THE INFLUENCE OF A SULFATE PROCESS PAPER MILL ON THE CORTICOLOUS LICHENS IN THE IMMEDIATE VICINITY OF MOSINEE, WISCONSIN

BY

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INTRODUCTION

"If seven maids with seven mops
   Swept it for half a year,
'Do you suppose,' the Walrus said
   'That they could make it clear?'
'I doubt it,' said the Carpenter
   And shed a bitter tear."

Lewis Carroll

The first researcher to associate the disappearance of lichens with air pollution was Nylander in 1866. He declared that the absence of lichens in the Garden of Luxembourg in Paris was due to air pollution originating from the surrounding buildings. This causal relationship has received increasing support from researchers in the twentieth century (Arnold, 1890-1901; Beschel, 1958; Fenton, 1960, 1964; Gilbert, 1965, 1968, 1969, 1970a, 1970b; Gordon and Gorham, 1963; Hawksworth and Rose, 1970; LeBlanc, 1968; Pearson and Skye, 1965; Rao and LeBlanc, 1965). In recent studies of the lichen flora of London (Laundon, 1967), Stockholm (Skye, 1968), and Montreal (LeBlanc and DeSloover, 1970), the diversity of the lichen population on corticolous substrates was found to be directly proportional to the distance from the industrial or urban heart of the city. In the central portions of these cities large zones were observed which were free of lichens. In all of the above instances of lichen disappearances in urban areas, the respective authors associated such disappearances with an increase in air pollution, in particular an increase in sulfur dioxide.

Rydzak, the leading critic of this theory (1958), believed that the lack of lichens surrounding a town is due to a desiccation phenomenon rather than air pollution. He based this view on two groups of data. First of all, he found that even in some small towns without industry there were lichen deserts in their centers. Secondly, epigeic lichens seemed to thrive better in an urban environment than the corticolous species. Rydzak concluded that when only corticolous species were used in an air pollution study, serious errors may result. This view has been supported by Klements (1956, 1958), Steiner and Schulze-Horn (1955), and others.

A third group of researchers feels that it is not simply a question of air pollution or a desiccation phenomenon but a combination of factors which includes aridity and air pollution (Brodo, 1966; Barkman, 1958).

However, zonations similar to those found around London, Stockholm, and Montreal have been found surrounding point sources of pollutants. Gordon and Gorham (1963), in their analysis of the plant community surrounding an iron-sintering plant at Wawa, Ontario, found that vegetation along the path of the prevailing northeast winds was seriously affected by the emissions (especially SO_2) from the mill. The first tree species to be found in the plant community was Betula papyrifera. This persistence of Betula did not occur within nine miles NE of the mill. The lichen population surrounding the Wawa mill was studied by Rao and LeBlanc (1967) and LeBlanc (1968). The desert area of lichen cover extended about 22 kilometers northeast of the mill. It is difficult to explain these findings by a desiccation phenomenon which according to Skye could have an effect on about 10 square kilometers of arable land (Skye, 1968).

According to Saunders (1970), SO_2 is the most widespread phytotoxic pollutant occurring in the atmosphere in sufficient enough concentrations to measure. Gilbert (1969, 1970a, 1970b) did extensive work on the effect of SO_2 on lichens and bryophytes. He found that the strongest influences on the survival of a species were shelter, the pH and the buffering capacity of the substrates, and nutrient flushing of the surface of the thallus. Gilbert concluded that the water relations of the lichen had very little influence upon survival.

The present study is an inquiry into the distribution and composition of the corticolous lichen population surrounding a sulfate paper processing plant. From the work summarized above (Gilbert), it appears that air pollution and not water availability is the limiting factor in the distribution of lichens surrounding a pollutant source. Therefore, it is of interest to ascertain whether emissions, in particular SO_2, from this point source affect the surrounding lichen community and, if so, how seriously the lichen population is disrupted.

The Mosinee Paper Mill

The Mosinee Paper Mill is located along the east bank of the Wisconsin River in Mosinee, Wisconsin. The mill, built in 1910 and put in operation in November of 1911, was the first Kraft process plant in North America. Originally the plant hired 158 men and produced 12 to 15 tons of wrapping paper per day. Today over 600 men are employed at the plant and production has increased to 200 tons per day from 175 tons per day of pulp. The plant operates on a 24 hours per day, 7 days a week schedule. Some of the products manufactured today are: flameproof paper, foil laminating paper, paper to be saturated with resins, "Nevermold" - mold resistant paper, transformer paper, and oleophobic paper (for doggy bags).

The Kraft method of paper production is a sulfate pulp process. The logs (pine, balsam, spruce, or hemlock) are first debarked by tumbling them in a steel drum. The cleaned wood is then ground into 1/2 to 5/8 inch chips. Eleven cords of chips are placed into a digester (pressure cooker) with a solution containing sodium hydroxide (NaOH), sodium sulfide (Na_2S), and sodium carbonate (Na_2CO_3). The sodium hydroxide and the sodium sulfide dissolve the lignin present in the cell walls and free the cellulose macrofibrils. The sodium carbonate acts as a buffer controlling the speed of the reactions. This mixture of strongly alkaline cooking liquor and chips is steamed under high pressure for several hours. Turpentine is recovered by condensing the gases released from the digesters.

The pulp is then washed and separated from the digestive liquor in a rotary vacuum washer. The lignin and residual chemicals are washed free from the pulp and pumped through evaporators to remove most of the water. Saltcake (Na_2SO_4) is added to this lignin soup and the mixture is sprayed into a furnace and burned. In the burning process, the saltcake is converted to sodium sulfide and the "ash," in the form of molten chemicals, flows out the bottom of the furnace and is mixed with water. Lime is then added and the resulting chemical reaction yields a sludge and the original digesting liquor containing sodium hydroxide, sodium sulfide, and sodium carbonate.

The cellulose pulp fraction remaining after the digestion process is circulated in a 2000 lb. capacity "beater." Bleaching agents and other chemicals are added to control the characteristics of the final product.

The next step is termed the Jordan treatment. Essentially, this is nothing more than a cone-shaped vat fitted with rotating knives which shear the cellulose fibers into uniform lengths.

The pulp is then diluted to less than one per cent solution in water and is allowed to flow over a fine wire screen. The water portion of this cellulose solution passes through the screen leaving a layer of cellulose fibrils behind. This sheet of pulp is then pressed and dried. A finishing surface is produced by exposing the sheet to high pressures. The sheet of paper is then rolled for shipping (Ainsworth, 1959).

Emissions

In the production of paper at the Mosinee plant, 23 smokestacks have been constructed. Table 1 lists all 23 of these stacks and enumerates what portion of the paper making process they vent.

The Ray F. Weston, Inc., Environmental Scientists and Engineers was hired by the Mosinee Paper Mills to make a stack analysis and submit a report on the extent of air pollution and suggest possible plans for its reduction. This report was made available on July 1, 1971. The above analysis divided the emitted substances into two classes: the particulate emissions and the gaseous emissions.

Particulate Emissions

The particulate emissions were divided into three different components: fly ash, saltcake, and lime dust. Table 2 gives a complete list of the stacks and the amount of particulate emissions evolving from each. Table 3 analyzes the type of particulate emissions from stacks 15, 17 and 23. The analysis would be similar for all other stacks (Ray F. Weston, Inc., 1971).

Gaseous Emissions

Five different sulfur containing gases were found to be present in the plume of the Mosinee mill. These gases were

TABLE 1

Approximate Stack Elevations

Stack No.	Source of Pollutants	Stack Elevations
1	Power Boiler No. 1	90' 0"
2	Power Boiler No. 2	90' 0"
3	Power Boiler No. 3	90' 0"
4	Power Boiler No. 4	90' 0"
5	Main Power Boiler No. 5	110' 0"
6	Power Boiler No. 12	110' 0"
7	Turpentine Condenser Relief to atmosphere	
8	Turpentine Condenser Blow Gases and Vapor to Atmosphere	77' 6"
9	Digester Condenser Blow Gases and Vapor to Atmosphere	54' 0"
10	Digester Blow Gases Through Relief Valve	39' 0"
11	Foam Breaker Stack to Atmosphere	
12	First and Second Stage Washer Vacuum	73' 6"
13	Third, Fourth, and Fifth Stage Washer Vacuum Relief Stack	18' 3"
14	Swenson-Effect Evaporator	56' 0"
15	Precipitator-Dish Evaporator and Kraft Furnaces	130' 0"
16	Smelt Desolving Tank No. 6	59' 6"
17	Smelt Desolving Tank No. 7	58' 6"
18	Smelt Desolving Tank No. 8	59' 6"

Table 1 continued on following page.

Table 1 (continued)

Stack No.	Source of Pollutants	Stack Elevations
19	Smelt Desolving Tank No. 9	59' 6"
20-21	Smelt Desolving Tank No. 10	53' 6"
23	Lime Kiln Off-Gases	76' 0"

TABLE 2

Particulate Emissions from the Mosinee Paper Mill

Stack No.	Type Particulate	Emission Rate, lb/hr	Estimated or Actually Sampled*
1	Fly Ash	300	Estimated
2	Fly Ash	300	Estimated
3	Fly Ash	300	Estimated
4	Fly Ash	300	Estimated
5	Fly Ash	198	Calculated
6	Off-gas combustion products	85	Estimated
15	Saltcake	144	Calculated
16	Saltcake	9	Estimated
17	Saltcake	13	Calculated
18	Saltcake	13	Estimated
19	Saltcake	9	Estimated
20	Saltcake	9	Estimated
23	Lime Dust	10	Calculated

* Estimated by the Roy F. Weston, Inc., based upon general experience of the company for the particular type of equipment and fuel analyses.

TABLE 3

Particle Size Distributions in Vent Gas Streams

Stack No.	Particle Size in Microns	<1	1-5	>5
15		65	21	14
17 (representative of stacks 16-20)		0.85	27.4	71.8
23		12.0	44.3	43.7

sulfur dioxide (SO_2), hydrogen sulfide (H_2S), methyl mercaptan (CH_3SH), dimethyl sulfide ($(CH_3)_2S$), and dimethyl disulfide ($(CH_3)_2S_2$). 78% of the sulfur emitted from the plant came from the recovery furnace flue (Stack #15). This was also the source of 70% of the particulate emissions. The digester relief, recovery blow, turpentine decanter, and pulp washer system operations accounted for 20% of the sulfur compounds emitted (Table 4).

Sulfur dioxide and hydrogen sulfide are the two toxic substances emitted in the plume. Hydrogen sulfide is an active reducing agent. Even small amounts of H_2S in the air can cause headaches while still larger amounts cause paralysis in the nervous centers of the lungs and heart causing fainting and death (Nebergall, 1963).

Methyl mercaptan and dimethyl sulfide are odorants and are used in industry to give natural gas a discernable odor. Dimethyl sulfide is a stable compound while methyl mercaptan oxidizes to yield a stable product, dimethyl disulfide (Karchmer, 1970).

Reactions of SO_2

The reactions and movements of SO_2 molecules in the atmosphere are complex, since a molecule may escape into space or adhere to buildings or the surrounding vegetation. SO_2 may be absorbed in rain droplets forming H_2SO_3, and these droplets may aggregate together to form an aerosol. In the presence of sunlight photo-oxidation

TABLE 4

Gaseous Emissions from the Smokestacks of Mosinee Paper Mills

			Sulfur lb/hr	
Stack No.	SO_2-lb/hr	H_2S-lb/hr	as H_2S & CH_3SH	as $(CH_3)_2S$ & $(CH_3)_2S_2$ & SO_2
1 est.	75 est.	---	---	---
2	75 est.	---	---	---
3	75 est.	---	---	---
4	75 est.	---	---	---
5	120 est.	---	---	---
6	60 est.	---	---	---
7	---	---	---	---
8	---	---	0.06	---
9	---	---	6.78	12.9
10	---	---	---	8.4
11	---	---	---	---
12	---	---	---	6.0
13	---	---	---	6.0 est.

Table 2 continued on following page.

Table 4 (continued)

Stack No.	SO_2-lb/hr	H_2S-lb/hr	Sulfur lb/hr	
			as H_2S & CH_3SH	as $(CH_3)_2S$ & $(CH_3)_2S_2$ & SO_2
14	---	---	1.08	0.4
15	---	143.5	28.3 CH_3SH only	0.4 $(CH_3)_2S_2$ only
16	---	---	0.01 est.	0.36 est.
17	---	---	0.01	0.54
18	---	---	0.012 est.	0.54 est.
19	---	---	0.01 est.	0.36 est.
20	---	---	0.01 est.	0.36 est.
21-22	---	---	---	---
23	---	---	---	0.54

est. = estimated values

occurs. A molecule of SO_2 is capable of absorbing solar radiation in the spectrum range of 2900 to 3300 Å. Approximately 0.1% of the SO_2 in the air can be changed by the process of photo-oxidation to ions of $-SO_4$ or H_2SO_4 within an hour (Gerhard and Johnstone, 1955). Or, an SO_2 molecule may be absorbed in cloud droplets and oxidized by dust particles of metals such as iron or manganese salts (Johnstone and Coughenowr, 1958; Katz, 1952; Los Angeles County Air Pollution Administration, 1949-1950). According to Johnstone and Coughenowr, an oxidation rate of up to 1%/min. is possible.

There is no possible means of determining how much SO_2 emitted at any one time will eventually arrive unchanged at the surface of the vegetation or will become associated with the soil (Junge, 1963). Nor is it possible to estimate how much SO_2 will be oxidized by the above methods into H_2SO_4, H_2SO_3, or the ions of these acids. It is known, however, that SO_2 is capable of remaining in the atmosphere for as much as 3-4 days, and that much of this SO_2 is eventually removed by the surface adhesion to plants and to buildings (Katz, 1949; Junge, 1963).

Acute damage to the lichen thallus due to air pollution results in a whitening of the thallus (chlorosis), and large necrotic patches. The margins of these lichens are often curled and the thalli are usually small. Sterility is yet another feature of many lichens at the borderline of their ranges of distribution around a polluting source (Skye, 1968).

Rao and LeBlanc (1965) have done extensive work on how SO_2 produces the effects described above. They exposed thalli of Xanthoria to 5 ppm. of SO_2. After 24 hours of such exposure, the following abnormalities were found in the algal cells: bleached chlorophyll, permanent plasmolysis, and brown spots on the chloroplasts. With the finding of sulfurous acid and Mg^{++} in an 80% acetone extract of finely ground lichen thalli and the change in absorption patterns of chlorophyll a to 667 mμ, characteristic of phaeophytin a, Rao and LeBlanc concluded that the Mg^{++} had been removed from the chlorophyll, thus converting chlorophyll a to phaeophytin a. This change in the composition of the chlorophyll in the chloroplasts explained the brown spots on the algal chloroplasts. These spots were the direct result of an abundance of SO_3^{--} and SO_4^{--} ions produced when SO_2 is dissolved in water. Thus, they concluded that it is the algal symbiont that is the most vulnerable to SO_2.

Coker (1967), on the other hand, found that both the buffering and the ion exchange capacities of a lichen thallus were reduced by sulfur dioxide pollution. This correlates with the findings of Skye (1968) that the lichens with the lowest buffering capacity, those less capable of neutralizing the SO_3^{--} and the SO_4^{--} ions, are the first to be eliminated from a polluted area. Yet, another possible effect of SO_2 proposed by Gilbert, Laundon, and Skye

(Gilbert, 1965; Laundon, 1967; Skye, 1968) is that SO_2 inactivates the sulphydryl groups of thallus enzymes.

Although in Rao and LeBlanc's study, the lichen alga Trebouxia was found to be more sensitive to air pollution than the fungi, the following non-lichen forming fungi have been reported to be drastically affected by air pollution: Microsphera alphitoides (Koch, 1955), Puccinia gramminis (Skye, 1968), Diplocarpon rosae (James, 1965; Saunders, 1966), and Hysterium pulicare (Skye, 1968). Diplocarpon rosae is effectively eliminated from rose gardens when the concentration of SO_2 is in an excess of 100 $\mu g/m^3$ of air (Saunders, 1966, 1970). It is possible, therefore, that both symbionts are affected by SO_2 pollution although the phycobiont is the more sensitive of the two.

Lichens appear to be the most sensitive to SO_2 pollution at the time of "spore" germination (Couey, 1965; Saunders, 1966). Like the spores of many fungi and the protonema of bryophytes, lichen propagule germination requires conditions of high relative humidity or even the presence of surface water to achieve successful germination. Sulfur dioxide is readily absorbed in water forming sulfurous acid. This acid ionizes strongly in the following manner:

$$H_2SO_3 \rightleftharpoons HSO_3^- + H^+$$

$$HSO_3^- \rightleftharpoons SO_4^{--} + H^+$$

Sulfurous acid acts as an effective bleaching and reducing agent (Heslop and Robinson, 1969; Rao and LeBlanc, 1965), and when concentrated enough can effectively stop spore germination.

Laundon (1967) found that some species such as Caloplaca heppiana "are incapable of colonizing new surfaces, although the old thalli themselves are able to survive as relict." (Laundon, 1967, p. 284). Numerous spores of these relict species are present in polluted areas. These have been blown into the polluted region by the prevailing wind from pollution free areas. Their failure to germinate is direct evidence of the sensitivity of these propagules to air pollution.

Though SO_2 with the exception of smoke and soot is the most widespread phytotoxic pollutant, it is not the only air pollutant which damages and destroys lichens. Laundon in his study of the lichens of London mentions soot and dust particles as being detrimental to lichen growth (Laundon, 1967). Nash (1971) found extensive lichen damage with dilute (4 $\mu g\ F/m^3$) concentrations of hydrogen floride (HF). Phytochemical or oxidant pollutants are listed by Saunders (1970) as principal phytotoxic atmospheric pollutants. These oxidants include: ozone, peroxyacyl nitrates, oxides of nitrogen, ethylene, aldehydes, and photochemical smog. Heavy metals, e.g., iron, lead, etc., also are considered by Saunders as principal air pollutants. Most of the above materials are derived from industrial processes, from domestic heating, or from the operation of motorized vehicles. The photo-oxidant of petroleum hydrocarbons released in automobile exhaust is the major source of oxidant pollutants.

MATERIALS AND METHODS

A total of 80 investigation points were sampled. These "stations" were located along transect lines radiating from the Mosinee Paper Mills along 8 points of the compass radiating east, northeast, north, northwest, west, southwest, south, and southeast. The stations were located at 1.5 to 2 mile intervals along these transects. Each transect was 18 miles long.

A "station" consisted of 5 trees each of 4 different species: Tilia americana, Quercus borealis, Acer rubrum, and Pinus strobus. A total of 1454 trees were sampled in the summer of 1970. The sampled trees were 1/8 to 1/4 of a mile from the nearest road and were located in wooded areas. Every visible lichen species growing at a height of 4 to 5 feet from the base of the tree was removed with a chisel and placed in a 1/2 lb. paper bag for laboratory examination and classification. The primary sources used in classifying these lichens were Hale's How to Know the Lichens, and Fink's Lichen Flora of the United States. Both the sample tree and the bag in which the bark was placed were numbered. The circumference of the tree at the point sampled was measured and recorded. An eye estimate of the per cent of lichen cover at the height of sampling was also made. The health of the tree was also recorded.

Whenever possible, trees having a single perpendicular trunk and a circumference of 30-40 inches were used in the study. When the study was begun it was hoped that *Acer saccharum* could be used as a sample species rather than *Acer rubrum* due to the fact that *A. rubrum* has a tendency towards multiple trunks. The sample area, however, had been 50-60% cleared and had been extensively farmed. The only wooded areas left were along the streams and in the lowlands. In these lower, wetter areas *A. rubrum* was the only abundant *Acer* and had to be substituted as a sample species. In selecting the samples of *Acer*, those trees with the fewest number of trunks and the largest trunks were used. The number of trunks was also recorded.

The remaining woodlots are often used for the grazing of dairy cattle. When a woodlot is grazed, several drastic changes occur to the environment surrounding the lichen thallus.

1. Cattle remove much of the ground cover. This results in an increase in the amount of light and the velocity of the wind at ground level.
2. Cattle compact the soil by effectively trampling the area. This compaction increases the amount of run-off, thus decreasing the amount of ground water available to the plants in the woodlot. Consequently, the area becomes more arid.
3. The grazing of a woodlot prevents the growth of seedlings; and the woodlot cannot reestablish itself. Thus, the diversity of the community will decrease as individual trees die and are not replaced.

4. Cattle tend to use the trees as rubbing posts. The semi-rhythmic movement of cattle against bark leaves a brown oily film over the lichen thallus and on very extensively used trees, the cortex is actually stripped from the foliose lichen thallus. These cattle rubbing trees contain much poorer specimens of the lichen community than would normally be expected.

For the above reasons, grazed woodlots were avoided as much as possible. If the sample area was grazed, this was noted and this factor was taken into account when the data were analyzed.

Analysis of SO_2 Concentrations

The concentration of SO_2 at ground level along the vector of the northwest winds was found using the formula:

$$X_{(x,0,0;H)} = \frac{Q}{\pi \; \sigma_y \; \sigma_x \; u} \; \exp \; -1/2 \; \left(\frac{H}{\sigma_y}\right)^2 .$$

when:

X = the concentration of emitted gases at the coordinates listed (Figure 1).

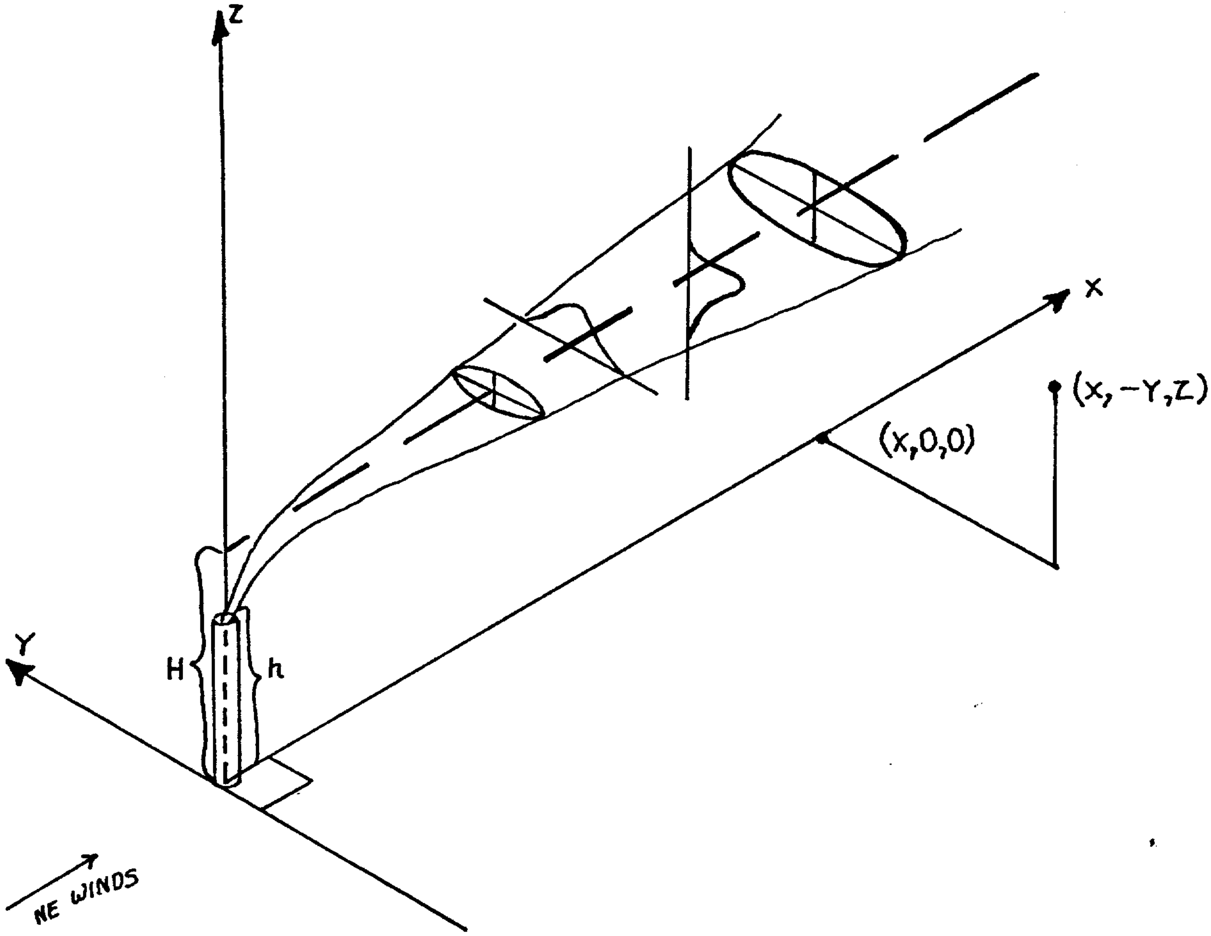
σ_y = The concentration of the plume in the y direction.

σ_z = The concentration of the plume in the z direction.

H = Effective emission height; that is, the height of the smokestack (h) plus the height of the center-line of the plume when it becomes essentially level.

Q = Uniform pollutant emission rate from the smokestacks.

Figure 1.



Plume Coordinate System

(Turner, 1969)

A stack height of 90 feet (27.2 meters) was used in the calculations because four of the six smokestacks emitting SO_2 were this height. These four stacks accounted for 2/3 of the SO_2 pollution. The other two stacks emitting SO_2 in a quantity sufficient to measure were each 110 feet high.

The height of the plume was figured by averaging the heights of the plumes from 10 photographs taken throughout the summer. The average plume rose 43.7 meters above the ground with a center-line at 35.45 meters.

The average wind speed in the Mosinee area is 10 m.p.h.

Values for σy and σz were taken from graphs prepared by the U.S. Department of Health, Education, and Welfare (Turner, 1969). These values vary with the turbulent structure of the atmosphere, the surface structure of the landscape, wind speed, and the cloud cover. Values were calculated considering the landscape to be relatively open, considering both day and night stratifications, various cloud cover states, and various wind speeds.

The uniform pollutant emission rate from the smokestacks was calculated as the sum of the SO_2 emissions from stacks 1 through 6. This value was 60.5 g/sec.

It should be pointed out that the concentration figures produced by this method are the mean values. As the wind velocity increases the effluent emitted at a constant rate from a source is introduced into a greater volume of air per unit time interval. The concentration of pollutants in a cubic unit of air is, therefore, inversely proportional to the wind velocity.

These calculated figures do not hold when extremely unstable atmospheric conditions are present. Such unstable conditions include such things as temperature inversions and thunder storms. At best these figures represent an average value of SO_2 concentration at a given distance northeast of the Mosinee Paper Mill.

The pH of the Bark Samples

0.5 grams of epiphyte free outer bark was pulverized to a consistency of coarse sawdust. 0.5 grams of pulverized bark is between 1.5 and 2.0 cc. of material. This bark-dust was placed in 10 ml. of double distilled water, covered, and allowed to stand for 24 hours at room temperature. The pH of the bark solution was taken using a Sargent-Welch model #PBX-S-30009-10 portable pH meter (Graph 1, p. 31).

RESULTS AND DISCUSSION

The vegetational damage to lichens resulting from the operation of the Mosinee Paper Mills is mainly concentrated in the northeast to southeast direction. This channeling of the emitted pollution effect is noticeable regardless of whether one looks at the community of lichens growing on a particular tree species or whether one looks at the lichen population as a whole, regardless of substrate. Figures 2-5 map the points where several common lichens begin to be found in the lichen population on a particular substrate. In all cases this northeast to southwest distribution pattern is clearly evident. The fewest lichens were found on _Pinus strobus_. This sparsity of lichen cover may be due to two reasons. First, the bark of _P. strobus_ is readily shed. This characteristic does not allow time for the establishment of a lichen community. Second, _P. strobus_ has a bark that is very acidic (Graph 1). The pH of _P. strobus_ averages around 4.05 ± .3 units. Ahmadjian (1967) has reported that the optimal pH range for _Trebouxia_ (the algae found in most temperate climate lichens) is 4.0-7.4 and that for most mycobionts the pH optimum lies between 4.5 and 7.4. The pH of the bark of _P. strobus_ is lower than the optimum required by most fungi which comprise lichen thalli and is at the threshold range of _Trebouxia_. The lower pH of the bark of _P. strobus_, then, may inhibit the germination and the establishment of soredia and isidia of many lichen thalli (Saunders, 1970).

Figure 2

THE POINT WHERE SEVERAL COMMON LICHENS BEGIN TO BE FOUND ON <u>ULMUS AMERICANA</u>

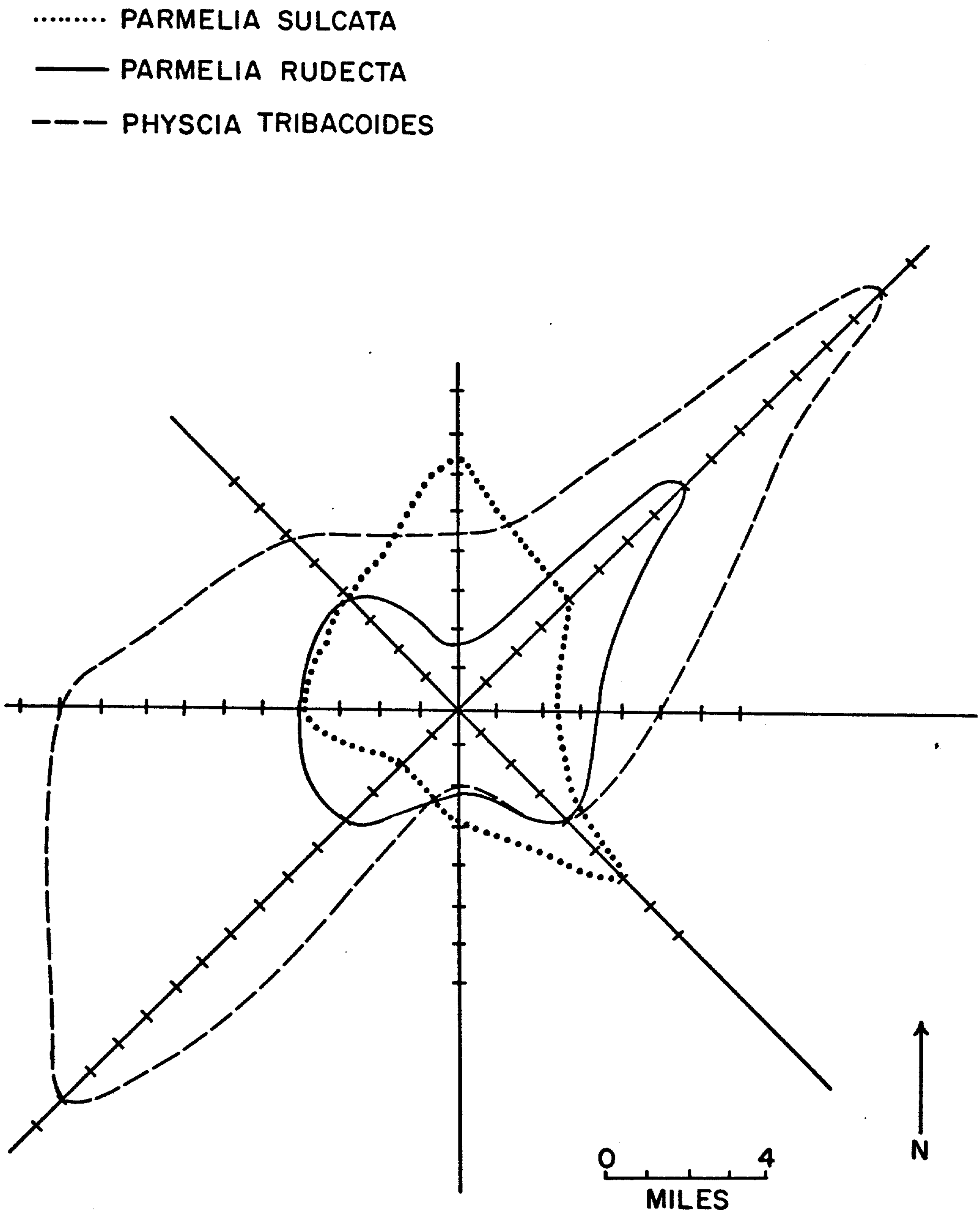


Figure 3

THE POINT WHERE SEVERAL COMMON LICHENS BEGIN TO BE FOUND ON <u>ACER RUBRUM</u>

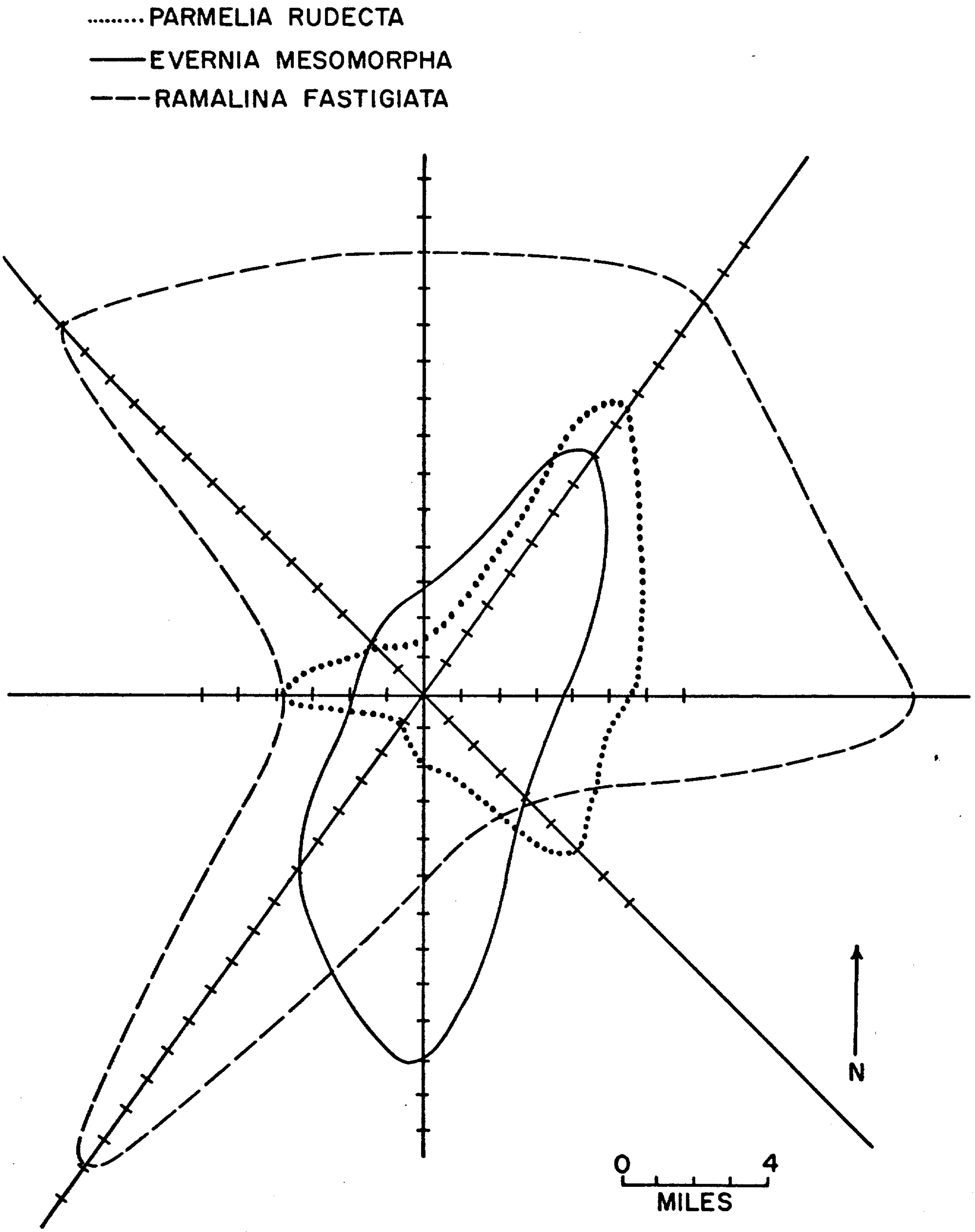


Figure 4

THE POINT WHERE SEVERAL COMMON LICHENS BEGIN TO BE FOUND ON QUERCUS BOREALIS

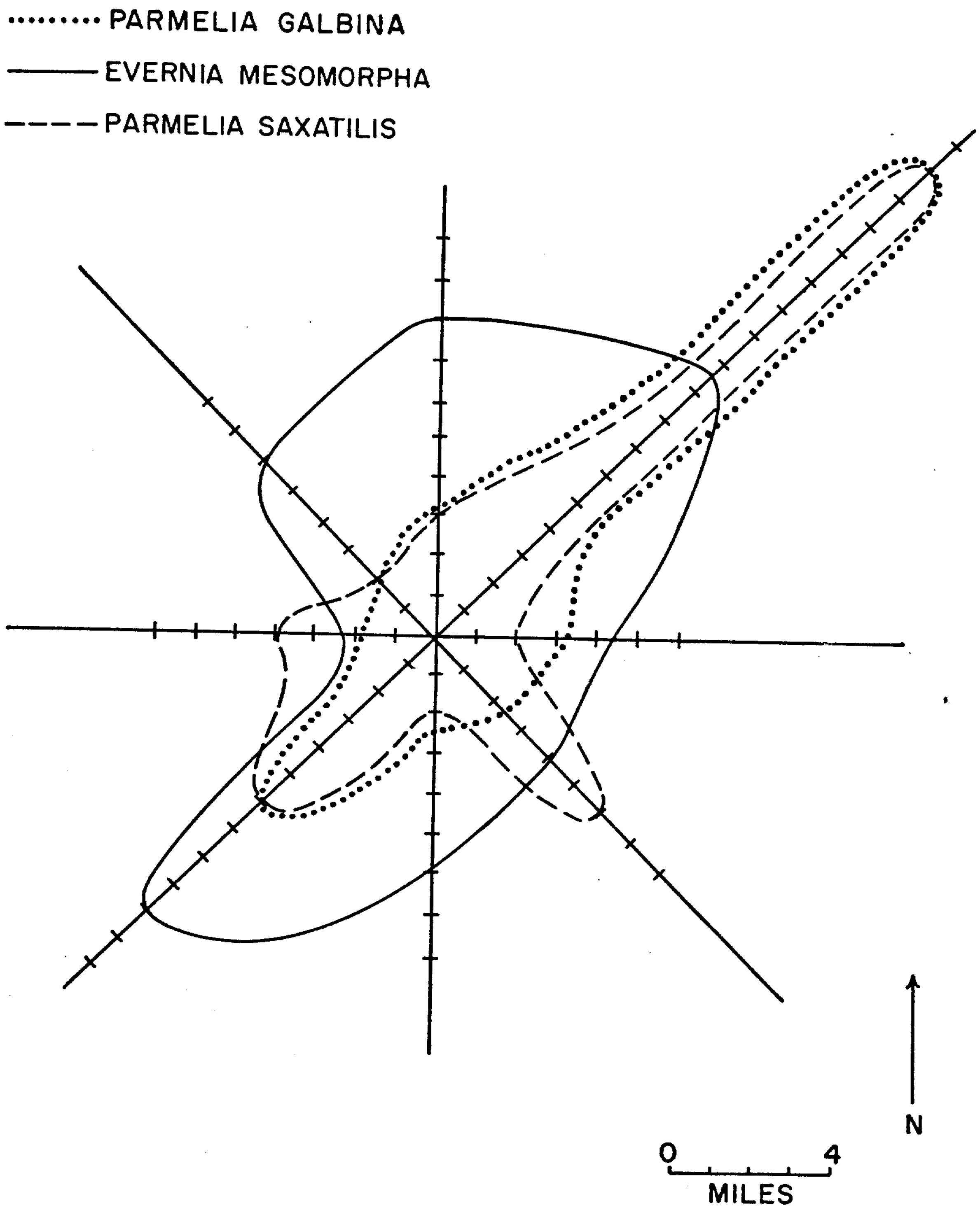
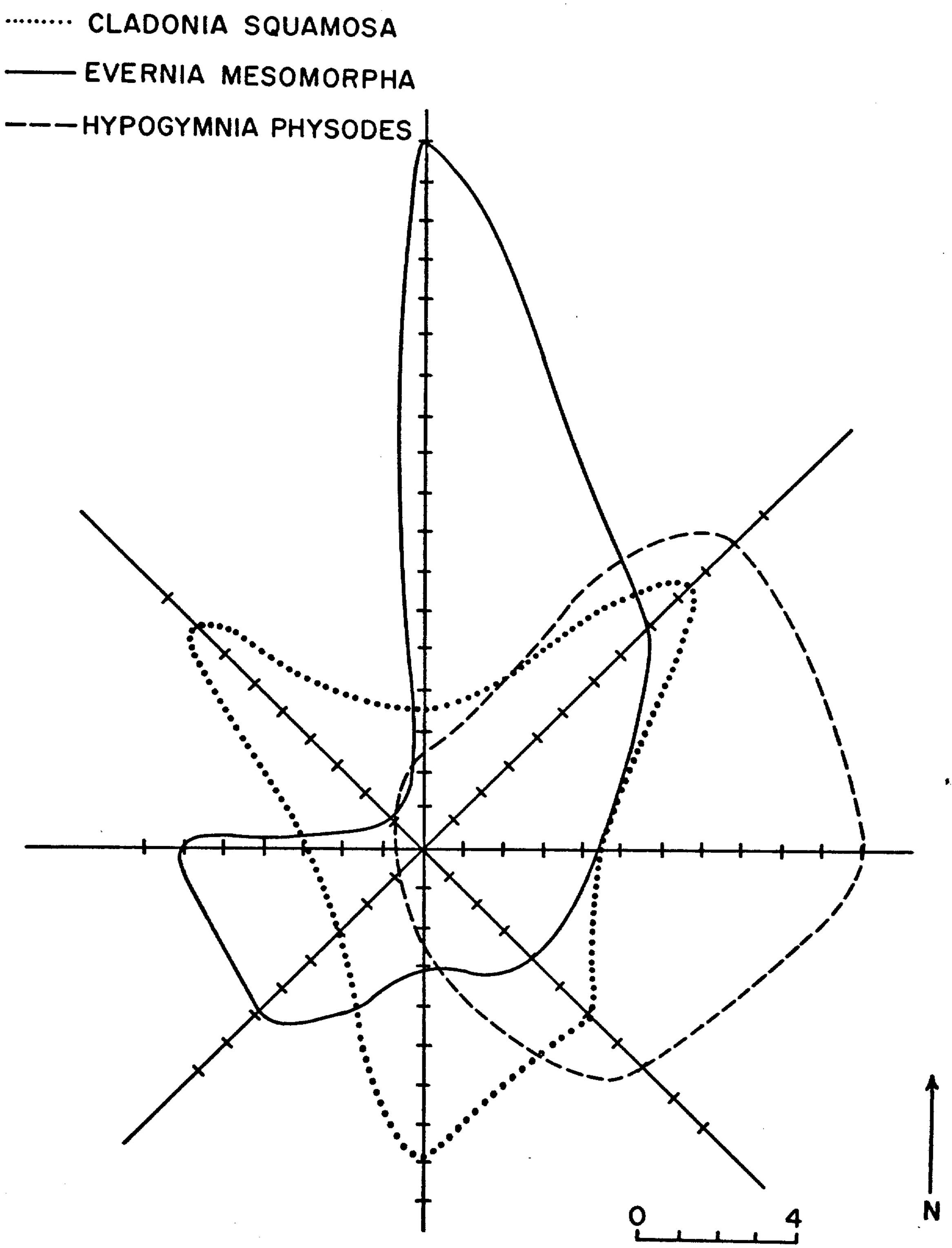


Figure 5

THE POINT WHERE SEVERAL COMMON LICHENS BEGIN TO BE FOUND ON PINUS STROBUS



Key to Graph 1 - pH analysis of bark

● = Test tree between 1-5 miles from Mosinee Paper Mills

o = Test tree between 6-10 miles from Mosinee Paper Mills

× = Test tree between 11-18 miles from Mosinee Paper Mills

GRAPH I. pH ANALYSIS OF BARK

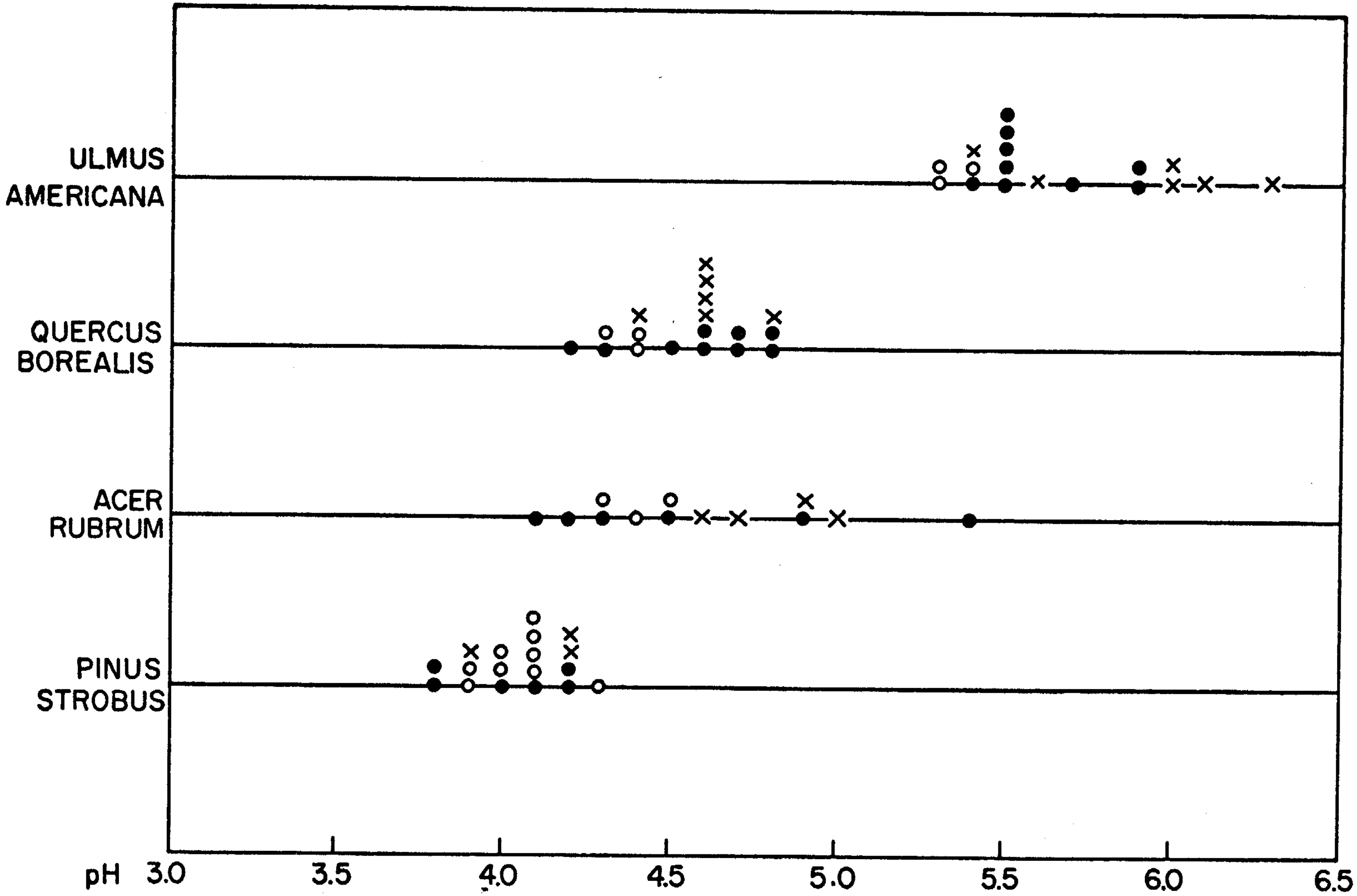


Figure 6 maps where several common species begin to be found in the lichen community regardless of substrate. Since this figure is similar to Figures 2-5, it would seem that something other than substrate may affect the distribution of lichen species. Furthermore, it is evident from the preceding Figures 2-6 that the distribution pattern is not an anomaly of just a few species but that a wide range of foliose and fruticose lichens are affected.

The northeast to southwest distribution correlates rather closely with the wind patterns of the area. According to the Wisconsin Department of Agriculture (1961), the prevailing winds are west and northwest approximately 18% of the time and from the southwest 14% of the time. A wind rose pattern developed from wind direction data collected by Archie C. Towle from January 1, 1941, to December 31, 1945, is found in Figure 7.

The effect of the northwest wind is seen in a slight ballooning out of the distribution patterns towards the southeast (Figures 2-6). However, the winds from the northwest are disrupted by Rib Mountain (640 feet) and Marathon Hill (320 feet) before they reach the Mosinee Paper Mill's area. Marathon Hill and Rib Mountain are located northwest and north-northwest of the paper mill at a distance of 8 and 10 miles, respectively. With the Mosinee Paper Mill on the lee side of these two monadnocks, the important wind vector is the one from the southwest.

Figure 6

THE POINT WHERE SEVERAL COMMON LICHENS ARE FIRST FOUND IN THE LICHEN COMMUNITY REGARDLESS OF SUBSTRATE

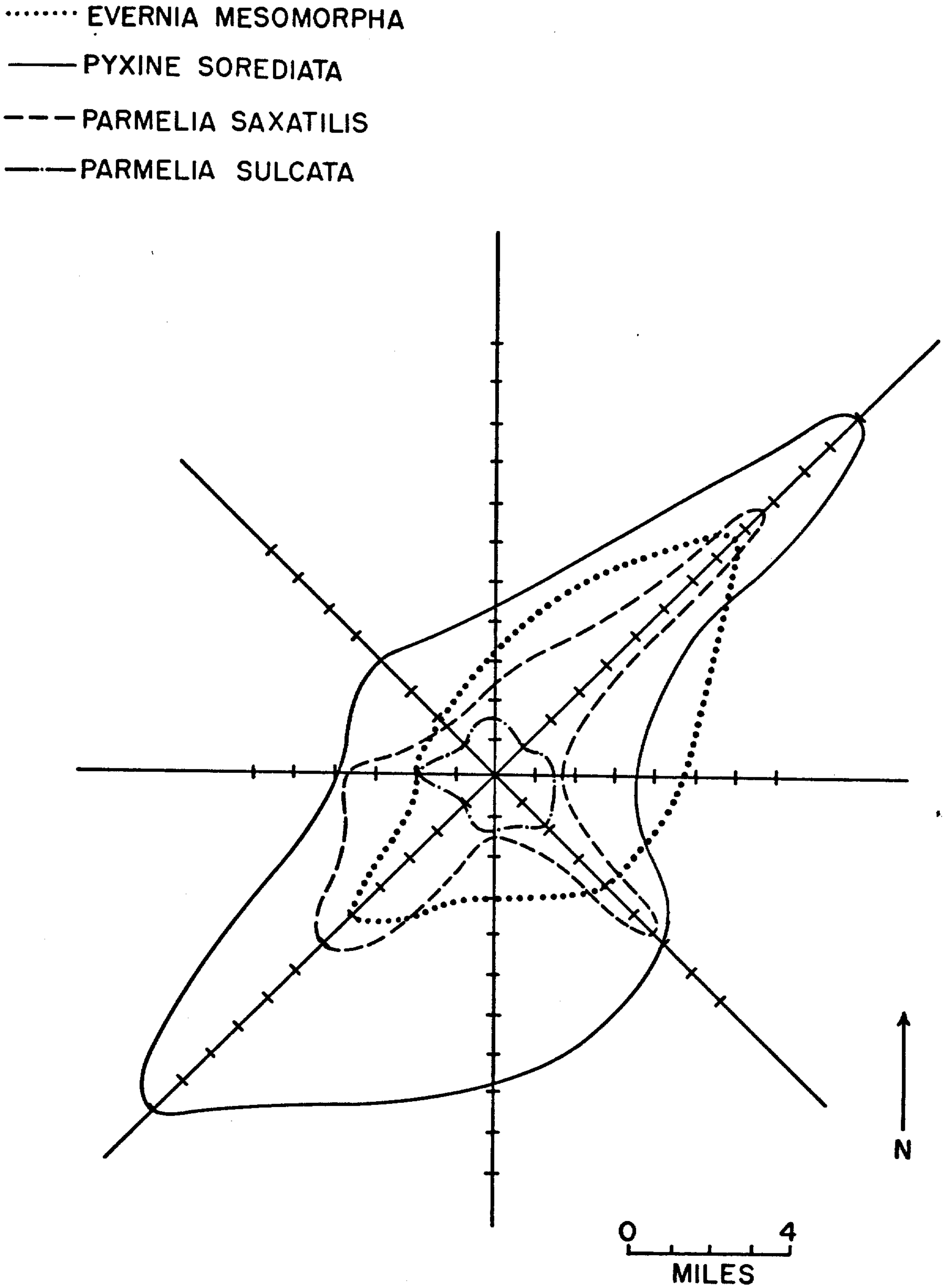
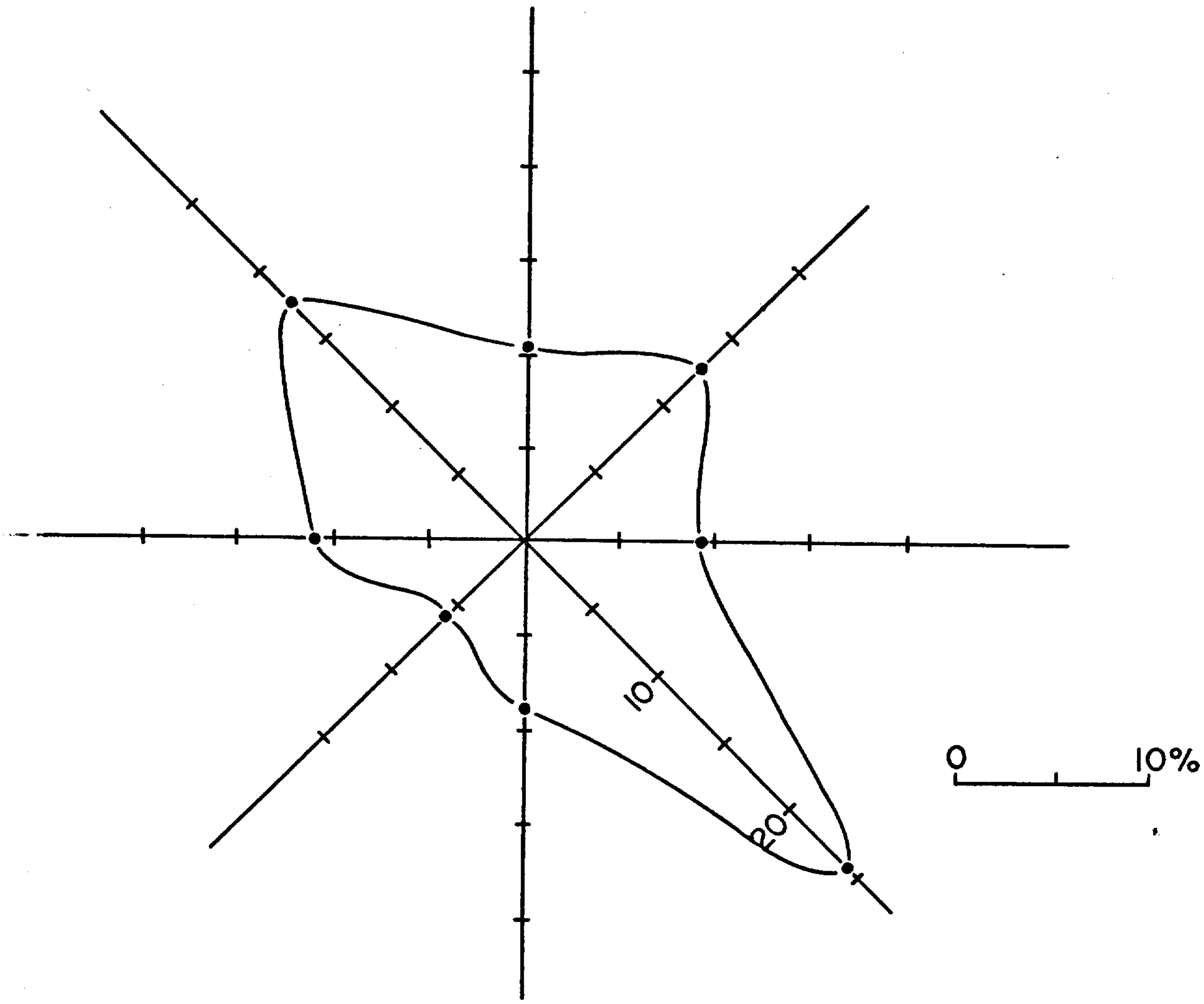


Figure 7



MARATHON CO. WIND PATTERNS: Per cent of time wind blows in a particular direction.

The land southwest of Mosinee is flat and dissected by farms. There is little topographic variation to disrupt the flow of the wind. Therefore, the wind sweeping over this area picks up particulate matter and sulfate compounds from the plume of the Mosinee Paper Mill's smokestacks and diffuses them along the northeast transect from the paper mill. The concentration of sulfur dioxide along the northeast transect is given in Table 5.

The southwest wind vector accounts for the impoverishment of the lichen community to the northeast of the mill but does little to explain the southwest tongue of lichen impoverishment seen in Figures 2-6. Winds from the southeast, south-southeast, and south occur whenever a low is present in the area. These winds deflect off Rib Mountain and Marathon Hill and are diverted to the southeast and the northeast. Thus, the sulfur compounds emitted by the Mosinee Paper Mill are also diverted in these directions.

The lichen population as a whole can be grouped into five basic categories:

1. Ubiquitous and undamaged.
2. Ubiquitous and showing necrotic and bleached patches.
3. Moderately affected, i.e., reestablishing itself in the lichen community within 8 miles (more than 8.7×10^{-1} µg SO_2/m^3) from the paper mill along the NE transect.

TABLE 5

SO_2 Concentration Values along the NE Transect

No. of miles NE	Conc. in the daytime with ≤ 3/8 cloud cover and 10 m.p.h. wind	Conc. during day or night, overcast, and with no wind	Conc. at night with no wind, and ≤ 3/8 cloud cover
1.0	2.8×10^{-1} μg/m^3	3.7 μg/m^3	4.0 μg/m^3
2.0	7.8×10^{-2} μg/m^3	2.2 μg/m^3	3.0 μg/m^3
4.0	2.1×10^{-2} μg/m^3	4.7×10^{-1} μg/m^3	1.7 μg/m^3
6.0	1.1×10^{-2} μg/m^3	2.5×10^{-1} μg/m^3	1.1 μg/m^3
8.0	7.0×10^{-3} μg/m^3	1.8×10^{-1} μg/m^3	8.7×10^{-1} μg/m^3
9.5	5.0×10^{-3} μg/m^3	1.4×10^{-1} μg/m^3	7.17×10^{-1} μg/m^3
11.0	3.79×10^{-3} μg/m^3	1.08×10^{-1} μg/m^3	5.93×10^{-1} μg/m^3
13.0	2.7×10^{-3} μg/m^3	8.6×10^{-2} μg/m^3	5.15×10^{-1} μg/m^3
15.0	2.12×10^{-3} μg/m^3	7.0×10^{-2} μg/m^3	4.3×10^{-1} μg/m^3
17.0	1.7×10^{-3} μg/m^3	6.1×10^{-2} μg/m^3	3.73×10^{-1} μg/m^3

4. Drastically affected, i.e., those lichens found only after a distance of 8 miles has been reached away from the paper mill along the NE transect (SO_2 concentration of less than 8.7×10^{-1} $\mu g/m^3$).
5. Those lichens which occur too infrequently to correlate their appearance with a definite distance from the paper plant.

In all cases no lichens found in category #5 were located closer than 8 miles from the paper plant. The greatest effect of the Mosinee Paper Mill on the lichen population was found in the NE transect as is summarized in Table 6. Species of lichens occurring consistently on <u>Ulmus americana</u> are well established in the lichen community within 8 miles of the paper plant, while the "normal" lichen population occurring on all other substrates seem not to become completely established until well beyond this 8 mile limit (Table 6).

The "Index of Similarity" was used to compare those lichen populations growing on the same substrate near the paper mill with those populations growing in pollution free areas (Beals, 1960; Bray and Curtis, 1957; Cox, 1969). This index of similarity (C) was found for each station sampled by use of the following formula:

$$C = \frac{2w}{a + b}$$

when:

b = The number of morphologically recognizable species, varieties, and forms found at the particular

TABLE 6

Classification	On *Ulmus americana*	On *Pinus strobus*	On *Acer rubrum*	On *Quercus borealis*
Ubiquitous and showing no effect	*Candelaria concolor* *Lecanora piniperda* *Physcia elaeina* *Physcia orbicularis* *Xanthoria fallax*	*Bacidia chlorococca* *Lepraria* sp.	*Buellia punctata* var. *polyspora* *Candelaria concolor* var. *effusa* *Lepraria* sp. *Physcia orbicularis* *Physcia orbicularis* f. *rubropulchra*	*Allarthonia caesia* *Bacidia chlorococca* *Buellia punctata* var. *polyspora* *Lecanora piniperda* *Lepraria* sp. *Graphis scripta*
Ubiquitous but showing nectrotic and/or bleached patches	*Parmelia caperata* *Physcia millegrana* *Physcia stellaris*	*Parmelia caperata* *Parmelia rudecta*	*Parmelia aurulenta* *Parmelia caperata* *Parmelia sulcata* *Physcia millegrana*	*Candelaria concolor* var. *effusa* *Parmelia aurulenta* *Parmelia caperata* *Parmelia rudecta* *Parmelia sulcata* *Physcia millegrana* *Physcia orbicularis*
Moderately damaged (re-establishing itself in the lichen community within 8 miles NE of the paper mill	*Buellia punctata* var. *polyspora* *Candelaria concolor* var. *effusa* *Lepraria* sp. *Parmelia aurulenta* *Parmelia flaventior* *Parmelia rudecta* *Parmelia sulcata* *Physcia adscendens* *Physcia aipolia* *Physcia grisea*	*Allarthonia caesia* *Evernia mesomorpha* (very necrotic) *Lecanora piniperda* *Parmelia flaventior* *Parmelia sulcata* *Parmelia ulophyllodes*	*Allarthonia caesia* *Bacidia chlorococca* *Buellia punctata** *Candelaria concolor* *Evernia mesomorpha* *Lecanora piniperda* *Lecanora symmicta* *Lecidea vernalis** *Parmelia flaventior* *Parmelia ulophyllodes* *Physcia orbicularis* var. *albociliata**	*Candelaria concolor* *Parmelia flaventior* *Physcia stellaris* *Parmelia subaurifera* *Parmelia ulophyllodes* *Physcia orbicularis* var. *rubropulchra*

Table 6 continued on following page.

Table 6 (continued)

Classification	On *Ulmus americana*	On *Pinus strobus*	On *Acer rubrum*	On *Quercus borealis*
	Physcia orbicularis var. *albociliata* *Physcia orbicularis* var. *rubropulchra* *Xanthoria polycarpa**		*Physcia stellaris* *Physcia subaurifera* *Rinodina pachysperma*	
Drastically affected (not reappearing in the lichen community until more than 8 miles NE of the Mosinee Paper Mills)	*Allarthonia caesia** *Anaptychia psudo-speciosa* var. *tremulans** *Caloplaca holocarpa** *Hypogymnia physodes** *Lobaria quercizans** *Parmelia saxatilis** *Pyxine sorediata** *Rinodina pachysperma**	*Hypogymnia physodes* *Lecanora symmicta* *Parmelia saxatilis* *Usnea hirta*	*Cladonia squamosa** *Graphis scripta* *Ochrolechia pallescens* *Parmelia galbina* *Parmelia saxatilis* *Parmelia rudecta* *Physcia grisea* *Rinodina fastigiata** *Xanthoria fallax**	*Cladonia chlorophaea** *Cladonia squamosa** *Ochrolechia pallescens** *Parmelia galbina* *Parmelia saxatilis** *Parmelia subrudecta** *Physcia elaeina** *Physcia grisea* *Pertusaria pertusa** *Pyxine sorediata**

* Rare, found only at one sampling station on the NE transect.

station in question on a particular substrate.

a = The number of morphologically recognizable species, varieties, and forms found in a "normally" populated unpolluted station.

w = The number of morphologically recognizable species, varieties, and forms which the two stations (a and b) have in common.

A low index of similarity means that there is little similarity between the lichen population at a particular station and the lichen population in the least disturbed area. The low initial inset of similarity figured for Pinus in Graph 2 means that the most disturbance has occured here. As the distance from the paper mill increases the figures for index of similarity increase indicating that the lichen population is becoming more like the undisturbed areas.

Although theoretically identical communities should have an index of similarity of 1.00, replicate samples for a single community usually show indexes of only about 0.85 (Cox, 1969).

The "normal" population stands were selected from stations greater than or equal to 17 miles southeast or south of the paper plant (Tables 7-10). The "normal" stations were defined as those with the greatest amount of lichen diversity within the sampling area. Graphs 2-9 show the corresponding C values of the foliose and fruticose lichens for a particular substrate along the transects sampled. The values for U. americana in this analysis

TABLE 7

The Normal Population of Corticolous Lichens Found on *Ulmus americana* 18 Miles South of the Mosinee Paper Mills

FOLIOSE AND FRUTICOSE:
Candelaria concolor
Candelaria concolor var. *effusa*
Evernia mesomorpha
Parmelia aurulenta
Parmelia bolliana
Parmelia caperata
Parmelia rudecta
Parmelia sulcata
Parmelia ulophyllodes
Physcia aipolia
Physcia elaeina
Physcia grisea
Physcia millegrana
Physcia orbicularis
Physcia orbicularis f. *albociliata*
Physcia orbicularis f. *rubropulchra*
Physcia stellaris
Xanthoria candelaria
Xanthoria fallax
CRUSTOSE:
Buellia punctata var. *polyspora*
Caloplaca ulmorum
Lecanora piniperda
Lepraria sp.
Rinodina pachysperma

TABLE 8

The Normal Population of Corticolous Lichens Found on _Acer rubrum_ 14-16 Miles Southwest of the Mosinee Paper Mills

---

FOLIOSE AND FRUTICOSE:

Candelaria concolor
Candelaria concolor var. _effusa_
Parmelia aurulenta
Parmelia caperata
Parmelia flaventior
Parmelia galbina
Parmelia rudecta
Parmelia saxatilis
Parmelia subaurifera
Parmelia sulcata
Parmelia ulophyllodes
Physcia millegrana
Physcia orbicularis
Physcia orbicularis f. _rubropulchra_
Ramalina fastigiata
Xanthoria fallax

CRUSTOSE:

Bacidia chlorococca
Buellia punctata var. _polyspora_
Lecanora piniperda
Lecanora symmicta
Lepraria sp.
Pertusaria velata
Rinodina pachysperma

TABLE 9

The Normal Population of Corticolous Lichens Found on *Quercus borealis* 14 Miles South of the Mosinee Paper Mills

FOLIOSE AND FRUTICOSE:

Candelaria concolor
Candelaria concolor var. *effusa*
Evernia mesomorpha
Parmelia aurulenta
Parmelia bolliana
Parmelia caperata
Parmelia flaventior
Parmelia galbina
Parmelia rudecta
Parmelia subaurifera
Parmelia sulcata
Parmelia ulophyllodes
Physcia elaeina
Physcia grisea
Physcia millegrana
Physcia orbicularis
Physcia orbicularis f. *albociliata*
Physcia orbicularis f. *rubropulchra*
Ramalina fastigiata
Usnea hirta
Xanthoria fallax

CRUSTOSE:

Allarthonia caesia
Bacidia chlorococca
Buellia punctata var. *polyspora*
Graphis scripta
Lepraria sp.
Pertusaria velata

TABLE 10

The Normal Population of Corticolous Lichens Found on *Pinus strobus* 18 Miles South of the Mosinee Paper Mills

---

FOLIOSE AND FRUTICOSE:

Cladonia squamosa
Evernia mesomorpha
Hypogymnia physodes
Nephroma helveticum
Parmelia caperata
Parmelia flaventior
Parmelia rudecta
Parmelia sulcata
Physcia millegrana
Usnea hirta

CRUSTOSE:

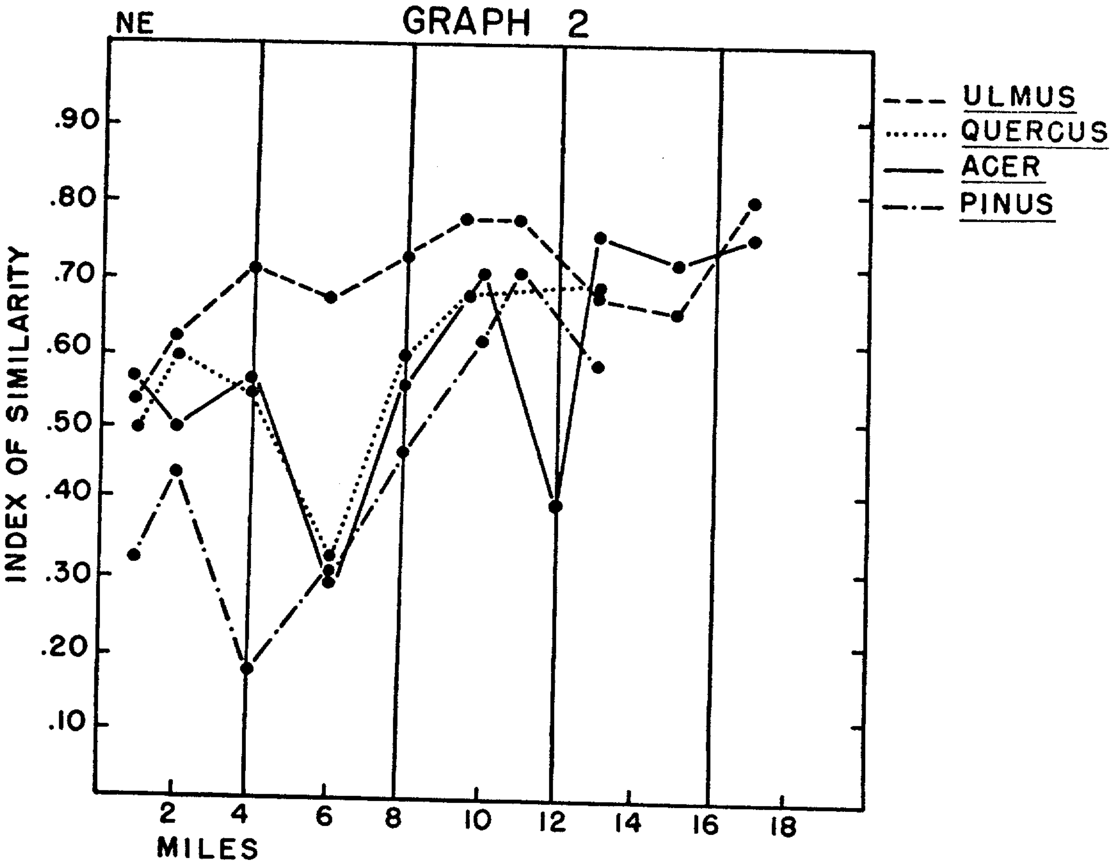
Allarthonia caesia
Bacidia chlorococca
Buellia punctata var. *polyspora*
Lecanora piniperda
Lepraria sp.

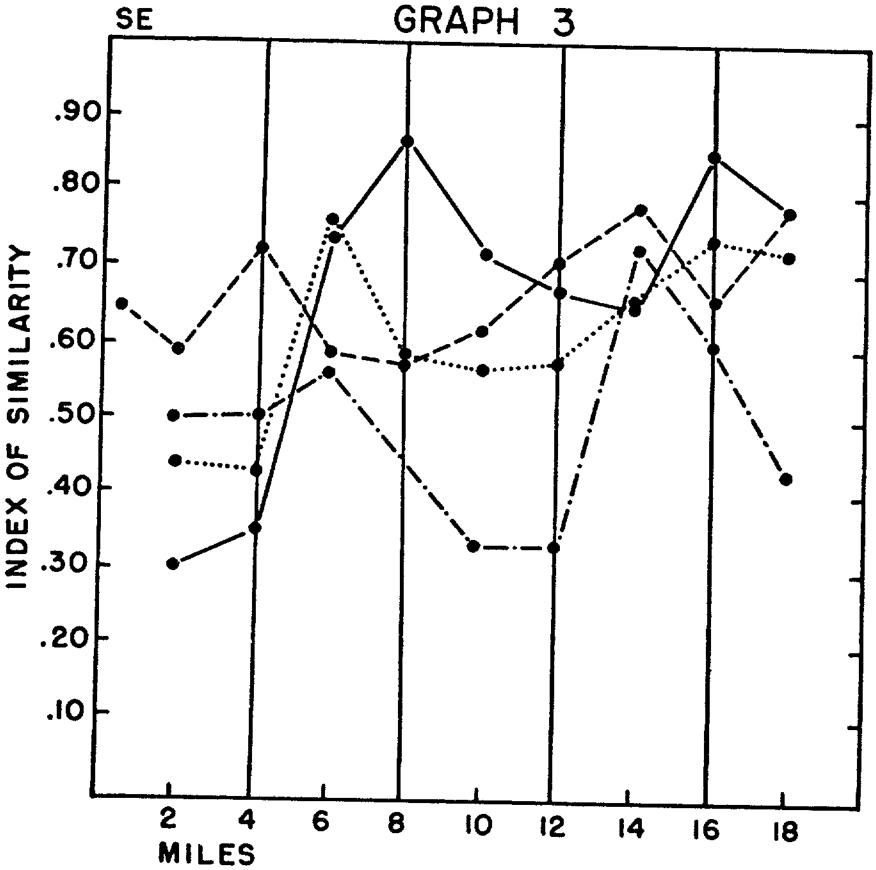
Graph 2

Index of similarity calculated from the foliose and fruticose lichens along the northeast transect

Graph 3

Index of similarity calculated from the foliose and fruticose lichens along the northeast transect


NE
GRAPH 2
ULMUS
QUERCUS
ACER
PINUS
INDEX OF SIMILARITY
.90
.80
.70
.60
.50
.40
.30
.20
.10
2 4 6 8 10 12 14 16 18
MILES


SE
GRAPH 3
INDEX OF SIMILARITY
.90
.80
.70
.60
.50
.40
.30
.20
.10
2 4 6 8 10 12 14 16 18
MILES

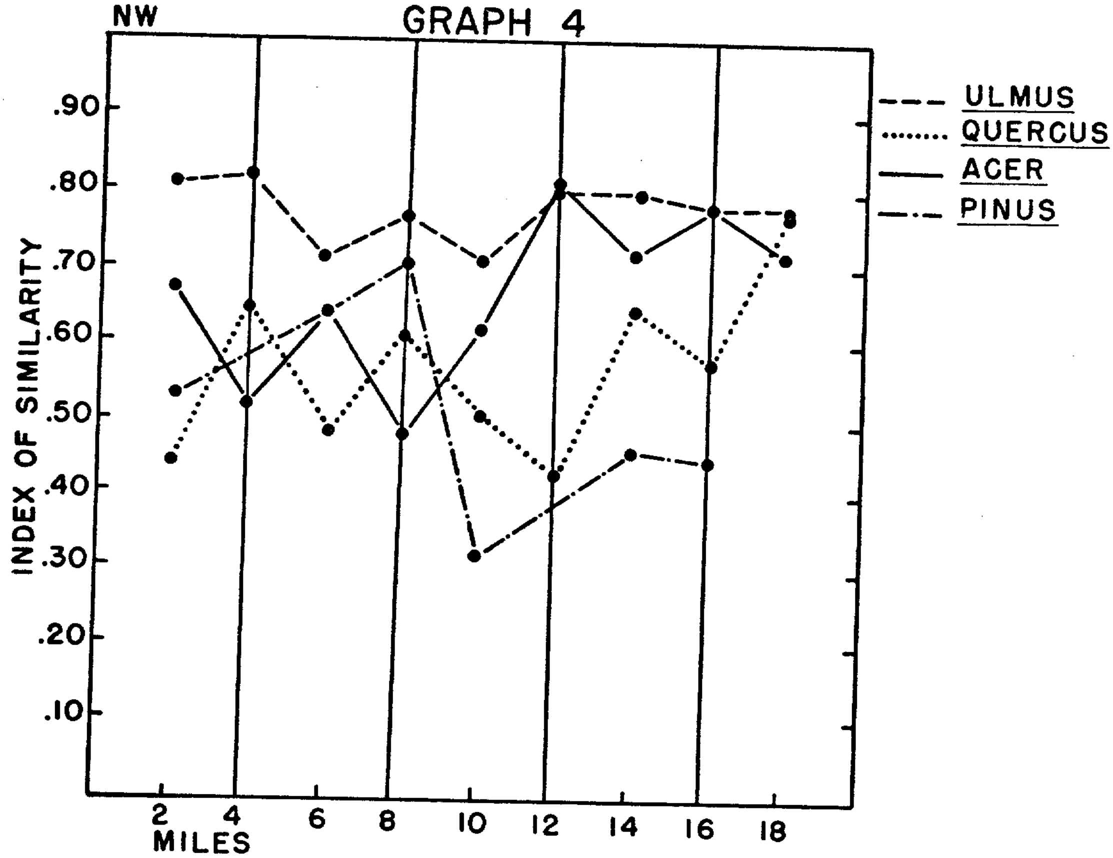
Graph 4

Index of similarity calculated from the foliose and fruticose lichens along the northwest transect

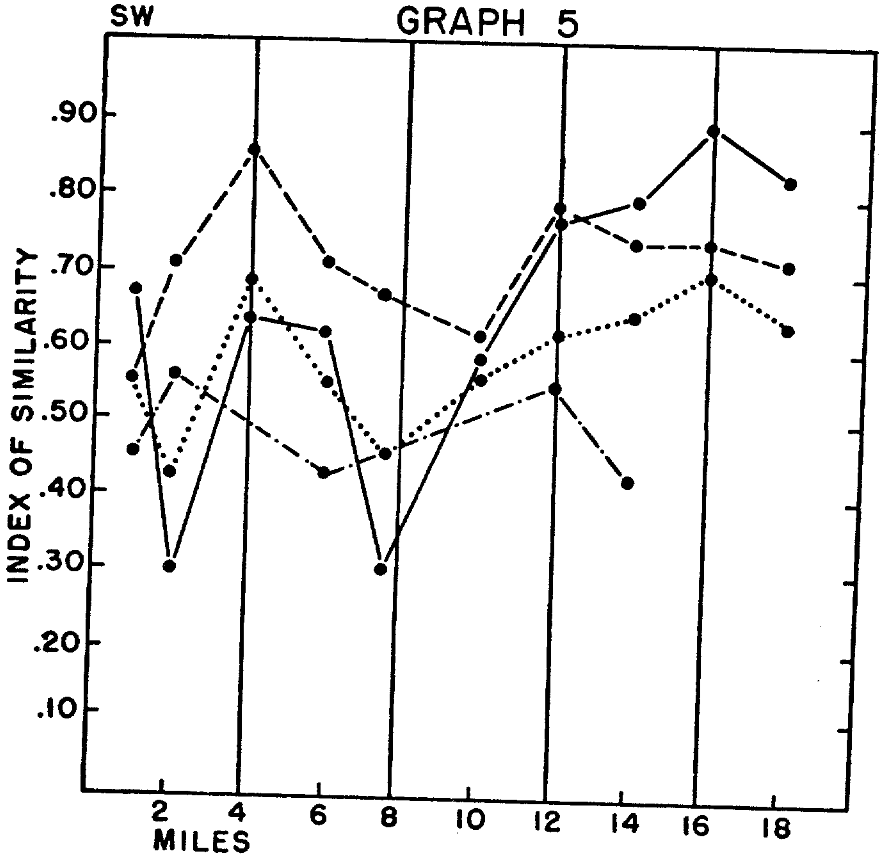
Graph 5

Index of similarity calculated from the foliose and fruticose lichens along the southwest transect

GRAPH 4



GRAPH 5

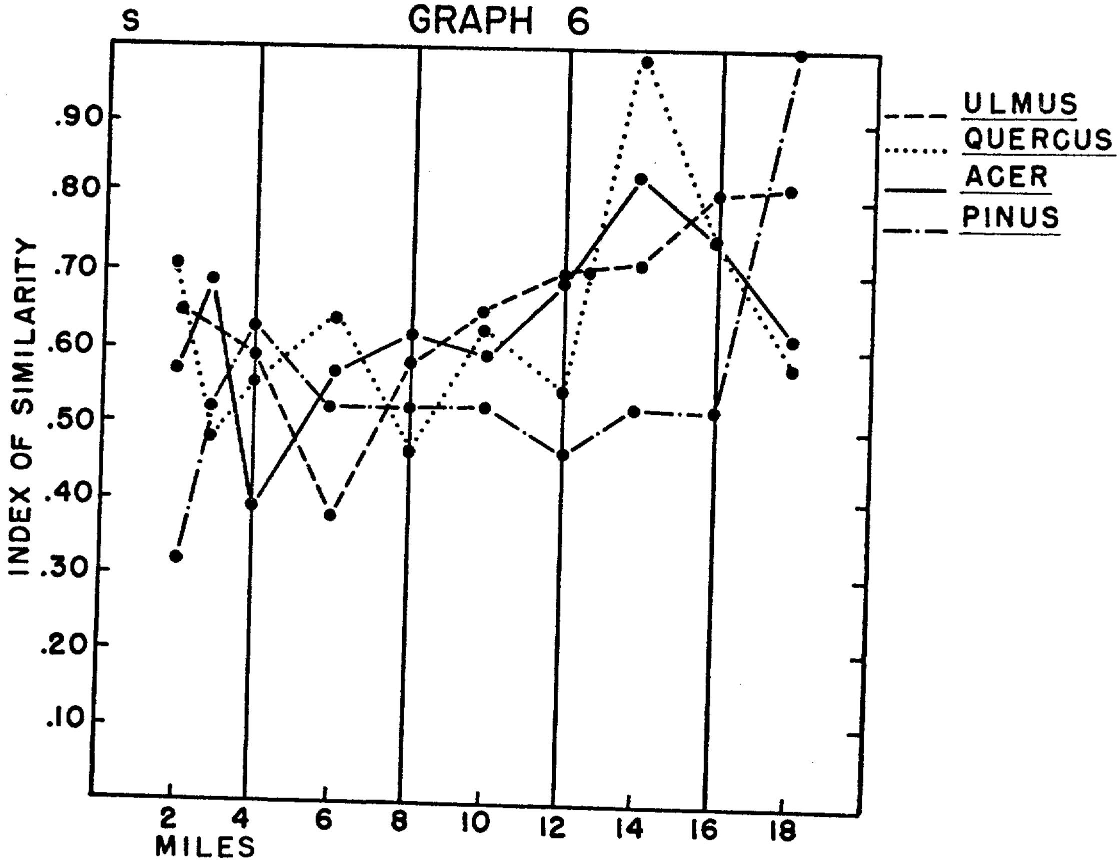


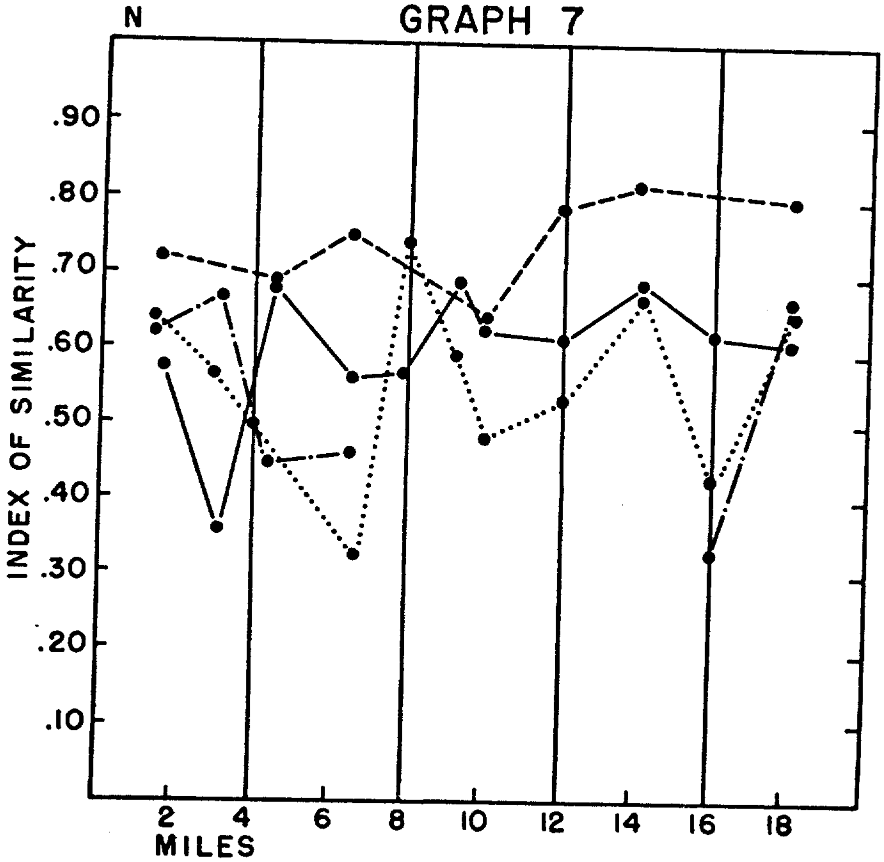
Graph 6

Index of similarity calculated from the foliose and fruticose lichens along the southern transect

Graph 7

Index of similarity calculated from the foliose and fruticose lichens along the northern transect


S
GRAPH 6
ULMUS
QUERCUS
ACER
PINUS
INDEX OF SIMILARITY
.90
.80
.70
.60
.50
.40
.30
.20
.10
2
4
6
8
10
12
14
16
18
MILES

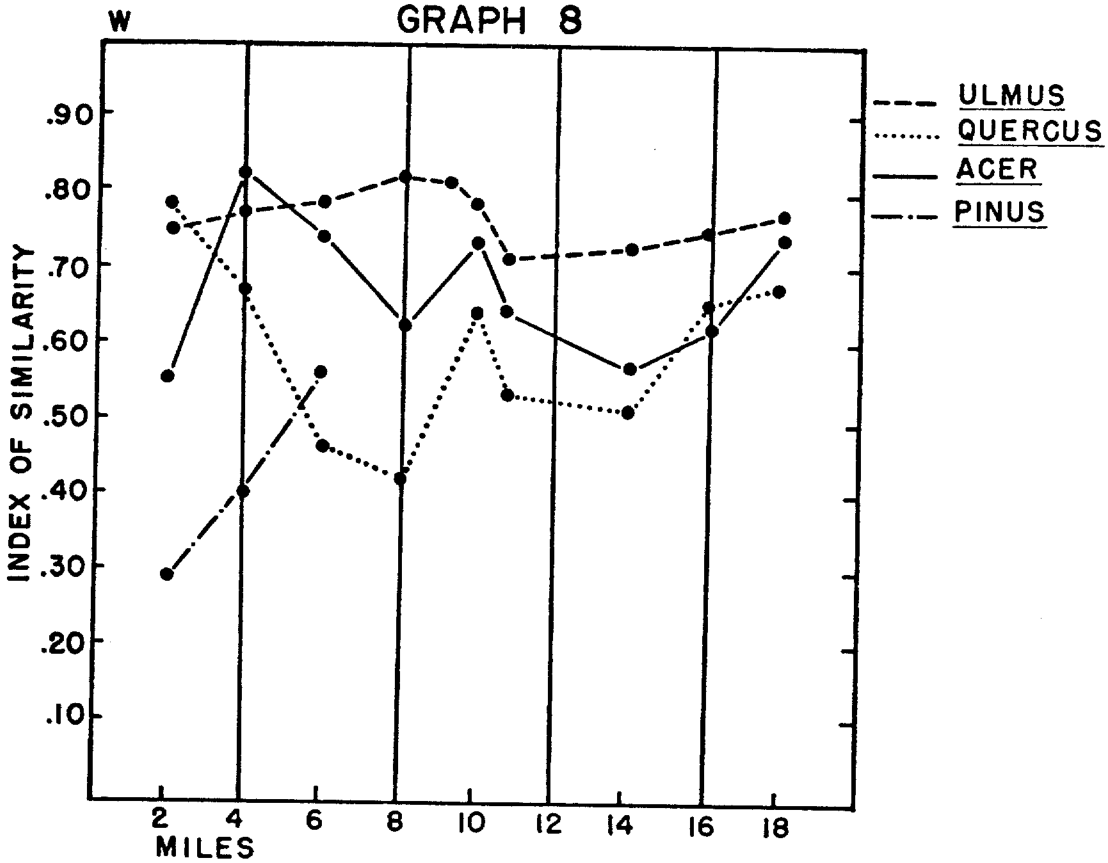

N
GRAPH 7
INDEX OF SIMILARITY
.90
.80
.70
.60
.50
.40
.30
.20
.10
2
4
6
8
10
12
14
16
18
MILES

Graph 8

Index of similarity calculated from the foliose and fruticose lichens along the western transect

Graph 9

Index of similarity calculated from the foliose and fruticose lichens along the eastern transect


W
GRAPH 8
ULMUS
QUERCUS
ACER
PINUS
INDEX OF SIMILARITY
.90
.80
.70
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.50
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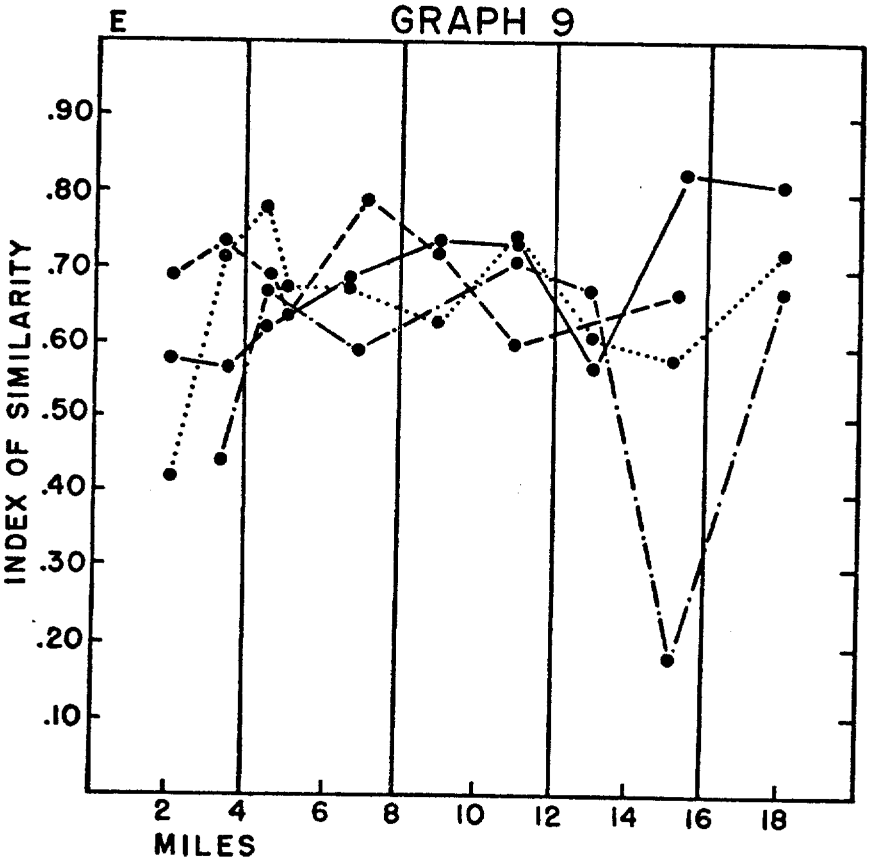
.20
.10
2
4
6
8
10
12
14
16
18
MILES


E
GRAPH 9
INDEX OF SIMILARITY
.90
.80
.70
.60
.50
.40
.30
.20
.10
2
4
6
8
10
12
14
16
18
MILES

are generally higher nearer to the paper mill than the C values for any other tree substrate sampled. It is also evident that the indexes of similarity values for stations whose substrate is P. strobus are consistently lower than for the other three substrates. The indexes of similarity for the stations containing Q. borealis and A. rubrum are quite similar. Graphs 10-17 show the C values calculated for the stations along the transect using the foliose, fruticose, and crustose lichens. It is evident from an analysis of these graphs that the curves found in Graphs 2-9 appear to be flattened. This masking effect suggests that the crustose lichens are not as sensitive to air pollution as the foliose and fruticose forms. To test this hypothesis the index of similarity was calculated using just the crustose forms. The results of the analyses including the crustose species are found in Graphs 18-25. A study of these graphs shows that air pollution, at least in the concentrations found surrounding the Mosinee Paper Mills, seems to have little effect on the diversity of the crustose lichen population.

The seemingly greater tolerance of the crustose lichens to air pollution could be due to the fact that most of the thallus of these forms is not exposed directly to the polluted atmosphere. Instead, they are imbedded in tree bark which provides a buffered microenvironment for the crustose thallus. The foliose and fruticose lichen forms, on the other hand, are exposed directly to the polluted air.

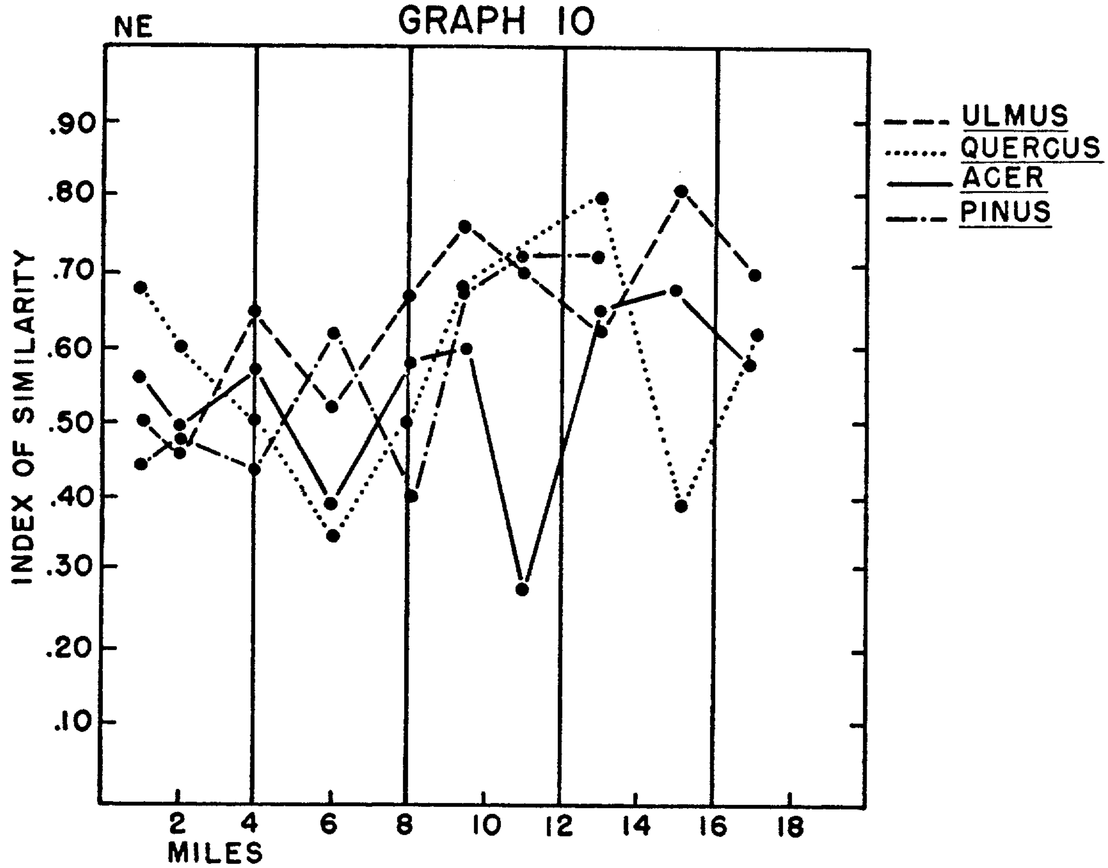
Graph 10

Index of similarity calculated from the foliose, fruticose, and crustose lichens along the northeast transect

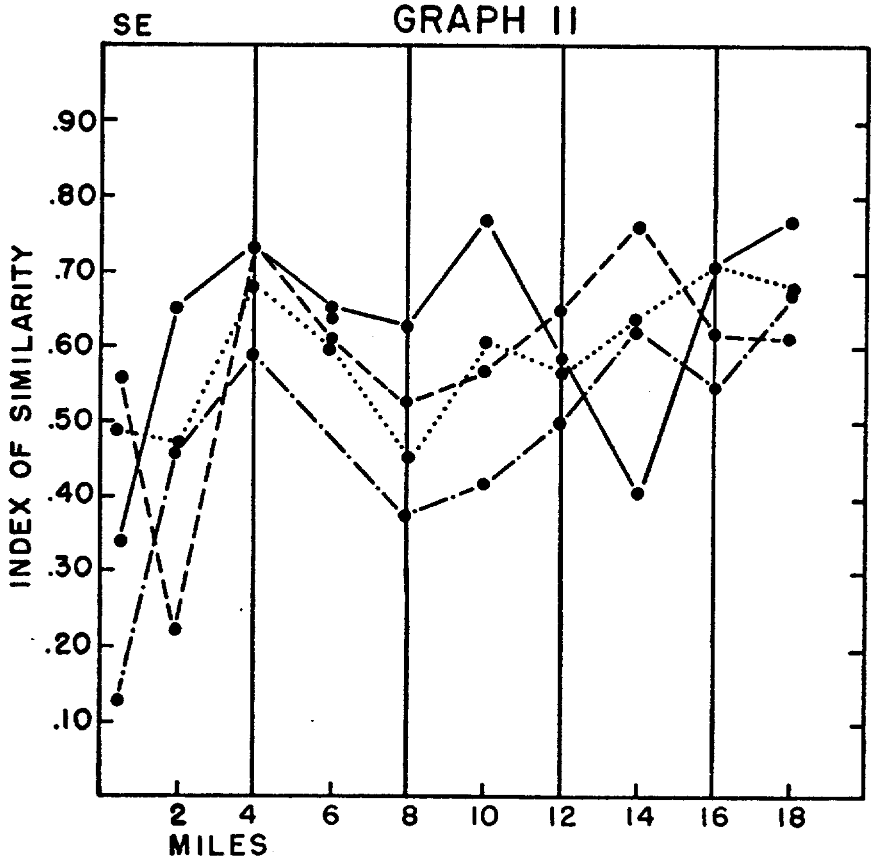
Graph 11

Index of similarity calculated from the foliose, fruticose, and crustose lichens along the southeast transect

GRAPH 10



GRAPH 11



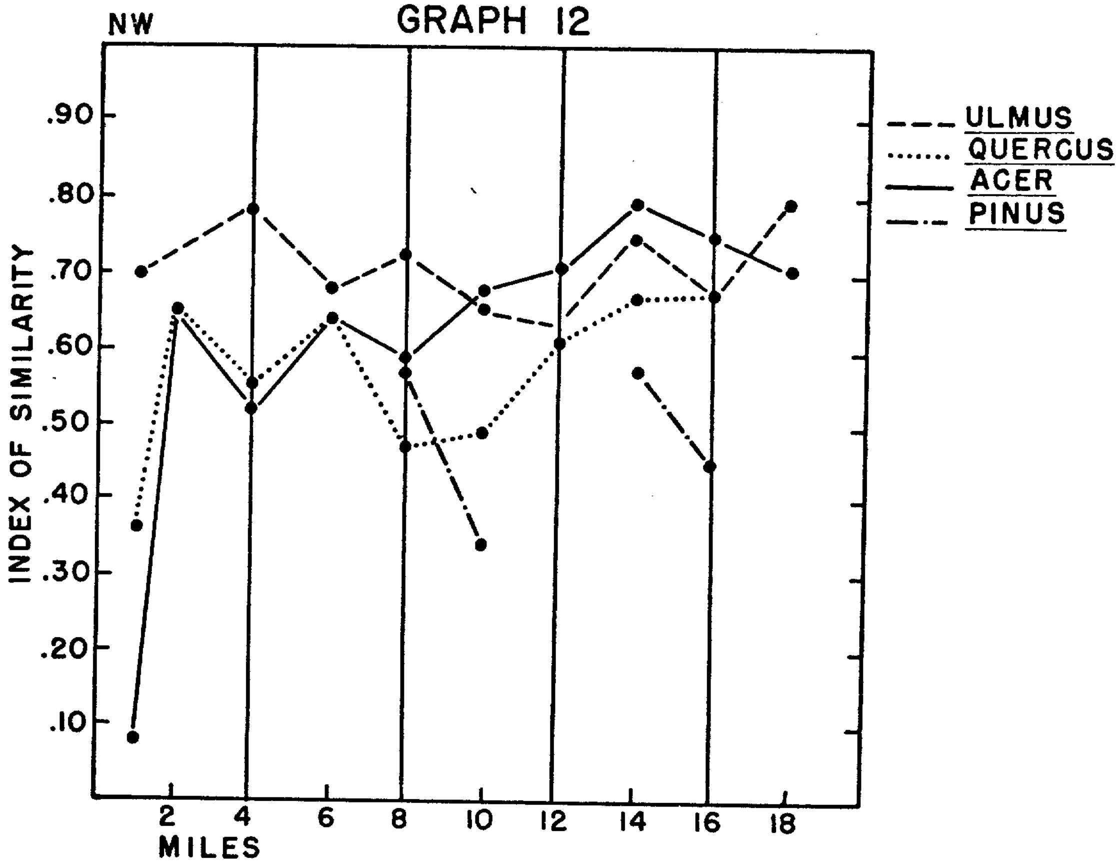
Graph 12

Index of similarity calculated from the foliose, fruticose, and crustose lichens along the northwest transect

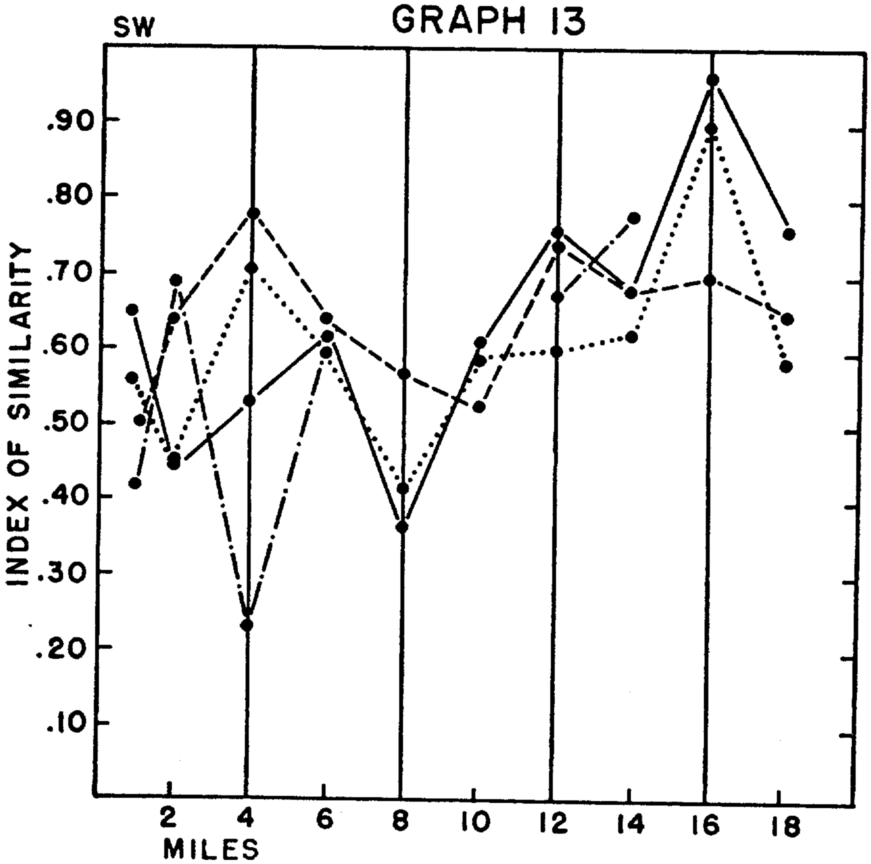
Graph 13

Index of similarity calculated from the foliose, fruticose, and crustose lichens along the southwest transect

GRAPH 12



GRAPH 13



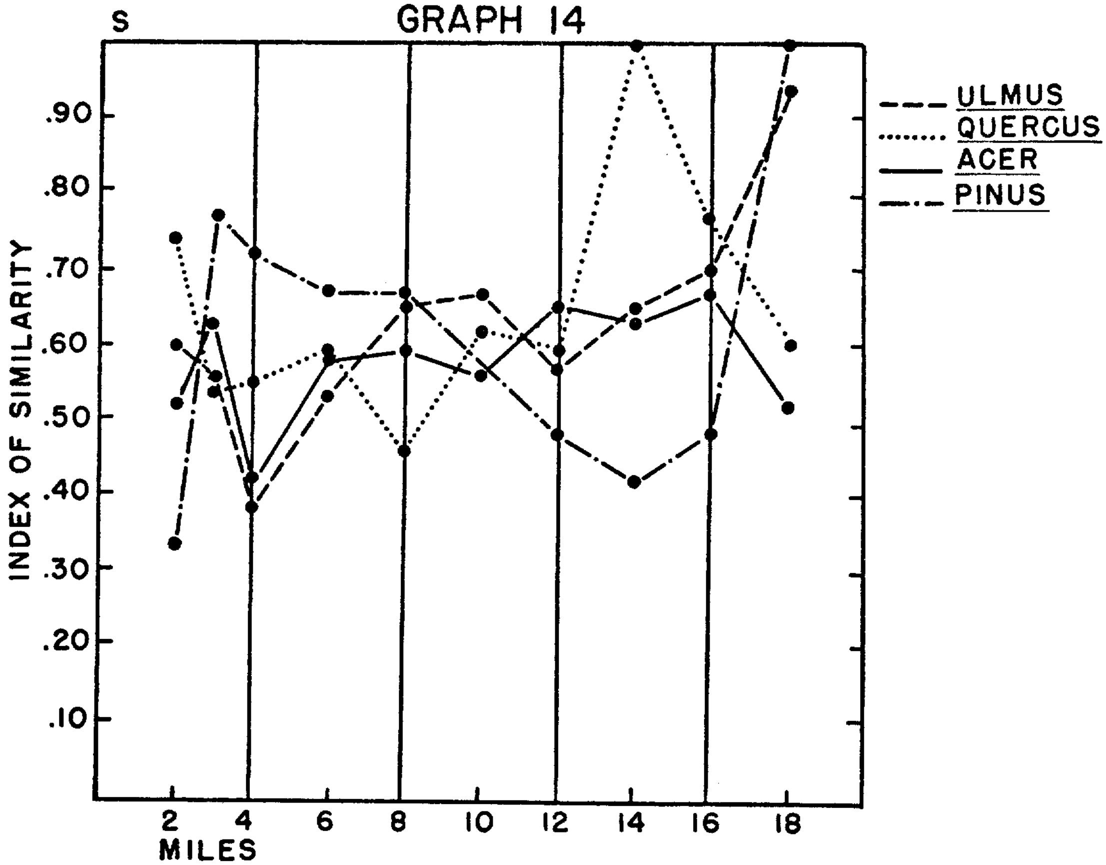
Graph 14

Index of similarity calculated from the foliose, fruticose, and crustose lichens along the southern transect

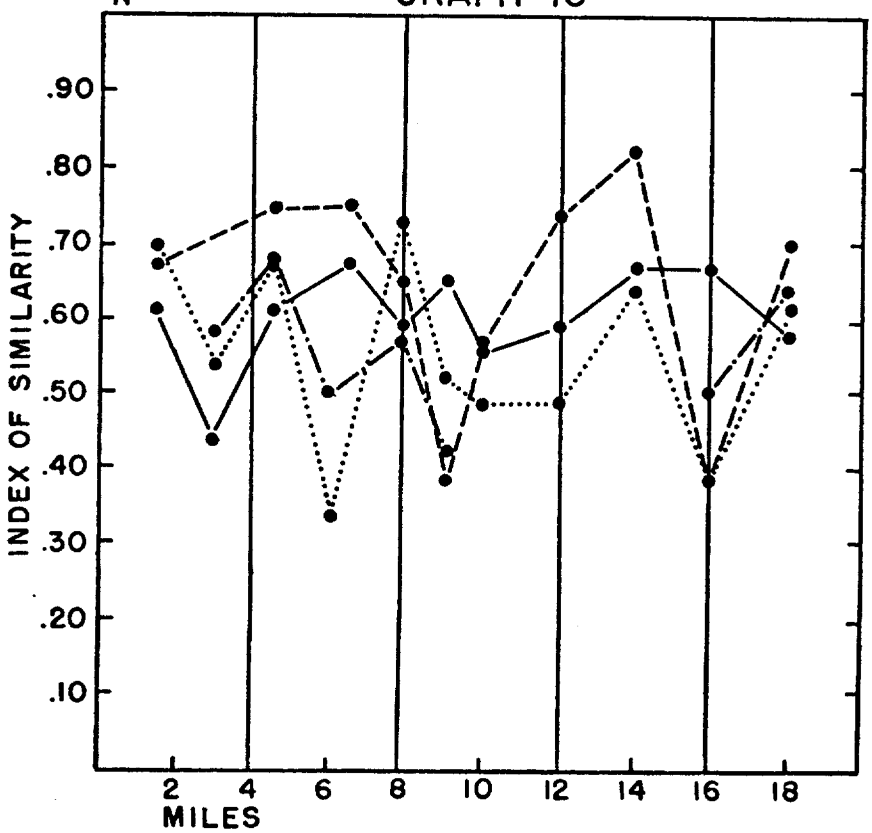
Graph 15

Index of similarity calculated from the foliose, fruticose and crustose lichens along the northern transect

GRAPH 14



GRAPH 15



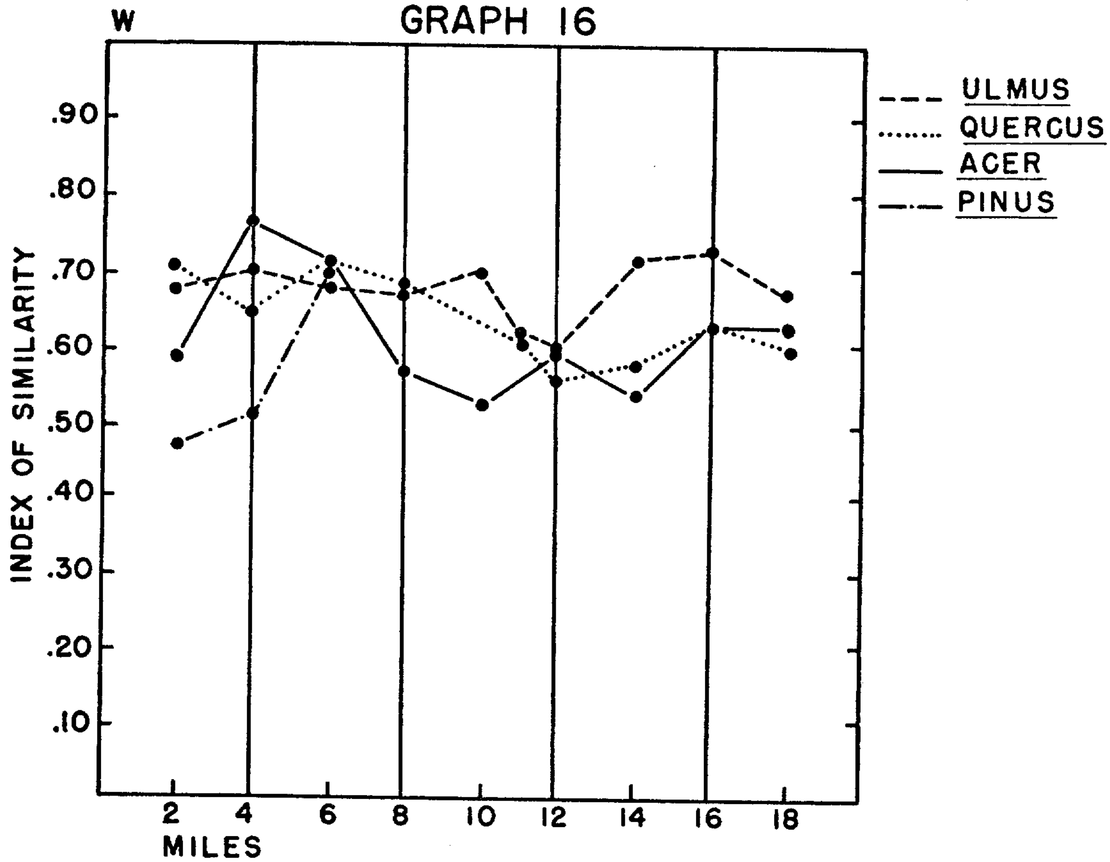
Graph 16

Index of similarity calculated from the foliose, fruticose, and crustose lichens along the western transect

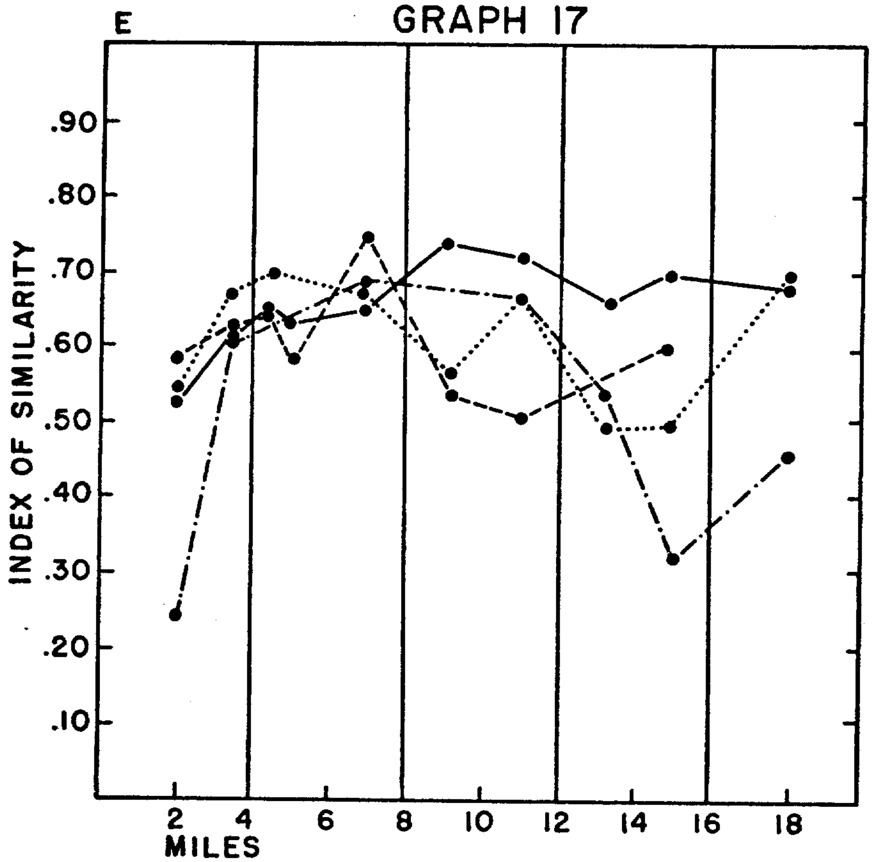
Graph 17

Index of similarity calculated from the foliose, fruticose, and crustose lichens along the eastern transect

GRAPH 16



GRAPH 17

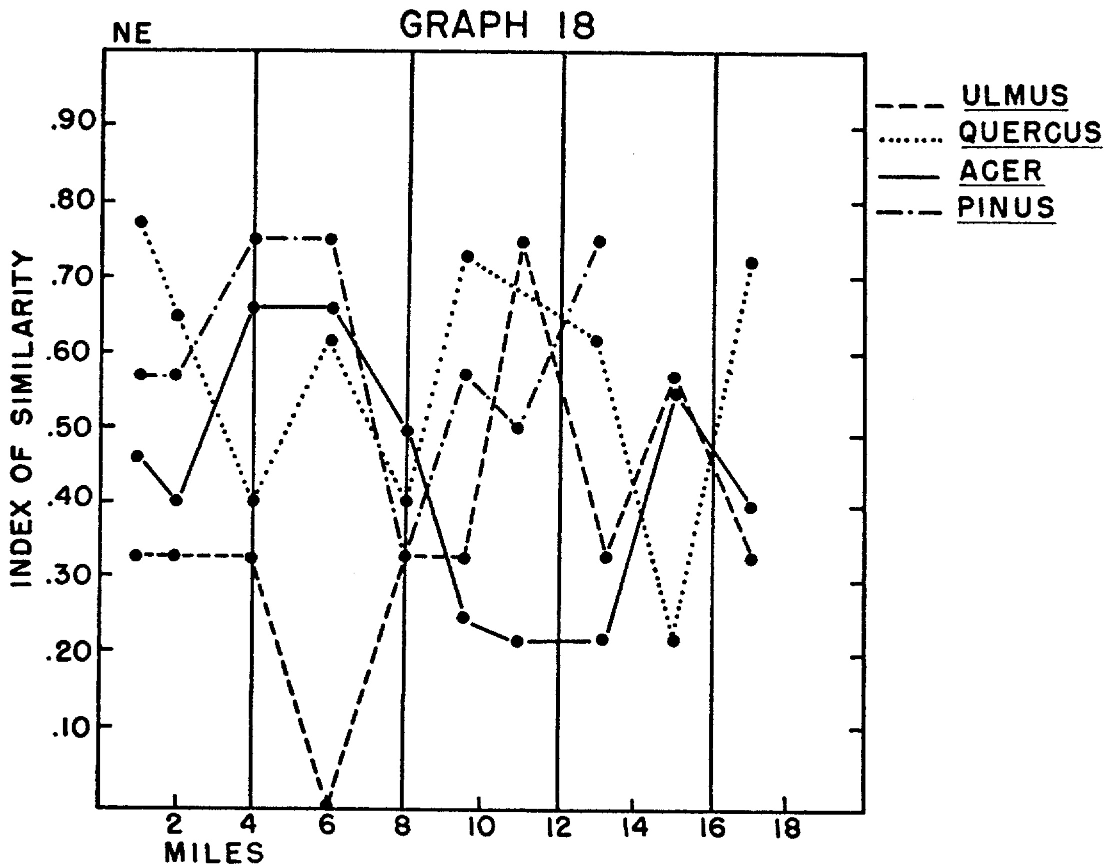


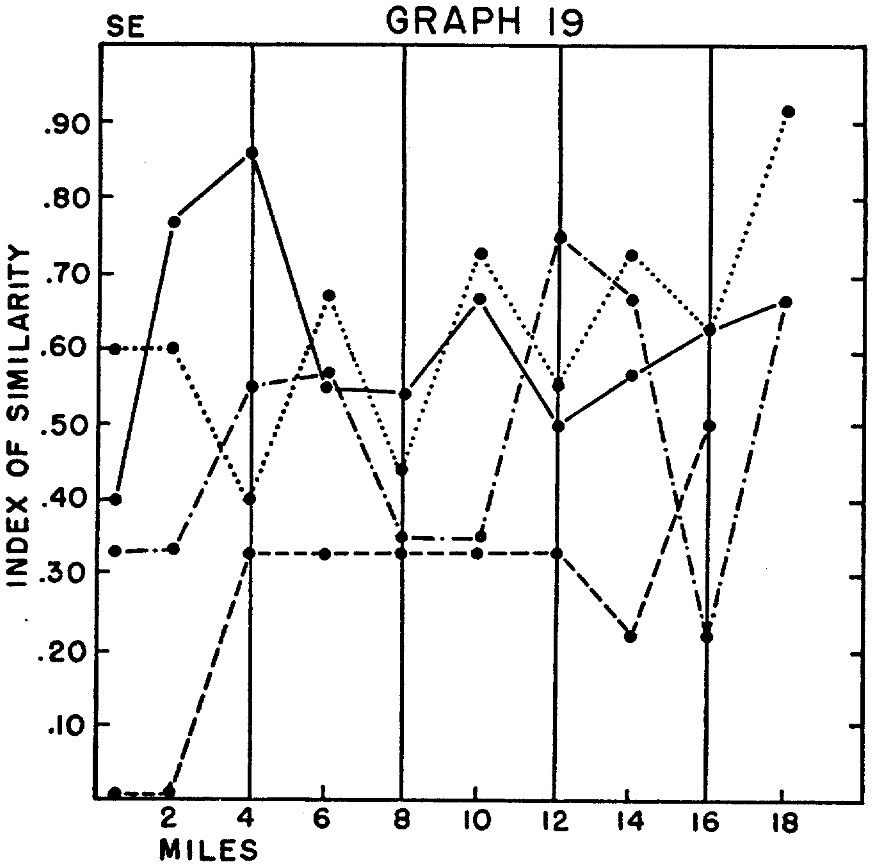
Graph 18

Index of similarity calculated from the
crustose lichens along the
northeast transect

Graph 19

Index of similarity calculated from the
crustose lichens along the
southeast transect


NE
GRAPH 18
ULMUS
QUERCUS
ACER
PINUS
INDEX OF SIMILARITY
.90
.80
.70
.60
.50
.40
.30
.20
.10
2 4 6 8 10 12 14 16 18
MILES


SE
GRAPH 19
INDEX OF SIMILARITY
.90
.80
.70
.60
.50
.40
.30
.20
.10
2 4 6 8 10 12 14 16 18
MILES

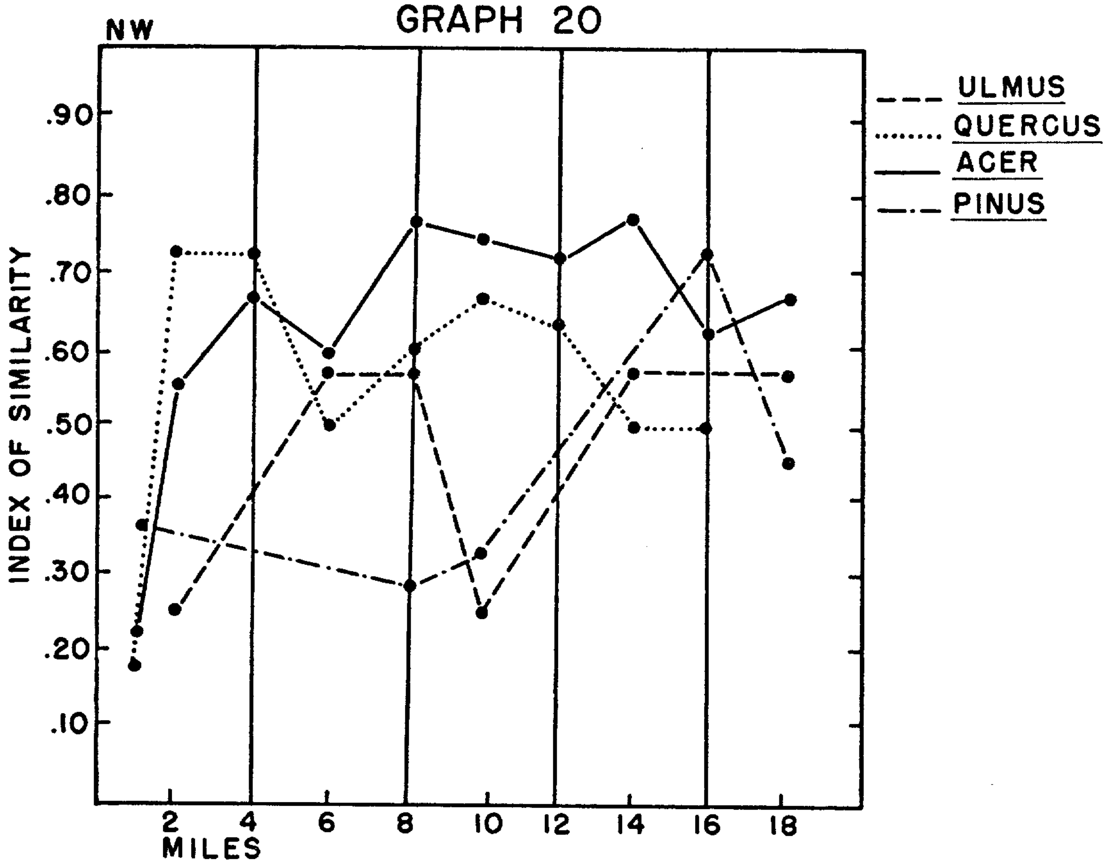
Graph 20

Index of similarity calculated from the crustose lichens along the northwest transect

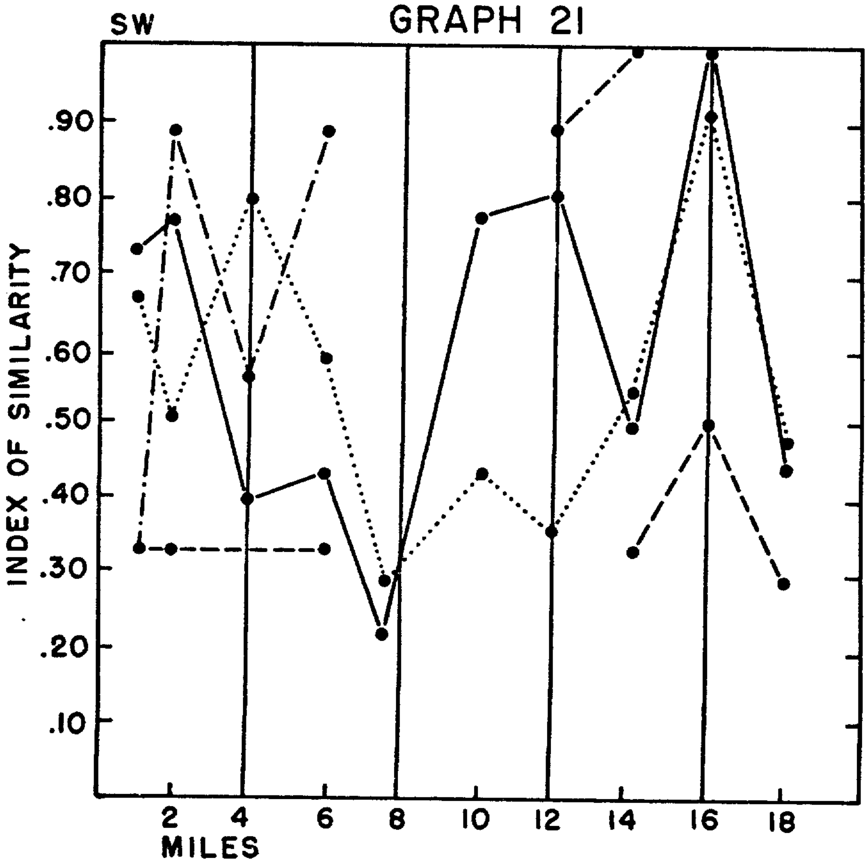
Graph 21

Index of similarity calculated from the crustose lichens along the southwest transect

GRAPH 20



GRAPH 21



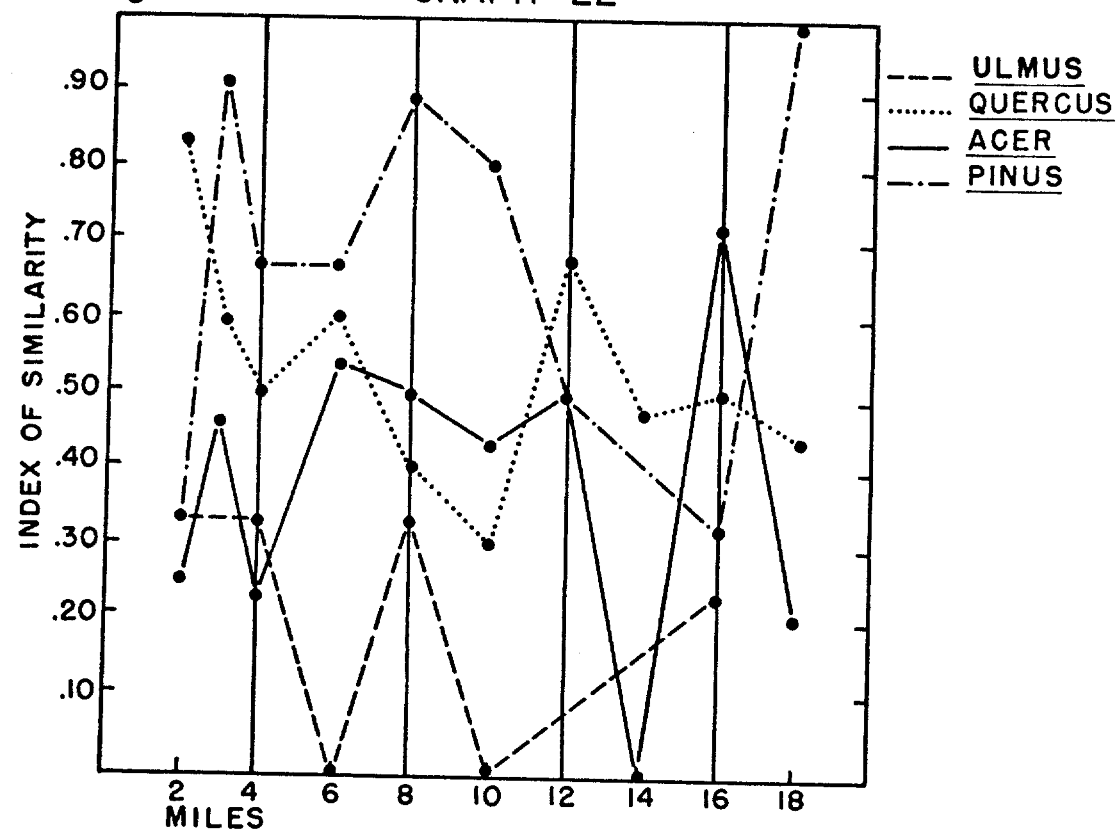
Graph 22

Index of similarity calculated from the
crustose lichens along the
southern transect

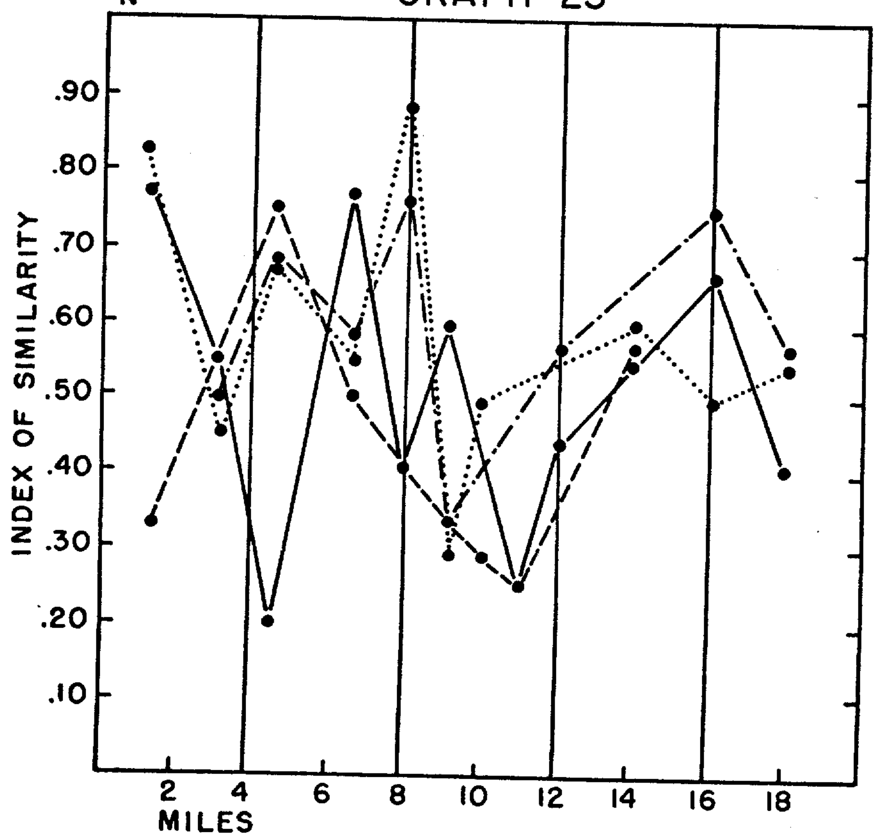
Graph 23

Index of similarity calculated from the
crustose lichens along the
northern transect

GRAPH 22



GRAPH 23



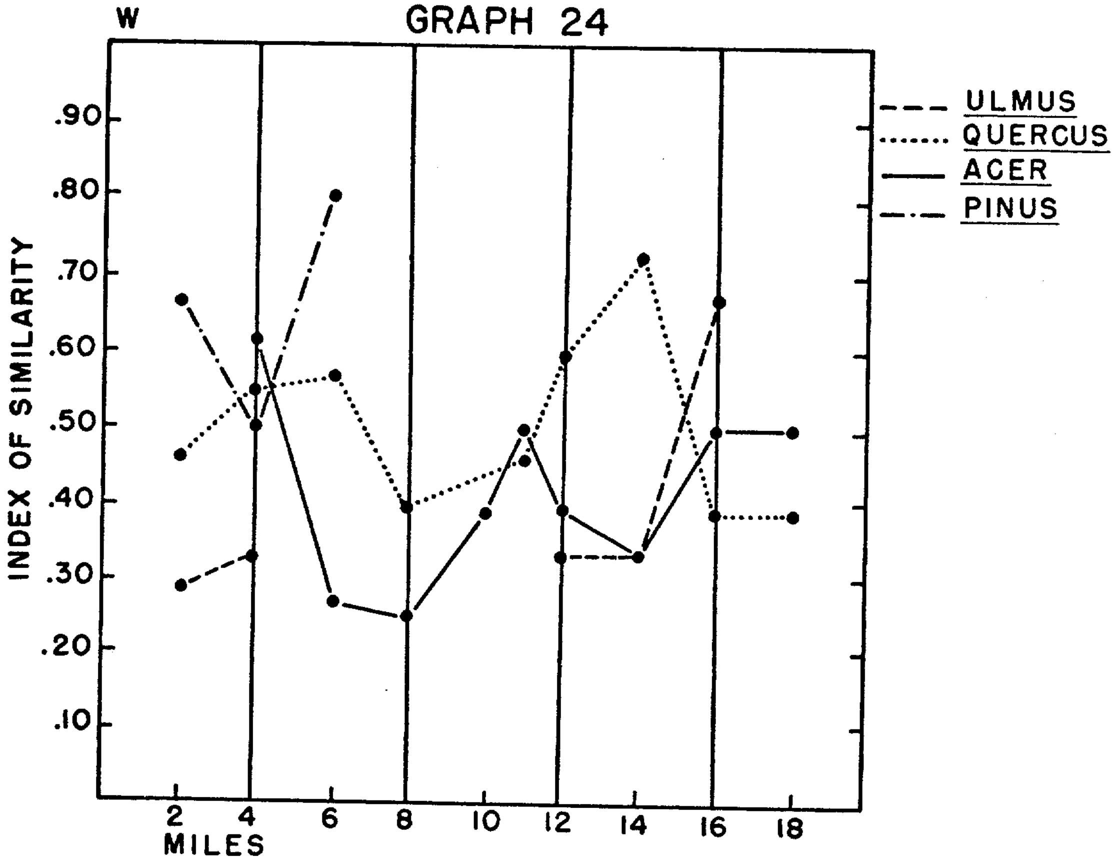
Graph 24

Index of similarity calculated from the crustose lichens along the western transect

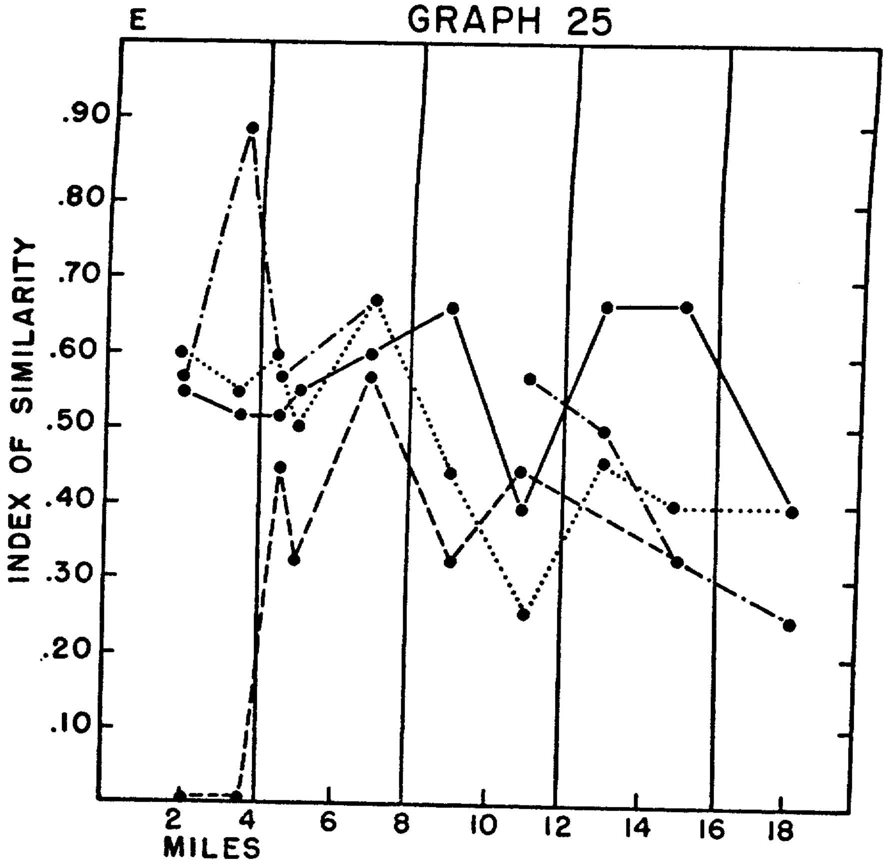
Graph 25

Index of similarity calculated from the crustose lichens along the eastern transect

GRAPH 24



GRAPH 25



The larger the thalli and the more squamulose their structures, the more surface area is exposed to the SO_2 laden air.

If one carries this argument further, it could be predicted that if the crustose lichens are the most tolerant to air pollution then the fruticose lichens may be the least tolerant. Only six fruticose lichens were found in this study: Cladonia chlorophaea, C. squamosa, Evernia mesomorpha, Ramalina fastigiata, Usnea hirta, and U. comosa. Of these six species only Cladonia squamosa and Evernia mesomorpha were found within 8 miles northeast of the paper mill. When the specimens of Evernia mesomorpha found 6 miles northeast of the mill were examined they were found to be less than 2 cm. high and very necrotic. One small thallus of Cladonia squamosa without podetia was found 6 miles northeast of the mill in the furrows of the bark of a Pinus strobus. All other fruticose forms were found much further out. Ramalina fastigiata was found to be necrotic at a distance of 13 miles northeast. Cladonia chlorophaea was very rare, occurring at only one point 13 miles northeast of the mill. Here it appeared normal in all respects. Usnea hirta was found at a distance of 11 miles northeast and appeared small (less than 2 cm. high), but was not necrotic. Usnea comosa did not appear at all along the northeast transect but was found within 8 miles of the paper mill at two stations, 6 miles southeast and 6 miles northwest.

It, therefore, seems evident that the growth form of the lichen thallus has a great deal to do with its tolerance to a polluted environment. This tolerance to air pollution by lichens appears to be inversely proportional to the amount of surface area directly exposed to a polluted atmosphere.

All the sampled trees for a particular station were taken within the same wooded area so that the environmental factors such as light, humidity, and exposure to the wind were as uniform as possible for the given station. From the above results (Graphs 2-9), it appears that the persistence of the foliose and fruticose lichen community on a given substrate is not entirely dependent on the pollution of the environment. The substrate on which the lichen is found appears to play a very important role in the tolerance of a lichen to a polluted environment.

In an effort to find a possible explanation for the observed differences in the index of similarities of the foliose and fruticose (Graphs 2-9), pH analysis of the bark of each of the tree species was performed. The procedure used for these pH tests was a modification of that developed by Hale (Ph.D. thesis, 1953).

A study of a few of the possible sources of error in this method of bark pH determination was made by Hale (Ph.D. thesis, 1953). He found that the degree of pulverization of a bark sample was not a critical factor in obtaining consistent pH results. On corresponding tests made by the author, it was found that within a pulverization range of fine sawdust to that comparable to pipe tobacco the pH values were not noticeably affected since the pH readings in the pulverization tests did not vary more than 0.2 units. Hale also investigated the significance of varying the amount of water in which the bark was soaked. He found that by varying the water from 2-15 cc. the pH readings did not change more than 0.2 units. In a similar analysis, it was found that when less than 5 cc. of water was used, the water was absorbed by the bark bits and not enough "mother liquor" remained after 24 hours to make an accurate pH reading. When the water was squeezed out of the pulverized bark, variations in the pH readings in excess of 0.5 to 0.8 units were observed. With all water concentrations above 5 cc., however, there were no such variations. Hale's observation that the length of time of soaking was significant was corroborated. It took 18-20 hours for many samples to reach equilibrium. After 38-48 hours fermentation and bacterial growth seriously altered the results. Some investigators have found that the size of the sample of bark was important when dealing with small samples. Sjogren (Sjorgen, 1961, quoted by Skye, 1968, p. 106) discusses pH results from small and large samples of bark. He found that samples of less than 1 $cm.^2$ showed a lower pH value than larger bark samples. Culberson (1954) found that pH readings for a particular sample were fairly consistent when a sample was 1.5 $cm.^2$ or larger. In this study several sample sizes were tested: 0.5 g., 1.0 g., 2.0 g., and 3.0 g.

The variation within multiple samplings from the same tree amounted to not more than 0.3 units regardless of sample size.

The sampled tree bark had been stored in paper bags for eight months prior to the pH tests. It was feared that partial oxidation of the bark had taken place during this time period. To check the validity of these pH readings fresh bark was collected from trees growing in a similar wooded area. pH readings were taken on these samples immediately upon returning to the laboratory. Five trees of each of the four sampled species were sampled in this manner and all results corresponded with the bagged specimens.

pH readings were performed on trees from the stations on the northeast transect. A total of 18 trees were located from 1 mile to 17 miles from the paper plant. The results of the pH test performed in this study are enumerated in Graph 1. Skye (1968) found in the region surrounding Stockholm that the nearer a particular species of tree grows to a pollution center, the lower the pH of the bark. This phenomenon of lower pH of a substrate nearer a pollution source was not found in the region surrounding the Mosinee Paper Mill. The pH for a particular tree species varied over a range of 1-2 pH units but this is within the range of individual variability of a given species. This variability was haphazard in nature and showed no geographical correlation.

The pH ranges are specific for each tree species. *U. americana* has the most basic bark of any tree sampled, with a pH average of 5.64. Average pH values for the barks of *Q. borealis* and *A. rubrum* are 4.53 and 4.62, respectively. *P. strobus*, as discussed earlier, has an average pH value of 4.03.

The fact that *U. americana* has the most basic bark and is the substrate upon which lichens persist the longest in a polluted environment, seems to correlate too closely to be just due to chance. Likewise, *P. strobus* which has the most acidic bark, has the fewest number of species of lichens which populate it, and the increase in population of lichens is at a lesser rate as the distance from the plant is increased.

Q. borealis and *A. rubrum* not only have pH values that are intermediate to *U. americana* and *P. strobus*, but also have lichen populations which increase diversely at a rate that lies between the values found for *U. americana* and *P. strobus*.

Skye (1968) not only found *Ulmus* was the most basic bark but it also had the best buffering capacity. In bark buffering capacity tests he found that *Pinus sylvestris* had a very poor buffering bark at low pH values. *Quercus robur* and *Acer platanoides* were intermediate between *Pinus* and *Ulmus* in their buffering capacities. Though the species of *Pinus*, *Quercus*, and *Acer* are not the same as those used in this study, the pH values are similar. It is therefore probable that *Quercus borealis*, *Pinus strobus* and *Acer rubrum* have similar buffering capacities to the European species in the same genera.

The pH of the bark and its buffering capacity are of vital importance in a polluted atmosphere. With the production of H_2SO_4 and H_2SO_3 from emitted SO_2 via photochemical oxidation (Gerhard and Johnstone, 1955) and catalytic oxidation (Johnstone and Coughanowr, 1958), and the absorption of SO_2 in water to form acids, a very acidic environment is produced. The rate of acidification of the bark is affected by its buffering capacity. Those tree species which can retain a high pH (those with high buffering capacities) will be the species on which lichens will most abundantly be found in a polluted environment.

% of Cover

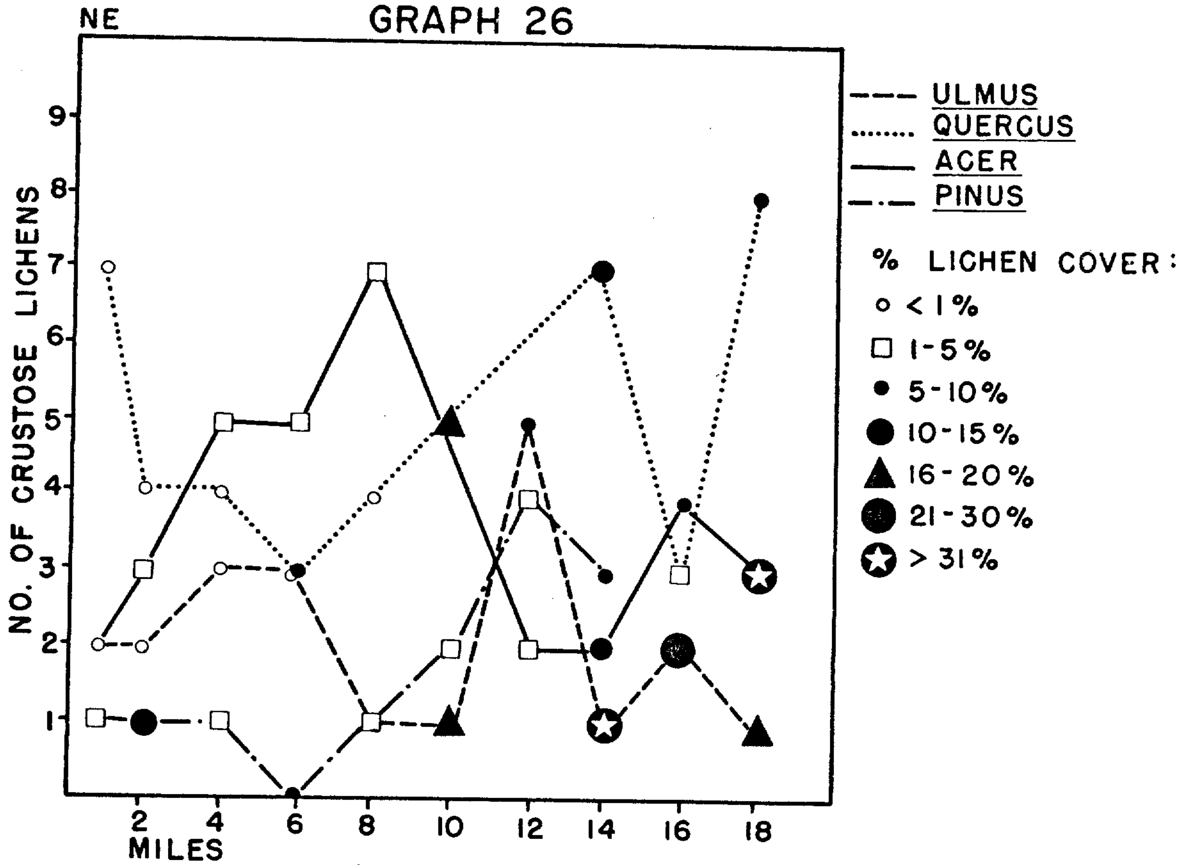
As a general rule, the per cent of lichen cover on the bark of a particular tree species increases as the distance from the Mosinee Paper Mill increases (Graphs 26-33). The greatest injury is found northeast of the paper plant. Along this transect a lichen cover of more than 30% is not reached until 14 miles from the mill. Furthermore, this percentage of cover is only found on *U. americana* at this distance. A distance of 18 miles away from the plant along the northeast transect must be transversed before a similar percentage of lichen cover is found on the other tree species sampled. The per cent of cover, however,

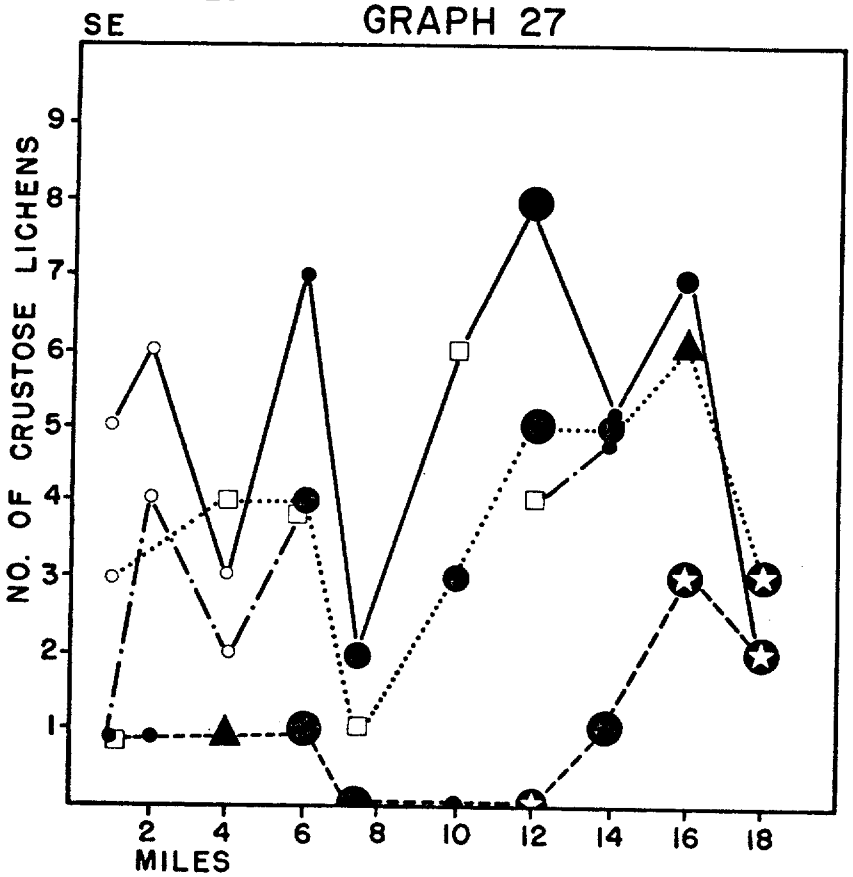
Graph 26

Number of crustose lichens and per cent cover along the northeast transect

Graph 27

Number of crustose lichens and per cent cover along the southeast transect


NE
GRAPH 26
NO. OF CRUSTOSE LICHENS
MILES
ULMUS
QUERCUS
ACER
PINUS
% LICHEN COVER:
< 1%
1-5%
5-10%
10-15%
16-20%
21-30%
> 31%


SE
GRAPH 27
NO. OF CRUSTOSE LICHENS
MILES

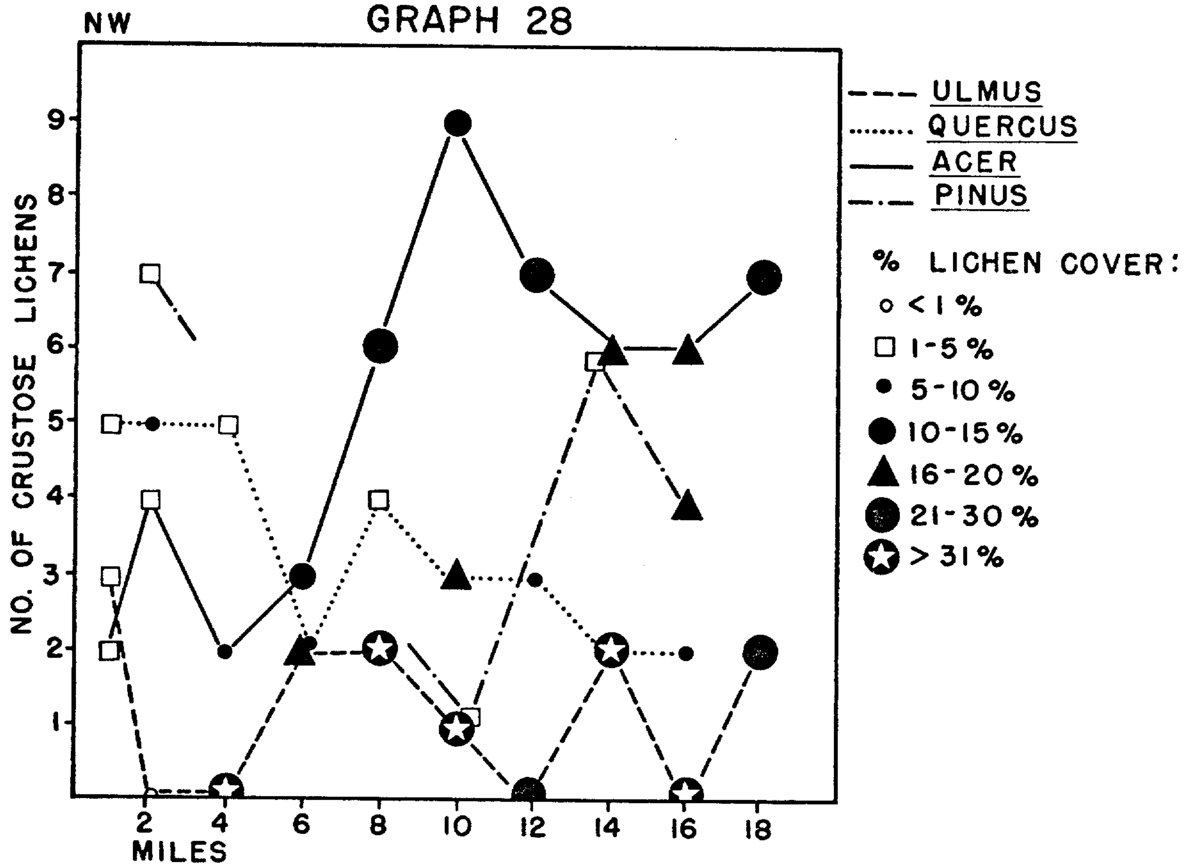
Graph 28

Number of crustose lichens and per cent cover along the northwest transect

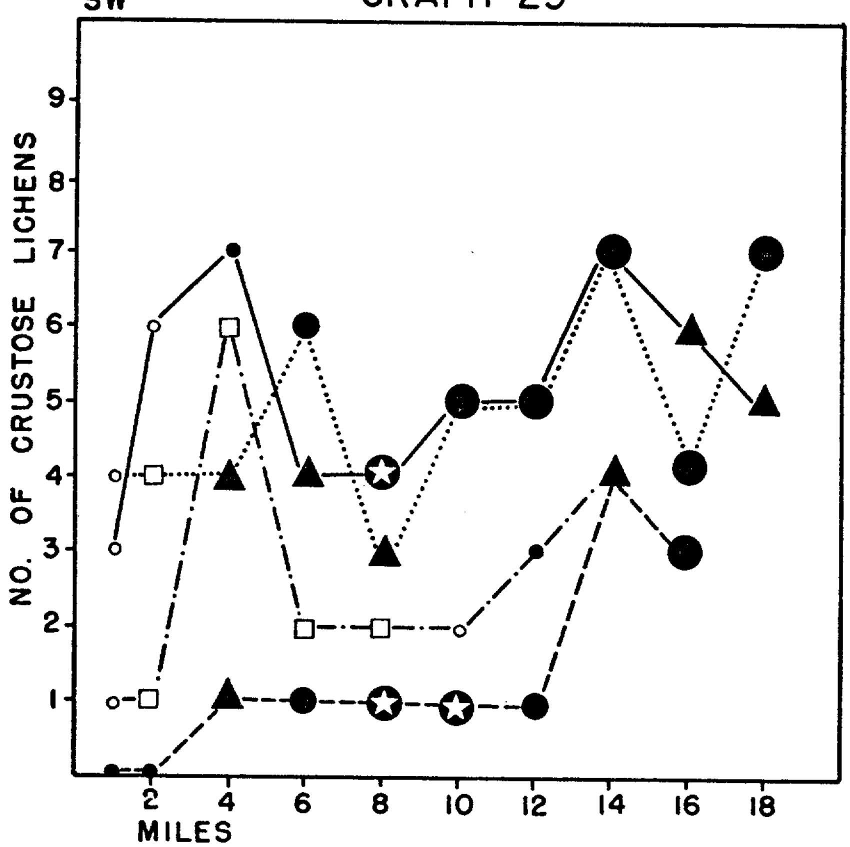
Graph 29

Number of crustose lichens and per cent cover along the southwest transect

GRAPH 28



GRAPH 29



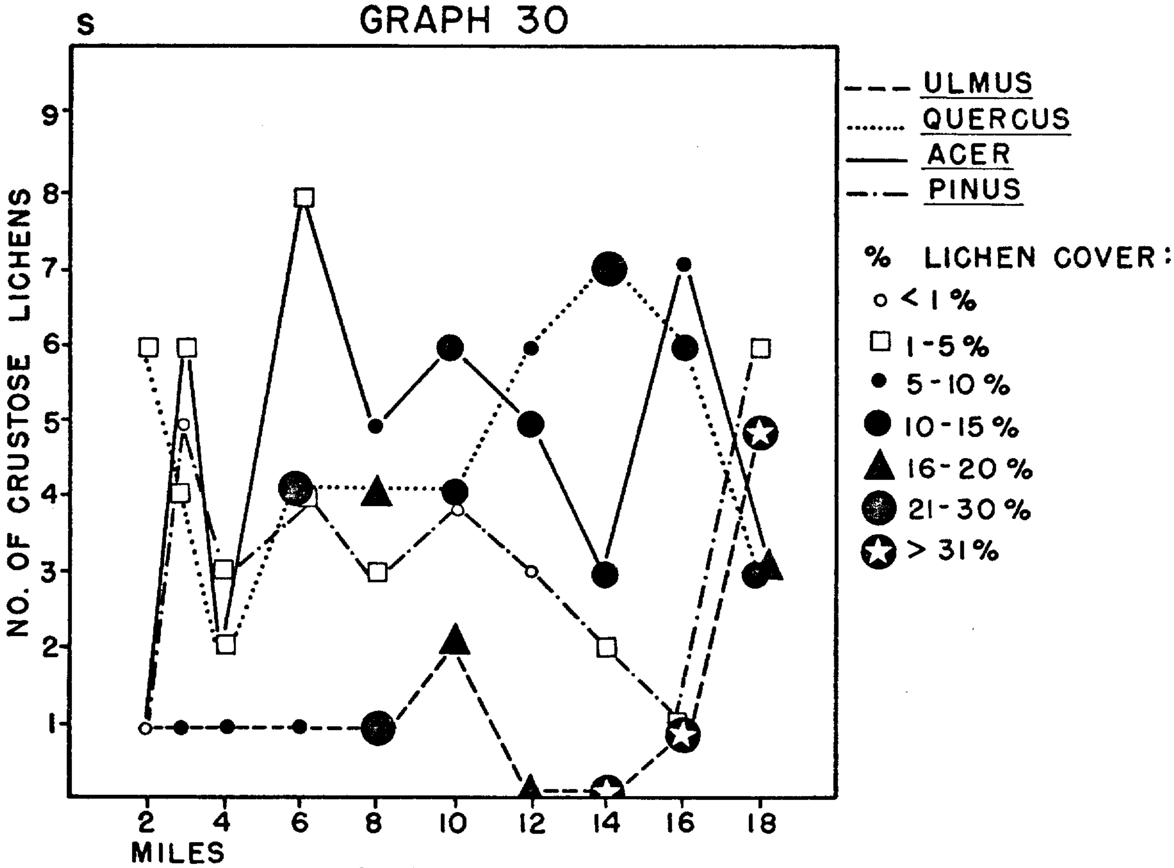
Graph 30

Number of crustose lichens and per cent cover along the southern transect

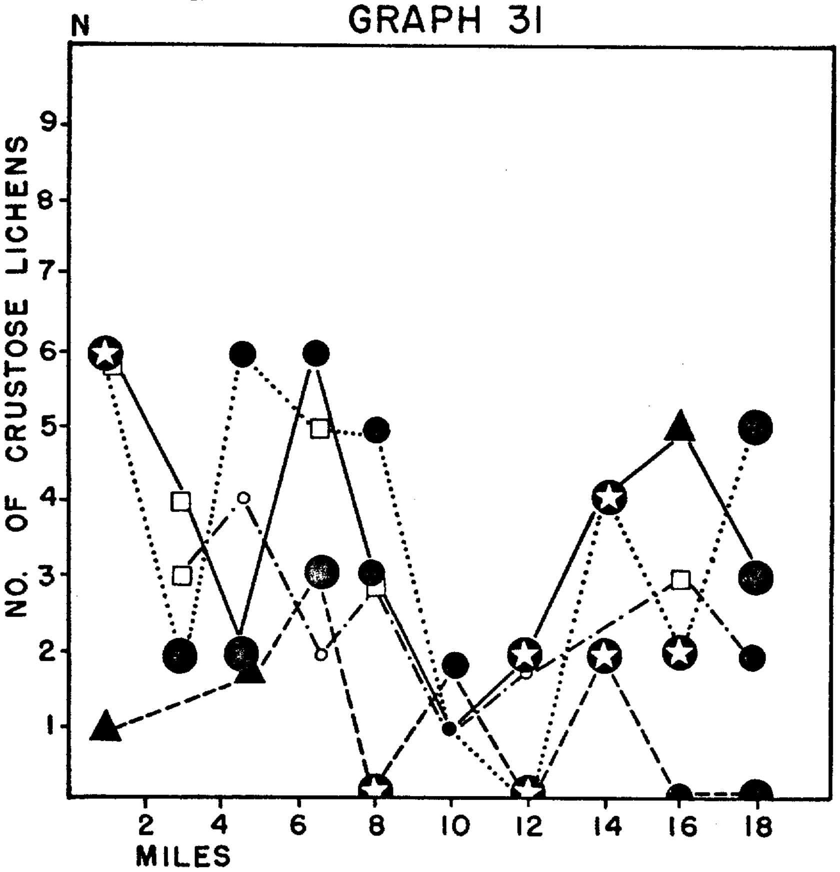
Graph 31

Number of crustose lichens and per cent cover along the northern transect

GRAPH 30



GRAPH 31

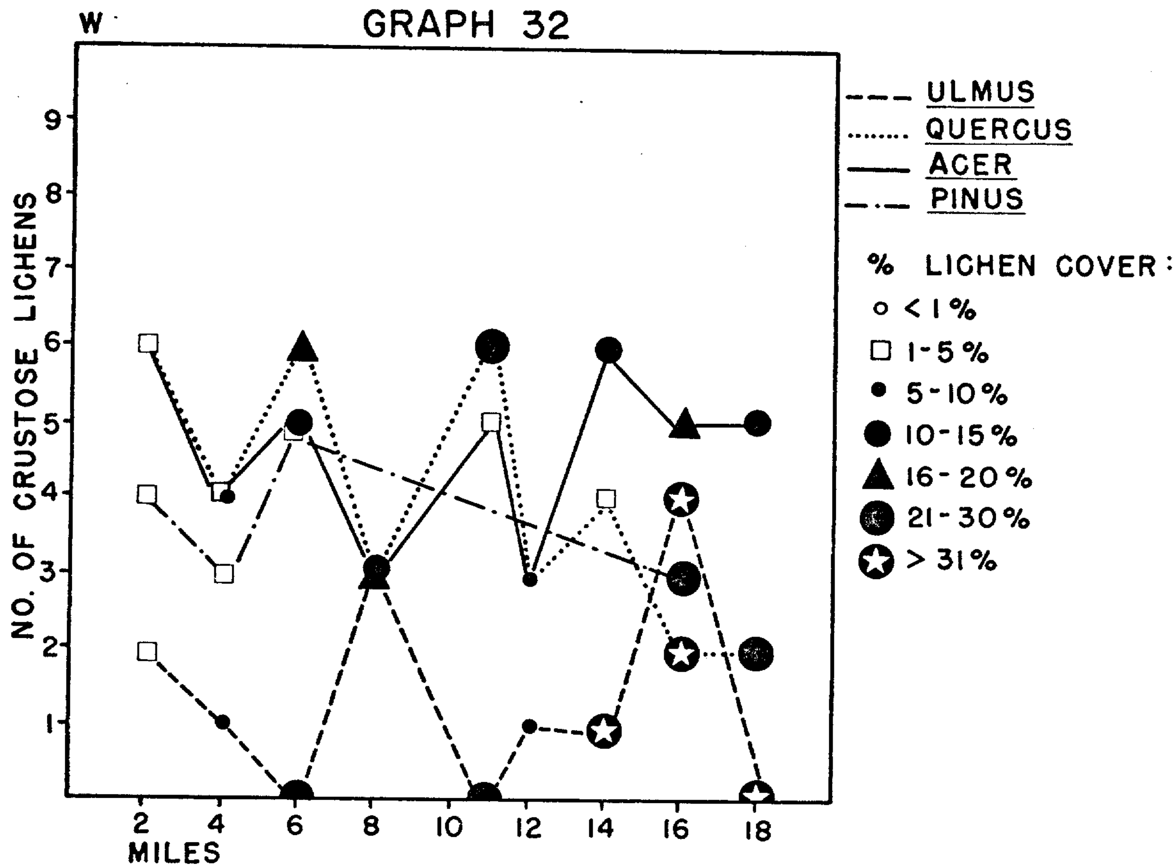


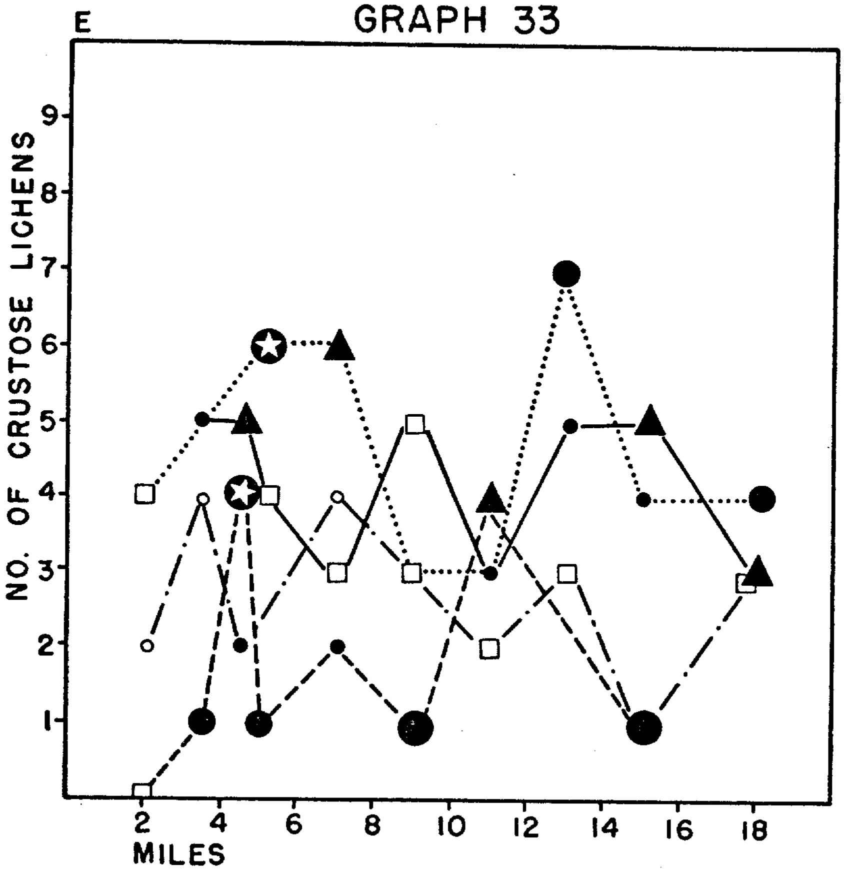
Graph 32

Number of crustose lichens and per cent cover along the eastern transect

Graph 33

Number of crustose lichens and per cent cover along the western transect


W
GRAPH 32
NO. OF CRUSTOSE LICHENS
1
2
3
4
5
6
7
8
9
2
4
6
8
10
12
14
16
18
MILES
ULMUS
QUERCUS
ACER
PINUS
% LICHEN COVER:
< 1 %
1-5 %
5-10 %
10-15 %
16-20 %
21-30 %
> 31 %


E
GRAPH 33
NO. OF CRUSTOSE LICHENS
1
2
3
4
5
6
7
8
9
2
4
6
8
10
12
14
16
18
MILES

increases more rapidly on the northwest, southeast, north, east, and west transects. These regions are away from the prevailing winds which disperse the sulfur pollutants from the Mosinee plant. In the southeast and south directions just the reverse is true. Winds carry SO_2 from the paper mill stacks and disperse it along these transects.

It is evident from Graphs 26-33 that _U. americana_ is the substrate upon which the lichen cover increased the most rapidly as the distance from the pollution source increased. On _P. strobus_ the per cent remained low and never reached the extremes found on _U. americana_. The per cent of cover of lichens on _Q. borealis_ and _A. rubrum_ consistently lies between these two extremes. These findings are consistent with those for the indexes of similarity (Graphs 2-9) and the bark pH values discussed earlier. This again suggests that the pH of the substrate has a great deal to do with the rapidity of the lichen population reaching a normal diversity on the periphery of a polluted area.

When these percentage of cover values are compared with the distribution of crustose lichens on _P. strobus_, _Q. borealis_, _A. rubrum_, and _U. americana_, a general trend can be seen. As the per cent increases, the number of crustose lichens found on a particular substrate becomes very erratic with a general trend to a reduction in the number of crustose species. The best examples of this phenomenon are found north and northwest of the paper mill on _Q. borealis_.

U. americana had very few crustose lichens throughout the sampling area. This is probably due to the rapidity of the "return to normalcy" on this particular substrate. It is possible the foliose and fruticose lichens physically shade out the crustose forms.

The "return to normalcy" of the lichen community on a corticolous substrate does not occur uniformly over the whole tree. Three lichen rich zones develop as the distance from the paper mill increases. These zones are: 1. the area of bark between the ground and the depth of annual snow fall; 2. the side of the tree away from the paper plant, and 3. the rain channels and crevices in the bark.

The best examples of the abundant lichen cover below the snow line were found two miles east of the paper mill. Snowfall in the Mosinee area averages 50-60 inches/year but may be as low as 30 or as great as 100 inches (Wisconsin Statistical Reporting Service, 1970) (Table 11). Throughout, the winter the lower 25-30 inches of the tree is buried in snow. It is in this area below 30 inches where the lichens are first found. In this zone large healthy colonies of _Parmelia caperata_ are often found (Phote 1). This phenomenon is probably due to the protection from air-borne pollutants given the lichen thalli by the snow during the winter months.

During the winter months, the wind velocity surrounding a tree trunk increases due to the decreased density of the woods caused by the loss of foliage from deciduous plants. When the wind velocity increases, more desiccation occurs

TABLE 11

Snow Depth in the Mosinee Area

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
% probability of snow on the ground*	90%	100%	60-70%	10%	<1	<1	<1	<1	<1	<1	10-12%	60-70%
Average snow depth 1949-1968 (in inches)*	6-8	8-10	10-12	2-4	0	0	0	0	0	0	2-4	4-6
Mean snow fall in inches 1970++	9.7	11.5	12.3	2.9	0.5	0.0	0.0	0.0	0.1	0.2	6.1	8.4
Number of days in 1969-1970 with one inch of snow or more on the ground++	31	28	27	0	0	0	0	0	0	0	0	24

* (Wisconsin Statistical Reporting Service, 1970)

++ (U.S. Department of Commerce, 1970)

Photo 1

Zone #1 is shown at the base of an Acer rubrum 1.5 miles E of Mosinee Paper Mills. Area below annual snow line is populated by large colonies of Parmelia caperata.

to exposed plants and the length of time pollutants remain air-borne increases. The shielding effect produced by the snow during these adverse conditions probably promotes lichen growth. When the snow melts it provides a very moist environment which favors the growth of lichen propagules and rinses the bark of air-borne debris and pollutants.

The best examples of the increased abundance of lichens on the side of the tree away from the paper mill can be observed 2 miles north of the mill. In this region the SO_2 ladened winds are channeled north in the valley of the Wisconsin River. The sampling station at the two mile north point was located on the east bank of the river. Photos 2, 3 and 4 illustrate the drastic change from a near 100% coverage on the north side of an open grown _U. americana_ to virtually no lichen cover on the south side. The most abundant lichen on the north side of this tree is _Xanthoria fallax_. Here at the north side of the mill the wind carrying sulfur pollutants from the plume of the Mosinee Paper Plant hits the south side of the tree with the greatest force. These winds deposit SO_2 and other pollutants picked up from the plume in the greatest concentration on the southern side of the tree. On the north side, which is sheltered by the tree from the pollutant laden winds, the lichen community is thriving. Similar lichen distribution patterns are found on trees in a nearby wooded area (Photo 5).

Photo 2

North side of an _Ulmus americana_ 2 miles N of the Mosinee Paper Mill.

Photo 3

West side of the same _Ulmus americana_ pictured in Photo 2.

Photo 4

South side of the same _Ulmus americana_ pictured above.

The best examples of the rain channel effect on increasing lichen cover was noted 2 miles east of the paper mill. Phote 6 shows such an effect on A. rubrum. In the rain washed shaded areas the lichens appear to thrive for two main reasons. First, these rain washed areas are more moist providing an optimum climate for the growth of lichen propagules. Second, the rain continually washes the surface free of air-borne pollutants.

As a distance of 4 miles from the plant is reached, these zones of lichen development blur and no clear cut zonation is visible. These zones appear to be distinct only when very adverse pollution conditions are present.

Photo 5

East side of a _Quercus_ _borealis_ 2 miles N of the Mosinee Paper Mill. The dominant lichens on the N side are _Parmelia_ _caperata_ and _Parmelia_ _rudecta_.

Photo 6

An _Acer_ _rubrum_ 2 miles E of paper mill showing rain channel effect.

(*Candelaria concolor*, *Parmelia caperata*, *Physcia millegrana*, for example) are very tolerant of sulfur pollution, at least in the concentrations emitted by the Mosinee Paper Mill, and are found within a mile of the mill. Other foliose lichens (*Hypogymnia physodes*, *Parmelia saxatilis*, *Xanthoria fallax*, for example) are found in the lichen population only when the SO_2 concentration is less than 7.17×10^{-1} $\mu g/m^3$.

When a foliose or a fruticose species was first found along one of the transects it was usually small and had necrotic and/or bleached patches (Photos 7, 8 and 9). Similar necrotic patches were found by Rao and LeBlanc when they exposed *Parmelia caperata* and other lichens for 24 hours in an atmosphere containing 5 ppm SO_2.(Rao and LeBlanc, 1965). It is possible, therefore, that SO_2 emitted by the Mosinee Paper Mill is the cause of the necrotic and bleached patches found on lichen thalli which approach nearest to the mills. The Appendix notes the occurrence of all lichens along each transect and notes the health of the thallus of each at each station sampled.

In this study the bark from four different species of trees was analyzed for its lichen cover. Of the four species sampled, *Ulmus americana* showed the most rapid increase in foliose and fruticose lichen diversity as the distance from the paper mill was increased. On *Acer rubrum* and *Quercus borealis* the diversity of this lichen community remained low until a greater distance from the mill was reached. The diversity of the lichen population on *Pinus strobus* remained

Photo 7

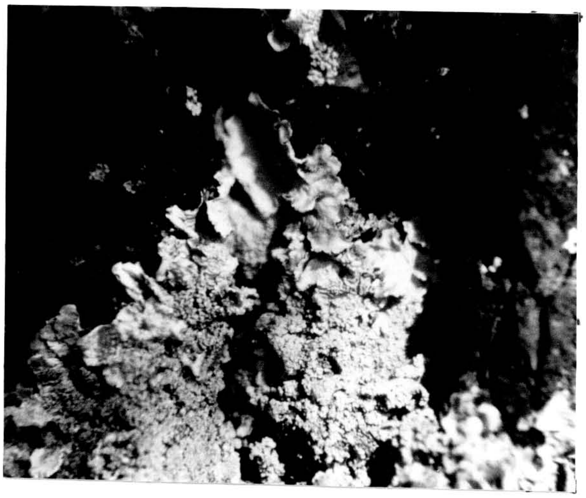
Bleached patches on the thallus of *Parmelia caperata*.

Photo 8

Necrotic area on the thallus of *Parmelia caperata*.

Photo 9

Necrotic spots on *Parmelia sulcata*.



fairly low throughout the sampling area. This difference in the type of substrate and the persistence of its lichen flora surrounding a point pollution source is correlated directly with the pH of the substrate and its buffering capacity. The pH and the buffering capacities of *Acer* and *Quercus* are very similar and lie directly between the extremes of *Pinus* and *Ulmus*.

When the per cent of cover was calculated from the lichens on a particular corticolous substrate, similar results were obtained. The per cent of cover increased the most rapidly on *U. americana* and the per cent of cover figures for *P. strobus* remained extremely low along all transects. Again, values for *Q. borealis* and *A. rubrum* increased as the distance from the pollution source increased but this increase in the persisting lichens was noted at a much greater distance than in the case of *U. americana*.

It is evident from this study that the emissions from the Mosinee Paper Mill inhibit the number and variety of lichens found nearest the mill. It is also evident that the nature of the substrate influences greatly the persistence of the lichen population surrounding a point source of pollution.

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APPENDIX

A CHECK LIST OF LICHENS FOUND IN THIS STUDY

Allarthonia caesia
Anaptychia palmatula
Anaptychia psudospeciosa var. tremulans
Bacidia chlorococca
Bacidia schweinitzii
Buellia parasema
Buellia punctata
Buellia punctata var. polyspora
Buellia dialyta
Buellia zahlbruckneri
Caloplaca aurantiaca
Caloplaca holocarpa
Caloplaca ulmorum
Candelaria concolor
Candelaria concolor var. effusa
Cetraria ciliaris
Cetraria halei
Cladonia bacillaris
Cladonia chlorophaea
Cladonia squamosa
Evernia mesomorpha
Graphis scripta
Hypogymnia physodes
Lecanora piniperda
Lecanora subfusca group
Lecanora symmicta
Lecanora varia
Lecidea vernalis
Lepraria sp.
Lobaria quercizans
Nephroma helveticum
Ochrolechia pallescens
Parmelia aurulenta
Parmelia bolliana
Parmelia caperata
Parmelia crinita
Parmelia flaventior
Parmelia galbina
Parmelia rudecta
Parmelia saxatilis
Parmelia septentrionalis
Parmelia subaurifera
Parmelia subcrinita
Parmelia subrudecta
Parmelia sulcata
Parmelia ulophyllodes
Pertusaria pertusa
Pertusaria pustulata
Pertusaria velata
Physcia adscendens
Physcia aipolia
Physcia elaeina
Physcia grisea
Physcia millegrana
Physcia orbicularis
Physcia orbicularis f. albociliata
Physcia orbicularis f. rubropulchra
Physcia stellaris
Physcia tribacoides
Pyxine sorediata
Ramalina fastigiata
Rinodina pachysperma
Rinodina polyspora
Usnea comosa
Usnea hirta
Xanthoria candelaria
Xanthoria fallax
Xanthoria polycarpa

APPENDIX

Key to charts of transect data

x = All specimens sampled necrotic

xx = Some of the specimens sampled necrotic

xxx = All specimens sampled healthy

BO = Black oak - *Quercus velutina*

BU = Burr oak - *Q. macrocarpa*

CR = Cattle rubbed tree

RO = Red oak - *Q. borealis*

WO = White oak - *Q. alba*

THE FOLIOSE AND FRUTICOSE LICHENS ON <u>ULMUS AMERICANA</u> ALONG THE NE TRANSECT

Species	1 mi.	2 mi.	4 mi.	6 mi.	8 mi.	9.5 mi.	11 mi.	13 mi.	15 mi.	17 mi.
Parmelia caperata	x	x	x		x	x	xx	x CR	xxx	xx
Physica millegrana	x	xx	x	xx	xx	xx	xxx	xxx CR	xx	xxx
Physica orbicularis	xxx		xx	xx	xxx	xxx	xxx	xxx	xxx	xx
Physica stellaris	x	xx	xx	xx	xx	xxx	xx			
Xanthoria fallax	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xx	xxx
Physicia elaeina	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Candelaria concolor	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Physcia grisea		x	xx		xx	xxx	xxx	xxx	xxx	xxx
Physcia orbicularis f. rubropulchra		x		xx		xxx	xx	xxx	xxx	xxx
Physcia adscendens		x	x	xx	xxx	xxx				
Physcia aipolia		x			xxx	xxx	xx		xxx	xxx
Candelaria concolor var. effusa			xxx	xxx	xxx	xxx	xxx			
Parmelia sulcata			x	xx	xxx	xx				
Parmelia flaventior			xx		xxx	xx	xxx			

Continued on following page.

The Foliose and Fruticose Lichens on <u>Ulmus americana</u> Along the NE Transect (continued)

Species	1 mi.	2 mi.	4 mi.	6 mi.	8 mi.	9.5 mi.	11 mi.	13 mi.	15 mi.	17 mi.
Parmelia aurulenta			x			xxx	xxx	xxx	xx	xxx
Physcia orbicularis f. albociliata			xxx				xxx	xxx		xxx
Anaptychia palmatula			x							
Xanthoria polycarpa				xxx			xxx			
Parmelia rudecta					x	xxx	x	xx GR		xx
Parmelia saxatilis						xxx				
Hypogymnia physodes	only 3			only 4			xxx			only 4
Lobaria quercizans	trees			trees				xxx		trees
Pyxine sorediata	sampled			sampled				xxx		sampled
Anaptychia psudospeciosa var. tremulans								xxx CR		
Evernia mesomorpha									xxx	
Physcia tribacoides									xxx	

CRUSTOSE LICHENS ON ULMUS AMERICANA ALONG THE NE TRANSECT

Species	1 mi.	2 mi.	4 mi.	6 mi.	8 mi.	9.5 mi.	11 mi.	13 mi.	15 mi.	17 mi.
Lecanora piniperda	XXX				XXX					
Buellia punctata var. polyspora		XXX					XXX		XXX	
Lepraria sp.			XXX			XXX	XXX	XXX	XXX	XXX
Rinodina pachysperma	only 3			only 4			XXX			only 4
Caloplaca holocarpa	trees			trees			XXX			trees
Allarthonia caesia	sampled			sampled			XXX			sampled

THE FOLIOSE AND FRUTICOSE LICHENS ON ACER RUBRUM ALONG THE NE TRANSECT

Species	1 mi.	2 mi.	4 mi.	6 mi.	8 mi.	9.5 mi.	11 mi.	13 mi.	15 mi.	17 mi.
Parmelia aurulenta	x	xxx						xxx	xxx	xx
Parmelia sulcata	x	x	x	xxx	xxx	xx		xxx	xxx	xx
Parmelia caperata	x	x	x		x	x	x	x	x	xx
Physcia orbicularis f. rubropulchra	xxx	x						xxx	xxx	xxx
Physcia orbicularis	xxx		x						xxx	xxx
Physcia millegrana	x	x	xxx	xxx	xxx	xx	xx	xxx	xxx	xxx
Candelaria concolor var. effusa	xxx					xxx				
Physcia orbicularis f. albociliata		xxx								
Candelaria concolor		xxx	x		xxx				xxx	
Physcia stellaris			xxx	xxx			xxx		xxx	xxx
Parmelia subaurifera			xxx		xxx	xxx		xxx	xxx	xxx
Parmelia flaventior					xxx	xx			xxx	xxx
Parmelia ulophyllodes					xxx	xxx		xxx		

Continued on following page.

The Foliose and Fruticose Lichens on <u>Acer rubrum</u> along the NE Transect (continued)

Species	1 mi.	2 mi.	4 mi.	6 mi.	8 mi.	9.5 mi.	11 mi.	13 mi.	15 mi.	17 mi.
Evernia mesomorpha					x				xxx	
Parmelia saxatilis		only 3		only 4		xx		xxx		
Parmelia rudecta		trees		trees		x	xxx	xx	xxx	xxx
Ramalina fastigiata		sampled		sampled				x		
Parmelia galbina								xxx	xxx	
Cladonia squamosa								xxx		
Physcia grisea									xxx	xxx
Xanthoria fallax										xxx

THE CRUSTOSE LICHENS ON <u>ACER</u> <u>RUBRUM</u> ALONG THE NE TRANSECT

Species	1 mi.	2 mi.	4 mi.	6 mi.	8 mi.	9.5 mi.	11 mi.	13 mi.	15 mi.	17 mi.
Lepraria sp.	xxx	xxx		xxx	xxx	xxx		xxx	xxx	xxx
Buellia punctata var. *polyspora*	xxx					xxx			xxx	
Allarthonia caesia		xxx	xxx	xxx	xxx	xxx	xxx		xxx	xxx
Lecanora piniperda		xxx	xxx		xxx					
Bacidia chlorococca			xxx	xxx	xxx					
Lecanora symmicta			xxx	xxx	xxx					
Rinodina pachysperma			xxx	xxx			xxx		xxx	
Buellia parasema		only 3			xxx					
Lecidia vernalis		trees		only 4	xxx					
Graphis scripta		sampled		trees		xxx				xxx
Ochrolechia pallescens				sampled		xxx		xxx		

THE FOLIOSE AND FRUTICOSE LICHENS ON <u>QUERCUS</u> <u>BOREALIS</u> ALONG THE NE TRANSECT

Species	1 mi.	2 mi.	4 mi.	6 mi.	8 mi.	9.5 mi.	11 mi.	13 mi.	15 mi.	17 mi.
Parmelia caperata	x	x	x	x	x	x	no	x	x	xx
Physcia millegrana	x	x	xx	xx	xxx	xx	red	xx	xxx	xxx
Physcia orbicularis	xxx	x	x		xxx	xxx	oaks			
Parmelia sulcata	x	x	xx		xx	xx		xxx	xx	xx
Parmelia rudecta	x	xxx				x		x		xxx
Candelaria concolor var. *effusa*	x	xxx	xxx	xxx		xxx		xxx		xxx
Parmelia aurulenta	x	x	xxx		xxx	xxx		xxx	xxx	xxx
Parmelia flaventior		xxx				xx		xxx		
Physcia orbicularis f. *rubropulchra*		xxx	xxx					xxx		xxx
Physcia stellaris			xx	xx	xx			xxx		
Candelaria concolor					xxx	xxx		xxx	xxx	
Parmelia ulophyllodes					xx					
Parmelia subaurifera					xxx	xxx				

Continued on following page.

The Foliose and Fruticose Lichens on Quercus borealis Along the NE Transect (continued)

Species	1 mi.	2 mi.	4 mi.	6 mi.	8 mi.	9.5 mi.	11 mi.	13 mi.	15 mi.	17 mi.
Evernia mesomorpha						xxx				
Cladonia squamosa						x				
Physcia grisea								xxx	xxx	
Parmelia galbina				only 1				xxx		xxx
Parmelia subrudecta				tree				xxx	only 1	
Cladonia chlorophaea				sampled				xxx	tree	
Physcia elaeina								xxx	sampled	xxx
Pyxine sorediata								xxx		
Parmelia saxatilis										xxx

THE CRUSTOSE LICHENS ON QUERCUS BOREALIS ALONG THE NE TRANSECT

Species	1 mi.	2 mi.	4 mi.	6 mi.	8 mi.	9.5 mi.	11 mi.	13 mi.	15 mi.	17 mi.
Lepraria sp.	xxx	xxx		xxx	xxx	xxx	no	xxx	xxx	xxx
Bacidia chlorococca	xxx		xxx	xxx		xxx	red oaks			xxx
Graphis scripta	xxx					xxx		xxx		xxx
Lecanora piniperda	xxx	xxx	xxx		xxx				xxx	xxx
Allarthonia caesia	xxx	xxx	xxx	xxx	xxx	xxx		xxx		xxx
Buellia punctata var. polyspora	xxx	xxx						xxx		xxx
Lecanora subfusca group	xxx									xxx
Rinodina pachysperma			xxx	only 1	xxx	xxx		xxx	only 2	
Ochrolechia pallescens				tree				xxx	trees sampled	
Pertusaria pertusa				sampled				xxx		
Lecanora symmicta									xxx	xxx

THE FOLIOSE AND FRUTICOSE LICHENS ON PINUS STROBUS ALONG THE NE TRANSECT

Species	1 mi.	2 mi.	4 mi.	6 mi.	8 mi.	9.5 mi.	11 mi.	13 mi.	15 mi.	17 mi.
Parmelia caperata	x	x		x	x	xx	x	x		
Parmelia reducta	x				x	xxx	xx	xxx	no	no
Parmelia sulcata		x	x		xxx	xxx	xx	xxx	pines	pines
Parmelia ulophyllodes		x				xxx				
Parmelia flaventior		x		xx		xxx	xxx	xxx		
Cladonia squamosa				xx		xxx				
Evernia mesomorpha					xxx	xxx	xx	xxx		
Usnea hirta							xxx			
Hypogymnia physodes							xxx	xxx		
Parmelia saxatilis								x		

THE CRUSTOSE LICHENS ON PINUS STROBUS ALONG THE NE TRANSECT

Species	1 mi.	2 mi.	4 mi.	6 mi.	8 mi.	9.5 mi.	11 mi.	13 mi.	15 mi.	17 mi.
Lepraria sp.	xxx	xxx	xxx	xxx			xxx	xxx	no	no
Bacidia chlorococca	xxx	xxx	xxx	xxx		xxx	xxx	xxx	pines	pines
Allarthonia caesia			xxx			xxx				
Lecanora piniperda				xxx	xxx			xxx		
Lecanora symmicta				x			xxx			

THE FOLIOSE AND FRUTICOSE LICHENS ON ULMUS AMERICANA ALONG THE N TRANSECT

Species	1.5 mi.	3 mi.	4.5 mi.	6.5 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Candelaria concolor	xxx	no	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Parmelia caperata	x	lichens	x	x	x	x	x	x		
Parmelia rudecta	x		x		x		xx	xx		xxx
Physcia orbicularis	xxx		xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Physcia orbicularis f. rubropulchra	xxx		xxx	xxx	xxx	xxx	xxx	xxx	xx	xxx
Physcia millegrana	x		xx	xx	xxx	xx	xxx	xx	xx	xxx
Xanthoria fallax	xxx		xxx	xxx		xxx	xxx	xxx	xxx	xxx
Physcia aipolia	xxx			xxx	xxx		xxx	xxx		xxx
Physcia grisea	xxx		xxx	xxx	xx	xx	xx	xx		xxx
Physcia orbicularis f. albociliata	xxx			xxx			xxx	xxx	xxx	xxx
Physcia elaeina	xxx		xxx		xxx		xxx	xxx		xxx
Parmelia aurulenta			xxx	xxx	xx	xxx	xxx	xxx		xxx
Anaptychia palmatula							xxx			
Candelaria concolor var. effusa			xxx	xxx			xxx	xxx		xxx

Continued on following page.

The Foliose and Fruticose Lichens on Ulmus americana Along the N Transect (continued)

Species	1.5 mi.	3 mi.	4.5 mi.	6.5 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Physcia adscendens			xxx	xxx	xxx		xxx	xxx		
Pyxine sorediata			x		x					
Parmelia sulcata				x	xxx					xxx
Parmelia flaventior					xxx		xxx			xxx
Parmelia saxatilis					xx					
Physcia stellaris					xxx	xxx	xxx	xxx		xxx
Parmelia bolliana						only 4	xxx			
Hypogymnia physodes						trees	xxx			
Physcia tribacoides						sampled				xxx

THE CRUSTOSE LICHENS ON ULMUS AMERICANA ALONG THE N TRANSECT

Species	1.5 mi.	3 mi.	4.5 mi.	6.5 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Lepraria sp.	xxx		xxx	xxx		xxx		xxx		
Buellia punctata var. polyspora			xxx							
Rinodina pachysperma			xxx	xxx				xxx		
Bacidia chlorococca				xxx						
Allarthonia caesia						xxx				

THE FOLIOSE AND FRUTICOSE LICHENS ON ACER RUBRUM ALONG THE N TRANSECT

Species	1.5 mi.	3 mi.	4.5 mi.	6.5 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Parmelia caperata		x	x	x	x	x	x	xx	x	
Parmelia rudecta	x		x	x	xx	xx	xxx	xx	xx	
Parmelia sulcata	x	xx	xx	xx	xx	xxx	xx	xxx		x
Parmelia millegrana	xxx		xx	xx	xx	xx	xx	xx	xx	xxx
Physcia orbicularis	xx		xxx			xxx		xxx	xxx	xxx
Physcia orbicularis f. rubropulchra	xxx		xxx			xxx			xxx	xxx
Parmelia aurulenta	xxx		xxx	xx		x		xxx	xxx	
Physcia stellaris	x					xxx				
Parmelia subaurifera		xx	xx	xx	xx					xxx
Evernia mesomorpha		x			xxx		xxx			xxx
Parmelia flaventior		xxx	xx	x	xx	xxx	xxx			xxx
Physcia grisea						xxx				
Candelaria concolor			xxx			xxx			xxx	xxx
Hypogymnia physodes					xxx		xxx			

Continued on following page.

The Foliose and Fruticose Lichens on Acer rubrum Along the N Transect (continued)

Species	1.5 mi.	3 mi.	4.5 mi.	6.5 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Parmelia saxatilis					xxx		xxx			
Usnea comosa					xxx					
Pyxine sorediata			xxx							
Physcia adscendens										
Physcia elaeina						xxx				
Candelaria concolor var. effusa					xxx	xxx	xxx	xxx		
Xanthoria fallax						xxx			xxx	xxx
Ramalina fastigiata							xxx			
Parmelia ulophyllodes							xxx	xxx		xxx
Usnea hirta							xxx			xxx
Parmelia galbina								xxx		
Parmelia subrudecta										xxx

THE CRUSTOSE LICHENS ON *ACER RUBRUM* ALONG THE N TRANSECT

Species	1.5 mi.	3 mi.	4.5 mi.	6.5 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Allarthonia caesia	xxx	xxx	xxx	xxx	xxx			xxx		xxx
Lepraria sp.	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Bacidia chlorococca	xxx	xxx		xxx	xxx			xxx	xxx	xxx
Lecanora symmicta	xxx			xxx						
Rinodina pachysperma	xxx								xxx	
Buellia punctata var. *polyspora*	xxx			xxx			xxx	xxx	xxx	
Lecanora piniperda		xxx		xxx						
Graphis scripta									xxx	

THE FOLIOSE AND FRUTICOSE LICHENS ON QUERCUS BOREALIS ALONG THE N TRANSECT

Species	1.5 mi.	3 mi.	4.5 mi.	6.5 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Parmelia caperata	x	x	x	x	x	x	x	x	xx	x
Parmelia flaventior	xxx	xx			xxx			xx		
Candelaria concolor var. effusa	xxx	xxx	xxx				xxx	xxx	xxx	xxx
Parmelia aurulenta	x	xxx	xxx		xx			xxx		xxx
Physcia millegrana	xx	xxx	xx	xxx	xxx	xxx	xx	xx	xxx	xxx
Physcia orbicularis f. rubropulchra	xx		xxx		xxx	xx	xx		xxx	xxx
Parmelia rudecta	x	xxx	x		x	xxx		x	xx	xxx
Physcia grisea	xxx									xxx
Physcia elaeina	xxx								xxx	
Candelaria concolor	xxx		xxx		xxx	xxx	xxx	xxx		xxx
Parmelia sulcata		x	xx	x	xx	xxx	xx	xxx		xxx
Physcia stellaris		xxx	xxx		xx	xxx				
Parmelia subaurifera		xxx			xxx					
Parmelia galbina		xxx						xxx		

Continued on following page.

The Foliose and Fruticose Lichens on *Quercus borealis* Along the N Transect (continued)

Species	1.5 mi.	3 mi.	4.5 mi.	6.5 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Parmelia saxatilis		x	xxx		xxx		xx	xxx		xxx
Cladonia squamosa			xxx						xxx	
Physcia orbicularis					xxx	xxx	xxx			xxx
Evernia mesomorpha					x					
Usnea hirta					x					
Ramalina fastigiata					x			xxx		
Xanthoria fallax					xxx					xxx
Xanthoria polycarpa					xxx					
Parmelia ulophyllodes							xxx	xxx		
Pyxine sorediata						only 3 red oaks				xxx
Parmelia bolliana						xxx				

THE CRUSTOSE LICHENS ON QUERCUS BOREALIS ALONG THE N TRANSECT

Species	1.5 mi.	3 mi.	4.5 mi.	6.5 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Graphis scripta	xxx					xxx			xxx	xxx
Bacidia chlorococca	xxx			xxx	xxx					xxx
Lepraria sp.	xxx		xxx	xxx	xxx	xxx		xxx	xxx	xxx
Pertusaria velata	xxx	xxx	xxx		xxx					
Allarthonia caesia	xxx	xxx	xxx	xxx	xxx			xxx		
Lecanora piniperda	xxx		xxx		xxx					
Lecanora subfusca group		xxx								
Buellia punctata var. polyspora			xxx					xxx		
Lecanora symmicta			xxx	xxx						
Lecidea vernalis				xxx						
Rinodina pachysperma								xxx		
Bacidia schweinitzii										xxx
Ochrolechia pallescens										xxx

THE FOLIOSE AND FRUTICOSE LICHENS ON PINUS STROBUS ALONG THE N TRANSECT

Species	1.5 mi.	3 mi.	4.5 mi.	6.5 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Parmelia caperata	no	x	x		x	no	no	no		xxx
Physcia millegrana	lichens	xxx				white	lichens	white		
Parmelia sulcata		x	xxx	xxx		pines		pines		
Cladonia squamosa		xxx	xxx	xxx					xxx	xxx
Cladonia bacillaris		xxx								
Parmelia flaventior		xxx	xxx	xxx	xxx					
Parmelia rudecta			xxx	3 trees	xxx				xxx	xxx
Parmelia ulophyllodes				with no						xxx
Evernia mesomorpha				lichens						xxx

THE CRUSTOSE LICHENS ON PINUS STROBUS ALONG THE N TRANSECT

Species	1.5 mi.	3 mi.	4.5 mi.	6.5 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Lepraria sp.	no	xxx	xxx	xxx	xxx	no	xxx	no	xxx	xxx
Lecanora subfusca group	lichens	xxx				white		white		
Bacidia chlorococca		xxx	xxx	xxx	xxx	pines	xxx	pines	xxx	xxx
Allarthonia caesia			xxx	3 trees	xxx				xxx	
Lecidea vernalis			xxx	with no lichens						

THE FOLIOSE AND FRUTICOSE LICHENS ON ULMUS AMERICANA ALONG THE NW TRANSECT

Species	1 mi.	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Candelaria concolor	xxx	no	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Parmelia caperata	x	elms	x	x	xxx	x	x	xxx	xx	xx
Physcia millegrana	xxx		xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Physcia orbicularis	xxx		xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Physcia stellaris	xxx		xxx	xxx				xxx	xxx	xxx
Xanthoria fallax	xxx		xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Physcia grisea	xxx		xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Physcia aipolia	xxx				xxx					xxx
Physcia orbicularis f. rubropulchra	xxx		xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Physcia orbicularis f. albociliata	xxx		xxx	xxx	xxx	xxx		xxx	xxx	xxx
Physcia elaeina	xxx		xxx		xxx			xxx	xxx	xxx
Parmelia aurulenta	xxx		xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Parmelia rudecta	x		xx	xxx	xx	xx	xxx	xxx	xxx	xx

Continued on following page.

The Foliose and Fruticose Lichens on Ulmus americana Along the NW Transect (continued)

Species	1 mi.	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Candelaria concolor var. effusa			xxx			xxx	xxx	xxx		xxx
Parmelia sulcata			xxx		xxx		xxx			
Physcia adscendens			xxx				xxx			xxx
Physcia tribacoides				xxx						xxx
Parmelia subcrinita					xxx					
Anaptychia palmatula					xxx					
Parmelia crinita						xxx				
Parmelia flaventior							xxx	xxx		
Parmelia bolliana							xxx			
Ramalina fastigiata										xxx

THE CRUSTOSE LICHENS ON <u>ULMUS AMERICANA</u> ALONG THE NW TRANSECT

Species	1 mi.	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Graphis scripta		xxx	no							
Rinodina pachysperma		xxx	elms							xxx
Allarthonia caesia		xxx								
Caloplaca ulmorum				xxx	xxx					
Lepraria sp.				xxx	xxx	xxx		xxx		xxx
Buellia punctata var. *polyspora*								xxx		

THE FOLIOSE AND FRUTICOSE LICHENS ON *ACER RUBRUM* ALONG THE NW TRANSECT

Species	1 mi.	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Candelaria concolor var. *effusa*		xxx	xxx	xxx	xxx		xxx	xxx	xxx	xxx
Parmelia caperata		x	x	xx	xx	x	xx	xx	xx	xxx
Parmelia rudecta		x	xxx	xx	x	xxx	xxx		xxx	xxx
Parmelia sulcata		x	xxx	xx	xxx		xxx	xx	xxx	xxx
Physcia millegrana		xx	xx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Physcia orbicularis		xxx				xxx	xxx		xxx	
Parmelia flaventior		xxx					xxx	xxx	xxx	xxx
Parmelia subaurifera		xxx					xxx	xxx		xxx
Evernia mesomorpha		xxx		xxx				xxx		xxx
Candelaria concolor		xxx		xxx	xxx	xxx			xxx	
Parmelia aurulenta			xxx	xxx		xxx	xxx	xxx	xxx	xxx
Physcia orbicularis var. *rubropulchra*				xxx		xxx	xxx	xxx	xxx	
Parmelia saxatilis							xxx	xxx		xxx
Physcia grisea					xxx	xxx			xxx	xxx

Continued on following page.

The Foliose and Fruticose Lichens on Acer rubrum Along the NW Transect (continued)

Species	1 mi.	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Parmelia bolliana					xxx		xxx	xxx		xxx
Xanthoria fallax						xxx		xxx	xxx	xxx
Parmelia ulophyllodes							xxx			
Cladonia squamosa				only 4			xxx			
Physcia stellaris				trees			xxx			
Ramalina fastigiata				sampled				xxx		xxx
Physcia elaeina								xxx	xxx	
Parmelia galbina									xxx	

THE CRUSTOSE LICHENS ON ACER RUBRUM ALONG THE NW TRANSECT

Species	1 mi.	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Allarthonia caesia	xxx	xxx				xxx				xxx
Lepraria sp.	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Bacidia chlorococca		xxx	xxx		xxx	xxx	xxx	xxx		xxx
Lecanora piniperda		xxx			xxx	xxx	xxx	xxx	xxx	xxx
Rinodina pachysperma				xxx				xxx	xxx	xxx
Buellia punctata var. polyspora				xxx	xxx	xxx		xxx	xxx	xxx
Graphis scripta					xxx	xxx	xxx		xxx	xxx
Pertusaria velata					xxx	xxx	xxx	xxx		
Lecanora symmicta				only 4		xxx	xxx			
Lecanora subfusca group				trees		xxx				xxx
Lecidea vernalis				sampled			xxx			
Buellia punctata									xxx	

THE FOLIOSE AND FRUTICOSE LICHENS ON QUERCUS BOREALIS ALONG THE NW TRANSECT

Species	1 mi.	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Parmelia caperata	x	xx BO RO	x	xx	xx	xx	xxx	xxx	xxx	no
Parmelia rudecta	x	x RO	x	xx	x	x		x	x	red oaks
Physcia orbicularis	xxx	xxx RO	xxx		xxx		xxx	xxx	xxx	
Parmelia sulcata	xxx	xx BO		xxx			xxx		xxx	
Physcia millegrana	xxx	xxx BO RO	xxx	xxx	xxx	xxx	xxx	xxx	xxx	
Parmelia subrudecta	xxx								xxx	
Candelaria concolor	xxx	xxx RO		xxx			xxx	xxx		
Candelaria concolor var. effusa		xxx RO	xxx	xxx	xxx	xxx	xxx		xxx	
Physcia orbicularis f. rubropulchra		xxx BO RO	xxx	xxx	xxx	xxx	xxx	xxx	xxx	
Parmelia saxatilis		x BO		xxx						
Parmelia galbina		xxx RO		xxx					xxx	
Parmelia aurulenta		xxx RO	xxx	xxx	xxx	xxx	xxx	xxx	xxx	
Pyxine sorediata			xxx							
Evernia mesomorpha				xxx				xxx	xxx	

Continued on following page.

The Foliose and Fruticose Lichens on <u>Quercus</u> <u>borealis</u> Along the NW Transect (continued)

Species	1 mi.	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
<u>Physcia</u> <u>elaeina</u>				xxx						
<u>Usnea</u> <u>comosa</u>				xxx						
<u>Parmelia</u> <u>flaventior</u>				xxx			xxx			
<u>Physcia</u> <u>stellaris</u>				xxx			xxx	xxx		
<u>Cladonia</u> <u>squamosa</u>						xxx		only 1		
<u>Parmelia</u> <u>ulophyllodes</u>							xxx	tree		
<u>Parmelia</u> <u>bolliana</u>							xxx	sampled	xxx	
<u>Ramalina</u> <u>fastigiata</u>								xxx	xxx	

THE CRUSTOSE LICHENS ON <u>QUERCUS</u> <u>BOREALIS</u> ALONG THE NW TRANSECT

Species	1 mi.	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Buellia punctata	xxx									
Lepraria sp.	xxx	xxx BO RO	xxx	xxx		xxx	xxx	xxx	xxx	no
Lecanora piniperda	xxx									red
Lecanora subfusca group	xxx		xxx							oaks
Lecidea vernalis	xxx									
Allarthonia caesia		xxx BO RO			xxx		xxx			
Bacidia chlorococca		xxx BO	xxx			xxx	only 1			
Lecanora symmicta		xxx RO					tree			
Buellia punctata var. *polyspora*		xxx RO	xxx	xxx	xxx		sampled			
Graphis scripta			xxx		xxx	xxx		xxx	xxx	
Rinodina pachysperma					xxx		xxx			

THE FOLIOSE AND FRUTICOSE LICHENS ON PINUS STROBUS ALONG THE NW TRANSECT

Species	1 mi.	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Parmelia caperata	xx	no	no	no	xx	xxx	no	xxx	xx	no
Parmelia rudecta	xxx	lichens	lichens	lichens	xxx	xxx	pines	xxx		pines
Hypogymnia physodes	xxx				xxx					
Evernia mesomorpha	xxx				xxx			xxx		
Cetraria ciliaris	xxx								xxx	
Parmelia sulcata					x				xxx	
Cladonia squamosa					xxx					
Usnea comosa					xxx					
Parmelia flaventior									xxx	
Physcia adscendens									xxx	
Candelaria concolor									xxx	
Physcia orbicularis var. rubropulchra									xxx	
Parmelia subaurifera									xxx	
Physcia millegrana									xxx	
Physcia orbicularis f. albociliata									xxx	
Parmelia ulophyllodes									xxx	

THE CRUSTOSE LICHENS ON PINUS STROBUS ALONG THE NW TRANSECT

Species	1 mi.	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Lecanora varia	xxx	no	no	no			no	xxx		no
Bacidia chlorococca	xxx	lichens	lichens	lichens			lichens	xxx	xxx	pines
Lepraria sp.	xxx				xxx	xxx		xxx	xxx	
Lecanora symmicta	xxx							xxx		
Lecanora subfusca group	xxx								xxx	
Buellia dialyta	xxx				xxx					
Allarthonia caesia								xxx		
Pertusaria pustulata								xxx		
Lecidea vernalis									xxx	

THE FOLIOSE AND FRUTICOSE LICHENS ON <u>ULMUS AMERICANA</u> ALONG THE W TRANSECT

Species	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	11 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Candelaria concolor	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Parmelia aurulenta	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Parmelia caperata	x	x	xx	xx	xxx	xx			xx	xx
Anaptychia palmatula		xxx					xxx			
Physcia adscendens	xxx		xxx			xxx		xxx		xxx
Physcia grisea	xxx	xxx	xx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Physcia millegrana	xx	xx	xxx	xxx	xxx	xxx	xx	xx	xxx	xxx
Physcia orbicularis	xxx	xxx		xxx	xxx	xxx	xxx	xxx	xxx	xxx
Physcia orbicularis f. rubropulchra	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	
Physcia stellaris	xxx		xxx		xxx	xxx	xxx			xxx
Xanthoria fallax	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Physcia elaeina	xxx	xxx			xxx	xxx	xxx	xxx	xxx	xxx
Candelaria concolor var. effusa	xxx	xxx	xxx	xxx	xxx		xxx	xxx	xxx	
Physcia orbicularis f. albociliata	xxx	xxx	xxx	xxx			xxx	xxx	xxx	xxx

Continued on following page.

The Foliose and Fruticose Lichens on <u>Ulmus americana</u> Along the W Transect (continued)

Species	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	11 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Parmelia rudecta		x	x	xx	xx	xxx		xx	xx	xxx
Parmelia sulcata		xxx	xx	xxx						xxx
Pyxine sorediata		xxx		xxx						
Parmelia flaventior			xxx		xxx					
Parmelia saxatilis			xxx							
Physcia aipolia			xxx		xxx					xxx
Parmelia ulophyllodes			xxx							
Evernia mesomorpha				xxx	xxx					
Cladonia squamosa				xxx						
Physcia tribacoides					xxx		xxx	xxx	xxx	xxx
Parmelia bolliana						xxx				
Parmelia galbina						xxx				
Parmelia subaurifera										

THE CRUSTOSE LICHENS ON ULMUS AMERICANA ALONG THE W TRANSECT

Species	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	11 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Buellia punctata	xxx		no		no	no				no
Buellia punctata var. polyspora	xxx		crustose		crustose	crustose				crustose
Lepraria sp.		xxx	lichens	xxx	lichens	lichens	xxx	xxx	xxx	lichens
Buellia zahlbruckneri				xxx						
Graphis scripta									xxx	
Rinodina pachysperma									xxx	
Caloplaca ulmorum									xxx	
Rinodina polyspora				xxx						

THE FOLIOSE AND FRUTICOSE LICHENS ON <u>ACER</u> <u>RUBRUM</u> ALONG THE W TRANSECT

Species	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	11 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Candelaria concolor	xxx	xxx				xxx				
Parmelia caperata	x	xx	xx	xx		xx	xxx	xx	xxx	xx
Parmelia sulcata	xx		xx	xx		xx		xxx	xxx	xxx
Physcia millegrana	xx	xx	xxx	xxx		xx	xx	xx	xxx	xxx
Physcia stellaris	x	xx				xx	xxx			xxx
Evernia mesomorpha	xxx		xx	xx		xxx		xxx		
Parmelia subaurifera	x	xx	xxx	xx						
Physcia orbicularis	xxx	xx	xxx	xxx		xxx	xxx		xxx	xxx
Parmelia ulophyllodes	xxx	x	xxx						xxx	
Parmelia flaventior		xxx	xxx	xxx		xxx		xxx	xxx	xxx
Parmelia rudecta		x	xx	xx			xxx	xxx	xx	xxx
Physcia grisea		xxx							xxx	
Physcia orbicularis f. *rubropulchra*		xxx	xxx	xxx		xxx	xxx		xxx	xxx
Parmelia saxatilis		xxx	xx							

Continued on following page.

The Foliose and Fruticose Lichens on <u>Acer rubrum</u> Along the W Transect (continued)

Species	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	11 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Parmelia aurulenta		xx	xxx	xxx		xxx	xx	xxx		xxx
Physcia elaeina		xxx						xxx		
Ramalina fastigiata		xxx								
Candelaria concolor var. *effusa*		xxx	xxx			xxx	xxx	xxx	xxx	xxx
Xanthoria fallax			xxx							
Parmelia subrudecta				xxx						
Pyxine sorediata				xxx				xxx		
Parmelia galbina								xxx		
Xanthoria candelaria									xxx	
Parmelia subcrinita									xxx	

THE CRUSTOSE LICHENS ON ACER RUBRUM ALONG THE W TRANSECT

Species	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	11 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Lepraria sp.	xxx	xxx	xxx	xxx		xxx	xxx	xxx	xxx	xxx
Allarthonia caesia	xxx	xxx	xxx			xxx		xxx	xxx	xxx
Lecanora piniperda	xxx		xxx						xxx	
Buellia punctata var. *polyspora*	xxx	xxx	xxx	xxx				xxx	xxx	xxx
Rinodina pachysperma	xxx					xxx				
Bacidia chlorococca	xxx					xxx	xxx	xxx	xxx	
Graphis scripta		xxx	xxx	xxx			xxx			xxx
Lecanora symmicta						xxx		xxx		
Pertusaria pustulata								xxx		
Pertusaria velata										xxx

THE FOLIOSE AND FRUTICOSE LICHENS ON QUERCUS BOREALIS ALONG THE W TRANSECT

Species	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	11 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Parmelia caperata	x	xx	xx	xx		xxx	xxx		xx BO WO BU	xx
Parmelia sulcata	xx	xxx	xxx	xx		xxx				
Evernia mesomorpha	xxx	xxx								
Candelaria concolor	xxx	xxx	xxx			xxx	xxx		xxx WO BU	xxx
Physcia millegrana	xx	xx	xx	xx		xx	xx	xxx	xx BO WO BU	xxx
Physcia orbicularis	xxx	xxx	xxx	xxx		xxx	xxx	xxx	xxx BO	xxx
Physcia orbicularis f. rubropulchra	xx	xx	xxx	xxx			xxx	xxx	xxx BO WO	xxx
Physcia stellaris	xxx		xxx	xxx		xxx	xxx		xxx WO	xxx
Candelaria concolor var. effusa	xxx	xxx	xxx			xxx	xxx	xxx	xxx BO WO	
Parmelia subaurifera	xxx		xxx							
Parmelia aurulenta	xxx	xxx	xxx	xxx		xxx	xxx	xxx	xxx BO BU	xxx
Parmelia flaventior	xxx	xxx	xxx			xxx		xxx	xxx BO	
Ramalina fastigiata	x									
Physcia grisea	xxx								xxx BU	

Continued on following page.

The Foliose and Fruticose Lichens on <u>Quercus</u> <u>borealis</u> Along the W Transect (continued)

Species	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	11 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Parmelia rudecta	x	x	xx	xxx			xx	xx	xx WO BU	xx
Parmelia saxatilis		xxx								xxx
Xanthoria fallax			xxx			xxx			xxx BO WO	xxx
Physcia elaeina			xxx			xxx				xxx
Cladonia bacillaris				xxx				only 2		
Pyxine sorediata				xxx				trees		
Physcia aipolia				xxx		xxx		sampled	xxx BO	
Parmelia bolliana						xxx				
Parmelia ulophyllodes									xxx BO	xxx
Physcia adscendens									xxx BU	
Parmelia subrudecta									xxx BU	

THE CRUSTOSE LICHENS ON *QUERCUS* *BOREALIS* ALONG THE W TRANSECT

Species	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	11 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Lepraria sp.	xxx	xxx	xxx	xxx		xxx	xxx	xxx	xxx BO	
Rinodina *pachysperma*	xxx		xxx			xxx				
Bacidia *chlorococca*	xxx		xxx				xxx			
Lecanora *piniperda*	xxx		xxx			xxx				
Allarthonia *caesia*	xxx		xxx			xxx				
Lecanora *symmicta*	xxx					xxx				
Graphis *scripta*		xxx	xxx	xxx			xxx	xxx	xxx WO	xxx
Buellia *punctata* var. *polyspora*		xxx				xxx		xxx		xxx
Buellia *punctata*		xxx								
Lecidea *vernalis*			xxx							
Caloplaca *holocarpa*				xxx						
Pertusaria *velata*								xxx		

THE FOLIOSE AND FRUTICOSE LICHENS ON PINUS STROBUS ALONG THE W TRANSECT

Species	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	11 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Parmelia caperata	x	x	xx	no	no	no	no	no	xx	no
Parmelia sulcata	x		xx	white	white	white	white	white	xxx	white
Parmelia rudecta		x	xx	pine	pine	pine	pine	pine	xxx	pine
Physcia millegrana		xxx								
Parmelia saxatilis		xxx								
Parmelia flaventior		xxx	xxx							
Parmelia aurulenta			xxx							
Parmelia ulophyllodes			xxx							
Evernia mesomorpha			xxx							
Usnea hirta			xxx							

THE CRUSTOSE LICHENS ON PINUS STROBUS ALONG THE W TRANSECT

Species	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	11 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Lepraria sp.	xxx	xxx	xxx	no	no	no	no	no	xxx	no
Allarthonia caesia	xxx		xxx	white	white	white	white	white		white
Bacidia chlorococca	xxx	xxx	xxx	pine	pine	pine	pine	pine	xxx	pine
Lecanora symmicta	xxx	xxx	xxx							
Lecanora piniperda			xxx						xxx	

THE FOLIOSE AND FRUTICOSE LICHENS ON *ULMUS AMERICANA* ALONG THE SW TRANSECT

Species	1 mi.	2 mi.	4 mi.	6 mi.	7.5 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Candelaria concolor	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Physcia grisea	xxx		xxx				xxx	xxx	xxx	xxx
Physcia millegrana	xxx	xx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Candelaria concolor var. *effusa*	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Physcia orbicularis	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Physcia orbicularis f. *albociliata*	xxx	xxx					xxx	xxx		xxx
Physcia elaeina	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Parmelia caperata		x	x	x	x	x	x	x	xx	
Physcia stellaris		xxx	xxx	xxx	xxx	xxx	xxx	xxx		xxx
Physcia orbicularis f. *rubropulchra*		xxx	xxx	xxx	xxx	xxx	xxx			xxx
Xanthoria fallax		xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Parmelia subaurifera		x								
Parmelia sulcata		xxx	xxx							

Continued on following page.

The Foliose and Fruticose Lichens on _Ulmus americana_ Along the SW Transect (continued)

Species	1 mi.	2 mi.	4 mi.	6 mi.	7.5 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Parmelia aurulenta			xxx	xxx		xxx	xxx		xxx	xxx
Physcia aipolia	only 4		xxx						xxx	
Parmelia rudecta	trees		x	xxx	xxx	xx	xx		xx	
Parmelia bolliana	sampled		xxx							
Physcia adscendens			xxx	xxx		xxx				
Parmelia flaventior					xxx		xxx			
Physcia tribacoides								xxx	xxx	

THE CRUSTOSE LICHENS ON ULMUS AMERICANA ALONG THE SW TRANSECT

Species	1 mi.	2 mi.	4 mi.	6 mi.	7.5 mi.	10 mi.	12 mi.	14 mi.	16 mi	18 mi.
Buellia punctata var. polyspora	xxx									
Lepraria sp.		xxx	xxx					xxx	xxx	
Rinodina pachysperma	only 4			xxx					xxx	xxx
Allarthonia caesia	trees								xxx	
Caloplaca holocarpa	sampled									xxx

THE FOLIOSE AND FRUTICOSE LICHENS ON <u>ACER RUBRUM</u> ALONG THE SW TRANSECT

Species	1 mi.	2 mi.	4 mi.	6 mi.	7.5 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Parmelia caperata	x		x	xx		x	xxx	xxx	x	xx
Parmelia rudecta	x			xx			xxx	xx	xx	xxx
Physcia millegrana	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Candelaria concolor	xxx					xxx		xxx	xxx	xxx
Candelaria concolor var. *effusa*	xxx		xxx	xxx			xxx	xxx	xxx	xxx
Parmelia aurulenta	xxx		xxx		xxx		xxx		xxx	xxx
Parmelia sulcata	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Physcia stellaris	xxx	xxx	xxx	xxx		xxx	xxx	xxx		xxx
Physcia elaeina	xxx									
Physcia orbicularis	xxx		xxx			xxx	xxx		xxx	xxx
Parmelia subaurifera			xxx	xxx		xxx		xxx		
Parmelia flaventior				xxx			xxx	xxx	xxx	xxx
Evernia mesomorpha				xxx			xxx			
Parmelia ulophyllodes							xxx	xxx	xxx	xxx

Continued on following page.

The Foliose and Fruticose Lichens on Acer rubrum Along the SW Transect (continued)

Species	1 mi.	2 mi.	4 mi.	6 mi.	7.5 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Xanthoria fallax								xxx		
Physcia orbicularis f. rubropulchra							xxx		xxx	xxx
Cladonia squamosa							xxx			
Parmelia galbina							xxx	xxx	xxx	
Parmelia bolliana								xxx		
Parmelia saxatilis									xxx	
Ramalina fastigiata									xxx	

THE CRUSTOSE LICHENS ON ACER RUBRUM ALONG THE SW TRANSECT

Species	1 mi.	2 mi.	4 mi.	6 mi.	7.5 mi.	10 mi.	12 mi.	14 mi.	16 mi	18 mi.
Lepraria sp.	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Bacidia punctata var. polyspora	xxx	xxx		xxx		xxx	xxx	xxx	xxx	
Lecanora symmicta	xxx			xxx			xxx		xxx	
Rinodina pachysperma	xxx	xxx				xxx	xxx	xxx	xxx	
Bacidia chlorococca		xxx	xxx	xxx		xxx	xxx		xxx	
Allarthonia caesia		xxx	xxx	xxx	xxx	xxx	xxx	xxx		
Lecanora piniperda		xxx		xxx		xxx	xxx		xxx	xxx
Lecanora varia				xxx			xxx			
Lecidea vernalis								xxx		
Pertusaria velata									xxx	

THE FOLIOSE AND FRUTICOSE LICHENS ON QUERCUS BOREALIS ALONG THE SW TRANSECT

Species	1 mi.	2 mi.	4 mi.	6 mi.	7.5 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Parmelia caperata	x	x	x	xx	xxx	xx	xx	xx	xx	xx
Parmelia aurulenta	xxx		xxx	xxx	xxx		xxx	xxx	xxx	xxx
Physcia millegrana	xx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Candelaria concolor	xxx	xxx	xxx			xxx	xxx	xxx	xxx	
Parmelia rudecta	x		x	x	xxx	xxx	xx	x	xxx	x
Parmelia sulcata	x	xxx	xx	xxx		xxx	xx	xxx	xxx	xxx
Candelaria concolor var. effusa	xxx	xxx	xxx	xxx		xxx	xxx	xxx	xxx	xxx
Physcia orbicularis	xxx		xxx	xxx	xxx		xxx	xxx	xxx	xxx
Parmelia flaventior		xxx						xxx		xxx
Physcia stellaris		xxx		xxx		xxx	xxx	xxx	xxx	xxx
Xanthoria fallax			xxx					xxx		
Physcia orbicularis f. rubropulchra			xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Ramalina fastigiata			xxx						xxx	

Continued on following page.

The Foliose and Fruticose Lichens on Quercus borealis Along the SW Transect (continued)

Species	1 mi.	2 mi.	4 mi.	6 mi.	7.5 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Parmelia bolliana				xxx			xxx		xxx	
Parmelia galbina				xxx			xxx		xxx	
Parmelia saxatilis	only 4			xxx		xxx	xxx	xxx	xxx	
Parmelia ulophyllodes	trees				only 4	xxx				xxx
Evernia mesomorpha	sampled				trees	xxx	xxx	only 4		
Pyxine sorediata					sampled	only 4	xxx	trees		
Parmelia subaurifera						trees		sampled	xxx	
Usnea hirta						sampled			xxx	

THE CRUSTOSE LICHENS ON <u>QUERCUS</u> <u>BOREALIS</u> ALONG THE SW TRANSECT

Species	1 mi.	2 mi.	4 mi.	6 mi.	7.5 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Allarthonia caesia	xxx	xxx	xxx	xxx		xxx	xxx	xxx	xxx	
Lepraria sp.	xxx		xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Bacidia chlorococca	xxx	xxx							xxx	
Lecanora varia		xxx								
Lecanora piniperda		xxx		xxx		xxx	xxx	xxx		
Rinodina pachysperma		xxx					xxx	xxx		xxx
Buellia punctata var. *polyspora*	only 4	xxx	xxx	xxx	only 4	only 4			xxx	
Pertusaria velata	trees		xxx		trees	trees		xxx	xxx	xxx
Lecanora symmicta	sampled				sampled	sampled	xxx	only 4 trees		
Graphis scripta								sampled	xxx	

THE FOLIOSE AND FRUTICOSE LICHENS ON PINUS STROBUS ALONG THE SW TRANSECT

Species	1 mi.	2 mi.	4 mi.	6 mi.	7.5 mi.	10 mi.	12 mi.	14 mi.	16 mi	18 mi.
Parmelia caperata	x	x	only 2 trees	x	no pines	no pines	x	xxx	no pines	no pines
Physcia millegrana	xxx	xxx					xxx			
Parmelia rudecta	x	x		xx			xxx			
Parmelia sulcata		xxx					xxx	xxx		
Evernia mesomorpha				xxx						
Parmelia ulophyllodes	only 2			xxx			xxx			
Parmelia flaventior	pines						xxx	xxx		
Parmelia subaurifera	sampled						xxx			
Parmelia saxatilis							xxx			

THE CRUSTOSE LICHENS ON *PINUS STROBUS* ALONG THE SW TRANSECT

Species	1 mi.	2 mi.	4 mi.	6 mi.	7.5 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Lepraria sp.	xxx	xxx	xxx	xxx	no pines	no pines	xxx	xxx	no pines	no pines
Allarthonia caesia		xxx		xxx			xxx	xxx		
Buellia punctata var. *polyspora*		xxx		xxx				xxx		
Bacidia chlorococca		xxx	xxx	xxx			xxx	xxx		
Lecanora piniperda							xxx	xxx		

THE FOLIOSE AND FRUTICOSE LICHENS ON *ULMUS AMERICANA* ALONG THE S TRANSECT

Species	2 mi.	3 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Candelaria concolor	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Candelaria concolor var. *effusa*	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Parmelia aurulenta	xxx				xxx	xxx			xxx	xxx
Parmelia rudecta	xx				x	xxx			x	xx
Physcia adscendens	xxx	xxx			xxx		xxx	xxx		
Physcia grisea	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Physcia millegrana	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Physcia orbicularis	xxx	xxx		xxx	xxx	xxx	xxx	xxx	xxx	xxx
Xanthoria fallax	xxx	xxx			faded xx		xxx	xxx	xxx	xxx
Physcia tribacoides	xxx		xxx		xxx				xxx	
Physcia orbicularis f. *albociliata*	xxx							xxx	xxx	xxx
Physcia elaeina	xxx	xxx	xxx		xxx	xxx	xxx	xxx	xxx	xxx
Parmelia sulcata		x		xxx		xxx		xxx		xxx

Continued on following page.

The Foliose and Fruticose Lichens on Ulmus americana along the S Transect (continued)

Species	2 mi.	3 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Physcia orbicularis f. rubropulchra		xxx		xxx	xxx	xxx	xxx	xxx	xxx	xxx
Physcia stellaris		xx	xxx	xxx	xxx	xx	xxx	xxx		xxx
Parmelia flaventior				xxx					xxx	
Physcia aipolia				xxx		xx		xxx	xxx	xxx
Parmelia ulophyllodes										xxx
Parmelia caperata					x	x	x	xxx	x	xxx
Pyxine sorediata					xxx			xxx		
Xanthoria polycarpa								xxx		
Parmelia bolliana										xxx
Xanthoria candelaria										xxx
Evernia mesomorpha										x

THE CRUSTOSE LICHENS ON <u>ULMUS</u> <u>AMERICANA</u> ALONG THE S TRANSECT

Species	2 mi.	3 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Caloplaca ulmorum	xxx						no	no		xxx
Lepraria sp.		xxx	xxx		xxx		crustose	crustose	xxx	xxx
Lecanora symmicta				xxx		xxx	lichens	lichens		
Rinodina pachysperma						xxx				xxx
Allarthonia caesia						xxx				
Buellia punctata var. *polyspora*										xxx
Lecanora piniperda										xxx

THE FOLIOSE AND FRUTICOSE LICHENS ON ACER RUBRUM ALONG THE S TRANSECT

Species	2 mi.	3 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Parmelia caperata	x	x		x	xx	xx	xx	xxx	xx	xx
Parmelia aurulenta	xx	x		xx	xxx	xx	xxx		xxx	
Parmelia rudecta	x					xx	xxx		xxx	xx
Physcia millegrana	xx	xx	xx	xx	xxx	xxx	xxx	xxx	xxx	xxx
Physcia orbicularis	xxx	xxx			xxx	xxx	xxx	xxx		xxx
Parmelia ulophyllodes	xxx			xxx	xx			xxx	xxx	xxx
Parmelia saxatilis	x						xxx	xxx		
Physcia orbicularis var. rubropulchra		xxx			xxx		xxx	xxx	xxx	
Parmelia sulcata		xx		xx	xxx	xx	xxx	xxx	xxx	xxx
Physcia stellaris		x				xxx		xxx	xxx	
Xanthoria fallax		x						xxx		
Candelaria concolor var. effusa		xxx	xxx		xxx			xxx		xxx
Candelaria concolor			xxx			xxx	xxx	xxx		
Parmelia flaventior			xxx	xxx			xxx	xxx	xxx	xxx

Continued on following page.

The Foliose and Fruticose Lichens on <u>Acer rubrum</u> Along the S Transect (continued)

Species	2 mi.	3 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Parmelia subaurifera				xxx		xxx				
Cladonia squamosa					xxx				xxx	
Evernia mesomorpha						xxx				
Cladonia bacillaris						xxx				
Usnea comosa						xxx				
Physcia grisea						xxx				xxx
Physcia orbicularis f. *albociliata*							xxx			
Physcia elaeina							xxx			

THE CRUSTOSE LICHENS ON ACER RUBRUM ALONG THE S TRANSECT

Species	2 mi.	3 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Lepraria sp.	xxx	xxx	xxx	xxx	xxx	xxx	xxx		xxx	xxx
Allarthonia caesia		xxx		xxx	xxx	xxx		xxx		xxx
Bacidia chlorococca		xxx		xxx	xxx	xxx			xxx	
Buellia parasema		xxx		xxx						
Rinodina pachysperma		xxx	xxx		xxx	xxx		xxx		
Lecanora symmicta		xxx							xxx	
Buellia punctata var. polyspora				xxx			xxx		xxx	
Lecanora varia				xxx	xxx		xxx		xxx	xxx
Pertusaria velata				xxx			xxx		xxx	
Lecanora subfusca group				xxx			xxx	xxx		
Lecanora piniperda						xxx				
Lecidea vernalis						xxx				
Ochrolechia pallescens						xxx				

THE FOLIOSE AND FRUTICOSE LICHENS ON QUERCUS BOREALIS ALONG THE S TRANSECT

Species	2 mi.	3 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Parmelia caperata	x	x	x	x	x	x	x	xx	xx	xx
Parmelia aurulenta	xx	xx			xxx	xxx	xxx	xxx	xxx	
Physcia millegrana	xxx	xxx	xxx	xx	xxx	xxx	xxx	xxx	xxx	xxx
Physcia orbicularis	xxx	xxx	xxx		xxx	xxx	xxx	xxx	xxx	xxx
Candelaria concolor var. effusa	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Parmelia rudecta	x		xx		xx	xxx	xxx	xx		xx
Parmelia sulcata	xxx	xxx	xx	xx		xx		xxx	xxx	
Parmelia saxatilis	x	x		xx						
Parmelia subaurifera	xxx			x				xxx		
Candelaria concolor	xxx		xxx					xxx	xxx	xxx
Parmelia galbina	xxx			xxx			xxx	xxx	xxx	
Physcia orbicularis f. rubropulchra	xxx	xx	xxx		xxx	xxx	xxx	xxx	xxx	xxx
Physcia grisea	xxx							xxx	xxx	
Parmelia flaventior		x	xx					xxx	xxx	

Continued on following page.

The Foliose and Fruticose Lichens on Quercus borealis Along the S Transect (continued)

Species	2 mi.	3 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Physcia stellaris		xx	xx			xx				xxx
Xanthoria candelaria			xxx							
Ramalina fastigiata				x		x		xxx		xxx
Evernia mesomorpha				x		xxx		xxx		
Parmelia ulophyllodes				xxx				xxx		xxx
Pyxine sorediata					xxx					
Xanthoria fallax								xxx	xxx	
Usnea hirta								xxx		
Physcia orbicularis f. albociliata								xxx		
Physcia elaeina								xxx		
Parmelia bolliana								xxx	xxx	

THE CRUSTOSE LICHENS ON QUERCUS BOREALIS ALONG THE S TRANSECT

Species	2 mi.	3 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Lepraria sp.	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Allarthonia caesia	xxx	xxx	xxx	xxx		xxx	xxx	xxx	xxx	xxx
Pertusaria velata	xxx				xxx		xxx		xxx	
Bacidia chlorococca	xxx	xxx		xxx				xxx		
Buellia punctata var. polyspora	xxx					xxx				
Lecidia vernalis	xxx	xxx								
Lecanora varia				xxx	xxx			xxx		
Lecanora subfusca group					xxx		xxx	xxx	xxx	
Buellia punctata										
Lecanora piniperda						xxx		xxx		
Rinodina pachysperma							xxx		xxx	
Graphis scripta							xxx			
Lecanora symmicta								xxx	xxx	xxx

THE FOLIOSE AND FRUTICOSE LICHENS ON PINUS STROBUS ALONG THE S TRANSECT

Species	2 mi.	3 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Parmelia flaventior	xxx		xxx		xxx		xxx	xxx	xxx	xxx
Parmelia caperata	x	x	xx	xx	xx	xxx	xxx	xx	x	xxx
Parmelia sulcata		x	xx	xx		xxx		xxx		xxx
Evernia mesomorpha		xxx		xxx		x				xxx
Parmelia rudecta		x	x	xx	xx	x	xxx	xx	x	x
Hypogymnia physodes		x								
Physcia millegrana			xxx							xxx
Parmelia ulophyllodes			xxx	xxx	xxx	xxx		xxx	xxx	
Cladonia squamosa					xxx				xxx	xxx
Parmelia aurulenta						only 3		xxx		
Usnea hirta						trees		xxx		xxx
Parmelia galbina						sampled		xxx		
Physcia grisea								xxx		
Nephroma helvetium										xxx

THE CRUSTOSE LICHENS ON *PINUS STROBUS* ALONG THE S TRANSECT

Species	2 mi.	3 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Lepraria sp.	xxx	xxx	xxx	xxx	xxx				xxx	xxx
Bacidia chlorococca		xxx		xxx	xxx	xxx	xxx			xxx
Lecanora symmicta		xxx				xxx	xxx			
Allarthonia caesia		xxx			xxx	xxx				xxx
Lecanora piniperda		xxx	xxx		xxx	xxx				xxx
Buellia punctata var. *polyspora*		xxx	xxx	xxx		xxx	xxx			xxx
Lecidea vernalis			xxx	xxx						xxx

THE FOLIOSE AND FRUTICOSE LICHENS ON <u>ULMUS AMERICANA</u> ALONG THE SE TRANSECT

Species	½ mi.	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Candelaria concolor var. effusa	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Parmelia flaventior	x			xxx	xx				xxx	
Parmelia aurulenta	xxx		xxx	xxx		xxx	xxx	xxx		
Physcia elaeina	xxx		xxx	xxx			xxx	xxx	xxx	xxx
Physcia grisea	xxx		xxx	xxx		xxx	xxx	xxx	xxx	xxx
Physcia millegrana	xxx		xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Physcia orbicularis	xxx		xxx	xxx		xxx	xxx	xxx	xxx	xxx
Physcia orbicularis f. rubropulchra	xxx		xxx		xxx	xxx	xxx	xxx	xxx	xxx
Physcia stellaris	xxx		xxx				xxx	xxx		xxx
Xanthoria fallax	xxx		xxx	xxx		xxx	xxx	xxx	xxx	xxx
Physcia adscendens	xxx			xxx			xxx	xxx	xxx	xxx
Candelaria concolor	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Parmelia caperata		x	x	xx	xx		xx	xx		
Parmelia rudecta			x	x	xxx	xx			xxx	

Continued on following page.

The Foliose and Fruticose Lichens on <u>Ulmus</u> <u>americana</u> Along the SE Transect (continued)

Species	½ mi.	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Physcia tribacoides			xxx	xxx		xxx			xxx	
Physcia orbicularis f. albociliata			xxx	xxx				xxx	xxx	xxx
Parmelia sulcata				xxx	xx			xxx		
Pyxine sorediata		only 2		xxx					xxx	
Anaptychia palmatula		trees		xxx						
Anaptychia psudospeciosa var. tremulans		sampled		xxx						
Parmelia ulophyllodes					xxx					
Xanthoria polycarpa								xxx		
Physcia aipolia								xxx	xxx	
Xanthoria candelaria								xxx		xxx

THE CRUSTOSE LICHENS ON ULMUS AMERICANA ALONG THE SE TRANSECT

Species	½ mi.	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Lepraria sp.	no	no	xxx	xxx	xxx	xxx	xxx	xxx	xxx	no
Rinodina pachysperma	crustose	crustose						xxx	xxx	crustose
Allarthonia caesia	lichens	lichens						xxx		lichens
Caloplaca aurantiaca								xxx	xxx	

THE FOLIOSE AND FRUTICOSE LICHENS ON <u>ACER RUBRUM</u> ALONG THE SE TRANSECT

Species	½ mi.	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Physcia millegrana	x	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Parmelia aurulenta	xxx		xxx	xxx		xxx			xxx	xxx
Physcia orbicularis	xxx	xxx	xxx				xxx	xxx	xxx	xxx
Candelaria concolor var. effusa		xxx		xxx	xxx	xxx			xxx	xxx
Parmelia caperata		x	xx	xx	xx	x	xx	xx	xxx	xx
Parmelia sulcata		xx	xx	xx	xxx	xx	xxx	xx	xxx	xxx
Physcia orbicularis var. rubropulchra		xxx		xxx		xxx			xxx	xxx
Candelaria concolor		xxx	xxx		xxx		xxx	xxx	xxx	xxx
Physcia elaeina		xxx							xxx	
Parmelia ulophyllodes			xxx		xxx		xxx	xxx		xxx
Parmelia flaventior			xxx	xxx	xxx		xxx		xxx	xxx
Parmelia subaurifera			xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Physcia stellaris			xx	xx	xxx		xxx	xxx	xxx	
Evernia mesomorpha			xxx		xxx	xxx	xxx	xxx	xxx	xxx

Continued on following page.

The Foliose and Fruticose Lichens on Acer rubrum Along the SE Transect (continued)

Species	½ mi.	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Usnea hirta			xxx							
Hypogymnia physodes			xxx							xxx
Ramalina fastigiata			xxx		xxx		xxx		xxx	xxx
Parmelia rudecta				xxx		xx				xxx
Parmelia saxatilis				xxx		xxx		xxx	xxx	xxx
Parmelia galbina				x		xxx				
Cladonia squamosa				xxx			xxx			
Usnea comosa							xxx			xxx
Physcia adscendens								xxx	xxx	
Pyxine sorediata										xxx
Parmelia subrudecta										xxx

THE CRUSTOSE LICHENS ON ACER RUBRUM ALONG THE SE TRANSECT

Species	½ mi.	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Allarthonia caesia	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Bacidia chlorococca	xxx	xxx	xxx	xxx		xxx	xxx	xxx	xxx	xxx
Rinodina pachysperma	xxx	xxx	xxx				xxx	xxx		
Lepraria sp.		xxx	xxx	xxx		xxx	xxx		xxx	xxx
Lecanora symmicta		xxx	xxx		xxx	xxx			xxx	
Buellia punctata var. polyspora		xxx	xxx	xxx	xxx	xxx		xxx	xxx	xxx
Lecanora piniperda			xxx		xxx			xxx		xxx
Lecidea vernalis							xxx	xxx		
Lecanora varia								xxx		
Lecanora subfusca group									xxx	

THE FOLIOSE AND FRUTICOSE LICHENS ON QUERCUS BOREALIS ALONG THE SE TRANSECT

Species	½ mi.	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Parmelia caperata	x		x	x	xx	xx	xxx	xxx	xx	xxx
Parmelia aurulenta	xxx	xxx	xxx	xxx	xxx	xxx	xxx		xxx	xxx
Physcia millegrana	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Physcia orbicularis	xxx	xxx	xxx	xxx		xxx	xxx		xxx	xxx
Physcia orbicularis f. rubropulchra	xxx		xxx	xxx		xxx	xxx		xxx	
Candelaria concolor var. effusa	xxx	xxx	xxx	xxx	xxx			xxx	xxx	xxx
Physcia stellaris		xxx	xxx		xxx		xxx	xxx		xxx
Candelaria concolor		xxx	xxx		xxx		xxx		xxx	
Physcia elaeina		xxx		xxx					xxx	
Evernia mesomorpha			xxx				xxx	xxx	xxx	
Parmelia flaventior			xxx		xxx		xxx	xxx		xxx
Physcia tribacoides			xxx							
Parmelia subaurifera			xxx			xxx	xxx	xxx		xxx
Parmelia sulcata			xxx	xx	xx	xx	xx	xx		xx

Continued on following page.

The Foliose and Fruticose Lichens on Quercus borealis Along the SE Transect (continued)

Species	½ mi.	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Parmelia rudecta			x		x	x			xxx	xx
Xanthoria fallax			xxx						xxx	
Parmelia ulophyllodes			xxx		xxx			xxx		xxx
Parmelia saxatilis				xxx		x			xxx	
Parmelia bolliana		only 4		xxx					xxx	
Pyxine sorediata		trees				xxx				xxx
Ramalina fastigiata		sampled				xxx			xxx	xxx
Cladonia bacillaris							xxx			
Usnea comosa							xxx	xxx		
Parmelia septentrionalis							xxx			
Physcia grisea								xxx		
Usnea hirta								xxx		
Cladonia squamosa								xxx		

THE CRUSTOSE LICHENS ON QUERCUS BOREALIS ALONG THE SE TRANSECT

Species	½ mi.	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Pertusaria pustulata	xxx		xxx							
Lepraria sp.	xxx	xxx	xxx	xxx	xxx	xxx	xxx		xxx	xxx
Buellia punctata var. polyspora	xxx			xxx		xxx		xxx		xxx
Allarthonia caesia	xxx	xxx	xxx	xxx	xxx		xxx	xxx		xxx
Graphis scripta		xxx				xxx			xxx	
Rinodina pachysperma		xxx	xxx		xxx			xxx		xxx
Bacidia chlorococca				xxx			xxx	xxx		xxx
Lecanora symmicta			only 4	xxx						xxx
Lecanora piniperda			trees	xxx			xxx	xxx		
Lecanora subfusca group			sampled			xxx			xxx	
Lecidea vernalis							xxx	xxx		
Pertusaria velata						xxx		xxx	xxx	xxx

THE FOLIOSE AND FRUTICOSE LICHENS ON PINUS STROBUS SE OF THE MOSINEE PAPER PLANT

Species	½ mi.	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Parmelia caperata		x	xxx	xx				xxx	xx	xxx
Parmelia flaventior		xxx	xxx		xxx			xxx	xxx	xxx
Parmelia sulcata		xxx	xx	xx	xxx			xxx	xx	
Parmelia ulophyllodes		xxx	xxx		xxx			xxx	xxx	
Parmelia subaurifera		xxx	xxx						xxx	
Parmelia rudecta		xxx		xx		xx	xxx			xxx
Evernia mesomorpha			xxx				xxx	xxx	xx	
Cladonia squamosa				xxx		xxx		xxx		
Hypogymnia physodes					xxx				xxx	
Physcia millegrana						only 2	only 1	xxx		
Physcia orbicularis var. rubropulchra						pines	pine		xxx	
Usnea hirta						sampled	sampled		xxx	
Cetraria halei									xxx	
Parmelia aurulenta										xxx
Cladonia bacillaris										xxx

THE CRUSTOSE LICHENS ON PINUS STROBUS ALONG THE SE TRANSECT

Species	½ mi.	2 mi.	4 mi.	6 mi.	8 mi.	10 mi.	12 mi.	14 mi.	16 mi.	18 mi.
Lepraria sp.	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Lecanora varia			xxx							
Bacidia chlorococca			xxx				xxx		xxx	xxx
Allarthonia caesia			xxx	xxx			xxx	xxx		
Buellia punctata var. polyspora			xxx					xxx		xxx
Lecidea vernalis			xxx					xxx	xxx	
Lecanora symmicta					xxx				xxx	xxx
Lecanora piniperda						xxx				

THE FOLIOSE AND FRUTICOSE LICHENS ON <u>ULMUS</u> <u>AMERICANA</u> ALONG THE E TRANSECT

Species	2 mi.	3.5 mi.	4.5 mi.	5 mi.	7 mi.	9 mi.	11 mi.	13 mi.	15 mi.	18 mi.
Candelaria concolor	xxx	xxx	xxx	xxx	xxx	xxx	xxx	no		no
Physcia elaeina	xxx		xxx		xxx	xxx		elms	xxx	elms
Physcia millegrana	xxx	xxx	xxx	xxx	xxx	xx	xxx		xxx	
Physcia orbicularis	xxx	xxx	xxx	xxx	xxx	xxx	xxx		xxx	
Physcia orbicularis f. rubropulchra	xxx	xxx	xxx	xxx		xxx	xxx		xxx	
Xanthoria fallax	xxx	xxx	xxx	xxx	xxx	xxx			xxx	
Parmelia sulcata	xxx	xxx	xxx		xxx	xxx				
Candelaria concolor var. effusa	xxx	xxx	xxx	xxx	xxx	xxx	xxx			
Physcia stellaris	xxx	xxx	xxx			xxx	xxx			
Physcia grisea	xxx	xxx		xxx	xxx	xxx	xxx		xxx	
Parmelia caperata		x	x		x	x			x	
Parmelia rudecta		x	x	x	x		x		xx	
Physcia adscendens		xxx	xxx	xxx	xxx	xxx	xxx			
Physcia aipolia		xxx			xxx	xxx				

Continued on following page.

The Foliose and Fruticose Lichens on Ulmus americana Along the E Transect (continued)

Species	2 mi.	3.5 mi.	4.5 mi.	5 mi.	7 mi.	9 mi.	11 mi.	13 mi.	15 mi.	18 mi.
Pyxine sorediata		xxx								
Parmelia aurulenta			xxx	xxx	xxx				xxx	
Parmelia flaventior			xxx			xxx				
Parmelia subaurifera	only 2	only 4	xxx				xxx			
Xanthoria polycarpa	trees	trees	xxx				xxx			
Physcia tribacoides	sampled	sampled		xxx					xxx	
Physcia orbicularis f. albociliata				xxx	xxx				xxx	
Lobaria quercizans				xxx						
Anaptychia psudospeciosa var. tremulans									xxx	

THE CRUSTOSE LICHENS ON <u>ULMUS AMERICANA</u> ALONG THE E TRANSECT

Species	2 mi.	3.5 mi.	4.5 mi.	5 mi.	7 mi.	9 mi.	11 mi.	13 mi.	15 mi.	18 mi.
Allarthonia caesia	no crustose		xxx				xxx	no elms		no elms
Lepraria sp.	lichens		xxx	xxx	xxx		xxx		xxx	
Caloplaca aurantiaca			xxx			xxx				
Rinodina pachysperma			xxx				xxx			
Caloplaca ulmorum	only 2 trees	only 4 trees			xxx					
Lecanora symmicta	sampled	sampled					xxx			

THE FOLIOSE AND FRUTICOSE LICHENS ON ACER RUBRUM ALONG THE E TRANSECT

Species	2 mi.	3.5 mi.	4.5 mi.	5 mi.	7 mi.	9 mi.	11 mi.	13 mi.	15 mi.	18 mi.
Candelaria concolor var. *effusa*	xxx			xxx	xxx	xxx	xxx		xxx	xxx
Physcia millegrana	xx	xxx	xxx	xxx	xxx	xx	xxx	xxx	xxx	xxx
Physcia orbicularis	xx	xx	xxx		xx	xxx	xxx	xxx	xxx	xxx
Physcia stellaris	x								xxx	xxx
Parmelia caperata	xxx	x	x	x	x	x	x	x	xx	xx
Physcia orbicularis f. *rubropulchra*	xx	xxx			xxx	xxx	xxx	xxx	xxx	xxx
Candelaria concolor	xxx	xxx	xxx				xxx			
Evernia mesomorpha		xxx	xx				xxx	xxx		xxx
Parmelia flaventior		xxx		xxx	xxx		xxx			xxx
Parmelia sulcata		xx	xx	xx	xx	xx	xxx	xxx	xx	xxx
Parmelia subaurifera		xxx	xxx	xxx		xxx	xxx	xxx	xxx	xxx
Hypogymnia physodes		xxx								
Physcia elaeina		xxx								

Continued on following page.

The Foliose and Fruticose Lichens on Acer rubrum Along the E Transect (continued)

Species	2 mi.	3.5 mi.	4.5 mi.	5 mi.	7 mi.	9 mi.	11 mi.	13 mi.	15 mi.	18 mi.
Parmelia aurulenta			xxx		xxx	xxx	xxx	xxx	xxx	xxx
Parmelia ulophyllodes			xxx	xxx		xxx				xxx
Parmelia rudecta				x		xxx	xxx		xxx	
Usnea comosa							xxx			
Parmelia galbina									xxx	xxx
Ramalina fastigiata									xxx	xxx
Pyxine sorediata										xxx

THE CRUSTOSE LICHENS ON ACER RUBRUM ALONG THE E TRANSECT

Species	2 mi.	3.5 mi.	4.5 mi.	5 mi.	7 mi.	9 mi.	11 mi.	13 mi.	15 mi.	18 mi.
Lepraria sp.	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Bacidia chlorococca	xxx	xxx	xxx			xxx	xxx	xxx	xxx	
Allarthonia caesia	xxx	xxx	xxx	xxx		xxx	xxx	xxx	xxx	
Rinodina pachysperma	xxx			xxx		xxx			xxx	
Lecanora piniperda		xxx		xxx	xxx					
Buellia punctata var. polyspora		xxx	xxx		xxx	xxx		xxx	xxx	xxx
Lecanora symmicta			xxx					xxx		
Lecidea vernalis										xxx

THE FOLIOSE AND FRUTICOSE LICHENS ON QUERCUS BOREALIS ALONG THE E TRANSECT

Species	2 mi.	3.5 mi.	4.5 mi.	5 mi.	7 mi.	9 mi.	11 mi.	13 mi.	15 mi.	18 mi.
Candelaria concolor	xxx	xxx	xxx	BO xxx	xxx		xxx		xxx	xxx
Parmelia caperata	x	x	x	BO x	x	x	x	xxx		xxx
Parmelia sulcata	x	xx	xx	BO xxx	xx	xxx	xxx	xxx		xxx
Physcia millegrana	xx	xxx	xxx	BO xxx	xxx	xxx	xxx	xxx	xx	xxx
Physcia orbicularis	xxx	xxx	xxx	BO xxx	xxx	xxx				xxx
Physcia orbicularis f. *rubropulchra*	xxx	xxx	xxx	BO xxx	xxx	xxx	xxx		xxx	xxx
Physcia stellaris	x	xxx		BO xxx		xxx	xxx	xxx	xxx	
Candelaria concolor var. *effusa*	xxx	xxx	xxx	BO xxx	xxx	xxx	xxx			xxx
Parmelia saxatilis	x		x		xxx	xxx		xxx		xxx
Parmelia subaurifera		xxx			xxx		xxx	xxx		xxx
Parmelia galbina		xxx	xxx			xxx		xxx		xxx
Parmelia rudecta		x	x	BO x	x		x	x	x	xxx
Ramalina fastigiata		xxx	xxx					xxx	xxx	
Parmelia ulophyllodes		xxx	xxx			xxx	xxx		xxx	xxx

Continued on following page.

The Foliose and Fruticose Lichens on Quercus borealis Along the E Transect (continued)

Species	2 mi.	3.5 mi.	4.5 mi.	5 mi.	7 mi.	9 mi.	11 mi.	13 mi.	15 mi.	18 mi.
Evernia mesomorpha			xxx		xxx			x		xxx
Parmelia aurulenta			xxx	BO xxx	xxx	xxx	xxx	xxx	xxx	xxx
Parmelia flaventior			xxx	BO xxx		xxx	xxx		xxx	
Xanthoria fallax				BO xxx			xxx			xxx
Physcia grisea				no Q.			xxx			
Anaptychia psudospeciosa var. tremulans				borealis				xxx		xxx
Cladonia squamosa				in area						xxx
Pyxine sorediata										xxx

THE CRUSTOSE LICHENS ON <u>QUERCUS</u> <u>BOREALIS</u> ALONG THE E TRANSECT

Species	2 mi.	3.5 mi.	4.5 mi.	5 mi.	7 mi.	9 mi.	11 mi.	13 mi.	15 mi.	18 mi.
<u>Lepraria</u> sp.	xxx	xxx	xxx	BO xxx	xxx		xxx	xxx	xxx	xxx
<u>Allarthonia</u> <u>caesia</u>	xxx	xxx	xxx	BO xxx	xxx	xxx			xxx	
<u>Buellia</u> <u>punctata</u> f. <u>polyspora</u>	xxx		xxx					xxx		xxx
<u>Rinodina</u> <u>pachysperma</u>	xxx			BO xxx	xxx	xxx		xxx	xxx	
<u>Bacidia</u> <u>chlorococca</u>		xxx		BO xxx	xxx	xxx		xxx		
<u>Ochrolechia</u> <u>pallescens</u>		xxx								
<u>Pertusaria</u> <u>pertusa</u>		xxx						xxx		
<u>Lecanora</u> <u>symmicta</u>			xxx							xxx
<u>Lecanora</u> <u>piniperda</u>				BO xxx	xxx			xxx		
<u>Graphis</u> <u>scripta</u>				BO xxx	xxx					
<u>Lecanora</u> <u>subfusa</u> group								xxx	xxx	xxx

THE FOLIOSE AND FRUTICOSE LICHENS ON PINUS STROBUS ALONG THE E TRANSECT

Species	2 mi.	3.5 mi.	4.5 mi.	5 mi.	7 mi.	9 mi.	11 mi.	13 mi.	15 mi.	18 mi.
Parmelia caperata		x	x	no pines	x	no	x	x	xx	xxx
Physcia millegrana		xxx			xxx	pines				xxx
Parmelia sulcata		xxx	xx		x		xxx	xxx		xx
Parmelia ulophyllodes		xxx							xxx	
Parmelia rudecta			xxx				x	x	x	
Cladonia squamosa			xxx							xxx
Evernia mesomorpha			x		xxx		xxx	xxx		xxx
Candelaria concolor var. *effusa*					xxx					
Physcia aipolia					x					
Parmelia flaventior					xxx		xxx			

Continued on following page.

The Foliose and Fruticose Lichens on *Pinus strobus* Along the E Transect (continued)

Species	2 mi.	3.5 mi.	4.5 mi.	5 mi.	7 mi.	9 mi.	11 mi.	13 mi.	15 mi.	18 mi.
Hypogymnia physodes		only 4					xxx	xxx	only 4	
Parmelia saxatilis		trees					xxx		trees	xxx
Parmelia subaurifera		sampled						xxx	sampled	
Xanthoria fallax								xxx		xxx
Usnea comosa								xxx		
Physcia orbicularis										xxx

THE CRUSTOSE LICHENS ON PINUS STROBUS ALONG THE E TRANSECT

Species	2 mi.	3.5 mi.	4.5 mi.	5 mi.	7 mi.	9 mi.	11 mi.	13 mi.	15 mi.	18 mi.
Lepraria sp.	XXX	XXX	XXX	no pines	XXX	no pines		XXX	XXX	
Bacidia chlorococca	XXX	XXX	XXX		XXX		XXX	XXX		XXX
Allarthonia caesia		XXX								
Lecanora piniperda		XXX			XXX		XXX			
Lecanora symmicta					XXX					XXX
Lecanora subfusca group								XXX		
Graphis scripta										XXX

Approved: John W. Thomson

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