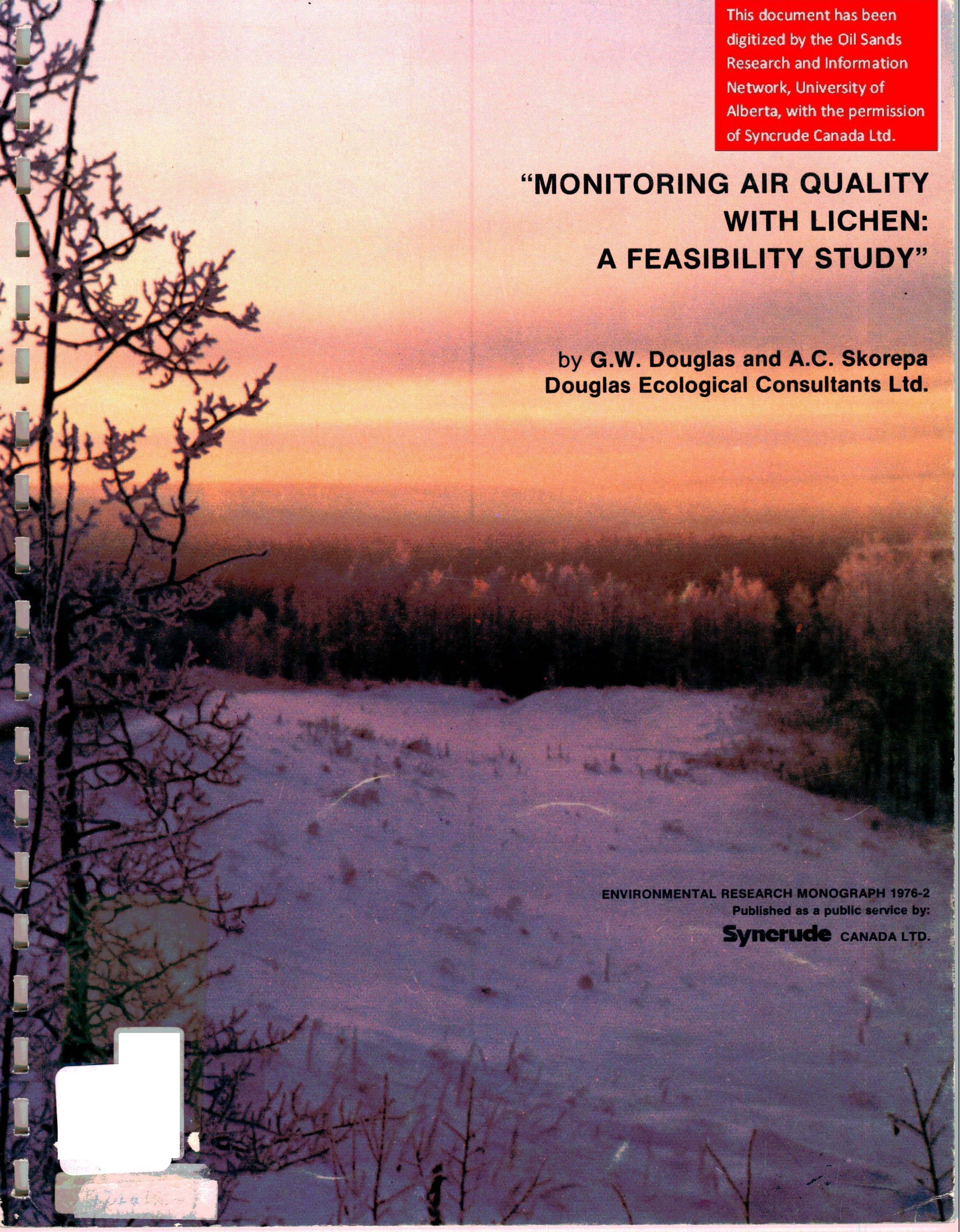

"MONITORING AIR QUALITY WITH LICHEN: A FEASIBILITY STUDY"

by G.W. Douglas and A.C. Skorepa
Douglas Ecological Consultants Ltd.

ENVIRONMENTAL RESEARCH MONOGRAPH 1976-2
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FOREWORD

Syncrude Canada Ltd. commissioned Douglas Ecological Consultants Ltd. to undertake a study of the feasibility of establishing a network of lichen plots. The extent of the impact of atmospheric sulfur on vegetation can be predicted with such a network, since lichens will show signs of stress well before higher plant species. This monograph consists of Douglas's final report to Syncrude, recommending that a such network be established. During 1976 Syncrude followed through on this recommendation.

It is Syncrude's policy to publish its consultants' final reports as they are received, withholding only proprietary technical information or that of a financial nature. Because we do not necessarily base our decisions on just one consultant's opinion, recommendations found in the text should not be construed as commitments to action by Syncrude.

Syncrude Canada Ltd. welcomes public and scientific interest in its environmental activities. Please address any questions or comments to Syncrude Environmental Affairs, Box 5790, EDMONTON, Alberta, T6C 4G3.

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ERRATA

Table 1 should be entitled "Composition of lichen communities on trunks in original sample stands."

Table 2 should be entitled "Composition of lichen communities in resurveyed stands."

Table 3 should be entitled "Composition differences of lichen communities on branches in original sample stands."

Table 4 should be entitled "Composition of lichen communities on branchesin original sample stands."

Table 5 should be entitled "Composition of lichen communities on branches in resurveyed stands."

([a]) Abbreviations used in tables

C: Cover
F: Cover Frequency
PV: Prominence Value

Values listed represent above parameters ± standard deviation.

p. 14 " .. mosaic of our major" should read "..Mosaic of four major.. "
p. 58 " .... *centraria* . . . " " " " " ". . . . *cetraria* ..."
p. 68 "..F. Leblank" " " " " "..F. Leblanc".

AUTHOR'S NOTE

During the summer of 1975 a study of the technical and economic feasibility of establishing a biological monitoring grid network using lichens was undertaken by Douglas Ecological Consultants Ltd. for Syncrude Canada Ltd. in the Fort McMurray region. This study was not designed to examine lichen diversity or abundance nor to detect any changes that may have already taken place in the region. As a result of the 1975 study a lichen monitoring network was considered feasible and was established in 1976. This biological monitoring network will enable detection of changes in lichen diversity and abundance, thus providing an "early warning system" with respect to future biological changes in the region.

George W. Douglas
Douglas Ecological Consultants
Victoria, B.C.

ABSTRACT

A study was undertaken in 1975 to determine the scientific, technical and economic feasibility of establishing air pollution effect gradients using lichenological methods on a radially arranged pattern of observation sites.

The data acquired from 12 lichen sample plots indicate that the flora is sufficiently rich and wide-spread to allow establishment of a lichen air quality monitoring system. A grid network, containing 56 permanent plots, will provide adequate coverage of the region. Partial resurveys should be conducted annually, at least during the first years of the Syncrude plant's operation. Complete resurveys will only be required if a partial resurvey indicates adverse changes are occurring.

1. INTRODUCTION

The sensitivity of lichens to air pollution was first noted in Paris more than a century ago (Nylander, 1866). During recent years, botanists have analyzed lichen populations around major sources of pollution to determine how the lichens have been affected. They have also been interested in finding species that are most sensitive to air pollution and that possibly may be used as biological indicators of air pollution. Some of these studies have been conducted in North America (Brodo, 1966; Rao & LeBlanc, 1967; LeBlanc & DeSloover, 1970; Nash, 1971, 1972; LeBlanc, *et al* , 1972; Mathis & Tomlinson, 1972; LeBlanc, *et al*, 1974). Studies in Europe include Skye (1958), Fenton (1960, 1964), Gilbert (1965, 1970), Skye & Hallberg (1969), and Hawksworth & Ross (1970). Ferry, *et al*, (1973) have summarized the literature.

Past studies of lichens in relation to air pollution have always been conducted around long established sources of pollution. Many of these pollution sources have created "lichen deserts" in immediately adjacent areas, lending themselves nicely to the construction of lichen distribution maps, or to the formulation of zones of pollution based on the gradual appearance of certain species and the number of species in lichen communities at varying distances from the pollution source (Hawksworth & Rose, 1970). DeSloover & LeBlanc (1968) developed a statistic called the Index of Atmospheric Purity, in which pollution zones are mapped and characterized by certain species which were found to be sensitive or, in some cases, resistant to air pollution.

Lichens are prominent in the floras of most areas of the earth. Due to their sensitivity to air pollution, researchers are often able to determine if the air is relatively pure or not by noting the composition and luxuriance of a lichen flora within a given region. Lichens may provide an "early warning system" indicating that air pollution is promoting biological changes in the ecosystem. This prompted Gilbert (1970), working in England, to suggest that people with respiratory disorders should try to live in areas having a rich lichen flora. He also suggested that farmers and city planners should select pollution resistant strains of rye and shade trees if their areas are devoid of lichens. Other advantages in studying lichens in relation to air pollution includes: 1) a given lichen flora reflects the average, cumulative effects of air pollution over a long period of time, 2) data from lichen studies supplement those gathered by SO_2 monitoring devices, and, lichens are also excellent for comparative photographic records over a period of time, since they do not change appreciably (aside from limited growth) from season to season or year to year as do most other plants.

2. OBJECTIVES

1. To determine the scientific, technical and economic feasibility of air pollution effect monitoring using lichens in association with air monitoring sites.

2. To determine the scientific, technical and economic feasibility of establishing air pollution effect gradients using lichenological methods on a radially arranged pattern of observation sites.

3. To add to Syncrude's general inventory of environmental information by the collection of lichen floristic data.

3. METHODS

3.1 Data Analysis

Twelve sampling plots were established, ten of which were located in spruce communities. Associations dominated by white spruce *(Picea glauca)* and by black spruce *(P. mariana)* are the most common and widespread in the Fort McMurray area. In some local situations larch *(Larix laricina)* is more abundant than spruce and displays a similar lichen flora; consequently larch communities can be used in areas that lack an adequate spruce population. Of the two non-spruce areas sampled in this study, one was a larch stand, while the other was an aspen *(Populus tremuloides)* community. The aspen community was situated adjacent to a sulfur dioxide monitoring station; this location may provide an opportunity to correlate atmospheric SO_2 readings with reactions in the lichen flora. Aspen also supports species not found on spruce, a circumstance which adds to the diversity of species studied. Two disadvantages of using aspens, however, are that they do not provide a good substrate (habitat) for lichens in the study area and that they are less widespread than spruce.

At each plot, 40 permanent quadrats were established—20 on trunks and 20 on branches. The selection of a stand was based on the availability of both suitable branches and trunks. Only living, apparently healthy trees with a diameter at breast height (DBH) of greater than 12 cm were used. Permanent trunk quadrats were established within a 10 by 20 cm wire rectangle strung on nails driven into the trees. Quadrats were divided into eight equal sections and estimates of cover, frequency (number of individual thalli per quadrat) were made. The abundance figure was often difficult to determine when thalli merged or when large numbers of small thalli were present. In such cases, abundance was recorded as numerous. One or two (rarely six) trunk quadrats were placed on each tree. It is best to use no more than two quadrats per tree. This lessens the chances of losing too many quadrats due to the destruction of a few trees on the plot.

The frequency and cover values obtained in this study were converted to prominence values, both for easy recognition of the most prominent or important species in a given plot and for possible future use in analyzing changes in the lichen flora. Prominence values were calculated by multiplying cover by the square root of the frequency of each species in each plot. This index is a modification of the procedure used by Beals (1960).

Each quadrat was marked with a plastic tag on which the plot and quadrat numbers were recorded. Trees within each plot were marked with surveyors' flagging tape and their position was mapped to facilitate relocation. Color photographs were taken of each quadrat using a single lens reflex camera and natural light. Plot and quadrat numbers were included in each photograph.

Permanent branch quadrats were established using a 25 cm segment of a branch. The 25 cm segment, measured from the end of the branch, was subdivided into five segments to facilitate quantitative estimates. Frequency and abundance data were recorded for each branch quadrat and 10 branches were photographed on each plot.

3.2 Plot Locations

Eight of the 12 plots established during 1975 were located south of the Syncrude lease along the Fort McMurray -

Fort McKay highway (Figs. 1, 2, 3, and 4). The remaining four plots (plots 9-12) were located along the southern boundary of the Syncrude lease (Figs. 1 and 5).

3.3 Taxonomic Considerations

There are few taxonomic problems involving the lichen flora of the Fort McMurray area, but some difficulty is encountered in the field identification of several groups. *Alectoria, Ramalina,* and *Usnea* are not well known in North America and even if they were better known, intermediate specimens or chemical characters used for identification make some of them difficult or impractical to identify in the field. All but two specimens of *Alectoria* examined and collected were *A. glabra,* but other species *(A. fuscescens, A. fremontii, A. nadvornikiana)* could occur and should be looked for during future work. The major problem with *Ramalina* in the field is that a small *R. fastigiata* could be mistaken for *R. minuscula*. *Usnea* is the most difficult genus. The species may be divided into two groups. The most common are the "tufted" Usneas, which are not much longer than broad (rarely over 10 cm long). This group of poorly defined species may someday be lumped into one or two species. It is impractical to try to differentiate these forms in the field, since the number of individuals is great and since they must be partly destroyed for chemical identification. It is best to refer to the group as "tufted" Usneas. The second, less common, group may be differentiated as "pendulous" Usneas (much longer than broad). These grow mostly on larch trees and consist mainly of *Usnea alpina*. Squamules of *Cladonia* sometimes occur in trunk quadrats near the ground. These fragments are not identifiable.

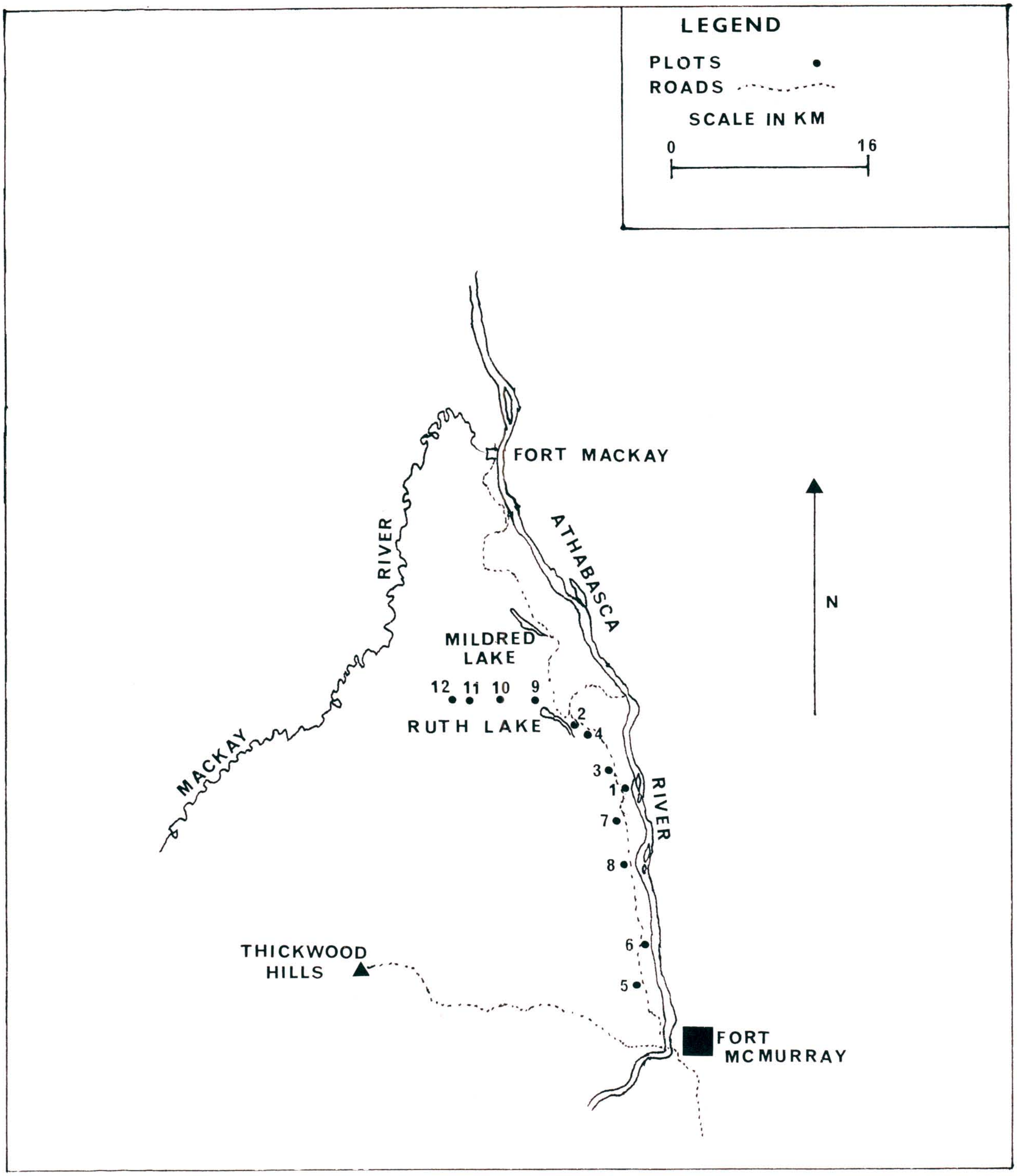

Figure 1. Location of plots established during 1975.

Figure 2. Detailed location of plots 1,3,7 and 8.

Figure 3. Detailed location of plots 2 and 4.

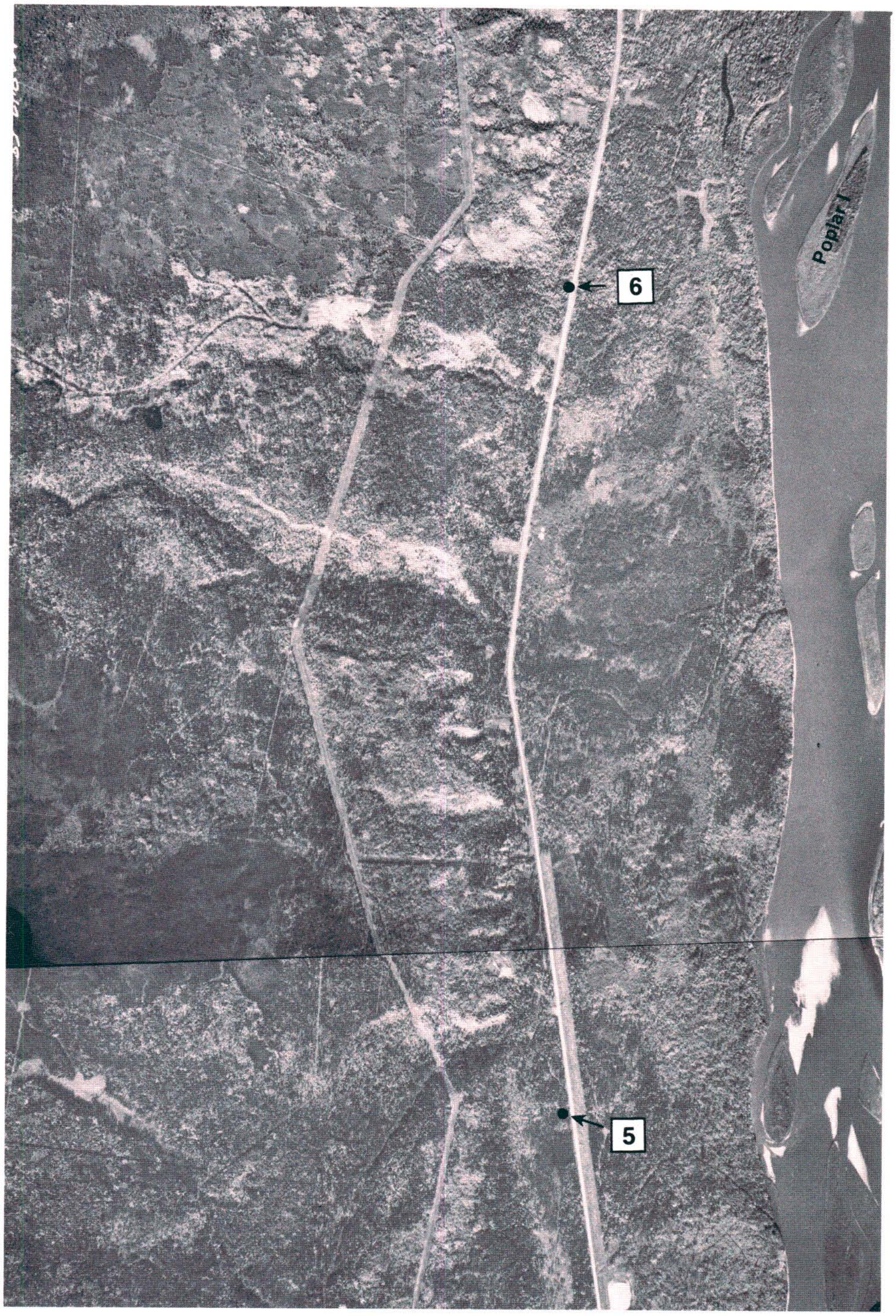

Figure 4. Detailed location of plots 5 and 6.

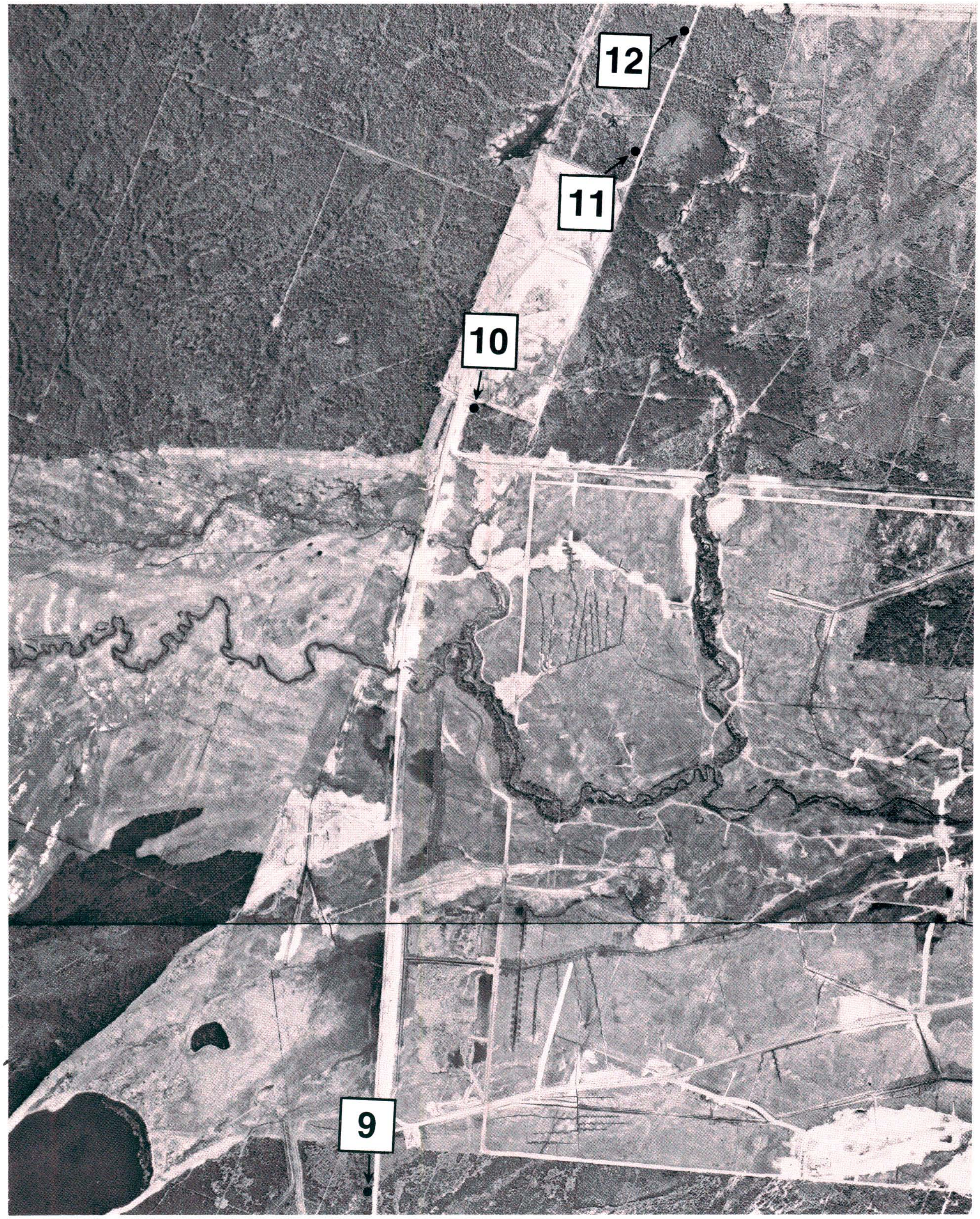

Figure 5. Detailed location of plots 9,10,11 and 12.

Nomenclature, authorities, taxonomy, and common names follow Moss (1959) for vascular plants, Crum *et al* (1973) for mosses, and, with the exception of *Anaptychia* and *Cladina*, Hale and Culberson (1970) for lichens.

4. RESULTS

4.1 General Vegetation of the Area

In the Fort McMurray area a mosaic of our major forest types may be distinguished (Fig. 6). These types are dominated by either white spruce *(Picea glauca)*, black spruce *(Picea mariana)*, jack pine *(Pinus banksiana)*, or aspen *(Populus tremuloides)*.

4.1.1 White Spruce Forest Type

The white spruce forest type is widespread in the area and occurs mainly on well-drained, mesic to moderately dry glacial till deposits (Fig. 7). The several stands examined during this study had a white spruce canopy cover ranging from 30 to 60%. Occasionally aspen or balsam poplar *(Populus balsamifera)* may occur as a minor component in the canopy. Tree reproduction in the understory consisted almost solely of white spruce.

Prickly rose *(Rosa acicularis)* and buffalo-berry *(Shepherdia canadensis)* are the most prominent species in the tall shrub stratum. Low-bush cranberry *(Viburnum edule)* and beaked willow *(Salix bebbiana)* are also consistent but less abundant shrubs in this forest type.

The herbaceous stratum is dominated by twin-flower *(Linnaea borealis)*, bunchberry *(Cornus Canadensis)*, and bastard toad-flax *(Geocaulon lividum)*. A dense carpet of mosses (mainly *Pleurozium schreberi* and *Hylocomium splendens*) usually occurs in the stands.

Figure 6. Typical vegetation mosaic in the Fort McMurray region. White spruce and aspen dominate the better drained sites while black spruce dominates the poorly drained sites.

Figure 7. An example of a white spruce stand.

The lichen flora of the white spruce forest type is relatively rich and typical of boreal regions. *Parmelia sulcata* and *Usnea sorediifera* are the major species on most branches and tree trunks. *Hypogymnia physodes* is also important on the latter substrate. The only consistent ground lichen is *Peltigera aphthosa*. Large downed logs in this forest type are often covered with *Parmeliopsis ambigua*, *Cladonia* species, and *Hypogymnia physodes*.

4.1.2. Black Spruce Forest Type

The black spruce forest type is also widespread in the Fort McMurray area and is associated with poorly drained, moist sites (Fig. 8). Stands of this type are dominated by black spruce with canopy covers of 30 to 80%. Larch is often an important species in these stands.

Labrador tea *(Ledum groenlandicum)* is usually the major species in the tall shrub stratum. Important low shrub and herb species include bog cranberry *(Vaccinium vitis-idaea)*, marsh reed grass *(Calamagrostis canadensis)*, and woodland horsetail *(Equisetum sylvaticum)*. Mosses often provide a nearly continuous cover on the forest floor. The most frequent species encountered in the stands examined was *Pleurozium schreberi*. Important associates in the cryptogamic stratum include *Sphagnum sp.*, *Tomenthypnum nitens*, *Aulocomnium palustre*, and *Dicranum sp.*

The lichen flora of the black spruce forest type is relatively rich and quite similar to that found in the white spruce forest type. *Parmelia sulcata* and *Usnea sorediifera* are the most important species on branches and tree trunks. *Evernia mesomorpha* is also frequent on branches while *Hypogymnia physodes* is common on tree trunks. Prominent ground lichens include *Peltigera aphthosa*, *Cladonia gracilis*, *C. mitis*, and *C. rangiferina*. Rotten logs are often overgrown by *Parmelia sulcata*, *Hypogymnia physodes* and *Cladonia* species (Fig. 9).

Figure 8. An example of a black spruce stand.

4.1.3. Aspen Forest Type

The aspen forest type is quite common in the area, due to the frequent fires that have occurred in the past (Fig. 10). These stands are dominated by a closed canopy of aspen. Paper birch *(Betula papyrifera)* is also a frequent, but less important associate.

The tall shrub stratum in the stands examined was well developed and dominated by low-bush cranberry, beaked hazelnut *(Corylus cornuta)*, prickly rose, green alder *(Alnus crispa)*, and service-berry *(Amelanchier alnifolia)*. Major species in the low shrub and herb stratum include twin-flower, wild sarsaparilla *(Aralia nudicaulis)*, and showy aster *(Aster conspicuous)*. Few mosses, other than *Brachythecium* species at the base of aspens, occur in this type.

Due to the extremely smooth bark of aspens in the area this forest type is extremely depauperate with respect to lichens. Only one stand was encountered which had bark sufficiently rough textured to support lichen growth (Fig. 11). In this stand *Physcia aipolia*, which is rare on conifers, occurred quite frequently. Several other lichens *(Physcia adscendens*, *Caloplaca* species, *Candelariella vitellina*, and *Xanthoria polycarpa)* were also encountered solely in this aspen stand.

4.1.4. Jack Pine Forest Type

This forest type is less common in the area, occurring mainly on sandy ridges. Since an aerial reconnaissance readily indicated that this forest type could not be used for a grid network in the area no stands were sampled. In addition the two jack pine stands briefly examined on the ground had a relatively poor lichen flora compared to the spruce stands.

Figure 9. Parmelia sulcata dominates this fallen tree in a black spruce stand.

Figure 10. An example of an aspen stand.

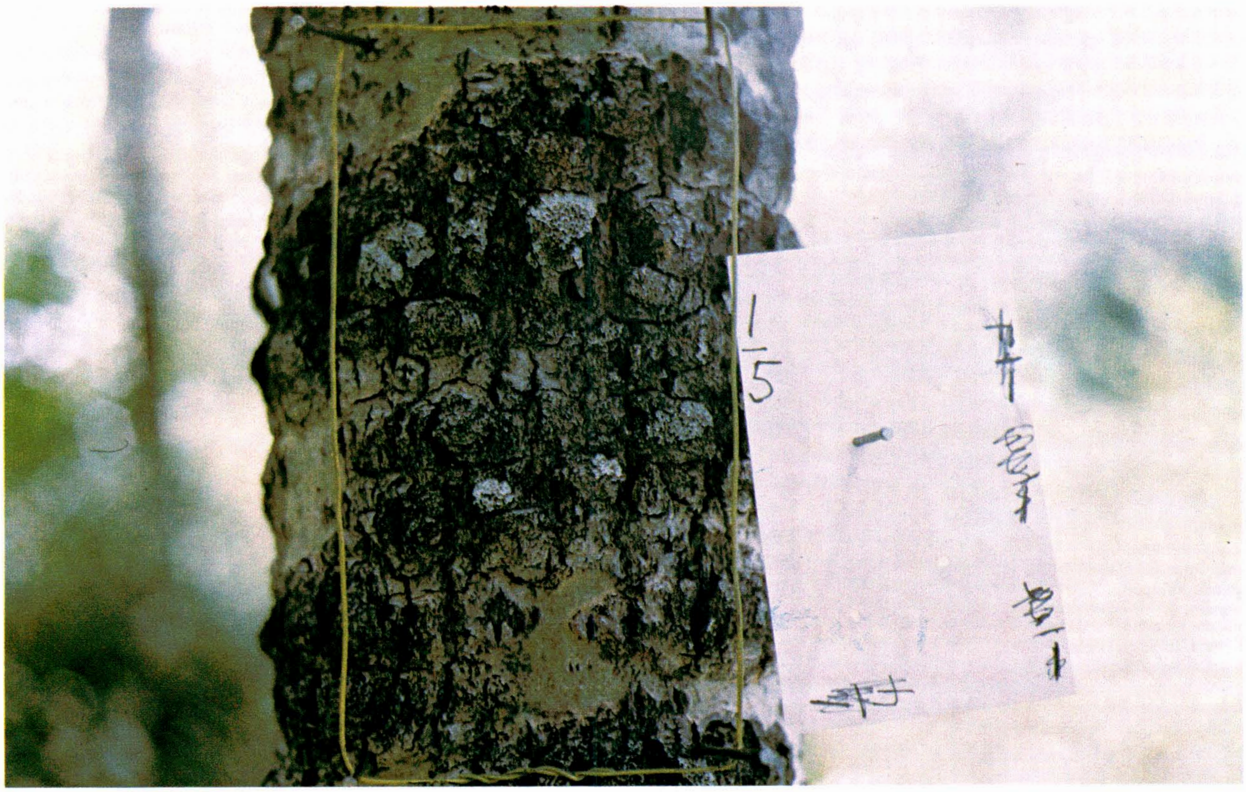

Figure 11. *Physcia adscendens* and *P. aipolia* are the only conspicuous lichens in this aspen quadrat.

4.2 Lichens Used in the Study

4.2.1. Aspen Forest Type

In the single aspen stand examined, the foliose lichens *Physcia adscendens* and *P. aipolia* were the dominant species. Fruticose lichens, which were very prominent on conifers, were virtually absent on aspen. The species of *Physcia* grow in association with orange and yellow crustose lichens (*Calaplaca* and *Candelariella*) and with the foliose, orange lichen *Xanthoria polycarpa*. Quantitative data are easily obtained for these lichens, but photography is of value only with *Physcia* species, since the others are too small (Fig. 11). Aspen is a poor subject for lichenological studies in the Fort McMurray area, because it supports a relatively poor flora of mostly small species.

4.2.2. Black and White Spruce Forest Types

The lichen vegetation on conifers is rich in the Fort McMurray area. Several genera and growth forms are of value in this study. Fruticose lichens including *Evernia mesomorpha*, *Alectoria glabra*, *Ramalina fastigiata*, *R. minuscula*, and especially *Usnea* species are common on the branches (Fig. 12). *Parmelia sulcata* and *Hypogymnia physodes* are the most common foliose species on branches. All of the branch lichens may also grow on trunks of spruce trees, but *Alectoria* and *Ramalina* are much less common. *Parmelia sulcata*, *Hypogymnia*, *Evernia* and *Usnea* are the most important trunk species throughout the area (Figs. 13 and 14). These large lichens are easily photographed and are the most important to the study. Less conspicuous foliose lichens are sometimes present and may be of importance on some of the trees. These include *Centraria halei, C. pinastri, Parmelia subaurifera,* and *Parmeliopsis* species.

The crustose lichens (*Lecanora, Lecidea, Rinodina*) are infrequent and are usually overgrown by larger species. They may be included in quantitative field data but are of no use for photographic records.

4.3 Data Analysis

4.3.1. Trunk Quadrats

Thirteen species occurred on aspen at plot one. Most of these were insignificant, having prominence values of less than one. The dominant species were *Physcia adscendens* and *P. aipolia* with prominence values of 24.7 and 19.0, respectively (Table 1). The only other important species at this plot was *Caloplaca holocarpa*, with a prominence value of 12.2. This is the highest prominence value for any crustose lichen found in the study.

The larch trees at plot 9 were dominated by *Evernia mesomorpha, Parmelia sulcata,* and "tufted" Usneas (Table 1). The prominence value (145.8) for *Parmelia sulcata* was the highest found in the study for that species. Prominence values for *Evernia* (20.4) and *Usnea* (67.8) were also among the highest found, being exceeded only in black spruce communities. Only 7 species were found on larch, but the three dominants were abundant and luxuriant.

Three plots were established in black spruce communities, which supported 10-11 species per plot. The quadrats were dominated by "tufted" Usneas. *Usnea* at plot 2 had a prominence value of 323.8, which was the highest value for any species recorded in the study (Table 1). The lowest prominence values for *Parmelia sulcata* were recorded on black spruce.

Figure 12. *Evernia mesomorpha*, "tufted" Usneas, and *Hypogymnia physodes* dominate this black spruce branch.

Figure 13. *Parmelia sulcata* is the major species in this white spruce quadrat.

Figure 14. This black spruce quadrat is dominated by "tufted" Usneas, *Parmelia sulcata* is also conspicuous in the lower part of the quadrat.

Table 1. Composition of lichens on trunks in original sampled stands.

	Plot 1 - Aspen			Plot 2 - Black Spruce		
Species	C[a]	F	PV	C	F	PV
Alectoria glabra				0.9±1.3	31.3±39.6	7.3±11.7
Caloplaca cerina	0.1±0.5	5.0±22.4	1.0±4.5			
Caloplaca holocarpa	1.3±1.2	81.9±29.4	12.2±12.5			
Candelaria concolor	0.01±0.02	0.6±2.8	0.02±0.09			
Candelariella vitellina	0.13±0.14	31.9±29.1	0.9±1.2			
Cetraria halei				0.3±0.5	15.0±20.1	1.7±3.1
Cetraria pinastri				0.3±0.3	45.6±33.5	2.3±3.3
Cladonia spp.				0.05+0.2	1.3+5.6	0.3+1.1
Evernia mesomorpha				3.7±7.9	53.1±41.3	35.0±79.4
Hypogymnia physodes				0.5+0.8	26.3+30.9	3.8+6.6
Lecanora allophana				0.01±0.02	1.3±5.6	0.03±0.1
Lecidea glomerulosa	0.09±0.2	4.7±8.3	1.6±1.0			
Parmelia subaurifera	0.07±0.2	1.3±3.9	0.3±0.8			
Parmelia sulcata	0.2±0.6	3.8±10.0	0.9±3.8	1.8±3.4	41.9±36.8	16.3±34.1
Parmeliopsis ambigua				2.1±7.3	16.3±26.3	17.7±63.6
Pertusaria multipuncta	0.06±0.3	1.3±5.6	0.3±1.4	1.0±4.0	7.5±24.5	9.4±40.2
Physcia adscendens	2.5±1.9	88.8±25.6	24.7±18.2			
Physcia aipolia	2.5±2.4	45.6±28.5	19.0±21.2			
Physcia orbicularis	0.07±0.2	2.5±6.5	0.3±0.8			
Usnea ssp. (tufted)				32.4±16.0	98.1±8.4	323.8±160.0
Xanthoria polycarpa	0.4±0.1	1.9±4.6	0.2±0.4			

Table 1. Continued

	Plot 3 - White Spruce			Plot 4 - Black Spruce		
Species	C	F	PV	C	F	PV
Alectoria glabra				0.4±0.8	12.5±18.6	2.4±6.0
Cetraria halei				0.01±0.04	0.6±2.8	0.04±0.2
Cetraria pinastri	0.2±0.2	21.3±21.9	1.1±1.4	0.1±0.1	13.1±16.5	0.5±0.8
Cladonia spp.	0.01±0.04	1.3±5.6	0.05±0.2			
Evernia mesomorpha				2.0±1.2	53.8±21.9	15.6±9.9
Hypogymnia austerodes				0.1±0.3	3.8±11.5	0.6±1.9
Hypogymnia physodes				0.2±0.4	13.8±19.0	1.2±2.6
Parmelia subaurifera	0.5±0.9	26.3±32.2	3.8±7.3	0.03±0.1	0.6±2.8	0.1±0.4
Parmelia sulcata				0.3±0.3	20.6±25.7	1.7±2.5
Parmeliopsis ambigua				0.1±0.1	6.3±13.1	0.3±0.8
Pertusaria multipuncta	0.2±0.6	7.5±23.4	1.8±5.9			
Ramalina fastigiata	0.01±0.02	0.6±2.8	0.4±1.1	0.2±0.7	5.6±16.0	1.7±2.6
Ramalina minuscula	0.02±0.1	4.4±13.6	0.1±0.3			
Usnea spp. (tufted)	0.5±0.5	50.0±36.1	4.5±5.2	7.0±5.9	90.6±19.4	68.6±59.9
Usnea alpina				0.3±1.1	4.5±11.8	1.8±7.9

Table 1. Continued

	Plot 5 - White Spruce			Plot 6 - White Spruce		
Species	C	F	PV	C	F	PV
Alectoria glabra	1.0±0.7	22.5±30.5	7.8±15.9	0.7±1.0	24.4±27.9	4.9±8.0
Cetraria halei				0.03±0.1	1.25±3.9	0.1±0.4
Cetraria pinastri				0.1±0.2	15.0±19.7	0.7±1.1
Evernia mesomorpha	1.8±0.9	75.0±22.2	15.6±8.0	1.2±0.9	73.1±35.7	11.2±8.4
Hypogymnia austerodes	1.8±3.0	25.0±26.3	12.3±20.0	8.9±0.6	18.8±24.5	6.5±11.5
Hypogymnia physodes	0.03±0.1	1.3±5.6	0.1±0.6			
Parmelia flaventior				4.6±20.6	5.0±22.4	46.0±205.7
Parmelia subaurifera	0.01±0.2	8.8±14.7	0.6±1.4	0.04±0.1	4.4±9.3	0.2±0.3
Parmelia sulcata	5.4±6.0	89.4±12.4	52.3±58.9	182.0±9.1	1800.0±90.0	1784.0±89.2
Ramalina farinacea				0.6±2.0	9.4±19.0	1.1±2.6
Ramalina fastigiata	0.2±0.3	9.4±18.1	1.0±2.2	14.8±0.7	575.0±28.8	124.0±6.2
Ramalina minuscula	0.4±1.1	12.5±18.6	2.8±9.6	0.03±0.1	8.8±21.5	0.2±0.5
Usnea spp. (tufted)	3.3±3.2	83.1±30.2	32.8±32.7	75.0±3.9	1676.0±83.8	768.7±38.4
Usnea alpina	0.3+1.1	4.5+11.8	1.8+7.9			

Table 1. Continued

	Plot 7 - White Spruce			Plot 8 - White Spruce		
Species	C	F	PV	C	F	PV
Alectoria glabra	1.3±1.8	35.0±29.7	10.4±15.9	0.1±0.3	6.9±13.7	0.7±1.6
Cetraria halei	0.2±0.4	10.6±18.7	1.4±2.8	0.1±0.1	3.8±8.2	0.2±0.4
Cetraria pinastri	0.1±0.1	16.9±26.7	0.6±1.0	0.1±0.2	18.8±19.7	0.8±1.2
Cladonia spp.	0.01±0.04	1.9±8.4	0.01±0.3	0.04±0.2	3.1±14.0	0.3±1.3
Evernia mesomorpha	2.0±1.7	80.0±21.6	18.2±17.7	1.3±1.3	70.6±37.0	12.4±12.3
Hypogymnia austerodes	0.4±0.3	20.0±18.8	2.0±2.2	0.5±0.6	25.0±28.1	3.6±5.3
Hypogymnia physodes				0.1±0.3	2.5±11.2	0.5±2.0
Hypogymnia spp.				0.1±0.2	6.9±17.9	0.5±1.5
Lecanora allophana	0.02±0.1	1.3±3.9	0.1±0.2	0.1±0.2	6.9±17.9	0.5±1.5
Parmelia subaurifera	0.3±0.4	19.4±29.7	1.8±3.1			
Parmelia sulcata	5.1±5.1	83.8±26.4	49.0±50.8	12.9±12.0	91.3±16.3	127.0±120.6
Parmeliopsis ambigua	0.01±0.04	0.6±2.8	0.04±0.2	0.01±0.02	0.6±2.8	0.02±0.1
Peltigera aphthosa				0.6±2.7	2.5±11.2	4.2±19.0
Ramalina crinalis				1.4±6.3	5.0±22.4	15.0±62.6
Ramalina farinacea	0.2±0.5	7.5±22.0	1.4±4.4	0.4±1.3	10.0±28.9	4.0±12.5
Ramalina fastigiata	0.1±0.2	6.9±14.9	0.4±1.0	0.6±1.4	21.3±32.0	4.9±13.6
Ramalina minuscula	0.1±0.2	10.6±20.0	0.5±1.2	0.04±0.1	3.8±11.5	0.2±0.8
Usnea spp. (tufted)	2.3±3.0	71.3±38.5	22.2±30.3	1.1±1.4	51.8±42.4	8.5±12.1

Table 1. Continued

	Plot 9 - Larch			Plot 10 - White Spruce		
Species	C	F	PV	C	F	PV
Alectoria glabra				0.03±0.1	1.3±5.6	0.5±0.6
Cetraria halei	0.1±0.2	4.4±10.9	0.5±1.2			
Cetraria pinastri	0.8±1.3	47.5±27.7	4.0±6.1	0.02±0.04	3.8±9.2	0.1±0.2
Evernia mesomorpha	2.2±2.1	70.0±28.5	20.4±21.5	0.03±0.1	1.9±6.1	0.2±0.6
Hypogymnia austerodes	0.6±0.9	21.9±24.6	4.4±6.6			
Hypogymnia physodes	0.2±0.7	3.6±1.4	1.3±5.8	0.3±0.5	10.6±12.4	1.4±3.2
Parmelia subaurifera				0.8±1.0	21.3±29.0	5.8±8.1
Parmelia sulcata	15.6±13.5	94.4±14.9	145.8±138.6	5.3±4.2	96.3±8.2	52.3±42.4
Ramalina minuscula				0.01±0.02	0.6±2.8	0.02±0.1
Usnea spp. (tufted)	6.8±7.8	92.5±17.9	67.8±78.7	4.2±16.7	23.1±21.6	3.3±6.3

Table 1. Continued

	Plot 11 - White Spruce			Plot 12 - Black Spruce		
Species	C	F	PV	C	F	PV
Alectoria glabra	0.5±1.02	11.9±23.8	3.5±7.5	0.8±1.1	34.4±26.6	3.8±3.3
Cetraria halei	0.2±0.1	0.6±2.8	0.1±0.3	0.1±0.1	3.1±6.9	0.1±0.2
Cetraria pinastri	0.1±0.1	12.5±21.8	0.3±0.5	0.3±0.3	50.6± 22.4	2.1±2.4
Evernia mesomorpha	0.5±0.5	26.3±28.4	3.8±6.6	4.4±6.6	38.1±28.2	5.02±5.0
Hypogymnia austerodes	0.5±0.9	13.1±18.4	2.9±7.2	0.5±0.7	21.3±21.1	2.8±4.2
Hypogymnia physodes	0.2±0.5	5.6±14.3	1.2±3.4			
Parmelia subaurifera	1.7±1.7	40.0±34.1	13.6±16.5	0.02±0.1	2.5±6.5	0.1±0.3
Parmelia sulcata	5.4±3.4	77.3±37.1	52.5±35.3	2.4±5.6	54.4±40.0	23.4±55.7
Peltigera aphthosa				0.4±0.7	16.3±29.6	2.2±5.9
Physcia aipolia	0.01±0.04	1.3±5.6	0.1±0.2			
Ramalina minuscula	0.03±0.1	4.4±14.8	0.2±0.9	0.01±0.03	1.3±3.9	0.04±0.1
Usnea spp. (tufted)	3.9±34.5	51.9±34.5	16.2±39.3	8.0±16.3	86.9±27.9	79.3±162.8

The more moist habitat of black spruce stands appears to favour growth to *Usnea* rather than *Parmelia*. *Evernia* was also best developed on black spruce. The usually unimportant species, *Cetraria pinastri* and *Parmeliopsis ambigua*, were well developed at plot 2 with prominence values of 45.6 and 17.7, respectively.

White spruce communities supported the largest number of species having 8-15 species per plot. The dominant species was *Parmelia sulcata* with prominence values of 49.0-145.8.

Other abundant lichens were "tufted" Usneas, with prominence values of more than 30 at most plots, and *Evernia mesomorpha* and *Hypogymnia spp.*

Seven of the plots were resurveyed to determine the accuracy of coverage and frequency estimates and the subsequent prominence values (Table 2). In many cases the differences and the standard deviations were too great to detect slight changes in the lichen flora from one survey to the next (Table 3). For instance, the mean prominence value for "tufted" Usneas at plot 8 was 8.5 ± 12.1. On the resurvey it was 11.3 ± 15.6 for a difference of 2.7 ± 5.1. The original prominence value for *Evernia mesomorpha* at plot 2 was 35.0 ± 79.4. On the resurvey it was 34.2 ± 89.3 for a difference of 7.6 ± 12.7 (Tables 2, 3). Similar differences could be found in every resurvey.

4.3.2. Branch Quadrats

The lichen flora of branches is less diverse than that of trunks. Nineteen species were found in the branch quadrats, while 34 occurred on trunks, but the development of lichens on many branches was very luxuriant. For instance, the branches of larch at plot 9 supported 11 species. They were mostly overgrown by *Evernia*, *Parmelia*, and *Usnea*.

Table 2. Composition of lichens on trunks in resurveyed stands.

	Plot 2 - Black Spruce			Plot 3 - White Spruce		
Species	C	F	PV	C	F	PV
Alectoria glabra	0.9±1.2	31.3±38.2	7.8±11.3			
Cetraria halei	0.2±0.3	13.8±20.6	1.1±2.2			
Cetraria pinastri	0.2±0.3	41.9±34.5	1.8±2.5	0.3±0.5	20.0±16.9	1.5±2.5
Cladonia spp.	0.05±0.2	1.3±5.6	0.3±1.1	0.01±0.02	1.3±5.6	0.03±0.1
Evernia mesomorpha	3.4±8.9	56.9±40.5	34.2±89.3	0.4±21.0	91.9±20.0	9.9±4.4
Hypogymnia physodes	0.4±0.7	21.9±29.5	3.0±6.2	0.03±0.1	1.3±5.6	0.6±2.5
Lecanora allophana	0.0±0.0	0.0±0.0	0.0±0.0			
Parmelia subaurifera				0.4±0.6	23.8±29.2	2.5±4.3
Parmelia sulcata	1.6±3.5	40.6±36.9	15.1±35.0	10.6±11.0	90.6±15.1	103.0±111.1
Parmeliopsis ambigua	2.0±6.2	28.7±26.4	15.9±53.9			
Pertusaria multipuncta	1.0±4.5	6.4±22.8	10.0±44.7	0.2±0.7	8.1±25.1	6.2±40.4
Ramalina fastigiata	0.03±0.1	0.6±2.8	0.09±0.4	0.01±0.02	0.6±2.8	0.4±1.1
Ramalina minuscula				0.2±0.9	5.0±13.7	1.5±6.3
Usnea spp. (tufted)	27.3±15.1	98.1±8.4	272.3±151.5	0.6±0.6	33.5±48.1	5.1±5.3

Table 2. Continued

	Plot 6 - White Spruce			Plot 7 - White Spruce		
Species	C	F	PV	C	F	PV
Alectoria glabra	0.6±0.8	22.5±25.5	4.3±6.0	1.3±1.6	34.4±29.5	10.4±14.5
Cetraria halei	0.03±0.1	1.3±3.9	0.1±0.4	0.5±1.1	11.9±19.7	2.5±5.9
Cetraria pinastri	0.2±0.5	15.0±20.9	1.1±2.1	0.1±0.1	16.9±26.4	0.5±1.0
Cladonia ssp.				0.1±0.1	1.9±8.4	0.1±0.3
Yellow crust				0.02±0.1	1.9±6.1	1.2±0.2
Evernia mesomorpha	1.2±1.0	73.1±35.9	11.2±9.0	2.2±2.3	78.1±28.6	21.0±22.7
Hypogymnia austerodes				0.4±0.4	20.0±19.6	2.1±2.3
Lecanora allophana				0.02±0.1	1.3±3.9	0.1±0.2
Lobaria spp.	4.6±20.6	5.0±22.4	46.0±205.7			
Parmelia subaurifera	0.03±0.1	2.5±5.1	0.1±0.3	0.6±0.4	20.0±30.2	2.0±3.2
Parmelia sulcata	9.6±13.9	90.0±17.5	93.7±139.2	5.0±4.8	84.4±25.0	47.7±46.9
Parmeliopsis ambigua				0.1±0.3	0.6±2.8	0.04±0.2
Ramalina farinacea				0.1±0.2	25.0±11.2	0.4±1.6
Ramalina fastigiata	0.8±1.1	33.8±29.3	6.3±10.5	0.3±0.6	11.3±21.0	1.7±4.9
Ramalina minuscula	0.1±0.4	13.1±27.7	1.2±3.7	0.1±0.2	13.8±24.6	0.6±1.2
Usnea spp. (tufted)	4.5±3.4	85.0±29.7	39.3±32.5	2.0±2.4	71.9±37.6	19.3±24.1

Table 2. Continued

	Plot 8 - White Spruce			Plot 10 - White Spruce		
Species	C	F	PV	C	F	PV
Alectoria glabra	0.4±1.1	6.9±16.5	2.7±7.4	0.04±0.1	2.5±6.5	0.2±0.6
Cetraria halei	0.1±0.1	4.4±9.3	0.3±0.7			
Cetraria pinastri	0.1±0.2	16.9±20.4	0.8±1.3	0.02±0.04	4.4±10.9	0.1±0.2
Cladonia spp.	0.04±0.2	3.1±14.0	0.3±1.3			
Evernia mesomorpha	1.2±1.1	71.3±37.0	11.2±10.0	0.04±0.2	2.5±6.5	0.2±0.6
Hypogymnia austerodes	0.5±0.5	24.4±25.5	3.2±4.2			
Hypogymnia physodes	0.1±0.3	2.5±11.2	0.5±2.4	0.3±0.4	10.6±12.4	1.6±3.4
Parmelia subaurifera				0.9±1.2	21.3±29.0	6.4±9.2
Parmelia sulcata	12.9±14.2	89.4±17.3	127.0±142.4	5.3±3.5	96.3±8.2	52.2±34.9
Parmeliopsis ambigua	0.1±0.02	12.5±2.8	0.4±0.1			
Peltigera aphthosa	0.6±2.5	2.5±11.2	3.9±17.4			
Ramalina crinalis	1.5±6.7	5.0±22.4	15.0±67.1			
Ramalina fastigiata	1.5±2.7	36.9±40.7	13.9±27.5			
Ramalina minuscula	0.02±0.1	3.1±9.0	0.1±0.3	0.2±0.03	25.0±3.9	0.8± 0.1
Usnea ssp. (tufted)	1.2±1.5	51.9±41.6	11.3±15.6	0.6±0.9	23.1±21.6	4.1±8.2

Table 2. Continued

Plot 11 - White Spruce			
Species	C	F	PV
Alectoria glabra	0.4±0.7	12.8±21.5	2.1±4.6
Cetraria halei	0.01±0.02	1.6±5.0	0.02±0.1
Cetraria pinastri	0.03±0.1	8.8±19.9	0.2±0.4
Evernia mesomorpha	0.4±0.6	23.8±26.6	3.0±4.5
Hypogymnia austerodes	0.6±0.8	18.8±19.2	3.7±6.4
Parmelia subaurifera	1.9±2.0	38.8±34.2	15.2±18.4
Parmelia sulcata	5.6±3.7	81.3±33.3	54.0±38.1
Physcia aipolia	0.02±0.1	1.3±5.6	0.1±0.3
Ramalina minuscula	0.01±0.02	1.3±5.6	0.03±0.1
Usnea spp. (tufted)	1.5±2.2	51.3±34.9	12.3±22.1

Table 3. Composition differences of lichens on trunks between original and resurveyed stands.

	Plot 2 - Black Spruce			Plot 3 - White Spruce		
Species	C	F	PV	C	F	PV
Alectoria glabra	0.7±0.8	2.5±5.3	5.7±7.3			
Cetraria halei	0.2±0.6	1.3±4.0	1.1±3.1			
Cetraria pinastri	0.1±0.2	4.5±7.9	0.7±1.3	0.3±0.7	3.6±10.3	0.8±2.4
Evernia mesomorpha	0.8±1.3	0.02±0.06	7.6±12.7	0.4±0.4	3.8±11.5	3.1±4.3
Hypogymnia austerodes				0.3±0.4	5.2±8.4	1.5±1.9
Hypogymnia physodes	0.2±0.3	1.1±3.8	1.3±2.3			
Parmelia subaurifera				0.3±0.5	6.3±8.8	2.5±4.3
Parmelia sulcata	0.4±0.4	1.7±4.4	3.2±4.1	4.2±9.3	2.5±5.1	41.3±92.9
Parmeliopsis ambigua	1.1±1.7	1.6±4.4	11.1±22.6			
Pertusaria multipuncta				0.8±0.4	6.3±8.8	6.7±2.8
Ramalina fastigiata				0.0±0.0	0.0±0.0	0.0±0.0
Ramalina minuscula				1.9±2.7	0.0±0.0	13.5±19.0
Usnea spp. (tufted)	6.6±7.8	0.0±0.0	66.5±77.5	0.2±0.3	8.6±9.9	1.7±1.7

Table 3. Continued

	Plot 6 - White Spruce			Plot 7 - White Spruce		
Species	C	F	PV	C	F	PV
Alectoria glabra	3.0±7.8	6.3±8.8	4.0±5.1	0.6±0.7	2.3±5.0	5.2±6.7
Cetraria halei	0.0±0.0	0.0±0.0	0.0±0.0	0.7±1.5	4.2±12.5	3.9±7.2
Cetraria pinastri	0.3±0.6	2.5±5.3	1.1±2.0	0.01±0.03	2.3±5.1	0.2±0.4
Cladonia spp.				0.0±0.0	0.0±0.0	0.0±0.0
Yellow crust				0.0±0.0	0.0±0.0	0.0±0.0
Evernia mesomorpha	0.02±0.2	0.8±3.1	1.7±1.8	0.5±0.7	2.2±6.3	4.7±7.1
Hypogymnia austerodes	0.2±0.4	1.6±4.4	1.9±3.0	0.01±0.04	1.8±4.5	0.1±0.3
Hypogymnia physodes				0.1±0.2	0.0±0.0	0.3±0.7
Lecanora allophana				0.0±0.0	0.0±0.0	0.0±0.0
Parmelia subaurifera	0.03±0.1	0.0±0.0	0.1±0.2	0.1±0.2	1.4±4.2	0.4±1.0
Parmelia sulcata	1.3±2.3	0.0±0.0	12.6±23.4	0.7±0.9	0.7±2.9	7.2±8.7
Parmeliopsis ambigua				0.0±0.0	0.0±0.0	0.0±0.0
Ramalina farinacea				0.0±0.0	0.0±0.0	0.0±0.0
Ramalina fastigiata	0.2±0.2	0.0±0.0	1.6±1.8	0.4±0.9	10.0±26.3	0.7±1.1
Ramalina minuscula	0.1±0.1	0.0±0.0	0.8±1.2	0.02±0.04	10.4±14.6	0.3±0.4
Usnea spp. (tufted)	0.6±0.9	1.3±3.9	6.9±8.8	0.5±0.8	0.7±3.0	4.5±8.1

Table 3. Continued

	Plot 8 - White Spruce			Plot 10 - White Spruce		
Species	C	F	PV	C	F	PV
Alectoria glabra	1.5±1.8	9.4±12.0	10.8±11.8	0.0±0.0	0.0±0.0	0.0±0.0
Cetraria halei	0.1±0.1	3.1±6.3	0.6±0.7			
Cetraria pinastri	0.1±0.1	2.3±5.1	0.3±0.4	0.0±0.0	4.2±7.2	0.03±0.1
Evernia mesomorpha	0.3±0.4	0.7±3.0	2.5±3.6	0.0±0.0	0.0±0.0	0.0±0.0
Hypogymnia austerodes	0.3±0.3	14.8±22.2	1.9±1.8			
Parmelia subaurifera	0.4±0.5	4.7±13.3	2.7±3.3			
Parmelia sulcata	2.5±3.0	1.9±8.4	23.8±31.0	1.1±0.9	0.0±0.0	10.1±8.9
Ramalina fastigiata	0.8±0.6	9.7±29.2	2.9±6.0			
Ramalina minuscula	0.1±0.2	4.2±7.2	0.8±1.3			
Usnea spp. (tufted)	0.3±0.5	1.6±6.5	2.7±5.1	0.2±0.3	0.0±0.0	1.1±2.5

Table 3. Continued

Plot 11 – White Spruce			
Species	C	F	PV
Alectoria glabra	0.5±0.1	6.3±2.5	3.4±0.7
Cetraria pinastri	0.0±0.0	5.0±6.9	0.1±0.1
Evernia mesomorpha	0.2±0.3	3.4±6.8	1.8±3.2
Hypogymnia austerodes	0.1±0.2	1.6±4.4	1.0±1.6
Parmelia subaurifera	0.5±0.6	3.6±10.3	3.5±3.8
Parmelia sulcata	0.8±0.8	0.0±0.0	8.1±8.2
Ramalina minuscula	0.0±0.0	0.0±0.0	0.0±0.0
Usnea spp. (tufted)	0.5±1.8	0.7±2.9	5.1±18.2

Evernia mesomorpha had a mean frequency of 95% on larch at plot 9, the highest value recorded for that species. "Tufted" Usneas occurred in every quadrat, and *Parmelia sulcata* had a mean frequency of 94%. Other important species on larch were *Alectoria glabra* and *Centraria halei* with mean frequencies of 52 and 51%, respectively (Table 4).

Eleven to twelve species occurred on branches in the three black spruce plots. The branch flora in these stands was dominated by "tufted" Usneas which had mean frequencies of 100, 98, and 93%. *Evernia mesomorpha* was abundant at plots 4 and 12 with frequencies of 63 and 72%, respectively, but was scarce at plot 2 with a frequency of only 3%. *Ramalina minuscula* had an unusually high frequency of 48% at plot 5 (Table 4).

Nine of twelve species occurred in branch quadrats on white spruce. The development of *Usnea* is often less luxuriant on white spruce than on black spruce. On some plots (6,11) however, "tufted" Usneas had mean frequencies of over 90%. *Parmelia sulcata* was the most frequently encountered species in white spruce stands having mean frequencies of 80% or more at most plots (Table 4). Species such as *Ramalina fastigiata* and *Parmelia subaurifers* showed uneven patterns of occurrence. They were common at some plots but rare or absent at others. This could be related to the age of the stand. There was no branch for study in the aspen stand.

The resurvey of seven plots showed that frequency values were often close to those found in the original survey (Table 5). In many cases, however, the differences and standard deviation were too great to detect minor changes in the lichen flora from one survey to the next (Table 6). For instance, the mean frequency for *Hypogymnia austerodes* at plot 6 was 6.0 ± 14.7. On the resurvey it was 8.0 ± 13.6 resulting in a difference of 5.0 ± 10.0 (Tables 5,6).

Table 4. Composition of lichens on branches in original sampled stands.

Species	Plot 2 – Black Spruce (F)	Plot 3 – White Spruce (F)	Plot 4 – Black Spruce (F)
Alectoria glabra	34.0±43.1	1.0±4.5	51.0±38.6
Cetraria halei	24.0±29.5		15.0±24.2
Cetraria pinastri	1.0±4.5	1.0±4.5	2.0±6.2
Evernia mesomorpha	3.0±9.8	89.0±23.8	63.0±36.3
Hypogymnia austerodes		3.0±9.8	41.0±39.2
Hypogymnia physodes	19.0±25.5	2.0±8.9	1.0±4.5
Lecanora allophana	4.0±10.5	1.0±4.5	10.0±26.4
Parmelia subaurifera		49.0±35.2	10.0±26.4
Parmelia sulcata	69.0±31.4	84.0±25.6	83.0±30.6
Pertusaria cf. multipuncta	1.0±4.5	5.0±14.3	2.0±6.2
Ramalina fastigiata	44.0±39.3	9.0±22.9	
Ramalina minuscula			48.0±42.3
Usnea spp. (tufted)	100.0±0.0	30.0±30.1	98.0±6.2
Usnea scabrata	1.0±4.5		

Table 4. Continued

	Plot 5 - White Spruce	Plot 6 - White Spruce	Plot 7 - White Spruce
Species	F	F	F
Alectoria glabra	4.0±8.2	5.0±14.3	32.0±32.1
Cetraria halei		1.0±4.5	1.0±4.5
Cetraria pinastri		1.0±4.5	
Evernia mesomorpha	52.0±29.3	77.0±27.9	27.0±35.1
Hypogymnia austerodes	7.0±13.4	6.0±14.7	9.0±18.9
Hypogymnia physodes	2.0±8.9	2.0±8.9	
Parmelia subaurifera	38.0±27.5	44.0±38.2	25.0±27.4
Parmelia sulcata	87.0±25.4	80.0±33.1	96.0±8.2
Pertusaria cf. multipuncta			1.0±4.5
Physcia orbicularis	1.0±4.5		
Ramalina fastigiata	19.0±22.9	47.0±36.3	19.0±24.7
Ramalina minuscula	8.0±13.6	34.0±33.2	13.0±32.6
Usnea spp. (tufted)	8.1±25.5	91.0±23.8	59.0±34.0
Usnea scabrata		5.0±22.4	

Table 4. Continued

	Plot 8 - White Spruce	Plot 9 - Larch	Plot 10 - White Spruce
Species	F	F	F
Alectoria glabra	14.0±24.4	52.0±38.6	4.0±13.9
Black crust		2.0±8.9	
Cetraria halei	1.0±4.5	51.0±37.0	
Cetraria pinastri	20.0±6.2	22.0±30.4	
Evernia mesomorpha	51.0±31.4	95.0±11.0	4.0±10.5
Hypogymnia austerodes	24.0±19.0	44.0±30.9	1.0±4.5
Hypogymnia physodes	2.0±8.9		4.0±13.9
Lecanora allophana		11.0±16.5	
Parmelia subaurifera	32.0±36.4	1.0±4.5	48.0±28.2
Parmelia sulcata	82.0±36.7	94.0±22.6	80.0±28.3
Physcia aipolia			1.0±4.5
Ramalina fastigiata	41.0±40.3		
Ramalina farinacea	1.0±4.5		
Ramalina minuscula	11.4±25.0	30.0±35.8	27.0±27.7
Usnea spp. (tufted)	78.0±28.2	100.0±0.0	52.0±29.3

Table 4. Continued

	Plot 11 - White Spruce	Plot 12 - Black Spruce
Species	F	F
Alectoria glabra	35.0±36.1	52.0±40.2
Cetraria halei	24.0±29.5	13.0±19.8
Cetraria pinastri		1.0±4.5
Evernia mesomorpha	61.0±33.4	72.0±20.9
Hypogymnia austerodes	26.0±29.1	15.0±26.7
Hypogymnia physodes	1.0±4.5	2.0±8.9
Lecanora allophana	2.0±6.2	2.0±6.2
Parmelia subaurifera	24.0±32.2	3.0±9.8
Parmelia sulcata	79.0±35.8	43.0±35.7
Parmeliopsis ambigua		2.0±6.2
Pertusaria cf. multipuncta	1.0±4.5	
Ramalina fastigiata	1.0±4.5	
Ramalina minuscula	12.0±16.4	5.0±14.3
Usnea spp. (tufted)	94.0±22.6	93.0±22.7

Evernia mesomorpha had a mean frequency of 95% on larch at plot 9, the highest value recorded for that species. "Tufted" Usneas occurred in every quadrat, and *Parmelia sulcata* had a mean frequency of 94%. Other important species on larch were *Alectoria glabra* and *Centraria halei* with mean frequencies of 52 and 51%, respectively (Table 4).

Eleven to 12 species occurred on branches in the three black spruce plots. The branch flora in these stands was dominated by "tufted" Usneas which had mean frequencies of 100, 98, and 93%. *Evernia mesomorpha* was abundant at plots 4 and 12 with frequencies of 63 and 72%, respectively, but was scarce at plot 2 with a frequency of only 3%. *Ramalina minuscula* had an unusually high frequency of 48% at plot 5 (Table 4).

Nine of twelve species occurred in branch quadrats on white spruce. The development of *Usnea* is often less luxuriant on white spruce than on black spruce. On some plots (6, 11) however, "tufted" Usneas had mean frequencies of over 90%. *Parmelia sulcata* was the most frequently encountered species in white spruce stands having mean frequencies of 80% or more at most plots (Table 4). Species such as *Ramalina fastigiata* and *Parmelia subaurifers* showed uneven patterns of occurrence. They were common at some plots but rare or absent at others. This could be related to the age of the stand. There was no branches for study in the aspen stand.

The resurvey of seven plots showed that frequency values were often close to those found in the original survey (Table 5). In many cases, however, the differences and standard deviation were too great to detect minor changes in the lichen flora from one survey to the next (Table 6). For instance, the mean frequency for *Hypogymnia austerodes* at plot 6 was 6.0 ± 14.7. On the resurvey it was 8.0 ± 13.6 resulting in a difference of 5.0 ± 10.0 (Tables 5, 6).

Table 5. Composition of lichens in branches in resurveyed stands.

	Plot 2 - Black Spruce	Plot 3 - White Spruce	Plot 6 - White Spruce
Species	F	F	F
Alectoria glabra	41.0±43.8	1.0±4.5	5.0±14.3
Cetraria halei	22.0±24.2		1.0±4.5
Cetraria pinastri	1.0±4.5	1.0±4.5	1.0±4.5
Evernia mesomorpha	3.0±9.8	89.0±23.8	81.0±24.7
Hypogymnia austerodes		1.0±4.5	8.0±13.6
Hypogymnia physodes	14.0±20.6	4.0±12.3	2.0±8.9
Lecanora allophana	2.0±8.9	1.0±4.5	
Parmelia subaurifera		50.9±37.0	44.0±36.5
Parmelia sulcata	70.0±30.8	85.0±24.2	84.0±28.0
Pertusaria cf. multipuncta	0.0±0.0	4.0±10.5	
Ramalina fastigiata	42.0±35.5	10.0±22.9	48.0±36.4
Usnea spp. (tufted)	100.0±0.0	36.0±27.2	86.5±29.8
Usnea scabrata	1.0±4.5		5.0±22.4

Table 5. Continued

	Plot 7 - White Spruce	Plot 8 - White Spruce	Plot 10 - White Spruce
Species	F	F	F
Alectoria glabra	34.0±34.0	14.0±24.4	5.0±14.3
Cetraria halei	1.0±4.5	1.0±4.5	
Cetraria pinastri	1.0±4.5	1.0±4.5	
Evernia mesomorpha	27.0±35.1	52.0±32.7	5.0±11.0
Hypogymnia austerodes	10.0±20.0	22.0±19.4	
Hypogymnia physodes		2.0±8.9	5.0±14.3
Parmelia subaurifera	27.0±27.2	28.0±33.4	59.0±28.6
Parmelia sulcata	95.0±11.0	8.1±36.4	82.0±26.7
Pertusaria cf. multipuncta	2.0±8.9		
Physcia aipolia			1.0±4.5
Ramalina fastigiata	22.0±28.2	41.0±40.3	
Ramalina farinacea		2.0±8.9	
Ramalina minuscula	13.0±32.6	11.0±24.7	29.0±32.1
Usnea spp. (tufted)	60.0±36.1	80.0±29.0	53.0±28.5

Table 5. Continued

Plot 11 - White Spruce	
Species	F
Alectoria glabra	31.0±33.4
Cetraria halei	17.0±24.5
Cetraria pinastri	1.0±4.5
Evernia mesomorpha	62.0±35.5
Hypogymnia austerodes	31.0±27.9
Lecanora allophana	3.0±7.3
Parmelia subaurifera	23.0±32.6
Parmelia sulcata	88.0±24.6
Pertusaria cf. multipuncta	1.0±4.5
Ramalina fastigiata	1.0±4.5
Ramalina minuscula	13.0±19.8
Usnea spp. (tufted)	99.0±4.5

Table 6. Composition differences on branches between original and resurveyed stands.

	Plot 2 - Black Spruce	Plot 3 - White Spruce	Plot 6 - White Spruce
Species	F	F	F
Alectoria glabra	4.4±13.3	0.0±0.0	0.0±0.0
Cetraria halei	11.1±20.3		
Cetraria pinastri	0.0±0.0	0.0±0.0	
Evernia mesomorpha	0.0±0.0	2.1±6.3	5.6±11.5
Hypogymnia austerodes	6.7±10.0	0.0±0.0	5.0±10.0
Hypogymnia physodes		0.0±0.0	
Lecanora allophana	10.0±14.1	0.0±0.0	
Parmelia subaurifera		9.3±14.9	4.6±8.8
Parmelia sulcata	9.5±15.5	3.2±7.5	1.1±4.7
Pertusaria cf. multipuncta		6.7±11.6	
Ramalina fastigiata	8.3±18.0	0.0±0.0	2.9±7.3
Ramalina minuscula			20.0±20.0
Usnea spp. (tufted)	0.0±0.0	4.0±11.2	0.9±0.0
Usnea scabrata	0.0±0.0		

Table 6. Continued

	Plot 7 - White Spruce	Plot 8 - White Spruce	Plot 10 - White Spruce
Species	F	F	F
Alectoria glabra		0.0±0.0	0.0±0.0
Evernia mesomorpha		5.9±11.8	0.0±0.0
Hypogymnia austerodes		4.3±11.6	
Hypogymnia physodes			0.0±0.0
Parmelia subaurifera		7.3±13.5	1.1±4.6
Parmelia sulcata		1.2±4.9	2.1±6.3
Ramalina fastigiata		0.0±0.0	
Ramalina minuscula	0.0±0.0	5.0±10.0	3.3±7.8
Usnea spp.		2.0±6.2	1.1±4.7

Table 6. Continued

Plot 11 – White Spruce	
Species	F
Alectoria glabra	25.5±23.8
Cetraria halei	11.4±22.7
Evernia mesomorpha	14.1±20.9
Hypogymnia austerodes	10.9±13.8
Lecanora allophana	0.0±0.0
Parmelia subaurifera	14.3±29.9
Parmelia sulcata	3.5±7.9
Ramalina minuscula	4.0±8.9
Usnea spp. (tufted)	2.1±6.3

5. DISCUSSION

5.1 Proposed Methodology

5.1.1 Data Collection and Analysis

The establishment of an adequate biological monitoring system using lichens requires a relatively large number of monitoring plots. Location of these plots is best accomplished by a grid network system. We propose that 56 plots be established along eight transects radiating from the periphery of the Syncrude lease (Fig. 15). Distances between plots on a transect vary from two to six km. These distances increase with distance from the plant since air pollution should decrease. There are seven plots along each transect ranging up to about 40 km from the plant.

The stands used in the study will be dominated by white spruce, black spruce, or occasionally larch. In some situations (such as plot 9 of the 1975 study) larch trees support a more abundant lichen flora than do black spruce. Twenty permanent trunk quadrats will be established at each plot. One or two quadrats will be placed on each tree using nails set in a 10 by 20 cm rectangle. Each quadrat will be marked with an aluminum tag; plot and quadrat numbers will be on each tag. The trees used will be marked with flagging tape, tagged, and their positions mapped within the site.

Since the observers error in estimating cover in the field was too great to monitor slight changes in cover, more precise methods involving laboratory analysis of photographs will be used. Each photograph will be taken with a set scale in each

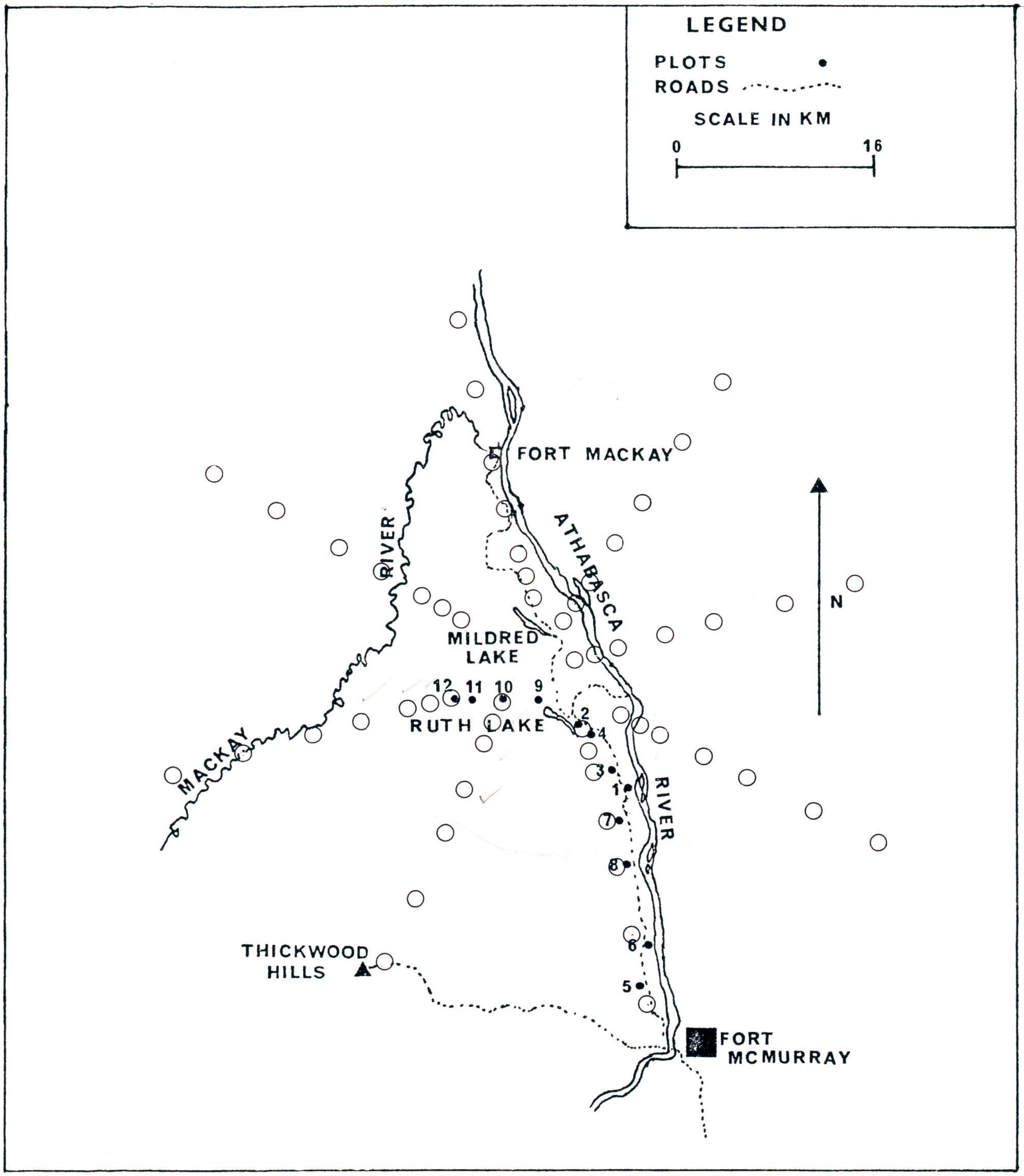

Figure 15. Grid network with proposed study sites (circles).

photograph. To insure that good photographs are obtained of each quadrat, two photographs will be taken using two cameras equipped with a ring-light flash attachment. We believe that flash photography should be used because of difficult lighting situations that are often encountered in the field. When only part of a quadrat is in sunlight, it is difficult or impossible to obtain a good photograph using available light. A shadow box made of sheet metal will be used to darken the entire quadrat; the ring-light should then correctly expose all of the lichens in the quadrat. The shadow box technique will be developed prior to field work. Photographs will be quantitatively analyzed in the laboratory by projecting them onto a dot grid. Accurate coverage values may then be obtained by adjusting the projection to scale and counting the dots covered by each lichen.

Photographic records will be of primary importance in this study, but other forms of data will be obtained as well. The species in each quadrat will be listed. In many cases, special notes will be taken including the occurrence of fertile individuals, or of moribund individuals, or of unusually luxuriant development. A general floristic survey will be made at each site. Since it may be desirable in the future to determine the SO_2 content of lichens at each plot, certain species will be collected and preserved in air tight containers for comparative material. Large, common species will be used such as *Parmelia sulcata*, *Hypogymnia physodes*, "tufted" Usneas, and possibly *Evernia mesomorpha* and *Peltigera aphthosa*.

Five branches will also be examined and photographed at each plot. Frequency and abundance data will be obtained for the lichens on each branch, and the branches will be marked by aluminum tags. Trunk quadrats are better for comparative, long-range studies than are branches, but some branches should be examined since they include some species (i.e., *Ramalina minuscula*) that may be important. It is also possible that lichens on branches may react differentlv to air pollution than do the same species on trunks. Photographic problems are a major difficulty working with branches. Back lighting sometimes makes it impossible to get a good photograph, and it is difficult to obtain several photographs of a given branch from the same position. The use of only a few select branches will minimize these problems. Branch quadrats also have the disadvantage of being more likely to be destroyed over a period of years, and, in some stands, it is difficult, or impossible, to locate 20 good branches.

A ground marker will be needed for relocation of the plots from the air. We may use two large, painted boards, but this area needs further consideration. Plots will be precisely located on air photos.

5.1.2. Personnel Required

Establishment of the grid network, prior to the opening of the Syncrude plant, should be carried out by a professional lichenologist familiar with problems involving lichen air quality monitoring. A field assistant will also be required during this phase of study. Office and laboratory work will be done by the lichenologist and a secretary/technician.

The partial or complete resurveys may be conducted by an experienced technician without the aid of a field assistant. The technician and a secretary/technician will conduct the office and laboratory work.

5.2 Lichen Flora

Considering that there are few, if any, dry, open hillsides or rock outcrops in the Fort McMurray area, the 79 species found in 30 days of collecting represent a relatively large flora. The flora is composed mostly of common montane and boreal forest species, which have western or northern distribution patterns in North America. Genera such as *Alectoria, Evernia,* and *Hypogymnia* have strictly northern affinities. *Cetraria pinastri, Parmelia sulcata, P. subaurifera, Parmeliopsis ambigua, Ramalina crinalis, R. minuscula,* and many Usneas are most characteristic of northern coniferous forests. Some species, especially those found on aspen, are widespread in North America. These include *Physcia aipolia, P. orbicularis, Caloplaca cerina, C. holocarpa,* and *Xanthoria polycarpa.* Most of the species are common in North America, but some of the collections represent range extensions or unusual discoveries. *Lobaria pulmonaria,* a large foliose lichen, was found about 640 km northeast of its known range. The specimem of *Biatorella* is unusual and could represent an undescribed species although more material is required for verification. Crustose species that are not too often collected are *Bacidia obscurata* and *B. sphaeroides.*

The presently known flora is composed of 31 fruticose species, 26 foliose species, and 22 crustose species. *Cladonia* is the largest genus with 17 species; these are conspicuous lichens of logs and the forest floor. *Centraria* and *Parmelia* are represented by 5 species each. *Parmelia sulcata* is the dominant foliose lichen on conifers. Other species of *Parmelia* and *Cetraria* are much less prominent. The largest crustose genus is *Lecidea* with 5 species. Crustose lichens are the most difficult to find, and further collecting should reveal more species.

This annotated checklist includes all the lichens collected during the present study. Collection numbers preceded by "D" represent collections by G.W. Douglas, those preceded by an "S" are collections by A.C. Skorepa. Voucher specimens are deposited in the B.C. Provincial Museum and G.W. and G.G. Douglas (private) herbaria.

Annotated Lichen Checklist

Alectoria glabra Mot. A common, black fruticose lichen on conifers. It is most often found on the branches of black spruce trees; S9876, S9875, S9865, S9847, S9780, S9769, S9766, S9767, S9910.

Alectoria nidulifera Norrl. Rare. Found once on black spruce (S9661) and one on white spruce (S9873).

Anaptychia speciosa (Wulf.) Mass. This foliose lichen is rare in the area; found on an aspen (S9627) and a white spruce (S9721).

Bacidia obscurate (Somm.) Zahlbr. On balsam poplar; found once, S9752.

Bacidia sphaeroides (Dicks.) Zahlbr. Found only at plot 6 on balsam poplar, S9761.

Biatorella sp. Found once on a larch tree at plot 9, S9826.

Buellia triphragmioides Anzi. On white spruce; found once S9719.

Buellia zahlbruckneri J. Stein. On white spruce; found once S9856.

Calcium salicinum Pers. Found once on white spruce S9711.

Caloplaca cerina (Ehrh.) Th. Fr. Found on aspens at plot 1. D8658c, S9634, S9785.

Caloplaca holocarpa (Hoffm.) Wade. This species is commonly found with *C. cerina* on aspens. S9642, S9639, S9909, S9630, D8659, D9658b, D9664.

Candelaria concolor (Dicks.) B. Stein. This yellow, foliose species was rare on aspens at plot one; found in the quadrats but not collected.

Candelariella vitellina (Ehrh.) Mull. Arg. This yellow, crustose species is common on aspens and is also rarely found on spruce trees: D9658a, S9631.

Cetraria chlorophylla (Willd.) Vain. Rare on black spruce at plot four. S9647.

Cetraria ericetorum Opiz. Rare, found on a log in a pine stand. S9925.

Cetraria halei W. Culb. & C. Culb. This species is widespread in coniferous forests. It is most often found on branches of spruce and pine: S9709, S9811, S9812, D8655b.

Cetraria nivalis (L.) Ach. Rare on sandy ground. S9922.

Cetraria pinastri (Scop.) S. Gray. Common and typical of conifers; found mostly on trunks near the ground: D8652, S9708, S9736.

Chaenotheca chrysocephala (Ach.) Th. Fr. Found once on black spruce at plot 2. S9655.

Cladonia alpestris (L.) Rabenh. On the ground in a jack pine stand and in a black spruce stand; not common: D8684, S9923.

Cladonia arbuscula (Wallr.) Rabenh. A large shrub-like species; on the ground in a white spruce stand. S9786.

Cladonia botrytes (Hag.) Willd. On a log; found once. S9676.

Cladonia cariosa (Ach.) Spreng. Rare on the ground in a white spruce stand. D8715.

Cladonia cenotea (Ach.) Schaer. On the ground in a black spruce woods; not common. S9667.

Cladonia coniocraea (Florke) Spreng. Common on rotten logs. D8647, D8722b, D8689, S9806, S9794.

Cladonia cornuta (L.) Hoffm. Fairly common on the ground in black spruce stands. S9657, S9668, S9897.

Cladonia crispata (Ach.) Flot. Found on logs, the ground, and the base of a spruce tree. D8721, D8722a, S9646, S9760.

Cladonia deformis (L.) Hoffm. Occasional on the ground. S9645, S9793, S9670.

Cladonia fimbriata (L.) Fr. Common on rotten logs; sometimes on the bases of spruce trees. D8646, S9673, S9762, S9798.

Cladonia gracilis (L.) Willd. Found on logs and the bases of trees; common. D8723, D8720a, D8719, S9693, S9788, S9896.

Cladonia hookeri Tuck. Found once on the ground in a black spruce stand. D8682.

Cladonia mitis Sandst. A common shrub-like species on the ground in spruce forests. D8686, Lulman *s.n.*, S9745, S9759, S9825, S9669.

Cladonia multiformis Merr. Common on the ground and on rotten logs. D8645, D8713, D8712, D8688, D8685, D8656, D8681, D8717, S9792, S9656, S9694, S9695.

Cladonia pyxidata (L.) Hoffm. Infrequent on the ground and at the base of balsam poplar. D8714, D8716.

Cladonia rangiferina (L.) Wigg. Occasional on the ground in spruce forests. S9713, S9781.

Cladonia uncialis (L.) Wigg. Found once on sandy ground in a jack pine stand. S9921.

Evernia mesomorpha Nyl. This is a common fruticose lichen of spruce trunks and branches. It is best developed on branches of black spruce. D8642a, D8653, S9660, S9685, S9725, S9758, S9814, S9816, S9818, S9819, S9851, S9867, S9871, S9878, S9885, S9893, S9894.

Hypogymnia austerodes (Nyl.) Ras. Found mostly on the wood of dead branches and logs; also fairly common on the trunks of living spruce trees. S9927.

Hypogymnia physodes (L.) W. Wats. Common on logs, branches, and trunks of conifers. S9654, S9664, S9672, S9678, S9716, S9722, S9731, S9879, S9886, S9924, D8654a.

Icmadophila ericetorum (L.) Zahlbr. Found at plot 2 on mosses and once in a black spruce stand. D8637, S9662.

Lecanora allophana (Ach.) Nyl. Fairly common on the branches of spruce trees. S9650, S9727, S9790, S9823.

Lecanora coilocarpa (Ach.) Nyl. Found once on black spruce. S9651.

Lecidea elabens Fr. Found once on white spruce. S9831.

Lecidea glomerulosa (DC.) Steud. On the bark of balsam poplar. D8661, S9633, S9898, S9907, S9911.

Lecidea granulosa (Hoffm.) Ach. Found on sandy soil and on the floor of a black spruce stand. D8683, S9919.

Lecidea scalaris (Ach.) Ach. Found once on black spruce. S9688.

Lecidea vernalis (L.) Ach. Found on mosses at the base of a white spruce, and on the bark of larch and white spruce. S9754, S9763, S9789, S9774, S9712, S9822.

Leptogium saturninum (Dicks.) Nyl. On balsam poplar; rare. S9744.

Lobaria pulmonaria (L.) Hoffm. This large foliose lichen is usually found on deciduous trees in mesic forests in North America. It occurs in eastern North America, the Rocky Mountains of southern Alberta, and along the west coast (Jordon, 1973). At Fort McMurray it was found once at the base of a white spruce. S9801.

Parmelia flaventior Stirt. This species is rare on spruce trees. S9675, S9782.

Parmelia multispora Schneid. Rare, found on white spruce. S9715.

Parmelia perlate (Huds.) Ach. Rare, found on black spruce. S9671.

Parmelia subaurifera Nyl. This species is fairly common on spruce trees. S9684, S9686, S9700, S9707, S9714, S9729, S9784, S9899, S9902.

Parmelia sulcata Tayl. Very common on spruce and on logs; this is the most common lichen in the area. D8643, D8654b, D8655a, S9677, S9728, S9765, S9901.

Parmeliopsis aleurites (Ach.) Nyl. Found mostly on logs and on the branches of conifers. S9777, S9783.

Parmeliopsis ambigua (Wulf.) Nyl. This species is fairly common with *Cetraria pinastri* at the base of spruce trees. S9665.

Peltigera aphthosa (L.) Willd. Very common among mosses on the ground and sometimes at the base of trees. D8711, S9689, S9692.

Peltigera canina (L.) Willd. Frequent on logs and on the ground. D8644, D8648b, S9679, S9690, S9799.

Peltigera polydactyla (Neck.) Hoffm. On a rotten log; found once. D8648a.

Peltigera cf. *scabrosa* Th. Fr. Rare, found on a rotten log. D8718.

Pertusaria amara (Ach.) Nyl. On white spruce; not common. S9674, S9776.

Pertusaria multipuncta (Turn.) Nyl. This crustose species is common on aspen and balsam poplar. D8665, S9723, S9732, S9743.

Physcia adscendens (Th. Fr.) Oliv. This species is typically found on deciduous trees and was collected several times on aspen at plot 1. D8662, S9635, S9638.

Physcia aipolia (Ehrh.) Hampe. Usually on aspen or balsam poplar; rare on white spruce. D8663, S9629, S9637, S9848.

Physcia ciliata (Hoffm.) Du Rietz. Found on balsam poplar; not common. S9741, S9749.

Physcia orbicularis (Neck.) Poetsch. On aspen and spruce; not common. D8660, S9628, S9710.

Physconia detersa (Nyl.) Poelt. Found on aspen and balsam poplar; not common. S9637, S9739, S9740.

Ramalina crinalis (Ach.) Gyeln. This boreal forest species is not common in the Fort McMurray area. It was found on white spruce. S9747, S9795, S9796.

Ramalina farinacea (L.) Ach. Found on balsam poplar and commonly on white and black spruce branches. S9687, S9697, S9701, S9724, S9737, S9779, S9800, S9803, S9804.

Ramalina fastigiata (Pers.) Ach. Infrequent on the branches of white and black spruce. S9911.

Ramalina minuscula (Nyl.) Nyl. Frequent on white spruce but most common on black spruce branches. S9643, S9644, S9680, S9683, S9815, S9828.

Rinodina archaea (Ach.) Arn. Found once on white spruce. S9691.

Rinodina exigua (Ach.) S. Gray. Common on white spruce and larch. S9820, S9821, S9827, S9824, S9829.

Stereocaulon alpinum Laur. Found once on sandy ground in a jack pine stand. S9918.

Usnea alpina Mot. Found on spruce trees and on larch; not common but sometimes locally abundant. S9652, S9698, S9702, S9804, S9787, S9834, S9835, S9892, S9841, S9842, S9843, S9849, S9850, S9853, S9854, S9857, S9861, S9883.

Usnea cavernosa Tuck. An uncommon member of the pendulous Usnea group; found on white and black spruce. S9658, S9703, S9705.

Usnea sorediifera (Arn.) Lynge. An extremely common species on most spruce and larch trees in the area. D8642, S9653, S9659, S9730, S9748, S9755, S9756, S9764, S9772, S9805, S9817, S9860, S9862, S9863, S9870, S9877, S9881, S9882, S9887, S9891.

Usnea subfloridana Stirt. Common conifers with *U. sorediifera*. S9666, S9682, S9699, S9771, S9802, S9832, S9833, S9838, S9839, S9855, S9866, S9868, S9872, S9880, S9888, S9889, S9895, S9813.

Xanthoria polycarpa (Ehrh.) Oliv. Found on aspens at plot 1. D8666, S9641.

6. SUMMARY

A study was undertaken in 1975 to determine the scientific, technical and economic feasibility of establishing air pollution effect gradients using lichenological methods on a radially arranged pattern of observation sites. A total of 12 lichen samples plots were quantitatively examined and 7 of them resurveyed. The data acquired, along with an aerial survey of the region around the Syncrude lease, indicates that the lichen flora of black and white spruce stands is sufficiently rich and widespread to allow establishment of a lichen air quality monitoring system.

A grid network, containing 56 permanent plots, is proposed. This network, radiating from the Syncrude lease, will provide adequate coverage of the region. It will allow continuous quantitative and qualitative monitoring of the lichen flora and, due to the susceptability of lichens to air pollution, will detect any adverse changes in the lichen flora. Detection of these changes will therefore provide an "early warning system", indicating that biological changes are beginning to take place in the ecosystem. Appropriate action, if necessary, may then be taken to minimize further biological changes in the ecosystem.

Establishment of the grid network should take place during the 1976-1977 fiscal year, prior to the opening of the Syncrude plant. During the first years of the plant's operation partial resurveys of the grid network should be conducted annually. The partial resurveys will be relatively economical since only 20 plots, all accessible by road, will be examined. If no adverse changes in the lichen flora are detected during partial resurveys, several years may then elapse before a subsequent partial resurvey is necessary. Complete resurveys will only be required if a partial resurvey indicated adverse changes are occurring.

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