JOB COMPLETION REPORT

John Hanshaw 1964

JOB COMPLETION REPORT

State: Alaska

Project No: W-6-R-4 Name: Alaska Wildlife Investigations

Work Plan: C Caribou Management Studies

Job No: 5 Title: Environmental Factors Governing Caribou Winter Activity

PERIOD COVERED: November 15, 1961 - March 15, 1962 and February 1, 1963 - May 30, 1963.

ABSTRACT:

Two winters of field observation of caribou activity and measurement of related environmental factors were completed. Caribou feeding, moving, and resting activities were recorded in relation to snow depth and hardness, wind speed, temperature and other environmental conditions. Comparable measurements were taken in randomly selected control areas where caribou activity was absent. Preliminary data analysis indicates that snow depth and hardness are primary factors of the environment controlling caribou movements and feeding activities. Secondarily wind speed and associated topographic variation appear to govern selectivity of resting areas by caribou.

OBJECTIVES:

To identify the variable environmental factors which stimulate and influence the patterns of movement and activity of arctic caribou during winter.

INTRODUCTION:

An animal normally possesses the inherited ability to recognize and occupy a suitable environment for which it is adapted. As environmental composition is dynamic with the passage of time, specific animal activities will be influenced, and even regulated, by different environmental conditions.

This study is concerned with some winter environmental conditions

ambient to caribou (Rangifer arcticus) in northwestern Alaska and the observed responses of the animals to variation in these conditions. The arctic caribou population occupy a nival environment for at least 8 months of each year, consequently, this study places a major emphasis on the depth and hardness of snow. Other factors examined include topography, temperature, wind, light intensity and general weather conditions. It is recognized that physical features of the environment are usually interrelated and sometimes interdependent and that any single factor may not be entirely responsible for exhibited responses by the animals.

This report is preliminary as environmental factors have been largely treated discretely and have not yet been given perspective according to their interrelationships. Statistical tests have not yet been applied and any expressed significances are apparent only and considerable modification may occur as a result of more comprehensive analysis. Conclusions would be out of place in this report and a summary would likewise be lacking in significance.

Parts of two winters were spent collecting field data which are presented in two different ways. During the first winter, data were obtained through selective sampling methods and Part I of this report contains a fundamental analysis of the resulting information. Part II contains randomly sampled data which are presented and discussed on the basis of the winter's progression. In order to limit the size of this report, some data has been summarized and only samples of maps drawn to illustrate the situation of each caribou observation have been included.

Literature studies and more intensive analysis of the data will be effected as soon as possible and it is hoped to complete the study by May, 1964. The writer will be utilizing the data in conjunction with studies to be conducted at the University of Manchester, England.

Field work during the winter of 1961/1962 was financed in part by the Department of Biological Sciences, University of Alaska and in 1963 by the Alaska Cooperative Wildlife Research Unit.

TECHNIQUES:

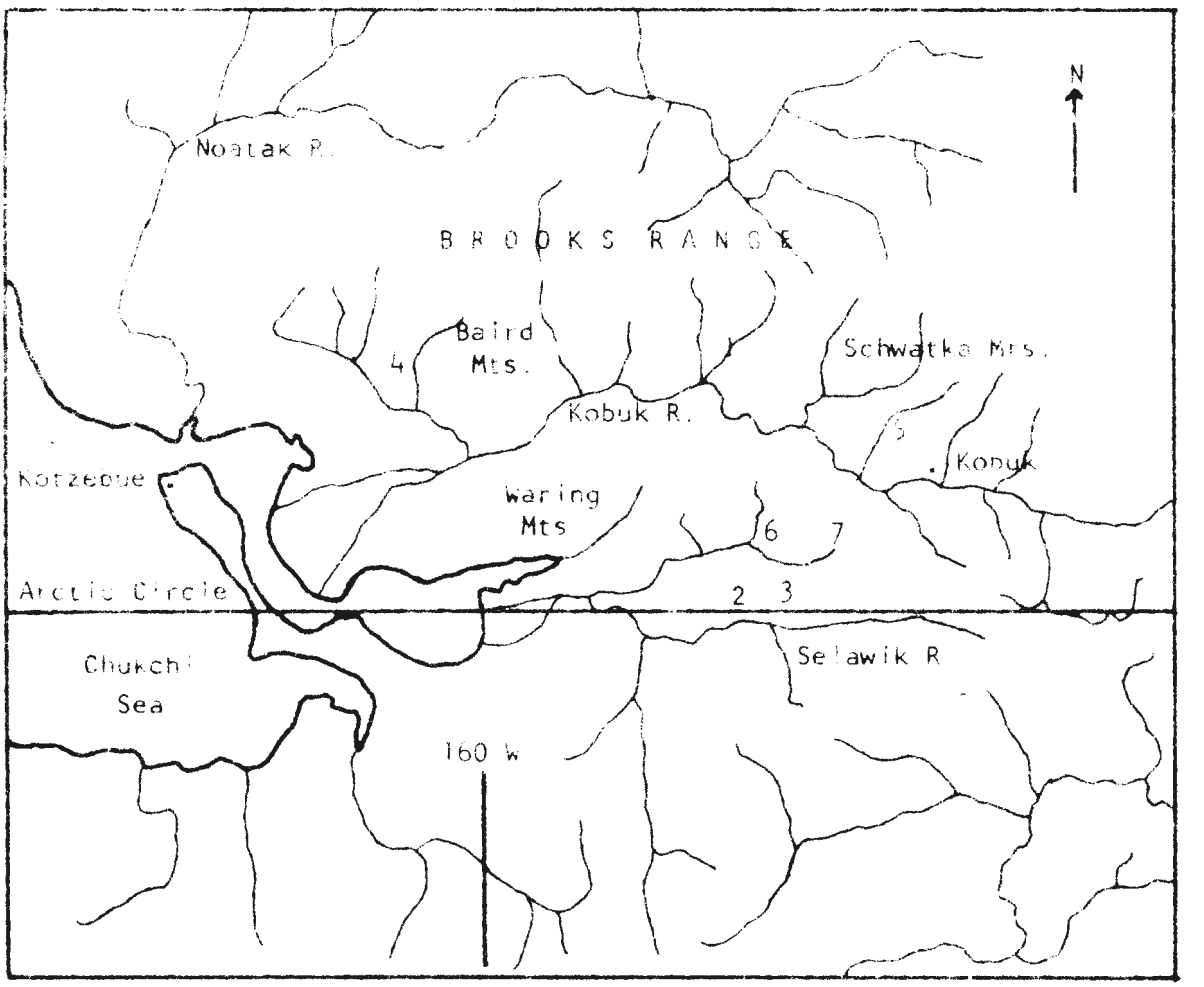
Travel

A ski equipped Piper Family Cruiser based at Kotzebue and (in 1963) a ski equipped Piper Super Cub based at Kobuk were used for transporting self and equipment when searching for caribou and landing amongst them to set up camp. The Kobuk based plane was also used to effect surveys of caribou incidence in the upper Kobuk River drainage.

During the winter of 1961/1962 the writer worked alone in the field, so that travel on the ground was limited to an area of about 10 miles radius

PART OF N.W. ALASKA

Map 1



1 inch equals approximately 40 miles. Camp locations marked by numbers

from each camp. Walking and the use of snowshoes were abandoned in favour of touring skis which allowed greater daily milage to be covered with less effort.

Near the end of the second winter a traverse was made through caribou habitat in the Ambler Lowlands - Schwatka Mountains region in company with three assistancts. Skis were again used and, although individual loads were back-packed, much of the camp equipment and supplies was hauled by three dogs pulling a 4' 6" sled (Akhlo). This system of small party travel proved to be most efficient as a larger dog team would have necessitated a greater dependence on hunting for food.

Shelter

A 10' x 8' x 7' 6" floorless wall tent with attached liner was used during the first winter. Ground insulation was provided by cutting spruce or willow for a mat and a wood burning "Yukon" stove provided heat. Gathering fuel for the stove took up valuable daylight time and a smaller tent would have necessitated less effort in this direction. Severe winds damaged this tent partly on account of the large wall sections exposed to the elements and it was not always possible to prevent snow from drifting in under the wall bottoms even though snow walls were constructed around the tent. This tent was white, the worst possible colour for spotting either from the ground or the air. During one blizzard the writer spent 5 hours searching for the tent and was only successful in locating it when he fell over a guy line.

A very much smaller, bright orange tent with sewn in floor, double door and with complete fly coverage was used the following winter, The ease of spotting this tent at considerable distances was a useful factor when working the surrounding country. The tent was pitched low in the snow on top of a spruce or willow mat and a "Coleman" double burner, white gasoline, pressure stove was used for both cooking and heating purposes. With a single burner lit a temperature rise of -42 F. to +100 was achieved. On another occasion an inside temperature of +75 F. was maintained when the outside temperature was -58, again with only a single burner lit.

During the final traverse no stove was used and cooking was effected over an open fire. A single skin mountain tent was carried and the warmer temperatures obviated the need for heat inside the tent.

General Observation Methods

A preconceived classification of post rutting season caribou behaviour was made separating predominant band activities into the 5 following types:

A - Feeding/Travelling
B - Stationary Feeding

C - Feeding/Resting
D - Resting
E - Travelling

Field work substantiated the validity of this activity separation as no arbitrary band behaviour could be recognized.

The entire field work data obtained during the first winter consists of paired environmental recordings which are correlated to observed caribou band activities. Data were discarded when it was not possible to complete a set of recordings.

After locating caribou, the writer would approach to within a few hundred yards if the animals were stationary, or would manoeuver to lie in wait in the case of shifting caribou. The final distance between the two recording stations was often regulated by the necessity for causing no disturbance to caribou activities. A set of environmental measurements was taken at the location described hereafter as the obeerver's position and the caribou would be watched during this time. It was often entirely necessary to take advantage of the terrain when approaching caribou and the observer's position records cannot be regarded as non-selective. Immediately after these measurements had been completed the observer moved directly towards the animals, disturbed them from their position and made a repeat set of measurements of the vacated environment. In the case of moving caribou, the 2nd set of recordings was sometimes obtained without disturbing the animals as they might be unaware of the observer moving into the trail they had just made.

The environmental factors recorded were: Snow depth plus hardness of the surface and the hardest layers; temperatures at ground level, snow surface and 3' 6" above snow surface (approximating caribou head height); windspeed and direction; light intensity; the incidence of sun; cloud; precipitation; also general weather conditions. Caribou numbers, composition, activity and direction of movement prior to and after disturbance by the observer were noted and additional field notes were made as necessary. A map was finally drawn to show relief, protrudent vegetation, location of recording stations and the activities of the caribou. Instruments and methods of their use are described in the data discussion pages.

During the second winter, with the support of field assistants, it was possible to traverse caribou habitat to obtain a more random sampling of some environmental factors. The methods involved are described in the relevant section of this paper.

Bias

It may be impossible to achieve absolute randomness in sampling the physical environment and activities of wintering caribou. Bias is first

introduced by using aircraft for transport to locate caribou and set up a camp amongst them. In order to lessen the possibility, one might be justified in saying - probability, of losing contact with transient caribou, the decision to land and make camp is determined by the density of animals on the ground. Habitat only thinly occupied by caribou is rejected in favour of habitat containing a bountiful supply. A second, and unavoidable, bias results from topographic variation, itself a factor under study. Camp can only be located where caribou occupy an area suitable for a plane landing and as a consequence, some important mountain habitat is neglected.

The two position environmental sampling procedure used throughout the first winter is open to hearty condemnation, particularly from the desk bound theoretician. It can be argued that an observation of the environment occupied by caribou should be equated with randomly arranged multiple observations of the peripheral environment. In view of the dynamic nature of environmental factors, some of which are changeable within minutes, individual stations that comprise a multiple set would need to be obtained within a very short period of time or, better still, at the same time as each other. A set of multiple recordings taking several hours to complete would introduce a flow of environmental change that would only serve to compound the problem of eventual data analysis, and would prove of little correlative value to caribou activity as the process of such sampling would be antipathetic to caribou from its onset. We are purely concerned with the activities of caribou undisturbed by the human presence and observations were made following this discipline.

Further bias is evident when the timing of observations is considered. An inability to observe during darkness and some blizzards, particularly during mid-winter, effects the qualitative (as well as the quantitative) value of data presented here and there is no way of knowing if daylight activities are representative for the 24 hour period.

Towards the end of the second winter of field work a 16 day traverse was undertaken to randomly sample snow conditions over an area of scattered caribou occupancy. Straight map lines were followed and snow conditions recorded at regular and predetermined intervals. Although three experienced mountaineers were recruited (the leader and two of his companions from the 1962 successful Mt. McKinley assult) we failed to overcome one mountainous section of the predetermined route, which had to be redrawn to be kept within the bounds of practicability. The completed traverse follows a geometrical form but some degree of bias is present precluding a claim that the sampling was non-selective for this particular area of caribou habitat.

A quantitative evaluation of bias will prove to be a biometricians nightmare and it cannot be guaranteed to suggest many improved field techniques.

Key to Observation Maps

All maps

Spruce (*Picea* Sp.)

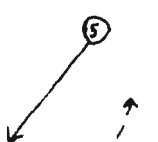
Willow (*Salix* Sp.)

Rivers and creeks

Lakes

Area occupied by caribou

Twin observation maps (numbered)



Windspeed (max.) & direction

Route of undisturbed caribou

Route of disturbed caribou

Observer's position and point of reference for contours

Caribou position

Random sampling maps (lettered)

Existing caribou trails

Area of cratering

\+ Recording station

X Point of reference for contours.

All contours are in feet above or below reference points.

FINDINGS:

PART I - Winter of 1961-1962

Caribou Band Composition

During late winter some early born calves may have been counted as cows (small) and some small cows may have been counted as calves especially if they were antlerless.

The calf ratio may seem to be particularly high but there is no method of determining any possible error in these data. The majority of animals counted were inhabiting the Squirrel River valley and were part of a discrete concentration of caribou that made no major movement for several months. Cows accompanied by two calves were seen quite often and lone calves or two calves unaccompanied by adult caribou were not uncommon. The location of the Squirrel River camp is marked by the figure 4 on map 1.

Snow Depth

Either a stout wooden folding rule or a ski pole, graduated in inches, was used to measure snow depth and the average of several probes was recorded owing to the uneven nature of the ground.

Given a treeless, plane landscape and a windless winter, any pair of measurements (observer's and caribou position) could have shown identical snow depth provided that ground substrates were not too dissimilar. Wind and, perhaps to a lesser degree, solar radiation combine with land form and the shadowing and binding properties of vegetation to produce unequal distribution and retention of snow. Although snow depth variation over short distances is a resultant of other factors in the environment of caribou, its influence upon the animals is direct and primary.

The average snow depth from all positions that were occupied by caribou is 13.37" whilst that from the observer's positions is 27.54" and in 49 instances out of 54, caribou were utilizing the location of shallower snow. Pruitt (1960) thought that caribou in Canada possessed a threshold of tolerance to about 60 cm. (24") of snow and that when depths exceeded this amount, caribou reacted by moving. Certainly, the average snow depth recorded for travelling caribou (activity E) in N.W. Alaska is greater than that for any other activity (table 3) and this could well be a reflection of an urge to move until shallower snow is encountered. Each route taken by travelling caribou showed some degree of selection for locally shallower snow which lends support to the hypothesis that snow depth is of primary importance to discrete caribou activities. It is evident that caribou require very shallow snow if they are to feed whilst moving (table 3) and that feeding becomes a more stationary activity when medium depths occur.

Table 1. Caribou Band Composition, Winter of 1961/1962

Camp number	Observation number	Date	Time	Bulls	Cows	Calves	Total
2	1	29 Nov.61	1215	29	43	19	91
2	2	30 Nov.61	1100	5	8	3	16
2	3	1 Dec.61	1100	4	9	4	17
2	4	1 Dec.61	1300	4	4	3	11
2	5	2 Dec.61	1215	2			2
2	6	3 Dec.61	1115	2	2	2	6
3	7	5 Dec.61	0945	1	4	3	8
3	8	6 Dec.61	1200	2	5	2	9
4	9	7 Feb.62	1000	4	3	2	9
4	10	7 Feb.62	1200	54	37	21	112
4	11	8 Feb.62	1030	5	9	7	21
4	12	8 Feb.62	1130	14	11	7	32
4	13	9 Feb.62	1430	6	7	6	19
4	14	10 Feb.62	1100	27	19	13	59
4	15	10 Feb.62	1200	17	8	5	30
4	16	11 Feb.62	1215		14	15	29
4	17	11 Feb.62	1500	9	6	5	20
4	18	12 Feb.62	1145		7	3	10
4	19	12 Feb.62	1300	7	7	6	20
4	20	13 Feb.62	1300	2	8	5	15
4	21	13 Feb.62	1600	51	64	49	164
4	22	14 Feb.62	1115			2	2
4	23	14 Feb.62	1215		3	2	5
4	24	15 Feb.62	1100		1	1	2
4	25	15 Feb.62	1630	14	18	13	45
4	26	16 Feb.62	1230		1	1	2
4	27	16 Feb.62	1330	17	13	11	41
4	28	17 Feb.62	1500		3	3	6
4	29	17 Feb.62	1600	9	11	8	28
4	30	18 Feb.62	1000	1	5	4	10
4	31	18 Feb.62	1330	1	5	4	10
4	32	19 Feb.62	1215		3	3	6
4	33	20 Feb.62	1130	7	7	5	19
4	34	21 Feb.62	1200	3	2	2	7
4	35	27 Feb.62	1230		1	1	2
4	36	27 Feb.62	1600	19	13	12	44
4	37	28 Feb.62	1100		4	1	5
4	38	28 Feb.62	1645			1	1
4	39	1 Mar.62	1200	57	54	49	160
4	40	1 Mar.62	1530			1	1
4	41	2 Mar.62	1030		3	2	5
4	42	2 Mar.62	1130		1	1	2
4	43	3 Mar.62	1100	8	2	2	12
4	44	3 Mar.62	1600		5	4	9
4	45	4 Mar.62	1200	47	55	49	151
4	46	4 Mar.62	1330	2	3	2	7
4	47	5 Mar.62	1200		2	1	3
4	48	5 Mar.62	1600	9	9	8	26
4	49	6 Mar.62	1100		1	1	2
4	50	6 Mar.62	1230	8	15	11	34
4	51	7 Mar.62	1000	18	11	7	36
4	52	7 Mar.62	1615	11	5	5	21
4	53	8 Mar.62	1145	8	9	9	26
4	54	8 Mar.62	1245	4	11	8	23
			Total:	488	551	414	1453

The performance of discrete activities within grades of snow depth is probably relative to overall depths that are generally increasing with the progression of winter, so that distinct tolerance limits cannot be readily assumed except when snow is sufficiently deep (and soft) as to prevent caribou from moving through such conditions. However, selectivity for snow depth condition congruous to the performance of specific activities does appear to be continual over the winter.

Snow Hardness

Gauges for measureing snow hardness were push-type spring balances on which pressure discs could be mounted. These gauges are standardized by the National Research Council of Canada, Committee on Snow and Soil Mechanics, and are fully described by Klein et al (1950). A hole in the snow was excavated to ground level and a section scraped with a knife to expose a profile of undisturbed snow layers. Testing each layer with the pressure gauges resulted in recognition of the hardest layer and the snow surface was also measured. Units of snow layer hardness are expressed in grammes of pressure per square centimetre required to collapse the structure of the snow.

The hardness of a snow layer is dependent to a limited degree upon its crystallographic composition, water content and its positional comparison to the ground and other snow layers. Solar radiation, temperature profile, windforce, land form and disturbance by animals are modifying variables that help to create unequal snow hardness conditions from place to place.

It is not altogether surprising that 34 of the total of 54 paired observations show equal surface hardnesses at the observer's and caribou occupied locations. The top layer of snow was likely to be the newest in both locations unless redistribution by strong winds had occurred since it fell. Layers below the surface layer were more likely to have experienced variable modification due to their longer existence. The top layer occasionally became the hardest due to the impacting effect of winds or the wind caused dispersal of soft, loose surface snow until a harder layer was exposed.

Surface layer snow was more often harder at the caribou than the observer's position, with by far the hardest recordings occurring with the incidence of travelling caribou (table 5). Obviously, the harder the snow, the greater is its flotation effect to travelling animals. The highest average from hardest layer recordings is also reflected by caribou performing activity E. It should be noted at this point that purely travelling caribou are characterized by what we might describe as the "severest" snow depth and hardness conditions, and that both of these factors are "mildest" when caribou feed as they travel. The stationary activities are performed in intermediate snow hardness conditions

Table 2. Snow Depth Observations, Winter of 1961/1962

Observation number	Number of caribou	Caribou activity	Snow depth at observer	Snow depth at caribou	Deeper at caribou	Deeper at observer	
1	91	A	10	7		*	
2	16	A	12	5		*	
3	17	C	9	5		*	Camp
4	11	C	8	6		*	Two
5	2	A	9	6		*	
6	6	B	11	8		*	
7	8	A	11	4		*	Camp
8	9	B	14	6		*	Three
9	9	A	28	16		*	
10	112	B	27	14		*	
11	21	C	32	13		*	
12	32	A	23	9		*	
13	19	B	29	8		*	
14	59	B	29	8		*	
15	30	A	21	24	*		
16	29	A	25	7		*	
17	20	B	21	23	*		
18	10	A	16	9		*	Camp
19	20	D	29	13		*	Four
20	15	C	18	15		*	
21	164	E	26	18		*	
22	2	D	23	16		*	
23	5	B	11	11	----------		
24	2	B	17	11		*	
25	45	B	34	18		*	
26	2	A	13	16	*		
27	41	B	33	26		*	
28	6	D	27	24		*	
29	28	D	26	21		*	
30	10	D	33	12		*	

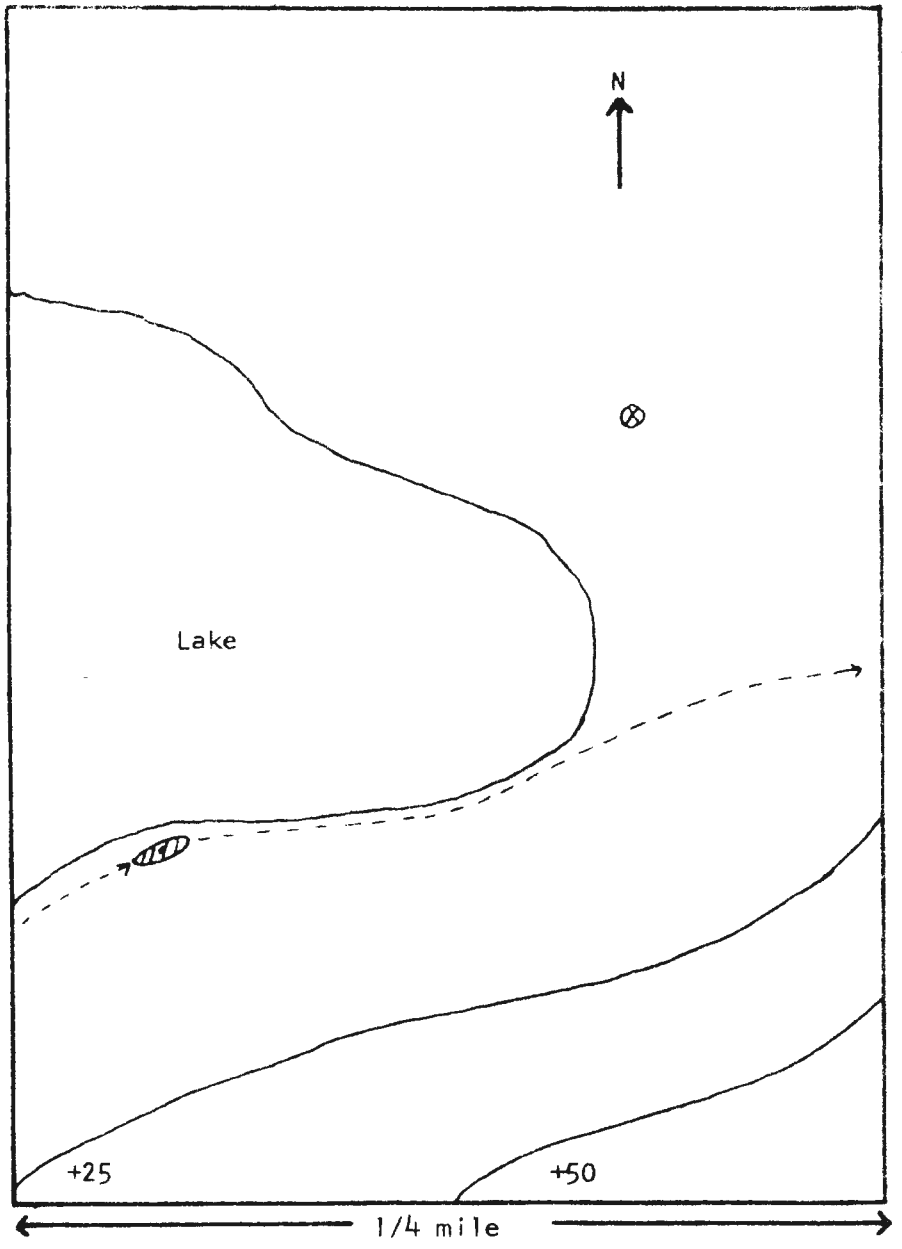
31	10	B	35	11		*	
32	6	D	2	5	*		
33	19	C	39	4		*	
34	7	E	37	18		*	
35	2	B	46	21		*	
36	44	E	34	27		*	
37	5	B	42	0		*	
38	1	B	28	9		*	
39	160	C	14	11		*	
40	1	B	23	9		*	
41	5	D	40	19		*	Camp
42	2	D	44	21		*	Four
43	12	B	39	5		*	
44	9	D	41	19		*	
45	151	C	35	27		*	
46	7	E	26	4		*	
47	3	A	44	3		*	
48	26	C	43	13		*	
49	2	B	54	6		*	
50	34	C	31	20		*	
51	36	E	38	22		*	
52	21	A	49	7		*	
53	26	E	44	41		*	
54	23	C	33	21		*	
					4	49	

Snow measurements in inches

Table 3. Caribou Activity - Snow Depth, Winter of 1961/1962

caribou activity	number of observations	total caribou	range of snow depth	average snow depth
A - Feeding/Travelling	12	253	3 - 24	8.6
B - Stationary Feeding	17	351	0 - 26	11.4
C - Feeding/Resting	10	477	4 - 27	13.5
D - Resting	9	88	5 - 24	16.7
E - Travelling	6	284	4 - 41	21.7
Observer's position (no caribou)	54	-	2 - 54	27.5

Snow measurements in inches



Map 2 Snowdepth Situation Example

Observation number: 47
Camp number: 4
Date: 5th March 1962
Time: 1200

Caribou activity: A-moving slowly, feeding as they follow the lake shore.

	observer's position	caribou position
Snow depth	44	3
Surface hardness	8	10
Maximum hardness	85	10
Air temperature	-8	-7
Surface temperature	-7	-7
Ground temperature	+18	+3
Windspeed	0	0
Windchill	540	535
Direction	-	-
Light intensity	170	170

Weather: Fine with clear sky and unrestricted visibility.

Bulls	0
Cows	2
Calves	1

Remarks: This is a good example of variable snow depth resulting from the combined effect of wind and micro relief. From March 1st to 3rd inclusive an 8 to 38 m.p.h. wind from the N.E. eroded the snow structure on the south shore of the lake. Only the lip on the south shore appeared to have been exposed by erosion and the caribou were able to feed whilst travelling as pawing out feeding craters was unnecessary. The absence of spruce or willow on the lake shore was advantageous to caribou in this situation as it allowed a maximum erosion potential to exist.

which also compares with the analysis of snow depth relationships. The interrelationship of snow depth and snow hardness has not yet received sufficient attention to allow adequate explanation of these phenomena.

Caribou are certainly responsive to snow hardness variation over short distances and Pruitt's (1960) suggested sensitivity threshold of 50 gm./sq./cm., which refers to forest as opposed to lake stations, is worthy of comparison to these Alaskan data. Pruitt showed that lakes which were commonly used by caribou for resting or travelling often carried much harder snow than the above figure. Table 5 indicates that snow hardnesses (hardest layer) for resting and travelling caribou were generally higher than 50 gm./sq./cm. and that all other activities show hardnesses generally lower than this figure.

Windspeed and Windchill

A "Dwyer" wind meter was used to measure windspeed at a height of 3' 6" above the surface of the snow cover. This simple instrument comprises a tube graduated in m.p.h. in which a pith ball is forced to rise by windforce. Although the ball oscillates, an average windspeed is fairly readily recognized. Wind direction was also recorded.

Windchill was obtained by combining windspeed and air temperature according to the method described by Siple and Passel (1945). Windchill is a measure of the quantity of heat which the atmosphere is capable of absorbing within an hour from an exposed surface one metre square at a temperature of 91.4 F. To correlate heat loss with the customary values used to express human heat production and food requirements, the quantity of heat is expressed in kilogramme calories per square metre per hour per degree centrigrade (0.369 BTU per square foot per hour per degree fahrenheit).

Combining windforce with air temperature to produce a windchill factor may not result in a completely valid index for determining the response of caribou to their ambient environment as relative humidity is not accounted for. Heat loss in caribou could be precipitated by humidity as during instances when wind driven snow builds up in the fur of animals.

A temperature of zero F. and a 4 m.p.h. wind produce a windchill recording of about 1065 kg.cal./sq.m./hr., but only in relation to stationary animals. Caribou walking at 4 m.p.h. in the identical direction of this wind and caribou walking at the same speed in the opposite direction should be related to windchill factors of 495 and 1245 respectively. The difference of 750 kg.cal./sq.m./hr. that exists between the two hypothetical recordings is identical to the windchill factor difference between 62 F. above zero and 80 degrees below zero when no wind is blowing. It would seem that interpreting comparative windchill discomfort from the use of Siple and Passel's formula could be hazardous and it does

Table 4. Snow Hardness Observations, Winter of 1961/1962

observation number	number of caribou	caribou activity	observer's position: snow depth	observer's position: hardness of surface layer	observer's position: hardness of hardest layer	caribou position: snow depth	caribou position: hardness of surface layer	caribou position: hardness of hardest layer	surface snow layer: harder snow at observer	surface snow layer: harder snow at caribou	hardest snow layer: harder snow at observer	hardest snow layer: harder snow at caribou	
1	91	A	10	1	25	7	2	10		*	*		
2	16	A	12	2	40	5	2	22	-------		*		
3	17	C	9	2	45	5	2	25	-------		*		Camp
4	11	C	8	7	50	6	5	15	*		*		Two
5	2	A	9	1	90	6	1	70	-------		*		
6	6	B	11	1	30	8	1	30	-------		-------		
7	8	A	11	2	95	4	1	10	*		*		Camp
8	9	B	14	2	85	6	2	45	-------		*		Three
9	9	A	28	3	60	16	3	50	-------		*		
10	112	B	27	3	50	14	3	50	-------		-------		
11	21	C	32	1	90	13	1	35	-------		*		
12	32	A	23	1	65	9	1	30	-------		*		
13	19	B	29	1	45	8	1	25	-------		*		
14	59	B	29	7	90	8	2	65	*		*		
15	30	A	21	8	95	24	2	70	*		*		
16	29	A	25	2	75	7	2	35	-------		*		Camp
17	20	B	21	2	75	23	1	35	*		*		Four
18	10	A	16	1	90	9	1	55	-------		*		
19	20	D	29	1	45	13	1	70	-------			*	
20	15	C	18	2	80	15	2	65	-------		*		
21	164	E	26	2	55	18	2	95	-------			*	
22	2	D	23	1	70	16	1	95	-------			*	
23	5	B	11	1	65	11	1	35	-------		*		
24	2	B	17	2	70	11	2	45	-------		*		
25	45	B	34	2	45	18	2	45	-------		-------		

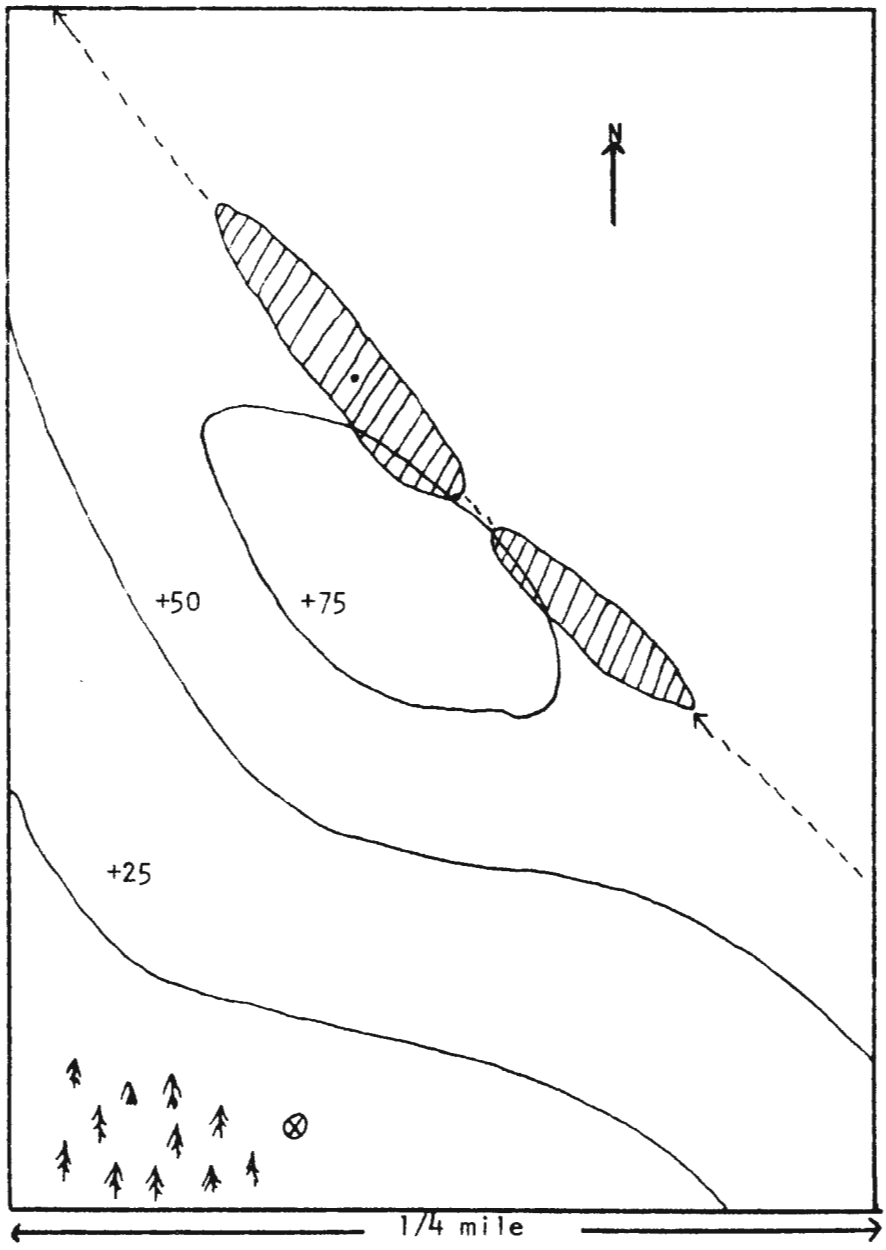
26	2	A	13	1	95	16	1	50	-------	*		
27	41	B	33	2	45	26	1	45	*	-------		
28	6	D	27	0	75	24	0	70	-------	*		
29	28	D	26	0	45	21	0	80	-------		*	
30	10	D	33	25	45	12	70	85	*		*	
31	10	B	35	20	45	11	120	120	*		*	
32	6	D	2	35	35	5	6	6	*	*		
33	19	C	39	0	90	4	0	2	-------	*		
34	7	E	37	60	95	18	70	70	*	*		
35	2	B	46	10	90	21	15	65	*	*		
36	44	E	34	6	70	27	35	75	*		*	
37	5	B	42	10	85	bare	of	snow	*	*		
38	1	B	28	6	55	9	8	25	*	*		
39	160	C	14	15	60	11	15	50	-------	*		
40	1	B	23	0	60	9	0	45	-------	*	Camp	
41	5	D	40	0	75	19	0	55	-------	*	Four	
42	2	D	44	0	55	21	0	60	-------		*	
43	12	B	39	0	85	5	0	25	-------	*		
44	9	D	41	0	70	19	0	45	-------	*		
45	151	C	35	35	90	27	40	45	*	*		
46	7	E	26	25	55	4	40	40	*	*		
47	3	A	44	8	85	3	10	10	*	*		
48	28	C	43	8	100	13	15	45	*	*		
49	2	B	54	0	90	6	0	25	-------	*		
50	34	C	31	0	60	20	0	70	-------		*	
51	36	E	38	7	80	22	9	100	*		*	
52	21	A	49	8	85	7	8	35	-------	*		
53	26	E	44	0	70	41	0	100	-------		*	
54	23	C	33	0	75	21	0	65	-------	*		
									8	12	39	11

Snow depth in inches.
Snow hardness in gms. per sq. cm. of pressure required to collapse the structure of the snow.

Table 5. Caribou Activity - Snow Hardness, Winter of 1961/1962

caribou activity	number of observations	total caribou	surface layer		hardest layer	
			range	average	range	average
A-Feeding/Travelling	12	253	1 - 10	2.8	10 - 70	37.2
B-Stationary Feeding	17	351	0 -120	9.4	25 - 120	42.7
C-Feeding/Resting	10	477	0 - 40	8.0	2 - 70	41.7
D-Resting	9	88	0 - 70	8.7	6 - 95	62.9
E-Travelling	6	284	0 - 70	26.0	40 - 100	80.0
Observer's position (no caribou)	54	-	0 - 60	6.3	25 - 100	68.3

Snow hardness in gms. per sq. cm. of pressure required to collapse the structure of the snow



Map 3 Snow Hardness Situation
Example

Observation number: 21
Camp number: 4
Date: 13th February 1962
Time: 1600

Caribou activity: E-Travelling

	observer's position	caribou position
Snow depth	26	18
Surface hardness	2	2
Maximum hardness	55	95
Air temperature	-4	-7
Surface temp.	-5	-7
Ground temp.	+8	+5
Windspeed	0	0
Direction	-	-
Windchill	520	535
Light intensity	35	60

Weather: Overcast with light snow, visibility about 1 1/2 miles.

Bulls	51
Cows	64
Calves	49

Remarks: Winter winds in the region of this observation usually originate from the N.E. or N.W. which probably accounts for the incidence of spruce in the lee of the ridge In addition to the windbreaking property of the spruce stand, softer and deeper snow conditions are more likely to occur near the observer's position when northerly winds have blown snow off the ridge. Windblown snow during northerly winds would probably gravitate in the area of the spruce stand. The slight north easterly facing slope of the ridge probably experienced a greater wind striking action over the winter than any other part of the area illustrated, consequently, snow hardness would be maximum for this section. It is significant that the travelling caribou should be following the northern edge of the ridge. It should be remembered that above freezing temperatures did not occur during the study period and the snow texture showed no signs of above freezing temperatures for other periods. Wind was the primary cause of localized variation in snow hardness.

not take account of the lie of an animal's fur in realtion to wind direction.

Wind is a modifying agent to temperature, snow depth and hardness, but is itself modified by topography and protrudent vegetation which can create variations to its speed over short distances. The windspeeds and windchill factors given in this paper are only relative to stationary animals and will need to be treated with circumspection until the factor of caribou movement, particularly its direction, has been introduced to all relevant observations.

Wind and windchill were usually greater at the observer's than the caribou occupied position, the average windspeed difference being about 4 m.p.h. and the maximum difference occurring with resting caribou (average 11.4 m.p.h.). The topographic maps drawn for each observation indicate a tendency for caribou to utilize land form to evade a proportion of windforce, particularly during strong winds and blizzards. Resting caribou were able to evade an average of 40% of the windspeed present at the observer's position whereas feeding/resting caribou evaded only 12%.

The reaction of caribou to blizzards and other strong wind conditions was notable in that movement was restricted with caribou usually lying down (table 7). Lower windspeeds are reflected by stationary activities that include feeding, and travelling caribou showed a marked preference for windless or near windless conditions.

Critchell-Bullock (1930/1931) presented records to show that the direction of caribou travel was independent of wind direction but Kelsall (1960) thought that caribou drift with wind during winter. Sufficient data have been obtained to examine the directional relationship between wind and moving caribou, both prior to and after disturbance by the observer, but this problem should not be examined until the windchill factor has been rendered less enigmatic.

Temperature

Standard U. S. Weather Bureau red liquid thermometers were used, none of which possessed an error in excess of 0.15 F. One thermometer was inserted in the snow with its bulb touching the ground substrate, one was placed flat on the snow surface and the third was held with the bulb about 3' 6" above the snow. Several minutes were allowed for the liquid to settle. The snow surface and air temperatures are biased as they were taken in the shade of the observer's body during sunny conditions. All temperatures were recorded in degrees fahrenheit, and as they were mostly obtained close to noon they will not be representative of the 24 hour period.

Theoretically, temperature inversions (reversal of the normal cooling

Table 6. Windspeed and Windchill Observations, Winter of 1961/1962

observation number	number of caribou	caribou activity	observer's position: air temperature	observer's position: wind direction	observer's position: wind speed	observer's position: wind chill	caribou position: air temperature	caribou position: wind direction	caribou position: wind speed	caribou position: wind chill	wind stronger at observer	wind stronger at caribou	windchill greater at observer	windchill greater at caribou
1	91	A	+13	S.E.	2	800	+12		0	430	*		*	
2	16	A	+13	N.E.	8	1050	+13	N.E.	3	870	*		*	
3	17	C	+12	N.E.	10	1130	+12	N.	8	1080	*		*	
4	11	C	+11		0	440	+12		0	430	-----		*	
5	2	A	+ 9	N.W.	4	960	+ 9	N.W.	1	740	*		*	
6	6	B	- 4	S.E.	4	1110	- 4	S.E.	2	980	*		*	
7	8	A	- 8	E.	2	1020	-10		0	550	*		*	
8	9	B	-37		0	700	-29		0	660	-----		*	
9	9	A	+20	E.	4	850	+20	E.	4	850	-----		-----	
10	112	B	+20	N.E.	5	900	+20	N.E.	5	900	-----		-----	
11	21	C	+23	N.	2	700	+25	N	2	680	-----		*	
12	32	A	+20	N.E.	2	730	+22	N.E.	2	710	-----		*	
13	19	B	+19		0	400	+23		0	375	-----		*	
14	59	B	-15		0	580	-12		0	555	-----		*	
15	30	A	-11		0	550	-12		0	555	-----			*
16	29	A	-21		0	620	-21		0	620	-----		-----	
17	20	B	-27		0	645	-26		0	635	-----		*	
18	10	A	+10	N.W.	3	915	+10	N.W.	5	1005		*		*
19	20	D	+ 4		0	480	+ 7		0	460	-----		*	
20	15	C	+ 8	S.W.	3	930	+ 8		0	450	*		*	
21	164	E	- 4		0	520	- 7		0	535	-----			*
22	2	D	+ 5		0	470	+ 6		0	460	-----		*	
23	5	B	+ 6		0	460	+ 3		0	480	-----			*
24	2	B	-26		0	640	-22		0	615	-----		*	
25	45	B	-33	N.E.	6	1550	-31	N.E.	1	1100	*		*	

26	2	A	-24		0	630	-26		0	640	-----		*	
27	41	B	- 4		0	520	- 2		0	505	-----	*		
28	6	D	+14	S.E.	8	1060	+14	S.E.	2	790	*	*		
29	28	D	- 3	S.E.	11	1350	- 3	S.E.	4	1105	*	*		
30	10	D	+ 8	N.E.	55	1450	+ 8	N.E.	40	1420	*	*		
31	10	B	+ 5	N.E.	3	955	+ 5	N.E.	3	955	-----	-----		
32	6	D	+22	N.E.	42	1210	+22	N.E.	18	1100	*	*		
33	19	C	+18	S.W.	25	1170	+18	S.W.	15	1100	*	*		
34	7	E	-22	S.W.	2	1135	-21	S.W.	2	1125	-----	*		
35	2	B	+ 6		0	465	+ 7		0	455	-----	*		
36	44	E	- 5		0	525	- 4		0	520	-----	*		
37	5	B	- 1	N.E.	4	1090	- 1	N.E.	4	1090	-----	-----		
38	1	B	-11		0	560	-10		0	550	-----	*		
39	160	C	0	N.E.	8	1250	+ 1	N.E.	8	1265	-----		*	
40	1	B	+ 5	N.E.	20	1360	+ 5	N.E.	20	1360	-----	-----		
41	5	D	+ 8	N.E.	35	1400	+ 8	N.E.	20	1310	*	*		
42	2	D	+ 9	N.E.	38	1410	+10	N.E.	30	1375	*	*		
43	12	B	+ 7	N.E.	20	1330	+ 8	N.E.	12	1190	*	*		
44	9	D	+ 3	N.E.	15	1350	+ 3	N.E.	10	1250	*	*		
45	151	C	- 4		0	520	- 2		0	505	-----	*		
46	7	E	- 7		0	535	- 6		0	530	-----	*		
47	3	A	- 8		0	540	- 7		0	535	-----	*		
48	26	C	-12		0	560	-11		0	555	-----	*		
49	2	B	- 8	N.W.	3	1105	- 7	N.W.	3	1095	-----	*		
50	34	C	- 5	N.W.	2	990	- 4	N.W.	2	985	-----	*		
51	36	E	-19		0	605	-19		0	605	-----	-----		
52	21	A	-23		0	630	-22		0	625	-----	*		
53	26	E	- 5	N.W.	1	880	- 5	N.W.	1	880	-----	-----		
54	23	C	- 5	N.W.	2	980	- 4	N.W.	2	975	-----	*		
											17	1	40	6

Air temperature in degrees fahrenheit 3' 6" above the surface of the snow.
Wind speed measured in miles per hour " " " " " " " "
Wind chill is expressed in kilogram calories per square meter per hour per degree centigrade (see accompanying section for definition).
Wind direction is expressed by its origin.

Table 7. Caribou Activity - Windspeed, Winter of 1961/1962

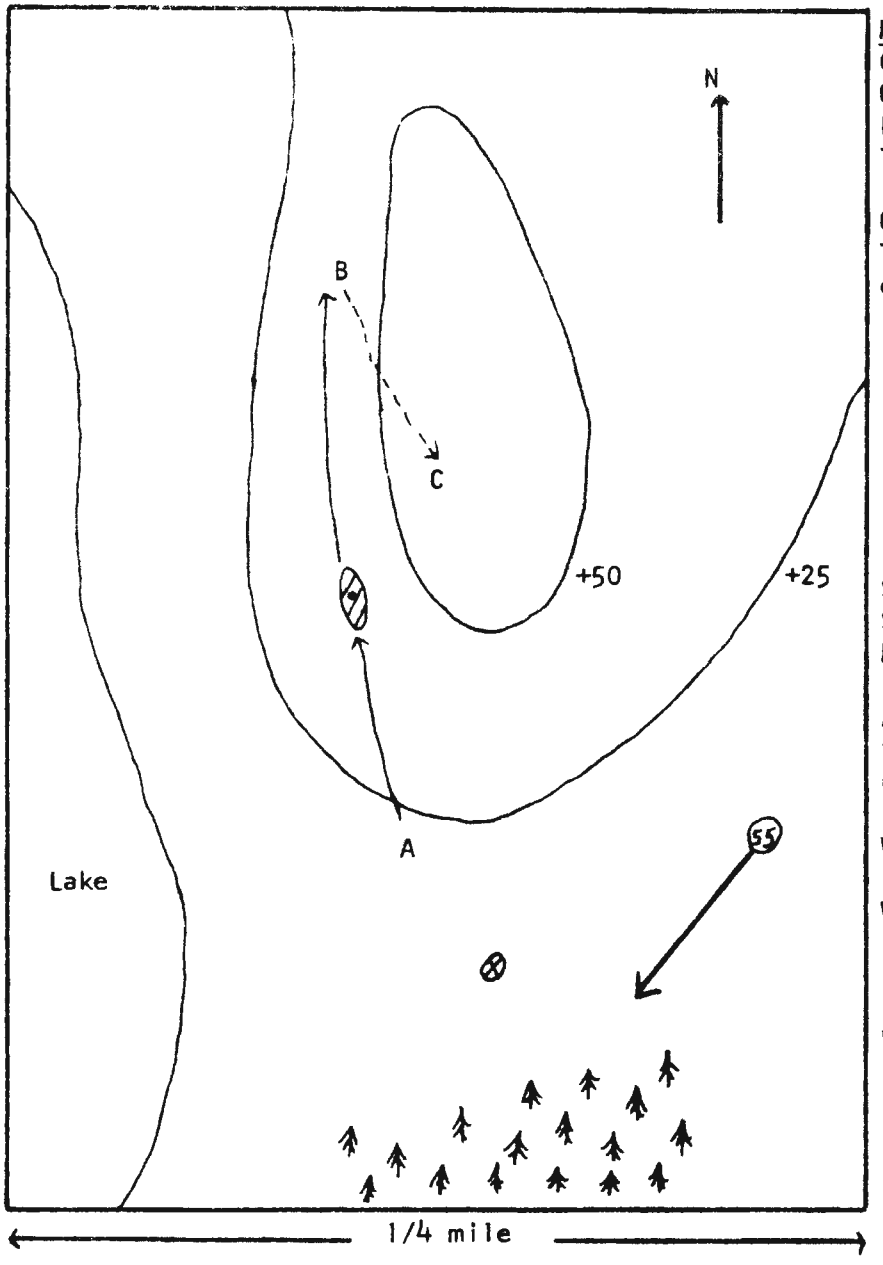
caribou activity	number of observations	number of winds		range of speeds		average speed	
		observer's position	caribou position	observer's position	caribou position	observer's position	caribou position
A-Feeding/Travelling	12	7	5	2 - 8	1 - 5	3.6	3.0
B-Stationary Feeding	17	8	8	3 - 20	1 - 20	8.0	6.5
C-Feeding/Resting	10	7	6	2 - 25	2 - 15	7.4	6.2
D-Resting	9	7	7	8 - 55	2 - 40	29.0	17.7
E-Travelling	6	2	2	1 - 2	1 - 2	1.5	1.5
Totals:	54	31	28	1 - 55	1 - 40	11.3	8.2

Wind speed in miles per hour at 3' 6" above the surface of the snow.

Table 8. Caribou Activity - Windchill, Winter of 1961/1962

caribou activity	number of observations	windchill range		average windchill	
		observer's position	caribou position	observer's position	caribou position
A-Feeding/Travelling	12	540 - 1050	430 - 1005	775.5	677.5
B-Stationary Feeding	17	400 - 1550	375 - 1360	904.0	794.5
C-Feeding/Resting	10	440 - 1250	430 - 1265	867.0	802.5
D-Resting	9	480 - 1450	460 - 1420	1125.0	1030.0
E-Travelling	6	520 - 1135	530 - 1125	200.0	699.0
Totals	54	400 - 1550	375 - 1420	866.0	799.0

Windchill is expressed in kilogram calories per square meter per hour per degree centigrade (.0369 BTU per square foot per hour per degree fahrenheit). See accompanying section for definition. Air temperature and windspeed recorded at 3' 6" above the snow surface have been used to obtain windchill factors.



Map 4 Wind Situation Example

Observation number: 30
Camp number: 4
Date: 18th February 1962
Time: 1000

Caribou activity: D-Resting. The animals only moved when disturbed by the observer until the strong wind had abated.

	observer's position	caribou position
Snow depth	33	12
Surface hardness	25	70
Maximum hardness	45	85
Air temperature	+8	+8
Surface temp.	+8	+8
Ground temp.	+18	+12
Windspeed	55	40
Direction	N.W.	N.W.
Windchill	1450	1420
Light intensity	40	45

Weather: Ceiling invisible, horizontally flying snow, visibility about 50 yards.

Bulls	1
Cows	5
Calves	4

Remarks: The caribou were first seen when at point A and were lying down. After taking the observer's position recordings the caribou were traced to the point marked on the map as the caribou position. Although disturbed at point A the animals were lying down again when approached. The caribou moved on to point B and again lay down. By 1330 the caribou had moved to point C and commenced to feed. The windspeed had fallen by this time to 3 m.p.h., snow was no longer airborn and the temperature had begun to fall. The caribou in this situation had utilized the hill in the centre of the map as a partial windbreak and they were unwilling to move far in view of the conditions experienced. A change from resting to feeding activity was only made when the severe windchill factor was reduced.

with increased altitude) result from heavy cold air masses flowing down hillsides to settle in topographic depressions, and often being further cooled through contact with the snow surface. The snow surface is itself cooled by radiation losses into space, especially during long winter nights that are windless with clear skies. A subsequent wind will usually mix the (previously stratified) air layers to create non-inversion temperature conditions, at least within the atmosphere occupied by standing caribou. Temperature inversions are a reflection of steady, storm free weather conditions and are consequently experienced most frequently after the onset of a period of fine cold weather.

Caribou were observed during 12 instances of a temperature inversion and the number of animals recorded for each activity is given below.

A - Feeding/Travelling	18	out of a total of 253
B - Stationary Feeding	156	" " " " " 351
C - Feeding/Resting	328	" " " " " 477
D - Resting	6	" " " " " 88
E - Travelling	0	" " " " " 284

The absence of movement is conspicuous during inversions particularly since the absence of movement can also be related to windy conditions which are rarely prevalent during temperature inversions. It is also significant that all but 6 animals observed during inversions were associated with feeding activities. If any conclusion can be drawn at this stage it might be that inversions, which accompany steady and fine weather, are reflected by steadiness in caribou activity, with little movement occuring. Darling's (1937) comments are comparable as he noted that red deer (Cervus elaphus) in Scotland were much affected by great variations in temperature and that their movements were toward steadier temperature conditions. The average caribou band size during temperature inversions was 42.3 animals as against 22.5 during non-inversion conditions, and it could be conceded that more changeable weather might be responsible in part for dispersal of the larger aggregations that form with steadier conditions.

On most occasions air and snow surface temperatures were slightly warmer in the caribou position than the observer's position but one cannot assume that caribou select a warmer location when differences occur over short distances. Temperature variation from place to place at the same time is greatly influenced by land form which is itself largely responsible for snow depth and hardness variations.

Ground temperatures were considerably higher than snow surface and air temperatures (table 11) and the depth of snow is reflected as an insulating factor. Moving from the observer's position into the caribou position frequently resulted in the recording of a lower ground temperature and the vegetation consumed by caribou may be relatively cold when

Table 9. Temperature Observations, Winter of 1961/1962

observation number	number of caribou	caribou activity	observer's position: air temperature	observer's position: surface temperature	observer's position: ground temperature	caribou position: air temperature	caribou position: surface temperature	caribou position: ground temperature	air: colder at observer	air: colder at caribou	surface: colder at observer	surface: colder at caribou	ground: colder at observer	ground: colder at caribou
1	91	A	+13	+15	+24	+12	+13	+23		*		*		*
2	16	A	+13	+ 8	+20	+13	+10	+20	-----		*		-----	
3	17	C	+12	+10	+19	+12	+11	+18	-----		*			*
4	11	C	+11	+12	+20	+12	+12	+22	*		-----		*	
5	2	A	+ 9	+11	+11	+ 9	+ 6	+11	-----			*	-----	
6	6	B	- 4	+ 2	+23	- 4	- 3	+15	-----			*		*
7	8	A	- 8	- 8	+ 5	-10	- 8	+15		*	-----		*	
8	9	B	-37	-38	+15	-29	-31	+11	*		*			*
9	9	A	+20	+20	+15	+20	+20	+15	-----		-----		-----	
10	112	B	+20	+19	+21	+20	+19	+15	-----		-----			*
11	21	C	+23	+26	+11	+25	+25	+16	*			*	*	
12	32	A	+20	+23	+18	+22	+23	+15	*		-----			*
13	19	B	+19	+20	+15	+23	+22	+16	*		*		*	
14	59	B	-15	-11	+ 6	-12	- 8	+ 5	*		*			*
15	30	A	-11	- 9	+ 5	-12	-10	0		*		*		*
16	29	A	-21	-20	+ 8	-21	-19	+ 1	-----		*			*
17	20	B	-27	-24	+11	-26	-24	+15	*		-----		*	
18	10	A	+10	+16	+11	+10	+11	+10	-----			*		*
19	20	D	+ 4	+ 5	+16	+ 7	+ 9	+13	*		*			*
20	15	C	+ 8	+13	+14	+ 8	+10	+14	-----			*	-----	
21	164	E	- 4	- 5	+ 8	- 7	- 7	+ 5		*		*		*
22	2	D	+ 5	+ 9	+ 9	+ 6	+ 9	+11	*		-----		*	
23	5	B	+ 6	+ 9	+10	+ 3	+ 4	+ 6		*		*		*
24	2	B	-26	-19	+14	-22	-18	+11	*		*			*
25	45	B	-33	-28	+17	-31	-27	+13	*		*			*

26	2	A	-24	-25	+ 7	-26	-26	+12		*		*	*	
27	41	B	- 4	- 5	+11	- 2	- 2	+ 8	*		*			*
28	6	D	+14	+14	+14	+14	+13	+11	-----			*		*
29	28	D	- 3	- 2	+11	- 3	- 3	+ 9	-----			*		*
30	10	D	+ 8	+ 8	+18	+ 8	+ 8	+12	-----		-----			*
31	10	B	+ 5	+ 5	+17	+ 5	+ 5	+12	-----		-----			*
32	6	D	+22	+22	+11	+22	+23	+26	-----		*		*	
33	19	C	+18	+18	+19	+18	+18	+ 7	-----		-----			*
34	7	E	-22	-23	+11	-21	-21	+ 5	*		*			*
35	2	B	+ 6	+ 5	+20	+ 7	+ 6	+19	*		*			*
36	44	E	- 5	- 4	+18	- 4	- 2	+16	*		*			*
37	5	B	- 1	- 2	+11	- 1	- 1	- 1	-----		*			*
38	1	B	-11	-11	+13	-10	- 9	+ 7	*		*			*
39	160	C	0	0	+13	+ 1	0	+ 7	*		-----			*
40	1	B	+ 5	+ 5	+14	+ 5	+ 5	+ 9	-----		-----			*
41	5	D	+ 8	+ 8	+24	+ 8	+ 8	+17	-----		-----			*
42	2	D	+ 9	+ 9	+23	+10	+10	+20	*		*			*
43	12	B	+ 7	+ 7	+24	+ 8	+ 7	+16	*		-----			*
44	9	D	+ 3	+ 3	+21	+ 3	+ 3	+11	-----		-----			*
45	151	C	- 4	- 5	+13	- 2	- 4	+ 9	*		*			*
46	7	E	- 7	- 8	+11	- 6	- 6	0	*		*			*
47	3	A	- 8	- 7	+18	- 7	- 7	+ 3	*		-----			*
48	26	C	-12	-11	+17	-11	-10	+ 9	*		*			*
49	2	B	- 8	- 8	+25	- 7	- 8	+ 9	*		-----			*
50	34	C	- 5	- 5	+21	- 4	- 4	+17	*		*			*
51	36	E	-19	-18	+15	-19	-18	+11	-----		-----			*
52	21	A	-23	-22	+18	-22	-21	+ 3	*		*			*
53	26	E	- 5	- 4	+19	- 5	- 4	+18	-----		-----			*
54	23	C	- 5	- 4	+13	- 4	- 4	+ 9	*		-----			*
									27	6	22	12	8	42

Observation number 32 caribou position and observation number 38 observer's position were located on lakes therefore ice surface temperature has been substituted for ground temperature.
Observation number 37 caribou position was free of snow therefore the same measurement was used for both surface and ground temperatures.

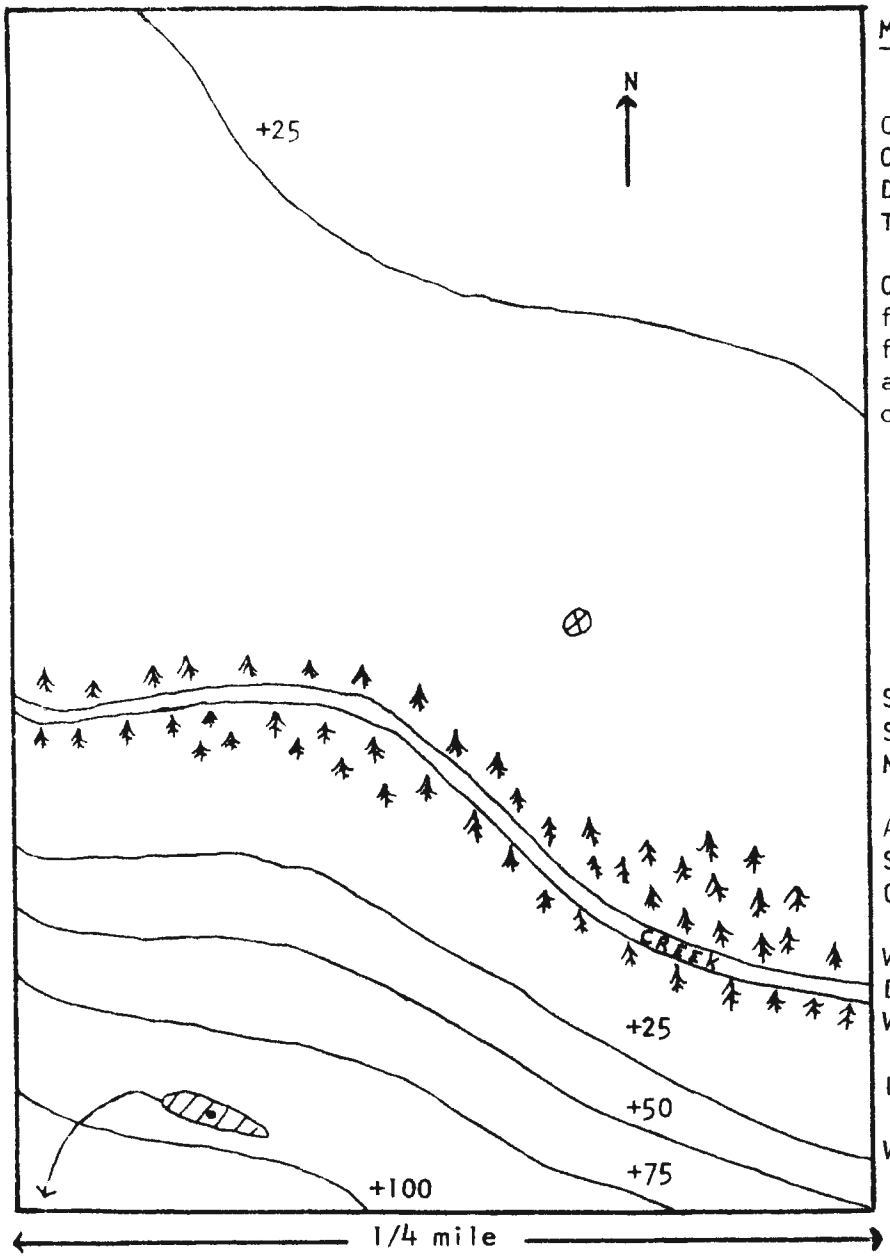
All temperatures given in degrees fahrenheit.
Air temperature was measured at 3' 6" above the surface of the snow.
Surface temperature refers to the surface of the snow.
Ground temperature was measured at the surface of the ground substrate.

Table 10. Caribou Activity - Temperature, Winter of 1961/1962

Caribou activity	number of observations	total caribou	air temperature range	air temperature average	surface temperature range	surface temperature average	ground temperature range	ground temperature average
A-Feeding/Travelling	12	253	-26 +20	- 1.0	-26 +23	- 0.7	0 +23	+10.7
B-Stationary Feeding	17	351	-31 +23	- 4.3	-31 +22	- 3.7	-1* +19	+11.0
C-Feeding/Resting	10	477	-11 +25	+ 5.5	-12 +25	+ 5.4	+7 +22	+13.7
D-Resting	9	88	- 3 +22	+ 8.3	- 3 +23	+ 8.9	+9 +26	+14.4
E-Travelling	6	284	-21 - 4	-10.4	-21 - 2	- 9.7	0 +18	+ 9.1
Total:	54	1453	-31 +25	+ 0.3	-31 +25	+ 0.3	-1* +26	+11.8
Observer's position: (no caribou)	54	-	-37 +23	- 1.0	-38 +26	- 0.1	+5 +25	+15.1

* Single instance of ground temperature where no snow cover was present (observation number 37).

All temperatures given in degrees fahrenheit.
Air temperature was measured at 3' 6" above the surface of the snow.
Surface temperature refers to the surface of the snow.
Ground temperature was measured at the surface of the ground substrate.



Map 5 Temperature Situation Example

Observation number: 8
Camp number: 3
Date: 6th December 1961
Time: 1200

Caribou activity: B-Stationary feeding. There was no movement from caribou position until the animals were disturbed by the observer.

	observer's position	caribou position
Snow depth	14	6
Surface hardness	2	2
Maximum hardness	85	45
Air temperature	-37	-29
Surface temp.	-38	-31
Ground temp.	+15	+11
Windspeed	0	0
Direction	-	-
Windchill	700	660
Light intensity	20	35

Weather: Fine with clear sky and unrestricted visibility.

Bulls	2
Cows	5
Calves	2

Remarks: The 7 to 8 degree drop in temperature over a vertical distance of 100 feet signifies a prominent temperature inversion. However, it is unlikely that the temperature variation is a major influent to the caribou of this situation. Both snow depth and hardness are significantly more suitable for feeding activity in the caribou position and these factors may be responsible for the selection of a higher location. The insulating properties of a snow cover are represented by a difference of 42 degrees with 6 inches of snow and 53 degrees with 14 inches.

compared to all that is available.

The role of temperature in the environmental complex of wintering caribou may be largely secondary though it could be of a regulating nature. Wide variations to snow surface temperatures could cause thawing and subsequent freezing of the snow surface through which the animals must feed. This phenomenon did not occur during the period of the first winter's field work but its occurrence prior to the second winter's work has been noted.

Atmospheric environment

Light intensity is expressed in candles per square foot and was obtained by using a standard "Weston Master", mark 2, photographic light meter. A Kodak neutral test card, no. R-27, size 10" x 8" was held with the grey side away from the sun, or away from the estimated direction of the sun, in a vertical position with the lower 10" edge resting on the snow surface. The light meter was held horizontally, scale side up and cell flap closed, against the centre of the grey side of the card.

The average light intensity recorded from the caribou positions is about 6 1/2% greater than the average from the observer's positions. The sun was obscured during all instances when caribou were purely resting and the recorded light intensity was significantly the lowest for this activity. As resting caribou were usually observed during winds of moderate to high velocity a prevalence of airborn snow is partly responsible for the low light intensity recordings. Increases of movement are reflected by brighter atmospheric conditions with purely travelling caribou being observed when light intensities were maximum.

Light intensity will need to be related to other environmental conditions before its importance to caribou can be evaluate.

Topography

Edwards (1958) compared two maps of British Columbia, one showing land form and one showing the areas used by caribou in winter. From this comparison and notes obtained during field work, Edwards concluded that caribou in British Columbia did not inhabit precipitous mountain masses, but found suitable environment where rolling mountains and tablelands permitted the existence of extensive arctic-alpine meadows with associated open subalpine forests.

Field work for this study was undertaken in areas which approximate the northern limit of spruce. The lowest part of mountain slopes supported most of the total tree growth and caribou largely utilized wide valley floors where trees were only found in small isolated clumps or in ribbon formation along river and stream banks. Caribou were more often

Table 11 Atmospheric Environment - Caribou Activity, Winter of 1961/1962

observation number	number of caribou	activity	Sky condition: clear	cloudy	overcast ceiling invisible	windspeed	no snow in the air	snow falling or airborn	Limit of human vision: miles (est.)	unrestricted	Light intensity: observer's position	caribou position	light stronger at observer	light stronger at caribou	sun visible	sun invisible
1	91	A			*	2	*			*	45	25	*			*
2	16	A			*	8	*			*	35	60		*		*
3	17	C			*	10	*			*	40	25	*			*
4	11	C			*	0	*			*	35	45		*		*
5	2	A			*	4		*	1.0		30	30	-----			*
6	6	B			*	4		*	1.0		25	35		*		*
7	8	A			*	2	*			*	10	10	-----			*
8	9	B	*			0	*			*	20	35		*	*	
9	9	A			*	4	*			*	210	180	*			*
10	112	B			*	5	*			*	80	150		*		*
11	21	C			*	2		*	5.0		110	80	*			*
12	32	A			*	2		*	1.0		75	80		*		*
13	19	B			*	0	*			*	20	20	-----			*
14	59	B	*			0	*			*	110	150		*	*	
15	30	A	*			0	*			*	90	100		*	*	
16	29	A	*			0	*			*	180	160	*		*	
17	20	B	*			0	*			*	80	80	-----		*	
18	10	A			*	5	*			*	95	95	-----			*
19	20	B			*	0	*			*	55	60		*		*
20	15	C			*	3		*	3.0		105	95	*			*
21	164	E			*	0		*	1.5		35	60		*		*
22	2	D			*	0	*			*	95	115		*		*
23	5	B			*	0	*			*	85	110		*		*

24	2	B	*				9	*			*	145	160		*		*			
25	45	B	*				6	*			*	25	45		*		*			
26	2	A	*				0	*			*	120	120		-----		*			
27	41	B	*				0	*			*	90	130		*		*			
28	6	D			*		8		*	1.0		30	25	*				*		
29	28	D		*			11		*	1.5		30	20		-----			*		
30	10	D				*	55		*	0.03		40	45		*			*		
31	10	B		*			3	*			*	150	150		-----			*		
32	6	D				*	42		*	0.03		100	105		*			*		
33	19	C				*	25		*	0.03		85	90		*			*		
34	7	E	*				2	*			*	120	120		-----		*			
35	2	B	*				0	*			*	170	180		*		*			
36	44	E		*			0	*			*	50	55		*			*		
37	5	B		*			4	*			*	120	110	*				*		
38	1	B		*			0	*			*	15	20		*			*		
39	160	C	*				8	*			*	160	170		*		*			
40	1	B		*			20		*	0.5		65	60	*			*			
41	5	D				*	35		*	0.06		70	70		-----			*		
42	2	D				*	38		*	0.06		55	55		-----			*		
43	12	B			*		20		*	0.5		80	90		*			*		
44	9	D			*		15		*	0.5		70	65	*				*		
45	151	C	*				0	*			*	190	180	*			*			
46	7	E	*				0				*	180	180		-----		*			
47	3	A	*				0	*			*	170	170		-----		*			
48	26	C		*			0	*			*	70	80		*			*		
49	2	B		*			3	*			*	110	130		*		*			
50	34	C		*			2	*			*	90	90		-----			*		
51	36	E	*				0	*			*	180	180		-----		*			
52	21	A	*				0	*			*	90	100		*		*			
53	26	E			*		1		*	1.0		90	90		-----			*		
54	23	C			*		2		*	1.5		85	90		*			*		
Totals:			17	9	23	5		36	18		36			11	27		19	35		

Light intensity is recorded in candles per square foot.
No distinction has been made between falling snow (precipitation) and previously fallen snow made airborn by wind (10th col).
The column heading "Ceiling invisible" relates to those occasions when blizzard conditions were recorded.
Windspeed is given in miles per hour and is the greater of the speeds recorded from the observer's and caribou position. As relief and protrudent vegetation are more likely to have a decremental than incremental effect on windspeed the greater of two recordings taken in a zone of variable micro-relief may be the truer "free" windspeed.

Table 12. Atmospheric Environment - Caribou Activity, Winter of 1961/1962

caribou activity	number of observations	sun		sky		snow in the air		light intensity		
		visible	invisible	visible	invisible	yes	no	range		average
A-Feeding/Travelling	12	5	7	5	7	2	10	10	180	102.5
B-Stationary Feeding	17	9	8	12	5	3	14	20	180	91.5
C-Feeding/Resting	10	2	8	4	6	4	6	25	180	94.5
D-Resting	9	0	9	1	8	7	2	20	115	62.2
E-Travelling	6	3	3	4	2	2	4	55	180	114.2
Totals:	54	19	35	26	28	18	36	10	180	91.2
Observer's position:								10	210	86.6

Light intensity in candles per square foot (see accompanying section for definition)
Snow in the air refers to both precipitation and old snow made airborn by wind.

found near to trees than in areas greatly distant from tree growth and this association was more frequent when clumps were adjacent to lakes.

Topography and protrudent vegetation will be studied as possible discrete influences to caribou and as modifying agents to other environmental factors. It is hoped to introduce statistical methods for the analysis of the topographical maps which accompany each observation.

PART II - Winter of Early 1963

Over the last week of December 1962 and the following first two weeks of January, temperatures were unusually high in many areas in central and northern Alaska. Rain fell in Fairbanks, Kotzebue, and the Kobuk village area. Snow conditions were greatly affected as much thawing and subsequent re-freezing took place. By early February temperatures had returned to more normal levels with occasional spells of extreme cold to -60 degrees fahrenheit being experienced in the upper Kobuk drainage.

On February 5th I flew out of Kotzebue to locate a concentration of 20,000 to 30,000 caribou that had been reported in November as having settled in the headwaters region of the Noatak River. The weather at Kotzebue was clear with zero degrees and a 5 mph wind. Our heading was approximately N.E. and only a very few caribou were seen (occupying mountain summit locations) on the first stage of the flight which was to a gasoline cache by the Noatak River. The temperature on landing was -44 and there was no wind. Although the snow depth at this point was about three feet, it was evident that considerable thawing had taken place as a 7" layer of vesiculated ice was present, being equidistant from the ground and the surface. This layer was so hard that axes had to be used to cut out the gasoline cans. After taking off we flew along the Noatak in an easterly direction for about 120 miles to a second gasoline cache located on the river at a point almost due north of Kobuk village. Throughout this stage of the flight we did not see the tracks of a single animal of any kind despite excellent spotting conditions. It was notable that the entire mountain surfaces were glazed with ice. After re-fuelling we proceeded in an easterly direction once more and immediately came upon a band of about 25 caribou that were occupying a small snow free area on a low south facing slope. A continued search in the headwaters area proved that the original caribou concentration was no longer present and we could not see any signs of recent caribou movement. Consequently, we turned south to traverse the Schwatka Mountains.

The Schwatka Mountains also showed many glazed surfaces although there were a few summits that had remained wind blown and free of snow. When we encountered south running valleys some mat surfaced snow was seen at low elevations and some caribou bands were spotted in the Shungnak River valley. A landing was effected in this area and I set up camp at

the location marked by the figure 5 on map 1. Field observations were commenced the following day.

The caribou in the Shungnak valley proved to be too thinly scattered to allow quantitative observation and a large wolf pack caused some dispersal to the animals. Extreme cold conditions were experienced at this camp and caribou were difficult to approach due to maximum noise transference. Caribou could hear skis sliding over snow at ranges up to two miles. Data obtained at camp 5 are immediately following.

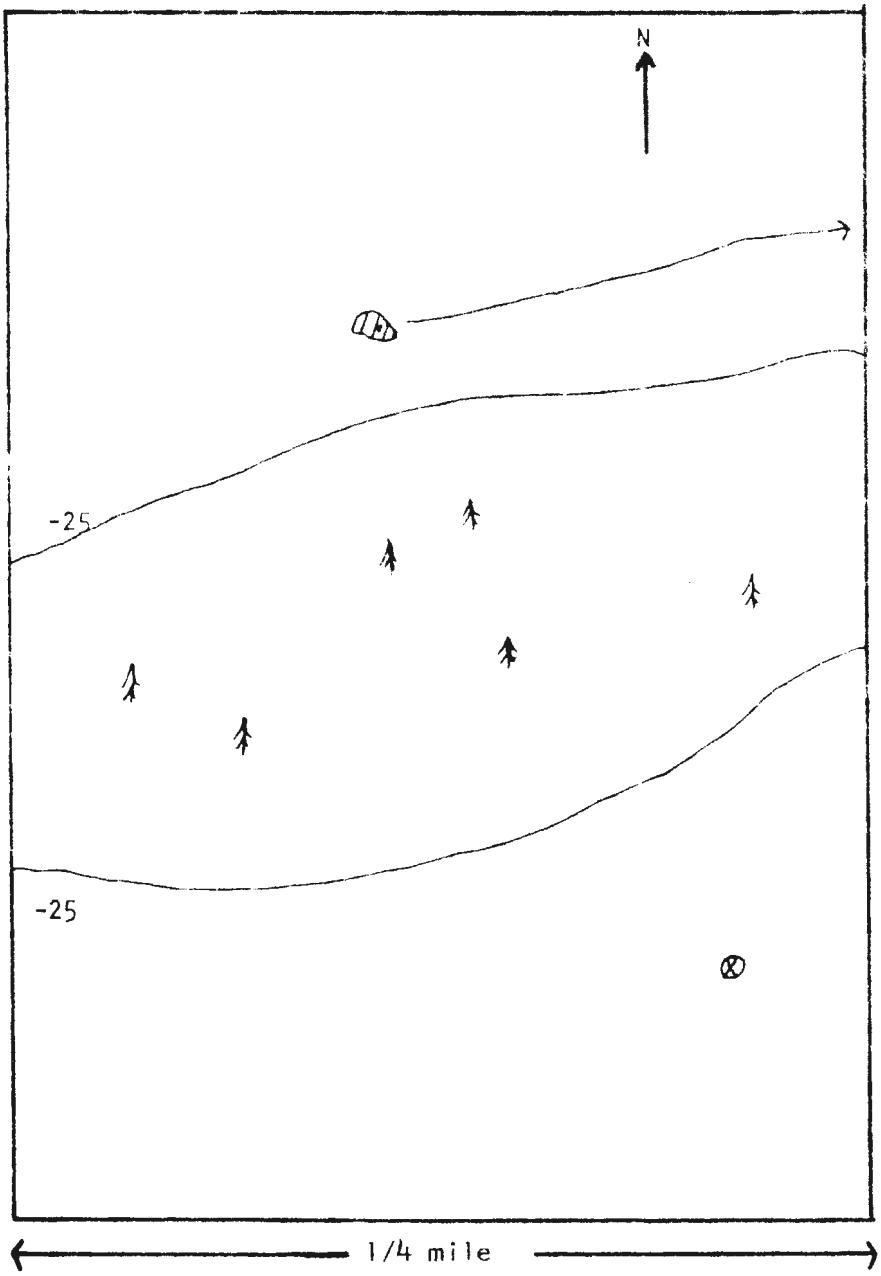
Random Sampling - Map A.

Twelve snow stations were measured for depth and hardnesses across a slightly domed depression that was bordered on the north and south by creeks, protrudent vegetation and hillsides. As the traverse took about 5 hours to complete, environmental factors that are apt to change within a short period of time were not recorded. Generally, the day was cool with temperatures ranging between zero and -10 degrees and there was no wind. The caribou remained in their indicated positions until the activities of the northward working observer disturbed them. All trails were mapped even though some of them had obviously been made several days before.

The edge of the south facing slope at the northern end of the traverse showed very shallow snow and small isolated patches of clear ice, indicating a previous and almost complete thaw. The snow cover was judged to have fallen subsequently to the thaw. The occasional patches of ice were sufficiently few in number as to offer no hindrance to a band of feeding caribou. The greatest snow depth is in an area that would have been shadowed from sunlight until a much later date than the parts reaching further north due to the hill at the southern extremity of the map. However, it was probably high overall temperatures rather than direct solar radiation that caused melting to occur. Willows along the southern creek bank had come into bud and most of the tips were encased in a sheath of ice indicated a previous rainfall, which probably occurred when surface temperatures were below freezing level.

The range in snow hardness conditions is striking and shows much higher recordings than any obtained during the first winter's field work. The open, central area held layers of dense, extremely hard snow with a texture approaching that of vesiculated ice. The surface layer was sastrugi patterned.

It is evident that caribou were using the hard central area for travelling and no feeding craters were detected in this snow cover. The incidence of feeding, especially the heavy utilization on the north side, can only be related to snow depth and hardness and is undoubtedly a response to the favorableness of these factors. The caribou may not have detected the soft, shallow snow area as a result of random movement.



Map 6
Observation number: 55
Camp number: 5
Date: 6th February 1963
Time: 0900

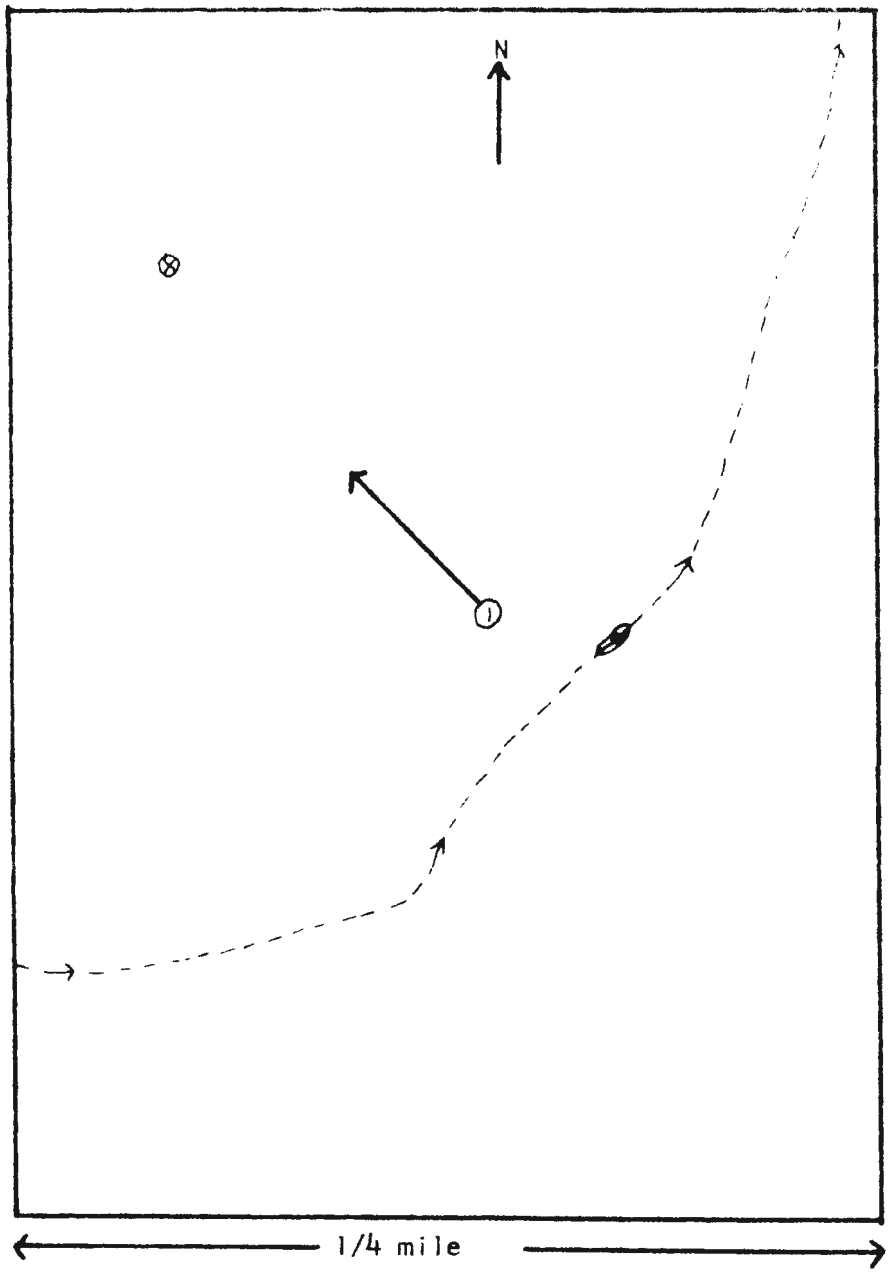
Caribou activity: B-stationary, feeding

	observer's position	caribou position
Snow depth	13	8
Surface hardness	70	23
Maximum hardness	240	65
Air temperature	-42	-41
Surface temp.	-44	-44
Ground temp.	+ 7	0
Windspeed	0	0
Direction	-	-
Windchill	720	710
Light intensity	95	95

Weather: Fine with clear sky and unrestricted visibility.

Bulls	7
Cows	2
Calves	1

Remarks: On being disturbed, the caribou ran away leaving a trail of ice fog that hung above the ground for about 30 minutes before dispersing. Snow conditions show evidence of earlier slight thawing, particularly on the south side of the gully. Surface snow at the observer's position is deeper and more densely packed. A temperature inversion is evident.



Map 7
Observation number: 56
Camp number: 5
Date: 6th February 1963
Time: 1530

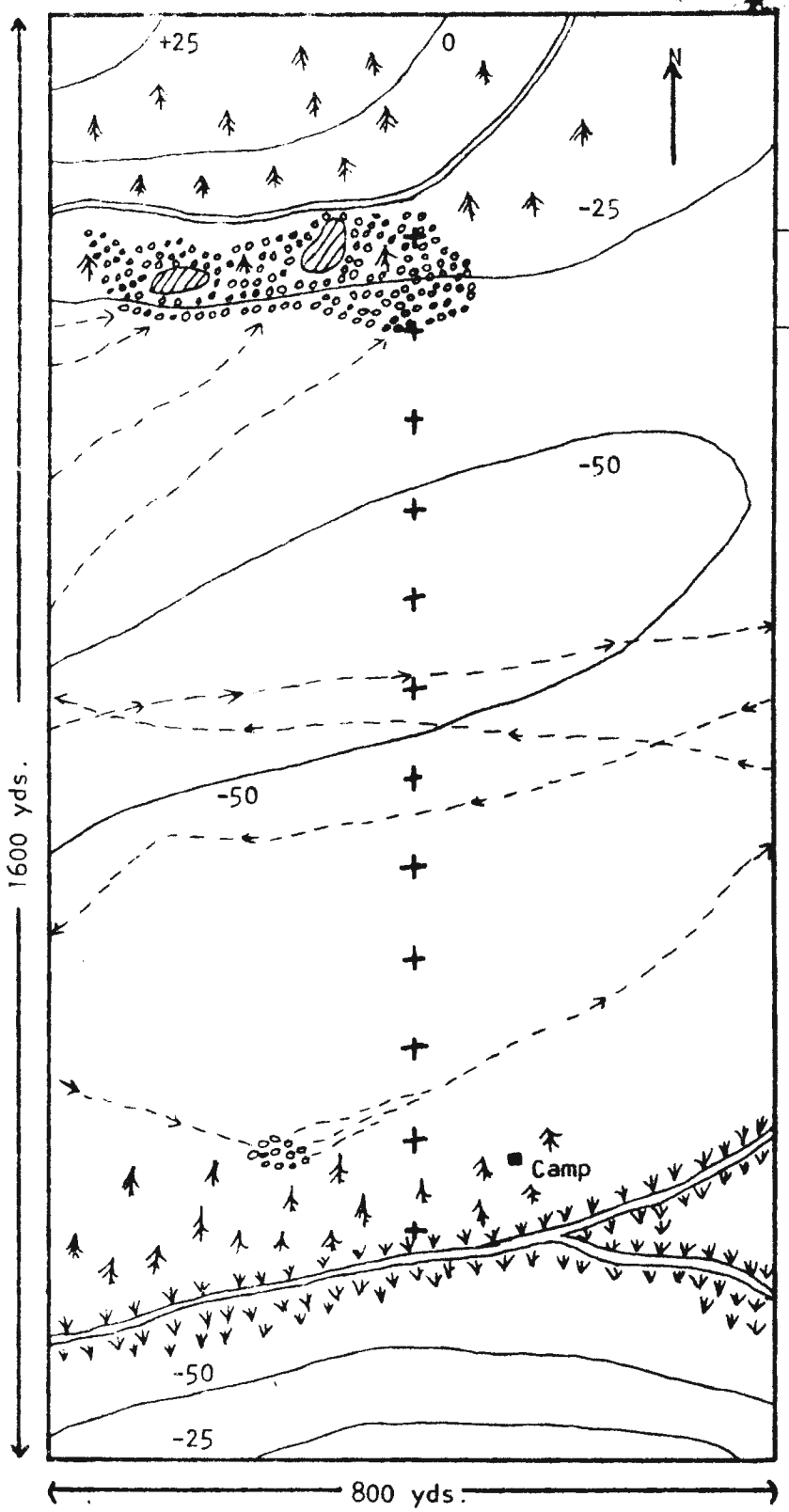
Caribou activity: E-travelling

	observer's position	caribou position
Snow depth	14	14
Surface hardness	95	240
Maximum hardness	160	240
Air temperature	-54	-54
Surface temp.	-56	-55
Ground temp.	- 3	+ 1
Windspeed	1	1
Direction	S.E.	S.E.
Windchill	1280	1280
Light intensity	110	110

Weather: Fine with clear sky and unrestricted visibility.

Bulls	0
Cows	3
Calves	1

Remarks: The observer was wearing white clothing and as he had remained stationary while the animals were approaching they were unaware of his presence. The path taken by the caribou may have been to some extent pre-determined by hardness of the snow surface as an apparent selection is present. This observation may be representative of the maximum insulation offered by a snow cover. The 56 degree difference in temperature when 14 inches of snow is present is comparable to observation number 8 when a 53 degree difference was recorded with the same depth of snow. The air and snow surface temperatures of this observation were the lowest recorded except for some overnight temperatures. The maximum snow hardness of this observation is identical to the maximum obtained for the previous observation which was situated about one mile to the N.W. The caribou left a trail of ice fog which drifted away with the slowly moving air. These animals were probably being watched by a wolf pack lying on a hillside to the South as investigation made the following morning indicated that 6 or 7 wolves had come down from the hillside to follow the caribou.



snow depth	surface hardness	maximum hardness
3	25	25
7	27	27
8	1800	4500
8	1800	7500
7	1800	9000
8	2200	8500
5	2500	7500
5	4500	9000
8	4500	8500
7	2600	8500
13	70	70
9	65	65

100 yds.

Contours are in feet from the point X on the southern base line.

Interrupted lines indicate caribou trails.

Small circles indicate areas of feeding craters.

Random Sampling Map A.

Camp number: 5
Date: 7th February, 1963

Four trails lead into the feeding area and all of these trails were typical of travelling caribou as they indicated single file, or close to single file movement. The shallowness of the snow cover close to the creek could be recognized at a distance of about 1/2 mile to the S.W. as protruding tussocks could be seen. However, the limitations of caribou vision are not known.

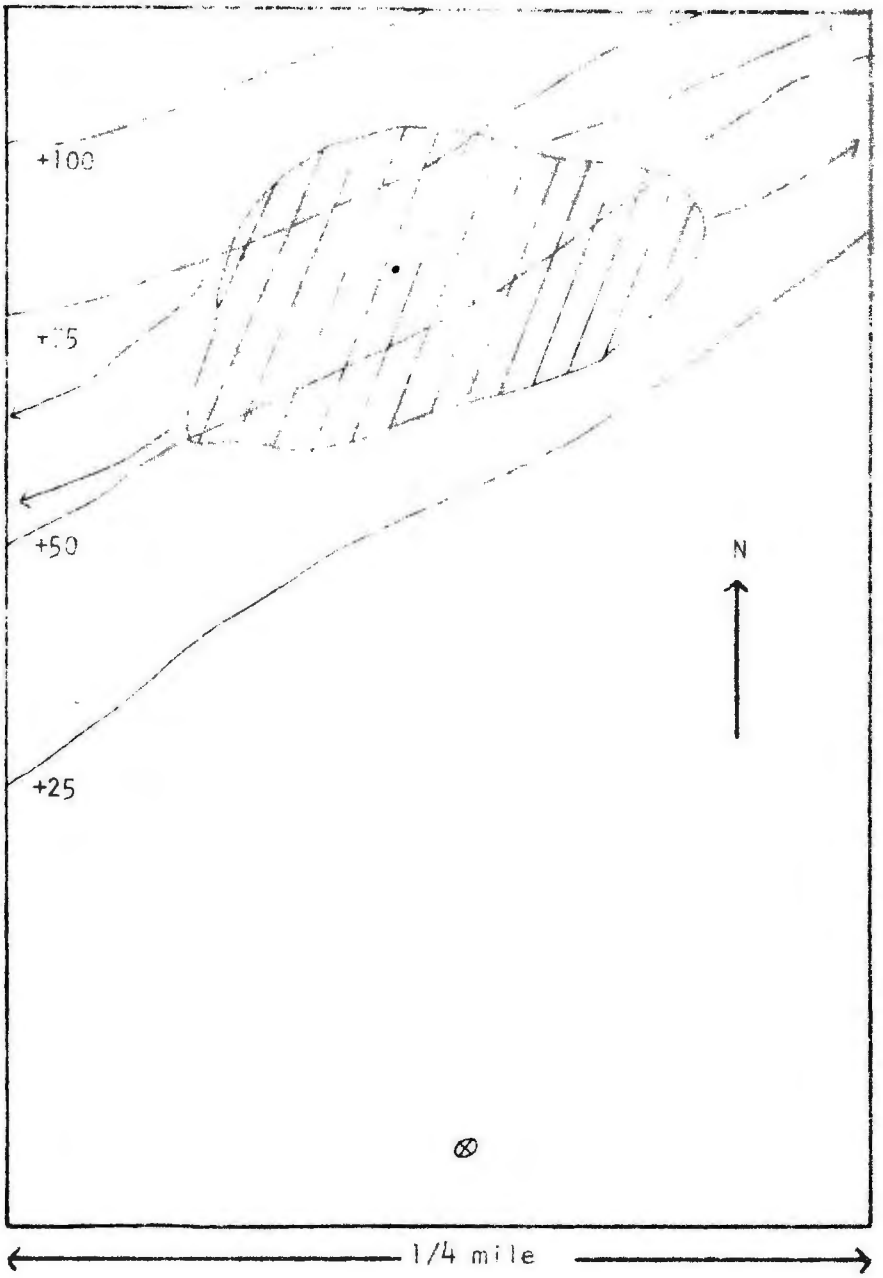
Although the feeding craters near the southern end of the traverse were in the latitude of deepest snow they were coincident with the latitude of change in hardness conditions. The route taken by the caribou that had made these craters is not particularly suggestive of random movement.

On February 12th pilot Nelson Walker flew out from Kotzebue to camp 5 and as caribou numbers were insufficient for quantitative observation it was decided to move camp. We flew in a southwesterly direction without seeing many animals until we crossed the Shaklukshuk Range between the Kobuk and the Selawik River. Caribou were scattered along the south side of the Shaklukshuk Mountains and were particularly dense on the south slope of Rabbit Mountain, which lies near the confluence of the Rabbit and the Kugarak River. We estimated that about 5,000 caribou were concentrated along the 10 mile length of Rabbit Mountain, being densest at its foot and thinning out over the flats that extended to the south. A lake suitable for landing the plane on was found and camp 6 was set up on its shore, being about three miles from the mountain foot.

I remained at camp 6 until the end of February and in this time the numbers of caribou progressively lessened until there were none present. The movement away from Rabbit Mountain was usually to the East or S.East. This study area was the only one to have been visited by hunters (Eskimos with dog teams) but it is not known if the disturbance caused by these men was responsible for the caribou movement away from the area. Nelson Walker informed me that a concentration of caribou had been present in this area since early December and some sections of the range showed evidence of almost continguous cratering.

A Selawik Eskimo, Napatulik, told me that the south side of Rabbit Mountain was particularly tussocky with little lichen but that the north side supported more lichen and less tussocks. Rabbit Mountain was climbed in order to scan the northern slopes for caribou but low cloud precluded any observation. Napatulik also informed me that the area was known for frequent and prolonged winds that originate from the East and N.East and subsequent experience bore out the validity of this statement.

Snow depths were very shallow with much evidence of clear ice, vesiculated ice and vesiculated snow. Loose surface snow was frequently being re-distributed by winds and invariably formed sastrugi patterns when being eroded or re-deposited. The overall snow cover was such that both



Sec. B
Observation number: 57
Camp number: 6
Date: 14th February, 1963
Time: 1300

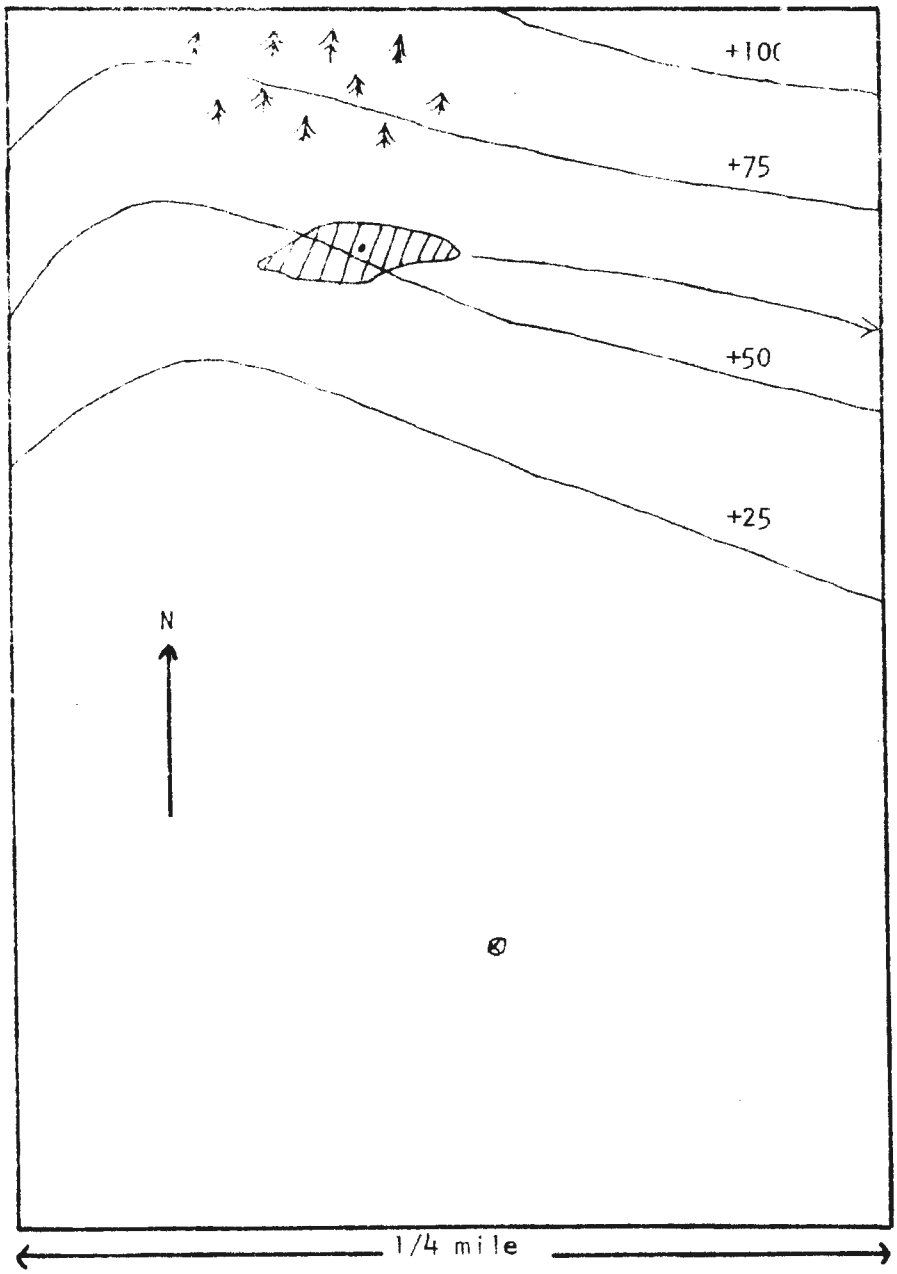
Caribou activity: B-Stationary feeding

	observer's position	caribou position
Snow depth	6	2
Surface hardness	4500	4500
Maximum hardness	7500	4500
Air temperature	-34	-22
Surface temp.	-37	-22
Ground temp.	-11	-11
Windspeed	0	0
Direction	-	-
Windchill	690	605
Light intensity	110	110

Weather: Clear and fine with unrestricted visibility.

Bulls	106
Cows	78
Calves	39

Remarks: A most prominent temperature inversion exists in this situation with caribou occupying the warmer environment. The vegetation temperature is extremely low due to the shallow snow cover and a prolonged period of cold weather. The caribou were aware of the observer when he was about two miles away but they did not show alarm until a close approach was made. The animals divided into two bands which ran in opposite directions along the approximate contours of the slope. The snow surface at the caribou position was of a combination of hardness and depth that the animals had cracked and broken up the layer through walking and digging. The surface was brittle and separated into quite small pieces that lay scattered around. Caribou were observed brushing these small pieces out of their way with forehooves in order to clear a patch of ground for feeding purposes. Although many caribou had previously moved over the snow close to the observer's position, its depth was probably responsible for the absence of a broken up appearance, and no cratering was evident in this section.



Map 9
Observation number: 58
Camp number: 6
Date: 14th February, 1963
Time: 1200

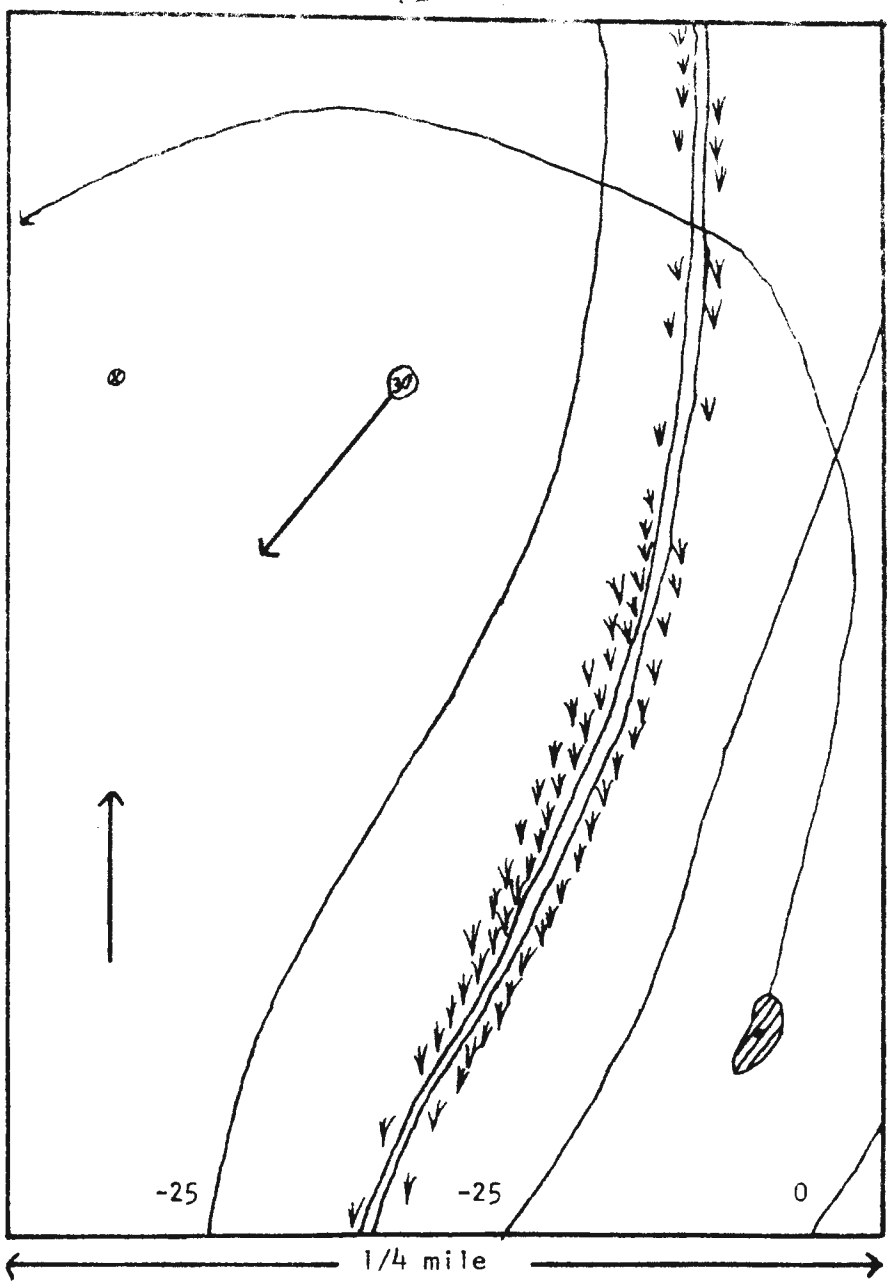
Caribou activity: B-Stationary feeding

	observer's position	caribou position
Snow depth	7	2
Surface hardness	3200	2500
Maximum hardness	7000	2500
Air temperature	-29	-18
Surface temp.	-33	-19
Ground temp.	- 4	- 8
Windspeed	0	0
Direction	-	-
Windchill	650	595
Light intensity	210	210

Weather: Clear and fine with unrestricted visibility.

Bulls	13
Cows	16
Calves	11

Remarks: This situation is about one mile to the east of observation number 57. The temperature inversion is still present and the snow depths are almost identical to those recorded during observation no. 57. The texture of the snow at the caribou position was also similar to that of the previous observation, i.e., vesiculated, brittle, of constant hardness (single layer) and broken into small pieces by the actions of the animals. The snow at the lower elevation had not been penetrated by caribou.



Map 10
Observation number: 59
Camp number: 6
Date: 15th Februbary 1963
Time: 1200

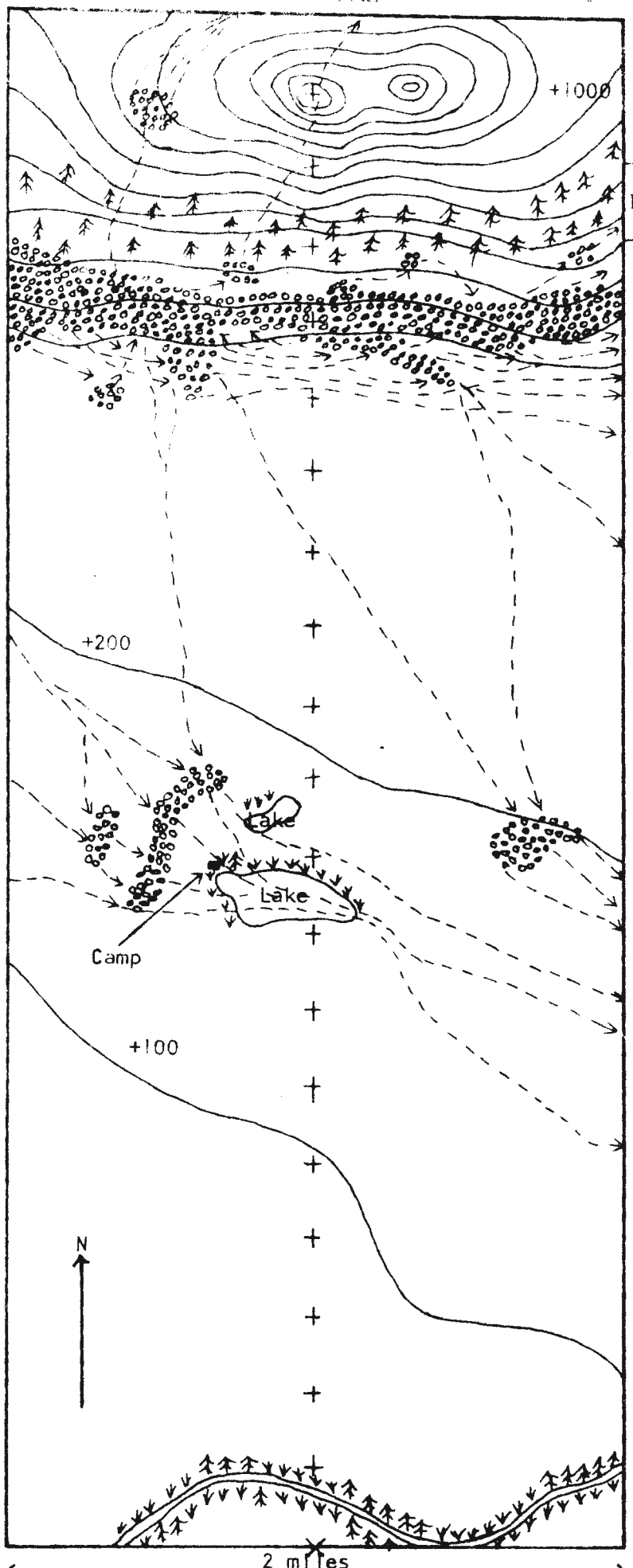
Caribou activity: D-Resting

	observer's position	caribou position
Snow depth	2	4
Surface hardness	650	9000
Maximum hardness	650	Ice
Windspeed	30	18
Direction	N.E.	N.E.
Windchill	1190	1105
Air temperature	+21	+20
Surface temp.	+16	+18
Ground temp.	+11	+12
Light intensity	100	100

Weather: Cloudy with much wind born snow - occasionally flying horizontally. Visibility about 1 mile.

Bulls	7
Cows	6
Calves	4

Remarks: The caribou were displaying their typical reaction to high wind and flying snow and they had used a slope to avoid the strongest winds. On being disturbed, the animals ran with the contour of the slope and may have veered round after experiencing an increased windspeed. They finally ran out of sight in a south westerly direction. The temperature inversion had ceased overnight, and it became much warmer with the advent of wind.



Snow depth	Surface hardness	Underlying hardness
6	Ice	Ice
14	2	15
18	2	1800
3	60	225
3	70	70
5	7	4500
4	Ice	Ice
5	9000	Ice
5	7	6250
7	6	6250
8	3000	9000
7	90	6000
7	190	5500
9	9	Ice
8	650	Ice
11	1000	4500
11	250	3500
14	90	3500
23	7	1400

1/4 mile

Random Sampling - Map B.
Camp [illegible] 22nd - 24th
[illegible]ry, 1963

tussocks and lichens were exposed particularly along the southern edge of Rabbit Mountain. The caribou in this area were extremely difficult to approach and observe. There was little cover that an observer could take advantage of and few gullies to move along. In cold weather the animals would usually take fright when they heard skis scraping along the ice or hard snow and the very numbers of caribou ensured that at least a few animals would spot the observer approaching when wind and higher temperatures restricted noise transference. Had the distribution of caribou along the southern edge of the mountain not been continuous the observer could probably have achieved better manoeuvrability and considerably more recordings. Data obtained at camp 6 follow overleaf. The data include a transect of snow conditions and samples of twin position environmental recordings.

Random Sampling - Map B.

Contours are in feet from the point X on the southern base line. Intervals are 100'.

Interrupted lines indicate the major caribou trails.

Small circles indicate areas of cratering.

Other definitions will be found in the map key immediately following the introduction.

Nineteen snow stations were recorded over a three day period along a line joining the Rabbit River and the western summit of Rabbit Mountain. The work was accomplished after the region had been deserted by caribou, and most of the features were mapped by observation from the upper slopes of the mountain. The result is more diagramatic than a consequence of accurate surveying.

At the southern extremity, snow depths were quite high due in part to the sheltering and shadowing effects of tall vegetation growing along the river. As most winds originated from the north east and east it would seem logical for snow to build up on the northeasterly facing river bank as windforce would receive a braking influence in this area.

Moving northward brings the commencement of shallower and harder snow with much evidence of sastrugi and patches of ice formed during the previous thaw. Although caribou had been feeding in the central region, the transect line did not pass through any cratering.

The shallow snow cover at the mountain foot had been greatly modified by feeding, resting and walking caribou, but the measurements indicate depth and hardnesses of untouched snow sections. However, the total area of untouched snow would probably only be a very small proportion of the whole.

The choice of a south facing slope for intensive feeding is comparable to the situation in the Shungnak River valley (Map A) and the general conditions are similar. In both instances the snow was shallower and softer when a south facing slope rises from open flats. Snow depth increases with the incidence of spruce cover and its hardness would have been less affected by solar radiation and wind.

It was interesting to find a caribou trail leading over the summit. No feeding had taken place close to the summit, which consisted of rock outcrops which were partly bare of snow and partly covered with an ice layer. Caribou have been known to travel over areas offering no food supply and Anore Bucknell and Jim Mack (viva voce) have reported travelling caribou on glaciers from 6,000 to 10,000 feet in the Mt. McKinley region.

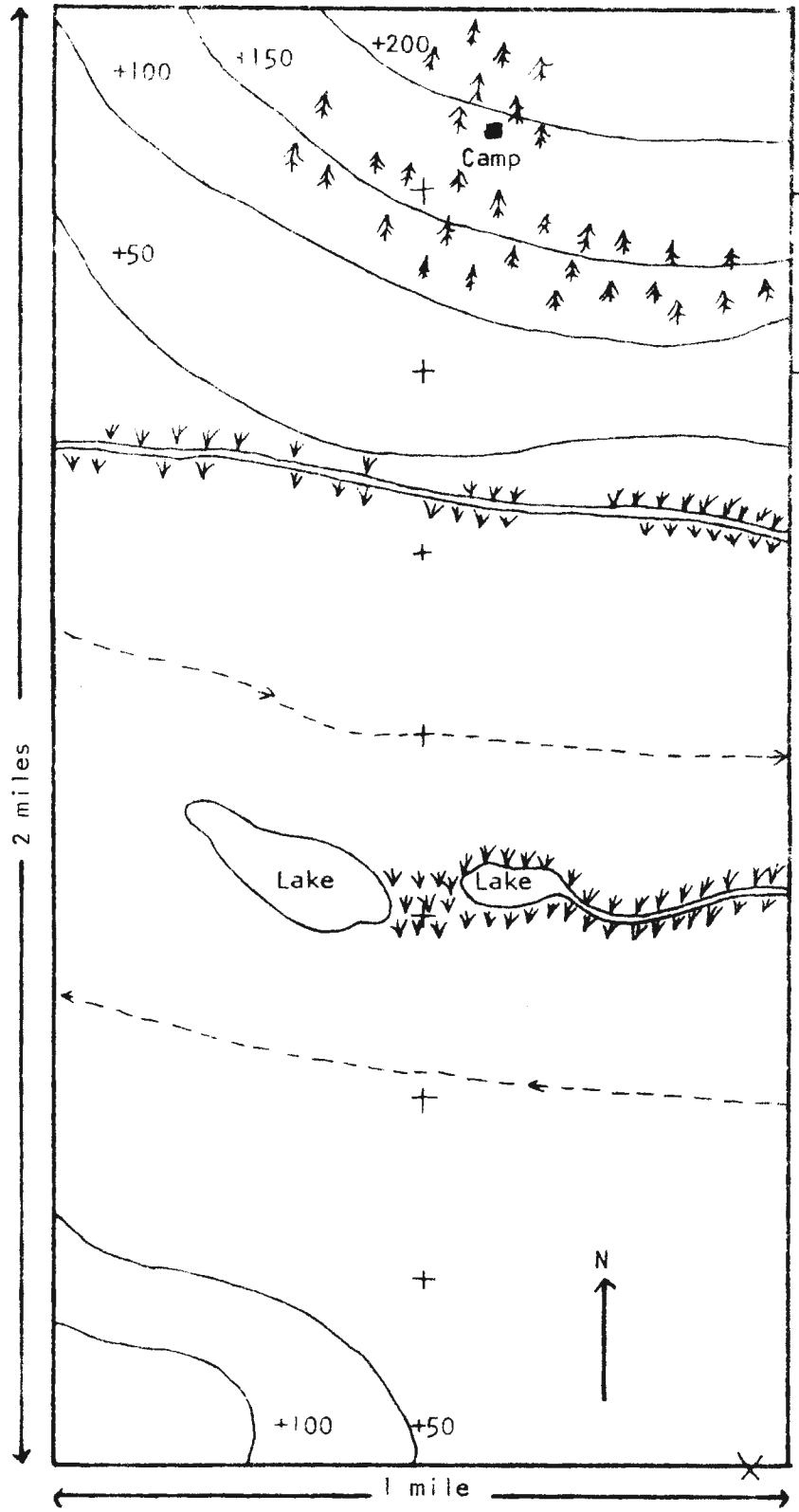
Due to the caribou movement from the Rabbit Mountain area the location of camp had to be altered. The majority of animals had travelled in an easterly direction along the southern edge of the Sheklukshuk Range and, as these mountains curve round in a wide arc to the south and west, it was thought that caribou might break through the mountains at one of the passes. Camp 7 was set up at Angmanorak ("hole in the mountains") about 11 miles to the east of camp 6. Several Eskimo hunters had anticipated the same thing as myself and were found to have camped in this location on our arrival. However, apart from a few travelling bands of caribou, little movement was detected in the area of camp 7. The following traverse was made at Angmanorak.

Random Sampling Map C.

Seventeen caribou were spotted from the camp whilst they were travelling in an easterly direction over the flats below. The time was 0600 and one hour later the same band had returned to travel over the flats in the opposite direction.

Snow measurements were made in the first trail made by the animals and work was continued to complete a traverse of random recordings from this position.

The snow was shallow in the areas of both trails with very hard surfaces. The texture of the cover at the point of the first trail was heavily vesiculated snow approaching the appearance of ice. The caribou had fractured the cover in several places but only with the anterior sections of their hoofs. The caribou had been observed to be walking quite slowly (but steadily) and there were no dew claw impressions. The cover hardness was tested immediately adjacent to the fractures and it was found to register in the order of 7,000 grammes per square centimetre for each instance. The caribou did not fracture the surface near the recording station that is close to their return trail and this was probably due to the deeper cover, as the hardness was slightly less than at the first trail.



snow depth	surface hardness	maximum hardness
14	5	95
6	150	Ice
14	7	100
2	7000	7000
12	55	90
4	6500	6500
3	6000	6000

Random Sampling Map C.

Camp number 7
Date: 27th February, 1963

Snow depths were greater in vegetated areas and the snow was markedly less hard due to the shelter effects.

Camp 7 was rather unproductive from the research point of view and as the caribou south of the Shoklukshuk Range were no longer stable, it was decided not to establish another camp in the area and to conserve the money remaining for aircraft charter. Heavy camp equipment was flown to a point on the Kobuk River about 5 miles to the east of Kobuk village and pilot Nelson Walker was asked to discontinue flying out from Kotzebue until any message was received to the contrary.

The journey from Angmanorak (camp 7) to the Kobuk River was made overland on skis and it was apparent that snow conditions north of the Shoklukshuk Range were very similar to the conditions experienced on the south side. The surface showed sastrugi when loose snow was encountered with many intermediate patches of pure ice and vesiculated snow and ice. No caribou were seen on the journey and caribou sign was very rare.

Tony Bernhardt, the only pilot normally resident in the upper Kobuk drainage, was in Anchorage taking examinations for his commercial license, and it was necessary to wait for his return to Kobuk village before any further flights could be made. I was anxious to charter Bernhardt as he was familiar with most of the country and he could save the 4 hours air time required by a Kotzebue pilot to fly out to Kobuk and return. Tony Bernhardt was delayed in Anchorage and did not return to Kobuk until March 19th.

During the first half of March about three feet of snow fell in the Kobuk village area. Gales bringing blizzard conditions were almost continual for 10 days but the incidence of airborn snow became less frequent when the surface snow had become well packed. Overall snow depths were by this time similar to those recorded during February and March of the previous winter, but the lower, hard layers remained as a significant difference. The third week of March brought further high winds (without precipitation) with short intermediate cold spells with temperatures down to -42 degrees fahrenheit. Toward the end of March weather conditions became more settled and on the 28th I made a survey flight over the Ambler Lowlands - Schwatka Mountains region to the north of Kobuk village.

About 725 square miles were covered, the area of random sampling map D., in an effort to plot the total areas occupied by caribou. Parallel lines were flown either in an easterly or westerly direction with about 4 miles between each line and, due to optimum spotting conditions, it is thought that all caribou bands were seen. About 2200 caribou were spotted in 21 separate areas and two major topographic zones were utilized. Caribou were either in generally small bands on smooth, wind blown ridges or summits or in generally larger bands on open valley floors. Timber covered slopes were not occupied and caribou were not seen on the steeper mountains that terminated in jagged rocky peaks. The still, fine weather had resulted

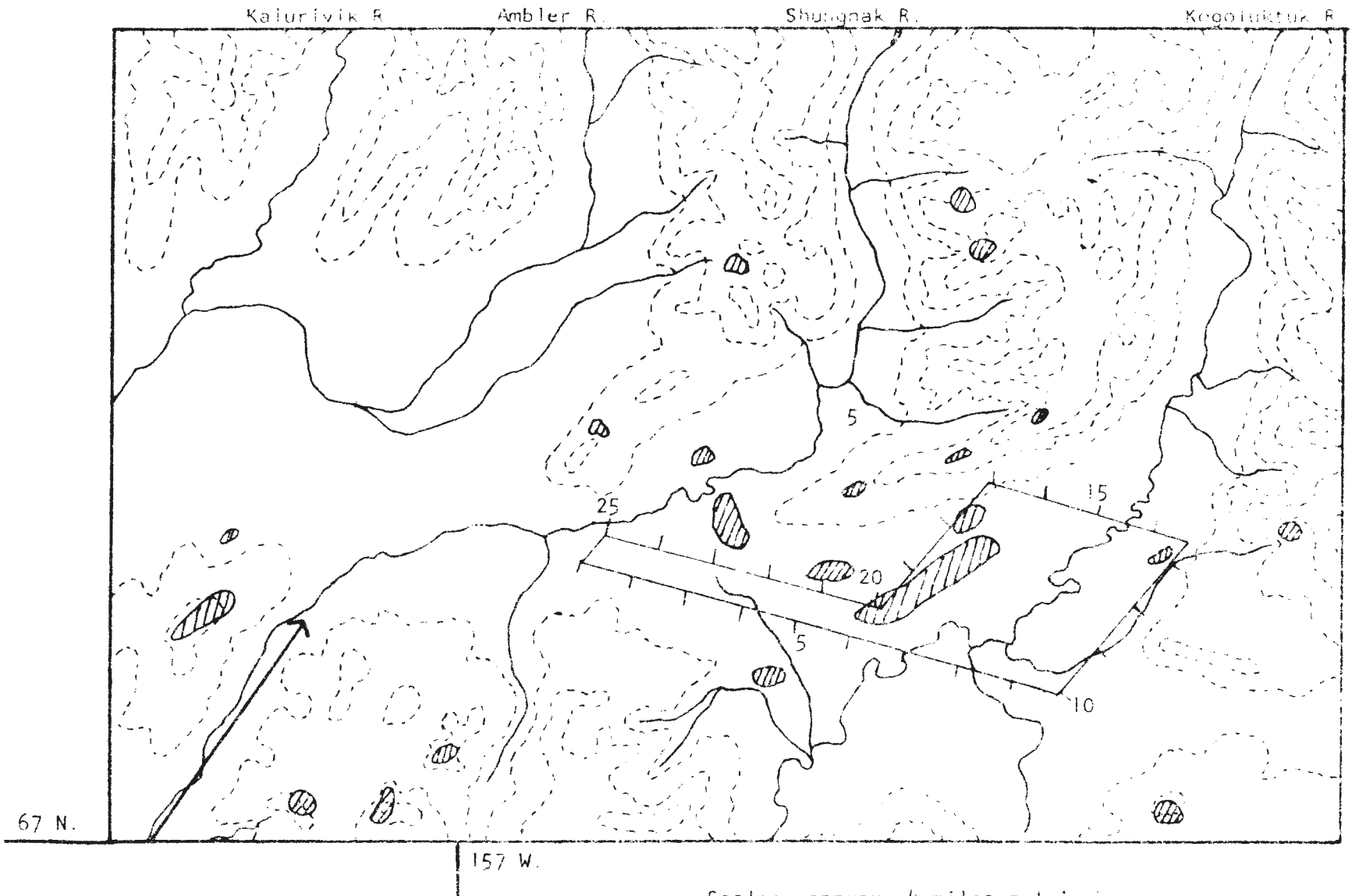
in stratification to air layers. Temperatures a few hundred feet above low lying areas were betweem -25 and -30 degrees. A warmer layer about zero degrees was static from 1500 to 2200 feet above the valley floors and at 5000 feet it was colder, being from -7 to -11 degrees.

On 30th March, in company with assistants Jones, Bucknell, and Mack, I left the Kobuk River to make a survey of environmental conditions over part of the region shown in map D. The objective was to randomly sample snow conditions in relation to territory occupied and not occupied by caribou. As has been previously explained, observation of this nature cannot be truly random as some habitat types offer no access. A traverse in the form of a parallelogram had been drawn, but the northern side of this figure included a mountainous section that could not be overcome. The route eventually completed was in the form of two adjacent parallelograms. The traverse consists of 25 snow stations arranged at intervals of 1 1/2 miles and the sampling took 9 days to complete with an additional 7 days being required for travel in and out of the study area. The sampling was commenced at station number 1 on map D and followed in a generally anti-clockwise direction to station number 25.

Four pits, approximately 100 yards apart, were dug along a straight line which had its centre at the approximate station point. The direction of the line of pits was changed with each station. Commencing with a north to south line at station no. 1, the successive lines were oriented to follow clockwise compass changes so that station no. 2 had a northeast to southwest line of pits, etc. Snow hardnesses were recorded at each pit and the depth of the hardest layer was measured. Temperature profiles were also recorded as this information can supplement earlier data for analysis of snow depth, ground temperature relationships and overall temperature profile analyses. Each station was mapped and all caribou sign was recorded on the maps together with the incidence of lichen discovered in the pits. The symbol L on the station maps indicates that lichen was found under the snow cover. In order to standardize the probability for finding lichen, approximately one square foot of ground was scraped free of snow in each pit. All traces of caribou activity were mapped and general weather records were kept so that some idea of the age of caribou sign could be estimated. Whilst travelling between stations, a watch was kept for signs of caribou movement and efforts were made not to create undue disturbance to those bands that were encountered. Some disturbance was unavoidable as caribou had to be killed for thekdog's and our own comsumption.

After our return to the Kobuk River, bad weather delayed a second survey flight necessary to discover the extent of caribou movement in the traverse area. This flight was made on April 10th and it was learned that no changes in the territories marked on map D had occurred. Although the originally observed caribou had remained static throughout the 19 day period between survey flights, about 450 caribou had begun to move into the study area along the lower Shungnak River valley. Their direction of

Random Sampling Map D. Schwatka Mountains - Ambler Lowlands



Scale: approx. 4 miles = 1 inch
Contours at 1,000 ft. intervals

travel is indicated by the arrow on map D. The position of an earlier camp (number 5) is indicated in the upper Shunganak River valley.

Discussion of data obtained during the traverse follows together with a table of snow recordings and samples of the maps drawn for each station.

Random Sampling Traverse, Schwatka Mountains - Ambler Lowlands

Tony Bernhardt (viva voce) is of the opinion that the region of map D experiences two characteristic types of wind conditions. The four rivers that flow out of the mountains at the northern edge of the map have fairly narrow valleys which widen as these rivers enter the east/west Ambler Lowlands valley. These four valleys, according to Bernhardt, experience frequent and very strong north winds which are not usually felt in the Ambler Lowlands. The Ambler Lowlands are known for frequent east winds which normally occur at different times than the north winds mentioned above. The traverse and air surveys added substance to Bernhardt's observations as recent wind directions were readily recognizable from the lie of sastrugi and snow shadows leading from rocks and trees. No major valley in the area is likely to be sheltered from prevailing winds (the Kobuk Eskimo say that the Shungnak River Valley is the "coldest and windiest place in the world") and hard surface snow could probably be found in any of the low lying parts of the area at most times during the winter.

A striking topographical feature is the presence of canyons along all the larger creeks and rivers and where these canyons do not parallel the direction of prevailing winds, one invariably finds corniced snow. Some cornices were as much as 70 feet from top to bottom and a mile or more in length, creating positive fences to caribou movement.

The depth of ice in most of the waterways was probably about 4 to 6 feet where the current was sluggish and resulting pressure was responsible for frequent overflowing. Caribou exhibited a marked preference for frozen overflow when moving around in areas containing many creeks. Makridin (1962) states that wild reindeer (Rangifer tarandus) were observed to follow river channels during the spring migration in the Taimyr (U.S.S.R.). Overflow ice is a typical feature in the Alaskan Arctic from March to June but, unfortunately, Makridin does not mention if overflow was present on the Taimyr rivers.

The weather during the traverse was relatively warm with a temperature range from +32 to -11 degrees fahrenheit. Surface snow hardnesses were not noticably affected by the higher temperatures.

Apart from the track of a single animal, there were no caribou traces from station 1 to station 5. Practically all of the pits dug along this

section of the route showed evidence of a previous thaw (table 13). Station 5 showed traces of caribou that had been travelling, and fairly recent feeding had taken place near the pits where softer snow was recorded. A small number of caribou had been feeding in the area of station 6 and this activity could also be related to the softer snow patches. Lichens were not recorded in the latitude of the feeding craters. No caribou traces were noted in the vicinity of the Kogoluktuk River at station 7 and absence of caribou sign continued round to station 17. Stations 11, 12, and 13 had comparatively "mild" snow conditions but only a very few animals were present on this side of the Kogoluktuk. The canyons, cornices, and timber belts along the river constituted a considerable barrier and it seemed unlikely that caribou would attempt to cross the Kogoluktuk in this area.

Stations 14 and 15 contained slightly harder snow than the previous three stations, probably because of their more exposed location, but stations 16 and 17 were in situations offering great protection due to dense timber that was present. Snow depth reaches its maximum at station 17 which is located on a very steep, timber clothed slope. Caribou were found in, or very close to, the areas covered by stations 18 to 21 inclusive. The maps that illustrate stations 20 and 21 give some indication of the way in which caribou were affected by snow conditions in this part of the traverse. Very wide variations in snow hardness occur over extremely short distances and this is reflected by particularly intensive responses by the caribou. Cratering of a small area would be quite complete with no undistrubed snow remaining. There would be a sharply defined edge to the cratered area with rarely a single crater being found beyond the periphery. Movements around the general area were also intensive with single tracks being rare and vesiculated ice or frozen overflow along creeks often being the base of caribou trails. It was apparent that only a proportion of the ground vegetation was accessible to caribou yet 700 to 900 animals remained in the area for at least three weeks. Three mature bulls were killed in this area and all of them showed fair amounts of depot fat to heart, kidneys, and rumen.

Stations 22 to 25 inclusive revealed a range of snow conditions not dissimilar to those obtained on the outward trail just a mile to the south. Only the very occasional trail was encountered although good numbers of caribou were seen a short distance to the north.

It is difficult to suggest any conclusions at this stage. However, the selection by caribou for <u>relative</u> grades of snow depth and hardness for the performance of discrete activities appears to be continual despite the dynamicism of the nival environment and its observed winter to winter differences. It is of interest that the phenomena can be recognized by selective as well as random sampling but the acid, statistical test is to be applied before the analysis can be complete.

Table 13

Random Sampling Data
Schwatka Mountains - Ambler Lowlands Traverse

Station number	Date	Snow depth	Surface hardness	Maximum hardness	Depth of hardest layer	Lichen present
1	3rd April	34	190	6200	7	*
		19	130	3800	4	*
		14	90	2900	2	*
		25	850	9000	11	*
2	3rd April	23	750	8400	6	*
		25	35	5200	8	*
		23	600	6800	6	*
		17	900	8300	7	*
3	3rd April	17	3	1450	6	*
		21	18	7300	7	*
		22	70	6600	3	*
		27	1100	4800	5	*
4	3rd April	28	45	Ice	7	*
		19	70	150	2	*
		17	84	2400	2	*
		22	22	3500	3	*
5	4th April	12	70	180	2	*
		19	70	700	2	*
		28	3000	3600	7	*
		27	3600	5700	8	*
6	4th April	27	70	8600	8	*
		13	75	350	2	
		18	80	490	3	
		29	65	3400	7	
7	5th April	16	20	2300	2	
		10	12	2300	2	
		27	35	3900	4	
		30	65	3700	4	

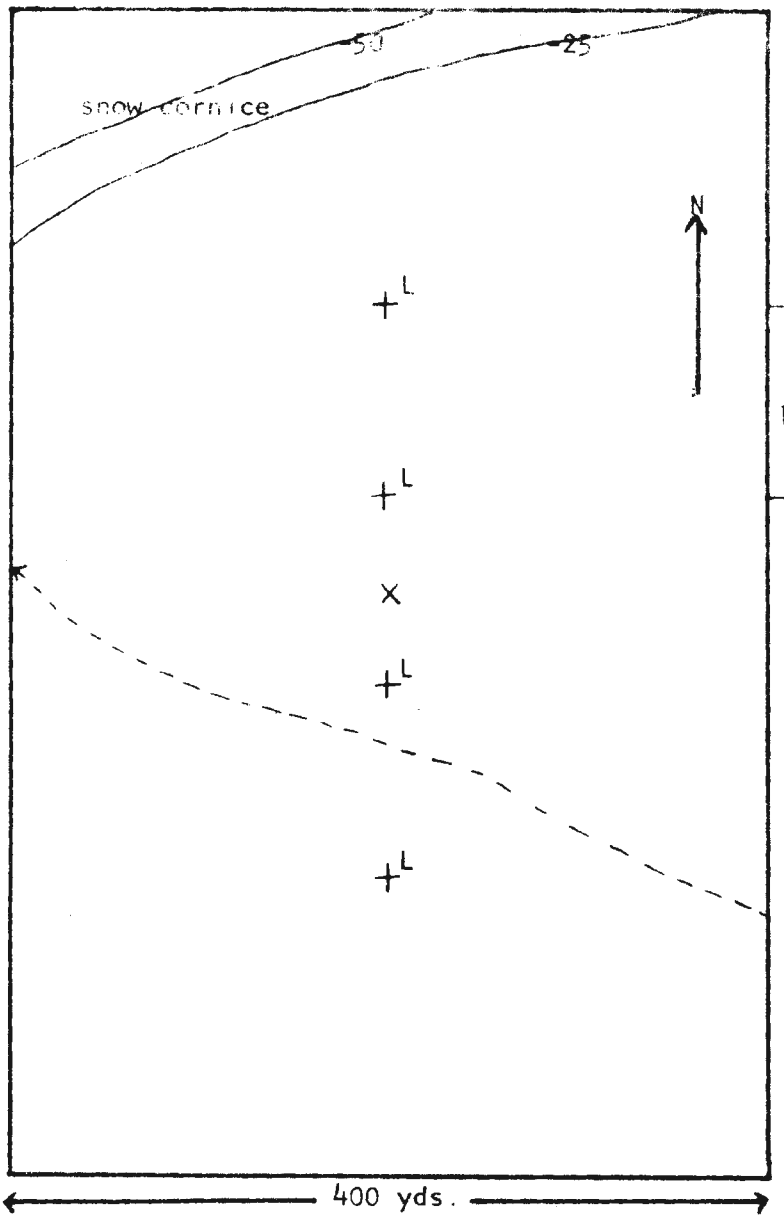
All sites on Kogoluktuk River or its overflow.
Pure ice lay below all snow stations.

8	6th April	19	150	9500	7	*
		28	24	9500	3	*
		22	80	9000	6	*
		21	120	8500	6	*
9	6th April	17	160	8500	7	*
		23	110	8500	7	*
		21	95	9000	6	*
		25	100	7200	5	*
10	6th April	24	65	6600	8	*
		27	75	6200	8	*
		23	62	7500	6	*
		29	47	7000	9	*
11	6th April	8	16	40	2	*
		12	16	45	3	*
		13	35	70	3	*
		21	110	650	9	*
12	6th April	9	24	110	2	*
		7	20	100	3	*
		7	45	160	3	*
		6	35	220	2	*
13	6th April	20	8	90	2	
		20	10	90	2	
		24	10	95	3	
		25	9	90	3	
		The first two stations were situated on a lake, consequently, pure ice lies below the snow cover.				
14	7th April	31	110	550	3	*
		25	400	3200	2	*
		29	40	500	3	*
		34	35	460	5	*
15	7th April	27	10	130	3	*
		24	8	180	4	*
		25	14	95	3	*
		28	20	125	6	*
16	7th April	38	8	100	3	*
		30	6	85	3	*
		32	16	95	4	*
		29	10	80	5	*

17	7th April	54	6	35	21	
		63	4	22	24	*
		49	2	30	18	
		52	3	16	19	
18	8th April	27	210	4500	4	*
		24	200	9500	5	*
		32	240	1200	7	*
		25	260	2200	6	*
19	9th April	13	45	190	6	*
		22	40	1400	5	
		Pure ice surface being overflow on creek.				
		37	30	2600	6	
20	10th April	21	35	8000	6	*
		23	20	5500	7	*
		20	40	180	8	*
		14	40	190	7	*
21	10th April	28	3200	Ice	9	*
		32	3700	Ice	8	*
		29	4000	Ice	9	*
		23	4500	Ice	11	*
22	10th April	23	45	Ice	12	*
		24	40	Ice	14	*
		19	75	Ice	13	*
		27	30	Ice	16	*
23	11th April	21	170	6500	5	*
		22	210	6200	4	*
		19	190	7000	7	*
		24	190	6800	7	*
24	11th April	37	45	2300	7	*
		33	65	1800	8	*
		34	30	2100	11	*
		29	110	1800	11	*
25	11th April	22	190	8000	7	*
		18	75	5500	4	*
		15	90	2600	3	*
		17	120	4300	5	*

Where ice is given as the maximum hardness this refers to vesiculated ice as opposed to pure ice.

Random Sample Area Map D 1



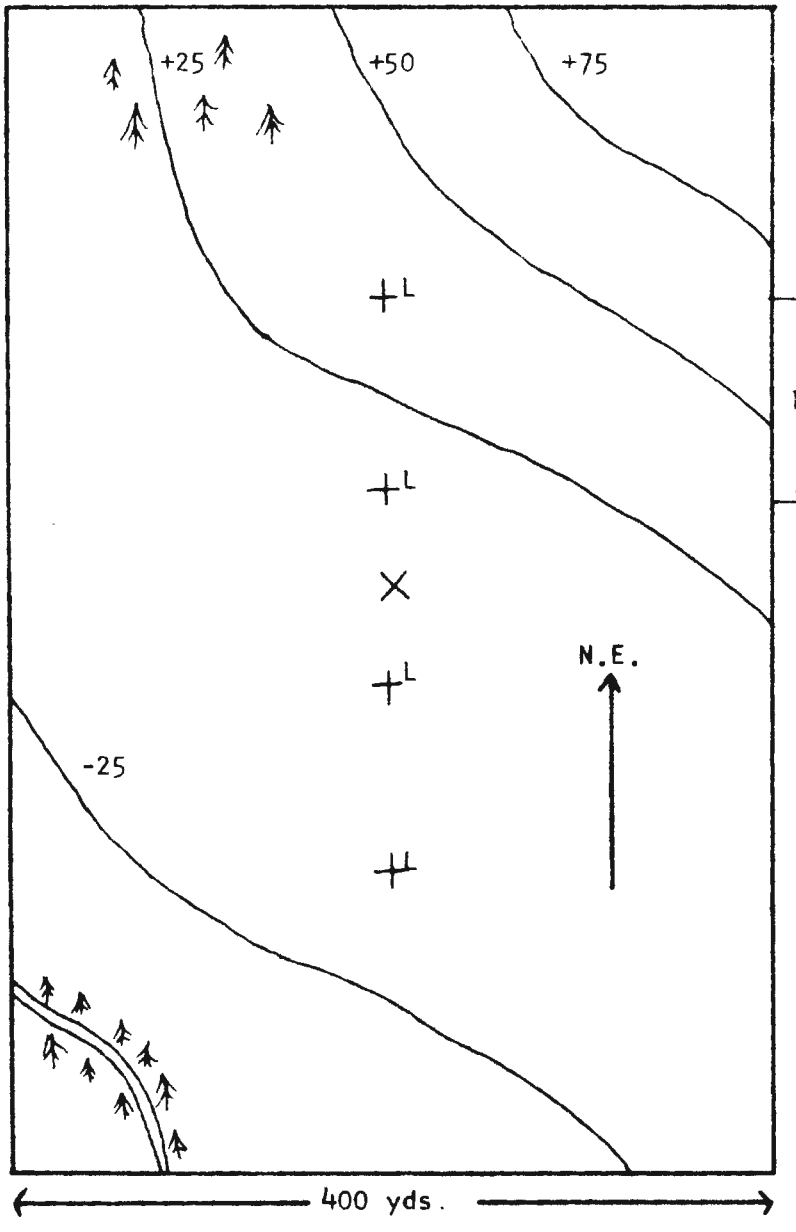
Date: 3rd April 1963

	snow depth	surface hardness	maximum hardness
L	34	190	6200 7"
L	19	130	3800 4"
L	14	90	2900 2"
L	25	850	9000 11"

Remarks: Single caribou trail made some days previously.

Ramdon Sampling Map D 2

Date: 3rd April 1963

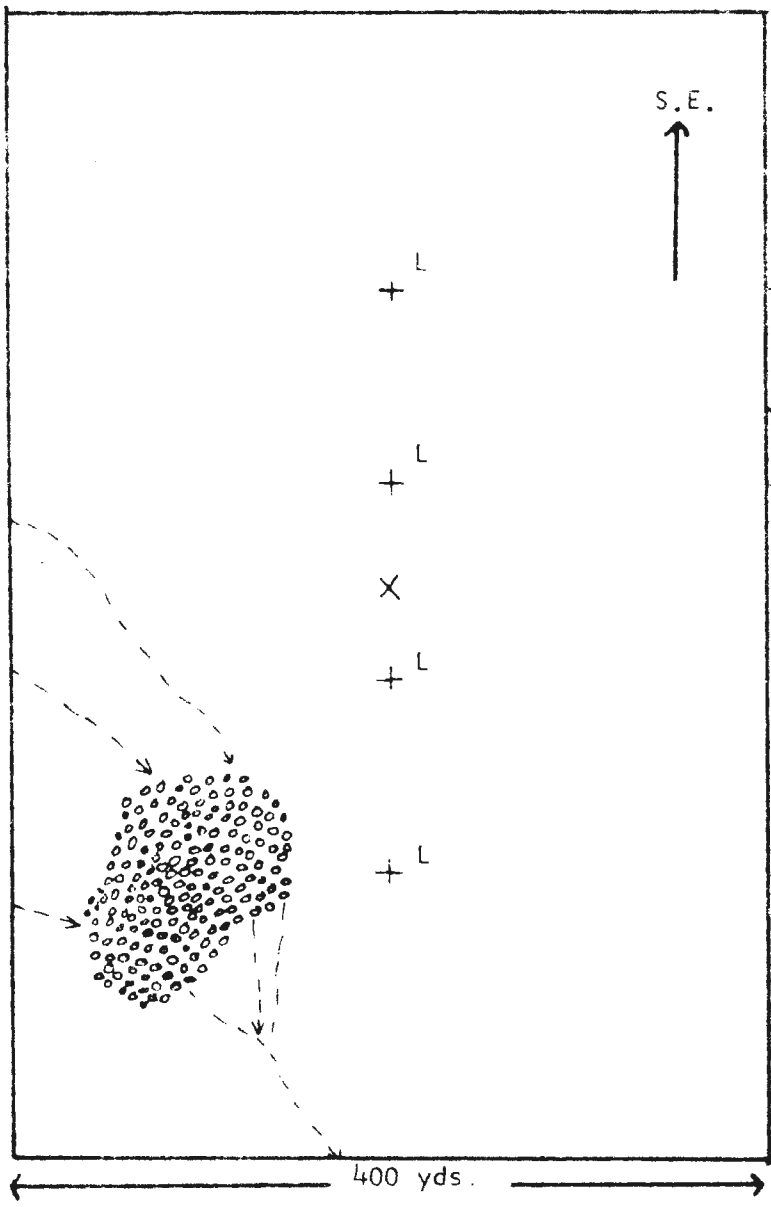


	snow depth	surface hardness	maximum hardness	depth of hardest layer
L	23	750	8400	6
L	25	35	5200	8
L	23	600	6800	6
L	17	900	8300	7

Remarks: No caribou sign. Hardest snow layer shows vesiculation as a result of a previous thaw.

Random Sampling Map D 20

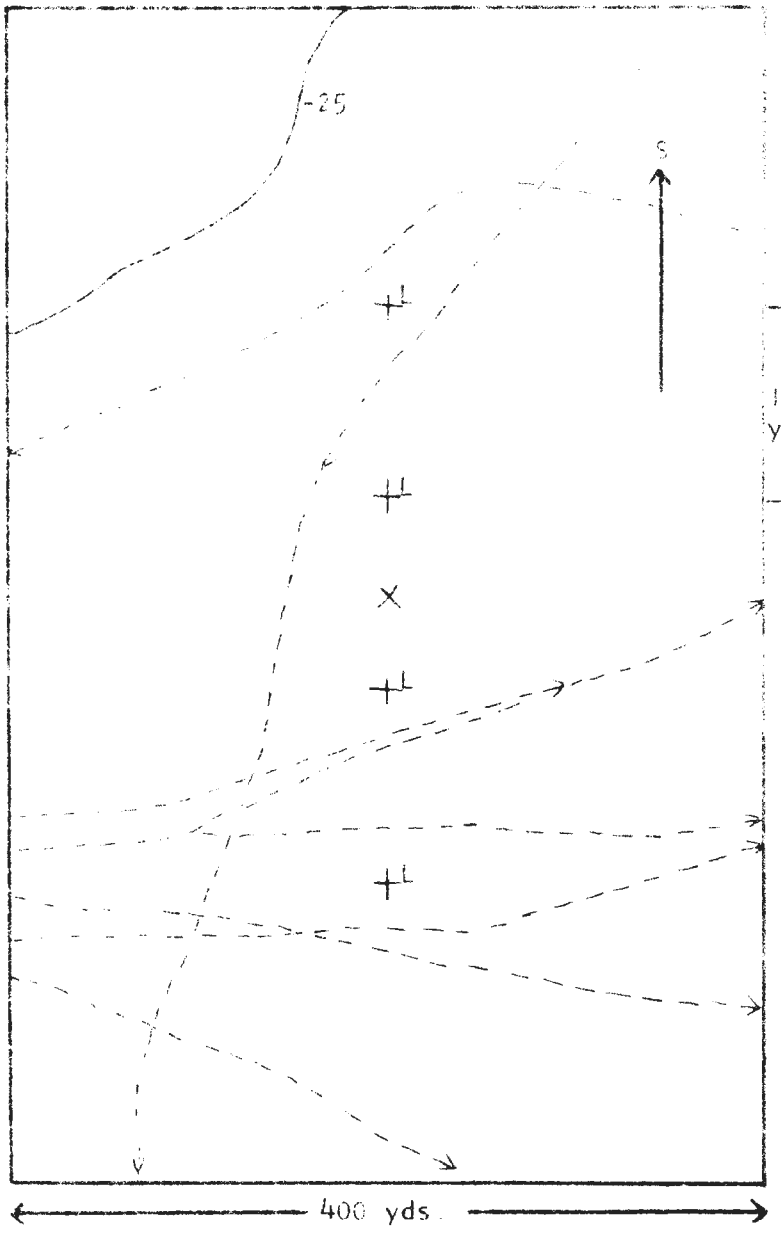
Date: 10th April 1963



snow depth	surface hardness	maximum hardness	depth of hardest layer
21	35	8000	6
23	20	5500	7
20	40	180	8
14	40	190	7

Remarks: The utilization here has been effected by caribou belonging to the large concentration located in the area where the Kogoluktuk River enters the Ambler lowlands. There is no obvious reason for the wide disparity in maximum snow hardnesses obtained in the area but caribou seem to have recognized a suitable location for feeding if the measurements are representative for their latitudes.

Random sampling area B-2



Site		Surface snow	Maximum hardness	Depth of hardest layer
	31	3700	Ice	9
	32	3700	Ice	8
	29	4000	Ice	9
	23	4500	Ice	11

Remarks: This observation includes the hardest surface snow to be recorded. The hardest layer was vesiculated ice which required considerable chipping with a shovel before the ground could be reached. Vegetation under such snow cover such as this would remain inaccessible to caribou until late May or early June in an average year. The situation of this observation is close to caribou concentrations but has only been used for travelling. The recorded conditions are probably optimum for travelling caribou, and track depths were in the order of 1 - 2 inches.

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