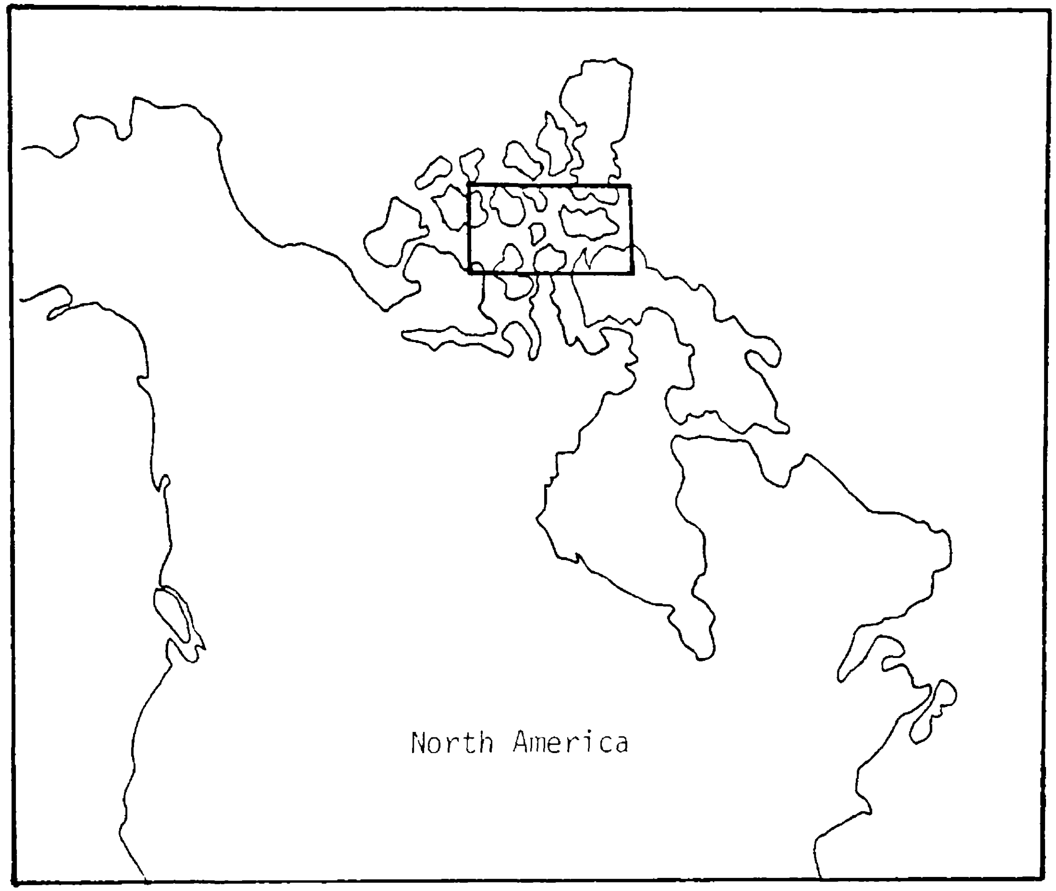
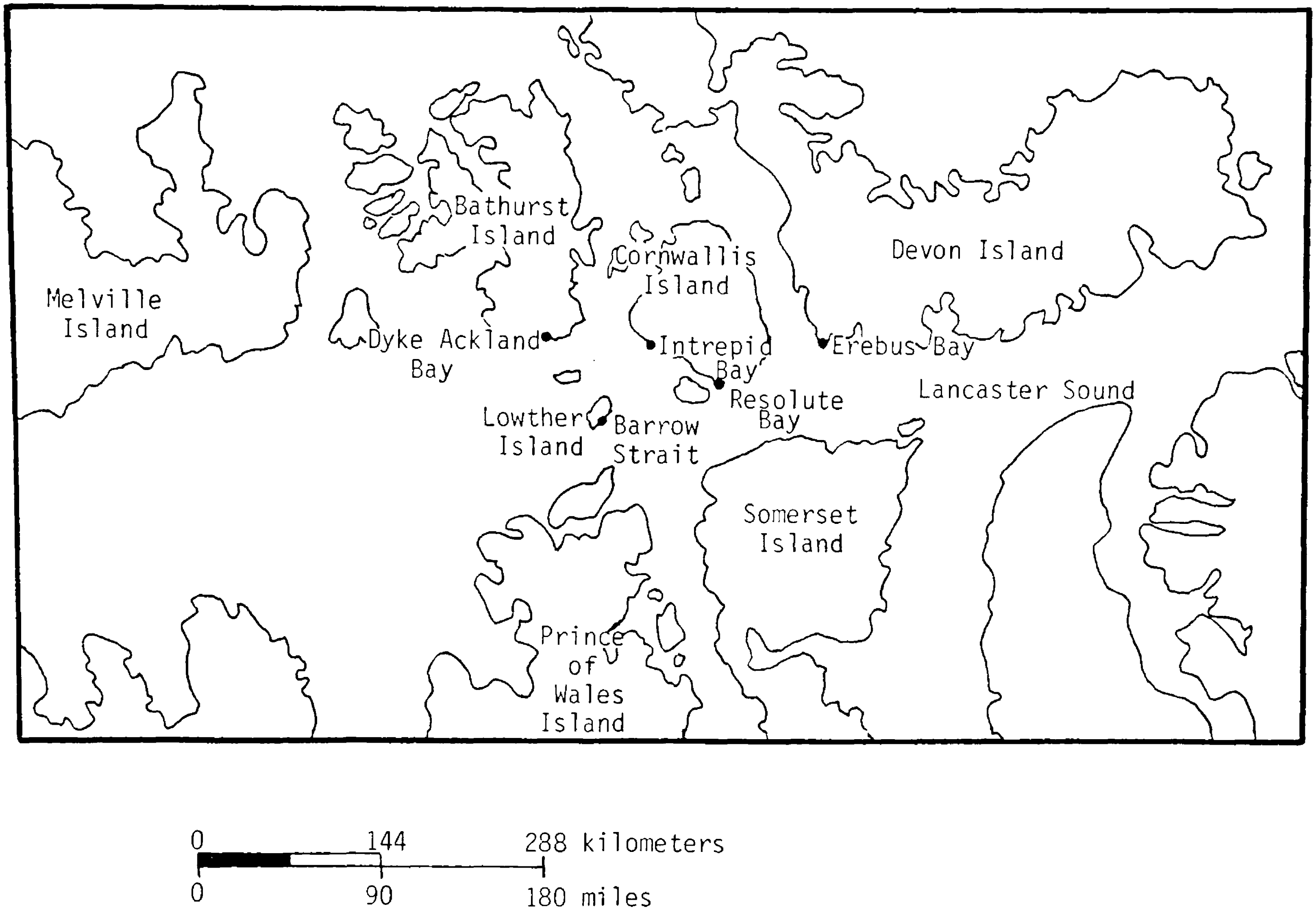

North America

Fig. 2. Field camps and Resolute Bay base camp shown with dots.



Melville Island
Bathurst Island
Cornwallis Island
Devon Island
Dyke Ackland Bay
Intrepid Bay
Erebus Bay
Resolute Bay
Lancaster Sound
Lowther Island
Barrow Strait
Somerset Island
Prince of Wales Island
0
144
288 kilometers
0
90
180 miles

influenced by a permanent eddy at the eastern end of the Sound (Collin 1963).

Only top layers of water enter Barrow Strait from the west as a sill at 490 feet (150 m) depth occurs between Bathurst and Prince of Wales islands (Collin 1963). The sea floor slopes eastward down into Lancaster Sound where depths reach almost 2600 feet (800 m). Between 490 and 820 feet (150 and 250 m) in the water column there is a uniform increase in temperature and salinity below which lies the Atlantic water layer.

The waters of the Archipelago are ice-covered at least 7 months of the year (Collin 1963). The permanent polar pack does not penetrate into Parry Channel. Freeze-up can begin as early as the end of August and is usually complete by mid-October. Break-up begins in May and in most years by mid-June the major channels are open. The edge of the ice floe first appears in eastern Lancaster Sound and moves northwestward as break-up continues (Schweinsburg et al. 1977). The ice edge is not oriented directly north-south as it moves through Lancaster Sound, but rather lies southwest-northeast, with ice extending farther east along the northern half of the sound.

Ice disintegration is not restricted to the ice floe edge. As spring run-off from the islands flows into coastal waters, the ice may break free and begin to disappear. Currents may keep ice concentrations relatively low in some areas throughout the winter and break-up begins locally at these sites and spreads outward (Collin 1963). One such area of perennial low concentration occurs in Barrow Strait southwest of Cornwallis Island.

The sea ice may not completely disappear during the summer in these high latitudes. Ice persist in areas with weak surface currents. Bays and inlets can collect ice floes driven by currents and winds in addition to remnants of locally formed ice. The northwest direction of ice recedence concentrates remaining floes in bays on the southern coasts of Devon, Cornwallis, and Bathurst islands, along the north edge of Barrow Strait and Lancaster Sound, but winds may concentrate the floes along north and west coasts.

In 1978 and 1979, anomalous weather conditions delayed ice break-up. Continuous snow cover was present on the sea ice in Barrow Strait until 3 July 1978. When field work was completed on 24 July, the channel was still frozen over. The ice floe edge was near the eastern end of Lancaster Sound. Similar conditions were found during the 1979 field season.

CHAPTER IV

METHODS AND MATERIALS

Field Methods

Two field camps were established in 1978. The first was on Hamilton Island ($74^{o}11'$N, $99^{o}10'$W), 90 miles (144 km) southwest of Resolute Bay in Barrow Strait. The camp was occupied from 28 May to 4 June. The Island is approximately 0.25 X 1 mile (0.4 X 1.6 km) and rises to 76 feet (25 m). The nearest land mass is Russell Island, which lies 12.5 miles (20 km) to the southeast. During camp occupation, the sea ice surrounding the Island was surveyed several times a day with either a 20 power telescope or 10 power binoculars. Visibility was very poor at least 50% of the time because of fog and blowing snow.

The second field camp was placed on Garrett Island ($74^{o}44'$N, $98^{o}18'$W), 60 miles (96 km) west of Resolute Bay, on 17 June and occupied through 23 June. Garrett Island is approximately 2 X 4 miles (3.2 X 6.4 km) in size and 363 feet (120 m) above sea level at its highest point. Camp was established on the southeast coast of the Island. The coast away from camp was explored only once. The sea ice was surveyed and all observations of seals and birds were recorded. A 4-day storm prevented more extensive observations.

Aerial surveys of the ice were conducted using Twin Otter fixed-wing aircraft and Jet Ranger helicopters. Surveys were done on 4, 8, and 14 June, and 11, 13, 15, 18, and 21 July 1978. Flight time totaled 57.5 hours. Most of the surveys in June were accomplished by accompanying Canadian Wildlife Service biologists on ungulate surveys. The July flights were furnished by Canadian Widlife Service biologists conducting counts of sea bird nesting colonies. The areas flown over included Barrow Strait, Peel Sound, Lancaster Sound, Prince Regent Inlet, M'Clintock Channel, McDougal Sound, Viscount Melville Sound, and numerous islands. The pattern of flight was to follow island coasts at an altitude of 150 feet (49 m). Survey flights over Barrow Strait and Peel Sound included extensive time flying over central sections of the channels. My assistant and I observed the areas below opposite sides of the airplane. If polar bears or seals were sighted, the following were recorded on data sheets; number of animals, age-sex classes, and whether the animals were on or near smooth ice, a crack, a lead, or a pressure ridge. If bear tracks were sighted, information was recorded on the general direction of travel and which type of ice was associated with the tracks.

Ice type was delineated as smooth, pressure ridge, crack, and lead during the first 25 hours of aerial surveys. More detail was then incorporated in the ice classification scheme. It was expanded to include the following categories; smooth ice, frozen crack, open crack, frozen lead, open lead, and 3 categories of rough ice. A crack was defined as being a few inches wide and a lead as being wider. The rough ice types were: low rough ice, with ice ridges or protruding blocks less than 1 foot (0.3 m) in height; medium rough ice, with ice ridges between 1 and 5 feet (0.3 and 1.5 m) high; and high rough ice, with ridges over 5 feet (1.5 m) tall (Figs. 3 to 6). The increasing height of ice features corresponded with an increase in density of ice features in rough ice areas. Ridges and hummocks were least dense in low rough ice and most dense in high rough ice. This relationship has been noted and quantified by other workers (Wadhams 1975). Ice pans floating freely in open water were classified as open ice. The ice represented less than 90% of total area in open ice areas.

Sea ice surveys have been conducted regularly for many years by governments with Arctic territories, and ice categories have been delineated (Ice Forecasting Central 1970, Lindsay 1974). However, existing classification systems are used at much larger scales than were appropriate for this study, requiring the classification scheme developed above for use in this investigation.

Polar bear tracks were searched for and followed using Jet Ranger helicopters. Five flights were conducted between 29 June and 4 July 1978. Deteriorating snow conditions after these dates precluded further use of this technique.

The initial direction travel for each flight was arbitrarily predetermined. The decision was based on daily weather conditions and the desire to evenly investigate Barrow Strait. The chosen direction of travel was followed until polar bear tracks were found, usually within 20 minutes.

The tracks were followed in the direction that they were the most

Fig. 3. Smooth ice with an open crack (approximately 8 inches (20 cm) wide).

Fig. 4. An open lead approximately 3 feet (0.9 m) wide. The lead is surrounded by smooth ice in the foreground and high rough ice in the background.

Fig. 5. Low rough ice in the foreground and medium rough ice behind the polar bear.

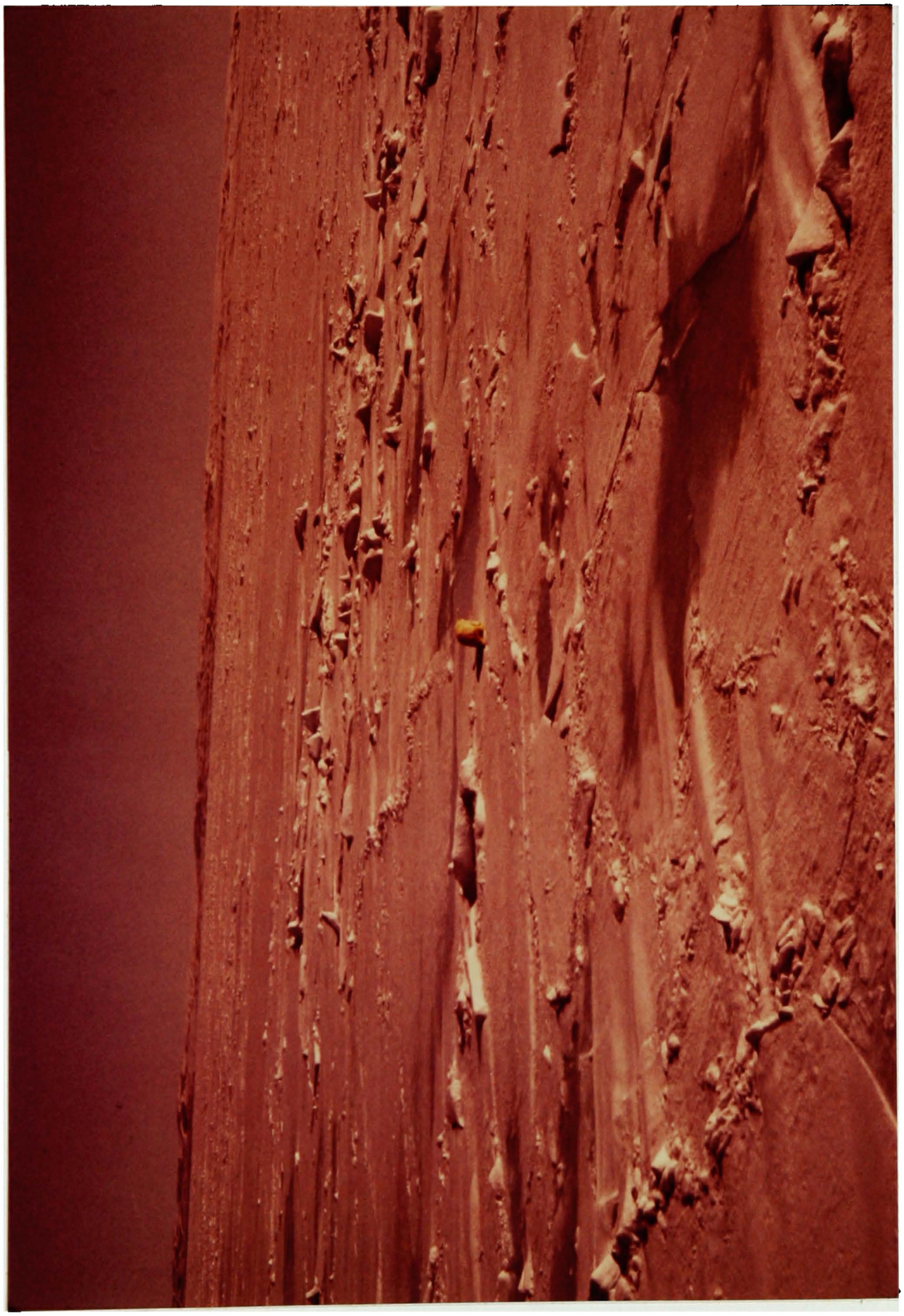


Fig. 6. High rough ice. The tallest ice feature is approximately 15 feet (4.5 m) in height.

clear. The helicopter was flown at approximately 150 feet (49 m) altitude and at a constant air speed. Velocity varied from flight to flight between 30 and 60 miles per hour (48 and 96 km per hour).

Data were recorded at 30 second intervals. Information was taken from the sea ice visible below the front edge of the helicopter. Ice type was noted using the 9 categories developed for the aerial surveys. Distance of the tracks from the ice feature was recorded, when appropriate. The compass direction of the bear's travel was estimated by orienting on distant land masses. The relative deviation of the tracks from a straight line was subjectively gauged as wandering or straight. A facsimile of a data sheet used during helicopter tracking is presented in Appendix I.

The activity of the bear was interpreted from the tracks. Three activity categories were used to record this information. The predation-attempt category designated tracks that led to a seal hole in the ice or to a snow drift (seal lair) that had been dug out by a bear. Blood on the ice at such sites could have implied successful predation, but in the absence of other evidence was categorized as predation-attempt. A predation-successful category was used for tracks that lead to carcasses obviously killed by the bear being tracked. Tracks that did not lead to predation sites were classified as traveling.

All seals observed were recorded during flights following polar bear tracks. The technique developed for the aerial surveys was used to report seal information.

The tracks were followed as far as possible in the deteriorating snow. When they could no longer be followed, the helicopter was landed and the tracks were measured. These dimensions are an index to the size of the bear and roughly indicate the age of the animal (Best 1976).

The availability of the various ice types was recorded for several sets of tracks followed. The percentages of ice categories along a random transect indicated the habitat forms available to a polar bear. Comparison of these data with the ice types recorded while following bear tracks revealed preferences for or against specific ice categories exhibited by the bear.

Transects for comparison were straight lines flown at altitudes and air speeds similar to those used in following tracks. For each set of tracks, a comparison transect was chosen approximately 180^{0} from the direction of the bear's travel. The transect was oriented to a distant landmark. The widely wandering pattern of bear travel gave reasonable assurance that the straight line transect did not retrace the path of the bear we had followed.

In 1979, 4 field camps were successively established to observe coastal sea ice and its biota. The first camp was placed on the southeast coast of Lowther Island ($74^{0}28$'N, $97^{0}35$'W) and was occupied from 19 May to 5 June. The camp was placed on a 600 foot (182 m) cliff overlooking Barrow Strait. The second camp was established on a 500 foot (152 m) cliff 0.5 miles (0.3 km) west of Dyke Ackland Bay on the southern coast of Bathurst Island (75°01'N, 99°00'W) from 8 to 21 June. The Bay and part of Barrow Strait could be viewed from vantage points on shore. From 27 June to 9 July, the third camp was placed on top of Beechey Island at an elevation of 1000 feet (304 m; 74°42'N, 91°52'W). The camp was 1 mile (1.6 km) off the southwestern coast of Devon Island. Erebus Bay, parts of Lancaster Sound, and the southern section of Wellington Channel were observed from Beechey Island. The final camp was set up on the western shore of Intrepid Bay, southwestern Cornwallis Island (74°56'N, 96°12'W) at an elevation of 300 feet (91 m), from 13 to 19 July. The long, narrow Bay and its wide mouth were observed.

These study areas were chosen to provide 2 areas known to have been consistently utilized by polar bears and 2 areas known to have been relatively little used by bears. Site selection was based on observations by researchers conducting recent polar bear tagging programs in the vicinity of Barrow Strait (C. Jonkel pers. comm.). The Lowther Island and Erebus Bay study areas were chosen to represent habitat heavily utilized by polar bears. The study areas at Dyke Ackland and Intrepid bays represented lightly utilized habitat.

The coastal ecosystem near each camp was under constant observation. The sea ice was surveyed every hour and a half and all basking seals in an area of approximately 10 sq miles (25 sq km) were counted using 7 power binoculars and a 20 to 60 variable power spotting telescope. Other mammals and birds using the area were tabulated. Polar bears were watched continuously, and a careful record was made of their activities and the types of ice used.

Bear activity categories included travel, play, sleep, feeding, swimming, mating, caching prey carcasses, and 5 types of hunting behavior. Searching was defined as walking with nose to ground or sniffing the air. Travel was defined as walking or running without sniffing activity. Stalking was evident when a bear crept towards a basking seal. Still-hunting occurred when a bear stood unmoving over a seal breathing hole or near a snow mound. When a bear reared up on its hindlegs and came pouncing down on a snow bank, a predation attempt was recorded. Only once was such behavior successful and this instance was recorded as killing behavior. Most feeding behavior recorded involved the utilization of carrion.

Ice classification during the 1979 field season used 5 of the categories delineated during the 1978 field work; smooth ice, open lead, and the 3 categories of rough ice. The sea ice in a 10 sq mile (25 sq km) area was mapped in each study area using these categories.

Plankton and small invertebrate organisms were sampled at each study site with 3 to 5 vertical hauls using a fine mesh plankton net, 0.5 m in diameter at its mouth and 3 m in length. The solid ice cover was 3 to 5 feet (1 to 1.5 m) thick in all 4 study areas, dictating the use of seal breathing holes to accomplish the plankton hauls. This requirement limited the choice of sampling sites. Haul sites were reached on foot at Dyke Ackland Bay and by helicopter in the other 3 areas. The net was lowered to a depth of 30 m or to within 3 m of bottom in shallower waters. After 5 minutes, the net was hauled to the surface and the contents flushed into collecting bottles. Volumes of the plankton samples were found by displacement of water in a graduated cylinder.

The amount of on-shore cover by vegetation and fine inorganic material was estimated visually in 1-m^2 plots placed every 200 feet (61 m) along transects. At each study area, a transect was located on the beach adjacent to the sea ice under observation and another was placed on top of the cliff directly above the beach transect. Beach transects were situated halfway between the edge of the sea ice and the foot of the cliff. Cliff-top transects were placed 15 feet (6 m) from the cliff edge. Plant specimens were collected for later identification.

Weather data were recorded at least twice a day, including temperature, wind speed and direction, visibility in miles, cloud cover in tenths of sky hemisphere, cloud type and cloud ceiling altitude. Visibility and cloud parameters were estimated.

Data Analysis Methods

Data collected on aerial survey flights 9 to 13 conducted from 11 to 21 July 1978, were analyzed separately from those of earlier flights. The ice classification system used during the flights was expanded after the eighth flight. Data from later flights are also included in analysis of the total information collected during aerial surveys.

My hypothesis was that the numbers of polar bears using the different ice categories along the survey routes was a function of relative seal densities in the various ice types. The data were examined with a x^2 test. The observed number of bears was taken as the number of bears and separate sets of bear tracks seen in each ice category. Expected numbers were generated by multiplying the total number of bears by the proportion of seals found in each ice type. Data pooled from all survey flights were tested, and data from flights 9 to 13 only were tested.

The availability of ice categories was investigated for 4 sets of polar bear tracks followed by helicopter in 1978. The statistical difference between observed and expected use of ice categories by polar bears was inspected with x^2 tests for these 4 data sets. Observed use was taken directly from the bears' tracks. Expected use was calculated using the proportions the various ice categories represented on the entire availability transect sampled for each set of tracks.

The levels of use of ice categories relative to their availability were found for 2 data sets. Simultaneous confidence intervals around the differences between availability and use of ice categories were calculated (Marcum and Loftsgaarden 1977). Confidence intervals were calculated at the 97% significance level. Inclusion of 0 in the confidence interval indicated that an ice type was being used in proportion to its availability. If the entire confidence interval was positive, an ice type was being used less than predicted, based on its availability. An ice type was used more than expected, based on its availability, when the entire confidence interval was negative.

The level of use of an ice type by polar bears relative to its availability was calculated from data collected in each of the 3 coastal areas studied in 1979 that received use by polar bears. The availability of the different ice categories was taken from maps drawn in the field. A fine grid of dots was placed over a map and the number of dots falling in each ice type were counted. Availability was defined as the percentage of dots in 1 ice type as compared with all dots on the map. Discrete observations of polar bear use of each study area were obtained from the continuous records of bear activity by noting the ice category used at 10-minute intervals.

The average walking speed of a polar bear is 1.1 m/sec (Best 1976). At this speed, a bear could travel 660 m in 10 minutes, and thereby would have had a choice of the complete array of ice types in any of the study areas within each observation period. Chi-square tests were used to determine whether or not there were significant differences between observed use and expected use of ice types in a study area. Expected use was calculated as the product of total discrete observations (number of 10-minute intervals + 1) and the porportion of ice type relative to all available ice. Simultaneous confidence intervals around the differences between availability and use were calculated to test use relative to availability of ice types in each study area.

The number of surveys of the sea ice in each study area were categorized into those that resulted in the sighting of a polar bear and those that did not. A row X column test of independence using the G-test was computed to examine the null hypothesis that the number of surveys resulting in bear sightings was independent of the area being studied (Sokal and Rohlf 1969). The number of birds sighted per half hour of observation time were compared among the study areas with a Kruskal-Wallis test (Sokal and Rohlf 1969).

The correlations between density of basking seals and 3 different weather parameters were investigated with calculation of the coefficients of determination (r^2). The average numbers of seals observed basking per square mile in a 12-hour period were compared separately with 12-hour averages of temperature (^{o}C), wind speed (mph), and cloud cover (tenths of sky hemisphere). Averages were computed for all parameters for the 2400 to 1200 period and the 1200 to 2400 period from each day on which observations were made. Comparisons between seal densities and weather parameters were made separately for seal observations collected in each study area. Comparisons were categorized further by isolating seal observations made on ice inside major bays from those made on ice adjacent to coastlines outside of a major bay. The Lowther Island study area did not contain a major bay, and the Intrepid Bay area consisted only of a long, narrow bay and its wide mouth. There were 3 areas in the bay ice category and 3 in the coastal ice category. The data from each of the 3 areas were also pooled and used to calculate r^2 values with seal density observations.

The amount of plant cover on beaches adjacent to sea ice study areas and on the tops of the cliffs directly above the beaches was calculated from the average of the visual estimates of plant cover, e.g., as percent of 1-m^2 plots. These plots were placed every 200 feet (60 m) along transects on the beaches and cliff tops. These data were analyzed using a test of equality of percentages (Sokal and Rohlf 1969). The testing procedure is explained in Appendix II.

The areal extent of ice in each ice category was converted to percent of the total area observed near each field camp. These percentages were tested to find similarity or difference among the amounts of ice types present in each study area with the equality of percentages test. Ice types within bays and coastal ice were analyzed separately.

Differences among study areas in the amount of time polar bears spent in each of 5 activity categories were analyzed. The continuous record of bear observation was sampled to provide groups of independent data points for each study area. Sample size was determined by multiplying the total number of minutes of observation by 0.1. Each sample was greater than 100. A random number table was used to generate the appropriate group of sample points. The sampling procedure began with calculating the number of minutes a particular polar bear was observed. Multiplying this number by 0.1 gave the sample size for that bear. Appropriate random numbers were obtained. Each random number was added to the time of the beginning of observation of that bear. The sum was the sample point in the continuous observation record, and the activity of the bear at that point in time was entered on the sample sheet. When the records of all bears in a study area had been sampled, the number of sample points in each of the following behavior categories were summed; hunting, sleeping, traveling, feeding, and playing. These figures were converted to percentages of all sample points by study area. Similarities or differences among study areas in the amount of time bears spent in each activity were found using the equality of percentages test.

The sampling procedure described above was also used to compare among study areas the use of ice types by bears relative to total time spent in all ice types. The ice category being used at the point in time indicated by each random number was entered on the sample sheet. The sample points in each ice category were added together and divided by the total number of sample points from the record of activity in each area. These figures were used to find similarities or differences among study areas in the amount of time bears spent in each ice type with the equality of percentages test.

The differences between amounts of time polar bears spent hunting in each ice type and the availability of the ice categories were examined with x^2 tests in each study area where bears were observed. Observed hunting in the ice types was taken from the continuous observation record of polar bears made in each area. Expected figures were calculated using the availability of the different ice categories (percentages of the total area). The levels of hunting in each ice type relative to availability of the categories were found in each study area using simultaneous confidence intervals.

Comparisons of levels of use of ice types by polar bears observed in 1978 with use by polar bears observed in 1979 were made using the equality of percentages test. All data collected on aerial surveys in 1978 were compared with all 1979 data pooled together, and separately with data from each area investigated in 1979. The 1979 data were reorgainzed into ice classification categories used during the first 8 flights in 1978. These categories were broader than those used in flights 9 to 13 and in 1979, and fewer in number. Equality of percentages tests were employed to compare polar bear use of ice categories observed on flights 9 to 13 in 1978 with all 1979 data, and with data from each of the study areas. The expanded ice classfication system was used.

CHAPTER V

RESULTS

1978 Field Season

Field Camps. Several ringed seals were sighted on the sea ice adjacent to Hamilton Island during occupation of that camp. One seal was observed periodically for 10 hours on 31 May. The species' persistently alert behavior was evident, as documented by other workers (Stirling 1974). Fifty ringed seals were counted basking on the sea ice adjacent to Garrett Island from 21 to 23 June. All were observed basking singly or in groups of 2 to 3 next to breathing holes on smooth ice. Two bearded seals were seen basking next to an open lead and 2 observations of single bearded seals laying at the edge of a polynia were recorded.

Bear tracks were found on the sea ice from the air within several hundred meters of shore at both islands. However, no polar bears were sighted during field camp occupation in 1978.

Aerial Surveys. Aerial surveys were conducted between 4 June and 21 July (Tables 1 and 2). A χ^2 test was used to determine the statistical difference between the number of polar bears and bear tracks found in 4 ice categories (smooth ice, rough ice, lead, and crack) during all survey flights and the expected number of bears and their tracks in these ice types (Table 3). A χ^2 value of 165.94 was calculated and compared with $\chi^2_{\alpha=0.05,\ d.f.=3} = 7.815$. The null hypothesis was rejected; the number of bears and bear tracks found in the various ice types was significantly different from the number expected, based on relative levels of seals seen basking in these ice types. A similar x^2 test was calculated using data obtained on flights 9 to 13, during which an expanded ice classification system was used (Tabel 4). A x^2 value of 223.44 was found and compared to $x^2_{\alpha=0.05,\ d.f.=8} = 15.507$. The test indicated that a significant difference existed between observed and expected numbers of bears and their tracks seen in different ice categories.

Helicopter Tracking. The data collected on use of different types of sea ice in offshore areas by individual polar bears are presented in Table 5 by activity category and as proportions of total activity. The tracks of the bears were followed by helicopter.

Habitat selection by individual polar bears on offshore sea ice was examined in the analysis of 4 sets of bear tracks followed by helicopter on 1 and 2 July. Data on the availability of the ice categories to each bear followed were collected. Differences between observed and expected use of ice types by the bears were examined with x^2 tests (Table 6). Two of the 4 tests found significant differences between observed and expected use. Both sets of data were collected on 2 July in western Barrow Strait. The first set of data, collected between 0920 and 0931, yielded a x^2 value of 25.04. This figure was compared with $x^2_{\alpha=0.05,d.f.=4} = 9.488$. Analysis of the second set of data, obtained between 0957 and 1010, found a x^2 value of 74.24. The comparable table value is $x^2_{\alpha=0.05,d.f.=7} = 14.067$. In both cases the null hypothesis was rejected and significant difference between observed and expected use of ice categories by the bears was indicated.

The levels of use of each ice type relative to its availability were calculated for these 2 data sets using simultaneous confidence intervals (Table 7). The polar bear tracked in the first data set used smooth ice and frozen cracks less than in proportion to their availability. The bear used medium rough ice more than expected, based on that ice category's availability. Low and high rough ice were used proportional to their availability.

The second polar bear used frozen cracks more and medium rough ice less than in proportion to their availability. The bear used all other ice types in proportion to their respective availability.

1979 Field Season

Habitat Selection. Chi-square tests found significant differences at the 95% level between observed and expected polar bear use of ice types in all 3 study areas receiving use by polar bears (Table 8). Simultaneous confidence intervals calculated around differences between availability and use are recorded in Table 9. Ice categories used more than expected (based on their availability) included low rough ice at Lowther Island, medium rough ice at Lowther Island and Dyke Ackland Bay, and open leads at Erebus Bay. Smooth ice was consistently used less than in proportion to its availability in all 3 areas.

Differences between use of ice types for hunting by polar bears and availability of the types in each study area were examined with χ^2 tests (Table 10). These differences were significant at the 95% level in all areas.

Simultaneous confidence intervals were calculated to indicate the level of hunting by polar bears in each ice type relative to availability of the type. The intervals are presented in Table 11. Smooth ice was hunted on less (in proportion to its availability) in all 3 areas receiving use by bears. Polar bears observed in the Lowther Island area and those seen at Erebus Bay hunted in both low and medium rough ice more than expected, based on the availability of these ice types. These ice categories were used proportionally at Dyke Ackland Bay. High rough ice was used less than in proportion to its availability at Lowther Island. The same ice type was used more than expected for hunting by bears at Dyke Ackland Bay.

Comparison of Study Areas. The null hypothesis that the number of surveys resulting in polar bear sightings was independent of the area being studied was examined with a row X column test. A G value of 17.77 was obtained for the test. This value was then compared with $\chi^2_{\alpha=0.05, d.f.=3} = 7.815$, and the null hypothesis was rejected, indicating that bears were not randomly distributed. The number of surveys resulting in bear sightings, and the total number of bears observed, are shown for each study area in Table 12.

The average number of seals basking per square kilometer at any point in time during the observation period for each study area are presented in Table 13. These data are organized into 2 categories; (1) seals observed in major bays present on 3 of the 4 study areas, and (2) seals observed basking on ice adjacent to the shoreline outside of any bay. Differences in observed seal densities between areas were due to real density differences and to the time of the season of observation. These data are not analyzed statistically because of the influence of seasonal progression.

Nearly all pinnipeds observed were ringed seals. As air temperature increases, the proportion of any ringed seal population basking at a given time will increase, peaking at approximately 50% during mid-July (Smith 1973). In this study, the seal density figures calculated for each study area were obtained at different periods of late spring and summer and are not directly comparable. Because the geographic location of sea ice studied was considered in the analysis also, seal densities on bay ice were compared separately from those on coastal ice.

Seal densities on coastal ice at Lowther Island and Dyke Ackland Bay were nearly identical. However, the Dyke Ackland Bay area was observed 3 weeks after the initiation of the Lowther Island field work, and a subsequent increase in the density of basking seals would be expected if real population densities were identical. Lack of such an expected increase indicates that actual population density in the coastal ice at Dyke Ackland Bay was lower than the population density at Lowther Island.

The density of basking seals on the coastal ice of the Erebus Bay area was more than 6 times greater than that at Dyke Ackland Bay. The proportion of this difference due to effects of seasonal progression, and the proportion caused by real differences in population densities, cannot be clearly discerned. A comparison of basking seal densities between the Lowther Island and Erebus Bay areas is difficult, too, but an incomplete survey adjacent to Lowther Island at 1500 on 26 June found a density of 7.44 seals/sq mile (2.92/sq km). Based on these data, the actual population densities of seals on coastal ice were greater at both Lowther Island and Erebus Bay than at Dyke Ackland Bay.

The basking seal density on bay ice at Erebus Bay was greater than that at Dyke Ackland Bay. The density at Intrepid Bay was lower than either of the other figures. Field work at Intrepid Bay was conducted in mid-July, and the basking seal density should be greatest at that time. If actual population densities were similar in the bays, the basking seal density should be highest at Intrepid Bay. Data from this study show that the opposite is the case. Therefore, it is safe to say that actual population densities of seals on bay ice were smaller at Dyke Ackland and Intrepid bays than at Erebus Bay.

The effects of 3 different weather parameters on the average number of seals basking were examined by calculating coefficients of determination (r^2). These values are listed in Table 14 by weather parameter and study area along with the calculated correlation coefficients (r). Average values for basking seal densities, temperature, wind speed, and cloud cover are listed in Appendix III. The greatest amount of variability in basking seal densities was accounted for by average temperature at Intrepid Bay (r^2 = 0.48). Temperature was responsible for 30% of the variability in basking seal density at Lowther Island, 26% of the variability on coastal ice at Erebus Bay, and 28% of that for all coastal ice data pooled together. All other r^2 values are less than 0.25.

A comparison of the number of birds sighted per half hour of observation with a Kruskal-Wallis test obtained an H value of 49.92. The appropriate χ^2 value is $\chi^2_{\alpha=0.05,d.f.=3}$ =7.815. The null hypothesis that the study areas did not differ in the location of ranked data was rejected. The test indicated that the area being observed did affect the number of birds sighted per half hour of observation differentially. These data are given in Table 15. Appendix IV contains lists of bird and mammal species observed in each study area and the number of times each species was sighted.

The amounts of plant cover on cliff tops in all 4 study areas were found to be different, compared one to another at the 95% significance level. Percentages of plant cover on the beaches of the Dyke Ackland and Intrepid bay areas were not significantly different, but tests of all other possible pairs of beach plant cover indicated a significant difference. Plant cover data are presented in Table 16.

The volume of organic matter obtained in each plankton haul conducted in 1979 are listed in Table 17 by study area. All information collected regarding oceanographic and meteorological factors are also included. Detailed drawings of individual specimens representing all species collected were made in the field by B. Taylor. Species identification was made from these drawings by J. Tibbs. Species collected in each plankton haul are noted in Table 17.

The amounts of ice types present in each study area were compared and found to be different from one another at the 95% significance level. The differences were found in both coastal and bay ice areas; the data are presented in Table 18.

Activity. The proportion of time polar bears spent in each of 5 activity categories is recorded in Table 19 for each study area. The percentages in each activity category were tested against each other for difference at the 95% significance level. Similarities were found between travel at Lowther Island and Dyke Ackland Bay; sleep, feeding and play at Lowther Island and Erebus Bay; and hunting and feeding at Dyke Ackland and Erebus bays. All other tests found significant difference between the percent of time spent in an activity in each pair of study areas.

Table 20 presents the use of ice types by polar bears as percent of total activity observed in each study area. The equality of percentages tests calculated at the 95% significance level found similarities between the use of medium and high rough ice at Lowther Island and Dyke Ackland Bay, and high rough ice at Lowther Island and

Erebus Bay. All other possible pairs exhibited a significant difference from each other.

Comparison of 1978 and 1979 Data. The use of ice categories by polar bears observed during 1978 aerial survey flights and bears observed in the 1979 study areas were compared using the equality of percentages test. The use of ice types as percent of total activity are listed in Table 21. Comparison of the 1978 data with pooled 1979 data found a significant difference only between use of smooth ice. Use of all ice types by polar bears at both Dyke Ackland and Erebus bays were significantly different from use of these ice categories by bears seen in 1978. No significant differences occurred between use of ice types observed in 1978 and at Lowther Island in 1979.

An analysis similar to that described above was conducted, substituting data collected on 1978 aerial survey flights 9 to 13 for data collected on all survey flights (Table 22). Equality of percentages tests comparing the 1978 data with pooled 1979 data found significant differences between use of low and medium rough ice. Similar results were procured from comparison of 1978 data with data collected at Lowther Island in 1979. Uses of all ice types were significantly different between bears observed during 1978 and bears at Dyke Ackland Bay in 1979. Use of medium rough ice and open leads were significantly different between bears at Erebus Bay and bears observed in 1978.

CHAPTER VI

DISCUSSION

1978 Field Work

Aerial Surveys. No conclusions regarding habitat selection by seals or polar bears can be drawn from the data collected during aerial surveys because the availability of the ice types to the animals is not known. Most seals sighted were found on smooth ice. Two possible explanations for this phenonmenon can be constructed; most seals present on the ice were using smooth ice, or many seals were using rough ice, but were not sighted. The latter explanation is most likely because seals in rough ice use subnivean lairs (McLaren 1958), and if basking, select areas of smooth ice where visibility (to watch for predators) is better (C. Jonkel pers. comm.). The seals using lairs would not be visible from the air.

A majority of polar bears or their tracks in any 1 ice category is not evident. Chi-square tests were used to examine the hypothesis that the number of polar bears and their tracks found in each ice category were proportional to the number of seals seen in each ice category. The number of seals necessarily meant the number of basking seals, because of the invisibility of seals in lairs to airborn observers. One test utilized all data collected on aerial surveys in 1978, but the number of ice categories was restricted by the classification system used during the first 8 flights. A second test was conducted using only data collected on flights 9 to 13, on which the expanded ice classification system was used. The second test was conducted to examine the possibility that finer detail in ice classification would reveal a positive relationship between the numbers of polar bears and basking seals found in each category, not evident when much broader ice types were used in classification.

The execution of the x^2 tests resulted in rejection of the hypothesis in both cases. However, the polar bears' relative use of ice types was possibly influenced directly by seal densities. Use of rough ice by bears was higher than expected, perhaps because seal densities in these areas were higher than indicated by numbers of basking seals. Actual seal densities may be higher in rough ice than on smooth ice.

Another factor important in explaining relative levels of use of ice types by polar bears is the different hunting methods each ice type dictates for the bears, and the resulting predation efficiencies. Stirling and Archibald (1977) report 6.4 to 8.6% success by polar bears hunting at subnivean lairs compared with less than 2% success by bears stalking basking seals and still-hunting at breathing holes on bare ice (Stirling 1974). Rough ice contains many seal lairs, and smooth ice abounds with breathing holes. My data collected on aerial surveys confirms a proclivity for smooth ice by seals for basking.

Helicopter Tracking. Addition of all predation attempts recorded while following polar bear tracks by helicopter, and their categorization by ice type, reveals a majority in low rough ice (12/30 = 40%). Medium rough ice and smooth ice contained 8 attempts each, representing 26.6% in each category. Two attempts (7%) were found on frozen cracks. The predation attempts in the 2 rough ice categories together comprise over half of all recorded attempts. This is most likely explained in part by the higher predation efficiency polar bears experience by hunting for seals in their subnivean lairs as opposed to stalking basking seals (Stirling and Archibald 1977). The possibility of higher seal densities in the rough ice categories as compared to smooth or refrozen ice is another explanation for the difference.

Only 2 activities could be discerned from a line of polar bear tracks as they were observed from an altitude of approximately 150 feet (46 m) and flown at speeds of 40 mph (64 km ph); travel and predation. As explained below, hunting behavior includes more than actual digging in snow to find seals in their lairs, or investigating a breathing hole (both evidence of predatory behavior). Much detail concerning the types of use the ice received from polar bears was lost in gathering data only from the bears' tracks. Searching behavior, such as the sniffing of snow or the air by a polar bear, cannot be read in tracks; nor can the length of time spent stalking a basking seal.

Information on the availability of ice types was gathered for 4 sets of tracks. Polar bears that produced only 2 of these sets exhibited significant differences between observed and expected use of ice types. The relative levels of use of ice categories were not consistent between the 2 sets of tracks. One polar bear used smooth ice less than in proportion to its availability, while the other used smooth ice proportionally. The first bear used medium rough ice more than expected, based on this ice type's availability, but the other bear used it less than expected. It is important to keep in mind the small amount of activity the lines of tracks represent, relative to an entire day in a polar bear's life. The average length of the tracks followed was approximately 7 miles (11 km). A polar bear walking at an average speed of 1.1 m/sec (Best 1976) could travel this distance in 2.8 hours. Conclusions are difficult to draw from the inconsistent results presented above except to note that individual polar bears show variability in their selection of ice types over short periods of time.

1979 Field Work

Habitat Selection. Polar bears observed in all 3 study areas in which they occurred exhibited habitat selection on the sea ice. The habitat selection found in this study represents choices made by the animals only after selections in more general categories have been concluded. The first habitat "choice" an animal makes is regarding its home range. There may be little actual choice involved; the fact that the animal was born into a particular population often dictates its home range, and this range is affected by a host of biotic and abiotic factors. Social pressures may influence location of an animal's home range, as in causing subordinate sub-adult members of a population to disperse. Seasonal movements within a home range are common in many species and appear to occur in polar bear populations, also (Jonkel 1976, Kiliaan et al. 1978, Stirling et al. 1975). These movements represent another level of habitat selection. Seasonal needs of a polar bear will influence these movements, such as the requirement of denning habitat for females with young in the fall (Harington 1968). Antipathy for social contact can space individuals, and influence their travel routes. As the sea ice breaks up, the movement of the substrate itself can dictate local areas of polar bear concentration (Schweinsburg et al. 1977). The dependence of location on previous movements is also important; where a bear is, is affected by where the bear just was.

Two distinct types of areas exist within the home range of the polar bears occupying the Barrow Strait-Lancaster Sound section of the Canadian Archipelago. These are coastal and offshore ice. The channels are up to 60 miles (96 km) wide, offering vast areas of sea ice that are not adjacent to the surrounding islands. The nearby channels that the bears often use, such as Peel Sound, Prince Regent Inlet, and Wellington Channel, are similar. Polar bears often move into certain coastal sectors of the channels, as this study has indicated. Stirling et al. (1977b) found polar bear sightings made during winter and spring concentrated along pressure ice which paralleled island coastlines, and in offshore areas of dynamic ice. While no conclusions can be garnered regarding relative use of coastal and offshore ice by polar bears observed in this investigation, all observations made in 1979 indicated purposeful movement by bears from the central channel toward the coastal area under observation. These bears were not moving laterally along the island coast and into the observation area. In almost every case, the bears were first observed several kilometers offshore, heading directly for the coast. Their departure was similarly directed abruptly toward the central channel. Travel routes to and from the coastal areas were not perpendicular to the coastline, but angular. At both Dyke Ackland and Erebus bays, the direction of departure was the opposite of arrival. For instance, a polar bear traveling from the southwest toward the coast would leave toward the southeast. Many of the bears observed at Lowther Island departed the coastal area in the same direction from which they came. Others exhibited travel patterns similar to those seen at Dyke Ackland and Erebus bays. The diversity observed at Lowther Island may have been influenced by the small island's inner-channel location. The vast coasts of the major islands bordering the channel may have had a greater affect on travel directions of polar bears than Lowther Island did.

The intent to visit the observed coastal areas, as indicated in the bears' travel patterns, suggests that selection of those areas was occurring. Most predatory behavior exhibited by the polar bears was seen within the coastal area itself. Behavior of bears as they moved toward an area was dominated by walking, although hunting could be discerned at times. Seal densities could be higher close to shore, as seals prefer stable ice (McLaren 1958). This study has also documented behaviors other than hunting in rough ice (see below). Higher concentrations of rough ice are more likely near shore, because much deformation can occur as moving ice sheets encounter land masses (Sater 1969).

Although the reasons for travel into 3 of the 4 coastal study areas by polar bears cannot be known, once the bears were in these areas they did exhibit habitat selection. Smooth ice was consistently used less than in proportion to its availability. This ice type represented more than half of the area observed at Lowther Island, in all of the major bays within the study areas, and of the coastal ice at the Erebus Bay study area. The greatest use of this ice type by polar bears was observed at Lowther Island, where its use totalled 34% of the observation time. The rough ice categories recieved expected amounts of use or more than expected, based on the categories' availability.

The discussion above relates habitat selection by polar bears for all activity. Habitat selection for hunting alone was also examined. Hunting is an important activity for a polar bear, since it is a top-level carnivore in the arctic marine food web. Chi-square tests indicated that polar bears selected their habitat while hunting in all study areas where they were observed.

The relative levels of use of the ice types by hunting polar bears did not differ much from levels of use found when all activity was considered. Polar bears at Lowther Island used high rough ice less than in proportion to its availability when hunting, but used it proportionally for all activities. Hunting polar bears at Dyke Ackland Bay used medium rough ice proportional to availability, and high rough ice more than in proportion to availability. The results were just the opposite for these 2 ice types when all activities were considered. Both low and medium rough ice were used more than expected for hunting, but were used proportional to availability for all activities, at Erebus Bay.

Stirling et al. (1975) discuss polar bear distribution in the Beaufort Sea in relation to sea ice types. They delineated 5 categories for ice that they used between late fall and late spring. These categories are:

"1) stable flat ice areas interspersed with pressure ridges that have not moved for a long time; are drifted with snow and suitable for seal lairs...;

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

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

4) areas of 9/10 or 10/10 ice cover but in 'active zones',

such as around Baillie Hamilton Island, where wind and sea currents cause much movement of ice, followed by refreezing, creating intermittent lanes or patches of refrozen young ice, bare or only slightly drifted...;

5) areas of continuous heavy pressure ice that have not moved for a long time..."

The ice categories used in this investigation do not include the ice floe edge or any analogy to the "active zones" delineated in the terminology of Stirling et al. (1975). Sea ice placed in category 5 above would probably be classified as high rough ice in this study. Low and medium rough ice are analogous to categories 1 and 2. However, the delineating parameters are different in the 2 classification schemes; the presence of snow in one and the height and density of ice blocks in the other.

Smooth ice was used the most for travel in all 3 study areas in which polar bears were found during this study. Other activities watched on smooth ice included predatory searching at Lowther Island and Erebus Bay, and stalking of basking seals at Dyke Ackland Bay.

Sleep was the most common activity seen on low rough ice at both Lowther Island and Dyke Ackland Bay. Bears in the latter study area also used low rough ice for travel, as did bears at Erebus Bay. Searching behavior was recorded on low rough ice at Lowther Island and still-hunting on this ice type occurred at Erebus Bay. Bears at this bay were also observed to feed on low rough ice.

Three types of predatory behavior were seen on medium rough ice at Lowther Island. These were searching, still-hunting, and predation attempts at subnivean lairs. Some travel and play were also recorded at Lowther Island in this ice category. Polar bears at Dyke Ackland Bay used medium rough ice for travel, sleep, and feeding. Travel was also observed on this ice type at Erebus Bay. Bears at Erebus Bay exhibited stalking, searching, and predation attempts at subnivean lairs in medium rough ice.

High rough ice was used for play and feeding at Lowther Island. Bears at Dyke Ackland Bay traveled on this ice type and also pounced at subnivean lairs. High rough ice was used for a wide variety of activities by bears at Erebus Bay, including travel, sleep, play, predatory searching, and still-hunting.

A polar bear traveled along the beach at Lowther Island for several hundred meters. Open leads occurred only in the Erebus Bay study area, where they were used for travel, play, sleep, swimming, predatory searching, and some stalking of seals laying at the lead's edge.

Stalking of seals by polar bears was observed on smooth ice because of the propensity of seals to bask on this ice type. Polar bears were also seen sniffing the air and the ice in this ice type. Seal lairs do occur in this ice type, created by hollowing areas in the ice adjacent to breathing holes. Several such lairs were found at Dyke Ackland Bay.

Much travel was recorded on smooth ice in all study areas. Travel was defined, for the purposes of this investigation, as locomotion without sniffing of the air or ice. Travel is movement with the absence of any other defined activity than to relocate to areas in which other activities can be executed. Smooth ice lacks features utilized in most activities other than travel; the exception is the harboring of basking seals stalked by polar bears. Therefore, much travel would be expected on smooth ice.

Sleeping bears used low rough ice at 2 study areas. Their bed sites were consistently found next to a low ice ridge or hummock. The ice blocks were lower in height than the sleeping bears and little protection from the elements or concealment could have been afforded. However, the proximity of topographical relief may have given a psychological sense of protection to a sleeping bear or increased solar radiation absorption in the bear's pelt, while not restricting its vision when a quick scan of the landscape was required.

Predatory searching and still-hunting were not surprising activities to observe in low rough ice, as they were at Lowther Island and Erebus Bay. The presence of seals in subnivean lairs would prompt hunting behavior in polar bears. Most of all feeding watched during the 1979 field season was on carrion. Feeding probably occurred in low rough ice because this was where the earlier kills had been made.

Subnivean lairs also would occur in medium rough ice. The hunting behaviors seen in this ice type in all 3 study areas were no doubt a response to this presence of seals. Sleeping in medium rough ice was observed at Dyke Ackland Bay. The ice features in this category would provide concealment for a sleeping bear and protection from the wind. The ice features appeared to be incidental to the polar bear observed playing in this ice type at Lowther Island. The bear uncovered an arctic fox carcass and tossed it about, much like a cat with a piece of yarn, for many minutes.

Polar bears at Dyke Ackland Bay were seen traveling in both low and medium rough ice. These bears spent less time in the area individually than bears observed at the other 2 areas. The bears at Dyke Ackland Bay appeared to be moving through the area, while bears in the other 2 areas utilized the ice under observation.

Polar bears played on high rough ice at Lowther Island and Erebus Bay. The tall ice blocks were utilized in the play. Bears would climb up on the ice blocks and jump off into slush pools or onto companions. The feeding observed in this ice type at Lowther Island was again on carrion. The carcass of a seal was dragged from its kill site in adjacent medium rough ice to the high rough ice, were it was consumed. One bear was observed sleeping on top of an ice block approximately 3 m high at the back of Erebus Bay. Such a perch would have offered a view of all of the bay, including its 2 entrances. In an area heavily used by polar bears, surveillance might be necessary to avoid an encounter with a conspecific.

The open leads in the Erebus Bay study area appeared to be very attractive to polar bears. While representing only 1% of the total area available to the bears, the leads were used for 48% of all activity observed in this area. The leads received considerable use by seals, also, and this fact explains the predatory behavior of polar bears at the leads. Play activity in the leads involved much swimming. Two cubs-of-the-year used the leads to frolic in, and a lone adult bear spent several hours at one lead, during which it pushed ice chunks floating in the lead back and forth with its nose while swimming. This same bear was observed performing somersaults in medium rough ice prior to approaching the lead. When an observed activity was recorded simply as swimming, the bear was doing nothing else but this locomotion.

The major differences between the ice habitat classification scheme used by Stirling et al. (1975) and that used in this investigation prevent strong comparisons from being drawn. Most bears observed by Stirling et al. (87.3% of the total sighted) were using the floe edge or the "active zones". Other workers have also noted concentrations of polar bears and their prey along floe edges (Jonkel 1976, McRoy and Goering 1974). Atypically cold summers in both 1978 and 1979 delayed ice break-up 6 weeks or more in Parry Channel, and this study was carried out entirely on coastal sea ice that was a contiguous section of solid cover over the whole channel. The ice recedes from east to west in Parry Channel, and the floe edge was still over 100 miles (160 km) east of the study areas when field work was complete in 1979. Stirling et al. (1975) record no bear sightings in category 5, "... areas of continuous heavy pressure ice...". This category can be most closely compared to high rough ice. Polar bears observed in the 3 study areas used this ice type very little. Jonkel (1976) also noted an absence of seals and bears in "very broken ice" in the Lancaster Sound-Admiralty Inlet area.

Comparison of Study Areas. Four coastal areas were chosen for comparative investigation before field work began in 1979. Two were to represent habitat heavily used by polar bears, and 2 were to be lightly used by bears. The numbers of polar bears observed in each area has substantiated this dichotomy. Surveillance of the sea ice in each area involved inspection of sections of approximately similar extent. The total number of times each study area was surveyed varied among areas because of the different number of days each site was occupied, and the different number of hours of surveillance the weather permitted. These differences invalidated direct comparison of numbers of bear sightings between study areas, but the proportions of surveys that resulted in sightings of bears could be compared. A row X column test was used to examine the null hypothesis of independence between these proportions and the areas in which the surveys were made. The results of the test rejected the null hypothesis, and indicated that polar bears were not randomly distributed among the study areas. This leads to the conclusion that the area, or rather the sum of the biotic and abiotic paramters which is an area, affected the number of bears choosing to use that area. Although periods of inclement weather were experienced in each study area, preventing continuous surveillance of the sea ice, these periods were in the minority and the data collected are realistic indices of the levels of use these 4 study areas recieved from polar bears.

All of the areas are within the home range of 1 subpopulation of polar bears (Schweinsburg et al. 1977). This fact excludes the possibility of differential use due to a simple lack of a polar bear population in the geographic range of 1 or more of the study areas. The effects of human hunting pressure on the polar bears must be examined. The locations of known kills of polar bears by Inuit hunters from Resolute Bay and Arctic Bay between 1968 and 1974 have been recorded by Jonkel (1976). These sites include all 4 study areas. All of the areas are within a 100 mile (160 km) radius of the settlement of Resolute Bay, and hunting pressure is roughly similar for all 4, although Lowther Island is on a travel route from Resolute Bay to caribou hunting grounds (C. Jonkel pers. comm.).

The relative levels of use of these coastal sectors by polar bears was affected by the biotic and abiotic parameters within the areas themselves. The 2 areas receiving the most use by bears, Lowther Island and Erebus Bay, appeared to be the most biologically productive ecosystems of the 4 studied. These 2 areas held the greatest number of seals, the most numerous avian populations, and the adjacent beaches had the highest percent plant cover.

The average densities of basking seals cannot be directly compared among study areas, but examination of the figures (while keeping in mind the effects of seasonal progression on basking seal densities) does reveal differences among the 4 areas. Densities of populations using the coastal ice were greater in the high-bear-use areas, Lowther Island and Erebus Bay. Population densities on bay ice were lower at the low-bear-use areas, Dyke Ackland and Intrepid bays.

The effects of seasonal progression on basking seal densities can be seen in the 12-hr averages presented for the entire 1979 field season in Appendix III. A general increase in the basking seal density can be found at each study area except Intrepid Bay. Observations were made in this study area over a span of 6 days. The period was most likely entirely within the duration of high summer, during which the temperature is high, and without significant variation. A diurnal rhythm in the basking seal densities is also evident. Usually, the average density taken from the latter half of the 24-hr period is greater than that from the first half. The diurnal rhythm in basking seal densities has been reported by Stirling (1977). The rhythm is a probable response to diurnal vertical migratory patterns of zooplankton.

The correlations between the density of basking seals and 3 different weather parameters were calculated, using data from each study area separately and also pooling the data. Correlations on coastal ice and bay ice were inspected individually, because basking seal densities differed so greatly between the 2 regions. The best correlations were found between average temperature and basking seal density, but none of the results suggested a strong relationship between any of the weather parameters and the number of basking seals present. It is doubtful whether finer detail in anaysis would reveal different relationships. Dramatic differences in the numbers of seals sighted on the sea ice between surveys, approximately every 1.5 hr, were rare. Other possible factors affecting the basking regime would include social attractions and feeding requirements.

The number of birds sighted during a half hour of survey time must have been affected by numerous parameters involving the human observer, time of day, and the avian species present. However, these parameters were roughly the same in each study area. A Kruskal-Wallis nonparametric test was used to compare the number of birds sighted among study areas. The results rejected the null hypothesis that the number of sightings per half hour were independent of the study area.

The study area is equated with the sum of the ecosystem parameters it represents. Avian species are involved in reproduction during the high arctic summer. Besides the basic life requirements of food, water, and shelter, their environment must include breeding habitat. For many species, reproduction requires irregular cliff faces, occupied by dozens or hundreds of their kind at once. The relative number of sightings of birds made in each area was representative of the amount of use an area was receiving from breeding colonies. The cliff face below the Lowther Island field camp harbored a breeding colony of 20-30 Glaucous Gulls (Larus hyperboreus). The east-facing cliffs of Beechey Island at Erebus Bay were used as nesting habitat by thousands of Glaucous Gulls, Thayer's Gulls (Larus thayeri), Black Guillemots (Cephus grylle), and Thick-billed Murres (Uria lomvia). The topography of the land surrounding Intrepid Bay did not include cliffs, and consequently very few bird sightings were recorded. The west shore of Dyke Ackland Bay did provide cliffs, but only 1 pair of Glaucous Gulls nested there.

Besides appropriate nesting habitat, food is a major requirement for birds using these areas. The feeding radius of the birds cannot be documented here, but many observations of hundreds of birds using the open leads in the Erebus Bay study area were recorded. These birds were of the same species as those using the cliff faces. Glaucous Gulls were often seen perched on ice blocks below their breeding cliffs at Lowther Island. On more than 1 occasion several were seen feeding on carrion. The abundance of nesting habitat no doubt had a major effect on avian densities in the 4 study areas. The reduced biological productivity of the entire food chain at Dyke Ackland Bay, and possibly at Intrepid Bay, resulting in lower amounts of biomass at all trophic levels, provided diminished food sources for the birds and therefore also limited the number the area could support.

The islands surrounding Parry Channel are classified as a polar desert (Tedrow 1966). Vascular plants are sparse in the polar desert and seldom cover more than 25% of the ground. The peak summer temperature in this region is approximately 5°C and annual precipitation seldom exceeds 8 cm. Most of this precipitation is in the form of snow, and the majority is sublimated. Organic matter content of polar desert soils is generally less than 2%, but occasionally is present in higher quantities. Fine inorganic material that may form on the surface tends to be removed by wind erosion or frost action.

The composition of vegetative communities shows little variation throughout the western Canadian Archipelago because of the uniform, dry, cold climate and similar topography found on all of the western islands (Porsild 1964). The same plant species were found in all study areas. These included the highly ubiquitous Saxifraga oppositifolia, Draba Bellii, Eriophrum callitrix, Carex sp., Dryas sp., and several unidentified species of mosses and lichens.

The relative amounts of soil present were similar in all study areas except Intrepid Bay. The cliff-tops at the other 3 areas held very little fine material. Ground cover was in the form of rocks, ranging from small pebbles to hefty boulders. The beaches, however, contained pockets of continuous fine material, often several centimeters thick. These "oasises" were probably the result of protection from the wind, and mass-action depositing the fine inorganic material at lower elevations. The patches of fine material harbored the greatest amount of plant life, although plants were also found on the cliff-tops.

The topography of the area surrounding Intrepid Bay included a plateau and steep hillsides leading to a narrow beach. Much more fine inorganic material was present on the plateau than was encountered on any of the cliff-tops in other study areas. At the time camp occupation in mid-July, temperatures were nearly constantly above freezing, and many small pools (5 to 20 m in diameter) of standing water were on the plateau. The permafrost in the Arctic prevents drainage of water into the soil beyond a few centimeters (Rieger 1974). Perhaps these conditions occur annually and help to prohibit vegetative colonization.

Although the greatest amount of plant cover found among the study areas was only 8.8% (Lowther Island beach), most of the percent cover figures were statistically different from one another. The only similarity found (95% significance level) was between plant cover on the beaches of the Dyke Ackland and Intrepid bays study areas. The cliff-tops in the high-bear-use areas, Lowther Island and Erebus Bay, had more plant cover than similar areas at Dyke Ackland and Intrepid bays. Plant cover on the beach at Lowther Island was greater than that at the low-bear-use areas. The data indicate that the beach at Erebus Bay had the least plant cover of all 4 areas. However, the sampling was not truly representative, as collection of these data at Erebus Bay was hampered by weather and logistic difficulties. Independent observations indicated large areas of tundra rich in vegetation on the flatlands draining into Erebus Bay and this condition is not evident in the data.

Just as the presence of seals and birds indicates the inclusion of their respective prey species in the local food web, the presence of plants requires that nutrients important to their maintenance and growth be available in the soil substrate. One factor allowing greater plant biomass to exist in an area would be higher concentrations of nutrients. The late spring and summer brings thaw and draining from the land masses into adjacent lakes or the marine ecosystem. This drainage can relocate nutrients important to plant growth from the terrestrial areas to the marine systems. The increased nutrient load in the water column would then provide for greater phytoplankton production, and could concievably have indirect effects on biological production throughout the entire food web. A similar mechanism of nutrient increase in the marine system has been suggested by Apollonio (1973) concerning calving glaciers. Higher terrestrial productivity (based on a richer substrate) could be 1 reason that the marine ecosystems at Lowther Island and Erebus Bay were more productive than those in the other 2 study areas. Other factors important to primary productivity in the sea in these areas would include the amount of upwelling and convergence of water currents (affecting nutrient replenishment), the thickness of the ice cover, and the extent of the average ice-free period each year. The last 2 factors listed would affect the light regime, which is the key factor inducing phytoplankton bloom (Grainger 1971). Although these parameters have not been measured in the study areas, the relative numbers of organisms on the higher trophic levels are indices of primary productivity.

An attempt was made in this investigation to sample the primary trophic level directly. Plankton hauls were performed in each area, and the volumes of organic matter were to be compared and taken as an index of standing crop of phytoplankton, zooplankton, and small invertebrates. The lack of expected ice break-up limited the sites at which hauls could be made to leads and seal breathing holes during these 2 very unusual years. In addition, the diameter of the mouth of the plankton net used was fixed at 0.5 m, and only openings in the ice which could accommodate the net could provide haul sites. As a result, only 3 to 5 hauls were made in each area, and there was little control over the sampling scheme.

The volumes of all organic matter collected in each haul varied from 0.5 to 13.0 ml among the 4 study areas. An indeterminate amount of each sample represented organic debris from seals (skin flakes and hair). This was an unfortunate result of conducting plankton hauls through seal breathing holes. The techniques used after collection were not refined enough to remove the seal debris before measuring the volume of the sample. However, even if all of each sample had been organisms, the volume relative to the total amount of water through which the net passed was extremely small. All but 2 of the hauls were made from 30 m depth. Maximum primary production probably occurs between depths of 4 to 30 m in high arctic waters (Schweinsburg et al. 1977). The column of water the net passed through therefore contained 23.6 m^3.

The invertebrate species collected were similar among the study areas. The microscopic fauna and flora were a different color in each area. This could be interpreted as seasonal progression of species or real differences in community composition.

The entire productivity of a marine ecosystem rests on the base trophic level of the phytoplankton. Ultimately, the primary productivity of an area will have an effect on the relative level of polar bear use the area receives. This conclusion has been reached by other workers, also (Jonkel 1976, Stirling et al. 1977b). This assumes an essentially closed system.

There are little data yet available on seasonal or daily movements of arctic seals. However, seals are most likely seasonally sedentary before ice break-up, as they are dependent on an intimate knowledge of their breathing hole complexes for successful predator avoidance and access to the surface (Stirling 1977). Ringed seals, the most common pinniped in all 4 study areas, are opportunistic feeders (Stirling et al. 1975), and the exact species composition of the lower trophic levels would not have great influence on their movements.

The abundance of invertebrates and zooplankton are most likely affected by a host of factors, including passive movement by local currents. At this level, the system may not be closed. Annual cycles of herbivorous zooplankton numbers have been documented (Mansfield 1975). However, if viewed within the time restraints of 1 season, the marine system could reasonably be modelled as "closed."

This construction does not include polar bears, whose mobility allows them to move in and out of the system. Their selection of each area will in part be based on the biological productivity found within the closed system described.

The physical components of the ecosystems also affected habitat selection by polar bears. The amounts of ice in each classification were compared among coastal areas and major bays in the 4 study areas. All figures were statistically different from one another. The 2 coastal areas receiving the most use from polar bears were those at Lowther Island and Erebus Bay. Both of these sectors contained greater amounts of smooth ice than that at Dyke Ackland Bay. The presence of smooth ice indicates a lack of deformation, and therefore movement of the ice. The only major bay receiving any use by polar bears was Erebus Bay. All of the bays in general had greater amounts of smooth ice than the adjacent coastal regions. The stability of the ice was greater in the bays than in the coastal areas, and the relative basking seal densities observed in these 2 regions emphasized that fact.

The polar bears appeared to select the most stable coastal ice.

This is probably directly related to the seals' preference for this habitat. The bears did not select the most stable bays. This may in part be explained by the lower hunting efficiency polar bears experience on smooth ice, even though a bay may harbor large numbers of their prey. Erebus Bay was more diverse in terms of ice categories than either of the other 2 major bays observed. The open leads in Erebus Bay may have been the prime attractant to the bears using it, but the bay also contained 27% high rough ice, and this ice type was utilized, also.

Polar Bear Activity and Use of Ice Types Among Study Areas. To examine differences in activity among polar bears in the 3 study areas in which they were observed, behavior was classified in 5 broad categories: hunt, sleep, travel, feed, and play. All predatory behavior was incorporated in the hunt category. The sleep classification included some sitting and laying, but was primarily true sleep. Miscellaneous activities that did not occur in all 3 areas were not included in the comparison. For instance, polar bears were observed swimming and mating at Erebus Bay, and successful predation was watched at Dyke Ackland Bay.

The continuous records of polar bear observation made at each study area were sampled to provide data for statistical testing. These samples were used rather than the total amounts of time recorded in each behavior category, to ensure independence among data points. The probabilities of the occurrence of each behavior calculated from the samples did not differ much from the total amounts of time in each category, when these were transformed to percentages of all observation time. Not all of the figures were statistically different from one another. The least difference was found between polar bear activities observed at Lowther Island and Erebus Bay; no significant differences were found in the sleep, feed, or play categories. The relative amount of time spent traveling was similar between polar bears seen at Lowther Island and Dyke Ackland Bay. Relative amounts of time spent hunting and feeding were similar at Dyke Ackland and Erebus bays. Interpreting these similarities and differences in behavior is difficult. While the structure of the habitat surely affects behavior, a number of other factors can also be cited, including physiological state and social pressures.

The relatively low percent of time spent hunting by polar bears observed at Dyke Ackland Bay (14%) and the great percent of total activity spent sleeping (58%) in this area were influenced by the fact that a kill was recorded there. A female with 1 cub-of-the-year pulled a ringed seal from its lair next to the pressure ridge at the mouth of the bay. She and her cub spent the following 8 hours alternately feeding and sleeping. Successful hunting precluded the need for further predatory behavior. However, the other 4 bears watched in this study area were not successful in their hunting, and their behavior is summed in the figures, also.

Travel was distributed more evenly over all ice types at Dyke

Ackland Bay than at the other 2 study areas. This is most likely explained by less interest in prolonged utilization of the area, as discussed above. The greatest relative amount of time spent traveling was recorded for the bears at Erebus Bay. This bay is located on the southwest corner of Devon Island, at the confluence of 2 major channels. It may lie on a heavily traveled route used by polar bears to cross from one channel into the next. Other observations documented this area's utilization for activities besides travel, though.

When the time budget reported by Stirling (1974) for polar bears observed at Radstock Bay on Devon Island in mid-summer was compared to all activity data gathered in this study, the similarities were remarkable. Several of Stirling's behavior categories were consolidated to adhere to the classification used in this study, producing the following amounts as percent of total observed activity:

Activity	Radstock Bay	All 1979 Data	Erebus Bay
Hunt	22.6	28.5	22.3
Sleep	42.0	37.6	23.3
Travel	29.7	22.2	34.6
Feed	2.3	5.9	5.7
Play	----	5.0	12.1

Stirling's time budget did not include a play category or any analogous behavior. The activity data from Erebus Bay alone are included in the table above because Radstock Bay is only 10 miles

(16 km) east of Erebus Bay. The percent of total observation time the polar bears spent hunting at Radstock and Erebus bays were nearly identical. The figures in the sleep category in these 2 areas did differ quite a bit, though. However, when all the data from Radstock Bay were compared to that from all study areas pooled together, great similarity was found for all 4 behavior categories. Radstock Bay is more secluded than Erebus Bay, and therefore may provide more protection from possible disturbances. In general, however, these time budgets may be typical of polar bears in coastal sectors of Parry Channel in late spring and summer.

The percentages of total observation time the polar bears in each study area spent in the various ice categories available to them were compared. The continuous records of observation were sampled to provide independent data points for statistical analysis. Similarities were found between relative use of medium and high rough ice at Lowther Island and Dyke Ackland Bay. The statistically similar use of high rough ice by bears at Lowther Island and Erebus Bay is also interesting. Analysis of habitat selection discussed above showed that levels of use of these ice types relative to their availability were the same for each pair of study areas where similarities in relative use were found, strengthening the point overall.

The relative use of smooth ice was highest at Lowther Island and Erebus Bay. Availability of this ice type was also highest in these study areas. The relative use patterns exhibited among the study areas (Table 20) were analogous to those patterns found in the relative availability of the ice categories (Table 18). The habitat selection analysis has shown that use of an ice type was not necessarily proportional to its availability. However, comparing data between study areas suggests that the amount of use an ice type received could have been influenced by its abundance.

Comparison of Use of Ice Types by Polar Bears, 1978 and 1979

The number of ice categories used in comparing the use of ice by polar bears observed during the 1978 and 1979 field seasons was restricted to 3. The classification scheme used during the first 8 aerial surveys conducted in 1978 was limited to these categories, and other data were consolidated for this examination. The classification scheme does not convey much useful information. No significant differences were found between the use of rough ice and leads in the 1978 and 1979 data. Polar bears observed in 1978 exhibited statistically greater use of smooth ice.

Comparisons of 1978 and 1979 data were essentially comparisons of offshore and coastal ice regions in the same geographic locale. The data did not indicate relative use of ice categories, because information on ice availability was not collected during the 1978 aerial surveys. More smooth ice may have been present in offshore areas, relative to the total extent of the ice sheet, than in coastal areas.

Comparisons of 1979 data with that collected on flights 9 to 13 allowed examination in more detail. In this test, use of smooth ice was not significantly different between years. Relative use of low and medium rough ice were different between the years. Polar bears in offshore areas (1978 data) used medium rough ice more than bears in coastal areas (1979 data). The opposite was true for low rough ice.

Management Implications and Suggestions for Further Research

Polar bears observed in this study were attracted to habitat that was a mosaic of different ice types. The study was conducted in summer, but the solid ice cover encountered during 1978 and 1979 was more typical of spring conditions in the Canadian Archipelago. Large areas of smooth ice did not appear to attract polar bears. The low use received by high rough ice suggests that continuous sections of very rough ice would be equally unattractive to polar bears.

Polar bears are top-level carnivores in the arctic marine food web, and hunting was a priority activity. Schweinsburg et al. (1977) identify feeding areas as key habitat for polar bears in late spring and early summer. Low and medium rough ice represented prime hunting habitat for the bears observed in this study, but only in areas where these ice types were interspersed with much smooth ice, and where the local food web was biologically productive. The amount of smooth ice an area possesses correlates with the stability of the sea ice. Ringed seals, the polar bears' primary prey, prefer stable ice for construction of their lairs. A juxtaposition of patches of smooth with rough ice creates a mosaic of habitat types. Although the physical structure of the habitat is important for provision of life requirements to polar bears and their prey, the local ecosystem must also be able to supply adequate food sources to the members of its food web. The most biologically productive areas harbor the greatest seal densities, and are most attractive to polar bears.

Low and medium rough ice, interspersed in smooth ice, also appeared to be good habitat for other important polar bear activities. Bears slept in these ice types, fed in them, and interacted with other bears in them.

The information gathered in this study is applicable to management decisions involving disruption of coastal ecosystems in the High Arctic islands. An example of such disruption would be the development of facilities for exploitation of mineral resources. I suggest that more research be conducted to gather information similar to that presented here. This research would establish the amount of variation to be expected in polar bear use of coastal habitat in spring and early summer. Information on habitat selection and utilization during and after ice break-up in the main channels would be of great interest to scientists and resource managers.

Information that would allow predictions on the quality of sea ice as polar bear habitat to be made from ice survey data currently gathered for meteorological and transportation purposes would provide a very useful tool to resource managers. The level of resolution of these ice surveys is too low to provide data that could be analyzed using the information presented in this study.

Two methods of studying movements of polar bears are currently in use. Tagging programs provide information on movements of bears over several days or several months. Satellite telemetry studies are providing locations of individual bears every few days for several months, and may soon allow a bear to be tracked for a year or more. Analyses of these movements often includes discussion of the bears' habitat. Continued research along this avenue with as much detail of the ice habitat as can be applied will be important to our understanding of polar bear utilization of the sea ice. Information gathered at this level of resolution may provide the link to developing existing ice surveys as a polar bear management tool.

The remoteness of the arctic wilderness, and its harsh climate, prohibit easy collection of information on the small-scale utilization of the sea ice by polar bears, but it is important to obtain it. Although all levels of habitat selection by polar bears should be investigated, this final level of utilization is the one at which individual animals perform the actions that bring them the requirements of life. All other aspects of the animal's ecology develop from there.

CHAPTER VII

SUMMARY

During the summers of 1978 and 1979, an investigation of polar bear habitat on the sea ice was conducted in Barrow Strait and adjacent channels of the Queen Elizabeth Islands, Northwest Territories, Canada. The area comprises the home range core of 1 subpopulation of polar bears. The sea ice is the bears' primary habitat.

Field methods used from 20 May to 25 July 1978 were observation of the sea ice environment from 2 field camps established on island coasts, surveillance of sea ice by fixed-wing aircraft, and following polar bear tracks by helicopter. All basking seals, polar bears, sets of bear tracks, and the ice type each was sighted in were recorded on ice survey flights. Data collected from polar bear tracks followed by helicopter included activity of the bear, ice type, and direction of travel.

Four field camps were successiviely established between 19 May and 19 July 1979 in coastal sectors of Barrow Strait. The sea ice and its biota were observed from these camps. Previous research was used to choose 2 areas that were heavily utilized by polar bears and 2 areas that received light use.

Field work was similar at all 1979 study areas. The sea ice was surveyed every 1.5 hours. All basking seals were counted. Polar bears sighted in the areas were watched continuously. All other mammals and birds observed were recorded. Percentages of plant cover were estimated visually in 1-m^2 plots placed along transects on beaches adjacent to the sea ice under surveillance, and on the tops of cliffs above the beaches. The sea ice in a 10 sq mile (25 sq km) area was mapped using the ice classification scheme developed during this investigation.

Analysis of data collected during the 1978 aerial surveys found no strong relationship between numbers of polar bears and sets of bear tracks seen in the various ice types and the numbers of seals basking in those ice types. Many seals in a population could be using subnivean lairs constructed in snow drifts among rough ice, and would not be visible from aircraft. Therefore, polar bear use of different ice types may have reflected differential seal densities among these ice categories that were not evident from counting basking seals alone.

Habitat selection by some polar bears occurred in offshore areas of sea ice, as indicated by data collected during helicopter tracking in 1978. Consistent patterns of use relative to availability of ice types were not found in these data. The small sample size precludes conclusions being made, except to note that individual polar bears can show variability in their selection of ice types over short periods of time.

Polar bears observed in all 3 1979 study areas in which they occurred exhibited habitat selection on the sea ice. Smooth ice was consistently used less than in proportion to its availability. The rough ice categories received expected amounts of use, or more than expected, based on the categories' availability.

Habitat selection for hunting alone was also examined. The relative levels of use of the ice types by hunting polar bears did not differ much from levels of use found when all activity was considered.

The numbers of polar bears observed in each of the 1979 study areas substantiated the high-low bear use dichotomy hypothesized before field work began. The 2 study areas receiving the most use by polar bears, Lowther Island and Erebus Bay, appeared to be the most biologically productive ecosystems of the 4 studied. These 2 held the greatest number of seals, the most numerous avian populations, and the adjacent beaches had the highest percent plant cover.

Two distinct regions were identified within the study areas; coastal ice and ice within major bays. Coastal ice areas receiving the greatest polar bear use had the greatest amounts of smooth ice, indicating greater stability. The bay receiving most use by polar bears had more diversity in ice types than the unused bays.

Polar bear behavior was classified in 5 broad categories; hunt, sleep, travel, feed, and play. The relatively low percent of time spent hunting by polar bears observed at the Dyke Ackland Bay study area (14%), and the great percent of total activity spent sleeping (58%) in this area, were influenced by the fact that a female bear with a cub-of-the-year killed and consumed a ringed seal there.

The greatest relative amount of time spent traveling was recorded for the bears at Erebus Bay. This bay may lie on a heavily traveled route used by polar bears to cross from Wellington Channel to Lancaster Sound, and back.

The patterns of relative use of ice types exhibited among study areas were analogous to those patterns found in the relative availability of the ice categories. Comparisons of use of ice types by polar bears observed in 1978 and 1979 were essentially comparisons of offshore and coastal ice regions in the same geographic locale. Little difference was found between polar bear use of ice types in these 2 regions.

This investigation was conducted in summer, but the solid ice cover encountered during 1978 and 1979 was more typical of spring conditions in the Canadian Archipelago. Habitat most attractive to polar bears was a mosaic of ice types, where low and medium rough ice were interpersed with smooth ice. Large proportions of smooth ice in the mosaic indicated stability of the ice and thus prime habitat for the polar bears' main prey, the ringed seal. Another factor important to quality polar bear habitat is the biological productivity of an area. The primary productivity of an area will have an ultimate effect on the relative level of polar bear use that area receives through its support of the food web. The polar bear is a top-level carnivore in the arctic marine food webs. Higher levels of primary productivity will provide a base trophic level for a more productive food web, and support greater amounts of use of an area by polar bears.

REFERENCES CITED

Aagard, K. and L.K. Coachman. 1977. Recent studies of Arctic currents. In M.J. Dunbar, ed. Polar oceans. Arctic Inst. of North Am., pp. 87-98.

Ackley, S.F. and W.D. Hibler. 1977. Measurements of Arctic Ocean ice deformation and fracture patterns from satellite imagery. In M.J. Dunbar, ed. Polar oceans. Arctic Inst. of North Am., pp. 227-238.

Alexander, V. 1974. Primary productivity regimes of the nearshore Beaufort Sea, with reference to potential roles of ice biota. In J.C. Reed and J.E. Sater, eds. The coast and shelf of the Beaufort Sea. Arctic Inst. of North Am., pp. 609-635.

Allen, M.B. 1971. High-latitude phytoplankton. Annu. Rev. Ecol. and Syst. 2: 261-276.

Apollonio, S. 1961. Chlorophyll content of arctic sea ice. Arctic 14: 197-200.

Apollonio, S. 1973. Glaciers and nutrients in arctic seas. Science 180: 491-493.

Best, R.C. 1976. Ecological energetics of the polar bear. M.Sc. thesis, Univ. Guelph, Ont., 136 pp.

Carey, A.G., Jr. and R.E. Ruff. 1977. Ecological studies of the benthos in the western Beaufort Sea with special reference to bivalve molluscs. In M.J. Dunbar, ed. Polar oceans. Arctic Inst. of North Am., pp. 505-530.

Coachman, L.K. and K. Aagard. 1974. Physical oceanography of Arctic and subarctic seas. In Y. Herman, ed. Marine geology and oceanography of the Arctic seas. Springer-Verlag, New York, pp. 1-72.

Collin, A.E. 1963. Waters of the Canadian Arctic Archipelago. In Proc. of the Arctic Basin Symp., Oct. 1962, Arctic Inst. of North Am., pp. 128-142.

Dunbar, M. and W. Wittman. 1963. Some features of ice movement in the Arctic basin. In Proc. of the Arctic Basin Symp., Oct. 1962, Arctic Inst. of North Am., pp. 90-108.

Fay, F.H. 1974. The role of ice in the ecology of marine mammals of the Bering Sea. In D.W. Hood and E.J. Kelly, eds. Oceanography of the Bering Sea. Proc. Intl. Symp. Bering Sea Study, 31 Jan. - 4 Feb., Hakodate, Japan. Occas. Publ. No. 2, Inst. Marine Sci., Univ. Ak., pp. 283-299.

Grainger, E.H. 1959. The annual oceanographic cycle at Igloolik in the Canadian Arctic. 1. The zooplankton and physical and chemical observations. J. Fish. Res. Board Can. 16(4): 453-501.

Grainger, E.H. 1971. Biological oceanographic observations in Frobisher Bay. Fish. Res. Board Can.Tech. Rep. No. 265, 42 pp.

Harington, C.R. 1968. Denning habits of the polar bear (Ursus maritimus). Can. Wildl. Serv. Rep. Ser. No. 5, 30 pp.

Horner, R.A. 1977. History and recent advances in the study of ice biota. In M.J. Dunbar, ed. Polar oceans. Arctic Inst. of North Am., pp. 269-283.

Ice Forecasting Central. 1970. Ice terminology. Halifax, N.S., mimeo, 3 pp.

Jacobs, J.S. R.G. Barry, and R.L. Weaver. 1975. Fast ice characteristics, with special reference to the eastern Canadian Arctic. Polar Record 17(110): 521-536.

Johnson, M.W. 1963. Arctic Ocean plankton. In Proc. of the Arctic Basin Symp., Oct. 1962, Arctic Inst. of North Am., pp. 173-196.

Jonkel, C.J., G.B. Kolenosky, R.J. Robertson, and R.H. Russell. 1970. Further notes on polar bear denning habits. In Bears-their biology and management. IUCN, Morges, Switzerland, IUCN New Series No. 23: 142-158.

Jonkel, C.J. 1976. Lancaster Sound-Admiralty Inlet polar bear studies, Strathcona Sound Project. Dept. of Indian and Northern Aff., Ottawa, Ont., 33 pp.

Jonkel, C.J., P. Smith, I. Stirling and G.B. Kolenosky. 1976. The present status of the polar bear in the James Bay and Belcher Islands area. Can. Wildl. Serv. Occas. Pap. No. 26, 42 pp.

Kiliaan, H.P.L., I. Stirling and C.J. Jonkel. 1978. Polar bears in the area of Jones Sound and Norwegian Bay. Can. Wildl. Serv. Progress Notes No. 88, 21 pp.

Kovacs, A. and M. Mellor. 1974. Sea ice morphology and ice as a geologic agent in the southern Beaufort Sea. In J.C. Reed and J.E. Sater, eds. The coast and shelf of the Beaufort Sea. Arctic Inst. of North Am., pp. 113-164.

Lentfer, J.W. 1972. Polar bear-sea ice relationships. In S. Herrero, ed. Bears-their biology and management. IUCN, Morges, Switzerland, IUCN New Ser. 23: 165-171.

Lentfer, J.W. 1975. Polar bear denning on drifting sea ice. J. Mammal. 56(3): 716-718.

Lindsay, D.G. 1974. Sea-ice atlas of Arctic Canada 1961-1968. Energy, Mines and Resources, Canada, Ottawa, Ont., 213 pp.

McLaren, I.A. 1958. The biology of the ringed seal in the eastern Canadian Arctic. Fish. Res. Board Can. Bull. No. 118, 97 pp.

McRoy, C.P. and J.J. Goering. 1974. The influence of ice on the primary productivity of the Bering Sea. In D.W. Hood, ed. Oceanography of the Bering Sea. Univ. of Ak. Inst. of Marine Sci. Occas. Publ. No. 2, p. 403-421.

Mansfield, A.W. 1975. Marine ecology in Arctic Canada. In Proc. Circumpolar Conf. on Northern Ecol., Ottawa, Ont., pp. 220-231.

Marcum, G.L. and D. Loftsgaarden. 1977. A non-mapping technique for studying utilization versus availability of environmental components. Univ. of Mt. Interdisciplinary Ser. No. 2, 16 pp.

Meguro, H.K., K. Ito and H. Fukushima. 1967. Ice flora (bottom type): a mechanism of primary production in polar seas and the growth of diatoms in sea ice. Arctic 20(2): 114-133.

Mohr, J.L. an J. Tibbs. 1963. Ecology of ice substrates. In Proc. of the Arctic Basin Symp., Oct. 1962, Arctic Inst. of North Am., pp. 245-252.

Porsild, A.E. 1964. Illustrated flora of the Canadian Arctic Archipelago. Nat. Mus. of Can. Bull. No. 146, 218 pp.

Rieger, S. 1974. Arctic soils. In J.D. Ives and R.G. Barry, eds. Arctic and alpine environments. Methuen & Co., Ltd., London, pp. 747-769.

Sater, J.E., ed. 1969. The Arctic basin. Arctic Inst. of North Am., pp. 14-62.

Schweinsburg, R.E., I. Stirling, S. Oosenburg and H. Kiliaan. 1977. A status report on polar bear studies in Lancaster Sound, Dec. 1977. N.W.T. Fish and Wildl. Serv. Rept. to Norlands Petroleum, Ltd., 45 pp.

Smith, T.G. 1973. Censusing and estimating the size of ringed seal populations. Fish. Res. Board Can. Tech. Rep. No. 427, 22 pp.

Smith, T.G. 1976. Predation of ringed seal pups (Phoca hispida) by the arctic fox (Alopex lagopus). Can. J. Zool. 54(10): 1610-1616.

Smith T.G., and I. Stirling. 1975. The breeding habitat of the ringed seal. The birth lair and associated structures. Can. J. Zool. 53: 1297-1305.

Sokal, R.R. and R.J. Rohlf. 1969. Biometry. W.H. Freeman and Co., San Francisco, pp. 388-390, 598-600, 608-609.

Stirling, I. 1974. Midsummer observations on the behavior of wild polar bears (Ursus maritimus). Can. J. Zoo. 52(9): 1191-1198.

Stirling, I. 1977. Adaptions of Weddel and ringed seals to exploit the polar fast ice habitat in the absence and presence of surface predators. Proc. 3rd SCAR Symp. on Antarctic Biol, pp. 741-748.

Stirling, I., D. Andriashek, P. Latour and W. Calvert. 1975. The distribution and abundance of polar bears in the eastern Beaufort Sea. Beaufort Sea Tech. Rep. No. 2, Dept. of Environ., Can., 59 pp.

Stirling, I. and W.R. Archibald. 1977. Aspects of predation of seals by polar bears. J. Fish. Res. Board Can. 34(8): 1126-1129.

Stirling, I., C.J. Jonkel, P. Smith, R. Robertson and D. Cross. 1977a. The ecology of the polar bear along the western coast of Hudson Bay. Can. Wildl. Serv. Occas. Pap. No. 33, 64 pp.

Stirling, I., R.E. Schweinsburg, W. Calvert and H.P.L. Kiliaan. 1977b. Population ecology of the polar bear along the proposed Arctic Islands gas pipeline route. Prog. Rep. to the Environ. Mgmt. Serv., Dept. of Environ., Edmonton, Alta., 69 pp.

Stirling, I. and T.G. Smith. 1975. Interrelationships of Arctic Ocean mammals in sea ice habitat. In Proc. Circumpolar Conf. on Northern Ecol., Ottawa, Ont., 7 pp.

Stroganov, S.U. 1962. Carnivorous mammals of Siberia. Acad. of Sci. of the USSR, Siberian Branch, Biol. Inst. Publ. by the Smithsonian Inst. and Natl. Sci. Found., 522 pp.

Tedrow, J.C.F. 1966. Polar desert soils. Soil Sci. Amer. Proc. 30: 381-387.

Volkov, N.A. 1972. On the state of long-range ice forecasting techniques. In T. Karlsson, ed. Sea ice. Proc. of an Intl. Conf., Reykjavik, Iceland, May 1971, Natl. Res. Conc., Reykjavik, pp. 172-179.

Wadhams, P. 1975. Sea ice morphology in the Beaufort Sea. Beaufort Sea Tech. Rep. No. 36, Dept. of Environ., Can., 36 pp.

Weeks, W.F. and O.S. Lee. 1958. Observations on the physical properties of sea ice at Hopedale, Labrador. Arctic 11(3): 135-155.

Table 1. Numbers of basking seals, polar bears, and bear tracks recorded on survey flights conducted between 4 June and 3 July 1978.

Date	Flight area	Seals				Polar bears				Bear tracks[e]			
		Sm[a]	Ri[b]	L[c]	C[d]	Sm	Ri	L	C	Sm	Ri	L	C
4 June	Western Barrow Strait, Baring Channel, Peel Sound	26	22	0	9	6	0	0	0	0	1	0	0
4 June	Western Barrow Strait, Peel Sound	3	0	0	1	1	1	0	1	1	0	0	0
8 June	Western Barrow Strait	127	28	0	10	0	0	0	0	2	4	0	2
8 June	Barrow Strait, Aston Bay, Peel Sound	13	6	0	2	0	0	0	0	6	5	0	0
1 July	Barrow Strait	61	0	1	25	0	0	0	0	0	0	0	0
2 July	Western Barrow Strait	32	4	1	4	0	0	0	0	0	0	0	0
2 July	Western Barrow Strait	108	0	0	0	0	0	0	0	0	0	0	0
3 July	Barrow Strait	17	0	9	3	0	0	0	0	0	0	0	0

[a]Sm = smooth ice

[b]Ri = rough ice

[c]L = lead

[d]C = crack

[e]these figures indicate the number of separate lines of tracks observed

Table 2. Numbers of basking seals, polar bears, and bear tracks recorded on survey flights conducted between 11 and 21 July 1978.

Date	Flight area	Seals									Polar bears and bear tracks[a]								
		Sm[b]	Lf[c]	Lo[d]	Cf[e]	Co[f]	Rl[g]	Rm[h]	Rh[i]	O[j]	Sm	Lf	Lo	Cf	Co	Rl	Rm	Rh	O
11 July	Lancaster Sound	150	37	36	5	2	3	15	0	5	3:3	0:1	0:3	0:0	0:0	0:5	2:13	0:4	0:5
13 July	Prince Regent Inlet	69	48	1	0	0	3	6	0	0	0:0	0:0	0:0	0:0	0:0	0:0	0:1	0:0	0:0
15 July	Baillie Hamilton Island, western Barrow Strait	141	55	45	0	4	21	9	0	0	1:0	0:0	0:0	0:0	0:0	0:0	0:0	0:0	0:0
18 July	Viscount Melville Sound	46	45	7	2	0	37	2	0	0	0:0	1:0	0:0	0:0	0:0	1:0	0:0	0:0	0:0
21 July	Baillie Hamilton Island, Wellington Channel	40	2	0	1	0	3	0	0	0	0:0	0:0	0:0	0:0	0:0	0:0	0:0	0:0	0:0

[a] No. bears: No. lines of separate bear tracks

[b] Sm = smooth ice

[c] Lf = frozen lead

[d] Lo = open lead

[e] Cf = frozen crack

[f] Co = open crack

[g] Rl = low rough ice

[h] Rm = medium rough ice

[i] Rh = high rough ice

[j] O = open water

Table 3. Comparison of observed and expected use of ice categories by polar bears recorded during survey flights conducted between 4 June and 21 July 1978.

	Ice Type				
	Smooth	Rough	Lead	Crack	Total
Seals	1193 (69.9%)	159 (9.3%)	287 (16.8%)	68 (4.0%)	1707
Polar bears	11	4	1	1	17
Bear tracks	12	33	4	2	51
Total bears[a]	23	37	5	3	68

X^2 test

Observed = Total bears in ice type Y

Expected = 68 x (percent of seals in ice type Y)

	Smooth	Rough	Lead	Crack
Observed	23	37	5	3
Expected	47.5	6.3	11.5	2.7

$$X^2 = 12.64 + 149.60 + 3.67 + 0.03 = 165.94$$

$$X^2_{\alpha=0.05,\ d.f.=3} = 7.815$$

[a]Total bears = bears + separate sets of bear tracks

Table 4. Comparison of observed and expected use of ice categories by polar bears recorded during survey flights 9 to 13, conducted between 11 and 21 July 1978.

	Ice Type									
	Smooth ice	Frozen lead	Open lead	Frozen crack	Open crack	Low rough ice	Medium rough ice	High rough ice	Open	Total
Seals	446	187	89	8	6	67	32	0	5	840
Polar bears	4	1	0	0	0	1	2	0	0	8
Bear tracks	3	1	3	0	0	5	14	4	5	35
Total bears	7	2	3	0	0	6	16	4	5	43

X^2 test

Observed = Total bears in ice type Y

Expected = 43 x (percent of seals in ice type Y)

	Smooth ice	Frozen lead	Open lead	Frozen crack	Open crack	Low rough ice	Medium rough ice	High rough ice	Open
Observed	7	2	3	0	0	6	16	4	5
Expected	22.8	9.6	4.6	0.4	0.3	3.4	1.6	0	0.3

$$X^2 = 10.95 + 6.02 + 0.56 + 0.40 + 0.30 + 1.99 + 129.60 + 0 + 73.63 = 223.44$$

$$X^2_{\alpha=0.05,\ d.f.=8} = 15.507$$

Table 5. Numbers of sample points found in the different ice categories on helicopter tracking flights conducted between 30 June and 3 July 1978.

Bear track No.	Date	No. of bears	Track length by width	Area	Ice Type Sm[a]	Lf[b]	Lo[c]	Cf[d]	Co[e]	Rl[f]	Rm[g]	Rh[h]
1.	30 June	1	10.5 x 8 in	Eastern Barrow Strait								
			26.7 x 20.3 cm	Total activity	6	--	4	--	--	1	--	--
				Travel	6	--	4	--	--	--	--	--
				Predation attempt	--	--	--	--	--	1	--	--
2.	1 July	1	10 x 7.5 in									
			25.4 x 19.1 cm	Barrow Strait, north of Russel Island								
				Total activity	15	--	1	--	--	8	1	--
				Travel	13	--	1	--	--	6	--	--
				Predation attempt	2	--	--	--	--	2	1	--
3.	1 July	1	11 x 7 in	Barrow Strait, north								
			27.9 x 17.8 cm	of Somerset Island								
				Total activity	16	--	6	--	--	19	18	1
				Travel	14	--	6	--	--	15	13	1
				Predation attempt	2	--	--	--	--	4	5	--
				Ice availability	12	--	--	--	--	10	7	3
4.	2 July	1	16 x 10.5 in	Western Barrow Strait								
			40.6 x 26.7 cm	Total activity	8	2	--	--	--	12	3	--
				Travel	7	2	--	--	--	12	3	--
				Predation attempt	1	--	--	--	--	--	--	--
				Ice availability	8	--	--	3	--	13	6	2
5.	2 July	2 (♀ + cub)	8.5 x 5.5 in	Western Barrow Strait								
			21.6 x 14.0 cm	Total activity	--	--	--	--	--	2	8	--
				Travel	--	--	--	--	--	1	7	--
				Predation attempt	--	--	--	--	--	1	1	--
				Ice availability	8	--	--	3	--	13	6	2

Table 5. Continued.

Bear track No.	Date	No. of bears	Track length by width	Area	Ice Type Sm	Lf	Lo	Cf	Co	Rl	Rm	Rh
6.	2 July	1	no dimensions	Western Barrow Strait								
				Total activity	2	--	5	--	--	7	--	--
				Travel	1	--	5	--	--	6	--	--
				Predation attempt	1	--	--	--	--	1	--	--
7.	2 July	1	no dimensions	Western Barrow Strait								
				Total activity	12	--	3	8	2	--	--	2
				Travel	11	--	3	6	2	--	--	2
				Predation attempt	1	--	--	2	--	--	--	--
				Ice availability	16	3	2	1	--	4	5	1
8.	2 July	1	12.5 x 7.5 in 31.8 x 19.1 cm	Western Barrow Strait, east of Lowther Island								
				Total activity	4	--	1	2	3	1	--	--
				Travel	3	--	1	2	3	1	--	--
				Predation attempt	1	--	--	--	--	--	--	--
9.	2 July	2 (♀ + cub)	no dimensions	Western Barrow Strait, east of Lowther Island								
				Total activity	2	--	--	--	--	6	--	--
				Travel	2	--	--	--	--	4	--	--
				Predation attempt	--	--	--	--	--	2	--	--
10.	3 July	1	no dimensions	Barrow Strait, north of Somerset Island								
				Total activity	2	1	--	--	--	4	3	--
				Travel	2	1	--	--	--	3	2	--
				Predation attempt	--	--	--	--	--	1	1	--

[a] Sm = smooth ice
[b] Lf = frozen lead
[c] Lo = open lead
[d] Cf = frozen crack
[e] Co = open crack
[f] Rl = low rough ice
[g] Rm = medium rough ice
[h] Rh = high rough ice

Table 6. Comparison of observed and expected use of ice categories by polar bears recorded during tracking flights, 1 and 2 July 1978.

Observed = Total sample points on bear tracks in ice type Y

Expected = (Total sample points on bear tracks) x (percent availability of ice type Y)

	Bear track number			
	3	4	5	7
Observed				
Smooth ice	16	8	0	12
Frozen lead	--	2	--	0
Open lead	6	--	--	3
Frozen crack	--	0	0	8
Open crack	--	--	--	2
Low rough ice	19	12	2	0
Medium rough ice	18	3	8	0
High rough ice	1	0	0	2
Expected				
Smooth ice	22.5	6.3	2.5	13.5
Frozen lead	----	0	----	2.6
Open lead	0	----	----	1.7
Frozen crack	----	2.4	0.9	0.8
Open crack	----	----	----	0
Low rough ice	18.8	10.1	4.1	3.4
Medium rough ice	13.1	4.7	1.9	4.2
High rough ice	5.6	1.5	0.6	0.8
Calculated X^2 Value	7.50	5.35	25.04	74.24
Table X^2 Value	9.49	11.07	9.49	14.07

Table 7. Confidence intervals around differences between availability and use of ice types from data taken while following bear tracks on 2 July 1978.

Bear track number and ice type	97% Confidence[a] interval	Use relative to availability
Bear track no. 5		
Smooth ice	(+0.084, +0.416)	Less
Frozen crack	(+0.088, +0.100)	Less
Low rough ice	(-0.127, +0.539)	Same
Medium rough ice	(-0.925, -0.299)	More
High rough ice	(-0.030, +0.155)	Same
Bear track no. 7		
Smooth ice	(-0.227, +0.338)	Same
Open lead	(-0.209, +0.112)	Same
Frozen lead	(-0.018, +0.206)	Same
Open crack	(-0.183, +0.035)	Same
Frozen crack	(-0.467, -0.063)	More
Low rough ice	(-0.002, +0.252)	Same
Medium rough ice	(+0.017, +0.296)	Less
High rough ice	(-0.171, +0.085)	Same

[a] 97% Confidence interval =

$$(P_{1A}-P_{2A}) \pm Z_{0.985}\sqrt{\frac{P_{1A}(1-P_{1A})}{N_1} + \frac{P_{2A}(1-P_{2A})}{N_2}}$$

N_1 = total sample points on ice availability transect

P_{1A} = fraction of sample points from ice availability transect in ice type A

N_2 = total sample points on bear track

P_{2A} = fraction of sample points from bear track in ice type A

Table 8. X^2 values calculated for use (sample points at 10 min intervals in record of continuous observation) of ice types in each 1979 study area in which polar bears were observed.

Study area and ice type	Observed[a] use	Expected[b] use	Calculated X^2 value	Table $X^2_{\alpha=0.05}$ value
Lowther Island				
Smooth ice	19	47.2		
Low rough ice	18	5.5	64.4	7.815
Medium rough ice	21	8.7		
High rough ice	10	6.6		
Dyke Ackland Bay				
Smooth ice	12	45.1		
Low rough ice	16	15.2	229.1	7.815
Medium rough ice	34	4.4		
High rough ice	4	1.3		
Erebus Bay				
Smooth ice	7	34.5		
Low rough ice	5	1.9		
Medium rough ice	4	3.3	8381.3	9.488
High rough ice	8	13.2		
Open lead	29	0.1		

[a]Observed use = sample points in ice type Y

[b]Expected use = (total sample points) x (proportion of ice in type Y)

Table 9. Confidence intervals around differences between availability and use of ice types by polar bears in 1979 study areas.

Study area and ice type	97% Confidence[a] interval	Use relative to availability
Lowther Island		
Smooth ice	(+0.297, +0.533)	Less
Low rough ice	(-0.315, -0.054)	More
Medium rough ice	(-0.323, -0.040)	More
High rough ice	(-0.163, +0.064)	Same
Dyke Ackland Bay		
Smooth ice	(+0.358, +0.646)	Less
Low rough ice	(-0.157, +0.133)	Same
Medium rough ice	(-0.593, -0.304)	More
High rough ice	(-0.112, +0.028)	Same
Erebus Bay		
Smooth ice	(+0.374, +0.663)	Less
Low rough ice	(-0.155, +0.038)	Same
Medium rough ice	(-0.108, +0.082)	Same
High rough ice	(-0.043, +0.242)	Same
Open lead	(-0.695, -0.398)	More

[a]97% Confidence interval =

$$(P_{1A}-P_{2A}) \pm Z_{0.985}\sqrt{\frac{P_{1A}(1-P_{1A})}{N_1} + \frac{P_{2A}(1-P_{2A})}{N_2}}$$

N_1 = total points over study area

P_{1A} = fraction of points in ice type A

N_2 = total bear sightings in study area

P_{2A} = fraction of bear sightings in ice type A

Table 10. X^2 values calculated for hunting use (total minutes of observed hunting) of ice types in each study area in which polar bears were observed.

Study area and ice type	Observed[a] use	Expected[b] use	Calculated X^2 value	Table $X^2_{\alpha=0.05}$ value
Lowther Island				
Smooth ice	264	461.4		
Low rough ice	170	86.0	590.34	7.815
Medium rough ice	343	132.9		
High rough ice	5	101.7		
Dyke Ackland Bay				
Smooth ice	48	74.9		
Low rough ice	84	86.4	152.75	7.815
Medium rough ice	33	26.9		
High rough ice	27	3.8		
Erebus Bay				
Smooth ice	23	159.8		
Low rough ice	67	9.4		
Medium rough ice	45	11.8	1681.50	9.488
High rough ice	47	51.7		
Open lead	53	23		

[a]Observed use = minutes of hunting observed in each ice type

[b]Expected use = (total minutes of hunting) x (proportion of ice in type Y)

Table 11. Confidence intervals around differences between availability and use for hunting in ice types by polar bears in 1979 study areas.

Study area and ice type	97% Confidence[a] interval	Use for hunting relative to availability
Lowther Island		
Smooth ice	(+0.140, +0.365)	Less
Low rough ice	(-0.824, -0.749)	More
Medium rough ice	(-0.359, -0.179)	More
High rough ice	(+0.117, +0.130)	Less
Dyke Ackland Bay		
Smooth ice	(+0.014, +0.266)	Less
Low rough ice	(-0.121, +0.146)	Same
Medium rough ice	(-0.128, +0.064)	Same
High rough ice	(-0.183, -0.058)	More
Erebus Bay		
Smooth ice	(+0.473, +0.692)	Less
Low rough ice	(-0.322, -0.168)	More
Medium rough ice	(-0.215, -0.068)	More
High rough ice	(-0.086, +0.126)	Same
Open lead	(-0.279, -0.153)	More

[a]97% Confidence interval =

$$(P_{1A}-P_{2A}) \pm Z_{0.985}\sqrt{\frac{P_{1A}(1-P_{1A})}{N_1} + \frac{P_{2A}(1-P_{2A})}{N_2}}$$

N_1 = total points over study area
P_{1A} = fraction of points in ice type A
N_2 = total amount of time polar bears spent hunting
P_{2A} = fraction of hunting time in ice type A

Table 12. Total numbers of polar bears observed in each study area and numbers of sea ice surveys with and without polar bear sightings. A row X column test of independence using a G-test was performed on the data.

Study area	Polar bears observed	Sea ice surveys: with bear observations	Sea ice surveys: without bear observations	Total
Lowther Island	20	14	133	147
Dyke Ackland Bay	6	3	96	99
Erebus Bay	13	11	52	63
Intrepid Bay	0	0	43	43
		28	324	352

Row X column test of independence using the G-test (Sokal and Rohlf 1969):

1. Sum of transforms of the frequencies of the body of the contingency table (polar bears observed excluded):

   $\sum^{b}\sum^{a} f_{ij} \ln f_{ij} = 14 \ln 14 + 133 \ln 133 + \ldots + 43 \ln 43 = 1522.410$

2. Sum of transforms of the row totals:

   $\sum^{b}(\sum^{a} f_{ij}) \ln (\sum^{a} f_{ij}) = 147 \ln 147 + \ldots + 43 \ln 43 = 1611.260$

3. Sum of the transforms of the column totals:

   $\sum^{a}(\sum^{b} f_{ij}) \ln (\sum^{b} f_{ij}) = 28 \ln 28 + 324 \ln 324 = 1966.263$

4. Transform of the grand total:

   $352 \ln 352 = 2063.998$

5. $G = 2\left[\text{quantity 1} - \text{quantity 2} + \text{quantity 3} + \text{quantity 4}\right] = 17.77$

   The G value is compared with $X^2_{\alpha=0.05,\ d.f.=3} = 7.815$, where

   $d.f. = (a-1)(b-1)$ and a = number of columns and b= number of rows in the table.

Table 13. Average number of seals observed basking per square kilometer of sea ice in 1979 study areas.

Study area	Coastal ice	Bay ice
Lowther Island	0.04	----
Dyke Ackland Bay	0.05	1.93
Erebus Bay	0.33	3.13
Intrepid Bay	----	0.80

Table 14. Coefficients of correlation (r) and determination (r^2) between basking seal densities in 1979 study areas and 3 weather parameters.

Study area	Average 12-hr temperature (°C)		Average 12-hr wind speed (mph)		Average 12-hr cloud cover (X/10 sky hemisphere)	
	r	r^2	r	r^2	r	r^2
<u>Coastal ice</u>						
Lowther Island	0.549	0.301	-0.227	0.052	0.293	0.086
Dyke Ackland Bay	0.082	0.007	-0.171	0.029	-0.064	0.004
Erebus Bay	0.511	0.261	-0.477	0.227	0.296	0.087
Pooled data	0.532	0.283	-0.182	0.033	0.183	0.033
<u>Bay ice</u>						
Dyke Ackland Bay	0.339	0.115	0.120	0.015	0.286	0.082
Erebus Bay	-0.272	0.074	-0.419	0.176	-0.098	0.010
Intrepid Bay	0.692	0.478	-0.482	0.232	-0.231	0.054
Pooled data	0.122	0.015	-0.232	0.054	0.131	0.017

Table 15. Numbers of birds of all species observed per half hour of observation time in 1979 study areas.

Study area	Birds observed per 0.5 hr observation time
Lowther Island	1.27
Dyke Ackland Bay	0.90
Erebus Bay	24.03
Intrepid Bay	0.33

A Kruskal-Wallis test was used to determine differences in location of data from each study area ranked by number of birds seen per 0.5 hr observation time (Sokal and Rohlf 1969):

1. Individual half hours were ranked according to number of birds seen, from smallest to largest:

Number of birds sighted per 0.5 hr observation time	Total number of sightings (all 1979 data pooled)	Rank
1	34	17.5
2	41	55.1
3	14	82.5
4	3	91
5	13	99
6	3	107
7	2	109.5
8	2	111.5
9	1	113
10	3	115
12	5	119
14	1	122
15	3	124
18	2	126.5
29	1	128
30	3	130
31	1	132

Table 15. Continued.

Numbers of birds sighted per 0.5 hr observation time	Total numbers of sightings (all 1979 data pooled)	Rank
37	3	134
44	1	136
50	2	137.5
51	1	139
60	3	141
62	1	143
70	1	144
71	1	145
73	1	146
100	1	147
215	1	148
226	1	149
250	1	150

2. Original data were replaced by ranks.

3. Ranks for each study area were summed:

Study area	Sum of ranks (n_{i_R})	Number of observations (n_i)
Lowther Island	3596.8	54
Dyke Ackland Bay	2224.0	35
Erebus Bay	5329.6	53
Intrepid Bay	406.3	7

4. An H value was computed (the numbers 12 and 3 are constants):

$$H = \frac{12}{(\overset{a}{\Sigma}\, n_i)(\overset{a}{\Sigma}\, n_i + 1)} \Sigma \frac{a(\overset{n_i}{\Sigma} R)}{n_i} - 3(\overset{a}{\Sigma}\, n_i + 1) = 48.23$$

5. A correction factor was computed:

$$D = 1 - \frac{\overset{m}{\Sigma} T_j}{(\overset{a}{\Sigma}\, n - 1)\overset{a}{\Sigma}\, n\, (\overset{a}{\Sigma}\, n + 1)} = 0.966$$

Where T_j is a function of the number of variates tied in the j^{th} group

Table 15. Continued.

of ties = 114,396.

6. Adusted $H = \frac{H}{D} = 49.92$

The adjusted H value is compared with $\chi^2_{\alpha=0.05,\ d.f.=3} = 7.815$

where d.f. = the number of study areas - 1.

Table 16. Averages of visual estimates of plant cover as percent of 1-m^2 plots along transects in 1979 study areas.

Study area	Average percent plant cover	
	Cliff	Beach
Lowther Island	4.9	8.8
Dyke Ackland Bay	1.0	5.3
Erebus Bay	3.5	3.9
Intrepid Bay	0.5	6.4

Table 17. Weather parameters and volume and contents of organic matter collected during plankton hauls in 1979 through seal breathing holes in a continuous ice cover.

Study area	Haul no.	Date	Time	Air temp. (°C)	Water temp. (°C)	Cloud cover (X/10 sky)	Wind speed (mph)	Haul depth (m)	Volume of organic matter (ml)	Contents of haul
Lowther Island	1[a]	26 June	1701	+2	-2	6	0	30	1.0	*Calanus* sp., *Clione* sp., seal hair, seal skin, fine brown plankton of unidentified species
	2	26 June	1744	+2	-2	6	0	30	0.5	*Clione* sp., seal hair, fine brown plankton of unidentified species
	3	26 June	1822	+2	-2	6	0	30	2.0	*Calanus* sp., seal hair, seal skin, fine brown plankton of unidentified species
	4	26 June	1903	+2	-2	6	0	30	0.5	*Calanus* sp., seal hair, seal skin, fine brown plankton of unidentified species, unidentified organic matter
	5	26 June	1929	+2	-2	6	0	30	2.5	*Calanus* sp., seal hair, seal skin, fine brown plankton of unidentified species
Dyke Ackland Bay	1	9 June	1642	0	-2	0	12	30	13.0	*Pseudalibrotus nansenii*, *Calanus* sp., fine red-brown plankton of unidentified species, unidentified organic matter
	2	14 June	1510	-0.5	-2	9	10	30	2.0	*Pseudalibrotus nansenii*, *Calanus* sp., seal hair, fine red-brown plankton of unidentified species

Table 17. Continued.

Study area	Haul no.	Date	Time	Air temp. (°C)	Water temp. (°C)	Cloud cover (X/10 sky)	Wind speed (mph)	Haul depth (m)	Volume of organic matter (ml)	Contents of haul
	3	14 June	1540	-0.5	-2	9	10	30	0.5	*Psuedalibrotus nansenii*, *Calanus* sp., seal hair, seal skin, fine red-brown plankton of unidentified species
	4	15 June	1556	0	-2	7	10	30	4.0	*Pseudalibrotus nansenii*, *Calanus* sp., seal hair, seal skin, fine red-brown plankton of unidentified species, unidentified organic matter
Erebus Bay	1	9 July	2226	+3	0	7	5	14	2.0	*Pseudalibrotus nansenii*, *Calanus* sp., *Clione* sp., seal hair, seal skin, fine green plankton of unidentified species, unidentified organic matter
	2	9 July	2252	+3	0	7	5	30	1.0	*Pseudalibrotus nansenii*, *Calanus* sp., *Clione* sp., fine green plankton of unidentified species
	3[a]	9 July	2315	+3	0	7	5	30	3.75	*Pseudalibrotus nansenii*, *Clione* sp., seal hair, fine green plankton of unidentified species
Intrepid	1	13 July	1635	+2	0	9	10	22	3.5	*Pseudalibrotus nansenii*, seal hair, seal skin, fine salmon-colored plankton of unidentified species, unidentified organic matter

Table 17. Continued.

Study area	Haul no.	Date	Time	Air temp. (°C)	Water temp. (°C)	Cloud cover (X/10 sky)	Wind speed (mph)	Haul depth (m)	Volume of organic matter (ml)	Contents of haul
	2	13 July	1700	+2	0	9	10	30	2.5	*Pseudablibrotus nansenii*, *Calanus* sp., seal hair, seal skin, fine salmon-colored plankton of unidentified species
	3	13 July	1720	+2	0	9	10	30	3.5	*Pseudalibrotus nansenii*, *Calanus* sp., seal hair, seal skin, fine salmon-colored plankton of unidentified species, unidentified organic matter
	4	13 July	1745	+2	0	9	10	30	1.0	*Calanus* sp., seal hair, fine salmon-colored plankton of unidentified species
	5	13 July	1820	+2	0	9	10	30	0.75	*Calanus* sp., seal hair, fine salmon-colored plankton of unidentified species, fine brown plankton of unidentified species

[a]Haul conducted through open lead

Table 18. Percent of ice types present in each 1979 study area.

Study area	Smooth ice	Low rough ice	Medium rough ice	High rough ice	Open lead
Coastal ice					
Lowther Island	59	11	17	13	--
Dyke Ackland Bay	39	45	14	2	--
Erebus Bay	70	6	5	18	1
Bay ice					
Dyke Ackland Bay	91	6	0	3	--
Erebus Bay	67	2	4	27	--
Intrepid Bay	95	4	1	0	--

Table 19. Polar bear activities as percent of total bear observation time in each 1979 study area.

Activity	Lowther[a] Island	Dyke[b] Ackland Bay	Erebus[c] Bay
Hunt	49	14	19
Sleep	32	58	29
Travel	13	18	35
Feed	2	9	8
Play	4	1	9

[a]n = 189 sample points from continuous observation record

[b]n = 147 sample points from continuous observation record

[c]n = 108 sample points from continuous observation record

Table 20. Use of ice types by polar bears as percent of total activity observed in each 1979 study area.

Ice type	Lowther[a] Island	Dyke[b] Ackland Bay	Erebus[c] Bay
Smooth ice	34	7	20
Low rough ice	41	63	20
Medium rough ice	19	28	5
High rough ice	6	2	7
Open lead	--	--	48

[a]n = 189 sample points from continuous observation record

[b]n = 147 sample points from continuous observation record

[c]n = 108 sample points from continuous observation record

Table 21. Comparison of use of ice types by polar bears as percent of total activity in 1978 and 1979.

Year or study area	Smooth ice	Rough ice	Lead
1978[a]	35	57	8
1979[b]	22	66	12
Lowther Island[c]	34	66	0
Dyke Ackland Bay[c]	8	92	0
Erebus Bay[c]	21	31	48

[a]Percent of total numbers of polar bears and separate lines of tracks observed in each ice type summed over all 1978 aerial survey flights.

[b]Percent of sample points taken from continuous record of polar bear observation made in each 1979 study area, summed over all study areas.

[c]Percent of sample points taken from continuous record of polar bear observation made in study area named.

Table 22. Comparison of use of ice types by polar bears as percent of total activity observed on survey flights 9 to 13 in 1978 and in 1979 study areas.

Year or study area	Smooth ice	Low rough ice	Medium rough ice	High rough ice	Open lead
1978[a]	24	16	42	10	8
1979[b]	22	43	18	5	12
Lowther Island[c]	34	41	19	6	0
Dyke Ackland Bay[c]	7	63	28	2	0
Erebus Bay[c]	20	20	5	7	48

[a]Percent of total numbers of polar bears and separate lines of bear tracks observed in each ice type summed over flights 9 to 13 conducted in 1978.

[b]Percent of sample points taken from continuous record of polar bear observation made in each 1979 study area, summed over all study areas.

[c]Percent of sample points taken from continuous record of polar bear observation made in study area named.

APPENDIX I

HELICOPTER TRACKING DATA FORM

A facsimile of the data form used during the following of polar bear tracks is shown below.

DATE: 7/2/78
TIME: 0908.00 - 0920.00
BEARS: 1
TRACK DIMENSIONS: length 16" width 10.5"

AIR SPEED: 40 mph
WEATHER: estimated cieling 10,000 feet, scattered alto-cumulus clouds

TIME	ACTIVITY	ICE TYPE	DIRECTION	TRACK	REMARKS
0908.00	T	S	SE	S	
	T	S	SE	S	
0909.00	T	Rl		S	crosses ridge
	T	S		S	
0910.00	T	S		S	snow cover 4-5", 10/10
	T	S	SW	S	S turn, wide
0911.00	Pa	S	SE	S	by-passes seal hole
	T	S		S	at seal hole
0912.00	T	Rl	S	W	
	T	S	SE	W	
0913.00	T	Rm	S	S	
	T	Rm	S	S	crosses ridge
0914.00	T	Rl	SE	W	
	T	Lf	E	W	crosses lead, 2 feet wide
0915.00	T	Rl	S	S	
	T	Rl	Se	S	
0916.00	T	Rl		W	
	T	Rl	S	S	
0917.00	T	Rl	SW	S	odd diversion
	T	Rl	SE	S	crosses ridge
0918.00	T	Rl	SW	S	
	T	Lf	E	S	30 feet wide
0919.00	T	Rl	SE	S	
	T	Rl	E	S	
0920.00	T	Rl	S	S	

Activity codes: T = travel, R = rest, Pa = predation attempt

Ice type codes: S = smooth ice, Lf = frozen lead, Rl = low rough ice,

Rm = medium rough ice

Directions are given in compass direction abbreviations.

Track Codes: S = straight, W = wandering.

APPENDIX II

THE EQUALITY OF PERCENTAGES TEST

To use the equality of percentages test, the data from each study area must first be organized into 2 categories; those with the parameter of interest and those without it (Sokal and Rohlf 1969). These figures are converted to percentages. An example is given below:

Study area	Number of sample points taken from continuous record of polar bear observation		Percent of all sample points taken from continuous record of polar bear observation	
	Hunting	Not hunting	Hunting	Not hunting
Lowther Island	92	97	49	51
Dyke Ackland Bay	21	126	14	86
Erebus Bay	21	87	19	81

The percentages computed from the with-parameter category are compared in tests of pairs. Arcsine transformations are applied to the 2 percentages. A t_s value is computed using the equation:

$$t_s = \frac{\arcsin\sqrt{p_1} - \arcsin\sqrt{p_2}}{\sqrt{820.8\ (1/n_1 + 1/n_2)}}$$

where 820.8 is a constant. The calculated t_s value is compared with the appropriate value from the normal distribution. An example of required computations is given below for the data presented above:

Lowther Island and Dyke Ackland Bay;

$$\arcsin\sqrt{0.487} = 44.26 \qquad n_{L.I.} = 189$$

$$\arcsin\sqrt{0.143} = 22.22 \qquad n_{D.A.B.} = 147$$

$$t_s = \frac{44.26-22.22}{\sqrt{820.8\ (1/189 + 1/147)}} = \frac{22.04}{3.15} = 7.00$$

The comparable Z value is 1.96 at the 95% significance level. Calculated

t_s is greater than 1.96, indicating a significant difference between the amounts of time polar bears spent hunting in the Lowther Island and Dyke Ackland Bay study areas.

Lowther Island and Erebus Bay;

$$\arcsin\sqrt{0.487} = 44.26 \qquad n_{L.I.} = 189$$

$$\arcsin\sqrt{0.194} = 26.13 \qquad n_{E.B.} = 108$$

$$t_s = \frac{44.26 - 26.13}{\sqrt{820.8\ (1/189 + 1/108)}} = \frac{18.13}{3.46} = 5.25$$

Comparison of the t_s value with Z = 1.96 again indicates a significant difference between amounts of time polar bears spent hunting in each of the 2 study areas.

Dyke Ackland and Erebus bays;

$$\arcsin\sqrt{0.143} = 22.22 \qquad n_{D.A.B.} = 147$$

$$\arcsin\sqrt{0.194} = 26.13 \qquad n_{E.B.} = 108$$

$$t_s = \frac{22.22-26.13}{\sqrt{820.8\ (1/147 + 1/108)}} = \frac{|-3.91|}{3.64} = 1.07$$

Comparison of this t_s value with Z = 1.96 finds no significant different between amounts of time polar bears spent hunting at Dyke Ackland and Erebus bays.

APPENDIX III

TWELVE HOUR AVERAGES FOR BASKING SEAL DENSITIES ON COASTAL AND BAY ICE, TEMPERATURE, WIND SPEED AND CLOUD COVER FROM 20 MAY TO 19 JULY 1979

The average of each parameter for the 2400 to 1200 period is shown first for each date and the average of the parameter for the 1200 to 2400 period is shown second.

Study area and date	Average basking seals: Coastal ice #/sq mi	Coastal ice #/sq km	Bay ice #/sq mi	Bay ice #/sq km	Temp. (°C)	Wind speed (mph)	Cloud cover (X/10 sky)
Lowther Island							
May							
20	0.03	0.01			-15	15	9
	----	----			---	--	--
21	----	----			---	--	--
	0.21	0.08			-7	5	3
22	0.04	0.02			-10	2	0
	0.04	0.02			-8	0	10
23	0	0			-8	0	10
	0	0			-6	0	10
24	0	0			-9	0	10
	0.05	0.02			-7	3	9
25	0.03	0.01			-13	17	6
	0	0			-10	22	2
26	0	0			-12	20	8
	0	0			-10	35	5
27	0	0			-10	29	0
	0	0			-11	30	0
28	0.04	0.02			-12	9	0
	0.07	0.03			-8	4	0
29	0.08	0.03			-10	0	0
	0.09	0.03			-7	6	7
30	0.07	0.03			-7	10	9
	0.39	0.27			-15	8	1
31	0	0			-8	20	4
	0.06	0.02			-5	8	1
June							
1	0.02	0.01			-8	0	1
	0.58	0.25			-5	0	10
2	0.14	0.06			-8	0	10
	0.40	0.17			-8	3	10
3	0.08	0.03			-10	5	10
	0.14	0.06			-6	6	10

Study area and date	Average basking seals: Coastal ice #/sq mi	Coastal ice #/sq km	Bay ice #/sq mi	Bay ice #/ sq km	Temp. (°C)	Wind speed (mph)	Cloud cover (X/10 sky)
4	0.03	0.01			-7	7	10
	----	----			---	--	--
Dyke Ackland Bay							
8	----	----	----	----	---	--	--
	0.97	0.42	----	----	0	9	1
9	0	0	2.56	1.01	-5	13	2
	0	0	1.60	0.63	0	12	0
10	0.04	0.02	3.40	1.33	-4	25	7
	0.12	0.04	1.97	0.76	0	12	10
11	0.07	0.03	3.83	1.50	-4	14	9
	0.25	0.10	4.96	1.94	-1	0	10
12	----	----	----	----	---	--	--
	0	0	0	0	-4	10	10
13	0.08	0.03	0.43	0.17	-3	8	10
	0.32	0.13	1.84	0.71	+1	12	10
14	0.50	0.20	6.60	2.58	-4	6	10
	0.05	0.02	3.90	1.53	-2	22	8
15	0.04	0.02	2.13	0.83	-4	12	10
	0.09	0.04	4.79	1.87	0	13	8
16	0.42	0.17	6.69	2.61	-2	1	9
	0.09	0.04	4.62	1.80	+1	2	7
17	0.18	0.08	5.11	1.99	-3	2	8
	0.11	0.04	3.91	1.52	+2	6	4
18	0.03	0.01	2.98	1.16	-2	9	4
	0.12	0.04	6.38	2.49	+2	24	10
19	0.51	0.20	6.38	2.49	-1	14	10
	0.30	0.12	9.57	3.74	+3	4	8
20	0.10	0.04	6.39	2.49	-3	20	8
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Erebus Bay							
28	----	----	----	----	---	--	--
	0.27	0.11	----	----	-2	6	6
29	0.09	0.04	5.56	2.19	-2	8	5
	0.78	0.32	9.48	3.88	+2	4	10
July							
1	0.04	0.02	6.51	2.57	0	3	2
	0.09	0.04	7.88	3.11	+5	10	7
2	0.02	0.01	7.46	2.88	0	9	10
	1.5	0.87	11.99	4.63	0	7	10

Study area and date	Average basking seals: Coastal ice #/sq mi	Coastal ice #/sq km	Bay ice #/sq mi	Bay ice #/sq km	Temp. (°C)	Wind speed (mph)	Cloud cover (X/10 sky)
3	----	----	----	----	---	--	--
	1.15	0.45	9.29	3.59	+3	5	9
4	1.25	0.49	5.40	2.13	+2	20	10
	----	----	----	----	---	--	--
5	----	----	9.52	3.75	-1	25	9
	0.28	0.11	4.53	1.78	0	20	8
6	0.62	0.24	8.09	3.18	+1	14	8
	0.51	0.20	12.54	4.93	+3	9	3
7	2.99	1.17	11.38	4.47	+4	2	8
	3.11	1.22	7.20	2.83	+6	1	10
8	0.87	0.34	4.92	1.94	+6	10	8
	0.28	0.11	2.70	1.06	+3	21	10
Intrepid Bay							
14			0.93	0.37	0	18	9
			1.39	0.55	+3	18	7
15			2.71	1.07	+1	13	8
			2.04	0.81	+6	13	4
16			2.03	0.81	+5	2	5
			4.78	1.91	+6	8	6
17			0.34	0.14	+2	30	8
			----	----	--	--	--
18			0.19	0.08	+1	29	9
			2.28	0.91	+4	15	5
19			1.38	0.55	+2	4	10
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APPENDIX IV

BIRDS AND MAMMALS SIGHTED IN 1979 STUDY AREAS

Polar bears (*Ursus maritimus*) and ringed seals (*Phoca hispida*) are not included in the following lists.

Study area and animals	Number of sightings
Lowther Island 19 May to 5 June, 26 June	
Mammals:	
arctic fox (*Alopex lagopus*)	1
Birds:	
Glaucous Gull (*Larus hyperboreus*)	169
Snow Bunting (*Plectrophenax nivalis*)	4
Rock Ptarmigan (*Lagopus mutus*)	4
Rough-legged Hawk (*Buteo lagopus*)	1
Hoary Redpoll (*Acanthis hornemanni*)	1
Lapland Longspur (*Clacarius lapponicus*)	1
Dyke Ackland Bay 8 to 21 June	
Mammals:	
arctic fox	2
Birds:	
Glaucous Gull	51
Snow Bunting	18
Brant (*Branta nigricans*)	12
Knot (*Calidris canutus*)	6
Snow Goose (*Chen cauerulescens*)	5
Long-tailed Jaeger (*Stercorarius longicaudus*)	4

	Number of sightings
Rock Ptarmigan	4
Unknown	60
Erebus Bay 27 June to 9 July	
Mammals:	
arctic fox	6
Birds:	
Black Guillemot (*Cephus grylle*)	1389
Thick-billed Murre (*Uria lomvia*)	350
Glaucous Gull	54
Thayer's Gull (*Larus thayeri*)	20
Common Eider (*Somateria mollissima*)	4
Snow Bunting	3
Peregrine Falcon (*Falco peregrinus*)	3
Oldsquaw (*Clangula hyemalis*)	2
Long-tailed Jaeger	1
Intrepid Bay 13 to 19 July	
Birds:	
Black-legged Kittiwake (*Rissa tridactyla*)	7
Glaucous Gull	3
Thayer's Gull	1
Arctic Tern (*Sterna paradisaea*)	1
Common Eider	1
Snow Bunting	1