LONG-TERM POPULATION FLUCTUATIONS AND WINTER FORAGING ECOLOGY OF ARCTIC TUNDRA CARIBOU

BY

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ABSTRACT

Caribou (*Rangifer tarandus*) are affected by density-dependent and -independent processes at various temporal scales. Populations residing on Arctic tundra can be affected by both density-independent climatic events and density-dependent grazing impacts which may accumulate over several decades. Recovery of overgrazed forage can require several decades. Indigenous peoples (*Homo sapiens*) possess knowledge about caribou, dating back generations and covering extensive areas. Researchers and management agencies may benefit from regional summaries of such knowledge of long-term changes in populations of caribou and ecological processes that may cause such changes.

During 1983-94, I developed a method to collect and analyse Inuit knowledge about a caribou population on southern Baffin Island. Based on comparisons with other information, I retained the accuracy and precision inherent in Inuit oral traditions. During 1982-94, I also conducted aerial surveys and satellite telemetry to scientifically examine population changes that were both predicted and observed by Inuit within two winter ranges on Foxe (FP) and Meta Incognita (MIP) peninsulas. In April 1992, I studied the physical condition, forage selection and foraging ecology of caribou in these two winter ranges.

Caribou distributions were extensive, and abundance was high, in most coastal areas from c1900 until the 1920s. Subsequently, caribou distributions contracted, and abundance declined about 9% annually, until the 1940s. From the 1950s until the mid-1980s, distributions expanded and abundance increased about 8%. Increases in caribou abundance followed phases of winter range expansion, range drift and finally range shift. When abundance was low, caribou frequently and unpredictably shifted their winter ranges. Inuit knowledge suggested that population fluctuations of South Baffin caribou may be cyclic, each cycle occurring over the life of an elder.

The population essentially abandoned its main wintering area on FP during the late 1980s, emigrating to MIP. Caribou density on FP dropped from 6.2 in 1984 to $0.3\cdot\mathrm{km}^{-2}$ in 1992. FP caribou began emigrating during winter 1988-89. Caribou density on MIP increased from 0.2 in 1982 to $5.0\cdot\mathrm{km}^{-2}$ in 1992. In April 1992, caribou on MIP were in better physical condition than those on FP. Fecundity and recruitment were lower on FP. However, MIP caribou were in poorer condition than expected.

In April 1992, caribou on FP dug feeding craters in shallower, softer snow. Biomasses of most fruticose lichens were greater within foraging sites on MIP than on FP. *Dryas integrifolia* was the only plant class that had higher biomass on FP than on MIP. *Cladina/Cladonia* spp., *Sphaerophorus fragilis*, and *Cetraria nivalis* were eaten less frequently by FP caribou than by MIP caribou. Proportions of fruticose lichens in caribou rumens on both peninsulas were similar to those on other overgrazed tundra winter ranges. Overgrazing on FP reduced important forage resources on accessible sites, but plant associations were not fundamentally different. Caribou on FP were probably impacted largely by cumulative density-dependent overgrazing. Although grazing had affected forage resources on MIP, physical condition of caribou had not yet deteriorated to the same degree as on FP.

Even with predation and harvesting of caribou, cumulative overgrazing on winter ranges can eventually compromise physical condition and productivity of Arctic tundra caribou. Other synergistic ecological processes may then influence Arctic tundra populations unable to emigrate to better range. Some ecologists may have ignored influences of long-term cumulative overgrazing either because of apparent dominance of short-term processes (e.g., climatic events) or because they lack adequate historical information.

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I first thank my wife, Marian, whose enduring encouragement and patience over the past 18 years has helped me persevere, especially when progress seemed elusive as I pushed many strings. Second, I am grateful to Adam and Matthew who have grown well despite having a father often distracted by less important issues. My family has always provided a safe haven to come home to.

I thank the many Inuit and other northerners who have patiently shared their insights and concepts about the Arctic world. They have shown kind tolerance of my many faux pas, as well as ample faith that I could eventually understand at least portions of their distinctive view of caribou and other Arctic wildlife. Over the years, I have especially appreciated the support provided by the many Directors of the Hunters and Trappers Organizations of Kimmirut, Cape Dorset, Pangnirtung and Iqaluit, the Qikiqtaaluk Wildlife Board, and the Nunavut Wildlife Management Board.

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DEDICATION

This thesis is dedicated to the memory of Simonie Alainga and Johnny Shoo who, along with six other Iqaluit hunters, died at sea during a walrus hunt in late 1994, a tragic reminder of the survival basis underlying Inuit ecological knowledge.

Simonie played a critical role as the first Inuit informant in this study, helping in the development of the methodology, and being an active participant as recently as February 1994. I had many educational exchanges with this expert hunter who also showed the wisdom of an elder.

Although Johnny Shoo was not directly involved in this research, he and other hunters assisted me in several field collections to document the physical condition and diseases of caribou in the Iqaluit area during the mid-1980s. I enjoyed the laughter of Johnny and his colleagues as we shared caribou stew in the warmth of a tent or igloo after those long cold days on the land.

Both first and last, I dedicate this thesis to the memory of my grandfather, Winston Ferguson. He gave me my first inspiration to become involved in wildlife during those too-few adventures with him in the woods of northern New Brunswick. As a full-time hunter, fisherman, trapper and guide, he was an expert on and of the land, like Simonie and Johnny.

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1. GENERAL INTRODUCTION

Elton (1924) suggested that climatic cycles with a periodicity of 3.5 years caused numeric fluctuations and genetic changes in northern animal populations. According to Elton, periodic climate change was the only factor that could synchronize population cycles over wide areas. His hypotheses helped shape subsequent ecological research into proximal factors causing fluctuations in wildlife populations. However, others have suggested that impacts of herbivores on their forage can be the dominant force influencing population cycles. For example, Keith (1974) suggested that density-dependent interactions between snowshoe hares (*Lepus americanus*), their forage and their predators were responsible for the ten-year population cycles of these species. Further, Windberg and Keith (1976) and Keith et al.(1984) suggested that dispersal of snowshoe hares during years of food shortage is sufficient to explain synchrony of population cycles over large areas.

Caribou ecologists must elucidate the roles of density-independent (e.g., climate) and density-dependent (e.g., forage, predators) processes that may cause fluctuations in caribou populations. The difficulty of this task becomes obvious when considering the variety of ecological situations that caribou occupy, and the complexity of each of those situations. Habitats are aggregated spatially into "patches" of varying sizes (Arditi and Decoronga 1988). At a fine spatial scale, frost and snow affect structure of terrestrial micro-habitats used by Arctic herbivores (Sigafoos 1952; Zoltai and Tarnocai 1981; Walker et al. 1993). As spatial scale increases, habitat patches are in turn assembled into larger and larger clusters (Kotliar and Wiens 1990) as they become aggregated by elevation, aspect, ruggedness, marine influences and other factors.

Animals organize their behaviours into temporal aggregations or "bouts" that may last minutes or hours (Slater 1974). These bouts are subsequently assembled into larger temporal clusters, such as circadian rhythms, seasonal migrations and inter-annual emigration. The current distribution of animals has been shaped by the ecological circumstances experienced over past weeks, years, decades, centuries, and millennia.

Scientific ecological data in the Canadian Arctic is limited historically, making it difficult for Arctic ecologists to build and subsequently test models that predict processes occurring over several decades, centuries or millennia. As a result, ecologists face a formidable task in studying the ecology of adaptable Arctic herbivores within the reality of both multiscale spatial structures and multiscale temporal processes. This introductory chapter attempts to synthesize a variety of evolutionary and ecological issues associated with potential impacts of climate on caribou and caribou on their forage. I will describe the ecological rationale that makes long-term research a necessity, and review some hypotheses on the effects of density-dependent and -independent processes on Arctic tundra caribou.

1.1 Winter foraging ecology of Arctic tundra caribou

I identify *Rangifer* that occupy Arctic tundra habitats year-round as "Arctic tundra caribou". In Canada, this ecotype is found on Arctic islands from Coats and Baffin islands in the southeast, north to Ellesmere Island, and west to Banks Island, and on the northeast mainland of Nunavut (Fig. 1.1). These caribou include the subspecies, *R. t. pearyi* and *R. t. groenlandicus* in Canada and Greenland. Arctic tundra caribou also occur on Svalbard (*R. t. platyrhynchus*) and on islands

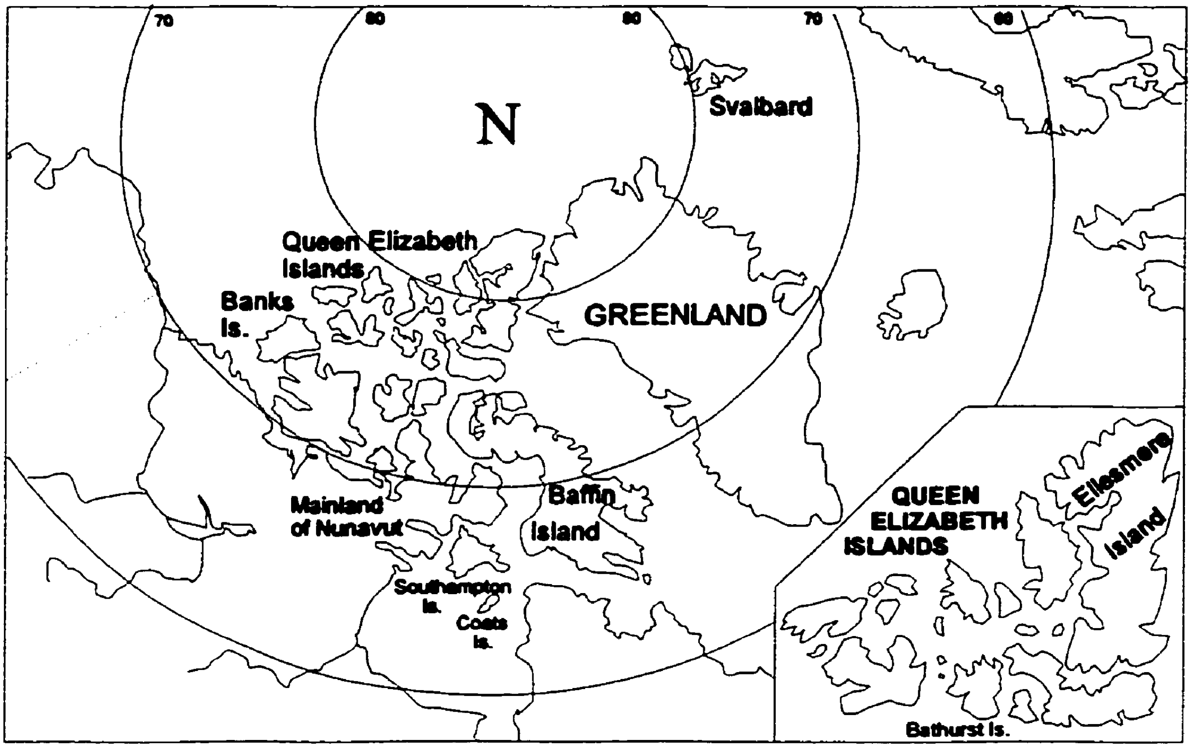

Figure 1.1. Locations inhabited by Arctic tundra caribou in the northern hemisphere.

north of mainland Siberia (*R. t. tarandus*). Although Arctic tundra caribou include several subspecific types, their foraging ecology is similar because they cannot use relatively productive and extensive continental treed habitats during winter. During winter, these caribou feed on vegetation that is exposed by wind that removes snow from ridges, or dig (or crater) through wind-hardened snow cover. At the bottoms of these craters, they find senescent tundra vegetation that is largely of low digestibility, except for lichens. In most winters, forage across a large portion of their annual range is inaccessible, reducing usable winter forage to a fraction of that on their summer range.

Population dynamics of caribou may also be influenced by wolf (*Canis lupus*) or human predation (Bergerud 1988, 1996), summer weather and/or habitat productivity (Crête and Huot 1993; LeHénaff and Luttich 1988; Skoog 1968) and interspecific competition (Vincent and Gunn 1981). However, these data come from populations that live within forests year-round or at least during winter. Predation and interspecific competition could be limiting factors in some circumstances, but the literature does not provide supporting evidence for populations of Arctic tundra caribou. It is unlikely that summer forage could be a major factor because the effective range of Arctic tundra caribou is many times greater during and after snow melt (Skogland 1986), and potential forage increases substantially in quantity, quality and diversity during summer (White 1983). During population crashes of *Rangifer* on St. Matthew Island near Alaska (Klein 1968) and west Greenland (Thing 1984), summer forage suffered little from previously high densities of *Rangifer*, while lichens had been depleted and essentially eliminated from the reindeer's winter diet.

The many spatial and temporal scales that influence the winter foraging ecology of Arctic tundra caribou can be visualized by considering foraging choices of individual animals. At the smallest spatial scale, each caribou can choose between specific parts of plants present at the bottom of each crater dug through the snow. When cratering, the individual makes choices within foraging sites (i.e., 10s of m), and between foraging sites (i.e., 100s-1000s of m), depending partially on snow-cover characteristics (Skogland 1978). The largest spatial scale affecting foraging choices during any given winter begins during the animal's summer-autumn migration. This migration theoretically gives each caribou many choices across all potential wintering terrain within the animal's migratory range, or a radius of up to 600 km for some caribou on southern Baffin Island (Ferguson 1989). Clearly, individual caribou can adapt to the habitats that they encounter at many spatial scales, ranging from 5-10 mm (dependent on bite size and plant architecture) to hundreds of km (dependent on their migratory behaviour, fidelity to seasonal habitats, and physical barriers).

Temporal scales affecting caribou ecology are similarly variable. Caribou are affected by weather events that change the snow pack over periods of hours, days and months, as well as between years. In turn, individual caribou can adapt to such changes with simple choices such as expanding a previously dug crater instead of digging a new one or moving to alternative foraging sites nearby (Thing 1977). Over a longer time scale, each individual caribou is affected by the impacts that previous grazing may have had on forage currently available below the snow (Klein 1968; Thing 1984). Such impacts can last more than 20 years (I. Jåma in Vibe 1967; Klein 1987). In these situations, caribou could adapt to previous grazing through emigration to new or well-rested winter ranges, assuming no physical barriers to dispersal (Leader-Williams 1988).

1.2 Impacts of climate and forage resources on Arctic tundra caribou

Although Miller (1982) recognized that forage is the ultimate limiting factor for caribou populations, he suggested that other mortality factors do not allow caribou to reach densities at which forage would regulate populations on most ranges. According to Miller (1982) and Caughley and Gunn (1993), caribou populations are limited more by access to forage through the snow cover than by a shortage in the absolute food supply or other ecological factors.

Vibe (1967) reviewed available weather records and indices of wildlife populations on Greenland back to the 1700s. His hypothesis was that periods of wet, warm winters are unfavourable for caribou because deep snow and/or icing makes forage unavailable. During such periods, most Greenland caribou populations supposedly declined and in some cases became extinct. However, examination of Vibe's data reveals an inconsistent picture. "After 30 years' increase, the West Greenland (Sisimiut) population of caribou peaked around 1845-50, and from then . . . fell rapidly," and this decline "may to some extent have been caused by overgrazing" (Vibe 1967). Furthermore, the unstable wet winters began around 1865 (Vibe 1967), while the population crash was largely complete by 1860 (Meldgaard 1986). Although the period of wet winters may not have initiated the decline, it probably maintained the population at low densities as Vibe (1967) suggested. Thing (1984) concluded that low lichen biomass on winter ranges due to excessive grazing was the primary cause of the next major decline of West Greenland caribou during the late 1970s.

On the other hand, Miller et al. (1977) found at least short-term (i.e., 1-2 years) evidence supporting Vibe's climate hypothesis during a decline of Peary caribou on the Queen Elizabeth Islands during the early 1970s. After a winter with restrictive snow conditions in 1973-74, Miller et al. (1977) detected a decline of 45% and 69% on the western Queen Elizabeth Islands and adjacent Bathurst Island, respectively. During that winter, malnutrition resulted in high mortality among all age groups, and lower population productivity during the following summer. Unfortunately, Miller et al. (1977) did not provide data on forage resources and snow cover conditions to support conclusions based on general observations.

Between 1961 (Tener 1963) and 1973 (Miller et al., 1977), caribou had declined from 15,300 to 4,200 on the western Queen Elizabeth Islands and from 3,200 to 770 on Bathurst Island. Miller et al.'s (1977) study could not address the causes of these declines which occurred before the severe winter of 1973-74. On the other hand, Inuit reported that caribou were emigrating from Bathurst Island at least during the late 1960s and early 1970s (Freeman 1975).

Miller (1991) suggested that sporadic mass movements are caused entirely by widespread forage unavailability produced by unfavourable snow/ice conditions. Although he suggests that these movements allow Peary caribou maximal use of ranges with the best forage, Miller (1991) did not suggest that such movements are caused primarily by density-dependent forage depletion. Between 1974 (Miller et al. 1977) and 1986-88 (Miller 1987, 1988, 1991), caribou numbers on the western Queen Elizabeth Islands declined by about 1000, while numbers on adjacent Bathurst Island increased by about 800. Because Miller et al. (1977) and Miller (1991) did not provide direct information on snow cover conditions, forage resources and/or inter-island caribou movements during these population changes, I cannot evaluate the roles of these and other ecological factors.

Mass emigrations of caribou are poorly understood, but may be density-dependent (Miller 1982). According to Baffin Inuit, caribou sub-populations periodically emigrate en masse once local winter forage becomes depleted. Some Inuit also suggested that severe snow cover conditions and ground icing will not cause major problems unless there have been too many caribou for too long. Klein (1968) found that on St. Matthew Island where emigration was not possible and after previous high densities of reindeer had depleted their winter forage, almost the entire reindeer population starved to death during a winter of extreme snow accumulation.

Similarly, Skogland (1985) suggested that density-dependent winter forage is the primary factor in regulation of population size among wild *Rangifer* populations on arctic and alpine tundra on Svalbard and in Norway where predators are absent. Further, he suggested that density-independent factors (e.g., snow conditions) play a role only at high population densities. Based on studies of several wild tundra populations, Skogland (1986, 1989) pointed out that the dynamics of a given population also depend on several other factors, including the ratio of winter-to-total range, terrain characteristics within the winter range, and the type of winter diet (i.e., vascular plants or lichen).

Reindeer in Svalbard apparently are limited by snow cover conditions that restrict accessibility to forage in most winters (Reimers 1982). During especially severe winters, Svalbard reindeer do suffer high rates of mortality (Reimers 1982, 1983; Tyler 1987). However, limitation of population growth by climatic factors occurred after Svalbard reindeer eliminated terricolous lichens in historic times and subsequently switched to low quality winter forage (Brattbakk and Rønning 1978 and Ekern and Kildemo 1978 in Reimers 1983).

Lindsay (1973), Kightley and Smith (1976) and Leader-Williams et al. (1981) have reported major impacts of reindeer on the subantarctic island of South Georgia. Lichens and a preferred dwarf shrub were depleted first, while tussock grass, *Poa flabellata*, has become the reindeer's major winter forage and has been affected only at high reindeer densities. However, subantarctic tussock grasslands and other communities have higher productivity compared to similar plant communities in the Arctic (French and Smith 1985). Leader-Williams (1988) suggested that the persistence of reindeer on tundra islands depends on such resilient vascular plants. For island tundra populations, Leader-Williams (1988) viewed climate and emigration as playing secondary roles to forage resources in limiting population growth, and contrasted these with continental populations for which predation may be a dominant or secondary factor to forage.

Caribou on Coats Island have had little opportunity to emigrate in recent years because of year-round open water between Coats and Southampton islands (Gates et al. 1986). Adamczewski et al. (1988) attributed limitation of this population to an interaction between historically depleted forage resources and variable snow-cover conditions. Forty-eight caribou were introduced to adjacent Southampton Island in 1968, and increased to 13,700 by 1991 (Heard and Ouellet 1994). Although some evidence of overgrazing has been detected (Ouellet et al. 1993), Southampton caribou have not yet suffered high winter mortality during years when caribou on Coats Island did (Heard and Ouellet 1994). This led Heard and Ouellet (1994) to suggest that the effect of adverse weather on Arctic tundra caribou is dependent on population density.

As pointed out by Ouellet et al. (1996), it is important to distinguish between the roles of density-dependent processes (e.g., forage depletion) that may dampen population fluctuations of Arctic tundra caribou (i.e., regulatory factors) and the roles of density-independent processes (e.g., climate) that may introduce variability into those fluctuations (i.e., limiting factors). Distinguishing between regulating and limiting factors that may initiate population declines of Arctic tundra caribou is critical for future management. If population declines are initiated primarily by density-independent processes, then populations should be kept at maximum sizes over large areas to ensure long-term persistence. However, if declines are initiated primarily by density-dependent forage depletion, then maintaining populations of Arctic tundra caribou at moderate densities may maintain forage quality and quantity at high levels, and minimize fluctuations due to density-independent processes.

1.3 Research needs

Studies on Coats and Southampton islands, Greenland, Svalbard, Norway and South Georgia support the density-dependent role of winter forage depletion in both short- and long-term population dynamics of Arctic tundra caribou. Additionally, the different dynamics of these populations illustrate the importance of dispersal over large islands or across archipelagos. Future trends of a given population will also depend on the grazing history, snow cover, density and other features of populations in adjacent areas, if emigration is possible.

Jefferies et al. (1994) recommended short- and long-term studies into the interactions between plant communities and northern herbivores. Studies examining spatial scales, from habitat micro-sites to continental expanses, will need to be integrated. These spatial scales must be overlaid with temporal scales extending over the decades necessary for the regrowth of heavily grazed tundra forage.

In the early 1980s, I became aware that high densities of caribou were wintering on Foxe Peninsula on southern Baffin Island. At that time, Inuit hunters reported that the physical condition of these caribou was beginning to decline. As well, they reported that some elders were predicting that caribou would soon abandon the peninsula after wintering there for a few decades. The Inuit had knowledge and concepts relevant to caribou population ecology that dealt with the problems of spatial and temporal scales, issues that caribou ecologists began discussing in the literature later in the 1980s and 1990s. In the mid-1980s, I started to develop methods to document Inuit knowledge about caribou at the landscape and regional spatial scales and at temporal scales ranging from several decades to seasonal migration patterns. Inuit knowledge was then used to strategically plan scientific research during 1982-95 within specific study areas, and to allow interpretation of the results of that research within a broad spatial and temporal context. The scientific studies numerically quantified changes in the dynamics, physical condition and food habits of these Arctic tundra caribou that were observed and predicted by the Inuit. Scientific ecological research was also conducted to examine some predictions of causative hypotheses offered by Inuit elders (i.e., forage depletion), and alternative hypotheses offered by Miller (1982) and Caughley and Gunn (1993).

2. COLLECTION AND ANALYSIS OF TRADITIONAL ECOLOGICAL KNOWLEDGE ABOUT A POPULATION OF ARCTIC TUNDRA CARIBOU

2.1 Introduction

In remote parts of the world, the ecological knowledge of indigenous peoples is often geographically and/or temporally more extensive than scientific knowledge (e.g., Freeman 1993; Johnson 1992; Reid et al. 1992). In this thesis, "traditional ecological knowledge" denotes the insights that indigenous peoples, through their traditional methods, have gained about the interrelationships between animals, plants, and the physical environment. I use "traditional" ("indigenous", "Inuit" or "aboriginal") and "scientific" to indicate how and why the knowledge was acquired. I do not imply any connotation about the intrinsic value of each form of knowledge or the validity of the terminology. Freeman (1985), Feit (1988), Gunn et al. (1988) and Berkes (1993) have discussed distinctive characteristics of indigenous and scientific ecological knowledge.

Aboriginal peoples have requested that their extensive knowledge be incorporated into the management of wildlife populations (Wavey 1993). Major mapping projects (Freeman 1976; Brice-Bennett 1977; Riewe 1992) have emphasized aboriginal land use for land claim negotiations. However, ecologists (e.g., Freeman 1975; Johannes 1980; Nakashima 1993) have only begun to document traditional ecological knowledge for wildlife management purposes. For example, the Beverly-Qamanirjuaq Caribou Management Board has striven toward that goal since its creation in 1982, yet the knowledge and views of aboriginal hunters may not be understood adequately to incorporate them effectively into caribou management (Usher 1993).

One reason for this problem has been limited availability of Inuit knowledge beyond local communities. A methodology is required to compile aboriginal knowledge of long-term regional changes in wildlife populations and the ecological factors that may influence these changes. Such a methodology must preserve the inherent accuracy and precision of observations by individual Inuit informants (Arima 1976; Woodman 1991; Freeman 1993). Understanding Inuit knowledge is dependent on the investigative techniques used to record it, the researcher's assumptions about the cultural basis for that knowledge (Woodman 1991), and the researcher's conscious and unconscious assumptions derived from his or her own culture. Beginning in 1983, I worked with Inuit and others to develop and implement a methodology to compile Inuit knowledge of historical distributions, densities and ecology of caribou on southern Baffin Island. As did Woodman (1991), I assumed that Inuit knowledge was factual. The ultimate goal was to integrate Inuit and scientific knowledge to broaden the historical and ecological context of future caribou management.

The objective of this chapter is to describe a method that could be adapted for other wildlife species and/or geographic regions, allowing the compilation of regional histories of changing wildlife distributions, densities and ecology using indigenous knowledge. Some specific historical examples illustrate that the regional compilation retained the inherent veracity of the oral knowledge of individual informants. I also discuss insights provided by Inuit advisers that proved critical to the collection and interpretation of Inuit ecological knowledge.

2.2 Methods

2.2.1 General development

In describing the methodology and its development, "we" refers to all who participated in the interviews as described below. Initially, we attempted to use a detailed questionnaire to standardize interviews. In 1983, Goo Arlooktoo and I interviewed the late Simonie Alainga in Iqaluit (Fig. 2.1) to test the draft questionnaire. With comments from Goo and Simonie, I made major revisions to the questionnaire in 1984. In 1985, Pauloosie Kilabuk used the revised questionnaire to interview ten elders and hunters in Iqaluit, but this questionnaire also proved impractical. Written questions did not mesh well with the manner in which Inuit informants relayed information, often through detailed accounts of hunting trips. Pauloosie recorded most of the informants' information on plastic overlays over 1:250,000 topographic maps.

Subsequently, the questionnaire was abandoned in favour of a standardized, yet flexible interview protocol. Michel Labine and Martha Jaw tested a preliminary protocol during seven interviews in Cape Dorset in 1985. These interviews were tape-recorded and transcribed into English, and geographic information was recorded on 1:250,000 maps.

After consulting Inuit elders and advisors, a final interview protocol was used during 1990-94 in eight interviews in Pangnirtung and five interviews in Kimmirut. Peter Kilabuk, Amie Nashalik and Jonah Kilabuk of Pangnirtung and Matthew Akavak of Kimmirut participated in these interviews as interpreters. Notes were written during the tape-recorded interviews. Geographic information was recorded on plastic overlays over 1:500,000 maps. All tapes were later translated and transcribed into English.

The 1985 interviews in Iqaluit were not tape-recorded, making many details required by the final protocol unavailable

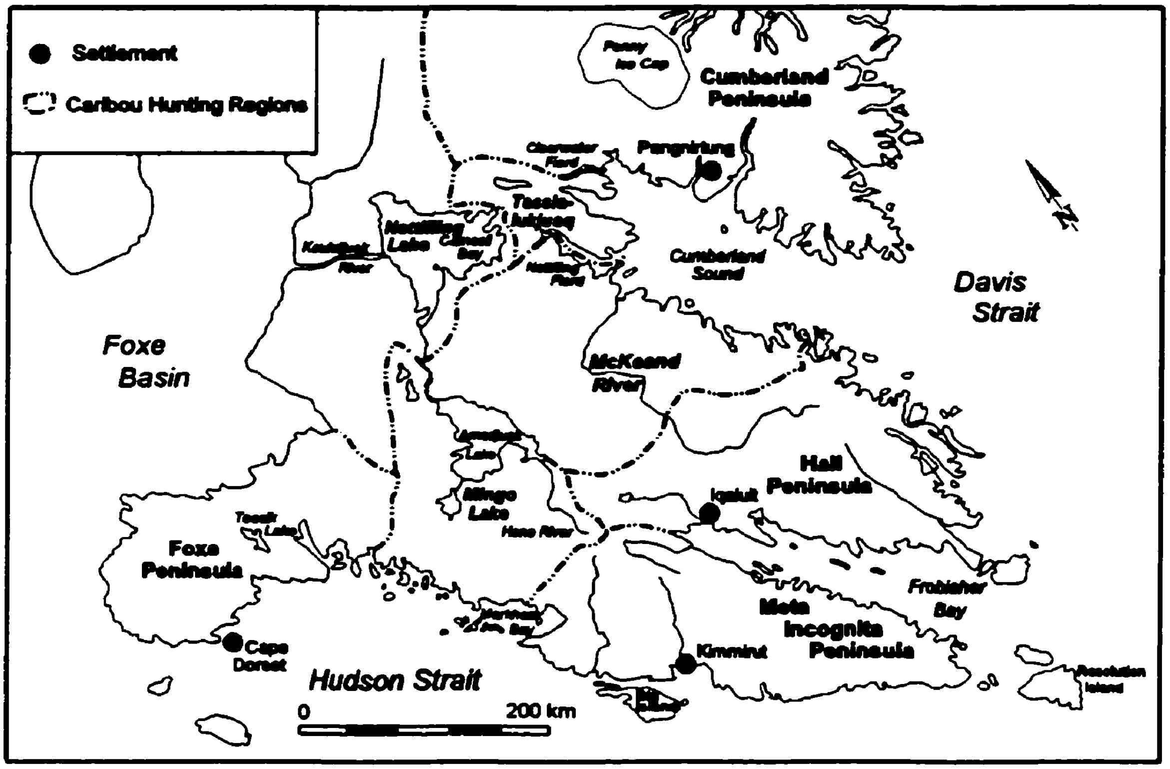

Figure 2.1. Settlements and caribou hunting regions on southern Baffin Island, Nunavut.

for analysis. Therefore, I compiled a series of map overlays showing a preliminary analysis of information provided by Iqaluit informants. In 1994, Aiju Peter and I met with all available informants to obtain missing details, to resolve apparent discrepancies, and to update the information from 1985 to 1994. Six of the original ten and one new informant participated in the meeting. Two had died, another was ill and one could not take time from his job.

To maintain consistency, the transcripts of interviews conducted by Labine and Jaw were analysed based on requirements of the final interview protocol. I briefly interviewed four former or current residents of Cape Dorset by telephone in 1995, to update information from 1985 to 1994. Finally, George Koonoo and Joe Tigullaraq conducted one partial interview in Pond Inlet in 1995.

2.2.2 Community consultation and selection of informants

We interviewed all persons that members of local Hunters and Trappers Organizations (HTOs) and other advisors identified as "local caribou experts", i.e., persons recognized by their peers as knowledgeable about caribou. Besides local experts, we selected additional potential informants who, together, would maximize the geographic and temporal scope of the study. While identifying additional informants, I asked local advisors to avoid selecting persons whose information would largely overlap that of earlier informants because this would have increased costs. Nevertheless, enough overlap was obtained to evaluate concurrence among informants' observations. Elders and older active hunters were selected over younger hunters because they had firsthand knowledge covering longer periods, and the HTOs wanted to record the elders' knowledge before they died. Women were not explicitly excluded from the study. However, HTOs or other advisors did not recommend any women for interviews because most women did not usually accompany men on the hunt.

Other criteria determined whether individuals participated. These included: their willingness to participate, their availability while the interviewer was in the community, and the likely reliability of their information as suggested by local advisors. Only one potential informant refused to participate, apparently because of his concerns about confidentiality. On the other hand, two persons, whose participation was not solicited, asked to be interviewed (and were).

In 1994, L. Siddon of the Science Institute of the Northwest Territories recommended that we ask all future informants to review and sign a consent form before conducting full interviews. The consent form (Appendix A) described the study's objectives and methods. It allowed each informant to specify where raw data must be deposited, who must approve other uses of the data, and if the informant had to be acknowledged for his contribution. All informants specified similar conditions, and included the following: tapes, maps and transcripts from each interview must be deposited at a local resource centre (i.e., not in government or university archives), permission for further use should be obtained from the informant or his named heir (i.e., not a local committee), and his contribution must be acknowledged. The tapes and transcripts contain many personal details of each informant's life which caused some concern about future unauthorized use of the raw data. At the outset, I agreed that each informant personally owns the information that he provided to us for the explicit purpose of developing a collective description of caribou distributions and ecological factors on southern Baffin Island.

2.2.3 Interview preparation, duration and decorum

The interview team usually included an interviewer and an interpreter. Each interpreter was trained for 1-3 h, depending on his/her experience, to explain the goals and rationale, the interview process and his/her role. An ideal interpreter could effectively express literal meanings and nuances of questions and answers, advise the interviewer on cultural sensitivities, and contribute scientific and Inuit technical terminology, including place names. As pointed out by Johnson and Ruttan (1992), indigenous peoples have many technical terms that cannot be readily translated into English. In this study, the interview team accepted the onus to understand terminology used by the informants. We avoided using technical scientific terminology. For example, instead of asking about "the density of caribou", the interviewer asked the informant to describe how many caribou he saw in a specific area relative to other periods or places and to his family's needs.

Interviews, including coffee breaks, lasted two to seven hours. Interviews lasting more than three hours were broken into two or more parts, separated by at least a one-hour break. The duration of each interview depended on the clarity and detail of information that the informant willingly provided, the ability of the interview team to understand the information, the map reading skills of the informant, and the endurance and time commitments of the informant and interview team. Interviews occurred in closed meeting rooms to reduce interruptions and background noise.

Many informants provided information by recalling a factual event (or story) that best addressed each question, as opposed to making generalizations from several observations. The interviewer accepted the position of a student who, in Inuktitut, must listen to the elder's complete story that contains the important points to be learned. Effective interpreters did not allow the interviewer to interrupt whenever the informant paused, if he sensed that the informant was not yet finished. Although Inuit generally do not question elders and hunters about their information (Nelson 1969), the interviewer discretely tried to obtain any details that he did not understand or the informant omitted. Some questions pertained to how frequently an informant may have undertaken similar hunts and how the distributions and densities of caribou differed from the one that the informant described in detail. Usually, the informant either gave a concise summary of the variations, or recounted several similar hunting trips, emphasizing the differences in caribou observations. If the interview team detected resistance by the informant to a particular line of questioning, it was abandoned. Consequently, some information was not obtained during some interviews. I suspect that informants probably found the interviews somewhat rigorous, but when asked to return for subsequent sessions, they willingly did so.

From 1983-93, most informants were given gifts in appreciation for their contributions. Most elders stated that they did not expect payment. However, some HTOs questioned why the informant (or teacher) was not paid, and in 1994, we paid each informant at an hourly rate if his interview lasted at least one hour.

2.2.4 The final interview: Biographies and time-lines

To begin, the interview team explained the objectives, procedures and products of the study. The informant read the consent form, requested clarification if needed, and then completed and signed the form in either Inuktitut or English.

Then, to develop a biographical map and time-line, we asked the informant to indicate where and when he was born. His birth place was marked as location one (1) on clear plastic over a 1:500,000 map. If the informant expressed doubt about his officially recorded birth date, the informant's best estimate of his birth year was used. The informant was then asked sequentially to show the base camps or settlements where he lived during his life and when he moved there (i.e., location 2, 3 . . .).

Reliable determination of the years that an informant moved was difficult because many Inuit on Baffin Island did not have calendars until the 1970s. To establish a time-line, we determined one or more memorable events that roughly coincided with each move, and that could be dated through published or archival records (i.e., dateable events). If the informant remained in one location for more than seven years, we asked him to recall additional dateable events to obtain a minimum precision of ±3 years (arbitrarily chosen as an acceptable limit).

For an informant's childhood, calendar years were often estimated based on his year of birth and recollections of his maturity and activities. Some elders remembered seeing or hunting caribou while: being carried by their mothers on summer hunting trips (i.e., usually 2-5 years old), walking on long summer trips but remaining with their mothers while hunters went to find caribou (i.e., 4-7 years old), following their fathers on summer hunts and learning to hold a rifle (i.e., 6-9 years old), going with their fathers on winter hunts and learning to clean and gut caribou (i.e., 8-13 years old), being a teenager and starting to hunt with persons other that his parents (i.e., 12-19 years old), and getting a dog team and becoming an independent hunter (i.e., 15-25 years old). These approximations were refined for each informant using additional information about his family's circumstances (e.g., the presence, health and age of his parents (Hantzsch 1977)), and dateable events that occurred during his youth.

Recollections of events that affected the informant personally (e.g., death of a family member) were most reliable. With permission from the informant, I examined death, birth and marriage records to help establish dates of these events. Death records were usually accurate, if found. Sometimes, I could estimate when an informants' grandparent or parent was born from the parent's age on their death certificate. Before 1940, many births were not recorded for several years, making some records unreliable. Marriage records also could be inaccurate because Inuit often had traditional marriages years before having it recorded. Other methods were used to cross-reference date estimates along each time-line. By recalling and counting each summer (or winter) that they lived at a certain location, informants could usually estimate how many years that they hunted in certain areas (i.e., if less than 8-10 years). Several informants could reliably remember specific years for important events in their lives. One informant provided information from a short personal diary of events dating back more than 30 years. All of his records agreed with the official records.

Other cross-references were memorable historic events that occurred during an informant's life. Examples included: overland expeditions by Dewey Soper (Kiameatie, in Inuktitut) and Tom Manning (Kupanuak); opening of Hudson's Bay Company (HBC) posts, Royal Canadian Mounted Police (RCMP) detachments, the Pangnirtung hospital and the Distance Early Warning system; importation of reindeer by the Hudson Bay's Reindeer Company; beginning and ending of World War II; caribou bag limits imposed on the Inuit by the RCMP; an epizootic that killed most sled dogs in Cumberland Sound (Fig. 2.1); and ear-tagging of caribou on the Koukdjuak River and eastern Nettilling Lake. Such historic events were used mainly to verify and/or resolve conflicts in time-lines established from other information.

2.2.5 The final interview: Historical caribou distributions, movements, and ecology

To start the second part of the interview, we explained that we wanted information about the informant's own observations of caribou or those of their parents. We asked him to tell us whenever he provided secondhand information from other hunters. Secondhand information was often vague both spatially and temporally, and thus potentially misleading.

Next, the informant was asked to recall his first memory about caribou (e.g., the first time they ate caribou meat or that they saw caribou) and show where he lived then. All informants could recall details about the first caribou that they killed. After those initial memories, the informant was asked to recall his observations of caribou for each place that he lived in sequential order. If the informant lived at a location for many years, he was asked to describe caribou distributions for each period between dateable events along his time-line.

On the map, the informant outlined each area where caribou were seen and each area where none were seen. For each area, we attempted to obtain information on: where, when (i.e., month or season), and how many caribou or tracks were seen, what sex/age the caribou were, and what direction the caribou travelled. We sequentially numbered each area, while the numbers, Inuktitut names and descriptive information were tape-recorded. Because the interviewer could not learn the Inuktitut names for all locations across southern Baffin Island, he relied mainly on the mapped numbers. Inuktitut place names can be informative about the use of an area by caribou and other wildlife (G. Williams pers. comm.). The interviewer learned such names whenever their significance became apparent.

Informants could readily describe caribou densities based on seasonal and interannual changes in relative abundance, differences in abundance between each informant's hunting areas, and the informants' needs. When caribou were rare, many informants could recall details of individual hunting trips that occurred up to 60 years previously. However, when caribou were more abundant than their needs, their recall usually became more generalized when describing caribou abundance. Most informants mapped the routes that they travelled and the areas that they searched in order to illustrate typical distributions of caribou between dateable events.

In the final part of the interview, informants were asked to discuss ecological factors that might cause either short- or long-term changes in the caribou populations. This part of the interview was less structured. Our aim was to let the informant select factors that he viewed as important.

2.2.6 Data analysis and presentation

Each tape was translated and transcribed into English by an experienced interpreter who was usually not the interpreter who participated in a particular interview. This maximized the likelihood of detecting alternative interpretations, or nuances, in the Inuktitut portion of the interviews. Translators with knowledge of local dialects and place names were selected, if possible. I scrutinized translated transcripts for inappropriate wording of questions and eliminated affected answers (see examples in Discussion). As well, I examined the wording of answers to determine the certainty of the informant's reply.

The caribou observations of each informant were summarized chronologically and plotted on clear plastic over a 1:500,000 map for each decade, producing a time series of overlays. The written summaries and overlays for all informants were merged; from which, the collective knowledge of Inuit informants about long-term changes in caribou distribution and density was compiled (Chapter 3).

Occasionally, we could not meet the minimum precision of ±3 years, usually due to inadequate interviewing rather than the inadequacy of an informant's memory. If precise timing was not crucial to the relevance of the informant's knowledge (e.g., typical seasonal migration patterns), such information was used. Otherwise, temporally imprecise information was ignored.

The reliability of each informant's observations was ranked based on the source of each observation as follows: (1) "personal" information or firsthand observations by the informant; (2) "parental" information or secondhand knowledge from parents, grandparents or other family members who assumed responsibility for training the informant as a youth (Laughlin 1968); (3) "secondhand" information from other hunters; and (4) "speculative" information or unconfirmed extrapolations from observations. Parental information was accepted as reliable because of the survival importance that it had for the parent's offspring. This importance was evident in the greater detail of parental information provided by informants, as compared with secondhand information from other hunters. Secondhand information from other hunters was used only if it was at least partially corroborated by personal or parental knowledge.

Speculative information was considered least reliable. This type of information commonly arose after animal densities decreased in a given area. When animal numbers apparently increased in another area soon after declining in the former area, informants sometimes speculated that the animals moved between the two areas. However, the trends in each local population may have been independent (e.g., animals may have immigrated from and/or emigrated to a third unknown area). This could be true for both seasonal migrations and long-term population changes. Speculative information about caribou abundance and distribution was not used, but speculation about ecological factors that might cause population change was.

Inuit recognize six ecological seasons based on changes in sea and terrestrial snow and ice conditions, and daylight period (e.g., Brody 1976, Map 45). The timing of these seasons within southern Baffin Island varies with differences in sea ice (e.g., proximity of the floe edge) and/or terrain conditions (e.g., elevation and aspect). Inuit informants usually described seasonal movements of caribou for their own seasons, which were then translated into appropriate months of the year based on the usual timing of a season near each settlement. This translation was somewhat artificial because a given ecological season may occur in certain months in most years, but then may have occurred in different months in the year(s) for which the informant was describing seasonal caribou distributions.

2.3 Results

Arima (1976) found a high degree of concurrence between published recollections of Inuit informants and written records from other sources. Inuit do not need written evidence to confirm the veracity of their oral knowledge and traditions, and we do not question this inherent veracity. Nevertheless, I needed to assess whether or not I unintentionally introduced inaccuracies while establishing time-lines for individual informants, and then accumulated possible inaccuracies while compiling information for all informants. I examined concurrence between the time-lines and other data of different informants (e.g., when the parental knowledge of one informant overlapped the personal observations of older informants). I found no contradictory evidence in any such comparisons, although parental knowledge was usually somewhat vague compared with personal observations (e.g., references to Amadjuak Lake as a whole as opposed to the northeastern shore of the lake). Many comparisons involved the personal observations of two or more informants hunting caribou in the same or adjacent areas at the same time. Although I examined all such cases, no clear examples of contradictory evidence could be found.

The precision, accuracy and detail of Inuit recollections also agreed with written archival records. For example, Paulassie Pootoogook (pers. comm.) stated unequivocally that in 1944 he received a large supply of caribou skins and meat from his brother and brother-in-law living at Nettilling Lake. In the May 1944 diary summary for the HBC post in Cape Dorset (HBC 1944), the post manager remarked that two members of the Pootoogook family had been at Nettilling Lake for a full year and returned on 18 May 1944 with a supply of caribou skins and meat for the next year. I did not detect any cases in which an informant incorrectly stated a year or other fact without himself assigning some equivocation in his statement.

Overlapping information among informants for 1945-58 initially suggested that the methods may have produced some gaps and discrepancies, but historical information verified that none existed. In the following case description, years stated directly by informants are worded to reflect any uncertainty stated by the informants. Years obtained from time-lines are shown in brackets, [], some with examples of dateable events used to establish those time-lines.

- No Cape Dorset informants reported hunting near Nettilling Lake [during 1946-50], although caribou were not found closer to the coast of Hudson Strait [until the 1950s] (Chapter 3). During 1946-48, hunters from Cape Dorset who lived at Nettilling Lake began travelling to Pangnirtung to trade (J. Mike pers. comm.). This suggested a temporal gap in information obtained from Cape Dorset informants.
- During a "ban" on caribou hunting [in the late 1940s], Pauloosie Angmarlik (pers. comm.) was asked by the HBC to change his fox trapping area from Nettilling Lake to southeastern Cumberland Peninsula for two years. Jamesie Mike suggested that the "ban" started sometime during 1943-45. Jamesie and other hunters moved with Pauloosie to Cumberland Peninsula where they lived during 1946-48.
- Jaco Evic (pers. comm.) reported that during 1945-50, Inuit in Cumberland Sound were told by the RCMP to stop harvesting caribou during winter, and to take no more than five caribou during summer. Several informants in Pangnirtung heard of these "regulations", but understood several versions of them. Only one "Cape Dorset" family, originally from Pond Inlet, lived at Nettilling Lake during this five-year "ban", and the RCMP told that family to leave Nettilling Lake because they were no longer allowed to hunt caribou in winter (J. Evic pers. comm.).

- John Tongak (pers. comm.) moved with his parents and grandparents from Pond Inlet, to Igloolik, to Cape Dorset, and finally to Nettilling Lake [during the 1940s]. His first dateable recollection while living in Nettilling Lake was learning about the sinking of the RMS Nascopie near Cape Dorset [in 1947 (Appleton 1968)]. John's father and grandfather initially travelled to Cape Dorset to trade. Later, a Pangnirtung elder, Aksayuk, guided them to Pangnirtung, where John's father and grandfather subsequently traded. More than a year later, John's family moved to Cumberland Sound until his grandfather returned to Pond Inlet in 1951 on the medical ship, CCGS C.D. Howe [which was launched in 1950 (Appleton 1968)], and his father's family returned in 1952.
- Lucassie Nutaraluk (pers. comm.) moved from Cape Dorset to Iqaluit in 1951, where the RCMP told him that he could take only two caribou each year. Harry Kilabuk (pers. comm.) reported that for about four years beginning around 1950, he was allowed to harvest five caribou in winter and any number in summer.
- Sandy Akavak (pers. comm.) reported that the RCMP first limited caribou hunting by Kimmirut Inuit in 1953 or 1954 when caribou first returned to Meta Incognita Peninsula (Fig. 2.1). A married hunter could take five caribou annually, while a single Inuk could take only one (S. Akavak pers. comm.). The law was implemented for four to five years near Kimmirut [i.e., until 1957-59].

To resolve the apparent information gaps and timing discrepancies, I first examined the federal Northwest Game Act and Regulations which did not limit caribou harvesting by Inuit during the 1940s. The Northwest Game Act was repealed in April 1949 and replaced by the Northwest Territories (NWT) Game Ordinance. In September 1949, Section 33 of the Ordinance was amended to permit hunting of caribou on Baffin and Bylot islands only during August 1 - September 15, up to a limit specified on each hunter's license. In June 1953, the Ordinance was revised and section 25 specified that a hunter with a family could take five caribou and single hunters could take only one caribou during the summer season. These limitations were removed via Section 3(2) in June 1955, and then reenacted from January 1957 to January 1958 through amendments to Sections 3(2), 3(3) and 25. This legislative history suggested that the accounts of L. Nutaraluk, H. Kilabuk, and S. Akavak in Iqaluit and Kimmirut in the 1950s were correct, but that the timing of those of J. Evic, J. Mike, J. Tongak and P. Angmarlik near Pangnirtung [during the late 1940s] were off by five years.

All of the apparent gaps and discrepancies were resolved through a March 1947 letter from R.A. Gibson, Deputy Commissioner of the NWT to R.H. Chesshire of the HBC regarding government concerns about depletion of caribou numbers on southern Baffin Island (HBC 1947). That letter stated the following:

- In summer 1945, 17 families from Cape Dorset lived year-round near Nettilling Lake. During 1945, the HBC and Baffin Trading Company in Cape Dorset agreed not to outfit Inuit to trap foxes near Nettilling Lake. By summer 1946, 15 of the 17 families had returned to Cape Dorset.
- In autumn 1946, the RCMP in Pangnirtung reported that the remaining two families originally from "Igloolik" visited Pangnirtung and "promised . . . (to) return to Igloolik before spring (1947)."
- Gibson asked Chesshire to again "instruct" HBC Post Managers at Cape Dorset and Pangnirtung to "discourage . . . (the Inuit) in the excessive taking of caribou."

Gibson's letter confirmed that the selection of Cape Dorset informants did not accidentally create the only information gap identified in the study's temporal coverage. The letter also corroborates information provided by Inuit almost 50 years later; including active government-directed discouragement of caribou harvesting by Cape Dorset and Pangnirtung Inuit before legislation was set up in 1949. Combined with probable linguistic misinterpretations, the lack of specific regulations in the 1940s, RCMP discretion in specifying harvest limits on individual licences during 1949-53, and the on-and-off effect of amendments during 1955-58 probably account for the variety of restrictions understood by individual hunters. The HBC Post Managers in Cape Dorset and Pangnirtung effectively met the goals outlined by Gibson. After committing to a "ban" of five years near Pangnirtung (J. Evic pers. comm.), the RCMP apparently used considerable discretion in where and when they applied the legislated regulations during the 1950s. The RCMP apparently had little success limiting the harvest of caribou along Hudson Strait at least during 1952 and 1953 (Scott 1953-54).

2.4 Discussion

This methodology had several similarities with that of Freeman (1976) and others who used map biographies to document aboriginal land use. Although precise time-lines might be generated from the raw data (P. Usher pers. comm.), Freeman (1976) did not present the results with sufficient precision to allow wildlife managers to identify population changes that may have been ecologically important. Additionally, much of the questioning in interviews focussed on differentiating between areas with target animals (i.e., specific sex/age categories), areas with animals at densities too low for efficient hunting, areas with non-target animals, and areas without animals (e.g., travel routes). Given that Freeman (1976) focussed on land use (i.e., areas that Inuit used for any purpose) that data probably did not attain the detail sought in this study.

2.4.1 Factors which influenced the results

The firsthand and parental knowledge of any given number of informants is unlikely to represent a complete picture of all indigenous knowledge about historical changes within any wildlife population. In this study, each informant provided new insights, suggesting that I had not exhausted all potential information that might have been available from Inuit in Pangnirtung, Iqaluit, Kimmirut and Cape Dorset. Logistical constraints inevitably limit the number of settlements and informants that can be included in any study. As a result, local consultation is critical in identifying potential informants with the most extensive and reliable knowledge, and researchers must balance the conflicts between thoroughness, accuracy, precision and costs.

Other factors may have created some response bias during each interview, including: reluctance of informants to reveal proprietary or sensitive knowledge, withholding of information that the informant assumes is known or obvious to the interview team, lack of recall of specific facts during the interview, intentional deference to other informants who may be seen as more knowledgeable, inadequate or inappropriate questioning by the interview team, and/or inadequate comprehension by the interview team of information that was provided. Most of these factors were reduced by briefing the interpreters and informants before and during the interviews. The potential effects of these factors depend largely on the trust and patience of the interview team and each informant. Discussion of the consent form allowed the interview team to familiarize themselves with the concerns of each informant and take steps not to inflame his sensitivities.

The informant may filter some information if he or she perceives the interviewer as an expert who might either disbelieve or misuse the information. Relating similar examples of information from informants in other settlements or through scientific research helped lower such barriers. Barker and Cross (1992) also used this technique in Africa. The researcher must be convinced of the authenticity of each example, and of aboriginal knowledge overall, or informants may detect the researcher's skepticism and/or misunderstanding in the retelling of Inuit knowledge. As well, the interviewer must not draw on closely overlapping examples because the informant may be led to provide only corroborating evidence that he or she thinks the interviewer wants to hear. Several informants were reluctant to provide information for which other informants were viewed as having more expertise. These informants often provided their information after they were given examples of how similar information from several informants refined spatial and temporal details, as in the case described in the Results.

Johannes (1993) suggested that the reliability of an informant's evidence can be determined by asking a series of plausible questions for which the informant could not know the answer. I discourage any attempt to employ such a tactic with Inuit informants. The greatest potential for incorrect conclusions occurred when the interviewer asked leading questions, like "Did caribou migrate from Foxe Peninsula to Nettilling Lake in spring 1925?" For many Inuit, questioning other persons about their facts is impolite (J. Tigullaraq pers. comm.). When we inadvertently asked such leading questions, the Inuit informants usually responded affirmatively, but sometimes without any personal knowledge, assuming that the interviewer had a sound basis for the question. To disagree openly, an Inuk may need to have personal knowledge to the contrary and consider that stating that disagreement is sufficiently important. Perhaps more important, once any informant suspects that the interviewer intentionally employs Johannes' (1993) tactic, the interviewer risks losing credibility with all informants.

The long seasonal migrations of Baffin Island caribou (i.e., up to 240 km), as depicted by Brody (1976, Map 46), suggests that Freeman (1976) accepted speculative information. During the 1985 interviews in Cape Dorset, the interviewer extracted agreement from several informants about similar long-distance migrations, using leading questions. However, no informant suggested that he had followed caribou throughout their migrations. When leading questions were avoided, the precision of the informants' knowledge became readily apparent. Informants usually described seasonal migrations only within their immediate hunting areas by placing small arrows in specific locations on maps, and in some cases by refusing to suggest any migration. For example, Etuangat Aksayuk (pers. comm.) indicated that he saw caribou along the north and south shores of Koukdjuak River in summer during c1916-23. However, he stated that he did not know if they migrated across the river because he never saw them crossing the river. Most informants displayed similarly disciplined memories of empirical facts.

After the interviewer initially explained the importance of personal and parental information over secondhand and speculative information, informants usually prefaced secondhand or speculative information with phrases such as "I have not seen it myself, but . . . " Although secondhand and speculative information may be correct, extensive reliance on it could lead to wrong conclusions that could leave the incorrect impression that Inuit knowledge is not dependable. Local indigenous experts are as concerned about correct facts as any scientific researcher (Johannes 1993).

Different types of Inuit hunters (e.g., seal and caribou hunters) differ in the extent and types of knowledge that they can provide (P. Kilabuk pers. comm.). As well, different hunters have differing levels of demand for different species, and consequently expend differing amounts of effort to harvest each species (P. Kilabuk pers. comm.). Seal hunters usually harvest caribou opportunistically along the coast, rather than undertaking extensive trips inland to areas with higher caribou densities. Although seal hunters usually had fragmentary information about caribou, their knowledge rarely duplicated that of caribou hunters. For example, seal hunters were often the first to detect the return of caribou to coastal areas after years of absence.

The differing characteristics of seal and caribou hunters were incorporated into the strategy of data collection and analysis. Most hunters born before 1930 on southern Baffin Island were caribou hunters, while those born during the late 1930s and 1940s were predominately seal hunters, probably due to low densities of caribou during the latter period (Chapter 3). When initiating interviews in a new area, interviews with younger hunters were intentionally scheduled before older hunters, if possible. When an older caribou expert was interviewed first, the interviewer sometimes became confused by extensive detailed information. Sensing a lack of full comprehension, some informants appeared to withhold some details to make their interviews more efficient. On the other hand, by initially interviewing younger seal hunters, the interviewer built a background that enabled him to adequately comprehend details provided by local caribou experts.

Caribou hunters who witnessed gradual changes among caribou over several decades sometimes had difficulty recalling when and where specific population changes occurred. Sometimes this can be overcome by having the informant recall details of specific hunting trips (i.e., once every 4-6 years, if possible). As well, other hunters who infrequently hunted the same area more precisely indicated the timing of major changes in caribou density and distribution because their observations were separated by longer periods. This became most evident after 1960 when several informants temporarily left their traditional homes to take jobs for five to ten years in other settlements. When each returned to hunt caribou in his traditional area, he could define specific temporal and spatial changes in caribou distribution. If he had hunted extensively near his temporary home, he could provide specific information about that area too. Therefore, the observations of transient and part-time hunters should not be ignored.

2.4.2 Resolving apparent discrepancies

Seal and part-time hunters had less demand for caribou than did caribou hunters, and the demands of individual hunters changed depending on the size of their extended families, availability of store goods and other factors. Consequently, comparative descriptions of caribou abundance in different areas and periods were important in resolving apparent discrepancies relative to the needs of different hunters.

Attention was also given to the year, season and sex/age of the caribou observed. Two different informants (or one informant at different points in the interview) may apparently contradict each other (or himself) for a given area, but they may be discussing different distributions among seasons, years and/or sex/age groups (L. Nutaraluk pers. com.). Generally, informants were patient, allowing many questions to clarify such potentially confusing details.

Inevitably, apparent discrepancies arose in spatial and temporal changes in caribou distribution based on the observations of different informants. For example, some informants provided valuable information for their traditional hunting areas in some years, but not in other years. In some years, circumstances (e.g., employment, health problems) may reduce the hunting opportunities that an informant may have had, causing the informant's geographic coverage to shrink. Superficially, his observations may suggest a reduction in the spatial distribution of caribou, in apparent contradiction with the observations of other informants. Informants' biographies and time-lines were critical in determining which informants had adequate opportunities to observe changes during specific years in specific areas (i.e., primary informants). If circumstances changed for one primary informant, we sought additional informants who could fill the apparent gaps.

Informants' wording of their observations also allowed assessment of the relative weight to give to observations of each informant. On occasion, an interpreter suggested that the informant was certain of a specific point, but examination of the translated transcript revealed some uncertainty (and vice versa). In some situations, informants suggested that the observations of another informant should be trusted more than their own, or recommended additional persons who could provide greater detail. Although useful and valid, this was not always possible logistically. With few exceptions, Inuit informants tended to understate, rather than overstate, confidence in their knowledge.

The personal knowledge of some informants may also appear to conflict with that of other informants because of preferences for traditional hunting areas. In the early 1900s, several families from Cumberland Sound hunted female and immature caribou west of Nettilling Lake during summer and autumn (E. Aksayuk and P. Angmarlik pers. comm.), although caribou were available in several other areas (Chapter 3). Similarly, J. Evic (pers. comm.), Simeonie Keenainak (pers. comm.) and their families hunted in southern Nettilling Lake during autumn in the 1980s, while most other informants got caribou near the coast of Cumberland Sound. Secondhand knowledge helped determine whether an informant was implying that caribou were not present outside his preferred hunting area. However, the researcher should not depend on secondhand information to delineate specific areas where caribou occurred because of the inherent vagueness of such information.

Usher and Wenzel (1987) reported that subsistence hunters can recall precise quantities of their harvest when harvesting is rare or done under special circumstances. When harvesting at higher rates, they found that hunters recall whether they obtained enough. In this study, several informants provided precise estimates of total numbers seen and harvested by themselves and/or members of their hunting party, especially when numbers were insufficient to meet their needs. Most of these informants had worked for non-Inuit employers and developed some understanding of numerical quantification. Several individuals could state numerical rates (e.g., number of caribou harvested per hunter) and interpret such numerical concepts in terms understandable to other hunters who had limited numerical abilities. In the analysis, these informants were used as primary sources to assign indices of relative densities for specific areas during specific years. Nevertheless, all informants could express caribou densities in terms compared with other geographic areas, other periods and their own needs.

By accurately and precisely placing these estimates of relative densities along seasonal and yearly time-lines, almost all potential discrepancies in density estimates were resolved. An example of a remaining conflict arose in northeastern Cumberland Sound during the 1940s. Most informants reported that they had to take all the caribou that they could. Only one informant reported that he was always selective in his harvesting and never had to take all that he saw. This and similar responses by this informant were typical of a hunter who was satisfied with fewer caribou than most caribou hunters. When resolving such apparent conflicts, I accepted the views of older informants who could express relative densities over broad temporal and spatial backgrounds and who were identified as the primary caribou hunters in the area.

2.4.3 Potential improvements in the methodology

After breaks during interviews, informants often provided clarification of answers to previously asked questions once the interview reconvened. During a break, an informant may recall new relevant information, or may think of alternative ways to present his information to the interview team. After each interview, I usually reviewed the time-line data and subsequently discussed any confusing information with the informant, if necessary. I recommend strategic breaks to separate the three main parts of each interview: the informant's biography and time-line, historical changes in the wildlife population, and ecological factors influencing those changes. P. Usher (pers. comm.) recommends that follow-up interviews should be planned a day or two later.

The first stage of the interview, the mapped biography and recollection of dateable events, could be followed by a break so that the interview team could consult written archival information to establish the informant's time-lime. In the second stage of the interview, the interview team could review the informant's time-line with him and correct or improve it, if necessary. Then, the interview could continue with the recording of the informant's knowledge about wildlife distributions and relative densities. The time-line could be used during the remainder of the interview (and the informant could keep a copy for his records).

Before the last stage of the interview, the interview team should review the information obtained during the second stage to identify important information that may have been missed or misunderstood. During the third stage, the interview team could clarify such information with the informant, and then collect information about ecological factors that may have caused changes in animal distribution and density. At the end of the interview, the researcher could ask whether the informant hunted caribou as much or less than most hunters in his settlement, and when and why that status changed during his life.

A checklist of subject areas could guide the interview team (Johnson and Ruttan 1992) and reduce errors of omission. Inuit often organize their oral knowledge with a complex chronological flow (i.e., not necessarily sequential; R.G.

Williamson pers. comm.). Inuit informants apparently found it natural to recall their observations of a wildlife species from their childhood through to the present. Use of any checklist should not restrict the flow that an informant wishes to follow. Questionnaires lacked sufficient flexibility to be useful tools in these interviews.

Some studies of traditional ecological knowledge have collected information during meetings of groups of informants (Johnson 1992). The meeting of informants held in Iqaluit in 1994 successfully met its limited objectives (see "Methods: General development" above). However, such group interviews can be confusing (Johnson and Ruttan 1992). At the Iqaluit meeting, some informants, especially seal hunters, did not participate as fully as others. Individual interviews are probably preferable in most situations to reduce confusion felt by the interview team (Johnson and Ruttan 1992), and so that each informant can fully participate in the study. Nevertheless, the findings of such studies should be presented at local meetings of informants and other hunters to learn if the results are supported by a consensus.

Another consideration is the location and atmosphere of the interview. I opted for private interview rooms to maximize the efficiency of the interviews and enable audible tape recording. However, informants may be most comfortable being interviewed in their own home. In such a setting, the informant could consult other family members about the timing of events and the exact locations of caribou seen. As a compromise, a preliminary meeting in the informant's home could be held 12-48 h in advance to discuss the consent form and the interview protocol, after which the informant could discuss the subjects of the interview with family and friends (R.G. Williamson pers. comm.).

The appropriate gender of informants should be discussed directly with local advisers (e.g., HTOs). This study may have missed the oldest available data because in some settlements women are the oldest Inuit. Although women did not hunt extensively, they have direct observations, and extensive spousal and parental knowledge (R.G. Williamson and G. Williams pers. comm.), and may be more likely to recall quantities of animals retrieved by hunters (Usher and Wenzel 1987). From their traditional roles in butchering and preparing carcasses, women also know wildlife anatomy, food habits, physical condition and diseases, knowledge that may be pertinent to ecological factors affecting wildlife populations.

The appropriate age and gender of interviewers and interpreters also should be discussed locally. Young and/or female interviewers may be slow to gain credibility with informants in some cultures and areas of study (Barker and Cross 1992; Johnson and Ruttan 1992). On the other hand, older and/or male interviewers sometimes seemed reluctant to ask about knowledge that they should already have, and may have had difficulty maintaining objectivity about specific information.

Johnson and Ruttan (1992) pointed out that four months of training during a 18-month study was inadequate to train local interviewers with little experience. On the other hand, outside researchers could have misinterpreted indigenous knowledge without extensive cultural training by local people (Johnson and Ruttan 1992). A team with a local interpreter and an outside researcher can provide both the local, cultural knowledge and the objectivity needed to enable successful interviews.

2.4.4 Future directions

Indigenous peoples see a need for linkage of traditional and scientific ecological knowledge to deal with environmental problems; yet they are concerned about how scientists may participate and how managers may ultimately use their knowledge (Wavey 1993). Once traditional ecological knowledge with its inherent geographic, time-specific detail about wildlife populations becomes available, it could be considered equitably with scientific data in the management of Arctic wildlife populations. Full integration may not (and perhaps should not) be accomplished because of unique assumptions and decision-making processes inherent to the aboriginal and Euro-scientific cultures (Feit 1988). Nevertheless, co-management of wildlife should be aided by conscientious efforts to integrate indigenous and scientific databases.

My goal was to develop a method that could allow aboriginal and scientific ecologists to accomplish this integration. The methodology was developed over 12 years during which I worked and lived with Inuit on Baffin Island. Such experience and cooperation is needed to gain trust and insights shared between aboriginal people and researchers (Usher and Wenzel 1987; Berkes 1990). Aspects of the methodology may not be culturally appropriate for other indigenous peoples and/or Inuit in other areas, given their social diversity (Damas 1968). To successfully adapt and carry out this methodology with other indigenous peoples and/or for other wildlife species, researchers need a sound understanding of the cultural basis of aboriginal knowledge. Whenever ecologists undertake such efforts, the onus will be to conserve the accuracy and precision of aboriginal knowledge, and to understand the cross-cultural assumptions that could lead to either enlightenment or misunderstanding.

3. INUIT KNOWLEDGE OF LONG-TERM CHANGES IN A POPULATION OF ARCTIC TUNDRA CARIBOU

3.1 Introduction

Historically, caribou in Alaska (Skoog 1968), the mainland of Nunavut (Parker 1972), northern Québec (Messier et al. 1988; Crête and Payette 1990), Greenland (Meldgaard 1986) and Bathurst Island (Tener 1963; Miller et al. 1977; Miller 1991) have undergone large fluctuations in population size over several decades. Manning (1943), Soper (1944), Ferguson (1989) and Stenton (1991) used fragmentary secondhand information to suggest similar fluctuations in caribou populations on Baffin Island. Information from Inuit suggests that entire sub-populations on Baffin Island and elsewhere occasionally undertake predictable, periodic shifts in distribution and abundance. This phenomenon has obvious implications for wildlife management decisions because hunting and predation are unlikely to cause such movements. Additionally, caribou sub-populations may simply rotate between ranges, having little consequence for overall population abundance, or entire populations may decline if decreases occur simultaneously among several sub-populations. If the latter occurs, then population fluctuations of Arctic tundra caribou may be cyclical as suggested by Baffin Inuit. Unfortunately, no one has assembled firsthand information to detect the temporal and spatial extent of sub-population fluctuations. As well, written records and scientific studies of caribou resident on the Canadian Arctic tundra are too scattered to address these questions.

Many successful non-aboriginal explorers of the Arctic used Inuit knowledge. Hall (1864) was the first non-Inuit to record the geographic and historic knowledge of Inuit on southern Baffin Island in 1860. Using the knowledge of several Inuit, Hall (1873) described much of the geography of Baffin Island that remained unseen by non-Inuit until after Hall's death. Arima (1976) and Chapter 2 have also shown the accuracy and precision of Inuit knowledge.

Freeman (1985), Feit (1988), Gunn et al. (1988) and Berkes (1993) have discussed distinctive characteristics of indigenous ecological knowledge relative to scientific knowledge. Despite differences, many parallels exist between both forms of knowledge. Individual Inuit have mentally recorded empirical data about wildlife distributions, movements and abundance that could be useful in the management of wildlife populations. The Inuit understanding of ecology is distinct from scientific understanding partially because of the rationale for its collection: human survival. Although Inuit can recall many years of numerical information (Freeman 1975), the survival need emphasizes the question "Are there enough?" over "How many are there?" (Unaaluq pers. comm., to R. Williamson pers. comm.). The geographic extent of a hunter's firsthand knowledge expands as the hunter searches larger areas after declines in the abundance of local sub-populations of game animals. Once survival needs are met, hunters continue to observe population trends and changing ecological conditions accurately, but without numerical quantification. Unlike the hunter, wildlife ecologists numerically quantify selected variables, but because of costs, ecologists usually collect data on relatively few variables within specific geographic areas for short periods. As a result, wildlife ecologists encounter problems when generalizing their findings to broader spatial and/or temporal scales. Keith and Windberg (1978) overcame this problem by using the observations of registered trappers to assess the spatial synchrony of snowshoe hare fluctuations across Alberta over a 15-year period.

Few persons (e.g., Freeman 1975; Johannes 1980; Nakashima

1993) have documented the extensive ecological knowledge of indigenous peoples so that it can be integrated with scientific ecological knowledge. During 1983-95, I collected Inuit knowledge about caribou on southern Baffin Island over the past 90 years to broaden the historical context for future management of this population. In this chapter, I present a composite view of caribou population changes on southern Baffin Island from observations of 43 Inuit elders and active hunters. I then present indices of changes in population abundance derived from Inuit knowledge. Finally, I discuss Inuit knowledge that suggest that fluctuations in the South Baffin caribou population are cyclic, and compare Inuit knowledge with reports by non-Inuit. Repeated inconsistency between non-Inuit reports and compilation of Inuit knowledge could indicate that one or both of the information sources was inaccurate, or that I failed to preserve accuracy during compilation. Chapter 2 presented evidence of the inherent veracity of Inuit knowledge. I conclude that either inaccurate non-Inuit reporting or errors in my compilation of Inuit knowledge would largely account for discrepancies between the two data sources.

3.2 Methods

Chapter 2 described the general methodology, and the roles of Inuit participants and advisors. The research effort was substantial; over 200 hr were spent in interviews, 700-800 person-hours in translating and transcribing interviews, and at least one person-year in data analysis and interpretation. The Hunters and Trappers Organizations (HTOs) in Pangnirtung, Iqaluit, Kimmirut and Cape Dorset (Fig. 3.1) and other local advisors suggested names of potential informants who, together, could cover the historical range of South Baffin caribou. The temporal coverage was maximized by selecting elders and older active hunters over younger hunters, although some younger hunters provided details about recent caribou distributions.

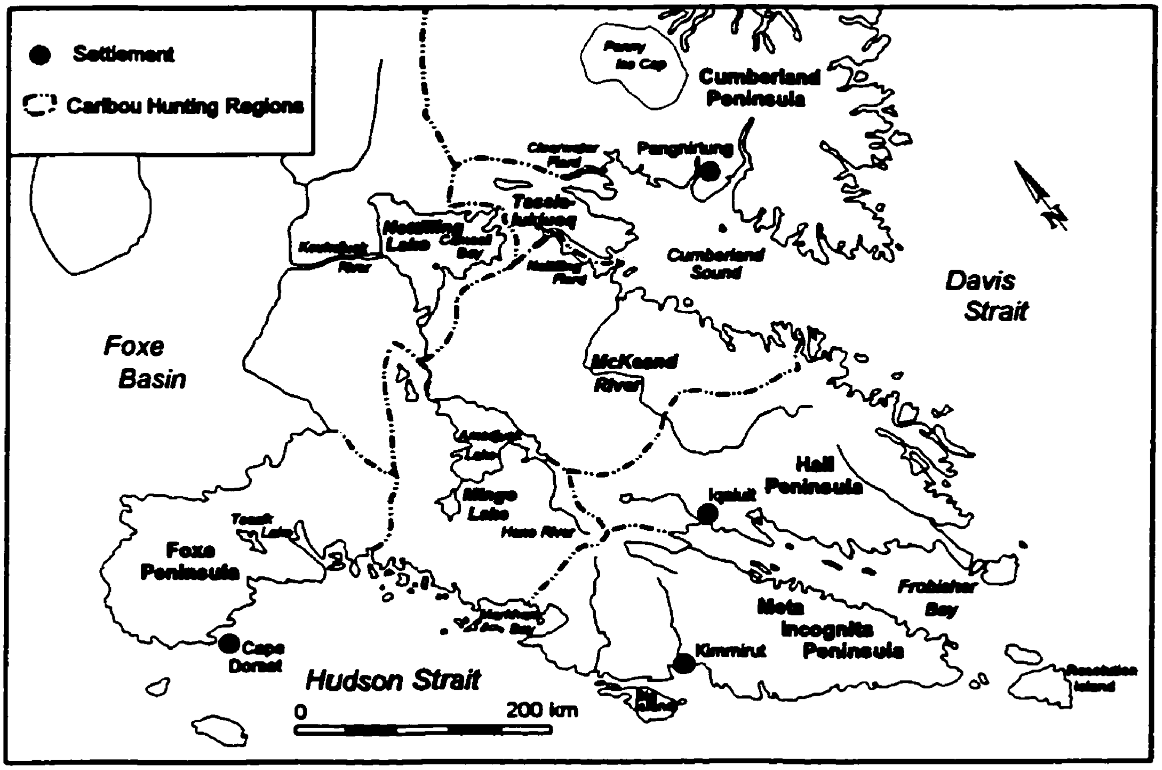

Figure 3.1. Caribou hunting regions on southern Baffin Island, Nunavut.

Informants interviewed in Pangnirtung and Kimmirut in 1994 (Table 3.1) signed consent forms, generally indicating that raw data should be deposited at local community resource centres, that permission for further use of raw data must be obtained from each informant or a named heir, and that their contributions must be acknowledged. Each informant personally owns his information and his initials (Table 3.1) appear in the text indicating a personal communication. Most informants were interviewed by a researcher and an interpreter for two to seven hours. Most interviews were tape-recorded, and geographic information was recorded on clear plastic over 1:250,000 or 1:500,000 topographical maps.

3.2.1 Interview protocol

During each interview, I developed a biographical map and detailed time-line for the informant from the informant's recollections of dateable events (Chapter 2). The informant then described and mapped seasonal and inter-annual changes in caribou distributions and relative abundance, based largely on his own observations of caribou (i.e., personal information) and observations of his parents and/or grandparents (i.e., parental information). Starting with the informant's first memory of caribou, the informant was asked to recall his observations while he lived at each of his homes in sequential order. I will report general circumstances in which the locations of Inuit residences affected their knowledge of caribou distributions, but I did not obtain permission to publish these locations.

For each observation of caribou, I elicited information about the location, timing (i.e., month or season), number of caribou or tracks, sex/age class of caribou, and direction of travel of the caribou. Informants were asked to distinguish areas with sex/age classes that were being hunted, areas with non-target classes of caribou, areas with no caribou and areas

Table 3.1. Inuit informants who provided information about caribou distributions, abundance and migrations on southern Baffin Island, Nunavut.

Informants		Interview		Interview team[b]	Type of interview[c]
Initials[a]	Name	Year	Location		
AE	Abraham Etungat	1985	Cape Dorset	ML, MJ	Complete
AN1	Akeeshoo Nowdluk	1988	Allen Island	MF	Partial
AS	Akaka Saataa	1985	Iqaluit	PK1	Complete
		1994		MF, AP	Meeting
CA	Charlie Akpalialuk	1994	Pangnirtung	MF, JK2	Complete
EA	Etuangat Aksayuk	1990	Pangnirtung	MF, PK2	Complete
EK	Elijah Keenainak	1994	Pangnirtung	MF, AN2	Complete
EN1	Enosik Nashalik	1994	Pangnirtung	MF, AN2	Complete
EN2	Equaluk Nungusuituk	1985	Cape Dorset	ML, MJ	Complete
EP	Ejeetsiak Peter	1985	Cape Dorset	ML, MJ	Complete
GU	Geosha Uniuqsaraq	1994	Iqaluit	MF, AP	Meeting
HK	Harry Kilabuk	1985	Iqaluit	PK1	Complete
II	Iola Ikkidluak	1994	Kimmirut	MF, MA	Complete
JA	Joe Ariooktoo	1994	Kimmirut	MF, MA	Complete
JE	Jaco Evic	1990	Pangnirtung	MF, PK2	Complete
JK1	Josephie Keenainak	1994	Pangnirtung	MF, AN2	Complete
JM	Jamesie Mike	1994	Pangnirtung	MF, JK2	Complete
JP	Josephie Pudloo	1994	Kimmirut	MF, MA	Complete
JT1	Joe Tikivik	1985	Iqaluit	PK1	Complete
JT2	John Tongak	1995	Pond Inlet	GK, JT3	Partial
JT3	Joe Tigullaraq	1995	Pond Inlet	MF	Partial
KK	Korgak Kilabuk	1985	Iqaluit	PK1	Complete
LN1	Lucassie Nutaraluk	1985	Iqaluit	PK1	Complete
		1994		MF, AP	Meeting
LN2	Lucassie Nowdluk	1985	Iqaluit	PK1	Complete
		1994		MF, AP	Meeting
MP	Markoosie Peter	1985	Iqaluit	PK1	Complete
MS	Mathew Saveakjuk	1995	Cape Dorset	MF	Partial
NI	Novayuk Ipeelie	1985	Iqaluit	PK1	Complete
		1994		MF, AP	Meeting

Informants		Interview		Interview team[b]	Type of interview[c]
Initials[a]	Name	Year	Location		
OA	Ohituq Ashoona	1995	Cape Dorset	MF	Partial
OP	Osuitsiaq Pudlat	1985	Cape Dorset	ML, MJ	Complete
OQ	Okaetok Quaraq	1985	Iqaluit	PK1	Complete
		1994		MF, AP	Meeting
PA1	Pauloosie Angmarlik	1990	Pangnirtung	MF, PK2	Complete
PA2	Peteroosie Anilniliak	1994	Pangnirtung	MF, AN2	Complete
PK1	Pauloosie Kilabuk	1994	Iqaluit	MF	Partial
PL	Pauloosie Lyta	1994	Kimmirut	MF, MA	Complete
PN1	Pauloosie Nowyook	1994	Pangnirtung	MF, JK2	Complete
PN2	Pudloo Nowdluk	1985	Iqaluit	PK1	Complete
		1994		MF, AP	Meeting
PP	Paulassie Pootoogook	1985	Cape Dorset	ML, MJ	Complete
SA1	Simonie Alainga	1983	Iqaluit	MF, GA	Complete
		1994		MF, AP	Meeting
SA2	Sandy Akavak	1994	Kimmirut	MF, MA	Complete
SK	Simeonie Keenainak	1995	Pangnirtung	MF	Partial
SQ	Simionie Quppapik	1985	Cape Dorset	ML, MJ	Complete
SR	Sakiassie Ragee	1985	Cape Dorset	ML, MJ	Complete
SS	Sagiatuk Sagiatuk	1985	Cape Dorset	ML, MJ	Complete
TM	Towkie Maniapik	1990	Pangnirtung	MF, PK2	Complete

[a] Initials used in text to indicate personal communications.

[b] Interviewers were: Aiju Peter (AP), Amie Nashalik (AN2), George Koonoo (GK), Goo Arlooktoo (GA), Jonah Kilabuk (JK2), Joe Tigullaraq (JT3), Mathew Akavak (MA), Martha Jaw (MJ), Michael Ferguson (MF), Michel Labine (ML), Pauloosie Kilabuk (PK1) and Peter Kilabuk (PK2).

[c] **Complete** interviews of individual informants were conducted to collect information throughout the life of the informants. **Partial** interviews and one **meeting** were conducted to fill specific information gaps.

that were not hunted due to terrain or other conditions. Distributions of mature males (bulls) and mature females (cows) with calves was emphasized because they exhibited the greatest geographic separation. Informants were asked to draw the routes and hunting areas that they used while hunting caribou.

When caribou were scarce, informants usually recalled precise numbers of animals that they and other hunters harvested and/or the total number seen. When the abundance of caribou was sufficient to meet the informant's needs, the informant usually did not know the number seen. As well, terms describing abundance (e.g., "few", "lots") depend on the informant's previous experience; e.g., five caribou may be "lots" if a hunter has not seen a caribou for several years, but not after he has seen hundreds of caribou daily. Consequently, the informant was asked to directly compare caribou abundance to that seen previously and later in his life within the same area and within other areas (e.g., "more", "less").

Seasonal migrations resulted in changes in caribou abundance in a specific area lasting several weeks or months, and were undertaken annually for several years or decades. Most informants were extremely disciplined and specific in reporting only the actual routes and directions of travel that they observed, avoiding speculation. Informants sometimes speculated in response to leading questions in which the interviewer suggested the ultimate destination (Chapter 2). I eliminated such speculative responses.

3.2.2 Data analysis and presentation

English transcripts of each interview were examined in detail to eliminate answers that may have been affected by inappropriate questions, secondhand information and other factors (Chapter 2). A minimum acceptable precision of ± 3 years was set arbitrarily for temporal data. A composite illustration of changes in caribou distribution and abundance was developed by plotting the observations of all informants on clear plastic over a 1:500,000 map for each decade. Major hunting regions became evident with each having relatively distinct historical patterns of caribou population changes and hunting by Inuit. Written synopses of informants' observations were merged in chronological order for each major caribou hunting region (Fig. 3.1). For presentation purposes, the composite overlays were redrawn to illustrate caribou distributions during the first four years of each decade, beginning with 1910-13. The four-year period was chosen to coincide with our accepted temporal precision, to allow sufficient time to illustrate inter-decade changes, and to portray generalized population distributions (as opposed to unusual distributions occurring in a specific year).

Caribou distributions were analysed for: "summer" (i.e., June to August), "autumn" (i.e., September to early December), "winter" (i.e., mid-December to mid-March) and "spring" (i.e., late March to May). Figures 3.2-3.5 show summer and winter distributions for the even-numbered decades from 1920 to 1980. The distributions for 1990-93 are given in Figure 3.6, since major changes have occurred since the 1980s.

After comparing statements of all informants about caribou abundance relative to other areas, years and seasons, I assigned a caribou abundance code to each hunting area for each season during the first four years of each decade (e.g., spring 1910-13). Although I used descriptions that directly compared spatial and temporal differences in caribou abundance, each category usually corresponded to typical Inuit descriptions of abundance relative to the needs of caribou hunters (Table 3.2). Descriptions based on need apply mainly to the 1950s and previous decades, before most of the informants moved into the communities. In discussing these abundance categories with Inuit, it became evident that the differences between the categories were probably exponential rather than arithmetic.

Table 3.2. Caribou abundance on southern Baffin Island, Nunavut, as described by Inuit caribou hunters relative to their needs[a], and corresponding approximate densities determined from aerial surveys during the 1980s and 1990s.

Map code	Abundance of caribou relative to needs	Aerial survey density (caribou·km^{-2})
0	No sign of caribou.[b]	0.0
1	Only caribou tracks seen.[b]	0.008
2	Not enough to meet their needs.	0.04
3	Enough to meet their needs.	0.2
4	Plenty of choice to meet their needs.	1.0
5	Too many caribou.[c]	5.0

[a] Abundance codes were assigned based on direct comparisons in the relative abundance of caribou in different years, seasons and areas, known to each informant. Abundance relative to needs was applicable mainly to years before most of the informants moved into communities.

[b] Obviously there were not enough caribou to meet their needs.

[c] Obviously there was plenty of choice, but this also represented concern about the ability of the habitat to sustain such abundance of caribou over the long term.

Thus, a simple numerical ranking of the six categories (e.g., 0-5) would misrepresent changes in abundance over time. To develop an appropriate scale for the relative change from one category to the next, I compared Inuit descriptions of abundance in specific areas with densities estimated from aerial surveys in those same areas during the 1980s and 1990s (unpublished data; Chapter 4). The abundances described by Inuit were generally consistent with densities estimated from aerial surveys (Table 3.2). Caughley (1977) recognized that persons thoroughly knowledgeable about an area and its wildlife can make realistic "guesses" about the abundance of animals. He pointed out that the value of a given guess depended on the length of time the person was in the area, the indicators used to derive the guess and the person's experience. Caughley also suggested that such guesses are useful checks of the accuracy of survey estimates. I reversed that process by using aerial survey results to develop a numerical scale for Inuit descriptions of caribou abundance. The combination of Inuit knowledge and survey data yields the only assessment of long-term population trends possible for this population. Overall abundance indices were obtained by combining the applicable assumed densities from Table 3.2 and amount of area known by the informants. Specific terminology was used consistently throughout this thesis (Table 3.3).

3.2.3 Comparisons with non-Inuit reports

The detail of observations preserved in Inuit oral traditions and corroborated by written records was remarkable (Chapter 2). As with Inuit knowledge, I examined the context of each historical report written by non-Inuit for an equitable comparison of the two types of information. For example, Soper (1944) did not see any caribou near Kimmirut during 1930-31, but neglected to report that from autumn 1930 to June 1931, he did not travel extensively due to an injury (Soper 1981). The

Table 3.3. Definitions of terminology in this chapter.

Term	Definition
Appear	Rapid occupation of an area through immigration (i.e., usually during 1-5 years).
Disappear, decrease	Reduced population abundance over a few years (i.e., usually less than ten), possibly due to emigration, reduced survival, and/or low calf production.
Emigration, immigration	Movements producing a large change in population abundance between years. Conclusive evidence of emigration was difficult to obtain.
Expand, increase	Increases in geographic distribution and population abundance, respectively.
Migration	Seasonal movements of caribou reported by the informants.
Range expansion	Overall increase in the size of a seasonal area occupied by caribou.
Range drift	Expansion of a seasonal area in one direction and a concomitant shrinkage in another, resulting in no, or little, net change in area occupied.
Range shift	Almost complete abandonment of one seasonal area and concomitant occupation of another area(s) that will be used for several years thereafter.
Range volatility	Frequent, unpredictable inter-annual changes in the seasonal distribution of caribou.
Special areas	Areas that the informants' elders had described as places that would have caribou "when all other areas have no caribou".

lack of firsthand observations in non-Inuit reports often reflects limited opportunities for observing wildlife rather than limited distributions of wildlife.

Relative quantification (e.g., "plenty") is also problematic. RCMP reports from Pangnirtung confirmed informant evidence that densities had decreased in the late 1920s. However, reports by two new RCMP officers in 1930-32 reported "plenty" of caribou near Pangnirtung and northern Cumberland Sound. I gave greater weight to descriptions of relative abundance by older Inuit because of their broader temporal context (Chapter 2). Temporal and spatial frames of reference were also viewed critically before using written reports.

Many written reports by non-Inuit about caribou are actually secondhand reports from Inuit, but the writers may not have understood Inuktitut and Inuit culture adequately to report Inuit knowledge accurately. For example, Hantzsch (1977) did not display an understanding of Inuit culture as Hall (1864) and Boas (1974) had. Hantzsch was annoyed when the Inuit delayed his expedition, especially on clear days suitable for travel and for drying caribou skins. He reported the number of caribou harvested for meat, but the skins of these caribou would have been insufficient to provide winter clothing for the entire party. When Inuit observations are reported by non-Inuit, the linguistic and cultural contexts often become difficult to judge.

The assumptions of each author in extrapolations made from actual observations were also examined. In 1931, Soper (1944: 249) observed caribou trails on Meta Incognita Peninsula that "appeared remarkably fresh", but had not been used "for a considerable period" because some parts of the trails were overgrown by 10-12 years old willows (*Salix* spp.). However, snow often protects vegetation during spring caribou migrations, and willows often remain lush in low parts of caribou trails even during summer migrations (unpublished data). In such situations, I accepted firsthand and parental observations of Inuit over non-Inuit inferences or speculation.

3.3 Results

To illustrate the accuracy and precision of the informants' recollections, a detailed description of their compiled knowledge follows for the Foxe Peninsula caribou hunting region. Shorter synopses are given for other hunting regions, but detailed compilations are available from me upon request. Place names are presented on Fig. 3.1.

3.3.1 Foxe Peninsula hunting region

By c1900 (EN2, NI) caribou were common throughout most of Foxe Peninsula in both summer and winter, inhabiting nearby islands in Hudson Strait by c1911 (EN2, LN1, NI, SQ, Fig. 3.1). This range extended east to the Mingo Lake region (SQ). Most caribou disappeared from Foxe Peninsula after c1923 (EN2, LN1, NI, SQ, Fig. 3.2.A), after caribou began to disappear first from coastal areas in c1918 (SQ, Fig. 3.3), and most caribou disappeared from Foxe Peninsula after c1923 (EN2, LN1, NI, SQ, Fig. 3.2.A). All informants, except OP, PP and SR, reported that caribou could not be found on Foxe Peninsula from c1926 until the late 1950s (AE, EN2, II, JA, LN1, NI, SQ). From c1926 to c1942, OP, PP, SR and/or their parents found some caribou during two to four winters each. Caribou abundance was very low, with none being found in some years and a maximum of three caribou taken during three weeks of hunting in other years (PP, Fig. 3.4). OP and SR knew of no caribou taken on the peninsula after c1935, but PP reported that his father found a few caribou in some winters until c1942.

By the late 1920s, several families from Foxe Peninsula were living for months or years near Mingo, Amadjuak and/or Nettilling lakes to hunt caribou and trap foxes (AE, LN1, NI,

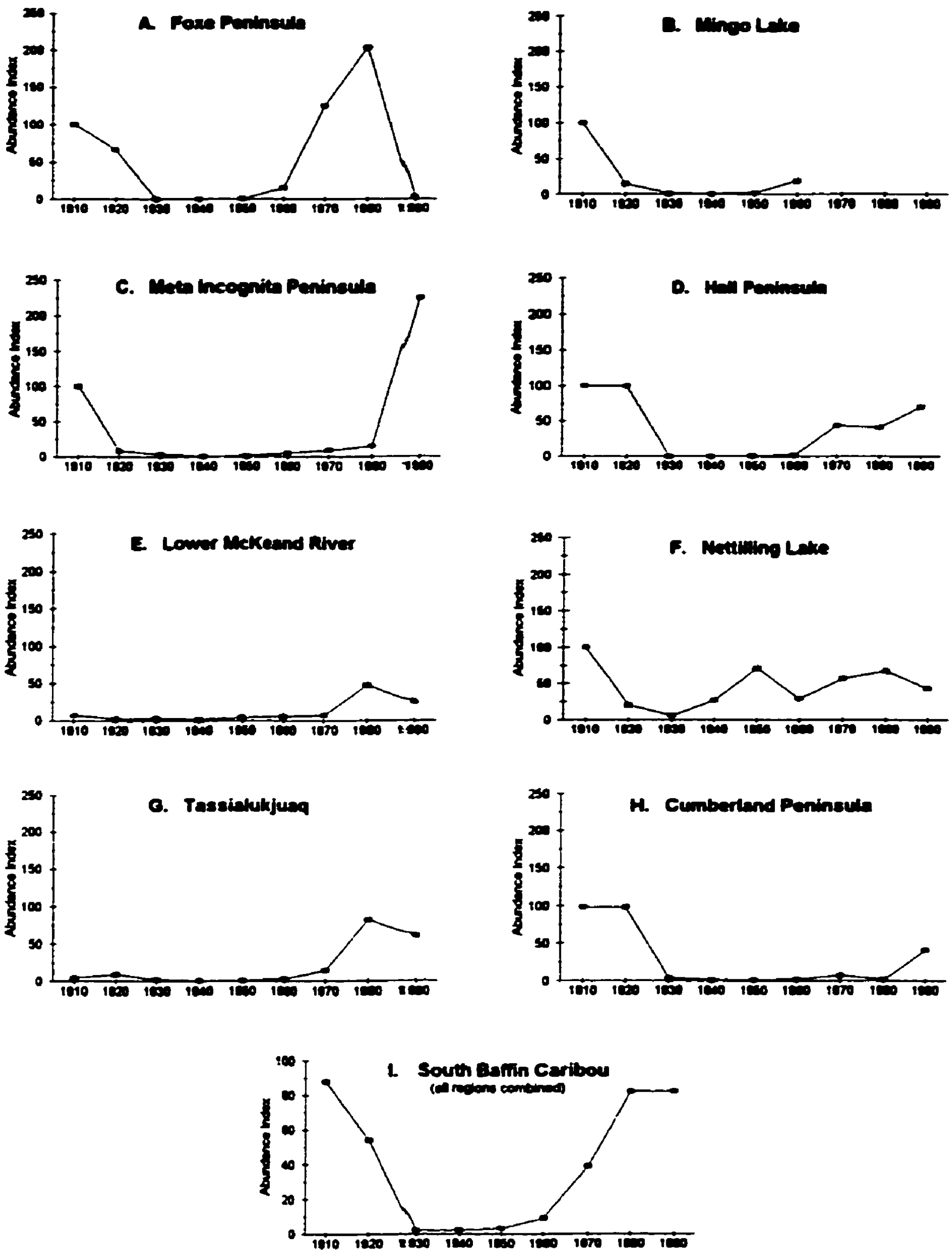

Figure 3.2. Relative abundance of caribou within major caribou hunting regions (A-H) and in all regions (I) on southern Baffin Island during winter, 1910-93.

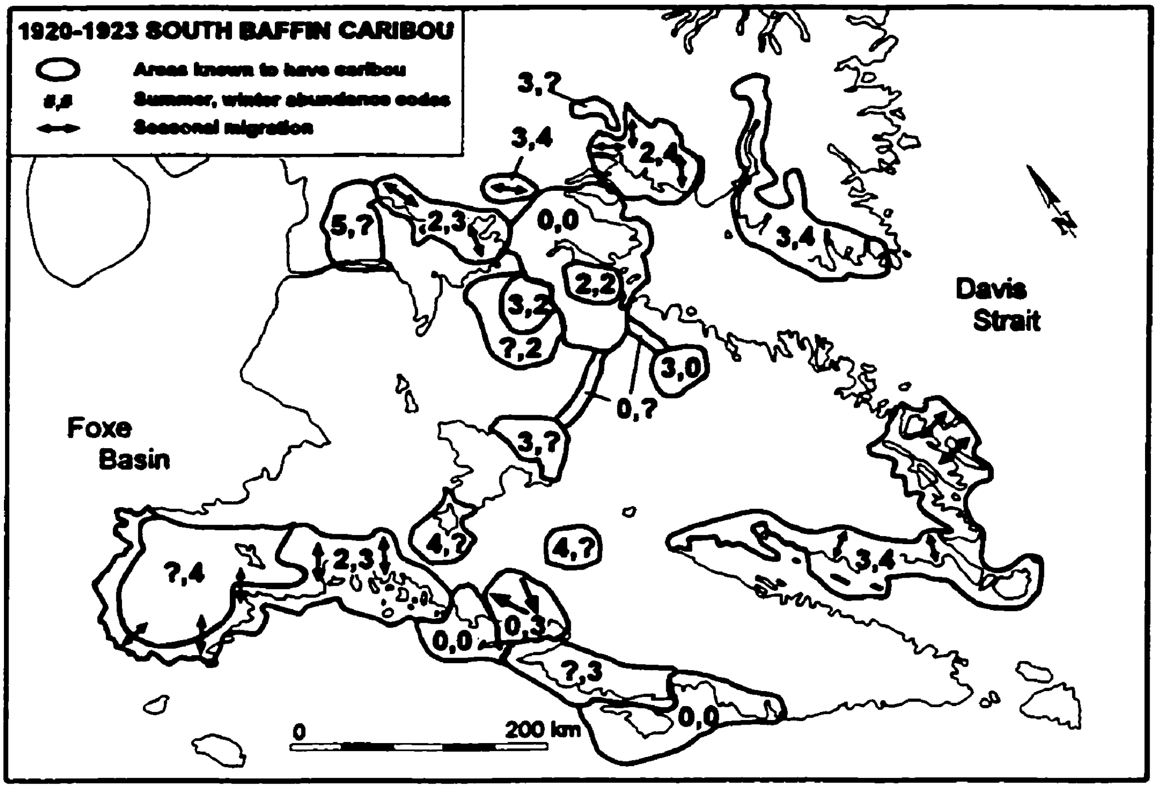

Figure 3.3. Distributions, abundance (Table 3.2) and seasonal migrations of caribou on southern Baffin Island during 1920-23, based on Inuit knowledge.

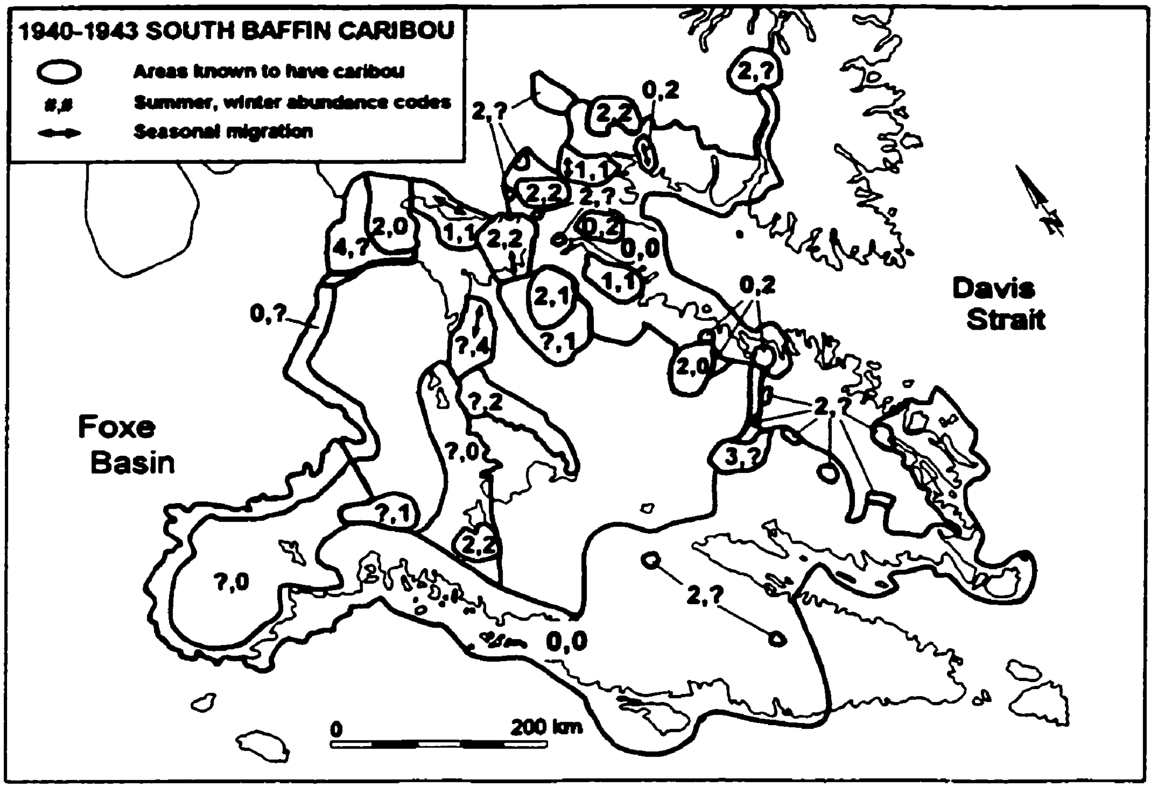

Figure 3.4. Distributions, abundance (Table 3.2) and seasonal migrations of caribou on southern Baffin Island during 1940-43, based on Inuit knowledge.

PP, SQ). By the early 1930s, Inuit near Cape Dorset obtained imported caribou skins and sinew at the Hudson's Bay Company (HBC) post (OP). Until 1944, Inuit living on Foxe Peninsula received caribou skins and meat from family members living at Nettilling Lake (PP). During 1946-50, none of the informants from Cape Dorset hunted caribou near Amadjuak and Nettilling lakes, although caribou had not yet returned to Foxe Peninsula. Trading posts in Cape Dorset discouraged harvesting of caribou near these lakes at the request of the Deputy Commissioner of the Northwest Territories (Chapter 2).

From the late 1920s through the early 1950s, informants travelled extensively on Foxe Peninsula in winter and spring and along the coast in summer despite the lack of caribou. If caribou had occupied the peninsula during this period, hunters would have detected some sign of them. The return of caribou to northeastern Foxe Peninsula began in c1955 when somebody reported tracks of two caribou (SR). AE first saw caribou in that area in winter c1957. Then in winter c1958, caribou were seen farther west near Tessik Lake (SR, SS).

In the early 1960s, caribou increased (Fig. 3.2.A) from Tessik Lake east to the Mingo Lake region and probably beyond (AE, II, Fig. 3.5). As caribou immigrated onto Foxe Peninsula in the late 1950s and early 1960s, cows and calves arrived each September-October, followed by bulls (AE). After c1960, mainly bulls were seen along the coast during winter, while cows and calves were usually 15 km or more inland near lakes (EP, SS, SR). Tessik Lake became the main winter hunting area of most informants during the 1960s. By the mid-1960s, bulls remained on the coast of eastern Foxe Peninsula during summer, and during the late 1960s some cows and calves were seen on this coast in summer (SS).

During winter in the early 1970s, caribou expanded westward past Tessik Lake (SR, SS). Their summer range extended from south of Tessik Lake east to the Mingo Lake region (SR, SS). Besides expansion of the winter and summer ranges, caribou

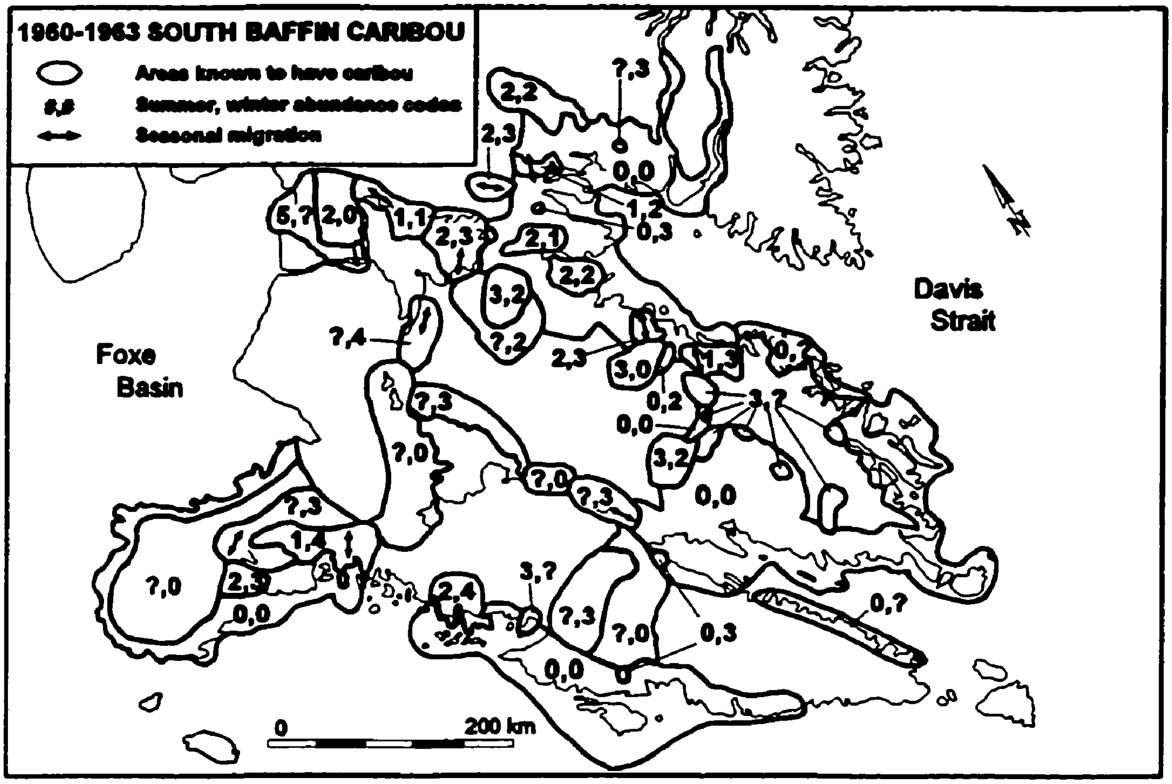

Figure 3.5. Distributions, abundance (Table 3.2) and seasonal migrations of caribou on southern Baffin Island during 1960-63, based on Inuit knowledge.

abundance increased from the 1960s into the 1980s (EN2, EP, OA, SS, SR, Fig. 3.2.A). By c1980, caribou occupied western Foxe Peninsula in winter, spring and summer (OA, SR, Fig. 3.6). Caribou continued to occupy the coastal area south of Tessik Lake (EP, MS) and expanded south and east along the coast by winter c1983 (EN2). In the 1980s, caribou continued to winter on eastern Foxe Peninsula (EP, MS). However, within that area, caribou densities decreased after winter c1983 (EP); the caribou range was drifting rather than expanding during the mid-1980s. Also during the 1980s, bulls moved onto nearby islands in Hudson Strait during winter and remained along the coast year-round (OA), while cows were on the coast mainly during winter (EN2, OA).

Seasonal migrations on Foxe Peninsula during the early 1900s (LN1, NI, Fig. 3.3) were similar to those during c1970-85 (Fig. 3.6), caribou abundance being highest during winter (EP, SS). In the 1970s, cows and some bulls migrated inland during May (EN2, EP, LN1, SS, SR). During summer, mainly males were harvested near the coast (NI). By c1980, most cows migrated inland late in May and returned to the coast with newborn calves in early August, remaining until the next spring (OA). Starting in c1983, some cows remained along the coast year-round, so EP believed that females calved close to Cape Dorset. None of the informants had observed calving females, although secondhand information suggested that a large calving area had been seen by other hunters on western Foxe Peninsula in the early 1980s (EN2). During September-October, bulls migrated inland to find cows (EP). There was no discrete rutting area because caribou moved extensively throughout the peninsula during October- November (EP).

In 1985, EP and PP predicted that caribou would soon leave Foxe Peninsula because of the above changes in distribution and migrations and past predictions of their elders. A sudden, major decrease occurred on Foxe Peninsula between spring and autumn 1989 or 1990, after which few caribou wintered on the

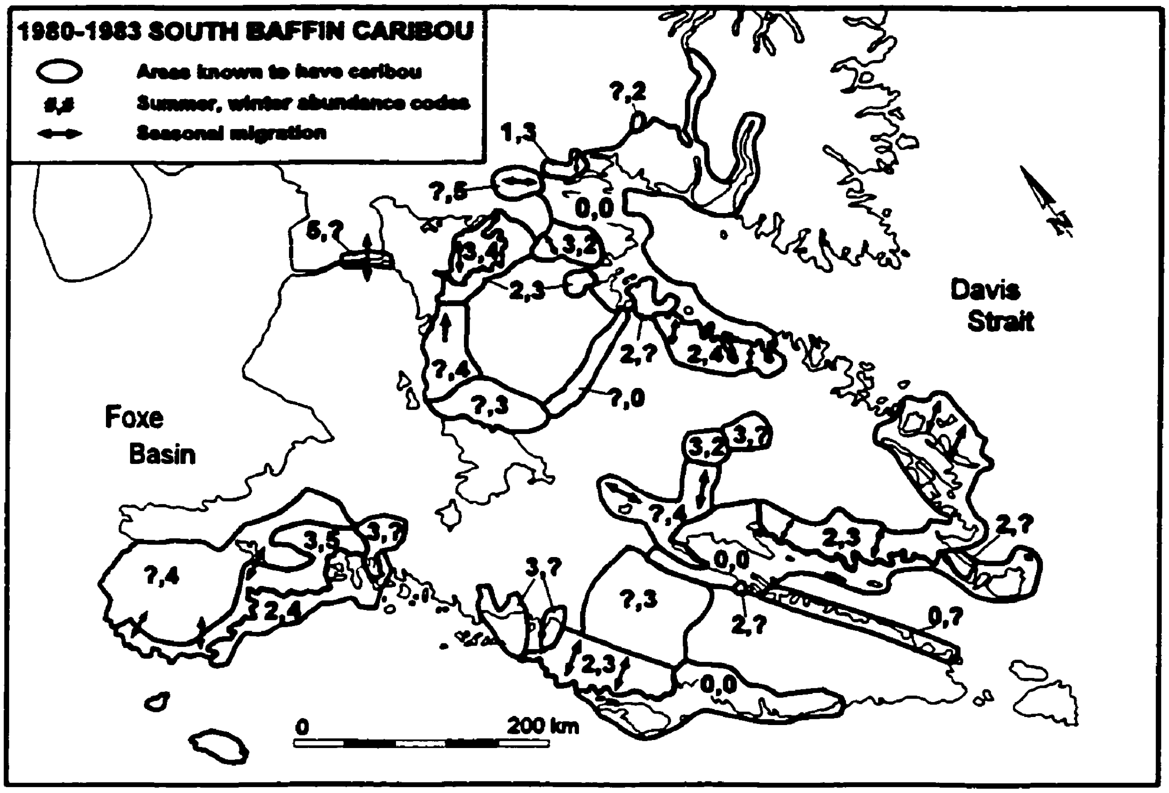

Figure 3.6. Distributions, abundance (Table 3.2) and seasonal migrations of caribou on southern Baffin Island during 1980-83, based on Inuit knowledge.

peninsula (MS, OA, Fig. 3.2.A, 3.6-3.7). Since then, caribou have been seen in groups of two to three and never more than ten (JT3, OA). OA has seen only three or four caribou per day of hunting in winter since c1990.

None of the informants reported a major increase in natural mortality, although a few caribou were found dead at the bottoms of cliffs. By 1994, caribou were so rare on Foxe Peninsula that friends in Iqaluit regularly sent meat to Cape Dorset residents, and some Cape Dorset hunters had hunted caribou on Southampton Island, about 250 km west of Cape Dorset (MS).

3.3.2 Mingo Lake hunting region

Informants did not hunt regularly near Hone River because of its distance from camps on Frobisher Bay and Hudson Strait. Nevertheless, informants knew it as a special area where caribou could be found if unavailable elsewhere. During summer c1919-24, caribou were found near the headwaters of Hone River (SA2, Fig.3.3). Some Kimmirut hunters got caribou near Hone River in summer throughout the 1930s (JP, SA2). From c1942 to c1953 during winter, a few caribou or at least tracks were seen near the river (AS, HK, JA, JP, PL, SA1). Subsequently, informants rarely hunted near Hone River as caribou began appearing nearer the coast.

Mainly cows with calves wintered along the coast of this region from c1917 (or before) until c1928 (SQ, Fig. 3.3). Many cows and newborn calves summered around Mingo Lake and southwestern Amadjuak Lake during c1917-22 (AE, SQ), but caribou abundance was low by summer c1928-32 (EN2, Fig. 3.2.B). During winter in the 1930s, 1940s (Fig. 3.3) and early 1950s, caribou abundance was very low throughout this region (AE, EN2, JT2, LN1, NI, SR, SQ). No sign of caribou was reported west of Amadjuak Lake during winter and spring. From c1939 until c1956, a few caribou were occasionally seen south of Mingo Lake in

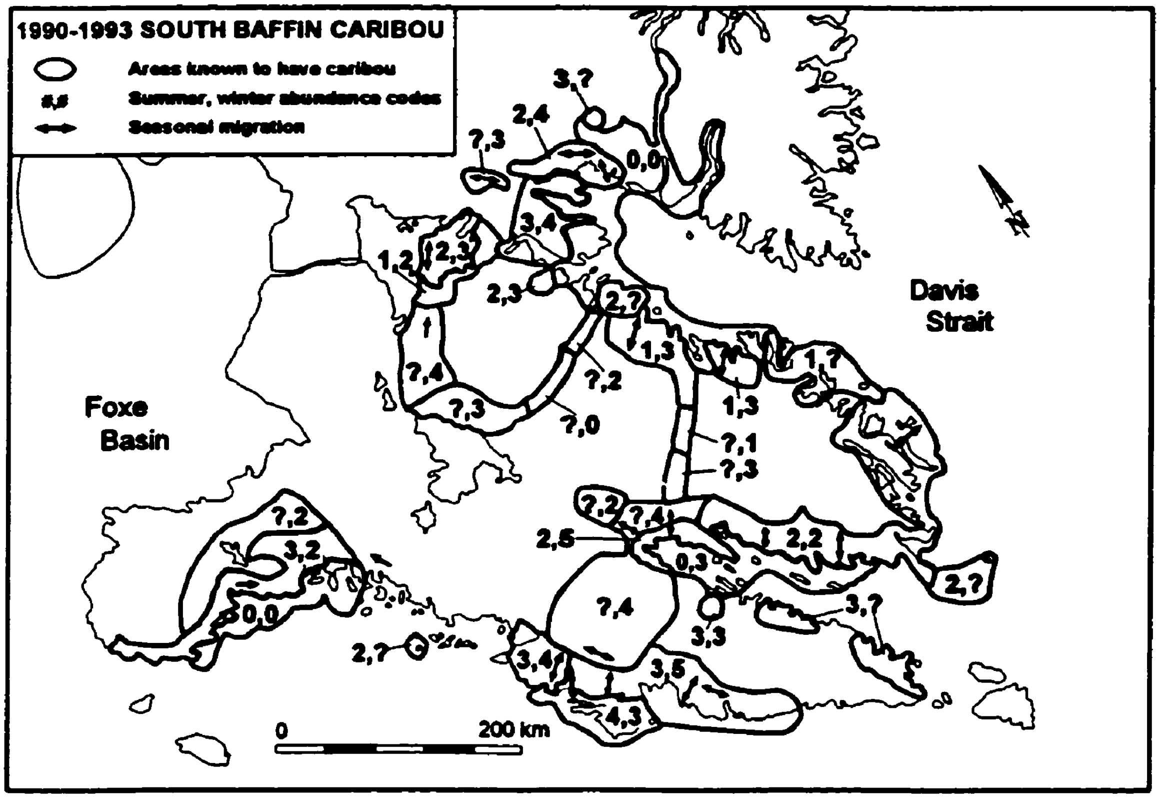

Figure 3.7. Distributions, abundance (Table 3.2) and seasonal migrations of caribou on southern Baffin Island during 1990-93, based on Inuit knowledge.

summer and winter (EP, JA, II, PL, SS, Fig. 3.3). Until c1956, each hunting party usually could get no more than two caribou in winter (II, PL, SS). Inuit living in this region during c1944-49 were often hungry and cold because of insufficient caribou and other wildlife (II). In c1956, caribou began returning to the coast in winter (EP, SS), but subsequent observations are limited because most residents moved to Cape Dorset or Kimmirut by c1959 as requested by the Royal Canadian Mounted Police (RCMP) (SQ). By c1960, caribou remained along the eastern coast of the region during summer, but abundance was higher during winter (II, Fig. 3.2.B, 3.5). During summer c1979-81, caribou were seen along the coast and on smaller islands (JP, Fig. 3.6).

3.3.3 Meta Incognita Peninsula hunting region

Caribou apparently occurred along the entire coast of Meta Incognita Peninsula in the early 1900s (JP, LN2, PL, SA2). By the early 1920s caribou disappeared from the coast of Hudson Strait southeast of Kimmirut and abundance decreased (PL, Fig. 3.2.C, 3.3), but some caribou continued to winter along the northwest coast until c1930 (JP, SA2). Informants rarely travelled among the interior plateaux and mountains of Meta Incognita Peninsula before c1939 (AS, JA, JP, PL, SA2), so caribou may have remained there throughout the 1930s (JA). From c1939 to c1950, groups of two to four caribou were occasionally found inland during summer, if any caribou were seen at all (AS, KK, PL, Fig. 3.3). In Kimmirut, caribou meat was extremely rare from c1946 to c1951 (JP, SA2).

During c1950-52, tracks of one caribou were seen among the mountains (AS, JA, NI, PL). Then, during winter from c1953 to c1956, signs of caribou increased with up to ten caribou being seen occasionally (JP, SA1, SA2). In c1958, SA2 noticed a marked increase in caribou abundance, seeing a total of c21 caribou during one hunt and more during another. More Kimmirut hunters started actively hunting caribou, taking 20-25 caribou that winter (SA2). The caribou population expanded and increased toward the southwest during winters of c1959-61 (JP, SA2, Fig. 3.5). After c1958, SA2 saw too many caribou to estimate the numbers that he saw or harvested.

During winter c1963, caribou range expanded again towards the coast, but most caribou remained at least c50 km north of Kimmirut (II, SA2). By the late 1960s, c10 caribou were harvested for every five hunters in Kimmirut (JA). By the mid-1970s, they had expanded their winter range within c20 km of Kimmirut (JA, JP, SA2). Iqaluit hunters occasionally saw caribou near the northwest coast of Frobisher Bay (LN1, MP, NI).

During the late 1970s and early 1980s, caribou expanded their spring range along the coast c70 km southeast of Kimmirut (SA2, Fig. 3.6). After c1978, caribou were seen near Markham Bay during summer, winter and spring (JA, JP, SA2). All sex/age classes of caribou were seen during winter and spring (SA2). In May, cows migrated inland, but returned near the coast in July (SA2). In c1980, caribou expanded their range onto islands in Markham Bay (JP).

In winter c1989, caribou range expanded and abundance increased suddenly and dramatically (JP, II, SA2, Fig. 3.2.C, 6). Since the c1989 increase, some cows have still migrated inland into the mountains in spring, but the majority have migrated northwestwards in spring, not returning until October-November (JP, SA2). In c1991 or c1992, bulls appeared on Big Island and other islands in Hudson Strait (JA, II, SA2). In spring c1993 cows also began to use small islands up to 25 km off Baffin Island (II, JA). Bulls that spend winter, spring and summer on Big Island swim back to the peninsula in September, apparently to meet females returning from the northwest (II).

In winter 1993-94, caribou decreased near Kimmirut (SA2). However, in spring c1994, more caribou than in previous years migrated northwestwards past Kimmirut, coming from southeastern

Meta Incognita Peninsula (SA2). The northwestwards migration past Kimmirut occurred in May, instead of April (SA2). The process of drifting winter range apparently began on Meta Incognita Peninsula only four years after the mass immigration of caribou, probably from Foxe Peninsula. In 1994, JA predicted that within ten years caribou will leave Meta Incognita Peninsula.

3.3.4 Hall Peninsula hunting region

From c1900-20, caribou occurred along most of the coast of Hall Peninsula and on islands in Frobisher Bay (HK, LN2, PN2, OQ, Fig. 3.3) until they largely disappeared after c1922 (PN2, Fig. 3.2.D). Caribou were so common that hunters got enough caribou while hunting other game (e.g., Arctic hare, (*Lepus arcticus*) (PN2). Caribou remained at the heads of fiords on western Hall Peninsula until summer c1928 (HK, KK, OQ). Only PN2 reported any knowledge of caribou along the coast of the peninsula until the late 1950s. During summers c1935-59, he and his father usually got a few caribou in a special area on eastern Hall Peninsula (Fig. 3.4-3.5), but in some years they found none.

In summer from c1929 to the mid-1960s (Fig. 3.4-3.5), caribou occurred on the interior of Hall Peninsula in a few special areas (HK, KK, LN2, NI, OQ, PN2, SA1). HK and PN1 found caribou near upper McKeand River in most summers, but each family usually got only four to seven caribou each summer. In the 1940s, caribou expanded and increased slightly east of McKeand River, but abundance remained low (HK, PN1, SA1, Fig. 3.2.D). Some families were starving in some summers while hunting caribou during the 1930s and 1940s (KK, PN1, PN2). Signs of caribou were seen near McKeand River only in winter and spring c1944, c1947 and c1950 (AS, EA, LN1, NI, SA1). Caribou gradually expanded their winter range from McKeand River toward Frobisher Bay from c1957 until c1985 (JT1, MP,

Fig. 3.2.D, 3.5-3.6). In the 1960s as caribou appeared along the coast of Hall Peninsula, hunters rarely hunted the interior so there was little knowledge of caribou on the plateau after c1965.

Beginning in c1956, small isolated groups of caribou were seen occasionally near the west coast of Hall Peninsula (JT1, OQ, SA1, LN2), but they did not appear every winter until after c1965 (AS, HK, JT1, NI, SA1). Subsequently, caribou increased and expanded gradually around the coast of Hall Peninsula until c1990 (KK, MP, NI, OQ, SA1, Fig. 3.6-3.7). From c1974 to c1984, caribou expanded through the mountains of eastern Hall Peninsula and onto islands east of the peninsula and in southern Frobisher Bay (GU, JM, KK, LN2, PK1, PN2, SA1, SA2, SK, Fig. 3.6). Then in the early 1990s, caribou abundance decreased on islands along eastern Hall Peninsula (Fig. 3.7). By winter c1993, caribou abundance on western Hall Peninsula had decreased to less than during the 1980s and caribou started to feed on very steep terrain (GU).

Caribou were relatively numerous around northern Frobisher Bay during c1900-26 (Fig. 3.3), but by the early 1930s they were rare (PN2). Caribou first reappeared c50 km north of the bay during c1947-49, and were usually seen in groups of only one or two during winter in the early 1950s (AS, HK, JA, JT1, KK, LN1, SA1). During c1956-59, some caribou wintered within c20 km of the bay (LN1, SA1), but then retreated farther inland until c1966 (AS, JT1, LN1, MP, SA1, Fig. 3.5). Caribou were more common near Amadjuak Lake from the 1930s until the 1960s (LN1, Fig. 3.4-3.5). In winter during the 1960s and 1970s, the area c50 km northwest of Frobisher Bay became the main Iqaluit hunting area (AS, SA1), but some Inuit hunted near McKeand River to the northeast (JT1, LN2, Fig. 3.5-3.6). During winter in the mid-1970s, caribou were c25 km inland (SA2), and expanded their range to the coast of Frobisher Bay by c1980 (JT1, LN1, PK1, SA1, Fig. 3.6).

By the mid-1980s, the winter range of caribou near northern Frobisher Bay was drifting south toward the coast as caribou abundance declined farther inland (PK1, Fig. 3.7). In winter c1989, caribou drifted southeast toward Hall Peninsula (GU, SA1). In the early 1990s, the winter range extended only 35 km north of Frobisher Bay, and caribou began using islands in the northern part of the bay (LN2, PK1), while caribou abundance was decreasing on the west coast of Hall Peninsula. Based on the changes in recent distributions of caribou seen by 1985, PN2 predicted that ". . . maybe there will be no caribou like my father said."

3.3.5 McKeand River hunting region

During the 1930s, no caribou were seen along the western coast of Cumberland Sound, except for a few during winter in one small valley (PN1). This area expanded slightly after c1939, and caribou were found in two other areas in c1941 (Fig. 3.4). In the early 1950s, abundance increased slightly (PN1). In winter c1955, caribou increased and expanded into other areas along western Cumberland Sound (CA, PN1, Fig. 3.5). During winter after c1964, caribou occupied most of the coast of western Cumberland Sound (CA, PN1, Fig. 3.6). Caribou abundance increased in all seasons until the late 1970s, but declined after the mid-1980s (JK1, PN1, Fig. 3.7).

During summer and winter, caribou occurred on the plateau north of McKeand River from c1921 (or before) until the early 1970s (EN1, PA2, Fig. 3.3-3.5). During summer, caribou abundance was always lower than that northwest of Nettilling Lake, and in winter caribou abundance was even lower (EN1, EN2, PA2). During the 1930s and 1940s, abundance north of McKeand River was highly variable, with none being found in some years (EN1, NI). In c1974, caribou increased west of the mouth of Nettilling Fiord (EN1), near areas where TM occasionally saw caribou during c1932-62 (Fig. 3.4-3.5). Subsequently, no informant hunted inland on the plateau during summer. A few caribou were seen in winter during the late 1980s and early 1990s (JE, SK).

Caribou occurred east of Amadjuak Lake in summer c1920, but there were fewer than northwest of Nettilling Lake (EA, Fig. 3.3). Caribou abundance declined during the late 1920s, 1930s and 1940s, but hunters usually got a few caribou within the special caribou area near Amadjuak Lake (EN2, EP, LN1, SA1, Fig. 3.2-3.5). No informants hunted near Amadjuak Lake from the mid-1960s to the mid-1970s. From the late 1970s until the early 1990s, the winter range of caribou was similar to earlier distributions, and abundance gradually increased during this latter period (JE, SK, Fig. 3.2.E).

3.3.6 Nettilling Lake hunting region

The plains north of Koukdjuak River were an important summer caribou hunting area from c1916 (or before) until c1967 (EA, PA1, EN1, TM, Fig. 3.3-3.5). During c1916-23 many caribou occurred along the northwestern shore of Nettilling Lake (Fig. 3.3), but subsequently hunters had to travel at least 35 km to the coastal wetlands along Foxe Basin or to Koukdjuak River before finding sufficient caribou (EN1, PA1). After c1924, either the overall abundance of caribou decreased, or caribou became more scattered near the lake in response to increasing numbers of hunters (PA1). Caribou abundance in summer was lowest during c1939-55 (PA1, Fig. 3.4). None of the elders reported a noticeable migration of caribou on the plains north of Koukdjuak River before c1960 (AE, Fig. 3.5), including c1916-23 when abundance was high (EA). During July and August c1977 to c1982, MS saw many caribou crossing eastern Koukdjuak River toward the south, and migrating eastward along the north shore of the river (Fig. 3.6).

During September and early October from c1916 (or before) until c1994, caribou migrated southeastward from northern Nettilling Lake across Camsell Bay (AE, EA, JE, JK1, MS, PA1, SK, TM, Fig. 3.3-3.7). Between c1924 and c1945, cows migrated through Camsell Bay mainly during September, while bulls occurred in southern Camsell Bay in August (EA, PA1, EN1, JE, TM). Compared with the 1940s, the numbers of migrating caribou increased substantially by the 1970s (JE). During the early 1980s, cows started migrating southward across the bay in mid-August (JE, MS, Fig. 3.5).

From the mid-1920s (or before) until at least the early 1960s, caribou wintered south and east of southern Nettilling Lake (AE, EN2, JT2, LN1, PP, SQ, SR, Fig. 3.3-3.5). During April-May, cows and some bulls migrated north toward Camsell Bay (AE, EN2, LN1, NI). Caribou apparently decreased around southern Nettilling Lake in winter during the late 1930s (NI, Fig. 3.4), but remained in numbers sufficient for the one family living there during c1944-49 (JT2).

During winter from c1916 to 1994, several informants (AE, CA, EA, EK, JE, JK1, PA1, PA2, SK) hunted caribou migrating north across Camsell Bay in late winter and spring (Fig. 3.3-3.7). Before the 1920s, the number of caribou apparently was quite consistent (EA, Fig. 3.3), but from the early 1920s to the mid-1950s, caribou abundance was highly variable, with none being seen in some years because of increased annual variations in timing of the migration (PA1, Fig. 3.2.F). From the mid-1960s to the mid-1980s, caribou abundance in Camsell Bay began to increase as caribou began to overwinter there (EN1, JE, Fig. 3.2.F). The abundance of caribou overwintering in Camsell Bay decreased noticeably by the early 1990s (SK, Fig. 3.2.F, 3.7).

3.3.7 Tassialukjuaq hunting region

JK1's father saw caribou throughout Tassialukjuaq region during c1900-10, but from c1920 until c1955 caribou were seen rarely (CA, EA, EK, JE, JK1, JM, PA1, PA2, TM, Fig. 3.2.G, 3.3-3.4,). Beginning in the late 1950s and early 1960s, caribou were seen more often (EK, JE, JK1, SK, Fig. 3.5). Along

Nettilling Fiord, caribou gradually increased in abundance and expanded their range towards the coast of Cumberland Sound from the 1960s into the 1980s (JE, SK, Fig. 3.5-3.6). From c1951 to c1985, caribou also increased and distribution expanded around Tassialukjuaq lake (JE, EK), but since winter c1985 caribou abundance has decreased markedly (JE, Fig. 3.2.G, 3.7). As abundance decreased near Tassialukjuaq in the late 1980s, caribou began overwintering closer to Cumberland Sound, first appearing at the coast in winter c1989 (JK1, Fig. 3.7).

3.3.8 Cumberland Peninsula hunting region

During summer in the late 1800s, caribou were rare near Clearwater Fiord, so hunters travelled c75 km inland to the Penny Ice Cap to get enough caribou (JK1). Subsequently, northeastern Cumberland Sound became an important hunting area as caribou increased and expanded into this region from Tassialukjuaq during the 1910s (EA, EK, PA1). In the early 1920s, caribou were found on islands in northern Cumberland Sound throughout winter (EK, PA1, Fig. 3.3). Until the mid-1920s, many caribou migrated southeastward toward Pangnirtung during September-October, returning to the northwest during spring (EA, EK, PA1). During the same period, other caribou migrated north to summering areas south of the ice cap (EK). Winter c1925 was the last year that caribou were found extensively between Clearwater Fiord and Pangnirtung; after that, the remaining caribou migrated only to the north (CA, EK, PA1, PA2). During the 1930s, fewer caribou returned each autumn to the coast from the inland summering areas, and by the 1940s groups of one or two caribou were seen occasionally near Clearwater Fiord during winter (EK, JK1, JM). No caribou were seen near Clearwater Fiord in winter between c1942 and c1962 (EK, Fig. 3.2.G).

During summer in the early 1930s, fewer caribou were seen near the Penny Ice Cap over c40 km inland (EK). In the 1940s and 1950s, caribou were seen rarely within c80 km of the coast in summer, and hunters often travelled inland to the plateau previously hunted by JK1's father in the late 1800s (CA, EK, JK1, PA1, Fig. 3.4)."There just was not any more caribou. In the winter, it touched all of us" because of inadequate supplies of caribou-skin clothing (EK).

After c1957, caribou slowly increased inland of Clearwater Fiord, but abundance was low and only bulls were found during winter (EK, JK1, JM). After c1962 distribution expanded noticeably in winter (EK, JK1), and the winter abundance of caribou increased mainly in inland areas until the late 1970s (CA, JK1, SK, Fig. 3.6). Then in the mid-1980s and 1990s, caribou abundance increased markedly along the coast (JK1, SK, Fig. 3.2.G, 3.7). During c1990, caribou started migrating in large numbers from the northwest along Clearwater Fiord (JK1, SK). This northwest-southeast migration was similar to that observed before the 1930s. In winter 1994, caribou began wintering on islands in northeastern Cumberland Sound (JK1, SK). SK reported that "thousands" of caribou migrated from the west in autumn 1994.

Pangnirtung (Pangnirtuq, in Inuktitut) means place with mature male caribou. In the early 1900s, JK1's father hunted near Pangnirtung, finding many bulls in summer and early autumn (EK, Fig. 3.3-3.4). The last caribou near Pangnirtung were seen during the early 1930s (EA, JM). The coastal area southeast of Pangnirtung was an important summer hunting area in the early 1900s (EA, EK, PA1, Fig. 3.3). In winter from c1923 to c1933, caribou were found in the valleys east of Pangnirtung and other fiords (EA). Only a few caribou remained in the valleys northeast of Pangnirtung in the 1940s (GU, Fig. 3.4). Nevertheless, more caribou apparently occurred on southeastern Cumberland Peninsula than near the coast of northern Cumberland Sound in the late 1940s (JM, PA1). In 1994, JK1 predicted that the caribou would soon migrate past Pangnirtung onto southeastern Cumberland Peninsula.

3.3.9 Area known by the informants

The informants did not know the entire potential range of South Baffin caribou in any period. Some areas were unknown to hunters in all seasons in all decades due to terrain ruggedness (SA1) or distances from informants' homes (EK), while others were inaccessible only in some seasons (EK, SA1). During winter in the 1940s, the known area peaked at 98,000 km^2 when hunters had to search larger areas because caribou were scarce. The known area during winter was lowest when caribou were close to the coast; i.e., an average of 54,000 km^2 during winter 1910-23 and 61,000 km^2 during winter 1970-93. During each decade, the area known during spring was 99-101% of that known during winter. The smallest known area occurred during autumn (50-67% of winter) when travel becomes difficult during freeze-up. During decades when caribou were abundant and/or increasing (i.e., 1910 and 1950-1993), the area known in summer was 61-71% of that known in winter. During the decline in caribou abundance during 1920-43, the known summer area was 82-84% of that in winter, reflecting increased need to find caribou during summer before caribou distributions became scattered and unpredictable during winter.

Other factors also affected the amount of area known by the informants. Most informants were active hunters from c1940 until 1963, while the older informants provided most earlier information and younger hunters provided most recent observations. As well, during the early 1900s, commercial whaling and sealing reduced the time available for caribou hunting in most seasons (EA). In the 1960s, movement into settlements, increasing employment and a die-off of sled dogs similarly reduced the mobility of most informants. Then, by the late 1960s the snowmobile allowed hunters to explore some rugged and/or distant areas that had been less accessible by dog team (EK). These combined factors would have yielded a historical pattern of land use inconsistent with that described collectively by the informants. Therefore, I concluded that changes in the proximity of caribou to the coast during the 1900s were the major influences on the amount of area known by the informants as detected in this study.

3.3.10 Population trends of South Baffin caribou

Some informants assumed that when caribou decreased in their hunting region, they emigrated to another, resulting in no overall change in the total population. In other words, local sub-populations were cyclic, but the overall population may not be. However, none of the informants hunted all regions, and did not have firsthand or parental knowledge to support such an assumption. Most hunters never knew where the caribou went once they became scarce (EK). Even though the overall abundance of caribou did change across southern Baffin Island, Inuit knowledge holds that caribou have never completely disappeared (LN1).

Although the timing of changes in caribou abundance varied somewhat between hunting regions (Fig. 3.2.A-H), the trends in all regions did produce major fluctuations in the overall abundance of the whole population during the 1900s (Fig. 3.2.I). The population apparently experienced a minimum average annual decrease of 9% (i.e., $r = -0.089$) from 1910 to 1943; followed by a minimum average annual increase of 8% (i.e., $r = 0.073$) from 1943 to 1983. The decline on Hall and Cumberland peninsulas began about ten years later than in other regions, but the sub-populations reached their lows in the 1940s when others did. Abundance began increasing in most areas in the 1950s, but the rates of increase varied between regions. Major increases in abundance in the 1990s in some regions could only be explained by immigration from adjacent regions. Based on Inuit knowledge, the abundance seen in the 1990s probably represents a long-term population peak for South Baffin caribou.

Fluctuations in caribou abundance and distribution on southern Baffin Island occurred regularly over the lifetime of an elder (JP, LN1, NI, SA1), a periodicity of 60-90 years. Keith (1974) called such predictable fluctuations, "cyclic". The informants' elders, now dead, accurately predicted changes in caribou abundance and distribution 30-80 years in advance, based largely on the cyclic nature of the population (GU, LN1, NI, SR). For example, if caribou numbers were high when the informant was a child, he was then told that there would be very few caribou and he might face starvation while he was raising his children, but when he became an elder, caribou would once again become abundant. As children, several informants could not visualize the changes predicted by their elders, but have seen most of these predictions fulfilled during their lives.

3.4 Discussion

Several types of recollections indirectly suggested changes in abundance and distribution of caribou, including: changes in hunting areas, age when the informant first saw or tasted caribou, ability to obtain sufficient skins or meat, references to being cold during winter and dependence on outside sources for caribou skins or meat. However, such recollections do not necessarily indicate changes in caribou populations because they can also be caused by illness, moving to a new residence (e.g., after a marriage), lack of hunting equipment (e.g., bullets), sled dog epizootics and many other factors. The initial discussion of the informants' biography usually revealed contextual information about such factors (Chapter 2). Whenever an informant directly or indirectly implied a population change among caribou, I asked several questions to refine the observed distribution of caribou and to directly compare the abundance with other areas and/or periods with which the informant was familiar.

Inuit knowledge described changes in the South Baffin population that were useful in predicting future changes because of their sequential pattern:

1. During periods of maximal caribou abundance, some wintering areas are used by cows exhibiting two distinct migratory patterns.
2. Before caribou decrease, they occupy small islands several km off Baffin Island, and feed on very steep terrain.
3. Caribou in a given wintering area usually decrease (or increase) between subsequent winters as fewer caribou (or more) return from their summering areas.
4. Sometimes sub-populations emigrate en masse to adjacent areas where a new winter range is established ("range shift").
5. During a decline and subsequent population low, caribou distributions become scattered and unpredictable from year to year ("range volatility"), except during summer west of Nettilling Lake.
6. During population lows, caribou are reliably found only in special areas, but both group size and group density are low.
7. During population increases, caribou re-occupy wintering areas abandoned for several decades, and then expand their range into adjacent areas ("range expansion").
8. Later in the increase phase, the winter range will expand on one front, but contract on other fronts ("range drift").

3.4.1 South Baffin caribou, 1900-1930

South Baffin caribou were at or near peak abundance during 1910-13, and subsequently declined to a low in the early 1940s (Fig. 3.2). In 1915, Duval estimated one million caribou on Baffin Island, and in 1925 Burwash suggested that each of five caribou populations contained many thousands (MacPherson 1963). Although unreliable, these estimates generally corroborate the abundance of caribou reported by Inuit about 60 years later. Written reports confirm that caribou occurred along the coast and islands of Hudson Strait in 1897, and inland on Foxe and Meta Incognita peninsulas and near Mingo and Amadjuak lakes at least until c1920 (CDMF 1898; Bell 1901; Fleming 1910, 1911, 1930z; Fleming in Millward 1930; Washburne and Anauta 1940; Pitseolak and Eber 1993). After low caribou abundance along western and northern Cumberland Sound from 1894 to 1909 (Hantzsch 1977), caribou increased there 12 or more years later than along Hudson Strait. Subsequent reports by Soper (1928) and RCMP (1928, 1932) corroborated Inuit knowledge that caribou were abundant on northern Cumberland Sound for no more than 20 years.

The virtual disappearance of caribou on Foxe Peninsula, the scarcity of caribou skins, and the change in caribou hunting areas to north of Amadjuak Lake during the mid-1920s was corroborated by Burwash (Millward 1930), Putnam (1928), RCMP (1928, 1930, 1931) and Soper (1928, 1944, 1981). Starvation of an Inuit family after a failed caribou hunt in 1929 was reported by McKellar (RCMP 1931). Nevertheless, some Inuit knew where a few caribou occasionally occurred on Foxe Peninsula (OP, PP, SR; Soper 1944). Caribou were more common (yet decreasing) on Meta Incognita Peninsula until 1927 (RCMP 1927, 1928; Soper 1928). By 1930, the HBC was importing caribou skins into Kimmirut from Alaska (Soper 1981). On Hall Peninsula, supplies of caribou skins were generally inadequate after 1928, with 1930 being an exception (RCMP 1928, 1929, 1930, 1931), indicative of unpredictable caribou distributions during periods of decline.

During 1900-30, the abundance of caribou northwest of Nettilling Lake during summer and in eastern Nettilling Lake during autumn was also observed by non-Inuit in 1902, 1910 and 1925 (Soper 1928; Millward 1930; Hantzsch 1977). Soper (1928, 1981) observed an abundance of caribou on eastern Nettilling Lake during spring in the mid-1920s. Consistent with informants' reports, neither Hantzsch (1977) nor Soper (1928) reported caribou migrating across Koukdjuak River during summer in 1910 and 1926, respectively. Hantzsch (1977) and Soper (1928) also reported that caribou abandon the plains west of Nettilling Lake from late autumn to early spring.

Although not reported by the informants, the HBC encouraged Pangnirtung Inuit to kill more caribou than they needed to ship hides and sinew to Labrador during the early and mid-1920s (RCMP 1926). As EK reported, the migration west of Pangnirtung changed in autumn 1925, making caribou clothing rare (RCMP 1927). From 1925 into the 1930s, several RCMP officers reported that caribou or caribou sign were found south and east of Pangnirtung (Soper 1928; RCMP 1928, 1930, 1932), although informants reported a general scarcity of caribou.

In summary, large increases near Cumberland Sound did not occur until c1910 as opposed to the late 1800s along the coast of Hudson Strait and Frobisher Bay. The subsequent decline of caribou occurred 5-10 years earlier on Foxe Peninsula (c1920) than on Meta Incognita (c1926) and Hall (c1928) peninsulas. About 5-10 years before caribou decreased in each area, caribou began using smaller islands. The decline on Cumberland Peninsula was marked by a change in the dominant migratory pattern, and by the late 1920s, caribou occurred mainly on eastern parts of the peninsula. As the decline began in most hunting regions, caribou abundance dropped within a few years, suggesting mass emigration. Although caribou abundance was higher near Nettilling Lake than elsewhere by the late 1920s, signs of decline also appeared in that region. By the late 1920s, winter ranges had become unpredictable except on eastern Cumberland Peninsula. Despite the overall decline, some caribou persisted within all hunting regions at the end of this period.

3.4.2 South Baffin caribou, 1930-60

Caribou across southern Baffin Island continued to decline during the 1930s, reached a low in the 1940s, and began a slow recovery in the 1950s (Fig. 3.2, 3.3). Throughout this period, caribou were generally rare and their distribution, unpredictable, even during summer. Special areas described by the informants' elders were the only areas where some caribou could be found reliably. Population estimates by non-Inuit during this period (Manning 1943; Wright 1944; Kelsall 1949; Turner to Berry in MacPherson 1963; Tener and Solman 1960) generally confirm the low abundance, but were unreliable (MacPherson 1963). After recalculating Tener and Solman's (1960) estimate, MacPherson (1963) suggested that only 25-30,000 caribou occurred on all of Baffin Island in 1960, but their numbers were increasing rapidly. Although inadequate by current standards, aerial surveys by Kelsall (1949) and Tener and Solman (1960) confirmed some wintering areas identified by informants, missed areas known by the informants and identified other areas unknown to the informants. Therefore, caribou distributions were greater than those known either to the informants in this study or those who conducted the surveys.

By the early 1930s, the most severe decrease in caribou abundance had occurred from Foxe Peninsula east to Hall Peninsula. Most Inuit in these areas were wearing 2-5-years-old caribou parkas (RCMP 1932, 1933). Some caribou occurred locally on Cumberland Peninsula in the 1930s (RCMP 1932, 1933, 1937). Manning's (1943) descriptions of caribou distributions and abundance on southern Baffin Island during 1938-40 agreed with those of the informants, where their information overlapped.

Using RCMP questionnaires and HBC reports during the early 1940s, Wright (1944) concluded that caribou were very scarce or absent west of Meta Incognita Peninsula, when 15 Cape Dorset families lived near Amadjuak and Nettilling lakes. As well, Cape Dorset Inuit traded 200 caribou skins annually with Inuit from Igloolik, and traders imported skins into Cape Dorset. A few small herds occurred on Meta Incognita Peninsula in spring 1942. Caribou were found about 120 km inland from Frobisher Bay and northwestern Cumberland Sound in autumn and early winter. Many caribou wintered near southern Nettilling Lake and summered on the coast of Foxe Basin. Wright's (1944) description of caribou distributions, although vague, agreed with those described by Inuit informants 40-50 years later.

Inuit knowledge suggested that the increase did not begin in all hunting regions at the same time or at the same rate. Apparently increases began west of Cumberland Sound and around Nettilling Lake during the 1940s (Fig. 3.2.E-F), and as predicted caribou increased near Mingo Lake a few years before caribou expanded onto Foxe Peninsula (Fig. 3.2.A-B). By 1960, the increase and expansion was well underway near Mingo Lake and onto Foxe Peninsula, but had barely begun elsewhere.

3.4.3 South Baffin caribou, 1960-94

Tener (1961), MacPherson (1963) and Chowns (1979) recognized some of the inadequacies in caribou survey design and execution over Baffin Island. In 1974, estimates from incomplete surveys suggested no increase in caribou abundance since the early 1940s (Elliott and Elliott 1974; Redhead 1979), and thus are incongruous with Inuit knowledge. In 1978, Chowns (1979) conducted the most accurate survey yet over some of southern Baffin Island, but he could not determine the population trend because of past and continuing survey problems. Nevertheless, Calef (1980) used Chowns' result to incorrectly conclude that caribou populations on Baffin Island were decreasing during the 1970s.

According to my compilation of Inuit observations, caribou abundance increased across most of southern Baffin Island from 1960 until the mid-1980s, after which caribou numbers have either peaked or stabilized (Fig. 3.2.I); Inuit knowledge suggests the former. Caribou winter ranges expanded from inland areas toward the coast; abundance increased at different rates in different regions; range expansion was followed by range drift as inland abundance decreased; and eventually caribou occupied small islands up to 20 km off the coast. On Foxe Peninsula, range drift was followed by a massive shift in winter distribution. The process of range expansion and drift has occurred on Meta Incognita and Hall peninsulas, and from northeastern Nettilling Lake to Tassialukjuaq to Cumberland Peninsula. Several informants have predicted that the process of range shift will occur in these areas within a few years.

Caribou on Foxe Peninsula increased and expanded throughout the 1960s (Rippin 1972). A caribou ear-tagging project from 1974 to 1982 (unpublished data; Kraft 1984) and aerial surveys in 1978 (Chowns 1979) and 1984 (Chapter 4) confirmed the expansion of winter range on the peninsula during the late 1970s and 1980s. About 3.5 caribou·km^{-2} occurred west of Meta Incognita Peninsula in autumn 1984. The emigration of caribou from Foxe Peninsula, predicted and subsequently observed by Inuit, was confirmed in April 1992 when only 0.2 caribou·km^{-2} were observed during an aerial survey (Chapter 4).

Caribou increased more slowly on Meta Incognita Peninsula than on Foxe Peninsula from the 1950s until the late 1980s. During an aerial survey in March 1982, caribou were found at a density of 0.2·km^{-2} mainly west of Kimmirut (Chapter 4). The sudden increase in winter abundance on Meta Incognita Peninsula in the late 1980s was corroborated in an April 1992 survey when a density of 5 caribou·km^{-2} was found (Chapter 4).

Reports by Bourque (1975), Chowns (1980) and Chowns and Popko (1980) confirmed caribou distributions in the Hall Peninsula region during the 1970s. Calving areas expanded from three watersheds in 1979 (Chowns and Popko 1980) into two adjacent watersheds by 1982 (unpublished data). During autumn 1984, caribou were concentrated from northern Frobisher Bay to 50 km inland (unpublished data). By the early 1990s, winter range was drifting into the town of Iqaluit and onto islands in northern Frobisher Bay.

Tener (1961), Rippin (1972), Elliott and Elliott (1974), Chowns (1979) and Ferguson (unpublished data) confirmed that caribou continued to winter south of Nettilling Lake and along eastern Amadjuak Lake from c1960 to the early 1990s. The increase near Tassialukjuaq in the 1970s was confirmed by Elliott and Elliott (1974), Redhead (1976) and Chowns (1979). Ear-tag data (unpublished data) corroborated that caribou from eastern Nettilling Lake wintered mainly near the coast of northern Cumberland Sound during the 1980s, and immigrated onto northwestern Cumberland Peninsula by the early 1990s. In April 1991, no sign of caribou was seen during an aerial survey (unpublished data) on eastern Cumberland Peninsula, the only unoccupied area that Inuit predict caribou will soon occupy.

3.4.4 Seasonal migrations and caribou ecotypes

Baffin caribou migrate most extensively during seasons of snow-melt and snow-accumulation when travel on the land by humans is most restricted, making firsthand knowledge of the migration difficult. Soper (1928, 1944, 1981), Elliott and Elliott (1974) and Brody (1976) reported lengthy, often complicated migratory patterns of caribou on Baffin Island. In this study, informants' firsthand observations of migration was limited to a few tens of km (Fig. 3.3-3.7). When informants speculated about the destinations of migrating caribou, they did not suggest complicated scenarios like those of Soper (1928). Satellite telemetry is probably the only tool that could elucidate longer seasonal migrations of the various sub-populations.

Based on observations of the informants, cows and immature caribou usually migrated inland away from wintering areas anytime between early March and late May, and returned between July and early December. Although cows usually occupied more rugged terrain inland from coastal terrain used by bulls in winter, they tended to move to coastal areas during periods of high abundance (e.g., 1910-23 and 1980-93). Also during periods of abundance, cows migrated inland later in spring and returned earlier in summer or autumn. Bulls moved inland during September, returning to their wintering and summering areas by early December. When cows and bulls were seen together during October and November, they were observed moving quickly over large areas. After the rut, mature cows and bulls remained segregated in different groups until the following autumn. Some bulls migrated inland in late spring or early summer, but apparently did not migrate as far as the females.

In summer, cows utilized wetlands along Foxe Basin and near large lakes and rivers on the peninsulas (Fig. 3.3-3.7). Thus, cows are widely scattered during summer, 10-400 km from known wintering areas. Bulls also distribute themselves widely across the island during summer, but usually on or within 100 km of their wintering areas.

Inuit observations of caribou distributions, seasonal migration patterns and physical characteristics suggest that South Baffin caribou are composed of two distinct ecotypes, Natsilik and mountain, and several sub-populations. Some informants in all four settlements could distinguish migratory Natsilik (or Nettilling) from resident mountain caribou. Natsilik cows exhibit the greatest migratory tendencies, usually migrating out of wintering areas earlier in spring and returning later in autumn than mountain caribou. Natsilik caribou also tended to utilize lower elevations year-round (i.e., uplands in winter and coastal wetlands in summer). In extremely mountainous terrain, mountain cows migrate to higher elevation, calving on snow-covered peaks and then congregating in snow-free valleys (AN1; Soper 1928). In other areas, mountain cows migrated inland in late spring and are found near lakes on high plateaux during summer.

Although CA, JK1, EK, EN1, KK, LN1, NI, SA2 and SQ recognized the two types of caribou by differences in migratory behaviours, EN1, KK, LN1, NI and SQ also reported that Natsilik and mountain caribou differ physically. Natsilik caribou are smaller with shorter legs. Reportedly, mountain caribou near Iqaluit are faster because of their longer, slender bodies and longer legs (LN1). LN1 and SQ thought that Natsilik caribou were descendants of Norwegian reindeer transplanted to the Hudson Strait coast in the early 1920s; while EN1 disagreed because the pelage of Natsilik caribou and the introduced reindeer differed.

Dominant migratory patterns in several areas changed as major changes in caribou abundance occurred. During the population high in 1910-23, both migratory patterns were observed near Clearwater Fiord (Fig. 3.3), but after abundance decreased in the 1930s, the remaining caribou migrated inland to higher elevations (EK), consistent with the behaviour of mountain caribou (Fig. 3.4-3.6). In the late 1980s, both migratory patterns reappeared in this area as caribou abundance increased in the area (JK1, SK). In the 1990s after continued increases, the northwestwards movement, characteristic of Natsilik caribou, dominated (SK), as in the 1920s (EK) (Fig. 3.7). Similar shifts in dominant patterns were also observed on Foxe Peninsula in the early 1980s (SQ), on Meta Incognita Peninsula in the early 1990s (SA2), and near northern Frobisher Bay during the 1980s and 1990s (KK, LN1, NI). Although the Natsilik migration pattern dominated after rapid population increases, informants reported that the less-dense mountain caribou continued their traditional migrations. During population lows, the migrations of mountain caribou dominate in areas where caribou can be found, except around Nettilling Lake.

3.4.5 Caribou population cycles and Inuit predictions

The compiled information from all Inuit informants suggested a period of 60-90 years between peak population levels during the 1900s (Fig. 3.2). Although personal and parental observations can document only the past 90 years, Inuit knowledge holds that fluctuations in the South Baffin caribou population are cyclic; i.e., repeating at regular intervals equal to the life span of an elder. All informants found this periodicity to be dependable based on predictions made by their elders and their own subsequent observations. By backdating the periodicity of the caribou population fluctuations, the previous population low should have occurred sometime during 1865-85 and the previous high, during 1835-55.

Caribou were rare in coastal areas during winter in the late 1870s and 1880s (Tyson 1879; CDM 1886, 1887; Boas 1974; Abbes 1992). During 1876-78, Kumlien (1879) reported that caribou numbers had declined in previous years on Cumberland Peninsula and northern Cumberland Sound. Bulls "no longer" lived near Pangnirtung in the early 1880s (Müller-Wille and Barr 1998, and Inuit from Cumberland Sound had to make extensive inland trips to hunt caribou (Kumlien 1879; Tyson 1879; Boas 1974). In the early 1880s, the supply of caribou skins in some winters was deficient (Boas 1974). Inuit from Cumberland Sound, Hudson Strait and Frobisher Bay sometimes met while hunting caribou near Nettilling and Amadjuak lakes (Boas 1974). Ashe (CDM 1886) and Tyrell (CDM 1887) recorded no observations of caribou while on Big Island during 1884-86. These caribou distributions and Inuit hunting patterns during the late 1870s and 1880s were similar to those during the population low in the 1940s, thus apparently corroborating the hypothesized periodicity.

Hall (1864) lived on Hall Peninsula during 1860-62, shortly after the estimated timing for the previous peak (i.e., 1835-55). His reports suggested that caribou populations were in the late stages of a population peak, i.e., similar to that in the mid-1920s and the early 1990s. Apparently, caribou had been abundant along the coast before his arrival. Several years before Hall's visit, caribou had been very numerous on Resolution Island c25 km off Baffin Island in Hudson Strait (Sharkey in Hall 1864). In June 1861 Hall (1864) saw recent traces but no caribou on a small island c45 km from Hall Peninsula in Davis Strait. During 1860-62, summer distributions in Frobisher Bay were similar to those in the early 1990s. By late August, Inuit had caribou skins "in immense numbers", and bulls were common along northern Frobisher Bay, including the present site of Iqaluit. On the plateau of Hall Peninsula, Inuit could catch many caribou, being as dense as flocks of sheep seen by Tukulitu on the British Isles (Hall 1864).

Although the written records from the 1800s are limited spatially and temporally, they generally support Inuit knowledge that the South Baffin caribou population cycles over periods of 60-90 years.

3.4.6 Future directions

MacPherson (1963) examined previous written descriptions of population trends and movements among South Baffin caribou, and found many of them flawed. Given evidence of the inherent accuracy and precision of Inuit recollections as reported in this chapter and Chapter 2, this account of historical caribou distributions, abundance and migrations on southern Baffin Island establishes a vital baseline for the future management of this caribou population.

The data from this study highlighted major differences between the Inuit concept of caribou populations and that used commonly by caribou biologists. The Inuit apparently view caribou in biological units, each unit moving together, sharing common behavioural and physical characteristics, and not being tied to a specific geographical area. According to the informants, a given geographic area can be occupied by two distinct units or populations at the same time. Most informants suggested that when caribou decreased in one hunting area, they emigrated to another area; i.e., the population may not have decreased, it just moved.

This initial conclusion by Inuit often opposes that of biologists who often define a population as members of a species occupying a particular area; i.e., geographical rather than biological units (Futuyma 1986; Krebs 1985; Wilson 1980). Many biologists view decreasing abundance in a specific area as a population decline. Thomas (1969) delineated caribou populations (or "herds") based on identifiable calving grounds where caribou aggregations could be surveyed efficiently. Such delineation would agree with that of the Inuit only if the vast majority of cows showed long-term fidelity to their calving grounds. However, Inuit in Baker Lake explained the 1970s decline of the Qamanirjuaq herd through emigration of some caribou to other calving grounds (Heard and Calef 1986). Gunn and Miller (1986) found insufficient scientific evidence to reject fidelity of caribou, but Heard and Calef (1986) had to use immigration to explain an "unanticipated" 315% increase in the herd between 1980 and 1982. Subsequent radio-telemetry studies suggested that about 85% of Qamanirjuaq cows showed fidelity to the calving ground during 1985 and 1988, leaving Heard and Stenhouse (1992) with insufficient evidence to explain the initial increase of the early 1980s. The problem may have been that the telemetry research and changes in caribou distribution did not coincide.

Keith's (1974) definition of a population as a "group of individuals" does not tie delineation of a given population to a geographic area; it could be a mobile biological unit as in the Inuit view. The Inuit concept also has similarities with the concept of "metapopulation", a population of local populations tied together by immigration and emigration (Hanski and Gilpin 1991; Wells and Richmond 1995). Current metapopulation models mainly address the rates of extinction of local populations and the colonization of unoccupied habitats through immigration. Baffin Inuit suggested that although local populations change in abundance, these groups emigrate to other habitats before becoming extinct, unlike the presumption inherent in metapopulation models. As well, metapopulations deal with "spatially disjunct" groups (Wells and Richmond 1995), and thus do not currently account for the Inuit distinction between groups of caribou that may cohabit during the rut and winter, but have differing migratory patterns during other seasons.

By integrating Inuit knowledge that may describe future distribution changes with some accuracy, biologists could develop and test predictive models for caribou populations that incorporate the phenomena of range expansion, drift, shift and volatility. Although most Inuit apparently base their predictions on the sequence of population changes described by their elders, some have suggested ecological factors that apparently cause these changes (unpublished data). Once these insights are integrated into predictive population models, caribou managers could take pro-active actions that would address both future population change and their proximal causes, rather than reactive actions to past trends that may not continue in the future. The potential for accelerated anthropogenic climate change makes collaboration between caribou biologists, other scientists and the Inuit especially urgent (Ferguson 1996).

Inuit will have a permanent role in the management of wildlife in Nunavut (Nunavut Final Agreement 1993), and could incorporate their knowledge in population management with or without the cooperation of wildlife biologists. However, wherever indigenous peoples have occupied remote regions for several generations, their ecological knowledge probably has a broader temporal and spatial context than that of scientific surveys of wildlife populations. Careful and culturally appropriate compilation of indigenous ecological knowledge should provide important insights for wildlife ecologists and managers throughout the world.

4. MASS EMIGRATION OF ARCTIC TUNDRA CARIBOU FROM A TRADITIONAL WINTER RANGE: POPULATION DYNAMICS AND PHYSICAL CONDITION

4.1 Introduction

To varying degrees, predation, forage resources, forage accessibility and other factors have limited populations of caribou and reindeer in different ecosystems (i.e., forests, forest - tundra ecotones, and Arctic tundra) (Bergerud 1980; Klein 1991; Messier 1995; Ferguson 1996). For caribou permanently residing on Arctic tundra, evidence of population limitation by forage has come mainly from islands without natural predators and with little harvesting by humans (Ouellet et al. 1996). In some cases, *Rangifer* populations on Arctic tundra have experienced major declines and occasionally extinctions (e.g., Meldgaard 1986). On South Georgia, long-term depletion of lichen led to successful diet changes to other plant species (Leader-Williams et al. 1981). In several cases, long-term diet changes have been followed by population fluctuations, caused by inter-annual variations in accessibility of winter forage through snow (Tyler 1987; Adamczewski et al. 1988).

Miller (1982) suggested that mortality factors other than forage production (e.g., adverse snow-icing conditions) usually limits caribou populations below levels where forage could become the limiting factor. Nevertheless, Gaare (1997) has hypothesized that *Rangifer* and lichen-dominated communities have co-evolved, whereby periodic overgrazing resets succession to prevent the eventual domination of tundra communities by vascular plants.

Inuit have suggested that Arctic tundra caribou periodically shift winter ranges (e.g., Chapter 3) in response to forage depletion caused by long-term overgrazing. Overgrazing occurs when a caribou population annually consumes more biomass of winter forage than is produced on the proportion of winter range that is accessible under "prevailing" snow conditions (sensu Nellemann 1997). As annual overgrazing eventually depletes forage biomass that accumulated over several decades, individual caribou compete for lower quality forage (Klein 1968; Leader-Williams 1988). Despite local overgrazing, shifts of winter ranges could allow Arctic tundra caribou to maintain access to adequate forage over the long term. Before a population shifts to a new winter range, I expect that body size, physical condition, reproduction and survival would decline. After the shift, physical condition, reproduction and survival should quickly recover among adult caribou, while the body size of animals born after the shift should increase.

Inuit described changes in caribou winter distributions on southern Baffin Island during the 1900s (Chapter 3). In 1985, Inuit elders in Cape Dorset (Fig. 4.1) predicted a range shift of caribou from Foxe Peninsula (FP), based on observed declines in physical condition of caribou, recent winter foraging by caribou on small offshore islands and cliff faces, delayed spring migration of females, and unusual calving on and near the wintering area. During the late 1980s, Inuit hunters in Cape Dorset and Kimmirut reported that most of the FP sub-population apparently emigrated about 350 km to Meta Incognita Peninsula (MIP). The ecological cause suggested by Inuit was cumulative density-dependent effects of caribou on their forage over the previous 10-30 years (E. Peter pers. comm.).

I conducted research to examine several aspects of caribou biology due to shifts in winter range on Arctic tundra. I tested whether the changes in caribou densities on FP and MIP between the early 1980s and 1992 were significant. I examined

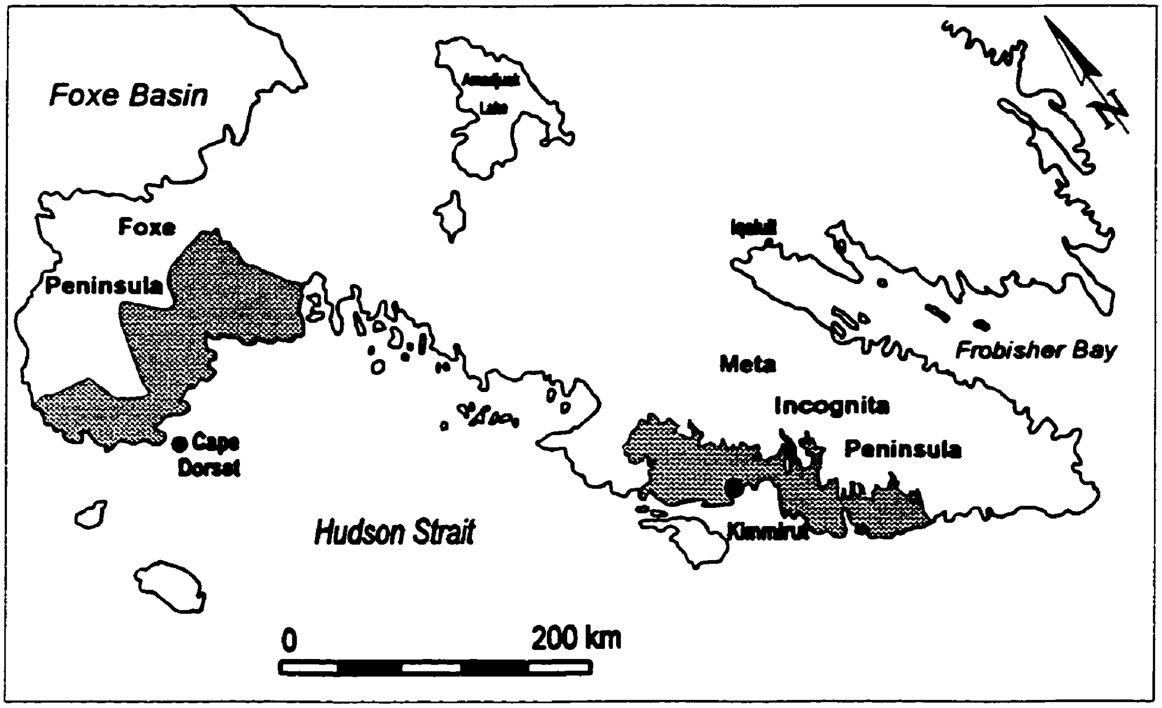

Figure 4.1. Intensive study areas (shaded) on Foxe and Meta Incognita peninsulas on southern Baffin Island, Nunavut during April 1992.

the predictions that during the period of range shift (1988-94), adult females (cows) on FP showed less fidelity to that winter range than caribou wintering on MIP. Assuming that adult males (bulls) also participated in the range shift, I predicted that after the shift, bull:cow ratios on the two peninsulas did not differ. I also predicted that caribou remaining on FP winter range had less fat and muscle reserves, and lower fecundity and recruitment than caribou on the MIP winter range in 1992. However, I predicted that body sizes of adult caribou on both ranges did not differ because most adults on MIP probably were born on FP.

4.2 Methods

4.2.1 Study area

Baffin Island (>500,000 km^2) forms the eastern margin of the Canadian Arctic archipelago, and the South Baffin caribou population occupies approximately half of the island (Ferguson 1989). Based on aerial surveys, the South Baffin population was estimated at 60,000 to 180,000 animals in the late 1980s (Ferguson and Gauthier 1992). The South Baffin population is composed of "sub-populations", defined as groupings of individuals within the population, each demonstrating fidelity to a local range over the short term (i.e., 10-30 years), leading to distinct short-term demographic characteristics due to differing ecological conditions among ranges (e.g., prevailing snow cover). Over the long term (i.e., 60-90 years), sub-populations interact through range shifts or mass emigrations, leading to shared long-term population trends (Chapter 3).

South Baffin caribou migrate onto their wintering areas during October-November and usually remain there until late April (Chapter 3). Satellite telemetry (unpublished data) showed that seasonal movements are most restricted from January to March, and migratory movements were not well underway until May. Fourteen caribou, which had been captured on MIP and FP and monitored for two years, had moved out of their wintering areas only three of 28 times by mid-April.

South Baffin caribou exhibit two seasonal migratory patterns; some migrating up to 400 km to their summering areas, and others remaining close to their wintering areas (Ferguson 1989, Chapter 3). Based on Inuit knowledge, movements that I observed during May 1992 and satellite telemetry (unpublished data), the majority of caribou in the two study areas spent summer on the extensive coastal lowlands south and west of Foxe Basin (Fig. 4.1) (Nettleship and Smith, eds. 1975, pp. 300-303). Some caribou may have been resident animals that would have summered near lakes and ponds near their wintering areas. Spatial differences in the quality of summer habitats of South Baffin caribou have not been studied.

In November 1978, Chowns (1979) estimated that 21,350 caribou (± 2230 SE) used central and eastern FP. This wintering area held 60% of all caribou within three major winter ranges occupied by South Baffin sub-populations. In the late 1970s and early 1980s, the FP winter range moved to the west and extended onto small islands in northwestern Hudson Strait, while eastern parts of the range were abandoned (Chapter 3). I refer to this as "range drift", expanding on one front while contracting on another. A subsequent survey in November 1984 confirmed the reported range drift and suggested that the sub-population had increased to about 34,410 (± 4650 SE) (unpublished data). In November 1988, J. Ikkidluak (pers. comm.) observed a massive immigration of caribou onto MIP.

No population estimates were available for caribou wintering on MIP before the 1980s. Chowns (1979) did not recognize it as a major wintering area in 1978. Although caribou had been increasing and expanding their winter range on MIP since the 1950s, abundance remained relatively low into the 1980s (Chapter 3). In March 1982, 1600 (± 335 SE) caribou were estimated to occur on MIP (unpublished data).

As muskoxen (*Ovibos moschatus*) do not occupy Baffin Island and Arctic hares are not known to occur in high densities, caribou are the primary prey of wolves (Clark 1971). Subsistence harvesting of caribou by Inuit has been unrestricted during the past 40 years. In 1982, Inuit in Cape Dorset and Kimmirut (Fig. 4.1) harvested 2260 and 550 caribou from the FP and MIP sub-populations, respectively (Donaldson 1988).

The terrain on the FP wintering area consists of rugged uplands up to 410 m above sea level (ASL). During winter, caribou largely abandon the northern coastal lowlands (25% of FP). Caribou occupy two terrain types on MIP: rugged coastal uplands below 305 m ASL and rugged plateaux 305-850 m ASL. Vegetation on most of FP and MIP is characterized by dwarf and prostrate shrub tundra, while some areas are in the low, erect shrub zone (Edlund 1990). Climatic conditions and plant communities on the plateaux of MIP resemble those at higher latitudes. Consequently, only uplands $\leq$ 305 m ASL on both peninsulas were included for aerial surveys and caribou sampling.

4.2.2 Caribou distribution and demography

To examine the predicted changes in caribou distribution and density, I utilized data from two aerial surveys of each peninsula conducted during winter. In late March 1982, caribou were surveyed on about 60% of MIP (18,350 km^2) where caribou were suspected to occur, and in early November 1984, on all of FP (11,650 km^2). Parallel transects were 6.4 km apart on MIP and 5.5 km apart on FP, and oriented approximately perpendicular to major river valleys. In both surveys, caribou were counted within 400-m wide strips on each side of a fixed-wing Cessna 337 flown about 122 m above ground level (AGL) at 140-195 km/h. I sub-sampled 20 random 7.5-km segments of transects from each of the 1982 MIP and 1984 FP surveys to compare between the two areas, and with subsequent surveys (see below).

Surveys of FP and MIP were also conducted in April 1992, after the winter range shift was observed by Inuit (Chapter 3). To assess differences in density, recruitment, and sex-age ratios, study areas of 6,540 km^2 on FP and 5,210 km^2 on MIP were established based on the knowledge of Inuit hunters (Chapter 3) and satellite telemetry data (unpublished data). Within each of the two study areas, caribou were counted along 20 7.5-km transects located randomly, with no transect being closer than 5.5 km to another. The transects were flown in a Bell 206L helicopter about 75 m AGL at 60-130 km/h, with a strip width of 400 m to each side of the aircraft (Miller 1991).

I tested for differences among the four surveys using Kruskal-Wallis one-way analysis of variance by ranks (Mehta and Patel 1997), followed by multiple comparisons between pairs of surveys (Siegel and Castellan 1988). Although the statistical tests were based on the actual number of caribou counted along each 7.5-km transect, mean densities are presented as $caribou{\cdot}km^{-2}$.

In 1992, after surveying each transect, I classified caribou by sex and age as the helicopter crisscrossed along the transect, staying within 2.5 km of the transect. Caribou were initially categorized as calves (i.e., ten months old), yearlings and adults. As large yearlings may have been mistakenly classified as adults, all yearlings were treated as adults in data analyses. The presence or absence of a vulva was used for sex determination. I attempted to classify at least 25 caribou along each transect. Because of low caribou density on FP, this objective was not met for any of the 20 transects, so caribou groups encountered incidentally while off transects were also classified. On MIP, the objective of at least 25 caribou per transect was met for all but one transect ($n = 11$ for that transect). The proportions of calves and cows, and bulls and cows were compared between the two peninsulas using the Z test (Zar 1984). Calf:cow and bull:cow ratios are presented with 90% confidence intervals (Czaplewski et al. 1983).

4.2.3 Winter range fidelity and emigration

During 7-22 April 1987-92, satellite telemetry collars (Telonics, Inc., Mesa, Arizona, USA) were placed on eight cows on FP (five in 1987, and one in each of 1988, 1989 and 1992) and six on MIP (four in 1988 and two in 1989). The majority of collars were deployed before the major range shift of autumn 1988, while some collars were deployed later to assess if FP cows continued to emigrate in subsequent years. Collars were distributed throughout occupied portions of the peninsulas. Caribou were captured using a gun net from a Bell 206 B or L helicopter. The collars transmitted data to satellites for 6-7 hours every four days for two years. Locations of the collars were determined by Service Argos, Inc. (Landover, Maryland, USA) based on the Doppler shift in signal frequency (Fancy et al. 1988).

To assess the fidelity of cows to wintering ranges on FP and MIP, I assumed that each animal represented the peninsula where it was initially captured. Cows with strong fidelity to a given wintering area should be found there during at least 75% of subsequent winters, while those with little fidelity should subsequently winter elsewhere in at least 50% of the time. To test for differences in fidelity to the two wintering areas, I grouped animals by the peninsula that they were assumed to represent, and compared the two groups by the wintering area occupied in each of two subsequent years, based on mid-February locations. These data were analysed using a X^2 likelihood ratio test (Mehta and Patel 1997). I also determined the distances from the capture location to relocations in the subsequent two years during mid-February for each animal. These distances were compared between the two peninsulas using the Wilcoxon-

Mann-Whitney test (Mehta and Patel 1997). To examine the timing of the emigration from FP as reported by Inuit, I used the Fisher exact test (Mehta and Patel 1997) to compare the fidelity of FP caribou during winter 1987-88 to that during subsequent winters.

4.2.4 Body size, physical condition, and fecundity

In April 1992, I collected samples and measurements from adult caribou on FP and MIP. The study area on each peninsula was divided into thirds along its longest side, and three cows and two bulls were to be randomly sampled from each third. This distribution was accomplished on MIP, with ten females and five males sampled. On FP, the ground crew could not locate animals in two-thirds of the study area, resulting in the collection of eight cows and six bulls from five different groups in the remaining third.

The age of each animal was determined from cementum annuli counts of incisors at Matson's Laboratory (Milltown, MT, USA). The age of one female from MIP was not determined due to a shipping error. The following data were recorded from each caribou: body length (nose to base of the tail, Langvatn 1977), femur length (Langvatn 1977), carcass weight (with metacari and metatarsi removed, Adamczewski et al. 1987*a*), gastrocnemius muscle weight (fresh, towel-dried, fat and tendons removed), back fat depth (Riney 1955), trimmed kidney fat weight (Dauphiné 1976), and fat content of femur marrow (by oven drying at 60°C for at least five days, Neiland 1970). The left femur, gastrocnemius muscle, and kidney with fat were collected from each animal. If a specimen on the left side was damaged by a gun shot, the specimen was collected from the right side. The presence or absence of a gravid uterus was recorded for each cow. Dissectible muscle and fat weights for each animal were estimated from the gastrocnemius muscle weight, and the back fat depth and trimmed kidney fat weight, respectively

(Adamczewski et al. 1987*a*).

Data on age, body size, and physical condition of each sex were compared between the two study areas using the Wilcoxon-Mann-Whitney test (Mehta and Patel 1997). Pregnancy rates of cows was compared using the Fisher's exact test (Mehta and Patel 1997). All statistical results are presented with two-tailed probability levels unless otherwise stated. Means are reported with standard errors.

Use of non-parametric statistical tests and my small sample sizes, especially for bulls, limited my power to detect differences between caribou in the two study areas. This low statistical power, coupled with supporting observations by Inuit hunters, makes me confident that the detected statistical differences are biologically significant.

4.3 Results

4.3.1 Caribou densities

Densities of caribou differed among the four aerial surveys ($X^2_3 = 43.0$, $P < 0.001$), allowing multiple comparisons between pairs of surveys. In the early 1980s, the density of caribou on FP ($6.2 \cdot \text{km}^{-2} \pm 1.6$) was higher ($P < 0.001$) than that on MIP ($0.23 \cdot \text{km}^{-2} \pm 0.10$). Between 1984 and 1992, caribou density on FP decreased ($P < 0.001$) to $0.28 \cdot \text{km}^{-2}$ ($\pm$ 0.12), while the density of caribou on MIP increased ($P < 0.001$) to $5.0 \cdot \text{km}^{-2}$ ($\pm$ 1.0) between 1982 and 1992. In April 1992, caribou densities were less ($P < 0.001$) on FP than on MIP.

4.3.2 Winter range fidelity and emigration

As predicted, cows collared initially on FP demonstrated less fidelity ($X^2_2 = 11.3$, $P = 0.005$) to that area than those collared on MIP (Table 4.1). FP cows were found in the same area seven of 16 times (44%) in subsequent years, compared to

Table 4.1. Fidelity[a] of radio-collared adult female caribou from wintering areas on Foxe (FP) and Meta Incognita (MIP) peninsulas on southern Baffin Island, Nunavut, during winter 1988-94.

Area at capture	Fidelity after capture		
	FP	MIP	Other areas
FP ($n = 8$)	7	8	1
P		0.005[b]	
MIP ($n = 6$)	0	12	0

[a] The frequency that individuals collared on a given peninsula were found there one and two years later during mid-February.

[b] Likelihood ratio test.

12 out of 12 times for MIP cows (100%). FP cows returned to their wintering area less often than my threshold of 50% suggesting little fidelity, while MIP cows surpassed my threshold of 75% that would indicate strong fidelity.

During mid-February, FP females were found 216 km (± 34) from their initial capture location, farther than MIP females (71 km ± 10, $U_{12,16} = 150$, $P = 0.01$). When FP females did return to their initial wintering area, the distance from their capture location (82 km ± 23, $n = 7$) was comparable to that of MIP females. When they wintered on MIP, they were 327 km (± 25, $n = 8$) from their capture location. The female that wintered elsewhere moved 279 km north of Amadjuak Lake (Fig. 4.1) to a wintering area previously identified by Chowns (1979).

Telemetry data corroborated Inuit reports of the timing of the initial emigration from FP (i.e., autumn 1988), with more cows returning to FP during winter 1987-88 than in subsequent winters (Fisher exact test, $P = 0.10$). Overall, the fidelity of all collared FP cows decreased from 80% (four of five relocations on FP) during winter 1987-88, to 33% (two of six) during winter 1988-89 and 20% (one of five) during winters from 1989-90 to 1992-93. Of four FP cows that emigrated to MIP in the first winter after capture, three returned to MIP again in the second winter, suggesting that they adopted it as a new wintering area (based on my threshold of 75% for strong fidelity). All MIP cows remained faithful to their wintering area throughout these years.

We had no direct evidence on whether bulls emigrated from FP at the same time as females. Assuming that both males and females emigrated from FP to the same extent, and that they both emigrated largely to MIP, the proportion of bulls among adult caribou should not have differed between the two peninsulas in April 1992. The relative proportion of bulls on FP (117 ± 33 : 100, $n = 127$) was similar ($z = 1.53$, $P = 0.13$) to that on MIP (86 ± 9 : 100, $n = 894$). The subsistence harvest of FP caribou by Inuit may have skewed the late winter bull:cow ratio on FP because of their 2:1 preference for cows to bulls during winter (Pattimore 1986) and the potential effects of high subsistence demand (Donaldson 1988) on this small subpopulation. Such sex-biassed harvesting would not have similar effects on the larger population on MIP. Because of these potential effects on FP and the similarity of the bull:cow ratios on both peninsulas, I conclude that adults of both sexes participated in the range shift.

4.3.3 Body size, physical condition, fecundity, and recruitment

The two measures of body size (i.e., body and femur lengths) did not differ ($P \geq 0.47$) between the two peninsulas for either sex (Table 4.2). The ages of females and males did not differ significantly between the two peninsulas ($P \geq 0.26$), although cows on FP were on average one year older than on MIP, and bulls on FP averaged one year younger (Table 4.2). Carcass weights of cows were lower ($P = 0.008$) on FP than on MIP (Table 4.3), probably due to differences in body condition (see below).

Gastrocnemius muscle weight for females on FP was less ($P = 0.04$) than that on MIP (Table 4.3). However, gastrocnemius muscle weight of males did not differ between the two peninsulas ($P = 1.0$). All three indices of fat reserves (i.e., back, kidney, and femur marrow fat) indicated better physical condition on MIP than on FP for both cows ($P \leq 0.001$) and bulls ($P \leq 0.03$). Both cows and bulls on FP had negligible amounts of estimated dissectible fat, lower than those on MIP ($P \leq 0.004$).

Because of the probable negative effects of overgrazing on productivity and calf survival, I predicted that fecundity (pregnancy rates) and recruitment (calf:cow ratios) on FP should be less than on MIP, and thus conducted one-tailed statistical tests. The ratio of 42 ± 16 calves : 100 cows on

Table 4.2. Mean age, body size and carcass weight (± SE) of adult caribou (> 1 year old) on historically grazed (Foxe Peninsula, FP) and recently occupied (Meta Incognita Peninsula, MIP) winter ranges on southern Baffin Island in April 1992.

Study area *U*, *P*[a]	Age (year)	Body length (cm)	Femur length (mm)	Carcass weight (kg)
Female				
FP (*n* = 8)	4.9 ±1.0	159 ±3	267 ±4	33 ±1
U, *P*	41, 0.67	48.5, 1.0	48.5, 0.47	69, 0.008
MIP (*n* =10)[b]	3.9 ±0.6	158 ±2	265 ±2	37 ±1
Male				
FP (*n* = 6)	2.8 ±0.5	166 ±3	282 ±7	41 ±4
U, *P*	21.5, 0.26	17.5, 0.70	17.5, 0.67	20.5, 0.35
MIP (*n* = 5)	3.8 ±0.8	167 ±6	277 ±7	45 ±4

[a] Wilcoxon-Mann-Whitney test.

[b] Except for age, for which *n* = 9.

Table 4.3. Mean body condition (± SE) of adult caribou (> 1 year old) on historically grazed (Foxe Peninsula, FP) and recently occupied (Meta Incognita Peninsula, MIP) winter range on southern Baffin Island in April 1992.

Study area *U*, *P*[a]	Gastrocnemius muscle weight (g)	Back fat depth (mm)	Kidney fat weight (g)	Femur marrow fat (%)	Dissectible muscle (kg)	Dissectible fat (kg)
Female						
FP (*n* = 8)	252 ±9	0 ± 0	5 ±1	26 ±1	23 ±1	0.0 ±0.04
U, *P*	63, 0.04	72, <0.001	72, <0.001	72, <0.001	63, 0.04	72, <0.001
MIP (*n* =10)[b]	276 ±7	13 ±2	31 ±4	89 ±1	25 ±1	2.8 ±0.4
Male						
FP (*n* = 6)	332 ±29	0 ± 0	7 ±1	31 ±0.03	31 ±3	0.1 ±0.04
U, *P*	15, 1.0	27, 0.03	30, 0.004	30, 0.004	15.0, 1.0	30, 0.004
MIP (*n* = 5)	326 ±28	2 ±1	33 ±6	89 ±0.3	30 ±3	1.7 ±0.4

[a] Wilcoxon-Mann-Whitney test.

[b] Except for kidney fat and dissectible fat weight, for which *n* = 9.

FP (*n* = 84) was less ($z = 1.68$, $P = 0.05$) than the 64 ± 7 : 100 ratio on MIP (*n* = 789). Only two of eight sampled cows were pregnant on FP, fewer than on MIP where all of ten sampled cows were pregnant (Fisher exact test, $P = 0.002$).

4.4 Discussion

Caribou returned to FP in the 1950s after a virtual absence of 30 years (Chapter 3). The abundance of caribou on FP gradually increased until a sudden decline in the late 1980s. After an absence of 40 years, caribou on MIP increased slowly from the late 1950s until the mid-1980s (Chapter 3). In November 1988, hunters saw more caribou on MIP than seen previously in living memory (J. Ikkidluak pers. comm.). The aerial surveys revealed that caribou densities declined by about 95% on FP between 1984 and 1992, and those on MIP increased by about 2000% between 1982 and 1992.

Inuit suggest that such shifts in caribou distribution are predictable and caused by cumulative density-dependent effects of caribou on forage resources (Chapter 3). Given the slow recovery of lichen forage (Klein 1987), annual overgrazing of winter forage would lead to such effects on Arctic tundra, if caribou show fidelity to specific wintering areas for several years or decades. Inuit knowledge suggested that caribou returned annually to the FP winter range for about 30 years (Chapter 3). During 1988-94, caribou captured on MIP showed strong fidelity (100%) to that wintering area, and caribou that emigrated from FP to MIP also showed strong fidelity to their new winter range.

Although winter range fidelity by Arctic tundra caribou has not been described in the scientific literature, fidelity to tundra calving grounds is well known among migratory ecotypes that winter in forested habitats (Gunn and Miller 1986). Winter range fidelity among Arctic tundra caribou may occur because areas with rugged terrain provide predictable access to winter forage (Nellemann 1997), and caribou that develop traditional movements to such habitats would have a selective advantage. This argument parallels Skoog's (1968) rationale for calving ground fidelity among Alaskan caribou because tundra habitats needed for calving are spatially limited to alpine and arctic coastal areas within Alaska. Tundra habitats for calving should not be spatially limited for caribou residing on Arctic tundra because availability of snow-free tundra, and the quality and quantity of tundra forage, increases as snow melts within the same habitats occupied during winter.

As population density increases on a traditional winter range, annual overgrazing may lead to severe nutritional stress and eventually to a selective advantage for abandonment of that winter range. Traditional use of specific areas is not necessarily permanent (Gunn and Miller 1986). During 1988-1994, collared cows from FP showed less fidelity to that wintering area (44%) than those from MIP. On average, collared cows from FP were about three times farther from their capture locations than MIP cows in subsequent winters. This change in winter range fidelity was predicted by Inuit in 1985, when the early signs included redistribution of wintering caribou onto small islands, foraging on cliff faces, and delayed spring migrations (Chapter 3). The similarity of bull:cow ratios on FP and MIP in 1992 Bull:cow ratios indicated that both sexes participated in the range shift. Although some animals emigrated to other wintering areas, most FP caribou apparently emigrated to MIP.

Comparable shifts in the winter ranges of Arctic tundra caribou have not been well documented, possibly due to the perception that mass emigrations of caribou are neither predictable nor of known cause (Miller 1982). Nevertheless, range shifts by Arctic tundra caribou may have occurred on the Queen Elizabeth Islands and northwestern Greenland during the 1980s and 1990s (Ferguson and Gauthier 1992). Freeman (1975) documented evidence of the emigration of caribou from Bathurst

Island on the Queen Elizabeth Islands during the early 1970s, reportedly in response to seismic exploration. Inter-annual changes in winter distribution have also been attributed to severe snow and icing conditions (Miller 1982). Inuit did not implicate either human disturbance or snow conditions in the winter range shift of caribou from FP to MIP (Chapter 3).

If mass emigration of Arctic tundra caribou from traditional winter ranges is caused by cumulative density-dependent effects of grazing, caribou on older traditional ranges should be in poor physical condition during winters before the emigration. Declining physical condition in the early 1980s was one reason Inuit predicted the impending range shift (Chapter 3). In April 1992, indices of both fat and muscle reserves showed that emigrating from FP to MIP was advantageous for cows. Bulls on MIP also had greater fat reserves than bulls on FP, but not greater muscle mass.

We expected that caribou wintering on FP would have similar fat and muscle masses to other Arctic tundra caribou on overgrazed range. Mean fat reserves among FP cows were lower than among female adults isolated on overgrazed Coats Island (Adamczewski et al. 1988), about 250 km southeast of FP during both mild and severe winters (Adamczewski et al. 1987*b*), suggesting that forage on FP was more overgrazed than on Coats Island. Differences in previous maximum densities may explain this difference (highest density recorded on Coats Island = 0.7 caribou·km^{-2}, Gates et al. 1986, compared to 6.2·km^{-2} on FP). Caribou on Coats Island experienced high mortality during severe winters, but not in other years (Gates et al. 1986). I had no evidence of similar mortality on FP during 1984-94.

Because the coastal uplands of MIP had been occupied by few caribou for over 50 years (Chapter 3) before winter 1988-89, the condition of MIP caribou was expected to be comparable to that of caribou on Southampton Island, about 500 km to the west. Caribou disappeared from Southampton Island in 1953, and 48 caribou were reintroduced in 1967 (Ouellet 1992). Late winter fat and muscle indices in MIP caribou were much less than those of Southampton caribou (Ouellet et al. 1997). In fact, cows on MIP were in poorer condition than those using overgrazed winter foraging areas on Coats Island during the mild winter of 1982-83 (Adamczewski et al. 1987*b*). The caribou density of $5 \cdot km^{-2}$ on MIP in April 1992 was greater than the highest densities on Southampton Island (2.1 caribou$\cdot km^{-2}$ in the densest stratum in 1991, Heard and Ouellet 1994). I suspect that the immigration of high densities of caribou on MIP may have already impacted forage resources on MIP during the four years before sample collections. Caribou winter range on MIP was already drifting southeast along MIP by 1994 (Chapter 3; unpublished data). In 1994, J. Arlooktoo predicted that caribou would have to leave MIP within ten years (Chapter 3).

Although I lack direct data on possible temporal changes about summer habitat condition on southern Baffin Island, I believe that summer habitats did not substantively influence either the emigration of caribou from FP to MIP or the late winter physical condition or recruitment on the two peninsulas. Inuit knowledge and aerial observations during the spring migration suggested that the majority of caribou wintering on the coastal uplands on FP and MIP occupied the same summering area. None of the satellite collared caribou shifted their summering areas during 1987-92 (distance between two subsequent mid-July locations, 27.3 km ± 29.6, $n = 14$).

Arctic tundra caribou that can emigrate en masse from overgrazed to relatively ungrazed winter ranges should not only improve their body condition, but also benefit from higher productivity and survival. Relationships between fat reserves and pregnancy rates have been reported for Arctic tundra caribou (Thomas 1982). Both pregnancy rates among sampled cows and calf:cow ratios during the aerial survey in April 1992 were lower on FP than on MIP. Emigration from FP to MIP appeared advantageous for cows in terms of reproduction and/or survival of calves.

On smaller tundra islands and overgrazed portions of large islands, current dynamics of caribou populations (e.g., die-offs during a single severe winter) may appear density-independent (Tyler 1987). Because density-dependent effects of grazing could persist during the entire period required for forage to fully recover (e.g., 20-40 years), current dynamics of Arctic tundra caribou may be dependent on the densities of sub-populations that were present more than a decade earlier. During the next 20 or more years, dynamics of the remnant caribou wintering on FP and their potential recovery will be dominated by grazing pressure exerted during 1960-88. Inuit have predicted the complete disappearance of caribou from FP (Chapter 3).

Winter range shifts by sub-populations of Arctic tundra caribou on large islands and archipelagos could delay the regulatory effects of density-dependent food limitation at the population level. Messier et al. (1988) suggested that caribou can overshoot carrying capacity because of a time lag of at least 20 years between food availability and food limitation. This lag could be accentuated by the processes of range expansion, drift, and shift by caribou. During periods of population increase, more winter ranges become overgrazed, as sub-populations shift their winter ranges and eventually converge on the same range. At that point, the entire population would enter a period of decline, perhaps lasting several decades. Inuit from across southern Baffin Island have provided evidence of such a process, leading to population cycles lasting 60-90 years (Chapter 3). Cumulative density-dependent effects of grazing on accessible winter forage may produce a decline of the South Baffin population in the future, lasting several decades, as apparently occurred during 1920-55 (Chapter 3).

4.4.1 Management implications

Expanding, drifting and shifting winter ranges of Arctic tundra caribou (Chapter 3) poses a paradigm conflict in the conventional application of caribou management options. Most definitions of animal populations and metapopulations are often based on static geographic areas (Wells and Richmond 1995), often resulting in geographically static management regimes (e.g., wildlife management zones, ecological reserves). Inuit apparently view caribou populations as biological units that use space in an adaptive manner over several decades (Chapter 3). My definition of a population recognizes the need for long-term management of caribou at regional scales, while the definition of transitory sub-populations (with delineation of new boundaries as required) allows short-term management regimes for local areas, as these biological units move through space.

In the future, intensive harvesting of Arctic tundra caribou may reduce growth of selected sub-populations, and potentially limit forage depletion on winter ranges during the increase phase of long-term cycles. Reduction of caribou population growth rates may delay effects of cumulative overgrazing and allow recovery of previously abandoned ranges, avoiding overall population declines in the long term. Given lag effects lasting two or more decades, robust predictive indicators and population models may enable such pro-active management of Arctic tundra caribou. Baffin Inuit identified specific indicators with about five years lead time before mass emigration (Chapter 3). Inuit elders have also made predictions several decades in advance of population changes; further understanding of their rationale may support refinement of both conceptual and mathematical models.

The process of range drift may allow sufficient lead time for management experiments since the distribution of FP caribou began to drift 10-15 years before the shift occurred (Chapter

3). Intensive harvesting on FP in the 1970s may have maintained the sub-population at 50-60% of its 1984 density, and thereby reduced cumulative overgrazing during the intervening period. However, stabilization of 20,000 caribou would be logistically difficult, so actions to reduce growth must be attempted before population size is too large.

The current management dilemma for FP is the maintenance of subsistence harvesting of caribou, given the sub-population's low density and productivity. Assuming that forage resources have been largely depleted, disappearance of wintering caribou from FP appears inevitable, as happened in the mid-1900s (Chapter 3). Since the South Baffin caribou population as a whole apparently is not in decline, I suggest that management of caribou harvesting on FP should preserve the reproductive potential of the remnant sub-population through male-only harvesting.

When the South Baffin caribou population as a whole enters the next anticipated phase of long-term decline, intensive management options will be needed to deal with an estimated subsistence demand of about 8-10,000 caribou annually (based on per-capita harvest rates, Donaldson 1988).

5. WINTER FORAGING ECOLOGY OF A POPULATION OF ARCTIC TUNDRA CARIBOU AFTER A MAJOR RANGE SHIFT

5.1 Introduction

Skogland (1985) suggested that density-dependent competition for winter forage is the primary factor in regulating populations of wild *Rangifer* populations on tundra in Svalbard and Norway. Further, he suggested that density-independent factors play a role only at high population densities. Based on studies of several wild tundra populations, Skogland (1986, 1989) argued that the dynamics of a given population also depend on several other factors, including the ratio of winter range to total range, terrain characteristics within winter range, and the type of winter diet (i.e., vascular plants or lichen). Similarly, Leader-Williams (1988) viewed vegetation as the primary limiting factor on island tundra populations, while climatic factors had secondary roles. After studying Svalbard reindeer, Tyler (1987) concluded that density-independent factors (e.g., severe snow conditions) cause exaggerated density-dependent effects on overgrazed ranges. In these and other areas where density-dependent grazing impacts have occurred (e.g., Klein 1968, Tyler 1987, Adamczewski et al. 1988, Ouellet et al. 1996), both wolf predation and harvesting by humans were absent or very limited.

In contrast, short-term fluctuations and occasional die-offs of caribou and reindeer wintering on Canadian Arctic tundra have been commonly attributed to reduced access of vegetation through snow/ice in some years, rather than to an absolute shortage of food (Miller 1982, Caughley and Gunn 1993). Miller (1982) suggested that mortality factors other than density-dependent food limitation usually do not allow caribou to reach densities at which forage could limit populations. Jefferies et al. (1994) concluded that scientific research has rarely shown that vertebrate herbivores have affected unperturbed northern plant communities at landscape scales.

Landscape-level grazing impacts on the calving grounds of a migratory caribou herd has been detected in northern Quebec and Labrador (Manseau et al. 1996). For this population, the tundra habitats where calving occurs are geographically limited compared to the taiga available as winter range. For caribou permanently resident on Arctic tundra, it is likely that winter range would be more important as a limiting factor because snow effectively restricts accessible forage to a fraction of that available on summer range. That fraction is dependent on the interactions between snow, wind and terrain structure (Nellemann 1997). The geographic extent, quality and quantity of forage on Arctic tundra increase during snow melt and into summer.

Gaare (1997) hypothesized that *Rangifer* and lichen-dominated communities have coevolved through periodic overgrazing that resets succession and prevents domination of tundra communities by vascular plants. Where overgrazing has depleted forage resources on tundra islands, recovery of lichen-dominated communities can take over 20 years (Klein 1987) and up to 40 years before being suitable for re-colonization by reindeer or caribou (I. Jâma in Vibe 1967, S. Ragee pers. comm.). After fire, the biomass of "caribou" lichens (i.e., *Cladina* spp. and *Cetraria nivalis*) in northern forests increases for up to 80 years (Thomas et al. 1996).

In 1985, Inuit predicted that South Baffin caribou would soon abandon their highest-density winter range (Chapter 3) because there had been "too many caribou for too long" (L. Nutaraluk pers. comm.). Inuit offered indirect evidence of winter nutritional stress, including: declining physical condition of caribou, grazing on cliff faces and small islands in Hudson Strait (Fig. 5.1), delayed spring migration by females, and calving on or near the winter range. In Chapter 4, I confirmed several of these observations. The Inuit prediction of range shift was based on a cumulative density-dependent decline in forage resources, rather than density-independent climatic factors. Nutaraluk (pers. comm.) stated that over the long term (i.e., 60-90 years), snow cover is not usually a problem for caribou because the land can not be completely covered by hard snow and/or ice, and caribou will feed where snow allows access to forage. However, during the short term (e.g., 1-30 years) snow cover may be problematic, if cumulative overgrazing by caribou has reduced forage resources on accessible sites during some winters when snow cover is unusually restrictive (L. Nutaraluk pers. comm.).

The predicted shift in winter range began during the autumn migration of 1988 (Chapters 3 and 4). In April 1992, I took the opportunity to examine hypotheses regarding the interaction of density-dependent and -independent factors, offered independently by Skogland (1986), Tyler (1987) and Nutaraluk (pers. comm.). Specifically, I tested the null hypotheses that there were no differences in caribou forage resources, forage selection, cratering characteristics, and snow conditions between upland foraging sites on mostly abandoned winter range (i.e., FP) and those on recently occupied winter range (i.e., MIP). Further, I suggest that cumulative overgrazing of winter range can be the dominant ecological process limiting populations of Arctic tundra caribou.

5.2 Methods

5.2.1 Study area

Baffin Island (>500,000 km^2) forms the eastern margin of

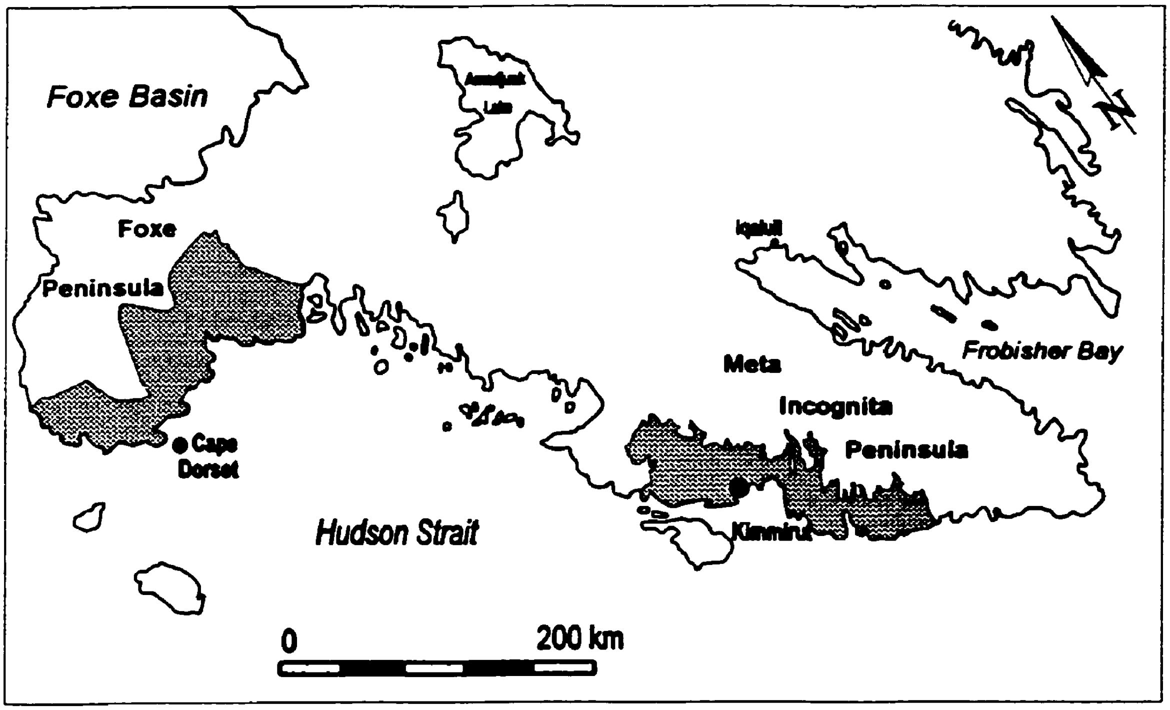

Figure 5.1. Caribou wintering areas (shaded) on Foxe and Meta Incognita peninsulas on southern Baffin Island, Nunavut, Canada, April 1992.

the Canadian Arctic archipelago. The South Baffin caribou population occupies approximately half of the island (Ferguson 1989) and was estimated at 60,000 to 180,000 animals in the late 1980s (Ferguson and Gauthier 1992). The population is composed of "sub-populations", defined as groupings of individuals within the population, each demonstrating fidelity to a distinct part of the population's range over the short term (i.e., 10-30 yr), leading to distinct demographic characteristics. Over the long term (i.e., 60-90 yr), sub-populations interact through range shifts, leading to shared long-term population trends (Chapter 3). In April 1992 I studied two sub-populations within a 6,540-km^2 study area on FP and a 5,210-km^2 area on MIP (Fig. 5.1).

South Baffin caribou migrate to wintering areas during October-November and usually remain there until late April. In November 1978, central and eastern FP held the largest number of caribou (21,400 caribou ± 2200 SE) (Chowns 1979) among the three major winter ranges of the South Baffin population. In the late 1970s and early 1980s, the winter range on FP drifted (i.e., expanded on one front while contracting on another) to the west and onto small islands along northwestern Hudson Strait (Chapter 3). In November 1984, the sub-population had increased to about 34,400 (± 4600 SE) (unpublished data). Subsequently, caribou density in the FP study area declined from 6.2$\cdot$km^{-2} in 1984 to 0.3$\cdot$km^{-2} in April 1992 (Chapter 4).

Chowns (1979) did not recognize MIP as a major wintering area in 1978. Although caribou had been expanding their winter range on MIP since the 1950s, abundance remained relatively low into the 1980s (Chapter 3). In March 1982, 1600 (± 340 SE) caribou were estimated to occur on MIP (unpublished data). Between 1982 and 1992, caribou density within the MIP study area suddenly increased from 0.2 to 5.0$\cdot$km^{-2} (Chapter 4).

Because muskoxen do not occupy Baffin Island and Arctic hares are not known to occur in high densities, caribou are the primary prey of wolves (Clark 1971). Subsistence harvesting of caribou by Inuit has been unrestricted during the past 40 years. In 1982, Inuit in Cape Dorset and Kimmirut (Fig. 5.1) harvested about 2260 and 550 caribou from the FP and MIP subpopulations, respectively (Donaldson 1988).

Terrain within the FP wintering area consists of rugged uplands up to 410 m above sea level (ASL). During winter, caribou tend to abandon the northern coastal lowlands (25% of FP). Caribou occupy 2 terrain types on MIP: rugged coastal uplands below 305 m ASL and rugged plateaux 305-850 m ASL. Vegetation on most of FP and MIP is characterized by dwarf and prostrate shrub tundra, while some areas are in the low, erect shrub zone (Edlund 1990).

Because climatic conditions and plant communities on the plateaux of MIP resemble those at higher latitudes, only uplands < 305 m ASL on both peninsulas were included in this study. In MIP study area, group sizes of caribou were determined while flying within 2.5 km of 19 7.5-km transects in a Bell 206L helicopter. Because low caribou densities on FP caused small sample size, all groups seen within the study area were counted.

5.2.2 Snow cover and vegetation at foraging sites

To assess the physical characteristics, forage resources, and snow cover conditions of foraging sites, I selected a recently-used foraging site near each randomly placed transect in each study area. On MIP, foraging sites, at least 15 m in diameter, were found and sampled within 1 km of all 19 transects; however, because of low caribou densities on FP, foraging sites were found within 8 km of only 14 of 19 transects.

For each foraging site, I recorded the elevation, slope, aspect, length, width, and shape. The length, width, and shape (i.e., rectangle, triangle, ellipse or a combination thereof) were used to estimate the area of each foraging site. I laid out a 30-m transect oriented to cross as many feeding craters as possible. Transects were usually straight, but the shape and size of some sites required transects to be bent or broken in two parts. Where only small foraging sites were found, the remainder of the transect was placed in a nearby site. The starting point of each transect was determined blindly.

Along each transect, three sampling points were selected randomly without replacement and at least 3 m apart. The feeding crater closest to each sampling point was selected to measure minimum and maximum snow depth, and maximum integrated snow hardness (ramsonde penetrometer; Lent and Knutson 1971) 15 cm away from the deepest side of the crater. I also measured basal width, length, and shape of the crater to estimate its basal area.

At 0.5 - 5 m from each of two random craters, I measured snow hardness in undisturbed snow similar in depth and appearance to that at the crater. Vegetation was collected from below the point where snow hardness was determined, if the substrate (e.g., soil, sand, gravel, bedrock, frozen moss) was similar to that at the sampled crater. If not, another place was selected for snow hardness and vegetation sampling. Snow was carefully removed to within 1-2 cm of the vegetation mat, and all vegetation was collected down to the substrate within a 31-x-61-cm (0.19-m^2) quadrat. Samples were kept frozen in plastic bags until they were thawed and air dried.

Each sample was screened through a series of four sieves (i.e., 12.5, 6.3, 3.35 and 2.0 mm), and total mass of material in each sieve was weighed. Sub-samples were taken from each sieve so that approximately 200 fragments of vegetation were sorted and weighed. From material on the 2.0-mm sieve, 0.30-0.40 g were sub-sampled; from the 3.35-mm sieve, 1.00-1.25 g; from the 6.30-mm sieve, 2.25-2.5 g; and from the 12.5-mm sieve, up to 20 g were sub-sampled. When a sieve contained less than the sub-sample target, 100% of the sieve contents were sorted. Material passing through the 2.00-mm sieve was not sorted and not included in the estimates of biomass.

Vegetation was sorted and air-dried weights were determined for the following 18 plant classes: *Alectoria/Cornicularia* spp., Brown *Cetraria* spp., *Cetraria cucullata*, *C. nivalis*, *Cladina* spp., *Cladonia* spp., *Dactylina* spp., *Siphula ceratites*, *Sphaerophorus fragilis*, *Stereocaulon* spp., *Thamnolia* spp., foliose lichens, *Cassiope tetragona*, *Dryas integrifolia*, other shrubs, graminoids, mosses, and plant debris. Plant debris included leaf litter from herbs and shrubs and dead twigs. Graminoids included both senescent and green leaves. Other shrubs included *Betula glandulosa*, *Diapensia lapponica*, *Empetrum nigrum*, *Ledum decumbens*, *Vaccinium* spp., and *Salix* spp. Most shrubs, except *Cassiope tetragona*, were live twigs, occasionally with a few leaves attached. Smaller twigs without leaves could not always be identified, unless they were either *Cassiope tetragona* or *Dryas integrifolia*. Non-plant materials (e.g., gravel, caribou and lemming faeces) were also weighed.

The biomass of a plant class in each vegetation sample was estimated according to the following formula:

$$[1] \quad B_J = \sum_{i=1}^{4} \left[b_{iJ} \bullet M_i \Big/ \left(n_i + \sum_{j=1}^{18} b_{ij} \right) \right]$$

where B_J is the estimated biomass of plant class J in the sample; b_{iJ} is the mass of plant class J in the sub-sample from sieve i; M_i is the total mass of all material in sieve i; n_i is the mass of non-plant material in the sub-sample from sieve i; and b_{ij} is the mass of each plant class j in the sub-sample from sieve i. The estimated biomasses from the two vegetation samples from each foraging site were pooled for data analyses.

5.2.3 Food selection by caribou

In April 1992, the study area on each peninsula was divided into thirds along its longest side, and three cows and two bulls were to be sampled randomly from each third. This distribution was largely accomplished on MIP, with ten cows and five bulls sampled. On FP, the sampling crew could not locate animals in two thirds of the study area, resulting in the collection of eight cows and six bulls from five different groups in the remaining third. I collected and froze 1.0-1.5 L of well-mixed rumen contents from each adult caribou sampled on FP (n = 14) and MIP (n = 15).

Each rumen sample was thawed and washed through a 2-mm sieve and preserved with 10% formalin until analysed. Each sample was then rinsed with water through a 0.425- or 0.85-mm sieve, two well-mixed sub-samples (25-30 g) were collected, and each sub-sample was spread in a 17-x-24-cm tray over 5-mm-deep water. Occurrence of plants in each sub-sample was estimated by point sampling (Chamrad and Box 1964), with 50 systematic points per sub-sample, each point 2.0 cm from any adjacent point. Plant fragments were classified into the same categories as the vegetation samples collected at foraging sites, with the following exceptions: *Cladina* and *Cladonia* spp. were placed in one class, and classes of unknown fruticose lichens, unknown lichens, and unknown vascular plants were added. The class of non-plant material was also added.

5.2.4 Statistical analyses

Except for aspect, physical characteristics of foraging sites were compared using the Wilcoxon-Mann-Whitney test (Mehta and Patel 1997). The distributions of aspects of foraging sites on the two peninsulas were compared using the Fisher-Freeman-Halton test (*FI*), an extension of the Fisher exact test for RxC tables (Mehta and Patel 1997).

The depths and integrated snow hardness of the three craters within foraging sites were compared between peninsulas using a GLM nested ANOVA (SPSS 1997). Levene's test was used to examine equality of the error variances. In one case, Levene's test indicated unequal variances, so I also used the Wilcoxon-Mann-Whitney test (Mehta and Patel 1997), treating the three random craters within foraging sites as independent samples. I used the Wilcoxon signed rank test, t_{SR} (Mehta and Patel 1997), to compare maximum depth and hardness of snow at each crater with that where I collected matched vegetation samples.

Total biomasses of plant classes at each foraging site, and the occurrence of plant classes in rumens, were examined for differences between the two study areas using GLM MANOVA (SPSS 1997). Levene's test of equality of variances showed that several plant classes had unequal error variances ($P < 0.05$). I could not find a transformation that improved this problem for all plant classes. As a result, differences between the two peninsulas for total biomasses of plant classes at foraging sites and occurrence of plant classes in rumens were compared using Wilcoxon-Mann-Whitney tests (Mehta and Patel 1997), instead of univariate ANOVAs.

We also determined plant groups within foraging sites that might be affected by long-term grazing histories on the two peninsulas. I could not use cluster or principal components analyses to assess these aspects because of the non-normal data distributions and inequality of variances. Therefore, I conducted ordinations by non-metric multi-dimensional scaling (NMDS) (Kruskal 1964), specifying one to five dimensions and Euclidean distances, using SPSS 8.0. Solutions for a given number of dimensions were accepted when S-stress improvements between iterations were less than 0.001 (Norušis 1997). For each data set, stress values were plotted against the number of dimensions to detect a flexion point, having a stress value < 0.10 at two or more dimensions. If no flexion point was evident, the one-dimensional solution was accepted if the stress value was < 0.15. In the NMDS analyses of vegetation biomass at foraging sites, I treated the two samples in each foraging sites as independent samples because the two samples could be up to 40 m apart and potentially come from different plant associations.

NMDS was first conducted across plant classes to determine natural groups of plant classes within foraging sites. Each group of plant classes was then analysed in a sample-wise NMDS to assess differences between MIP and FP. For groups which differentiated between the two peninsulas, I compared the sample coordinates of each dimension, using the Wilcoxon-Mann-Whitney test (Mehta and Patel 1997), to determine which dimension(s) represented differences between the two peninsulas.

5.2.5 Differences in food selection vs. forage availability between study areas

I calculated the ratio of mean percent occurrence of each plant class in rumens from FP to that of MIP. I also calculated the ratio of mean biomass ($kg \cdot m^{-2}$) of each plant class within caribou foraging sites on FP to that of MIP. To assess selection based on availability, I could not directly compare occurrence of plants in the rumens with the biomass available within foraging sites because this would underestimate the relative importance of highly digestible plants (e.g., most fruticose lichens) which pass through the rumen more rapidly than do less digestible plants (e.g., mosses) (Gaare et al. 1997). Consequently, I determined relative ratios of selection-availability between heavily grazed winter range on FP and recently occupied MIP, by dividing the ratios of mean occurrence by ratio of mean biomass for each plant class. For plant classes with a selection ratio of 0.5-1.5, I concluded that selection was similar in both study areas. For those with a selection ratio of $\leq$ 0.4, I concluded that use of that plant was less on FP than on MIP when standardized for availability. For those with a selection ratio of $\geq$ 1.6, use was greater on FP.

5.3 Results

5.3.1 Characteristics of foraging sites and craters

Foraging sites were located mainly on terraces within generally rugged terrain. Because individual terraces varied in area, caribou foraging sites were highly variable in size, but their areas did not differ ($P = 0.42$) between the two wintering areas (Table 5.1). Caribou wintering on the upland terrain of FP and MIP foraged on similar slopes ($P = 0.57$). As expected, the elevation of foraging sites on MIP was somewhat higher ($P = 0.08$) than on FP because lower elevations were less available. Caribou foraged on sites with a wide variety of aspects on both peninsulas ($FI = 6.69$, $P = 0.66$).

Density of craters within foraging sites was lower ($P = 0.06$) on FP than on MIP (Table 5.1). Cratering density was not correlated with either estimated biomass of the five most abundant fruticose lichens ($|r_S| \leq 0.22$, $P \geq 0.24$) or integrated hardness of snow at feeding craters ($r_s = 0.21$, $P = 0.27$). Cratering density may have been related to differences in mean group size in the two wintering areas (3.4 on FP, $n = 48$, vs. 6.0 on MIP, $n = 199$). The basal area of individual craters did not differ ($P = 0.67$) between the two peninsulas (Table 5.2).

Caribou on FP initiated their craters in shallower snow ($P < 0.01$) and dug to shallower maximum depths ($P < 0.01$) than did caribou on MIP (Table 5.2). Snow hardness near craters on FP was only 25% of that near craters on MIP ($P < 0.01$). Maximum depth of craters did not differ from snow depths where I determined snow hardness adjacent to craters on FP ($t_{SR} = 138$, $P = 0.35$) and on MIP ($t_{SR} = 402$, $P = 0.45$). Snow depth and hardness adjacent to craters were also similar ($P \geq 0.29$) to that where I collected matched vegetation samples 0.5-5.0 m away (Table 5.3).

Table 5.1. Physical characteristics of caribou foraging sites on Foxe (FP) and Meta Incognita (MIP) peninsulas on southern Baffin Island, April 1992.

Characteristic	Mean (± SE)		Wilcoxon-Mann-Whitney test (*U*, *P*)
	FP	MIP	
Area (m^2)	1624 (± 496)	2635 (± 691)	156, 0.42
Slope (°)	4.4 (± 0.9)	5.2 (± 0.8)	149, 0.57
Elevation (m)	131 (± 22)	178 (± 17)	182, 0.08
Cratering density[a]	12.5 (± 1.8)	17.7 (± 1.9)	167, 0.06

Note: *n* = 14 for FP and 19 for MIP, except for cratering density on MIP where *n* = 17.

[a] Number of craters completely or partially within a 30-x-1.7-m strip-transect through the most intensively used portion of the foraging site.

Table 5.2. Characteristics of caribou feeding craters on Foxe (FP) and Meta Incognita (MIP) peninsulas on southern Baffin Island, April 1992.

Characteristic	Mean (± SE)		Nested ANOVA
	FP	MIP	(*F*, *P*)
Basal area (cm^2)	3611 (± 436)	3822 (± 328)	0.22, 0.67
Minimum depth (cm)	3.3 (± 0.5)	10.4 (± 0.8)	213, <0.01
Maximum depth (cm)	12.0 (± 1.2)	24.3 (± 1.4)	116, <0.01
Snow hardness (kg·cm)	162 (± 33)	648 (± 70)	31.1[a], <0.01

Note: Three craters were sampled at each of 14 foraging sites on FP and 19 sites on MIP.

[a] Levene's test indicated that error variances were unequal ($P < 0.01$). Treating all craters as independent, Wilcoxon-Mann-Whitney test confirmed difference between FP and MIP ($U = 2160$, $P < 0.01$).

Table 5.3. Characteristics of snow cover at feeding craters of caribou and at matched sites where vegetation samples were collected on Foxe (FP) and Meta Incognita (MIP) peninsulas on southern Baffin Island, April 1992.

Study area	Vegetation sample	Feeding crater	Wilcoxon sign rank test (t_{SR}, P)
FP (n = 28)			
Maximum depth (cm)	11.2 (± 1.5)	10.4 (± 1.4)	138, 0.35
Snow hardness (kg·cm)	135 (± 23.1)	160 (± 48.0)	144, 0.29
MIP (n = 38)			
Maximum depth (cm)	22.4 (± 1.6)	23.2 (± 1.7)	402, 0.45
Snow hardness (kg·cm)	598 (± 60.2)	601 (± 72.1)	167, 0.43

5.3.2 Vegetation within foraging sites

In MANOVA, biomasses of all plant classes at foraging sites on FP differed ($F_{18,14}$ = 5.20, $P < 0.01$) from those on MIP. Using the Wilcoxon-Mann-Whitney test, biomasses of most fruticose lichens was lower ($P \leq 0.06$) on FP than on MIP (Table 5.4). *Cladina* spp., which had the highest biomass on MIP, was the fifth most abundant fruticose lichen on FP. Total biomass of the five most abundant fruticose lichen classes was 400% greater at foraging sites on MIP than on FP. *Siphula ceratites, Dactylina* spp. and *Thamnolia* spp. were the only fruticose lichens that did not differ ($P \geq 0.14$) between the two peninsulas. Biomasses of foliose lichens and mosses did not differ ($P \geq 0.88$) between FP and MIP.

Among vascular plants, other shrubs and plant debris had higher biomasses at caribou foraging sites on MIP than on FP (Table 5.4). *Cassiope tetragona* and graminoids did not differ ($P \geq 0.57$) in biomass between the two peninsulas. *Dryas integrifolia* was the only plant class that was more abundant at foraging sites on FP (P = 0.06). Biomasses of mosses were similar (P = 0.97) on both peninsulas.

NMDS suggested that a two-dimensional solution (*stress* = 0.04, r^2 = 0.997) portrayed natural groups of plant classes that could be assessed for impacts of caribou grazing. Plants within each of groups 1 and 2 were closely associated on both dimensions while being disjunct from other plant groups (Fig. 5.2). Other shrubs and plant debris were closely associated on Dimension 2. Because most plant debris (i.e., leaf litter and dead wood) would be derived from other shrubs, I treated these two plant classes as a natural group that could be impacted by grazing. Moss and *Cassiope tetragona* appeared unassociated with other plant classes within foraging sites, and thus were not analysed further. Sample-wise NMDS of Group 1 (i.e., *Alectoria/Cornicularia* spp., *Cetraria nivalis, Cladina* spp.,

Table 5.4. Biomass of plant material at caribou foraging sites on Foxe (FP) and Meta Incognita (MIP) peninsulas on Baffin Island, April 1992.

Plant class	Biomass ($g \cdot m^{-2}$ ± SE)		Wilcoxon-Mann-Whitney test (*W, P*)
	FP	MIP	
Fruticose lichens			
Cladina spp.	4.4 ± 1.7	46.8 ± 15.6	186, 0.06
Cetraria nivalis	6.7 ± 1.5	33.2 ± 4.9	132, <0.01
Alectoria/Cornicularia spp.	6.4 ± 1.2	31.6 ± 4.8	134, <0.01
Cladonia spp.	14.0 ± 2.2	26.2 ± 3.6	169, 0.01
Sphaerophorus fragilis	9.2 ± 2.0	25.2 ± 4.1	170, 0.01
Brown *Cetraria* spp.	3.9 ± 0.7	8.4 ± 1.1	153, <0.01
Cetraria cucullata	1.5 ± 1.3	4.8 ± 1.7	155, <0.01
Stereocaulon spp.	0.01 ± 0.01	1.3 ± 0.5	180, <0.01
Siphula ceratites	1.8 ± 0.9	4.7 ± 1.8	198, 0.14
Dactylina spp.	0.64 ± 0.20	1.0 ± 0.5	229, 0.74
Thamnolia spp.	1.5 ± 0.6	0.51 ± 0.13	294, 0.29
Foliose lichens	3.7 ± 1.2	4.6 ± 1.5	234, 0.88
Shrubs			
Cassiope tetragona	72.2 ± 39.6	55.7 ± 16.8	223, 0.57
Dryas integrifolia	92.0 ± 43.0	14.2 ± 9.4	280, 0.06
Other shrubs[a]	23.0 ± 16.7	124 ± 42	129, <0.01
Graminoids	19.6 ± 6.5	19.4 ± 3.9	229, 0.74
Mosses	424 ± 118	428 ± 90	237, 0.97
Plant debris	138 ± 37	207 ± 27	181, 0.04
Total biomass	823 ± 135	1036 ± 131	207, 0.26

Table 5.4 continued.

Note: Two 0.19-m^2 vegetation samples were collected at each of 14 caribou foraging sites on FP and 19 sites on MIP. Statistical analyses were conducted on the sums of the two samples at each site.

[a] Included: *Betula glandulosa*, *Diapensia lapponica*, *Empetrum nigrum*, *Ledum decumbens*, *Salix* spp., and *Vaccinium* spp.

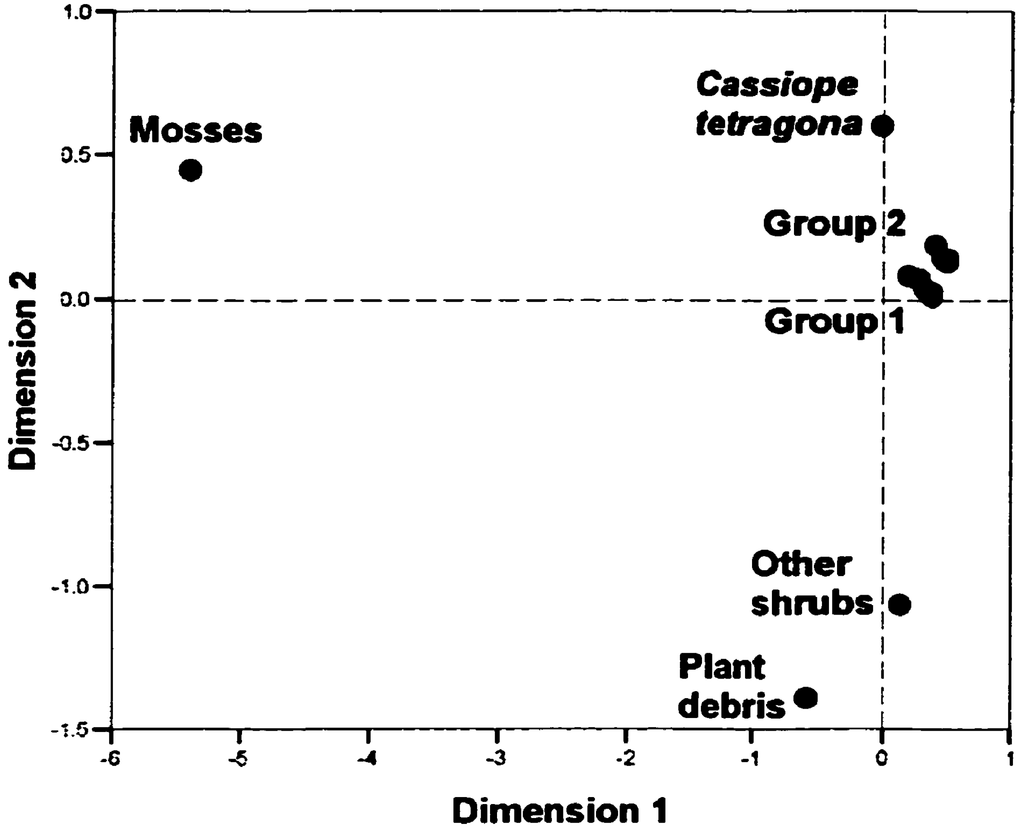

Figure 5.2. Ordination of plant groups found within caribou foraging sites on Foxe and Meta Incognita peninsulas on southern Baffin Island in April 1992, as determined by non-metric multi-dimensional scaling: Group 1, *Alectoria/Cornicularia* spp., *Cetraria nivalis*, *Cladina* spp., *Cladonia* spp., *Sphaerophorus fragilis*, and graminoids; and Group 2, Brown *Cetraria* spp., *Cetraria cucullata*, *Dactylina* spp., *Siphula ceratites*, *Stereocaulon* spp., *Thamnolia* spp., foliose lichens, and *Dryas integrifolia*.

Cladonia spp., *Sphaerophorus fragilis*, and graminoids), Group 2 (i.e., Brown *Cetraria* spp., *Cetraria cucullata*, *Dactylina* spp., *Siphula ceratites*, *Stereocaulon* spp., *Thamnolia* spp., foliose lichens, and *Dryas integrifolia*) and the other shrubs - plant debris group suggested acceptable two-dimensional solutions for each group (*stress* = 0.11, r^2 = 0.98; *stress* = 0.02, r^2 = 0.99; and *stress* = 0.0, r^2 = 1.0, respectively).

Group 1 included the five most abundant fruticose lichens within MIP foraging sites, all of which were less abundant on FP (Table 5.4). FP samples were concentrated within a small portion of the distribution for MIP samples where few MIP samples occurred (Fig. 5.3). Sample coordinates for Dimension 1 were less ($U_{28,38}$ = 673, P = 0.07) for MIP foraging sites than for FP sites, while those for Dimension 2 were greater ($U_{28,38}$ = 874, P < 0.01) for MIP than for FP. Together Dimensions 1 and 2 explained 98% of the variation in biomass among plants in this group. Although graminoids were associated with these lichens, biomass of graminoids apparently was not affected (P = 0.74) by the different grazing histories on the two peninsulas (Table 5.4).

The sample coordinates for Group 2 showed extensive overlap in the distribution of samples from the two peninsulas. This suggested that this plant group did not readily portray differences in grazing impacts between the two peninsulas.

For other shrubs and plant debris, FP samples were concentrated along one margin of the more dispersed distribution of MIP samples (Fig. 5.4). Sample coordinates for Dimension 1, which explained 97% of the variation in the biomasses for this group, were less ($U_{28,38}$ = 800, P < 0.01) for MIP than for FP foraging sites. Coordinates for Dimension 2 did not differ ($U_{28,38}$ = 545, P = 0.87) between the two peninsulas. Biomasses of both other shrubs and plant debris were lower at winter foraging sites on FP than on MIP (Table 5.4).

In my study design, I assumed *a priori* that caribou on MIP foraged in upland habitats similar to those on FP. The general

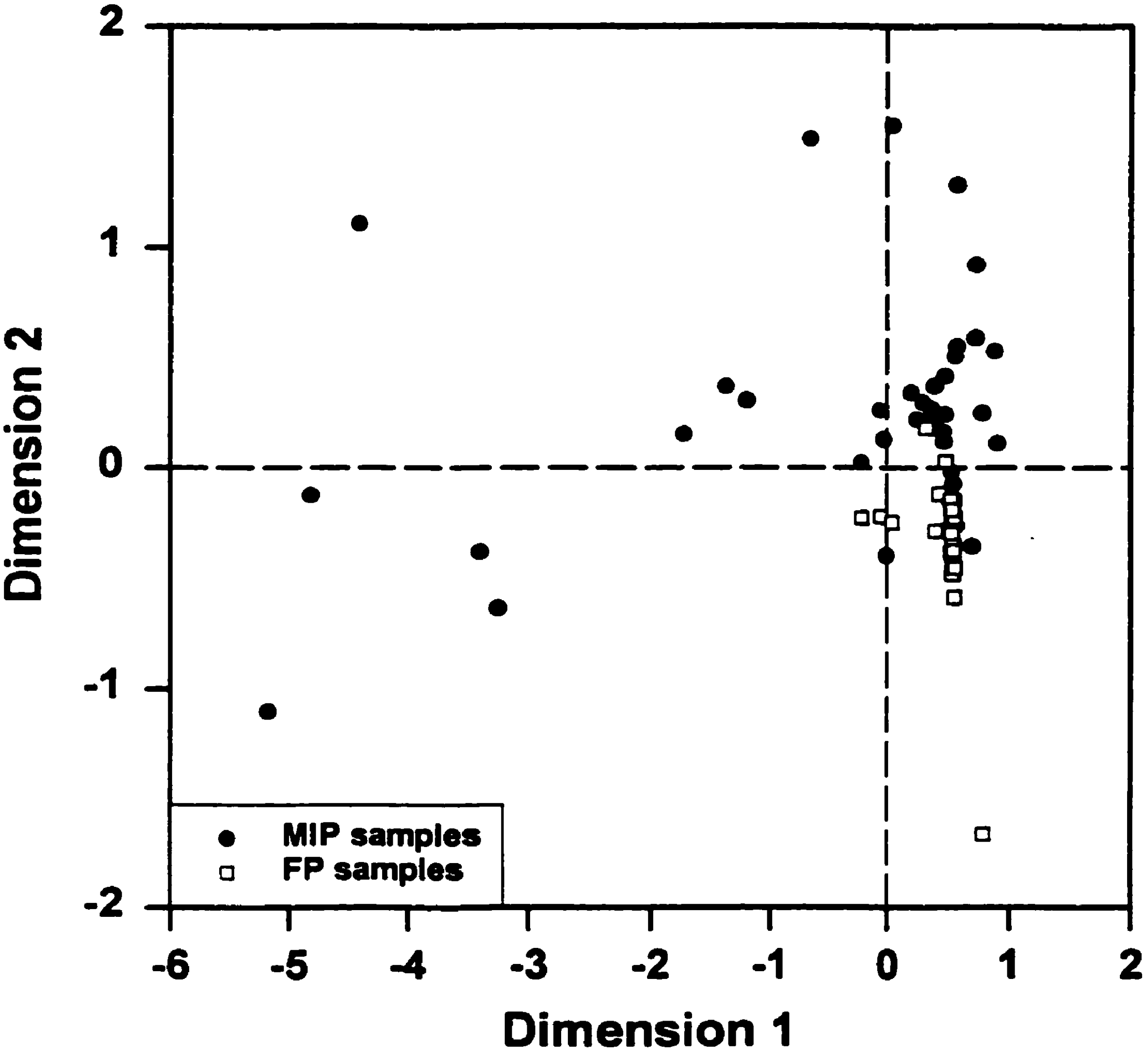

Figure 5.3. Ordination of foraging sites on Meta Incognita (MIP) and Foxe (FP) peninsulas on southern Baffin Island in April 1992, based on plant group 1 (Fig. 5.2) using non-metric multi-dimensional scaling.

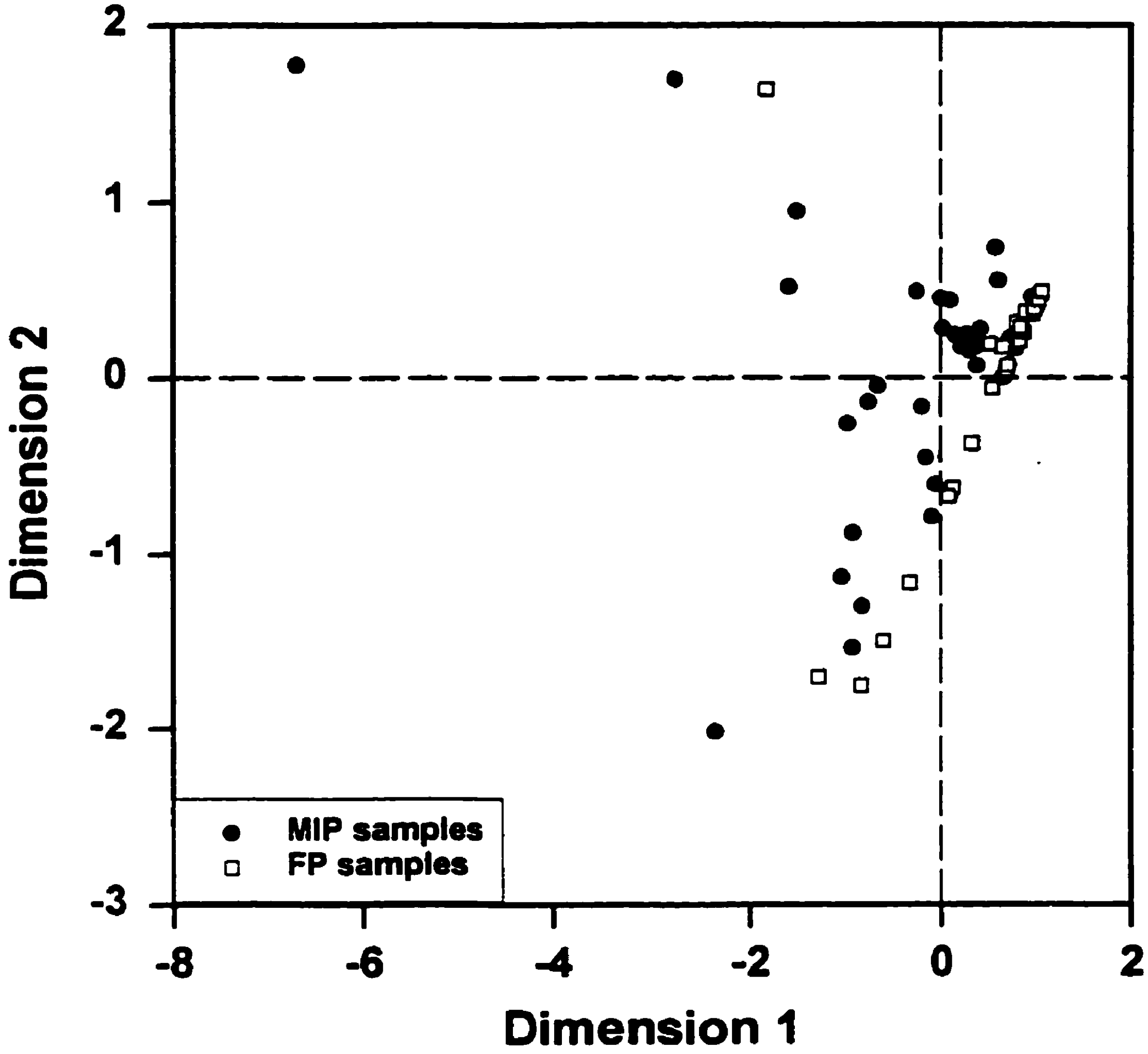

Figure 5.4. Ordination of foraging sites on Meta Incognita (MIP) and Foxe (FP) peninsulas on southern Baffin Island in April 1992, based on other shrubs and plant debris (Fig. 5.2) using non-metric multi-dimensional scaling.

similarity between the two peninsulas in the NMDS ordinations support this assumption. Even for Group 1 and the other shrubs - plant debris group, NMDS did not show disjunct distributions between foraging sites on FP and MIP; instead, FP samples were concentrated immediately adjacent to the more dispersed distributions of MIP samples (Fig. 5.3, 5.4).

Field observations on MIP indicated that substantial physical damage or trampling of plants occurred during cratering. Margins of caribou feeding craters in late winter contained large quantities of broken and dislodged plant parts, mainly fruticose lichens, broken stems of shrubs (up to 1 cm in diameter) and leaf litter. Shrubs with long, loose stems (e.g., *Salix* spp., *Vaccinium* spp.) apparently suffered greater damage than species with more compact, prostrate overwintering forms (e.g., *Dryas integrifolia*). Dislodged lichens and leaf litter were often blown by wind into small depressions and nearby streams.

5.3.3 Rumen contents

Using MANOVA for all plant classes, late winter rumen contents differed between the two peninsulas ($F_{18,8} = 2.83$, $P = 0.07$), but not between the sexes ($F_{18,8} = 1.22$, $P = 0.40$). There was no peninsula-sex interaction ($F_{18,8} = 0.68$, $P = 0.77$). Because unequal error variances ($F_{1,25} \geq 3.28$, $P \leq 0.04$ for 10 of 17 classes) tends to make MANOVA results conservative, I accepted the F value for the peninsula factor as being significant.

In total, fruticose lichens on MIP made up about 10% of rumen contents, but only 4% on FP. Using the Wilcoxon-Mann-Whitney test, the occurrence of only three classes of lichens in rumen contents differed ($P \leq 0.04$) between MIP and FP (Table 5.5). These lichens, *Cladina/Cladonia* spp., *Sphaerophorus fragilis* and *Cetraria nivalis*, made up 9% of rumen contents on MIP, but only 2% on FP. Additionally, more caribou ($FI \geq 3.0$,

Table 5.5. Percentage occurrence of items identified in rumen contents of caribou on Foxe (FP) and Meta Incognita (MIP) peninsulas on southern Baffin Island, April 1992.

Items	Mean percentage (± SE) FP (*n* = 14)	Mean percentage (± SE) MIP (*n* = 15)	Wilcoxon-Mann-Whitney test (*U*, *P*)
Lichens			
Cladina / Cladonia spp.	0.9 ± 0.2	5.9 ± 1.4	173, <0.01
Sphaerophorus fragilis	0.9 ± 0.3	2.4 ± 0.8	155, 0.03
Cetraria nivalis	0.0 ± 0.0	0.5 ± 0.2	140, 0.04
Brown *Cetraria* spp.	0.4 ± 0.4	0.1 ± 0.1	106, 0.74
Stereocaulon spp.	0.0 ± 0.0	0.3 ± 0.1	133, 0.10
Alectoria/Cornicularia spp.	0.1 ± 0.1	0.1 ± 0.1	105, 1.00
Siphula ceratites	0.5 ± 0.3	0.1 ± 0.1	128, 0.12
Unknown fruticose	1.1 ± 0.4	0.8 ± 0.3	125, 0.38
Foliose lichens	0.1 ± 0.1	0.1 ± 0.1	105, 1.00
Unknown lichens[a]	1.6 ± 0.4	1.6 ± 0.5	109, 0.89
Shrubs			
Cassiope tetragona	4.1 ± 0.6	0.2 ± 0.1	202, <0.01
Dryas integrifolia	0.4 ± 0.2	0.0 ± 0.0	135, 0.04
Other shrubs[b]	7.7 ± 1.1	8.9 ± 1.2	123, 0.46
Graminoids	26.1 ± 2.9	30.1 ± 3.2	129, 0.32
Mosses	26.9 ± 2.1	22.0 ± 2.0	144, 0.09
Unknown plants[c]	6.8 ± 0.8	6.4 ± 1.1	120, 0.54
Plant debris[d]	22.0 ± 2.1	20.2 ± 1.6	123, 0.45
Non-plant material[e]	0.3 ± 0.2	0.2 ± 0.2	114, 0.56

Table 5.5 continued.

Note: Percentages determined by the number of plant fragments intercepted by 100 systematically placed pins (Chamrad and Box 1964). Points that did not intercept any rumen contents caused the number of plant fragments to vary from 74 to 92 per sample.

[a] Includes unidentifiable foliose and crustose lichens.

[b] Includes live twigs of *Diapensia lapponica*, *Empetrum nigrum*, *Vaccinium* spp. and *Salix* spp.

[c] Includes unidentifiable live plant parts.

[d] Includes deciduous leaves and dead twigs.

[e] Includes largely caribou hair, and small amounts of rock.

$P \leq 0.10$) on FP had none of these lichens in their rumens (43% had no *Cladina/Cladonia* spp.; 50%, no *S. fragilis*; and 100%, no *Cetraria nivalis*) compared to those on MIP (13%, no *Cladina/Cladonia* spp.; 13%, no *S. fragilis*; and 77%, no *Cetraria nivalis*).

Caribou on FP apparently made up for the reduced availability of fruticose lichens by consuming larger quantities of *Cassiope tetragona* ($P < 0.01$) and mosses ($P = 0.09$) (Table 5.5). Although all caribou on both FP and MIP consumed moss, more caribou on FP (13 of 14) consumed *C. tetragona* than ($FI = 19$, $P < 0.01$) did caribou on MIP (2 of 15). Four caribou on FP consumed some *Dryas integrifolia*, while none of the caribou from MIP did ($FI = 4.7$, $P = 0.04$).

All caribou on both wintering areas consumed graminoids, plant debris and other shrubs. Graminoids had the highest occurrence of all plant classes in the rumens (Table 5.5). Most of the graminoid tissue in the rumen contents was composed of basal clusters of green leaves, surrounded by an outer layer of senescent leaves. Caribou on both wintering areas consumed substantial quantities of plant debris (about 20%), largely leaf litter. Other shrubs made up about 8% of rumen contents in both areas.

5.3.4 Changes in forage selection with grazing history

Cladina/Cladonia spp. and *Sphaerophorus fragilis*, the most commonly eaten fruticose lichens on both peninsulas, were consumed at similar rates in both study areas when adjusted for availability (Table 5.6). Absent in the rumens of FP caribou, *Cetraria nivalis* and *Stereocaulon* spp. were selected less frequently there than on MIP. Utilization of *Siphula ceratites*, Brown *Cetraria* spp., and *Alectoria/Cornicularia* spp. increased relative to availability on FP, despite their relatively low abundance there. *Cetraria cucullata*, *Dactylina* spp. and

Table 5.6. Patterns of forage selection relative to availability at caribou foraging sites on Foxe (FP) and Meta Incognita (MIP) peninsulas on Baffin Island during April 1992.

Plant class	FP - MIP ratio		FP - MIP selection
	Plant occurrence in rumen	Plant biomass at foraging sites	
Fruticose Lichens			
Sphaerophorus fragilis	0.4	0.4	1.0
Cladina / Cladonia spp.	0.2	0.3	0.6
Cetraria nivalis	0.0	0.2	0.0
Stereocaulon spp.	0.0	0.01	0.0
Siphula ceratites	6.3	0.4	16
Brown *Cetraria* spp.	4.8	0.5	10
Alectoria/Cornicularia spp.	1.0	0.2	5
Cetraria cucullata	N/A	0.3	N/A
Dactylina spp.	N/A	0.6	N/A
Thamnolia spp.	N/A	2.9	N/A
Foliose Lichens	1.1	0.8	1.4
Shrubs			
Dryas integrifolia	4.6[a]	6.5	0.7
Cassiope tetragona	20.5	1.3	16
Other shrubs[b]	0.9	0.19	4.7
Plant debris	1.1	0.7	1.6
Mosses	1.2	1.0	1.2
Graminoids	0.9	1.0	0.9

Table 5.6 continued

Note: The FP-MIP ratio of selection was derived by dividing the ratio of plant occurrence in rumens by the ratio of plant biomass at foraging sites. A ratio of selection ≤0.4 indicated that caribou on FP preferred that plant less than those on MIP; 0.5-1.5 indicated similar preference by caribou on both peninsulas; and ≥1.6 indicated that FP caribou had stronger preference.

[a] 0.1% was added to both the numerator and denominator because this plant did not occur in rumens from MIP, the denominator.

[b] Included: *Betula glandulosa, Diapensia lapponica, Empetrum nigrum, Ledum decumbens, Salix* spp., and *Vaccinium* spp.

Thamnolia spp. were not consumed by sampled caribou on either peninsula. Foliose lichens were selected at similar rates in both areas.

Among all plant classes, *Cassiope tetragona* and *Siphula ceratites* had the greatest increase in selection vs. availability on overgrazed FP. Selection-availability ratios were also higher for other shrubs on overgrazed range. Although *Dryas integrifolia* was not consumed by caribou on MIP, its higher occurrence in the rumens of FP caribou was in line with its greater availability in that study area. Plant debris was consumed somewhat more frequently by caribou on overgrazed FP when standardized for availability. Each of graminoids and mosses which were both commonly eaten and differed little in biomass between the two study areas also had similar selection-availability ratios in both study areas.

5.4 Discussion

White (1983) discussed multiplier effects that selective foraging and digestion of northern ungulates can have at the population level. These are some of several synergistic processes that may impact on the short- and long-term population dynamics of Arctic tundra caribou. By understanding interactions between ecological processes, it should be possible to reconcile different population trajectories that similar ecological factors may produce in different populations.

5.4.1 Forage selection on overgrazed and recently occupied winter ranges

Rangifer wintering in tundra habitats often consume relatively little lichen (Shank et al. 1978, Adamczewski et al. 1988, Thomas and Edmonds 1983, Larter and Nagy 1997, this study) in comparison to those wintering in forests (Scotter

1967, Bergerud 1972, Thompson and McCourt 1981, Boertje 1984, Helle and Aspi 1983). On overgrazed Coats Island, 250 km southwest of FP, lichens made up about 12% of caribou rumen contents in March-April during a relatively mild winter, and about 3% in a severe winter (Adamczewski et al. 1988). I expected that caribou on MIP would have consumed more lichen than on Coats Island, while those on FP would have approached those on Coats Island. The 6% lichens in FP rumens were within the expected range, but caribou on MIP had no more lichen in their rumens than caribou on overgrazed Coats Island. Accordantly, physical condition of MIP caribou was also similar to that of Coats Island caribou during a mild winter (Chapter 4). The high density of caribou on MIP may have impacted availability of high-quality winter forage during the four years preceding this study.

Cladina and *Cladonia* spp. are usually the lichens most selected by *Rangifer*. Although rumens of caribou on MIP had six times more of these lichens than those on FP, preferences were similar on both peninsulas, as indicated by the selection-availability ratios. Total biomass of *Cladina* and *Cladonia* within FP foraging sites was only 25% of that on MIP, yet 60% of FP caribou had consumed these lichens. These and other fruticose lichens (e.g., *Cetraria* spp.) are highly digestible if sufficient N is available in the rumen (Thomas and Kroeger 1981, Thomas et al. 1984), making them important energy sources for caribou during winter (Nieminen and Heiskari 1989).

Like other caribou wintering on overgrazed tundra (Adamczewski et al. 1988, Leader-Williams 1988) and on high Arctic islands (Parker 1978, Shank et al. 1978, Thomas and Edmonds 1983), both FP and MIP caribou consumed a relatively high proportion of graminoids. Basal clusters of green graminoid tissue, like those consumed by caribou on MIP and FP, can be highly digestible and provide caribou with N needed for digestion of lichens (Thomas and Kroeger 1981, Thomas et al. 1984). Preferences for graminoids by caribou on FP and MIP were similar.

Cassiope spp. are rarely consumed by caribou or reindeer, even on Arctic islands with a limited diversity of plants (Parker 1978, Shank et al. 1978, N. Tyler pers. comm., D. Thomas pers. comm., D. Klein pers. comm.). Among all plant classes, caribou on FP had the greatest increase in preference for *Cassiope tetragona* and the low growing lichen, *Siphula ceratites*, relative to caribou on MIP.

Caribou tend to select against mosses, and senescent or waxy leaves of shrubs and herbs (Thomas and Kroeger 1980, 1981, Thomas et al. 1984). Although mosses are less digestible than graminoids and their biomass was about 20 times greater than graminoids in both study areas, occurrence of mosses in rumen contents was similar to graminoids. Thus, FP and MIP caribou apparently selected against mosses, at least relative to graminoids. Although other shrubs occurred as frequently in rumens on MIP and FP, caribou apparently increased their preference of these plants on FP where biomass was only 19% of that on MIP.

Thomas et al. (1984) suggested that caribou select against aromatic evergreens (e.g., *Cassiope tetragona*) in order to maintain a digestible diet. Such shrubs probably contain compounds that make them unpalatable to caribou and inhibit digestive processes within the rumen, thus being antinutritional (Person et al. 1980, Bryant and Kuropat 1980, Trudell et al. 1980, Dannell et al. 1994). As with Peary caribou (Thomas and Kroeger 1980), caribou on FP in April 1992 apparently attempted to select mainly palatable and digestible forage (e.g., *Cladina* and *Cladonia* spp.), but resorted to filling their rumens with whatever vegetation was readily available, including *C. tetragona* and other shrubs.

The quantity and composition of ruminal microorganisms are affected by the nutritional history of an animal (Nieminen et al. 1980). Caribou recycle N which helps digestion of lichens (Wales et al. 1975), and lichens are more digestible in ruminal fluids from caribou in better physical condition than from those in poor condition (Thomas et al. 1984). Unavailability of high quality forage due to long-term overgrazing by caribou on FP may have forced them to forage on less palatable vegetation, and eventually plants with antinutritional compounds, thereby increasingly reducing digestibility of consumed forage; in turn lowering physical condition and reducing N recycling within the animals, impeding digestion and compromising physical condition even further (White 1983).

5.4.2 Forage accessibility on overgrazed and recently occupied caribou winter ranges

Sites with forage accessible through the snow make up a small proportion of the winter range of Arctic tundra caribou. Interactions between snow, terrain and wind determines the accessibility of forage on any given winter range, and the proportion of each winter range with accessible forage depends on the given terrain structure (Nellemann 1997). Within an 50-km^2 alpine wintering area in Norway, rugged terrain with suitable snow cover accounted for < 9% of the area (Nellemann 1996). The effects of wind, terrain and other factors within a given wintering area cause the same sites to be accessible to caribou in most winters. Peary caribou made annual east-west movements within a 64,000-km^2 area during late winter to occupy sites that allowed predictable access to available forage (Miller et al. 1982). Throughout Baffin Island, I have noted many sites where snow cover allows caribou predictable access to available forage. Caribou on MIP and FP selected foraging sites with similar topographic characteristics, although elevation differed somewhat with availability.

Arctic tundra caribou typically crater through snow that is much harder than snow cratered by caribou on forested winter range (Ouellet et al. 1993). LaPerriere and Lent (1977) suggested 85 kg·cm as the usual maximum snow hardness for cratering caribou, while Collins and Smith (1991) estimated the maximum to be 105 kg·cm in 2.5 cm of snow (based on Thing 1977). Despite being in very poor physical condition (Chapter 4), caribou on FP dug through snow 12 cm deep, with a hardness of 162 kg·cm; however, they started their craters at a mean depth of only 3.3 cm. Shallower starting depths allow conservation of energy because wind-hardened snow fractures more easily along broken edges of craters (Collins and Smith 1991).

Rangifer can remove almost all lichens within specific foraging sites within three winters (Pegau 1972, Inglis 1975, Helle 1984). Nevertheless, Caughley and Gunn (1993) suggested that caribou are not usually limited by absolute food supply, but by the depth and hardness of snow above the forage. Caribou on FP foraged through shallower and softer snow than did caribou on MIP. If caribou on FP were not limited by absolute food supply (as per Caughley and Gunn 1993), they should have been in better physical condition and should have had higher fecundity than those on MIP because they expended less energy during cratering; however, the reverse relationship was true (Chapter 4).

Energetic costs of cratering increase with snow depth and/or hardness, but cratering caribou would enter an energy deficit if energy intake is lower than the cost of accessing forage (Fancy and White 1985, Thing 1977), regardless of snow depth and hardness. Cumulative overgrazing on foraging sites that are accessible in most winters would accelerate energy and nutrient deficits once caribou are forced to consume quantities of less digestible plants, especially those with antinutritional compounds. Physical condition could then decline very rapidly as caribou become less able to dig through deeper, harder snow where forage of highest quantity and quality probably would occur.

Cratering by caribou on FP through shallower and softer snow was probably caused by synergistic eco-physiological processes, initiated by cumulative grazing impacts on absolute food supply within foraging sites. Maximum cratering depth on FP was similar to that on Coats Island during a severe winter when caribou there were in poor condition (Adamczewski et al. 1987*b*, 1988). On Southampton Island where caribou were in better condition than on MIP (Ouellet et al. 1993, Chapter 4), caribou dug craters through snow with hardness of 790 kg·cm, compared to 648 kg·cm on MIP. Because of lower energy deficits, greater absolute supply of digestible forage probably improves physical condition, enabling caribou to crater through deeper, harder snow.

Arctic tundra caribou that crater through shallow, soft snow may be showing the impacts of cumulative overgrazing, rather than taking advantage of unusually favourable snow conditions. Caughley and Gunn (1993) were correct in that Arctic tundra caribou are limited by their ability to find and use their food supply; however, on FP this ability was related to long-term overgrazing. Despite their apparent attempts to conserve energy by digging in shallow snow, caribou on FP were unable to compensate for the energetic deficit while cratering for overgrazed forage.

5.4.3 Impacts of cumulative overgrazing on forage resources and caribou populations

Despite changes in the status of certain lichens and vascular plants, as well as in the diet of *Rangifer* populations, such populations can continue to increase for several years (Klein 1959, 1968), and high fecundity can be maintained even among 15-17-year-old females (Staaland et al. 1993). Caribou have a variety of morphological, physiological, and behavioural traits (Klein 1996) which allow them to adapt to changing ecological processes at several spatial and temporal scales (Ferguson 1996).

At scales of 1000s of km^2, cumulative overgrazing by caribou apparently does not drastically change plant associations found within foraging sites on tundra winter range, but it does reduce variability in plant biomass among foraging sites. The NMDS of plant group 1, and other shrubs and plant debris revealed that biomasses of grazing-susceptible plants were highly variable on recently occupied winter range (Fig. 5.3 MIP, 5.4 MIP). Long-term overgrazing on FP apparently removed that variability (Fig. 5.3 FP, 5.4 FP). Once characteristics of foraging areas that are accessible to caribou in most winters are documented, identification of plant groups most susceptible to grazing impacts in various regions should allow early detection of landscape-scale overgrazing. In some regions where overgrazing has had persistent impacts (e.g., parts of Svalbard, Tyler 1987), long-term exclosures may be required to determine the make-up of ungrazed plant communities.

Grazing by caribou can negatively impact tundra vegetation in two ways: feeding and trampling. Most fruticose lichens are susceptible to both types of impacts (Palmer and Rouse 1945, Pegau 1970), but a few (e.g., *Thamnolia* spp.) are relatively resistant to trampling (Klein 1968). Both feeding and trampling probably affected fruticose lichens in plant group 1. Trampling (as opposed to feeding) probably had the greatest impact on other shrubs and plant debris (Helle 1984).

Trampling impacts and plant recovery depend largely on plant growth form, relative proportion of below-ground biomass, and soil moisture and condition (Palmer and Rouse 1945, Forbes 1997). Recovery is also influenced by changing species competition after overgrazing (Klein 1959, Pegau 1970). *Dryas integrifolia* was the only plant class that was more abundant on overgrazed FP than on MIP. The compact growth form of *D. integrifolia* enhances its resistance to trampling, and it was rarely consumed by caribou on FP and MIP.

The vast majority of caribou wintering on FP emigrated to MIP beginning in autumn 1988 (Chapter 4), thereby occupying a winter range that had a higher abundance of digestible forage on sites accessible during winter. With improved winter forage, caribou on MIP were in better physical condition, and accessed forage through deeper, harder snow cover than did those remaining on overgrazed FP. If a winter range like that on MIP had not been available, the entire sub-population would have suffered declining physical condition and productivity, comparable to caribou that remained on FP.

Based on Inuit knowledge (Chapter 3), migratory Arctic tundra caribou may initially become less migratory once physical condition begins to decline under moderate nutritional stress. However, later they may emigrate in search of better winter range when nutritional stress becomes more severe. Living on overgrazed winter range, even sedentary Svalbard reindeer will emigrate from their winter range when faced with starvation (Tyler 1987; Tyler and Øritsland 1989). If a large proportion of the population can and do emigrate, then the winter range may begin to recover. If not, the winter range will not recover, and the remnant population will probably experience fluctuations in response to interannual variations in snow cover (Tyler 1987; L. Nutaraluk pers. comm.).

Although cumulative overgrazing probably began one or more decades before the emigration (sensu Klein 1959), synergistic density-dependent and -independent processes did not obviously impact caribou physical condition and migratory movements on FP until the mid-1980s (Chapter 3). That was probably when physiological and behavioural adjustments by caribou on FP became insufficient to maintain physical condition over winter. A future challenge for ecologists who study Arctic tundra caribou will be to understand and model both density-dependent and -independent ecological processes that interact synergistically over several decades in a part of the world where long-term ecological research is in its infancy (Ferguson 1996, Thomas 1998). Future population changes of Arctic tundra caribou may appear to be caused by identifiable annual variations in snow conditions, but the overriding cause may actually be historical grazing pressures for which supporting scientific evidence may be absent.

6. WINTER FORAGING ECOLOGY OF ARCTIC TUNDRA CARIBOU: MOVING TOWARDS A UNIFYING MODEL

6.1 Ecological effects, factors, processes, and scales

No single proximate ecological factor can act on a caribou population in isolation of other factors; there is a plurality of causes in any ecosystem (Messier 1991). Caribou ecologists have engaged an often ineffectual debate over the roles of three ecological factors commonly used to explain temporal changes in caribou populations: predation, depletion of forage resources, and severe snow cover conditions that may restrict access to forage. Where wolves are present, the debate has involved all three factors (e.g., VanBallenberghe 1985; Bergerud and Ballard 1988; Eberhardt and Pitcher 1992). On predator-free Arctic islands, both forage depletion and restrictive snow cover have been used to explain fluctuations in *Rangifer* populations (Klein 1968; Adamczewski et al. 1988; Ouellet et al. 1996). For some populations of Arctic tundra populations, the relative importance of these two factors in massive population fluctuations has swayed back and forth (e.g., Vibe 1967; Thing 1984; Meldgaard 1986). Populations of Peary caribou on the Queen Elizabeth Islands reportedly have been limited mainly by interannual variations in density-independent snow conditions (Miller et al. 1977). Despite the presence of wolf and human predation on southern Baffin Island, I could not envision a mechanism by which predation could cause the massive winter range shift that was predicted and later observed (Chapters 3 and 4). Therefore, I focussed on assessing the roles of snow cover and forage resources in determining subsequent population dynamics and physical condition of caribou on FP and MIP (Chapters 4 and 5).

The development of a unifying model for the population ecology and dynamics of Arctic tundra caribou probably has been plagued by issues of scale described by Wiens et al. (1986). Caribou ecologists sometimes disparage, or simply ignore, the results of others who work at other temporal and spatial scales (Ferguson 1996), rather than reconciling the differences or discrepancies, and drawing insights from that work.

Because of the seasonal and interannual mobility of Arctic tundra caribou, their population dynamics and ecology can not be adequately understood unless research at the scales of individual patches and population ranges is set within regional scales (Wiens et al. 1986). The remoteness of Arctic habitats makes it unlikely that scientific research alone will provide the information across large temporal and spatial scales, at least in the near future (Jefferies et al. 1994).

Astute observers of a local or regional wildlife population should draw similar conclusions about the roles of essential ecological processes, if the observers compile similar information at comparable temporal and spatial scales. Differing conclusions about these processes are probably caused by differences in scales of observation (Wiens et al. 1986), parameters selected for observation, and methods of recording and interpreting those observations. Once methods for sharing empirical information become available (e.g., Chapter 2), the knowledge of Inuit and scientists observing the same ecological system should yield common interpretations. In this study, Inuit knowledge (Chapter 3) provided hypotheses for subsequent scientific examination, as well as a regional, multi-decadal context (Wiens et al. 1986) for interpretation of the scientific research. Inuit knowledge thus enabled scientific results (Chapters 4 and 5) to be viewed within broad temporal and spatial population patterns, rather than confining interpretation to the narrow scales in which they occurred.

The obstacles to a unifying ecological model for Arctic tundra caribou may also include the terminology currently used within ecological science. "Factors" and "effects" imply specific inputs producing specific outputs, and thus it seems logical that a distinctive set of quantified factors should produce a given population effect. Caughley and Gunn (1993) offered high interannual variation in some weather variables (e.g., thawing-degree days) as evidence of unpredictability of snow cover and other climatic conditions that caribou encounter in late winter or spring. The assumed effects of such ecological factors would be highly variable effects on late winter survival and perhaps subsequent productivity of regional caribou populations. However, no ecologist has identified consistent correlations between such factors and the survival and productivity of caribou. In Chapters 4 and 5, I showed that caribou foraging through shallower, softer snow can be in poorer physical condition than those foraging through deep, hard snow.

In Chapter 5, I suggested that ecological factors and effects could be viewed as synergistic ecological processes, in conjunction with physiological processes and behavioural responses of the caribou. Each process may cause effects that are incorporated with other processes to cause secondary effects. Similarly, Tyler (1987) concluded that a dependent-independent factor may serve to exaggerate underlying density-dependent effects already operating within a given system.

Inuit express their understanding of the ecology of Arctic tundra caribou in a similar way. Although all ecological processes are always operating, Inuit elders afford increasing importance to specific processes depending on the state of other ecological conditions. Inuit seem to accept seasonal and interannual climatic variability as a predictable part of Arctic tundra ecosystem. Caribou are not static receptors of specific ecological factors, but respond adaptively to the entire assemblage of synergistic ecological processes. Using observations of active hunters (and ecologists), Inuit elders predict the adaptive responses of caribou, based on their understanding of the variability in ecological processes most relevant to current and future situations. The reliability of such predictions has been critical to the survival and success of active subsistence hunters and their families.

High interannual variability of late winter weather conditions (Caughley and Gunn 1993) is predictable over the lifetime, multi-generational and evolutionary time scales. Arctic tundra caribou have evolved the capability to adapt to much of that variability. Miller et al. (1982) has shown that Peary caribou can adapt to temporal and spatial variability in forage accessibility both within seasons and between years at the landscape scale. They also suggested that late calving by Peary caribou may be an evolutionary adaptation to this predictable interannual variability that may be more severe at higher latitudes.

Studies set within narrow spatial and temporal scales help us understand proximate cause-effect relationships in specific situations (Weins et al. 1986), but ecological information at broader scales is needed to develop a unifying model for the population ecology of Arctic tundra caribou. If ecologists accept the dynamism of caribou responses to synergistic ecological processes, they should begin to focus not on the differences between specific factors and effects in each study, but in the commonality of ecological processes within Arctic tundra ecosystems, including the caribou's adaptive responses. We need to understand how the processes operate and influence each other.

6.2 Initial elements of a unifying conceptual model

High winter densities among some populations of Arctic tundra caribou, followed by periodic mass emigration, must have short-term selective advantages (Chapter 4). Fryxell (1991) examined potential effects of foraging facilitation, and ideal free dispersion between habitat patches, on aggregations of large herbivores. Apparently either the energetic consequences of facilitation or habitat patchiness could promote aggregations. In some ecosystems, foraging facilitation occurs through the maintenance of productive seasonal grazing lawns with high quality (immature) forage. However, such facilitation is not applicable to tundra caribou feeding on lichen and other vegetation requiring long recovery times (e.g., shrubs other than *Dryas* spp., Chapter 5).

Nevertheless, facilitation during winter foraging could promote aggregations among Arctic tundra caribou because of reduced energetic costs in expanding and maintaining open feeding craters, especially for calves (Thing 1977; Collins and Smith 1991). This facilitation would occur during the season when foraging habitats are most patchy which would further promote aggregations. Where prevailing snow conditions on rugged terrain allows access to forage over extensive areas (Nellemann 1997), there would be little selective advantage to disperse from such areas, unless the accessible biomass of forage was inadequate to maintain a minimal level of physical condition, as apparently occurred on FP (Chapters 3 and 4).

Ecological research must not only consider the generation time of the species of interest, but also those of the species with which it interacts (Wiens et al. 1986). Cumulative overgrazing and its impact on forage resources may be the principal ecological processes affecting temporal demographic patterns of many populations of Arctic tundra caribou. Population dynamics of Arctic tundra caribou probably have a forage-related time lag of 30-40 years, longer than that suggested by Messier et al. (1988) for a population of migratory forest-tundra caribou. Unfortunately, some ecologists studying Arctic tundra caribou may have ignored the underlying influences of this potential lag either because of the apparent dominance of short-term processes (e.g., severe snow) or because of the lack of historical ecological information.

The processes of forage productivity, grazing impacts on forage resources and changes in caribou physical condition are inextricably intertwined. Whenever the energy costs of accessing forage through the snow are not compensated by the energy assimilated, physical condition will decline. Through cooperative cratering at foraging sites, nutritional stresses would be shared by all animals, prompting either mass emigration in search of foraging areas with better forage resources or population-level declines in caribou survival and productivity on depleted or unproductive winter range.

Assuming that Arctic tundra caribou distribute themselves in an ideal free manner at landscape and regional scales (Fretwell and Lucas 1970), many demographic characteristics would depend on the size and dispersion of sites accessible to foraging caribou in most winters. Where potential sites are small but numerous, caribou group sizes should be small but numerous. Where foraging sites are large but widely scattered (e.g., on high plateaux), group size may be large but scattered. Similarly, if overgrazing has reduced forage biomass within sites across a given landscape, group size and density should both drop to reflect forage resources potentially available to individual animals (Chapter 4 and 5).

Differences in the dispersion of winter foraging sites, and their proximity to other seasonal habitats, may lead to the evolution of differing seasonal movement patterns of Arctic tundra caribou. The existence of different landscapes in relatively close proximity at a regional scale may have produced the different types of South Baffin caribou identified by Inuit (Chapter 3).

Habitats that have inherently low primary productivity due to climate (e.g., high elevations or latitudes with short growing seasons) are likely to be affected by grazing at low caribou densities. Thing (1984) concluded that relatively low densities of caribou can maintain lichen resources in a perpetually overgrazed state. Even though forage lichens are rare on the Queen Elizabeth Islands, lichens occur in the winter diet of Peary caribou at a higher rate than expected by availability (Thomas et al. in preparation). Svalbard reindeer which usually feed on a wide variety of forage will prefer fruticose lichen where available (Staaland et al. 1993).

Over several decades or between different regions, the dominant migratory patterns of Arctic tundra caribou may change as Inuit reported for South Baffin caribou (Chapter 3), depending on the success of different migratory strategies. Low densities of caribou may survive on winter ranges with poor forage resources by conserving energy. When alternative winter ranges with adequate forage resources are available, selective advantages may favour migratory caribou that apparently tend to emigrate en masse (Chapter 3). However, when such alternatives are not available, resident caribou may have a selective advantage with lower energy requirements than migratory animals searching for better winter ranges. Inuit reported extensive evidence of range volatility during the 1940s when caribou were rare on southern Baffin Island, but some special areas consistently had low numbers of caribou in most seasons (Chapter 3).

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APPENDIX A: INTERVIEW CONSENT FORM FOR INUIT KNOWLEDGE STUDY

INTERVIEW CONSENT FORM

PROJECT TITLE: Inuit Knowledge about Historical and Seasonal Distributions of Caribou on Southern Baffin Island

PROJECT DESCRIPTION:
(Given to the interviewee before interview)

The objectives of this project are: to record eye-witness observations of caribou distributions made by Inuit elders and hunters, to develop a composite description of historical and seasonal changes in caribou distributions based on those observations, and to explore the potential causes of those changes.

The researcher will interview each Inuk who agrees to participate to record their personal knowledge about caribou distributions on southern Baffin Island. After conducting a number of interviews, the researcher will compile the information from all informants in each community and produce a series of composite maps and/or overlays showing changes in caribou distribution over time.

RESEARCHER'S NAME, ADDRESS, AND TELEPHONE:

Michael A.D. Ferguson
P.O. Box 202, Pond Inlet, NT X0A 0S0
Telephone: (819)899-8994.

CONSENT TO BE INTERVIEWED:

I, ____________________ of the Hamlet/Town of

____________________, have been informed of the objectives of the project being conducted by Michael A.D. Ferguson. I understand the objectives of the project and consent to being interviewed for the project. I also agree to have the interview recorded on audio-tape.

____________________ ____________________
Date Signature

____
Witness

CONDITIONS FOR THE USE OF THE INTERVIEW INFORMATION, AND ACKNOWLEDGEMENT OF THE INFORMANT:

(Below the informant is to initial either Yes or No, or fill in the appropriate blanks; and then sign at the bottom of the page)

1. The researcher may use the information that I provide to produce, publish and/or present information about the historical and seasonal distributions of caribou, and to explain the potential causes of changes in caribou distributions.

YES _____ / NO _____

2. The researcher may retain copies of the interview tapes, transcripts and maps/overlays to meet the objectives of this project.

YES _____ / NO _____

3. Within two years after the date of the interview, the researcher must provide copies of the interview tapes, transcripts and maps/overlays to:

____.

4. To use any information for other reasons, the researcher or other persons must obtain consent from:

____.

5. In any publication and/or presentation which uses the information that I provide, the researcher must acknowledge me as having contributed to the project.

YES _______ / NO ______

6. Other conditions are:

____.

Informant's signature: ____________________________.

BIOGRAPHICAL

1952	Born in Moncton, New Brunswick, Canada
1974	Bachelor of Science. Major in Biology. University of New Brunswick
1977	Bachelor of Science, First Class Honours in Biology. Carleton University
1980	Master of Science in Wildlife Ecology. University of Wisconsin - Madison

HONOURS

1976-77	James Rattray Bursary. Carleton University
1980	Aldo Leopold Scholarship. University of Wisconsin - Madison
1993	Lorraine Allison Memorial Scholarship. Arctic Institute of North America
1993	Scholarship. Beverly and Qamanirjuaq Caribou Management Board
1993-94	Grant. NWT Environmental Action Plan. Indian and Northern Affairs Canada
1994	Grant. Northern Science Training Program. University of Saskatchewan

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