ECOLOGICAL INVESTIGATIONS ON LICHENS IN WELLS GRAY PROVINCIAL PARK, WITH SPECIAL REFERENCE TO THEIR IMPORTANCE TO MOUNTAN CARIBOU

by

Teuvo Ahti

Department of Botany,

University of Helsinki,

Finland

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I. INTRODUCTION

Wells Gray Provincial Park, situated in the southern Cariboo Mountains, is well-known for its mountain caribou population (cf. Edwards 1954, 1956, 1958; Edwards and Ritcey, 1959, 1960), although the present number of these animals is probably less than 200 (Edwards and Ritcey, 1959). These authors have also outlined the characteristics of the migrations, feeding habits, and range conditions of the Wells Gray caribou.

This caribou's high dependence upon arboreal lichens in wintertime is a remarkable and almost unique fact. It is true that most caribou and reindeer in the world browse tree lichens to some extent, but hardly in any other region do these lichens regularly constitute the principal winter food. Therefore it is understandable that data on ecology and production of epidendric lichens with regard to caribou are scarce in the literature. However, Edwards, Soos and Ritcey (1960) made a quantitative study of these lichens in Wells Gray Park and, following them, Scotter (1962) in northern Saskatchewan.

The aim of the present study is to treat the major ecological factors affecting the abundance and distribution of arboreal lichens in general and in Wells Gray Park in particular. This kind of knowledge is necessary for a proper caribou range management in the area.

In connection with this work a considerable collection was made of lichens, mosses and vascular plants, and the ground vegetation in forests and subalpine meadows was sampled.

I wish to express my sincere thanks to Mr. H.G. McWilliams, Director of the Parks Branch, B.C. Department of Recreation and

Conservation, and particularly to Mr. R.Y. Edwards who made arrangements for the study to be undertaken.

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II. METHODS

In order to evaluate the amounts of lichen available to caribou on trees Edwards et al. (1960) weighed lichens of representative sample trees. This method is undoubtedly the most accurate, but a major disadvantage is the great amount of tedious work required for significant results in large areas.

The determination of abundance of epiphytic lichens by any other fairly accurate method presents more difficulties than that of ground vegetation. This is because the underlying substrate (dead and living twigs, stems) and the microclimate in the forest stand are often very variable, changing within small distances. This variation frequently results in ill-defined open groups of plants rather than in true vegetation composed of distinguishable plant communities.

Early authors who studied epiphytic vegetation usually only gave species lists, though some of them indicated which species were dominant, abundant, common, rare, etc.

Many European authors (cf. Barkman, 1958 p. 304) have used definite sample plots of various size and shape. However, their plots were mainly established on single trunks or branches of southern hardwood trees (oaks, beeches, etc.), and were small (e.g. one sq. foot) in size. The pendulous lichens of coniferous trees are mainly concentrated on very thin twigs close to the tree trunks, which is quite a different thing to study.

In North America few studies on epiphytic lichen vegetation have been conducted. In general, most (though not all) European authors 'believe' in recognizing plant communities on trees, rather than in studying abundance of individual species. The North American authors (e.g. Hale, 1955) have recently paid more attention to statistically calculated constancy values of species in various forests. However, Szczawinski (1953) has made a study on epiphytic vegetation on Vancouver Island in a more 'European' style.

In the present study the quality and quantity of lichens available to caribou are the determining factors. Therefore the degree of abundance of each species in different kinds of forests is one of the most interesting facts to be known. Several authors have estimated abundance of epidendric cryptogams, but mainly within tiny sample quadrats or on single trees. Usually special scales (e.g. 1 to 5) for visual estimation of density and cover have been developed. However, the writer considers it unnecessary to apply any special scale, if this is essentially based on cover percentage. The percentage scale (1 to 100) alone is much more descriptive because of its universal use, particularly to a person who is not well-acquainted with other scales. A simpler scale does not actually simplify the figures. In this paper percentages are used as much as possible.

The method developed by the author for this work is as follows:

(1) A circular plot, 1000 sq. m. in area (radius 17.9 m.)

was selected as representative of larger districts rather than at random. It was also presumed that each plot was homogeneous as to its tree stand and site type. However, since very wide areas could not be covered during the short time available, the plots taken do not necessarily represent the average situation in the park. In addition, the number of plots is small (41) and thus not statistically significant. It seems, however, that thanks to the occurrence of large, fairly uniform strips of forests in the park, a random method is not practical in this kind of extensive study. Scattered well-selected sample areas give results useful enough.

(2) In each plot the number of trees was counted. The trees were put in two classes according to their DBH: more and less than 6 inches. The species of trees were recorded, as well as the crown canopy, age, height, and abundance of twigs (below 10 ft.). No convenient and exact method to measure the abundance of lower twigs (Symbol B) was detected. Therefore the following subjective scale was used:

I sparse
II fairly sparse
III moderately present
IV fairly abundant
V very abundant

This scale was used in an absolute sense rather than, for instance, as related to the number of trees. The height of 10 ft., used as the upper limit of observations, is probably too high in most cases being frequently above the caribou's reach. Edwards *et al*. (1960) suggested that ordinarily the caribou may reach about 8 ft. in Wells Gray Park in wintertime. The present author measured the fall browsing limit to be 6 – 7 ft. at Azure Lake in the park, where it was clearly seen.

(3) The coverages of both fruticose and foliose lichen groups were estimated on the branches as well as separately on the trunks between the heights of about 2 ft. (the base is without any significant lichens) and 10 ft. from the ground on all trees within the whole sample plot. The totals of each of these two lichen groups were thought to be 100 per cent, since they form two vertical vegetational layers. (The here omitted crustose layer is the third one.) The four figures obtained (see Appendix III) indicate the relative abundance of lichenous parts of trunks and twigs and the distribution of fruticose and foliose layers in these parts.

(4) After the total coverages of the lichen layers, the proportion (cover) was estimated for each lichen species, both twigs and trunks now being included. These figures indicate the relations of the species, being independent of the total amount of lichen.

(5) Then a 'range index' (RI) was calculated according to the formula

$$RI = (B + b_1 + T + t_1) + \frac{(B + b_2 + T + t_2)}{10}$$

in which (as an example the values of sample plot 20 are given in brackets): -

B = branchiness value according to the scale mentioned above (V = 5)

b_1 – cover of fruticose lichens on twigs (40%)

b_2 - " " foliose " " " (60%)

t_1 – cover of fruticose lichens on trunks (5%)

t_2 - " " foliose " " " (10%)

T – class of stem number per acre. This was obtained by counting the number of stems per acre in the sample plot and then dividing the number of stems less than 6 in. DBH by two. (The possibilities of young trees to bear lichen loads are smaller than those of older trees.) This number was put in the following scale:

1	less than 201 stems
2	201 – 250 "
3	251 – 300 "
4	301 – 350 "
5	more than 350 "

(sample plot 20: $208 + \frac{240}{2} = 324$, class 4)

This fairly complicated method gave results that are highly parallel to the general impression on the abundance of lichens in the plots as indicated in the writer's field notes. However, it is not claimed that this method is completely satisfactory.

The range indices obtained may be understood in the following way:

0 – 50	very poor (vp)
51 – 100	poor (p)
101 – 150	fair (f)
151 – 200	good (g)
201 – 250	very good (vg)
251 – 1000	excellent (ex)

In the table presented (Appendix III) all the fruticose and foliose lichens in the plots were recorded. The percentage scale used was tr. or + both (less than 5 per cent), 5, 10, 15, 20, etc.

In most cases an analysis of ground vegetation was made in the same stand in which arboreal lichens were sampled. The plot size was 100 sq. m. in these cases.

Field work was conducted during June, July and August in 1961. The more accurately studied districts are the Hemp Creek area, the Murtle Lake area, and top of Battle Mountain. Two to three weeks were spent in each of these areas. Short visits were made to Clearwater and Azure Lakes, to Stevens Lakes, and to Blue River and Fish Lake Hill.

III. ZONATION AND TENTATIVE CLASSIFICATION OF VEGETATION IN WELLS GRAY PARK

In small-scaled maps most of the park is included in subalpine forest. However, as also stated by other authors, there are several distinct zones present. The following zones presented by Krajina (1959) may be distinguished:

(1) Interior Douglas-fir Zone

This zone or vegetation very closely related to it is found on the dry slopes of the Clearwater Canyon (on the Wells Gray Park road, at least). Whether it extends to the park proper is not known to the author. In any event, even the slopes of the Hemp Creek valley near the Ranger Station have several thermophilous plants typical of more arid districts and Hartman (1957) considered that the ridges in this area were partly covered by Douglas-fir forests before the 1926 burn, which devastated all of the climax vegetation. According to Edwards and Ritcey (1959) this zone would be found up to an altitude of about 2000 ft. in the area.

(2) Interior Western Hemlock Zone

This zone, frequently called the Interior Wet Belt, ranges from about 2000 ft. up to about 4000 ft. Thus most of the valley forests, as those found in the Hemp Creek - Murtle River area and around Clearwater, Azure and Murtle Lakes and in the adjacent Blue River district, belong to this zone. Much of it has burned over, usually bearing stands rich in aspen or lodgepole pine. Climax stands dominated by western hemlock on drier sites and by red cedar on moister sites are also present.

(3) Subalpine Engelmann Spruce – Subalpine Fir Zone

This zone is present from about 4000 ft. up to about 6000 ft. (on Battle Mtn.), but the upper levels (above 5300 – 5500 ft.) are thinly stocked island-like stands, alternating with more or less wide subalpine meadows. This meadow zone and adjacent belt down to the upper limit of *Rhododendron albiflorum* thickets is here called the upper subalpine zone. It was studied on Battle Mtn. and (outside the park) on Fish Lake Hill. The lower subalpine zone was seen in the Stevens Lakes area and on the west slope of Battle Mtn. In the Murtle Lake district at the level of the lake there are forests dominated by Engelmann spruce and subalpine fir, but they clearly belong to the Western Hemlock Zone according to the characteristics of minor vegetation, though affinities to subalpine forests do occur in them.

(4) Alpine Zone

The Alpine Zone of Battle Mtn. was visited. There the ground is rich in stones and bare rocks with discontinuous vascular plant vegetation. A considerable number of species confined to this zone were found. The highest point (7635 ft.) is without any higher plants. Small snow-beds were present (at the end of July) near the patrolman's cabin and particularly on the eastern slopes. The Alpine Zone is represented by much larger areas on some other mountains in the park.

For long-range silvicultural calculations the productivity of a site as to the growth of tree stand is an essential thing, while in wildlife management studies the existing undergrowth is often of greater importance. Also, secondary stages of plant communities are frequently more favourable to game than the respective climax phases. However, as has been stated by many authors, caribou usually prefer climax to subclimax stands.

In any event, it is useful for ecological studies, in forested zones at least, to recognize the potential value of those site types where the studies are carried out. In North Europe the forest site types based on Cajander's theories have a universal use in national economy. Many different schools and many poor applications of some useful theories have confused the classification of sites to such a degree that one cannot readily accept any single method.

In B.C. much information on forest site types has not been published. It is, indeed, a very difficult country because of its highly varying climatic and edaphic conditions, which means that the existing types must be comparatively numerous and variable.

Some data concerning the site types in the Wells Gray Park area are found in Kujala's (1945) and Hartman's (1957) accounts. The zonal division and species lists by Krajina (1959) also contribute to the knowledge of the major types present. Other papers have not been consulted in this tentative report.

It is obvious here, as in any district, that mere forest types, i.e. cover-types distinguished according to the dominant tree species alone, do not often agree with the essential undergrowth types, which are generally more sensitive to environmental conditions than the trees with their usually broad ecological amplitude. In fact, all the components of a unified vegetation - site system or ecosystem type (see Rowe, 1960, and the other instructive papers in the same symposium) have to be taken into account in classification of sites.

Of course, the recognition of cover-types alone frequently gives an adequate picture of the range conditions of wildlife, but it may be claimed that the dynamic understanding of the cover-types is necessary for a proper range management. So, for example, it is useful to know, what will happen to secondary willow stands in different sites during the next 50 years or which species will dominate after cutting-over in a virgin hemlock stand in each region. The same sites-types in the same climatic region behave in the same way as to broad features. Hartman (1957), although he distinguished cover-types based on dominant trees in Wells Gray Park, was actually well aware that his types (Coniferous Type, Regeneration Type, Alder Type, etc.) are extremely heterogeneous.

The present author and particularly his wife made descriptions of the forest types and subalpine meadow types in the park, but a thorough treatment of these analyses and of the pertaining literature was not possible before the completion of this report. Only a preliminary classification is given in this connection. Division of other vegetation types is also outlined. It is to be noted that many kinds of habitat pockets having small areas (riverside forests, shoreline vegetation, etc.) are poorly represented or entirely omitted from the list given below.

1. ALPINE ZONE

1. Snow fields
2. Boulder beds
3. Stony grass-lichen heaths
4. Peat flats
5. Herb stands on brooksides

II. UPPER SUBALPINE ZONE

1. Forests (meadow-forests)
    a. *Arnica – Mitella* type
    b. *Luetkea* type
    c. *Lupinus – Valeriana* type

2. Upland meadows
    a. *Antennaria* – Lichen type
    b. *Anemone occidentalis* type
    c. Mesic *Antennaria* type
    d. *Caltha – Trollius* type
    e. *Phyllodoce – Luetkea* type
    f. *Valeriana* type

3. Peatlands
    a. *Carex nigricans* meadow
    b. *Calamagrostis* flood meadow
    c. Periodically wet sedge swales
    d. Sedge pools
    e. Sedge bogs
    f. Spring-fed brooksides

III. LOWER SUBALPINE ZONE

1. Forests
    a. Dry sites
    b. *Rhododendron* type
    c. Other fresh sites
    d. Bog forests

2. Open peatlands

IV. HEMLOCK ZONE

1. Forests
    a. Dry sites
    b. Fresh sites
    c. Moist sites
    d. Brookside sites flooded in spring
    e. Bog forests

2. Rock lands
    a. Lichenous rock outcrops
    b. Mossy rock outcrops

3. Open peatlands
    a. Eutrophic fens
    b. Mesotrophic bogs

IV. GENERAL NOTES ON THE ECOLOGICAL REQUIREMENTS OF LICHENS

The life-form group of fungi called lichens is by no means uniform in an ecological sense. Even the large lichens, the macrolichens, including the fruticose and foliose species, are distributed in very different climates.

Each lichen species is generally confined to rather limited climatic zones and within them to certain kinds of microenvironments. In fact, lichens are often better indicators of climate than are the vascular plants.

This last statement is especially true with epidendric lichens. Barkman (1958 p. 18) lists the following features that are of special importance to cryptogamic epiphytes in their relation to climate: (1) Their sensitivity to changes in atmospheric humidity and temperature; (2) the intensive contact with the air; and (3) the fact that they are perennial, evergreen, and active both in summer and in winter (snow cover on trees is less effective than on ground). Besides, they may grow very old.

Very roughly we can state that the macrolichens are most abundant in humid districts and, particularly the fruticose species, in cool districts. Thus, for instance, the writer has observed that on an average the coastal provinces of Newfoundland and British Columbia possess forests with heavier loads of epidendric lichens than do the interior areas of northern Ontario and the Great Slave Lake district. Of course, there are also poor lichen districts in British Columbia and good areas in Ontario, such as on the coasts of Lake Superior, Lake Nipigon, and Hudson's Bay.

Another decisive factor for the epidendric lichens is light. The macrolichens are generally clearly photophilous. Thus in dense forests they are poorly developed at lower levels, but closer to the crowns, where more light is available, they often flourish in considerable amounts. In thin forests lichens may be abundant down to the bases of trees, if the climate is humid enough. This fact is especially apparent in the coast forests of Vancouver Island, as emphasized by Szczawinski (1953), but it is also seen in Wells Gray Park.

Temperature has a great influence upon epiphytes through the rate of evaporation. Subalpine epidendric vegetation would be favoured, then, by low summer temperatures. Also, the snow cover in winter has a considerable thermic effect. Thus there are lichen species that clearly are dependent on the protective, thick snow accumulations, the qali formations (see Pruitt, 1959) on trees. These formations are characteristic of subarctic spruce forests (e.g., in Alaska and Lapland) and are undoubtedly well-developed in the treeline forests of Wells Gray Park.

Fruticose lichens draw their nutrition almost entirely from the air and from water running down the trunk, while foliose species may also profit by nutrients dissolved from the bark (Barkman, 1958). Thus the chemical properties of the bark particularly affect the growth of foliose lichens. The physical properties are more important for the fruticose species. The characteristics of the tree species of Wells Gray Park are discussed in Part VI in more detail.

Since the photosynthesis of lichens is less intensive than in higher plants, their growth rates are low even in optimal conditions. Adequate measurements on their growth rates are scarce. Frey (1952) is probably the only one who has studied the annual increase of *Alectoria* species, important in this study. He stated in Switzerland that *Alectoria jubata* grew 29 cm. in 21 years, which gives a rate of about 1.4 cm. per year. This is probably a maximum value rather than an average. In foliose lichens 0.2 – 0.5 cm. per year are common rates (Barkman, 1958 p. 17). In reindeer lichens 0.5 cm. is a frequent average.

V. THE EPIDENDRIC MACROLICHENS IN THE PARK

1. General

The lichen flora of British Columbia is very poorly known, especially in its interior areas. No modern lichen floras or floristic lists cover this province. However, the papers by Macoun (1902), Fink (1935), and Howard (1950), which are largely out of date, are available, besides scattered records on various species and genera in British Columbia. The paper by Howe (1911) on North American *Alectoria* may also be mentioned here. There are some common 'western' species in the province which are absent elsewhere in Canada, but the majority of the mountain species represent largely circumpolar, boreal elements.

Thus it is understandable that unsolved taxonomic problems are encountered in several western Canadian lichen groups. For this reason and for the short time available for identification some of the present writer's determinations are to be regarded as tentative only. However, a key for identification of most of the macrolichens found on trees in the park is presented. The majority of the species included are not abundant enough to be of any importance to caribou. All the macrolichens found are listed in Appendix I.

2. Keys

The keys include all of the macrolichens that are commonly found on trees in Wells Gray Park plus some rare ones. A few species (e.g. some species of *Cladonia* and *Nephroma*), which were collected on trees, are omitted because of their only occasional arboreal occurrence or their evident rarity. In addition, several species favouring settled areas were found, sparsely, in the Hemp Creek valley but are excluded from the keys.

Soredia are usually white, powdery masses produced by many lichen species. Isidia are minute, fingerlike or coralloid outgrowths particularly characteristic of several foliose lichens.

General Key

1 (8) Distinctly fruticose (without definite upper and lower surfaces), much branched, with cylindrical or angular branches.

2 (3) Bright yellow, branches rather coarse, short, and stiff with rough surface; scattered in all wooded zones.
- *Letharia vulpina*

3 (2) Blackish, brown, grey or green, more finely branched.

4 (5) Branches with white, tough, central cord (conspicuous when a branch is stretched), green, sorediate, forming tufts rarely exceeding 2 in. in length; scattered valley floor species. – *Usnea* cfr. *glabrata*

5 (4) Branches without any tough central cord, often not green.

6 (7) Forming loose tufts with short (not exceeding one inch), stiff, clearly flattened, ash-grey, and sorediate branches; rare species of valley floors (Helmcken Falls). – *Ramalina* cfr. *farinacea*.

7 (6) Branches usually longer, softer and finer, usually more or less cylindrical, often not grey.
- *Alectoria* (+ *Ramalina thrausta*), see spec. key 1.

8 (1) Foliose (with definite upper and lower surfaces), usually distinctly flattened.

9 (10) Lobes fairly broad, upper surface almost black, below densely

clothed with very short grey hairs; rare species of aspen and poplar trunks. – *Leptogium saturninum*.

10 (9) Upper surface not black or the species is very narrow-lobed.

11 (12) Light-brown, more or less erect, stiff and resembling fruticose species (upper and lower surfaces poorly differentiated); at bases of subalpine shrubs (especially *Rhododendron albiflorum*) and common on ground in subalpine meadows. – *Cetraria subalpina*.

12 (15) Sulphur-yellow, small (less than one inch in diameter).

13 (14) With marginal soredia, apothecia absent. – *Cetraria pinastri*.

14 (13) Without soredia, conspicuous blackish apothecia always present. – *Cetraria canadensis*.

15 (12) Not sulphur-yellow.

16 (19) Lobes often once inch broad, clearly ridged, brown, and truncate.

17 (18) Soredia or isidia on prominent ridges on the upper surface; common in rich forests below subalpine zone. – *Lobaria pulmonaria*.

18 (17) Similar but lacking soredia and isidia; sparsely found at tree bases at Murtle Lake, also on ground in alpine and subalpine zones. – *Lobaria linita*.

19 (16) Lobes smaller, ridgeless or less ridged, often rounded.

20 (23) Lobes 0.5-1 cm. in breadth, lower surface hairy, light-brown, upper surface dark-brown; less common species.

21 (22) Upper surface covered with numerous black isidia, lower surface clothed with long, light-brown rhizinae, marginal lobes short and indistinct; rare, in rich forests. – *Sticta fuliginosa*.

22 (21) Upper surface rather smooth with scattered, flattened isidia, lower surface with dark-brown rhizinae in the central parts; less common, in rich forests. – *Nephroma helveticum* var. *sipeanum*.

23 (20) Lobes more or less radiated, narrow (usually 0.1 - 0.3 cm. in breadth) and long, lower surface black in most cases, upper surface grey or brown; includes many common species. – *Parmelia* + *Parmeliopsis* + *Cetraria* + *Physcia*, see spec. key 2.

Special Keys

1. *Alectoria* (+*Ramalina thrausta*)

1 (6) Green to grey

2 (3) Green, extreme tips of the branches black (use hand lens!), main branches often coarse, soredia absent. – *Alectoria sarmentosa*

3 (2) Grey or greenish, extreme tips of branches not black, main branches not particularly coarse.

4 (5) Light-grey to greenish, finely branched, main branches clearly angular, extreme tips usually curved and with white soredia;

common in rich lowland forests. – *Ramalina thrausta*.

5 (4) Ash-grey, delicately branched, branches cylindrical, soft, without soredia; infrequent species of valley floor forests. – *Alectoria implexa*.

6 (1) Dark-brown to blackish.

7 (8) Stiff and prostrate at basal parts, not very densely branched, branches olive-brown, somewhat shiny, cylindrical, and divergent, white soredia frequent; common. – *Alectoria "chalybeiformis"*.

8 (7) Not clearly prostrate, usually densely branched, branches often angular, dull or lax, soredia infrequent.

9 (10) Reddish-brown, dull, rather stiff, branches angular, apothecia not uncommon, with ciliate margins; abundant in subalpine zone. - *Alectoria oregana*.

10 (9) Not distinctly reddish, softer, most branches more or less cylindrical, apothecia extremely rare.

11 (12) Blackish-brown, not very shiny, main branches rather thin and little differentiated; common.

- *Alectoria jubata*.

12 (11) Chestnut-brown to blackish-brown, usually very shiny, main branches thick, pitted, and twisted, rarely with yellow soredia. – *Alectoria fremontii*.

2. *Parmelia, Parmeliopsis, Cetraria,* and *Physcia*

1 (14) Upper surface brown or black.

2 (3) Lower side with rhizinae; infrequent species of hardwood

trees. – *Parmelia olivacea.*

3 (2) Lower side naked, rhizinae absent.

4 (5) Upper side partly grey or only light-brown, with rather narrow lobes; common in subalpine zone. – *Parmelia austerodes*.

5 (4) Upper side intensely brown.

6 (7) Margins of lobes with long ciliae, lobes broad; rare.
- *Cetraria ciliaris*.

7 (6) Lobes without ciliae.

8 (9) Margins of lobes with grey granular soredia, lower side pale brown; common. – *Cetraria scutata.*

9 (8) Soredia absent.

10 (11) Both sides black or black-brown; rare species of lodgepole pine forests. – *Cetraria merrillii.*

11 (10) Both sides usually light-brown.

12 (13) 0.5 – 2 inches in diameter, lobes broad, wrinkled, not much ascending, apothecia not very numerous; scattered on conifers. – *Cetraria platyphylla*.

13 (12) Usually less than 0.5 inches in diameter, lobes smooth, narrow, and ascending, with numerous apothecia; rare.
- *Cetraria sepincola*.

14 (1) Upper surface grey to yellowish.

15 (20) Lower side with rhizinae.

16 (17) Lobes somewhat convex, narrow (not exceeding 1 mm.); infrequent, only on aspen or poplar. – *Physcia aipolia*.

17 (16) Lobes flat or a little concave, broader; common on conifers.

18 (19) Upper side with white cracks, which produce soredia, lobes 1 – 5 mm. broad; common. – *Parmelia sulcata*.

19 (18) Upper side with short, chiefly marginal, isidia, lobes narrower; on *Abies* in hemlock zone, fairly common. – *Parmelia saxatilis* var. *divaricata*.

20 (15) Lower side without rhizinae.

21 (28) Rather coarse and often loosely attached to the substrate.

22 (23) Lobes flat, broad (0.5 – 1.5 cm.), usually with irregular, marginal, grey soredia and isidia; common. – *Cetraria glauca*.

23 (22) Lobes somewhat inflated, hollow, and narrow (0.1 – 0.8 cm.).

24 (25) Soredia absent, lobes often 0.5 - 0.8 cm. in breadth; common. – *Parmelia enteromorpha*.

25 (24) Soredia present in limited patches at the ends of the lobes, lobes narrower.

26 (27) Soredia on the lower sides of inflated spoon-like formations at lobe tips; common – *Parmelia physodes*.

27 (26) Soredia on the upper sides of cylindrical lobe tips; infrequent. – *Parmelia tubulosa*.

28 (21) Small, almost crustose, tightly attached to the bark; forming extensive covers on tree stems, especially in the subalpine zone.

29 (30) Yellowish-grey. – *Parmeliopsis ambigua*.

30 (29) Ash-grey. – *Parmeliopsis hyperopta*.

3. Notes on the major macrolichen species

FRUTICOSE LICHENS

Alectoria jubata

Taxonomically this species is a great mess. Recently Motyka (1958) split *A. jubata* into several species, some of which are very poorly defined. In any event, in the present study area the species is probably fairly uniform.

It is commonly found on conifers throughout the park, but it attains the greatest abundance in the upper subalpine zone. Its ecological amplitude is wide. For instance, it seems to be the most shade-tolerant *Alectoria* in Wells Gray Park, if the rare *A. implexa* is omitted. In a collective sense *A. jubata* is a common, circumpolar, boreal species.

Alectoria "chalybeiformis"

This form, closely related to *A. jubata*, is obviously a distinct species, but the epithet *chalybeiformis* does not seem to be correct, but belongs to a European type, which grows on shore rocks and birch trees. Following Howard (1950), the name *A. chalybeiformis* is tentatively used here. British Columbia specimens of this species and of *A. jubata* have been sent to the Polish specialist Dr. Jozef Motyka, for identification, but he has not completed this work yet.

A. "chalybeiformis" is very abundant in the subalpine forests, being concentrated to the lower parts of the trees. In the hemlock zone it seems to be less abundant. It does not withstand dense shade.

Alectoria fremontii

This species was reported by Edwards et al. (1960) to occur in all wooded elevations in Wells Gray Park. They stated that it is scarce or absent at those levels on trees which *A. sarmentosa* frequents, while it is common immediately above this level. Furthermore, *A. fremontii* was not found by them to invade tree tops as successfully as *A. jubata* s. lat., which was therefore considered to be more xerophytic. Generally *A. fremontii* is less abundant than *A. sarmentosa* and *A. jubata* in the park according to their observations. Szczawinski (1953) stated that on Vancouver Island the present species is confined to the most open and driest sites, being even found at the bases of tree stems (this was also noted by the present author at the Little Qualicum Falls, V.I.).

Ahlner (1948), who has extensively studied the distribution and ecology of this species in northern Europe, states that it is present in both continental and oceanic areas, but generally avoids districts with long and warm summers. However, in Scandinavia its most typical habitats are continental, open and dry Scots pine forests, which greatly resemble the lodgepole stands in Wells Gray Park, but which are more permanent climax stages in Europe. In spruce forests it is also found, though less abundantly.

A. fremontii is only distributed (cf. Howe, 1911, Ahlner, op. cit.) in northern Europe and western North America (Alaska, B.C., Alta., Wash., Ida., Mont., Ore., Wyo., Calif.). There may be some slight morphological differences between the populations of the two separate areas, as, for instance, the more sparse occurrence of yellow soredia in North America (Ahlner, op. cit.), but they are ill-defined. The North American population also seems to be more eurytopic in its ecological requirements. So it is sometimes found to be very abundant in fairly dense forests in Wells Gray Park, which would be very strange in Europe.

But even in Wells Gray Park *A. fremontii* is usually the most abundant species in lodgepole pine forests (in particular in old stands), and probably at all levels on pine trees, although Edwards et al. (1960) for some reason reached a more or less opposite result in their single sample plot in pine forest. Also, *A. fremontii* is perhaps the most abundant species in upper portions of all kinds of conifers in the park. This is not necessarily always the case, but several tops of fallen or wind-broken trees were examined and all of them proved to be dominated by the present species. Assessments with binoculars also seemed to offer evidence for this statement. The discrepancy between the observations by the writer and by Edwards et al. (op. cit.) might be explained by differences in delimitation of the species. Especially young and dark, finely branched threads of *A. fremontii* are extremely difficult to distinguish from *A. jubata*, as has also been pointed out by the certainly reliable Swedish authority on this species, Dr. Ahlner (1948). Extremely plastic phenotypes are typical of many lichen species.

In any event, the writer agrees with Edwards et al. in the fact that in lower elevations *A. fremontii* is not generally very abundant on lower twigs of trees, being frequently totally absent on them.

Alectoria sarmentosa

The abundance of this conspicuous species in the park has been emphasized by Edwards et al., although it is mainly confined to lower branches of trees in the hemlock zone, being scarce near timber-line.

The general distribution of *A. sarmentosa* is suboceanic in character (cf. Howe, 1911, Ahlner, 1948). In western North America its known range extends from Alaska down to California and westwards to Alberta. In the east it is distributed from Labrador to New England, but is not known with certainty in the interior of the continent. In Europe it is also present, but no reliable reports are available from Asia.

In northwestern Europe the optimal range of *A. sarmentosa* is situated in districts with comparatively cool summers (mean temperature of July below 15°C) and in habitats with fairly high humidity of air (Ahlner, 1948 p. 114). However, its ecological amplitude is wide.

In Wells Gray Park *A. sarmentosa* is abundant in the hemlock zone and locally in the lower subalpine zone, while in the upper sub-alpine zone it is hardly ever abundant though very frequent.

It prefers spruce and fir species all over its range, being particularly characteristic of their dead, thin, lower twigs. It is especially plentiful on entirely dead trees, often forming great masses on their lower branches. On pine trees it is also common and the individuals may grow large, but seldom does it attain any great abundance on them. The same is true with cedar and hemlock, which, however, may carry heavy loads on upper branches, inaccessible to caribou.

A. sarmentosa is more hygrophilous and shade-tolerant than *A. fremontii*. However, its most favourable habitats seem to be in rich lakeshore forests, where humidity is constantly high and a lot of light is available at the same time. Thus on Diamond Lake (south-western end of Murtle Lake) this species usually rises up to 55 – 60 feet on trees in a moist forest site type, while on drier sites it only reaches about 25 feet. In the valley floor between Hemp Creek and Dawson Falls 60 feet is attained everywhere on fresh or moist sites. In the best lakeshore habitats of the lower subalpine zone (Stevens Lakes) the upper limit of *A. sarmentosa* is at 40 ft., while generally in the subalpine forests this lichen is only found up to 20 – 30 ft. In very thick forests it does not thrive on lower branches at all, but in Wells Gray Park it is almost always present in some quantity within the reach of caribou.

As mentioned below under *Ramalina thrausta*, that species and *Alectoria sarmentosa* were not separated by Edwards et al. 1960).

Alectoria oregana

Little information is available on this reddish-brown species. Indeed, Howe (1911) compiled a map of its distribution, showing that it is a western North American species ranging from California to B.C. and westwards to Alberta and Montana. It seems to be preferably a subalpine species. In Wells Gray Park it is very abundant in the upper subalpine zone, forming mass vegetation on twigs. Below the subalpine forests it is absent or very rare. Its upper limit on trees was not studied in detail, but scattered observations indicate that it may be confined to comparatively low levels. It is probably a little more photophilous than *A. jubata* and *A. "chalybeiformis"*, being therefore most abundant at edges of subalpine meadows.

Ramalina thrausta (Alectoria thrausta)

This species resembles *Alectoria sarmentosa* very much, but is usually readily distinguished by its paler color and presence of soredia. Edwards et al. (1960) included *R. thrausta* with *A. sarmentosa*. In their sample plot no. 1 *R. thrausta* was more abundant, though *A. sarmentosa* was also present, as confirmed by the writer in the field. In the rest of their plots the greenish lichen was exclusively or mainly *A. sarmentosa*.

R. thrausta is a more or less circumpolar, boreal species, which prefers continental territories (Ahlner, 1948). In large areas it is not very common and therefore its distribution is rather poorly known.

In Wells Gray Park *R. thrausta* is common and even abundant in many places in the hemlock zone in both the Clearwater Valley and Murtle Lake areas. It was not found in the subalpine zone. Everywhere, but particularly in the Murtle Lake district, the species is restricted in low levels on trees, lower than *A. sarmentosa*. In the Murtle Lake area it hardly grows higher than 10 ft. above the ground. It occurs both on branches and trunks, even on cedar stems in very shaded forests, where the *Alectoria* species are scarce.

Ahlner (1948) states that also in Scandinavia *R. thrausta* has a narrower ecological amplitude than *A. sarmentosa*. There *R. thrausta* is almost always found in fresh, fairly shadowy spruce forest sites. It strictly avoids pine trees as substrate. In suitably damp and dense, old spruce forests it often forms heavy cover on twigs. In more open forests it is weak in competition with *A. sarmentosa*.

Letharia vulpina (Evernia vulpina)

This conspicuous bright-yellow species occurs in Wells Gray Park from the valley floors up to the timberline forests. However, its optimal habitats seem to be in ponderosa pine forests in more arid districts. Therefore, it is not normally very abundant in Wells Gray Park.

L. vulpina is a clearly photophilous species and in the park it grows most abundantly in lodgepole pine stands, on stumps and snags in burns, and on solitary trees or in small tree stands at the edges of subalpine meadows and at timber-line. In the upper subalpine zone it may attain considerable size (4 – 5 inches in length).

Outside western North America *L. vulpina* is only found in western Eurasia, being, however, distinctly continental in habitat requirements (Ahlner, 1948).

In Scandinavia this species was once much used for killing wolves and foxes, for the yellow substance, vulpinic acid, is highly poisonous.

FOLIOSE LICHENS

Foliose lichens have generally low palatability for caribou. In Wells Gray Park only *Cetraria glauca* may be of importance. The other common or conspicuous species listed are apparently utilized to a very limited extent.

Lobaria pulmonaria (*Sticta pulmonaria*) is restricted in the hemlock zone, being common both around Murtle Lake and in the Hemp Creek area. It prefers old, shaded and damp forests and is confined to the lowest twigs of various conifers. However, its local distribution is spotty, so that it is not found in every suitable looking locality. It often forms pure luxuriant covers on twigs, but does not usually exceed 10 ft. above the ground.

L. pulmonaria is probably a circumpolar, boreal species in general distribution.

Cetraria glauca (Platysma glaucum)

This bluish-grey species is extremely common and usually the most abundant foliose lichen in the coniferous stands of the hemlock zone in Wells Gray Park. In the subalpine zone it is scattered and rarely abundant.

The general distribution of *Cetraria glauca* shows boreal and oceanic tendencies. It is abundant in the coastal provinces of northeastern and northwestern North America, but rare or absent in the interior (e.g. in Ontario).

C. glauca has a wide ecological amplitude, but it attains greatest abundance in strongly to moderately shaded fresh spruce or fir forests, climbing fairly high up towards the tree crown.

Cetraria scutata (*C. chlorophylla*)

This brown species is common but scattered on twigs throughout Wells Gray Park. In North America it is only found in the western provinces and states.

C. scutata is present in all kinds of forests, but prefers rather open stands and seems to be most frequent in lodgepole pine forests. However, it is never very abundant, though some individuals attain about two inches in diameter.

Parmelia physodes (*Hypogymnia physodes*)

A very common circumpolar boreal-temperate species with wide ecological amplitude. In Wells Gray Park it is found on most of the mature individuals of trees, being frequently abundant, but also scarce in many cases. It favours open woods rather than shaded ones.

Parmelia enteromorpha (*Hypogymnia enteromorpha*)

Another very abundant species, which is usually even more plentiful than *P. physodes*. However, it is a western species in North America, also occurring on the Asiatic side of the northern Pacific coasts. It is taxonomically somewhat involved (cf. Imshaug, 1957), but there is only one common type in Wells Gray Park.

P. enteromorpha prefers rather open woods, and on fresh sites attains a good size (4 – 5 inches in diameter) being then easily browsed by caribou.

Parmelia austerodes (*Hypogymnia austerodes*)

A common species in the subalpine forests, though less abundant than *P. enteromorpha* and *P. physodes*. It was also found in the Murtle Lake area in the upper hemlock zone. It is a northern circumpolar species with continental tendencies. It is most common in woods with cold winters.

Parmelia sulcata

This is a very common circumpolar boreal-temperate species. However, in Wells Gray Park it is less abundant than in many other coniferous territories, though it is frequent even there. It finds its optimal habitats in moderately damp, rather open woods, being particularly characteristic of forests on riverbanks and lakeshores. In some other districts it is one of the typical species on birch trees.

VI. ABUNDANCE OF EPIDENDRIC LICHENS IN VARIOUS FORESTS

1. Tree species as sites for epidendric lichens

The physical and chemical qualities of the host trees, the phorophytes, of the epiphytic cryptogams are not the same in each tree species.

In Barkman's (1958 p. 139) division all the coniferous trees of Wells Gray Park seem to belong to his Group I, although he did not classify the North American phorophytes. The bark of the trees in this group is characterized by low total electrolyte concentration, low buffer capacity, low phosphate content, low pH, low water capacity and presence of resin and tannin. The type of crown is centrifugal, so that the trunk epiphytes receive only small amounts of precipitation.

The group has three subdivisions (op. cit.). Subdivision a – apparently includes *Abies lasiocarpa*, *Picea engelmannii*, *P. glauca*, and *Tsuga heterophylla*. Their common properties are obviously fairly smooth bark, its low rate of scaling, its higher pH (dead bark about 4 – 4.5) than in most trees of the Subdivision b, and small amount of light transmitted by the dense evergreen crown, which makes the whole forest site very shady.

The Subdivision b. (op cit.) includes *Pinus contorta*, *P. monticola*, *Pseudotsuga menziesii*, *Thuja plicata*, and *Betula papyrifera*. The scaling rate of their bark is higher, pH lower (about 3.5 – 4; in *Thuja* probably higher), surface rough, and the crown smaller and less shading than in the preceding subdivision.

In Subdivision c. (op. cit.) there are alder and oak species, and in the other two Groups remaining hardwood genera, all of which are without interest in this connection.

Below all of the important trees in Wells Gray Park are listed with notes on their facilities to carry fruticose and foliose lichens accessible to caribou in the park.

Subalpine Fir (*Abies lasiocarpa)*

Living branches usually reach down close to the ground and almost always many dead twigs are present within 10 ft. from the ground. In the subalpine zone the amount and branchiness of the twigs is clearly higher than in the hemlock zone (Murtle Lake).

The bark does not scale much at all and therefore foliose and sometimes also fruticose species are abundant on stems.

An important fact is the common occurrence of dried-up fir trees. The Murtle Lake and the Hemp Creek areas have many dead fir trees, and they are also frequent in the subalpine zone. On the other hand, young subalpine firs are very abundant in all zones. A comparatively short life span seems to be characteristic of this tree in the park, as elsewhere (Sudworth, 1908, Hartman, 1957). Dead standing trees offer excellent habitats for fruticose lichens.

Subalpine fir is no doubt the best tree for both fruticose and foliose lichens in Wells Gray Park.

Engelmann Spruce (*Picea engelmannii)*

Often this species has a tall, branchless lower bole, but in the subalpine zone, however, it frequently has a fair number of dead twigs within 10 ft. from the ground. The living twigs are not as near the ground as in the subalpine fir. Even in fairly small trees (20 ft. in height) in the Murtle Lake area dead twigs are common.

Dried-up spruces are not common. Young trees are much less frequent than mature ones in both the hemlock zone and the subalpine zone, especially the latter.

The bark is somewhat faster scaling than in the subalpine fir.

Engelmann spruce is rather abundant both in the subalpine forests and in the hemlock zone.

The local white spruce (*Picea glauca*), hybridizing with the Engelmann spruce in the valley floor forests, but mainly absent in the upper elevations, does not essentially differ from Engelmann spruce in producing lichens.

Lodgepole pine (*Pinus contorta* var. *latifolia*)

In middle-aged (50-70 years old) stands lichens may attain considerable abundance at lower levels thanks to a great number of dead twigs in this period. Old trees have a long, bare, effectively scaling trunk, where few lichens are able to grow.

Lodgepole pine usually grows in almost pure stands, but is not particularly abundant in the park. In the subalpine zone pine stands were seen only at Stevens Lakes.

Western White Pine (*Pinus monticola*)

This species is not common in Wells Gray Park. A few stands were observed in the Murtle Lake area and on the Fish Lake Hill road. It is a very poor tree for growth of lichens. In mature trees there are usually no twigs at lower parts and the bark is strongly scaling.

Douglas Fir (*Pseudotsuga menziesii* var. *glauca*)

A poor tree for lichens, resembling the pine species. The young trees have an extremely smooth bark, unfavourable for the attachment of lichens and the twigs are strongly shading. In old trees the lower trunk has no twigs at all. The tops of tall trees often carry heavy loads of lichen, but they grow very sparsely on lower levels.

Douglas fir is common only at lower elevations in the park. Within the present caribou range it was seen only in the Murtle Lake area.

Western Red Cedar (*Thuja plicata)*

Red cedar is an abundant tree in the virgin forests surrounding Murtle Lake, Azure Lake, Clearwater Lake, and Hemp Creek. However, it is a poor tree for lichen growth.

Young cedars often form thick bush in shaded places (also on shorelines), being almost completely devoid of fruticose lichens. Old trees seldom have branches near the base. However, dying young trees usually possess dead lower twigs supporting some kind of lichen cover that is occasionally abundant.

The physical and chemical properties of cedar bark differ considerably from those of the other trees. A few crustose lichens specific to cedar are common, while the black *Alectoria* species seem to be less abundant on this tree than on the others.

Western Hemlock (*Tsuga heterophylla)*

Although the pure hemlock stands are not particularly densely stocked, their foliage is so shading that this factor alone makes such stands poor lichen forests. In addition, old trees are not rich in twigs and lichens except in their upper levels. Even the young trees have very scanty lichen covers.

Hemlock seems to be a rather slowly growing tree in the area, but is dominant in old climax stands on dry or fresh sites. Such forests were observed on the North Arm and the south shore of Murtle Lake, on Azure Lake, and on the Fish Lake Hill road.

Hardwood Trees

The hardwood species present, *Betula papyrifera*, *Populus trichocarpa*, *P. tremuloides*, *Acer glabrum*, *Alnus tenuifolia*, *A. sinuata,* and *Salix scouleriana* are generally very poor sites for fruticose lichens. In Wells Gray Park even foliose lichens are not very plentiful on these trees.

2. Sample plot analyses

The data collected from the sample plots are presented in

Appendix III. Notes on site type and its fertility are excluded, since the abundance of lichens seems to be essentially dependent upon the density and species of tree cover rather than directly upon the site. The composition of tree stands usually also gives indications of the site type.

Upper Subalpine Zone

The number of trees is rather high, the stem number class being from 2 to 5. Even very high numbers are sometimes reached. Nevertheless, the stands are rather open, since the trees are not equally distributed at all, but are usually growing in almost impenetrable clumps. Crown canopy is thus 20 to 50 per cent in most cases. Solitary trees and tree groups smaller than the sample plot are normally present at the edges of subalpine meadows and at alpine timber-line.

Subalpine fir and Engelmann spruce are the only tree species. The former is less long-lived than the latter and therefore the biggest trees are spruces, while the fir is more numerous and more important as to lichen loads. The fir is also rich in twigs (classes IV – V).

Fruticose lichens are abundant on twigs at both lower levels (cover usually 30 – 70 per cent) and on crowns. Foliose lichens are rather scarce (cover usually 5 – 20 per cent).

Alectoria oregana, *A. chalybeiformis*, *A. jubata*, and *A. fremontii* are constant and abundant species with varying cover degrees. *A. sarmentosa* is sparse. *Letharia vulpina* is occasionally abundant.

Parmelia enteromorpha is the dominant foliose species and *P. physodes* and *P. austerodes* are also constant though less abundant. The small species *Parmeliopsis ambigua* and *P. hyperopta* (not included in the records) reach high cover values on basal parts.

Most by far of the upper subalpine stands give very good to excellent range values.

Lower Subalpine Zone

The tree stands are denser than in the upper subalpine zone, though the number of trees is not very high. Subalpine fir is dominant, but Engelmann spruce is more abundant than in the upper subalpine zone. Lodgepole pine may be present in burns.

The lichen loads are usually rather heavy in the old forests, although the branchiness is generally lower than in the preceding zone. The pine stands are always poor in accessible lichen.

One of the most conspicuous differences from the upper subalpine stands is decreased abundance of *Alectoria oregana*. It seems to be replaced by increased amounts of *A. jubata*. Among foliose lichens *Cetraria glauca* is locally abundant, but usually only sparsely present. *Cetraria subalpina* is sometimes abundant at bases of the shrubs *Rhododendron albiflorum* and *Menziesia ferruginea*.

The average range values of the lower subalpine zone are somewhat less than those of the upper zone, being usually from fair to excellent.

Western Hemlock Zone

There are five main types of forest stands in this zone; (1) subalpine fir – spruce, (2) red cedar, (3) hemlock, (4) pine, and (5) aspen stands.

The fir-spruce forests are particularly common in the Murtle Lake area in this zone. Most stands are clearly denser (crown canopy usually 30 to 70 percent) and the abundance of lower twigs is considerably smaller than in the subalpine forests. This means that the amount of lichen is also fairly low. The fruticose species do not attain remarkable abundance near tree bases, except in some localities on lakeshores and margins of open bogs. *Alectoria sarmentosa* is the major species, *A. jubata*, *A. fremontii*, and *Ramalina thrausta* being abundant, too. However, in most stands the abundance of lichen is distinctly greater on higher twigs, above the reach of caribou. On the other hand, the foliose lichens, particularly *Cetraria glauca* and more locally *Lobaria pulmonaria*, are more plentiful in the hemlock zone than in the subalpine zones.

The cedar stands are often extremely dense (crown canopy 60 to 90 percent) and, therefore, the lichen cover is usually less significant.

The hemlock forests are generally still poorer than the cedar stands as to lichen production. On the shore of Azure Lake, however, even hemlocks bear more lichen than in closed forests. Most hemlock stands are very shady and many trees are almost lacking basal twigs.

The pine (and Douglas fir) stands also possess rather insignificant lichen resources. This is mainly due to the scarcity of twigs and to the low age of pine stands. However, occasionally pine trees are rich in available lichen, mainly *Alectoria fremontii*, rather than *A. sarmentosa* which avoids excessively dry habitats.

The secondary aspen forests, dominant in the Hemp Creek valley, are extremely poor lichen range. Only in certain shrubs (e.g. *Prunus*) may be found a few threads of *Alectoria* or *Usnea* with *Parmelia* and *Cetraria* species.

Summing up, the subalpine fir – Engelmann spruce forests, found in the upper parts of the hemlock zone, represent the best lichen range in this zone. However, their range values vary from poor to excellent. Typical hemlock, cedar, and pine stands have a range value from very poor to poor, but in favourable conditions (which are overrepresented in the sample plot material) higher values may be reached.

3. Phytosociological aspects

As stated in Chapter II, even among epiphytic lichen, vegetation associations and other communities are distinguished and named (cf. Barkman, 1958).

The writer attempted delimitation of some kinds of such units in Wells Gray Park. However, most epiphytic lichen covers in the park give an impression of being very immature. They are growing in ecologically highly variable conditions, and, therefore, the formation of real regular vegetation is not easy. For instance, stems and branches and other variable qualities of tree species, microclimate of environment changing in small distances, etc., make the variation considerable. The influence of interspecific competition remains weak and surfaces of trees never get completely filled with lichens. Thus, theoretically, most of the epiphytic vegetation may be regarded as poorly developed successional communities or ill-defined groupings of single individuals or, as expressed by Barkman (op. cit.), fragments of plant communities.

However, in the upper subalpine zone the lichen covers are frequently so closed that we may speak about real lichen communities. This is also generally true of the upper parts of trees in the other zones. In valley forests well-developed lichen covers on basal twigs are usually scattered. Crustose lichens do form extensive covers even in lowland forests.

The number of lichen species with strong powers of competition is small in Wells Gray Park. This kind of condition easily results in communities with only one abundant and dominant species. The composition of a few frequently seen communities were analyzed by the author, but since sociology is a question of peripheral interest in this report, only some general features of the communities are outlined here. The following tentative associations may be distinguished:

1. *Alectoria fremontii* association

Alectoria fremontii is dominant (cover 50 to 90 percent in the writer's records). Other *Alectoria* and *Parmelia* species are present in variable degrees. Prefers open, light, and rather dry stations, being chiefly found on small exposed twigs in the upper parts of trees. In the subalpine forests also present close to the tree bases. It is also common in northern sections of boreal forests in N. W. Europe (Barkman, op. cit. p.476).

2. *Alectoria jubata* association

A rather common community, probably found in all zones in the park, but often poorly developed or with *A. jubata* considerably mixed with other Alectoriae. In a broad sense it is this association that is abundant at lower levels on trees in subalpine forests. It varies in composition, but it seems fairly arbitrary to distinguish other associations according to dominant species. However, an *Alectoria oregana* association might be often distinguishable in the upper subalpine zone on greater parts of lower branches exposed to sun.

3. *Alectoria sarmentosa* association

Besides *Alectoria sarmentosa*, *Cetraria glauca* is typical of this association. Although *A. sarmentosa* is present in the upper subalpine zone, it is not dominant in any community there. In the hemlock zone the association is rather common in moist and fresh forests. More or less the same association is mentioned by Barkman (op. cit. p.477) under the name *Letharietum divaricatae* from Europe. According to him it is 'skio, psychro- and very aerohygrophytic', having 'a strong preference for *Picea*, particularly the lower dying branches'.

3. *Ramalina thrausta* association

Ramalina thrausta, *Cetraria glauca* and *Alectoria sarmentosa* are characteristic of this association. It is ecologically closely related to the preceding association, but is confined to still more sheltered and moist forests. In the park it is scattered in rich forests, but largely poorly developed and fragmentary only.

4. *Cetraria glauca* association

Typical of lower branches of shaded fir and spruce trees in the hemlock zone. Besides *Cetraria glauca*, *Parmelia* species are found more or less sparsely, while *Alectoria* species are very scarce. Common in the park.

5. *Parmelia physodes – enteromorpha* association

Very common in the hemlock zone, but mainly rather fragmentary. It occurs both on branches and on stems.

6. *Lobaria pulmonaria* association

Conspicuous but fairly uncommon community of rich and moist forests. It is usually restricted to the very lowest branches near the ground. Some bryophytes are often present with it. In Europe it is confined to humid regions, being very sensitive to drought (Barkman, op. cit. p.523).

4. <u>Relations of availability of lichens and silviculture</u>

Since most of the Wells Gray caribou range is situated in a Provincial Park, logging companies' operations do not greatly affect its range conditions. However, considering some relations between silviculture, fire protection, and caribou range management may be profitable even in this connection.

Clear-cutting and fires are very unfavourable to caribou in this area, as has been demonstrated by Edwards (1954), but selective cutting might be practiced within caribou ranges. In Lapland, the co-operation of logging and reindeer husbandry is generally good because of selective cutting, but in cases where large areas of too old or otherwise undesirable forests have been cut over, conflicts have arisen.

Abundance of *Alectoria* lichens on trees in boreal or montane coniferous forests primarily indicates old age and slow growth in the trees. This fact means a contradiction between forestry and caribou management.

For instance, old people remember the abundance of "beard lichens" on trees in South Finland at the beginning of this century, but now when the majority of these forests have been changed into so called "economy forests", where no old or poorly growing trees are allowed, the amount of fruticose lichens is not conspicuous at all. *Alectoria sarmentosa* has particularly suffered from intensive silviculture in N.W. Europe, as was also pointed out by Ahlner (1948). The same holds true with *A. fremontii*, while *A. jubata* has somewhat better adapted to the new conditions, being, however, fairly small in size nowadays. Also the general thinning of forests has been often unfavourable to *Alectoria* species in Finland. They are hygrophilous and shade-tolerant to such a degree that thinning makes the forests too dry for luxuriant growth in normal boreal conditions.

Romell (1922) discussed the problem, whether the *Alectoria* species cause damage to conifers in North Sweden. He came to the conclusion that the damage is evidently negligible. Although this statement may need checking in some conditions, later authors have generally agreed with it.

In British Columba lowered productivity of lichens is well seen in secondary forests. A decrease of lichen abundance would be also expected to follow intensive silvicultural measures in older forests. However, in very dense stands and on humid sites moderate thinning would improve lichen production. Moreover, in the upper subalpine zone, which is not silviculturally interesting, lichens will remain more abundant than elsewhere for climatic reasons. In that zone lichens possibly hinder the growth of trees to some extent by killing needles, etc.

Cringan's (1957) statement that falling trees would be important to caribou (this was also discussed by Edwards et al., 1960, and Scotter, 1962) does not seem to be generally valid for several reason. Fallen trees are usually very scattered and most of them are not presumably found by caribou at the time when the lichens on them are still palatable or accessible (note snow conditions!) or when the animals are anxious to browse lichens (with the exception of very limited areas like the Slate Islands, Cringan's study area). Many dried-up trees leaning to other trees have almost totally lost their lichens before falling down. The same kind of condition is true with lichen falling on snow or on ground. Therefore, the importance of the heavy lichen loads above 10 feet from the ground seems to be practically insignificant to caribou. The same opinion was expressed by Scotter (1962).

In most of the lichen stands on trees in Wells Gray Park no browsing by caribou could be assessed. Only at Azure Lake could definite evidence of utilization be seen. Therefore, it seems correct to assume that a considerably higher number of caribou than at present is found there could live on the existing lichen resources. Ranges of early and late winter, when the animals migrate down to valleys (Edwards and Ritcey, 1959), may be the most critical point to the population. However, it seems that even the valley range, if kept undisturbed, is able to maintain a higher number of caribou over the annually rather brief early and late winter periods.

VII. PALATABILITY AND NUTRITIONAL VALUE OF EPIDENDRIC LICHENS

Observations and experiments made all over the caribou and reindeer districts fairly uniformly give the following order of lichen groups as to their palatability to the animals of the genus *Rangifer*:

1. Highly palatable

   Reindeer lichens (*Cladonia*, subgenus *Cladina)*

   Epidendric 'beard' lichens (*Alectoria, Usnea, Evernia*)

   Stereocaulon spp. (data on palatability partly contradictory)

2. Fairly palatable

   Most *Cetraria* species (epidendric and terrestrial species)

   Cup-lichens (small *Cladonia* species)

   Umbilicaria spp.

   etc.

3. Less palatable

   Peltigera spp.

   Parmelia spp.

   Terrestrial *Alectoria* species

   etc.

Thus the epidendric Alectoria species, abundant in Wells Gray Park, are classified in the same category as the true 'caribou mosses', which are famous for their high palatability. Two Russian authors (Rabotnov and Govorukhin, 1950) even claim that the reindeer may prefer epidendric lichens to ground lichens. In any event, in most districts epidendric lichens are not abundant enough to support great herds of reindeer or caribou.

The characteristic nutritional properties of lichens are:

(1) scarcity of nitrogenous compounds and minerals

(2) high content of carbohydrates

(3) presence of special lichen substances, many of which are bitter acids

The following data on the composition of lichens are mainly based on the compilation by Rabotnov and Govorukhin (1950) in the Russian handbook "Forage Plants of Hayfields and Pastures in the U.S.S.R.". It is to be noted that the composition of the reindeer lichens is fairly well known, while analyses of epidendric lichens are few and, therefore, partly very preliminary.

<u>Protein content</u>

According to the Russian authors the protein content of different lichen groups is as follows (percent of dry weight):

Epidendric lichens (*Alectoria, Usnea, Evernia*)	6.8 – 7.8%
Reindeer lichens, average,	2.5 – 2.9
Cetraria islandica and allied species	3.5 – 5
Cladonia gracilis agg. (incl. *C. ecmocyna*)	4.5

As to species, Räsänen (1928) reported 4.14 and 7.31 percent in *Alectoria* "*prolixa*" and Florovskaya (1939) 7.31 to 7.77 percent in *A. "chalybeiformis"*.

In spite of variations we may conclude that the protein content of *Alectoria* species attains fairly good levels, being two to three times higher than in the true reindeer lichens. However, in most experiments the digestibility of lichen proteins has proved to be negative or very low (one to two percent). No experiments with solely epidendric lichens are known to the writer, but they are not expected to give results essentially different from the reindeer lichens.

Mineral content

Only one incomplete analysis of epidendric *Alectoria* is reported by Rabotnov and Govorukhin. It is compared with the reindeer lichens:

	Total Mineral Content per cent of dry weight	Per Cent of Total	
		P_2O_5	CaO
Alectoria "*chalybeiformis*"	1.01	15.0	35.0
Reindeer lichens	1.2 – 2.2	2.8 – 5.4	0.5 – 5.2

Räsänen (1928) determined the total amount of minerals in *Alectoria* "*prolixa*" to be 1.0 percent.

These data indicate that the total mineral content in epidendric Alectoriae is about the same or lower than in the ground lichens. On the other hand, the phosphorus and calcium contents are essentially higher in *Alectoria* than in *Cladonia*.

The major portion of minerals is formed by silica (SiO_2) and, therefore, the digestibility of minerals is comparatively low. One experiment on this subject in the U.S.S.R. yielded 36.5 percent (in *Alectoria ochroleuca*, a ground lichen).

In foliose *Parmelia* species very high mineral contents have been reported.

Carbohydrates

Some Russian analyses are summarized below:

		Percent of Dry Weight		
		polysaccharids		
	monosacch.	hemicell.	cellulose	total
Alectoria (l anal.)	0.6	81	1.6	84
Reinder l. (ll an.)	0.3 – 0.4	56 – 83	4 – 7.3	82 – 93

No great difference is probably found between the two groups of lichens. Lichen is almost pure carbohydrate nourishment, mainly composed of hemicellulose.

In the numerous experiments conducted, the reindeer's digestibility of carbohydrates has varied from 60 to 90 percent. For cow and goat their digestibility is considerably lower and still lower for sheep (about 40 percent). For pigs, they are almost indigestible.

Fat content

The amount of "raw fat" given in analyses also includes the often bitter lichen substances. Some Russian data on the quantity of raw fat (percent of dry weight):

Alectoria "*jubata*"	1.3 – 1.4%
Reindeer lichens	0.4 – 5.5
Parmelia spp.	17. – 19.

The amount of fat is usually negligible. There seems to be a positive correlation between low fat content and good palatability. Thus the low palatability of *Parmelia* species is probably partly caused by their high acid content, which makes these lichens too bitter. The slight bitterness of reindeer lichens and epidendric *Alectoria* does not seem to be harmful.

Regional differences have been noted in chemical contents of lichens. Therefore, it is possible that in Wells Gray Park some local peculiarities might be revealed. Especially *Alectoria oregana* and *A. sarmentosa*, which probably have not been analyzed before, may yield results different from the above values.

VIII. OCCURRENCE OF GROUND LICHENS IN THE PARK

Ground lichens, the staple food of caribou in most caribou districts, are very poorly represented in Wells Gray Park. However, they are not completely lacking there.

The reindeer lichens (*Cladonia*, subgenus *Cladina*) were found in all zones, but only very locally. In the hemlock zone *Cladonia arbuscula* spp. *beringiana* (concerning the nomenclature, see Ahti, 1961) was found on the Murtle River at Mushbowl and Helmcken Falls, at Hemp Creek (very sparsely), on the edge of the Clearwater Canyon south of the park, on Azure Lake, on Murtle Lake, and at Blue River. *Cladonia rangiferina* is frequently associated with it, but sparser. *Cladonia mitis* is present at Murtle Lake and *Stereocaulon paschale* at Murtle Lake and at Azure Lake. However, only at Azure Lake and in the rock-beds on south slope of Ramsay Mtn., Murtle Lake (plus in lodgepole pine stands at Blue River, outside the park) do reindeer lichens attain some abundance.

The last-mentioned places (except Blue River) are also grazed by caribou. On the rock-beds of Ramsay Mtn. only some scattered lightly grazed patches were found, while near the middle of the southern shore of Azure Lake a few small rock outcroppings, 100 to 200 yards in from the lake, are heavily grazed. It is apparent that the caribou feed regularly on the lichen mats of these outcrops every year (in fall and spring).

The subalpine zone is also very poor in reindeer lichens. Scattered patches of *Cladonia mitis* were in meadows near Fight Lake, and

Battle Mountain, but were not found at all on Fish Lake Hill. In subalpine meadows and open woodlands the grey cup-lichen, *Cladonia ecmocyna* var. *intermedia*, is common and often abundant. In dry subalpine meadows *Cetraria subalpina*, *C. islandica*, and *C. crispa* are common. All these lichens are certainly palatable for caribou, though no signs of grazing were seen in them. It should be noted that the subalpine ground lichens are accessible to caribou chiefly in summertime (cf. Edwards and Ritcey, 1959), when the animals prefer vascular forage richly available in the same meadow habitats.

In the alpine zone many ground lichens are found. The major species include *Cladonia ecmocyna* var. *intermedia*, *Cetraria islandica*, and *C. crispa*. *Cladonia mitis* and many other species are sparsely present. The importance of alpine lichens to caribou seems to be insignificant.

The main reasons for the scarcity of ground lichens in the park are undoubtedly due to a fertile soil and sparsely revealed bedrock. The reindeer lichens are most abundant in areas with sandy or granitic ground and with cool climate (Ahti, 1961). Also, in Wells Gray Park the growing period of reindeer lichens is short because of thick snow cover, long winters and rather dry summers.

IX. SUGGESTIONS FOR CARIBOU WINTERING RANGE MANAGEMENT

With more intensive land use in the future, special management of lands used by mountain caribou may prove to be necessary. Silvicultural measures are often essential to wildlife management. Being a climax animal the caribou is easily influenced by the activities of man. Fires and clearcut logging could never favour caribou which live on arboreal lichens in winter. The elimination of these two factors in caribou ranges is of primary importance for successful caribou management. Some other general principles are outlined below:

1. The upper subalpine zone should be entirely protected from cutting since the regeneration of forests is very slow in that zone. Destroying timberline stands probably results in permanent meadows, which may be good summer ranges but of no use in winter time. In many countries timberline forests have been designated as shelter forest belts, where commercial cutting is prohibited by law. In British Columbia such areas might act as excellent caribou game preserves.

2. In the lower subalpine zone and in the upper hemlock zone selective cutting might be allowed. It may even improve the production of arboreal lichens to some extent, if the ages of tree stands are not lowered too much.

3. In general, the great density of forests in Wells Gray Park is one of the most important conditions limiting the abundance of lichens on lower twigs. Therefore, moderate thinning of forests by selective cutting would be profitable for both lichens and trees. Even in the upper subalpine zone

cautiously conducted thinning could prove to be useful.

4. However, thinning should not be made according to purely silvicultural principles. It seems to be advisable not to take out all dead or old trees, particularly such trees that are rich in lichens and are thus centres of dispersal. It is subalpine fir and spruce that have lower twigs and thus lichens near the ground in greater amount than other tree species. Richly branched individuals of fir and spruce might be left growing.

5. Any disturbance of critical points on major migration routes, as, for instance, the area where caribou cross the Murtle River, should be avoided. The wintering districts situated in the valley floors (Murtle Lake, Azure Lake) should also be preserved in undisturbed condition as much as possible.

6. The forests of lower hemlock zone (Hemp Creek, etc.) do not seem to offer much potential for winter food for caribou. Therefore, the upper and lower subalpine zones may be regarded as optimal, the upper hemlock zone as submarginal and the lower hemlock zone as marginal range for mountain caribou.

7. Experimental cutting plots may prove to be useful in studies on productivity of lichens. Such plots should be situated in each wooded zone and in different habitats. The effects of various intensities of thinning, dispersal of lichens from lichenous trees, changes in lichen cover on artificially dried-up trees, falling of basal branches in different light conditions, etc., are suitable objects for study in these plots. Other silvicultural and wildlife management experiments might be included in the same program.

X. SUMMARY

Distribution and abundance of lichens on trees in Wells Gray Park were the main objects of the present study.

The upper subalpine zone proved to be richest in epidendric lichens, which condition is due to the slow growth, the great age (to 250 years), the high summer humidity and the low density of its forests. The tree species, subalpine fir and Engelmann spruce, with their numerous basal twigs, are also favourable to the occurrence of lichens. The most abundant fruticose species are *Alectoria oregana*, *A. "chalybeiformis"* (identification as yet tentative), *A. jubata*, and *A. fremontii*. Winter food resources for caribou in this zone are excellent and, therefore, availability of food is no restricting factor to considerable increase of the number of caribou. So far these forests are under very light grazing.

The lower subalpine zone is fairly rich in lichens, and the species composition is much the same as in the preceding zone, but other circumstances like the abundance of thicket-forming shrubs (particularly *Rhododendron albiflorum*) make it less favourable as caribou range.

The western hemlock zone, where the caribou also frequent in wintertime, possesses much lower amounts of available lichen than the subalpine zones. High density of forests, their good growth, and the high frequency of tree species that are poor sites for fruticose lichens result in low value of the hemlock zone as caribou wintering range. When compared to the subalpine forests it is also evident that the number of

lower twigs on trees is much smaller in the hemlock zone. However, there are localities like lakeshores, riversides, bogs, moist forests, etc., which may produce considerable amounts of available lichen. The most abundant species include *Alectoria sarmentosa*, *A. jubata*, *A. "chalybeiformis"*, *A. fremontii*, *Ramalina thrausta*, and *Cetraria glauca*. Even in this zone tops of trees usually carry heavy loads of lichen (mainly *A. fremontii*), which is not accessible to caribou in great quantities.

According to data found in literature the palatability and nutritional values of the abundant fruticose, epidendric lichen species of Wells Gray Park are not lower than those of the true reindeer lichens growing on ground. The mineral and protein contents of the epidendric lichens are frequently even higher than those of the reindeer lichens.

Ground lichens are fairly scarce in the park. However, locally (at Azure Lake) they have some importance for caribou in wintertime. The major species are *Cladonia arbuscula* ssp. *beringiana* and *C. rangiferina*.

As to range management it is suggested that the wintering grounds of caribou, i.e., the upper subalpine zone and some parts of the valleys (Murtle Lake, Azure Lake) should essentially be protected from cutting, fires, and excessive human influence. In the lower subalpine zone selective cutting may be practised, at least locally. Most of the hemlock zone is very marginal as caribou range and generally insufficient production of lichen in this zone cannot be improved to any great extent. However, since some parts of this zone are necessary for migrating and wintering caribou, local management is useful. Certain procedures like thinning and leaving dead and other trees rich in lichens standing may increase lichen resources considerably in some places. Experimental cutting with regard to lichen production in different zones is suggested.

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APPENDIX I

Checklist of the Macrolichens in Wells Gray Park

C = common in large areas
S = scattered or locally common
R = more or less rare

The Hemp Creek Valley (outside of the park) is included in the list. Many identifications are tentative.

Alectoria	*fremontii* Tuck.	C
	implexa (Hoffm.) Nyl.	R
	jubata (L.) Ach.	C
	nigricans (Ach.) Nyl.	R
	ochroleuca (Ehrh.) Nyl.	R
	oregana Tuck.	C
	pubescens (L.) Howe	R
	sarmentosa Ach.	C
Baeomyces	*rufus* (Huds.) Rabenh.	R
Cetraria	*canadensis* Ras.	R
	ciliaris Ach.	R
	commixta (Nyl.) Th. Fr.	R
	crispa (Ach.) Nyl.	S
	cucullata (Bell.) Ach.	R
	glauca (L.) Ach.	C
	hepatizon (Ach.) Vain.	S
	islandica (L.) Ach.	S
	merrillii DR.	R
	nivalis (L.) Ach.	R
	pinastri (Scop.) S. Gray	C
	platyphylla Tuck.	S
	scutata (Wolf.) Poetsch.	C
	sepincola (Ehrh.) Ach.	S
	subalpina Imsh.	C
Cladonia	*alpicola* (Flot.) Vain.	R
	amaurocraea (Flk.) Schaer.	R
	arbuscula (Wallr.) Rabenh. ssp. *beringiana* Ahti	S
	bacillaris (Ach.) Nyl.	S
Cladonia	*bacilliformis* (Nyl.) Lang.	R
	bellidiflora (Ach.) Schaer.	S
	botrytes (Hag.) Willd.	R
	cariosa (Ach.) Spreng.	S
	carneola (Fr.) Fr.	S
	cenotea (Ach.) Schaer.	C
	chlorophaea (Flk.) Spreng.	C

	coccifera (L.) Zopf	R
	coniocraea (Flk,) Sandst.	C
	cornuta (L.) Schaer.	S
	crispata (Ach.) Flot.	R
	cyanipes (Sommerf.) Vain.	R
	decorticata (Flk.) Spreng.	R
	deformis (L.) Hoffm.	R
	degenerans (Flk.) Spreng.	R
	digitata Schaer.	R
	ecmocyna (Ach.) Nyl.	
	var. *intermedia* (Robb.) Evans	C
	fimbriata (L.) Fr.	R
	gonecha (Ach.) Asah.	C
	gracilis (L.) Willd.	
	var.*gracilis*	R
	var. *dilatata* (Hoffm.) Vain.	C
	mitis Sandst.	S
	multiformis Merr.	S
	pleurota (Flk,) Schaer.	C
	pyxidata (L.) Fr.	S
	rangiferina (L.) Wigg.	S
	squamosa (Scop.) Hoffm.	R
	subulata (L.) Wigg.	R
	uncialis (L.) Wigg.	R
	verticillata (Hoffm.) Schaer.	R
Coriscium viride (Ach.) Vain.		R
Cornicularia aculeata (Schreb.) Ach.		R
	normoerica (Gunn.) DR.	R
Dactylina madreporiformis (Wulf.) Tuck.		R
Dermatocarpon fluviatile (Wigg.) Th. Fr.		R
Leptogium saturninum (Dicks.) Nyl.		R
Letharia vulpina (L.) Hue		C
Lobaria linita (Ach.) Rabenh.		R
	pulmonaria (L.) Hoffm.	S
Massalongia carnosa (Dicks.) Körb.		R
Nephroma arcticum (L.) Torss.		R
	bellum (Spreng.) Tuck.	R
	helveticum Ach.	
	var. *sipeanum* (Gyeln.) Wetm.	R
	parile (Ach.) Ach.	R
	resupinatum (L.) Ach.	R
Parmelia alpicola Th. Fr.		R
	aspera Mass.	R
	austerodes Nyl.	C
	centrifuga (L.) Ach.	R
	enteromorpha Ach.	C
	exasperatula Nyl.	R
	fraudans Nyl.	R
	incurva (Pers.) Fr.	R

	obscurata Bitt.	R
	olivacea (L.) Ach.	R
	physodes (L.) Ach.	C
	saxatilis (L.) Ach.	
	var. *saxatilis*	R
	var. *divaricata* Nyl.	S
	somediosa Almb.	R
	stenophylla (Ach.) Heug.	R
	stygia (L.) Ach.	R
	subargentifera Nyl.	R
	subaurifera Nyl.	R
	sulcata Tayl.	C
	tubulosa (Hag.) Bitt.	S
	vittata (Ach.) Nyl.	R
Parmeliella	*corallinoides* (Hoffm.) Zahlbr.	R
	lepidiota (Sommerf.) Vain.	R
Parmeliopsis	*aleurites* (Ach.) Lett.	R
	ambigua (Wulf.) Nyl.	C
	hyperopta (Ach.) Vain.	C
Peltigera	*aphthosa* (L.) Willd.	C
	canina (L.) Willd.	S
	horizontalis (Huds.) Baumg.	S
	leucophlebia (Nyl.) Gyeln.	C
	malacea (Ach.) Funck	R
	polydactyla (Neck.) Hoffm.	C
	rufescens (Weis) Humb.	C
Peltigera	*scabrosa* Th. Fr.	R
	scutata (Dicks.) Duby	R
	spuria (Ach.) DC.	R
	venosa (L.) Baumg.	R
Physcia	*adscendens* (Th. Fr.) Oliv.	R
	aipolia (Ehrh.) Hampe	R
	caesia (Hoffm.) Hampe	R
	dubia (Hoffm.) Lett.	R
	lithotodes Nyl.	R
	muscigena (Ach.) Nyl.	R
	sciastra (Ach.) DR.	R
	stellaris (L.) Nyl.	R
Ramalina	cfr. *farinacea* (L.) Ach.	R
	thrausta (Ach.) Nyl.	C
Solorina	*crocea* (L.) Ach.	S
	bispora Nyl.	R
Sphaerophorus	*globosus* (Huds.) Vain.	R
Stereocaulon	*evolutoides* (H. Magn.) Frey	R
	paschale (L.) Hoffm.	R
	tomentosum Fr.	R
Sticta	*fuliginosa* (Dicks.) Arn	R
Thamnolia	*vermicularis* (Sw.) Ach.	R
Umbilicaria	*cylindrica* (L.) Del.	R
	deusta (L.) Baumg.	S
	hyperborea (Ach.) Hoffm.	R

muehlenbergii Ach.	R
polyphylla (L.) Baumg.	R
torrefacta (Lightf.) Schrad.	R
vellea (L.) Ach.	R
Usnea cfr. *glabrata* (Ach.) Vain.	S
hirta (L.) Wigg.	R
Xanthoria candelaris (L.) Arn.	R
elegans (Link) Th. Fr.	R
polycarpa (Ehrh.) Rieb.	R

APPENDIX II

LOCATIONS OF THE SAMPLE PLOTS

Field
No.

Upper Subalpine Zone

28. Battle Mtn., W corner of Fight Lake Meadow. July 21.

29. ” " " " " " " " " "

30. ” " " " " " " " " "

31. ” " between Fight Lake and Caribou Meadows. July 22.

32. ” " SW margin of Caribou Meadows. July 22.

33. ” " N slope of Bull Valley, timberline. July 23.

34. ” " 1 mi. E of Fight Lake. July 25.

39. ” " S side of Fight Lake Meadow. July 28.

40. ” " " " " " " " " "

Lower Subalpine Zone

35. Stevens Lakes cabin. July 26.

36. 1.5 mi. SW of Stevens Lakes cabin. July 26.

37. 2.5 mi. SW of ” " " " "

38. West shore of the uppermost Stevens Lake. July 26.

41. Battle Mtn., SW slope, on trail. July 30.

Hemlock Zone

1. Hemp Creek, end of Green Mtn. Trail. June 17.

2. Murtle River, Mushbowl Falls, S side. June 20.

3. Murtle Lake, NE side of Diamond Lake. June 23.

4. " " N " " " " " "

5. Murtle Lake, SW side of Diamond Lake. June 23.

6. " " SE shore. June 24.

7. " " end of Blue River Trail. June 24.

8. " " on the Blue River Trail 0.5 mi. E of the lake. June 24.

9. " " on the Blue River Trail 1 mi. E of the lake. June 24.

10. " " Patrolman's cabin. June 27.

11. " " 0.5 mi. E of Patrolman's cabin. June 27.

12. " " 1 mi. " " " " " "

13. " " 1 mi. SE of " " " "

14. " " North Arm, 1 mi. up the Murtle River. June 28.

15. " " North Arm, 1 mi. NE of mouth of Vachon Creek. June 28.

16. " " " " NE slope of Ramsay Mtn. June 28.

17. " " 1 mi. E of Diamond Lake. June 30.

18. " " 1.5 mi. E of Diamond Lake. June 30.

19. " " peninsula on S side opposite to Ramsay Mtn. July 1.

20. " " bay on S side opposite to Patrolman's cabin. July 1.

21. " " 0.5 mi. N of the mouth of File Creek. July 1.

22. Blue River, about 5 (?) miles SW of the village, on Fish Lake Hill road. July 13.

23. Hemp Creek, top of hill between Ranger's Station and Dawson Falls on road. July 14.

24. Ditto. SW. slope.

25. Ditto

26. Ditto

27. Azure Lake, SW shore. July 15.