Biology of the Kaminuriak Population of barren-ground caribou Part 3

by Donald R. Miller
Errata

Biology of the Kaminuriak Population of barren-ground caribou

Part 3: Taiga winter range relationships and diet
by Donald R. Miller

Canadian Wildlife Service
Report Series Number 36

Page 16, Figure 4:
The figure originally printed should be replaced with the graph shown on the reverse side of this page.

Page 17, Table 8, heading for third column from the left:
For Mean *%
Read Mean *g

Page 29, right column, second sentence:
For Cladina alpestris, on the other hand, is a less preferred reindeer forage in Scandinavia and northwestern Manitoba (Scotter, 1965c),....
Read Cladina alpestris, on the other hand, is considered questionable as a preferred forage in Scandinavia and northwestern Manitoba (Scotter, 1965c),....

Page 31, middle column, end of first sentence in last paragraph:
For....which was slightly less than Pegau (1968b) found on the Seward Peninsula in (C. rangiferina).
Read....which was slightly less than Pegau (1968b) found on the Seward Peninsula in Alaska at three locations, 4.3–5.8 (C. alpestris) and 5.0–5.8 (C. rangiferina).

Page 32, left column, first paragraph, end of first sentence:
For...., somewhat less than Beckel's estimate of 0.25 per cent for approximately the same area during the 20-year period 1935–66 (Table 16).
Read...., somewhat less than Beckel's estimate of 0.25 per cent for approximately the same area during the 20-year period 1935–55 (Table 16).

Page 32, left column, first paragraph, second sentence:
For In contrast, forest fires burned an estimated 0.87 per cent of land area annually from 1940 to 1955 on a study area in northcentral Saskatchewan (Scotter, 1964).
Read In contrast, forest fires burned an estimated 0.87 per cent of land area annually from 1945 to 1959 on a study area in northcentral Saskatchewan (Scotter, 1964).
Figure 4
Lichen standing crop plotted against age of tree stand on study sites

Figure 4
Lichen standing crop
(kg/10^3)

- Upland spruce
- Lowland spruce
- Mixed spruce & jackpine
- Jackpine
- Fenced enclosures

Age (yr.)
Biology of the Kaminuriak Population of barren-ground caribou

Part 3: Taiga winter range relationships and diet

by Donald R. Miller

Canadian Wildlife Service
Report Series Number 36

A series to consist of four parts:
Part 1: Total numbers, mortality, recruitment, and seasonal distribution by G. R. Parker
Part 2: Age and sex composition and segregation of the population by F. L. Miller
Part 3: Taiga winter range relationships and diet by D. R. Miller
Part 4: Growth, reproduction and nutritional condition by T. C. Dauphiné, Jr.
Cover: Caribou trail in mid winter to feeding site in semi-open spruce, northwestern Manitoba. Note the muzzle marks along the trail where caribou searched for the scent of forage beneath the snow.

Photo by Donald R. Miller
Table 9. Percentage frequency of heavily cratered sites among habitat types observed from the air in February 1967 and 1968.

Table 10. Percentage frequency of forage items found in crater and aroreal forage collections in early, mid, and late winter, 1967-68.

Table 11. Occurrence of lichens and vascular plants at caribou feeding sites used in mid and late winter, 1968, at Hara Lake, Saskatchewan.

Table 12. Location, date established, size, and forest cover of crater enclosures.

Table 13. Percentage intermediate and ground cover in the caribou crater enclosures at Hara Lake, Saskatchewan.

Table 14. Percentage occurrence of plants in caribou rumen samples.

Table 15. Seasonal comparison by weight of rumen contents.

Table 16. Comparison of aerial photograph interpretations of samples of caribou winter range made in taiga of northern Saskatchewan and northwestern Manitoba.

List of figures

8. Figure 1. Forest regions in the range of the Kamutik caribou population (after How., 1959).  
11. Figure 2. Proportions of major land and cover types of a 12,106-km² area of caribou winter range in northwestern Manitoba as determined by air photo interpretation.  
12. Figure 3. Areas burnt by forest fires on 11,432 km² of caribou range in northwestern Manitoba between 1955 and 1967, and areas with conifer reproduction less than 0.3 m high and between 0.3 and 1.8 m high in 1955 (after Becket, 1958).  
16. Figure 4. Lichen standing crop plotted against age of tree stand on study sites.  
24. Figure 5. Weight of the five major forage items found in caribou rumens collected in 1966-68.  
26. Figure 6. Daily range of temperatures recorded at sites within caribou range in the taiga during early, mid, and late winter periods, 1967-68.  
27. Figure 7. Range of snow depths and crust hardness measured in cover types during early, mid, and late winter periods, 1967-68.  
30. Figure 8. A comparison of percentage occurrence of the four most common lichen genera.

List of appendices

38. Appendix 1. Forest type, location, topography, density, size, and age of trees in study plots and enclosures.  
39. Appendix 2. Percentage cover of plant species occurring in more than four study plots or enclosures.  
40. Appendix 3. Mean and range of percentage by weight of major lichen genera in study plots and enclosures.  
41. Appendix 4. Location and forage plant cover of square metre plots established in 1967.
Introduction

Caribou winter on the taiga, the far northern boreal forest. Winter range is a possible factor limiting caribou populations and forest fires have reduced its capacity to support caribou. Therefore CWS included a study of the winter range in their intensive investigation of the biology of the Kaminuriak population. The objectives of the study were to appraise the amount and quality of vegetation on the winter range, to relate seasonal changes in caribou food habits to availability, to estimate capacity of the taiga to sustain current use, and to collect data on the physical environment especially snow conditions. Since caribou use the taiga only during winter, I separated the food habits study into four periods according to snow characteristics: early winter, a period of snow accumulation and major restrictions to caribou movements; mid winter, a period of continued snow accumulation and major restrictions to caribou movements by deep and wind-crusted snow; late winter, a period when the snow forms a hard crust because of alternating freezing and thawing; and spring, when snow crusts deteriorate and depths decrease. I included information on forage use on theundra and the ecotone between tundra and taiga to give the reader a more complete picture of the caribou’s food habits.
The study area was the part of the taiga inhabited by caribou of the Kaminuriak Population during the study. I did all vegetation studies in northwestern Manitoba, except for analyses of some crater sites in northeast Saskatchewan.

The winter range of the Kaminuriak Population, according to tagged caribou returns (Miller and Robertson, 1967) lies almost completely in forest (called the Northwestern Transitional Section by Brown, 1959). A small portion of the winter range extends northwest into the Forest-Tundra Section, a transition zone between the subarctic forest and tundra (Fig. 1).

The landscape is patterned with all the forms of glacially moulded drift overlying Precambrian granites and gneisses. The two major land forms (Blicharz, 1962) are patternless and drumlinized drift plains. In patternless drift plains the relief is low and rolling with extensive bogs between drumlins, rock outcrops and major moraines. In drumlinized drift plains the relief is moderate with extensive elongated bogs and occasional fens in the depressions between ridges.

Soils are mainly fine and coarse sand. Podzols are common on the better drained sites. The main portion of the area lies within the discontinuous permafrost region with the northwest corner in the region of continuous permafrost (Brown, 1969).

The vegetation is a mosaic of forest muskeg and fen cut across by sandy eskers and areas of open water. The most abundant tree is black spruce (Picea mariana). Jack pine (Pinus banksiana) is abundant on upland sites in the southern part of the range. White spruce (Picea glauca) grows on the favourable soils of eskers and sand plains. White birch (Betula papyrifera) is often found in association with spruce and pine on dry sites, and tamarack (Larix laricina) with spruce on wet sites. White aspen (Populus tremuloides) and balsam poplar (Populus balsamifera) are uncommon, growing only on sheltered sites. Willow (Salix spp.), dwarf birch (Betula spp.), alder (Alnus crispa), scattered white birch, and tamarack border the lakes and streams.

Dominating the shrub vegetation on upland sites are the ericoid shrubs Vaccinium vitis-idaea, V. uliginosum, and Ledum groenlandicum in the north, and K. myrsinites in the south. Cladina rangiferina, Calypoglossum viride, and Andromeda polifolia are common in wet sites. In the fens, along lake and stream shores are Calamagrostis canadensis, Carex spp., and Sphagnum spp., with Eriophorum spp., Juncus spp., and Equisetum fluviatile locally abundant.

Ground cover on many upland sites is made up of dense muskeg mats. The major lichen species at these sites in the drumlinized drift plains, according to Scottot (1965a), are Cladina mitis, C. rangiferina, Cladonia alpestris, C. amaura, and C. uncialis. Cladonia gracilis can be added to this list in the patternless drift plains. The feather mosses, principally Hylocomium splendens, Pohlia nutans, and Polytrichum spp., are common in the ground cover of the better drained sites along with the liverwort Plagiomnium philolaum. Sphagnum spp. dominate the muskeg on wet sites.

Winters are long and severe, and summers are short, dry, and cool. Annual precipitation is about 38 cm and falls mainly in the warmest months, July and August. Minimum precipitation occurs in February. The total snowfall is about 152 cm, and the period with the largest accumulation on the ground is in February and March.
I surveyed the winter forage to assess the types and areas of habitats, and the distribution, quantity, and quality of the potential forage within the habitat types.

1. Methods

1.1. Aerial photography

An area of 12,106 km² was photographed in colour from the air during late June and July 1967 at an altitude of about 2,743 m. Scale of the photographs was 1:15,840.

The area photographed included the entire Whiskey Jack Lake Topographic Map Sheet 64K of NTS 1:250,000 Series, published in 1962 by the Surveys and Mapping Branch, Department of Mines and Technical Surveys, Ottawa. The same area had been photographed in black-and-white during July and August 1955 at a scale of 1:60,000, and the plant cover of 11,452 km² had been interpreted and mapped (Becket, 1958).

M. R. Robinson interpreted the aerial photos; he marked the following habitat types with India ink on one of the stereo pairs:

- Sparse spruce
- Dense spruce
- Sparse jack pine
- Treed swamp (where drawn)
- Meadows (fras)
- Recent burn
- Water
- Miscellaneous
- Boulder fields
- Small islands of mixed habitat
- Cabin community sites

Minimum size of any one habitat type marked was 2 acres and a dot grid overlay was used to determine acreages at a rate of one dot equals 0.5 acres.

1.2. Study plots

I selected sites for vegetational studies in four areas of traditional caribou winter range in northwestern Manitoba. Crown canopy and drainage conditions served as a basis for categorizing cover types. I allotted the number of sites in each

Table 1

<table>
<thead>
<tr>
<th>Position of region sampled</th>
<th>Total area (hectares)</th>
<th>Muskeg</th>
<th>Browse draw</th>
<th>Meadow</th>
<th>Spurce</th>
<th>Dense</th>
<th>Jack pine</th>
<th>Dense</th>
<th>Burn</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northwest quarter</td>
<td>311,400</td>
<td>24</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>9</td>
<td>17</td>
<td>17</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Northeast quarter</td>
<td>267,710</td>
<td>23</td>
<td>1</td>
<td>6</td>
<td>30</td>
<td>3</td>
<td>6</td>
<td>6</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Southwestern quarter</td>
<td>310,049</td>
<td>26</td>
<td>5</td>
<td>0</td>
<td>5</td>
<td>13</td>
<td>24</td>
<td>14</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Southeast quarter</td>
<td>312,735</td>
<td>38</td>
<td>7</td>
<td>3</td>
<td>33</td>
<td>6</td>
<td>14</td>
<td>14</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Entire region</td>
<td>1,210,755</td>
<td>28</td>
<td>6</td>
<td>32</td>
<td>2</td>
<td>6</td>
<td>2</td>
<td>5</td>
<td>19</td>
<td></td>
</tr>
</tbody>
</table>

Map sheet 64K (Whiskey Jack Lake), Canadian topographical maps 1:250,000 series. Department of Energy, Mines and Resources.

of the standing crop from 25-1 m² plots described in "Study plots," and partially air-dried them in the field. In the laboratory, foreign material was removed and air-dried and the pure samples weighed. A 100-gm subsample from each 1-m² plot supporting over 100 g of pure sample was analyzed for energy and protein.

The samples were ground, air-dried, and analyzed using a calorimeter to determine energy, and micro-Kjeldahl technique for nitrogen content. The same techniques were used on additional samples of Cladonia alpestris and C. rangiferina collected from dense stands and divided into living and non-living components for separate energy and nitrogen analyses.

2. Results

2.1. Aerial photography and occurrence of fires

Interpretation of coloured aerial photographs of 12,106 km² in northwestern Manitoba showed that the area is comprised of about 20 per cent water and 80 per cent land. The land surface includes about equal proportions of upland, with 80 per cent spruce and 20 per cent jack pine, and lowland, with 80 per cent muskeg and 20 per cent meadow (see in Scandinavian and Russian literature) (Fig. 2). The upland is dominated by semi-open to open canopy and a
However, includes 1961, a year when forest fires in northern Manitoba were unusually numerous and extensive.

A comparison of the locations of recently burnt areas with those reported by Beekel (1958) as supporting conifers under 0.3 m tall and 0.3 to 1.8 m tall suggests that some areas are more susceptible to forest fires than others (Fig. 3).

I attempted to distinguish between recent, old and intermediate-aged burns that had occurred between 1955 and 1967, and to assess changes in the frequency of fires in the area (Table 2). Although it is not safe to assume that the three categories represented equal periods of time, the figures do not indicate any major change in frequency or size of forest fires between 1955 and 1967. Forest fires burnt over both upland and lowland regions, and from data for the southeast quarter of the photographed area, upland regions were burnt more than lowland. Of the 0.047 ha that had burned since 1955 in that quarter, 5.85 ha were in upland regions.

2.2. Vegetation on study plots. Appendix 1 describes 25 plots and six enclosures on which I studied vegetation. The plots were located on sites representing the most common topographical types of the treated portion of the winter range. I did not sample muskegs, meadows, or lichen ground cover.

The size and density of trees in the macroplots varied considerably within each cover type (Table 3). Age of the stands sampled ranged from 30 to 181 years.

Low woody plants were more abundant on sparsely than jack pine sites and on lowland in contrast to upland sites (Table 4, Appendix 2). Found Vaccinium vitis-idaea on all study sites; it has the greatest ecological amplitude of any vascular plant in the study area. Ledum groenlandicum and E. decumbens were abundant in spruce stands and especially on lowland sites.

Lichens dominated the ground cover except on two lowland spruce plots where mosses covered the ground (Table 5, Appendix 2). The relative size, number and size range of forest fires that occurred in a 12,106-km$^2$ area of northwestern Manitoba between 1955 and 1967 as determined from coloured aerial photographs. The relative age, number and size range of forest fires that occurred in a 12,106-km$^2$ area of northwestern Manitoba between 1955 and 1967 as determined from coloured aerial photographs.
Table 5
Mean and range of percentages by weight of major lichen genera in study plots and enclosures

<table>
<thead>
<tr>
<th>Plot type</th>
<th>No. of plots</th>
<th>Cladina</th>
<th>Cladonia</th>
<th>Stereocaulon</th>
<th>Ceratonia</th>
<th>Peltigera</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upland spruce</td>
<td>7</td>
<td>16.6</td>
<td>0.0</td>
<td>4.7</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Lowland spruce</td>
<td>6</td>
<td>25.5</td>
<td>3.9</td>
<td>12.5</td>
<td>0.0</td>
<td>5.5</td>
</tr>
<tr>
<td>Mixed spruce</td>
<td>5</td>
<td>24.6</td>
<td>18.5</td>
<td>0.1</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Jack pine</td>
<td>6</td>
<td>17.0</td>
<td>25.7</td>
<td>0.0</td>
<td>2.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Enclosures</td>
<td>4</td>
<td>17.3</td>
<td>17.2</td>
<td>0.0</td>
<td>5.3</td>
<td>0.0</td>
</tr>
</tbody>
</table>

*Disc samples were not collected from Plot B.

Table 6
Re-establishment of lichens on 1 m² plots during the first 27 months after complete removal of lichens in June 1967

<table>
<thead>
<tr>
<th>Lichen cover</th>
<th>% cover of primary thalli June 1968</th>
<th>% cover of primary thalli Sept. 1969</th>
<th>% cover of secondary thalli Sept. 1969</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cladina alpina</td>
<td>15</td>
<td>50</td>
<td>Tr</td>
</tr>
<tr>
<td>Stereocaulon spp.</td>
<td>50</td>
<td>75</td>
<td>50</td>
</tr>
<tr>
<td>Cladonia rangiferina</td>
<td>10</td>
<td>10-15</td>
<td>Tr</td>
</tr>
<tr>
<td>Ceratonia nivalis</td>
<td>20</td>
<td>50</td>
<td>10</td>
</tr>
<tr>
<td>Mixed spp.</td>
<td>5</td>
<td>10</td>
<td>Tr</td>
</tr>
<tr>
<td>Stereocaulon spp.</td>
<td>5</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>B. Mixed spp.</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mixed spp.</td>
<td>5</td>
<td>50</td>
<td>Tr</td>
</tr>
<tr>
<td>Mixed spp.</td>
<td>10</td>
<td>25</td>
<td>Tr</td>
</tr>
<tr>
<td>Cladina alpina and Cladonia spp.</td>
<td>0</td>
<td>50</td>
<td>10</td>
</tr>
<tr>
<td>Cladonia alpina and Cladonia spp.</td>
<td>0</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>Cladina alpina and Cladonia spp.</td>
<td>0</td>
<td>25</td>
<td>0</td>
</tr>
</tbody>
</table>

*Two inches of turf and mineral soil removed.

Table 7
Protein and energy values of forage plant species taken in summer from 1-m² plots. Protein is calculated by multiplying total nitrogen by 6.25. Dates given in appendix 3.

<table>
<thead>
<tr>
<th>Plots no.</th>
<th>Forage type</th>
<th>Protein, %</th>
<th>Energy, k cal./100 g</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lichen, 75% Cladina alpina</td>
<td>2.54</td>
<td>434</td>
</tr>
<tr>
<td>2</td>
<td>Lichen, 95% Stereocaulon pinastri</td>
<td>10.16</td>
<td>480</td>
</tr>
<tr>
<td>3</td>
<td>Lichen, 50% Cladonia rangiferina</td>
<td>2.00</td>
<td>425</td>
</tr>
<tr>
<td>4</td>
<td>Lichen, 50% Ceratonia nivalis</td>
<td>2.34</td>
<td>426</td>
</tr>
<tr>
<td>5</td>
<td>Lichen, mixed</td>
<td>2.09</td>
<td>414</td>
</tr>
<tr>
<td>6</td>
<td>Lichen, mixed</td>
<td>2.89</td>
<td>416</td>
</tr>
<tr>
<td>7</td>
<td>Lichen, 75% Stereocaulon pinastri</td>
<td>6.42</td>
<td>435</td>
</tr>
<tr>
<td>8</td>
<td>Lichen, mixed Cladonia alpina and Cladonia rangiferina</td>
<td>2.71</td>
<td>431</td>
</tr>
<tr>
<td>9</td>
<td>Lichen, mixed</td>
<td>8.27</td>
<td>566</td>
</tr>
<tr>
<td>10</td>
<td>Vaccinium vitis-idaea</td>
<td>5.77</td>
<td>509</td>
</tr>
<tr>
<td>11B</td>
<td>Vaccinium vitis-idaea</td>
<td>6.27</td>
<td>551</td>
</tr>
<tr>
<td>12</td>
<td>Lichen, mixed</td>
<td>2.82</td>
<td>433</td>
</tr>
<tr>
<td>13</td>
<td>Lichen, mixed</td>
<td>3.16</td>
<td>433</td>
</tr>
<tr>
<td>14</td>
<td>Lichen, mixed Cladina alpina</td>
<td>2.21</td>
<td>433</td>
</tr>
<tr>
<td>15</td>
<td>Lichen, mixed</td>
<td>2.60</td>
<td>457</td>
</tr>
<tr>
<td>16</td>
<td>Lichen, mixed</td>
<td>2.10</td>
<td>428</td>
</tr>
<tr>
<td>17</td>
<td>Lichen, mixed</td>
<td>2.12</td>
<td>434</td>
</tr>
<tr>
<td>18</td>
<td>Lichen, mixed</td>
<td>4.54</td>
<td>468</td>
</tr>
<tr>
<td>19</td>
<td>Ceratonia nivalis</td>
<td>5.25</td>
<td>412</td>
</tr>
<tr>
<td>20</td>
<td>Vaccinium vitis-idaea</td>
<td>13.71</td>
<td>383</td>
</tr>
<tr>
<td>21</td>
<td>Lichen, mixed Cladina alpina</td>
<td>8.36</td>
<td>569</td>
</tr>
<tr>
<td>22</td>
<td>Vaccinium vitis-idaea</td>
<td>5.76</td>
<td>448</td>
</tr>
<tr>
<td>23</td>
<td>Ceratonia nivalis</td>
<td>2.65</td>
<td>356</td>
</tr>
<tr>
<td>24</td>
<td>Lichen, mixed</td>
<td>1.82</td>
<td>345</td>
</tr>
<tr>
<td>25</td>
<td>Lichen, mixed Cladina alpina</td>
<td>4.14</td>
<td>366</td>
</tr>
</tbody>
</table>

Lichen growth on carrot pellets

In September 1968, two summers after the pellets had been deposited, they had disappeared off sites where Stereocaulon pinastri was the dominant lichen, but were still conspicuous where Cladina spp. and Ceratonia nivalis were dominant. On Stereocaulon sites the pellets had filtered down to the base of the podetia and were covered over by the upper parts. In both lichen communities the pellets had

Table 8
Cladonia alpina growing in full-like clumps at Breekr, Manitoba, where a similar colonization has not occurred for more than a half-century. The author has observed this growth from only among the several boulder sites within the utilized area of the tundra sinter range.

Aboretal lichens on a jack pine growing on an esker at Durham Lake, Manitoba.

Table 8
Lichen growth on carrot pellets

In September 1968, two summers after the pellets had been deposited, they had disappeared off sites where Stereocaulon pinastri was the dominant lichen, but were still conspicuous where Cladina spp. and Ceratonia nivalis were dominant. On Stereocaulon sites the pellets had filtered down to the base of the podetia and were covered over by the upper parts. In both lichen communities the pellets had...
kept their shape but had become smaller and covered by small cracks.

In September 1969, when marked pellet groups were three summers old, they were no longer conspicuous in Cladina, Cladina, and Cetraria lichen communities.

On close examination the pellets were found, and on many primary lichen thalli had covered up to 10 per cent of the pellet surface area. The thalli were on the area of the pellet that was protected from direct exposure. On one pellet a podetium of nearly 1 cm in length was growing among the primary thalli. I also observed primary thalli on the sheltered sides of moose pellets placed inside Enclosures No. 6, in June 1967, 3 years earlier. Evidently lichen regeneration is quite rapid on certain substrates in favourable environments.

2.4. Standing crop and nutritional analysis.

Chemical analyses of sub-samples from 1-m² plots showed that the protein content of lichens ranged from 5 to 122 mg/g (mean = 34 mg/g) and in vascular plants from 5 to 377 mg/g (mean = 68 mg/g). The two Streptocladina lichen samples were especially high in protein (82.9 mg/g) and energy (467 kcal/100 g) as were autumn-collected samples of Lecanora gregora, Cetraria alpestris and Cladonia rangiferina. Protein content of samples of the latter species varied widely. This might be explained by different collection periods. For example, Equisetum Sample 22 with twice the protein content was collected before, and Equisetum Sample 25 after, a heavy frost and light snow cover. Appendix 4 shows the dates on which 1-m² plots were established, with locations and forage types.

The energy content of dead podetia of Cladina alpestris and Cladonia rangiferina differed little from that of living podetia (Table 7), but protein content was lower in dead podetia.

Lichens at most plots appeared free of litter at first glance. However more than two-thirds by weight of the material removed from any single plot consisted of litter.

![Figure 4](image)

**Figure 4** Lichen standing crop plotted against age of tree stand on study sites

<table>
<thead>
<tr>
<th>Lichen standing crop (kg/ha x 10³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upland spruce</td>
</tr>
<tr>
<td>Lowland spruce</td>
</tr>
<tr>
<td>Mixed spruce &amp; jackpine</td>
</tr>
<tr>
<td>Jackpine</td>
</tr>
<tr>
<td>Fenced enclosures</td>
</tr>
</tbody>
</table>

![Table 8](image)

**Table 8** Estimation of standing crop of terrestrial lichens from cover measurements and weights of lichen divers

<table>
<thead>
<tr>
<th>Plot</th>
<th>Mean* % lichen cover</th>
<th>Lichen material per threat/10 in lichen cover</th>
<th>Standing crop, kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>92</td>
<td>5.42 ± 0.35</td>
<td>5,082</td>
</tr>
<tr>
<td>2</td>
<td>84</td>
<td>7.30 ± 0.40</td>
<td>5,193</td>
</tr>
<tr>
<td>3</td>
<td>86</td>
<td>7.42 ± 0.37</td>
<td>6,383</td>
</tr>
<tr>
<td>4</td>
<td>81</td>
<td>5.18 ± 0.40</td>
<td>4,196</td>
</tr>
<tr>
<td>5</td>
<td>84</td>
<td>7.21 ± 0.38</td>
<td>4,904</td>
</tr>
<tr>
<td>6</td>
<td>79</td>
<td>7.54 ± 0.30</td>
<td>5,957</td>
</tr>
<tr>
<td>7</td>
<td>80</td>
<td>7.28 ± 0.31</td>
<td>5,924</td>
</tr>
<tr>
<td>8</td>
<td>59</td>
<td>4.65 ± 0.30</td>
<td>2,741</td>
</tr>
<tr>
<td>9</td>
<td>70</td>
<td>6.35 ± 0.55</td>
<td>4,450</td>
</tr>
<tr>
<td>10</td>
<td>21</td>
<td>3.37 ± 0.50</td>
<td>708</td>
</tr>
<tr>
<td>11</td>
<td>18</td>
<td>3.11 ± 0.20</td>
<td>560</td>
</tr>
<tr>
<td>12</td>
<td>82</td>
<td>6.39 ± 0.33</td>
<td>5,230</td>
</tr>
<tr>
<td>13</td>
<td>79</td>
<td>6.08 ± 0.22</td>
<td>4,913</td>
</tr>
<tr>
<td>14</td>
<td>79</td>
<td>5.79 ± 0.32</td>
<td>5,053</td>
</tr>
<tr>
<td>15</td>
<td>48</td>
<td>5.16 ± 0.68</td>
<td>2,477</td>
</tr>
<tr>
<td>16</td>
<td>81</td>
<td>6.53 ± 0.48</td>
<td>5,389</td>
</tr>
<tr>
<td>17</td>
<td>76</td>
<td>5.77 ± 0.79</td>
<td>4,315</td>
</tr>
<tr>
<td>18</td>
<td>77</td>
<td>5.79 ± 0.32</td>
<td>4,389</td>
</tr>
<tr>
<td>19</td>
<td>92</td>
<td>7.00 ± 0.44</td>
<td>4,440</td>
</tr>
<tr>
<td>20</td>
<td>62</td>
<td>6.05 ± 0.46</td>
<td>3,739</td>
</tr>
<tr>
<td>21</td>
<td>72</td>
<td>5.66 ± 0.35</td>
<td>4,073</td>
</tr>
<tr>
<td>22</td>
<td>79</td>
<td>5.88 ± 0.34</td>
<td>4,640</td>
</tr>
<tr>
<td>23</td>
<td>64</td>
<td>4.71 ± 0.43</td>
<td>3,014</td>
</tr>
<tr>
<td>24</td>
<td>88</td>
<td>5.74 ± 0.37</td>
<td>5,051</td>
</tr>
<tr>
<td>25</td>
<td>80</td>
<td>6.72 ± 0.37</td>
<td>5,276</td>
</tr>
<tr>
<td>Enc.</td>
<td>Jack pine</td>
<td>85 ± 0.65</td>
<td>5,891</td>
</tr>
<tr>
<td>2 Jack pine</td>
<td>80</td>
<td>5.46 ± 0.62</td>
<td>4,184</td>
</tr>
<tr>
<td>Mixed spruce</td>
<td>79</td>
<td>7.86 ± 0.69</td>
<td>6,205</td>
</tr>
<tr>
<td>Jackpine</td>
<td>85</td>
<td>6.93 ± 0.49</td>
<td>5,891</td>
</tr>
</tbody>
</table>

* Based on 20 macroplots, one-die in each, except in macroplots no. 6 and 7, in which numbers were 19, 18, and 16, respectively.

Caribou would ingest some litter along with lichens.
Forage utilization

The previous section described the potential forage available to caribou in different habitats. The following section describes the forage on which the caribou were feeding or known to have fed.

1. Methods

1.1. Winter forage utilization

I made aerial observations of heavily grazed sites during mid winter according to habitat:

- Storm on lake shores
- Uplands: densely treed to treedless
- Lowlands: densely treed, sparsely treed to treedless

I observed caribou feeding behaviour, feeding sites, and feeding period movements during all winter trips, using binoculars, a tripod mounted telescope, and a flashlight, sometimes also a blind built of snow.

1.2. Feeding crater observations and enclosures

I examined fresh snow caribou dug by foraging caribou and recorded the species occurrence of food plants. I also recorded signs of fresh browsing on tall shrubs, trees, and on arborescent lichens. I collected samples of browsed shrubs and grazed lichens, forbs, and grasslike plants1 found in fresh caribou. I followed many miles of caribou trails to collect feeding information.

I constructed 15 enclosures on cratered sites in winter and one in summer to observe the effects of caribou on forage during winter and the subsequent recovery of the plants. The enclosures, from 70 to 900 m², were in heavily grazed sites in treedless to densely treed types.

Within the enclosures I marked individual caribou by a tripod of saplings tied together at the top. I used larger tripods of long poles to mark off areas that were not grazed. I tied a string around the trunks of trees on which lichens had been utilized. I made sketches of the enclosed areas and recorded locations of spots to be examined during the summer. I constructed three crater enclosures in January and February 1967 and 12 from November 1967 until May 1968.

I constructed one enclosure of woven wire mesh in September 1967 on a heavily grazed site, and I marked the boundaries of conspicuously grazed patches of lichens with blaze-orange paint. I also marked grazed sites outside the wire enclosure with stakes and paint to permit observation of the recovery of the grazed lichens, and sampled the vegetation inside the crater enclosures similarly to the permanent enclosures, with 10 randomly located microplots measured with the 20 x 50 dm frame (Deshemtire, 1959). The macroplot was 20 x 5 m instead of the 25 x 5 m sample in the permanent enclosures.

1.3. Rumen contents

Although the interpretation of analyses of rumen samples is complicated by the problem of differential digestion rates (Devendra and Russell, 1963), rumen sampling provides quantitative information on food habits of wild ruminants. I analyzed rumen samples from 340 caribou in the study area for physiological and demographic study. From 1966 to 1968, I analyzed an additional 279 rumen from caribou in the study area and between tundra and taiga during the same years.

I collected about one litre of rumen contents from each caribou, mixed it with either 10 per cent formalin solution or 95 per cent ethyl alcohol and transferred it to the laboratory. I shook the sample and took a 100 ml subsample which I washed, sieved, and sorted into the following categories: (1) mosses and liverworts, (2) twigs, (3) leaves, (4) grasses and grasslike plants, (5) conifer needles, (6) lichens, and (7) mushrooms. No more than 2 hours was allowed for the sorting after which the sample was air-dried, weighed, and preserved in 10 per cent alcohol. I discarded material unsorted after the 2-hour limit.

I repeated the analyses of two rumen samples, from each winter collection period, to check the consistency of the technique. I divided according to species, genus or broader group the samples of the broad categories: mosses and liverworts, leaves, grasslike plants, conifer needles, and lichens.

2. Results

2.1. Winter forage utilization

From aerial observations during February 1967 and 1968, upland, semi-open to open spruce stands appeared to be the sites most frequently used by feeding caribou during mid winter (Table 9). Lowland sites comprising muskeg, meadows, and grassy river and lake shores received more use in 1966–67 than in 1967–68. Caribou were in continuous movement northeast along drainage systems in 1966–67 and comparatively stationary in 1967–68.

In November-December 1967, migrating caribou were not restricted to the usual routes along water or eskers. Their movements were not impeded by snow depth or crust. Caribou were observed feeding mainly at dawn and dusk on both upland and lowland sites and on lake and stream shores. They consistently fed during early winter in *Equisetum fluviatile* and *Carex aquatilis* communities on the shores of streams and lakes.

By February 1967, I observed caribou feeding less along lake and stream shores and more in semi-open upland spruce and jack pine stands, though along the Cochrane River they still fed extensively on *Equisetum fluviatilis* and *Carex aquatilis*.

At Bonokowski Lake in northeastern Saskatchewan I saw feeding activity in upland, semi-open, white birch, and spruce stands and in lowland spruce sites where eutrophic plants and terrestrial lichens were abundant. I observed caribou feeding at midnight in late February at the shore of Bonokowski Lake and migrating in daylight or darkness. They migrated most consistently during the coldest periods.

In mid February 1968, caribou under observation at Hara Lake, Saskatchewan migrated steadily northward. They fed in early morning and early evening though steady movements occurred anytime. Most feeding was on uplands in semi-open to dense spruce, and in white birch stands on islands. By the end of February, caribou had become stationary in the Hara Lake area, and daily feeding and resting periods became more regular. Caribou fed at similar sites as in mid February but I observed them resting on the lake ice more regularly and for longer intervals after early morning feeding periods.

In April the hardening of the snow crust from 2 months of trampling (Parker, 1972), and the effects of the sun and wind, caused a dramatic change in food habits. At Hara Lake, by mid April 1968, caribou fed almost exclusively on arborescent lichens and twigs of deciduous shrubs and trees, at midday as well as in early morning and evening.

By the end of April when the snow crust had softened, caribou no longer fed on arborescent lichens or browse. Instead they fed on terrestrial lichens and eutrophic plants that became available at thawed patches at the bases of trees, and on southern exposed slopes, grassy drainage, and eskers. Earlier in winter, caribou grazed repeatedly on the newly exposed foliage on southerly exposed slopes, created earlier in winter. As the snow reeded with each day, feeding activities became more frequent and intense.

Only one animal fed in a crater at any time and caribou competed for certain crater sites. In early spring caribou fought with antlers and forehead for preferred feeding sites.

2.2. Feeding crater observations and enclosures

The collection of plants from craters showed that grasses (*Galium latifolium*), sedges (*Carex*), and horsetails (*Equisetum*) were slightly more numerous than lichens at the feeding sites used in November and December (Table 10). As winter progressed, lichens became the most common forage item. Lichens was the most common woody...
Table 9  Percentage frequency of heavily cratered sites among habitat types observed from the air in February 1967 and 1968

<table>
<thead>
<tr>
<th>Habitat Type</th>
<th>Upland Sites</th>
<th>Lowland Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Spray and jack pine, semi-open</td>
<td>Spray and jack pine, semi-open and dense</td>
</tr>
<tr>
<td></td>
<td>1967</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td>1968</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>1969</td>
<td>57</td>
</tr>
<tr>
<td>*</td>
<td>Branch Brook Lake area.</td>
<td></td>
</tr>
<tr>
<td>**</td>
<td>Branch Lake area.</td>
<td></td>
</tr>
</tbody>
</table>

Table 10  Percentage frequency of forage items found in crater and arboreal forage collections in early, mid, and late winter, 1967-68

<table>
<thead>
<tr>
<th>Location</th>
<th>Date</th>
<th>Forage Items</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2.3. Rumen contents

I combined the plant species found in caribou rumens into forage classes. Table 14 shows rumen contents of caribou collected in the taiga.

Using chi-square tests, I found no differences in forage classes used between sexes or between cows in different reproductive conditions. I found few significant differences between locations within seasons. However, forage utilized changed markedly according to the season.

2.3.1. Locational changes

Caribou were usually killed on lakes at several locations during each season (Miller, 1974). I found no significant difference (P > 0.05) in rumen contents between locations within seasons, except in June 1967, and April and June 1968 (P < 0.001). Most caribou were shot while resting on lakes, and their immediately previous movements and feeding were unknown. However, some caribou were observed before being killed, and the feeding observations agreed closely with the rumen analyses. Rumen samples from nine caribou collected in January and February 1967, when they were migrating northward, suggested a shift during a 4-month period from a predominately lichen diet on the lower Cochrane River, Manitoba to twigs and leaves at Bulyea Lake, Saskatchewan. Grasslike plants were an important forage class in rumen samples collected in the Misty Lake area along the upper Cochrane River during early February.

2.3.2. Seasonal changes

Analysis of 13 rumen samples collected in winter 1967–68 suggested that the caribou foraged on grasslike plants and lichens in early winter, and lichens and twigs and leaves of broad-leaved shrubs in mid and late winter, with lichens making up the major portion of the combined sample.

A seasonal comparison of the sample of 543 rumens (Table 15, Fig. 3) shows marked changes in proportions of the forage.

Table 14

<table>
<thead>
<tr>
<th>Plants</th>
<th>Collection period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Jan–Feb.</td>
</tr>
<tr>
<td><em>Bryophyta</em></td>
<td>14(16)</td>
</tr>
<tr>
<td><em>Pteridium aquilinum</em></td>
<td>4(10)</td>
</tr>
<tr>
<td><em>P. juniperum</em></td>
<td>50(16)</td>
</tr>
<tr>
<td><em>P. polypodioides</em></td>
<td>36(10)</td>
</tr>
<tr>
<td><em>B. bisnaga</em></td>
<td>50(10)</td>
</tr>
<tr>
<td><em>P. angustifolius</em></td>
<td>14(10)</td>
</tr>
<tr>
<td><em>P. B. lenticellatus</em></td>
<td>37(10)</td>
</tr>
<tr>
<td><em>Hesperis spicata</em></td>
<td>0(0)</td>
</tr>
<tr>
<td><em>P. purpureum</em></td>
<td>14(10)</td>
</tr>
<tr>
<td><em>P. calcaratum</em></td>
<td>64(66)</td>
</tr>
<tr>
<td><em>Lichens</em></td>
<td>17(26)</td>
</tr>
<tr>
<td><em>B. juniperum</em></td>
<td>100(100)</td>
</tr>
<tr>
<td><em>U. montana</em></td>
<td>100(100)</td>
</tr>
<tr>
<td><em>V. vacuolata</em></td>
<td>0(0)</td>
</tr>
<tr>
<td><em>B. pratensis</em></td>
<td>100(100)</td>
</tr>
<tr>
<td><em>B. angustifolia</em></td>
<td>100(100)</td>
</tr>
<tr>
<td><em>B. pusilla</em></td>
<td>100(100)</td>
</tr>
<tr>
<td><em>B. purpureum</em></td>
<td>100(100)</td>
</tr>
<tr>
<td><em>P. umbellata</em></td>
<td>55(16)</td>
</tr>
<tr>
<td><em>Squarrosa angustifolia</em></td>
<td>(12)</td>
</tr>
<tr>
<td><em>Salsola tomentosa</em></td>
<td>0(0)</td>
</tr>
<tr>
<td><em>B. juniperum</em></td>
<td>17(19)</td>
</tr>
<tr>
<td><em>R. echinata</em></td>
<td>0(0)</td>
</tr>
<tr>
<td><em>E. angustifolia</em></td>
<td>67(10)</td>
</tr>
<tr>
<td><em>C. longa</em></td>
<td>0(0)</td>
</tr>
<tr>
<td><em>C. sowerbyi</em></td>
<td>42(10)</td>
</tr>
<tr>
<td><em>A. oblonga</em></td>
<td>25(10)</td>
</tr>
<tr>
<td><em>C. angustifolia</em></td>
<td>0(0)</td>
</tr>
<tr>
<td><em>A. angustifolia</em></td>
<td>0(0)</td>
</tr>
<tr>
<td><em>F. vesiculosus</em></td>
<td>92(10)</td>
</tr>
<tr>
<td><em>F. angustifolia</em></td>
<td>92(10)</td>
</tr>
<tr>
<td><em>C. vulgaris</em></td>
<td>105(10)</td>
</tr>
<tr>
<td><em>C. umbellata</em></td>
<td>0(0)</td>
</tr>
<tr>
<td><em>S. angustifolia</em></td>
<td>0(0)</td>
</tr>
<tr>
<td><em>C. erosa</em></td>
<td>100(100)</td>
</tr>
<tr>
<td><em>S. angustifolia</em></td>
<td>100(100)</td>
</tr>
<tr>
<td><em>C. umbellata</em></td>
<td>0(0)</td>
</tr>
<tr>
<td><em>S. angustifolia</em></td>
<td>0(0)</td>
</tr>
<tr>
<td><em>C. erosa</em></td>
<td>100(100)</td>
</tr>
<tr>
<td><em>S. angustifolia</em></td>
<td>100(100)</td>
</tr>
<tr>
<td><em>C. umbellata</em></td>
<td>0(0)</td>
</tr>
<tr>
<td><em>S. angustifolia</em></td>
<td>0(0)</td>
</tr>
<tr>
<td><em>C. erosa</em></td>
<td>100(100)</td>
</tr>
<tr>
<td><em>S. angustifolia</em></td>
<td>100(100)</td>
</tr>
<tr>
<td><em>C. umbellata</em></td>
<td>0(0)</td>
</tr>
<tr>
<td><em>S. angustifolia</em></td>
<td>0(0)</td>
</tr>
<tr>
<td><em>C. erosa</em></td>
<td>100(100)</td>
</tr>
<tr>
<td><em>S. angustifolia</em></td>
<td>100(100)</td>
</tr>
</tbody>
</table>
The amounts of twigs and leaves were significantly greater in November than in April, June, and July. In November, grasslike plants were collected in the southern portion of the taiga and were the second most abundant forage item, and that finding was supported by observations of grazing caribou. Although in April the proportion of grasslike plants had significantly increased, they were less abundant than in November. In April, there were significantly different proportions of twigs and leaves and mushrooms. Between April, June, and July, there were changes in the diet of caribou, with lichens being a major component of the contents of some rumens collected in April. Dead portions of lichen podetia in the April rumen samples, when compared to November, suggests that the caribou were either selecting forage differently or feeding in different lichen communities in the 2 months. The primary lichen thallus from some seasons was Cladina stellaris. However, a more detailed study of the availability of lichen podetia suggests that caribou fed more frequently in muskegs in early and mid-winter. That was particularly evident when the relative abundance of the two plants in rumens was compared between the three winter seasons (Table 14). Equisetum was found in some rumens collected in September, but was most common in November samples, and became progressively less common in the mid and late winter periods (Table 14). Jack pine needles appeared frequently in November rumens, the period when caribou were collected in the southern portion of the taiga. Winter range where jack pine stands are common. The occurrence of tamarack needles in rumens from the three winter periods suggests that caribou feed partly in lowland areas throughout winter. Tamarack is a common tree in the transition zone where the September 1966 caribou collections were made, and was the most common tree species in those rumens. Mosses occurred frequently in caribou rumens, either selected or accidentally eaten with other food. Eight moss species were identified in winter rumens and six were common in some seasons (Table 14). Polypodium ciliatum, however, was the only moss well represented during each collection period.
Physical environment

1. Methods

Measurements of the climate, in particular snow characteristics, helped to determine foraging patterns of the caribou.  

1.1. Climatic measurements

I took climatic readings from 1966 to 1968 in the study area. I recorded temperatures from lake and coniferous forest sites using Taylor maximum–minimum thermometers. I placed the thermometers about 1 m above the snow surface. On lakes, I attached a thermometer to a spruce sapling anchored in snow at the edge of the wind shadow and, in forests, to the trunk of a spruce tree. The thermometers faced approximately north to prevent direct exposure to the midday sun. I recorded temperatures every morning and evening, and during the day when weather changes were conspicuous. I used a Weston dial thermometer with a 20-cm stem to record air temperatures away from camp and to measure temperatures below the snow over ground and lake ice, and periodically to check the accuracy of the maximum–minimum thermometers.

1.2. Soil analysis

I collected soil samples from the study sites by extracting a plug from each corner and from the center of the macroplot. The Department of Soil Science at the University of Guelph analyzed soils for texture and pH and for phosphorus, potassium, magnesium, and calcium content.

2. Results

2.1. Climatic measurements

The winter climate on the taiga varies from year to year, especially the mid winter climate. Between February 18 and 27, 1967, temperatures I recorded during field studies ranged between –43° and –19°C, and between the same dates in 1968, the temperature extremes were –43° and –4°C. On five days of the latter period the temperature rose above –18°C.

A comparison of daily temperature ranges for 1967–68 shows that greater temperature fluctuations, both within and between days, occurred in mid winter than in either early or late winter (Fig. 6). Temperature rose above freezing on April 12, 1966, and April 24, 1968. The variation between years in the occurrence of above-freezing temperatures affects the timing of thawing of the snow surface.

The insulating effect of snow is important for the survival of forage plants. I recorded temperatures of –7 to –2°C beneath 66 to 71 cm of snow in January. Eriophorum vaginatum, young, green sprouts of Carex aquatilis, licorice, and other forage plants beneath the snow surface are supple at such temperatures. Temperature of the lake ice surface under 50 cm of snow was –4°C in February when the ambient temperature was –33°C.

The snow was deepest on the lake shores, whose drifts had accumulated among the first lines of trees and shrubs and in the lee of eskers.

In mid winter, 1967, the greatest snow depth recorded was 89 cm at a lake shore site, while on the same day depths on the open lake ranged from 35 to 38 cm and in semi-open conifer stands from 74 to 79 cm. In dense spruce stands the branches intercepted much of the snowfall in early winter, resulting in smaller depths on the ground. Strong winds in mid winter dispersed the snow from the branches making depths on the ground in dense spruce similar to those of other habitats (Fig. 7). Prior to extensive thaws in late winter, the snow depth on lake and stream shores commonly reached 0.9 to 1.2 m. Snow depths in both semi-open and dense cover types remained similar to those recorded in mid winter, but on lakes a sharp decrease occurred by late winter.

Hard crusts appeared on lake snow by mid February 1968, as a result of wind. Large, rounded or razor-edged drifts formed on lakes during February creating an extremely uneven surface. The hard crust extended inland a short distance from lake and stream shores; in semi-open and dense

---

Figure 6

Daily range of temperatures recorded at sites with coniferous cover, varying early, mid, and late winter periods, 1967–1968.

Figure 7

Range of snow depth measured in cover types during early, mid, and late winter periods, 1967–1968.
conifer cover types the snow surface was only slightly harder than in early winter. But by late winter snow crusts on both open and semi-open sites were hard. Strong crusts developed on exposed sites when the sun melted the surface snow which froze in the afternoon. In addition, snow particles disturbed by daily freezing and movement of conifer felled together to form strong crusts. By mid April soft snow remained only in undisturbed, dense conifer sites. Crusts deteriorated rapidly by early May, breaking down first in the open sites, especially on southern exposures or eskers, hills, and steep banks of streams and lakes. Crusts formed during cold nights but thawed quickly on sunny days. Snow depths decreased rapidly in the open during that period, but slowly in semi-open and densely treed areas except around tree bases where the vegetation became exposed early. Snow hardness was extremely important to conifer movement; it dictated the ease with which they could feed, migrate, and escape. Shallow, soft snow was no hindrance, but deep, soft snow impeded movements and excavation of craters. As a crust developed on the surface of deep snow conifer moved with increasing difficulty until it was strong enough to bear 5 kg/20 cm of weight. Juveniles were supported by snow with a crust strength of 1.5 to 2.3 kg per cm² and adults by snow with a crust strength of 2.1 to 2.8 kg per cm². Wolves walked on snow crusts with a crust strength of 1.1 kg per cm² and a 352-kg man walking on snow crusts with a strength of 1.8 kg per cm².

2.2. Soil analysis
Soils at study plots and eskers were extremely acid and all but one of the plots was on course sand. Except at Study Plot No. 10, magnesium and calcium were scarce. The conifer habitat of grazing uts and eskers suggests that the calcium shortage may be important.

1. Snow

Essential to the assessment of the taiga winter range is an understanding of conifer food habits, movements, and behaviour as related to the winter environment. That environment is constantly changing as a result of seasonal variation in depth and density of snow and hardness of crust (Forrester, 1946; Pruitt, 1959). The character of the snow cover determines both the mobility of conifer and food availability. Because conifers locate forage beneath the snow by smell (Skog, 1968), snow condition plays an important role in the location of feeding craters as well as in the number of craters that can be dug at any one site (Pruitt, 1959).

In early winter conifer movements are not impeded by snow. Caribou move freely over their range. Crater excavations showed that they did minimum damage to the terrestrial forage supply during that period. The preferred feeding sites appeared to be along stream and lake shores in dense stands of Equisetum fluviatile and Carex aquatilis.

As the snow depth increases caribou become confined to areas with the most favourable conditions (Henshaw, 1964). The critical limit of snow depth for caribou or reindeer is about 50 to 60 cm (Forrester, 1946; Pruitt, 1999; Henshaw, 1964). I observed that in about 50 cm of soft snow caribou confined to established trails that depth was attained between mid December and mid February and marked the change between early and mid winter periods.

Caribou continued migrating during the early stages of mid winter; later their movements become less predictable. In 1967 Kaminuriak caribou continued migrating until mid April, whereas in 1968 they were relatively sedentary between February and May. Forage use differed between the two winters although snow depths were similar. In 1967 migrating caribou used forest forage along streams, lakes, marshes, and meadows. Accessible feeding areas along well-used migration routes received intense use but for only a short time. Longer and more intensive use of small feeding areas was made in 1968 when the herds were more sedentary. Rotational analyses showed that mooses were consumed in larger amounts and in greater variety during winter than in any other season. Caribou were foraging on the margins of "quahogs" and were more sedentary. This suggests use of different habitats. Aerial and ground observations of caribou feeding craters during the two winters confirmed this. Utilization of different habitats during separate winters is an important factor in determining range capacities.

In late winter when snow crusts had formed caribou adapted by foraging on arboreal lichens, and on white birch and willow along lake and stream shores. Caribou used those sources of food increasingly until late winter and then intensively until spring. The extent of use of the above-mentioned forage depends on the density of caribou and the duration of the late-winter period. A delay in the softening of snow crusts could extend that period by as long as 3 weeks. Caribou became relatively sedentary each winter when the snow became generally crusted from thawing and freezing.

If snow is important to returns to a terrestrial forage diet during early winter when the snow crust is softed by sun. The crust softens first at south exposures, especially at the bottom of old craters and on steep banks of eskers, lakes, and streams. Snow depths increased rapidly and caribou seek out bare patches in old craters. Caribou use bare craters as long as the forage remains exposed and boundaries of craters show up clearly during the following summer. Steep south-facing exposed banks also become snow free and caribou may use 50 per cent or more of the terrestrial forage in those small, local areas. They graze bare banks even more repeatedly than old craters, and consume all but the smallest lichen podetia. They also intensively utilize vascular plants, especially Vaccinium vitis-idaea, on the exposed sites. A third site that becomes exposed in early spring is the area at the base of a conifer, called "quahug" by Pruitt (1959), where caribou graze on exposed lichens and vascular plants. In addition, according to summer observations, caribou dig in soft snow crusts, especially near the margins of "quahogs" and on the areas that forage there. Those lichens are more disfigured than heavily eaten, but crater margins are distinct. Caribou begin their migration towards the calving grounds about the same time that bare patches appear on the south-facing banks, and therefore damage is confined to a relatively small area along migration routes. Andrews (1964) stated that migrating reindeer keep strictly to areas where there are thawed patches and food is more easily obtainable and gradually move northward as the snow thaws.

2. Food habits

Studies of craters, cratered sites, and analyses of rumen contents collected during spring and early, mid and late winter have demonstrated that terrestrial lichens are the primary forage of caribou on the taiga winter range. However, caribou can thrive without lichens (Palmer, 1936; Marse, 1937; Seolet, 1960) and normally supplement their diet with other plants. Use of non-lichen forage probably increases digestibility of lichens (Seolet, 1965), although in certain areas of Russia (Pruitt, 1959; Seolet, 1963) although in certain areas of Russia (Pruitt, 1959) and northern America (Andrews, 1964; and Pajačević, 1965) it has been shown that caribou move on areas where lichens are the most important food. Caribou may use forest forage in early winter; later they forage on the margins of "quahogs" and are more sedentary. Caribou begin their migration towards the calving grounds about the same time that bare patches appear on the south-facing banks, and therefore damage is confined to a relatively small area along migration routes. Andrews (1964) stated that migrating reindeer keep strictly to areas where there are thawed patches and food is more easily obtainable and gradually move northward as the snow thaws.

The manner in which caribou utilize terrestrial lichens is important. Some investigators (Andrews, 1954; Skuneke, 1963; Scouler, 1964; Skog, 1907; Pajac, 1967) suggest that they rip off the living portions of terrestrial lichens and lichen recovery from such grazings depends on the per cent of caribou feeding on the lichens. I observed the diet preference of caribou feeding on forest lichens during a limited period in spring. During early and mid-winter periods the caribou plucks and eats the black portion of Cladina rangiferina which was common in rumen samples. Even the primary thallus, which is the portion of the lichen that is attached to the substrate, was common in winter rumen samples.
mosl common lichen genera

A comparison of percentage occurrence of the four most common lichen genera

<table>
<thead>
<tr>
<th>Occurrence</th>
<th>Cladonia</th>
<th>Sutecusculus</th>
<th>Genus</th>
<th>Plant cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>8</td>
<td>9</td>
<td>11</td>
<td>4</td>
</tr>
<tr>
<td>90</td>
<td>10</td>
<td>8</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>80</td>
<td>11</td>
<td>9</td>
<td>13</td>
<td>6</td>
</tr>
<tr>
<td>70</td>
<td>12</td>
<td>10</td>
<td>14</td>
<td>7</td>
</tr>
</tbody>
</table>

Inclusion of the dead portions of lichen poedite as well as the living portions increases the potential lichen forage supply by 100 per cent (Scott, 1963). During certain periods of early spring, however, caribou crop upper portions of exposed lichens from previously dug craters. Water appears in the thawed crater by day and freezes at night, and the exposed lichens thaw gradually from the top down. Figure 1 shows the observed top cropping of lichens in this study only during these limited periods of early spring, freeze-thaw conditions. Arborescent lichens are an important source of winter forage in the taiga, especially in periods of extremely hard snow conditions during late winter (Bastien, 1961; Bastie, 1964; Grignan, 1957; Edwars and Riteau, 1960). Arborescent lichens also probably help maintain a balanced rumen environment for microorganisms during the period when terrestrial lichens are inaccessible. Scotter (1965b) found arborescent lichens to be relatively abundant in northwestern Manitoba, and I observed them to be more abundant there than in taiga caribou ranges of central Alaska.

Grass-like plants are the major non-lichen forage utilized in the taiga during late winter and occasionally during early spring. Carex aquatilis and Equisetum fluviatile are the primary grass-like plants used in northwestern Manitoba. Carex aquatilis is the most abundant genus in the "marshland" of the area (Baldwin, 1963). This plant provides the richest forage of "underwater" green vegetation for reindeer in parts of Russia (Kareev, 1968), and is one of the most common plants in the area he examined in mid winter, and more often in late winter and early spring, the major non-lichen forage items among leaves and twigs of woody plants. Leaves of Carex aquatilis are the most utilized although moderate amounts of Vaccinium myrtillus and F. alpinum are also consumed. Scotter (1965b) observed that caribou had stripped leaves from Carex aiffuuea in northwestern Saskatchewan, and he thought that it might be an important source of protein. Skoog (1960) and Lutz (1965) mention that their observations support this view.

In mid winter, and more often in late winter and early spring, the major non-lichen forage items among leaves and twigs of woody plants are the most utilized although moderate amounts of Vaccinium myrtillus and F. alpinum are also consumed. Scotter (1965b) observed that caribou had stripped leaves from Carex aiffuuea in northwestern Saskatchewan, and he thought that it might be an important source of protein. Skoog (1960) and Lutz (1965) mention that their observations support this view.

The average annual linear growth rate of the podetium is 3.1 centimeters per year. This rate is not affected by the age of the podetium because the growth rate is constant throughout the period of podetia growth. The average annual linear growth rate of the podetium is 3.1 centimeters per year. This rate is not affected by the age of the podetium because the growth rate is constant throughout the period of podetia growth. The average annual linear growth rate of the podetium is 3.1 centimeters per year. This rate is not affected by the age of the podetium because the growth rate is constant throughout the period of podetia growth.

3. Lichen growth

Because lichens, principally Cladonia spp., are the dominant flora of caribou in the taiga, it is important to understand how the lichen podetium grows. Andrews (1954) explains how the Cladonia podetium passes through three growth stages. The first stage is called the growth-acclimation period which lasts an average of 10 years and varies from 5 to 25 years. There is no dying off of the podetium during that period. The second stage is the growth-recovery period when the podetium grows at its highest rate. However, the podetium dies off at the base at a rate equal to the growth. That period lasts a long time, extending to 100 years or more. The third stage which may also exceed 100 years, is the podetium degeneration period when the podetium dies off at a greater rate than it grows. Andrews (1954), Ahti (1959), Scott, 1963, and Pegau (1966b) have measured growth rates of various Cladonia spp. using the formula:

Length of living podetium / Number of nodes on living podetium = Average annual linear growth rate of the podetium

The average annual linear growth rate of podetium measured by Scott (1963b) at four locations in northwestern Manitoba, ranged from 4.5 to 4.9 (C. alpestris) and 4.1 to 5.1 (C. rangiferina), which was slightly less than Pegau (1966b) found in the Steward Peninsula in (C. rangiferina). Scott (1963b), Pegau (1966b), and the present study have found considerable variation between growth rates of podetia on a single site. Factors that probably contribute to variation in lichen growth include: the age of the podetium; the capacity of the podetium to compete with adjacent poedites; prior disturbance by animals including wind, and; site conditions such as substrate, drainage, and exposure. Another factor to be considered when studying lichen growth is used in production calculations in the number of lichen species found in various locations and is used in production calculations in the number of lichen species found in various locations.
are likely to attract caribou concentrations for extended periods of time.

The estimated percent age of land area burned annually on a study area in northern Manitoba during the 12-year period 1955-67 as measured from aerial photograph was 0.17 percent, somewhat less than Beckel’s (1958) estimate of 0.25 percent for approximately the same area during the 20-year period 1935-55 (Table 16). In contrast, forest fires burned an estimated 0.87 percent of land area annually from 1940 to 1955 on a study area in north-central Saskatchewan (Scotter, 1961). There is a great deal more upland in the Saskatchewan taiga winter range than that of Manitoba, and upland ranges are more susceptible to low grounds than lowlands to lightening strikes. Some upland sites in both areas are more susceptible to lightening-caused fires than others and burn more frequently.

Both Cladonia alpestris and C. rangiferina are climax lichen species that appear in stands 40 years or more after a fire, but there are a number of important lichens like C. nitschiana that become established earlier. Figure 4 shows that stands less than 40 years contained a switching crop of terro torial lichens and other forest plants. The accommodation of needle-leaf old conifer trees favours the growth of vascular plants such as Vaccinium vitis-idaea, Empetrum nigrum, and Arctostaphylos uva-ursi as well as mosses. Fires could affect that condition in favour of lichen growth.

Concerning the effects of forest fires on soil, Latz (1956) believed that it could be “impossible to prove” that soil destruction or deterioration occurred on the majority of burns in Alaska. He mentioned that there is usually a “reduction of soil acidity” after a fire, a large increase in “exchangeable calcium in the upper layers of mineral soil,” an increase in the “availability of nitrogen to vegetation” and that, “fires quickly make available the nutrient materials bound in organic matter.” Even during the early years after a forest fire, early invaders such as fireweed (Epilobium spp.), Vaccinium spp., grass (Calamagrostis canadensis), and sucker growths of white birch are potential forage for caribou.

5. Condition of range

Caribou affected their taiga winter range little during this study. Rumen analyses and field observations have shown that caribou utilize forage according to its availability, which depends throughout winter on snow depth and condition. That relationship ensures against over utilization of any forage species over a wide area. In addition, such forages as grassland plants and mushrooms are annual crops which appear unaffected by caribou utilization. Vascular plants such as Vaccinium vitis-idaea, Salix spp., and Betula spp. recover rapidly, and I saw no signs of permanent damage from burning. Lichens, because they grow more slowly than vascular plants, would be expected to show the effects of caribou use over other plants. However I observed no difference in lichen stands used by caribou in the presence of a complete snow cover. According to standing crop calculations of terrestrial lichens and the percentage cover of lichens in the ground cover, a large reserve of potential lichen forage exists in the taiga. There is also a large reserve of potential arboreal lichen forage, Scotter (1965c).

Caribou can damage lichen stands locally during the spring migration when lichens become exposed on southern exposures of eskers, and stream and lake banks. Repeated use of lichens on such

![Lichen growth on the ground cover](image)

sites has resulted in the development of dense stands of Arctostaphylos uva-ursi and Empetrum nigrum. Lichens are sparse and small if present at all. The phecomass can be observed on eskers and steep lake and stream banks in much of northern Manitoba, especially in the forest-tundra. Snow lichen is an important lichen component in the caribou winter diet, although it is unevenly distributed and relatively scarce compared with Cladonia, Cladina, or Cetraria (Fig. 8). Stereocaulon recovers from grazing more readily than Cladonia, Cladina, or Cetraria. Ritchie (1959) suggested that Stereocaulon might be an indicator of overuse by caribou. Scotter (1966a) agreed in part with Ritchie that the abundance of Stereocaulon on some sites may be the result of intensive grazing by caribou. Scotter suggested, however, that in some sites moisture was the cause of Stereocaulon dominance. My observations support the idea of a relationship between lichen grazing and Stereocaulon abundance especially in respect to intensive use of exposed lichen stands in early spring.

Small, puré or nearly pure stands of Stereocaulon are occasionally encountered on lichen-free slopes of southern and northern Manitoba and Saskatchewan and to the effects of early spring fires. Another factor, perhaps more important, favoring lichens in northern Manitoba and Saskatchewan is that the growing conditions favour them over vascular plants. Lichens can tolerate periods of desiccation on the predominantly sandy soils better than vascular plants and mosses (Ahti and Hepburn, 1967).

6. Capacity of the taiga range

It is difficult to estimate carrying capacity of the taiga range because caribou use it differently each winter. The number of caribou that enter the taiga varies from year to year as does the time the caribou spend there. Their distribution, density, and food habits vary according to snow conditions. However, by calculations based on taiga range with known stocking rates over extended periods of time, Poi-jarvi (1954) and Andreu (1954) in Russia and Skaucke (1963) in Sweden estimated that 8 hectares (20 acres) of lichen range were required to sustain each caribou during winter. Helle (1966), who considered the effects of snow on availability and utilization of forage, estimated that 10 to 15 hectares (25 to 37 acres) of lichen winter range were needed to support each reindeer in Finland. "Reindeer" lichens grow on the average of 3 to 5 mm annually in forest tundra of Finland, which is similar to northern Manitoba (Scotter 1965c). Therefore by extrapolation from Helle’s figures (10-15 hectares/ reindeer/winter) the 12,113 km²/area in northern Manitoba estimated from coloured aerial photographs could support 36,000 to 53,000 caribou on the 5,407 km² of upland regions that had not burned in the past 20 years. By extrapolating the proportion of unburned lichen range not burned in the past 20 years to the entire 121,701 km² taiga range (Parker, 1972) we can estimate carrying capacity at 360,000 caribou. That estimate,
which precludes caribou use of non-lichen forage as well as lichen forage on all lowlands and on uplands which had burned less than 20 years ago, is over 500 per cent greater than the 1968 estimate of the Kaminuriak Population (Parker, 1972).

Parker (1972) showed that during 4 months in the winter of 1967-68 some 50,000 caribou were grazed within an area of 9,303 km² for a density of 177 caribou per km². My visual observations within that area during February and again in April to May 1968, along with summer observations of caribou enclosures, showed that less than 25 per cent of the terrestrial lichen range had been grazed or trampled. A year later only the most heavily grazed spring craters and southern exposed banks comprising about 10 per cent of the lichen range used, showed little or no vegetative recovery while the remaining 90 per cent showed rapid regeneration. Southern exposed banks, which had sustained intensive use by caribou during spring 1968, supported an active growth of primary lichen thalli in July 1969. In addition, many of the fragmented podetia in the spring craters used repeatedly by caribou had become anchored to the substrate and showed growth by July 1969.

Skog (1968) observed that caribou used only two per cent of a feeding area during February to March in a heavily used part of Alaska. He stated of Alaskan caribou that, "there is little evidence to suggest that grazing itself has caused much damage," and goes on to say that "most damage can be assigned to the effects of trampling and trailing." The above is consistent with the restriction of damage found in the present study to lichen stands that first become bare in spring. Caribou sometimes suffer from unavailability of food under certain snow conditions. But it seems doubtful that under present conditions of caribou numbers and vegetation that such unavailability is related to the total forage reserves or the effects of lives on them. Some characteristics on the taiga as well as influencing availability of forage also affect the vulnerability of caribou to predators, including man. The fact that in some years the majority of caribou in the Kaminuriak Population have wintered on the tundra also suggests that dependency on taiga forage supplies is minor at present population levels.

The taiga winter range of the Kaminuriak Population is in northern Manitoba, northeastern Saskatchewan, southeast Mackenzie District, and southwest Keewatin District. I studied portions of northwestern Manitoba and northeastern Saskatchewan during this investigation. The winter range in northeastern Manitoba is roughly 20 per cent water, 40 per cent lowland and 40 per cent upland. Lowland areas include 80 per cent muskeg and 20 per cent meadow whereas the upland is 80 per cent spruce and 20 per cent jack pine. The upland areas are primarily semi-open to open lichen woodland. Between 1956 and 1967, according to aerial photograph interpretations of the same 20,000 km² area, 192 km² or 2.1 per cent of the area burned in 47 different forests fires.

Terrestrial lichens covered 50 to 90 per cent of the ground at 6 caribou enclosures and 23 of 25 study plots located in spruce, spruce and jack pine, and jack pine cover types. Cladonia lichens, primarily C. mitis and C. albocincta, were the most abundant in the plots and enclosures. Cladina spp., mainly C. gracilis, were common but only occasionally abundant. Cetraria lichens were common but not abundant, whereas Stereocaulon and Polycatena lichens were neither common nor abundant.

The standing crop of terrestrial lichens at the study plots and enclosures ranged from 2,000 to 7,000 kg dry weight per ha at all but two plots. The protein content in lichen samples ranged from 1.2 per cent in Cladina spp. to 16.26 per cent in primarily Stereocaulon paniculata samples. Stereocaulon samples also contained a higher amount of energy than Cladina, Cladonia, or Cetraria samples.

Lichen regeneration of primary thalli on artificially denuded 1-m² plots occurred on all plots after three growing seasons and covered from 10 to 75 per cent of the plot. Secondary thalli or podetia appeared on 66 per cent of the plots after three growing seasons. Primary thalli and in one instance a podetium were observed on caribou pellets after three summer grazing seasons. Removal of the stems and leaves of Ledum groenlandicum stimulated lichen growth whereas removal of only the leaves did not show a change in lichen growth.

Caribou rumen analyses showed that terrestrial lichens, primarily Cladina spp., and to a lesser extent Cladonia spp., made up the bulk of the winter diet on the taiga. Stereocaulon was also an important food, especially during April according to comparison of its abundance in rumens and its occurrence in the taiga. Twigs and leaves of woody plants as well as grasslike plants were also important winter forages, and mush­rooms were eaten when encountered. Seasonal availability appeared to dictate forage use by caribou after early winter.

The availability of forage depends on the depth, density, and crust hard­ness of snow as well as the proximity of travel routes, and treeless loafing and escape areas. Forage availability does not limit use in early winter, but as soon as snow depths reach about 50 cm various sites become unavail­able. Eleocharis fluviatilis and Carex aquatilis, preferred forage during the early winter, became less available in mid-winter. On the drifted shores of lakes and streams, Caribou remain close to loafing and escape areas and therefore make little use of continuous tree cover. In late winter with the lengthening of day-light hours a crest forms on the snow and caribou change to a diet of arboreal lichens and woody browse. As soon as the crust softens caribou return to a diet of terrestrial forage using the exposed sites. In addition, the buds of conifer trees become exposed and are heavily used. Cricket enclosures constructed during the early, mid and late winter and spring periods showed that the late winter and spring periods were the only time that the caribou damaged their forage stands. In late winter, arboreal lichen and woody browse crops were depleted locally and in spring the terrestrial forage crop was depleted on exposed sites along the migration routes.

Summary

The heterogeneity of plant cover in the taiga of northwestern Manitoba and northeastern Saskatchewan makes it well suited to sustain caribou use during the winter season because it offers caribou a wide range of depth, density, and hardness of snow. Forest lines help to maintain the heterogeneity.
### Appendices

#### Appendix 1

<table>
<thead>
<tr>
<th>Plot</th>
<th>Location</th>
<th>Topography</th>
<th>No. trees per acre</th>
<th>Mean lit.</th>
<th>Mean d.b.h.</th>
<th>Age, yr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Gorename River</td>
<td>High edge</td>
<td>284</td>
<td>8.3</td>
<td>10.9</td>
<td>78</td>
</tr>
<tr>
<td>2</td>
<td>Le Brocher</td>
<td>Flat</td>
<td>668</td>
<td>7.8</td>
<td>11.3</td>
<td>94</td>
</tr>
<tr>
<td>3</td>
<td>Le Brocher</td>
<td>Flat</td>
<td>3,174</td>
<td>6.8</td>
<td>9.6</td>
<td>133</td>
</tr>
<tr>
<td>4</td>
<td>Le Brocher</td>
<td>West slope, 5'</td>
<td>237</td>
<td>10.7</td>
<td>16.3</td>
<td>139</td>
</tr>
<tr>
<td>5</td>
<td>Le Brocher</td>
<td>West slope, 10'</td>
<td>2,574</td>
<td>7.8</td>
<td>10.3</td>
<td>133</td>
</tr>
<tr>
<td>6</td>
<td>Le Brocher</td>
<td>Flat</td>
<td>16</td>
<td>8.7</td>
<td>14.7</td>
<td>78</td>
</tr>
<tr>
<td>7</td>
<td>Le Brocher</td>
<td>Flat</td>
<td>189</td>
<td>9.1</td>
<td>16.7</td>
<td>61</td>
</tr>
</tbody>
</table>

#### Appendix 2

<table>
<thead>
<tr>
<th>Plot no.</th>
<th>Location</th>
<th>Topography</th>
<th>No. trees per acre</th>
<th>Mean lit.</th>
<th>Mean d.b.h.</th>
<th>Age, yr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Gorename River</td>
<td>High edge</td>
<td>284</td>
<td>8.3</td>
<td>10.9</td>
<td>78</td>
</tr>
<tr>
<td>2</td>
<td>Le Brocher</td>
<td>Flat</td>
<td>668</td>
<td>7.8</td>
<td>11.3</td>
<td>94</td>
</tr>
<tr>
<td>3</td>
<td>Le Brocher</td>
<td>Flat</td>
<td>3,174</td>
<td>6.8</td>
<td>9.6</td>
<td>133</td>
</tr>
<tr>
<td>4</td>
<td>Le Brocher</td>
<td>West slope, 5'</td>
<td>237</td>
<td>10.7</td>
<td>16.3</td>
<td>139</td>
</tr>
<tr>
<td>5</td>
<td>Le Brocher</td>
<td>West slope, 10'</td>
<td>2,574</td>
<td>7.8</td>
<td>10.3</td>
<td>133</td>
</tr>
</tbody>
</table>

*Also named Rjalmurn Lake,*

### Percentage cover of plant species occurring in more than one study plot or culture.

<table>
<thead>
<tr>
<th>Plant species</th>
<th>Gorename River</th>
<th>Le Brocher</th>
<th>Percentage cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vaccinium uliginosum</td>
<td>10.9</td>
<td>9.7</td>
<td>14.2</td>
</tr>
<tr>
<td>Empetrurn Geocaulon</td>
<td>10.2</td>
<td>10.2</td>
<td>12.9</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>217</strong></td>
<td><strong>217</strong></td>
<td><strong>217</strong></td>
</tr>
</tbody>
</table>
### Appendix 3

#### Mean and range of percentages by weight of major lichen genera in study plots and enclosures

<table>
<thead>
<tr>
<th>Plot</th>
<th>Cladonia</th>
<th>Candelina</th>
<th>Stereocaulon</th>
<th>Cetraria</th>
<th>Peltigera</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>77</td>
<td>20</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>96</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>90</td>
<td>1</td>
<td>7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>83</td>
<td>16</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>89</td>
<td>5</td>
<td>0</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>48</td>
<td>41</td>
<td>0</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>76</td>
<td>24</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8*</td>
<td>85</td>
<td>15</td>
<td>0</td>
<td>Tr</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>42</td>
<td>58</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>47</td>
<td>20</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>11</td>
<td>66</td>
<td>34</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>52</td>
<td>16</td>
<td>0</td>
<td>32</td>
<td>0</td>
</tr>
<tr>
<td>13</td>
<td>51</td>
<td>10</td>
<td>0</td>
<td>37</td>
<td>0</td>
</tr>
<tr>
<td>14</td>
<td>70</td>
<td>28</td>
<td>0</td>
<td>Tr</td>
<td>0</td>
</tr>
<tr>
<td>15</td>
<td>90</td>
<td>7</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>16</td>
<td>73</td>
<td>15</td>
<td>0</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>17</td>
<td>77</td>
<td>18</td>
<td>0</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>18</td>
<td>73</td>
<td>24</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>19</td>
<td>62</td>
<td>26</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>95</td>
<td>5</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>21</td>
<td>78</td>
<td>12</td>
<td>10</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>22</td>
<td>65</td>
<td>35</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>23</td>
<td>73</td>
<td>22</td>
<td>0</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>24</td>
<td>53</td>
<td>42</td>
<td>0</td>
<td>5</td>
<td>0</td>
</tr>
</tbody>
</table>

* Direct samples were not collected from Plot 8.

### Appendix 4

#### Location and forage plant cover of 1-m² plots established in 1962

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Date Established</th>
<th>Place</th>
<th>Lat.</th>
<th>Long.</th>
<th>Forage plants in sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>June 19</td>
<td>Lac-Brochet</td>
<td>58°59'15&quot;</td>
<td>100°52'15&quot;</td>
<td>Lichens, 25% Cladonia nivalis, 5% Cladina rangiferina</td>
</tr>
<tr>
<td>2</td>
<td>June 19</td>
<td>Lac-Brochet</td>
<td>58°59'15&quot;</td>
<td>100°57'15&quot;</td>
<td>Lichens, 25% Cladina rangiferina</td>
</tr>
<tr>
<td>3</td>
<td>June 19</td>
<td>Lac-Brochet</td>
<td>58°59'15&quot;</td>
<td>100°57'15&quot;</td>
<td>Lichens, 50% Cladina rangiferina</td>
</tr>
<tr>
<td>4</td>
<td>June 20</td>
<td>Lac-Brochet</td>
<td>58°59'15&quot;</td>
<td>100°57'15&quot;</td>
<td>Lichens, 50% Cladina rangiferina</td>
</tr>
<tr>
<td>5</td>
<td>June 20</td>
<td>Lac-Brochet</td>
<td>58°59'15&quot;</td>
<td>100°57'15&quot;</td>
<td>Lichens, mixed species</td>
</tr>
<tr>
<td>6</td>
<td>June 20</td>
<td>Lac-Brochet</td>
<td>58°59'45&quot;</td>
<td>100°57'20&quot;</td>
<td>Lichens, mixed species</td>
</tr>
<tr>
<td>7</td>
<td>June 20</td>
<td>Lac-Brochet</td>
<td>58°59'45&quot;</td>
<td>100°57'50&quot;</td>
<td>Lichens, mixed species</td>
</tr>
<tr>
<td>8</td>
<td>June 20</td>
<td>Lac-Brochet</td>
<td>58°59'45&quot;</td>
<td>100°57'50&quot;</td>
<td>Lichens, mixed species</td>
</tr>
<tr>
<td>9</td>
<td>June 20</td>
<td>Lac-Brochet</td>
<td>58°59'45&quot;</td>
<td>100°57'50&quot;</td>
<td>Lichens, mixed species</td>
</tr>
<tr>
<td>10</td>
<td>June 21</td>
<td>Lac-Brochet</td>
<td>58°59'15&quot;</td>
<td>100°57'15&quot;</td>
<td>Lichens, mixed species, Cladina &amp; Cetraria</td>
</tr>
<tr>
<td>11A</td>
<td>June 22</td>
<td>Lac-Brochet</td>
<td>58°59'15&quot;</td>
<td>100°57'15&quot;</td>
<td>Festucetum vivi-alpinorum</td>
</tr>
<tr>
<td>11B</td>
<td>June 22</td>
<td>Lac-Brochet</td>
<td>58°59'15&quot;</td>
<td>100°57'15&quot;</td>
<td>Festucetum vivi-alpinorum</td>
</tr>
<tr>
<td>12</td>
<td>June 25</td>
<td>Lac-Brochet</td>
<td>58°59'45&quot;</td>
<td>100°57'20&quot;</td>
<td>Lichens, mixed species</td>
</tr>
<tr>
<td>13</td>
<td>June 25</td>
<td>Lac-Brochet</td>
<td>58°59'45&quot;</td>
<td>100°57'20&quot;</td>
<td>Lichens, mixed species</td>
</tr>
<tr>
<td>14</td>
<td>June 26</td>
<td>Lac-Brochet</td>
<td>58°59'00&quot;</td>
<td>100°57'50&quot;</td>
<td>Lichens, mixed species</td>
</tr>
<tr>
<td>15</td>
<td>June 26</td>
<td>Lac-Brochet</td>
<td>58°59'00&quot;</td>
<td>100°57'50&quot;</td>
<td>Lichens, mixed species</td>
</tr>
<tr>
<td>16</td>
<td>June 28</td>
<td>Hornshaw Lake*</td>
<td>57°42'45&quot;</td>
<td>100°57'30&quot;</td>
<td>Lichens, mixed species</td>
</tr>
<tr>
<td>17</td>
<td>June 28</td>
<td>Hornshaw Lake*</td>
<td>57°42'45&quot;</td>
<td>100°57'30&quot;</td>
<td>Lichens, mixed species</td>
</tr>
<tr>
<td>18</td>
<td>June 28</td>
<td>Hornshaw Lake</td>
<td>57°48'45&quot;</td>
<td>100°57'15&quot;</td>
<td>Lichens, mixed species</td>
</tr>
<tr>
<td>19</td>
<td>Sept. 17</td>
<td>Lac-Brochet</td>
<td>58°59'45&quot;</td>
<td>100°57'30&quot;</td>
<td>Carex aquatils</td>
</tr>
<tr>
<td>20</td>
<td>Sept. 17</td>
<td>Lac-Brochet</td>
<td>58°59'45&quot;</td>
<td>100°57'30&quot;</td>
<td>Carex aquatils</td>
</tr>
<tr>
<td>21</td>
<td>Sept. 18</td>
<td>Lac-Brochet</td>
<td>58°59'45&quot;</td>
<td>100°57'30&quot;</td>
<td>Carex aquatils</td>
</tr>
<tr>
<td>22</td>
<td>Sept. 18</td>
<td>Lac-Brochet</td>
<td>58°59'45&quot;</td>
<td>100°57'30&quot;</td>
<td>Carex aquatils</td>
</tr>
<tr>
<td>23</td>
<td>Sept. 18</td>
<td>Lac-Brochet</td>
<td>58°59'45&quot;</td>
<td>100°57'30&quot;</td>
<td>Carex aquatils</td>
</tr>
<tr>
<td>24</td>
<td>Sept. 23</td>
<td>Cochrane River</td>
<td>58°59'45&quot;</td>
<td>100°57'30&quot;</td>
<td>Carex aquatils</td>
</tr>
<tr>
<td>25</td>
<td>Sept. 24</td>
<td>Cochrane River</td>
<td>58°59'45&quot;</td>
<td>100°57'30&quot;</td>
<td>Carex aquatils</td>
</tr>
</tbody>
</table>

* Also mixed Hymenostomum Lake.

---

*Source: [Reference](https://example.com)
No. 1
Whooping-crane population dynamics on the nesting grounds, Wood Buffalo National Park, Northwest Territories, Canada by N. S. Novakowski Cat. No. CW65-6/7, Price $0.50

No. 2
Biology of the sandhill crane by W. J. D. Stephen Cat. No. CW65-6/3, Price $0.75

No. 3
The breeding biology of Ross' goose in the Wood Buffalo National Park, Northwest Territories, Canada by A. H. Macpherson Cat. No. CW65-6/1, Price $1.00

No. 4
Behaviour and the regulation of numbers in blue grouse by J. F. Bendell and P. W. Elliott Cat. No. CW65-8/4, Price $1.00

No. 5
Dunning habits of the polar bear (Ursus maritimus) (Phipps) by R. E. Harrington Cat. No. CW65-6/5, Price $0.50

No. 6
Saskatchewan wetlands seminar Cat. No. CW65-8/6, Price $0.25

No. 7
Historique naturelle du Goin, Abnoua-Le, dans le golfe Saint-Laurent, province de Québec, Canada par J. Bilode Cat. No. CW65-8/7, Price $1.25

No. 8
The dynamics of Canadian Arctic fox populations by A. B. Macpherson Cat. No. CW65-8/8, Price $1.00

No. 9

No. 10
The mammals of Jasper National Park, Alberta by J. D. Super Cat. No. CW65-8/10, Price $2.50

No. 11
Causes and implications of an observed sex differential in the survival of wapiti by D. R. Flook Cat. No. CW65-8/11, Price $1.25

No. 12
Breeding biology of California and ring-billed gulls: a study of ecological adaptations to the island habitat by R. E. Torr Cat. No. CW65-8/12, Price $1.25

No. 13
Geographical variation in the polar bear (Ursus maritimus) (Phipps) by T. H. Manning Cat. No. CW65-8/13, Price $1.00

No. 14
Studies of bird hazards to aircraft Cat. No. CW65-8/14, Price $1.25

No. 15
Moose and deer behaviour in snow in Fundy National Park, New Brunswick by J. P. Kelaul and W. Prescott Cat. No. CW65-8/15, Price $1.00

No. 16
Effects of phosphamidon on forest birds in New Brunswick by C. D. Fowle Cat. No. CW65-8/16, Price $1.00

No. 17
Populations, movements and seasonal distribution of mergansers in northern Cape Breton Island by A. E. Kreiner Cat. No. CW65-8/17, Price $1.00

No. 18

No. 19
Vegetation of the Ngorgoro Conservation Area, Tanzania by D. J. Herlocker and H. J. Dirschl Cat. No. CW65-8/20, Price $1.25

No. 20
Biology of the Kaminuriak Population of barren-ground caribou.
Part 1: Total numbers, mortality, recruitment, and seasonal distribution by G. R. Parker Cat. No. CW65-8/20, Price $1.50

No. 21
Food habits and ecology of wolves on barren-ground caribou range in the Northwest Territories by E. Kuyt Cat. No. CW65-8/21, Price $1.00

No. 22
Background for managing grizzly bears in the national parks of Canada by K. R. D. Mundy and D. R. Flook Cat. No. CW65-8/22, Price $1.00

No. 23
The mammals of Waterton Lakes National Park, Alberta by J. D. Super Cat. No. CW65-8/23, Price $1.25

No. 24
Feeding ecology of Pintail, Gadwall, American Widgeon and Lesser Scaup ducklings in southern Alberta by L. C. Saylor Cat. No. CW65-8/24, Price $1.50

No. 25
Home range and breeding biology of the Shoveler by H. J. Frost Cat. No. CW65-8/25, Price $1.50

No. 26
Calf mortality during 1970 on the calving ground of the Kaminuriak caribou by F. L. Miller and M. C. Guthier Cat. No. CW65-8/26, Price $1.25

No. 27
Bird damage to fruit crops in the Niagara Peninsula by R. G. B. Brown Cat. No. CW65-8/27, Price $1.50

No. 28
Migration of Lesser Snow and Blue Geese in spring across southern Manitoba Part 1: Distribution, chronology, directions, numbers, heights and spreads by R. H. Kees Cat. No. CW65-8/28, Price $1.00

No. 29
CWS Woodlouse surveys in eastern Canada, 1969-73 edited by H. Boyd Cat. No. CW65-8/29, Price $5.00

No. 30

No. 31
Biology of the Kaminuriak Population of barren-ground caribou. Part 2: Dentition as an indicator of age and sex; composition and socialization of the population by F. L. Miller Cat. No. CW65-8/31, Price $3.00

No. 32
Migration of Lesser Snow and Blue Geese in spring across southern Manitoba Part 2: Influence of the weather and prediction of major flights by R. H. Kees and M. C. Guthier Cat. No. CW65-8/32, Price $1.00

No. 33
An investigation of caribou range on Southampton Island, Northwest Territories by C. R. Parker Cat. No. CW65-8/33, Price $2.75

No. 34
The northern interior grizzly bear (Ursus arctos) by A. M. Pearson Cat. No. CW65-8/34, Price $4.50

No. 35
The nesting population of Lesser Snow Geese in the eastern Canadian Arctic: a photographic inventory of June 1973 by R. H. Kees Cat. No. CW65-8/35, Price $5.25