ISSN 0701-581X

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by Susan K. Stevenson

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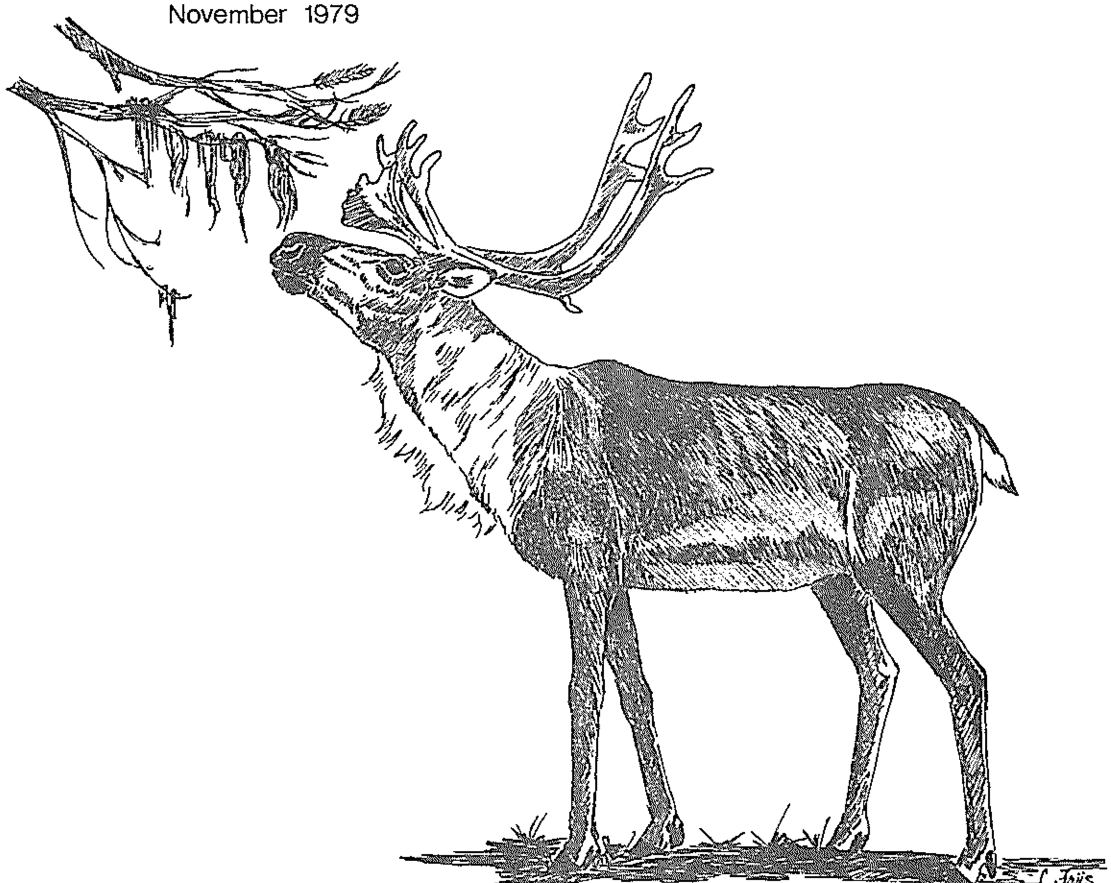

Province of British Columbia

Ministry of Forests

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Canadian Cataloguing in Publication Data

Stevenson, Susan K.
Effects of selective logging on arboreal lichens used by Selkirk caribou.

(Fish and wildlife report ; no. R-2 ISSN 0701-581X)

This report was prepared under contract with the B.C. Ministry of Forests, in cooperation with Kootenay Forest Products and the B.C. Fish and Wildlife Branch.
Bibliography: p.
ISBN 0-7719-8293-3

1. Caribou - British Columbia - Crutch Creek region - Food. 2. Lichens - British Columbia - Crutch Creek region. 3. Logging - Environmental aspects - British Columbia - Crutch Creek region. I. British Columbia. Ministry of Forests. II. Kootenay Forest Products. III. British Columbia. Fish and Wildlife Branch. IV. Title. V. Series.

QL737.U55S73 639.9'797357 C80-092026-0

ISSN 0701-581X

EFFECTS OF SELECTIVE LOGGING ON ARBOREAL LICHENS USED BY SELKIRK CARIBOU[1]

Susan K. Stevenson[2]

Ministry of Forests

Nelson, B.C.

This report was prepared under contract with the B.C. Ministry of Forests, in cooperation with Kootenay Forest Products and the B.C. Fish and Wildlife Branch. Views and recommendations are those of the author, and are not necessarily those of the sponsoring agencies.

November 1979*

1. Fish and Wildlife Report No. R-2

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* Reprinted June 1981

SUMMARY

As the first stage in a program to evaluate the effects of selective logging on caribou (Rangifer tarandus caribou), the biomass of forage lichens (Alectoria sarmentosa and Bryoria spp.) below 6 m on standing trees was quantified in an Engelmann spruce - subalpine fir (Picea engelmanni - Abies lasiocarpa) stand in the Selkirk Mountains of southeastern British Columbia. Assessment methods were a combination of ratio estimation and variable probability sampling. Total amounts of forage lichen within reach of caribou in the three mature timber plots were estimated at 67± 37 kg/ha, 103± 21 kg/ha, and 105± 37 kg/ha. This forage base is relatively low, both in terms of the herd's estimated food requirements, and compared with other caribou ranges. Selective logging to a 20 in. (51 cm) diameter at stump height limit would reduce available lichen to just over one-quarter of its original amount. Within the Selkirk caribou range, selective logging should be restricted to areas used by caribou for travel. Logging of any kind should be prohibited in areas where caribou concentrate in winter. Immediate research needs include: delineating critical winter ranges, reassessing available lichen after logging, and monitoring caribou use of logged areas. Methods are recommended for inventorying lichen abundance and measuring changes in lichen biomass over time.

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ACKNOWLEDGEMENTS

This study was funded cooperatively by three organizations. The British Columbia Ministry of Forests provided my salary and living accommodations. Kootenay Forest Products supplied a vehicle and vehicle expenses for the field season. The British Columbia Fish and Wildlife Branch provided a summer assistant, and secretarial help with the report. The British Columbia Surveys and Mapping Branch printed the report. The study was carried out with the encouragement of the International Mountain Caribou Technical Committee.

Many individuals within these organizations assisted with the project. In particular, I would like to acknowledge the help of K. Milner, J. Floyd, and the Research Division staff of the Nelson Forest Region; the staff of the Creston Ranger District; R. Dillabough of Kootenay Forest Products; and D. Eastman and K. Sumanik of the Fish and Wildlife Branch. Cathy Watkins typed the final copy of the report.

I am grateful to K. Iles, Faculty of Forestry, University of British Columbia for his advice on sampling and statistics. I wish to thank K. Plotnikoff and R. Weiss for their help in the field; and the College of New Caledonia, Prince George, for the use of its laboratory facilities to dry and weigh the lichen samples. I also appreciate the help of the following persons, who provided unpublished data: L. Glenn and H. Coates of the Ministry of Forests; A. T. Bergerud; and G. Schroeder.

L. Friis designed and illustrated the front cover.

INTRODUCTION

The purpose of this study was to assess the effects of selective logging on the supply of arboreal lichens used by the Selkirk caribou. This herd of 25-30 animals winters mainly in mature Engelmann spruce - subalpine fir forests in the southern Selkirk Mountains of British Columbia and the adjacent United States. Arboreal lichens are taken by these caribou from October through May, and are their primary food during much of the winter (Freddy 1974a, Layser 1974).

In recent years, the reliance of Selkirk caribou on lichens in mature timber stands has been a major influence on forest management policy. Freddy (1974a, 1974c) recommended stringent restrictions on clearcut logging within winter habitat, but suggested that small patch cutting or selective logging might be acceptable. He also noted (Freddy 1974c) that research would be needed to determine whether or not cutting would be detrimental to caribou from the standpoint of the production and availability of arboreal lichens. Within critical winter habitat, Johnson et al. (1977) recommended that logging be prohibited in open-canopied stands, and limited to small clearcuts in closed-canopied stands.

Recognizing the need for information on the impact of alternative logging methods, Kootenay Forest Products, the B.C. Ministry of Forests, and the B.C. Fish and Wildlife Branch began in 1977 an experimental program of selective logging in caribou range. The program called for diameter limit logging according to a prescription designed to remove approximately 40% of the merchantable stems.

The present study was the first stage of a long-term research program. It had the following objectives:

1) to develop improved methods for quantifying biomass of arboreal lichens at an intensive level, and to recommend methods for use at an inventory level.

2) to determine how much lichen is presently available with enough precision that the data can serve as a baseline for future monitoring.

3) to determine the immediate effects on lichen availability of selective logging, according to various prescriptions.

STUDY AREA

The study area is located in the Crutch Creek drainage of the Selkirk Mountains in southeastern British Columbia, approximately 36 km west of Creston, B.C., and 1.3 km north of the Idaho border. The location of the study area in relation to the range of the Selkirk caribou herd is shown in Fig. 1. Physical characteristics of the caribou range have been described by Freddy (1974a).

The lichen study plots are located in a WSW-facing valley of a Crutch Creek tributary at an elevation of approximately 1800 m a.s.l. Specific plot locations are illustrated in Appendix A. The topography is gentle, with slopes generally less than 35%. The parent material is a gleyed, decomposing schist. The soil is fine-textured, poorly to moderately drained, and variable in thickness. This variability in depth to bedrock probably contributes to the patchiness of the vegetation. The nutrient regime is mesotrophic to permesotrophic.

The forest in unlogged parts of the study area is a mature subalpine fir - Engelmann spruce stand typed on Forest Cover maps as BS 841-M. This means that the stand belongs in the 141-250 year age class and the 29-38 m height class; is stocked with more than 77 trees/ha over 28 cm DBH; and is located on a medium forest site. Merchantable timber volume in the area is roughly 300 m^3/ha, of which just over half is spruce.

The understory in the study plots is a fine-grained mosaic of shrub patches and herb patches. Major shrub species are rhododendron (_Rhododendron albiflorum_), blue huckleberry (_Vaccinium membranaceum_), false azalea (_Menziesia ferruginea_), and Utah honeysuckle (_Lonicera utahensis_). Dominant herbs include lovage (_Ligusticum canbyi_ and _L. verticillatum_), arrow-leaf grounsel (_Senecio triangularis_), tall bluebells (_Mertensia paniculata_), and mountain arnica (_Arnica latifolia_). Of the habitat types described by Daubenmire and Daubenmire (1968) for eastern Washington and northern Idaho, the study area most closely resembles the _Abies lasiocarpa_ - _Menziesia ferruginea_ habitat type. Of the site types proposed by Utzig et al. (1978) for the Nelson Forest District, the study area is intermediate between the _Vaccinium membranaceum_ - _Tiarella unifoliata_ type and the _Ribes lacustre_ - _Veratrum viride_ type, in the moist Engelmann spruce - subalpine fir subzone.

Detailed vegetation and soils data for the study plots may be found in Appendix B.

The main epiphytes in the study area are the forage lichens often known as "beard moss," "beard lichen," or "old man's beard." The light green beard lichen, _Alectoria sarmentosa_, is most abundant on the lower parts of tree crowns and on snags. The brown beard lichens, _Bryoria_ spp., share dominance with _Alectoria_ on the lower parts of crowns, and largely replace _Alectoria_ in the upper parts. The genus _Bryoria_, recently described by Brodo and Hawksworth (1977), includes species referred to in some caribou literature as "_Alectoria americana_,"

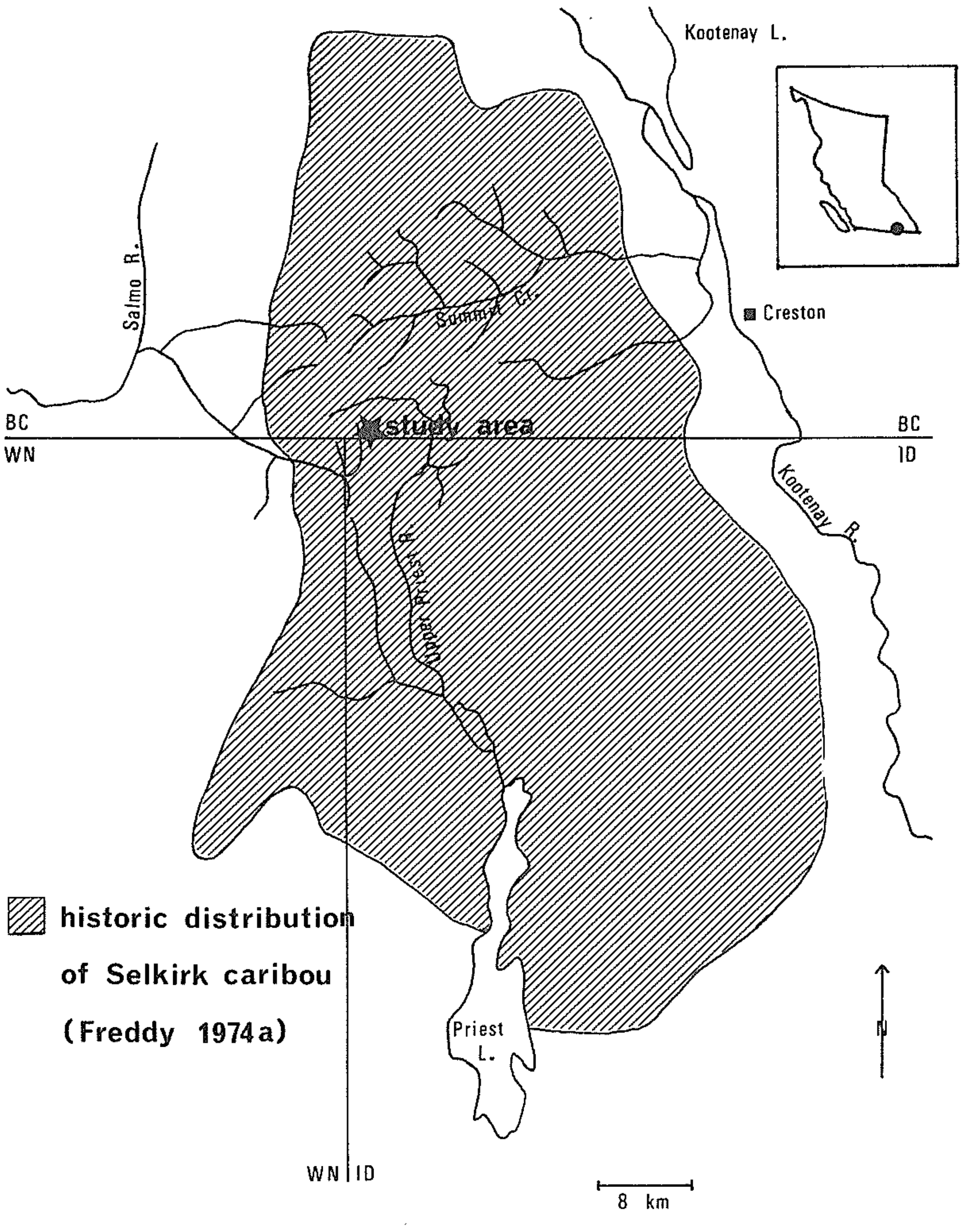

Figure 1. Location of the study area

"*A. jubata*," and "*A. fremontii*." The most abundant species of *Bryoria* in the plots are *B. fremontii*, *B. glabra*, *B. pseudofuscescens*, and *B. capillaris*. Other common arboreal lichens are *Platismatia glauca*, *Hypogymnia* spp., and *Letharia vulpina*. The lichen *Lobaria pulmonaria*, which is sometimes eaten by caribou, was not found in the plots. A list of arboreal lichens encountered during sampling is given in Appendix C.

The study area is located along a well-documented movement route of the Selkirk caribou, but historical and recent evidence do not suggest extended use of the area in winter. While sampling, I noted clumps of lichen in trees which appeared to have been grazed at heights up to 5.7 m, indicating that some winter feeding has occured. During the two-month field season I noticed fresh caribou tracks on three occasions; and on 1978 July 15, I observed three caribou in the Monk Creek drainage, about 1.4 km NNW of the study area (Appendix D).

The logging prescription for the area calls for the harvesting of all merchantable trees over 20 in. (51 cm)[1] in diameter at stump height (DSH). As taper differs among tree species, this prescription corresponds to a diameter at breast height (DBH) of 16 in. (41 cm) for subalpine fir and 15 in. (38 cm) for spruce (B.C. Forest Service 1978). The diameter limit prescription is applied with some flexibility, to leave a uniform cover of residual trees. In accordance with Workers Compensation Board policy, potentially hazardous snags are felled.

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[1] As logging was carried out according to English specifications, tree diameters are given in English units in this report. All other measurements are presented in metric units.

METHODS

OVERVIEW

Most previous attempts to quantify biomass of arboreal lichens used by caribou have involved selective sampling (Edwards et al. 1960, Scotter 1962) or random sampling (Schroeder 1972, Wein & Speer 1975). Some researchers (Ahti 1962) have used a system of quick estimates to calculate indices of lichen abundance. The present approach, like that of Pike et al. (1972, 1977) and Stevenson (1978) uses a combination of estimates and variable probability sampling. Unlike other methods, it yields an estimate of lichen biomass per unit area with confidence limits around the estimate.

A two-stage sampling scheme was used. The first stage involved selection of sample trees within plots, and the second stage involved selection of sample branches within trees. At each state, the sample units were selected with a probability that was proportionate to their predicted lichen biomass. This sampling scheme is similar to that used by foresters in 3P volume cruising, in which sample trees are selected with probability proportionate to their predicted volume (Grosenbaugh 1965, Dilworth & Bell 1971). The statistical basis for the technique was described by Cochran (1963:251-260), but the introductory treatment of Iles (1978) is easier for the non-statistician to understand.

At the first stage, the method involved:

a) an estimate of lichen biomass for every tree in the plot

b) selection of trees for sampling with probability proportionate to the estimate

c) sampling of lichen biomass on the selected trees

d) calculation of a correction ratio between measured and estimated lichen biomass on the sample trees

e) application of the correction ratio to all the trees in the plot.

An analagous procedure was followed at the second stage, for sampling branches within trees.

SELECTION OF PLOTS

Four, 20 x 50m (0.1 ha) lichen plots were established in the kind of area characteristically used by caribou, a gently sloping stream basin. To the extent possible, the four plots were matched for slope, aspect, timber type, vegetation, and lichen characteristics. Plots 1 and 2 were located in a cutblock scheduled for selective logging during the fall of 1978. Plot 3 was a control plot, located in an area which is to remain undisturbed throughout the course of the long-term study. Plot 4 was located in a cutblock that was selectively logged in the fall of 1977.

DESCRIPTIVE MEASURES

At each plot, standard field methods of the B.C. Ministry of Forests and Resource Analysis Branch (Walmsley 1978) were used to describe the vegetation and soils (Appendix B). Standard forest inventory methods were used to measure age and height of the trees selected for sampling, and to cruise the timber (B.C. Forest Service 1978). All trees 7.5 cm DBH or greater were numbered with temporary plastic tags, which were later replaced by permanent plastic or aluminum tags. I also spray-painted the numbers at the bases of the trunks, so that stumps could be identified after logging. Trees less than 7.5 cm DBH but which bore significant amounts of lichen were also tagged. Species, DBH, pathological indicators, tree class (residual, suspect, dead-potential, or dead-useless), and lichen estimates were recorded for each tree.

LICHEN ESTIMATES FOR TREES

All beard lichens (*Alectoria* spp. and *Bryoria* spp.) growing below 6 m on trees were included in the estimates. This upper limit represents the greatest possible reach of caribou, assuming a maximum snow depth of 3.0 m (Freddy 1974a) and a maximum caribou reach of 2-4 m when standing erect (Edwards et al. 1960). The drooping of snow-covered branches also increases the amount of available forage, but this was not estimated.

I used a 1.5 m stick to locate 0-3 m and 3-6 m height intervals on each tree, and recorded separately lichen estimates for each interval. For reference in making the estimates, I prepared a set of lichen clumps with oven-dried weights of 0.1 g, 0.5 g, 1.0 g, and 5.0 g, and mounted them on cards for use in the field (Fig 2). I arbitrarily designated the 5.0 g clump as a standard unit for tree estimates, and recorded estimates of lichen quantity to the nearest tenth of a unit.

For each layer, I also estimated the percent of the total lichen biomass consisting of the light green lichen *A. sarmentosa*.

SELECTION OF SAMPLE TREES

In Plots 1-3, a sample of trees was then selected for detailed study of lichen biomass. No sampling of lichen biomass was undertaken in Plot 4. Only living trees were eligible for sampling, because leaning a ladder against snags would have been hazardous. A small number of living trees were also eliminated from consideration because they leaned excessively, or for some other reason could not be sampled safely. In each plot, approximately 25-33% of the eligible trees were selected for sampling.

The method used for 3P selection was that described by Grosenbaugh (1965) and Iles (1978), with two modifications. The standard method involves drawing a random number between 1 and some upper limit (conventionally called K + Z) as each estimate is made. If the estimate is greater than or equal to the random number, the tree is sampled. The formula for choosing the top random number is:

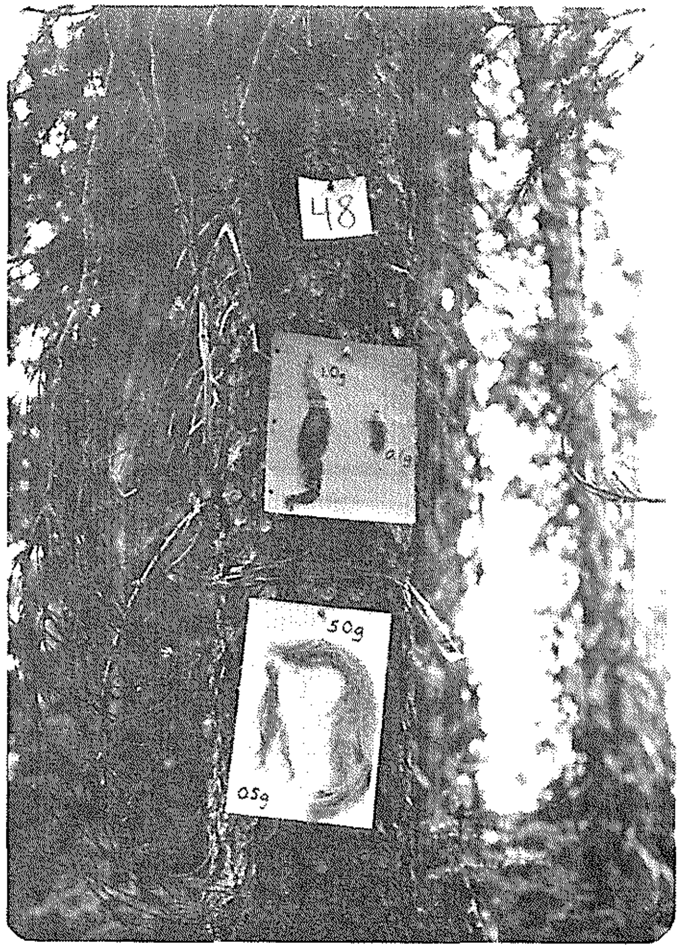

Figure 2. Standardized clumps used for estimating lichen biomass. The lower card was used primarily for tree estimates; the upper card was used primarily for branch estimates.

$$K + Z = \frac{\Sigma \widehat{KPI}}{n_e} \tag{1}$$

where $\Sigma \widehat{KPI}$ is the expected sum of the estimates, and n_e is the expected sample size.

Using this method, a tree would be selected or rejected for sampling immediately after its lichen biomass was estimated. This would be an advantage if the cost of returning to the tree were high. But in this case, it was easy to return to a tree, and I did not have a good estimate of Σ KPI in advance. Therefore, I altered the technique by selecting the sample trees after the estimates were complete, using the actual sum of the lichen estimates in a plot, rather than an expected Σ KPI.

The second modification involved selection of the top random number, K + Z. When I used Equation 1 to calculate the top random number, K + Z was smaller than the largest single estimate. This occurred because the frequency distribution of lichen estimates was skewed right. Had I used a K + Z that was smaller than the estimates for some trees, then trees with the largest lichen estimates would have been selected with equal probability rather than probability proportionate to prediction. The estimate of total lichen biomass would then have been biased (Cochran 1963:160). To prevent this, I used the formula

$$K + Z = 2\left[\frac{\Sigma \text{ KPI}}{n_e}\right], \tag{2}$$

and gave each tree two chances to be sampled. If a tree was selected for sampling by both random numbers, then it was counted twice in the calculations. In this way, all trees were sampled with probability proportionate to predicted lichen biomass.

SAMPLING OF LICHEN BIOMASS

All the lichen was removed from very small trees selected for sampling. In all other cases, I used the 3P method to select branches for sampling of lichen biomass. Because it would be inefficient to inventory the branches and return to them later, I selected the sample branches immediately after making the lichen estimates. The distributions of lichen estimates for branches, like those of lichen estimates for trees, were skewed right, so again I used Equation 2 with two random number lists, rather than Equation 1.

Only branches that originated at or below 6 m on the trunk, and bore 0.1 g or more of lichen, were eligible for sampling. Most sample trees had some branches that originated above 6 m, but bore lichen below that level. I estimated lichen biomass on the portions of these branches that drooped below 6 m, but it was impractical to sample them.

I used a heavy-duty 7.3 m, aluminum extension ladder for access to the branches, and a climber's belt to secure myself to the tree. The first step in sampling a tree was to mark the trunk with spray paint at one-metre intervals, up to 6 m. Then I made an approximate count of the number of branches eligible for sampling, and re-estimated lichen biomass on the tree, this time considering only branches eligible for sampling. These estimates were necessary to calculate the top random number, using Equation 2. K + Z was selected so that approximately 25-33% of the eligible branches on each tree would be sampled.

Using a 1.0 g clump of lichen as a standard unit, I estimated lichen biomass on each branch. I began with the branches that originated above 6 m, and tagged them with lettered strips of flagging tape as their estimates were recorded by my field assistant. Some branches originating above 6 m were out of reach; in those cases I estimated lichen biomass on the branches, but did not tag them. All branches eligible for sampling were tagged with numbered strips of flagging tape. If several branches originated from a single point on the trunk, they were treated as a single branch. As I made each estimate of lichen biomass, I also assessed the reliability of the estimate as high, medium, or low, depending on how well I could see the branch. My assistant read the next two numbers from a random number list, and compared them to the estimate. If the branch was selected for sampling, we recorded its approximate height, and whether it was living or dead. I sawed it off at the base with a pruning saw and dropped it to the ground, taking care not to break off lichens.

I also marked some branches with permanent aluminum tags, for future reassessment. Only branches with high-reliability estimates received tags. I did not permanently mark any branches which I thought would be affected by the sampling itself, e.g., ones which had been shaded by branches that were now missing. Branches were permanently marked only on trees expected to remain standing after logging.

I visually estimated lichen biomass on the trunks below 6 m.

The lichens were removed from the sample branches and placed in labelled paper bags. Then the bags were air-dried in a heated room for storage.

In the laboratory, the samples were first cleaned of twigs, needles, cones, and other debris. Then they were oven-dried at 60-65°C for 24 h, and weighed to the nearest 0.01 g with a Mettler P162N electric balance.

CALCULATIONS

I calculated lichen biomass totals and associated statistics, using methods described by Iles (1978). For each sample branch I computed the correction ratio

$$R_i = \frac{\text{measured lichen biomass}}{\text{estimated lichen biomass.}} \tag{3}$$

I determined the estimate of total lichen biomass for each tree, using the formula

$$\text{lichen biomass} = \begin{array}{c}\text{sum of estimates}\\ \text{on branches}\end{array} \times \begin{array}{c}\text{average}\\ \text{correction ratio}\end{array} \tag{4}$$

or

$$\hat{L}_{tree} = \sum_{i=1}^{N} (KPI_i) \times \frac{\sum_{i=1}^{n} (R_i)}{n}, \tag{5}$$

where $\hat{L}_{tree}$ is the estimate of lichen biomass for the tree, KPI_i is a lichen estimate on an individual branch, R_i is a ratio for an individual branch, N is the total number of branches, and n the number of sample branches.

I calculated lichen biomass totals for plots in an analogous manner, using computed lichen biomass values for trees. In the case of Plot 4, in which no sampling was done, I based an estimate of total lichen biomass on the average correction ratio from the other plots.

Cruise data were compiled by Timberline Consultants, Vancouver, B.C.

PROBLEMS ENCOUNTERED IN ANALYSIS

The 3P method does not permit exact control of sample size, nor is there any simple way to increase sample size if it is smaller than desired. In each of plots 1-3, there was one tree from which only two sample branches were drawn. This is probably too small a sample from which to calculate a correction ratio. The $t_{.05}$ value for one degree of freedom is 12.706, and it produces confidence limits so broad as to make the lichen biomass total meaningless. For this reason, I eliminated these three trees from the analysis. Examination of the t table suggests that the confidence interval could be kept within reasonable limits by aiming at a minimum sample size of 5, even if that represents more than 33% of the branches.

RESULTS

RELIABILITY OF THE LICHEN ESTIMATES

All the statistics in 3P sampling depend on the ratios of measured lichen biomass to estimated lichen biomass. The success of the estimation procedure is assessed by the standard deviation (SD), which measures the variability of the ratios; or the coefficient of variation (CV), which expresses the SD as a percent of the average ratio. The reliability of the estimates of total lichen biomass is expressed by the standard error (SE) around the average ratio, or by the confidence limits.

Statistical results for sample trees are given in Table 1; and for plots, in Table 2 and Fig. 3. Table 3 presents the statistical results for the branches with high-reliability estimates. The total lichen estimate for high-reliability branches is not given, as it would be meaningless; the statistics are presented because of their possible use in monitoring changes in lichen biomass.[1]

The CV's for trees ranged from 15% to 85% while CV's for Plots 1-3 were 73%, 27%, and 41%, respectively. The CV's for high-reliability branches in Plots 1-3 were very consistent: 35%, 37%, and 36%. Generally, all these CV's are within the range of those obtained in variable or fixed plot timber cruising, though only a few are as low as those expected with 3P timber cruising (Iles 1978).

The 95% confidence limits around the lichen estimates for trees ranged from ± 15% to ± 164 %. All limits were less than 80% of their means except for the two very poor values belonging to trees 1/04 and 3/53, on which only three branches were sampled. High-reliability branches had low confidence limits of ± 16%, ± 21%, and ± 23% for plots 1-3, respectively.

The consistency of the correction ratios ($\bar{R}$, the mean ratio of measured to estimated lichen biomass on trees) among plots is unimportant in this study, as the methods used to calculate lichen biomass compensate for any over-estimation or overestimation that might occur in each plot. However, consistency would be important in an inventory project in which lichen estimates were not backed up by biomass sampling. In plots 1-3, $\bar{R}$ was inconsistent at 23, 36, and 23, respectively (Table 2). As I was using a 5-g clump as a standard unit, this means that the estimates were low by factors of 4.6, 7.2, and 4.6. In an inventory project, the problem of inconsistency could be reduced by planning a number of replicate plots and by pooling the results of independent observers.

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[1] The total estimate for high-reliability branches may be slightly biased because the population from which each sample was selected with probability proportionate to prediction was the tree, rather than the population of high- reliability branches. However, the statistics give a correct impression of the reduced variability that surrounds high-reliability branch estimates. This statistical problem does not exist in the methods recommended for future use (Appendix F).

Table 1. Lichen biomass totals for trees.

plot no./ tree no.	n (branches)	$\overline{R}$[a]	SD_{R_i}	CV (%)	SE	SE (%)	$\hat{L}$ (g)[b]
1 / 04	3	1.6	0.9	54	0.5	32	60.9 ± 82.7
1 / 06	8	8.3	3.7	44	1.3	16	71.7 ± 26.7
1 / 12	8	2.9	0.6	22	0.2	8	105.5 ± 19.4
1 / 17	5	3.5	2.2	61	1.0	28	902.2 ± 687.7
1 / 18	13	3.0	2.5	85	0.7	23	200.9 ± 102.3
1 / 25	5	2.1	0.5	23	0.2	10	408.8 ± 114.8
1 / 27	6	1.4	0.5	34	0.2	14	294.8 ± 107.4
1 / 41	--------------------entire tree sampled--------------						2.4
2 / 43	--------------------entire tree sampled--------------						0.3
2 / 47	7	3.2	1.3	42	0.5	16	509.4 ± 199.8
2 / 48	4	2.8	1.2	44	0.6	22	218.8 ± 152.9
2 / 49	3	3.5	0.9	27	0.5	16	226.1 ± 152.2
2 / 52	12	3.1	2.5	79	0.7	23	338.4 ± 169.6
2 / 56	6	3.8	0.6	14	0.2	6	405.3 ± 61.8
2 / 67	--------------------entire tree sampled--------------						0.1
2 / 101	6	1.6	0.4	22	0.2	9	671.6 ± 149.4
2 / 104	10	2.2	1.4	63	0.4	20	869.0 ± 390.8
3 / 08[c]	7	2.0	1.3	63	0.5	24	618.6 ± 361.5
3 / 09	8	1.9	1.0	53	0.4	19	574.9 ± 254.8
3 / 10	6	2.6	0.6	21	0.2	9	377.1 ± 83.1
3 / 46	4	2.7	1.2	45	0.6	23	1038.2 ± 744.9
3 / 53	3	4.3	2.8	66	1.6	38	435.2 ± 717.0
3 / 54[c]	5	3.2	1.7	53	0.8	24	527.0 ± 345.2

[a]mean ratio of measured to estimated lichen biomass on branches.

[b]total estimated lichen biomass with 95% confidence interval.

[c]selected for sampling by two random numbers; counted twice in calculations.

Table 2. Statistics for lichen biomass totals for plots.

	Plot 1	Plot 2	Plot 3	Plot 4
n	8	9	8	
$\bar{R}^a$	22.7	36.4	23.2	28.4[b]
SD	16.5	9.7	9.6	
CV (%)	73	27	41	
SE	5.8	3.2	3.4	
SE (%)	26	9	15	
$t_{0.05} \cdot SE(\%)$	60	20	35	
Σ LET[c]	296.5	282.6	455.0	65.0
$\hat{L}$ (kg/ha)[d]	67.2 ±40.0	102.7 ±21.1	105.5 ±36.5	18.4[b]

[a] mean ratio of measured to estimated lichen biomass on trees.

[b] average of ratios, Plots 1-3.

[c] sum of lichen estimates for trees.

[d] total estimated lichen biomass with 95% confidence interval.

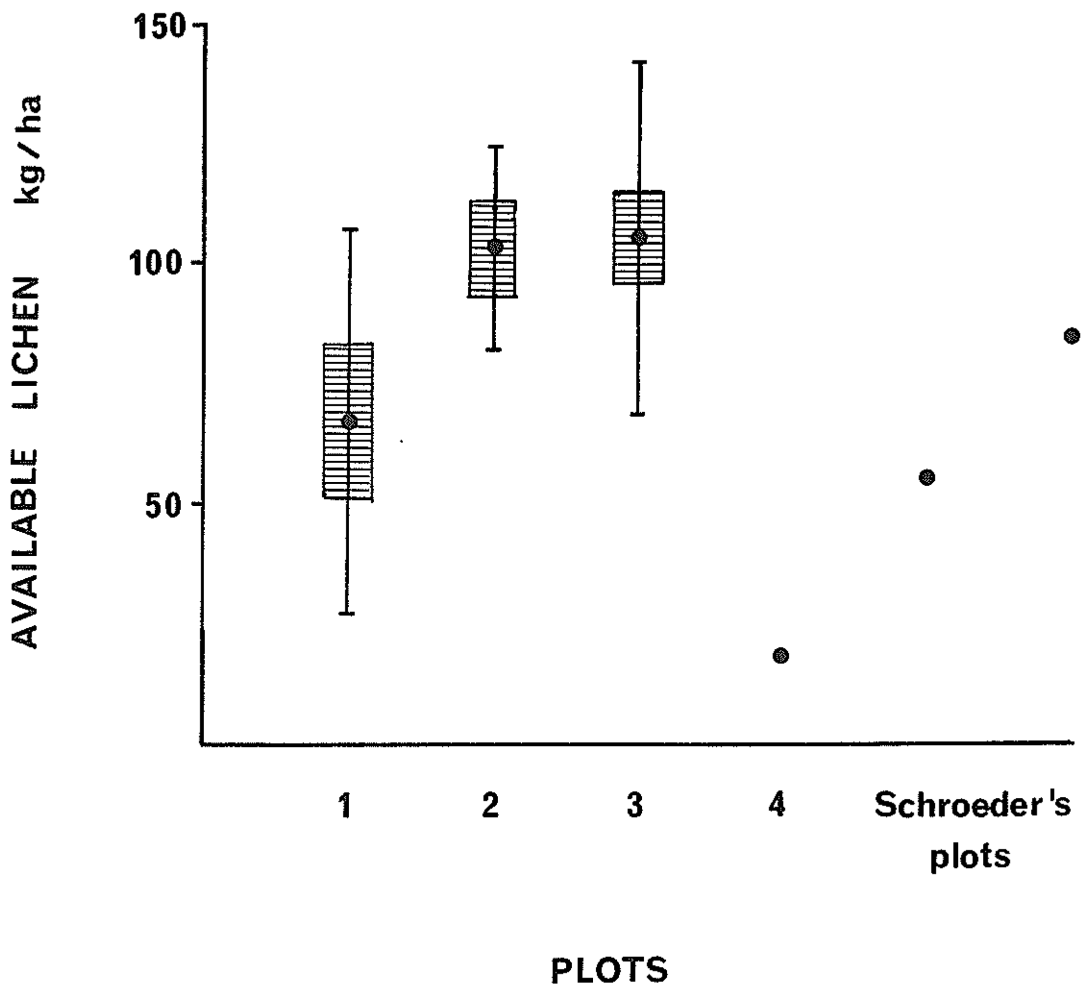

Figure 3. Lichen biomass available to Selkirk caribou, with standard deviation and 95% confidence limits. Data for Schroader's plots in Schroeder (1974).

Table 3. Statistics for branches rated high in reliability.

	Plot 1	Plot 2	Plot 3	All plots
n	21	15	12	48
$\bar{R}$[a]	2.0	2.0	2.1	2.0
SD	0.7	0.7	0.8	0.7
CV (%)	35	37	36	35
SE	0.2	0.2	0.2	0.1
SE (%)	8	10	11	5
confidence interval (%)[b]	±16.4	±21.1	±23.1	±10.3

[a]mean ratio of measured to estimated lichen biomass on branches.

[b]95% confidence interval for total lichen estimate.

On the branch level, $\bar{R}$ ranged from 1.4 to 4.3, except that one tree had a correction ratio of 8.3 (Table 1). Mean ratios of high-reliability branches were very consistent at 2.0, 2.0, and 2.1 in Plots 1-3, respectively. These results indicate that during the field season, I was able to estimate lichen biomass consistently on branches that I could see well, but that my estimates of lichen biomass on trees and on other branches varied with time and visibility of sample branches.

AMOUNTS AND DISTRIBUTION OF AVAILABLE LICHEN IN FOREST STANDS

On undisturbed sites, the estimated biomass of Alectoria and Bryoria available to caribou ranged from 67 kg/ha to 105 kg/ha (Table 2, Fig. 3). Estimates of lichen available to caribou in two other Engelmann spruce-subalpine fir stands within the range of the Selkirk caribou show a similar range of values (Fig. 3). For the single plot in the selectively logged site, the estimated amount of available lichen was considerably less at 18 kg/ha.

The distribution of available lichen varied with tree species, condition, and diameter; and with height on the tree. Thus, stand composition was important in determining total amounts of lichen available to caribou.

In the three unlogged plots, the average amounts of available lichen on living subalpine fir and spruce over 7 in. DBH were 310 g/tree and 212 g/tree, respectively. Snags bore an average of 138 g/tree, and trees 7 in. DBH or smaller bore only 13 g/tree.

Average quantities of lichen on subalpine fir and spruce trees varied with stem diameter (Fig. 4). In the lower diameter classes of 6 in. to 18 in., lichen quantities were generally greater on subalpine fir than on spruce. In the larger size classes, spruce bore as much or more lichen as subalpine fir. The very high value for spruce in the 23 in. + class was based on a single individual.

Most of the available lichen occurred between 3 m and 6 m: 91%, 87%, 92%, and 83%, respectively, in Plots 1-4 (Fig. 5). Schroeder (1972, 1973) also found very little lichen below 3 m in his two Engelmann spruce - subalpine fir plots in the Selkirks. He attributed this lack to the deterioration of lichens covered with snow.

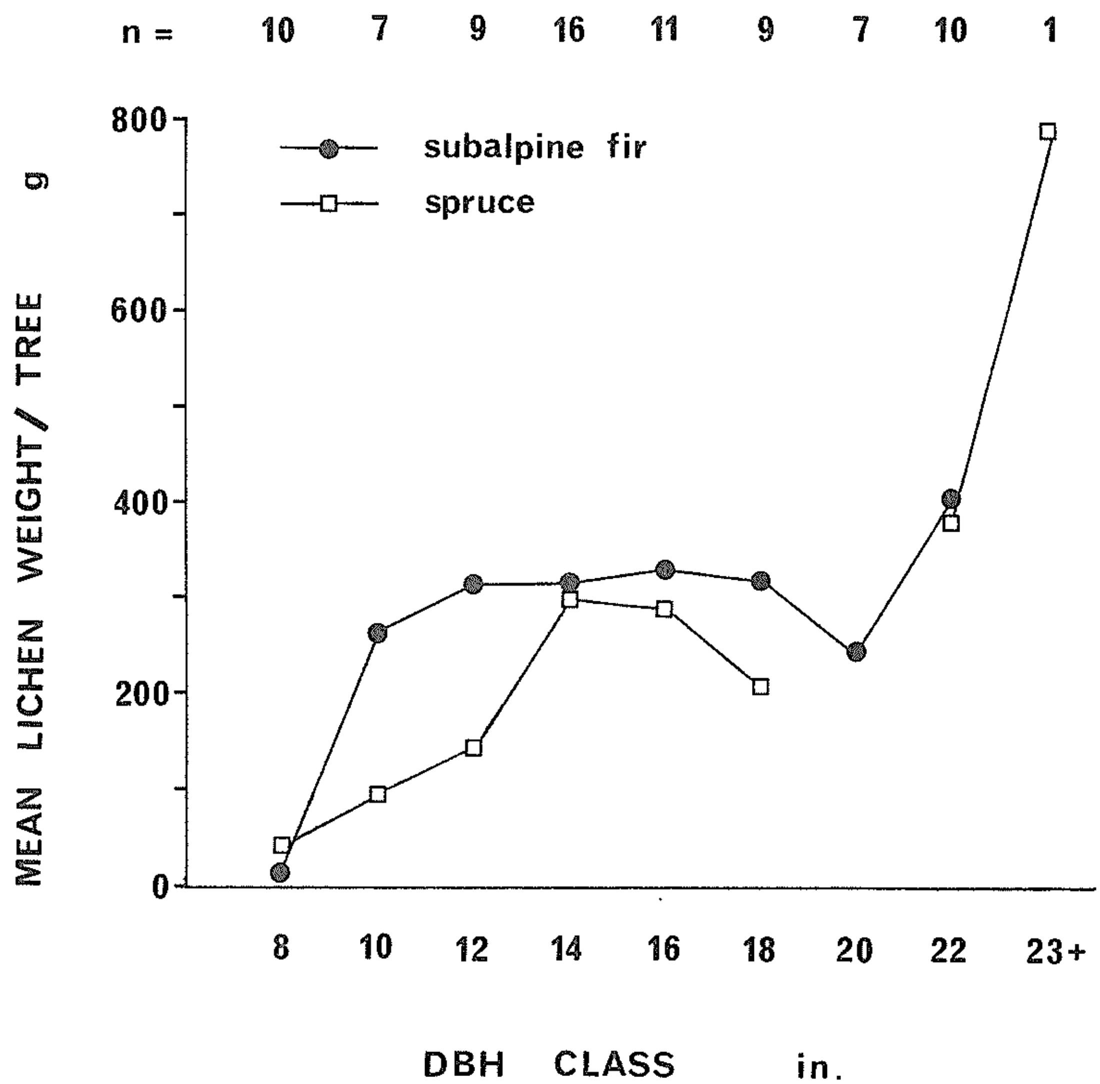

Figure 4. Mean lichen per tree on subalpine fir and spruce, by DBH class.

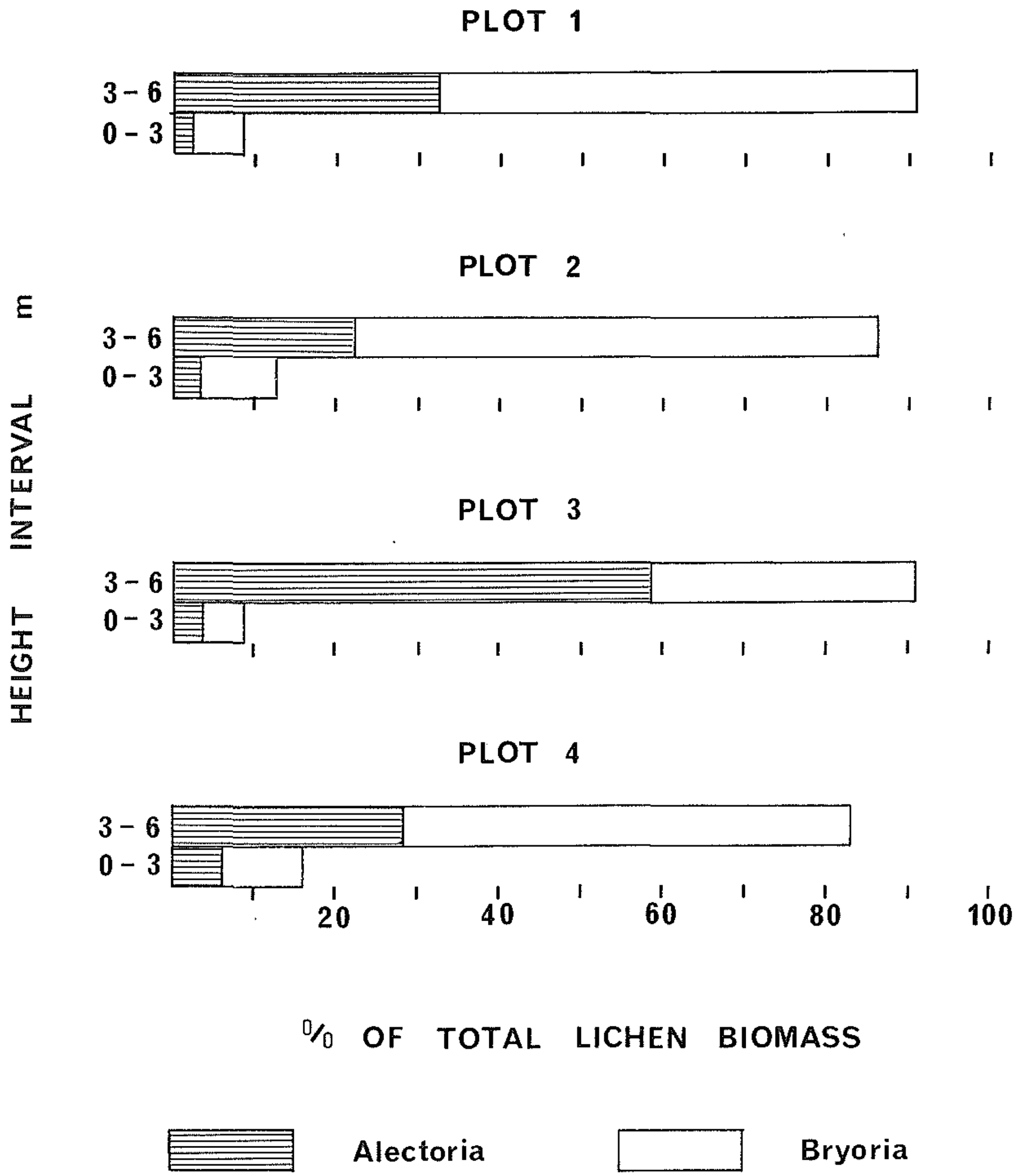

Figure 5. Distribution of Alectoria spp. and Bryoria spp. on trees, by height intervals.

The light green Alectoria sarmentosa was less abundant than the brown Bryoria species in all plots but Plot 3, where it was more abundant. This difference is unfortunate, as it makes Plot 3 a poor control plot for monitoring changes in species composition of the lichens.

The proportions of the total lichen biomass contributed by subalpine fir, spruce, snags, and trees less than 7.1 in. DBH varied among plots (Fig. 6). In general, the largest proportion of the lichen biomass was found on subalpine fir. The biomass on spruce contributed from 22% to 38% of the total available. The proportion of total lichen occurring on snags was much lower than on living trees -- 13% to 25%. Living trees less than 7.1 in. DBH contributed very little to total lichen biomass.

Fig. 7 shows the distribution of stems, volume, and lichen biomass on merchantable timber in unlogged plots, by DBH class. The distribution of stems is fairly even among diameter classes, with a slight bulge in the middle. Timber volume increases steadily with diameter. The distribution of lichen biomass appears to be related to that of stems, but it is exaggerated in the upper and middle diameter classes, and minimized in the lower diameter classes.

In Figure 8 the distribution of stems, volume, and lichen by DBH class is separated according to tree species. In this figure, the proportions shown for the two tree species together add up to 100%, e.g. about 18% of the lichen found on merchantable trees occurred on subalpine firs in the 13-15 in. DBH class. The greatest contribution of lichen by subalpine firs occurred in the middle diameter classes, whereas spruce contributed relatively more in the higher diameter classes.

EFFECTS OF SELECTIVE LOGGING ON LICHEN BIOMASS

Fig. 9 illustrates the hypothetical consequences of selective logging in the study area, based on data from Plots 1-3. I assume that departures from the prescription cancel one another out, so that the net result is the same as if the prescription were applied rigidly. For each of several possible cutting prescriptions, the proportion of the total volume of merchantable spruce and subalpine fir that would be harvested is shown. This is compared with the proportion of the total biomass of lichen on merchantable trees that would be left after logging. The histogram is based only on loss of lichen through removal of trees above the prescription diameter. Lichens present on non-merchantable trees, and lichens that might be knocked off residual trees during logging are not considered here.

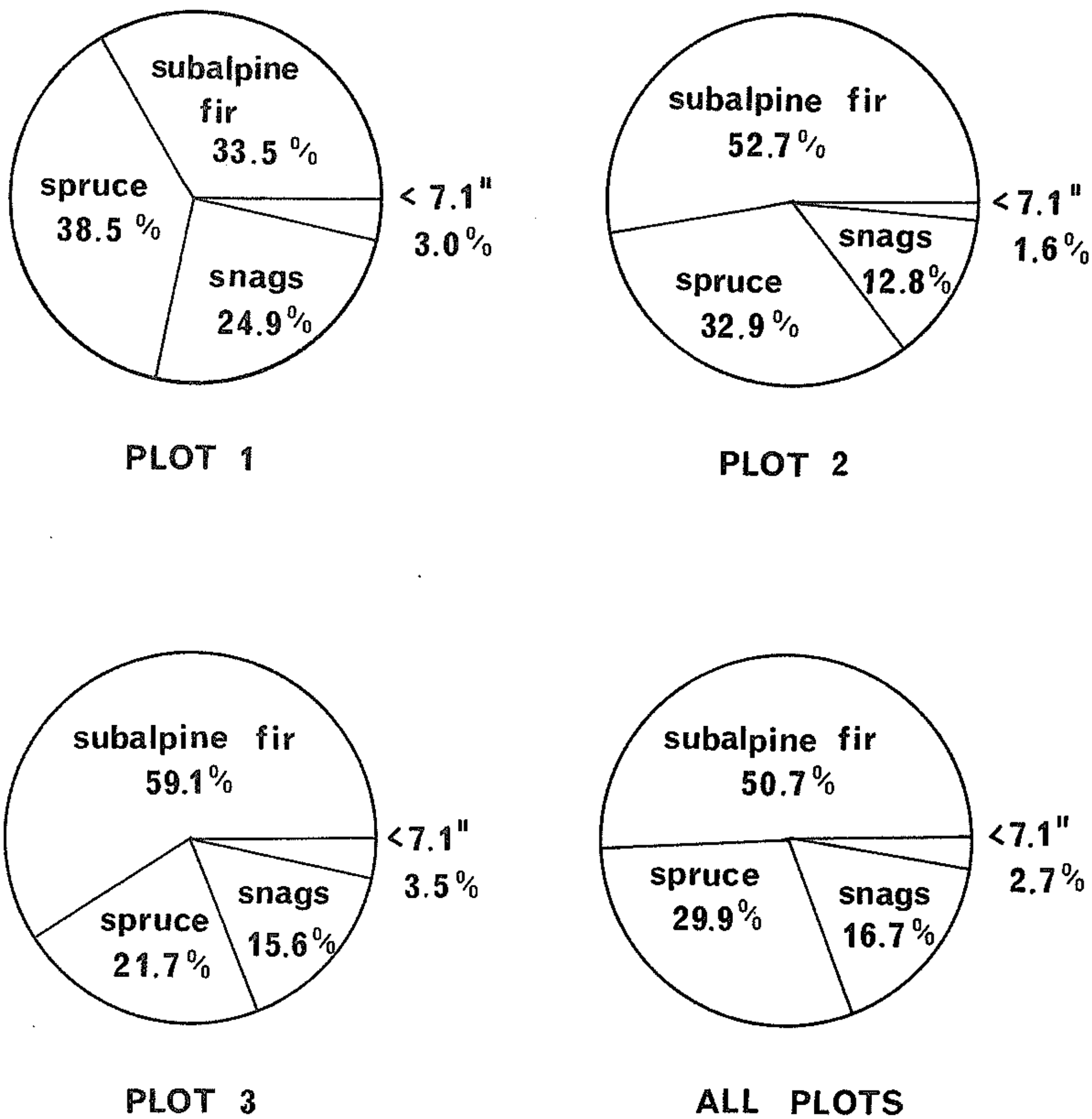

Figure 6. Proportions of total lichen biomass occurring on subalpine fir, spruce, snags, and trees less than 7.1 in. DBH (18 cm)

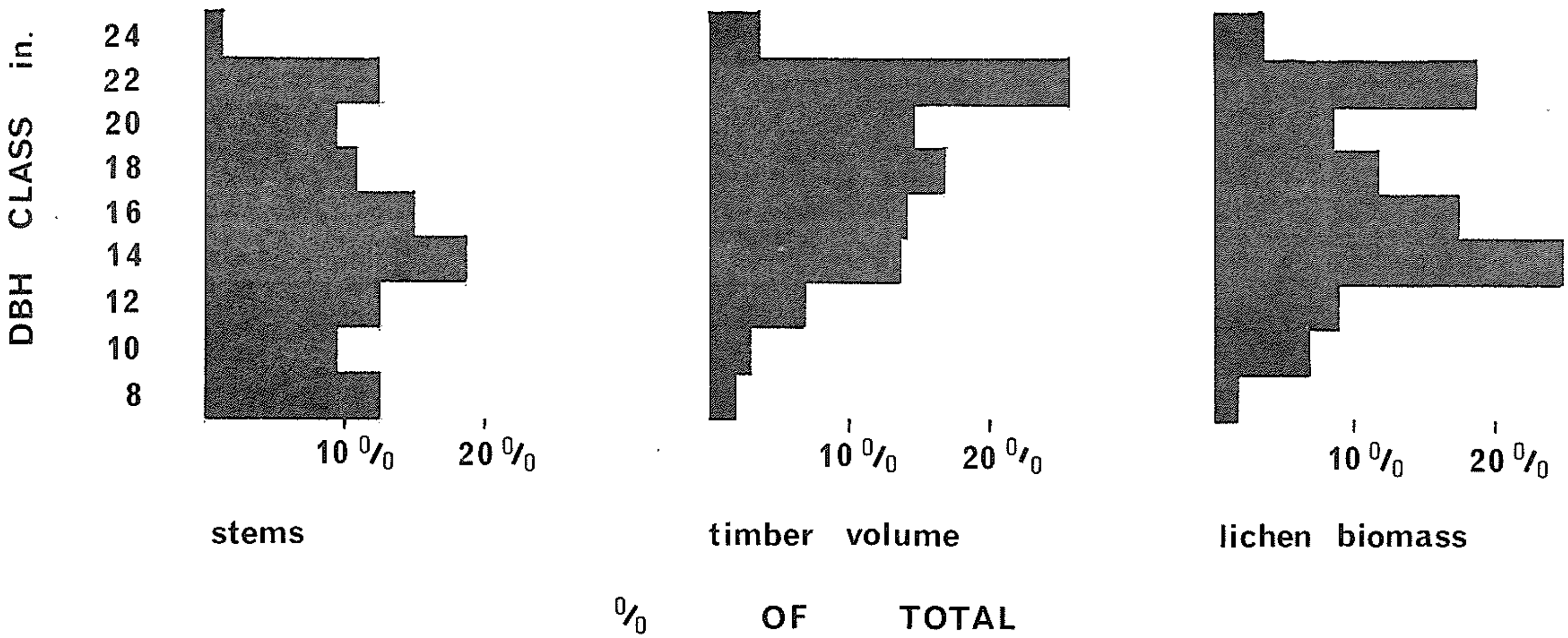

Figure 7. Distribution of stems, timber volume, and lichen biomass on merchantable timber, by DBH class.

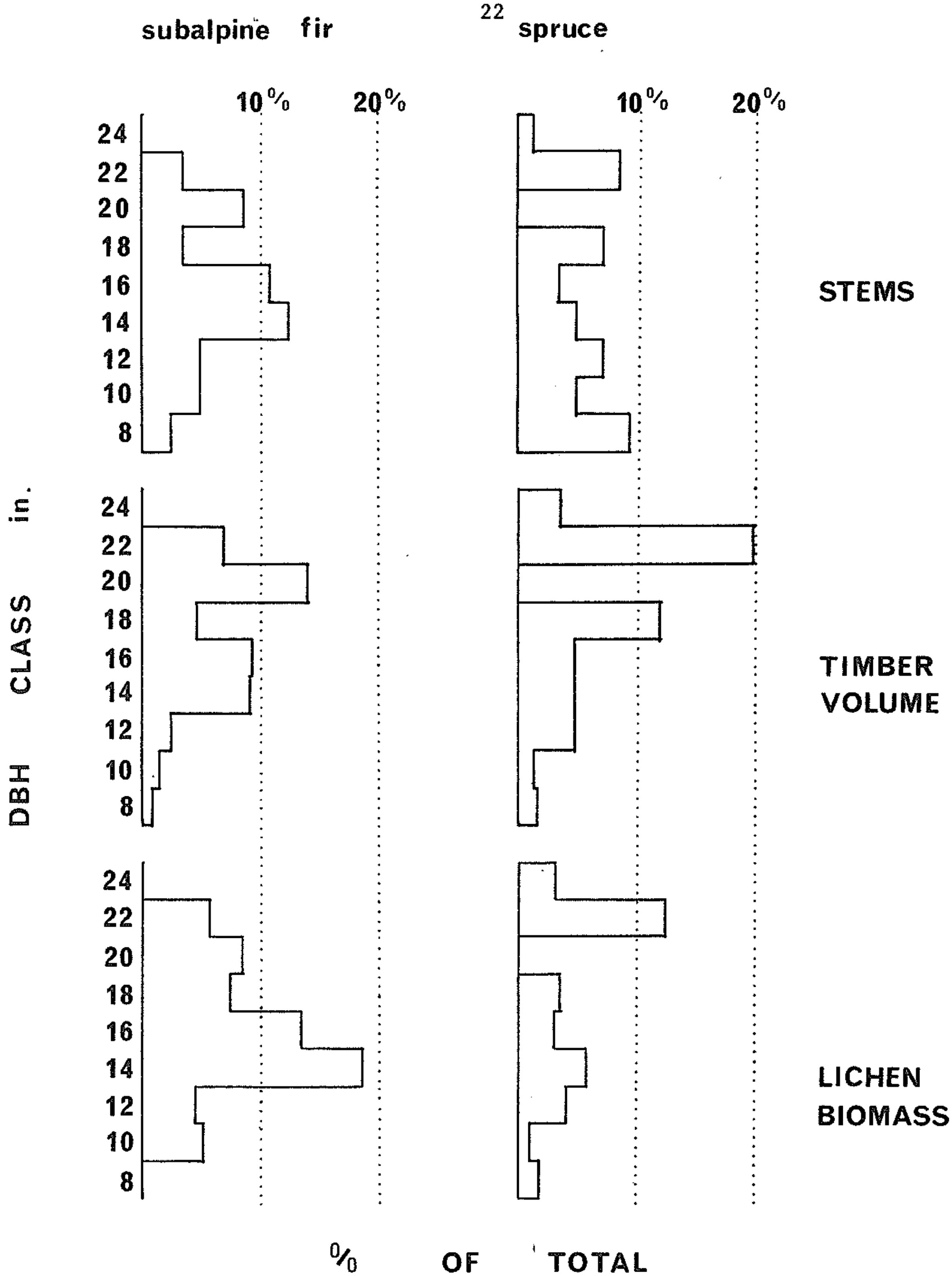

Figure 8. Distribution of stems, timber volume, and lichen biomass on merchantable timber, by tree species and DBH class.

The first prescription shown is the one for which the area is scheduled: all trees over 20 in. (51 cm) DSH are to be harvested.[1] The prescription would result in the harvesting of 70% of the merchantable volume (40% spruce, 30% subalpine fir). Theoretically, 48% of the lichen would remain.

A 24 in. (61 cm) DSH prescription[2] would increase remaining lichen to 68%, but would reduce timber harvested to 51%. A reduction of the prescription to 16 in. (41 cm) DSH[3] would increase timber harvested to 91%, but would reduce residual lichen to only 15%.

Because more lichen occurred on subalpine fir than on spruce, I thought that residual lichen might be substantially increased by raising the diameter limit for subalpine fir and lowering it for spruce. However, a prescription of 24 in. (61cm) DSH for fir and 14 in. (36 cm) DSH for spruce[4] would increase residual lichen only slightly, to 52%. Examination of Fig. 8 confirms that the gain in lichen biomass obtained by raising the fir cut-off from 16 in. DBH to 19 in. DBH is nearly offset by the loss of the spruce in the 11-15 in. DBH range. The total amount of timber harvested would not differ from the 20 in. prescription, but the proportion of spruce would be higher (49% spruce, 21% subalpine fir).

Fig. 9 is useful for comparing effects of cutting prescriptions, but it underestimates the overall effects of logging. When dominant and codominant trees are felled, entire branches as well as clumps of lichen are knocked off the residual trees. In practice, most snags are also felled. Furthermore, construction of landings, skid roads, and haul roads means that a portion of a selectively logged stand is actually clearcut. Hammond (1978) found that in eight cutblocks in the Nelson Forest Region the average area occupied by landings, skid roads, and haul roads (not including sidecast) was 23%. Based on additional data collected during the 1978 field season, Hammond (pers. comm., 1979 May 01) confirmed that 23% was a reasonable estimate of the area cleared for roads and landings on forest sites such as those studied. According to Hammond, the area occupied by roads and landings could probably be reduced to about 15% by following guidelines for reduction of site disturbance (Hammond 1979).

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[1] Corresponds to 16 in. (41 cm) DBH for subalpine fir; 15 in. (38 cm) DBH for spruce.

[2] 19 in. (48 cm) DBH for subalpine fir; 18 in. (46 cm) DBH for spruce.

[3] 13 in. (33 cm) DBH for subalpine fir; 12 in. (30 cm) DBH for spruce.

[4] 19 in. (48 cm) DBH for subalpine fir; 11 in. (28 cm) DBH for spruce.

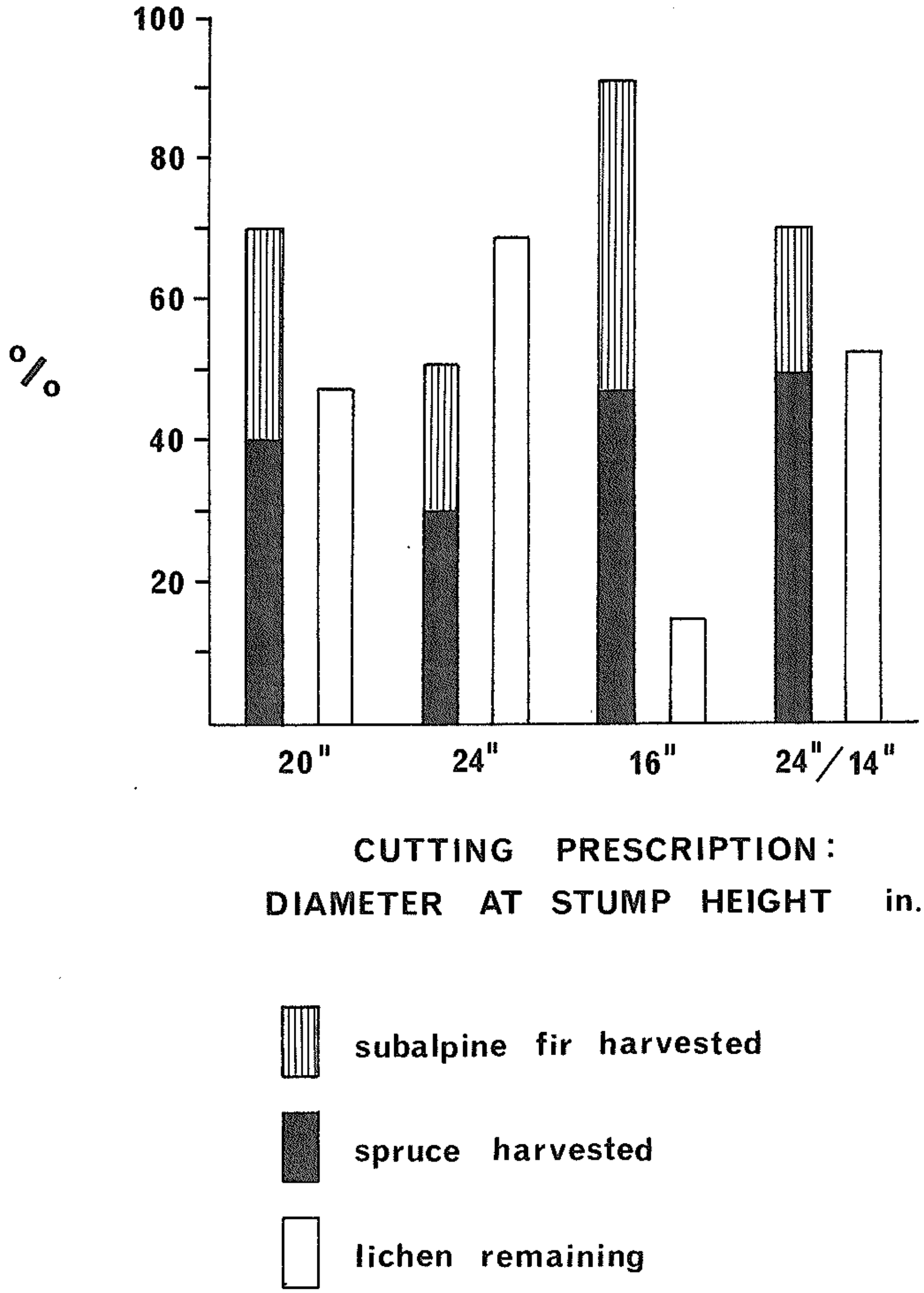

Figure 9. Comparison of timber harvested and lichen remaining under various cutting prescriptions. (Data in Appendix E).

In Fig. 10, I have attempted to incorporate these factors into estimates of available lichen quantities on all trees, before and after a selective cut. Estimates are based on the assumptions that all trees over 20 in. DSH are removed, 90% of the snags are felled, 20% of the lichen is knocked off the residual trees, and 23% of the logged area is occupied by skid roads, haul roads, and landings. Under these circumstances, 20% of the original lichen biomass would remain in Plot 1, 25% in Plot 2, and 32 % in Plot 3. Considering all three plots together, 26% of the original lichen would remain. In absolute terms, residual lichen would range from 12 kg/ha in Plot 1 to 32 kg/ha in Plot 3. The estimated amount of lichen (18 kg/ha) in Plot 4, which was selectively logged in 1977, falls within this range.

Thus, it seems reasonable to expect that in the type of forest represented by the study area and under current logging practices, the removal of trees over 20 in. DSH would result in the loss of nearly three-quarters of the lichen available to caribou on standing trees. If site disturbance is reduced to 15% of the block area by following the recommendations of Hammond (1979), then remaining lichen biomass would be greater: considering all plots together, an estimated 29% of the original amount of lichen would remain.

RELATIONSHIPS BETWEEN LICHEN BIOMASS AND TREE CHARACTERISTICS

The relationships between available lichen and DBH, height, age, and recent growth rates of trees, were examined (Fig. 11). Except for the fact that very small trees have little lichen, no relationship between lichen biomass and either DBH or tree height was apparent. Fig. 4, based on data from all merchantable trees in the three plots, similarly showed little relationship between DBH and lichen biomass, except at the extremes of the scale. Nor was there any significant relationship between lichen biomass and tree age, though a relationship might have been found had any very young trees been measured.[1] The relationship between lichen biomass and recent radial growth of trees was not strong, but the data suggested that faster-growing trees may bear more available lichen that slower-growing trees.

I had expected a loose but positive relationship between tree size and lichen biomass. Two hypotheses may explain the results. First, lichen biomass below 6 m may decrease because of the death and breakage of lower branches. This hypothesis is consistent with the observation that the trees with the greatest quantities of available lichen are moderate in size (Figures 12a, 12b). Second, the effects of other factors -- such as the growth-form of a tree, or its position in relation to neighboring trees -- may be so great as to obscure the effects of age and size. In the field I noticed that the trees with greatest available lichen tended to be distant from any neighbors that would compete with them for sunlight. Well-spaced trees may also have a

[1]Because of last-minute time constraints, ages of some trees below 18 cm DBH were not measured. Other missing data points represent trees with rotten centres.

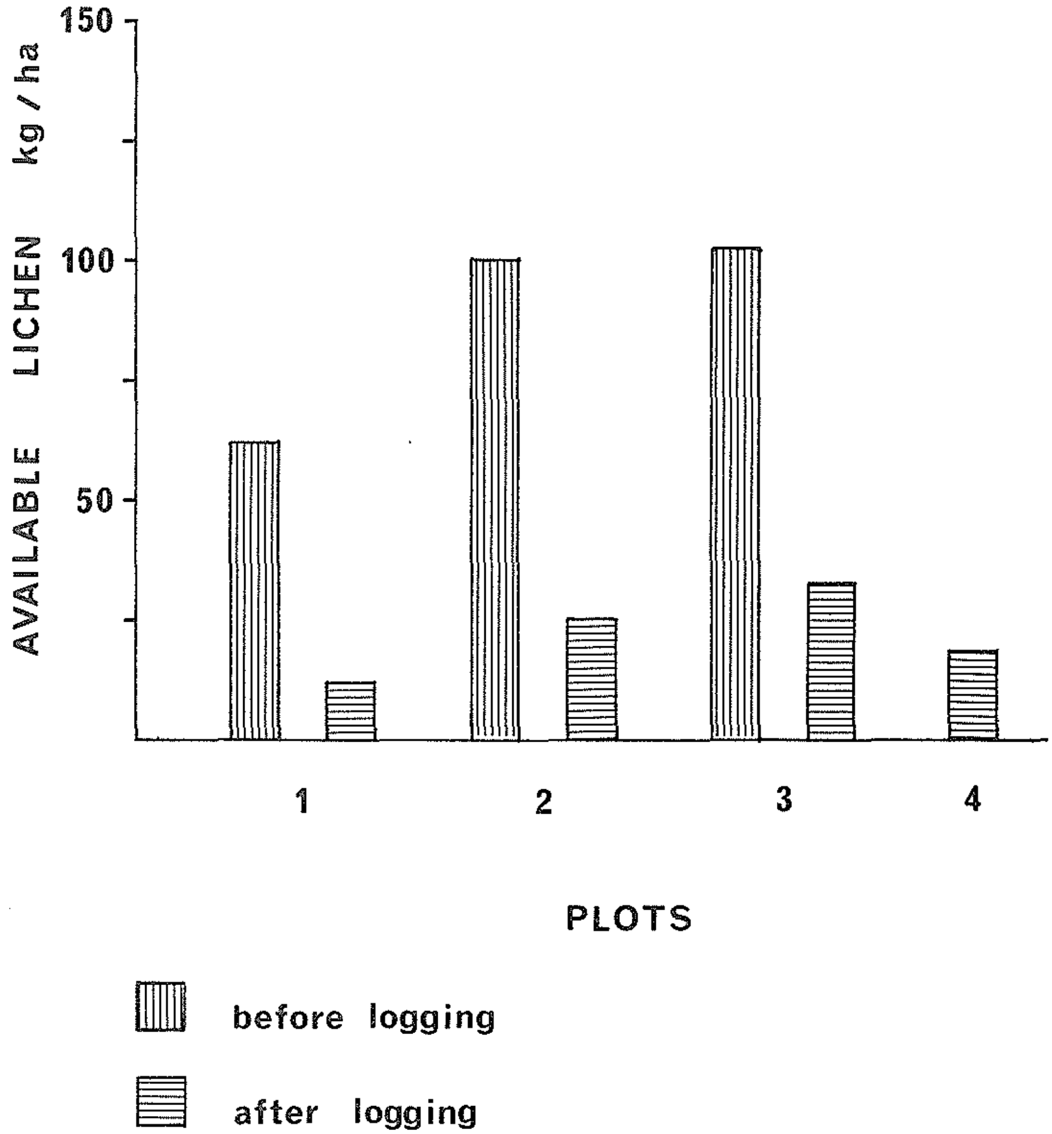

Figure 10. Estimated lichen quantities before logging and expected lichen quantities after selective logging, based on current logging practices. Lichen present after logging may be up to 3.5 kg/ha greater if guidelines for reducing site disturbance are followed.

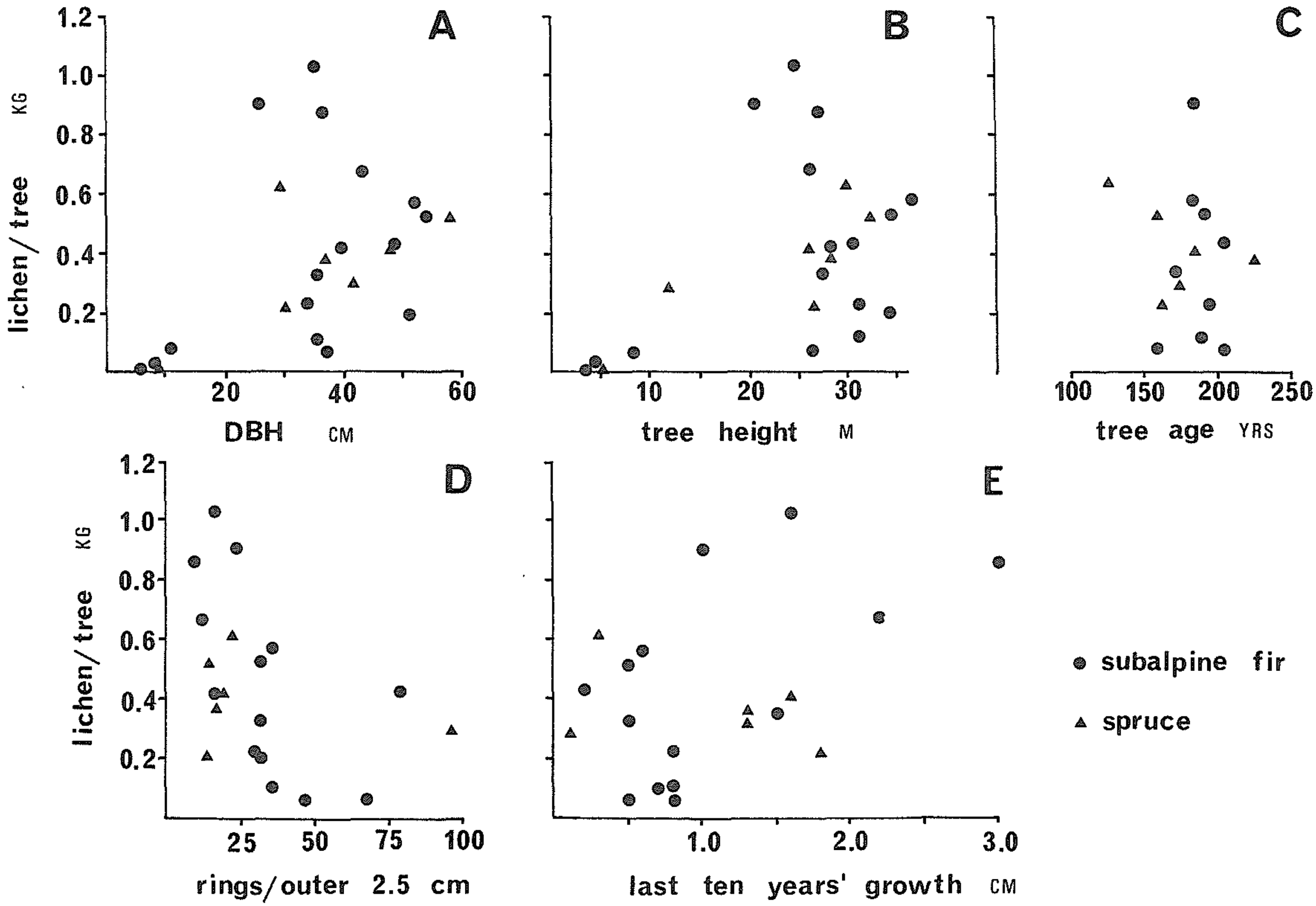

Figure 11. Relationships between lichen biomass and DBH, height, age, and growth rates of sample trees.

competitive advantage over clumped trees with respect to their own growth, which could explain the apparent tendency for high-lichen trees to have faster growth rates than their neighbors.

IMPLICATIONS TO CARIBOU

In this section I speculate on the importance of the lichen resource to the Selkirk caribou, and on the implications of logging within their range.

To discuss the adequacy of the lichen resource in relation to caribou needs, it is necessary to make some assumptions about the lichen requirements of the Selkirk caribou, and about the amount of lichen available on their range.

DAILY LICHEN CONSUMPTION OF CARIBOU

Based on a theoretical formula or on feeding trials with penned reindeer (e.g. Des Meules et al. 1969) an estimated 3 kg/day of dry forage are required for maintenance of adult animals. This level is almost certainly too low for free-roaming caribou during winter, and estimates based on these conditions have been higher. Kelsall (1968:81) calculated that 3.5-4.5 kg/day (dry weight) of lichens would be required by barren-ground caribou in Canada. Skuncke (1969) suggested that 5 kg/day was adequate for maintenance of reindeer in Scandinavia. Hanson et al. (1975) used fallout Cesium-137 to estimate rates of lichen consumption by free-roaming caribou during winter in Alaska. They concluded that the caribou consumed 4.5-5.0 kg/day (dry weight) of lichens. Thus, Selkirk caribou probably consume about 4.5 kg/day (dry weight) of lichens during winter, although the true value might be as low as 3.5 or as high as 5.0.[1]

ANNUAL PERIOD OF LICHEN USE

Freddy (1974a) reported that Selkirk caribou ate arboreal lichens from October to May. During October and November, vascular plants were also eaten, but as snow deepened in November many of these became unavailable. As Freddy (1974a) made no feeding observations from December to February, it is unclear at what time the animals shifted completely from understory species to arboreal lichens. However, Layser (1974) observed caribou feeding only on arboreal lichens in February and April of 1971. Freddy's observations also indicated that arboreal lichens were the primary food from March to May. Green forage began to appear in late April, and was undoubtedly used at that time.

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[1] This range of values is probably too low. Using the radiocesium method, Holleman et al. (1979) estimated mean lichen intake of 4.9 kg/day or 61.3 g/day of dry lichen per kg body weight, for a free-roaming 80-kg adult Alaskan caribou. Selkirk caribou belong to a much larger subspecies than the caribou studied; adults generally range from 100-200 kg (Banfield 1961, Cowan & Guiget 1973, Freddy 1974a and Layser 1974). Thus, it is likely that Selkirk caribou eat more than the smaller Alaskan caribou.

In Wells Gray Park, caribou were in low elevation forests from October through December, where they depended increasingly on arboreal lichens as snows deepened (Edwards and Ritcey 1959, 1960). From January through April they wintered in high elevation forests, feeding almost exclusively on arboreal lichens.

Since snowfall is heavy in the Selkirks, these caribou probably shift to exclusive use of arboreal lichens at least as early as Wells Gray Park caribou. I will assume that Selkirk caribou depend on lichens from January through April, and that lichens represent 50% of their diet in November and December. This is equivalent to 5 months (150 days) of lichen consumption annually.

QUANTITIES OF LICHEN AVAILABLE TO SELKIRK CARIBOU

Of the five spruce-fir plots in the Selkirk Mountains for which information is available -- two of Schroeder's (1974) and three from this study -- the average amount of lichen available to caribou on standing trees is 83 kg/ha. This is not an adequate data base from which to extrapolate to an entire range, but it is all that is available. My casual field observations -- mostly limited to the area between Highway 3 and the international border -- suggest that 83 kg/ha is probably an overestimate of the average amount of available lichen. This is consistent with Schroeder's observation (1972) that of his nine plots, the one with 84 kg/ha of available lichen probably had the highest lichen load.

I will assume that the average amount of available lichen on standing trees throughout the Selkirk caribou range is 75 kg/ha. This estimate assumes maximum snow depths. When the snowpack is not maximum, less lichen is within reach of the caribou.

In addition to lichens present on standing trees, lichens may be available to caribou as litterfall, on naturally fallen trees, and on felled trees in areas of active logging. In the Selkirks, Schroeder (1972, 1974) has argued that lichen litterfall and lichen on fallen trees are so quickly covered by snow that they are insignificant as sources of forage for caribou. I believe that this is true of litterfall, but not of fallen trees. Windthrows are irregular in occurrence, but they represent a concentrated source of a forage item which is otherwise sparsely distributed. Fallen trees are a major attraction to mountain caribou, and are used intensively when they are available (Edwards & Ritcey 1960; Layser 1974; D. Miller, pers comm. 1978 Dec. 01; T. Antifeau, pers. comm. 1979 Jan. 08). I have attempted to estimate the amount of lichen that might be available to caribou from that source.

Edwards et al. (1960) used a theoretical stand age table to calculate the number of trees aged 50 years or more that died each year in a spruce-fir forest. Their figures indicated an annual mortality rate of 1.9%. I made additional estimates of annual mortality, based on long-term plots maintained by the B.C. Forest Service in mature, uneven-aged *Picea glauca* - *Abies lasiocarpa* stands in the Aleza Lake Experimental Forest. Fraser and Alexander (1949) presented data which indicated an average mortality rate of 1.6% annually in 14 plots from 1928 to 1948. Additional information from three of these plots (B.C. Forest Service, unpublished data) indicated annual mortality rates of 1.9%, 1.3%, and 1.1% for trees 8.5 in. (21.6 cm) or greater, for the period 1928 to 1963. Fall rates of snags were not measured, but it may be assumed that in a mature forest, the rate at which snags are produced is approximately equal to the rate at which snags fall.

Based on these data, a long-term average rate of 1.5% per year was believed to be a reasonable estimate for an Engelmann spruce - subalpine fir forest. According to cruise data, there are 273.5 trees/ha in the study area. Assuming that half the windthrows occur during the winter season, an average of 2.05 trees/ha/winter may be expected to be available to caribou.

I did not measure lichen biomass on whole trees, but G. Schroeder (unpublished data) did so in a spruce-fir plot on Shedroof Mountain, Washington. His data indicate a mean value of 750 g of lichen per tree over 7.1 in. (18 cm) DBH. Using this value, the amount of lichen available on windthrown trees during winter would be about 1.5 kg/ha.

In calculating the amount of lichen available to caribou, it is necessary to consider the proportion of the standing crop that the animals may consume annually, without depleting their range. Without usable information on growth rates of <u>Alectoria</u> and <u>Bryoria</u>, it is difficult to determine how much of the lichen within reach of the caribou is surplus. If the assumption is made that lichen biomass is in a steady state in a mature forest (Pike et al. 1972), then annual litterfall rates provide a rough estimate of annual turnover and thereby annual growth. Stevenson (1978) reported litterfall rates of 10.5% to 16.1% of the standing crop of <u>Alectoria</u> and <u>Bryoria</u> on Vancouver Island. Data given by Bergerud (1978) indicate a turnover rate on the Slate Islands of 14.0%. Assuming an intermediate growth rate for the Selkirks approximately 13% of the standing crop of lichen on trees -- 9.75 kg/ha -- may be consumed annually by the caribou without depleting the range. No allowance is made for the unknown portion of the surplus standing crop that is lost to caribou by becoming litterfall before it is consumed. The addition of 1.5 kg/ha from windthrown trees makes a total of 11.25 kg/ha of forage lichens available to caribou when the snowpack is deep.

ADEQUACY OF THE LICHEN SUPPLY

The most recent population estimate of the Selkirk herd is 25-30 (Johnson 1976, Freddy 1979). Based on these reports, I will assume an average herd size of 27. It follows from the above assumptions that the amount of lichen consumed annually by the herd is roughly 18 225 kg. If a single animal ate so as not to deplete the range, there would be enough lichen on one hectare to feed it for 2.5 days. The entire herd would have to range over 1 620 ha in a winter, utilizing all the lichen on windthrows and 13% of the lichen within reach on standing trees. That is nearly half of the herd's potential winter range in British Columbia, calculated at 3 914 ha by Freddy (1974b). During winters of low snowfall, the animals would have to cover even more area to satisfy their food requirements because they could not reach as much of the heavier lichen loads in the 3-6 m height interval.

Rather than systematically covering an area as large as 1 620 ha in a single winter, caribou probably concentrate on smaller areas, though they do not exhibit the very restricted winter movements characteristic of some other ungulates. Evidence presented by Freddy (1974a:12-15, 24-25,43-45) indicates that caribou may concentrate in two or three adjacent drainages for much of the winter. His data also demonstrated that these ranges are not the same every year.

Areas selected by caribou for winter feeding may be above average in lichen abundance. It is also likely that lichens are utilized at a level greater than 13%. The behavioral pattern of rotating winter ranges would benefit caribou by allowing the lichens time to grow back.

Considering the relatively low level of lichen biomass that was found in the study area, it seems possible that the caribou behavior of rotating winter ranges over a large geographic area may be an adaptation to a sparse food supply. Evans (1964:445) proposed a "roam range" theory to account for the variation in year-to-year distribution of the Selkirk caribou that he observed:

> This term implies that caribou will roam over an area large enough to contain an adequate supply of lichens to feed on and the adequacy of the supply will be subject to the age of the forest, the frequency and intensity of the caribou grazing and even the annual variations in snow depth which permits feeding at different heights. That the "roam range" will be extensive is implied by keeping in mind the very slow regrowth of lichens.

If this formulation is correct, then Selkirk caribou may not be able to withstand major incursions into their range, particularly the portions which are used intensively during winter.

COMPARISON WITH OTHER CARIBOU RANGES

Estimated quantities of arboreal lichens available to caribou in other study areas are presented in Table 4. Only data from sites within known past or present caribou ranges are included. The maximum reach of caribou varies from one area to another because of differences in snowpack.

Quantities of arboreal lichen available to Selkirk caribou are low compared to amounts reported for Wells Gray Park and northern Saskatchewan. They fall at the low end of the range of values reported for Cape Breton Island. It is unclear whether or not the forage on the island is adequate to support caribou, as attempts to re-introduce the animals failed. Lichen quantities in the Selkirks are much greater than those reported by Sulkava and Helle (1975) for Finland. There, however, snowfall is much lighter than in the Selkirks. Terrestrial lichens and lichen litterfall, which are not included in the table, are major components of the winter diet of Finnish reindeer. In the Selkirks, litterfall is probably much less important, as it would soon be covered by the heavy and frequent snowfalls, and terrestrial lichens are completely inaccessible.

An exceptional instance of caribou surviving on extremely low food resources in a predator-free environment was described by Bergerud (1978b:9):

> ...even in this (subalpine) zone, my argument is that caribou are not limited by food supplies. I compared the lichen loads on mature trees from the Slate Islands, Ontario with those in Wells Gray Park (Edwards et al. 1960) and the Selkirk Mountains (Schroeder 1972 and 1973); all three populations depend almost entirely on tree lichens in late winter. Lichen loads were heavier in Wells Gray Park and the Selkirk Mountains than on the Slate Islands (Bergerud 1978b).[1] However, the density of animals on the Slates is about 10 to 15+ animals per square mile during 1974-77, whereas caribou densities in British Columbia were 0.05-0.20 animals per square mile. Counts of pellet pile groups on the Slate Islands in the summer of 1974 (Euler et al. 1976) were similar to those in 1949 (Cringan 1956) - the Slate Island population has varied but extremely dense populations (sic) dating back 30 years. There were few lichens for caribou in 1949 (Cringan 1956) - there are now no fruticose lichens within reach of the animals; the animals depend solely on blowdown lichens and foliose lichens on the bark of birch (Betula papyrifera). The Slate Islands are an extreme example of how caribou can survive with practically no food in winter - by their yardstick, tree lichens in Wells Gray and the Selkirk Mountains are super abundant.

If Bergerud is correct in rejecting the importance of winter forage, then it may not be necessary to protect the lichen resource of the Selkirk caribou. Before accepting this argument, several considerations should be weighed. First, until a complete report of the Slate Islands research is published, it is impossible to evaluate Bergerud's results or their relevance to caribou in the Selkirk Mountains. Based on Bergerud's data (1978a), 0.3-0.6 kg of lichen per day would be available to each animal during a 5-month winter. Even assuming 100% utilization, this amount is so far below maintenance levels of 3.5-5.0 kg/day reported by other researchers, that it is difficult to accept. Furthermore, Butler and Bergerud (1978) noted that although the population maintained itself, Slate Island caribou had greatly reduced body size, antler development, and birth rates, compared to mainland caribou. The main cause of mortality was winter starvation. Selkirk caribou, on the other hand, must contend with man-induced mortality, and probably some predation. The fact that a population can maintain itself

[1] Bergerud 1978a in this report

Table 4. Biomass of Available Arboreal Lichens in other Caribou Ranges

Source	Area	Forest Type	Maximum Sample Height	Lichen Biomass (Kg/ha)
Edwards et al. (1960)	Wells Gray Park, B. C.	Picea engelmannii - Abies lasiocarpa	20 ft. (6.1 m)	316.8, 1128.5
Scotter (1962)	northern Saskatchewan	Picea mariana Pinus banksiana	10 ft. (3.0 m)	679.5 380.0
Sulkava and Helle (1975)	Finland	young Pinus sylvestris mature P. sylvestris mature Picea abies	2.1 m	27.0 2.7 15.0
Wein and Speer (1975)	Cape Breton I., N. S.	Abies balsamea - Picea mariana	5.0 m	47.0 - 280.0
Schroeder (1974)	Selkirk Mts., B.C. and WA.	Picea engelmannii - Abies lasiocarpa	20 ft. (6.1 m)	84.1, 56.0
Bergerud (1978a)	Slate Islands, Ontario	Abies balsamea - Picea spp. - Betula papyrifera	8 ft. (2.4 m)	on trees - none litterfall- 3.5
this study	Selkirk Mts., B. C.	Picea engelmannii - Abies lasiocarpa	6.0 m	67.2, 102.7, 105.5

at a low nutritional level in a human-free, predator-free environment does not necessarily imply that a population subject to other sources of mortality can tolerate a reduction in its forage base, when that forage base is not clearly excessive.

It is possible that even Bergerud would agree that Selkirk caribou require range protection. Despite his emphasis on predation and overhunting as the factors controlling B.C. caribou populations, Bergerud (1978b:109) recommended that "forests above 4,000 feet in the subalpine zone in south-eastern B.C.... should be protected from logging and burning."

EFFECTS OF SELECTIVE LOGGING ON ADEQUACY OF LICHEN SUPPLY

The results of this study indicate that amounts of winter forage available to Selkirk caribou are relatively low, both in terms of the animals' forage requirements, and in comparison with amounts reported from most other caribou ranges. Given this low level of forage abundance, it is appropriate to ask whether the Selkirk caribou can tolerate any logging at all in their range.

If selective logging reduces lichen biomass to one-quarter of its original level, a caribou would have to range over four times as much area to obtain the same amount of food. An animal that would be supported for a winter on 60 ha of unlogged habitat would require 240 ha of selectively logged habitat. This represents a tremendous increase in the energy cost of feeding. Ecological theory (Wiens 1976, Pyke et al. 1977) would predict that caribou would spend little or no time feeding in selectively cut areas if undisturbed sites were available. It appears then, that until the lichen in selective cuts grew back to its original level, these areas would be inadequate for wintering caribou. The forage resources of the Selkirk caribou are low enough that it would be risky to remove timber from any areas in which caribou concentrate in winter.

It is not clear, however, that selective logging in small patches, in areas that are used as travel routes but not as wintering grounds, would have significant effects on caribou. Caribou often feed continually when travelling, but a moving animal encounters so much forage along its route that reduced forage availability in some areas would be unlikely to seriously affect it. In both the Selkirks and the Upper Fraser River drainage, I have observed tracks of caribou travelling through logged areas in winter and feeding on lichens from the residual timber.

The effect of any logging on forage lichens, and thus on caribou, changes with time. If the logging takes place during winter, it has the short-term effect of making the lichen on felled trees available to the animals. This source of food is temporary and erratic, and should not be considered part of the long-term forage supply. Logging is followed by a period during which lichen availability is reduced to a low level, in the case of selective logging; or to zero, in the case of clearcutting. With respect to regrowth of lichens, selective logging has a major advantage over clearcut logging. The opportunities for lichen fragments to disperse onto young trees and begin growing are much improved by the presence of residual, lichen-bearing trees. A selectively logged block is expected to regain its former level of lichen biomass in much less time than a clearcut block. In some stands, the increase in the amount of light reaching the remaining crowns may even enhance lichen growth, eventually resulting in more abundant lichen than was present before logging. Long-term effects of selective logging on lichen abundance may be studied by remeasuring lichen biomass in the Crutch Creek plots.

RECOMMENDATIONS

The recommendations proposed here are appropriate if the management objectives for the area are to ensure the survival of the Selkirk caribou herd, and to harvest timber where it is possible to do so without jeopardizing the animals.

MANAGEMENT RECOMMENDATIONS

Available data indicate that quantities of arboreal lichen within reach of Selkirk caribou are relatively low, both in terms of the animals' forage requirements and in comparison with other caribou ranges. Selective logging reduces available lichen to about one-quarter of its original amount. Unless future research shows that lichen supplies are much greater in winter ranges than in the study area, no logging should be carried out in areas where caribou concentrate in winter.

In areas that caribou use as travel routes, but not for extended feeding, selective logging might not be harmful from the standpoint of lichen availability. Selective logging may be practiced in such areas on an experimental basis. Logging plans should accord with the timber management practices recommended by Freddy (1974c). It is particularly important that corridors of mature timber be left along streams and other movement routes, as caribou might not travel through selectively cut areas under certain snow conditions. Caribou use of selectively logged areas during winter should be monitored.

The logging prescription that was used in the study area -- a 20 in. (50.8 cm) DSH diameter limit cut -- may represent the optimum compromise between timber harvested and lichen remaining. Lowering the diameter limit would drastically reduce residual lichen, and is not recommended. A prescription in which the diameter limit is raised for subalpine fir and lowered for spruce would slightly increase the amount of residual lichen. The amount of lichen gained is small enough that such a prescription should not be adopted unless considered desirable in terms of stand management.

Snags make a substantial contribution to the amount of lichen available to caribou. In some stands, the lichen remaining after a selective cut could be doubled by leaving snags. They should be left whenever possible.

The present practice of adjusting the diameter limit prescription to leave a uniform cover of residual trees may not be beneficial to caribou. The amount of energy required in feeding from uniformly spaced trees is probably greater than that required in feeding from trees that have a clumped distribution. Unless the present practice is advisable for silvicultural reasons, it would be better to replace it with one that produced a clumped distribution of trees.

Apart from its impact on the forage resource, logging affects caribou by creating roads, and thus increasing the risk of harassment and poaching. The recommendations of Freddy (1974a, 1974c) and Johnson et al. (1977) regarding access should be strictly followed; roads into areas used by caribou for travel should be closed after logging.

RESEARCH RECOMMENDATIONS

Identification of critical wintering areas is a high priority research need, because of its immediate importance to management. Tentative delineation of wintering areas may be accomplished using the information prepared by Freddy (1974a, and unpublished data and maps). As caribou use different ranges in different winters, it is important to consider historical as well as recent information on their distribution.

An inventory of lichen abundance and other habitat characteristics in the tentatively identified winter range areas and in selected non-winter range areas is essential. The inventory would permit an evaluation of the relative abundance of lichen in different areas; this would assist in delineating critical winter ranges. It would improve understanding of lichen ecology in subalpine forests, as correlations between lichen abundance and site characteristics could be tested. The data would be helpful in identifying characteristics of areas selected by caribou as winter range.

Such an inventory could be accomplished through the use of visual estimates of lichen abundance. Lichen estimates for trees could be carried out without associated biomass sampling. This method has been used by T. Antifeau, B.C. Fish and Wildlife Branch, Kamloops, in his work on caribou habitat in the North Thompson watershed. Antifeau used circular plots, generally 0.04 ha, and divided each plot into eight radial segments. Smaller plots were used in dense timber types. Tree inventory data were collected for the entire plot, but lichen data were collected for trees within only four of the eight segments. This scheme generally resulted in tree data for 15-30 trees, and lichen estimates for 8-15 trees, in each plot. After a season of use, Antifeau felt that this method was satisfactory for achieving extensive coverage, a moderately intensive lichen inventory, and good information on stand composition (T. Antifeau, pers. comm. 1978 July 20 and Oct. 05).

An inventory that is based on visual estimates of lichen abundance, without biomass sampling, will yield information on relative abundance of lichen at different sites, but not information on absolute abundance. The major problem with the method is the difficulty of achieving consistent estimates. In this study, the ratios of measured lichen biomass to estimated lichen biomass on trees were quite variable. Because of this variability, a large number of replicate plots within each site type will be needed.

The second major research need is for the reassessment of lichen biomass in the plots after logging. Reassessment is necessary to determine the actual effect of selective logging on lichen biomass, and to collect baseline data for monitoring regrowth of lichen in the residual timber. Reassessment should be carried out in Plots 1 and 2 during the first summer after logging. Reassessment in Plot 3, the control plot, is also desirable, and is essential if windstorms during the fall of 1978 significantly affected the area.

Detailed recommendations for methods to be used in reassessing lichen biomass are given in Appendix F. Two complementary projects are recommended. One involves repeating the lichen estimates and biomass sampling, using a smaller number of sample trees than was used the first summer. This will result in a new estimate of total available lichen biomass, with confidence limits, for each plot. The second project involves assessing, tagging, and sampling a set of high-reliability branches in each plot. Because the confidence limits around high-reliability branch ratios are relatively narrow, it should be possible to detect lichen growth on these branches more readily than in the plot as a whole. This project will provide baseline data for monitoring lichen growth rates on each plot, but no information about total amounts of lichen available.

Although both projects are recommended, it would be possible to carry out one without the other. If only one is feasible, I recommend the second. The information that could be gained from the high-reliability branch project is high, compared to the amount of effort involved. If this project alone is chosen, I recommend that it be expanded to include a second control plot.

Third, it is important to determine to what extent, and under what conditions, caribou actually use selectively cut areas. Winter use of selective cuts, clearcuts, and mature timber should be monitored. A study of snow conditions in these areas in relation to caribou use could easily be incorporated into such a project. It would require flying time, for the purpose of locating the animals, and field time spent tracking them.

Research in the three areas outlined above is urgently needed in order to plan and evaluate selective logging. Several other research needs are less immediate, but also important.

Opening the forest canopy by selective logging probably affects lichen growth differently on different types of forest site. The technique of assessing, tagging and sampling high-reliability branches, described in Appendix F, is a new approach to measuring growth rates that could be used in a moderately extensive project. By establishing plots on a variety of sites -- both selectively logged and undisturbed -- growth rates could be related to site characteristics and to logging method.

Changes in the forest microclimate induced by selective logging are likely to affect species composition as well as growth rates of forage lichens. Nutrient values differ between *Bryoria* spp. and *Alectoria sarmentosa* (Schroeder 1974, Stevenson 1978), and probably also among species of *Bryoria*. A study of changes in species composition and nutrient contents of lichens would indicate how selective logging affects quality as well as quantity of caribou forage.

Existing data are inadequate for estimating amounts of lichen available to Selkirk caribou over their entire range. D.R. Johnson and R. M. Feldman, University of Idaho, recently completed a map of potential caribou habitat in Washington and Idaho; comparable data for British Columbia have been available for several years. Quantification of lichen biomass in the major forest types would allow the total amount of available forage lichen to be estimated. Such a project should include non-commercial as well as commercial timber types, as they occupy a large area in the Selkirks (D.R. Johnson, pers. comm. 1978 Feb. 22).

The importance of windthrows to caribou has been discussed. An assessment of windthrow rates in the Selkirk caribou range, and of the amounts of lichen available on windthrown trees, would be valuable in determining the amount of forage available to caribou from this source. Windthrow rates should be examined in selectively logged blocks and in various mature timber types. This information would be valuable from the standpoint of forestry, as well as caribou biology.

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APPENDIX A

Location of the plots.
(Portion of mapsheet 82-F-3-a)

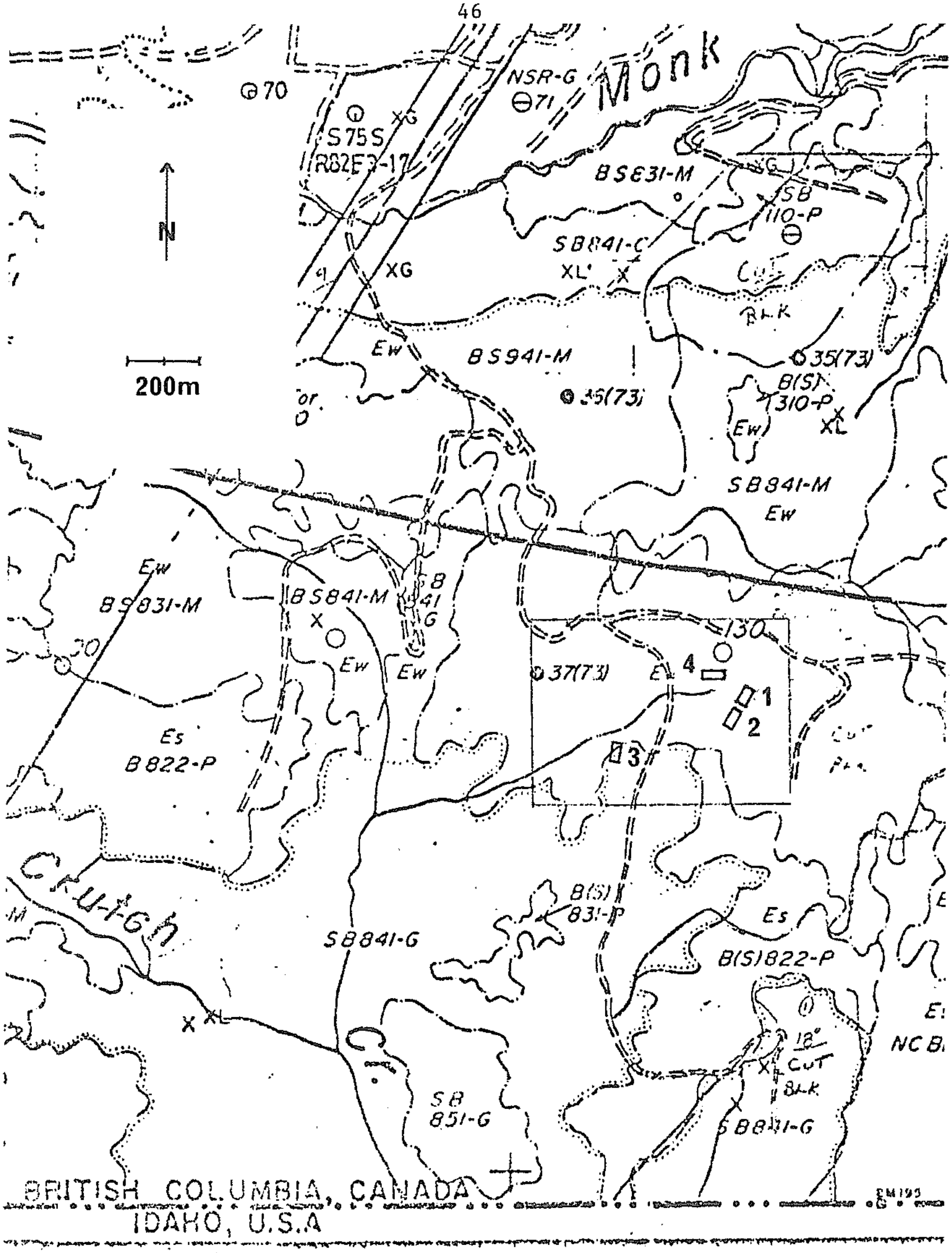

Figure 12. Location of the plots. Portion of map sheet 82-F-3-a.

APPENDIX B

Vegetation and soils data
(See Walmsley (1978) for description of data code.)

VEGETATION DATA FORM

(Second Draft — January, 1976)

NUMBERS 1-17 MUST BE RECORDED FOR EVERY PLOT. FOR DESCRIPTION OF DATA TERMS SEE V.D.F. EXPLANATION SHEET.

1a. Project Identification CARIBOU / LICHEN　　1b. Sampling technique SELECTIVE

2. Name of surveyor(s) and agency SUSAN STEVENSON, BCFS

3. Plot number CRUTCH CREEK 01　　4. Date 09 AUGUST 1978

5. Latitude 49 ° 00 ' 36 "　　6. Longitude 117 ° 02 ' 12 "

7. Topographical map TRAIL 82 F/SW　　8. Plot size 0.1 HA (20 x 50 M)

9. Location description

10. Slope 9° (°/%)　　11. Elevation 1825 M (meters/feet)

12. Aspect 290°　　13. Length upslope 200 M (meters/feet)

14. Moisture regime:
- a. hydric — i. hydric; ii. subhydric
- b. hygric — i. hygric; ii. subhygric
- c. mesic — i. mesic; ii. submesic
- d. xeric — i. subxeric; ii. xeric; iii. very xeric

15. Slope position macro:
- a. apex
- b. face
- c. upper slope
- d. middle slope
- e. lower slope
- f. valley floor
- g. plain

16. Surface shape:
- a. smooth convex
- b. irregular convex
- c. smooth straight
- d. irregular straight
- e. smooth concave
- f. irregular concave
- g. smooth flat
- h. irregular flat

17. Slope position moisture:
- a. shedding
- b. normal
- c. receiving
- d. collecting
- e. seepage

18. Exposure type:
- a. wind
- b. insolation
- c. frost pocket
- d. cold air drainage
- e. (other)
- f. not applicable

19. Site type

20. Climatic climax zone/subzone eSalF/m

21. Successional trend

22. Relative rate of succession

23. Cause of stand establishment

24. Present land use

25. Plot representing

26. Miscellaneous comments: (including sample identification of associated determinations)

27. Floristic List	STRATUM														
	Cover,												Quantity		
	VETERAN	A1	A2	A3	Total trees	B1	B2	Total shrubs	C	D	Seedlings	All strata	Epiphytes	Epiliths	Epixyles
Height of top of strata (m/ft.)		34	30	20											
Number of dead snags					7										
Total vegetation		2	25	5	30	8		35	60	6					
Picea engelmannii Parry ex. Engelm.		2	10	2	13	3	1				1/4				
Abies lasiocarpa (Hook.) Nutt.			15	3	17	5	2				1/4				
Rhododendron albiflorum Hook.							15/6								
Vaccinium membranaceum Dougl.							15/6								
Lonicera utahensis Wats.							1/4								
Ribes lacustre (Pers.) Poir.							1/4								
Menziesia ferruginea Sm.							1/2								
Lonicera involucrata (Rich.) Banks							1/1								
Valeriana sitchensis Bong.									2/4						
Erythronium grandiflorum Pursh									1/4						
Mitella breweri Gray									3/7						
Tiarella unifoliata Hook.									3/7						
Arnica latifolia Bong.									3/6						
Viola glabella Nutt.									1/6						
Viola orbiculata Geyer									1/6						
Luzula hitchcockii Hamet-Ahti									3/5						
Pedicularis bracteosa Benth.									1/4						
Mertensia paniculata (Ait.) G. Don var. *borealis* (Macbr.) Williams									3/5						
Ligusticum canbyi Coult. & Rose *Ligusticum verticillatum* (Geyer) Coult. & Rose									7/6						
Senecio triangularis Hook.									5/6						
Carex sp.									1/2						
Vahlodea atropurpurea (Wahl.) Fries subsp. *paramushirensis* (Kudo) Hulten									1/4						
Claytonia cordifolia Wats.									3/5						

	VETERAN	A1	A2	A3	Total trees	B1	B2	Total shrubs	C	D	Seedlings	All strata	Epiphytes	Epiliths	Epixyles	
Luzula parviflora (Ehrh.) Desv.									1/4							
Fragaria virginiana Duch.									1/5							
Parnassia fimbriata Konig.									1/4							
Aquilegia flavescens Wats.									1/1							
Osmorhiza occidentalis (Nutt.) Torr.									1/4							
Trollius laxus Salisb.									2/6							
Thalictrum occidentale Gray									7/5							
Veratrum viride Ait.									2/4							
Saxifraga mertensiana Bong.									1/2							
Elymus glaucus Buckl.									5/6							
Stenanthium occidentale Gray									1/4							
Agrostis thurberiana Hitchc.									1/3							
Platanthera stricta Lindl.									1/2							
Osmorhiza chilensis H. & A.									2/4							
Epilobium lactiflorum Hausskn.									1/5							
Athyrium filix-femina (L.) Roth.									1/3							
Xerophyllum tenax (Pursh.) Nutt.									1/2							
Stellaria nitens Nutt.									1/3							
Erigeron peregrinus (Pursh) Greene																
subsp. callianthemus (Greene) Cronq.									2/4							
Saussurea americana Eat.									1/2							
Goodyera oblongifolia Raf.									1/1							
Ranunculus eschscholtzii Schlect.									1/5							
Brachythecium leibergii Grout										5/6						
Brachythecium sp.																
Polytrichum commune Hedw.										1/6						
Rhizomnium nudum (Williams) Kop.										1/6						
Bryum sp.										1/6						

28. Substrate	% Grd. Cover	Thickness (cm/in.)	Type
Humus (L-F-H)	88		mor
Decaying Wood	10		
Bedrock	0		
Rocks	< 1		
Mineral Soil	< 1		exposed by pocket gophers

29. Parent material texture:
finer soil fragments (<2 mm)

A. coarse
- a. coarse
  - i. s
  - ii. ls
- b. moderately coarse
  - i. sl

B. medium
- a. medium
  - i. l
  - ii. sil
  - iii. si

C. fine
- a. moderately fine
  - i. scl
  - ii. cl
  - iii. sicl
- b. fine
  - i. sc
  - ii. c
  - iii. sic
- c. very fine
  - i. hc

D. organic
- a. organic
  - i. fibric
  - ii. mesic
  - iii. humic

30. Parent material texture:
coarser soil fragments (>2 mm)

- a. shape
  - i. rounded
  - ii. angular
  - iii. thin, flat
- b. size
  - i. 2-74 mm
  - ii. 75-149 mm
  - iii. 150-250 mm
  - iv. >250 mm
- c. volume
  - i. <20%
  - ii. 20-49%
  - iii. 50-90%
  - iv. >90%
- d. type
  - i. mixed
  - ii. (other)________

31. Parent material salinity:

- a. saline
  - i. weakly
  - ii. moderately
  - iii. strongly
- b. not saline

32. Parent material calcareousness:

- a. calcareous
  - i. weakly
  - ii. moderately
  - iii. strongly
- b. not calcareous

33. Parent material acidity:
pH________

34. Soil drainage:

- a. rapidly drained
- b. well drained
- c. moderately well drained
- d. imperfectly drained
- e. poorly drained
- f. very poorly drained

35. Landform________ 36. Bedrock type phyllite

37. Depth to lithological discontinuity________cm. 38. Depth to root restricting layer________cm.

39. Soil development________ 40. Soil association/member________

41. Soil profile description: W. Wells, 30 August 1978. Condensed from soils data sheet.

Horizon	Depth (cm/in.) Upper	Depth (cm/in.) Lower	Texture	Volume of Coarse Fragments	Colour	Comments (structure, pH, pan, etc.)
L	<0.5	0				
Ah	0	14	L	30	10 YR 2/3	
Bfgj	14	25	CSL	40	5 YR 4/7	common mottles 2.5 YR 4/8
Cg	25	(110)	CL	90	2.5 YR 5/4	many mottles 2.5 YR 4/6
R	5	(110)				

42. Tree mensuration data:

Species				
Horiz. distance (m/ft.)				
Top reading				
Bottom reading				
Height (m/ft.)				
Total height				
Boring height				
Age				
Total age				
DBH				

Prism number				
No. of trees				
BASAL AREA				
S.I. 100				
S.I.				

VEGETATION DATA FORM

(Second Draft — January, 1976)

NUMBERS 1-17 MUST BE RECORDED FOR EVERY PLOT. FOR DESCRIPTION OF DATA TERMS SEE V.D.F. EXPLANATION SHEET.

1a. Project Identification CARIBOU/LICHEN 1b. Sampling technique SELECTIVE

2. Name of surveyor(s) and agency SUSAN STEVENSON, BCFS

3. Plot number CRUTCH CREEK 02 4. Date 09 AUGUST 1978

5. Latitude 49 ° 00 ' 36 " 6. Longitude 117 ° 02 ' 12 "

7. Topographical map TRAIL 82F/SW 8. Plot size 0.1 HA (20 x 50 M)

9. Location description

10. Slope 9° (°/%) 11. Elevation 1825 M (meters/feet)

12. Aspect 290° 13. Length upslope 200 M (meters/feet)

14. Moisture regime:

- a. hydric
  - i. hydric
  - ii. subhydric
- b. hygric
  - i. hygric
  - ii. subhygric
- c. mesic
  - i. mesic
  - ii. submesic
- d. xeric
  - i. subxeric
  - ii. xeric
  - iii. very xeric

15. Slope position macro:

- a. apex
- b. face
- c. upper slope
- d. middle slope
- e. lower slope
- f. valley floor
- g. plain

16. Surface shape:

- a. smooth convex
- b. irregular convex
- c. smooth straight
- d. irregular straight
- e. smooth concave
- f. irregular concave
- g. smooth flat
- h. irregular flat

17. Slope position moisture:

- a. shedding
- b. normal
- c. receiving
- d. collecting
- e. seepage

18. Exposure type:

- a. wind
- b. insolation
- c. frost pocket
- d. cold air drainage
- e. (other)
- f. not applicable

19. Site type

20. Climatic climax zone/subzone eSalF/m

21. Successional trend

22. Relative rate of succession

23. Cause of stand establishment

24. Present land use

25. Plot representing

26. Miscellaneous comments: (including sample identification of associated determinations)

Veg. 1/76

27. Floristic List	STRATUM															
	Cover,												Quantity			
	VETERAN	A1	A2	A3	Total trees	B1	B2	Total shrubs	C	D	Seedlings	All strata	Epiphytes	Epiliths	Epixyles	
Height of top of strata (m/ft.)		33	30	20												
Number of dead snags					13											
Total vegetation					30		30		70	5						
Picea engelmannii Parry ex. Engelm.		2	15	5		2	1				1/4					
Abies lasiocarpa (Hook.) Nutt.			10	5		2	5				1/4					
Rhododendron albiflorum Hook.							12/6									
Vaccinium membranaceum Dougl.							7/6									
Lonicera utahensis Wats.							2/6									
Lonicera involucrata (Rich.) Banks							1/5									
Ribes lacustre (Pers.) Poir.							1/5									
Senecio triangularis Hook.									7/7							
Ligusticum canbyi Coult. & Rose } L. verticillatum (Geyer) Coult. & Rose									10/7							
Veratrum viride Ait.									2/4							
Erigeron peregrinus (Pursh) Greene subsp. callianthemus (Greene) Cronq.									5/4							
Mertensia paniculata (Ait.) G. Don var. borealis (Macbr.) Williams									5/5							
Tiarella unifoliata Hook.									2/6							
Galium triflorum Michx.									1/3							
Delphinium nuttallianum Pritz.									1/5							
Mitella breweri Gray									2/7							
Viola glabella Nutt.									1/4							
Osmorhiza chilensis									1/4							
Arnica latifolia Bong.									2/4							
Parnassia fimbriata Konig.									1/4							
Thalictrum occidentale Gray									3/6							
Ranunculus eschscholtzii Schlect.									1/5							

	VETERAN	A1	A2	A3	Total trees	B1	B2	Total shrubs	C	D	Seedlings	All strata	Epiphytes	Epiliths	Epixyles	
Luzula parviflora (Ehrh.) Desv.									3/5							
Claytonia cordifolia Wats.									3/5							
Elymus glaucus Buckl.									3/5							
Platanthera stricta Lindl.									1/4							
Agrostis thurberiana Hitchc.									2/5							
Stenanthium occidentale Gray									1/4							
Valeriana sitchensis Bong.									2/6							
Saxifraga mertensiana Bong.									1/4							
Osmorhiza occidentale (Nutt.) Torr.									2/5							
Trollius laxus Salisb.									2/6							
Pedicularis bracteosa Benth.									1/4							
Aconitum columbianum Nutt.									1/2							
Fragaria virginiana Duch.									1/3							
Saussuria americana Eat.									1/3							
Erythronium grandiflorum Pursh									2/4							
Viola orbiculata Geyer									1/4							
Luzula hitchcockii Hamet-Ahti									5/6							
Epilobium lactiflorum Hausskn.									1/4							
Xerophyllum tenax (Pursh) Nutt.									1/2							
Ranunculus uncinatus D.Don									1/4							
Polystichum lonchitis (L.) Roth									1/1							
Rhizomnium nudum (Williams) Koponen										3/6						
Brachythecium spp.										3/6						
Polytrichum commune Hedw.										1/5						

28. Substrate	% Grd. Cover	Thickness (cm/in.)	Type
Humus (L–F–H)	88		mor
Decaying Wood	10		
Bedrock	0		
Rocks	< 1		
Mineral Soil	< 1		exposed by pocket gophers

29. Parent material texture:
finer soil fragments (<2 mm)
- A. coarse
  - a. coarse: i. s; ii. ls
  - b. moderately coarse: i. sl
- B. medium
  - a. medium: i. l; ii. sil; iii. si
- C. fine
  - a. moderately fine: i. scl; ii. cl; iii. sicl
  - b. fine: i. sc; ii. c; iii. sic
  - c. very fine: i. hc
- D. organic
  - a. organic: i. fibric; ii. mesic; iii. humic

30. Parent material texture:
coarser soil fragments (>2 mm)
- a. shape: i. rounded; ii. angular; iii. thin, flat
- b. size: i. 2–74 mm; ii. 75–149 mm; iii. 150–250 mm; iv. >250 mm
- c. volume: i. <20%; ii. 20–49%; iii. 50–90%; iv. >90%
- d. type: i. mixed; ii. (other)________

31. Parent material salinity:
- a. saline: i. weakly; ii. moderately; iii. strongly
- b. not saline

32. Parent material calcareousness:
- a. calcareous: i. weakly; ii. moderately; iii. strongly
- b. not calcareous

33. Parent material acidity:
pH________

34. Soil drainage:
- a. rapidly drained
- b. well drained
- c. moderately well drained
- d. imperfectly drained
- e. poorly drained
- f. very poorly drained

35. Landform________ 36. Bedrock type phyllite
37. Depth to lithological discontinuity_____cm. 38. Depth to root restricting layer_____cm.
39. Soil development________ 40. Soil association / member________

41. Soil profile description: D. Macdonald, 30 August 1978. Condensed from soils data sheet.

Horizon	Depth (cm/in.) Upper	Depth (cm/in.) Lower	Texture	Volume of Coarse Fragments	Colour	Comments (structure, pH, pan, etc.)
L	3	2				
F	2	0				
Bhf	0	23	SiL		7.5 YR 3/2	
Bf	23	40	SiL		7.5 YR 4/4	fine, sandy lenses 7.5 YR 5/6
Bmg	40	(60)	SiCL		10 YR 4/1	many mottles 10 YR 3/4

42. Tree mensuration data:

Species				
Horiz. distance (m/ft.)				
Top reading				
Bottom reading				
Height (m/ft.)				
Total height				
Boring height				
Age				
Total age				
DBH				

Prism number				
No. of trees				
BASAL AREA				
S.I. 100				
S.I.				

VEGETATION DATA FORM

(Second Draft – January, 1976)

NUMBERS 1-17 MUST BE RECORDED FOR EVERY PLOT. FOR DESCRIPTION OF DATA TERMS SEE V.D.F. EXPLANATION SHEET.

1a. Project Identification CARIBOU / LICHEN   1b. Sampling technique SELECTIVE

2. Name of surveyor(s) and agency SUSAN STEVENSON, BCFS

3. Plot number CRUTCH CREEK 03   4. Date 20 AUGUST 1978

5. Latitude 49 ° ___ ' 32 "   6. Longitude 117 ° 02 ' 30 "

7. Topographical map TRAIL 82 F/SW   8. Plot size 0.1 HA (20 x 50 M)

9. Location description ______

10. Slope 7° (°/%)   11. Elevation 1740 M (meters/feet)

12. Aspect 272°   13. Length upslope 600 M (meters/feet)

14. Moisture regime:
- a. hydric
  - i. hydric
  - ii. subhydric
- b. hygric
  - i. hygric
  - ii. subhygric
- c. mesic
  - i. mesic
  - ii. submesic
- d. xeric
  - i. subxeric
  - ii. xeric
  - iii. very xeric

15. Slope position macro:
- a. apex
- b. face
- c. upper slope
- d. middle slope
- e. lower slope
- f. valley floor
- g. plain

16. Surface shape:
- a. smooth convex
- b. irregular convex
- c. smooth straight
- d. irregular straight
- e. smooth concave
- f. irregular concave
- g. smooth flat
- h. irregular flat

17. Slope position moisture:
- a. shedding
- b. normal
- c. receiving
- d. collecting
- e. seepage

18. Exposure type:
- a. wind
- b. insolation
- c. frost pocket
- d. cold air drainage
- e. (other) ______
- f. not applicable

19. Site type ______

20. Climatic climax zone/subzone eSalF/m

21. Successional trend ______

22. Relative rate of succession ______

23. Cause of stand establishment ______

24. Present land use ______

25. Plot representing ______

26. Miscellaneous comments: (including sample identification of associated determinations)

Veg 1/76

Browsing noted on Ligusticum spp., Xerophyllum tenax, Arnica latifolia

27. Floristic List	STRATUM															
	Cover,												Quantity			
	VETERAN	A1	A2	A3	Total trees	B1	B2	Total shrubs	C	D	Seedlings	All strata	Epiphytes	Epiliths	Epixyles	
Height of top of strata (m/~~ft~~)		36	30	22												
Number of dead snags					8											
Total vegetation					25			75	25	20						
Abies lasiocarpa (Hook.) Nutt.		2	20	3		2/4	2/4				1/4					
Picea engelmannii Parry ex Engelm.		1	5	1		1/4	2/4				1/4					
Vaccinium membranaceum Dougl.							25/6									
Lonicera utahensis Wats.							5/5									
Lonicera involucrata (Rich.) Banks							2/4									
Ribes lacustre (Pers.) Poir.							5/5									
Rhododendron albiflorum Hook.							50/8									
Menziesia ferruginea Sm.							2/5									
Sorbus scopulina Greene							1/1									
Aconitum columbianum Nutt.									1/2							
Ligusticum canbyi Coult. & Rose }									10/6							
L. verticillatum (Geyer) Coult. & Rose }																
Senecio triangularis Hook.									10/6							
Mertensia paniculata (Ait.) G. Don																
var. *borealis* (Macbr.) Williams									3/5							
Tiarella unifoliata Hook.									3/7							
Mitella breweri Gray									3/7							
Claytonia cordifolia Wats.									2/6							
Osmorhiza chilensis H. & A.									2/4							
Epilobium lactiflorum Hausskn.									2/6							
Vahlodea atropurpurea (Wahl.) Fries subsp. *paramushirensis* (Kudo) Hulten									1/5							
Erigeron peregrinus (Pursh) Greene																
subsp. *callianthemus* (Greene) Cronq.									2/6							
Galium triflorum Michx.									2/5							
Xerophyllum tenax (Pursh) Nutt.									1/4							

	VETERAN	A1	A2	A3	Total trees	B1	B2	Total shrubs	C	D	Seedlings	All strata	Epiphytes	Epiliths	Epixyles	
Valeriana sitchensis Bong.									3/4							
Ranunculus uncinatus D. Don									1/4							
Elymus glaucus Buckl.									2/6							
Luzula hitchcockii Hamet-Ahti									5/6							
L. parviflora (Ehrh.) Desv.									1/4							
Thalictrum occidentale Gray									5/6							
Stenanthium occidentale Gray									1/4							
Viola orbiculata Geyer									1/7							
Erythronium grandiflorum Pursh									1/4							
Viola glabella Nutt.									1/5							
Stellaria crispa Cham. & Schlect.									2/5							
Pedicularis bracteosa Benth.									1/4							
Veratrum viride Ait.									1/4							
Listera caurina Piper									1/2							
Ranunculus eschscholtzii Schlect.									1/4							
Arnica latifolia Bong.									5/7							
Orthilia secunda (L.) House									1/5							
Orobanche uniflora (L.)																
var. occidentalis (Greene) Tayl. & Macbr									1/3							
Trillium ovatum Pursh									1/2							
Fragaria virginiana Duch.									1/5							
Parnassia fimbriata Konig.									1/5							
Brachythecium spp.										20/9						
Polytrichum commune Hedw.										1/6						
Rhizomnium nudum (Williams) Kop.										1/3						

28. Substrate	% Grd. Cover	Thickness (cm/in.)	Type
Humus (L-F-H)	88		mor
Decaying Wood	10		
Bedrock	0		
Rocks	< 1		
Mineral Soil	< 1		exposed by pocket gophers

29. Parent material texture:
finer soil fragments (<2 mm)

A. coarse — a. coarse — i. s; ii. ls
— b. moderately coarse — i. sl
B. medium — a. medium — i. l; ii. sil; iii. si
C. fine — a. moderately fine — i. scl; ii. cl; iii. sicl
— b. fine — i. sc; ii. c; iii. sic
— c. very fine — i. hc
D. organic — a. organic — i. fibric; ii. mesic; iii. humic

30. Parent material texture:
coarser soil fragments (>2 mm)

a. shape — i. rounded; ii. angular; iii. thin, flat
b. size — i. 2-74 mm; ii. 75-149 mm; iii. 150-250 mm; iv. >250 mm
c. volume — i. <20%; ii. 20-49%; iii. 50-90%; iv. >90%
d. type — i. mixed; ii. (other)________

31. Parent material salinity:

a. saline — i. weakly; ii. moderately; iii. strongly
b. not saline

32. Parent material calcareousness:

a. calcareous — i. weakly; ii. moderately; iii. strongly
b. not calcareous

33. Parent material acidity:
pH________

34. Soil drainage:

a. rapidly drained
b. well drained
c. moderately well drained
d. imperfectly drained
e. poorly drained
f. very poorly drained

35. Landform________ 36. Bedrock type________

37. Depth to lithological discontinuity_____cm. 38. Depth to root restricting layer_____cm.

39. Soil development________ 40. Soil association/member________

41. Soil profile description: D. Macdonald, 30 August 1978. Condensed from soils data sheet.

Horizon	Depth (cm/in.) Upper	Depth (cm/in.) Lower	Texture	Volume of Coarse Fragments	Colour	Comments (structure, pH, pan, etc.)
L	3	2				
F	2	0				
Bhf1	0	18	SiL	10	10YR 3/6	
Bhf2	18	43	SiL	25	10YR 3/3	
BC	43	63	SiL	40	2.5Y 4/4	
C	63	(90)	SiL	45	10YR 5/4	

42. Tree mensuration data:

Species				
Horiz. distance (m/ft.)				
Top reading				
Bottom reading				
Height (m/ft.)				
Total height				
Boring height				
Age				
Total age				
DBH				

Prism number				
No. of trees				
BASAL AREA				
S.I. 100				
S.I.				

VEGETATION DATA FORM

(Second Draft — January, 1976)

NUMBERS 1-17 MUST BE RECORDED FOR EVERY PLOT. FOR DESCRIPTION OF DATA TERMS SEE V.D.F. EXPLANATION SHEET.

1a. Project Identification CARIBOU / LICHEN
1b. Sampling technique SELECTIVE

2. Name of surveyor(s) and agency SUSAN STEVENSON, BCFS

3. Plot number CRUTCH CREEK 04
4. Date 10 SEPTEMBER 1978

5. Latitude 49 ° 00 ' 44 "
6. Longitude 117 ° 02 ' 18 "

7. Topographical map TRAIL 82 F/SW
8. Plot size 0.1 HA (20 x 50 M)

9. Location description

10. Slope 8° (°/%)
11. Elevation 1790 M (meters/feet)

12. Aspect 224°
13. Length upslope 400 M (meters/feet)

14. Moisture regime:

- a. hydric — i. hydric; ii. subhydric
- b. hygric — i. hygric; ii. subhygric
- c. mesic — i. mesic; ii. submesic
- d. xeric — i. subxeric; ii. xeric; iii. very xeric

15. Slope position macro:

- a. apex
- b. face
- c. upper slope
- d. middle slope
- e. lower slope
- f. valley floor
- g. plain

16. Surface shape:

- a. smooth convex
- b. irregular convex
- c. smooth straight
- d. irregular straight
- e. smooth concave
- f. irregular concave
- g. smooth flat
- h. irregular flat

17. Slope position moisture:

- a. shedding
- b. normal
- c. receiving
- d. collecting
- e. seepage

18. Exposure type:

- a. wind
- b. insolation
- c. frost pocket
- d. cold air drainage
- e. (other)
- f. not applicable

19. Site type

20. Climatic climax zone/subzone eSalF/m

21. Successional trend

22. Relative rate of succession

23. Cause of stand establishment Logged to 20" DSH limit 1977

24. Present land use

25. Plot representing

26. Miscellaneous comments: (including sample identification of associated determinations)

Veg. 1/76

27. Floristic List	VETERAN	A1	A2	A3	Total trees	B1	B2	Total shrubs	C	D	Seedlings	All strata	Epiphytes	Epiliths	Epixyles	
	STRATUM															
	Cover,												Quantity			
Height of top of strata (m/ft.)																
Number of dead snags					1											
Total vegetation					12		50		50	20						
Abies lasiocarpa (Hook.) Nutt.			8	3	10	2/4	2/4				1/4					
Picea engelmannii Parry ex Engelm.			2	2	3	2/4	2/4				1/4					
Rhododendron albiflorum Hook.							30/9									
Vaccinium membranaceum Dougl.							20/9									
Lonicera utahensis (Rich.) Banks							7/6									
Ribes lacustre (Pers.) Poir.							1/5									
Ligusticum canbyi Coult. & Rose									7/6							
L. verticillatum (Geyer) Coult. & Rose																
Arnica latifolia Bong.									5/6							
Tiarella unifoliata Hook.									3/7							
Mitella breweri Gray									3/7							
Luzula hitchcockii Hamet-Ahti									2/5							
Erythronium grandiflorum Pursh									2/4							
Clintonia uniflora (Schultes) Kunth									2/6							
Viola orbiculata Geyer									1/6							
Senecio triangularis Hook.									3/6							
Orthilia secunda (L.) House									1/5							
Veratrum viride Ait.									1/2							
Osmorhiza occidentalis (Nutt.) Torr.									1/3							
Pedicularis bracteosa Benth.									1/1							
Mertensia paniculata (Ait.) G. Don																
var. borealis (Macbr.) Williams									5/5							
Erigeron peregrinus (Pursh) Greene																
subsp. callianthemus (Greene) Cronq.									3/4							
Osmorhiza chilensis H. & A.									1/4							

	VETERAN	A1	A2	A3	Total trees	B1	B2	Total shrubs	C	D	Seedlings	All strata	Epiphytes	Epiliths	Epixyles	
Viola glabella Nutt.									2/4							
Xerophyllum tenax (Pursh) Nutt.									1/5							
Bromus vulgaris (Hook.) Shear									3/5							
Luzula parviflora (Ehrh.) Desv.									5/5							
Galium triflorum Michx.									1/3							
Brachythecium spp.										20/6						
Bryum sp.										1/5						
Polytrichum commune Hedw.										1/5						

no soils data

28. Substrate	% Grd. Cover	Thickness (cm/in.)	Type
Humus (L–F–H)			
Decaying Wood			
Bedrock			
Rocks			
Mineral Soil			

29. Parent material texture:
finer soil fragments (<2 mm)
- A. coarse
  - a. coarse: i. s; ii. ls
  - b. moderately coarse: i. sl
- B. medium
  - a. medium: i. l; ii. sil; iii. si
- C. fine
  - a. moderately fine: i. scl; ii. cl; iii. sicl
  - b. fine: i. sc; ii. c; iii. sic
  - c. very fine: i. hc
- D. organic
  - a. organic: i. fibric; ii. mesic; iii. humic

30. Parent material texture:
coarser soil fragments (>2 mm)
- a. shape: i. rounded; ii. angular; iii. thin, flat
- b. size: i. 2–74 mm; ii. 75–149 mm; iii. 150–250 mm; iv. >250 mm
- c. volume: i. <20%; ii. 20–49%; iii. 50–90%; iv. >90%
- d. type: i. mixed; ii. (other)__________

31. Parent material salinity:
- a. saline: i. weakly; ii. moderately; iii. strongly
- b. not saline

32. Parent material calcareousness:
- a. calcareous: i. weakly; ii. moderately; iii. strongly
- b. not calcareous

33. Parent material acidity:
pH__________

34. Soil drainage:
- a. rapidly drained
- b. well drained
- c. moderately well drained
- d. imperfectly drained
- e. poorly drained
- f. very poorly drained

35. Landform__________ 36. Bedrock type__________

37. Depth to lithological discontinuity______cm. 38. Depth to root restricting layer______cm.

39. Soil development__________ 40. Soil association/member__________

41. Soil profile description:

Horizon	Depth (cm/in.)		Texture	Volume of Coarse Fragments	Colour	Comments (structure, pH, pan, etc.)
	Upper	Lower				

42. Tree mensuration data:

Species				
Horiz. distance (m/ft.)				
Top reading				
Bottom reading				
Height (m/ft.)				
Total height				
Boring height				
Age				
Total age				
DBH				

Prism number				
No. of trees				
BASAL AREA				
S.I. 100				
S.I.				

APPENDIX C

Epiphytic macrolichens encountered during sampling

EPIPHYTIC MACROLICHENS ENCOUNTERED DURING SAMPLING

<u>Alectoria imshaugii</u> Brodo & D. Hawksa. (one specimen)
<u>A. sarmentosa</u> (Ach.) Ach.
<u>Bryoria capillaris</u> (Ach.) Brodo & D. Hawksw.
<u>B. fremontii</u> (Tuck.) Brodo & D. Hawksw.
<u>B. fuscescens</u> (Gyeln.) Brodo & D. Hawksw.
<u>B. glabra</u> (Mot.) Brodo & D. Hawksw.
<u>B. oregana</u> (Tuck.) Brodo & D. Hawksw.
<u>B. pseudofuscescens</u> (Gyeln.) Brodo & D. Hawksw.
<u>Cetraria chlorophylla</u> (Willd.) Vain.
<u>C. ciliaris</u> Ach.
<u>C. platyphylla</u> Tuck.
<u>Hypogymnia austerodes</u> (Nyl.) Ras.
<u>H. bitteri</u> (Lynge) Ahti
<u>H. enteromorpha</u> (Ach.) Nyl.
<u>H. imshaugii</u> Krog
<u>H. metaphysodes</u> (Asah.) Rass.
<u>H. physodes</u> (L.) Nyl.
<u>H. tubulosa</u> (Schaer.) Hav.
<u>Letharia vulpina</u> (L.) Hue
<u>Parmelia sulcata</u> Tayl.
<u>Parmeliopsis ambigua</u> (Wulf.) Nyl.
<u>P. hyperopta</u> (Ach.) Arn.
<u>Platismatia glauca</u> (L.) Culb. & Culb.

APPENDIX D

Caribou sighting reports

CARIBOU SIGHTING REPORT

Susan Stevenson

1978 July 15, approximately 9:30 to 10:30 AM.

Location: Mile 32-33, Monk Road. The caribou were first observed at the edge of the B.C. Hydro right-of-way where the road enters the mature timber (Mile 32.7). Elevation 1800 m, aspect ENE, slope 10°. They were last seen browsing in the clearcut south of the road at approximately Mile 32.2.

Group composition:

an adult male with well developed antlers in velvet.

an adult female with antlers in velvet, approximately 2½ times ear length. Udder not distended.

a juvenile male with forked antlers in velvet, approximately 2 times ear length, shorter and thinner than those of the cow.

Activities observed:

bedding
browsing
travelling on road
drinking from puddle by road

Plants browsed (based on observation of feeding, followed by inspection of the area):

Huckleberry (*Vaccinium membranaceum*) - many instances of browsing
Rhododendron (*Rhododendron albiflorum*) - only one instance of browsing noted, although *Rhododendron* was as abundant as *Vaccinium*
Utah honeysuckle (*Lonicera utahensis*) - one instance
Foamflower (*Tiarella trifoliata* var *unifoliata*) - several plants browsed
Broadleaved montia (*Montia cordifolia*) - several plants browsed, although species was much less abundant than *Tiarella*

No browsing was noted on the following species, which were available in the area:

Mountain arnica (*Arnica latifolia*)
Woodrush (*Luzula hitchcockii*)
Trailing rubus (*Rubus pedatus*)
Mitrewort (*Mitella breweri*)
False hellebore (*Veratrum viride*)
Arrowleaf grounsel (*Senecio triangularis*)
Swamp gooseberry (*Ribes lacustre*)

Figure 13. Bull, cow and juvenile caribou at Mile 32.5, Monk Road, 1978 July 15.

CARIBOU SIGHTING REPORT

Susan Stevenson

1978 August 03, 7:00 to 7:40 PM.

Location: 4.3 km east of Salmo-Creston summit on Highway 3.

Group composition:

an adult female with forked antlers in velvet, slightly shorter than ear length

a calf

Behavior observed:

The caribou were on the highway when I first saw them. As I pulled over, they moved to the south side of the highway. They remained in that area for about 15 minutes, moving about restlessly. On three occasions the animals approached the highway as if to cross it, then ran back down the slope when a vehicle approached. During a break in traffic, the caribou moved onto the highway and slowly travelled west about 200 metres. The cow frequently stopped to lick the road. When a car approached, the caribou moved off the road to the north. About 15 minutes later, they returned to the highway where I had first seen them. When a car approached, the animals did not move off the highway; they were in the left lane when the car passed them.

Note: These caribou were also observed by Ron Kerr of the B.C. Parks Branch.

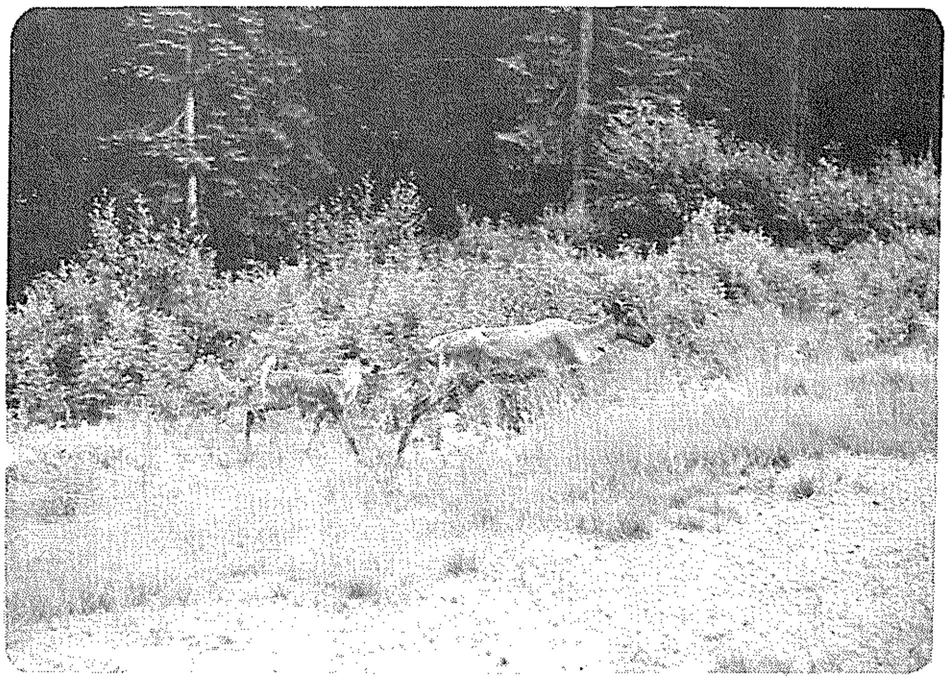

Figure 14. Cow and calf caribou by Highway 3, August 3, 1978.

APPENDIX E

Lichen biomass and timber volume data

Lichen biomass on merchantable trees and timber volume, by tree species and DBH class

DBH class (in.)	Lichen biomass (g)								Timber volume cu/acre	
	plot 1		plot 2		plot 3		plots 1-3		plots 1-3	
	sub. fir	spruce	sub. fir	spruce	sub. fir	spruce	sub. fir	spruce	sub. fir	spruce
7-9	7	39	0	207	0	116	7	362	17	68
9-11	959	50	0	244	95	0	1054	293	64	57
11-13	0	25	0	512	952	331	952	868	94	196
13-15	286	0	1590	265	1968	982	3844	1247	396	196
15-17	429	458	1955	396	513	0	2896	854	407	196
17-19	111	734	831	0	713	95	1655	830	194	519
19-21	269	0	389	0	1055	0	1713	0	612	0
21-23	0	270	480	1643	736	698	1215	2611	293	868
> 23	0	796	0	0	0	0	0	796	0	158
Σ	2061	2372	5245	3267	6032	2222	13336	7861	2077	2258

APPENDIX F

Recommended methods
for reassessing lichen biomass

Project A -- determining available lichen biomass after logging

1. This work should be carried out in Plots 1 and 2, and in Plot 3 if it was affected by windstorms.

2. Practice doing lichen estimates before beginning work in sample plots.

3. Redo lichen estimates for trees, as described under Methods. Standard units may be any convenient size; I used 5.0 g.

4. Select trees for sampling with probability proportionate to predicted lichen biomass. Use Equation 2 rather than Equation 1, and give each tree two chances to be sampled. If a tree is selected twice, then use the data twice.

   To save time and to prevent too much lichen biomass from being removed by sampling, reduce the number of sample trees to 5 or 6 in each plot. Do not reduce the number to less than 5, as the t-value increases rapidly with n less than 5.

   Because distribution of lichen biomass in the plots has been altered by sampling and by logging, most of the sample trees will probably be new.

   Use Iles (1978) for reference.

5. Sample lichen biomass on each sample tree, as described under Methods. Always sample at least 5 branches on each tree.

6. Remove the lichens from the sample branches and place them in labelled bags.

   Dry the samples. If they were collected in rainy weather, they may need to be spread out on labelled newspapers in a heated room, to prevent molding.

7. Clean, oven-dry and weigh the samples, as described under Methods. Time required for cleaning the 1978 samples was approximately 160 hours, or 1.2 h per branch.

8. Analyze the data, as described under Methods. When comparing 1978 lichen biomass with 1979 lichen biomass, amounts removed in 1978 sampling must be accounted for. These amounts are:

Plot 1	614 g
2	1073 g
3	1111 g

   Also, the contractor was asked to leave two sample trees that would otherwise have been logged. These were Tree 27 in Plot 1, and Tree 101 in Plot 2. An adjustment must be made for the lichen on these trees, which are above prescription DBH.

Project B -- determining lichen biomass on high-reliability branches

Rationale High-reliability branches are ones for which it is easy to make good lichen estimates. Because the ratios of measured to estimated lichen on high-reliability branches are very consistent, these branches are useful indicators of lichen growth. A large number of high-reliability branches should be permanently marked in each plot, and sampled with probability proportionate to their lichen estimates. This will result in a total lichen estimate for this artificial population, which should have relatively narrow confidence limits. The same population may be reassessed and resampled later, and the difference in the total lichen estimate -- if statistically significant -- will indicate a change in lichen biomass.

1. High-reliability branches should be assessed in Plots 1, 2, and 3. If possible, a second control plot should be established.

2. A large number of branches should be tagged, as this will ensure that resampling may be carried out several times in the future. I suggest that 100 (minimum 60) high-reliability branches be assessed in each plot, and 20 (minimum 15) be sampled.

3. The manner in which the high-reliability branches are selected is not really critical, as long as the sample is representative of the population of branches below 6 m. (High-reliability branches are usually smaller than average -- it is necessary to assume that growth rates on small branches and large branches are similar.) Only living branches should be selected, as changes in lichen biomass over time on dead branches may not be typical.

   High-reliability branches may be selected in any of several ways. It is best to use one consistent method, but practical considerations may make a combination of methods necessary in this case. If Project A is carried out, it would be efficient to tag all living high-reliability branches encountered during sampling, except those affected by the sampling itself. Another possibility is to reassess all living high-reliability branches tagged during the first summer. In general, the approach recommended is to visit each tree (or a random sample of trees) in the plot and to select, from each height interval (0-3 m; 3-6 m), the two or three living branches that can be most reliably assessed.

4. Record the lichen estimates for the high-reliability branches, mark them with permanent aluminum tags, and spray-paint them at the base so they can be easily located. Use a different colour from that used in 1978.

5. Select sample branches from the list of high-reliability branches, with probability proportionate to the lichen estimate. Note that in this case, the sample branches are selected after the estimates

have been completed, just as sample trees were selected after all the tree estimates were completed. The actual sum of the lichen estimates is used in the formula for calculating K+Z, rather than an expected KPI. The reason for this is obvious -- it would be impractical to estimate KPI in advance.

6. Remove the branches selected for sampling, and bag and label the samples. These bags should be labelled differently from Project A bags.

7. Clean, dry and weigh the samples.

   As high-reliability branches are generally small, less time per branch will be required for cleaning than in Project A.

8. Calculate the lichen biomass total, with associated statistics, for the high-reliability branches in each plot.

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