MUSKOX ABUNDANCE, HABITAT USE, AND DIET ON THE YUKON COASTAL PLAIN

Department of Renewable Resources
Yukon Territorial Government
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A/ Director, Fish and Wildlife Branch

Chief, Wildlife Management Section

ABSTRACT

This report presents information on muskox (*Ovibos moschatus*) population, habitat selection, and diet on the Coastal Plain of the Yukon. Aerial census flights taken in 1993 and 1995 indicated a population of approximately 150 animals which was steady between those two years. Unfortunately the 1996 census effort did not produce an adequate population estimate because of inclement weather.

In April, 1993, three female muskoxen were fitted with satellite collars and over the ensuing year they were relocated regularly. These locations were correlated with ground cover information provided by the Canadian Wildlife Service and used to identify habitat use and preferences of the muskoxen. No selection for any habitat type was found throughout most of the year, but in Aug-Sept and Oct-Nov, both selection for and avoidance of certain ground cover types did occur. This selection and avoidance showed no particular pattern, however, and it is not likely to be representative of muskox habitat choice.

In an effort to obtain information about muskox diet, fecal samples were collected four times throughout the year. The primary vegetation in the fecal samples consists of willow (Salix spp.), cotton grass (Eriophorum spp.), sedges (Carex spp.) and horsetail (Equisetum spp.). In general horsetail makes up a small percentage of the samples (< 2%) except for the October sample.

The implication of the data presented here for potential expansion of the muskox population is considered, but no strong conclusions are possible because of numerous limitations of the study which are discussed in the text.

List of Figures and Tables

FIGURES **Page**

TABLES

Muskoxen Abundance, Habitat Use and Diet on the Yukon Coastal Plain

INTRODUCTION

Although muskoxen (*Ovibos moschatus*) have inhabited the North Slope of the Yukon in historical times, they have been absent from the latter part of the 19th century until recently. Within the last two and a half decades, muskoxen have migrated into the Yukon from the adjacent Alaskan North Slope, where a re-introduced population exists. These immigrants have established a population on the Coastal Plain of the Yukon adjacent to the Beaufort Sea (see Figure 1) from which sporadic reports of further dispersal have been noted. The world-wide population of muskoxen is relatively small and muskox are specially protected wildlife in the Yukon Act and the Yukon Wildlife Act, but their expansion has raised local concerns that if the muskox population expands, there may be a detrimental effect on the Porcupine Caribou herd, a major resource for the people of the northern Yukon and the northwestern Northwest Territories. However, little is known about muskoxen in the Yukon.

Muskoxen were initially re-introduced to Barter Island, Alaska, in 1969 when 51 animals were released, followed by the release of an additional 13 animals on the mainland the following year. Some of these animals quickly dispersed, and such dispersal of this muskox population, along with high mortality, has been an important factor in the population dynamics of that group (Reynolds 1989). Six animals dispersed 150 km into Canada, and at least one bull crossed south through the Brooks range a distance of 170 km from its release point. In fact, throughout the period from 1970 to 1986 small numbers of muskoxen moved in all directions as much as 400 km from the release point. Muskoxen from this population were sporadically reported on the Yukon coastal plain between the time of their release at Barter Island in 1969 and the late 1980's (Reynolds 1989).

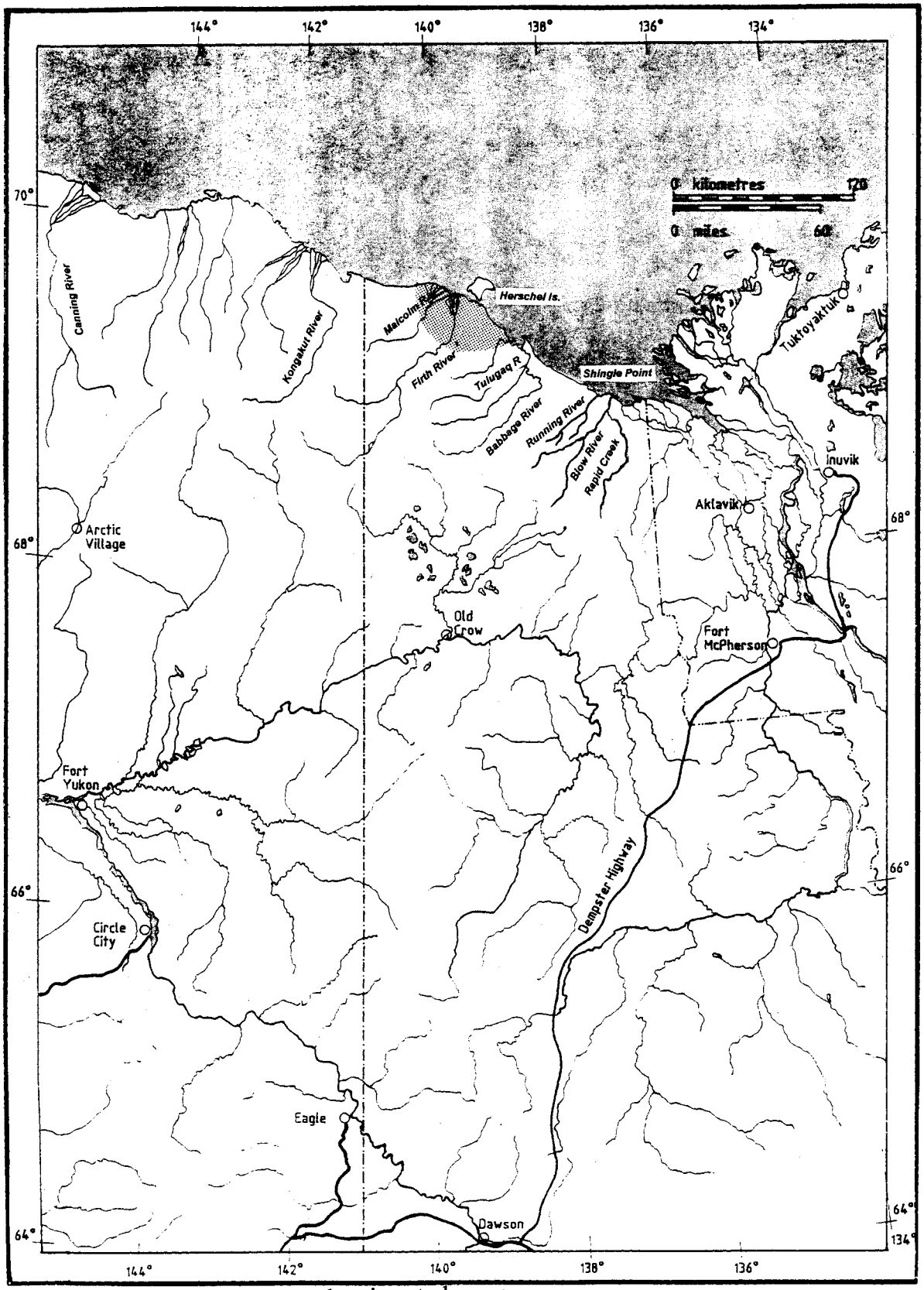

Figure 1. Map of area showing study area

OBJECTIVES

The information presented in this report summarizes the results of work conducted in 1993-95 with a goal of providing information on muskox population size, seasonal habitat use, diet and, to the extent possible, a brief perspective on the likely expansion of muskox range.

Prior to the initiation of this study in 1993, no systematic collection of information within the Yukon had been conducted. Although the species was surveyed and studied fairly intensively in Alaska on what has become the Arctic National Wildlife Refuge (ANWR), little was known of muskox population status or seasonal habitat use in the Yukon. Without this information, management agencies are unable to provide recommendations in such areas as habitat protection, harvest, or mitigation.

METHODS

Population Counts and Composition

On March 26 & 27, 1993, fixed-wing flights were conducted covering the potential muskox habitat in the Yukon between the NWT border in the east and the Alaska border in the west. The survey covered 100% of the coastal plain between the Running River in the east and the Alaska boundary. Between the Running River and the Firth River the flight path followed transects perpendicular to the coast spaced 5 km apart. Between the Firth River and the Alaska boundary more intensive transects (2 km intervals) paralleled the coast covering the depth of the coastal plain (approx. 9 km). The flight path also followed all the major drainages associated with the coastal plain including Rapid Creek in the Richardson Mountains near the NWT boundary, the Blow River , Running River, Babbage River, Firth River, and Malcolm River to the west. On July 5-7, 1993, a second survey was completed covering the area of the coastal plain from Running River/Shingle Point to the Alaska boundary.

Subsequent surveys in March of 1995, and 1996 were also intended to provide complete counts of muskoxen on the North Slope of the Yukon. In March, 1995, transects perpendicular to the coast and spaced at 5 km were flown across the entire coastal plain between the Alaska boundary and Shingle Point, Yukon. Searches were

also flown along the Babbage River, Tulugaq River, and Firth River and across Herschel Island. In March, 1996, transects perpendicular to the coast and spaced at 2 km were flown from the Alaska boundary to the Babbage River, and 5 km transects were flown east of the Babbage River to the MacKenzie Delta. The flight included Herschel Island, but no specific river-bottom searches were conducted in 1996.

In conjunction with the fixed wing flights in July, 1993, March, 1995, and March, 1996, a helicopter landed near as many groups as possible and muskox were classified by sex and age category from the ground.

Muskox Habitat Use – Satellite Collaring

It was necessary to determine not only muskox use of various habitat types, but also the relative availability of those types in the environment. Habitats which muskox preferentially select will be used in greater proportion than their availability, while those that are avoided will be used less. As explained in more detail below, muskox use of habitats was determined by regularly locating three muskoxen for a period of one year using a satellite relocation technique (Argos system) and then identifying the habitat at each location using satellite imagery. The availability of habitats was also determined using satellite imagery.

On April 3, 1993, three adult female muskoxen were located by helicopter using information from the survey conducted a few days before. Two cows were selected in separate groups approximately 20 km apart while the third was alone on the coastal plain approximately 15 km from the first two (see Figure 2). This muskox had previously been radiocollared in Alaska and so was known to have dispersed a considerable distance.[1]

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[1] This muskox (Alaskan # 58) was radiotagged and followed from 1988 to 1990 as it moved from just east of the Canning River in Alaska (April-July, 1988) to the Kongakut River, Alaska, where it remained for a time (August 1988 through the winters of 1988-89 and 1989-90) before it moved into Canada; secondary reports place the cow on Herschel Island in August, 1991 about a year and a half before it was collared for this study (Reynolds 1994, pers. comm.).

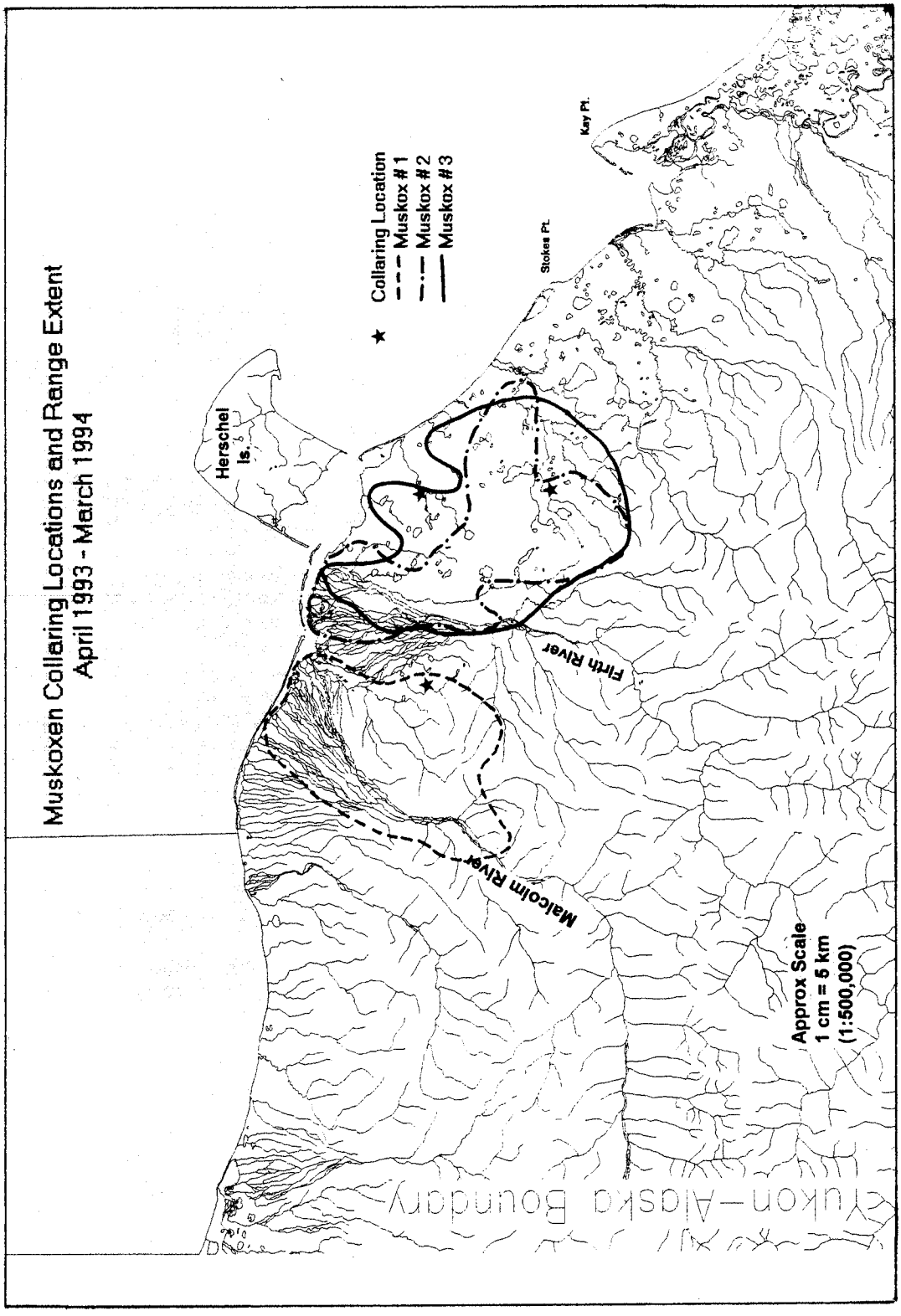

Figure 2. Muskox Collaring locations and range extent

Each muskox was immobilized using darts containing Acepromazine shot from the helicopter, fitted with a satellite collar, and revived with Naltrexone as soon as processing was completed (35 - 45 min). Each of the collared muskoxen was visually checked the following day by helicopter to insure that it was behaving normally. Muskoxen #1 and #2 had rejoined their respective groups, while the third remained alone. Other muskoxen were herded by helicopter to the vicinity of #3.

Data collection began on April 3, 1993 and continued until March 24, 1994 on an every-other-day basis. The collars had been set to transmit on a 6-hr on/42-hr off cycle, with the hours of transmission approximately 1600 hr to 2200 hr UT (0900-1500 PST).

In the Argos system, each data point is assigned a "Location Class" which is an estimate of the accuracy of the location. The numbers and accuracy of the data points are summarized in Table 1 below (Fancy, *et. al.,* 1988).

Table 1. Accuracy and Number of Satellite Locations of Three Muskoxen

Location Class	Estimated Accuracy	Number of satellite locations
1	1 km	1455
2	350 m	1306
3	150 m	254
TOTAL		3015

Data points in the most inaccurate category, Location Class 1, were excluded from the habitat use analysis because it was felt that the inaccuracy was too large for accurate determination of ground cover-type. However these points are included on the habitat selection maps presented in this report because they contribute to the overall picture of muskox locations.

The ground cover corresponding to each satellite muskox location was identified by overlaying the muskox locations on a ground cover map provided by the Canadian Wildlife Service (Hawkings, unpubl.). The ground cover map was provided in digital

format with a resolution (pixel size) of 30 meters. It covers the Yukon North Slope and identifies fourteen classes of ground cover, primarily vegetational complexes (see Appendix B) which have been extensively ground truthed (Hawkings, pers. comm.). The ground cover classes were used as defined by the Candian Wildlife Service except that a few ground cover classes on the map were excluded from the analysis[2]. No further characterization of the habitat at each location was attempted; rather the ground cover was used as a proxy for habitat type. Muskox use in each cover-type was calculated as the fraction of satellite locations occurring in that cover-type.

The relative availability of each cover-type was calculated as its proportion of the total study area from the same digital map. For purposes of calculating relative availability, the study area was defined as including land within 4 km of the muskox locations (see Results, Figure 5).

Because habitat preferences were expected to vary between seasons, the calendar year was broken down into 5 two-month periods with two months left out in order to provide a sharper break between seasons. Thus, each time period represents a distinct season:

April-May	(early spring—muskox calving)
June-July	(growing season)
August-September	(fall--muskox rutting season)
October-November	(early winter)
January-February	(late winter)

The use/availability analysis described below were carried out separately for each time period.

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[2] The classes excluded were cover classes 1-4, which are essentially aquatic habitat, and class 15, which is land of unknown cover type

Muskox Habitat Use -- Analysis

Identification of potential muskox preferences for particular vegetation cover-types was approached as a two-step process. To initially determine whether muskox either selected or avoided particular cover-types, the overall pattern of muskox use of cover-types in each season was compared with the availability of those cover-types using non-parametric analysis of variance (see below). Secondly, for those seasons in which muskox pattern of use differed from that of availability, the data were further analyzed to identify specific preferences using the least significant difference technique described below.

Of the several techniques available for analyzing use/availability data which are available (see Alldredge & Ratti 1986), Friedman non-parametric two-way analysis of variance based on ranks was selected for the first stage of the analysis. The characteristics of the Friedman technique which make it appropriate for analyzing the muskox data include the fact that, unlike some techniques of analysis (e.g., Neu *et. al.* 1974, Johnson 1980), it properly takes into account the number of animals surveyed; it does not require that repeated locations of each animal be independent of each other; and each animal is given the same weight in the analysis (Alldredge & Ratti 1992). The technique used in performing this test is to calculate for each animal the difference between percent use and percent availability of each cover-type and then rank these differences. The Friedman analysis is then carried out on the ranked data (Siegel & Castellan 1988:174, Conover 1971:265). The null hypothesis in this application of the Friedman technique is that the ranks are the same for all habitats, while the alternative hypothesis is that some habitats are ranked differently than others (i.e., more or less preferred). If the null hypothesis is rejected, it is necessary to use a multiple comparison technique to determine which habitats differ from the others.

For seasons in which the Friedman technique indicated a difference in the ranks of vegetation cover-types, the second step in determining muskox preferences was to determine which cover-types differed in their ranking from the others. Fisher's least significant difference (LSD) procedure was used for this purpose (see Alldredge & Ratti 1986, Siegel & Castellan 1988:180). In this technique the rank of each vegetative cover-type is compared with the others to determine whether the difference in ranks exceeds the minimum necessary for statistical significance.

Comparison of Study Area with Larger Potential Muskox Range

In order to compare the proportion of ground cover classes on the study area with the composition of a wider area along the Coastal Plain, an extended area was defined (Figure 3) running from just west of the Alaskan border to approximately Kay Point. Both the additional area and proportion of each ground cover-type in this extended area were calculated and compared with that existing in the study area.

Muskox Diet -- Fecal Samples

Vegetation identified in fecal matter can provide information on dietary intake, and an attempt was made to characterize muskoxen diets by examining fecal samples collected on the Yukon North Slope at four times during the year. Fresh fecal samples were collected at locations associated with groups of muskoxen in March (3 groups), July (3 groups), and October, 1993 (2 groups) and February, 1994 (2 groups). Because these samples were collected from only a few groups of muskoxen and were not collected in a systematic manner, they do not form an appropriate base for a statistical analysis of their contents, but may nevertheless provide an anecdotal indicator of muskoxen diets. The unweighted average proportion of each major vegetational component identified in the fecal samples was calculated for each of the collection dates.

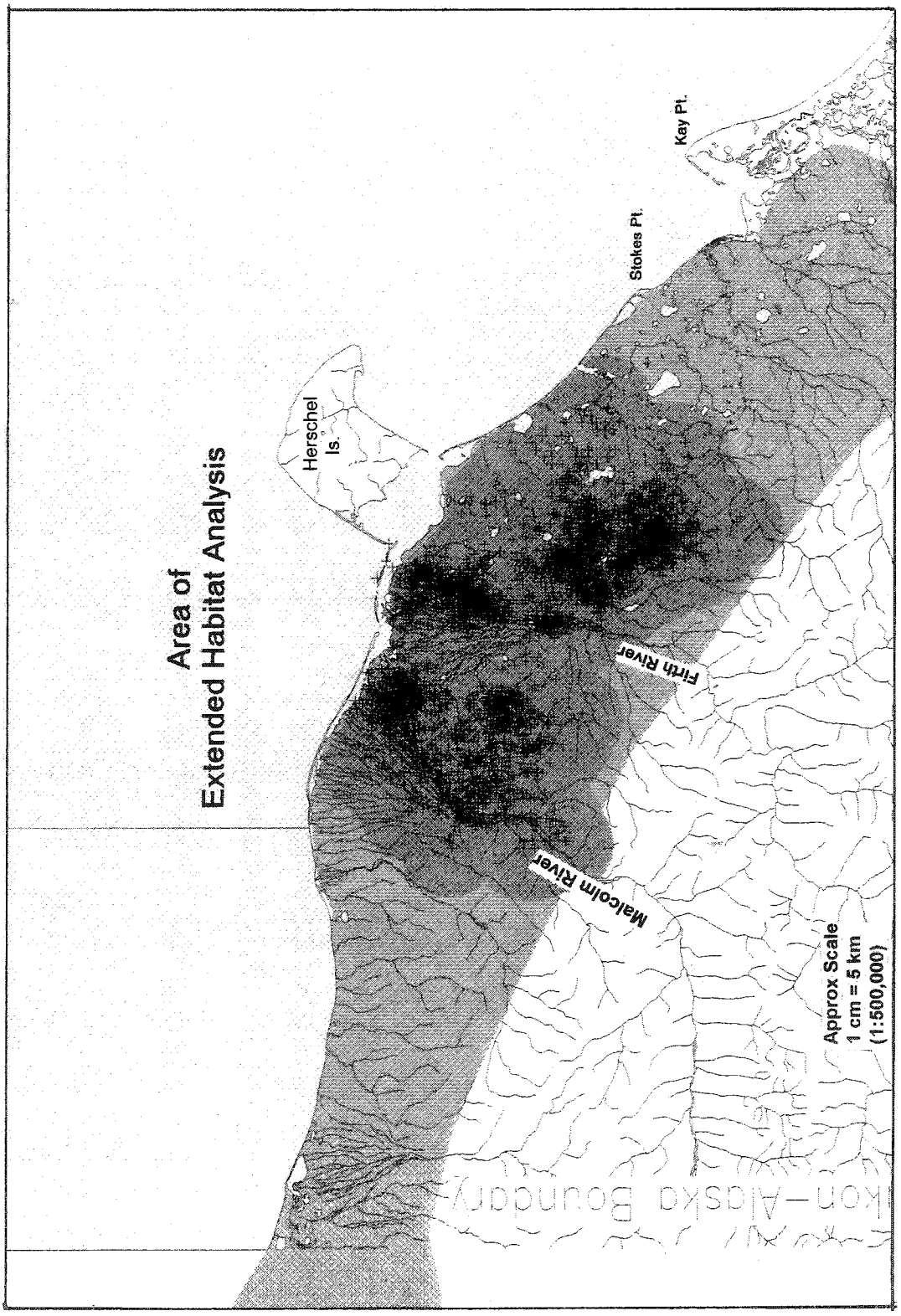

Figure 3. Area of extended habitat analysis

RESULTS

Muskox Population Counts

The aerial censuses for muskoxen were conducted in 1993, 1995, and 1996. With the exception of 1996, when bad weather interfered, these efforts were successful in their goal of providing a reasonably complete count of the muskoxen on the Yukon's North Slope. This conclusion is supported by the consistency of the 1995 results with two surveys conducted in 1993.

Table 2. Muskoxen Census Results in the Yukon

Date	Total Muskoxen Counted	Number of Groups	Number of Groups Classified	Adult Males	Adult Females	2 Yr Olds	Yearlings	Calves	Number animals Unclassified
March 1993	157	7	0						157
July, 1993	152	6	6	50	54	0	10	38	0
March, 1995	151	14	12	42	53	22	15	--[2]	14
March, 1996	120[1]	10	7	43	21	7	4	--[2]	46

[1] Probable underestimate. Count hampered by weather and flights limited to a total of 1.5 days (Cooley, pers. comm.)

2 No calves were seen on the March surveys because calving occurs later in the year.

Muskox Selection of Habitat

The number of relocations for each muskox was approximately equal (see Appendix A). As Figure 4 illustrates, one of the muskoxen remained in the area of the Malcolm River, while the other two spent a good deal of their time in close proximity along the Firth River and the area immediately to the east. None of the muskoxen migrated to another area or even took large excursions throughout the year, in spite of the previous dispersal history of muskox #3. In fact the maximum distance between the extremes of locations for any of the animals across the entire year is only about 30 km.

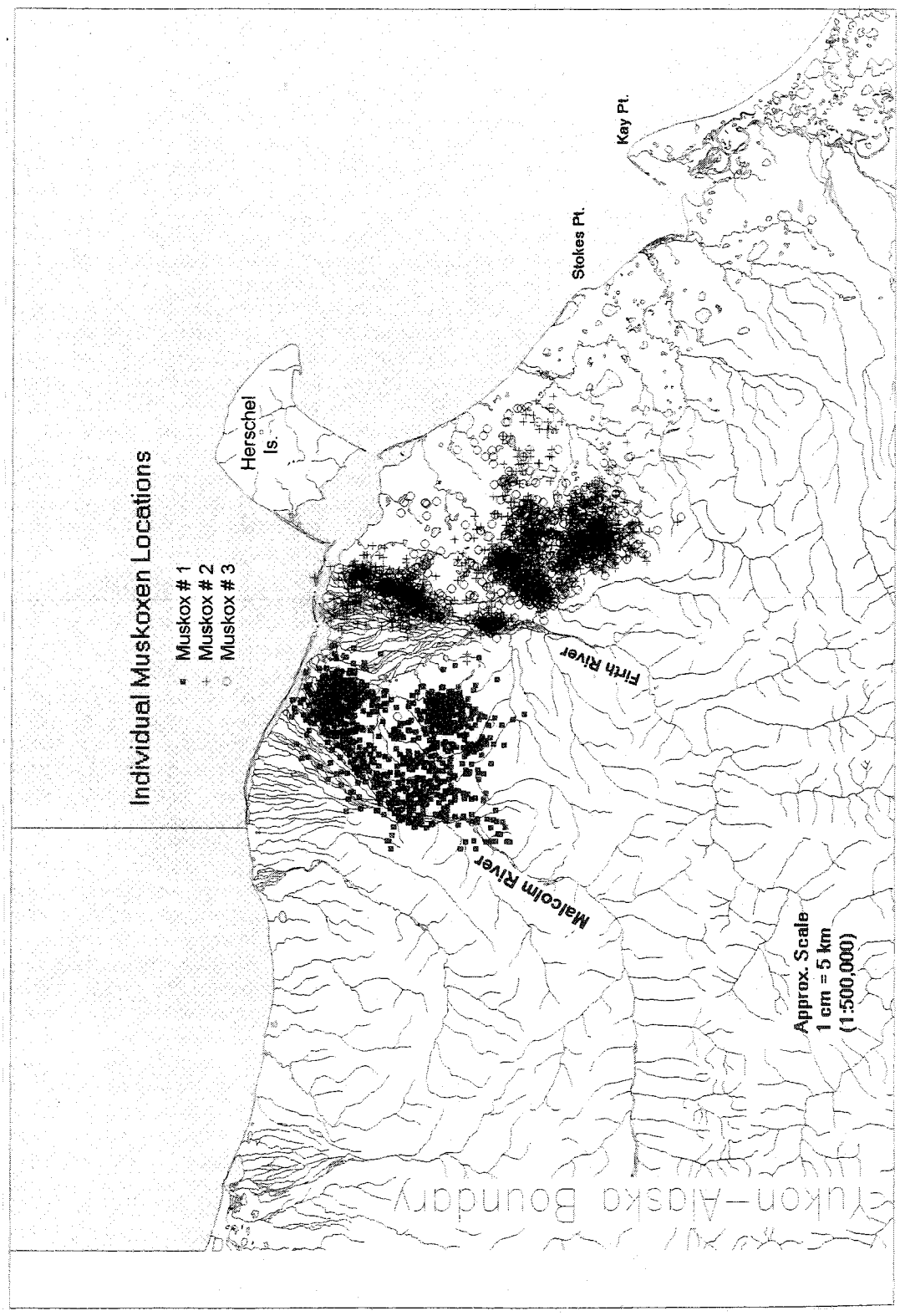

Figure 4. Individual Muskoxen Locations

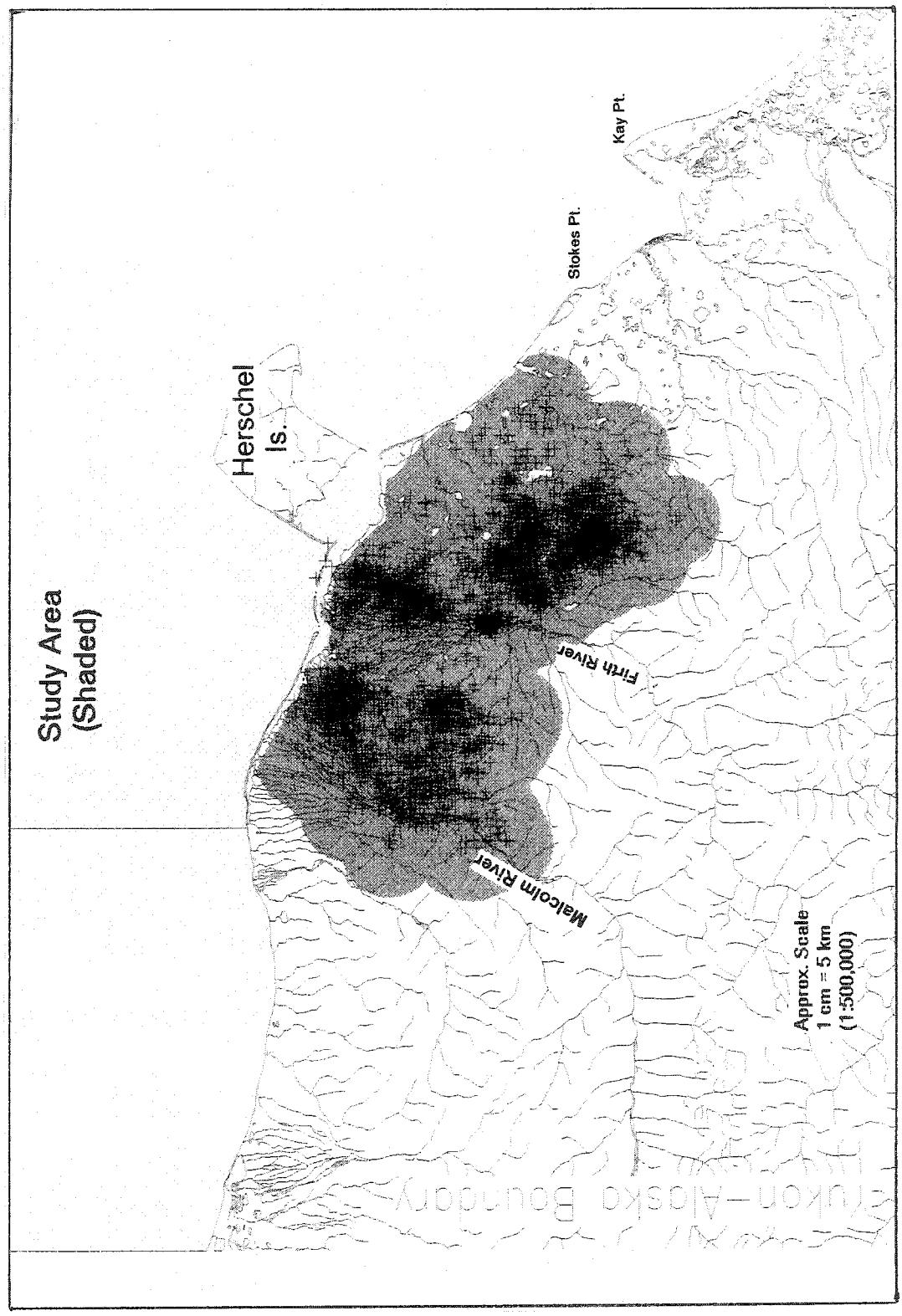

Figure 5. Study area for use/availability analysis (shaded)

The study area used in calculating the relative availability of ground cover-types is shown in Figure 5. As Table 3 illustrates, the largest single component of ground cover on the study area is moist cottongrass tussock, followed by dryas and low shrub types. Reference to the maps (e.g. Figure 5) indicates that although habitat along rivers and streams does not constitute a cover class category per se the study area contains a good deal of riparian habitat.

Table 3. Ground Cover Classes on the Study Area

Ground Cover-type	Area (ha)	Proportion
Moist Cottongrass Tussock	31968.8	0.28
Dry Dryas Tundra	15055.4	0.13
Low Shrub Tundra	14971.4	0.13
Moist Sedge (non-tussock)	11468.8	0.10
Moist Tundra with Wet Inclusions	11415.0	0.10
Wet Graminoid, Low Shrub	7664.2	0.07
Dry Partially Vegetated or Barren	7623.9	0.07
Wet Graminoid or Wet Bryophyte	5278.4	0.05
Wet Barrens	3512.5	0.03
Shrub Thicket	3602.5	0.03
Total	112560.9	1.00

Analysis of muskox selection of ground cover classes was performed for each season. The January-February analysis is shown below (Table 4) while the details of the remaining seasons are shown in Appendix C. Table 4A shows the percentage of satellite locations in each cover class, which represents the percent use of the cover class by each muskox. Table 4B shows the difference between use and availability with positive numbers indicating muskox using a cover class in greater proportion than its availability, while in Table 4C the same data is expressed as a ranking to be used in the Friedman analysis. Finally Table 4D presents the results of the Friedman analysis which

shows that the data do not indicate a muskox preference or avoidance for any of the ground cover classes during January-February.

Table 4. Muskox Selection of Cover-types (Jan-Feb)

A) Percent of Satellite Locations and Percent of Study Area in Each Cover Type, Jan-Feb

Percent Use	Moist Cottongrass Tussock	Dry Dryas Tundra	Low Shrub Tundra	Moist Sedge (Non-Tussock)	Moist Tundra with Inclusions	Wet Graminoid , Low Shrub	Dry Paritally Vegetated or Barren	Wet Graminoid or Wet Bryophyte	Wet Barrens	Shrub Thicket	Total
Muskox 1	16.1%	19.4%	19.4%	1.6%	1.6%	19.4%	12.9%	0.0%	0.0%	9.7%	100.0%
Muskox 2	62.0%	7.6%	2.5%	1.3%	15.2%	3.8%	0.0%	7.6%	0.0%	0.0%	100.0%
Muskox 3	60.9%	10.9%	0.0%	2.2%	21.7%	0.0%	0.0%	4.3%	0.0%	0.0%	100.0%
Percent Availability	28.4%	13.4%	13.3%	10.2%	10.1%	6.8%	6.8%	4.7%	3.1%	3.2%	100.0%

B) Difference = Percent Use minus Percent Availability

Muskox 1	-12.3%	6.0%	6.1%	-8.6%	-8.5%	12.5%	6.1%	-4.7%	-3.1%	6.5%
Muskox 2	33.6%	-5.8%	-10.8%	-8.9%	5.0%	-3.0%	-6.8%	2.9%	-3.1%	-3.2%
Muskox 3	32.5%	-2.5%	-13.3%	-8.0%	11.6%	-6.8%	-6.8%	-0.3%	-3.1%	-3.2%

C) Rank of Difference for Each Muskox

Muskox 1	10	5	4	9	8	1	3	7	6	2
Muskox 2	1	7	10	9	2	4	8	3	5	6
Muskox 3	1	4	10	9	2	8	7	3	5	6
sum of ranks	12	16	24	27	12	13	18	13	16	14

D) Friedman 2-Way Analysis of Variance by Ranks Results:

Test Statistic, Fr = 8.75, N = 3

Probability = 0.461

Conclusion: Not significant at 0.10 level, Ho not rejected.
There is not enough evidence to claim selection of any cover types.

The summary of results for all seasons (Table 5) shows that in two seasons, Aug-Sept and Oct-Nov, muskox use of ground cover classes differs from availability. In the remaining seasons the data do not demonstrate either a selection or avoidance of ground cover classes.

Table 5. Muskox Selection of Cover-types (Summary)

Season	N	Test Statistic F_R	P
Jan-Feb	3	8.75	0.461
Apr-May	3	6.85	0.652
Jun-Jul	3	10.05	0.346
Aug-Sept	3	23.00	0.006**
Oct-Nov	3	25.40	0.003**

Note: ** indicates statistical significance at alpha = 0.10 level

Data for the two seasons when selection of cover-types occurred, was further analyzed to identify specific patterns of preference or avoidance using the LSD analysis described in the methods section. Results of these analyses are shown Figure 6 and Figure 7.

Figures 6 and 7 indicate muskox selection or avoidance of each cover class. Each horizontal line (labeled A, B, ..., E) extends over a set of classes for which muskox selection does not differ significantly. Thus, muskox selection across each of the three cover classes under the 'E' line in Figure 6, (namely: dry partially vegetated or barren; dry dryas tundra; and wet barrens) does not differ statistically, but each of these does differ from all the cover classes under lines A, B, and C. It is important to note that the order along the x-axis differs between the two figures because the cover classes are sorted in order of muskox preference.

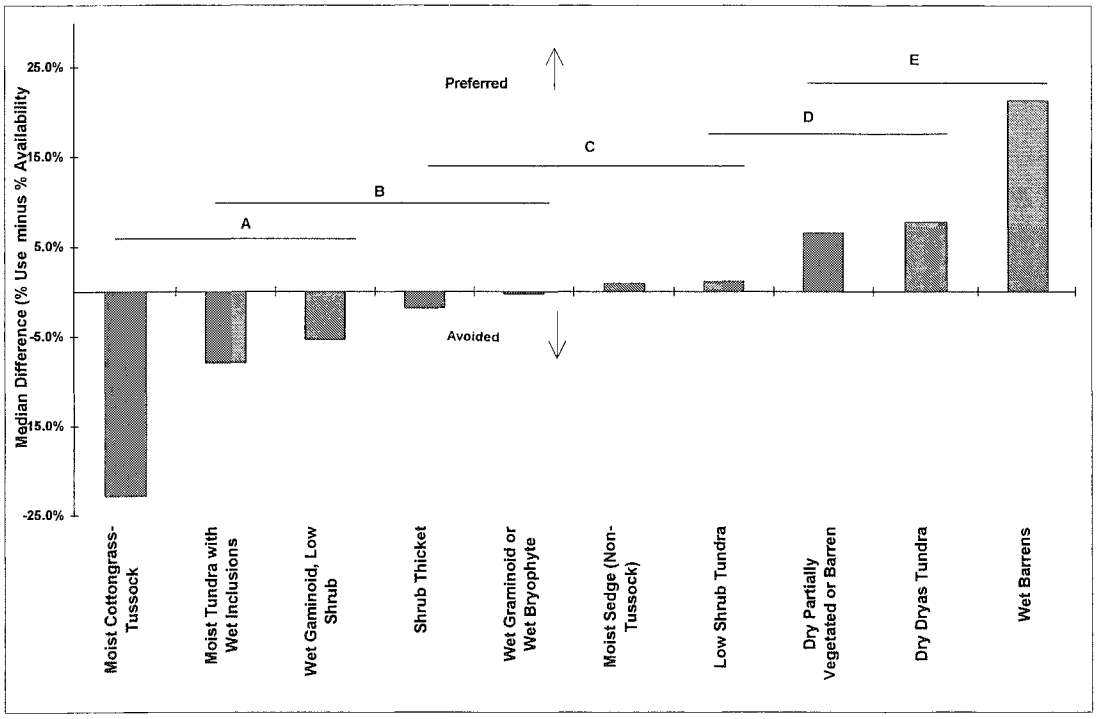

Figure 6. Muskox Selection of ground cover classes (Aug-Sept)

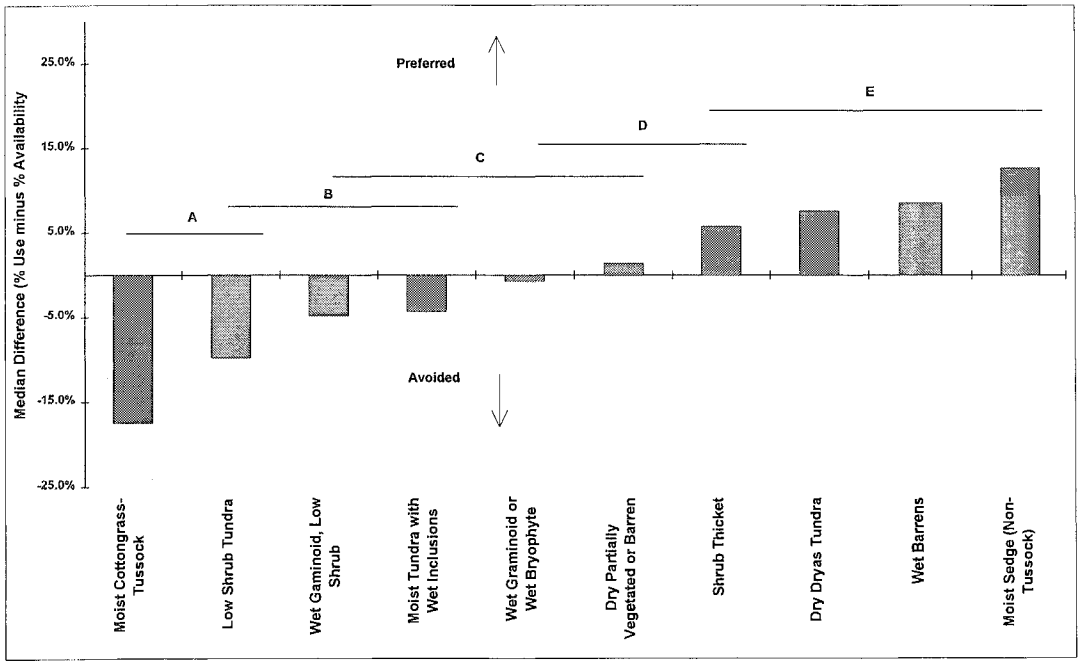

Figure 7. Muskox Selection of ground cover classes (Oct-Nov)

Comparison of Study Area with Larger Muskox Range

The proportion of each ground cover-type in the extended habitat area outside the study area (Figure 3) was calculated (Table 6) and compared (Figure 8) with that existing in the study area.

Muskox Diet – Fecal Samples

The primary vegetation in the fecal samples (Figure 9) consists of willow (Salix spp.), cottongrass (Eriophorum spp.), sedges (Carex spp.) and horsetail (Equisetum spp.). In general horsetail makes up a small percentage of the samples (<2%) except for October. However it is most likely that the October collection does not accurately represent muskox diet, as discussed below.

Table 6. Availability of Ground Cover Classes in Study Area and Larger Area on Coastal Plain

	Study Area		Larger Coastal Plain	
Ground Cover Type	Area (ha)	Proportion	Area (ha)	Proportion
Moist Cottongrass Tussock	31968.8	0.28	86476.0	0.33
Dry Dryas Tundra	15055.4	0.13	33987.6	0.13
Moist Sedge (non-tussock)	11468.8	0.10	21387.6	0.08
Moist Tundra with Wet Inclusions	11415.0	0.10	27903.4	0.11
Low Shrub Tundra	14971.4	0.13	34405.0	0.13
Dry Partially Vegetated or Barren	7623.9	0.07	12833.3	0.05
Wet Graminoid or Wet Bryophyte	5278.4	0.05	12899.0	0.05
Wet Barrens	3512.5	0.03	5733.6	0.02
Wet Graminoid, Low Shrub	7664.2	0.07	15261.5	0.06
Shrub Thicket	3602.5	0.03	10044.1	0.04
Total	112560.9	1.00	260931.1	1.00

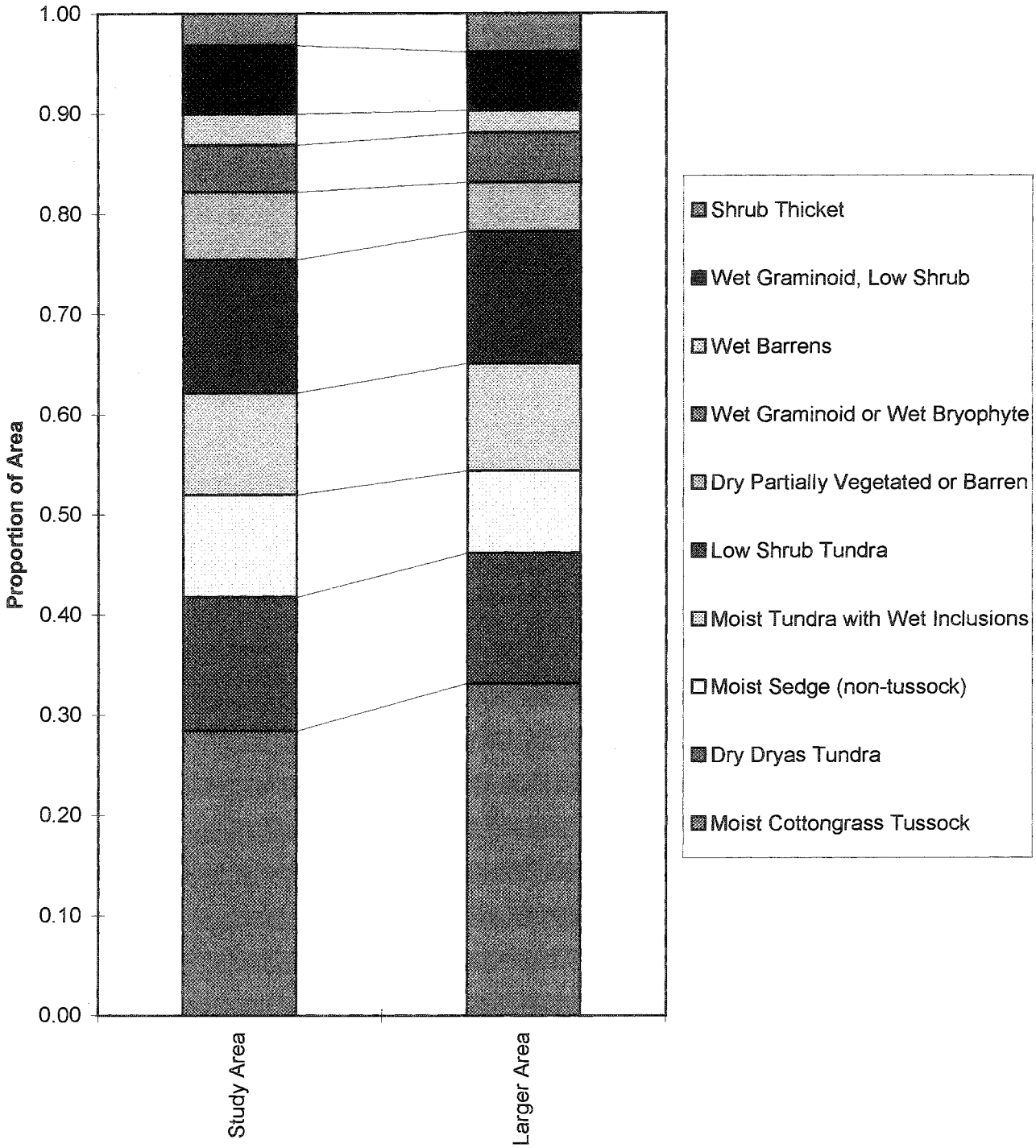

Figure 8. Comparison of Ground Cover in the Study Area and the Larger Area on the Coastal Plain.

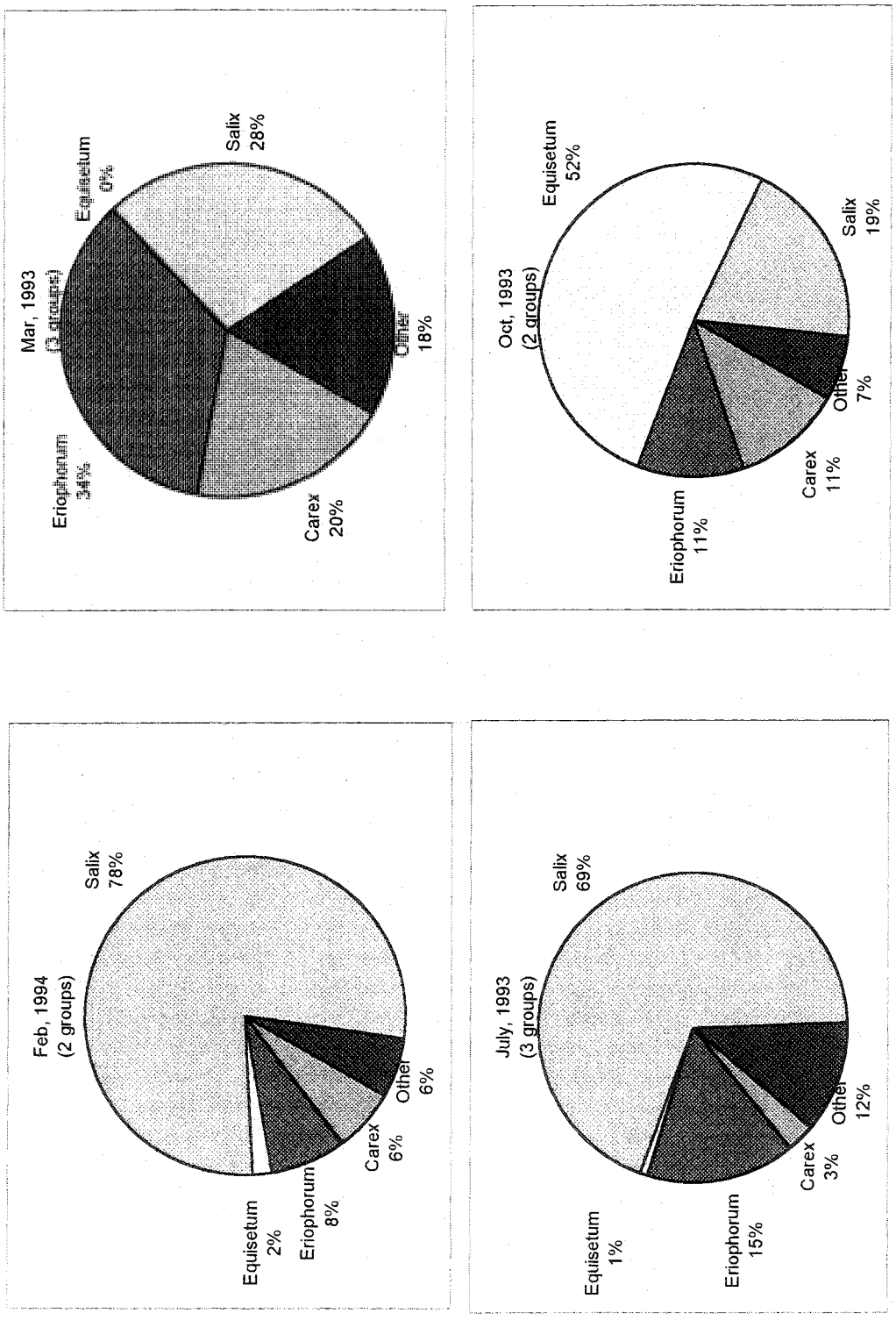

Figure 9. Average Proportion of Major Vegetation Components in Muskox Fecal Samples and Number of Groups Sampled.

DISCUSSION

Muskox Population

The census data indicate that the muskox population on the Yukon North Slope changed little between 1993 and 1995. It is unfortunate that the 1996 data provides only a minimum estimate because a count confirming the 1995 population would add more certainty to the data.

Muskox Selection of Habitat

For most of the year, there is no evidence that muskoxen in the Firth and Malcolm Rivers area selected ground cover-types in any proportion different from the distribution of cover-types across the study area. This would tend to indicate that the muskoxen observed are neither selecting nor avoiding any particular ground cover-type; however, the number of muskoxen observed is so low that little confidence can be placed in that conclusion outside of these individuals. We are left with a number of possibilities: 1) Muskoxen are not selecting or avoiding any particular habitats within the study area, 2) Selection is occurring, but not enough muskoxen were observed to demonstrate this statistically, and 3) Muskoxen are selecting for particular habitats, but the selection is based only partly (or not at all) on ground cover-types. The data are insufficient to distinguish between these possibilities.

During two periods of the year, the analysis did indicate a difference in preference ranking between habitats on the study area. However the category of cover preferred in the two adjacent time periods (see Category 'E' Figure 6 and Figure 7) is not consistent from one period to the next, and more importantly is composed of ground cover-types which do not logically belong together. The same is true of the category which shows as 'avoided' in the analysis (Category 'A'). Again, one is led to the conclusion that the data are insufficient to properly identify habitat selection.

Muskox Diet

Comparison with data from other studies suggests that the high proportion of horsetail measured in the October fecal samples probably exaggerates the importance of

horsetail in muskoxen diet. For example, although Robus (1981) reported observations of muskoxen foraging on Equisetum variegatum in October on the Sadlerochit river, Alaska, the percentage in the diet was only 4-5%. Muskoxen on Banks Island have been found to eat only minimal quantities of horsetail, and even that is thought to be an intake incidental to foraging on other species (Larter, pers. comm).

Aside from the October data, the results of the fecal analysis are roughly consistent with those found in other studies--Muskoxen on the Sadlerochit River, Alaska were also found to place a heavy reliance on various willow and carex species and to forage on cotton grass heavily in the spring (Robus 1981). Banks Island muskoxen also exhibit a high percentage of sedges and willow in their diet in all seasons, although they do not appear to consume cotton grass in the amounts indicated by the small sample of Yukon North Slope muskoxen in this study (Larter, pers. comm.).

It is difficult to compare the results of the fecal samples with that of the use/availability analysis, in part because of the anomalous October fecal sample results, and in part because of the lack of any statistically significant ground cover preferences in three of the five time periods analyzed.

Study Limitations

The use/availability data presented above examines only ground cover-type, not species of vegetation or physical availability. The ground cover-types provided by the CWS map are quite broad and a given type may contain both preferred and non-preferred species in varying amounts at different locations on the coastal plain (see Appendix B). As such this data is of only marginal usefulness in determining the true habitat requirements of muskoxen. Any attempt such as used in this study to characterize habitats in a uni-directional manner is likely to be weak and that is likely one reason why the data are inconclusive. For example it is quite likely that muskoxen select their winter habitat as much on abiotic factors as on vegetation cover. Muskoxen have been shown to respond to both the availability and quality of food and the depth and hardness of snow (Forchhammer 1995) and it is unlikely that a study such as this which focuses primarily on vegetation characteristics of the habitat will be successful in identifying the key characteristics of muskox habitat.

The approach used in this work is unable to characterize micro-habitat selection which likely plays a major role in determining the quality of muskox habitat, particularly in winter. It is likely that in addition to the overall characteristics of the environment which can be identified using remote sensing technology, the small-scale characteristics of the habitat play a crucial role in determining the quality of a given habitat for muskoxen.

For example, muskoxen are capable of adjusting both their seasonal range use and their dietary habits over a wide range of strategies depending on their environment. Their use of habitat has been found to follow flexible patterns which depend on the condition and availability of various forage species as well as abiotic factors, in particular snow hardness and depth, and their choice of habitat may vary dramatically between summer and winter. On the Seward Peninsula, Alaska, muskoxen selected windswept ridges in the winter in preference to areas of greater snow depth (Smith 1989a). Muskoxen in ANWR, the source population for the animals in the Yukon, were found to exhibit less dramatic seasonal variation in habitat use, but still preferred higher ground in late winter in contrast to the riparian habitats used during the rest of the year (Smith 1989b).

An additional limitation of the study, of course, is the small number of muskoxen which were collared. Although there are a great number of locations for these three animals it is unlikely that the movements of these three can be reliably extrapolated even to the rest of the adult muskox cows. To take but one example, it is known that dispersal is an important part of muskox survival strategy, and one of the cows collared is known to have moved a considerable distance during her lifetime, but all of the animals in this study were relatively sedentary during the year they were followed. Compounding this problem is the fact that two of the collared animals in this study (#2 and #3) were closely associated for most of the time they were tracked.

Comparison of study area with larger potential range

The question of possible expansion of the muskox population is an important one which can only be peripherally addressed in this report as the data developed in this study are not sufficient to provide a definitive answer. However, the muskox habitat use analysis suggests that muskox do not strongly select among the ground cover categories

on the study area during most of the year. Given this, and the general similarity of the composition of the extended area to the study area (Figure 8) the data provide no reason to expect muskoxen to be limited to their current numbers on the Yukon Coastal Plain. As discussed above, however, such a one-dimensional analysis must be considered to be at the level of a very preliminary assessment, and not one upon which management decisions should be based, particularly in view of the fact that muskoxen habitat selection on the Yukon Coastal Plain does not appear to be based on ground cover-types in the first place.

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APPENDICES

Appendix A. Number of Muskox Satellite Locations on the Yukon North Slope by Animal and Location Class

Animal ID	LC = 1	LC = 2	LC =3	TOTAL
1	513	403	64	980
2	487	475	102	1064
3	455	428	88	971
TOTAL	1455	1306	254	3015

Appendix B. CWS Vegetation Map Definition of Cover Classes on the Yukon Coastal Plain

Yukon Coastal Plain Cover Class		
Cover Class	Name	Description
1	Ice	Ice, including residual sea and lake ice, river icings, late snowbeds.
2	Clear Water	Clear water in the ocean, lakes, and rivers
3	Silty Water	Turbid water in the ocean, lakes, and rivers
4	Aquatic Tundra	Very wet tundra composed of 50 to 100 percent permanent water more than 20 cm deep. Includes many complexes of shallow water with varying types moist or dry tundra.
5	Wet Graminoid or Wet Bryophyte	Wet tundra areas with less than 50 percent permanent water more than 20 cm deep. Includes complexes of wet and moist tundra (usually low-centred polygons) dominated by wet tundra (51-90%).
6	Wet Graminoid, Low Shrub	Wet grass or sedge meadows with more than 10% cover of low shrubs. Usually sedge meadows with low willow, but more variable on the Mackenzie Delta.
7	Wet Barrens	Wet areas with more than 25% bare ground. Usually wet sand or silt in river delta, but some thaw slides in upland areas and wet gravels along rivers.
8	Moist Tundra with Wet Inclusions	Complexes of moist and wet tundra dominated by moist tundra (51-90%). Usually high-centred polygon complexes.
9	Moist Sedge (non-tussock)	Moist sedge communities found in better drained soils than Moist Cottongrass Tussock (10). Found largely in unglaciated areas west of the Firth River.
10	Moist CottongrassTussock	Typical sedge tussock landscape of the coastal plain, with varying amounts of low shrub and moss. In the west, willow, sedges and grasses are associated species, whereas in the east Dwarf Birch, Labrador Tea, and Lowbush Cranberry are more common associated species.
11	Low Shrub Tundra	Various types of tundra dominated by low shrubs (more than 30% cover). Includes typical cottongrass tussock tundra (above) with shrub overstorey, and variable types of tundra lacking sedge tussocks.
12	Shrub Thicket	Thickets dominated by medium to tall shrubs (10% or more cover). Most commonly found along rivers, sheltered slopes, and in the Mackenzie Delta.
13	Dry Dryas Tundra	Dry, well drained areas either on river terraces (especially west of the Firth River), or on hilltops and ridges.
14	Dry Partially Vegetated or Barren	Dry, well drained areas with less than 70% vegetation cover. Typically gravel and sand bars along rivers, coastal beaches and spits, and alpine areas.
15	Mountain Shadows	north facing slopes in the foothills and mountains that were in direct shadow at the time of the satellite imagery.

Appendix C. Detailed Analysis of Muskox Selection of Cover-types.

Detailed analysis of muskox selection of ground cover classes for January-February is given in the text. Details on other seasons are presented below.

Appendix C-1. Muskox Selection of Cover-types (Apr-May)

A) Percent of Satellite Locations and Percent of Study Area in Each Cover Type, Apr-May

Percent Use	Moist Cotton-grass-Tussock	Dry Dryas Tundra	Low Shrub Tundra	Moist Sedge (Non-Tussock)	Moist Tundra with Wet Inclusions	Wet Graminoid, Low Shrub	Dry Partially Vegetated or Barren	Wet Grainoid or Wet Bryophyte	Wet Barrens	Shrub Thicket	Total
Muskox 1	32.5%	15.6%	19.5%	6.5%	2.6%	10.4%	10.4%	0.0%	0.0%	2.6%	100.0%
Muskox 2	20.3%	22.7%	35.9%	0.0%	5.5%	3.9%	3.1%	2.3%	1.6%	4.7%	100.0%
Muskox 3	56.8%	12.8%	0.0%	7.2%	14.4%	4.0%	0.8%	3.2%	0.0%	0.8%	100.0%
Percent Availability	28.4%	13.4%	13.3%	10.2%	10.1%	6.8%	6.8%	4.7%	3.1%	3.2%	100.0%

B) Difference = Percent Use minus Percent Availability

Muskox 1	4.1%	2.2%	6.2%	-3.7%	-7.5%	3.6%	3.6%	-4.7%	-3.1%	-0.6%
Muskox 2	-8.1%	9.3%	22.6%	-10.2%	-4.7%	-2.9%	-3.6%	-2.3%	-1.6%	1.5%
Muskox 3	28.4%	-0.6%	-13.3%	-3.0%	4.3%	-2.8%	-6.0%	-1.5%	-3.1%	-2.4%

C) Rank of Difference for Each Muskox

Muskox 1	2	5	1	8	10	4	3	9	7	6
Muskox 2	9	2	1	10	8	6	7	5	4	3
Muskox 3	1	3	10	7	2	6	9	4	8	5
sum of ranks	12	10	12	25	20	16	19	18	19	14

D) Friedman 2-Way Analysis of Variance by Ranks Results:

Test statistic, F_r= 6.85
N= 3.00
Probability= 0.652
Conclusion: Not Significant at 0.10 level, H_0 not rejected.
There is not enough evidence to claim selection of any cover types.

Appendix C-2. Muskox Selection of Cover-types (Jun-Jul)

A) Percent of Satellite Locations and Percent of Study Area in Each Cover Type, Jun-Jul

Percent Use	Moist Cotton-grass-Tussock	Dry Dryas Tundra	Low Shrub Tundra	Moist Sedge (Non-Tussock)	Moist Tundra with Wet Inclusions	Wet Graminoid, Low Shrub	Dry Partially Vegetated or Barren	Wet Grainoid or Wet Bryophyte	Wet Barrens	Shrub Thicket	Total
Muskox 1	15.7%	28.9%	1.2%	12.0%	7.2%	0.0%	20.5%	6.0%	6.0%	2.4%	100.0%
Muskox 2	37.9%	6.9%	5.7%	13.8%	8.0%	2.3%	3.4%	6.9%	13.8%	1.1%	100.0%
Muskox 3	32.1%	12.8%	4.6%	7.3%	13.8%	6.4%	4.6%	7.3%	4.6%	6.4%	100.0%
Percent Availability	28.4%	13.4%	13.3%	10.2%	10.1%	6.8%	6.8%	4.7%	3.1%	3.2%	100.0%

B) Difference = Percent Use minus Percent Availability

Muskox 1	-12.7%	15.5%	-12.1%	1.9%	-2.9%	-6.8%	13.7%	1.3%	2.9%	-0.8%
Muskox 2	9.5%	-6.5%	-7.6%	3.6%	-2.1%	-4.5%	-3.3%	2.2%	10.7%	-2.1%
Muskox 3	3.7%	-0.5%	-8.7%	-2.8%	3.6%	-0.4%	-2.2%	2.7%	1.5%	3.2%

C) Rank of Difference for Each Muskox

Muskox 1	10	1	9	4	7	8	2	5	3	6
Muskox 2	2	9	10	3	6	8	7	4	1	5
Muskox 3	1	7	10	9	2	6	8	4	5	3
sum of ranks	13	17	29	16	15	22	17	13	9	14

D) Friedman 2-Way Analysis of Variance by Ranks Results:

Test statistic, F_r= 10.05
N= 3.00
Probability= 0.346
Conclusion: Not Significant at 0.10 level, H_0 not rejected.
There is not enough evidence to claim selection of any cover types.

Appendix C-3. Muskox Selection of Cover-types (Aug-Sept)

A) Percent of Satellite Locations and Percent of Study Area in Each Cover Type, Aug-Sept

Percent Use	Moist Cotton-grass-Tussock	Dry Dryas Tundra	Low Shrub Tundra	Moist Sedge (Non-Tussock)	Moist Tundra with Wet Inclusions	Wet Graminoid, Low Shrub	Dry Partially Vegetated or Barren	Wet Grainoid or Wet Bryophyte	Wet Barrens	Shrub Thicket	Total
Muskox 1	1.5%	37.3%	0.0%	13.4%	1.5%	1.5%	17.9%	6.0%	17.9%	3.0%	100.0%
Muskox 2	5.6%	21.1%	14.4%	11.1%	2.2%	2.2%	13.3%	4.4%	24.4%	1.1%	100.0%
Muskox 3	11.1%	12.5%	18.1%	9.7%	5.6%	0.0%	12.5%	2.8%	26.4%	1.4%	100.0%
Percent Availability	28.4%	13.4%	13.3%	10.2%	10.1%	6.8%	6.8%	4.7%	3.1%	3.2%	100.0%

B) Difference = Percent Use minus Percent Availability

Muskox 1	-26.9%	23.9%	-13.3%	3.2%	-8.6%	-5.3%	11.1%	1.3%	14.8%	-0.2%
Muskox 2	-22.8%	7.7%	1.1%	0.9%	-7.9%	-4.6%	6.6%	-0.2%	21.3%	-2.1%
Muskox 3	-17.3%	-0.9%	4.8%	-0.5%	-4.6%	-6.8%	5.7%	-1.9%	23.3%	-1.8%
Median Difference	-22.8%	7.7%	1.1%	0.9%	-7.9%	-5.3%	6.6%	-0.2%	21.3%	-1.8%

C) Rank of Difference for Each Muskox

Muskox 1	10	1	9	4	8	7	3	5	2	6
Muskox 2	10	2	4	5	9	8	3	6	1	7
Muskox 3	10	5	3	4	8	9	2	7	1	6
sum of ranks	30	8	16	13	25	24	8	18	4	19

D) Friedman 2-Way Analysis of Variance by Ranks Results:

Test statistic, F_r= 23.00
N= 3.00
Probability= 0.006
Conclusion: Significant at 0.10 level, H_0 rejected.
Some cover types are preferred over others.
Fisher's LSD: 7.60 (Critical difference between two rank sums for statistical signif. at 0.10 level)

Appendix C-4. Muskox Selection of Cover-types (Oct-Nov)

A) Percent of Satellite Locations and Percent of Study Area in Each Cover Type, Oct-Nov

Percent Use	Moist Cotton-grass-Tussock	Dry Dryas Tundra	Low Shrub Tundra	Moist Sedge (Non-Tussock)	Moist Tundra with Wet Inclusions	Wet Graminoid, Low Shrub	Dry Partially Vegetated or Barren	Wet Grainoid or Wet Bryophyte	Wet Barrens	Shrub Thicket	Total
Muskox 1	11.4%	21.4%	5.7%	22.9%	2.9%	1.4%	11.4%	2.9%	10.0%	10.0%	100.0%
Muskox 2	10.9%	17.8%	2.0%	20.8%	13.9%	2.0%	5.0%	4.0%	14.9%	8.9%	100.0%
Muskox 3	5.8%	20.9%	3.5%	26.7%	5.8%	3.5%	8.1%	7.0%	11.6%	7.0%	100.0%
Percent Availability	28.4%	13.4%	13.3%	10.2%	10.1%	6.8%	6.8%	4.7%	3.1%	3.2%	100.0%

B) Difference = Percent Use minus Percent Availability

Muskox 1	-17.0%	8.1%	-7.6%	12.7%	-7.3%	-5.4%	4.7%	-1.8%	6.9%	6.8%
Muskox 2	-17.5%	4.4%	-11.3%	10.6%	3.7%	-4.8%	-1.8%	-0.7%	11.7%	5.7%
Muskox 3	-22.6%	7.6%	-9.8%	16.6%	-4.3%	-3.3%	1.4%	2.3%	8.5%	3.8%
Median Difference	-17.5%	7.6%	-9.8%	12.7%	-4.3%	-4.8%	1.4%	-0.7%	8.5%	5.7%

C) Rank of Difference for Each Muskox

Muskox 1	10	2	9	1	8	7	5	6	3	4
Muskox 2	10	4	9	2	5	8	7	6	1	3
Muskox 3	10	3	9	1	8	7	6	5	2	4
sum of ranks	30	9	27	4	21	22	18	17	6	11

D) Friedman 2-Way Analysis of Variance by Ranks Results:

Test statistic, F_r= 25.40
N= 3.00
Probability= 0.003
Conclusion: Significant at 0.10 level, H_0 rejected.
Some cover types are preferred over others.
Fisher's LSD: 7.60 (Critical difference between two rank sums for statistical signif. at 0.10 level)