WILDLIFE MANAGEMENT BULLETIN

DEPARTMENT OF NORTHERN AFFAIRS
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NATIONAL PARKS BRANCH
CANADIAN WILDLIFE SERVICE
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CANADA
DEPARTMENT OF
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CO-OPERATIVE STUDIES OF BARREN-GROUND CARIBOU 1957-58

by

John P. Kelsall

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Issued under the authority of the
HONOURABLE WALTER DINSDALE, P.C., M.P.
Minister of Northern Affairs and National Resources

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CONTENTS

Page

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INTRODUCTION

General Considerations

An intensive research program on barren-ground caribou, Rangifer arcticus arcticus (Richardson), was officially commenced April 1, 1957. The original suggestion arose and tentative plans were made in the spring of 1956 at a meeting of the Technical Committee on Barren-ground Caribou Conservation. There it was decided that more value would accrue from intensive ground studies of caribou mortality in all its aspects than from continued survey and census work. The former could give management and administrative aids to halt the decline of the mainland herds, whereas the latter would serve merely to document an already well-recognized disaster. The work was planned to involve some segment of the seriously reduced herds on the mainland barren-grounds which stretch from Hudson Bay to the Mackenzie River.

The program was conceived as a co-operative venture, involving federal, provincial and territorial government agencies. In practice this arrangement worked very well. The Canadian Wildlife Service, the government of Manitoba, the Indian Affairs Branch of the Department of Citizenship and Immigration and the Northwest Territories Council jointly and successfully undertook the major financing of the project. Few financial difficulties were encountered, despite the fact that estimates of expenditure were in a state of almost constant revision upward as the size and scope of the project expanded.

The research, planning, and direction were undertaken largely by the writer, a Technical Committee, and various members of the Canadian Wildlife Service. Helpful suggestions were received from many other sources.

Field equipment, except for personal items and a few special needs supplied by the Manitoba and Saskatchewan Game Branches, the National Research Council and the Meteorological Branch of the Department of Transport, was supplied by the Canadian Wildlife Service.

It was decided early that the investigation should be confined to a specific caribou herd, for sound practical and biological reasons. The final choice of a herd was not made until March, 1957, a short time before the commencement of field operations. At that time it

appeared that the largest wintering herd was in northern Saskatchewan. Because of its large size and because of the financial advantage expected in operating with it, that herd was chosen for study. The choice, though partly fortuitous, proved wise. The herd turned out to be much larger than originally supposed. It probably included, throughout most of the study, at least half of the total mainland barren-ground caribou population.

Field personnel were assigned from various agencies as shown in the list of participants below. The Canadian Wildlife Service contributed a number of its regular field officers and some additional men hired on contract. The Province of Saskatchewan contributed two officers, both seconded exclusively to the research project for its duration. The National Research Council loaned two men for specific field investigations. One man, E. Ray of Michigan Conservation School, was a most welcome unpaid volunteer. As a group the men proved adaptable and resourceful, and maintained a continued high morale that was the subject of favourable comment from all visitors to the field camps.

Besides the writer, the actual field staff included the following:

1. Dr. Anton de Vos, Biologist, Ontario Agricultural College, Guelph, Ontario.

2. Dr. H.C. Gibbs, Pathologist, Canadian Wildlife Service, Ottawa.

3. Dr. J.S. Hart, Physiologist, National Research Council, Ottawa.

4. Dr. Olivier Heroux, Physiologist, National Research Council, Ottawa.

5. Mr. Ernie Kuyt, Wildlife Ecologist, Saskatchewan Game Branch, Regina.

6. Mr. A.G. Loughrey, Wildlife Biologist, Canadian Wildlife Service, Ottawa.

7. Mr. E.H. McEwen, Wildlife Biologist, Canadian Wildlife Service, Yellowknife.

8. Mr. J.A. Mills, Range Management Officer, Canadian Wildlife Service, Ottawa.

9. Dr. W.O. Pruitt, Jr., Biologist, Fairbanks, Alaska, (Canadian Wildlife Service contract).

10. Mr. Ed. Ray, Superintendent, Michigan Conservation School, Roscommon, Michigan.

11. Mr. F.W. Terry, Game Management Officer, Saskatchewan Game Branch, Prince Albert.

12. Mr. D.C. Thomas, Student Assistant, Prince, Saskatchewan, (Canadian Wildlife Service contract).

13. Mr. A.L. Wilk, Biologist, Camrose, Alberta, (Canadian Wildlife Service contract).

The above men constituted the regular field staff. Some of them were specialists who were actually on the ground only at specific seasons and for limited periods of time. Others were in the field almost continuously throughout the whole program, making only occasional visits at major bases of operation. They have all made important contributions to the following report, of which the writer was to a large extent merely the correlator and editor.

Acknowledgements

A large number of persons not directly connected with the caribou research project gave assistance during its course. Help was received from personnel of the Royal Canadian Mounted Police, the Department of Transport, the Department of Citizenship and Immigration, the National Research Council, and the Northern Administration Branch of the Department of Northern Affairs and National Resources. Personnel of the Game Branches of the Provinces of Manitoba and Saskatchewan were helpful in many ways. The Northwest Territories Council provided support whenever necessary.

A considerable debt is owed to private citizens in the North, particularly to the many bush pilots who participated in the enormous amount of flying involved. Personnel from the following companies performed, on occasion, considerably more than normally could be expected in a commercial endeavour: Koenen's Air Service, McMurray Air Service, Pacific Western Airlines, Saskatchewan Government Airways and Wardair.

Individual co-operators ranged from Indian hunters who supplied information, to laboratory scientists who made pathological examinations. Separate acknowledgements

cannot be made because the list is long and because not all the names of persons who helped the field men were known to the writer. However, many problems could not have been solved without the help received, and all who assisted may be assured of the warmest gratitude of the investigators.

Narrative

A complete itinerary of personnel and an account of camp moves during the caribou research program would serve no useful purpose. However, important developments of the field operations may be mentioned, and in some cases given in detail.

The program commenced in March, 1957, with search flying to discover a suitable study herd. Caribou wintering in northern Saskatchewan were chosen for study and the first regular field men commenced work from Stony Rapids in April, 1957. In May, when the caribou were approaching the barren-grounds during their northern migration, the field men at Stony Rapids moved to camps numbered 1 and 2 on Map 2. During the balance of the summer sometimes two camps were maintained in the field, and sometimes one. Successive movements of operational bases are shown on Map 2 as Camps 3 through 11.

Camp 12 on the Lockhart River was established shortly before freeze-up and Camp 13, which was not fully successful in its purpose, was established in the hope of remaining with animals through the critical freeze-up period. During that period a field party also was maintained for the purpose of gathering comparative data at Duck Lake in north-central Manitoba. This camp, not shown on the accompanying map, was occupied from September to mid-November.

Freeze-up was nearly complete by the time Camp 14 was established on the Fond du Lac River near Stony Rapids and from then through the winter Camps 15 through 19 were used.

In May, 1958, the northward movement of animals once more obliged the movement of camps to the barren-grounds. A large camp and laboratory were established at Mosquito Lake as Camp 22, and three other field parties were initially established at Camps 21, 23 and 24. Three separate camps were maintained until well into July, and two camps until near the end of the program in August. The last personnel from the field and Camp 35 were brought in to Yellowknife on August 27, 1958.

The field camps mentioned above were used as bases of operation for intensive ground studies of the caribou herd. A great deal of further work was done from the major bases of operation, Yellowknife and Stony Rapids. Search, and census flying, as well as other specialized projects were conducted from the main bases.

The survey flying and movement of camps and supplies necessitated aircraft usage beyond that of any previous northern wildlife projects undertaken. This was particularly true at such periods as during the calving season in 1958 when 13 men, in four separate camps, were established at distances up to 500 miles from an operational base. At such periods aircraft actually remained at the field camps for considerable periods. Table 1 gives the miles flown on the project each month, and shows the mileages flown by heavy, medium and light aircraft. While the total of 155,416 miles was being flown, three serious aircraft accidents were sustained in the field, but although two of the aircraft were damaged irreparably, no one was injured.

From November, 1957, to May, 1958, extensive use was made of two dog teams which were kept continuously at the field camps. Distances travelled were not recorded but approximated 1,500 miles in total. In open-water months a canoe and several rubber boats were maintained at the camps to provide local transportation.

This project was unique, in recent years at least, in that scientists and their assistants lived continuously on the northern taiga and tundra in tent camps throughout the study period. This period encompassed two springs, two summers and a winter. Air transport made it possible to remain always with the caribou, except for a few brief intervals. It was much to the credit of the men involved that they maintained high work standards, with no major accidents or illnesses, under circumstances which included, at times, the worst that the country could produce in the way of weather and ground conditions.

Table 1. Miles Flown on Caribou Research Project During the Months of Field Operation.

Month	Miles Otter	Miles Beaver	Miles *Cessna	Total Miles
March, 1957			682	682
April	3,988		1,620	5,608
May	686		2,990	3,676
June	2,251		4,305	6,556
July	910	5,150	2,914	8,974
August	6,276		5,365	11,641
September		1,825	2,188	4,013
October		1,550	4,594	6,144
November		1,222	6,199	7,421
December		832	1,623	2,455
January, 1958		335	9,788	10,123
February	288	1,100	14,263	15,651
March	9,317	5,693	10,166	25,176
April	1,504	1,142	4,082	6,728
May	3,857	1,595	9,356	14,808
June	2,529	828	5,126	8,483
July		3,110	5,885	8,995
August	1,976	741	5,565	8,282
TOTALS	33,582	25,123	96,711	155,416

* Almost entirely Cessna 180 aircraft but included a few thousand miles flown in Piper and Stinson aircraft.

Movement of the Study Herd

Routes and Ranges

During the migration of caribou southward in October and November, 1956, it was apparent that a major herd had entered northern Saskatchewan and northeastern Alberta. This was of interest at the time because no large numbers of animals had been in Saskatchewan or, indeed, anywhere in the western Arctic during the previous winter. In 1955-56 most of the caribou wintered in northern Manitoba and the northeastern corner of Saskatchewan. There was little doubt that the herd in Saskatchewan in 1956-57 included large numbers which had wintered far to the east in 1955-56. Reports in recent years had indicated a strong easterly shift of nearly all western caribou herds (Kelsall, 1955). The above data indicated the beginning of a reverse shift, which the following text will amplify.

Flying reconnaissance, and discussions with game officers in March 1957, led to the choice of the Saskatchewan caribou herd for continuing and intensive study. Their movements from April, 1957, until August, 1958, are shown on Maps 3 to 8. The maps indicate major migration routes at all seasons as well as calving areas and winter ranges.

During April, 1957, the study caribou were in full northward migration. On April 28, more than 14,000 caribou crossed Lake Athabasca between Stony Rapids and Camsell Portage. This mass movement had a depth of nearly 100 miles and extended toward the northeast on a front 150 miles wide. It was interesting to note that this front coincided closely with the disappearance of most of the snow from the ground, until the barren-grounds were reached about May 12. By June 7 the caribou had proceeded nearly 200 miles into the barrens, and had changed their direction northward. The herd split, as shown on Map 3, with the smaller group proceeding northward on the west side of the Thelon River. Exact movements of this group during the following several months were not known because the field men remained with the larger herds east of the Thelon River.

Calves were born throughout the month of June, with the height of calving about June 12. Areas where the majority of calves were dropped are designated on Map 3. During calving the caribou continued toward Beverly Lake and the Dubawnt River, having changed their direction of movement to the northeast once more. It was believed that during the calving period many bulls and other non-breeding

animals preceded the main herd across the Thelon River near Beverly Lake and into the high country to the northeast.

Toward the end of June the main group of cows and their calves were in the eastern calving area shown on Map 3. After the first week in July they bunched together along the west side of the Dubawnt River between Marjorie Lake and Beverly Lake. They also assembled west of Beverly Lake and moved toward the Thelon River. The animals on the Dubawnt crossed between July 12 and July 17 and a great many of them rapidly proceeded eastward toward Baker Lake. On the afternoon of July 18 the leading elements of the herd were only about 20 miles from the Baker Lake trading post. The same evening they reversed their direction of movement and travelled westward almost as fast as they had been travelling eastward only two or three hours previously. This appeared to be the turning point in their summer migration. The reversal in movement was remarkably abrupt although some caribou remained well to the north and to the east throughout most of July, in the general area shown on Map 4.

It was estimated that about half the study herd moved north of the Thelon watershed in July, and about half remained to the south. The heavy summer mosquito and black fly infestation had commenced by July 18. The abrupt reversal in movement on that date appeared to be partly, if not entirely, due to a change in wind direction and velocity which required the caribou to move westward to get relief from flies. For several weeks afterward most animals were in large, closely massed herds. Their erratic movement at this time made it impossible to move camps frequently enough to keep caribou always near at hand. When wind velocities were low and the fly nuisance bad, they moved so rapidly that a herd of 10,000 to 20,000 animals might be in sight for only a few hours.

By early August most of the large bands had dispersed and caribou were wandering westward in small groups. On August 1 only one major group of caribou could be found, and it was seen on the Thelon River more than 130 miles west of the nearest camp. By August 20 the majority of caribou were dispersed widely throughout the area south of latitude 64°30', as shown on Map 3. Only one concentration of animals was found at that time, and it was far to the west near Clinton-Colden Lake. The caribou had gone north of Artillery Lake and proceeded to the west. Topography probably played a major role in preventing their earlier dispersal in the manner of the other caribou.

During the whole period from August 17 to September 30, there were almost no movements by major groups of animals because of the dispersal referred to above. However, there were definite patterns of drift evident, as shown on Map 4. The southward drift seemed to terminate approximately at tree-line where the animals turned to the west and northwest. Following animals, which were strung out for more than a hundred miles, continued to move southwest.

By the end of September a true migration toward winter ranges was evident and the caribou once more had started to form into major groups. Instead of following a single broad migration path toward a single range, however, many diverse movements took place. Map 5 illustrates major lines of movement to winter ranges until early January, 1958.

In late September the research camps were maintained among that group of animals concentrated northwest of Artillery Lake. By the first week in October animals coming from the northeast followed the west shore of Artillery Lake and finding their movements obstructed by the swift Lockhart River, either swam the river and continued southward, or turned back northwestward.

Subsequent movements of the western portion of the herd are shown on Map 5. The groups which were north of Aylmer Lake proceeded to the barrens along the south side of Contwoyto Lake, and then turned southward to the vicinity of Yamba Lake which they reached in January, 1958, and wintered there. Another large group of caribou moved westward from Aylmer Lake and spent November and early December moving slowly north of MacKay Lake. At some time during December this group was augmented by animals coming from the northwest which had spent the previous winter near Great Bear Lake. This movement is not shown on Map 5. The combined herds subsequently travelled southwest nearly to Yellowknife and Gros Cap on Great Slave Lake before a remarkable mid-February migration took them once more to the barrens. Stragglers from this herd moved east of Thompson Landing, as shown on Map 5, and took up winter quarters along the north shore of McLeod Bay.

Further to the east, two-thirds of the study herd moved west of the east arm of Great Slave Lake in October. A minor movement, shown on Map 5, took animals around the southeast corner of McLeod Bay and out on to Douglas Peninsula. Only a few thousand caribou were involved in this movement. Some of them wintered in the Fort Reliance area and others crossed McLeod Bay and joined those animals al-

ready on the north shore of Great Slave Lake.

Another group, also shown on Map 5, followed the Snowdrift River and Nonacho Lake westward. By November 7 they were in the vicinity of Gagnon Lake and by January they had passed Rutledge Lake and taken up winter quarters in the area shown on Map 6. This was a large group which included some tens of thousands of animals and may have represented nearly a third of the whole study herd. Its migration into forested country was later than that of the more southern elements of the study herd and included caribou that had remained longer on the barrens.

The main southward movement of caribou towards Saskatchewan took place on a broad front, extending from Nonacho Lake to the Dubawnt River. As is shown on Map 5, the front was split by the Taltson River which was still open when caribou arrived. On October 7 numerous caribou were moving southwest along the open Taltson River between Rennie Lake and Gray Lake, in an effort to find easy places to cross. The animals continued to the southwest on a narrowing front throughout October until, by October 25, many of them were only about 40 miles north of Uranium City.

By early November most of the herds had split into two groups, possibly because the open water of Tazin Lake lay in their path. The larger of the two groups swung to Lake Athabasca and then proceeded rapidly eastward following the shore of the unfrozen lake. By November 7 some caribou had reached the Fond-du-lac River a few miles west of Stony Rapids and were crossing there on new ice. By November 20 most of them had crossed and proceeded southward to the general area where they subsequently wintered.

Animals diverted to the west of Tazin Lake wandered during the next two months in a triangle formed by Slave River, the north shore of Lake Athabasca and the Northwest Territories boundary. This is shown in simplified form on Map 5. Some of them remained for the winter south of Tazin Lake, but most followed the shore of Lake Athabasca nearly to Fort Chipewyan, then circled back until they were once more on the lake shore not far west of Camsell Portage. From there they made repeated attempts to cross Lake Athabasca which was still partly open. Shortly after the lake froze over in mid-December most animals succeeded in crossing to the vicinity of Jackfish and William Rivers.

The above movements during autumn and early winter produced eight separate wintering areas for the

study herd. These are shown on Map 6.

Movements of the easternmost wintering group shown on the map have not been described in the text. The number of animals involved was not more than one or two thousand. It was thought that they arrived on their winter range by migrating down the Dubawnt River and south to the position shown. A few other isolated bands, whose movements are not described in the text, are also shown on Map 6. Their numbers also were unimportant.

In most cases, the wintering caribou remained relatively static within the boundaries shown, with the exception of those which wintered just north of Great Slave Lake. They remained in motion throughout most of the winter and it was not until March that they settled into the areas of concentration shown.

Spring migrations from the winter ranges appear on Map 7. For the most part these movements commenced in late April, 1958. The two northwesterly movements shown on Map 7 are tentative because it was physically impossible to follow all the caribou from their winter ranges, and these two groups of animals were abandoned. The initial directions of movement are believed to be correct but it was not known where calving took place, nor where they travelled during the rest of the summer.

The other movements on Map 7 are essentially correct. In the spring animals in the Great Slave Lake area moved nearly eastward, and animals in Saskatchewan moved northward until tree-line was reached, where all migrations merged into a broad front. The herds split on the Thelon River, as they had done in 1957, however, movement to high ground west of the Thelon was numerically smaller. Most caribou moved east of the Thelon and proceeded to the Beverly Lake area. Some calving took place on high ground south of Beverly Lake, as in the preceding year, but the majority of animals crossed the Thelon River and Beverly Lake and had their calves near the north shore of Beverly Lake. The approximate area is shown on Map 7.

Additional calving took place far to the westward near Artillery Lake. Animals involved were only a few thousand strong, and likely included groups late in moving from forest to barrens.

Following calving, the majority of animals moved northeastward from Beverly Lake in much the same manner as

in 1957. There was no massing of caribou on the Dubawnt River because many animals had crossed Beverly Lake before break-up. Other animals swam the Dubawnt and proceeded eastward toward Baker Lake. Those animals which stayed south of the Thelon water system included less than one-quarter of the study herd. The various movements until the middle of July are shown on Map 7.

Following commencement of the fly season, about mid-July, caribou once more formed into large groups which wandered widely and erratically. For the most part these groups were well north of the Thelon River in the extreme north and east portion of the occupied area (Map 8). They moved to the height of land between the Thelon and Back Rivers, before turning abruptly and heading southeast. On July 30 many caribou were moving westward along Aberdeen Lake towards Beverly Lake, and by August 1 this movement included most of the animals in the area. On that date the lead animals were on the Thelon River some miles west of Beverly Lake, and stragglers extended about half way along Aberdeen Lake. This whole movement was accelerated after the big lakes were reached. Animals which passed the west end of Aberdeen Lake on July 30 were on the Thelon River over 30 miles distant on the afternoon of August 1. During August 1 they were stopped by the river but the same evening they commenced swimming across and most of them had crossed by August 3. It was estimated that at least 64,000 animals took part in this movement. It should be mentioned, however, that a few bands of caribou were still moving along the north shores of Aberdeen Lake and Beverly Lake as late as the first week in September.

After crossing the Thelon the study herd dispersed widely, as it had done the previous summer. By August 10 it was possible to find only one small concentration of animals. As in the previous year general directions of drift were apparent, as indicated by arrows on Map 8. Once again those animals far to the eastward turned north and northwest as they approached tree-line. For a few days in mid-August this produced a local concentration along the east shore of Artillery Lake. However, even this bunching was of short duration and by August 27 search flights between Artillery Lake and Mosquito Lake showed a dispersal of about one caribou per square mile. Nownere were more than two or three caribou seen travelling together.

Factors Governing Movement

Banfield (1954), Kelsall (1957), and many others have described the seasonal movements of caribou. Most authors made some speculations regarding the factors controlling movement and migration. Clarke (1940) not only described caribou movements, but detailed some of the current beliefs regarding these movements. He pointed out many fallacies in these beliefs, but left the exact nature of movement and migration open to further question. The present study has contributed to the understanding of movements and migration, and some of the findings which call for special comment are presented below.

Snow as a Factor Governing Movement

A study regarding snow as a factor governing caribou movement and migration has been published by Pruitt (1959). Briefly, he indicated that caribou movements in winter were governed by the depth, density and hardness of snow. These snow characteristics acted individually or in combinations of two or more. Movements appeared to be along definite snow gradients; that is, from areas of high density to areas of low density, from high hardness to low hardness, or from great depth to little depth. Thus, optimum areas of occupancy existed where minimum values prevailed under all three conditions. Since snow conditions in winter were subjected to frequent changes, movements down these gradients could be almost continuous.

Pruitt's data revealed that caribou wintering south of Lake Athabasca in 1957-58 remained almost exclusively in areas of favourable snow conditions. This was of great interest in view of past observations that caribou avoided good winter ranges not far distant from the marginal ranges they occupied. It was strongly suspected that these marginal ranges had optimum snow conditions, and adjacent good ranges had poor snow conditions.

Some of Pruitt's specific conclusions regarding caribou and snow are summarized as follows:

1. Areas of heavy caribou concentration were characterized by snow which was soft (hardness range 6.5 to 60 grams per square centimeter for forest stations, and 50 to 700 grams per square centimeter for lake stations); light (density range of .13 to .20 for forest stations and .13 to .32 for lake stations), and thin (thickness range of 19 to 50 centimeters).

2. Areas having no caribou were characterized by snow which was sometimes soft, but might be very hard (hardness range of 35 to 7,000 grams per square centimeter for forest stations and 150 to 9,000 grams per square centimeter for lake stations); dense (density range of .16 to .92 for forest stations and .17 to .92 for lake stations), and thick (thickness range of 31 to 82 centimeters).

3. Caribou appeared to have a threshold of sensitivity to hardness, density and thickness of the snow cover. The apparent threshold for hardness was approximately 50 grams per square centimeter for forest snow, and 500 grams per square centimeter for lake snow. The density threshold was approximately .19 or .20 for forest snow and .25 or .30 for lake snow. The thickness threshold was approximately 60 centimeters. When these thresholds were exceeded caribou reacted by moving until they found snow of less hardness, density, or thickness.

Banfield (1954) considered that large and recent burned areas in forested winter ranges were a major factor governing caribou movement and distribution. Kelsall (1957) agreed, but noted some exceptions. Pruitt's findings shed new light on the movement and distribution of caribou in winter. Burned areas are open and exposed, by comparison with adjacent unburned areas. As a result snow in the burns could be expected to have a greater density and hardness due to wind action. It might also be deeper because all of the snow would be on the ground and not retained on tree branches, as in heavy forest. Thus, caribou would avoid burned areas because snow conditions were not optium, as well as because of a lack of food.

Workers in recent years have been struck by the fact that caribou feed only once or twice over a given range in a single winter. Pruitt's investigations disclosed that the process of digging feeding craters, and walking around during the course of feeding, packed the snow sufficiently that hardness and density thresholds were exceeded.

Pruitt also speculated that snow might have an influence on caribou movement and direction during spring and autumn migration. To some extent this was true. Caribou moved northward in spring only after sunshine and thawing had modified the winter snow cover. The movement of breeding cows north from Beverly Lake in June, 1958,certain-

ly seemed to have been halted by late snow. Some autumn movements observed have been oriented between areas of greater snow cover and areas of lesser snow cover. However, most long autumn migrations took place when there was little or no snow.

It is important that the limiting role of snow on winter ranges have further study. Caribou thresholds of tolerance may frequently be exceeded on otherwise excellent ranges. If this is the case, it should be known for purposes of management and range assessment.

Topography and its Relation to Movement and Distribution

It often has been pointed out that during the course of the major spring and autumn migrations caribou follow routes of least topographic resistance. After freeze-up and before break-up frozen waterways commonly are used as highways for moving caribou. The present study with its intensive observations prompted the conclusion that, while topography was an important factor in caribou movement, it was generally not the controlling factor, even in cases where no other factor was apparent. In spring, for example, caribou were seen to follow long narrow lakes which presented easy walking on firm ice, even though the lakes pointed a few degrees off the course they were following. However, if a lake took an abrupt turn which would lead the animals many degrees off course, they usually abandoned it.

A unique topographical influence on migration was found in the region adjacent to the 64th parallel immediately east of the Mackenzie-Keewatin boundary. In this area an extensive series of parallel drumlinoid ridges ran in an east-west direction. In both 1957 and 1958 it appeared that the ridges were responsible for causing a deflection of the caribou movement to the east. They were bare of snow on top and provided excellent feeding and travelling conditions and were probably followed for that reason. These ridges were near the northern extremity of the spring migration and included part of the southern calving area. It was in this region where migration began to lose its directional impetus. It is doubtful if such a topographical feature would have deflected caribou if it were found nearer the midpoint of north-south migration.

During summer months, when caribou movements were erratic rather than directional, topography exerted more influence than at other seasons. Animals travelled and fed on any sort of terrain in summer, even so, open water of

larger lakes and rivers often controlled the direction of movement and acted as a factor in bunching or dispersal. Lawrie (1948) gave an excellent description of how caribou bunched at watercourses and dispersed when they had passed them. Three examples of that behaviour were noted during the present study and described above in the section on movements:

1. The bunching along the Dubawnt River in July, 1957, when the field men estimated that as many as 100,000 animals massed on the west side of the river before they started to swim across.

2. The massing of animals during their southward migration along the north side of Beverly Lake, and to the west along the Thelon River in early August, 1958.

3. The splitting of the herd in November, 1957, when it reached Tazin Lake in northern Saskatchewan, with one group proceeding east and one west along the open water of Lake Athabasca.

In each case there was pronounced dispersal of the massed herds once they had crossed the major water obstacles.

Topographical influences on caribou movement and distribution in winter were not pronounced. The animals apparently utilized almost any sort of terrain having suitable food and snow cover. On heavily forested winter range there appeared to be some predilection for areas with many lakes. This was probably because frozen lakes provided natural and preferred escape cover and resting grounds.

Wind as an Influence on Movement and Migration

As pointed out by Clarke (1940) there seemed, in the broad sense, to be no consistent correlation between wind and caribou migration. At certain seasons and under certain conditions caribou moved positively in relation to wind, particularly wind of high velocity. This was particularly the case in seasons of heavy black fly and mosquito infestation.

When winds were light, and insects were bad, caribou generally drifted into the wind. The rate of drift seemed to be adjusted so that combined air speed and ground speed were sufficient to keep insects away from the face.

When winds were strong, however, the animals usually drifted before them. Presumably when this happened air velocity was great enough to keep insects on the ground. Under conditions of heavy insect infestation and little wind the animals moved rapidly and erratically. They seemed to be attempting to escape from their tormentors by moving faster than the insects or by bunching so tightly in massed groups that only the outermost animals were exposed to the full force of fly attacks. Late in the season, when the animals showed evidence of exhaustion from this constant movement, they often would stand for hours at a time in a wind that swept their tormentors away.

Wind thus played a major role in caribou movements during the latter half of July and early August when insect infestations were at their height. It has been mentioned that a change in wind direction seemed responsible for halting an eastward migration near Baker Lake on July 18, 1957. Because prevailing winds in summer were generally light to moderate and from northward directions, it was believed that the northward movement of caribou after calving and during the worst of the fly season may have been controlled by these factors.

In winter, when directional movements were not strong, caribou avoided frozen lakes and other exposed areas during periods of low temperature and high wind. When caught in such exposed areas they drifted with the wind. Undoubtedly these movements were related to windchill. There probably are times when combinations of wind velocity and temperature make it impossible to face into the wind without suffering extreme discomfort.

An instance in which wind directly affected a major migration was noted on May 10 and 11, 1957. The migrating herd was moving strongly northeast on a front exceeding 100 miles and with an even greater depth. At that season only the most impassable topographical barrier would deflect the general direction of movement. On May 10 an unusually strong northwest wind developed and the animals changed direction abruptly to head into the wind and maintained their new direction for about a day and a half until the wind dropped. They then immediately resumed their northeast course, and apparently maintained it until the calving areas several hundred miles distant were reached two weeks later. It was notable that the animals headed into the strong wind rather than away from it, as they did in the fly season, or in winter.

August Dispersal of Caribou

It was mentioned previously tnat a wide dispersal of the study herd occurred in August of 1957 and 1958. In both years the only exceptions to complete dispersal occurred when the herd was influenced by major topographical obstacles.

This dispersal had not previously been reported as a consistent part of annual movement and distribution. It appears, however, that it occurs annually to a greater or less degree and explains the difficulty experienced in finding any groups in August during operations over the past ten years.

The thoroughness of the dispersal was illustrated by the experience of August 22 and 23, 1958. At tnat time no discrete herds had been seen for some time, altnough tne field parties were seeing small groups of animals daily. On two trips flown between Artillery Lake and Mosquito Lake nowhere were more than three animals seen travelling together, and most animals were alone. The distribution seemed to be about one animal per square mile. From the distance covered in the two flights it seemed that most of the study herd was dispersed over an area of nearly 50,000 square miles. Experience the previous August had paralleled the observations above. During 590 miles of flying most sightings involved only a single animal, and most groups of more than tnree or four animals were at such natural "bunching" spots as water crossings. Data from these two years are summarized in Table 2.

A curious feature of the observations in 1957 and 1958 was the dispersal of young calves, as well as all other age and sex classes. On the outward journey in 1958, when visibility was particularly good, 50 caribou were counted in 180 miles. Of these, 28 per cent (14) were calves, which ground segregations had shown to be close to the percentage of calves in the whole population. Only five of the calves were travelling with adult females, the other nine appeared to be completely alone. These observations corresponded to those of previous years when many lone calves were seen wandering the barrens in August. Often young calves are unwary so a relatively high calf mortality from accidents and predation might be expected during periods of dispersal.

Table 2. Dispersal of Caribou During August of 1957 and 1958, Giving the Frequency of Observation of Group Size, Total Caribou Seen, Miles Flown, and the Average Number of Caribou Seen per Mile.

No. of Caribou in Group	Frequence of Observation	
	August 17, 20 21, 1957.	August 22, 23, 1958.
1	70	88
2	16	9
3	6	3
4	4	0
5	4	0
6	3	0
7	1	0
8	1	0
10 or more	3	0
Total caribou seen -	239	115
Total miles flown -	590	316
Animals seen per mile -	0.40	0.36

The causes of caribou dispersal following the fly season were not understood. It may be that by then they were so lethargic and exhausted that concerted group movements were beyond their physical capabilities. Warble flies, which were abundant through August, may have dispersing influences. Certainly caribou could be driven almost to distraction by warble flies, and to escape them they dashed about the country at full speed, in complete indifference to almost everything else.

Summary

1. Movements and distribution of the study herd of caribou from April, 1957 to August 1958, are described.

2. In general, movements followed a predictable pattern of travel between forested winter ranges and barren-ground summer ranges.

3. The herd which began as a single unit late in the winter of 1956-57 split into eight widely separated herds during the autumn migration of 1957.

4. Not all the separate wintering groups rejoined on the summer ranges in 1958.

5. A major study of snow as a winter environmental factor was conducted in 1957-58. The results have been presented in detail in a separate report.

6. This study indicated that caribou movements in winter were along lines of definite snow gradients; that is, from areas of high density to low density, high hardness to low hardness, and great depth to little depth.

7. Thresholds of sensitivity to snow hardness, density and thickness were determined, and these may account for many caribou winter movements, previously inexplicable.

8. The influence of topography on movement and distribution was found to vary seasonally.

9. Topographical influences were weakest during migrations between winter and summer ranges.

10. In summer months topographical features such as lakes and rivers often controlled the direction of movement of caribou and acted as controls in the bunching or dispersal.

11. In the broad sense, there appeared to be no consistent correlation between wind and caribou migration.

12. At specific seasons and under specific circumstances wind controlled the speed and direction of caribou movement for limited periods.

13. Wind influences on movement were most pronounced during the season of heaviest insect infestation when the animals took advantage of the wind in escaping harassment.

14. In general, caribou drifted against a light wind but drifted with a strong wind, although one exception to this was noted.

15. A pronounced dispersal of the study herd was encountered following the insect seasons in 1957 and 1958.

16. Autumn dispersal, suggested as a consistent part of annual movement and distribution, had previously escaped attention.

17. There was evidence that the dispersal separated many calves of the year from their parents.

POPULATION STUDIES

Introduction

During the progress of the research program considerable statistical data relating to caribou were gathered in two categories:

1. Data, mostly from autopsies, were gathered relating to measurements and weights of individual caribou. A considerable body of such material has been presented by Banfield (1954) and Kelsall (1957), and there would seem little point in presenting further data at this time. However, some summarized material relating to calves will be given.

2. A large body of material was gathered relating to herd compositions. Since caribou were seen almost daily by the field men, some segregation data were gathered continuously. In addition, further material was supplied by aerial surveys and censuses. Comparable material has been presented, particularly by the writers mentioned above, but some of the new information is valuable because it includes larger samples and more accurate age and sex figures.

It was difficult to determine the age and sex composition of large herds of caribou. The primary difficulty was in recognizing and visually segregating different age and sex classes on the ground. Despite variances of opinion as to difficulty in this matter, all field workers seemed unanimous in believing that only experienced men could make worthwhile segregations, and even the best of observers made errors. Thus, we found during the winter of 1957-58 that our most competent field men, inadvertently shot 11 two-year females during collection of what were thought to be 63 adult females. The errors were not discovered until close examination was given by McEwen to the teeth and jaws of the caribou involved.

The segregation by sex of young age classes (calves and yearlings) was particularly difficult. Few significantly large such segregations were made, even during the present study. Such data as were gathered were mostly from obviously atypical groups of animals, and are scarcely worth presenting here.

The second difficulty inherent in determining population composition was the fact that at almost all times of the year caribou showed some degree of segregation on an age and sex basis. Thus, segregations made on calving grounds were not typical because mature bulls were present only as fractions of their true proportion in a herd. Even during the rutting period, distribution was not always as random as was generally believed.

The above matters should be kept in mind in reading the following text. The writer believes, however, that the population data given are the best gathered to date among mainland barren-ground caribou, and may be the best it will be possible to gather for some time.

Size of the Study Herd

When the research program started in April, 1957 it was desirable to get a close estimate of total herd strength. A proper aerial census, using strip transect methods, was not deemed advisable during the study because of financial limitations. However, it was possible to make herd estimates at five different times during the program. The results, although subjective, showed remarkably close correlation and are described below.

(a) Initial Estimate, April, 1957

When the study started almost the entire herd was congregated south of Lake Athabasca. On April 28 more than 14,000 animals were tallied crossing Lake Athabasca within a period of only a few hours. From the known duration of the movement at this time it was considered that 50,000 to 100,000 animals were involved. In retrospect, however, it appeared more likely that about one-sixth of the herd was seen April 28 and that 84,000 to 98,000 animals were present. These, together with a few animals which wintered north of Lake Athabasca, would place herd strength at very close to 100,000.

(b) Estimate from Camp 1

During the first ten days that field men were at Camp 1 (May 24 to June 2, 1957) they were able to tally the caribou which migrated through that particular area. Those numbered about 13,600 judging from tracks and sightings of animals during rather extensive flying at that period. It was thought

that caribou missed by the field men at Camp 1 would bring the total animals passing the Mosquito Lake area to about 20,000. This, in turn, constituted about one-quarter of the animals east of the Thelon River. An additional 10,000 to 15,000 were thought to have moved northward to the west of the Thelon. Here again a total numerical estimate would place herd strength close to 100,000 caribou.

(c) Estimate at Dubawnt River Crossing

During the second week in July, 1957, the study herd bunched remarkably along the west side of the Dubawnt River, described elsewhere. Most of the herd was involved, with the exception of caribou west of Thelon (10,000 to 15,000 animals) and other predominantly bull groups. Because of close bunching, rapid movement, and the large size of the various aggregations, only visual estimates of numbers could be made. However, of the various experienced field men and bush pilots who saw the concentration, none estimated less than 80,000 animals, and most thought there would be nearer to 100,000. A total estimate at this time therefore, would place herd strength between 105,000 and 125,000 animals. This correlated well with the earlier estimates, considering that the herd had just been augmented by more than 16,000 calves.

(d) Wintering Estimate, 1957-58

In the chapter on herd movements it was described how the herd split into eight separate wintering groups. The numerical strength of each group was estimated in various ways. The results of these estimates appear in Table 3, and the groups referred to are shown on Map 4.

The total figure of 142,500 was considerably larger than previous estimates. This was expected for two reasons.

1. The section devoted to movements described how the southward movement at Duck Lake in northern Manitoba involved exceptionally few caribou in the autumn, 1958. Through investigations of wintering caribou by J. Robertson of the Manitoba Game Branch left no doubt that the provincial population was the lowest for many years. A few

of the "missing" animals may have wintered to the north in Keewatin District. Most of them must have joined the study for the simple reason that there was no other place they could have gone. It was known that animals of the two groups met in the area between Baker Lake and Dubawnt Lake in July and August 1957, and movement from that area was predominantly south and west. Some tens of thousands of caribou which wintered in northern Manitoba in 1956-57 undoubtedly spent the following winter in northern Saskatchewan and southern Mackenzie District.

2. In 1956 a summer migration took a herd of about 50,000 caribou from southern Keewatin to wintering grounds north of Great Bear Lake. During the autumn of 1957 the majority of this herd moved east of Great Bear Lake and then south. In late December they joined caribou of the study herd near MacKay Lake. It was deduced that only one-third of the 48,300 caribou (shown for the MacKay Lake on Table 3) were originally elements of the study herd and that the balance (32,200) had joined them from the north.

   In the section devoted to human utilization it may be noted that the study herd strength during the 1957-58 "calf year" was about 101,000. At the time the above estimates were made human utilization and other losses had reduced the strength to about 92,000 animals. Assuming reasonable accuracy for all figures involved, we can account for the total population shown in Table 3 as follows:

Original study herd	-	92,000
Recruitment from northwest	-	32,200
Recruitment from Manitoba	-	18,300
TOTAL WINTERING CARIBOU		142,500

(e) Estimate at Thelon Crossing

A remarkable crossing of the Thelon River a few miles west of Beverly Lake, in early August 1958, has been described. On August 1 the writer flew the length of the restricted movement and estimated the caribou between Aberdeen Lake and the crossing to

number 64,000 animals. Stragglers in the wake of the main movement boosted the total to between 80,000 and 85,000. This was thought to include the bulk of the study herd plus those animals recruited from Manitoba during the previous winter. It probably did not include the 52,000 animals which wintered around Yamba and MacKay Lakes, or the scattered and relatively small groups already west or south of the Thelon before the crossing described.

When the research project started, the study herd was estimated at 100,000 caribou which number was augmented by caribou from the east and northwest so that the wintering population in 1957-58 was estimated at 142,500 animals. This herd probably constituted three-quarters of the remaining barren-ground caribou population. The only major groups outside the study area were found:

1. North of Great Bear Lake where Thomas made a limited census and estimated 16,000 animals.

2. In northern Manitoba where censuses were not made but where animals were less numerous than in any recent year, and almost certainly numbered less than 40,000.

There appeared to be no other significant wintering groups in 1957-58 anywhere on the mainland ranges. The total population therefore would be about 200,000 caribou.

Although the study herd was swollen numerically during the study, this did not indicate a net gain in caribou numbers. Most of the late arrivals were from wintering groups where human utilization was slight, and because they appeared late in the study, a basic figure of 100,000 will be used in this report to calculate herd gains and losses throughout the whole period.

Herd Composition

As mentioned in the introduction, determination of herd composition was difficult because animals were grouped to some degree by age and sex at almost all times of the year. Furtnermore, only practiced observers could make the necessary determinations of individual animals on the ground. Segregations involving tens of thousands of animals had to be made at all times of the year and a choice exercised to select those segregations which would show true herd composition.

Table 3. Numerical Estimate of Study Herd Wintering Groups, 1957-58, as Shown on Map 6.

Wintering Group	Method of Making Population Estimation	Numbers
Northern Saskatchewan		
Williams River	Air-ground observations	12,000
Tazin Lake	Air observations	2,000
Wapata-Pasfield Lakes	Air-ground observations	15,000*
Eastern group	Air observations	2,500*
Northwest Territories		
Thubun-Rutledge Lakes	Air observations	30,000*
Fort Reliance south	Air-ground observations	2,500
Northeast Slave Lake		
Gordon Lake	Random transect counts	6,200
McLeod Bay	Random transect counts	15,000
MacKay Lake	Strip transect counts	48,300*
Yamba Lake	Bush pilot reports	4,000
Small, scattered groups	Hunter repts. and air observations	5,000
TOTAL WINTERING ANIMALS	----------	142,500

* groups augmented by animals from outside the original study area.

Population Structure

Prior to the present study most workers considered that herd composition might be shown best by segregations at the rutting period. It was thought that if caribou ever would be randomly distributed it would be at that particular period. Recent work showed, however, that this was not necessarily true, particularly if the animals were migrating during the rut, as in 1957 and 1958. The momentum of migration caused some separation of breeding and non-breeding animals and also separated early breeders and late breeders. Thus, animals in the vanguard of the migration into Saskatchewan in October and November, 1957 included a relatively high proportion of early breeding adults. By November 7 they were virtually through the rut and most adult males had shed their antlers. At the same time the hindmost groups

were still actively in rut, and a relatively high proportion of yearling and other non-breeding animals were with them.

It seemed to the observers that caribou were as randomly distributed as could be hoped for during the period of August dispersal discussed previously. In 1958 it was possible to segregate the dispersed animals at four widely separated points between August 9 and 27. The results of these segregations presented in Table 4 are thought to present herd composition accurately. The table shows females over two years of age, males over two years of age, yearling animals and calves. From the data obtained in the field, a more complete break-down was not practical because insignificant numbers of yearlings and calves could be segregated by sex.

Table 4. Herd Composition as Shown by Segregations by Several Observers at Four Widely Separated Areas During the August Caribou Dispersal.

Place	Time (Aug./58)	Total	Female	%	Male	%	Yearling	%	Calf	%
Camp 31	9-11	286	99	34.6	81	28.3	42	14.7	64	22.4
33	11-15	401	206	51.4	68	17.0	24	6.0	103	25.6
34	11-22	206	98	47.6	47	22.8	14	6.8	47	22.8
35	16-22	1117	464	41.5	290	26.0	81	7.3	282	25.2
35	18-27	156	61	39.1	57	36.5	9	5.8	29	18.6
35	23-27	90	33	36.7	31	34.4	8	8.9	18	20.0
TOTALS		2256	961	42.6	574	25.4	178	7.9	543	24.1

The table shows that 42.6 per cent of the herd was composed of females more than two years old. These were all considered to be breeding animals. During random segregations at other times of the year the female percentage varied, depending on the herd segment being worked with at the time, from about 35 to 55 per cent. Adult males were calculated to make up 25.4 per cent of the herd. It was probable that not all of these would be breeding animals because it was suspected that males often did not breed until they are three years old. Yearlings were shown to make up 7.9 per cent of the herd and calves 24.1 per cent.

The adult male: female ratio was calculated to be 60:100, and was believed to be an accurate presentation of the situation in 1958. By comparison Banfield (1954) found a ratio of only 35.8 males:100 females. This was a considerably lower male percentage than anything that had been noted in recent years, except among predominantly female groups of animals on the calving grounds. Alaskan investigators have discovered much more even sex ratios among caribou ranging upward from 76 males:100 females (Skoog, 1957) to a ratio of nearly 100:100 (Olsen, 1957).

The breeding potential of the study herd would almost certainly not be impaired because there were fewer adult males than adult females. Verbal information from personnel connected with the Canadian reindeer industry in the Mackenzie Delta revealed that satisfactory breeding was maintained with a ratio of 18 males:100 females. Appreciably higher male percentages among reindeer resulted in more strife among males and less effective breeding.

The 7.9 per cent yearling composition encountered lends confidence to the herd figures presented earlier. It was shown previously that calves in the late winter of 1957-58 made up 12.1 per cent of total animals. In order to compare that figure with the one for August, 1958, it was necessary to delete the current calf crop (24.1 per cent). When the animals segregated in August, 1958 were totalled, excluding the calves, it was found that yearlings made up 178 of 1,713 caribou, or 10.5 per cent. This compared favourably with the 12.1 per cent found approximately six months earlier; the two per cent drop suggesting a 13 per cent mortality among that particular age class during the period between segregations.

In Table 4 it was determined that 56.5 per cent of cows had calves surviving in August, 1958 (961 cows:543 calves). In late July, and the first two days in August, segregations among post-calving bands of animals showed that 60.7 per cent of cows had calves. There probably was considerable calf mortality during the August dispersal of the animals, and this was reflected in the figures. In October, 1957 only 37.4 per cent of the cows had calves with them (940 cows:352 calves) but this reflected the fact that 1957-58 was a poor calf year, whereas 1958-59 was above average.

Differential Sex Ratios

It was pointed out in the preceding section that the study herd had a ratio of 60 bulls:100 cows. It would be expected that in common with most mammals, the sex ratio at birth was approximately 100:100. It also would be expected that, as is the case among larger polygamous ungulates, there was a differential sex mortality following birth which resulted in females becoming numerically dominant. Unfortunately our statistical data on this subject were few, primarily because of the difficulty connected with sexing any significant number of young caribou through visual observations of live animals.

Limited data indicated that the sex ratio at birth was about 50 males:50 females. In 1952, 1957 and 1958 a total of 105 dead calves were found on calving areas. The data involved are presented in Table 5, where 52 males were counted for 53 females. These figures indicated limited differential mortality, if any, immediately following birth and were thought to indicate true sex ratios at that time. Few of the calves involved would have been more than a week old at the time of death and probably the majority of them were only a day old.

Table 5. Sex Ratio at Birth as Determined by Examination of Dead Calves Found Over a Period of Years.

Year Found	Male	Female
1952	9	6
1957	6	6
1958	37	41
TOTALS	52	53

Insufficient numbers of dead calves were found following the calving period to assess sex differences in mortality. The only strong indication of conditions was in the segregation of live calves some months after birth. Between August 28 and October 8, 1957 McEwen and Thomas succeeded in sexing 17 additional calves. These data are presented in Table 6. Among the 196 calves segregated, 77 were males and 119 were females, for a sex ratio of 65

males:100 females. Even though the data were few, some confidence was placed in them because of the particular care which was given to securing them. It was remarkable that the unbalanced sex ratio found among calf caribou only two to four months old, compared closely with the 60 male:100 female ratio determined among adult animals. This indicated that differential mortality, favouring female survival, occurred during the first few months following birth. It also indicated that adult sex ratios for any particular year class of caribou were largely determined through the mortality at that time. The mechanics of differential sex mortality among young caribou were not understood although the fact itself was recognized. Leopold (1933) suggested that the males of some species are more subject to loss from disease and parasitism than the females. It may be worth noting, even as an isolated instance, that the only caribou ever found so heavily parasitized by intestinal tapeworms that its survival seemed doubtful was a male calf (Kelsall 1957). Furthermore, among ten calves drowned at a major crossing in August 1951, eight were males and two were females.

Table 6. Sex Ratio Among Calf Caribou Two to Four Months after Birth.

	Male		Female
August 12 - 14, 1958	8		9
August 28 - Sept. 24, 1957	31		49
October 4 - 8, 1957	38		61
TOTALS	77		119
Ratios	65	:	100

Summary

1. Segregating caribou by sex and ages classes proved to be a difficult task.

2. Estimates of size of the study herd placed the population at about 100,000 animals.

3. During the study some animals were recruited from Manitoba herds and some from the Great Bear Lake region.

4. Studies of herd structure revealed 42.6 per cent female adults, 25.4 male adults, 7.9 per cent yearlings and 24.1 per cent calves.

5. There was evidence of a differential mortality among caribou calves which produced a male:female ratio of 65:100 in the first few months following birth.

Birth of Calves

Introduction

As a result of recent studies the process of caribou calving has been better understood. The season of the year involved had restricted past research on the calving grounds because calving took place at break-up, when neither ski nor float-equipped aircraft could operate, and when travel by any other means was extremely difficult. Of eight expeditions to study calving, planned by the Canadian Wildlife Service since 1947, only three were reasonably successful.

Banfield (1954) and Kelsall (1957) presented what was known of calving among caribou under study. Murie (1944), and more recently, Skoog (1956) and Olsen (1957) presented material pertaining to those caribou inhabiting mountainous areas in Alaska. Useful analogies may also be drawn from European and Asian literature pertaining to reindeer -- Shaposhnikoff (1955) and Anon (1952).

Because calf survival among the mainland barren-ground herds had been poor in most years since 1949, a careful study of calving was desirable during the present research program. Special aircraft arrangements and additional manpower were procured in both 1957 and 1958 to ensure success.

Topography of Calving Grounds

The calving grounds used in 1957 and 1958 are shown on Maps 3 and 7. Field parties were located in the northeast sector near Beverly Lake. To the north of that lake the ground rises in a series of steep rolling hills to an altitude of over 1,000 feet half-way between Beverly Lake and Back River. South of Beverly Lake the ground rises less precipitously although Dubawnt Lake, 70 miles to the south, is 700 feet above sea level, and the intervening land may reach 1,100 feet. In the 1957 calving area shown on Map 3 the minimum elevation, except in river valleys, was 640 feet and the maximum elevation approximately 1,100 feet. Other calving areas shown on Maps 3 and 7, but not the subject of special study, also exhibited relatively high elevations. East of Artillery Lake the ground rises to 1,300 feet above sea level, and west of Beverly Lake to at least 1,000 feet.

Particular mention is made of the elevations because earlier observations (Kelsall, 1957) indicated that caribou habitually chose high rugged country for calving. This was true even though they utilized lower lush pastures immediately before the birth of their calves, and immediately afterward.

The calving area south of Beverly Lake is a rolling country characterized by an overlay of glacial till and rubble. It also has several prominent eskers and many drumlinoid ridges running in an east-west direction. Some lakes in the centre of the area were as much as six miles in length and three miles in width. Drainage flowed northerly through a series of small lakes, sloughs and streams which emptied into Beverly Lake, and adjacent rivers. Near the calving area the shores of the Thelon River and Beverly Lake were characterized by a series of raised beaches with intervening swampy areas of former lake bottom which rose to a height of at least 440 feet above sea level. Wright (1955), stated that the presence of a post-glacial arm of the sea was indicated by deposits of marine shells at a height of 360 feet above sea level near Beverly Lake.

North of Beverly Lake the area was characterized by glacial till and rubble-strewn hills, and some of the lakes were larger than those to the south. Northward, beyond the height of land, the country assumed a truly formidable aspect. It was generally rolling and boulder-strewn with vegetation as poor as anywhere on the mainland barrens.

Vegetation of Calving Grounds

Vegetation studies of the calving area were few and largely of a qualitative nature. However, they illustrated some points of interest.

As might be expected, vegetation of the Thelon Valley and the shores of Beverly Lake was luxuriant by comparison with the more xeric hilltops where calves were born. To obtain quantitative differences between the calving and post-calving areas, line point transects of 1,000 points each were taken in each area by Loughrey in 1957. Results from these transects are given in Table 7, and Loughrey's accompanying description follows:

Transect No. 1

"The first transect was in the rocky ridge country imme-

diately south of the camp on Beverly Lake. That area was characterized by sandy ridges with much boulder till and glacial debris. There had been some frost-sorting of smaller materials into polygons up to ten feet in diameter along the slopes of the hills. Quite a large percentage of this area was unvegetated, with 28.1 per cent of the sample points falling on clear ground, snow, water or rock. Mosses accounted for 8.8 per cent of the total ground cover; of these 4.5 per cent were of small unidentified types.

"Lichens were the predominant group, accounting for 28.8 per cent of the sample points. Of these points, 1.9 per cent consisted of small lichens of several insignificant species. Several species of lichens were identified; Cetraria cucullata and Alectoria divergens were the most important, accounting for 16.2 and 9.3 per cent of the total ground cover, respectively. Although numerous, neither of those lichens was large or densely massed enough to be considered of primary importance as potential caribou food.

"Shrubby plants made up 9.0 per cent of the total ground cover; Labrador tea, Ledum groenlandicum, (7.6 per cent) was the most important species. Dwarf birch, Betula glandulosa, accounted for 1.3 per cent of the ground cover. However, it should be noted that the latter species tended to grow in dense concentrations, some of which were missed by the transects. The rest of the vegetation consisted of four other plant species and a number of unidentified grasses, sedges, and small annual plants. Grasses and sedges accounted for 4.4 per cent of the total ground cover. Crowberry, Empetrum nigrum, represented 5.3 per cent. Bearberry, Arctostaphylos rubra, and bilberry, Vaccinium uliginosum, accounted for only minor percentages of the total ground cover (0.1 and 0.3 per cent respectively). Cranberry, Vaccinium Vitis-Idaea, 14.7 per cent, was second only to the lichen Cetraria cucullata in total ground cover.

"Plant succession in the sandy areas was noted as follows: sand, small mosses, small lichens, large moss, Cetraria cucullata, Alectoria divergens, Vaccinium Vitis-Idaea, Empetrum nigrum, and Ledum groenlandicum."

Transect No. 2

"Transect No. 2 was taken in the post-calving area extending inland from the south shore of Beverly Lake.

The transect, consisting of 1,000 points, commenced 100 yards from the gravel shore-line of the lake and extended to the base of the first ridge. This area consisted of former lake bottom and was characterized by a sphagnum-bog which was being almost completely invaded and colonized by hydrophylic species of grasses, sedges, and several shrubby plants.

"Only 12.1 per cent of the area was unvegetated and of this 9.1 per cent was snow and water. The snow was then in the process of melting and running off. Mosses accounted for 23.7 per cent of the ground cover, of which Sphagnum comprised the greatest proportion.

"Lichens accounted for only 4.7 per cent of the total ground cover with Cetraria cucullata the dominant species. It was found in the more xeric locations on the tops of the grass-sedge hummocks. Of the four lichens identified only Cetraria cucullata could be considered significant as a potential caribou food item.

"Shrubs accounted for 16.1 per cent of the total ground cover. Labrador tea, Ledum groenlandicum, 13.1 per cent, and dwarf birch, Betula glandulosa, 3.0 per cent, were the most important.

" Grasses and sedges were the primary group, accounting for 25.8 per cent of the total ground cover. The most important species in this group included - bentgrass, Calamagrostis sp., Carex sp., and cotton grass, Eriophorum sp. Cranberry, Vaccinium Vitis-Idaea was the most common species of vegetation. Crowberry, Empetrum nigrum, bilberry, Vaccinium uliginosum, and bearberry, Arctostaphylos rubra, accounted for a minor portion of the ground cover -- 2.2, 1.1 and 0.3 per cent respectively. Several unidentified annual plants together accounted for 1.0 per cent of the total ground cover."

Table 7. Composition of Ground Cover by Percentages on the Beverly Lake Calving and Post-Calving Areas of the Summer Range, June, 1957.

Item	Calving Area Transect No. 1	Post-Calving Area Transect No. 2
Snow	3.7	4.6
Water	0.3	4.5
Bare earth	13.9	2.8
Bare rock	10.2	0.2
Total unvegetated	28.1	12.1
Moss, small	4.5	1.0
Moss, large	4.3	-
Spnagnum	-	22.7
Total mosses	8.8	23.7
Lichens, small	1.9	0.1
Cetraria cucullata	16.2	4.0
Cladonia coccifera	0.3	0.2
Peltigera canina	0.3	-
Peltigera aptnosa	0.3	-
Alectoria divergens	9.3	0.3
Sphaerophorus globosus	0.4	0.1
Umbilicaria decussata	0.1	-
Total lichens	28.8	4.7
Salix sp.	0.1	-
Betula glandulosa	1.3	3.0
Ledum groenlandicum	7.6	13.1
Total snrubs	9.0	16.1
Grasses and sedges	4.4	25.8
Empetrum nigrum	5.3	2.2
Arctostapnylos rubra	0.1	0.3
Vaccinium uliginosum	0.3	1.1
Vaccinium Vitis-Idaea	14.7	13.0
Annual plants	0.5	1.0
Total ground vegetation	25.3	43.4
Total percentages	100.0	100.0

Vegetation Utilized During and after Calving

On the higher calving areas the choice of food was generally limited because it often could be found only on hilltops and along ridges where the ground was snow-free. In some areas lichens were dominant and were utilized. In other areas flowering plants took the form of scattered dried sedges and grasses, as well as Dryas integrifolia and Vaccinium Vitis-Idaea. Once the animals left the calving grounds they showed great preference for fresh green vegetation whenever it could be found.

The following sequences of feeding and phenology were noted by Loughrey during the present study. From June 15 to 20 feeding on green vegetation was confined to the fresh shoots of cotton grass, Eriophorum spp. About June 20, fresh shoots of other sedges and grasses became available and were eaten, either individually or with the cotton grass. From about July 1 to 10, the dwarf birch, Betula glandulosa, came into leaf and extensive feeding on it was noted. About July 10 leaves appeared on the willows and they then became a major food for caribou.

Cotton grass, and other sedges and grasses, first became available in the low areas along lakes and drainage systems. Most parturient cows sought the rocky ridges and remained there during the first few days after their calves were born. They had little opportunity to find fresh vegetation, consequently, their feeding habits were much the same as in winter. The bulls, on the other hand, were the first to seek out the marshy sloughs as soon as the cotton grass became green. As a consequence, there was a further separation of the calving females from bulls and other non-calving animals.

Weather

Weather during the calving period will be discussed in the section on the windchill study, and pertinent records are shown in the tables therein. It generally may be stated that in 1957 and 1958 conditions on the calving areas were colder, wetter and windier than had been recorded previously. It is possible that in spring the Beverly Lake area is less favourable meteorologically than other potential calving areas on the mainland.

Because weather has been suspected as an important factor in calf survival, its continued study is well worth while. Better knowledge of weather patterns and predict-

able weather conditions would provide an indication of the calf mortality to be expected in any year.

Recent History of Calving

Calving success has been studied annually in the western Arctic since 1950-51. It had been the practice to inspect wintering animals during late winter months, when all groups sighted were counted and calves were segregated and totalled separately. As far as possible random segregation flights were made over each herd in order to eliminate age and sex biases. The final result was a figure showing the per cent of calves among total animals. Such segregation counts appear in Table 8.

Table 8. Annual Increment Since 1950, as Measured by Calves against Total Animals in Late Winter.

Year	Total Segregated	Calves	Per Cent Calves
1950-51	1,503	108	7.2
1951-52	1,877	235	12.2
1952-53	5,982	1,692	28.3
1953-54	2,311	303	13.1
1954-55	3,293	361	11.0
1955-56	1,109	63	5.7
1956-57	1,985	155	7.8
1957-58	10,867	1,306	12.0
1958-59a	3,508	910	25.9
1958-59b	1,774	441	24.9*
Average per cent			13.7

* Figures gathered by Manitoba Game Branch in December, 1958 and not included in the average per cent figure.

Segregations from 1950 to 1958 inclusive were made during late winter and thus represent an actual increment figure. In other words, the calves segregated had survived the better part of their first year of life, including the crucial first winter. The figures for 1958-1959, however, are different. Those for 1958-1959(a) were gathered by field men, between August 1, 1958 and December 12, 1958. At that time the calves were only two to five

months old, and it can be assumed that there was considerable mortality during the remainder of the winter. The figures for 1958-1959 (b) were gathered in northern Manitoba in December, 1958, by J.Robertson of the Manitoba Game Branch.

Banfield's initial caribou study (Banfield 1954) showed that calf percentages of 20 per cent or greater might usually be expected. Among Alaskan caribou herds it also was usual for the annual increment to exceed 20 per cent of total animals, and on occasion even to exceed 30 per cent (Skoog 1956, 1957, Olsen, 1957). It may be assumed that the mainland barren-ground caribou under study are capable potentially of reproducing at a rate in excess of 20 per cent of total animals per year.

Table 8 shows that actual rates of annual increase were considerably below what might be expected. Since 1950 the average annual increase has been only 13.7 per cent of total animals. In three of the nine years involved (1950-51, 1955-56, and 1956-57) the annual increment was less than 10 per cent. In only two of the remaining years (1952-53 and 1958-59) did increment exceed 20 per cent of total animals.

The sizes of the samples from which the figures were derived have varied from year to year. In 1957-58 it approximated 10 per cent of total animals. In 1950-51, on the other hand, it included only about 1 per cent of total animals on western ranges. Despite the relatively small sampling in some years the figures are presented with confidence. Each year they have been checked frequently and no major discrepancies have developed. It has been interesting to note that trends in any given year were almost invariably range-wide. Thus, if increment was low in the west in a given year, it also was low in the east. The close agreement in calf percentages in Table 8 for the east and west in 1958-59 could be duplicated for the other years involved.

Because increment was low in seven of the last nine years and because it was annually uniform on a range-wide basis, grave concern was felt by all persons involved in caribou studies. In several years it was known from Indian and Eskimo hunter reports, and from field autopsies by Canadian Wildlife Service workers, that the pregnancy rate had been good, despite low calf crops. It also was determined that low calf percentages usually were apparent within a few weeks after the time of parturition. Although

in 1950-51 Indian hunter reports indicated a high rate of pregnancy, in mid-July, scarcely two weeks after the last calves were born, segregation counts among 4,000 caribou indicated an initial calf crop of only 9.9 per cent. Table 8 shows that the final increment measured in March and April of 1951 was only 7.2 per cent calves. Such reports and observations, and comparable ones covering other years, led to the conclusion that in the recent low calf years heavy mortality occurred on the calving grounds shortly after parturition. To carry such reasoning one step further, it was supposed that because low calf crops seemed to be range-wide, there might well be a single causative factor involved. Further development of this idea will be presented subsequently.

Parturition

In both 1957 and 1958 the first caribou calves of the season were seen on or about May 31. In both years some calves had been born before the cows arrived at major calving areas. In 1957 the birth rate rose rapidly from June 1 to a peak at about June 11 and 12, then tapered off rapidly and was considered to have terminated about July 3.

Similar quantitative data cannot be presented for 1958 because the field men lost contact with most of the caribou during the latter part of June, even though some observations of cows and young calves continued throughout the month. The limited observations possible indicated that the height of calving was slightly later in 1958 than in 1957, with the peak of parturition occurring no earlier than June 14, and possibly later. We were forced to this conclusion by the fact that the calf crop for 1958 was better than average and many, if not the majority, of calves born prior to June 11 perished. Only a few of the cows must have calved early in June.

Before 1958 actual parturition had not been observed closely, and had been recorded only imperfectly. During the studies in 1958 several of the field men were able to observe the process of birth. Notes concerning two such instances are of interest. The first involved observations of a cow by Dr. de Vos just before noon on June 12. The cow lay down almost immediately after being first observed. The rest of the herd lingered for ten minutes and then gradually left so that by 12:30 p.m. she was bedded down alone. The following notes were recorded:

12:30 - Cow lying down but reaching out to graze intermittently.

12:40-13:05 - During this period the calf was born, after which the cow expelled and ate the placenta.

13:05-14:00 - Calf tried repeatedly to stand but unable to do so for long. Cow licked and dried calf which finally stayed on its feet at the end of the period.

14:00-15:00 - Cow grazed a few minutes but turned most of her attention to her recumbent calf.

16:00 - Calf first tried to nurse but was not succesful. Eventually cow and calf moved slowly away and were out of sight by 16:50.

It was remarkable that in the above observations the new-born calf was seen trying to suckle only once during a period of nearly four hours. Possibly some suckling activity occurred but was not seen.

Somewhat comparable chronological data were given by Wilk, who discovered a cow with a newly born calf and during the succeeding 4½ hours recorded the following:

10:30-10:55 - Cow had just given birth to a calf when discovered. She continued to lick the calf until the end of the period during which time the calf finally succeeded in standing on its feet.

10:55-11:30 - Cow began to graze and the strength of the calf increased so that by the end of the period it was able to try to suckle.

11:30-12:24 - The cow continued to graze and the calf got up several times to follow her. The calf fed for the first time at the end of the period.

12:24-14:50 - Over the period the cow succeeded in expelling and eating all the placenta, she grazed and bedded down intermittently with the calf, but at the end of the period became alarmed and galloped away with the calf following.

The present writer, (Kelsall 1957) recorded the amazing precocity of caribou calves immediately after birth, in comparison with other young ungulates. Both calves

observed above were seen to stand within minutes of birth, both attempted walking with some success, within an hour or two, and both were fully mobile within two to three hours.

However, it should be noted that the first few hours following birth normally were relatively quiet for young calves. Although they were capable of walking and even running soon after birth, their chances of survival were greatly increased if there was no disturbance at that period. Mortality was greatly increased by such disturbances as adverse weather and predators.

Capturing Calves

As a necessary part of the windchill study in 1958 plans were made for the capture of young calf caribou. It was planned originally that capture might best be effected by having one man devote his full time to it. He would cruise known calving areas in a light aircraft and land whenever he saw what he thought to be a very young calf.

In practice it was not necessary to make such special efforts. The field men were so well located that early in June it would have been possible to take more than the ten calves that were captured. Some calves were picked up with the help of an aircraft as planned, but for the most part, they were captured by individual field men who found them conveniently near camp.

The reactions of female caribou varied somewhat when their calves were taken, as noted by Kelsall (1957). Most females showed alarm at first, and in some cases appeared to make a conscious effort to distract attention from the calf by dashing wildly about close at hand. Some females remained in the general area for a few hours or even for a day, apparently hoping to reclaim the lost calf. Others simply wandered away and were not seen again. Some of the field men thought that the tendency to distract attention from the calves, and to remain searching in the area, was stronger in older females than in young ones.

Most of the calves captured were estimated to be less than five hours old. In view of this it seemed that the process of imprinting, which forges the strong bond between a young animal and its parent, must start almost immediately after birth. In any event by the time a calf was one day old it was recognized by its dam, and she would search for it if it strayed. Even at that early age calf and parent seemed able to recognize each other by the

grunting noise characteristic of the cows during the calving period. Once contact had been achieved through grunting, sight and smell gave positive recognition. Calves could be decoyed by simulating the female's grunt.

In a large nursery band of caribou some calves and cows were always trying to establish recognition and the process was incredibly noisy. As the animals moved about their feeding or travelling the lively young calves were continually dashing through the herd and getting temporarily lost. As a result, there was a continuous grunting, startlingly similar to that made by a large group of pigs. Only at that season and under those circumstances were caribou at all vocal.

Breeding Females

During the course of the study the number of barren female caribou on the calving grounds could not be determined. At Stony Rapids Wilk and Terry gathered information during April and May of 1957 concerning the pregnancy ratio among cows killed by the local Indians. Of 63 adult cows reliably reported on, 50 (79 per cent) were pregnant.

In 1958, most female caribou examined were taken by the field crews for a histological study of reproduction. Between November 1957 and June 1958, 52 cows were examined, of which 36 (69 per cent) were pregnant.

This apparently low pregnancy ratio for 1958 was remarkable when compared with an almost 100 per cent ratio on the calving grounds. In reporting his histological studies McEwen gave an explanation that is both interesting and important. He examined lower jaws of all animals collected, in order to age them accurately. Of the 52 specimens taken, 11 were actually two-year females rather than adults, and none of them were pregnant. Excluding the two-year class, McEwen calculated that approximately 88 per cent of adult females were pregnant. This was a considerable difference from the 69 per cent pregnancy derived from the gross figures.

To make such a correction for the 1957 figures it would have to be assumed that field men could not differentiate between two-year and adult females in the field, and that the two-year class was present in proper proportion in each sample taken. These assumptions were probably not valid for 1957 because most examinations for pregnancy in that year were made, not on caribou taken by the field men

on the assumption that they were adult females, but on adult females shot by Indians and subsequently examined by the field men. There probably were not as many second year females included in the 1957 sample because it was easier to recognize an adult among animals dead on the ground.

Using the corrected data, despite those reservations, it was found that two-year-old females would make up 17 of the 63 sample animals, leaving 46 which could be considered adults. Because 50 of the 63 animals actually were found to be pregnant it was apparent that there either were fewer two-year-olds in the 1957 sample or that some of them were pregnant. The latter was not probable, in view of McEwen's findings. In either event, there was close to 100 per cent pregnancy among adult female caribou in 1957.

Calf Mortality

It has been noted elsewhere that a great deal of calf mortality occurred during the parturition period in 1957. In that year field men were able to make only limited observations because of the need to move their camps at a difficult period of the year. Only nine calves were found on the calving grounds, four of which had died of exposure or starvation, two had been killed by wolves, and three had died from undetermined causes.

In 1958 three different field camps were established on the calving grounds at the time of heaviest mortality, and more than 100 dead young calves were found. Although dead calves were found until about June 26, most of them were thought to have died during the adverse weather experienced up until June 11.

Most dead calves were from Camp 26 (Map 2) where 85 were discovered. In summarizing the data Wilk gave an interesting estimate of the mortality causes as follows:

1. Thirty-five per cent of the mortality was attributable directly to adverse weather. The blizzard conditions of June 6 and 7 were thought to have been most crucial.

2. Five per cent of the mortality was attributed to predation. Only five or six of the 85 dead calves had been killed or eaten by wolves. In such an area, with many dead calves lying about on the ground, wolves would scarcely have to kill any calves to feed themselves.

3. Forty per cent of the mortality was attributed to separation of the calves from the cows at too early an age and subsequent death from exposure and starvation. Separation could be caused by the presence of wolves in the calving area, when young calves were unable to relocate their mothers after disturbance. Separation could also be caused by young calves dropping from exhaustion as a herd kept moving during a blizzard. The field men also thought that the presence of their camps caused some separation of calves and females because of the inevitable disturbance.

4. Injuries were thought to account for about 10 per cent of calf mortality. A number of the dead calves had bruises which could have caused death, and several times a female was seen striking out with her front feet at a stray calf.

5. Other causes such as inherent weakness at birth and still-birth were thought to account for the remaining 10 per cent of mortality.

It should be noted that adverse weather could increase mortality in all cases mentioned above, in addition to the instances where it was considered the sole factor involved. Injuries would be more likely during blizzards. At such times separation of the calves from the cow would inevitably be more frequent, predators would find hunting easier, and calves with inherent weaknesses would be less likely to survive their first few days.

In both 1957 and 1958 mortality was seen which could be classed as accidental. In nearly every case the late season and adverse weather were major contributing factors. For example, Thomas recorded the finding of a week-old calf in 1957 as follows:

"The calf had apparently become stuck after crossing a small stream about two days previously. The calf had gone through five feet of water 12 to 18 inches deep, 12 feet of slush 12 to 18 inches deep, and then seven feet of snow, before becoming stuck. It had only three feet of snow to go through to reach bare ground. From tracks and pellets around the calf the cow had apparently stayed (in the area) for some time, possibly two days."

Further incidents analogous to the above were noted in 1958. Certainly persistently wet snow, such as encountered during both 1957 and 1958, was not a constant

factor on calving grounds, but must have contributed to mortality even under other than blizzard conditions. On July 17, 1957 Terry found five dead calves at a point on the Dubawnt River where an ice shelf persisted against the river bank and where caribou had tried to go ashore. Cows and older animals had been able to negotiate the shelf but calves, unable to climb out of the water, had died of exposure.

Wilk illustrated another occurrence which killed young calves under adverse conditions:

> "A dead calf (was found) on the blue ice of a small bay at Beverly Lake (on June 8, 1958). We suspected that the calf died of exposure during a storm after falling down and being unable to get on its feet again. After watching another calf cross a lake, it seemed to us that a young calf would have a great deal of trouble regaining its feet during a high wind such as occurred during the blizzard. The calf we watched fell repeatedly and struggled a long time in getting on its feet. At the same time the cow crossed the patch of slippery ice without much trouble."

Wilk also noted another hazard which can be fully appreciated only by persons who have experienced such blizzards as the field men did:

> "We believe that young calves born during a blizzard would find it difficult to get their first meal, especially if the wind was very strong. During a blizzard the calves have trouble getting to their feet in the high wind and it is doubtful that they could stand in the wind and suckle for the first time, unless sheltered by the mother's body. Those strong at birth would have a much better chance of succeeding than the weaker ones. The first meal is an important one, for without it the young calves would not gain the strength to withstand the cold and to travel, should it be necessary."

De Vos and Ray were at Camp 27 (Map 2) during the calving period in 1958, and they too made observations indicating mortality among very young calves. De Vos's assessment of mortality observed differs from the conclusions of the other field men and for that reason it is worth mentioning. He says in part:

> "On July 13 a survey was made of calf mortality on a drumlin on which a calving band of 600 head had spent

about 24 hours during the two previous days. On an area of about 25 acres seven dead calves were located. All of these calves, except one, had died during the previous 24 hours. Five of these calves were skinned and examined more closely. All had bruise marks, two had pierce marks, one had a broken skull, and another one a broken vertebral column, It seems that the pierce marks were made by antlers. It is thought that these calves had died as a result of violent action by adult caribou. They varied in age from one day to one week and it is possible that these animals became lost in the band, tried to attach themselves to strange females and were violently attacked by same. Since the previous day was fine, mortality as a result of inclement weather must be excluded. After disappearance of the snow, another five calves were found in the same 25 acres, also ranging in age from one day to one week. Thus, one calf was found per two acres of calving ground."

These observations were discussed, shortly after they were made, with de Vos and other of the field men. It seemed that something unusual was involved. While all field men had occasionally noted females striking or butting at strange calves, such incidents seemed to be uncommon among calving bands under reasonably normal conditions. In fact, serious intra-band strife seemed to be relatively uncommon at any time. It was supposed that some of the dead calves had died somewhat earlier than de Vos estimated, during periods of adverse weather. With as many as 600 adult caribou on a 25-acre hill, dead or dying calves might easily receive bruises and injuries through trampling. Also, if predators had seriously disturbed so large a herd, the resulting confusion might easily have resulted in injury to young calves, even in fine weather.

Pruitt made an effort to assess the effects of the blizzard of June 6 to 9, 1958, on a particular group of animals.

For about 8 hours on each of the four days he observed a particular hillside which was used during calving, and for only a short time afterward. During the days of observation he saw 7, 10, 8 and 4 calves. He assumed that calves seen on the hill had been born there, and that calves might be born at any hour of the day or night. He multiplied by 3 for a calculated total of 87 calves born on the hill during the entire period. At the end of the observations he searched the hill and found four dead calves, which gave him an approximate mortality figure of 5 per cent.

Summary

1. The birth of calves, among the mainland barren-ground caribou under study, had been little understood although analogies had been drawn from Alaskan and Russian literature.

2. Calving usually took place in high, rugged country described in the present study in some detail.

3. Vegetation on calving areas was poor in comparison with that of adjacent lower-lying country.

4. The results of limited vegetational analyses are presented.

5. Weather during calving, discussed in detail later, was generally relatively cold, wet and windy in 1957 and 1958 in comparison with 1948.

6. It is suggested that weather records from known calving areas should be kept annually as an aid in assessing early calf mortality and the annual increment to be expected.

7. Calving success on western ranges has been studied annually since 1950 and the data are presented in tabular form.

8. Caribou potentially are capable of producing annual calf crops in excess of 20 per cent of total animals although in most years reviewed the mainland barren-ground herds have fallen far short of this.

9. The average annual increase since 1950 was 13.7 per cent although in three of the nine years involved it was appreciably less than 10 per cent, and in only two years did it exceed 20 per cent.

10. Indications were that the mortality resulting in low calf crops generally occurred on the calving grounds at or immediately following parturition.

11. The first calves were noted about May 31 in both 1957 and 1958 and calving was at its height about June 11 in 1957, and a few days later in 1958.

12. Detailed field notes gave two examples of the actual process of parturition and activities for a few hours thereafter.

13. Even though young caribou calves were very precocious, tne first few nours following birth were normally quiet. At that time disturbances in a number of forms might result in mortality.

14. Little difficulty was involved in capturing very young calves for physiological studies in 1958.

15. Limited data of the pregnancy ratio among adult cows in 1957 and 1958 are presented.

16. The percentage of pregnancy was nearly 100 per cent in 1957 and considerably more than 80 per cent in 1958.

17. Calf mortality is described and speculations ventured regarding the mortality from various causes.

18. The most serious mortality factor in both years was adverse weather, which killed many calves directly and contributed to mortality from other causes.

19. Some of the mortality of very young calves was caused by early separation from the cows and subsequent death from exposure, starvation, predation or injury.

20. Some instances of accidental death caused directly by adverse weather are described.

The Windchill Study

Introduction

During studies near Bathurst Inlet in 1951, the writer and N.G. Perret noted considerable mortality among young calf caribou, which they ascribed, directly or indirectly, to adverse weather. These observations were recorded in a report by Kelsall (1957). It was stated therein that, "It seems likely that there is a chilling point at which the bodily functions of the caribou calf are greatly impaired. The crucial conditions are probably brought about by various combinations of high winds, low moisture content, low temperatures (not necessarily below freezing) and continuous or frequent precipitation. There is no shelter on the calving grounds except from winds, which seem to make caribou nervous and keep them on the move for greater distances and longer periods than usual. Many calves not killed outright (by adverse weather) must be separated from the herd and die later from exposure and hunger. Others must be drowned at water crossings, or taken by predators. It is believed that during the calving periods in 1950 and 1951 50 per cent of the young calves may have perished in this way."

In the spring of 1954 the author and Andrew Radvanyi investigated another calving area in the vicinity of Bathurst Inlet. Although caribou calving was not observed the area had been used as a calving ground during the previous spring. The nearly intact skeletons of 30 young calves were discovered during the course of a 100-mile walk which traversed the region. The skeletons were inconspicuous and difficult to find. The country had a high population of wolves and it seemed remarkable that they could have overlooked any dead calves. The high calf mortality indicated by these findings might be correlated with blizzard conditions which had prevailed in 1953 during the height of calving.

During several other years since 1949, when low calf crops were noted, it was suspected that adverse weather could be a major lethal factor. Because of this previous experience the field men, during the present study, were admonished to watch for weather conditions which might adversely affect calves at the time of birth.

Investigations in 1957 and 1958

In both years of the study, field camps were pro-

gressively nearer Beverly Lake for the first part of June, and close by Beverly Lake during the last half of the month. Calving caribou were observed at Camps Nos. 2, 3, 4, 5, 24, 25, 26, 27 and 28, as indicated on Map 2.

In 1948, A. H. Lawrie of the Canadian Wildlife Service spent the month of June at Beverly Lake to observe calving, (Lawrie, 1948). He was not fortunate enough to see parturient females although they must have been near by. Lawrie's 1948 records may be compared with those made in 1957 and 1958.

In 1948 the percentage of calves in the herds was exceptionally good. Of seven segregation counts of nearly 9,000 animals, none showed less than 17 per cent calves, and one was over 28 per cent. Lawrie later made limited segregation counts during the rutting period, which showed that calves comprised 25 per cent of the herd.

In 1957 calf survival was poor. Segregations of the largest herd immediately after parturition showed that calves comprised only 16 per cent of total animals and, because bulls were almost entirely absent at that time, the true calf percentage was expected to be lower than that. Segregations of thousands of animals, during the winter of 1957-58 indicated an average calf crop of 12 per cent of total animals. There were definite indications that survival for 1958 would be better than average, with calves representing 20 per cent or more, of total animals.

Weather records for the three years involved are detailed on Tables 9, 10 and 11. While some calving took place in late May and early July in both 1957 and 1958, the month of June was the period when nearly all calves were born. The tables provide a daily record of the maximum and minimum temperatures, precipitation, wind direction and velocity, and a windchill value. Maximum parturition occurred about June 11 in 1957 and about June 14 in 1958. Though specific dates for 1948 were lacking, it was assumed that maximum parturition was at a comparable time near the middle of June.

The weather records during the three years mentioned showed some remarkable differences, summarized as average monthly values in Table 12. The weather in 1948 was excellent in comparison with 1957 and 1958; temperatures were higher, strong winds were less frequent and of relatively short duration, and precipitation was comparatively light. The mean June temperature in 1948 (49.8°F.) was

more than 14 degrees higher than in 1958 (35.2°F.) and 10 degrees higher than in 1957 (39.8°F.) While precipitation was noted on ten days in 1948, snow was involved on only one of those days. In 1957 and 1958 precipitation was much more frequent and snow was recorded on a number of days. In both the latter years blizzard conditions of several days duration were recorded on different occasions.

In both 1957 and 1958 it was believed that calf mortality could be attributed, directly or indirectly, to prolonged periods of adverse weather. In 1957 the periods between June 1 and June 13, and between June 18 and June 22, were characterized by low temperatures, high winds, and precipitation. Calf mortality was noted during the first period mentioned. Unfortunately, observations of calving and calf mortality were interrupted in 1957 because of the necessity of moving camps, and by a major accident to the aircraft being used. In 1958 particularly adverse weather was encountered during the periods June 1 to 3, June 5 to 10, and June 17 to 20. Calf mortality occurred during the first two periods; but the same was not true of the period June 17 to June 20, probably because precipitation was negligible.

Windchill Values

A disadvantage of the weather records kept by the field parties was that they did not provide a quantitative measure of the cooling effect of the weather, as related to calf mortality. A more refined expression of the cooling effect of air temperature and wind velocity was afforded by employing the "windchill factor" developed by Dr. Paul A. Siple. Loughrey suggested this approach following his field work in the spring of 1957. Tabular data were extracted from a table of windchill values, prepared by the Climatic Research Unit, C.Q.M.G., U.S. War Department, January, 1943. The tables were calculated from the original formula developed by Siple and Charles F. Passel of the Antarctic Service.

Windchill is a measure of the quantity of heat which the atmosphere is capable of absorbing within an hour from an exposed surface one meter 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 transferred is expressed in kilogram calories per square meter per hour per degree centigrade (0.369 B.T.U. per square foot per hour per degree Fahrenheit).

Windchill expresses the rate at which an uninsulated body would lose heat if placed out of doors under ambient conditions. This value was calculated for the human body on the assumption that skin temperature remained at the comfortable level of 91.4°F. In actual fact, the skin temperature falls due to the loss of stored body heat, the rate of cooling dropping accordingly. The resultant rate of actual cooling can be obtained from the table by reducing the air temperature by the number of degrees difference between 91.4°F., and the reduced skin temperature.

The approximate windchill factor for each day in the month of June during the three years under discussion may be read from Tables 9, 10 and 11. It should be noted that the windchill measurement used here did not take into account a number of factors, some of which may prove on further investigation to be of considerable importance:

1. Windchill measurements do not allow for relative humidity, which may be an important factor in body heat loss at near-freezing temperatures. Neither do they take into account wetting of the exposed surface and subsequent cooling from evaporation. A new-born calf is wet after parturition which would enhance the chilling effects of wind velocity and air temperature. Comparable effects would be produced by periods of precipitation.

2. The body temperature of caribou is slightly higher than the 91.4°F., upon which the windchill factor is based, but this fact could be compensated for in an equation of caribou windchill.

3. The body surface of caribou is covered with hair which provides a variable amount of insulation, depending upon whether it is wet or dry. The insulating value of wet hair was determined experimentally to be almost zero.

4. The windchill effect would be most critical for newborn calves, and would decrease with increase in age and size of the animals, due to a more favourable surface to volume relationship.

5. The amount of body cooling is probably cumulative from hour to hour under extreme weather conditions. If physiological cooling continued to the point where the loss of energy through body heat dissipation exceeded the energy available from metabolic processes, then the

animal could be considered to be suffering physiological stress. If this stress was cumulative and severe, it undoubtedly could produce mortality.

6. The windchill factor does not take into account the added heat derived from solar radiation. In the Arctic on clear days this may equal 200 calories per square meter per hour.

Despite the above variables, it was thought that the windchill factor provided a crude means of indicating the specific meteorological conditions under which mortality among young calf caribou could be expected. Weather operated either as a direct or an indirect mortality factor. In the latter role it kept the caribou moving and thus weakened calves one or two days old which were not able to travel long distances. This promoted the separation of the cows from their calves and also increased the possibility of accidental death. We also might speculate that there was a loss immediately after parturition if adverse weather did not allow young calves an opportunity to become dry.

It was stated that warm weather prevailed in 1948 and that a good calf crop resulted. In 1957 the weather was poor and calves comprised only 12.1 per cent of total animals. A daily maximum windchill value of 1,000 or more was obtained for 16 out of 30 days in 1957, but for only two days in 1948. In 1957 there were several successive days of high windchill with associated precipitation and two periods of successive days with windchill factors of over 900, as can be seen from the tables. The first period, June 1 to 13 inclusive, had an aggregate daily maximum windchill amounting to 13,700. The second period, June 18 to 22 inclusive, had an aggregate of 4,900 for five days.

Although the 1957 observations of dead calves in the field were limited, of nine calves that died from natural causes, four appeared to have died from exposure or starvation. Seven of them found on June 13 and 14 were judged to have been dead from two to six days. This would place the time of death between June 8 and 10. This was a period of strong northwest winds with minimum temperatures below freezing and scattered snowstorms (Table 10) correlating with the first period of high aggregate windchill. Only one dead calf was found after the period June 18 to 21 when the weather was characterized by strong northwest winds and below freezing temperatures accompanied by snow, hail and rain. That period corresponded to the second period of high aggregate windchill. Maximum parturition in

1957 occurred during the first period of high aggregate windchill.

A different picture emerged during 1958. Many more dead calves were discovered because the field men had more opportunity to search for them. More than 100 dead calves found appeared to have died during the adverse weather of June 1 to 3 and June 5 to 10. Of 16 dead calves found by de Vos in a limited area, four were judged to have died on June 9. That date culminated a period of six days with an aggregate windchill of 7,100. Six of the calves were considered to have died on June 11, the day following the second period of high aggregate windchill. No date of death was designated for the other six calves. At Camp 26, where Wilk, Thomas and Pruitt discovered about 90 dead calves, most of the mortality had occurred during the first ten days of June.

There was a third period of high windchill between June 17 and 20 which was not entirely comparable to the earlier ones during the month because there was negligible precipitation. Because of the lack of this associated factor, and because calf survival was good despite early June mortality, it was concluded that lethal weather values were not reached. Although calf mortality was high during the first eleven days of June, 1958, the majority of calves were born following that period.

Loughrey suggested that "when the average daily maximum windchill factor exceeds 1,000 for a period of six days or more, or when the total of daily maximum windchill factors for a period of less than six days amounts to 6,000, calf mortality that may be attributed to weather conditions is to be expected." His statement is provisional because the variable factors previously discussed have not been evaluated.

National Research Council Study

Following the field work in 1957, it was anticipated that a windchill factor could be a useful index in predicting quantitatively the calf losses from known weather records. It also was considered that it might be possible to predict advance success on the basis of long term weather forecasts. However, distinct limitations were recognized, and it was felt that expert physiological assistance would be needed in order to further such work.

As a result, Dr. J.S. Hart and Dr. O. Heroux of the National Research Council joined the field parties in 1958. A base of operations for them was established at Mosquito Lake (Camp 22). During the first three weeks in June they conducted physiological research on new-born caribou, which were flown to them from the other field camps north of Beverly Lake.

Hart and Heroux used oxygen consumption as an index of the metabolic response of the calf caribou to the environmental factors of cold, wind and wetness. They found that oxygen consumption was at its lowest when the animals were in still air in the temperature range 10 to 20 degrees Centigrade. Below 10 degrees Centigrade metabolism was affected and oxygen consumption increased. When calves were exposed to wind of over 12 miles per hour in addition to cold, the oxygen consumption was still higher. Finally, the highest oxygen consumption was observed when the hair was wet and the calves were exposed to both wind and cold.

Their findings were limited by the fact that extreme weather conditions necessary for testing the extent of mortality were not encountered at Mosquito Lake in 1958. However, the investigators felt that their findings could be extrapolated beyond the figures derived from their field testing. Extrapolation would show values up to, and beyond, lethal points. The important thing that remained to be done was to expose calf caribou to conditions sufficiently severe to determine the lethal points quantitatively.

After they had determined basic metabolic changes by oxygen consumption measurements the investigators discovered that skin temperatures varied inversely with oxygen consumption. That correlation apparently functioned independently of changes in environmental conditions, (up to the critical temperature point where metabolism increased). Thus it was possible to conduct additional studies without having to set up relatively complex apparatus used for measuring metabolism.

Further experiments were proposed to determine the insulating values of hair of young calf caribou under conditions ranging from dry to wet. When these were determined one of the most important factors overlooked by a simple windchill aggregate measurement would be accounted for.

Hart and Heroux preferred to discard the windchill measurement of cooling power because it was not a true index

of heat loss, but rather an index of thermal comfort for man. They suggested the use of the thermal wind decrement which would express cooling power as a simple correction to the environmental temperature. Like windchill, it could be calculated as a lowering of the equivalent still air temperature by wind velocity, but would also be dependent on the metabolic rate of the animal. Like the windchill scale, however, thermal wind decrement would not take into account any lowering of insulating values of hair under given environmental conditions, or the effects of humidity. Such correlations remain to be worked out.

Table 9. Weather Records, June, 1948 (Wind Velocity in Miles Per Hour, Temperature Degrees Fahrenheit, Precipitation in Inches).

June 1948	Temperature Max.	Temperature Min.	Wind	Precipitation	Windchill Factors
1	85	53	5.5	nil	500
2	57	36	5.5	.01 Rain	700
3	56	32	2.0	Rain (trace)	600
4	68	32	10.0	nil	900
5	67	40	2.0	nil	500
6	60	34	5.5	.45 Rain	700
7	57	34	10.0	nil	800
8	54	33	2.0	.17 Rain	500
9	46	40	21.5	.42 Sleet	900
10	48	30	21.5	nil	1100
11	51	30	21.5	nil	1100
12	54	34	10.0	nil	800
13	49	30	5.5	nil	800
14	65	37	2.0	nil	500
15	62	37	5.5	nil	700
16	66	37	5.5	nil	700
17	80	42	2.0	nil	500
18	50	39	15.5	Rain (trace)	800
19	68	29	10.0	nil	900
20	56	45	2.0	nil	400
21	50	40	0.0	Rain (trace)	300
22	64	42	2.0	nil	400
23	60	36	10.0	nil	800
24	63	43	0.0	Rain (trace)	300
25	62	46	15.5	Rain (trace)	800
26	62	46	0.0	Rain (trace)	300
27	66	38	0.0	nil	300
28	79	34	5.5	nil	700
29	73	46	2.0	nil	400
30	74	42	2.0	nil	500

Table 10. Weather Records, June 1957 (Wind Velocity in Miles Per Hour, Temperature Degrees Fahrenheit, Precipitation in Inches).

June 1957	Temperature Max.	Temperature Min.	Wind	Precipitation	Windchill Factors
1	42	32	14	Sleet (trace)	1000
2	37	28	39	.16 Rain	1200
3	43	25	10	nil	1000
4	45	24	11	nil	1000
5	48	26	10	nil	1000
6	49	34	18	.13 Rain	1000
7	52	32	9	.05 Snow	900
8	42	25	21	Snow (trace)	1200
9	43	26	21	Snow	1200
10	43	25	30	.08 Snow	1200
11	45	28	14	nil	1000
12	42	28	14	.01 Snow	1000
13	54	29	16	nil	1000
14	42	34	9	.02 Rain	800
15	43	27	12	Rain (trace)	1000
16	42	34	8	.06 Snow	800
17	40	38	11	.05 Rain	800
18	37	32	21	.10 Snow	1000
19	38	32	24	.10 Rain	1100
20	40	33	14	Rain (trace)	900
21	44	32	15	Rain (trace)	1000
22	52	34	10	nil	900
23	57	32	3	nil	700
24	58	33	6	nil	800
25	70	34	4	nil	700
26	60	40	16	.02	800
27	74	38	nil	nil	300
28		42	11	nil	700
29	62	32	nil	nil	400
30	60	38	6	nil	700

Table 11. Weather Records, June, 1958 (Wind Velocity in Miles Per Hour, Temperature Degrees Fanrenneit).

June 1958	Temperature Max.	Temperature Min.	Wind	Precipitation	Windchill Factors
1	55	15	5	nil	1000
2	32	30	35	Snow	1200
3	25	18	25	Snow	1300
4	51	16	nil	nil	500
5	37	14	7	nil	1100
6	33	18	35	Snow (light)	1400
7	33	18	35	Snow (light)	1400
8	44	17	5	nil	900
9	36	20	30	Snow (light)	1300
10	35	22	8	Rain (light)	1000
11	43	28	7	nil	900
12	38	25	3	nil	800
13	42	25	3	nil	800
14	47	23	3	nil	800
15	47	28	5	nil	800
16	46	33	5	Rain (heavy)	700
17	36	30	15	Rain (light)	1000
18	38	27	10	nil	1000
19	38	30	10	nil	900
20	46	33	20	nil	1000
21	38	33	5	Rain	700
22	48	34	5	Rain (light)	700
23	44	33	3	nil	600
24	60	35	5	Rain	700
25	52	40	10	Rain (light)	800
26	47	36	15	Rain	900
27	37	37	20	Rain	1000
28	40	35	5	Rain (trace)	700
29	54	37	5	nil	700
30	61	38	1	nil	300

Table 12. Summarized Meteorological Data for the Months of June 1948, 1957 and 1958 From Beverly Lake, Northwest Territories.

Observation	1948	1957	1958
Mean minimum temperature	37.9°F.	31.6°F.	27.6°F.
Mean maximum temperature	61.7°F.	48.3°F.	42.7°F.
Mean temperature	49.8°F.	40.0°F.	35.2°F.
No. of days having freezing temperatures	5	18	18
No. of days having snow and/or rain	10	17	15
No. of days having snow alone	1	9	6
No. of days having winds over 10 m.p.h.	10	21	12
Average wind velocity	6.7 m.p.h.	13.2 m.p.h.	11.3 m.p.h.
Average windchill value	640	907	893

Summary

1. Observations after 1951 indicated heavy mortality among new-born caribou calves when the time of birth coincided with particularly adverse weather.

2. Weather records from 1957 and 1958 were compared with records kept in the same locality in 1948.

3. The calving period of June, 1948 was warm, calm and dry in comparison to June in 1957 and 1958 -- the calf crop was excellent in 1948, poor in 1957 and good in 1958.

4. In 1957 particularly, adverse weather coincided with the height of calving. Although most calving in 1958 occurred after periods of adverse weather, many calves died which were born early in June.

5. In order to better describe quantitatively the cooling effect of wind and temperature on young calves, windchill factors were introduced. These expressed the additional cooling effect introduced by winds of various velocities at given temperatures.

6. It was estimated that when accumulated average daily maximum windchill exceeded 1,000 for a period of six days or more, or when the total daily maximum windchill factors reached 6,000 in less than six days, calf mortality could be expected. Such periods were encountered in 1957 and 1958.

7. For accuracy several factors must be compensated for in using windchill index.

8. Weather killed young calves directly and indirectly through separation from their parents and increased vulnerability to accidents and predation.

9. A National Research Council study was conducted in 1958 in conjunction with the other field work.

10. Oxygen consumption was used as an index to the metabolic response of captive calf caribou to cold, wind and wetness.

11. Progressively greater oxygen consumption was found with lowering temperatures; with lowering temperatures and wind; and with lowering temperatures, wind, and wet fur.

12. Lethal points were not experienced during the testing but the values derived were extrapolated beyond the conditions encountered.

13. Simple skin temperature measurements were found to correlate inversely with oxygen consumption.

14. When precise lethal thresholds of windchill have been determined it may be possible to predict calving success either from long term weather forecasts, or from known weather on given calving grounds.

Predation

Introduction

It has long been recognized that, with the exception of man, Canis lupus is the only major predator barren-ground caribou regularly have to contend with. The following report deals largely with wolves and includes observational material, some of a quantitative nature, collected by the field men.

Mention will also be made of barren-ground bears because they are large and interesting part of the caribou range fauna and because recently they have increased their range and numbers (Banfield, 1960). Minor attention will be given to wolverine and black bears largely as a matter of interest, rather than because anything new is involved.

The field men kept more or less complete records on all mammals and birds which they observed during the research program. Some of the observations were interesting but their presentation would not be pertinent to the present report. It is sufficient to say that although many small birds and mammals were acting as scavengers on caribou ranges, none was seen to act as a direct predator.

Activities of Wolves

The whole subject of wolf predation is complex and worth serious study. Such a study was planned by the Canadian Wildlife Service and during the present work field men were requested to keep careful records of wolves and their activities wherever encountered. The material thus accumulated contributed little that was entirely new but did reinforce the findings of earlier biological workers and clarified some aspects of wolf activity in a reasonably objective manner.

Most of the material collected pertained to so-called barren-ground or tundra wolves, rather than timber wolves. The areas of forested winter range where the field parties worked in 1957 - 58 did not contain many wolves. This was probably due to the fact that extensive predator control operations had been undertaken therein during the previous several years. Additionally, wolves were very difficult to observe in forested areas and such observations were generally of short duration. On the barren-grounds on the other hand, where there were no trees and topography aided observation, animals could be watched for

considerable periods of time.

The field men were requested to make detailed notes chronologically during periods of wolf observations. A summary of the results is given in Table 13. The observations were made either when wolves were unaware of or indifferent to the presence of humans. Data were collected from seven in the morning to ten in the evening when the wolves were either among or at no great distance from caribou herds.

Unfortunately, the data were not sufficient to warrant a breakdown on a diurnal or seasonal basis but on the whole, they provided a representative example of wolf activities when caribou were present. Activities appear in the table under four main categories: travelling, resting, stalking and eating.

(a) Travelling

Most wolves were travelling when observed. Sometimes travel was in a straight line and at other times it was haphazard. It was assumed that wolves were looking continuously for prey, and were prepared at any time to cease travelling and begin hunting.

The first example, that of varied activity while travelling, might be drawn from Mr. Wilk's observation of June 28, 1957: "At 12:15 I saw two grey wolves lying on an esker approximately a mile southeast of the end of Spruce Grove Lake. Caribou were feeding and moving towards them but the wolves seemed to pay little attention. The wolves got up and walked closer to the caribou. When they were within 100 yards of the caribou the animals took fright and ran away. The wolves paid no further attention to them but wandered on the grassy flats smelling about in the bushes, then proceeded west to a small esker, which they walked along, smelling at bushes and scratching in the sand. Caribou beside the esker within 100 yards of the wolves looked up and noticed the wolves, then walked away and stood to watch them. The wolves walked up to a clump of spruce where they sniffed and pawed about for about five minutes. They noticed five caribou feeding in front of them at a hundred yards range and after looking them over the smaller wolf moved slowly toward them".

A second example was drawn from observations by the writer on June 12, 1954, at Bathurst Inlet. "When first seen, the wolf was on a snow bank on the east side

Table 13. Timed Wolf Observations with Specific Activities Separated

Date	No. of Wolves	Total Wolf Minutes	Activities			
			Travelling	Stalking	Feeding	Resting
25-5-50	1	50	50			
25-5-50	1	25	25			
26-5-50	1	95	30			65
29-5-50	1	65		7		58
2-6-50	1	57	19		38	
11-9-52	5	450				450
15-9-52	5	475	200	275		
12-6-54	1	21	21			
13-6-54	1	14	4	10		
26-5-57	3	60	60			
3-6-57	2	290	136	34	100	20
4-6-57	2	30			30	
5-6-57	11	10	10			
12-6-57	1	10	10			
16-6-57	1	5	5			
24-6-57	2	36	10	26		
28-6-57	2	120	10	90		20
28-6-57	2	60	40	20		
6-7-57	2	56	40	16		
6-7-57	2	110	40			70
10-7-57	2	6		6		
11-7-57	2	4		4		
16-7-57	1	2		2		
17-7-57	1	5			5	
25-10-57	2	120				120
25-10-57	1	45				45
29-10-57	2	30	30			
12-12-57	1	40	20		20	
28-5-57	1	1	1			
30-5-57	1	1	1			
31-5-58	1	7		7		
14-6-58	1	2	2			
19-6-58	1	7		7		
3-7-58	1	12		12		
30-6-58	1	140	60	60		20
1-8-58	1	30				30
9-8-58	1	20		20		
12-8-58	1	15	15			
23-8-58	2	26	26			
Totals	71	2,552	865	596	193	898
Per cent of total time		100	34	23	8	35

of a small river. It picked a better spot, swam the river, a distance of about 50 feet, and trotted slowly west. It continued in this direction until out of sight, twice crossing creeks which it had to wade. It stopped briefly once in a small sedge marsh to defecate. Duration of observation 21 minutes".

Travelling also included such actions as rolling in sand and playing, which latter activity was frequently encountered when a number of wolves are seen together. At such times they would romp much in the manner of young puppies.

(b) Stalking

Stalking included all activities where the observer could clearly see that the animals were in pursuit of specific prey. With the exception of Canada geese on one occasion, and small mammals and birds' nests on a number of other occasions, caribou were the only animals which wolves were observed to stalk actively. Most stalking activity included either a subtle stalk in which wolves attempted to creep up on caribou by stealth, or they involved a concerted dash at caribou. On one occasion the field men were fortunate in being able to observe a successful hunt by two wolves. The following is quoted from Mr. Wilk's field notes of June 3, 1957:

"On the night of June 3 at about 8:25 I was at a point some half mile south of camp watching three bands of caribou crossing the ice. They were almost a mile away. A couple of minutes later I was surprised to see the herds running at top speed just beyond a large pressure ridge. A wolf was running after the largest herd, which was following two smaller groups. The herds numbered 80, 28, and 28 respectively. The wolf appeared to be 100 to 150 yards to the rear. Almost 400 yards away was another wolf loping along at a leisurely pace in the direction of the chase (this was a smaller animal presumed to be a bitch). In a minute or so the caribou changed course and crossed the pressure ridge at top speed. The chase continued with the wolf slowly closing the gap. When the wolf was 50 yards or more away the herds joined in a tight mass of stampeding animals. The surface of the lake was rough and it appeared amazing that none of the caribou fell at this time or when crossing the pressure ridge. The wolf did not appear to speed up but kept some 50 yards to the rear. Eventually one of the animals in the centre of the herd, but toward the

rear, tripped over a drift and the wolf immediately put on a spurt and shortened the distance to half before the animal righted itself and rejoined the fleeing herd. The wolf now increased his speed and soon was only a few yards behind the hindmost animals. Some of the caribou swerved to one side, but the wolf kept on after the animal which had fallen and in a matter of moments grabbed it by the left hind leg about four inches above the hock. The caribou was down immediately. The wolf apparently held it by this grip for two minutes during which the balance of the herd ran almost a mile before slackening pace. At 8:34 the wolf let go his hold on the leg and attempted to seize the caribou by the throat. During this proceeding the caribou managed to get up on its front legs. At 8:36 the wolf and caribou were down again. At 8:42 the second wolf reached the scene and by this time the caribou was apparently dead because the wolf which had made the kill got up and seemed to be feeding."

Also included in the stalking category are a few inconsiderable periods when wolves seemed to be searching for lemmings, small birds or birds' nests. On June 19, 1958, one wolf was observed for a brief period chasing a flock of Canada geese. In the summer, particularly during the moulting period when most geese are flightless, they may constitute a readily available prey.

(c) Feeding

The feeding category included those periods when wolves were actually observed to be eating. Caribou were the only food which wolves were seen to eat during the observations in Table 13.

(d) Resting

The resting category of Table 13 included periods when wolves were asleep or when they were lying down but alert and looking about them occasionally. On September 11, 1952, five wolves were discovered near together, apparently in deep rest. It was believed that they had just completed feeding on a caribou. They were watched for a period of an hour and a half, during which time they remained stretched out in sleep, only occasionally changing their positions. Sometimes an individual wolf sat up for a few moments, looked about him then lay down again.

A wolf resting in an alert condition was the observation of May 26, 1950. At 2:45 p.m. a light-coloured wolf walked out on the sea ice where large numbers of caribou were migrating. At 2:50 the wolf approached a long file of caribou, the leaders of which turned and ran back to the rest of the group. The wolf immediately lay down and looked at the caribou. During the next 55 minutes the wolf remained lying on the ice, although on two occasions he sat up abruptly when caribou came within one hundred yards of him. On each occasion the caribou turned and fled and the wolf resumed his previous position. At 3:55 p.m. there was a shot from Eskimo hunting activity some distance away on shore, and the wolf immediately got up and moved across the ice away from the direction of the shot. In this instance the wolf made no effort to pursue caribou which came close to him although he easily could have done so with some hope of success.

The wolf minutes shown on Table 13 indicate that during daylight hours the animals spent approximately one-third of their time in travelling, one-third in resting and sleeping, and one-third in stalking prey and in feeding.

Wolf Dens

The field men were fortunate in discovering two occupied wolf dens in 1957. The first den was found in the vicinity of Camp 1 by Thomas on June 8, 1957. While he was watching a male wolf at a distance of about 200 yards, suspecting that there was a den in the vicinity, a female wolf rushed past him at a close range and went about 100 yards before stopping. On the following day the field crew went back to the den. Both wolves watched from a distance of 150 - 300 yards during the two hours the men were in the vicinity. Of the operations at the den site, Wilk said "A blizzard was raging and made operations difficult. The den was a hole dug in the east side of a clump of stunted spruce, growing on a slight sand ridge above the shore of a small lake. Don Thomas tried to crawl into the den but couldn't get in very far. The soil surrounding the entrance seemed to be frozen so it was decided to dig in from the back. From the entrance one could hear the pups within. After digging a couple of feet, the men broke into the main den some ten feet from the entrance. On enlarging a space to look in, they found the remains of three hindquarters of new-born calves, and a few ptarmigan feathers, as well as caribou fur from an older animal. They found the pups some

three feet away and six to seven feet from the main entrance. There was no lining in the den - the sand was clean and dry. The pups were very young and none had its eyes open. They were about 12 inches long from nose to tip of tail and were fat and chubby. There were three male pups and one female, judged to be three to four days old".

A second den was located on June 12, 1957, at Camp 2. At 3:15 in the afternoon a white wolf was noted loping along carrying a chunk of meat. It disappeared in the vicinity of a sand-gravel dune where the den was found later in the day. The field men returned to the den site on June 14 and discovered that the pups had been moved. The original site was on a low hill in a dry river bottom where the den consisted of four shallow holes 2½ feet deep dug into the sand. At the site were the remains of a new-born caribou calf. On looking around the men saw four wolves sitting on a hillside and nearby a den with a mound of freshly-dug earth. A fifth wolf suddenly appeared out of the den, and there the men found three pups in a shallow hole about two feet by two feet, dug into the side of a sandy gravel hill. The pups were still very young and had their eyes closed. The remains of at least three new-born calf caribou were near the den.

It is noteworthy that the above observations included two different types of wolf dens. In the first instance a large and well excavated den was involved, and in the second instance the shelter for the pups was minimal. In 1950 the author examined a den site which consisted solely of an excavation in the snow in an extensive copse of thick willows.

Except for the few ptarmigan feathers, there was no evidence that the wolves had been eating anything but caribou. At least five new-born calves and parts of an adult caribou had been consumed at the two den sites. The presence of so many calves on the dates involved indicated selective searching on the part of the wolves because the field men had seen few calves by then; the areas involved were well south of the main calving grounds. The calves could have been live animals killed by the wolves or they could just as easily have been animals found dead. It seemed likely that wolves would prefer young calves during the denning season because they would be easier to kill and carry back to the den. Certainly, during 1957 and 1958, wolves would not have had to kill their own food, because scattered about the countryside were abundant carcasses of young animals which had died from other causes.

Wolf Distribution

Wolves and evidence of wolves were seen everywhere that the field men worked. Sight records fell off sharply once the field camps were moved into timbered country in the autumn of 1957, but rose again once the animals and men returned to the open barrens in the spring of 1958.

On the barren-grounds wolves were seen more frequently in the vicinity of Camp 31 than elsewhere. This was probably because the Thelon River widened there, had many islands with thick willow and spruce growth, and an excellent variety of habitat for many birds and mammals. Wolves would do relatively well there even if caribou were not present. It was in this stretch of river that the author and Perret recorded the most wolves seen during a canoe journey in 1951 (Kelsall, 1952). Fewest wolves were seen at Camps 7 and 8 east of the Dubawnt River. Here the tundra was completely devoid of bush, often wet, and had few sandy areas to afford den sites.

In general, the whole area covered by the study herd and by the field camps, between the Thelon and Dubawnt Rivers, was good wolf habitat. Potential den sites were numerous in eskers and drumlins, caribou resorted to these areas in spring and summer during most years and, even when caribou were absent, the two river valleys with their relatively lush vegetation, ensured food from other sources.

Predator Control Operations

The field men discovered a number of recent but unoccupied wolf dens. It was wondered whether these might reflect the success of the extensive predator control operations of recent years.

Until the winter of 1958-59, control had not been extended to the barren-ground areas studied, but control on the winter ranges far to the south and west might have had effects reaching that far. The majority of wolves taken in the forested winter range of caribou were tundra wolves. Because it was known that they followed the caribou herds as far as 300 miles, it did not seem unlikely that wolves denning on the lower Thelon River in summer might have been many miles into forested country in winter.

During the winter of 1957-58, Predator Control Officer , George Magrum, took 397 wolves in the Aylmer -

MacKay Lake area; Matt Murphy took 125 wolves and Canadian Wildlife Service personnel and others took an additional 91 wolves from the vicinity of a herd of about 50,000 caribou in that region. Only wolves actually seen dead were tallied so the total of 613 wolves was a minimum number. It was not conceivable that all those wolves were resident there, especially because 400 - 500 wolves previously had been taken in predator control operations in that region since 1954.

The movement of wolves into forested caribou range between Great Slave Lake and Lake Athabasca, and their reverse movement in spring, were almost as well known to trappers as were the caribou movements themselves. During the course of extensive survey flying there in the spring of 1955, the writer also saw evidence of this movement. That year the caribou were late in moving back to the barrens and the wolves moved out ahead of them, probably because of the need to get back to their summer den sites prior to whelping. In mid-April hundreds of wolf tracks, trending in a northeast direction, were apparent in untrampled snow between Fort Reliance and Wholdaia Lake. Scarcely any of the wolves involved would have travelled less than 100 miles between the winter caribou ranges and their summer denning areas.

Wolf Utilization of Caribou

The mechanics of an individual wolf kill were given above from Wilk's field notes. This was the only instance in which the complete process was witnessed by field men. Other examples were encountered, however, where fresh footprints and fresh kill in combination gave a fairly complete story.

The examinations of caribou remains were seldom satisfactory because it was not always certain whether wolves had actually killed the animal. Also, after wolves had finished feeding, evidence of sex and age of the prey seldom remained. Careful documentation over longer periods of time would be required to give sound evidence of wolf preferences among caribou.

The result of carcass examinations classified by the field men as wolf kills are given below. With few exceptions the carcasses were found on the summer ranges. The remains of winter wolf kills were less readily found because snow usually hid such evidence promptly. There was reason for believing that some of the calves shown as wolf kills were animals that had died of other causes and had

been eaten by wolves. Certainly in both calving seasons studied there were sufficient dead calves on the ground that no wolf would have to kill through necessity.

Because the data were few, no effort was made to separate kills on an age basis other than that shown. Adults included any animals more than one year of age.

Age and Sex	Number
Female - Calf	4
Female - Adult	12
Total Female	16
Male - Calf	2
Male - Adult	2
Total Male	4
Calf - Sex Unknown	17
Adult - Sex Unknown	4
Total Unknown	21
Grand Total	41

On the basis of the above data it might seem that calf caribou were favoured over older animals as prey (23 to 18). However, because calves would be easier prey and because they were abundant in the areas where most of the examinations were made, it seemed unlikely that the data indicated any preference.

The data might also lead to the inference that wolves took more female caribou than males, because 16 female carcasses were identified as against only four males. However, on the calving areas where most wolf kills were actually found, cows were by far the most abundant sex so the ratios probably were biased.

It was felt by the field men that availability and chance played a greater part in utilization of age and sex classes of caribou than any predilection on the part of the wolves. Furthermore, calves would constitute a larger share of the prey because of their availability. Cows also would be preyed upon more often than bulls because they were more numerous and possibly because they were more available as well.

For practical reasons it would be worth while to know how many caribou an average wolf killed per year.

Although the research program did not answer this question fully, some speculations may be made and, even though the following suggestions are tentative, they have value in placing some tangible limits on the matter.

All evidence indicated that wolves lived largely on caribou and, except during the denning season, sought out caribou concentrations and remained with them. When caribou were available they were taken almost to the exclusion of any other type of food at any season.

Wolves, being somewhat larger than sled dogs, might need more food to maintain themselves. Six pounds of caribou per day would be a reasonable diet although for verification this matter could be tested using captive wolves. From a sample of 67 caribou, the average live weight was 163 pounds. If a wolf ate all of each caribou, which it does not do, it would eat the equivalent of 1 caribou every 27 days, or about 14 caribou per year. Even at this rate the 613 wolves taken from the study herd in 1957-58 could have accounted for 8,582 caribou a year, or 3,576 animals during the five months the winter range was occupied. The latter figure, incidentally, was very close to the calculated increment for the herd of caribou involved.

Although obvious sources of error appear in the above speculations, most of them are amendable to investigation and subsequent modification.

1. Six pounds of caribou per wolf per day may be slightly greater or less than was actually required.

2. A 163-pound caribou would not produce 163 pounds of useful wolf food.

3. Wolf kills were occasionally thoroughly cleaned up by wolves, but minor predators would finish a carcass promptly if wolves did not eat it immediately.

4. Wolves sometimes killed more caribou than they needed for food at the moment.

5. Wolves ate caribou carrion at almost any stage of deterioration.

6. To a limited extent all wolves utilized food other than caribou, even when caribou were present; and most wolves could not get caribou at all times throughout the year.

Items 2 to 4 inclusive would tend to increase the wolf kill of caribou beyond the mathematical projection suggested, and Items 5 and 6 would decrease it. Thus it is suggested that these factors might be compensatory, and that 14 caribou per wolf per year might be close to actuality.

Mr. J.D. Robertson of the Manitoba Game Branch independently made comparable speculations in a report of April 22, 1958. He considered that a wolf would eat 8 pounds of caribou per day and that it might get only about 100 pounds of usable food per average caribou. On that basis one wolf would require 30 caribou per year. Young and Goldman (1944) suggested no daily allowance for wolves but recorded that a wolf gorging itself after some days of starvation ate 19 pounds of meat at one feeding. It is evident that further investigation of this matter is necessary.

Barren-ground Bears

To the best of the writer's knowledge, barren-ground grizzly bears (Ursus richardsoni) were seen more frequently by members of the caribou-study group than by any previous field parties. Before that time Clarke (1940) had indicated how uncommon the species was considered until recently.

Table 14 presents information about the barren-ground bears seen. Approximately half the bears were seen during the course of survey flying, and the remainder were encountered on the ground. Nearly all the records were made within the Thelon Game Sanctuary, from the area south of Beverly Lake and west along the Thelon River.

The records included 64 bears, segregated to show cubs, yearlings and adults. Although some bears classified as adults were not yet of a breeding age, a more exact delineation in the field did not seem practical. There was a likelihood that some of the bears, noted in 1958, were seen on more than one occasion, particularly those in the vicinity of Camps 31 and 32.

Judging from the number of cubs and yearlings encountered during 1957 and 1958, the animals were at that time very productive. In recent years it appeared to persons interested in the species that it had greatly increased in numbers and extended its range, as Banfield (1960) recorded. As an example, bears had been found raiding

caches of the Baker Lake Eskimos in areas where they were virtually unheard of before 1950. During the summer of 1958 an adult male bear actually entered an occupied Eskimo tent at Aberdeen Lake. During the same summer a second adult male was shot at an Eskimo camp north of Beverly Lake and another was seen by the field men on the east side of the Dubawnt River. Since 1954 bears also had raided caches and camps at Muskox Lake in the central barrens, in the Coppermine - Bathurst Inlet areas, in the Dismal Lakes area and in the Courageous Lake area. They had not previously been a nuisance there and were thought to be rare, possibly because those areas had received little human activity until recently. This increase and range extension took place during a period when a total closed season was imposed. Nevertheless, it was likely that as many bears were shot in the past three or four years in defence of camps and caches as were taken in the years immediately preceding the closed season. It followed that the increase was a natural one, little influenced by human actions.

Field personnel of the caribou study had little trouble with bears although one or two of their experiences were hazardous. On June 15, de Vos was walking between Camps 26 and 27 when a bear reared up from a depression some distance in front of him, and then came down on all fours and charged. De Vos felt that he could escape by running into the Thelon River but within a few yards found that the bear was gaining rapidly. He threw down a knapsack which he was carrying, drew a .22 calibre pistol and turned to make a stand. The bear continued towards him until it was within a few feet and then suddenly veered to one side and kept on going. Needless to say, the incident caused much speculation as to whether the bear would have attacked de Vos had he kept running; also whether it finally recognized him as human when it got closer.

On August 7 Thomas and Kuyt returned to Camp 32 after spending the previous night at Camp 31. They found that a bear had raided their cache on the beach in front of the camp. It was possible that the animal had been frightened away by the sound of their outboard motor, because the following evening a large adult bear walked directly toward the camp. It reared up on its hind legs when about 100 yards from the men but left hurriedly when they fired a rifle over its head.

There was no evidence that barren-ground bears were killing caribou, although from their speed when running there seemed little doubt that they could do so occa-

sionally. They did scavenge and in 1957 particularly, were eating caribou calves that had died from natural causes. Some bear droppings contained bones and debris from adult and calf caribou, but the majority contained bones of small mammals, berries and other vegetation. Many times bears were seen searching for lemmings and ground squirrels, as was their custom during the spring and summer, and none was seen chasing caribou.

The general conclusion gathered from the field parties was that the bears were a most interesting part of the barren-ground fauna; that they rarely constituted any hazard to man; and that while they occasionally killed caribou for food their role in relation to caribou was that of scavengers.

Three black bears (Ursus americanus) were seen on the barrens in 1957, one on August 9 twenty miles northeast of Mosquito Lake; a second on August 20 sixty miles east of Artillery Lake, and a third on September 3 a few miles east of Eileen Lake. Although the last bear was only a few miles north of tree-line, the other two were quite a distance from the nearest bush. Black bears were not known to be predators on caribou but acted as scavengers on winter ranges after the caribou have left on their spring migrations.

Wolverine

During 1957 and 1958, wolverine (Gulo luscus) and their tracks were seen infrequently by the field parties. Not more than six wolverines were seen on the ground and about the same number from the air. One wolverine resident near the Mosquito Lake camp was seen on a number of occasions during the spring of 1957. In both 1957 and 1958 two or three individual animals were seen in the Spruce Grove-Beverly Lake area where Terry was fortunate enough to photograph one from a distance of little more than five feet. The animals were almost absent from the areas under study by the field parties during winter.

There was little evidence that wolverines were acting other than as scavengers among the caribou, although a bush pilot flying from Uranium City reported what appeared to him to be the pursuit of caribou by a wolverine. Wolverines might on occasion kill caribou but the impact of such predation would be negligible.

Table 14. Number and Class of Barren-ground Bears (*Ursus richardsoni*) Seen by Field Parties During 1957 and 1958.

Date	Bears Seen			Place
	Adult	Yearling	Cubs	
1-6-57	1	2		Mosquito Lake
14-6-57	1	1		Mosquito Lake
18-6-57	1	1		Cessna Lake
28-6-57	2			Beverly Lake
3-7-57	2			Beverly Lake
9-7-57	1			Spruce Grove Lake
11-7057	1			Spruce Grove Lake
18-7-57	1	2		Wharton Lake
12-8-57	1		3	East of Thelon River
2-6-58	1			Spruce Grove Lake
15-6-58	1			Beverly Lake
6-7-58	1		2	Dubawnt River
14-7-58	2	3		Thelon Delta
15-7-58	1			Spruce Grove Lake
15-7-58	1			Thelon Delta
16-7-58	1			Thelon Delta
16-7-58	2		2	Thelon Delta
18-7-58	2			Thelon Delta
24-7-58	1			Thelon Delta
29-7-58	1			Thelon Delta
2-8-58	1			Beverly Lake
3-8-58	1	2		Thelon Delta
4-8-58	1	3		Thelon Delta
4-8-58	1			Thelon Delta
4-8-58	1			Thelon Rapids
5-8-58	1	2		Thelon Rapids
5-8-58	1			Thelon Rapids
6-8-58	1			Thelon Rapids
8-8-58	1			Thelon Rapids
11-8-58	1	2	1	Thelon Delta
12-8-58	1	2		Thelon Delta
Sub-total, 1957	11	6	3	
Sub-total, 1958	25	14	5	
Total	36	20	8	

Summary

1. The subject of predation, so far as it pertained to wolves, bears and wolverine, is discussed. Most of the wolf data collected pertained to barren-ground wolves rather than timber wolves.

2. Wolf observations showed that the animals spent approximately one-third of their time in travelling, one-third of their time in resting and sleeping, and one-third of their time in stalking prey and feeding.

3. Two wolf dens were discovered and examined.

4. Evidence gathered during the present study and from other sources suggested that wolves fed almost exclusively on caribou when the latter were available as prey.

5. Wolves denned on the barrens in spring and summer and followed caribou long distances to their winter ranges.

6. It was speculated that an average wolf might eat 14 caribou per year.

7. At least 64 barren-ground bears were seen by the field parties, a large number indeed.

8. This suggested that barren-ground grizzlies had increased numerically and expanded their range in recent years.

9. While both bears and wolverines may occasionally act as predators, they must be considered largely as scavengers.

Human Utilization

Introduction

Most early writers dealing with the decline of barren-ground caribou from primitive numbers, assumed to have been in the millions, considered that the introduction and use of modern firearms by native peoples had been a major contributing factor. When Canadian Wildlife Service censuses in 1947-48 and in 1955 (Banfield, 1954, Kelsall, 1956) showed a truly alarming reduction in caribou numbers, there was much speculation as to whether other factors also might be playing a major role. It was partially because of this that the 18-month research program of 1957-58 was initiated.

As a consequence of that study it appeared that human utilization of barren-ground caribou was still the most important single decimating factor. Many people who had seen or had heard of the enormous caribou herds of past years found it nearly impossible to believe that human utilization alone could diminish their numbers. Unquestionably, the mainland herds at one time numbered in the millions and as recently as 1948 Banfield estimated that there were more than 670,000. Those numbers might look inexhaustible when viewed in relation to the few thousand humans resident in the caribou ranges, however, human utilization involved almost unbelievable numbers of caribou annually for many years. In 1948 Banfield estimated that humans were utilizing 100,000 animals per year. On the basis of returns from a caribou questionnaire the writer calculated that humans killed 65,750 caribou in 1954 and 73,400 in 1955. In either of these two years the numbers utilized could easily have constituted as much as 20 per cent of the entire population of the mainland herds. Because of their continued decrease in numbers since 1955 the caribou have been progressively less available to humans. In 1957-58 it was estimated that not more than 12,000 to 15,000 animals were taken. It was not felt that this sharp drop in human utilization reflected improved conservation and management to any large degree, but rather, that it reflected diminished availability, and consequently diminished hunter effort. As late as 1946 there were 9,238 caribou reported killed by Indians hunting from Rae, N.W.T., which almost equalled the total kill from the whole of the mainland in 1957-58. Certainly the Rae Indians, and other groups, continue capable of killing that many caribou again, should the opportunity present itself.

Figures were presented elsewhere showing that calf crops and herd increments, in recent years at least, have averaged little more than 10 per cent of total animals. It seemed likely that each year since 1949, with the possible exception of 1952-53, humans actually killed more caribou than had been born and survived their first year. As long as this condition prevailed a decreasing population was inevitable. Research workers considered that such low calf crops were abnormal, and a great deal of time and effort were spent in trying to determine the causes. It is possible, however, that low calf crops might be a usual rather than an unusual occurrence.

Before the advent of white men, when caribou numbers were presumably high, humans were killing them with primitive weapons and probably taking no more than were essential to their needs. It may be that under such conditions caribou could maintain their numbers with calf crops as low as those encountered in recent years. Many arctic and subarctic animal populations have delicate population balances, and it is possible that when northern natives were able to hunt more effectively with modern firearms they moved the caribou population into a continued state of decline by increasing their total take per year by only a few percentage points.

The following statistics were gathered during the recent research investigation and cover only a limited period in time and space. It should be remembered, however, that the caribou under study numbered nearly 100,000 at the start of the research program and probably constituted one-half of the total caribou remaining on the mainland barrens. It was felt that the degree of human utilization demonstrated was no better or no worse than might be found elsewhere, and that the results and conclusions involved might have been applicable through extrapolation to almost any other point in the caribou range.

Human Utilization Statistics

Statistics of human utilization of caribou from the study herd covered the period November, 1956 to September 1958. Until August, 1957 human utilization was confined to northern Saskatchewan and the lower Thelon River area of the Northwest Territories because of the limited area travelled by the study herd. Following the autumn and early winter migrations in 1957, however, the herd split so that people from a number of settlements in the Northwest Territories benefitted from their presence. The major areas

covered by the study herd during the period in question are shown on Map 1.

Statistics for the period November, 1956 to June, 1957 as given in Table 15, are thought to be reasonably accurate for this sort of data. They include all caribou taken from the study herd by humans during the "calf year" involved, excepting those that might have been secured by Eskimos during the summer of 1956. It was thought not more than 400 additional animals might have been killed by them.

The recorded kill of 7,537 animals was large and yet it did not include additional losses resulting from wounding and crippling of animals. Crippling losses were almost impossible to determine with accuracy. From the known wasteful habits of the people involved it was felt that a reasonable estimate might be 20 per cent of the recorded kill. Addition of this 20 per cent placed herd losses at 9,044 animals, which with the Eskimo kill of that year would place total loss to humans at 9,444 animals.

In relation to the herd increment, the loss of 9,444 caribou during the 1956-57 "calf year" to all mortality agencies would be a serious set back; to lose that many to human activity alone was a major catastrophe, the more so in the light of modern wildlife management practices.

Herd segregations made in late April 1957 showed only 127 calves among 1,566 animals on the winter range for a calf percentage of only 8.1. Even this percentage might have been artificially high because humans took adult caribou in preference to calves. A few years previously a close study of this factor among a herd of caribou near Yellowknife showed calf ratios to increase throughout the winter. The increase was directly attributable to selective shooting of mature animals. With no human utilization, the mortality of calves during their first winter would be expected to exceed mortality among a proportional number of mature animals, and the calf ratio would decrease.

Caribou in northern Saskatchewan in 1956-57 were thought to number very close to 100,000 animals. When this number was correlated with mortality figures it was seen that human utilization alone exceeded increment in 1956-57 by at least 1,300 animals. It was also considered that such other agencies as predation, disease and accidents removed another five to 10 per cent of the herd. The total deficit, therefore, would be somewhere between 6,300 and 13,300 animals. If herd strength at the start of the 1956-57 "calf

year" were assumed to be 100,000, and a median figure of 9,800 arbitrarily used to denote total deficit, then the herd at the end of the "calf year" would number 90,200 caribou.

The statistics for the 1957-58 "calf year" were more favourable than those above, but they still presented no cause for optimism. They are given as Table 16.

Some of the figures in Table 16 were not viewed with complete confidence, although the errors were thought to be small. The main sources of error lay in the fact that human utilization in northern Saskatchewan had to be estimated. A quota of three caribou per person had been imposed in the Province, and the many persons who exceeded that quota would not admit it except under unusual circumstances. Even so, the figures shown would be more indicative of the true state of affairs than any secured from hunting licence returns. They were determined by Mr. Terry and other of the field men through tallying hunter kills in the field, through frank discussion with a few individual hunters, and through extrapolation of the results. In other instances, notably at Contwoyto Lake, the figures were informed estimates rather than actual kill tallies.

Increment in 1957-58 was somewhat better than had usually been the case since 1949. It was calculated at 12.1 per cent of total animals and because the figures on which it was based were gathered earlier in the winter than usual, it was necessary to adjust them downward to account for selective hunting of older animals. The basic stock of 90,200 animals as calculated above, was augmented by 10,900 calves for a total theoretical strength during 1957-58 of 101,100.

The figures in Table 16 show a recorded loss to humans of 6,640 animals. A further 20 per cent (1,300 caribou) could be added to the grand total to allow for crippling loss. The result was a loss to humans of 7,940 caribou for the "calf year" 1957-58.

If five to ten per cent of the herd were again lost to non-human mortality agencies the total deficit for the year would be between 13,023 and 18,079 animals. Using the median figure once more gave a herd strength at the end of the year of 101,100, less 15,551, or 85,549 caribou.

The figures above, and the calculations derived from them, were subject to several errors. However, the basic demonstration of a net herd deficit in each of two

successive years could scarcely be wrong. In each of the years human utilization alone closely approached or exceeded annual increment. At such rates of human utilization no herd increase could be expected unless increment approached or exceeded 20 per cent of total animals, and even if there had been no human utilization in 1956-57 and 1957-58, the study herd would have done well to hold its original strength.

It is interesting to speculate on the possible fate of the herds, if human utilization should remain constant at about its present figure. The increment was approximately balancing mortality from causes other than human utilization, at about 10 per cent per year for each. If human utilization should remain at about 8,000 animals per year, the herd would be cut in half by 1963 and by 1965 it would number only about 30,000 animals. Each year human utilization would involve a progressively larger percentage of the herd so that what began as 8.5 per cent mortality in 1958 would be about 27 per cent by 1965. No possible increment could sustain such a kill and, theoretically, the caribou would be finisned by 1969.

Such a progression as suggested above would not occur in fact because hunter effort would diminish as herd strength diminished, and as the chase became progressively less rewarding most hunters would spend less and less time at it.

Additional Statistics

Some additional statistics were gathered for the "calf year" 1958-59. The Eskimo kill in the Baker Lake region for the summer of 1958, was determined accurately by Cpl. C. Dent, of the R.C.M. Police who managed to interview representatives at about half the camps in the area prior to September. Early in September he and the author, accompanied by an interpreter, visited several additional camps. In this way, reports were secured from 79 of the 93 Eskimos camped in areas traversed by the study herd.

It was found that 23 hunters took 180 caribou between the time the animals first appeared in late June, and the time the interviews were made. Any later kill would have been small because most of the herd had travelled well to the south by the end of August. The recorded kill worked out to 7.8 caribou per hunter, or 2.3 caribou per person, including all dependants. Extrapolation of the findings to include the 14 persons not interviewed led to the belief

that only 212 caribou were taken by those people.

During late August and early September of 1958 elements of the study herd were subjected to Indian hunting in the Fort Reliance area. Indians from Rae, Trout Rock, Yellowknife and Snowdrift took part in this hunt - some of them travelling over 300 miles by canoe to get there. Mr. Philip Mandeville of the Game Management Service, supervised their activities and reported that the 41 hunters killed 136 caribou, or 3.3 animals per hunter. The animals killed were almost all adult males. The relatively small kill was a result of several factors; among them were Mr. Mandevilles' supervision and the fact that the hunters encountered relatively few caribou, most of which were males.

Tables 15 and 16 show the number of caribou taken per hunter for each of the various points involved, as well as the number of hunters involved. It was felt that these statistics could be useful in indicating areas where intensive conservation or enforcement measures were needed. If caribou are to be maintained as a renewable and economically useful resource the human kill must be regulated by what the herds can stand and not by what the hunters need or can kill. The point has been reached where arguments over how many caribou an Eskimo, Indian or white trapper needs per year are purely academic. Under present conditions hunters should not be permitted to take all they need under any but the most exceptional circumstances. If all hunters got what they personally considered they needed they could eliminate the animals in a very few years.

The tables show varying hunter success ranging from 0.3 caribou per hunter to as high as 60.0 caribou per hunter. Where the lower figures were encountered it usually indicated that caribou were present in small numbers and that hunters could get only a few. Where more than ten caribou per hunter are shown the writer would suggest, arbitrarily but with a sense of urgency, that intensive and immediate educational and enforcement measures need to be taken.

Comments on Human Utilization

The above text has pointed out that the recent low reproductive rate among the caribou has made any human utilization unfortunate, however necessary. The present study showed some aspects of human activity that called for direct curbing action, and some that were of a distinctly hopeful nature.

In the latter category was the fact that fewer caribou were apparently taken in 1957-58 than in 1956-57. It was not at all certain, however, that this was any more attributable to conservation practices than to the fact that caribou were generally less easy to hunt. While 900 less caribou were taken in the latter year it was noteworthy that at Fond du Lac the kill increased by about 100 per cent. This was because that village had more caribou over a longer period of time in 1957-58. In both years it was felt that availability, rather than any particular respect for conservation measures, governed the kill.

The admirable restraint in hunting shown by Eskimos near Baker Lake was mentioned above. The highest estimated kill in recent years for that area was only 400 animals, or about 4.5 caribou per person. This was well below what it would be possible for these people to take in most years, and evidently demonstrated a conscious effort at conservation. It was all the more remarkable because those people had no other major resource to fall back on except fish, and because several of their near neighbours and relatives had starved to death on the Back River during the winter of 1958. Most of the Eskimo camps visited during summer were fishing assiduously.

The Contwoyto Lake Eskimos, on the other hand, were apparently still using caribou on a "shoot what you can, while you can" basis. Real efforts to get these people fishing had just started, and success was not yet apparent to any degree. The estimated kill of 60 animals per hunter was far beyond what should be considered reasonable, even though that number was probably necessary to a people who would not fish to supplement their needs. Caribou still provided virtually all human and dog food, and were still used to provide tools, utensils, bedding and most winter clothing. If sufficient fish could have been taken to feed the dogs and some of the humans, then the kill could have been reduced correspondingly.

Human utilization in northern Saskatchewan during the winter of 1956-57 was generally extravagant, and greater than the herds can be expected to survive if continued at the present rate. The situation at Stony Rapids, including Black Lake and Stony Lake, might serve in illustration. From early November, 1956, when the southward migration put animals within reach of local hunters, until mid-April 3,622 caribou were taken in that area. The total human population was about 367 so that ten caribou were taken per person -- including the youngest infants. This

gave the families involved close to 1,000 pounds of meat per person, if it were well looked after - far more meat than they reasonably could use for human consumption alone. Then the spring migration northward commenced and the Stony Rapids area was inundated with moving caribou. Enough caribou for human requirements already had been taken, and in spite of the fact that Indian Affairs and Saskatchewan Game Branch personnel explained repeatedly that meat would be spoiled by the warmer weather, the Indian and Metis hunters once more took their toll of the migrating animals. At least 1,090 more caribou were killed during the last few days in April and early May. Because cows and calves were in the forefront of the migration, and because the natives involved had a predilection for eating unborn calves, pregnant cows made up much of the kill during the spring hunt. This was an unfortunate occurrence because it not only wasted meat but also prevented the addition of the calves to an already depleted population.

Additional information gathered by field personnel in northern Saskatchewan in the spring of 1957 might be of interest and of importance in caribou management. Eighteen hunters from the Stony Rapids area reported killing 174 caribou. Only six of these hunters were Treaty Indians and the other 12, who took 119 caribou between them had either Metis or white status. It often has been argued that because Treaty Indians in hunting for food cannot be subjected to Provincial game regulations, their Metis and white neighbours living the same kind of life should not be brought under game regulations either. This argument could not be considered valid in cases where whites and Metis outnumbered Treaty Indians at a given settlement, or when the hunting involved was largely a luxury, as it was during the 1957 spring hunt in northern Saskatchewan. At the village of Fond du Lac, on the other hand, Treaty Indians were the sole participants in the spring hunt and here 35 families took 250 caribou. It seems certain that this take would have been greater if caribou had moved through that settlement in larger numbers. One of the reasons for a slaughter of this size was a belated attempt to fill the refrigerated storage, provided by the Indian Affairs Branch, with a supply of meat for summer use. It was felt by the investigators that there had been ample opportunity for the refrigerator to be filled during winter rather than waiting until spring when, in common with other points along Lake Athabasca, pregnant females were being shot selectively by the local hunters.

Many Northwest Territories Indians used to make long trips to points where caribou could be found at tree-line in the autumn. Originally this hunt served to secure hides for winter clothing, and until recently it was carried out each year from Rae as well as from Snowdrift and other points. The need for the hunt, however, all but vanished when the people involved made only occasional use of skin clothing. In the old days the hunt was a family affair with the women handling the hides and drying meat, but more recently it was indulged in mainly by the men who dried some meat but more often simply abandoned what they could not carry home. Thus the hunt, which was at one time a cultural adaption to life in the north, became largely a sporting proposition. As a consequence there have been some unfortunate examples of waste on the part of the Rae Indians. Such "luxury" hunts should have been eliminated entirely, or given the most careful supervision.

Discussion

Despite recent progress in publicizing the need for caribou conservation in the North, and in directing the native people towards other economic resources, it was apparent that humans still were utilizing too many caribou each year. Hoare (1927) and other early official investigators had made sound conservation recommendations, and many of these had been reiterated by subsequent workers. It is probable that if more of these suggestions had been implemented earlier the herds of caribou would not have been depleted to the point where their survival remains in serious doubt.

At current levels of herd recruitment the caribou are bound to decrease in any year that humans take between 7,000 and 10,000 animals. Thirty years ago when official concern was first felt, humans might safely have taken as many as 100,000 animals per year, and restrictive action then would have been relatively painless. But now, even if the human kill could be held to present figures, the herds would merely hold their own or increase so slowly that their return as an economic resource would not take place in the forseeable future.

The writer believes that if the animals are available, humans might take 10,000 caribou per year, even if universal enforcement of game legislation were possible. Until the present decade there were a number of native communities, in addition to Rae, in which the people were accustomed to take nearly that many caribou annually. Some of these communities were predominantly Eskimo and some were Indian.

Closed seasons and periodic censuses to determine herd productivity are measures which have been adopted in the past when a species of game animal has been threatened with extinction, as are the caribou in Northern Canada. But such a course has not yet been adopted for the caribou because obstacles to administrative action have stood in the way.

A most important obstacle has been that restrictive legislation, whether it pertained to total closed seasons or to less stringent measures, has not been applicable to all hunters within the range of the caribou. Treaty Indians have by right been excepted from legislative control of their hunting activity. Some have responded well to conservation education and exhortation, but as a group, they have continued to kill more than half of the caribou being utilized.

Discussions of this matter have raised certain moral and legal issues, but it generally is agreed by government agencies that despite these issues it is unfair to impose rigid hunting restrictions on all northern residents except Treaty Indians. As well, even if caribou hunting privileges were taken from Eskimo, Metis, and white hunters, such action would be a palliative at best because the Indians alone remain capable of eliminating the caribou resource unless their hunting can be controlled in some way.

Non-Treaty Indians, Metis and Eskimos would appear to have as strong moral rights to the fruits of their ancestral hunting grounds as do the Treaty Indians, even though their legal rights to unrestricted hunting have not been so strongly safe-guarded by past legislation. It seemed to investigators of the caribou situation that unless the yearly increment to the caribou population should increase enormously, the only hope for survival of the resource lay in some modification of Indian rights so that adequate restrictive measures could be imposed on all hunters. (The way of conservation education, though essential, is too slow to meet the present crisis.) Recent positive steps to effect control of take by Indians, where a wildlife species is endangered, can be viewed as most important in the management of caribou.

Table 15. Known Human Utilization of Caribou From November, 1956 to June, 1957.

Settlement	Hunters	Caribou	Caribou/Hunter
La Loche north	20	50	2.5
Reindeer Lake	21	6	0.3
Cree Lake	20	21	1.0
Wollaston Lake	56	650	11.6
Stony Rapids area	125	4,712	37.7
Fond du Lac	108	720	6.7
Uranium & Camsell Portage	30	900	30.0
Sask. predator control	2	25	12.5
Fort Chipewyan	40	300	7.5
Barren-ground trappers	6	150	25.0
✱ Survey group	2	3	1.5
	430	7,537	17.5

✱ Specimens taken for biological investigations.

Table 16. Known Human Utilization of Caribou From June, 1957 to June, 1958.

Settlement	Hunters	Caribou	Caribou/Hunter
Stony Rapids area	125	1,662	13.3
Fond du Lac	108	1,476	13.7
Uranium City	18	180	10.0
Camsell Portage	12	168	14.0
Fort Chipewyan	32	400	12.5
Sask. predator control	2	25	12.5
Fort Smith	20	150	7.5
Fort Resolution	9	40	4.4
Rocher River	24	166	6.9
Snowdrift	40	710	17.8
Yellowknife	32	260	8.1
Trout Rock	10	120	12.0
Rae	30	320	10.7
Barren-ground trappers	8	165	20.6
Baker Lake area	31	440	14.2
Contwoyto Lake area	5	300	60.0
✱ Survey group	6	60	10.0
N.W.T. predator control	2	8	4.0
Totals	514	6,650	12.9

✱ Specimens taken for biological investigations.

Summary

1. Human utilization seemed still to be the most important single factor decimating the barren-ground caribou.

2. It is suggested that the increase in hunting efficiency afforded native peoples by the introduction of modern firearms probably moved the caribou population into a state of decline, and that that condition has more or less continuously maintained itself.

3. Caribou calf crops and increment have been unexpectedly low since 1949, except in 1952-53, and it is possible that this might be the usual rather than the unusual situation.

4. Increment among the study herd during the 1956-57 "calf year" was low at 8.1 per cent of total animals; human utilization was high at 9.0 per cent of total animals.

5. With allowances for herd loss due to agencies other than human utilization it was thought that a net deficit of about 9,400 animals occurred and the herd strength dropped to about 90,200 animals.

6. Although increment during the 1957-58 "calf year" was calculated at 12.1 per cent of total, and although human utilization dropped to 8.9 per cent of total, this was scarcely a cause for optimism.

7. Again with allowances for additional loss, a total deficit of 15,500 was demonstrated, leaving herd strength at about 85,500 caribou - a net loss of about 14,500 caribou during the two year study period.

8. If human utilization continued at its present rate, and increment did not improve, the herd which started 100,000 strong in 1956 could theoretically be reduced to about 30,000 by 1965, and could be eliminated entirely by 1969.

9. The Eskimo kill at Baker Lake during the summer of 1958 was set at 212 animals (7.8 caribou per hunter) and it seemed evident that conservation was being practiced by the people involved.

10. The 1958 autumn hunt by Great Slave Lake Indians was described wherein 41 hunters took 136 caribou. Good supervision may have effected good conservation.

11. Tables are given showing the number of caribou per hunter taken annually during the study period at the various posts involved. It is suggested that where more than ten caribou per hunter are taken, intensive and immediate educational and enforcement measures are needed.

12. Nine hundred fewer caribou were taken by humans in 1957-58 than in 1956-57, but this could be attributed to decreased availability rather than to improved conservation practices.

13. The moderate hunt by Eskimos trading into Baker Lake is compared to the immoderate hunt by Contwoyto Lake Eskimos where the kill was estimated at 60 caribou per hunter.

14. A kill of 4,712 caribou was recorded in the Stony Rapids area by a population of only 367 persons, and a quarter of those caribou were taken during a spring hunt when pregnant females were selectively killed.

15. It is pointed out that despite recent gains in conservation programs in the north, progress on these programs has been painfully slow.

16. A continued decrease in population is forecast for any year in which human utilization exceeds 7,000 to 10,000 animals, unless caribou increment should enormously increase.

17. On the other hand, it seems unlikely that humans will take fewer than 10,000 caribou per year under existing circumstances if the animals are available for hunting.

18. The fact that Treaty Indians are not subject to restrictive legislation has been an obstacle to the maintenance and increase of the caribou population.

Range Studies

Introduction

As originally planned, range studies were to make up an important part of the Co-operative Research Program. It long had been acknowledged that intensive range studies were most desirable and that they called for expert planning and execution. A range management man was appointed to the Canadian Wildlife Service late in 1957, but his familiarization with caribou and their range requirements was not sufficient for active planning during the winter of 1957-58. Unfortunately he subsequently resigned from the Canadian Wildlife Service and as a consequence, range studies were carried forward very little beyond their point of progress at the start of the research program.

Despite this, some observations of interest were made during the research program by the field men, and a cover mapping project was started in 1957-58 to include the major wintering area in northern Saskatchewan.

In addition to studies by the regular field crews, a second project was arranged under contract with Mrs. D.K. Beckel. This involved a study of selected caribou ranges through air photo interpretation. It was hoped from this study to produce cover maps of caribou range. Cover maps were considered to be important to any range studies in order to learn the types of ranges, their location and their condition. The results of Mrs. Beckel's study will be published separately.

Caribou Range Requirements

Barren-ground ranges frequented by caribou during late spring, summer and early autumn had always been considered adequate by field workers, although in some places over-grazed areas had been found. However, for every hundred square miles showing signs of over-use, there were thousands more which appeared entirely adequate for caribou.

Forested winter ranges presented an entirely different picture. In the forested areas utilized by caribou, the most important parts were those which provided adequate food. Since fruticose lichens of the genera Cladonia and Cetraria formed the principal winter food of caribou, mature spruce-lichen forest was of prime importance. It was found that spruce-lichen forest was not by any means universal throughout the area occupied by caribou in winter.

Field workers had noted with increasing alarm, that those forests were exceptionally subject to damage by fires. In burned areas with sandy soil, burned spruce-lichen associations were replaced by less satisfactory jackpine-lichen forests. Kelsall (1957), Banfield (1954), and others had noted that caribou avoided burned forested areas, thus affecting the course of major migrations. It was thought that adequate winter range would be the major factor limiting eventual growth of the caribou population.

In view of the above, studies of winter ranges should have priority over studies of summer ranges. Cover maps, and sampling techniques, need to be developed to show the composition of the winter ranges by forest types, the progressive effects of forest fires must be measured quantitatively, and the adequacy of the various stages in forest succession following fire must be determined. Also, studies of caribou growth and nutrition must be closely integrated with any range studies because there is evidence that caribou grow larger on some ranges than on others.

Winter Feeding Habits

On forested areas barren-ground caribou utilized two main ecological types for feeding. These were:

(1) Forest proper, of either a spruce or jackpine type, but always with a significant growth of fruticose lichens of the genera Cladonia and Cetraria.

(2) Sedge areas along lake and stream margins and in swamps, which often included significant quantities of willow, alder and glandular birch.

The first type seemed to be preferred, but this may have been because sedge areas were generally much smaller in extent and number than forested areas.

In the absence of the above plant communities caribou sometimes utilized quite different types of country for feeding. Occasionally heavy feeding was noticed in areas of Juniperus communis and on rocky hilltops covered by the foliose lichen Umbilicaria hyperborea. Such use was not of regular occurrence, however, and seemed to be associated with an absence of preferred feeding types. The use of such marginal areas will not be considered further.

Where snow depth amounted to a few inches or less, caribou fed by grazing on exposed vegetation, with a great deal of random pawing to expose additional food. With snow two feet and more in depth, a characteristic pattern emerged. The animals consistently dug feeding craters with the fore-feet and fed on the vegetation exposed at ground level. In snow two feet deep (somewhat deeper than caribou prefer) a typical crater was two and one half to four feet wide at ground level. Occasionally craters were dug into a bank at an oblique angle rather than straight down to a horizontal surface. The craters rarely overlapped but often were immediately adjacent to one another. Only a fraction of the ground cover was utilized in a given area and as a consequence over-grazing was practically impossible in any one winter. In 1957-58 field men found that caribou sometimes fed twice over a given area during the winter, but a single feeding was far more likely.

A remarkable aspect of the feeding craters was that little effort appeared to be wasted in finding food, even in deep snow. Of hundreds of feeding craters inspected, not one was found that had no suitable food at the bottom. The ability of caribou to find sedges along river margins, and fruticose lichens in heavily burned areas was remarkable. The plants grew in such areas in widely separated clumps rather than in a continuous carpet, and the feeding craters usually hit these clumps accurately.

The use of craters on many winter ranges provided an excellent opportunity to investigate the feeding habits of caribou by examining the vegetation in each fresh crater. Although it was difficult to estimate the percentage of each plant species eaten from individual craters, the presence of a species therein could indicate percentage, if a sufficient number of craters were examined. Winter feeding habits of few big game animals lend themselves so well to quantitative analysis.

Crater Studies

From 1951 through 1954 examinations were made on winter ranges in the Mackenzie District, Northwest Territories. The results are presented in Table 17. These observations included a number of places where caribou had fed on sedges as well as in spruce-lichen forests, which are the dominant and preferred feeding areas. The 1958 examinations were made on northern Saskatchewan winter ranges in sub-climax jackpine-lichen forests. Although spruce-lichen forest seemed to be the original climax type in northern

Saskatchewan, as it was elsewhere in the North, the forest had been so fire-damaged that this climax association was found only on islands in the larger lakes. Replacement growth was predominantly jackpine.

Table 17 indicates that lichens, sedges and Vaccinium of several species, appeared in craters with greater frequency than other plants. Lichens were found in 76 per cent of craters examined, Vaccinium in 35 per cent and sedges in 21 per cent. Because of its growth habits Vaccinium was found frequently in craters containing lichen, but rarely in craters containing sedge. Similarly, sedges and lichens were seldom found together, and although a few lichens appeared in sedge-dominant areas, sedges rarely were found in lichen-dominant areas.

Because most feeding craters contained more than one species of utilized plant, as is shown on Table 17, a per cent occurrence against the number of craters examined did not provide a true picture of the utilization of any one plant. A more correct figure was obtained by totalling the individual occurrences of each plant in all the craters examined, and then making percentage comparisons with the total number of occurrences of all plants (Table 18).

Although Table 18 gives a more accurate picture of plant utilization, some bias is present because of the non-random choice of the samples. Lichen (47 per cent), Vaccinium (21 per cent) and sedge (13 per cent) made up the bulk of the material eaten, while Labrador tea (8 per cent) and willow (4 per cent) contributed more than incidental quantities. Together these five plant types made up 93 per cent of the total plant material involved.

The Vaccinium records involved Vaccinium Vitis-Idaea and V. uliginosum, more or less equally. V. Vitis-Idaea remained green throughout the winter and was a preferred food species. The leaves of V. uliginosum withered and fell at the first frosts, and its frequency of occurrence in feeding craters in lichen areas was ascribed to its prevalence therein. The withered leaves were eaten because they were lying among the preferred lichens. The bare stems did not appear to be eaten, except accidentally during the gathering of preferred food plants. V. uliginosum was almost universal in the craters examined in northern Saskatchewan, and it was felt that this reflected its abundance rather than a preference by caribou. It was much less abundant in the Northwest Territories and appeared in only 10 per cent of craters examined there.

Table 17. Utilized Plants Found in Feeding Craters Over a Period of Years, Showing the Plant, or Combination of Plants, Found in Each Crater.

Plants Found in Craters	No. of Craters 1951	1952	1953	1954	1958	Total	Percent of Total
Lichen, Vaccinium		2		12	113	127	29.7
Lichen		5	3	68	40	116	27.1
Lichen, Labrador tea		4		22		26	6.1
Lichen, Vaccinium, Labrador tea					10	10	2.3
Lichen, willow		9				9	2.1
Lichen, bearberry			3	4	1	8	1.9
Lichen, sedge		2		5		7	1.6
Lichen, moss		4	2			6	1.4
Lichen, crowberry				5		5	1.2
Lichen, Juniper				4		4	0.9
Lichen, Labrador tea, crowberry				3		3	0.7
Lichen, spruce		1				1	0.2
Lichen, grass			1			1	0.2
Lichen, sedge, saxifrage			1			1	0.2
Lichen, Vaccinium, sedge, moss			1			1	0.2
Sedge	18	1		27		46	10.7
Sedge, willow	16	1				17	4.0
Sedge, birch	4			4		8	1.9
Sedge, Vaccinium				6		6	1.4
Sedge, Labrador tea		1		1		2	0.5
Sedge, Willow, alder	1					1	0.2
Sedge, birch, alder	1					1	0.2
Vaccinium, Labrador tea				6		6	1.4
Vaccinium, Labrador tea, moss					1	1	0.2
Labrador tea				8	1	9	2.1
Bearberry			3			3	0.7
Willow	2					2	0.5
Grass				1		1	0.2
Totals	42	30	14	176	166	428	99.8

Table 18. Occurrences of Each Plant Type in the Feeding Craters with the Percentage Occurrence of Each. Specific Plant Determinations Given Below.

Species	No. of Occurrences	Percent Occurrence
1. Lichen	331	47.0
2. Vaccinium	151	21.5
3. Sedge	90	12.8
4. Labrador tea	57	8.1
5. Willow	29	4.1
6. Bearberry	11	1.6
7. Glandular birch	9	1.3
8. Moss	8	1.1
9. Crowberry	8	1.1
10. Juniper	4	0.6
11. Grass	2	0.3
12. Alder	2	0.3
13. Prickly saxifrage	1	0.1
14. Spruce	1	0.1
Totals	704	100.0

1. Lichen - complete specific determinations were not possible but the commonest species were Cladonia alpestris (L.) Rabh., C. mitis Sandst., C. rangiferina (L.) Rabh., Cetraria islandica (L.) Ach., C. nivalis (L.) Ach., and Stereocaulon tomentosum Fries.

2. Vaccinium - not listed specifically because of some confusion in the raw data. Vaccinium uliginosum L. and V. Vitis-Idaea L. were the commonest in about 50-50 ratio, and V. oxycoccos L. was present.

3. Sedge - a number of species of Carex.

4. Labrador tea - Ledum groenlandicum Oeder.

5. Willow - a number of species of Salix.

6. Bearberry - Arctostaphylos Uva-ursi (L.) Spreng. with some A. rubra (Rehd. & Wils.) Fern.

7. Glandular Birch - Betula glandulosa Michx.

8. Moss - not specifically determined but including at least three; Hylocomium splendens (Hedw.) Bry. Eur., Polytrichum sp., and Dicranum sp.

9. Crowberry - Empetrum nigrum L.

10. Juniper - Juniperus communis L.

11. Grass - not specifically identified.

12. Alder - Alnus sp.

13. Prickly saxifrage - Saxifraga tricuspidata Rottb.

14. Spruce - Picea mariana (Mill.) BSP

Labrador tea was an almost universal species on caribou ranges, and thus it too would be found in craters whether it was eaten or not. However, crater examinations and visual observations of caribou feeding led to the belief that it was actively sought. Willows, while common everywhere, were not closely associated with growths of lichen and sedge. Their representation in the caribou diet certainly demonstrated selective feeding.

Methods were developed for estimating plant preferences on the part of caribou, beyond those indicated by Table 18. One method compared the percentage composition of known species on the ranges, with their percentage utilization in feeding craters. During summer studies 5,000 point samples were taken on unburned, forested winter range (Kelsall, 1957). These were taken near to, and were reasonably representative of, the areas where winter crater examinations were made in 1951 through 1954. Table 19 compares the percentage occurrence of each plant in feeding craters with its average per cent in the total ground cover.

Comparing the figures for occurrence in craters and occurrence in ground cover revealed a clear scale of feeding preference. If grazing by caribou was completely random, both line point samples and crater examinations would produce much the same percentages for each plant. Plants which were utilized beyond their availability were preferred and, in varying degrees, actively sought by caribou. Plants eaten with the same frequency with which they were present in the ground cover were merely taken as available. Plants utilized to a lesser extent than their

availability were rejected in varying degrees, or were taken incidental to the gathering of preferred foods.

Using these considerations allowed the compilation of a table of preference for those plants shown in Table 19. It should be remembered that these data referred only to the spruce-lichen forest areas examined in Mackenzie District, and not to the jackpine-lichen areas of Saskatchewan.

Preference Rating	Plant
Preferred plants actively sought in apparent order of preference	Sedges Willows Labrador tea Lichens Glandular birch
Plants taken as available, little preference indicated	Vaccinium Bearberry Juniper Crowberry Alder Prickly saxifrage
Plants taken incidentally or actively rejected, including plants present on the range but not found in feeding craters.	Grasses Spruce Mosses

While lichens were by far the most frequently eaten plants, their preference rating was well below that of sedges and willows, and even slightly below that of Labrador tea. Sedges and willows were taken ten times more frequently than random feeding would permit. Labrador tea, lichens and glandular birch were taken about twice as often. All other species were taken about as available, or were rejected. A number of plants which showed up in the point sampling did not appear in the feeding craters at all, although no such species was individually numerous. Presumably they were not sought at all by caribou in winter and were not closely enough associated with preferred plants to be taken incidentally.

Of considerable interest was the low occurrence of mosses in the feeding craters in comparison to their availability because they often grew in close association with both sedges and lichens. This appeared to demonstrate an active rejection of mosses on the winter range.

Table 19. The Number of Occurrences of Each Plant in the Feeding Craters Examined in the Northwest Territories, the Percent Occurrence of Each and the Percentage which Each Made of Total Ground Cover as Measured in Summer by 5,000 Point Samples.

Species	No. of Occurrences	Percent Occurrence	Percent of Ground Cover
Lichen	161	40.6	21.7
Sedge	90	22.7	2.1
Labrador tea	45	11.4	5.9
Willow	29	7.3	0.7
Vaccinium	27	6.8	4.9
Bearberry	10	2.5	2.6
Glandular birch	9	2.3	1.2
Crowberry	8	2.0	2.6
Moss	7	1.8	11.6
Juniper	4	1.0	1.2
Grass	2	0.5	1.2
Alder	2	0.5	0.6
Prickly saxifrage	1	0.3	0.3
Spruce	1	0.3	4.4
Many other species	0	0.0	39.0
Totals	396	100.0	100.0

Forest Fire on Caribou Winter Ranges

During studies by the Canadian Wildlife Service since 1948, the importance of forest fires in the ecology of barren-ground caribou had been commented upon by all field workers. Caribou wintered each year in northern coniferous forests and favoured those spruce-lichen associations where fruticose lichens of the genera Cladonia and Cetraria constituted their principal winter food. The lichen areas were of the dry forest type which in summer was extremely susceptible to damage by fire. Spruce-lichen forests are climax associations and when burned may suffer complete destruction of values useful to caribou because seral stages after fires do not include any amount of the large fruticose lichens. This was especially true on Precambrian areas, underlying the chief winter ranges, where fires frequently removed even the thin soil covering the rock. Almost as complete destruction was suffered on sandy areas of winter range studied in northern Saskatchewan in

1957-58. South of Lake Athabasca and the Fond du Lac River the country was predominantly sandy, and burned spruce-lichen forests had been replaced almost universally by an inferior jackpine-lichen association.

Banfield (1954) and others had commented that burned areas may turn or halt caribou migrations. Besides being useless as winter pasture, burned tracts represented wasteland barriers which caribou were loath to cross. All those persons who studied the matter concluded that forest fire represented a major factor controlling caribou populations. In Alaska, Leopold and Darling (1953) recorded that fires had eliminated some caribou entirely by destroying their range, and had placed serious restrictions on almost all other caribou herds. One Alaskan authority quoted by Leopold and Darling estimated that there remained not more than 20 per cent of the original white spruce forest upon which caribou depended.

Most forested caribou ranges in Canada have received little or no protection from fire. In the Northwest Territories as an example, virtually all the extensive forested ranges, not already burned, lie outside the limits where it is considered economically feasible to fight fires.

An analysis of the effects of fire on winter ranges had long been desired by field workers. Such analysis would give data useful in estimating range carrying capacities, would aid in the prediction of movements and migrations, and would provide a basis for setting up priority areas for fire protection. No such work had been done until recently, because the project appeared too large to be attempted. During the late winter of 1955-56, the writer was able to map accurately a relatively small burned area in the Mackenzie District. Because the results of this first tentative study seemed encouraging, further work was done in 1957-58 by Kuyt on the winter ranges in northern Saskatchewan. Although the findings were limited, they indicated what has happened to unprotected forest ranges.

(a) The 1955-56 Study

The study area shown on Map 9 included a block of land 9,214 square miles in extent. The area was a critical one for those caribou herds which wintered in forests between Great Bear Lake and Great Slave Lake. Banfield (1954) found more than 200,000 caribou wintering between the two lakes, and westwards toward the Mackenzie River. These herds have shown progressive deple-

tion since that time, although the area remained one of the most important of the western wintering areas.

Forest fires have been common between Great Bear Lake and Great Slave Lake. Each summer since 1950 all except one or two fires, which happened to endanger mining camps, burned out unchecked. In 1952 aircraft pilots reported 24 fires burning in that area at one time.

Prior to 1950 the area was commonly used as a wintering area for caribou and small scattered bands continued to winter there in recent years. Recent burning was so extensive, however, as to preclude the possibility of large herds wintering there in the near future.

The area surveyed lay just within the western edge of the Precambrian Shield. Forest cover originally was mature spruce forest with a heavy lichen growth. The rugged nature of the country caused frequent breaks in the forest so that hilltops were almost devoid of trees, and the lower areas with poor drainage supported muskeg with a comparatively poor lichen growth. The deciduous tree growth included balsam and aspen poplar, birch, alder and willow.

North-south transects were flown at 10-mile intervals, and at an altitude of 750 to 1,000 feet. Burned areas were plotted on maps with a scale of eight miles to the inch. Flight strips and burned areas are presented on Map 9.

When the study area had been defined, its size in square miles was calculated with a planimeter, as was each burned area. As a check on the sizes of burned and unburned areas each flight line was projected to the edge of the study area, and the lengths of the burned and unburned strips along those lines were measured and totalled. No direct mechanical method of measuring water areas was available so a point sampling technique was adopted and the following categories were recorded: burned (land), burned (water), unburned (land), unburned (water). The results gave the water and land percentages in both burned and unburned areas.

Table 20 gives the sizes of the burns plotted on Map 9 as determined by planimeter measurement. Burned areas, including water bodies within the burns, made up 26.5 per cent of the total study area. Burn sizes cal-

culated using the line sample measurement constituted 26.9 per cent of the total area. With the point sample measurements burned areas were calculated to include 26.7 per cent of the study area.

The results of the point sampling for land and water areas are given in Table 21. The table, and additional simple calculations, revealed that of 9,214 square miles in the study area, 2,193 square miles were water and only 7,021 square miles were land. The eight mile to the inch map sheets, on which this work was done, did not show all of the water bodies by any means. From the table it can be seen that the ratio was 2,009 square miles of burned land to 5,012 square miles of green forest, or about 29 per cent to 71 per cent.

(b) The 1957-58 Study

Map 10 shows the area in which Kuyt attempted to plot burns during the winter of 1957-58. It comprised an area of approximately 16,610 square miles. For various reasons the results were not as satisfactory as the 1955-56 study, although the methods were the same. The primary stumbling block was that there were no detailed four mile to the inch maps of the southern section of the area involved. This, coupled with an absence of lakes and other obvious topographical features on the larger scale maps, made it virtually impossible to accurately plot many of the small burns encountered. A second major difficulty was that almost the entire area had been burned at least once and little of the mature spruce-lichen forest was left. Original spruce-lichen forest was found only on islands in the larger lakes, in small refugia along stream banks and lake margins, and in the two small areas shown on Map 10. As a result of this Kuyt was obliged to plot burns within burns, rather than burns within mature forest.

Because of these limitations it was not worth while to plot burned areas, as opposed to unburned areas. If the small and scattered refugia were not included, unburned areas totalled no more than 300 square miles, or less than 2 per cent of the entire area. It is likely that even this small amount of unburned forest was in damp areas which would not be of major importance for feeding caribou.

Mr. Kuyt aged many of the burns which he plotted, and also aged the forest outside some of the more recent

ones. Virtually all of the plotted burns were less than 30 years old, coinciding with the period of intensive prospecting and mining development which commenced about 1936. It was suspected that here, as in other places in the north, some burning was deliberate in order to expose the country to easier prospecting. Outside the plotted burns the sample ages varied, although many of them were approximately 100 to 110 years old. This indicated that during the 1850's there had been a high fire hazard and a great deal of forest fire damage.

(c) General Considerations

In the area investigated in the Northwest Territories, spruce-lichen forest destruction was followed by a succession which commenced with poplar, willow and birch growth, with a direct return to spruce forest thereafter. Succession varied in different areas, and depended on the severity of the burning, but most of the country was returning to its original floral composition. In northern Saskatchewan, on the other hand, destruction of spruce forest by fire seemed to result in either a deciduous growth followed by jackpine, or a direct jackpine growth. In hardly any instance observed was succession following fire returning to spruce forest. Thus, the floral composition of the country even after one hundred years showed little evidence of returning to its original state.

That the new jackpine forests of northern Saskatchewan would support caribou was demonstrated by the fact that thousands of them wintered there. However, there was little doubt that these forests were not as satisfactory for caribou as comparable spruce-lichen forests. While quantitative measurements were not made it was apparent that lichens generally were not as dense or luxuriant under jackpine as they were under spruce. In spruce forests tall forms such as Cladonia alpestris, Cladonia rangiferina and Cetraria nivalis were common and abundant. In the jackpine forests, on the other hand, such relatively low-growing forms as Cetraria nivalis, Cetraria islandica and Cladonia mitis seemed to predominate.

Table 20. The Size of Burned Areas on a Study Plot in the Northwest Territories, Shown on Map 9.

Burn Number	Size Sq. Mi.	Burn Number	Size Sq. Mi.
1	36.1	9	4.4
2	15.2	10	1,278.7
3	69.1	11	21.4
4	538.9	12	4.4
5	30.6	13	30.6
6	335.4	14	7.0
7	8.3	15	0.6
8	13.4	16	39.9
Total			2,434.0

Table 21. Result of Sampling for Land and Water Areas, in Burned and Unburned Areas, on the Study Plot in the Northwest Territories, Shown on Map 10.

	Totals	Burned (land)	Burned (water)	Unburned (land)	Unburned (water)
Number of sample points	588	128	29	320	111
Per cent of total	100	21.8	4.9	54.4	18.9
Number of square miles	9,214.1	2,008.7	451.5	5,012.5	1,741.4

Discussion

The data given above are believed to present a general picture of the effects of forest fire on forested caribou winter ranges. Some further considerations might be of interest.

The extremely large number of water bodies, as measured on the study area of 1955-56, were more or less

typical of caribou ranges. They detracted from the value of the area by reducing the actual food-producing surface - in this case by more than 30 per cent. Lakes and rivers were not as abundant in the northern Saskatchewan area but even there water bodies represented more than 20 per cent of the total surface area. Exact measurement will have to await the production of more detailed map sheets.

Water areas did provide certain advantages. Caribou used them extensively in winter as easy routes of travel and as places of escape and refuge. Water also limited forest fires, as may be seen by close examination of Map 9, where water bodies turned or halted the course of fires. Except for rain and other burns, lakes, streams and bogs represented the only significant controls to burning. Without these wet areas there would be little or no forest left.

The data show that a winter range area covered with mature spruce forest in the Northwest Territories was reduced 29 per cent by fire and that a comparable block of country in northern Saskatchewan was reduced to the point where virtually no mature forest remained. In most northern areas, mature forests have been seriously reduced where there has been intensive human activity. This was as true for many miles around Yellowknife as it was for northern Saskatchewan. The 1955-56 study area was remote, but even so, it had received increased human use after mineral exploration commenced.

It was difficult to estimate the economic values destroyed by fires on the study area. The timber generally was worth little, except possibly as pulp wood at some future stage of development. Certainly a fire which destroyed 800,000 acres, such as the one numbered 10 on Map 9, would be a major disaster in any lumbering region. The absence of timber values does not, however, make a country valueless. Fish, fur and game are economic resources of the greatest importance. The Canadian northland was opened up by persons interested in the fur resources and to a large extent these pioneers depended upon the fish and game which the land provided.

In the present developmental stage when the fur resources have a lessened economic importance, it is easy to lose sight of the fact that a revived interest in fur, fish and game can be expected in the Northwest Territories as human population increases, as transportation becomes easier, and as tourists find the country more accessible.

In almost all regions in North America where wildlife has survived the initial development essential to building a civilization, it has been found that the later development of sport hunting and sport fishing have provided an economic resource of the first magnitude. It can be predicted confidently that this will prove true in the Northwest Territories, provided our forests are safeguarded, so that the fish and mammals are there for the sportsmen when the means to exploit them develops.

Carrying Capacity of Winter Ranges

It has been pointed out that the carrying capacity of caribou winter ranges requires further investigation. If carrying capacity could be determined for the major forest types, and if cover maps were available to give the proportional representation of each major type, then capacities could be worked out for the whole range, or for any part of it.

Dr. Pruitt made some speculations along this line based on his observations during the winter of 1957-58. These are presented below in a somewhat modified form. The results obtained were not conclusive in themselves, except that they gave tentative indications of carrying capacity on two forest types.

Ahti (1957) quoted a Finnish worker who stated that reindeer need 9 to 11 pounds of damp lichens per day for winter sustenance. By examining sample areas Pruitt discovered that each feeding crater might be expected to yield from 0.15 to 4.0 ounces of fodder. He also found that caribou dug about 732 craters per acre of range or 468,480 craters per square mile (assuming that the animals would feed twice over a given area per winter, which was not usually the case).

On the better lichen areas among young jackpine 8 to 10 feet high, growth was sufficient that 40 craters per day could provide a caribou with 10 pounds of lichens. At that rate a square mile of forest would support 11,712 caribou for a 24-hour period or 78 caribou for the 150-day winter season.

On the poorest lichen area, represented by 40-foot jackpine on a dry south-facing slope, growth was such that it would take 1,066 craters per day to provide a single caribou with 10 pounds of lichens. At that rate a square mile of forest would support 439 caribou for a day

or 3 caribou for the entire season. Presumably, range in the latter category would be highly marginal, and would support caribou only for brief periods.

When the co-operative study commenced in the spring of 1957 it was estimated that there were approximately 100,000 caribou in northern Saskatchewan. If nothing but the best ranges were available, and if snow conditions and other factors did not prohibit the use of any of those ranges, then only 1,282 square miles would be needed to winter the herd. On the other hand, if only the poorest ranges were available, and if caribou were able to maintain life on them, then 33,333 square miles would be necessary.

Actually during the winter of 1956-57, caribou utilized an area of approximately 15,000 square miles, which included lakes, total burns and other country barren of food. Because the actual carrying capacity of the country undoubtedly lay between the two extremes recorded above, it seemed probable that the animals were near the saturation point on the ranges utilized. In utilizing the country which they did, the animals covered most of the range readily available to them.

Summary

1. Unfortunately, the co-operative research program did not appreciably advance our knowledge of caribou ranges, although it was felt that some useful groundwork had been laid to assist future studies.

2. Forested ranges, utilized by caribou in winter, should have priority in any future studies because they are being damaged and depleted by fire.

3. Studies of growth and nutrition of caribou should be closely integrated with any future range studies.

4. The determination of plants present in feeding craters gave a quantitative evaluation of preference shown by caribou for the various foods available to them.

5. Results of the pilot study showed that lichen, Vaccinium, willows, sedges and Labrador tea made up more than 90 per cent of material eaten by caribou.

6. Lichens alone made up nearly 50 per cent of caribou winter diet, but there was evidence that availability, rather than preference, made them so important.

7. By comparing the frequency with which plants were found in feeding craters, and their availability on the ranges, preferences for each were established.

8. A study of fire damage to caribou winter range is described.

9. In a study area of 9,000 square miles in a remote area of the Northwest Territories 29 per cent of the forest was found to be burned.

10. In a study area of 16,000 square miles in northern Saskatchewan all but one or two per cent of original mature forest was found to be burned.

11. Heaviest burning was found in areas having received greatest human utilization.

12. Fire damage in northern Saskatchewan had all but eliminated the original spruce-lichen forest and an inferior jackpine growth had replaced it.

13. It was estimated that poor jackpine forest could support only 439 caribou per day per square mile, whereas good jackpine forest could support 11,712 caribou per day per square mile.

Accidents, Parasites and Disease

Accidents

Accidents probably play a minor but continuous role in caribou mortality. During the 1957-58 research program the field men saw evidence of accidental death of a young calf caribou, as described elsewhere. Young calves were found dead at river crossings having been unable to climb out of the water, some apparently had died through exhaustion and malnutrition following early separation from their parents, and in one instance, a young calf was found stuck in deep spring snow and had been unable to get out.

Drowning appeared to be the most commonly reported form of accidental caribou mortality. Kelsall (1957) detailed an instance in 1951 where more than 400 caribou were drowned at the narrows of Aberdeen Lake. It appeared that a large herd had undertaken to swim at least 4½ miles, that a wind had arisen during the swim, and that many young and other weak animals were unable to hold their heads above the waves and had drowned. Clarke (1940) mentioned some of the more hazardous sites on the caribou range where mortality might be expected. Certain rapids, canyons and waterfalls appeared to constitute a frequent and expected source of accidental drownings, although not necessarily on an annual basis. Banfield (1954) also made specific mention of mortality from drowning and cited the Lockhart River near Fort Reliance as a particularly hazardous site.

During the present study only two or three cases of adult animals having drowned were noted during the summer months. In each instance exhaustion from fly harassment may have been a contributing factor. Caribou often were seen to swim rivers in large numbers without loss even at such hazardous places as above large rapids. Some were even swept over such rapids and emerged unscathed. It is remarkable that more drownings were not encountered. As long as caribou had some freedom of movement in the water, and some free choice of swimming direction, they seemed to be able to meet almost any normal circumstances in the water. It can be imagined, however, that when several thousand animals simultaneously swam particularly dangerous streams interference and congestion would result in some mortality.

That new ice created a drowning hazard each autumn has been recognized but has never been reported previously. During November of 1957 caribou were moving east-

ward in large numbers along Lake Athabasca and attempting to cross to the south wherever a possibility presented itself. New ice was forming in bays at that time but it was not until the animals reached the eastern extremity of the lake that a solid surface stretched from shore to shore. Observations from the air indicated that caribou began crossing as soon as new ice was formed, and before it was thick enough to be completely safe. On November 7, during a flight from Stony Rapids to Uranium City, four caribou were seen to be frozen into the ice, apparently having broken through and been unable to climb back. Several other such incidents occurred while the field crews were camped on the Fond du Lac River at Camp 14.

Later in the month, before freeze-up was complete, Indians and bush pilots reported that many caribou had attempted to cross Lake Athabasca west of Camsell Portage. Animals were seen standing at the edge of open water miles from land, or were returning to shore. Certainly some of the ice was so thin that it would not safely support the weight of a man. Observations of caribou moving on such thin ice showed that they recognized the hazard involved because they moved with unusual deliberation. Even the presence of aircraft flying overhead seldom sped them beyond a slow walk.

Caribou of all ages and sexes appeared frequently to be subject to such injuries as sprains and broken limbs. Such injuries may have occurred when the animals were travelling rough and rocky country, when swimming rapid and rocky rivers, or when harassed by predators, insects and the like. Animals with crippling leg injuries, or infections, were almost invariably seen in the wake of a large migrating herd. Some injured animals may have recovered but more were lost through predation or other causes.

Murie (1944) cited a number of incidents of crippled caribou. Kuyt described several typical cases.

"On July 18, 1957 in a band of 14 cows and 10 calves, a cow was observed with a peculiar labouring gait. The animal's head bobbed up and down with every step. Closer observation showed a large swelling immediately below the carpal joint on the right front leg. Although the cow seemed greatly handicapped, she and her calf swam across the Dubawnt River just above the falls without incident and the two animals were observed grazing on the other side about an hour later.

"On July 27 an adult male caribou was examined. This animal had a decided limp and was destroyed. It was found that it had been suffering from an abscessed fetlock on the right front leg. An open wound found between the dew claws could have been responsible for this abscess.

"On August 15 the writer observed a limping caribou which was later destroyed by F.W. Terry. The caribou, a female, had a slightly swollen carpal joint, but otherwise she was in good condition. Upon incising the swollen joint, the writer observed two pockets filled with caseous pus and three pockets filled with a semi-liquid substance."

Crippling accidents of the type described doubtless constituted a small but steady drain on any herd of caribou. When crippled animals were examined, infected wounds of various sorts were found frequently.

No observations of caribou having received crippling or fatal injuries through falls were noted during the present research program. However, evidence of such incidents had been noted in the past. In the Bathurst Inlet area where the country was often very precipitous, caribou often travelled terrain which would be more suitable for mountain goats. In 1950, McEwen and the writer watched a closely packed herd of 4,000 caribou stand for two hours at the edge of a precipice which would have meant certain death had any fallen over. In such a case a predator or a human could have stampeded some of them over the brink.

Parasites and Disease

On a number of occasions obviously incapacitated animals were shot and examined. Dr. Harold Gibbs of the Wildlife Service spent various periods in the field, and examined all material gathered by others. The results of this work was contained in his report, a summary of which appears as Appendix 1.

One item, which resulted from the windchill study may prove on further investigation to be of importance. Hart and Heroux collected tissue samples from seven dead young calves for later pathological examination. Of the seven calves, one was found to have a severe pneumonic condition and the other six showed degrees of atelectasis, a condition in which the lungs were not fully inflated and functioning.

In a personal communication Heroux advised that this in itself could not have caused death of the animals involved, but it was possible that whatever caused the atelectasis might also have been responsible for the deaths. It seemed possible that the condition could be a contributing factor to death under certain conditions.

Atelectasis in new born animals is not a thoroughly understood condition. One of its chief known causes is nervous stress (Davies, 1947), and the process under which captive calves were secured in the field and flown to a base of operations might well have contributed to the condition. However, the condition was more severe in three female calves that had been found dead than on two males that were killed following the physiological studies at the base camp.

Summary

1. Accidental death seemed to play a minor role in annual caribou mortality.

2. Drowning appeared to be the most commonly recognized form of accidental caribou mortality.

3. Few caribou were found drowned in summer months during the present investigation, but newly frozen ice created a drowning hazard in early winter and a number of cases were observed where animals drowned in Lake Athabasca in 1957.

4. Caribou appeared to be subject to injuries, particularly sprains and broken limbs, and some cases observed are detailed.

5. Caribou may fall to their death in rough country.

6. Pneumonia and atelectasis were found in very young calves autopsied at the windchill study camp.

7. Atelectasis, found in six out of seven calves examined, is recommended as a matter for further study.

8. Blood sera of 20 male and 44 female caribou were examined for evidence of brucellosis and sera of 18 males and 42 females were examined for evidence of brucellosis and sera of 18 males and 42 females were examined for evidence of leptospirosis. The results were negative, although one barren female gave a questionable reaction for brucellosis. (See Appendix 1 for summary items 8 - 16)

9. From a two-day-old calf showing symptoms of enteritis a coliform organism was isolated. A Streptococcus was found in the stomach of an unborn calf but no pathological significance was attached to this.

10. Twelve species of parasites were obtained from caribou but none was believed to be of significance in caribou mortality.

11. During the height of the fly season in 1957, one animal examined appeared to be suffering from anemia caused by bloodsucking insects, and death from a similar cause was suspected in several other animals found by the field men.

12. A fungus, presumably Actinobacillus ligneresi was found in the lungs of one of the specimens examined.

13. Chronic inflammations were found in lung, kidney, liver and lymph tissues.

14. The two most important conditions appeared to be foot rot and fly predation, which could be very damaging in years of severe insect abundance.

15. No instances of lumpy jaw (actinomycosis) were found during the present study, although it had been reported in the past.

16. It was concluded that diseases and parasites were not major factors operating at the present time to decrease the herds.

Appendix 1. Disease Investigation of Barren-Ground Caribou

July 1957-August 1958 - Harold C. Gibbs.

Introduction

As part of the continuing study by the Canadian Wildlife Service on the barren-ground caribou the writer was employed to study pathological conditions which might be present in these animals. It was hoped that any diseases which might be important factors in controlling the number of those animals would be revealed as well as diseases that might be of importance as health hazards to the people who depend on these animals for food and clothing.

This work is a follow-up on that of Banfield (1954) who discussed disease conditions in the barren-ground caribou.

The report has been divided up into the following sections:

I - Serological survey

II - Bacteriological studies

III - Parasitological studies

IV - Pathological conditions

V - Normal haematological values

I - Serological survey

One of the major questions facing the investigators was an explanation of the apparently low calf crop that has prevailed in the herds over the past few years. Some of the caribou herds migrate through Wood Buffalo Park where they come into contact with the bison range. It has been shown by Novakowski (1958) that the bison have a high incidence of infection with Brucella abortus which causes abortion. It was therefore felt that there was a distinct possibility of the caribou having acquired this disease. In addition, in recent years much attention has been focussed on another bacterial disease, namely leptospirosis, which has been shown to be very prevalent in wildlife, especially Cervidae. This disease also causes abortion and

reproductive tract disorders in animals.

A reliable serological test exists for the diagnosis of both these diseases and a survey for these two diseases was therefore undertaken on the sera of all animals slaughtered.

Method

Blood was taken from the jugular vein of animals immediately after shooting. It was collected in a sterile wide-mouth jar and allowed to clot over a period of about 12 hours in a cool place. The clear serum was then removed by a sterile syringe into blood tubes and Tinct. of Merthiolate added, at a concentration of 1:10,000, as a preservative. Under these conditions satisfactory samples were obtained and serum was shipped by air without refrigeration.

In order to prevent freezing in very cold weather, the blood collecting jars were kept under the parka next to the skin.

Results

The sera of 20 males and 44 females were examined for evidence of brucellosis and those of 18 males and 42 females were examined for evidence of leptospirosis. The results were negative. One barren female gave a questionable reaction for brucellosis; all serum dilutions were positive on the rapid plate test but on the tube test at 1:50 there was a partial reaction, and at 1:100 there was only a slight trace of clumping. In addition this cow showed evidence of a chronic endometritis.

Discussion

Although the sample examined (64 total) was small, it was taken over a fairly wide area and not from one segment of the population. The one questionable reaction to brucellosis is not considered significant because the sample was slightly haemolysed and this could have given a false positive reaction. Whether the chronic endometritis was significant is debatable. The Brucella organism tends to affect the foetus and foetal membranes rather than the uterus itself. Since the section of uterus had been fixed in 10 per cent Formalin, bacteriological culture was precluded.

From the above limited result it seems reasonable to conclude that neither brucellosis or leptospirosis is a problem in the caribou herds. This conclusion would be further strengthened if the serum survey were continued.

II - Bacteriological studies

After experience gained during the summer of 1957 it was decided that valuable information would be obtained if cultures could be made of any pathological lesions, especially those from calves, to ascertain what types of bacteria, if any, were causing the lesions.

Method

Three types of media were taken:

Robertson's meat medium

Tryptose agar medium

Nutrient broth medium

These media, which were all fluid, were taken in screw-cap culture tubes and kept as cool as possible without freezing. A small methanol burner was used for sterilizing the culture loop. The cultures were kept cool after being made and were shipped out as soon as possible.

Results

Unfortunately, opportunities for making cultures were not numerous. However, they were made from four a-i-mals as follows:

1. Unborn calf

The amniotic fluid of this calf was somewhat viscid, yellowish and smelt offensively. The uterus of the dam appeared normal and the calf had apparently been alive when the mother was shot. Cultures were made of the stomach contents from which a short chain Streptococcus sp. was isolated when they were incubated under carbon dioxide.

2. Two-day-old calf

This calf was found dead but in a good state

of preservation. The abomasum was full of milk and there were no major lesions except for a slightly inflamed area in part of the small intestine. There was no evidence of pneumonia.

Cultures were made from the heart blood and the area of enteritis. The former was negative but the latter gave a haemolytic coliform.

3. Day-old calf

This dead calf was found in a good state of preservation after a storm. The abomasum contained milk, some of the intestinal contents were very yellow but this was probably due to meconium. There was no evidence of pneumonia. No lesions were apparent but cultures were made from the heart and intestine. The former yielded nothing but from the latter a non-haemolytic coliform was obtained.

4. Adult cow

This animal was taken as a specimen. She showed what was considered to be a low leucocyte count.

Brain sections were cultured mainly as a matter of interest and with special emphasis on the isolation of Listeria sp. The findings were negative.

Discussion

The only finding that might be significant was that of a haemolytic coliform in calf No. 2, which was causing an enteritis. Colibacillosis is a very real problem in young animals resulting in death from scouring. However, the enteritis seen in calf No. 2 was comparatively mild and I feel that it alone was not sufficiently severe to cause death. This condition is worth further study.

The findings of a Streptococcus sp. in pure culture from the stomach contents of calf No. 1 is interesting. It might have been a contaminant but it did occur in pure culture under conditions of reduced oxygen pressure. It is not considered to be of any significance pathologically.

Unfortunately, due to confusion in arrangements only two calves were brought to me for examination, even though more were found dead and in good condition. However, if nothing else was gained, the few examples show that with a little care it is possible to make cultures in the field and to obtain satisfactory results.

III - Parasitological studies

Whenever possible animals were examined for parasites, external and internal. Due to the number of persons making observations and the variation in thoroughness with which animals were examined no incidence figures are given. Blood smears were made from all animals taken and examined for blood parasites by Dr. Marshall Laird of the Institute of Parasitology, Macdonald College.

Results

Twelve different species of parasites were obtained. The following is a list:

Arthropoda

Oedemagena tarandi	Warble Fly
Cephenemyia nasalis	Nostril bot-fly

Nemathelminthes

Dictyocaulus viviparus	Lung worm
Nematodirella longispiculata	Intestinal worm

Platyhelminthes

Larvae

Cysticercus tenuicollis	Long-necked bladder worm
C. tarandi	
Echinococcus granulosus	Hydatid cyst

Adult

Moniezia sp.

Avitellina sp.

Protozoa

Sarcocystis sp.

Fibrocystis sp.

Discussion

The commonest parasite of the barren-ground caribou is the warble fly. The degree of infestation varied, in one adult bull 314 grubs were found while in a yearling bull only six were found. The nasal bot-fly was less common than the warble fly, but some heavy infestations were observed. One animal had 156 grubs in its throat, which must have caused intense discomfort.

It is not known how seriously these flies affect the caribou. Certainly when the flies are ovipositing the caribou will run to evade them. Migration of larvae through the body must cause some inflammation and possibly may open up avenues of secondary infection. Once the parasites in the back of the caribou become walled off by fibrous tissue, they probably cause little discomfort. The throat bot must interfere with breathing and by constant irritation of the mucosa allow entry of secondary bacterial invaders. However, this is merely conjectural. In a group of animals it was impossible to tell which ones were heavily parasitized and which ones were not. Presumably therefore, the effects of these parasites are easily withstood by the host. One animal heavily infested with both types of fly larvae was comparatively thin but could run well and for sustained periods. Probably the main problem created by these flies is the extensive damage to the hides.

The most common cestode infection was with the larva form of *Taenia hydatigena*, *Cysticercus tenuicollis*. This parasite was found mainly in the liver where the cysts were deep in the tissue or subcapsular. In addition infections of the mesentery and heart muscle were also seen. The average number of cysts per liver was about five. The animals appeared to be unaffected by this parasite.

Infections of the muscles with *C. tarandi* were also present. Only one case of heavy infestation was found but infections with a few cysts were frequent. The main problem presented by these parasites is that they make meat unattractive for human consumption.

Hydatid cyst infections were fairly common. The cysts were all found in the lungs and varied in size from that of a marble to that of an orange. Infections with this parasite are important from a public health standpoint if infected meat is fed to sled dogs in settlements.

Two species of adult cestodes were obtained from the small intestine. One of these was a Moniezia sp. Species of this genus are of fairly common occurrence in wild northern ruminants. The other, a species of Avitellina, represents a new record for this genus in North America. Both of these genera belong to the same subfamily. Their pathogenicity is doubtful.

Infections with the lungworm Dictyocaulus viviparus were fairly frequent. This parasite causes a characteristic verminous pneumonia which in the cases observed was localized at the apex of the lobes. None of the infections observed could be classified as dangerous to life.

Nematodirella longispiculata, a nematode from the duodenum, was found in a few animals. The infections were not heavy and the pathological effects of this species are not considered to be severe. In addition a few larval nematodes, presumably fourth-stage N. longispiculata, were found in the duodenal mucosa but no inflammation was in evidence.

Although no gross lesions were seen on post-mortem examination, spores of a species of Sarcocystis were found in the blood smears. The pathogenicity of this organism is doubtful and unless the infestation was a very heavy one it would cause little trouble.

Another protozoan parasite Fibrocystis sp. was also found. This is seen as translucent, pin-head sized granules on the subcutaneous fascia of the legs, belly and flank. On section these cysts are thick-walled, spherical objects filled with numerous fusiform spores. Hadwen (1922) described F. tarandi from the reindeer and stated that this parasite involved the periosteum where it caused pitting of the bone. However, no evidence of this condition was present in the caribou. The pathogenicity of this parasite is uncertain. An extensive granulomatous reaction in the liver of one caribou might have been associated with this organism. However, this has not yet been confirmed. Other members of this group of organisms, for example, Globidia sp. and Besnoitia sp. do cause fatal disease in other animals, including ruminants. From the condition of the

animals infected with this parasite it is not considered serious but it warrants further investigation.

IV - Pathological conditions

(a) Foot rot

Examination of the affected limb of a very lame animal taken in the vicinity of the Thelon River in August 1957 showed that the fetlock was swollen with a sinus opening just distal and posterior to the joint. This sinus extended by means of a well defined tract internally up past the joint and there was some involvement of the suspensory ligament. There was inflammation, oedema and caseous pus in the area. This lesion could have been due to snagging but was considered to be a case of foot rot. No bacterial cultures were made. At the time this animal was taken a number of lame animals were seen in the vicinity, an aftermath of the main migration.

Another animal which was limping badly showed abscessation in the region of the fetlock with a sinus opening just between the dew claws. This was considered to be a fairly typical example of foot rot infection.

(b) Fly predation

In early August 1957 a caribou bull which appeared to be a victim of excessive fly predation was observed. The animal was lethargic when seen and was approached and caught. Its pulse was very irregular. It was literally swarming with mosquitoes which were particularly thick around the face and muzzle. After release the animal stayed around camp all night. In the morning, due to a stiff breeze, the flies were gone, the animal appeared more active and could not be approached and handled. It was shot. The post-mortem examination showed nothing of great significance. The mucous membranes were very pale. There appeared to be some subcutaneous emphysema and there was an infection with Fibrocystis sp. on the fascia. The lungs were normal. The liver was normal except for five C. tenuicollis cysts. The kidneys were pale. The mesenteries and omentum were tough and contained no fat. There was slight oedema in the lesser curvature of the abomasum; this was blood tinged. The abomasum contained a bezoar.

It was felt that this animal was suffering from anemia caused by blood-sucking insects.

(c) Actinobacillosis lesion in the lung

The specimen consisted of small nodules which had been taken from the lungs. Histological examination revealed the presence of a granulomatous lesion containing clumps of a ray fungus, presumably Actinobacillus ligneresi.

(d) Chronic inflammation

1. Lung

The specimen consisted of a small, dark and firm portion of lung. Histological examination showed a subpleural lesion characterized by foetalization of the alveolar lining. A number of alveoli contained cellular debris.

2. Kidney

The specimen consisted of sections of kidney showing pale, diffuse areas of necrosis. Histological examination showed a chronic granulomatous reaction, numerous eosinophiles being present.

3. Liver

This specimen consisted of sections of liver showing pale somewhat diffuse areas similar to those seen in the kidney. Histological examination revealed a similar granulomatous lesion to that seen in the kidney. In addition, a portion of a degenerating cestode was present as well as some cysts tentatively identified as Fibrocystis sp.

4. Lymph nodes

These were two green tinged, inflamed lymph nodes from the region of the loin on the left side. Histological examination showed an eosinophilic inflammation which might have been caused by migrating parasitic larvae.

(e) Miscellaneous

1. In July 1957, a caribou cow was observed with a

large spherical mass on her right carpus. This caused difficulty when the animal moved resulting in a rocking gait. However, this animal moved surprisingly rapidly and frequently despite her handicap and she appeared to be the mother of a healthy calf. The animal was not shot and so it was not possible to say whether the growth was a large fibroma or hygroma of the carpus.

2. In December 1957, an animal was seen which appeared to have a multiple abscess in the brisket region but this animal was not taken.

3. In June 1958, an adult bull was shot that was in good condition but a .22 bullet was found just below the skin encased in fibrous tissue.

4. Four dead adult females were found in June 1958. Unfortunately they were too badly mutilated or decomposed to discover much on examination. Three of these animals had been pregnant but the cause of death was not determined.

Discussion

Foot rot or some condition resulting in lameness appears to be fairly common in caribou. While only two animals suffering from this complaint were taken, numbers were seen limping at the same time of year as the specimen animals (early fall). It is difficult to assess the importance of this condition. It certainly makes animals more vulnerable to predation but whether or not it would end fatally is debatable. It is probable that the lesions would heal spontaneously. The greatest incidence of this condition was seen in late summer and early fall when the muskeg was thawed and surface heating of swampy areas would tend to favour the growth of the soil borne causative organisms.

The causes of the granulomatous inflammation are enigmatic. All sections for histological study were stained with an acid-fast stain to see if the presence of acid-fast organisms, of which Mycobacterium tuberculosis is a member, could be demonstrated. However, these were all negative. Banfield (1954) reported tuberculosis in caribou. The isolation was made using an acid-fast stain from a single lesion taken from a caribou thigh. It is rather unusual to find tuberculous lesions in muscle unless the case was one of miliary tuberculosis.

The problem of fly predation is felt to be a very real one. Apart from the loss of blood to the animal is the nuisance effect which causes aimless running leading to fatigue and loss of condition. At the height of the fly season in late July 1957 a few animals were found dead. These deaths were thought to be due to the effects of flies.

The finding of a few animals dead of unknown causes is always to be expected. The four females found in June 1958 probably died as a result of calving trouble. This might have been due to inability to calve normally or from diseases associated with pregnancy, such as pregnancy toxemia.

The finding of a small lung lesion resulting from an infection with Actinobacillus sp. is not considered to be very important.

Banfield (1954) reported a "widespread infection with a disease resembling lumpy jaw (actinomycosis)"; there was an incidence of 2.1 per cent in 380 jaws examined. Although over 150 animals were examined during the present survey no lesions attributable to this disease have been seen.

The presence of organisms resembling Fibrocystis sp. in granulomatous liver lesions is worth further study. In Africa organisms of this type are responsible for a serious disease of cattle known as Globidiosis. However, in the caribou the reaction is much less spectacular, and the disease does not appear to be serious.

V - Normal haematological values

During the course of these studies it was decided that some knowledge of a few of the values used in haematology would be valuable.

Method

Blood was collected from the jugular vein, immediately after the animal was shot, into 10 ml. vials containing potassium oxalate. The blood was then chilled in snow. Estimations were done within two hours after collection. Haemoglobin was estimated using a Sahli-Hayden haemoglobinometer.

For results see Table I.

Discussion

The results obtained were similar to those obtained for other Cervidae - see Table II.

Conclusions

It is difficult to assess the importance of the individual instances of disease found during the survey. It is felt that none of them could be classed as being of major importance. The majority of animals examined were considered to be healthy. The few instances of disease conditions which were a severe handicap to the animal suggests that disease is not a big problem in the caribou. There were no reports of widespread die-off or heavy morbidity among the herds by the observers who were with them over the entire eighteen-month period. It is true that a few carcasses of animals that died from unknown causes were found. However, both instances when there was an unusual number of animals found dead were times of comparative stress, the onset of the fly season in one and the calving season in the other. In the first instance the animals were of mixed sexes, in the second all were females. These findings were therefore not considered to warrant alarm.

A large number (100+) of new born calves were found dead in June 1958. This was during a period of very inclement weather - snow, wind and low temperatures - and the deaths were considered to be the result of this weather.

Parasites might produce subclinical disease in the host making them more susceptible to other conditions such as weather, poor food supply, bacterial or viral infection, or predators. With the exception of the warble fly infestation, none of the observed instances of parasitism could be described as heavy.

Of necessity, this survey is only of limited value. The sample of animals examined, although representative, was small. Epizootics tend to be cyclical and hence study over an extended period is often necessary before the presence or absence of such a condition can be determined with some certainty. I think especially of brucellosis in this respect.

It may, however, tentatively be said that disease, while being present to a limited extent in the caribou herds does not appear to be a major factor operating at the present time for the decrease of these herds.

Acknowledgements

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Table I - Estimation of Some Blood Values in Caribou

Animal	Sex	Haemoglobin	Leucocyte count	Erythrocyte count	Remarks
No. 171 4 June 1958	F	16.5 gm 96.5 per cent	5,100 per mm^3	11.83 $mill/mm^3$	Pregnant Mature
No. 172 5 June 1958	F	11.55 gm 70.0 per cent	5,400 per mm^3	10.55 $mill/mm^3$	Pregnant Mature
No. 176 22 June 1958	M	16 gm 95 per cent	4,100 per mm^3	11.4 $mill/mm^3$	 Mature
No. 177 25 June 1958	F	14.5 gm 84.5 per cent	4,150 per mm^3	10.81 $mill/mm^3$	Barren Mature
No. 178 26 June 1958	F	14 gm 82 per cent	2,250 per mm^3	9.46 $mill/mm^3$	Lactating Mature

Table II - Comparison of Haematological Values Obtained for Some Deer

Species	Haemoglobin	R.B.C.	W.B.C.	Authority
Odocoileus hemionus	16.89 gm	10.1	-	Rosen and Bischoff (1952)
Rocky mountain mule deer	12.8 gm	9.2	3	Browman and Sears (1955)

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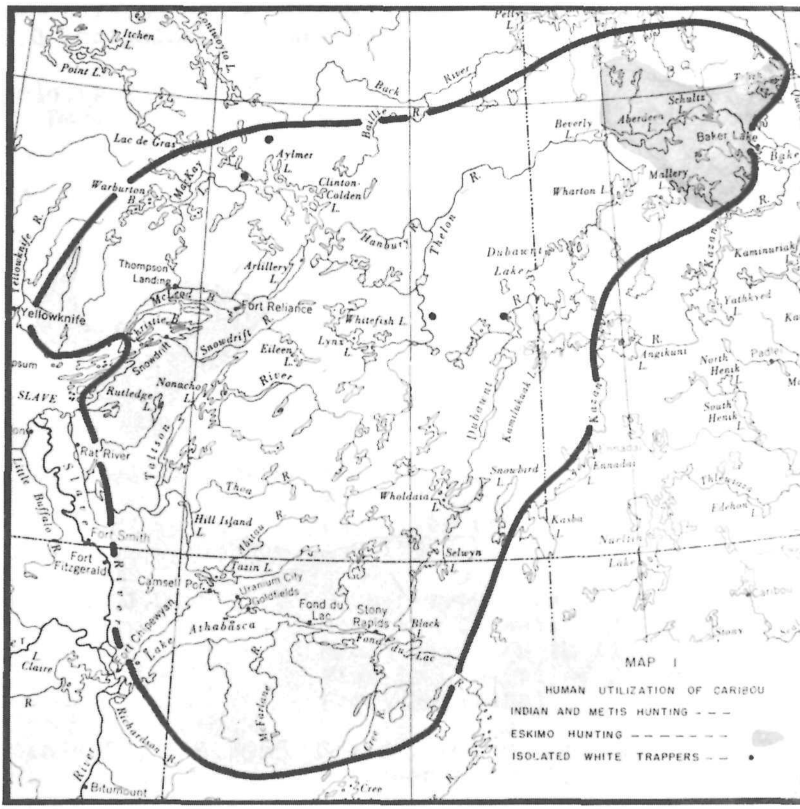
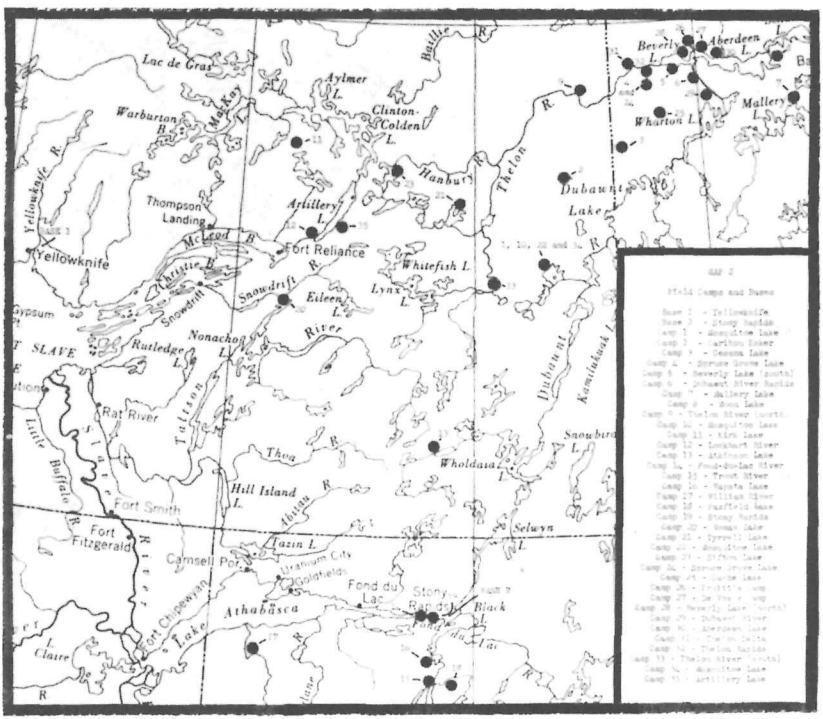
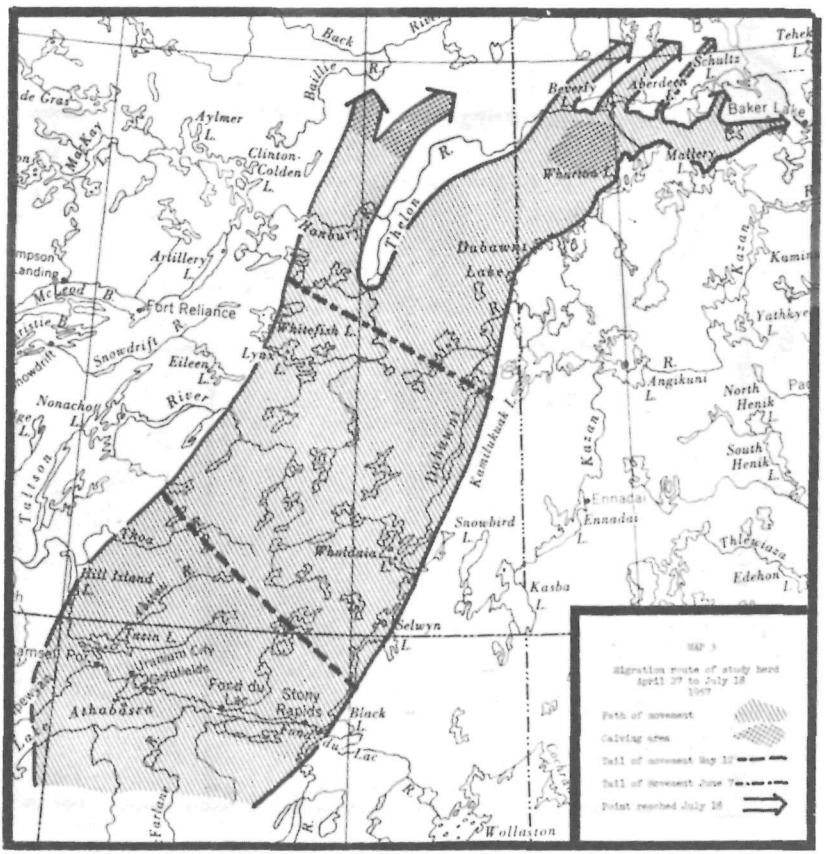
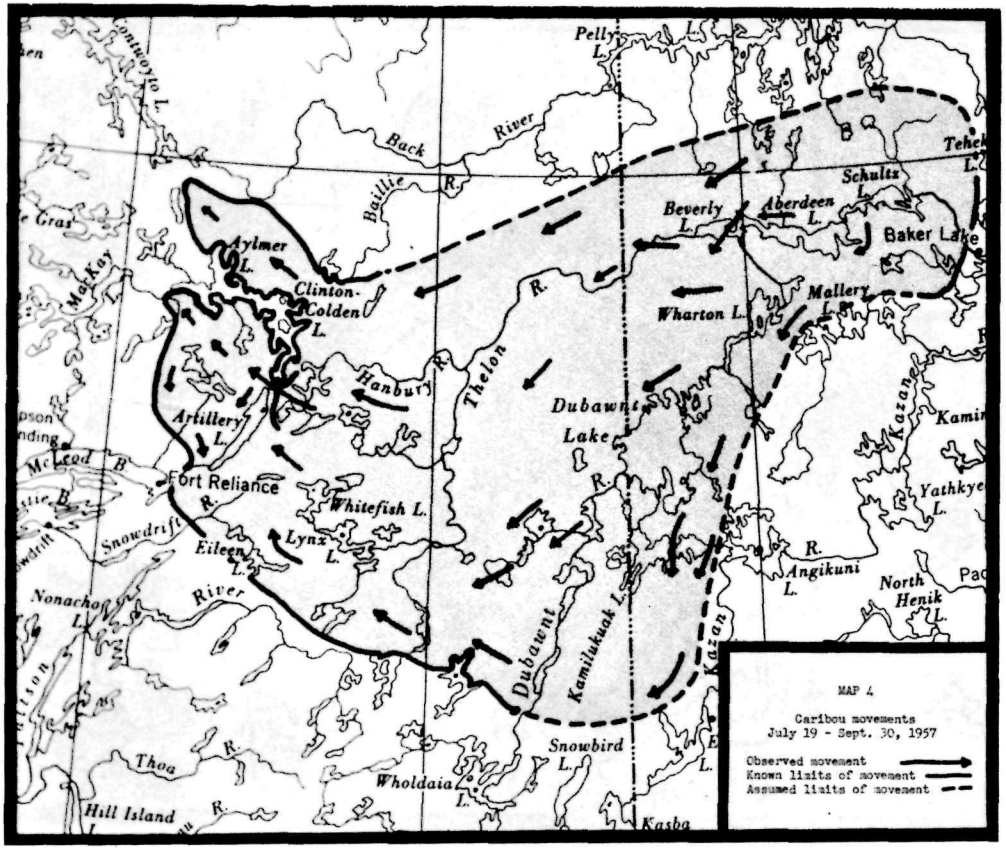
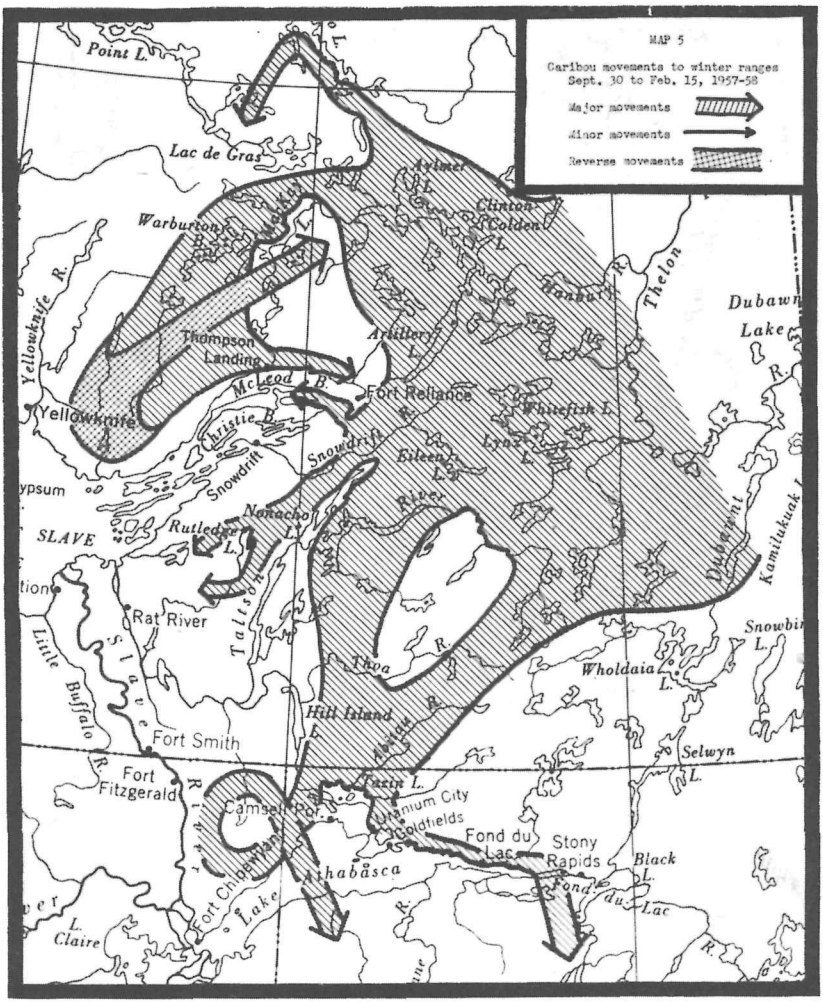
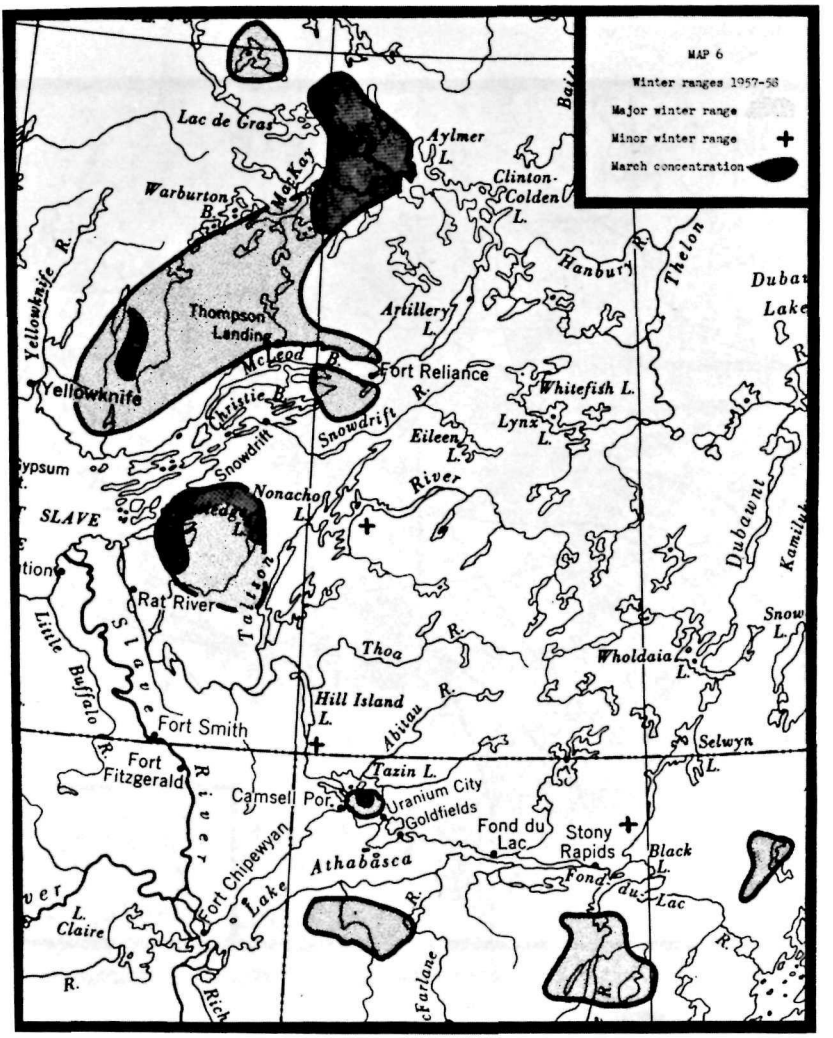

MAP I
HUMAN UTILIZATION OF CARIBOU
INDIAN AND METIS HUNTING
ESKIMO HUNTING
ISOLATED WHITE TRAPPERS
Yellowknife
Fort Reliance
Baker Lake
Fort Smith
Fort Fitzgerald
Rat River
Thompson Landing
Camsell Pcr.
Uranium City
Goldfields
Fond du Lac
Stony Rapids
Bitumount
Lake Athabasca
Lac de Gras
Aylmer L.
Clinton-Colden L.
Artillery L.
Whitefish L.
Dubawnt Lake
Thelon
Kazan
Beverly L.
Aberdeen L.
Schultz L.
Wharton L.
Warburton B.
Nonacho L.
Rutledge L.
Wholdaia L.
Selwyn L.
Hill Island L.
Tazin L.
Black L.
SLAVE

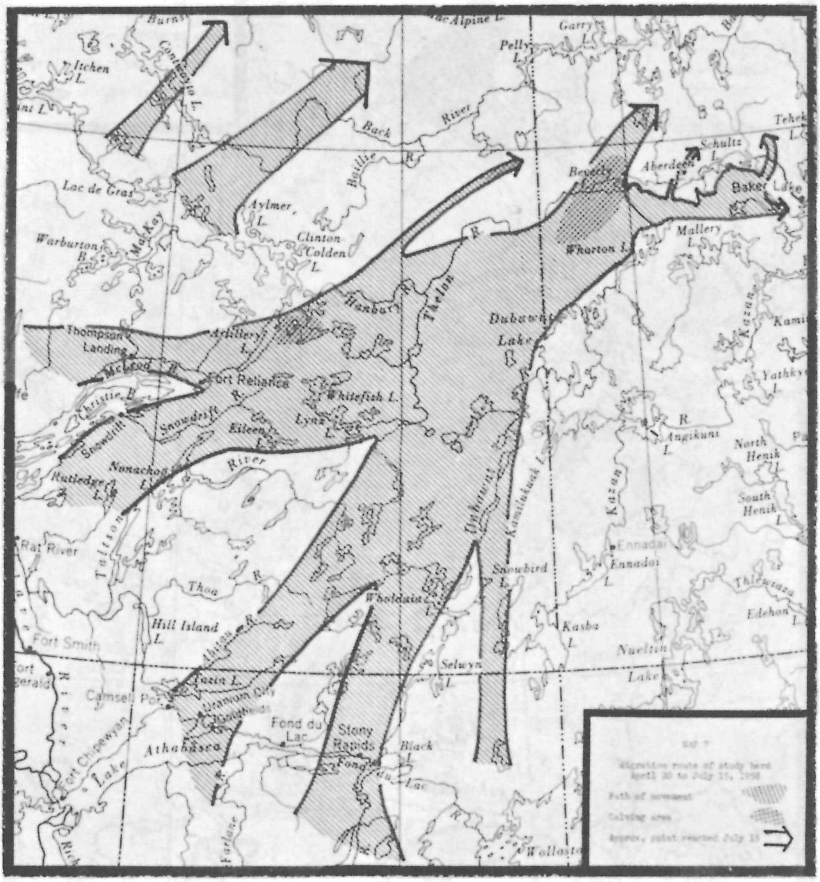

Lac de Gras
Aylmer L.
Warburton R.
Mackay L.
Clinton-Colden L.
Hanbury R.
Thelon R.
Dubawnt Lake
Thompson Landing
Artillery L.
Yellowknife R.
McLeod R.
Fort Reliance
Yellowknife
Whitefish L.
Lynx L.
Eileen L.
Snowdrift
Nonacho L.
Rutledge L.
Rat River
Little Buffalo R.
Taltson R.
Thoa R.
Hill Island L.
Fort Smith
Fort Fitzgerald
Tazin L.
Camsell Portage
Uranium City
Athabasca
Fond du Lac
Stony Rapids
Black
Fort Chipewyan
Lake Claire
Wholdaia L.
Selwyn L.
Snowbird L.
Kamilukuak L.
Beverly L.
Aberdeen L.
Wharton L.
Mallery L.

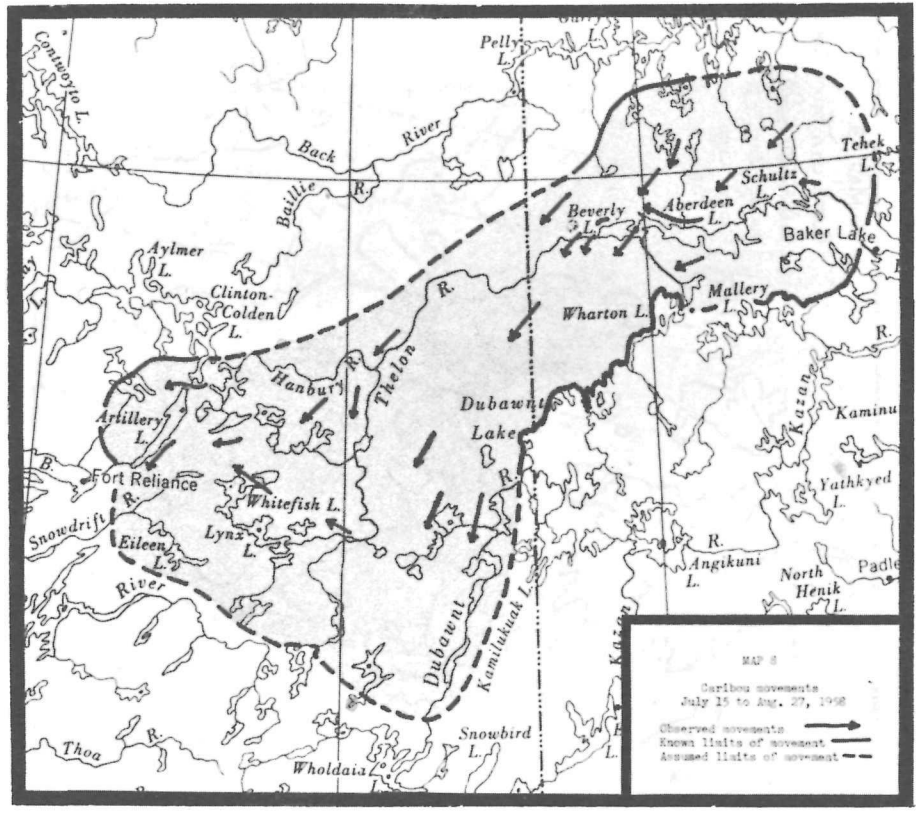

Back R.
Baillie R.
Aylmer L.
Clinton-Colden L.
Artillery L.
Fort Reliance
Snowdrift R.
Eileen L.
Nonacho L.
River
Tallson R.
Hill Island L.
Athabasca
Lake
Contwoyto L.
Beverly L.
Aberdeen L.
Schultz L.
Baker Lake
Mallery L.
Wharton L.
Thelon R.
Dubawnt Lake
Whitefish L.
Lynx L.
Angikuni L.
North Henik L.
South Henik L.
Ennadai L.
Snowbird L.
Wholdaia L.
Kasba L.
Selwyn L.
Stony Rapids
Black L.
Wollaston
Kazan R.
Kamilukuak L.
Yathkyed L.
Thlewiaza R.
Edehon L.
MAP 3
Migration route of study herd
April 27 to July 18
1967
Path of movement
Calving area
Tail of movement May 15
Tail of movement June 7
Point reached July 18

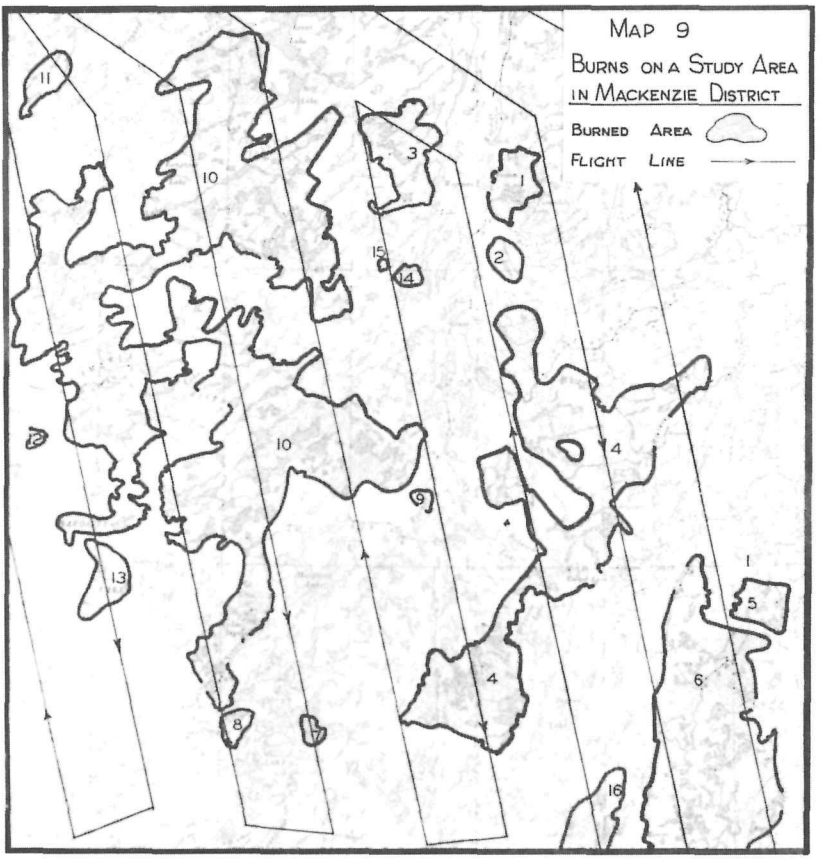

Pelly L.
Back River
Baillie R.
Schultz L.
Beverly L.
Aberdeen L.
Baker Lake
Aylmer L.
Clinton-Colden L.
Wharton L.
Mallery L.
Hanbury R.
Thelon R.
Dubawnt Lake
Artillery L.
Fort Reliance
Whitefish L.
Snowdrift R.
Eileen L.
Lynx L.
Yathkyed L.
Angikuni L.
North Henik L.
Nonacho L.
River
Dubawnt R.
Kamilukuak L.
Snowbird L.
Wholdaia L.
Thoa R.
Hill Island L.
Kasba
MAP 4
Caribou movements
July 19 - Sept. 30, 1957
Observed movement
Known limits of movement
Assumed limits of movement

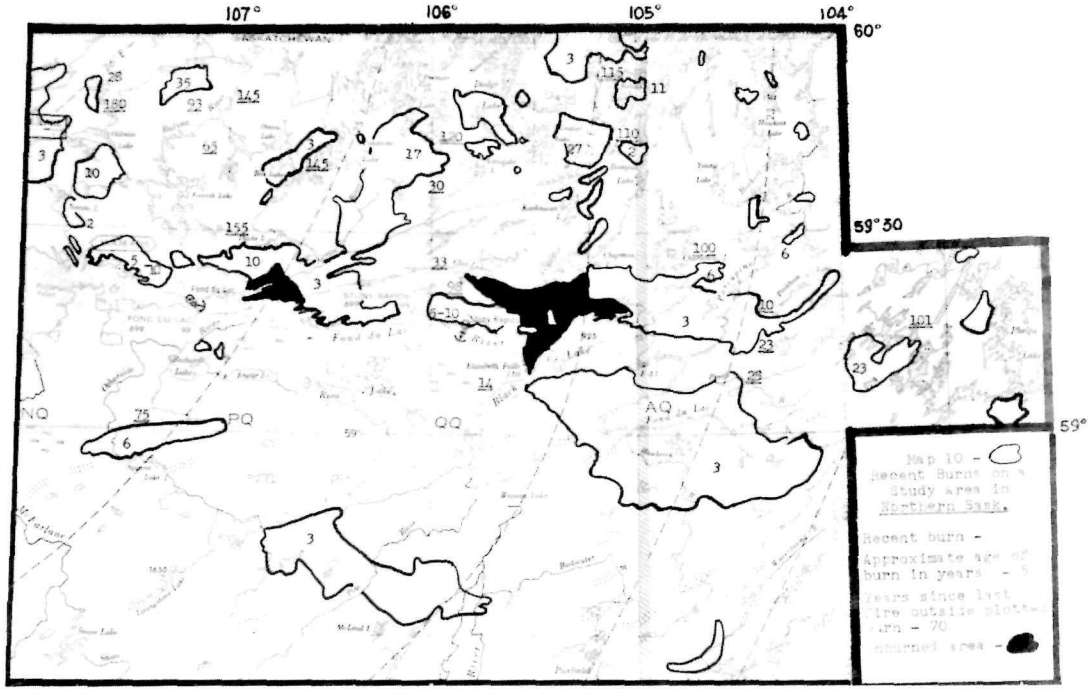

MAP 5
Caribou movements to winter ranges
Sept. 30 to Feb. 15, 1957-58
Major movements
Minor movements
Reverse movements
Point L.
Lac de Gras
Aylmer L.
Clinton Colden L.
Warburton B.
Yellowknife R.
Thompson Landing
McLeod B.
Yellowknife
Christie B.
Snowdrift
Artillery L.
Hanbury R.
Thelon
Dubawnt Lake
Fort Reliance
Whitefish L.
Lynx L.
Eileen L.
Snowdrift River
Nonacho L.
Rutledge L.
SLAVE
Rat River
Talston R.
Thva R.
Wholdaia L.
Snowbird L.
Dubawnt
Kamilukuak L.
Little Buffalo R.
Slave R.
Hill Island L.
Fort Smith
Fort Fitzgerald
Camsell Por.
Fazin L.
Uranium City
Goldfields
Fond du Lac
Stony Rapids
Athabasca
Fond du Lac
Black L.
Selwyn L.
Fort Chipewyan
Lake
L. Claire


MAP 6
Winter ranges 1957-58
Major winter range
Minor winter range
March concentration
Lac de Gras
Aylmer L.
Clinton-Colden L.
Warburton B.
Mackay
Yellowknife R.
Thompson Landing
Artillery L.
Hanbury R.
Thelon
Dubawnt Lake
Yellowknife
McLeod B.
Fort Reliance
Whitefish L.
Christie B.
Snowdrift R.
Lynx L.
Eileen L.
Snowdrift
Nonacho L.
River
SLAVE
Rat River
Talston
Dubawnt
Kamilukuak
Little Buffalo R.
Slave River
Thoa R.
Wholdaia L.
Snow L.
Hill Island L.
Abitau R.
Fort Smith
Selwyn L.
Fort Fitzgerald
Tazin L.
Camsell Por.
Uranium City
Goldfields
Fond du Lac
Stony Rapids
Black L.
Athabasca
Fond du Lac
Fort Chipewyan
Lake
L. Claire
R.
Richardson
McFarlane R.


Itchen L.
Lac de Gras
Back River
Pelly L.
Garry L.
Aylmer L.
Clinton Colden L.
Warburton B.
Beverly
Aberdeen
Schultz L.
Baker Lake
Wharton L.
Mallery L.
Hanbury R.
Thelon
Dubawnt Lake
Thompson Landing
Artillery L.
Fort Reliance
Whitefish L.
Christie B.
Snowdrift
Eileen L.
Lynx L.
Nonacho L.
Rutledge L.
Taltson
Rat River
Thoa R.
Hill Island L.
Fort Smith
Camsell Port
Tazin L.
Uranium City
Fond du Lac
Stony Rapids
Black L.
Athabasca
Lake
Wholdaia
Selwyn L.
Snowbird L.
Kasba L.
Dubawnt
Kamilukuak L.
Kazan
Angikuni L.
Ennadai
Ennadai L.
North Henik
South Henik L.
Nueltin Lake
Edehon L.
Yathkyed L.


Contwoyto L.
Pelly L.
Back River
Baillie R.
Tehek L.
Schultz L.
Aberdeen L.
Beverly L.
Baker Lake
Aylmer L.
Clinton-Colden L.
Wharton L.
Mallery L.
Hanbury R.
Thelon R.
Dubawnt Lake
Kaminu
Artillery L.
Fort Reliance
Whitefish L.
Yathkyed L.
Snowdrift R.
Eileen L.
Lynx L.
Angikuni L.
North Henik L.
River
Dubawnt R.
Kamilukuak L.
Snowbird L.
Thoa R.
Wholdaia L.
MAP 6
Caribou movements
July 15 to Aug. 27, 1948
Observed movements
Known limits of movement
Assumed limits of movement


MAP 9
BURNS ON A STUDY AREA
IN MACKENZIE DISTRICT
BURNED AREA
FLIGHT LINE
11
10
3
15
14
2
10
9
4
13
1
5
6
4
8
16


107°
106°
105°
104°
60°
59°30
59°
NQ
PQ
QQ
AQ
Map 10 -
Recent Burns on
Study Area in
Northern Sask.
Recent burn -
Approximate age of
burn in years -
Years since last
fire outside plott-
ern - 70
Gourmel area -