STATUS OF CARIBOU AND MUSKOX POPULATIONS WITHIN THE PRINCE OF WALES ISLAND-SOMERSET ISLAND-BOOTHIA PENINSULA COMPLEX, NWT, JULY-AUGUST 1995

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ABSTRACT

Caribou (*Rangifer tarandus*) have almost disappeared from Somerset and Prince of Wales islands. Inuit hunters from Resolute, Cornwallis Island, Northwest Territories, reported poor hunting success and few caribou seen during hunting trips on Somerset and Prince of Wales islands in the early 1990s. In response to their concerns, we aerially surveyed caribou and muskoxen (*Ovibos moschatus*) within the Prince of Wales Island - Somerset Island-Boothia Peninsula complex between 21 July and 3 August 1995 to determine their status. The 1995 aerial survey was directly comparable to the surveys flown in 1980 for caribou and muskoxen on Prince of Wales, Russell and Somerset islands (which led to an estimate of 5100 caribou) and in 1985 for caribou and muskoxen on the Boothia Peninsula. We used the same type of fixed-wing aircraft, a Helio-Courier, flown at ca. 150 m above ground level and an airspeed of ca. 160 km per hour. We covered all three major islands and the Boothia Peninsula at between 8 - 30% coverage. We saw only 5 caribou on Prince of Wales Island, 2 caribou on Somerset Island, and no caribou on Russell, Prescott, Pandora, and Vivian islands. The 7 caribou represented a 99.6% reduction in the number of caribou actually seen on those islands during the aerial survey in summer 1980. Our estimate of 6658±1728 SE (Standard Error) caribou on the Boothia Peninsula in 1995 is similar to the 1985 estimate. The estimated number of muskoxen (5259±414 SE) on Prince of Wales Island is nearly a 5-fold increase over the number estimated in 1980. Muskoxen also continue to increase in number (1140±260 SE) and to expand their ranges on Somerset Island with nearly a 13-fold increase in the number seen during the survey in 1995 (n=455) compared to 1980 (n=29: no estimate was made in 1980). Muskoxen are recolonizing the Boothia Peninsula, with 61 being seen in 1995, where none were seen in 1985. Possible reasons for the caribou decline are discussed.

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INTRODUCTION

Inuit hunters from Resolute, Cornwallis Island (74.700^{o} N, 94.833^{o} W), Northwest Territories (NWT) reported finding it increasingly difficult to find caribou (*Rangifer tarandus* spp.) during winter hunting trips in the early 1990s on Prince of Wales, Russell, and Somerset islands. Those reports suggested a serious problem, as the island previously held an estimated 5100 $\pm$ 710 SE (Standard Error) caribou in 1980 (Gunn and Decker 1984). The caribou on those island were nationally recognized in 1990 as a “Threatened” form of wildlife in Canada by the Committee on the Status of Wildlife in Canada (COSEWIC 1990). In response to hunters’ concerns and because 15 years had elapsed since the last population estimate, we surveyed Prince of Wales, Somerset, Russell, Prescott, Pandora, and Vivian islands and the Boothia Peninsula for caribou and muskoxen (*Ovibos moschatus*) in 1995.

Surveys and environmental studies in the 1970s associated with the proposed Polar Gas pipeline collected ecological information on Prince of Wales and Somerset islands (Fischer and Duncan 1976, Russell et al. 1978, Miller and Gunn 1978, Thomas 1982, Thomas and Everson 1982). The most recent aerial survey of Prince of Wales and Somerset islands was in 1980 and Gunn and Decker (1984) concluded that the caribou population, an estimated 5100, was stable or slightly declining.

Inuit local knowledge and seasonal differences in caribou numbers during aerial surveys in the 1970s suggested that caribou were wintering on Somerset and moving to Prince of Wales to calve and spend the summer (Miller and Gunn 1978). Caribou left Somerset where ground-fast ice depths were greater in spring to forage on Prince of

Wales where the snow was more shallow and retreated more quickly (Miller *et al.* 1982). As well as moving between Prince of Wales and Somerset islands some caribou moved from the Boothia Peninsula to Somerset and Prince of Wales in late winter/spring and subsequently returned to the Boothia Peninsula each autumn or winter.

Because of these inter-island movements we decided to survey the Boothia Peninsula at the same time as Prince of Wales, Russell and Somerset islands. The Boothia Peninsula was last surveyed in 1985 when Gunn and Ashevak (1990) estimated the population to have 4831 $\pm$ 543 1^{+}-yr-old caribou.

The objective of our survey was to estimate caribou numbers on the Prince of Wales Island-Somerset Island-Boothia Peninsula complex. We followed similar methods and timing as the 1980 survey to ensure that the estimates were comparable. As in 1980 and 1985, we also recorded muskoxen sightings to estimate their population sizes.

METHODS

Our survey design was a systematic transect survey with effort varying between strata. Stratification was based on 1980 caribou and/or muskox mean densities - the highest mean density strata receiving the greatest aerial coverage. We flew in the same aircraft as in 1980 - a Helio-Courier on tundra tires. The survey crew included the same pilot and navigator as in 1980 and a left observer with extensive local knowledge of the islands. The pilot plotted locations on 1:250 000 map sheets while the navigator recorded the observer's sightings of caribou and muskoxen as being “on” or “off” transect . From Resolute, we set up a camp at Crooked Lake (Fig. 1) as a base for surveying Prince of Wales, Russell, Prescott, Pandora, Vivian and Somerset islands. We moved to Taloyoak (63.533^{o} N, 93.517^{o} W) for the Boothia Peninsula survey. We had fuel cached at Crooked Lake, Creswell Bay and the northeast coast of Boothia Peninsula.

We divided Prince of Wales Island into 4 strata (Stratum I, II, III, IV), made Russell Island Stratum V, and grouped Prescott, Pandora, and Vivian islands as Stratum VI. Transect lines were 8 km apart in strata I-VI. Somerset Island was also divided into 4 strata. Transects in Stratum I were 16 km apart while those in strata II, III, IV were 5 km apart . The Boothia Peninsula was divided into two strata with transect lines in the northern part of Stratum I and Stratum II were 16 km apart. Transects 129-132 in Stratum I on the central Boothia Peninsula were 8 km apart.

Transect lines were run at as much of a right angle as possible to the coast or to major rivers to avoid sampling bias caused by animals being concentrated in and

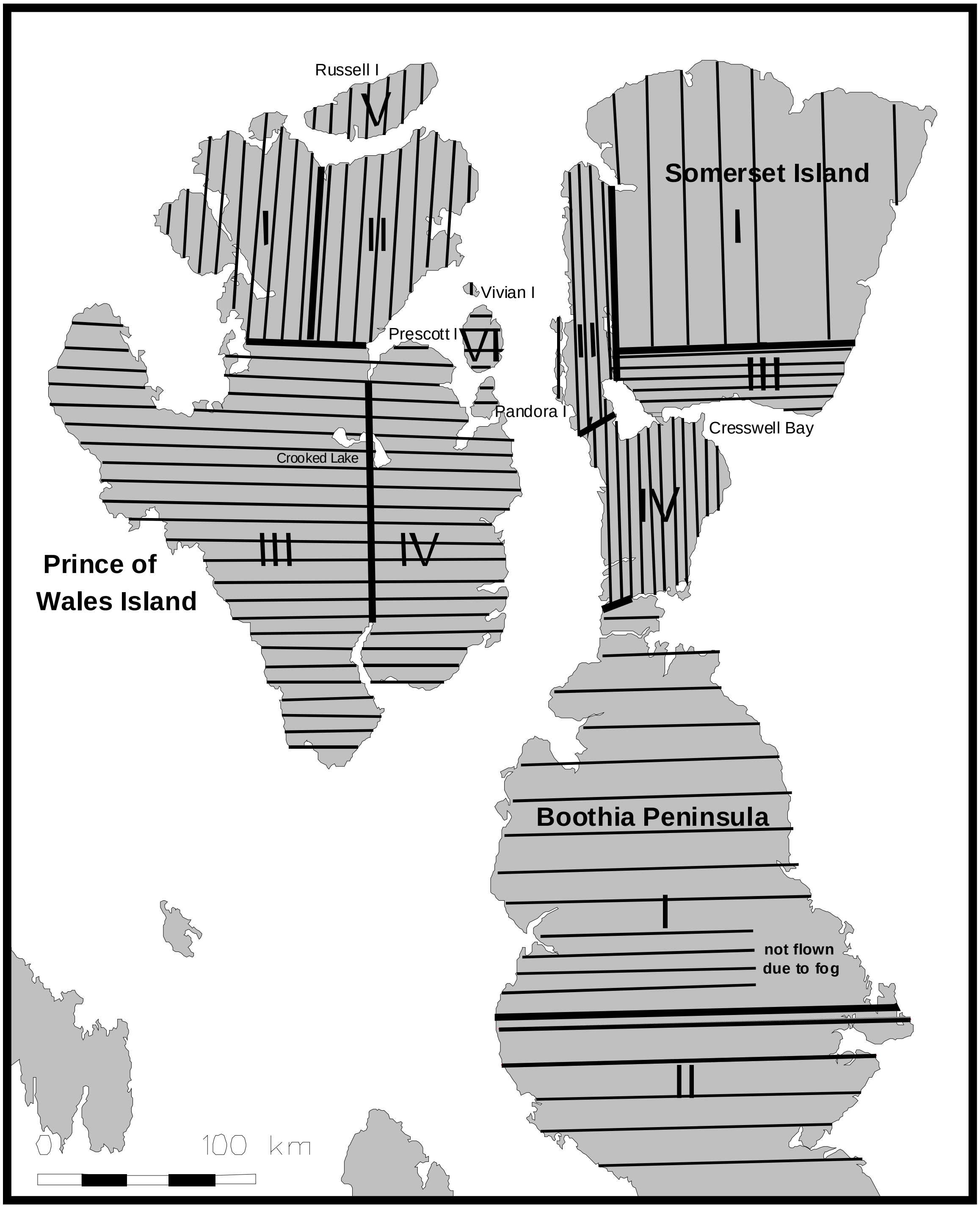

Figure 1. Aerial transect survey of Prince of Wales Island-Somerset Island-Boothia Peninsula complex, NWT, July-August 1995, showing strata and approximate locations of transect lines.

along valleys.

Transect strip width was 1.6 km (0.8 km strip on each side of the aircraft flight path). Transect boundaries were calculated (Norton-Griffiths 1978) and marked on rope stretched from an eyebolt on the fuselage of the plane to an eyebolt on each wing. The survey altitude was 150 m above ground level and the survey air speed was ca 160 km/hr.

Jolly's method #2 for unequal-sized sample units (transect lines are not the same length) was used to calculate population estimates (Jolly 1969). We used the Wilcoxon matched pairs signed rank test to determine if there were differences between the counts of caribou and muskoxen by the left and right observers (SigmaStat for Windows, Jandel Scientific Software 1994).

RESULTS

We flew 113 hours between 21 July and 3 August 1995 including ferry flights between Norman Wells and the survey area. Average sampling intensity for Prince of Wales Island was 20% (Table 1). Stratum I on Somerset Island received low (8%) coverage and was dropped from the calculation of the population mean estimate for muskoxen as none were seen there. Coverage of strata II, III and IV averaged 30% (Table 2). Sampling intensity for the Boothia Peninsula was 11% for Stratum I and 9% for Stratum II. (Table 3).

Survey conditions were favourable for the Prince of Wales, Russell, Prescott, Pandora, Vivian and Somerset islands portion of the survey as visibility was good and we were grounded by fog only once. Fog was a problem on the Boothia Peninsula and resulted in dull visibility preventing us from flying the eastern portions of transects 129 - 132 (App. A). Eastern portions of lines 133-137 were flown on July 31 but western portions of these transects were not flown until the following day due to fog and poor visibility.

Caribou

<u>Prince of Wales, Somerset, Russell, Pandora, Prescott and Vivian islands</u>

We counted 7 caribou: 5 on Prince of Wales Island, 2 on Somerset Island, and none on Russell, Prescott, Pandora, or Vivian islands. On Prince of Wales Island two single bulls were seen “on” transect and a group of 3 cows were seen “off” transect. On Somerset island a group of 2 cows was seen “off” transect (Fig 2).

Table 1. Data from an aerial transect survey of Prince of Wales, Russell, Prescott, Pandora and Vivian islands, NWT, July 1995, used to calculate a population mean estimate for muskoxen.

	Island/Stratum						
	Prince of Wales				Russell	Prescott/ Pandora/ Vivian	Totals of all strata
Variables	I	II	III	IV	V	VI	
Stratum area, km^2	4896	4713	15 262	8075	975	564	34 487
Sampling area, km^2	1002	970	2971	1650	200	116	6911
Sampling intensity (%)	20	21	19	20	21	21	20
No. possible transects	48	44	120	99	35	30	376
No. transects flown	9	8	28	20	7	7	79
No. muskox counted	104	72	393	452	21	14	1056
Mean density, $muskox/km^2$	0	0.07	0.13	0.27	0.10	0.12	0.15
Population mean estimate	508	350	2019	2212	102	68	5259
Standard error	121	147	257	250	54	48	414
Variance	14 658	21 661	66 223	62 508	2886	2300	17 236
Coefficient of variation	0.24	0.42	0.12	0.11	0.53	0.71	0.39

Table 2. Data from an aerial transect survey of Somerset Island, NWT, July 1995, used to calculate a population mean estimate for muskoxen.

Variables	Stratum/Somerset Island				Total*
	I	II	III	IV	
Stratum area, km^2	15 274	2188	2603	3753	8544
Sampling area, km^2	1251	772	643	1182	2597
Sampling intensity (%)	8	35	25	31	30
No. possible transects	93	18	18	35	71
No. transects flown	7	5	5	12	22
No. muskox counted	0	154	31	182	367
Mean density, muskox/km^2	0	0.20	0.05	0.15	0.14
Population mean estimate	-	437	125	578	1140
Standard error	-	155	58	201	260
Variance	-	23 989	3309	40 509	67 807
Coefficient of variation	-	0.35	0.46	0.35	0.23

* Stratum I was dropped from totals.

Table 3. Data from an aerial transect survey of the Boothia Peninsula, NWT, July-August 1995, used to calculate a population mean estimate for muskoxen.

Variables	Stratum/Boothia Peninsula	
	I	II
Stratum area, km^2	18 855	13 860
Sampling area, km^2	2044	1209
Sampling intensity (%)	11	9
No. possible transects	98	109
No. transects flown	14	5
No. muskox counted	60	1
Mean density, muskox/km^2	0.03	<0.01
Population mean estimate	554	-
Standard error	205	-
Variance	42 113	-
Coefficient of variation	0.37	-

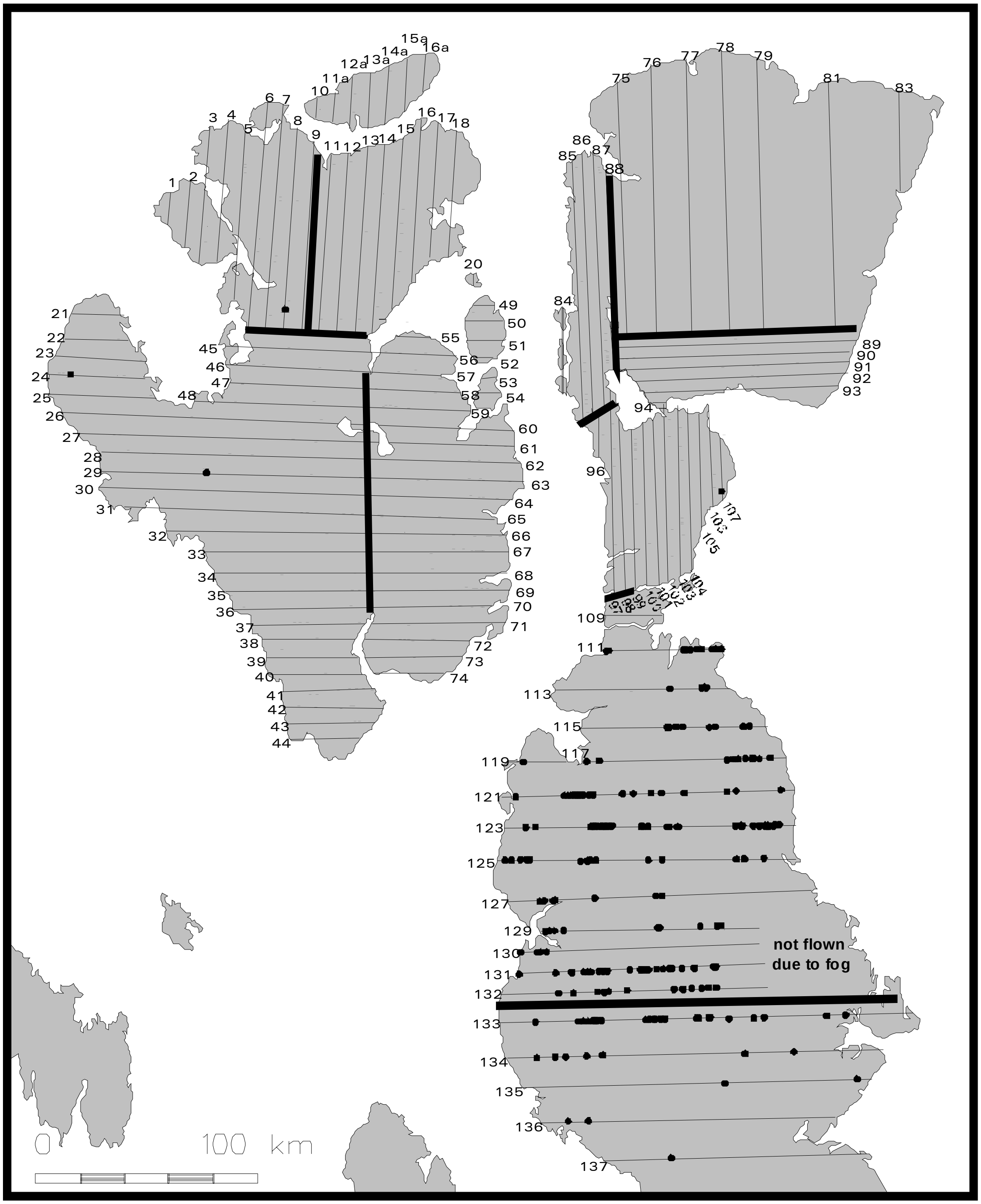

Figure 2. Locations of observations of caribou seen “on” and “off” transect during an aerial survey of Prince of Wales Island-Somerset Island-Boothia Peninsula complex, NWT, July-August 1995, data presented by each transect line.

Boothia Peninsula

We counted 693 caribou on 3253 km^2 of transects for a mean estimate of 6658 $\pm$ 1728 SE (Table 4). This is not a significant increase over the 4831$\pm$ 543 SE estimated in 1985 (t= -1.17, 45 df; P=0.25). The observers did not distinguish between arctic-island and barren-ground caribou during the survey although both types were seen. A Wilcoxon signed rank test showed there to be no difference (P = 0.35) in the number of muskoxen and/or caribou observed on transect by the left or the right observers.

Muskoxen

Prince of Wales, Russell, Pandora, Prescott and Vivian islands

We counted 1056 muskoxen on 6911 km^2 of transect for a mean estimate of 5259 $\pm$ 414 SE (Table 1). This is nearly a five-fold increase over the 1980 mean estimate of 1126 $\pm$ 276 SE. In 1980, muskoxen were found only on the eastern third of Prince of Wales Island. Results show that, in 1995, this is still the area of highest mean density (Stratum IV: 0.27 muskoxen / km^2) but that muskoxen are now distributed over the remainder of Prince of Wales Island and onto Russell Island (Fig. 3).

Somerset Island

We counted 367 muskoxen on 2597 km^2 of transect strips for a mean estimate of 1140 $\pm$ 260 SE (Table 2). In 1980, only 29 muskoxen were counted on Somerset Island and no population mean estimate was made. Stratum I data was not included in the calculations of population estimates as no muskoxen or caribou were seen (Table 2) and the almost total lack of vegetative cover, seemingly, makes it unfavourable habitat for muskoxen and caribou.

Table 4. Data from an aerial transect survey of the Boothia Peninsula, NWT, July-August 1995, used to calculate a population estimate for caribou.

Variables	Stratum		Total
	I	II	
Stratum area, km^2	18 855	13 860	32 715
Sampling area, km^2	2044	1209	3253
No. possible transects	98	109	207
No. transects flown	14	5	19
No. caribou counted	575	118	693
Mean density, caribou/km^2	0.28	0.10	0.21
Population mean estimate	5305	1353	6658
Standard error	564	1633	1728
Variance	318 247	2 666 913	2 985 160
Coefficient of variation	0.12	1.2	0.26

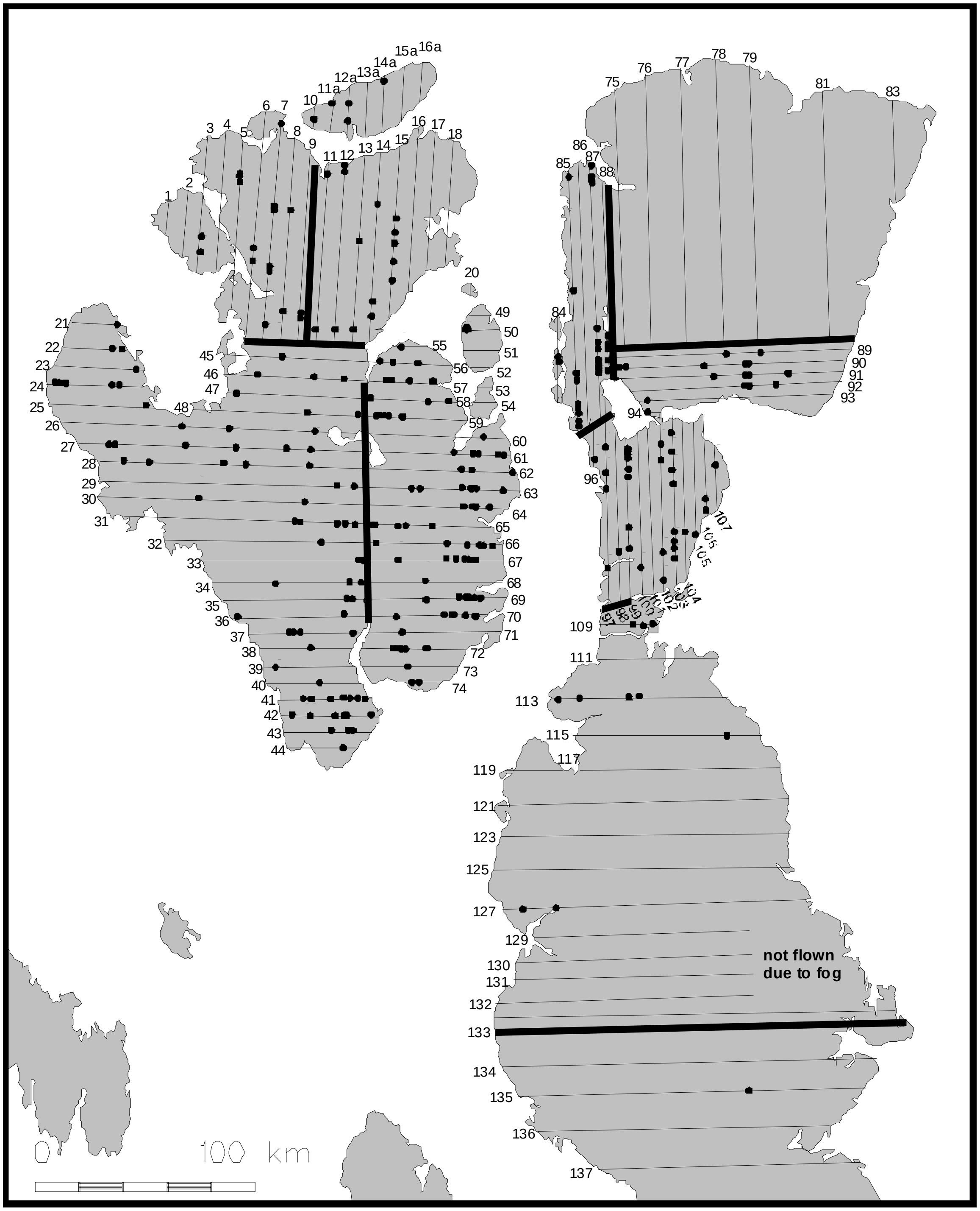

Figure 3. Locations of observations of muskoxen seen “on” transect during an aerial survey of Prince of Wales Island-Somerset Island-Boothia Peninsula complex, NWT, July-August 1995, showing strata and approximate locations of transect lines.

Boothia Peninsula

We counted 61 muskoxen on 3253 km^2 of transect strips. The population mean estimate for Stratum I was 554 $\pm$ 205 SE (Table 3). This is a significant increase as no muskoxen were counted on the Boothia Peninsula in 1985. Too few muskoxen were counted in Stratum II to calculate a usable population estimate.

DISCUSSION

Reasons for the caribou's virtual disappearance from Prince of Wales, Somerset and their satellite islands are not conspicuous. The first possible line of speculation is that we missed seeing hundreds of caribou because of technical problems with the survey - either in the design and/or execution. The design and methods used were the same as those that led to the estimate of 5100 $\pm$ 710 SE caribou in 1980. The survey's geographic coverage of both islands was extensive enough that we were not likely to miss large parts of the caribou's distribution. We covered both the main winter range (Somerset) and spring-summer range (Prince of Wales) based on our knowledge of past seasonal movements (Miller *et al.*1982).

Observers for aerial surveys almost inevitably miss some individual animals and this would hold true for our survey. We flew at the usual altitude and speed for caribou surveys but we would have missed some caribou no matter how conspicuous they might have been. However, we had an experienced Inuit hunter, survey biologist and pilot which gives us confidence that we would not have missed many caribou. Weather conditions were favourable for seeing caribou, except on occasion on the Boothia Peninsula.

After our survey, we cooperated with the Canadian Wildlife Service and Frank L. Miller who surveyed Prince of Wales and Somerset islands in May 1996. During his unsystematic but extensive survey, he found only two caribou (Miller 1997). Under bright sunlight and against a fresh snow background, caribou tracks, feeding craters and the caribou themselves are conspicuous. The virtual absence of caribou sign during Miller's survey, together with the 1995 summer results, offer evidence for the absence of caribou on an essentially year-round basis. These combined results should remove any serious doubt, about our ability to see caribou if they were there in summer 1995.

If our survey and design were suitable, then what other explanations can be supported? Evidence for any explanation is scanty. For Prince of Wales, Russell, and Somerset islands, we have two estimates of population size 15 years apart and weather information from Resolute during that time period. We know from the Inuit that wolves *(Canis lupus)* and hunters were taking caribou. We are handicapped by not being able to estimate rates of predation, hunting or other mortality and by having essentially no information on birth rates or emigration. We have no reports about die-offs or disease. We have to draw on existing knowledge from other declines in caribou populations.

Possible mechanisms to explain the disappearance, either singly or in combination, are emigration, increased death rates (hunting, predation, malnutrition) and reduced birth rates. Possible agents directly causing increased deaths, either singularly or in combination, are wolves and hunters. Severe weather, intra- or inter-specific competition may have acted indirectly by reducing forage availability causing malnutrition which would have reduced pregnancy and survival.

Emigration

Most of the caribou that used to summer on Prince of Wales Island seasonally migrated from Somerset Island with fewer caribou migrating from Boothia Peninsula (Miller and Gunn 1978, Miller et al. 1982). The caribou from Somerset moved to the northwest coast of Prince of Wales to calve. However, the large body-size of five bulls collected on Prince of Wales Island in summer 1978 (Thomas and Everson 1982) indicate they may have been summer migrants, possibly from Victoria Island. Their skull shape and pelage coloration were similar to the seven bulls collected on Prince of Wales Island in summer 1958 (Manning and Macpherson 1962). If these animals were from Victoria Island, then it raises the question of how extensive was the migration between Victoria Island and Prince of Wales Island and why did it ceased. We have recorded caribou increasing on Victoria Island, but the increase began in the 1970s (Gunn 1990). That timing suggests that a sudden influx from Prince of Wales Island to Victoria Island in the early 1980s was less likely, but it neither precludes a later influx nor a steady trickle of caribou over years.

We know that in addition to seasonal migrations between or among islands (and sometimes between islands and mainland peninsulas) caribou on the Canadian Arctic Archipelago make sporadic movements in response to severe icing and/or snow conditions that reduce forage availability (Miller 1990). We do not know, however, whether survivors from such movements return to the island that they occupied before being forced to migrate or if they remain on one of the islands or mainland areas that they reached during migration to either colonize it or join an existing caribou population. We have had no sightings or records of such movements from Prince of Wales, Russell, or Somerset islands. However, based on weather recorded at Resolute and described in the following section on weather, there were winters in the mid-1990s similar to the 1973-74 winter that did trigger “desperation” moves with caribou leaving Bathurst Island. This suggests that we cannot discount environmentally-forced movements as a possible cause for the absence of caribou on Prince of Wales, Russell, and Somerset islands.

Hunters in Gjoa Haven have reported that some caribou came from Prince of Wales Island to King William Island in the early or mid-1970s (J. Keanik pers. comm. 1998). As well, some hunters from Resolute (D. Kaomayok, pers. comm.) believe that Prince of Wales caribou did move to Bathurst Island in the 1990s. However, researchers from the Canadian Wildlife Service working on Bathurst Island in the early 1990s did not see sufficient numbers of caribou during range-wide aerial searches for caribou to account for a redistribution from Prince of Wales and Somerset islands. Nor did they see any large-bodied caribou that would indicate that they were arctic-island caribou, which are significantly larger than the Peary caribou from Bathurst Island (Thomas and Everson 1982) . Likewise, we have heard no comments from Inuit hunting on Bathurst Island that they have spotted arctic-island caribou.

Our population estimate for the Boothia Peninsula does not indicate that Prince of Wales and Somerset islands caribou emigrated to the Boothia Peninsula in any substantial numbers, at least between 1986 and 1996, or if they did, they did not live long enough to be detected in 1995.

Increased deaths and/or decreased births

We have no estimates or even guesses for death rates. The few data on birth rates and recruitment indicate that pregnancy rates vary annually and over-winter calf survival is low. Thomas (1982) determined pregnancy rates during caribou collections from 1974 to 1977. The rates were 40% (5 cows collected), 92% (12), 73% (26) and 100% (9) for >2-year-old cows. Although those rates were relatively high for 3 of the 4 years, over-winter calf survival seems low. We only have data on calf survival for 2 years and those are from ground counts during behavioural studies (Miller and Gunn 1978). Yearling percentages were 2.2% in 1976 compared to a pregnancy rate of 92% in 1975 and 3.7% in 1977 compared to a pregnancy rate of 73% in 1976.

Factors affecting birth and death rates

Hunting: Caribou from Prince of Wales and Somerset islands were harvested only by Inuit from Resolute. In 1975, after a die-off on Bathurst Island, the Inuit voluntarily stopped hunting on Bathurst Island and shifted their hunting to Prince of Wales and Somerset islands until 1990 when a few caribou were killed on Bathurst. Unfortunately, we have almost no data on the harvest from Prince of Wales and Somerset islands. Gunn and Decker (1984) suggested the annual harvest was 150-250 during the late 1970s and early 1980s. By the late 1980s, caribou hunting became less important as more people took jobs or left the community (J. Stevenson, pers. comm.). The Baffin Harvest Study (BRHTC and DRR 1995), which ran from 1987 to 1990, only tables a recorded harvest of 102 caribou for 1988-89 for Resolute most of which were taken in August 1988.

Wolf predation: We only know that wolves occur throughout the region and that wolves have denned on Prince of Wales Island (Miller 1993b) and most likely on Somerset and Russell islands. There is no information on wolf diet although a few wolf-killed caribou were found in the mid-1970s. We cannot comment on predation rates or their influence on caribou numbers as we totally lack the necessary quantitative data. However, we note that Resolute hunters have reported increases in wolves during the

1990s and we suggest that the five fold increase in muskoxen on Prince of Wales between 1980 and 1995 would probably support a high number of wolves.

Diseases and parasites: Between 1975 and 1977, no evidence of disease was found during autopsies and serum tested negative for brucellosis. However, a single clinical case of brucellosis was reported subsequently and brucellosis is recorded on Boothia Peninsula (Forbes 1991). Counts of warble fly larvae varied among years but were less than recorded for the mainland (Thomas *et al.* 1977).

Some carcasses on the west coast of Somerset were recorded in winter 1992 and hunters suspected disease as the caribou were not in poor condition (F. L. Miller pers. comm. 1998).

Winter weatherr: Snow depth, density and hardness affect forage availability and can significantly increase the energetic costs of foraging or preclude it altogether. The relationship between snow/ice conditions, caribou behaviour and movements is well-documented for some arctic islands (Miller *et al.* 1982, Miller 1992, 1993a and 1994). Adverse foraging conditions can be severe enough to reduce body condition to the point of death (e.g. Parker *et al.*1975).

The few data that we have on calf survival (from 1976 and 1977) show no correlation, however, with winter snowfall for those two winters, based on weather records from Resolute (the nearest weather station). We have no means of knowing how representative trends in snowfall for Resolute are representative of trends for Prince of Wales and/or Somerset islands but Maxwell (1980) included Prince of Wales and western Somerset in the same climatic region as Bathurst and Cornwallis islands.

Thus we have some confidence in extrapolating from the Resolute weather records. In the 1975-76 winter, total annual snowfall (83 cm) was above the long-term average (69$\pm$ 21 SD) but not significantly. For the 1976-77 winter, snowfall (39 cm) was below average. Total snowfall is not the sole criterion of severe weather for caribou, but is useful as a coarse index. During exceptional winters, when die-offs have occurred, total snowfall was above the long-term average (e.g. Parker *et al.* 1975).

Inspection of the weather data does suggest a trend towards increasing snowfall in the 1980s (Maarouf 1992) and again in the mid-1990s. However, we have little information on the extent to which winters with above average snowfall translate into lower pregnancy and/or survival rates. During the late 1980s and early 1990s, winter conditions were favourable on Bathurst Island and caribou numbers increased with high calf survival. Between 1994 and 1997, severe winters and trends of increasing snowfall coincided with caribou die-offs and population declines (F. L. Miller pers. comm.).

Summer weather r: The relationship between fat reserves and pregnancy rates (Thomas 1982) is well-documented. However, pregnancy rates did not correlate with winter weather, probably because conception depends on adequate fat reserves during the rut which depends on summer foraging. We have no direct evidence from the Canadian arctic but Tyler (1987) described an interaction between summer weather, reindeer (*R. t. platyrhynchus*) densities and winter survival for reindeer on the arctic island of Svalbard (northern Europe). Tyler (1987) suggested high mortality coincided with below average summer rainfall preceding a cold winter (he did not include snow depth or freezing rain) and high reindeer densities (> 2.7 reindeer/km^2). When densities exceeded >5.1 reindeer/km^2 in the 1983/84 winter, mortality and emigration were greater although the winter was less severe.

Winter ranges on Svalbard are heath and scree communities with exposures that ensure that snow remains shallow. However, the productivity of such dry communities is limited by summer moisture (Tyler 1987). Svalbard reindeer, despite their prodigious fat accumulations by fall, still rely on winter foraging for 75% of their energy requirements. Tyler (1987) concluded that it was unclear how the influence of snow and ice conditions compared to the influence of summer plant growth, on annual variations in the reindeer's winter diet.

On the Canadian Arctic Islands, caribou in winter feed on xeric exposed plant communities dominated by dwarf cushion plants (references in Miller 1990) whose primary productivity is relatively low and moisture limited (Svoboda 1977). Summers were increasingly drier during the late 1970s, although the trend reversed in the early 1980s (Maarouf 1992). Evidence for whether moisture was ever reduced to a level where it would have retarded plant growth causing or adding to caribou malnutrition is circumstantial and tenuous at the low mean densities of caribou recorded in the Canadian Arctic Archipelago. We suggest, however, that the role of summer rainfall and caribou population densities in determining absolute forage availability as well as the effect of winter conditions on relative forage availability, should be figured into any evaluation of the effect of severe winters.

Competition with muskoxen: If we are handicapped by not knowing either the effect of caribou or weather on forage growth, then we are in an even shakier position in understanding relationships among herbivores and their forage. Almost all attention has focused on the relationship between muskox and caribou rather than on the role of invertebrates or smaller vertebrates.

There has been a long-standing controversy about the relationship between caribou and muskoxen. The idea of muskox competing with caribou seems to have originated in the early 1970s, when Inuit from Sachs Harbour on Banks Island voiced concerns about caribou dying and muskox increasing, and has continued into the 1990s. We include, as Appendix E, the sequence of events surrounding the debate about muskox-caribou relationships as we have been able to cobble them together from various reports. We include this information neither to add to nor to subtract from contentions about competition but to reveal the context that existed when the concerns were first made apparent in the NWT.

Muskox-caribou relationships operate at different scales of space and time. On the evolutionary timescale, muskox and caribou have have long co-existed and have evolved different strategies in adapting to arctic ecosystems (Parker *et al.* 1990, Adamczewski 1995, Staaland *et al.* 1997). But caribou and muskoxen evolved in more complex communities that include more species of large herbivores and predators. It is by no means certain how current relationships would reflect the 'ghost of competition past'.

At a regional scale, trends in caribou and muskox population sizes suggest that either their trajectories are independent of each other or relationships are inconsistent. Caribou and muskoxen both increased on the NWT mainland and Victoria Island during the 1970s (Ferguson and Gauthier 1992, Barr 1991, Gunn 1990). On the mainland, caribou numbers have continued to increase while some muskox populations have decreased (J. Nishi in prep.). In contrast, the sharp decline in caribou on Banks and northwestern Victoria islands since the 1970s and on Prince of Wales and Somerset islands coincided with an increase in muskoxen. On the western High Arctic islands, between 1961 and 1997, Peary caribou and muskoxen tended to increase and decrease in parallel (Gunn and Dragon in prep.).

Also at the regional scale, large climatic, vegetative and terrain differences may result in different relationships between caribou and muskoxen within the arctic islands and the mainland. Banks Island is the only arctic island with extensive well-vegetated rolling hills. The North American Land Cover database, for example, uses satellite imagery to illustrate this difference by revealing that Banks Island falls mostly within the wet tundra class. Banks may be especially suitable range for muskoxen and is the only island where prehistoric people harvested muskoxen on a large-scale with at least five cycles of abundance over decades to centuries (references in Lent in press).

Within the regional scale (landscape), a hierarchy of scales describes herbivore foraging behaviour that leads to grazing distribution patterns (Bailey *et al.* 1996). Previous studies on muskox-caribou relationships, that compare diet or habitat use, only dealt indirectly with behaviour at two scales. Describing the mechanisms that lead to diet selection and distribution patterns would make including environmental variability possible. By focusing on diet and habitat use, the studies did not deal with behavioural exclusion although Inuit identified that as one of the mechanisms for how muskox exclude caribou. Inuit hunters have suggested that the packed and hardened snow typical of the site-intensive foraging of muskoxen would handicap caribou foraging.

Most distributional and diet studies point to little overlap between caribou and muskoxen in habitat use and diet although those studies deal neither with high muskox densities nor deep snow foraging conditions (Larter and Nagy 1997). On Prince of Wales and Somerset islands and Boothia Peninsula in the mid-1970s, Russell *et al.* (1978) documented little overlap between caribou and muskox seasonal ranges based on distribution of fecal pellets. The exception was Prince of Wales where both caribou and muskoxen fed in summer on willow-moss-lichen patterned ground, one of the most common plant communities. Information on caribou diet in the late 1970s came from analysis of plant fragments in rumen and fecal pellets, behavioural observations and examination of feeding areas (Thomas and Edmonds 1983). Between year variability in the late winter diet, determined rumen analysis, was high (1974 to 1977) but purple saxifrage was a major component in rumens and plant communities. Summer diet was sampled for 5 caribou in early August 1978 and their diet was almost exclusively willow leaves and catkins. Elsewhere in the High Arctic, willow is an important summer forage but it may not be a key element in winter diet.

Overlap in Greenland muskox and reindeer diet followed when reindeer shifted their winter foraging from over-used lichens to grasses and sedges (references in Staaland and Olesen 1992). The reindeer had shifted to inland ranges where introduced muskoxen were also foraging. Although reindeer omasal and caecum-colon size indicated some adaptation to the graminoid diet, Staaland and Olesen (1992) concluded that muskoxen were still more adapted to digesting grasses and sedges. Staaland and Olesen (1992) referred to the relationship between muskoxen and reindeer as “severe competition” but without any justification. It is unclear if they were implying that without the muskoxen foraging on the grasses and sedges, the reindeer would increase faster in number. It has been said before (e.g. Wilkinson and Shank 1974) that overlap in diet is not in itself evidence for competition.

Changes in foraging behaviour imposed by environmental variation, such as severe winters, are to be expected both within and between species. Within a species, individuals can modify their behaviour. Individual traits that determine foraging efficiency will also determine how well they do when faced with either natural or experimentally-induced forage shortages. Illius *et al.* (1995), working with Soay sheep (*Ovis aries*), describe how incisor arcade breadth and gastrointestinal parasite loads with their effects on foraging efficiency and nutrient absorption, respectively, influenced survival during a die-off when forage was depleted. Other research has demonstrated how individuals modify their behaviour when faced with forage shortage. White-tailed deer (*Odocoileus virginianus*), like caribou, are selective feeders. When experimentally faced with forage depletion, the deer foraged less selectively, increased bite size and reduced movements (Kohlmann and Risenhoover 1994). Their use of the experimental forage patches could not be predicted by available forage biomass; protein gain was a better predictor of their behaviour.

Environmentally reduced forage availability, when it leads to changes in foraging behaviour, can also shift relationships between species. For example, Jenkins and White (1987) described a shift to possible inter-specific competition between moose (*Alces alces*), elk (*Cervus elaphus*) and white-tailed deer (*Odocoileus virgianus*) during winters with deeper than average snowfall.

Deeper snow may force muskoxen to crater for forage on the same slopes where caribou forage. Larter and Nagy (1997) indicated that this happened on Banks Island during the 1992-93 winter. This accentuated an existing trend to recording a greater proportion of willow in muskox diet than during the 1970s. But it is difficult to interpret whether muskoxen increased their use of willow or whatever availability was greater as the study areas differed; Larter and Nagy (1997) worked on south central Banks Island while Wilkinson and Shank (1974) worked on northern Banks Island and there are regional differences in the habitats. Larter and Nagy (1997) suggested that muskox browsing willow would reduce its availability for caribou.

Again, the question of timescale comes into play when predicting the consequences to caribou of muskox browsing on willow. A single bout of overgrazing will have different consequences than more prolonged heavy use. Plant responses span from compensatory growth through to plant damage and death depending on browsing intensity and season (references in Nishi 1993). Browsing during the plant growing season causes more shrub damage. Nishi (1993) investigated willow responses to reindeer browsing and N. Griller and G. Henry (pers. comm.) are currently investigating willow responses to muskox browsing.

Studies of habitat use and diet have not really brought us much closer to untangling the relationship between caribou and muskox forage and environmental variables. It is conceivable that a competitive relationship between caribou and muskoxen could develop either through increasing muskox densities or deeper snow forcing muskoxen to forage outside their usual habitat. However, to clearly demonstrate a competitive relationship, we suggest that we will need to describe the behavioural mechanisms for caribou or muskox distributional patterns (sensu Bailey *et al.* 1996) and the effect of environmental variability on those mechanisms (Caughley 1982).

One aspect of the relationship between caribou and muskoxen that has received almost no attention is disease and parasites. An exception is the case of Korsholm and Olesen (1993) who investigated gastro-intestinal parasites and reported that reindeer and muskoxen in Greenland carried the same species of abomasal nematodes. The consequences of cross transmission between the two herbivores feeding in the same areas was not addressed.

The only previous information for Prince of Wales and Somerset islands indicated that caribou and muskoxen did not overlap in habitat use, at least in the mid-1970's (Russell *et al.* 1978). Whether that changed, perhaps as snowfall increased or because of some other environmental factor, we do not know. Muskox densities have not reached the level of those on Banks Island and, in any case, Banks Island is not comparable in range types to Prince of Wales and Somerset islands. Therefore, at this stage in our knowledge, we have no reason to attribute the caribou decline on Prince of Wales and Somerset islands to the increase in muskoxen but we cannot with confidence assume that the high muskox numbers would not influence caribou recovery.

Rate of and factors driving the caribou decline

Gunn and Decker (1984) concluded that the caribou on Prince of Wales and Somerset islands in 1980 were stable or slightly declining. Their conclusion followed from the low recruitment, the relatively high annual harvest (150-250 per year) and comparison of their 1980 survey with the 1974 and 1975 surveys. If the harvest was 250 per year (5% of the 1980 mean estimate, assuming the estimate was accurate) and recruitment was 2-4%, a slow decline could have started which would have been accelerated by predation or winter malnourishment. A decline in pregnancy rates probably would have accelerated the decline. In 15 years, a caribou population annually decreasing at a constant 15% would drop from 5000 to about 500. Our estimate of 15% is not unrealistic based on, for example, the decline of caribou on Banks Island from the 1970s into the early 1990s. The estimated number of caribou on Banks Island dropped from about 12 000 in 1972 to 700 in 1994 (Nagy *et al.* 1996).

However, we do not know with any certainty what happened. Caribou numbers are now so low that recovery will be slow and questionable. Community involvement will be necessary to foster recovery of the caribou and to determine if there is support for exceptional measures such as translocating arctic-island caribou from Boothia Peninsula, as well as wolf and human harvest management.

RECOMMENDATIONS

1. Consult with Inuit hunters to exchange ideas about fostering caribou recovery.
2. Prepare a co-management plan for Peary and arctic-island caribou.

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APPENDIX A. Weather and light conditions during an aerial survey for both caribou and muskoxen in the Prince of Wales Island-Somerset Island-Boothia Peninsula complex, NWT, July - August 1995.

Date	Transects flown (Stratum)	Light and weather conditions
<u>Prince of Wales, Russell, Prescott, Pandora and Vivian islands</u>		
21 July	11 - 18 (II), 20, 49-52(VI) (19 dropped)	Clear, 5^{O} C, light winds, visibility good, North coast of Russell Island - fog patches.
22 July	1 - 10 (I, V), 45 - 47 (III)	Scattered cloud, 4^{O} C, winds from east at 10 - 15 kt, visibility good.
23 July	21 - 30, 48 (III)	Scattered cloud, 14^{O} C, winds < 5 - 10 kt, visibility good.
24 July	53 - 74 (IV, VI)	Scattered cloud, 10^{O} C, winds 1 - 10 kt, visibility good.
25 July		Too foggy to survey.
26 July	44 - 31 (III)	Cloud conditions variable from clear to foggy, 2 ^{O} C, winds from the west then south at 10 kt, visibility good to dull.
<u>Somerset Island</u>		
27 July	90 - 94 (III), 86 - 88 (II) northern segment of 85 (II) 89 dropped 95 dropped	Foggy with variable ceiling, 5^{O} C, winds 10 kt southeasterly, visibility dull.
28 July	84 (II), 96-107 (IV) southern segment of 85 (II)	Foggy with >600 m ceiling, 6^{O} C, winds from east at < 5 kt , visibility good to dull. Fog southern portions of lines of lines 101 and rain on 103.
29 July	75 - 83 (I) 80 dropped - no muskox 82 dropped - no muskox	Scattered cloud with some fog, 4^{O} C, winds 10 kt easterly then northerly, visibility good to dull.

APPENDIX A (CONT'D).

Date	Transects flown (Stratum)	Light and weather conditions
Boothia Peninsula		
30 July	133 - 137 (II) eastern portions only	Fog with ca. 150-300m ceiling, rain showers, winds from the northeast at 5 kt, visibility dull. Western portions of all lines not flown due to fog.
31 July	132 - 137 (II) western portions only	Fog with ca. 150-300m ceiling, 6^{O} C, winds from the northwest at 5 kt, viability variable mostly dull. Western portions of all lines flown.
1 August	129 - 131 (I)	Fog and snow showers, 2^{O} C, winds from the northwest at 10 - 15 kt, visibility variable bright to dull. Eastern portions of all lines not flown due to fog.
2 August	117, 119, 121, 123, 125, 127(I)	Fog with snow showers, 5^{O} C, visibility variable bright to dull.
3 August	109, 111, 113, 115 (I)	Scattered cloud, 4^{O} C, winds < 5 kt, visibility good.

APPENDIX B. Muskoxen observed on transect during an aerial survey of Prince of Wales, Russell, Prescott, Pandora, and Vivian islands, NWT, July 1995.

Transect number	Transect length (km)	Transect area (km^2)	No. muskox observed by transect
Stratum I			
1	16.8	26.9	0
2	29.8	47.7	0
3	60.5	96.8	2
4	63.0	100.8	0
5	75.5	120.8	17
6	105.5	168.8	18
7	98.5	157.6	19
8	93.0	148.8	16
9	83.3	133.3	32
(Totals)	**(625.9)**	**(1001.5)**	**(104)**
Stratum II			
11	85.3	136.5	14
12	87.3	139.7	8
13	88.3	141.3	4
14	83.5	133.6	14
15	76.5	122.4	32
16	65.0	104.0	0
17	59.3	94.9	0
18	60.8	97.3	0
(Totals)	**(606)**	**(969.7)**	**(72)**
Stratum III			
21	22.5	35.7	0
22	27.5	44.0	3
23	39.0	62.4	11
24	42.5	68.5	6
25	45.3	72.5	14
26	132.5	211.7	7
27	130.6	196.0	34
28	122.5	196.0	9
29	119.5	191.2	8

APPENDIX B (CONT'D)

Transect number	Transect length (km)	Transect area (km^2)	No. muskox observed by transect
Stratum III (Cont'd)			
30	120	192.0	16
31	70.0	112.0	27
32	70.5	112.8	
33	81.0	129.6	28
34	75.5	120.8	20
35	71.3	114.1	15
36	67.8	108.5	14
37	62.5	100.0	20
38	47.5	76.0	3
39	43.3	69.3	1
40	42.5	68.0	9
41	41.5	66.4	56
42	45.5	72.8	25
43	39.3	62.9	11
44	30.8	49.3	3
45	61	97.6	1
46	64.8	103.7	12
47	61	97.6	12
48	79.5	127.2	25
(Totals)	**(1857.2)**	**(2971)**	**(393)**
Stratum IV			
55	19.0	30.4	2
56	35.5	56.8	24
57	32.3	51.7	16
58	42.3	67.7	14
59	46.3	74.1	29
60	63.8	102.1	8
61	60.3	96.5	32
62	69.3	110.9	24
63	70.0	112.0	49
64	61.8	98.9	22

APPENDIX B (CONT'D).

Transect number	Transect length (km)	Transect area (km^2)	No. muskox observed by transect
Stratum IV (Cont'd)			
65	56.8	90.9	18
66	61.3	98.1	36
67	61.8	98.9	52
68	55.8	89.3	10
69	61.5	98.4	30
70	61.0	97.6	47
71	59.5	95.2	10
72	48.0	76.8	22
73	49.3	78.9	3
74	15.5	24.8	4
(Totals)	**(1650)**	**(561)**	**(452)**
Russell Island			
10	9.0	14.4	10
11b	15.8	25.3	2
12b	24.8	39.7	8
13b	22.8	36.5	0
14b	23.5	37.6	1
15b	19.0	30.4	0
16b	10.3	16.5	0
(Totals)	**(125.2)**	**(200.4)**	**(21)**
Vivian/Prescott/Pandora islands			
20	5.5	8.8	0
49	11.0	17.6	0
50	18.3	26.3	14
51	15.8	25.3	0
52	7.0	11.2	0
53	5.3	8.5	0
54	11.5	18.4	0
(Totals)	**(74.4)**	**(116.1)**	**(14)**

APPENDIX C. Muskoxen observed on transect during an aerial transect survey of Somerset Island, NWT, July 1995.

Transect number	**Transect length (km)**	**Transect area (km^2)**	**No. muskox observed by transect**
Stratum I			
75	118.8	190.1	0
76	125.0	200.0	0
77	120.5	192.8	0
78	130.3	208.5	0
79	125.0	200.0	0
81	114.3	182.9	0
83	48.5	77.6	0
(Totals)	**(782.4)**	**(1251.9)**	**(0)**
Stratum II			
84	39.5	63.2	35
85	117.5	188.0	44
86	119.0	190.4	0
87	116.3	186.1	45
88	90.0	144.0	30
(Totals)	**(482.3)**	**(771.7)**	**(154)**
Stratum III			
90	105.3	168.5	2
91	103.5	165.6	4
92	95.3	152.5	22
93	88.0	140.8	3
94	10.0	16.0	0
(Totals)	**(402.1)**	**(643.4)**	**(31)**
Stratum IV			
96	20.0	32.0	8
97	84.3	134.9	11
98	77.0	123.2	1
99	72.0	115.2	80
100	74.8	119.7	2

APPENDIX C (CONT'D)

Transect number	Transect length (km)	Transect area (km^2)	No. muskox observed by transect
Stratum IV (Cont'd)			
102	78.8	126.1	17
103	75.0	120.0	54
104	69.5	111.2	0
105	51.3	82.1	0
106	34.3	54.9	2
107	26.8	42.9	6
(Totals)	**(738.3)**	**(1181.3)**	**(182)**

APPENDIX D. Muskoxen and caribou observed on transect during an aerial transect survey of Boothia Peninsula, NWT, July 1995.

Transect number	Transect length (km)	Transect area (km^2)	No. caribou observed	No. muskox observed
Stratum I				
109	26.5	42.4	0	6
111	62.3	99.7	17	0
113	78.0	124.8	37	18
115	82.5	132.0	27	8
117	92.3	147.7	42	0
119	19.8	31.7	2	0
121	129.0	206.4	44	0
123	130.0	208.0	91	0
125	135.0	216.0	48	0
127	138.5	221.6	33	28
129	87.0	139.2	44	0
130	104.5	167.2	36	0
131	91.8	146.9	106	0
132	100.0	160.0	48	0
(Totals)	**(1277.2)**	**(2043.6)**	**(575)**	**(60)**
Stratum II				
133	186.3	298.1	90	0
134	166.8	266.9	17	0
135	150.8	241.3	3	1
136	132.3	211.7	6	0
137	119.3	190.9	2	0
(Totals)	**(755.5)**	**(1208.9)**	**(118)**	**(1)**

APPENDIX E. History of muskox-caribou studies on Banks Island. .

In the late 1960s, trappers reported that caribou on Banks Island were abundant and in good condition (Usher 1971). There were no comments on the relationship between caribou and muskoxen, probably because muskox numbers were considered low. Circumstances changed and concerns for caribou started to be voiced, first, because of oil exploration and then, because of more muskox sightings and caribou deaths after heavy snowfall in fall 1970.

By the late 1960s, the federal government had issued exploration permits to oil companies for all Banks Island but people in Sachs Harbour were unaware until an oil company arrived in Sachs Harbour in June 1970 to announce seismic exploration would start the following winter (Usher 1971). Sachs Harbour people were particularly concerned that it was unknown whether oil and gas exploration could affect caribou and arctic foxes. Their concerns did little to slow down the exploration but they did lead to a research program that began in fall 1970 to investigate the effects of exploration on wildlife (Usher 1971, Urquhart 1973).

Also in June 1970, the Canadian Wildlife Service had initiated aerial surveys to identify critical areas for caribou and muskoxen as part of their on-going efforts to identify and map wildlife areas exposed to industrial activity. The June 1970 survey of northern Banks Island revealed more muskoxen than expected (Kevan 1972). People were also seeing more muskoxen around Sachs Harbour (T.W. Barry pers. comm.).

Other aerial surveys had started in fall 1970 to investigate the possible effects of oil exploration. Urquhart (1973) commented that the 1970 fall had unusually heavy snow and some caribou left Banks Island heading to the mainland while others died from malnutrition. Hunters reported that many caribou died during the winter and Urquhart (1973) extrapolated from 39 carcasses counted in June 1971 to estimate that 879 caribou died.

The caribou deaths became linked with the reports of more muskoxen on northern Banks Island - hunters were aware that the caribou moved to the island's north end for calving and the summer (Urquhart 1973). During the preceding decades since people had started to trap and then live on Banks Island, caribou numbers had fluctuated with severe winters in the early 1950s causing deaths and desperation movements off Banks Island (Usher 1971, Urquhart 1973). During this time, those trappers had virtually no experience with muskoxen as there were reportedly few on Banks Island.

The Territorial Government responded to concerns for the caribou and during fall 1971, the Superintendent of Game for the Territorial Government contracted L. Bouckhout who was working in Elk Island National Park on range use by large herbivores (L. Bouckhout pers. comm.). Bouckhout undertook his fieldwork on Banks Island between May and November 1972 and besides observations of range use, his studies included collecting muskoxen at Castel Bay in August helped by the Game Division.

Both Kevan (1972) and Bouckhout (1972) found that muskox and caribou distribution overlapped slightly on northern Banks Island. That overlap, coupled with concerns that the muskox numbers had suddenly increased, lead to a larger and more comprehensive study to investigate the relationship between caribou and muskoxen (Wilkinson and Shank 1974). The study's conclusion was that muskoxen do not compete with caribou. The study results did not, however, alleviate fears that an increasing number of muskoxen would cause caribou

APPENDIX E (CONT'D)

on the same range to decrease. Those concerns have been reiterated since the 1970s for Banks Island (Nagy *et al.* 1996, Larter and Nagy 1997). And those concerns have lead to Larter and Nagy's (1997) study in the 1990s on Banks Island looking at habitat and diet overlap between caribou and muskoxen 20 years after Wilkinson and Shank's (1974) study.