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ECOLOGICAL STUDIES ON LICHENS IN THREE HABITATS AT THE UNIVERSITY OF MICHIGAN BIOLOGICAL STATION AREA IN MICHIGAN

A Dissertation

Presented for the

Doctor of Philosophy

Degree

The University of Tennessee

Carlos Ramirez Reyes

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ABSTRACT

Lichen frequency distributions were determined at breast height (1.3 m) on the bole of each of five species of trees, Pinus banksiana, Populus grandidentata, Quercus rubra, Ulmus americana, and Acer saccharum in the forest as a whole by combining the results of sampling in three habitats, forest centers, beside unpaved and paved roads in upland situations at the University of Michigan Biological Station area (Cheboygan and Emmet Counties) Michigan. The meaning of these frequencies were investigated in terms of lichen-tree pairs associations by means of Cole's indices of interspecific associations. Similarities and dissimilarities among lichen communities on these tree species and the same habitats were also studied using Kulczynski's index of coefficients of similarity. The pH of bark substrates was measured to find out any correlation between this factor and lichen distribution.

Inferences from these results were drawn in regard to habitat effect on lichen distribution and community composition, and given below.

Trees in the habitat beside unpaved roads seemed to be more suitable for lichens, with those of the forest centers next, and those along paved roads last. Tree species on tree boles alongside paved roads showed fewer number of species, number of lichen-tree pairs associations by chance

and non-chance probability. The environment within forest centers was stable enough to allow each of these five tree species to support a lichen vegetation that in terms of similarity closely follows the linear floristic gradient of vascular plants in the area.

Correlation coefficients between pH and number of lichens showed no association. However, pH of bark was more acid along paved roads than in the other two habitats.

Inferences derived from these studies indicate that the most important factors determining corticolous distribution of lichens in this area are those of the general habitat in which the tree-stands were located.

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I. INTRODUCTION

Customarily ecological studies on lichens to establish their normal distribution patterns in a region have been made in localities which are considered environmentally undisturbed such as those found in forest stands where peripheral phenomena such as edge lighting, wind, dust, etc., are negligible (Culberson, 1955a,b, 1958; Hale, 1955; Jonescu, 1970; and Adams and Risser, 1971a,b). Lichen behavior along roads, forest edges, cities, etc., is regarded as affected by environmental disturbances that prevail about them (Jones, 1952; Brightman, 1959; Brodo, 1966; Coker, 1967; Skye and Hallberg, 1966; Saunders, 1970; and Gilbert, 1971). However, the fact cannot be neglected that in forests subject to human visitation there are many different types of habitats which are crossed by various kind of roads and trails contributing to differing factors which may act in various ways upon lichen environment. Consequently, roads should be considered as part of the total forest habitat in many areas and as such they must be taken into account when studies of this kind are undertaken. Results obtained from ecological investigations of lichens considering these environmental situations in a study of this type offer a better basis for an interpretation of lichen community composition across a wide region.

The objectives of this study were:

1. To ascertain the frequency distribution of lichen species at breast height on the bole of the tree species Pinus banksiana, Populus grandidentata, Quercus rubra, Ulmus americana, and Acer saccharum in upland situations at the University of Michigan Biological Station area (Cheboygan and Emmet Counties).

2. To investigate the degrees of interspecific associations across frequency distributions in the forest as a whole and in three habitats, forest centers, along unpaved and paved roads.

3. To compare those degrees of interspecific associations found in the habitats among themselves and those of forest centers with those of the forest as a whole.

4. To discover degrees of similarity among lichen communities on tree species: (a) in the forest as a whole, (b) among different habitats, (c) on each tree species at each habitat, and (d) on each tree species as compared among the habitats.

5. To draw inferences from the above data in regard to the effect of the habitat on the distribution of lichen-tree pair associations and similarity of lichen communities in the more protected areas such as forest centers, in comparison to the forest as a whole.

6. To correlate pH of tree-bark as measured from trees located at these habitats with lichen distribution.

A study of this type has not been reported before. One similar to it was undertaken on one species of tree, Populus tremuloides, in West-Central Canada by Jonescu (1970) who investigated the behavior of lichens according to aspects in forest and barkland conditions. She concluded that species occurrence and abundance at each site depended on aspect differences and possibly on differences in annual precipitation, bark conditions and nutrient supply.

There are other studies more restricted in regard to distribution of lichens in habitats. Culberson (1955) studied the corticolous communities of lichens and bryophytes in the upland forests of northern Wisconsin but restricted his study to protected areas in forest interiors. He concluded that substrate preference is of great importance in determining the distribution of cryptogams. By using Kulczynski's coefficient index of community, Culberson placed the major tree species which he investigated for lichens in a linear order in accordance with the climax tree adaptation number (Brown and Curtis, 1952) by using the similarity of the corticolous population which they supported.

Hale (1955) in a similar study made in the interiors of upland forests of southern Wisconsin concluded that stand composition in regard to the dominant tree species is the main factor in limiting the distribution of cryptogams.

Adams and Risser (1971a) studied the effect of host tree specificity on the association of lichen pairs on two

oak species in interiors of the upland forest stands in north central Oklahoma. They found that the associations between lichens varied from one tree to another.

Russell (1973) made a comparative study of the lichen flora on Ulmus americana in northern Michigan in two habitats inside lowland elm swamps and beside upland roads. He found by means of Kulczynski's index of community similarity that similarity of lichen communities between swamp elms and roadside elms were very low.

Brodo (1961) in a study of lichen ecology in Central Long Island, New York, concluded that host-specificity, in one vegetation type sometimes differs from those in other vegetation types and that the most important factors in lichen distribution on a local level were moisture and light.

Rydzak (1961, 1970) studied lichens on trees in the forest communities of the Bialowieza National Park, Poland. He pointed out that in the case of lichen species in distinct forest associations, quantity and similarities or differences depended on some special microclimatic and ecological conditions, and that lichen community similarities from diverse forest associations can be partly ascribed to the presence of tree species of different ages. For this latter reason the lichen flora of stands next to each other could be different even though other conditions were identical. The same author made another study of the lichen flora and ecology of roadside trees in eastern Poland and found that lichens were

absent on numerous trees, particularly on young as well as on older ones that "shaded each other." He concluded that more prosperous lichen communities arose where "microclimatic-ecological factors" were more appropriate. He did not consider pollution as a limiting factor for lichens.

There is considerable literature which deals with those factors affecting and determining the distribution of corticolous lichens, most of them related to climate and microclimatology of the habitat and porophytes as summarized in Barkman (1958). Since that time extensive field and experimental work has been done to try for a better understanding of the way in which some of these factors act on lichens.

Adams and Risser (1971b) found in forest interiors in north central Oklahoma that lichen species occur with higher frequency on one particular tree and that precipitation was the most important factor in determining the frequency behavior of corticolous lichens in this area of study.

Pearson (1969) in a distributional study of lichens in a Minnesota bog noted that lichen cover and abundance was higher in places of high light intensities and low relative humidity but more variable than in the woods.

Harris (1971) investigated the zonation of corticolous lichens on oak and birch. He detected a clear vertical zonation on both species and related it to possible roles of microclimatological gradients, competition and succession.

Kappen, et al., (1970) in a study to find the cold resistance of lichens subjected 23 species from Europe, tropical and subtropical areas to cold temperatures of -78.5° C during 33 hours. He concluded that lichen resistance to cold temperatures is an innate character derived from the relationship between the symbionts.

Laudon (1966) discussed the effect of a severe winter on Parmelia caperata on trees beside roads in England in 1963 where temperatures at or below freezing levels remained for long periods from December to March. He discarded the damage effected by pollution because this species showed signs of recuperation several months thereafter.

Gordon and Gorham (1963) made a study of the ecological aspects of air pollution from an iron-sintering plant. They determined that damage to plant vegetation was restricted to the track of the predominant wind in the area. Damage was traced for 20 miles downwind.

Gurholt (1968) in a distributional study of lichens on tree stems in regard to industrial air pollution found that under moderate pollution lichens that usually characterized the bark of Populus species were found instead on Pinus bark.

Saunders (1970) in his study of air pollution in relation to lichens and fungi stated that pollutants are derived from industrial combustion and processing from motor

vehicles and domestic systems, SO_2 being one of the most important pollutants. He considered that once released SO_2 remains in the atmosphere for three to four days. He also found correlation between SO_2 concentrations and number of species present, and that lichen establishment on tree bark could be prevented by its low pH. As acidification of bark depends on its buffering capacity and dust load, SO_2 concentration is important because this pollutant reduces that buffering capacity.

Gilbert (1970), by studying the effect of SO_2 on lichens and bryophytes, stressed the controlling influences of the habitat listed below on the survival of lichens and bryophytes. He considered the controlling factors, shelter, pH, and buffer capacity of the substratum to be the most important. In a study at Blyth on the Northumberland coast in England, Gilbert (1971a) suggested that under the effect of SO_2, substrate preference of lichens was affected, the same species of lichens changing from acid substrates to more alkaline ones. The same author Gilbert (1971b) found the abundance of lichens and bryophytes increased around an aluminum plant with increasing distance from the factory. The effect of the pollutants was most noticeable downwind.

Skye and Hallberg (1969) in their study about changes in the lichen flora following air pollution in Sweden, observed changes in lichen distribution in an 18-year span. Species which normally grew on moderately acid substrates

were displaced by species which grew on more acid substrates. They regarded that this was the result of increasing SO_2 in the atmosphere which brought about acidification of the substrate.

Coker (1967) regarded the ability of lichens to absorb SO_2 in polluted areas in relation to their capacity to readily absorb water in any form. He related their high sensitivity to pollution to the quick inactivation of the small amount of chlorophyl (as a result of their structure) in lichens.

Rao and LeBlanc (1965) noted that SO_2 is soluble in water producing a solution of sulfurous acid. It ionizes, producing, among others, the ions $SO_3^=$ and $SO_4^=$ which could be responsible for the plasmolysis of algal cells and the denaturation of algal proteins thus preventing deplasmolysis. They also seemed to act in the conversion of chlorophyll "a" to phaeophytin "a".

Baddeley, et al., (1971) in describing a new method for measuring respiration in lichens discovered that SO_2 in solution had inhibitory effects. In 1972 these same authors determined that SO_2 in solution at concentrations of 30 ppm inhibits respiration in lichens, and that at pH 5.2, SO_2 is less toxic, and that the buffering power of the substrate and that of thalli control their toxicity to SO_2 in the natural environment.

Rao and LeBlanc (1967) in a study of the influence

of an iron-sintering plant on corticolous epiphytes in Canada found correlations between the epiphytic vegetation and the fallout pattern of SO_2 and the chemical indices (pH and SO_4-) of water and soil. They noted a marked reduction of epiphytes both in number and abundance of species with the rise in the concentration of SO_2 in air and a rise of sulfate in water and soil. With increasing distance from the center of pollution there was a decrease in sulphur content of the vegetation.

Nash III (1972a) studied and compared the composition of two lichen communities. One was near a zinc company around Palmerton, Pennsylvania, and the other 50 kms E N E away. He found lichen communities near the zinc factory simpler in composition than those 50 kms away. The same author measured lichen sensitivity to hydrogen fluorides in the field and in the laboratory. He observed algal chlorosis within the lichen thalli when the level of fluoride exceeded 80 ppm. Later all lichen pigments were degraded.

Nieboer, et al., (1972) in an investigation of the heavy metal content of lichens in relation to their distance from a copper smelter determined that the content varied inversely with the distance from the smelter, and that the heavy metals were derived from atmospheric fallout.

II. STUDY AREA

This investigation was made in the State of Michigan which extends northward from latitude 41-25' to 48-20' and westward from longitude 82-25' to 90-34'. The state is divided into northern and southern peninsulas separated by the Straits of Mackinaw. The southern peninsula can be separated in two highland masses (Veatch, 1953), the southern upland and the northern highland. The specific area of study was in Cheboygan and Emmet Counties located in the northern highland known as The University of Michigan Biological Station area. It extends northward from latitude 45-10' to 45-50' and westward from longitude 84-15' to 85-00' at the northern tip of the southern peninsula. It attains an elevation of approximately 1100 to 1400 feet above sea level. The area is bordered by Lake Michigan to the west and by Lake Huron to the east. Inland are found lakes and connecting rivers. Douglas Lake, on whose south shores is located The University of Michigan Biological Station, is connected to Burt Lake which lies two miles southward, by the Maple River. Crooked Lake, Burt Lake, Mullet Lake, Black Lake are interconnected by Crooked River, Indian River, Black River and Cheboygan River which flows to Lake Huron. All these bodies of water have their influence on the climate of the area which, depending on wind conditions, varies from continental to semimaritime.

The surface of the area consists mostly of flat, sandy plains which are altered occasionally by plateau crests and hilly clay lands. The whole surface was covered by ice during recent glacial periods and its topography is considered to be the result of the glacial activity. It is thoroughly dissected by roads and trails. The main roads are the I-75 highway which runs north-south; the Riggsville road from Pellston to Cheboygan; the US 31 highway from Petoskey to Mackinaw; and State highways M-27 from Cheboygan to Indian River; M-68 from Indian River to Afton and southward; and US 23 and 27 from Mackinaw to Cheboygan to Alpena.

The area lies in a transition zone between coniferous forests to the north and deciduous forests to the south, containing many elements of both regions. Four distinct types of forests are found in the area. The hardwood forests are composed of Tsuga canadensis, Tilia americana, Betula lutea, Fagus grandifolia, Ulmus americana, and Acer saccharum. Hardwood coniferous forests are a mixture of Fagus grandifolia, Ulmus americana, Tilia americana, Abies balsamea, Thuja occidentalis, and Picea glauca. The pine forests consist mostly of Pinus strobus, Pinus banksiana, and Pinus resinosa. The swamp coniferous forests consist of Abies balsamea, Thuja occidentalis, Larix laricina, and Picea glauca (Foster, 1939). These forest types comprise a wide range of lowland and upland forests. On the upland forests tree stands

form a continuum (Brown and Curtis, 1952), grading from the most pioneer type (Pinus banksiana) to an upland climax dominated by Acer saccharum and Fagus grandifolia. Lowland successions on peat end in black spruce muskeg, on mineral soils in thuja swamps. Along water courses are elm swamps, greatly altered in recent years by the Dutch Elm Disease. The forests of this area have not been disturbed by any major fire since the 1920's. From that time and after the earlier logging of the hardwoods and softwoods that occurred between the 1850's to 1900's a second growth forest sprang up dominated by Populus grandidentata (Kilburn, 1960). If northern Michigan forests are assumed to be somewhat similar to those of northern Wisconsin, a linear successional forest continuum (Brown and Curtis, 1952), depending on the relative abundance of each tree species can be said to exist in this area. The trees sampled for this investigation are ranked for climax expectancy according to the series of Brown and Curtis (1952), as follows: number one Pinus banksiana, number two Populus grandidentata, number six Quercus rubra, number eight Ulmus americana and number ten the climax tree Acer saccharum. In this area Quercus rubra tree stands often form oak openings. Ulmus americana tree stands were found forming mesic stands characterized by more or less closed canopies. The undercover of the stands studied is made up mostly of the ground lichens, Cladonia sp., Cladina sp., and Pteridium aquilinum. In forest centers

of the climax tree species there is macrophytic understory, only litter.

Climate

Data about the mean annual temperature and precipitation during 10 years (1961-1971) obtained from three National Weather Stations (U. S. Department of Commerce) located at Cheboygan, Onaway and Pellston areas are shown in Table I.

While the average 10 year annual mean temperature varies relatively little between Cheboygan and Pellston, it does show variation between them and the Onaway area which is located southward. Variation in precipitation is also observed between the Cheboygan and Pellston regions. The Onaway and Pellston areas show almost identical means.

In general the climate of the area of study is characterized by long cold winters, with heavy snowfalls, and short summers with cool nights and hot days, and mild autumns. The prevailing winds are westerly. The average frost-free season within the area of study ranges from 140 days in the northern part where lakes exert more influence upon the climate to about 116 days southward where the lake influences are less (National Weather Stations, U. S. Department of Commerce, 1961-1971).

Tree Stands and Localities of Sampling

During the summer of the year 1970, the spring and

TABLE I

ANNUAL MEAN TEMPERATURE AND PRECIPITATION DURING 10 YEARS (1961-1971)*

Station	Temperature °F	Precipitation Inches
Cheboygan	44.05	29.67
Onaway	49.48	35.59
Pellston	45.23	35.04

*At three National Weather Stations (U. S. Department of Commerce), Cheboygan, Onaway and Pellston regions, located in the area of study.

summer of 1971, and the summer of 1972, field data were collected in the area of study. The area was traveled extensively by car and on foot to find the maximum possible number of potential tree-stands for sampling. These were located within three general habitats: (1) in forest centers defined as a closed forest, 100 m from any exposed place, (2) along unpaved roads, and (3) along paved roads. Tree-stands were selected where the tree species tended to form pure stands, in order to eliminate as much as possible the environmental influence of other tree species. Trees were sampled by the quarter method (Cottam and Curtis, 1956). A total of 78 tree-stands were noted, of which 22 were chosen for this study by means of random numbers (Snedecor, 1956). The environmental locations, tree-stands and localities of sampling were the following:

Forest Centers

Acer saccharum. Emmet County. R4W, T34N, Section 14. Little Field Township. On the left side of Banwell road from Alanson village to Mission road.

Pinus banksiana. Cheboygan County. R1E, T37N, Section 20 and Section 21. Grand Township. On the left side of Old Alpena State road from U. S. 23 to Twin Lakes.

Populus grandidentata. Cheboygan County. R1E, T37N, Section 7. Benton Township. On the left side of Old Alpena State road near Duck Marsh.

Quercus rubra. Cheboygan County. R3W, T36N, Section 33 and Section 32. Munro Township. On the right side of Riggsville road between The University of Michigan Biological Station and Pellston.

Ulmus americana. Emmet County. R5W, T37N, Section 17. Sentor Township. On the right side of Van road near Larks Lake.

Ulmus americana. Emmet County. R4W, T36N, Section 5. Maple River Township. On the left side of Robinson road between School road and Ayr road.

Unpaved Roads

Acer saccharum. Emmet County. R4W, T35N, Section 31. McKinley Township. On the right side of Robinson road from Pellston to Ayr road.

Acer saccharum. Emmet County. R4W, T34N, Section 34. Spring Vale Township. On the right side of Harmon road just from the County road that borders the Charlevoix County.

Pinus banksiana. Cheboygan County. R1W, T34N, Section 34 and Section 27. Koehler Township. On the right side of Onaway road from Indian River to M-68 highway.

Pinus banksiana. Cheboygan County. R1E, T37N, Section 20 and Section 21. Grand Township. On the left side of Old Alpena State road from U. S. 23 highway to Twin Lakes.

Populus grandidentata. Cheboygan County. R2W, T36N, Section 34. Munro Township. On the left side of the road

between Riggsville road and Hogback road.

Populus grandidentata. Cheboygan County. R1E, T37N, Section 7. Benton Township. On the left side of Old Alpena State road, near Duck marsh.

Quercus rubra. Cheboygan County. R1W, T33N, Section 32. Walker Township. On the left side of Montgomery road from M-68 highway to Webb road.

Ulmus americana. Emmet County. R4W, T36N, Section 8. Maple River Township. On the left side of School road from Tower road just on the corner with Ringler road.

Paved Roads

Acer saccharum. Emmet County. R3W, T36N, Section 27. Carp Lake Township. On the left side of US 31 highway from Levering village to Carp Lake.

Acer saccharum. Emmet County. R4W, T34N, Section 14. Little Field Township. On the left side of Banwell road from Alanson village to Mission road.

Pinus banksiana. Cheboygan County. R2W, T34N, Section 30. Koehler Township. On the right side of M-68 highway from Indian River to Afton.

Pinus banksiana. Cheboygan County. R3W, T35N, Section 35. Tuscarora Township. On the left side of Straits highway from Indian River to Wolverine village.

Populus grandidentata. Cheboygan County. R2W, T36N, Section 33 and 34. Munro Township. On the left side of Riggsville road between the University of Michigan

Biological Station and Burt Lake road.

Populus grandidentata. Cheboygan County. R3W, T36N, Section 20. Aloha Township. On the left side of M-33 highway between Duvereaux Lake road and Mann School road.

Quercus rubra. Cheboygan County. R3W, T36N, Section 33 and Section 32. Munro Township. On the right side of Riggsville road between the University of Michigan Biological Station and Pellston.

Ulmus americana. Cheboygan County. R3W, T36N, Section 2. Munro Township. On the left side of I-75 from Levering road to Brandan road.

III. METHODS

To establish an adequate number of a given tree species to be sampled in order to give an accurate picture of the lichen population found on each species, a species-area curve as described by Cain (1938) and modified by Phillips (1959) was constructed for each. Samples were taken from groups of 10 individuals of each species and the lichen species listed until very few additional species were found. The sampling was considered adequate when an additional 10 percent increase in sampled trees resulted in an increase of lichen species that was equal to or less than 10 percent of the total (Figure 1).

Quadrats were located on the bole of trees at a constant height because corticolous vegetation is known to vary with height (Hale, 1952, 1955). Breast height (1.3 m) was chosen for the sake of convention and convenience. Trees less than 4 inches in diameter at breast height were not sampled. Tree limbs at the level of sampling were not taken as part of quadrats. Lichen species were identified in situ as far as possible, and their presence recorded within a 10 cm X 10 cm frame placed on each aspect of trees. Specimens that could not be identified in the field were determined in the laboratory by means of the use of microscopes, proper keys, and chemical reagents. Some of them were sent to lichen specialists for identification and

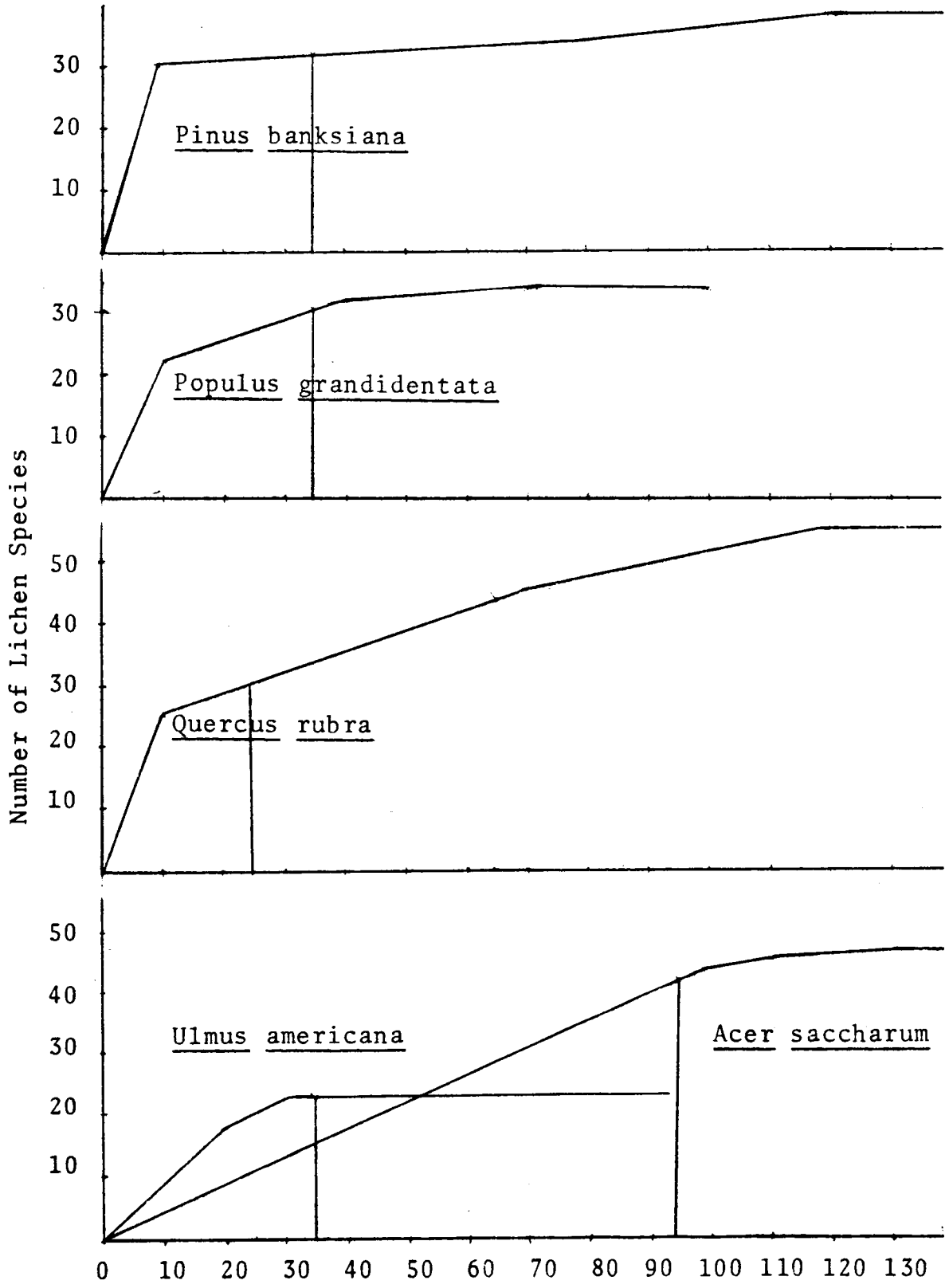


Figure 1. Adequate sample size of trees.

verification. The lichen nomenclature follows that of Hale and Culberson (1970).

The following statistical analysis was performed from the data gathered in this study: the frequency of each lichen species in the forest as a whole based on the total number of individuals of each tree species sampled; the frequency of each lichen species on each of five tree species in each habitat based in the total number of individuals of each tree species sampled; the overall frequency based on the total number of trees sampled. Constancy (percentage of stands in which a species occurred in at least one quadrat X 100) was calculated for each lichen species on each of five tree species in the forest as a whole.

Bark pH was determined by using the method given by Gilbert (1968) which consists of soaking thin, dead surface flakes of bark in two and half times their volume of distilled water two hours before measuring it by a Beckman pH-meter with glass electrodes. Samples of surface bark were taken from each aspect of 10 trees each of Pinus banksiana, Populus grandidentata, and Acer saccharum at each habitat. These data were used to test the degree of association between bark pH and the number of lichen species on each tree species at each habitat by means of Correlation Coefficients. Computations of Correlation Coefficients were made using a Wang model 700B Advanced Programming Calculator. The effect

of each of the environments, i.e., within forest centers, along unpaved and paved roads, was investigated to determine their influence on the distribution of lichens found at breast height on trees.

The degree of interspecific associations was calculated by means of the Cole's (1949) index. Cole's index expresses quantitatively the degree to which species occur together in a given unit of sampling (Adams and Risser, 1971; Cole, 1949; Hale, 1955). If there is no association between the two species the index assumes the value of zero, which indicates that both species are independently distributed. Values above zero to plus one show positive association with plus one being the maximum positive value (perfect positive association) they possibly could have. Values below zero to minus one show negative association, with minus one being the minimum negative value (perfect negative association) they possibly could have. An index value of 0.40 indicates that they are associated together 40 percent of the maximum value and so on. In order to have these degrees of interspecific associations expressed as percentages each was multiplied by 100 in this investigation. To each Cole's index value a Chi-square test with one degree of freedom (Cole, 1949) was calculated to ascertain their statistical significance. Any Chi-square value of any Cole's index that is 0.95 level of significance or less is assumed to indicate that the lichen-tree pair

association occurs only by chance probability. Any Chi-square value of any Cole's index that is larger than 0.95 level of significance is assumed to indicate that the lichen-tree pair association occurs by non-chance probability but probably influenced by some environmental factors.

Only those lichen species that occurred with a frequency of 10 percent or greater on each of the five trees investigated were taken into account for this study.

The basic information required for the computations of Cole's index includes total number of occurrences of a lichen species on the tree species sampled and the number of times the lichen species was found on each of the tree species in question.

The computations of the Cole's index coefficient of interspecific association was done by arranging the data in the form of a 2 x 2 table, with the provision that species "A" (the lichen species) occurs in less of the samples than species "B" (the tree species). (Table XXII , Appendix).

Formulas of three types are used according to the magnitude of the figures in the table. A standard computer program developed at The University of Tennessee Computer Center on the basis of these formulas was used to investigate degrees of interspecific associations for lichen-tree pair associations.

Similarities of the lichen population found on trees in the forest as a whole, among different habitats, on each

tree at each habitat, and on each tree species as compared among habitats were determined taking into account the frequency percentage of the total number of species sampled on each tree.

To determine similarities of lichen populations a method of vegetational analysis developed by Kulczynski (1937) and used widely by plant ecologists (Beals, 1965; Adams and Risser, 1971; Culberson, 1955; Foote, 1966; Hale, 1955; Kalgutkar and Bird, 1969; and Russell, 1973) was utilized. This method involves determining a coefficient of community which measures the level of similarity for any pair of communities from a set of quantitative measurements taken for both. It consists of the following: all measurements are expressed as frequencies. For each community the frequencies are summed. The total of the first community to be compared are identified as "a", of the second as "b". A summation "w" is made of the lower of the frequency values for each species that the community share in common. The coefficient of community is calculated from the formula $\frac{2w}{a+b} \times 100$. If two communities have no species in common the resultant index value is zero; this indicates a total dissimilarity because "w" based on species shared is zero. If two communities are identical the value indicates 100 percent similarity because "w" will equal "a+b". Thus there is a range of "0-100" percent into which any community compared with any other must fall. The higher the

value, the more similar they are; the lower the value, the more different they are. A standard computer program developed at The University of Tennessee Computer Center on the basis of the above formula for the coefficient of community similarity was used to investigate degrees of similarities of lichen communities in this study.

IV. RESULTS AND DISCUSSION

From a total of 78 tree-stands located in the area of study, 22 were chosen for this investigation. A total of 689 trees distributed among five tree species were sampled at breast height (1.3 m) for lichens within three different general habitats (Table II).

On each tree-trunk a frame 10 cm X 10 cm was placed at breast height (1.3 m) on each of its four cardinal aspects to record the lichen vegetation found there. A total of 2756 quadrats were analyzed. For the purpose of this investigation the four quadrats sampled on each tree species were taken as only one quadrat (Table III).

The sample size for each species of tree was determined by the indicated method. The results given in Figure 3, page 20, show that for Pinus banksiana, Populus grandidentata, and Ulmus americana the adequate sample size was between 30 and 40 trees; for Quercus rubra, between 20 and 30 and for Acer saccharum, between 90 and 100 trees.

Lichen Flora

The following 72 lichen species were collected and identified either in situ or in the laboratory when special methods were necessary:

Foliose Growth Forms

Candelaria concolor (Dicks) B. Stein.

TABLE II

TREE SPECIES AND NUMBER OF TREE SPECIES SAMPLED FOR LICHENS AT BREAST HEIGHT (1.3m) WITHIN THREE DIFFERENT HABITATS

Tree Species	Fc[a]	Urd	Prd	T
Pinus banksiana	50	50	50	150
Populus grandidentata	52	50	38	140
Quercus rubra	56	47	56	159
Ulmus americana	30	30	30	90
Acer saccharum	50	50	50	150
	238	227	224	689

[a]Fc = Forest centers; Urd = Unpaved roads; Prd = Paved roads, T = Total.

TABLE III

TREE SPECIES AND NUMBER OF QUADRATS EXAMINED AT BREAST HEIGHT (1.3 m) FOR LICHENS ON EACH ASPECT WITHIN THREE DIFFERENT HABITATS

Tree Species	Fc[a]				Urd				Prd				
	N[b]	E	S	W	N	E	S	W	N	E	S	W	T
Pinus banksiana	50	50	50	50	50	50	50	50	50	50	50	50	600
Populus grandi-dentata	52	52	52	52	50	50	50	50	38	38	38	38	560
Quercus rubra	56	56	56	56	47	47	47	47	56	56	56	56	636
Ulmus americana	30	30	30	30	30	30	30	30	30	30	30	30	360
Acer saccharum	50	50	50	50	50	50	50	50	50	50	50	50	600
	238	238	238	238	227	227	227	227	224	224	224	224	2756

[a]Fc = Forest centers; Urd = Unpaved roads; Prd = Paved roads.

[b]N = North; E = East; S = South; W = West; T = Total.

Candelaria fibrosa (Fr.) Müll. Arg.

Candelariella vitellina (Ehrh.) Müll. Arg.

Cetraria ciliaris Ach.

Cetraria fendleri (Nyl.) Tuck.

Cetraria pinastri (Scop.) S. Gray

Evernia mesomorpha Nyl.

Hypogymnia physodes (L.) W. Wats

Parmelia aurulenta Tuck.

Parmelia bolliana Müll Arg.

Parmelia caperata (L.) Ach.

Parmelia exasperata De Not

Parmelia olivacea (L.) Ach.

Parmelia rudecta Ach.

Parmelia saxatilis (L.) Ach.

Parmelia sulcata Tayl.

Parmelia subaurifera Nyl.

Parmelia ulophyllodes (Vain.) Sav.

Parmeliopsis ambigua (Wulf.) Nyl.

Parmeliopsis placorodia (Ach.) Nyl.

Physcia adscendens (Th. Fr.) Oliv.

Physcia aipolia (Ehrh.)

Physcia caesia (Hoffm.) Hampe

Physcia ciliata (Hoffm.) Durietz

Physcia millegrana Degel.

Physcia orbicularis (Neck.) Poetsch

Physcia setosa (Ach.) Nyl.

Physcia stellaris (L.) Nyl.

Physcia tenella (Scop.) Dc.

Physconia grisea (Lamb.) Poelt

Physconia pulverulenta (Schreb.) Poelt

Xanthoria fallax (Hepp) Arn.

Xanthoria polycarpa (Ehrh.) Oliv.

Crustaceous Growth Forms

Arthonia caesia (Flot.) Körb

Arthonia radiata (Pers.) Ach.

Arthopyrenia punctiformis (Pers.) Mass.

Bacidia chlorococca (Graewe ex Stzemb.) Lett.

Bacidia sabuletorum (Screb.) Lett.

Buellia dialyta (Nyl.) Tuck.

Buellia punctata (Hoffm.) Mass.

Buellia schaereri De Not.

Buellia stillingiana J. Stein

Caloplaca aurantiaca (Lightf.) Th. Fr.

Caloplaca cerina (Ehrh.) Th. Fr.

Caloplaca ferruginea (Huds.) Th. Fr.

Caloplaca holocarpa (Hoffm.) Wade

Graphis scripta (L.) Ach.

Icmadophila ericetorum (L.) Zahlbr.

Micarea prasina (Fr.) Körb

Lecanora hypoptoides Nyl.

Lecanora pallida (Schreb.) Rabenh.

Lecanora subfusca (L.) Ach.

Lecanora subrugosa Nyl.

Lecanora varia (Ehrh.) Ach.

Lecidea vernalis (L.) Ach.

Opegrapha pulicaris (Hoffm.) Schrad.

Pertusaria amara (Ach.) Nyl.

Pertusaria marginata Nyl.

Pertusaria multipuncta (Turn.) Nyl.

Pertusaria velata (Turn.) Nyl.

Pertusaria xanthodes Müll. Arg.

Rinodina archaea (Ach.) Arn.

Rinodina exigua (Ach.) S. Gray

Rinodina populicola Magn.

Tripethelium virens Tuck.

Fruticose Growth Forms

Alectoria nidulifera Norrl.

Ramalina farinacea (L.) Ach.

Ramalina fastigiata (Pers.) Ach.

Usnea subfloridana Stirt.

Usnea dasypoga (Ach.) Röhl

Usnea hirta (L.) Wigg.

Imperfect Lichen

Lepraria aeruginosa (Wigg.) Sm.

Representative specimens of lichens collected are deposited in the Cryptogamic Herbarium of The University of

Tennessee and in the Herbarium of the Instituto Pedagogico, Caracas, Venezuela. All of the lichen species found had been reported before from the Straits Counties of northern Michigan (Hinds, 1968).

Lichen Behavior in the Forest as a Whole

Frequency distribution. Table IV shows 38 species of lichens which occurred with a frequency of at least 10 percent on at least one tree species. These represented 53 percent of the 72 collected in the area. Of the total number of trees sampled, Acer saccharum represented 22 percent, Pinus banksiana 22 percent, and Quercus rubra 23 percent, Populus grandidentata 20 percent, and Ulmus americana 13 percent of the total number of trees sampled. Table XXIII (Appendix) shows those lichen species found in forest centers along unpaved roads and paved roads with frequencies less than 10 percent.

Examination of Table IV in regard to the number of lichens that each tree species had on their boles at breast height (1.3 m) reveals that species of lichens were more frequent and diversified on Quercus rubra followed, in order, by Ulmus americana, Populus grandidentata, Acer saccharum and Pinus banksiana.

Each of the lichen species in Table IV occurred with greatest frequency on one particular tree. For example 14 lichen species reached their highest frequency on Quercus

TABLE IV

LICHEN SPECIES WITH 10 PERCENT OR GREATER FREQUENCY FOR THE FOREST AS A WHOLE, AND FOR EACH OF FIVE SAMPLED TREE SUBSTRATES FOR A TOTAL OF 689 SAMPLED TREES[a]

Lichen Species	Overall Frequency	Constancy	Pinus banksiana	Populus Grandident	Quercus rubra	Ulmus americana	Acer saccharum	Group
Arthopyrenia punctiformis	6	20	-	-	-	-	25	I
Buellia stillingiana	9	20	-	-	-	-	23	I
Graphis scripta	6	20	-	-	-	-	24	I
Parmelia rudecta	4	20	-	-	-	-	15	I
Cetraria ciliaris	7	20	29	-	-	-	-	I
Lecanora varia	5	20	-	28	-	-	-	I
Lecidea vernalis	3	20	-	21	-	-	-	I
Parmelia olivacea	7	20	-	23	-	-	-	I
Rinodina exigua	4	20	-	24	-	-	-	I
Candelariella vitellina	5	20	-	-	21	-	-	I
Parmelia saxatilis	3	20	-	-	11	-	-	I
Physcia tenella	6	20	-	-	24	-	-	I
Ramalina farinacea	3	20	-	-	11	-	-	I
Ramalina fastigiata	8	20	-	-	30	-	-	I
Rinodina populicola	6	20	-	-	24	-	-	I
Xanthoria polycarpa	6	20	-	-	22	-	-	I
Arthonia radiata	3	20	-	-	-	10	-	I
Xanthoria fallax	2	20	-	-	-	23	-	I
Lecanora subfusca	12	40	20	-	27	-	-	II
Candelaria fibrosa	4	40	-	-	19	12	-	II
Pertusaria velata	5	40	-	-	11	18	-	II
Physcia aipolia	10	40	-	-	36	30	-	II
Physcia ciliata	4	40	-	-	20	13	-	II
Buellia dialyta	5	40	-	-	-	18	14	II
Physcia millegrana	5	40	-	-	-	26	11	II
Arthonia caesia	9	60	-	44	19	-	30	III
Physcia stellaris	24	60	-	17	70	44	-	III
Caloplaca cerina	9	60	14	10	17	-	-	III
Evernia mesomorpha	17	60	24	36	22	-	-	III
Hypogymnia physodes	19	60	42	27	17	-	-	III

TABLE IV (continued)

Lichen Species	Overall Frequency	Constancy	Pinus banksiana	Populus Grandident	Quercus rubra	Ulmus americana	Acer saccharum	Group
Candelaria concolor	33	60	-	-	70	84	31	III
Physcia orbicularis	21	60	-	-	29	53	39	III
Physconia grisea	18	60	-	-	27	72	23	III
Caloplaca holocarpa	20	60	34	16	34	10	-	IV
Parmelia subaurifera	32	80	13	43	72	-	15	IV
Physcia adscendens	39	80	11	23	83	90	-	IV
Bacidia chlorococca	33	100	57	59	18	11	14	V
Parmelia sulcata	66	100	67	63	90	71	40	V

[a]Roman numeral groups indicate lichen species found on individual tree species, at a frequency of 10 percent or more, progressively from 1-5 tree species.

rubra, 11 on Ulmus americana, 7 on Populus grandidentata, 4 on Acer saccharum and 3 on Pinus banksiana. These results seemed to indicate that at breast height corticolous lichens in the forest as a whole do not tend to have a frequency gradient of arrangement that follows the climax adaptation number of the successional continuum of Brown and Curtis (1952). Hale (1955) found in his study in forest interiors in southern Wisconsin that frequencies of corticolous epiphytes decreased on trees from the most pioneer situation toward the climax forest.

In Table IV, page 33, lichen species were arranged in five artificial groups in an attempt to illustrate the adaptability of each lichen species found at breast height to grow on each of the five tree species in this area. This shows the lichen species found on one, two, three, four and five tree species, respectively. This suggests that not all of the tree-species in the forest as a whole are good substrates for all lichens. However, two species, Bacidia chlorococca and Parmelia sulcata, exhibit a broad range in their ecological requirements as they were found on each of the five trees with frequencies greater than 10 percent. Low frequencies of the majority of lichen species on each of these five tree species indicate that there are conditions which do not favor, with the proper ecological factors, the development of substrates for all lichens in this area of study.

Cole's index analysis. The frequencies disclosed in Table IV, page 33, were converted in Table V into degrees of interspecific associations for lichen-tree pairs as measured by Cole's index method. The list of the association indices was based on the occurrence of 38 lichen species for a total of 77 lichen-tree pairs. Table VI points out the number of those lichen species which formed positive and negative lichen-tree pairs associations. It also indicates the higher percentage of non-probability chance occurrence of positive and negative lichen-tree pairs associations in contrast to those that occurred by chance probability.

The highest frequency distribution of lichen species on a given tree species corresponded to their highest lichen-tree pair association index and these species may represent groups with similar ecological requirements. As examples, Parmelia sulcata with a 90 percent of frequency on Quercus rubra had a 72 percent of the maximum possible positive association with that species; Parmelia subaurifera with a 72 percent frequency on the same tree had a 62 percent of the maximum possible positive association with that tree; Physcia stellaris with a 70 percent frequency had a 54 percent of lichen-tree pair association.

Table VII illustrates that in the forest as a whole, the number of lichen-tree pairs associations, and the number of lichen species with their greatest frequencies on any

TABLE V

PERCENT COLE'S ASSOCIATION INDICES OF LICHEN-TREE PAIRS CORRESPONDING TO LICHENS WITH AT LEAST 10 PERCENT FREQUENCY ON EACH OF FIVE TREE SPECIES IN THE FORESTS AS A WHOLE

Lichen Species	Pinus banksiana	Populus grandident.	Quercus rubra	Ulmus americana	Acer saccharum	Group
Arthopyrenia punctiformis	-	-	-	-	20[a]	I
Buellia stillingiana	-	-	-	-	19[a]	I
Graphis scripta	-	-	-	-	19[a]	I
Parmelia rudecta	-	-	-	-	12[a]	I
Cetraria ciliaris	23[a]	-	-	-	-	I
Lecanora varia	-	25[a]	-	-	-	I
Lecidea vernalis	-	18[a]	-	-	-	I
Parmelia olivacea	-	20[a]	-	-	-	I
Rinodina exigua	-	21[a]	-	-	-	I
Candelariella vitellina	-	-	17[a]	-	-	I
Parmelia saxatilis	-	-	8[a]	-	-	I
Physcia tenella	-	-	19[a]	-	-	I
Ramalina farinacea	-	-	8[a]	-	-	I
Ramalina fastigiata	-	-	25[a]	-	-	I
Rinodina populicola	-	-	19[a]	-	-	I
Xanthoria polycarpa	-	-	18[a]	-	-	I
Arthonia radiata	-	-	-	8[a]	-	I
Xanthoria fallax	-	-	-	21[a]	-	I
Lecanora subfusca	10[a]	-	17[a]	-	-	II
Candelaria fibrosa	-	-	7[a]	13[a]	-	II
Pertusaria velata	-	-	13[a]	6[b]	-	II
Physcia aipolia	-	-	22[a]	17[b]	-	II
Physcia ciliata	-	-	8[a]	8[b]	-	II
Buellia dialyta	-	-	-	14[a]	9[a]	II
Physcia millegrana	-	-	-	6[a]	22[a]	II
Arthonia caesia	-	30[a]	-2[b]	-	13[a]	III
Physcia stellaris	-	31[b]	54[a]	30[a]	-	III
Caloplaca cerina	5[b]	2[b]	7[b]	-	-	III
Evernia mesomorpha	8[b]	23[a]	6[b]	-	-	III
Hypogymnia physodes	28[a]	10[b]	-12[b]	-	-	III
Candelaria concolor	-	-	60[a]	56[a]	-53[b]	III
Physcia orbicularis	-	-	7[b]	40[a]	23[a]	III
Physconia grisea	-	-	10[b]	61[a]	6[b]	III

TABLE V (continued)

Lichen Species	Pinus banksiana	Populus grandident.	Quercus rubra	Ulmus americana	Acer saccharum	Group
Caloplaca holocarpa	10[b]	-41[b]	11[b]	8[a]	-	IV
Parmelia subaurifera	-59[a]	15[b]	62[a]	-	-53[a]	IV
Physcia adscendens	-67[a]	0[b]	73[a]	80[a]	-	IV
Bacidia chlorococca	36[a]	41[a]	-45[a]	-66[a]	-58[a]	V
Parmelia sulcata	3[b]	7[b]	72[a]	0[a]	-38[a]	V

[a]Significance level larger than .95.

[b]Significance level .95 or lower.

TABLE VI

NUMBER OF LICHEN-TREE PAIR ASSOCIATIONS, CHANCE AND NON-CHANCE PROBABILITIES OF POSITIVE AND NEGATIVE LICHEN-TREE PAIRS ASSOCIATIONS IN THE FOREST AS A WHOLE

Number of Lichen-Tree Pairs	Positive Association	Percentage	Chance Association	Percentage	Non-Chance Association	Percentage	Negative Association	Percentage	Chance Association	Percentage	Non-Chance Association	Percentage
77	66	86	17	22	49	64	11	14	4	5	7	9

TABLE VII

NUMBER OF LICHEN SPECIES, LICHEN-TREE PAIR ASSOCIATIONS AND NUMBER OF LICHEN SPECIES WITH THEIR HIGHEST FREQUENCY ON EACH OF FIVE TREE SPECIES WITH POSITIVE AND NEGATIVE CHANCE AND NON-CHANCE PROBABILITIES

Lichen Species	Number of Lichen Species	Chance		Non-Chance		Number of Lichen Species with Their Highest Frequencies	Chance		Non-Chance	
		Positive	Negative	Positive	Negative		Positive	Negative	Positive	Negative
Pinus banksiana	10	4	-	4	2	3	-	-	2	-
Populus grandidentata	14	6	1	7	-	7	-	1	7	-
Quercus rubra	25	5	2	17	1	14	2	-	12	-
Ulmus americana	16	2	-	13	1	11	1	-	10	-
Acer saccharum	13	1	1	8	3	4	-	-	4	-
	78	18	4	49	7	39	3	1	35	-

tree, were accomplished in greater number by non-chance probability. Of all of the lichen species which occurred with their greatest frequency on a given tree only two formed lichen-tree pairs associations by chance probability on Quercus rubra: Caloplaca cerina and Caloplaca holocarpa; only one on Ulmus americana: Physcia ciliata; and none on the other trees.

Not all of the lowest frequencies distribution of a lichen species corresponded to a negative lichen-tree pair association. For example, Arthonia caesia which had its lowest frequency distribution on Quercus rubra had a negative lichen-tree pair association with this tree but Evernia mesomorpha in the same situation had a positive lichen-tree pair association on the same tree species.

Table V, page 37, demonstrates that a given tree species was not equally suitable as a substrate for all lichen species. For example, of all 13 lichen species on Acer saccharum, four were negatively and nine positively associated with it.

The response of a lichen species to a tree species can vary from one tree species to another as illustrated by the association indices of Parmelia sulcata with each of the five tree species. It evidences a non-chance probability perfect dissociation with Ulmus americana. On Quercus rubra and Acer saccharum the same lichen species had a high non-chance probability showing both positive and negative

lichen-tree pair associations, and two chance-positive lichen-tree pairs associations on Pinus banksiana and Populus grandidentata, respectively.

Table VIII shows with regard to the artificial groups that were arranged that in group I all of the lichen species were forming lichen-tree pairs associations by non-chance probability. In group II, out of 14 lichen-tree pair associations, only one lichen showed a chance arrangement, while 13 showed a non-chance probability. In group III, of 24 lichen-tree pairs, 13 indicated chance probability, while 11 indicated non-chance probability. In group IV, of 12 lichen-tree pairs, five showed chance and eight showed non-chance probability. In group V, two out of 10 lichen-tree pairs showed chance probability and eight showed non-chance probability associations.

This trend toward the formation of a greater number of lichen-tree pair associations by non-chance in regard to chance probability strengthens the suggestion about the effect of certain conditions in the forest as a whole that influence lichen establishment and development at breast height on the boles of trees sampled.

Lichen Behavior at Three Separate Habitats--Forest Centers, Unpaved Roads and Paved Roads

Frequency distribution. Table IX shows lichen distribution on each of five tree species within each of the

TABLE VIII

GROUP ARRANGEMENT OF LICHEN SPECIES IN THE FOREST AS A WHOLE IN REGARD TO CHANCE AND NON-CHANCE PROBABILITY OF LICHEN-TREE PAIRS ASSOCIATIONS

		Forest As Whole Probability							
Number of Groups	Number of Lichen-Tree Pairs	Chance				Non-Chance			
		Positive	%	Negative	%	Positive	%	Negative	%
I	18	-	-	-	-	18	100	-	-
II	14	1	7	-	-	13	93	-	-
III	24	10	42	3	13	11	46	-	-
IV	12	4	33	1	8	4	33	3	25
V	10	2	10	-	-	4	40	4	40
	78	17	22	4	5	50	64	7	9

TABLE IX

LICHEN SPECIES WITH AT LEAST 10 PERCENT FREQUENCY ON EACH OF FIVE TREE SPECIES* IN EACH OF THREE HABITATS

Lichen Species	Forest Centers					Unpaved Roads					Paved Roads					G[a]
	Pb	Pg	Qr	Ua	As	Pb	Pg	Qr	Ua	As	Pb	Pg	Qr	Ua	As	
Parmelia aurulenta	-	-	-	-	12	-	-	-	-	-	-	-	-	-	-	I
Lecanora hypoptoides	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	I
Lecanora subrugosa	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	I
Micarea prasina	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	I
Lecidea vernalis	-	50	-	-	-	-	-	-	-	-	-	-	-	-	-	I
Lecanora pallida	-	-	15	-	-	-	-	-	-	-	-	-	-	-	-	I
Parmelia bolliana	-	-	17	-	-	-	-	-	-	-	-	-	-	-	-	I
Parmelia saxatilis	-	-	31	-	-	-	-	-	-	-	-	-	-	-	-	I
Parmeliopsis ambigua	-	-	13	-	-	-	-	-	-	-	-	-	-	-	-	I
Rinodina archaea	-	-	-	-	-	-	-	14	-	-	-	-	-	-	-	I
Parmelia exasperata	-	-	-	-	-	-	-	-	-	-	-	-	13	-	-	I
Alectoria nidulifera	12	10	-	-	-	-	-	-	-	-	-	-	-	-	-	II
Usnea hirta	12	13	-	-	-	-	-	-	-	-	-	-	-	-	-	II
Physcia ciliata	-	-	-	-	-	16	-	39	60	-	-	-	-	-	-	II
Rinodina populicola	-	-	-	-	-	-	10	80	10	-	-	-	-	-	-	II
Parmelia caperata	-	-	19	-	-	-	-	-	-	-	-	-	-	10	-	III
Xanthoria fallax	-	-	-	-	-	-	-	-	50	-	-	-	-	35	-	III
Arthopyrenia punctiformis	-	-	-	-	24	-	-	-	-	-	-	-	-	-	50	III
Opegrapha pulicaris	-	-	-	-	10	-	-	-	-	-	-	-	-	-	18	III
Arthonia radiata	-	-	15	-	-	-	-	16	-	-	-	-	-	-	18	IV
Graphis scripta	-	-	-	-	30	-	-	-	-	24	-	-	-	-	18	IV
Parmelia olivacea	-	30	-	-	-	-	33	-	-	-	-	-	-	-	12	IV
Xanthoria polycarpa	12	-	-	-	-	-	-	75	-	-	-	-	-	20	-	IV
Physcia setosa	10	-	-	13	-	10	-	-	-	-	-	-	-	-	-	V
Cetraria ciliaris	38	10	-	-	-	36	-	-	-	-	12	-	-	-	-	V
Pertusaria velata	-	-	21	26	-	-	-	20	-	-	-	-	12	-	-	V
Ramalina fastigiata	-	20	31	-	-	-	-	32	-	-	-	-	29	-	-	V
Physcia aipolia	12	-	13	17	-	-	-	84	90	-	-	-	-	-	10	V
Hypogymnia physodes	52	40	38	-	-	30	33	-	-	-	44	-	10	-	-	V
Lecanora subfusca	34	23	17	-	-	16	-	19	-	-	10	-	19	-	-	V
Physcia orbicularis	14	-	21	96	26	-	-	55	60	52	-	-	10	-	40	V
Physcia stellaris	28	20	48	17	-	-	27	86	20	-	-	-	77	95	-	V
Candelaria fibrosa	-	-	-	26	-	-	-	36	30	-	-	-	-	-	-	VI
Ramalina farinacea	-	10	-	-	-	-	-	36	-	26	-	-	-	-	-	VI
Usnea subfloridana	-	15	-	-	-	12	10	-	-	-	-	-	-	-	-	VI
Candelariella vitellina	26	-	-	-	-	-	20	70	20	-	-	-	-	-	-	VI
Physcia tenella	16	-	-	-	-	-	17	82	10	-	-	-	-	-	-	VI

TABLE IX (continued)

Lichen Species	Forest Centers					Unpaved Roads					Paved Roads					G
	Pb	Pg	Qr	Ua	As	Pb	Pg	Qr	Ua	As	Pb	Pg	Qr	Ua	As	
Caloplaca cerina	24	15	-	-	-	18	13	52	-	-	-	-	-	-	-	VI
Caloplaca holocarpa	38	38	-	-	-	58	-	100	30	-	-	-	-	-	-	VI
Lecanora varia	-	35	-	-	-	-	43	27	-	-	12	-	-	-	-	VI
Rinodina exigua	-	-	43	-	-	-	20	11	-	-	-	-	-	-	14	VI
Buellia dialyta	20	-	-	-	-	-	10	18	10	32	-	-	-	45	10	VI
Parmelia rudecta	-	-	-	22	-	-	-	-	-	34	-	-	10	-	10	VI
Parmelia subaurifera	22	65	90	-	-	-	50	39	-	28	18	-	88	10	14	VI
Buellia stillingiana	22	-	-	-	10	-	-	-	10	26	-	-	-	-	34	VII
Physcia adscencens	26	33	71	74	-	-	30	100	100	14	-	-	79	95	14	VII
Physcia millegrana	-	-	15	-	-	-	-	-	20	10	-	-	-	55	18	VIII
Bacidia chlorococca	44	68	-	-	-	40	73	43	-	28	88	35	-	30	14	VIII
Parmelia sulcata	80	90	96	39	-	40	85	75	90	58	82	15	98	85	60	VIII
Arthonia caesia	-	55	15	-	14	-	20	22	-	32	-	55	19	-	44	IX
Candelaria concolor	20	-	56	61	-	-	-	82	90	52	-	-	73	100	40	IX
Evernia mesomorpha	34	53	25	-	-	20	47	11	-	-	18	-	29	10	-	IX
Physconia grisea	-	-	29	57	16	-	-	43	90	40	-	-	10	70	14	IX

*Pb = Pinus banksiana; Pg = Populus grandidentata; Qr = Quercus rubra; Ua = Ulmus americana; As = Acer saccharum.

[a]G = Group; Roman numerals progressively group lichen-tree associations by habitat.

habitats, forest centers, along unpaved roads and along paved roads. Fifteen lichen species that did not appear in Table IV, page 33, because of a frequency lower than 10 percent, were found with a frequency of at least 10 percent or greater on any of the five tree species studied in any of these three habitats. These are: Alectoria nidulifera, Lecanora hypoptoides, Lecanora subrugosa, Lecanora pallida, Micarea prasina, Opegrapha pulicaris, Parmelia aurulenta, Parmelia bolliana, Parmelia caperata, Parmelia exasperata, Parmeliopsis ambigua, Physcia setosa, Rinodina archaea, Usnea hirta, and Usnea subfloridana.

Table XXIII (Appendix) shows those lichen species found in forest interiors, along unpaved roads and paved roads with frequencies less than 10 percent.

Examination of Table IX, page 44, in regard to the number of lichen species that each of five tree species supported, indicates that Pinus banksiana and Populus grandidentata in forest centers, Quercus rubra and Ulmus americana along unpaved roads, and Acer saccharum when along paved roads were more suitable substrates for lichens. In contrast, Acer saccharum and Ulmus americana in forest centers and Pinus banksiana, Populus grandidentata and Quercus rubra along paved roads were less appropriate for lichens.

Table IX also lists lichen species divided into nine artificial groups in an attempt to show the suitability of a

tree species at breast height as a lichen substrate in each habitat studied.

Groups I and II included those lichen species with at least 10 percent frequency on one, two, and three different tree species. Lichen species in groups I and II were found only in one particular habitat, indicating that these lichens had narrow ecological requirements which were met only in the habitats in which they occur. In the first group these requirements were met only by the substrate of one tree species. In the second group lichen species found their requirements fulfilled by two or three different tree species but were still limited to one general habitat.

Groups number III and IV show those lichen species found on one of any of the five tree species in two and three different habitats, respectively. They appear optimally to develop on trees in only those habitats where environments fit them better. For example, Parmelia caperata and Arthopyrenia punctiformis were found in forest centers and along paved roads with at least 10 percent frequency. However, Parmelia caperata reached its greatest frequency on Quercus rubra in forest centers, and Arthopyrenia punctiformis on Acer saccharum along paved roads, which indicates that their requirements are different.

Groups V and VI included those lichens which appear on two or more trees in one habitat but occur on fewer

trees in each of the other two habitats. Lichens occurring on the largest number of trees in forest centers included Physcia setosa, Cetraria ciliaris, Pertusaria velata, Ramalina fastigiata, Physcia aipolia, Hypogymnia physodes, Lecanora subfusca, Physcia orbicularis and Physcia stellaris; those on most trees along unpaved roads were Candelaria fibrosa, Ramalina farinacea, Usnea subfloridana, Candelariella vitellina, Physcia tenella, Caloplaca cerina, Caloplaca holocarpa, Lecanora varia, Rinodina exigua, and Buellia dialyta; and along paved roads, Parmelia rudecta and Parmelia subaurifera. It could be said that lichen species of group V are found more frequently in forest centers, ten lichen species of group VI could be found in a predictable way along unpaved roads, while two lichen species of the group VI are found more often along paved roads. This suggests that a given species of tree seems to be a more suitable substrate for a particular lichen in one habitat than in another. For example, Candelaria concolor reached its higher frequency on Acer saccharum along paved roads; on Quercus rubra along unpaved roads; and on Ulmus americana along paved roads. From these facts it appears that at least those lichens involved in this study show environmental preferences for development. This seemed to be even more positive when we consider that trees were sampled in tree-stands almost pure in regard to tree composition in order to minimize the

possible influence of the environment created by other tree species (Hale, 1955).

This statement was more stressed with these other observations: groups VII and VIII exemplified those lichen species found on the same number of trees in two habitats but on fewer in another; and group IX illustrates those found on same number of trees in all of them. However, not all of the lichen species were found on the same species of trees in each habitat. For example, Buellia stillingiana was found on Acer saccharum and Pinus banksiana in forest centers, but it was not found on Pinus banksiana along unpaved roads but instead on Ulmus americana, and only on Acer saccharum along paved roads. Candelaria concolor was found on Pinus banksiana, Quercus rubra, and Ulmus americana in forest centers, but it was not found on Pinus banksiana in the other two habitats.

Nineteen lichen species were found with the highest frequency distributions beside unpaved roads in contrast to 14 in forest centers and 11 along paved roads. Examining groups V and VI it is found that 11 of these lichens were along unpaved roads; 8 in forest centers; and one along paved roads. When considering the total number of lichens in Table IX, page 44, the environmental conditions that seem to favor greater lichen diversification were found in forest centers with 48 lichen species (with 10 percent or greater) in contrast to 38 species beside unpaved roads and 31 species

along paved roads. However, when considering lichen species in regard to peak frequency distribution, the environmental conditions that seem to favor more lichens were found along unpaved roads where 19 lichens, also found in the other habitats, had their highest frequency distribution in contrast to 20 in forest centers and 12 beside paved roads.

The majority of lichen species were found on Quercus rubra. Along unpaved roads it bore 28 species, in forest centers 22 species, with 15 species along paved roads. Acer saccharum, a climax tree in the area, supported a lesser number of lichen species in forest centers. Among these were Graphis scripta, Arthonia caesia, and Arthopyrenia punctiformis. These species were considered by Hale (1955) as host-specific to Acer saccharum and restricted to forest interiors of southern Wisconsin. However, when individuals of this tree species were examined in this study in the other two environments, lichen species were still present on them, and the lichens, Arthonia caesia and Arthopyrenia punctiformis had higher frequencies. In addition, Acer saccharum supported a more diversified lichen vegetation along roads.

Cole's index analysis. The frequency distribution of the lichen species on each of the five tree species in each of the three habitats studied (Table IX, page 44) were translated into terms of Cole's associations indices in Table X based on the occurrence of 48 lichen species on five

TABLE X

PERCENT COLE'S ASSOCIATIONS INDICES OF LICHEN-TREE PAIRS* CORRESPONDING TO LICHENS WITH AT LEAST 10 PERCENT FREQUENCY ON EACH OF FIVE TREE SPECIES AT EACH OF THREE HABITATS

Lichen Species	Forest Centers					Unpaved Roads					Paved Roads					G
	Pb	Pg	Qr	Ua	As	Pb	Pg	Qr	Ua	As	Pb	Pg	Qr	Ua	As	
Parmelia aurulenta	-	-	-	-	8[a]	-	-	-	-	-	-	-	-	-	-	I
Lecanora hypoptoides	13[a]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	I
Lecanora subrugosa	10[a]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	I
Micarea prasina	14[a]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	I
Lecidea vernalis	-	37[a]	-	-	-	-	-	-	-	-	-	-	-	-	-	I
Lecanora pallida	-	-	11[a]	-	-	-	-	-	-	-	-	-	-	-	-	I
Parmelia polliana	-	-	12[a]	-	-	-	-	-	-	-	-	-	-	-	-	I
Parmelia saxatilis	-	-	22[a]	-	-	-	-	-	-	-	-	-	-	-	-	I
Parmeliopsis ambigua	-	-	9[a]	-	-	-	-	-	-	-	-	-	-	-	-	I
Rinodina archaea	-	-	-	-	-	-	-	10[a]	-	-	-	-	-	-	-	I
Parmelia exasperata	-	-	-	-	-	-	-	-	-	-	-	-	9[a]	-	-	I
Alectoria nidulifera	8[a]	6[b]	-	-	-	-	-	-	-	-	-	-	-	-	-	II
Usnea hirta	8[a]	8[b]	-	-	-	-	-	-	-	-	-	-	-	-	-	II
Physcia ciliata	-	-	-	-	-	11[a]	-	31[a]	55[a]	-	-	-	-	-	-	II
Rinodina populicola	-	-	-	-	-	-	4[b]	73[a]	8[b]	-	-	-	-	-	-	II
Parmelia caperata	-	-	13[a]	-	-	-	-	-	-	-	-	-	-	6[b]	-	III
Xanthoria fallax	-	-	-	-	-	-	-	-	35[b]	-	-	-	-	16[b]	-	III
Arthopyrenia punctiformis	-3[b]	-	-	-	-	-	-	-	-	-	-	-	-	-	34[a]	III
Opegrapha pulicaris	-	-	-	-	1[b]	-	-	-	-	-	-	-	-	-	10[b]	III
Arthonia radiata	-	-	6[b]	-	-	-	-	6[b]	-	-	-	-	-	-	13[a]	IV
Graphis scripta	-	-	-	-	8[b]	-	-	-	-	0[b]	-	-	-	-	-25[b]	IV

TABLE X (continued)

Lichen Species	Forest Centers					Unpaved Roads					Paved Roads					G
	Pb	Pg	Qr	Ua	As	Pb	Pg	Qr	Ua	As	Pb	Pg	Qr	Ua	As	
Parmelia olivacea	-	9b	-	-	-	-	14b	-	-	-	-	-	-	-	8a	IV
Xanthoria polycarpa	8a	-	-	-	-	-	-	68a	-	-	-	-	-	13b	-	IV
Physcia setosa	4b	-	-	8b	-	4b	-	-	-	-	-	-	-	-	-	V
Cetraria ciliaris	13b	-	-	6b	-	10b	-	-	-	-	-58b	-	-	-	-	V
Pertusaria velata	-	-	4b	17b	-	-	-	4b	-	-	-	-	-34b	-	-	V
Ramalina fastigiata	-	13a	1b	-	-	-	-	2b	-	-	-	-	5b	-	-	V
Physcia aipolia	8a	-	-55b	-29b	-	-	-	77a	87a	-	-	-	-	-	7b	V
Hypogymnia physodes	17b	18b	26a	-	-	-29b	9b	-	-	-	3b	-	-43b	-	-	V
Lecanora subfusca	-18b	14a	-34b	-	-	-20b	-	26b	-	-	-50b	-	-27b	-	-	V
Physcia orbicularis	10a	-	-22b	91a	-33b	-	-	38a	15b	-21b	-	-	-64a	-	1b	V
Physcia stellaris	21a	4b	5b	-63a	-	-	12b	75a	-58b	-	-	-	58a	91a	-	V
Candelaria fibrosa	-	-	-	11b	-	-	-	29a	16b	-	-	-	-	-	-	VI
Ramalina farinacea	-	6b	-	-	-	-	-	29a	-	19a	-	-	-	-	-	VI
Usnea subfloridana	-	6b	-	-	-	8a	1b	-	-	-	-	-	-	-	-	VI
Candelariella vitellina	-	19a	-	-	-	-	15a	63a	17b	-	-	-	-	-	-	VI
Physcia tenella	-	11a	-	-	-	-	12a	76a	8b	-	-	-	-	-	-	VI
Caloplaca cerina	-12b	5b	-	-	-	5b	3b	43a	-	-	-	-	-	-	-	VI
Caloplaca holocarpa	9a	26a	-	-	-	38a	-	100a	26a	-	-	-	-	-	-	VI
Lecanora varia	-	10b	-	-	-	-	21b	21a	-	-	8a	-	-	-	-	VI
Rinodina exigua	-	24a	-	-	-	-	-24b	8a	-	-	-	-	-	-	10a	VI
Buellia dialyta	14a	-	-	-	-	-	7b	13a	-47b	21a	-	-	-	32a	-29b	VI
Parmelia rudecta	-	-	-	14b	-	-	-	-	-	23a	-	-	6b	-	-32b	VI
Parmelia subaurifera	10b	39a	63b	-	-	-	13b	-59a	-	16a	5b	-	55b	6b	-5b	VI
Buellia stillingiana	16a	-	-	-	-57b	-	-	-	8b	3b	-	-	-	-	14b	VII
Physcia adscencens	19a	12b	32b	-75b	-	-	9b	100a	100b	-	-	-	50a	62b	5b	VII

TABLE X (continued)

Lichen Species	Forest Centers					Unpaved Roads					Paved Roads					G
	Pb	Pg	Qr	Ua	As	Pb	Pg	Qr	Ua	As	Pb	Pg	Qr	Ua	As	
Physcia millegrana	-	-	11[a]	-	-	-	-	-	-18[b]	0[b]	-	-	-	40[a]	10[b]	VIII
Bacidia chlorococca	-23[b]	18[b]	-	-	-	-30[b]	33[b]	31[a]	-	16[a]	72[a]	-43[b]	-	21[a]	0[b]	VIII
Parmelia sulcata	-39[b]	68[a]	59[b]	-61[a]	-	-42[a]	57[b]	-70[a]	71[b]	10[b]	45[b]	-78[a]	78[b]	56[b]	40[a]	VIII
Arthonia caesia	-	20[b]	-19[b]	-	-53[b]	-	-54[b]	5[b]	-	3[b]	-	18[b]	0[b]	-	20[b]	XIX
Candelaria concolor	14[a]	-	-25[a]	-82[b]	-	-	-	40[a]	47[b]	31[a]	-	-	12[a]	100[b]	13[b]	XIX
Evernia mesomorpha	-13[b]	25[b]	3[b]	-	-	-17[b]	16[b]	-49[b]	-	-	-25[b]	-	8[b]	6[b]	-	XIX
Physconia grisea	-	-	3[b]	-27[b]	-31[b]	-	-	23[b]	69[b]	22[b]	-	-	-64[b]	6[b]	-40[b]	XIX

[a]Significance level larger than .95.

[b]Significance level .95.

*Pb = Pinus banksiana; Pg = Populus grandidentata; Qr = Quercus rubra; Ua = Ulmus americana; As = Acer saccharum.

tree species within forest centers for 86 lichen-tree pairs associations of 38 lichen species; on five tree species along unpaved roads for 87 lichen-tree pairs; and 31 lichen species along paved roads for 58 lichen-tree pairs associations.

The highest frequency of each lichen in each environment meant positive associations, but the highest frequency of any lichen on a tree did not mean the highest degree of association with that tree. For example, Usnea subfloridana got its highest frequency distribution on Populus grandidentata in forest centers; however, its highest Cole's association index was found on Pinus banksiana along unpaved roads. Relative low frequencies of any species on any tree in any environment meant negative lichen-tree pair association. For example, Lecanora subfusca had a frequency of 17 percent on Quercus rubra in forest centers; along unpaved roads, 45 percent; and along paved roads, 19 percent. The lichen-tree pairs associations in forest centers and along paved roads were negative.

Table X, page 51, indicates that the lichen-tree pairs associations of Parmelia caperata and Arthopyrenia punctiformis in the habitats of their greatest frequency distributions were of non-chance probability. Physcia orbicularis in forest centers reached a 91 percent of the maximum positive lichen-tree pair association on Ulmus americana by non-chance probability while along unpaved roads it had a

low positive association by chance probability, and it was not present on the same species along paved roads. Buellia dialyta had its highest lichen-tree pair association on Ulmus americana along paved roads, corresponding to a 32 percent of the maximum possible positive value by non-chance probability. On the same tree species but along unpaved roads it had a -47 percent of the maximum possible negative value of a lichen-tree pair association by chance probability; and it was not found on Ulmus americana in forest centers but on Pinus banksiana on which it had a 14 percent of the maximum positive value by non-chance probability. The presence of Buellia dialyta on the other trees followed the same pattern, and the same was true of Parmelia rudecta. Its peak frequency distribution and the maximum possible positive value of a lichen-tree pair association was found by non-chance probability on Acer saccharum along unpaved roads whereas along paved roads on the same species, it had a negative association by chance probability. Buellia stillingiana had its highest frequency of distribution on Acer saccharum along paved roads. However, its maximum positive lichen-tree pair association was found on Pinus banksiana in forest centers by non-chance probability. Candelaria concolor had the maximum possible positive association (100 percent) on Ulmus americana along paved roads by chance probability as well as a chance negative and positive lichen-tree pair association on the same tree in forest

centers and along unpaved roads. The same lichen had non-chance negative lichen-tree pair association on Quercus rubra in forest centers and non-chance positive ones on the same tree species at the other habitats, its greater lichen-tree pair association being along unpaved roads. Four lichen-species: Graphis scripta and Physcia millegrana on Acer saccharum along unpaved roads; Bacidia chlorococca on the same tree species but along paved roads; and Arthonia caesia on Quercus rubra along paved roads showed perfect lichen-tree pairs associations by chance probabilities in this study.

Table XI shows the number of lichen species and the number of lichen-tree pair associations in each habitat as well as the kind of these associations and their percentage probabilities. Although along unpaved roads a smaller number of lichen species were found than in forest centers, there were in the former a greater number of lichen-tree pairs and positive associations by chance and non-chance probabilities as well as larger percentages of them. Also a smaller number of negative lichen-tree pairs associations by chance probability and smaller percentages of them were found along unpaved roads than in forest centers and paved roads.

To illustrate the distinctions between the number of positive and negative lichen-tree pairs associations occurring by chance and non-chance probability on different tree

TABLE XI

NUMBER OF LICHEN SPECIES AND OF LICHEN-TREE PAIRS AND OF POSITIVE AND NEGATIVE ASSOCIATIONS, CHANCE AND NON-CHANCE PROBABILITIES AND THEIR PERCENTAGES WITHIN THREE HABITATS

Habitat	Number of Lichen Species	Number of Lichen-Tree Pairs	Positive Association	Percentage	Chance	Percentage	Non-Chance	Percentage	Negative Associations	Percentage	Chance	Percentage	Non-Chance	Percentage
Fc	48	86	65	76	33	38	32	37	21	24	18	21	3	3
Urd	38	87	73	84	40	46	33	38	14	16	11	12	3	3
Prd	31	58	43	74	28	48	15	26	15	26	14	24	2	3

species, Table XII was constructed. On a basis of the number of lichen species on them, Pinus banksiana and Populus grandidentata seem to be the best substrates in forest centers; Quercus rubra and Ulmus americana, along unpaved roads; and Acer saccharum, beside paved roads.

Quercus rubra and Ulmus americana along unpaved roads showed a greater number of lichen-tree pairs associations as well as a greater percentage of positive associations by chance probabilities than those trees in the other two habitats. They also showed a less number of chance probability negative associations but a greater percentage than those trees in forest centers and lower than Acer saccharum along paved roads. Also manifested on these two trees were a lower number and percentage of positive lichen-tree pairs associations by non-chance probabilities than those trees in forest centers but greater than in Acer saccharum along paved roads.

Table XIII summarizes the number of lichen-tree pairs associations by habitats and the positive and negative chance and non-chance probabilities associations as well as their percentages in regard to the number of lichen-tree pairs associations of each of the nine groups into which lichens were arbitrarily separated (Table IX, page 44). The non-chance lichen-tree pair distribution of the lichen species of the first group and their restriction to one habitat was evident. In the other groups, most of the lichen

TABLE XII

BETTER BARK-SUBSTRATE TREE SPECIES WITHIN THREE HABITATS, THEIR LICHEN-TREE PAIRS, POSITIVE AND NEGATIVE ASSOCIATIONS, THEIR PERCENTAGES AND CHANCE AND NON-CHANCE PROBABILITIES

Tree Species	Number of Lichen-Tree Pairs	Chance					Non-Chance					Habitat*
		Positive	Percent.	Negative	Percent.	Total	Positive	Percent.	Negative	Percent.	Total	
Pinus banksiana	22	13	59	-	-	13	8	36	-	-	8	Fc
Populus grandidentata	23	4	17	5	22	9	16	70	-	-	16	FC
Quercus rubra	28	6	21	1	5	7	19	68	2	7	21	Urd
Ulmus americana	17	11	65	3	18	14	3	18	-	-	3	Urd
Acer saccharum	19	9	47	5	26	14	5	26	-	-	5	Prd

*Fc = Forest centers; Urd = Unpaved roads; Prd = Paved roads.

TABLE XIII

NUMBER OF LICHEN-TREE PAIRS AND OF POSITIVE AND NEGATIVE LICHEN-TREE PAIRS ASSOCIATIONS AND THEIR PERCENTAGES BY GROUP NUMBERS WITHIN THREE HABITATS

Group Number	Forest Centers									Unpaved Roads									Paved Roads								
	No. of Lichen-Tree Pairs	Probability								No. of Lichen-Tree Pairs	Probability								No. of Lichen-Tree Pairs	Probability							
		Chance				Non-Chance					Chance				Non-Chance					Chance				Non-Chance			
		Positive	%	Negative	%	Positive	%	Negative	%		Positive	%	Negative	%	Positive	%	Negative	%		Positive	%	Negative	%	Positive	%	Negative	%
I	9	-	-	-	-	9	100	-	-	1	-	-	-	-	1	100	-	-	1	-	-	-	-	1	100	-	-
II	4	2	50	-	-	2	50	-	-	6	2	33	-	-	4	67	-	-	-	-	-	-	-	-	-	-	-
III	3	1	33	1	33	1	33	-	-	1	1	100	-	-	-	-	-	-	4	3	75	-	-	1	25	-	-
IV	4	3	75	-	-	1	25	-	-	4	3	75	-	-	1	25	-	-	4	1	25	1	25	2	50	-	-
V	25	11	44	6	24	7	28	1	4	16	8	50	4	25	4	25	-	-	12	4	33	5	42	2	17	1	8
VI	16	8	50	1	6	7	58	-	-	30	9	30	2	7	18	60	1	3	10	4	40	3	30	3	30	-	-
VII	6	2	33	2	33	2	33	-	-	6	5	83	-	-	1	17	-	-	4	3	75	-	-	1	25	-	-
VIII	7	2	29	2	29	2	28	1	14	11	5	45	2	18	2	29	2	29	11	5	45	1	9	4	36	1	9
IX	12	4	33	6	50	1	8	1	8	12	7	58	3	25	2	17	-	-	12	8	67	3	25	1	8	-	-
Total	86	33	38	18	21	32	37	3	3	87	40	46	11	13	33	38	3	3	58	28	48	13	22	15	26	2	3

species in each habitat formed lichen-tree pairs associations by chance probabilities. An exemption to this was found in group six in forest centers and along unpaved roads where the non-chance probability of lichen-tree pairs associations were found in greater percentages.

In general the percentage of lichen-tree pair associations by non-chance probabilities were greater along unpaved roads as compared to the other habitats in regard to the total number of lichens and of lichen-tree pairs found at each of them.

Forest Centers and the Forest as a Whole

In forest centers in contrast to the total area each of five tree species can be arranged in a floristic order in regard to lichen species diversity that each of them supported. This follows the order of the climax adaptation number of Brown and Curtis (1952) and agreed with the studies of Hale (1955) and Culberson (1955). There was a decreasing number of lichens from the pioneer tree species, Pinus banksiana, which had the largest number in contrast to the climax tree species, Acer saccharum, which had the smallest number. Fourteen lichen species with greatest frequency occurred in forest centers. In contrast, 39 lichen species occurred with their greatest frequency across the forest as a whole.

By comparing the artificial groups in forest centers

in Table X, page 51, with the forest as a whole in Table IV, page 33, it may be clearly seen that in each group the percentages of positive and negative non-chance lichen-tree pair associations were greater in the forest as a whole than in forest centers where the positive and negative lichen-tree pairs associations by chance probabilities were greater indicating a more stable habitat in regard to environmental conditions.

Eleven lichen species were found to be restricted to forest centers in regard to their 10 percent frequency distribution. Nine of these were found on only one tree species; and two of them, on two tree species. None of them were found on Ulmus americana. However, in the forest as a whole 18 lichen species were found on only one tree species.

This fact seemed to point out the importance of adequate sampling in every environmental situation of a given area to give a faithful picture in this kind of ecological study.

Kulczynski's Index of Community Similarity

Community similarities in the forests as a whole. In Table XIV is the matrix of values of Kulczynski's similarity coefficients for lichen communities on five tree species in the forests as a whole. Degrees of similarity of lichen communities between trees range from a low of 27

TABLE XIV

KULCZYNSKI'S SIMILARITY-DISSIMILARITY COEFFICIENT VALUES FOR LICHEN COMMUNITIES IN THE FOREST AS A WHOLE

Tree Species[a]	As	Pb	Pg	Qr	Ua
As	100	30	31	35	41
Pb	70	100	57	43	34
Pg	69	43	100	45	27
Qr	65	57	55	100	58
Ua	59	66	73	42	100

[a]The upper right half of the table gives index of similarity values; the lower half gives index of dissimilarity values. As = Acer saccharum, Pb = Pinus banksiana, Pg = Populus grandidentata, Qr = Quercus rubra, Ua = Ulmus americana.

percent between the communities found on Populus grandidentata and Ulmus americana to a maximum coefficient of similarity value of 58 percent between the communities on Quercus rubra and Ulmus americana. The most dissimilar lichen community association in the forests as a whole seems to be that with Populus grandidentata and Ulmus americana. The most similar were those of Quercus rubra and Ulmus americana.

Coefficients of similarity values were in general low for the forest as a whole. This appears to indicate the particular influence of each of the forest habitat-environments on their lichen communities. The environment of each habitat affected each lichen community on the individuals of each lichen species differently. It may increase their complexities or make them simpler. However, it was noted that community similarity values between two trees increase gradually in a linear floristic gradient that follows the climax adaptation number (Brown and Curtis, 1952) within the successional continuum; as an example, the lichen community of Acer saccharum was compared to the remaining trees which indicated that lichen communities decreased in complexity on each tree as they approached the climax, closed forest.

Lichen community similarities among different habitats. Table XV shows the matrix of values for Kulczynski's similarity coefficients among lichen communities of the three

TABLE XV

KULCZYNSKI'S SIMILARITY-DISSIMILARITY COEFFICIENTS VALUES FOR LICHEN COMMUNITIES WITHIN EACH OF THREE GENERAL HABITATS

Habitats[a]	Fc	Urd	Prd
Fc	100	63	75
Urd	25	100	63
Prd	25	37	100

[a]The upper right half of the table gives index of similarity values; the lower half gives index of dissimilarity values. Fc = Forest centers, Urd = Unpaved roads, Prd = Paved roads.

different general habitats: forest centers, along unpaved roads, and along paved roads. This table shows that degrees of similarity resulting from this comparison were relatively high, and that lichen communities in forest centers were more similar to those found along unpaved roads than to those found along paved roads; and also that both lichen communities of forest centers and along unpaved roads had the same degree of similarity with that along paved roads. This result is in general agreement with the results described in Cole's indices studies in that forest centers and unpaved road habitats showed more likeness between themselves than with paved roads in regard to the environment they offered for the survival of lichens.

Lichen Community Similarity of Each Tree Species in Each Habitat

Forest centers. Table XVI contains the matrix of community coefficients of similarity among tree species in forest centers. They ranged from a total dissimilarity value of zero percent between the lichen communities found on Acer saccharum and Populus grandidentata (which means total dissimilarity) to a higher level of similarity between the lichen communities found on Pinus banksiana and Populus grandidentata of 54 percent. These two trees are next to each other in relation to the climax adaptation number along the successional continuum, and even though the coefficients

TABLE XVI

KULCZYNSKI'S SIMILARITY-DISSIMILARITY VALUES FOR LICHEN COMMUNITIES ON EACH OF FIVE TREE SPECIES WITHIN FOREST CENTERS

Tree Species[a]	As	Pb	Pg	Qr	Ua
As	100	4	0	12	25
Pb	96	100	54	43	36
Pg	100	46	100	48	15
Qr	82	57	52	100	38
Ua	75	64	85	62	100

[a]The upper right half of the table gives index of similarity values; the lower half gives index of dissimilarity values. As = *Acer saccharum*, Pb = *Pinus banksiana*, Pg = *Populus grandidentata*, Qr = *Quercus rubra*, Ua = *Ulmus americana*.

of similarity were not high, it still showed an approach in likeness of the habitat environments these two tree species offered under forest center conditions. Populus grandidentata and Acer saccharum which are respectively number two and ten in the climax adaptation number of Brown and Curtis (1952) along the successional continuum showed a coefficient of similarity in according with the environmental conditions their ranks represent.

Unpaved roads. Table XVII demonstrates in the matrix of community coefficients of similarity among tree species along unpaved roads. They ranged from a minimum value of 11 percent between the lichen vegetation of Acer saccharum and Pinus banksiana and Pinus banksiana and Ulmus americana to a maximum possible value of 51 percent between the lichen communities on Pinus banksiana and Populus grandidentata.

The higher community similarity value between the lichen vegetation of Acer saccharum and Populus grandidentata in this habitat in relation to that of the others did not reflect the position they have with respect to each other along the successional continuum. This fact seemed to confirm the existence of some environmental factors along unpaved roads which appeared to confer on the bark substrate of each tree attributes that favored the establishment of more similar lichen communities among trees and thence the degree of disturbance when compared to forest center habitats.

TABLE XVII

KULCZYNSKI'S SIMILARITY-DISSIMILARITY COEFFICIENT VALUES FOR LICHEN COMMUNITIES ON EACH OF FIVE TREE SPECIES ALONG UNPAVED ROADS

Tree Species[a]	As	Pb	Pg	Qr	Ua
As	100	11	47	32	38
Pb	89	100	51	18	11
Pg	53	49	100	37	23
Qr	68	82	63	100	46
Ua	62	89	77	54	100

[a]The upper right half of the table gives index of similarity values; the lower half gives index of dissimilarity values. As = Acer saccharum, Pb = Pinus banksiana, Pg = Populus grandidentata, Qr = Quercus rubra, Ua = Ulmus americana.

Paved roads. Examination of Table XVIII which provides the matrix of community coefficients of similarity among tree species along paved roads shows that community similarities between trees ranged from a similarity value of 7 percent between Pinus banksiana and Populus grandidentata to a similarity value of 55 percent between Quercus rubra and Ulmus americana.

The low lichen community similarity between Pinus banksiana and Populus grandidentata which are trees next to each other in the climax adaptation number along the successional continuum and the relatively higher lichen community similarity value between Acer saccharum and Pinus banksiana which are at opposite ends of this successional continuum shows the possible effects of the different environments and disturbances that prevail along paved roads in contrast to forest centers and along unpaved roads. It demonstrates that conditions prevailing in a given habitat could cause variations in the ecological conditions of a corticolous substrate when compared with those that are found in other general habitats.

Lichen Community Similarity of Each Tree Species Among Habitats

If the environment of each general habitat was affecting lichen community composition on each of these five tree species, the degree of this change could be evaluated by means of determining lichen community

TABLE XVIII

KULCZYNSKI'S SIMILARITY-DISSIMILARITY COEFFICIENT VALUES FOR LICHEN COMMUNITIES ON EACH OF FIVE TREE SPECIES ALONG PAVED ROADS

Tree Species[a]	As	Pb	Pg	Qr	Ua
As	100	24	10	39	35
Pb	76	100	7	31	31
Pg	90	93	100	10	12
Qr	61	69	90	100	55
Ua	65	69	88	45	100

[a]The upper right half of the table gives index of similarity values; the lower half gives index of dissimilarity values. As = Acer saccharum, Pb = Pinus banksiana, Pg = Populus grandidentata, Qr = Quercus rubra, Ua = Ulmus americana.

similarity values among the individuals of each tree species when considering them at each of these three habitats. Table XIX shows these values for each of the five tree species studied.

Lichen communities on Pinus banksiana had a lower similarity value between forest centers and along paved roads and the highest value between forest centers and along unpaved roads. There was an intermediate similarity value between the lichen communities of this tree along paved and unpaved roads. This discrepancy could be accounted for by differences in the number of lichen species on this tree at each of the three habitats. Table IX, page 44, shows that Pinus banksiana bore only 8 lichen species along paved roads, which were also found in the other habitats. In contrast, the same tree species bore 25 different lichen species in forest centers and 11 along unpaved roads. The environment of each general habitat seemed to have changed the substrate of Pinus banksiana making it more suitable for some lichens, and less, for others.

In comparing lichen communities on Populus grandidentata among these three habitats, the same trend as found on Pinus banksiana was observed, and it may be explained by the same logic.

The difference between the number of lichen species of Quercus rubra between forest centers and along paved roads

TABLE XIX

TOTAL NUMBER OF LICHEN SPECIES AND KULCZYNSKI'S SIMILARITY COEFFICIENT VALUES (PERCENTAGES) ON EACH OF FIVE TREE SPECIES WHEN COMPARED AMONG THREE HABITATS

Tree Species	Number of Lichens			Coefficients of Similarity		
	Fc[a]	Urd	Prd	Fc & Prd	Fc & Urd	Prd & Urd
Pinus banksiana	34	25	14	47	55	50
Populus grandi-dentata	30	25	14	19	72	29
Quercus rubra	32	43	35	66	46	47
Ulmus americana	14	17	16	56	46	57
Acer saccharum	15	34	27	43	32	62

[a]Fc = Forest centers, Urd = Unpaved roads, Prd = Paved roads.

was a matter of 3 species which they did not have in common. This was translated into a high degree of lichen community similarity which seems to indicate that the corticolous substrate had changed but very little in the ecological fitness for its lichen flora. When lichen communities in forest centers and along unpaved roads were compared, that difference widened and coefficients of lichen community similarities were lower. A difference of 11 lichen species non-commonly shared by Quercus rubra in these two habitats were found along unpaved roads; thus it seems that the general environments along unpaved roads have corticolous substrates which are ecologically better fitted (more suitable) for lichens.

Lichen communities on Quercus rubra along paved and unpaved roads were 1 percent more similar than those on the same tree species in forest centers and along unpaved roads. This small dissimilarity is accounted for because of a difference of eight lichen species between lichen communities along paved and unpaved roads; and 11 lichen species between forest centers and along unpaved roads.

In regard to Ulmus americana and Acer saccharum the environment at each habitat seemed to have operated in the same way on their corticolous substrates as on that of Quercus rubra. Variations in their community coefficients of similarity and their number of species in the same environments followed the same pattern. Along unpaved roads

these tree species have their canopies more open permitting the penetration of more light than in forest centers. Also they are more protected from environmental extremes. These characteristics could have helped their colonization by lichen species whose requirements find the smaller environmental variations limiting as found in forest centers and along paved roads.

V. INTERPRETATION

In view of the fact that lichens have highly efficient mechanisms which enable them to accumulate a wide variety of substances from any source and that they are active throughout the whole year, environmental conditions are of great importance to them (Barkman, 1958; Hale, 1967). The fact that in forest centers lichen coefficients of similarity between two trees increased or decreased in a given direction in regard to their climax adaptation number along the floristic gradient (Brown and Curtis, 1952) seemed to indicate that in forest centers each of these trees offered to lichens more undisturbed substrate environments because each tree had a lichen flora that reflected its rank in the floristic gradient. Because of the fact that the previous tendency was not observed regularly in lichen coefficients of similarities calculated between any of two trees in the habitats represented by unpaved and paved roads indicates that the substrate environmental conditions in these two habitats is disturbed. However, the results obtained in this study suggest that environmental conditions along unpaved roads were better than those in forest centers and beside paved roads for optimal lichen distribution.

Paved roads in the area of study are mostly rectilinear while unpaved roads have frequently sharp changes of

directions. The wind factor acts more strongly along paved roads. The roads cutting through a forest serve as channels through which winds flow at great speed affecting other factors such as humidity and evaporation which seem to make this habitat too extreme for corticolous epiphytes to flourish. Degelius (1935) noted that the construction of forest roads have a harmful effect on corticolous epiphytes, especially on lichens. Deforestation is known to contribute to lower air humidity, to great wind speed and therefore to increase the rate of evaporation. In contrast, unpaved roads by the manner in which they cross forests in this area with frequent changes in direction reduce wind speed. Also, other limiting factors for lichens affected by wind such as evapotranspiration, relative humidity, amount of sand and dust, etc., do not vary so widely.

Temperature and light in the wide, exposed areas provided by paved roads in forests, reach the highest intensities which persist for longer periods of time than in the other two habitats whose exposed areas are less wide and the canopies of trees overlap each other. Ahmadjian (1967) found that lichen development is lethally affected by constant conditions over long periods of time. Laudon (1966) cited the damage of Parmelia caperata thalli on roadside trees in England where temperatures at or below freezing levels remained for long periods during a single

season. However, when this same species was experimentally subjected to cold treatment with variations in temperature, it survived well (Kappen, 1970). Parmelia caperata, Evernia mesomorpha, Usnea subfloridana and Parmelia sulcata are considered as good indicators of light, temperature and moisture conditions (Pearson, 1969). These same species were found in the area of study with their lowest frequencies of distribution along paved roads and with their greatest frequencies in the other two habitats. All of this information suggests that variations of environmental conditions are of great significance for lichen distribution and that these variations seem to exist less frequently along paved roads in this area and more frequently along unpaved roads.

Other factors that harmfully affect corticolous lichens are dust and sand. Their effects are more pronounced in exposed areas where wind can blow them against the bark of trees with great force. Along paved roads the dust action may be more severe when considering the fact that they are in this area mostly asphalted. Therefore, dust coming from the pavement may contain amounts of sulphur or sulphur dioxide which are well-known lichen pollutants (Hausgja, 1930). In this study only one lichen species of group number one, Parmelia exasperata (Table IX, page 44) was recorded with a frequency of at least 10 percent along paved roads, while the larger number of lichens were along

unpaved roads and forest centers. The other groups showed lichen species along paved roads but in general lichens with their highest frequencies and number of lichen-tree pairs associations (Table X, page 51) were lesser than in the other two habitats. Those lichen species considered as the most sensitive to polluted areas such as those fruticose species belonging to the genus Usnea and the species Ramalina farinacea (Jones, 1952) were not found in this study on trees along paved roads. Other factors that may account for lower number of lichens along paved roads may be the effect of snow and ice-melting material used during winter to clear these roads, and in addition, of some other chemicals used to kill weeds which are sprayed along them.

Even though the area is free from the heavy pollutant industries of other regions of Michigan, it is a resort area with numerous towns, villages, and small communities with intensive travel by car, and somewhat by motorcycles and trains. All of them contribute with certain amounts and kinds of smoke or gases that may pollute the atmosphere of this area which in turn may affect lichen communities in the habitats described in this study as well as others. It is known that lichens on trees are absent in areas where the atmosphere is heavily polluted, and that complexity of lichen communities increases as pollution decreases (Jones, 1952; Gordon, 1963; Gilbert, 1965, 1970, 1971a,b; Rao and LeBlanc,

1967; Coker, 1967; Gurhort, 1968; Skye, et al., 1969; LeBlanc and DeSloover, 1970; Saunders, 1970; Hawsksworth, 1971; Nash III, 1971, 1972; Brown, 1972; Fidora, 1972; Sheridan, 1973). The present study showed that lichen species diversity increased from paved road habitats toward those along unpaved roads to forest centers which seemed to demonstrate differences in the environmental quality of these three general habitats for lichens.

When the composition of smoke and gases are known, their effect on the complexity of lichen communities and the distribution of lichen species can be better understood.

Gilbert (1970) made an extensive study of the effect of sulphur dioxide, one of the possible components of smoke or gases, on lichens and bryophytes. He considered that sulphur dioxide (SO_2) may have a devastating toxic action on these cryptogams when their substrate have a pH below 3.5. On the contrary those substrates with a pH between 4.0 and 6.0 and above can buffer and diminish the effects of sulphur dioxide by converting it to less toxic forms. This would permit the germination of sexual and vegetative reproductive units as well as thallus regeneration. The pH of the thallus is also important since a high cytoplasmic pH with a strong buffer capacity is important for survival; this would control the pollutant effect at a cellular level. Baddely, et al., (1972) indicated that experimentally, SO_2 in solutions at concentrations of 30 ppm inhibited respiration

in lichens but when this same concentration affected lichens with a cytoplasmic pH of 5.2, SO_2 was less toxic. The author measured pH of bark from each of the four aspects of ten individuals of three (Acer saccharum, Pinus banksiana, and Populus grandidentata) of the five tree species object of this study in the three habitats and converted them to [H+] values to determine any association with the number of lichen species that these trees bore on their aspects by means of Correlation Coefficients. Correlation Coefficients between aspect bark pH and the number of lichen species were slightly, but not significantly, different from zero correlation at 99 percent (.01) level of significance (Rohlf and Sokal, 1969) (Table XX). Table XXI shows the maximum and minimum pH of bark for these tree species at breast height in the three different general habitats. Their pH ranged from 3.8 to 5.9, but the majority were over 4.0. This may possibly account for the buffer capacity of these tree-bark substrates and for the almost lack of correlation between pH of bark and the number of lichen species on them. However, it seemed from the results shown in Tables XXIV to XXXII (see Appendix) that the occurrence of slight variations in the hydrogen ion concentrations [H+] on the bark of trees may have affected the number of lichens and frequency distributions on the trees in these habitats. For example, in this study it was found that on the three

TABLE XX

CORRELATION COEFFICIENTS BETWEEN pH AND NUMBER OF LICHENS ON THE FOUR ASPECTS OF THREE TREE SPECIES WITHIN THREE HABITATS

Tree Species	Forest Centers				Unpaved Roads				Paved Roads			
	N[a]	E	S	W	N	E	S	W	N	E	S	W
Pinus banksiana	-.234	-.103	.000	.181	-.259	.041	.128	-.140	.310	- 034	.152	.329
Populus grandidentata	-.444	-.755	-.440	-.314	-.377	-.441	-.571	-.235	-.179	-.615	-.372	-.688
Acer saccharum	.180	-.582	.078	-.147	-.061	-.496	-.404	-.486	.113	.031	.294	.296

Significance level .01.

[a]N = North, E = East, S = South, W = West.

TABLE XXI

MAXIMUM AND MINIMUM pH OF BARK SUBSTRATES FROM THREE TREE SPECIES WITHIN THREE HABITATS

Tree Species	Fca		Urd		Prd	
	Min[b]	Max	Min	Max	Min	Max
Acer saccharum	5.2	5.9	4.9	5.6	4.7	5.3
Pinus banksiana	4.0	4.7	3.8	4.6	3.9	4.5
Populus grandidentata	4.7	5.8	4.7	5.6	4.6	5.6

[a]Fc = Forest centers, Urd = Unpaved roads, Prd = Paved roads.

[b]Min = Minimum, Max = Maximum.

tree species with pH determinations of bark (Table XX, page 82), there was a slight tendency for them to be more acid from forest centers toward paved roads. Examining Table XIX, page 73, and Table IX, page 44, it is found that paved road lichens were less in number and had in general lower frequencies than in the other habitats.

VI. CONCLUSIONS

From the investigations described herein, the following conclusions were derived.

Cole's index method for the study of interspecific associations of organisms was found an invaluable tool for interpreting the meaning of lichen frequencies on each of five tree species studied in each general habitat. Kulczynski's coefficient of similarity was useful in an attempt to evaluate the effect of each habitat-environment on the lichen community composition.

The number of lichen species and number of lichen-tree pairs associations found by non-chance probability along unpaved roads as compared to those at the other habitats appeared to indicate the operation of undetermined environmental factors on the tree-bark habitats to make them more suitable for the ecological requirements of lichen species. Next in importance in respect to habitat modification was the shelter and stability of forest centers. The environment along paved roads seemed to have changed the ecological conditions of the tree-bark habitat so much that a reduced number of species, of lichen-tree pairs, and of chance and non-chance probability associations were found.

Forest centers in relation to the forest as a whole proved to be more stable in regard to environmental conditions. The positive and negative lichen-tree pair

associations occurring by chance probability were greater in forest centers. In contrast, the positive and negative lichen-tree pair associations occurring by non-chance probability were greater in the forest as a whole indicating in this way the effect of each of these general habitats in the total distribution of these cryptogamic plants in this region. For a better representation of the lichen ecology in a given area, not only one type of habitat has to be taken into account, but all that can be found and identified.

Not all of the tree-bark substrates were equally favorable for a lichen species in a given habitat and not all lichen species occurred in the three habitats with a frequency of at least 10 percent.

Lichen species with the highest lichen-tree pairs associations on a given tree and habitat could be considered as comprising communities which represented combinations of species with similar ecological requirements.

The importance of the habitat-environment is stressed on species such as Graphis scripta, Arthonia caesia, and Arthopyrenia punctiformis considered to be host-specific of Acer saccharum under forest centers conditions (Hale, 1955), were found in the other general habitats, and two of them, Arthonia caesia and Arthopyrenia punctiformis, with a higher frequency than in the forest centers.

Bark-substrates of the trees Pinus banksiana and

Populus grandidentata in forest centers; Quercus rubra and Ulmus americana along unpaved roads; and Acer saccharum along paved roads were more suitable for lichens than Acer saccharum and Ulmus americana in forest centers, and Pinus banksiana, Populus grandidentata and Quercus rubra along paved roads.

Coefficients of similarity studies indicated that the environment found within forest centers was stable enough to allow each of these five tree species to support a lichen vegetation that in terms of similarity closely follow the linear floristic gradient of vascular plants in the area. This same statement does not apply to lichen community similarities along unpaved and paved roads in which the data showed in the results of environmental effect on tree-bark substrates and also on lichen community composition. Along unpaved roads the environment was variable enough to promote more complex lichen communities on most of the tree species. Along paved roads extremes were detrimental to many lichens, promoting simpler lichen communities on most of the trees.

In the forest as a whole, frequencies of lichens did not increase or decrease on each of the tree species following the floristic arrangement of the climax adaptation number (Brown and Curtis, 1952).

The response of a lichen species or lichen community to a specific substrate offered by a tree species may be

different from one habitat to another. From this it is inferred that the most important factors determining corticolous distribution of lichens in this area are those of the environment in which the tree-stands examined were located. This is in contrast to the conclusions of Culberson (1955) who studied the upland forests of northern Wisconsin and concluded the structure of epiphytic corticolous vegetation is governed by factors of the substrate; and Hale (1955) who stated that in the upland forests of southern Wisconsin, stand composition was the most important factor determining cryptogamic distribution.

Actually almost no area in this region could be considered as undisturbed and free of polluting action. Several studies have demonstrated that pollutants can be carried far from their sources by wind, a fact that is important in this resort area with many polluting activities. Since lichens store substances, these may reach a critical point for survival of lichens and even rendering the substrates unfit for lichen regeneration and establishment.

Statistically there were no significant correlations between pH of bark of each of the trees tested from each habitat and numbers of lichen species they bore. However, by inspection of the pH data (Tables XXI, page 83, and XXIV to XXXII, see Appendix) of tree bark substrates, acidity increased gradually from forest centers toward sides

of unpaved roads and then to those of paved roads. This seemed to indicate a slight association between the pH of bark-substrate and the results obtained in this study.

VII. SUMMARY

During the summer of 1970 and spring and summers of the year 1971 and 1972 a field investigation of the corticolous lichen distribution in the upland forests at the University of Michigan Biological Station area (Cheboygan and Emmet Counties) Michigan was completed. The forest as a whole and three general habitats representing different environmental conditions were the object of this study.

Seventy-eight tree-stands were initially considered and 22 tree-stands were selected by random numbers to be the object of sampling. Tree-stands were chosen where each of five tree species respectively seemed to be the dominant species to avoid the action on lichen distribution of other tree environments. Six hundred eighty-nine trees encompassing five different tree species were sampled at breast height (1.3 m) by means of four 100 m x 100 m quadrats that were placed on each cardinal aspect of each tree species. The tree sampled and number were: Pinus banksiana, 150; Populus grandidentata, 140; Quercus rubra, 159; Ulmus americana, 90; and Acer saccharum, 150.

Bark samples were taken from 10 individuals of each tree species at each habitat to measure their pH to see what effect each general habitat had on the pH of the substrate and to see if it affected lichen distribution in these three habitats.

The final data were punched in 360/IBM cards for computing treatment following the directions for Cole's index of interspecific associations and Kulczynski's coefficients of similarity computer programs. Data on pH of the bark from three tree species at each habitat were analyzed by means of Correlation Coefficients in a Wang 700B Advanced Programming Calculator.

The analysis of lichen-tree pairs associations was made on the basis of being by chance or by non-chance probabilities. This was ascertained by calculating a Chi-square with one degree of freedom to each Cole's index value. Any Chi-square of any Cole's index that was 0.95 level of significance or less was assumed to indicate chance probability. Any Chi-square of any Cole's index that was larger than 0.95 level of significance was assumed to indicate non-chance probability and that the association was caused by the action of some environmental factors.

Eighty-six lichen-tree pairs associations were distributed in forest centers; 87, along unpaved roads; and 58, along paved roads, in contrast to 77 lichen-tree pairs found in the forests as a whole. The analysis of the distribution of lichen-tree pairs associations indicated that their percentages were greater along unpaved roads as compared to those in forest centers and along paved roads.

Analysis of Kulczynski's coefficients of similarity

indicated that along unpaved roads the environment seems to have modified conditions in the bark habitats of Quercus rubra, Ulmus americana, and Acer saccharum in such a way as to enhance their suitability as substrates for lichen communities. Conversely, it seems that the bark habitats on Pinus banksiana and Populus grandidentata were progressively impoverished from forest centers toward unpaved roads.

A comparison between the habitats in the forest as a whole and that in forest centers in regard to corticolous lichens showed that the percentages of positive and negative lichen-tree pairs associations by non-chance probability were greater in the forests as a whole than in forest centers. In contrast, positive and negative lichen-tree pairs associations by chance probability were greater in forest centers which indicates that it has a more stable environment.

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APPENDIX

TABLE XXII

2 X 2 TABLE TO TEST COLE'S INDEX* OF INTERSPECIFIC ASSOCIATION

Species A	Species B		Present + Absent
	Present	Absent	
Present	a	b	a+b
Absent	c	d	c+d
	a+c	b+d	a+b+c+d

Source: L. C. Cole, 1949, The measurement of interspecific association, Ecology 30(4):411-424.

Cole's Index Formulas

When $ad \geq bc$:

$$C_1 \pm 6c = \frac{ad - bc}{(a+b)\ (b+d)} \pm \sqrt{\frac{(a+b)\ (c+d)}{n\ (a+b)\ (b+d)}}$$

When $bc > ad$ and $d \geq a$:

$$C_2 \pm 6c = \frac{ad - bc}{(a+b)\ (a+c)} \pm \sqrt{\frac{(b+d)\ (c+d)}{n\ (a+b)\ (a+c)}}$$

When $bc > ad$ and $a > d$:

$$C_3 \pm 6c = \frac{ad - bc}{(b+d)\ (c+d)} \pm \sqrt{\frac{(a+b)\ (a+c)}{n\ (b+d)\ (c+d)}}$$

$$X^2 = \frac{(ad - bc)^2 n}{(a+b)\ (a+c)\ (c+d)\ (b+d)}$$

TABLE XXIII

LICHEN SPECIES WITH LESS THAN 10 PERCENT FREQUENCY ON EACH OF FIVE TREE SPECIES* AT EACH OF THREE GENERAL HABITATS

Lichen Species	Forest Centers					Unpaved Roads					Paved Roads				
	Pb	Pg	Qr	Ua	As	Pb	Pg	Qr	Ua	As	Pb	Pg	Qr	Ua	As
Alectoria nidulifera	-	-	-	-	-	5	7	-	-	-	9	-	-	-	-
Arthonia radiata	-	-	-	-	2	-	-	-	-	-	-	-	6	-	-
Arthopyrenia punctiformis	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
Bacidia chlorococca	-	-	-	-	-	-	-	-	-	-	-	-	8	-	-
Bacidia sabuletorum	-	-	-	-	-	-	-	7	-	-	-	-	-	-	-
Buellia dialyta	-	-	9	-	-	2	-	-	-	-	-	-	6	-	-
Buellia punctata	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-
Buellia schaerei	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-
Buellia stillingiana	-	3	-	-	-	-	3	5	-	-	-	-	-	-	-
Caloplaca aurantiaca	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-
Caloplaca cerina	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-
Caloplaca ferruginea	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Caloplaca holocarpa	-	-	2	-	-	-	-	-	-	-	-	4	-	-	2
Candelaria concolor	-	-	-	-	3	-	-	-	-	-	-	8	-	-	-
Candelariella vitellina	-	-	-	-	-	2	-	-	-	-	-	8	-	-	-
Catillaria prasina	-	-	2	-	-	-	-	-	-	2	-	-	-	-	-
Cetraria ciliaris	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-
Cetraria fendleri	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Cetraria pinastri	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-
Evernia mesomorpha	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-
Hypogymnia physodes	-	-	-	-	-	-	-	2	-	-	-	4	-	-	-
Icmadophyla ericetorum	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-
Lecanora pallida	-	-	-	-	-	-	-	-	-	-	-	4	4	-	-
Lecanora subfusca	-	-	-	-	-	-	7	-	-	-	-	4	-	-	-
Lecanora subrugosa	-	3	-	-	-	3	-	2	-	-	4	-	-	-	-
Lecanora varia	-	-	-	-	-	2	-	-	-	8	-	8	2	-	-
Lecidea vernalis	-	-	2	-	-	-	-	2	-	3	3	-	6	-	-
Lepraria aeruginosa	-	-	-	-	-	3	-	-	-	2	-	-	-	-	-
Opegrapha pulicaris	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-
Parmelia aurulenta	-	-	2	-	-	-	-	2	-	2	-	-	-	-	-
Parmelia bolliana	-	-	-	-	-	-	-	9	-	2	-	-	-	-	-
Parmelia caperata	-	3	-	-	-	-	-	2	-	3	-	4	6	-	5
Parmelia exasperata	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Parmelia olivacea	-	-	-	-	-	5	-	-	-	8	2	-	2	-	2
Parmelia rudecta	-	-	2	-	3	-	-	-	-	-	3	-	-	-	-
Parmelia saxatilis	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
Parmelia subaurifera	-	-	-	4	-	3	-	-	-	-	-	8	-	-	-
Parmelia sulcata	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-
Parmelia ulophyllodes	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-

TABLE XXIII (continued)

Lichen Species	Forest Centers					Unpaved Roads					Paved Roads				
	Pb	Pg	Qr	Ua	As	Pb	Pg	Qr	Ua	As	Pb	Pg	Qr	Ua	As
Parmeliopsis ambigua	-	-	-	-	-	-	-	2	-	2	-	-	6	-	3
Parmeliopsis placorodia	4	-	-	-	-	-	-	-	-	-	-	-	-	5	-
Pertusaria amara	-	-	8	-	-	-	-	2	-	-	-	-	2	-	-
Pertusaria marginata	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
Pertusaria multipuncta	-	-	-	-	-	-	-	7	-	-	-	-	8	-	-
Pertusaria velata	6	5	-	-	-	-	-	-	-	3	-	4	-	5	-
Pertusaria xanthodes	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Physcia adscendens	-	-	-	-	-	7	-	-	-	-	-	-	-	-	-
Physcia aipolia	-	3	-	-	3	3	-	-	-	-	-	-	-	5	-
Physcia caesia	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
Physcia ciliata	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Physcia millegrana	2	-	5	-	7	-	-	-	-	-	-	-	6	-	-
Physcia orbicularis	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-
Physcia setosa	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-
Physcia stellaris	-	-	-	-	-	3	-	-	-	2	-	-	-	-	4
Physcia tenella	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-
Physconia grisea	9	-	-	-	-	5	-	-	-	-	-	-	-	-	-
Physconia pulverulenta	-	-	-	-	2	-	-	-	-	-	-	-	4	-	-
Ramalina farinacea	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
Ramalina fastigiata	-	-	-	-	-	-	3	-	-	3	-	-	-	-	-
Rinodina archaea	-	3	-	-	-	-	7	-	-	2	2	-	-	-	-
Rinodina exigua	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-
Rinodina palustris	4	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Tripethelium virens	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-
Usnea subfloridana	6	-	-	-	-	-	-	-	-	-	-	-	-	-	4
Usnea dasypoga	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-
Usnea hirta	-	-	2	-	-	-	3	5	-	-	-	4	-	-	4
Xanthoria fallax	-	-	-	-	-	-	-	9	-	-	-	-	2	-	3
Xanthoria polycarpa	-	3	-	-	-	-	-	-	-	-	-	-	4	-	-

*Pb = Pinus banksiana, Pg = Populus grandidentata, Qr = Quercus rubra, Ua = Ulmus americana, As = Acer saccharum.

TABLE XXIV

pH AND [H+] OF THE BARK SUBSTRATE OF THE FOUR ASPECTS OF 10 POPULUS GRANDIDENTATA TREES ALONG PAVED ROADS

Tree	North		East		South		West	
	pH	[H+]	pH	[H+]	pH	[H+]	pH	[H+]
1	5.3	5.00×10^{-6}	5.2	6.30×10^{-6}	5.3	5.00×10^{-6}	5.4	4.00×10^{-6}
2	5.3	5.00×10^{-6}	5.3	5.00×10^{-6}	5.3	5.00×10^{-6}	5.3	5.00×10^{-6}
3	5.3	5.00×10^{-6}	5.4	4.00×10^{-6}	5.4	4.00×10^{-6}	5.3	5.00×10^{-6}
4	5.6	2.50×10^{-6}	5.2	6.30×10^{-6}	5.3	5.00×10^{-6}	5.4	4.00×10^{-6}
5	5.2	6.30×10^{-6}	4.9	1.20×10^{-5}	5.0	10.00×10^{-6}	5.0	10.00×10^{-6}
6	4.9	1.20×10^{-5}	5.1	8.00×10^{-6}	5.1	8.00×10^{-6}	5.0	10.00×10^{-6}
7	4.8	1.60×10^{-5}	4.9	1.20×10^{-5}	4.9	1.20×10^{-5}	4.9	1.20×10^{-5}
8	4.9	1.20×10^{-5}	4.8	1.60×10^{-5}	4.8	1.60×10^{-5}	4.6	2.50×10^{-5}
9	5.5	3.20×10^{-6}	4.9	1.20×10^{-5}	5.0	10.00×10^{-6}	5.0	10.00×10^{-6}
10	4.8	1.60×10^{-5}	5.0	10.00×10^{-6}	4.9	1.20×10^{-5}	4.9	1.20×10^{-5}

TABLE XXV

pH AND [H+] FROM THE BARK SUBSTRATE OF THE FOUR ASPECTS OF 10 PINUS BANKSIANA TREES ALONG PAVED ROADS

Trees	North		East		South		West	
	pH	[H+]	pH	[H+]	pH	[H+]	pH	[H+]
1	4.4	4.00×10^{-5}	4.3	5.00×10^{-5}	4.3	5.00×10^{-5}	4.5	3.10×10^{-5}
2	4.5	3.50×10^{-5}	4.4	4.00×10^{-5}	4.5	3.10×10^{-5}	4.3	5.00×10^{-5}
3	4.5	3.50×10^{-5}	4.2	6.30×10^{-5}	4.5	3.10×10^{-5}	4.2	6.30×10^{-5}
4	4.3	5.00×10^{-5}	4.1	8.00×10^{-5}	4.2	6.30×10^{-5}	4.3	5.00×10^{-5}
5	4.4	4.00×10^{-5}	4.5	3.10×10^{-5}	4.1	8.00×10^{-5}	4.3	5.00×10^{-5}
6	4.3	5.00×10^{-5}	4.2	6.30×10^{-5}	4.2	6.30×10^{-5}	4.4	4.00×10^{-5}
7	4.2	6.30×10^{-5}	4.0	10.00×10^{-5}	4.3	5.00×10^{-5}	4.2	6.30×10^{-5}
8	4.2	6.30×10^{-5}	4.1	8.00×10^{-5}	4.2	6.30×10^{-5}	3.9	1.20×10^{-5}
9	4.3	5.00×10^{-5}	4.0	10.00×10^{-5}	3.9	1.20×10^{-4}	4.2	6.30×10^{-5}
10	4.2	6.30×10^{-5}	4.1	8.00×10^{-5}	3.9	1.20×10^{-4}	4.1	8.00×10^{-5}

TABLE XXVI

pH AND [H+] OF THE BARK SUBSTRATE OF THE FOUR ASPECTS OF 10 ACER SACCHARUM TREES ALONG PAVED ROADS

	North		East		South		West	
Tree	pH	[H+]	pH	[H+]	pH	[H+]	pH	[H+]
1.-	5.1	8.00×10^{-6}	5.2	6.30×10^{-6}	5.0	10.00×10^{-6}	5.2	6.30×10^{-6}
2	4.9	1.25×10^{-5}	4.7	2.00×10^{-5}	5.1	8.00×10^{-6}	5.0	10.00×10^{-6}
3	5.1	8.00×10^{-6}	5.0	10.00×10^{-6}	5.1	8.00×10^{-6}	5.0	10.00×10^{-6}
4	5.0	10.00×10^{-6}	4.9	1.25×10^{-6}	5.0	10.00×10^{-6}	5.1	8.00×10^{-6}
5	4.9	1.25×10^{-6}	5.0	10.00×10^{-6}	5.2	6.30×10^{-6}	5.1	8.00×10^{-6}
6	5.1	8.00×10^{-6}	5.0	10.00×10^{-6}	4.9	1.25×10^{-5}	5.0	10.00×10^{-6}
7	5.1	8.00×10^{-6}	5.0	10.00×10^{-6}	5.0	10.00×10^{-6}	5.1	8.00×10^{-6}
8	5.2	6.30×10^{-6}	5.3	5.00×10^{-6}	5.1	8.00×10^{-6}	5.2	6.30×10^{-6}
9	5.3	5.00×10^{-6}	5.2	6.30×10^{-6}	5.0	10.00×10^{-6}	5.3	5.00×10^{-6}
10	5.2	6.30×10^{-6}	5.2	6.30×10^{-6}	5.2	6.30×10^{-6}	5.0	10.00×10^{-6}

TABLE XXVII

pH AND [H+] OF THE BARK SUBSTRATE OF THE FOUR ASPECTS OF 10 POPULUS GRANDIDENTATA TREES ALONG UNPAVED ROADS

Tree	North		East		South		West	
	pH	[H+]	pH	[H+]	pH	[H+]	pH	[H+]
1	5.0	10.00×10^{-6}	4.8	1.60×10^{-5}	5.2	6.30×10^{-6}	5.2	6.30×10^{-6}
2	5.1	8.00×10^{-6}	5.1	8.00×10^{-6}	5.1	8.00×10^{-6}	5.1	8.00×10^{-6}
3	5.2	6.30×10^{-6}	5.1	8.00×10^{-6}	5.1	8.00×10^{-6}	5.1	8.00×10^{-6}
4	5.0	10.00×10^{-6}	4.9	1.25×10^{-5}	5.4	4.00×10^{-6}	4.9	1.25×10^{-5}
5	4.7	2.00×10^{-5}	4.8	1.60×10^{-5}	5.0	10.00×10^{-6}	4.9	1.25×10^{-5}
6	5.0	10.00×10^{-6}	5.0	10.00×10^{-6}	5.1	8.00×10^{-6}	5.2	6.30×10^{-6}
7	4.9	1.25×10^{-5}	5.3	5.00×10^{-6}	5.1	8.00×10^{-6}	5.1	8.00×10^{-6}
8	5.6	2.50×10^{-6}	5.5	3.20×10^{-6}	5.2	6.30×10^{-6}	5.2	6.30×10^{-6}
9	5.0	10.00×10^{-6}	5.0	10.00×10^{-6}	5.3	5.00×10^{-6}	5.1	8.00×10^{-6}
10	5.3	5.00×10^{-6}	5.1	8.00×10^{-6}	5.1	8.00×10^{-6}	5.1	8.00×10^{-6}

TABLE XXVIII

pH AND [H+] OF THE BARK SUBSTRATE OF THE FOUR ASPECTS OF 10 PINUS BANKSIANA TREES ALONG UNPAVED ROADS

Tree	North		East		South		West	
	pH	[H+]	pH	[H+]	pH	[H+]	pH	[H+]
1	4.2	6.30×10^{-5}	4.1	8.00×10^{-5}	4.3	5.00×10^{-5}	4.2	6.30×10^{-5}
2	4.1	8.00×10^{-5}	4.2	6.30×10^{-5}	4.2	6.30×10^{-5}	4.6	2.50×10^{-5}
3	4.3	5.00×10^{-5}	4.5	3.20×10^{-5}	4.1	8.10×10^{-5}	4.2	6.30×10^{-5}
4	4.0	10.00×10^{-5}	4.2	6.30×10^{-5}	4.3	5.00×10^{-5}	4.0	10.00×10^{-5}
5	4.0	10.00×10^{-5}	3.9	1.25×10^{-4}	3.9	1.25×10^{-4}	4.5	3.20×10^{-5}
6	4.3	5.00×10^{-5}	4.2	6.30×10^{-5}	4.2	6.30×10^{-5}	4.3	5.00×10^{-5}
7	4.1	8.00×10^{-5}	4.0	10.00×10^{-5}	3.9	1.25×10^{-4}	4.0	10.00×10^{-5}
8	4.4	4.00×10^{-5}	3.8	1.60×10^{-5}	4.1	8.00×10^{-5}	4.0	10.00×10^{-5}
9	3.8	1.60×10^{-4}	4.2	6.30×10^{-5}	4.0	10.00×10^{-5}	4.0	10.00×10^{-5}
10	4.0	10.00×10^{-5}	4.1	8.00×10^{-5}	4.2	6.30×10^{-5}	4.1	8.00×10^{-5}

TABLE XXIX

pH AND [H+] OF THE BARK SUBSTRATE OF THE FOUR ASPECTS OF 10 ACER SACCHARUM TREES ALONG UNPAVED ROADS

	North		East		South		West	
Tree	pH	[H+]	pH	[H+]	pH	[H+]	pH	[H+]
1.-	5.3	5.00×10^{-6}	5.3	5.00×10^{-6}	5.5	3.20×10^{-6}	5.3	5.00×10^{-6}
2.-	5.4	4.00×10^{-6}	5.6	2.50×10^{-6}	5.3	5.00×10^{-6}	5.1	8.00×10^{-6}
3.-	5.1	8.00×10^{-6}	5.0	10.00×10^{-6}	5.1	8.00×10^{-6}	5.1	8.00×10^{-6}
4.-	5.0	10.00×10^{-6}	5.0	10.00×10^{-6}	5.4	4.00×10^{-6}	5.1	8.00×10^{-6}
5.-	5.5	3.20×10^{-6}	5.1	8.00×10^{-6}	5.0	10.00×10^{-6}	5.1	8.00×10^{-6}
6.-	5.0	10.00×10^{-6}	5.1	8.00×10^{-6}	5.0	10.00×10^{-6}	5.0	10.00×10^{-6}
7.-	5.0	10.00×10^{-6}	5.0	10.00×10^{-6}	4.9	1.25×10^{-5}	5.0	10.00×10^{-6}
8.-	5.0	10.00×10^{-6}	5.3	5.00×10^{-6}	5.0	10.00×10^{-6}	5.0	10.00×10^{-6}
9.-	5.0	10.00×10^{-6}	5.6	2.50×10^{-6}	5.0	10.00×10^{-6}	4.9	1.25×10^{-6}
10.-	4.9	1.25×10^{-6}	5.4	4.00×10^{-6}	5.2	6.30×10^{-6}	5.4	4.00×10^{-6}

TABLE XXX

pH AND [H+] OF THE BARK SUBSTRATE OF THE FOUR ASPECTS OF 10 POPULUS GRANDIDENTATA TREES IN FOREST CENTERS

Tree	North		East		South		West	
	pH	[H+]	pH	[H+]	pH	[H+]	pH	[H+]
1	4.7	2.00×10^{-5}	5.1	8.00×10^{-6}	5.1	8.00×10^{-6}	5.1	8.00×10^{-6}
2	5.1	8.00×10^{-6}	5.1	8.00×10^{-6}	5.3	5.00×10^{-6}	5.2	6.30×10^{-6}
3	5.1	8.00×10^{-6}	5.1	8.00×10^{-6}	5.1	8.00×10^{-6}	5.0	10.00×10^{-6}
4	5.0	10.00×10^{-6}	5.0	10.00×10^{-6}	5.1	8.00×10^{-6}	5.1	8.00×10^{-6}
5	5.1	8.00×10^{-6}	5.2	6.30×10^{-6}	5.0	10.00×10^{-6}	5.1	8.00×10^{-6}
6	5.1	8.00×10^{-6}	5.1	8.00×10^{-6}	5.1	8.00×10^{-6}	5.1	8.00×10^{-6}
7	5.1	8.00×10^{-6}	5.2	6.30×10^{-6}	5.3	5.00×10^{-6}	5.1	8.00×10^{-6}
8	5.1	8.00×10^{-6}	5.2	6.30×10^{-6}	5.3	5.00×10^{-6}	5.2	6.30×10^{-6}
9	5.2	6.30×10^{-6}	5.4	4.00×10^{-6}	5.8	1.60×10^{-6}	5.4	4.00×10^{-6}
10	5.1	8.00×10^{-6}	5.1	8.00×10^{-6}	5.2	6.30×10^{-6}	5.1	8.00×10^{-6}

TABLE XXXI

pH AND [H+] OF THE BARK SUBSTRATE OF THE FOUR ASPECTS OF 10 PINUS BANKSIANA TREES IN FOREST CENTERS

Tree	North		East		South		West	
	pH	[H+]	pH	[H+]	pH	[H+]	pH	[H+]
1	4.3	5.00×10^{-5}	4.3	5.00×10^{-5}	4.3	5.00×10^{-5}	4.3	5.00×10^{-5}
2	4.4	4.00×10^{-5}	4.2	6.30×10^{-5}	4.0	10.00×10^{-5}	4.2	6.30×10^{-5}
3	4.1	8.00×10^{-5}	4.1	8.00×10^{-5}	4.1	8.00×10^{-5}	4.3	5.00×10^{-5}
4	4.2	6.30×10^{-5}	4.4	4.00×10^{-5}	4.3	5.00×10^{-5}	4.2	6.00×10^{-5}
5	4.1	8.00×10^{-5}	4.1	8.00×10^{-5}	4.3	5.00×10^{-5}	4.1	8.00×10^{-5}
6	4.3	5.00×10^{-5}	4.4	4.00×10^{-5}	4.3	5.00×10^{-5}	4.3	5.00×10^{-5}
7	4.2	6.30×10^{-5}	4.3	5.00×10^{-5}	4.1	8.00×10^{-5}	4.1	8.00×10^{-5}
8	4.2	6.30×10^{-5}	4.2	6.30×10^{-5}	4.6	2.50×10^{-5}	4.5	3.20×10^{-5}
9	4.3	5.00×10^{-5}	4.5	3.10×10^{-5}	4.5	3.10×10^{-5}	4.5	3.10×10^{-5}
10	4.7	2.00×10^{-5}	4.4	4.00×10^{-5}	4.1	8.00×10^{-5}	4.5	3.00×10^{-5}

TABLE XXXII

pH AND [H+] OF THE BARK SUBSTRATE OF THE FOUR ASPECTS OF 10 ACER SACCHARUM TREES IN FOREST CENTERS

Tree	North		East		South		West	
	pH	[H+]	pH	[H+]	pH	[H+]	pH	[H+]
1-	5.9	1.25×10^{-6}	5.6	2.50×10^{-6}	5.4	4.00×10^{-6}	5.4	4.00×10^{-6}
2-	5.4	4.00×10^{-6}	5.4	4.00×10^{-6}	5.4	4.00×10^{-6}	5.3	5.00×10^{-6}
3-	5.5	3.20×10^{-6}	5.5	3.20×10^{-6}	5.5	3.20×10^{-6}	5.5	3.20×10^{-6}
4-	5.5	3.20×10^{-6}	5.4	4.00×10^{-6}	5.5	3.20×10^{-6}	5.4	4.00×10^{-6}
5	5.5	3.20×10^{-6}	5.2	6.30×10^{-6}	5.4	4.00×10^{-6}	5.5	3.20×10^{-6}
6	5.2	6.30×10^{-6}	5.2	6.30×10^{-6}	5.2	6.30×10^{-6}	5.2	6.30×10^{-6}
7	5.2	6.30×10^{-6}	5.2	6.30×10^{-6}	5.5	3.20×10^{-6}	5.2	6.30×10^{-6}
8	5.4	4.00×10^{-6}	5.4	4.00×10^{-6}	5.4	4.00×10^{-6}	5.3	5.00×10^{-6}
9	5.5	3.20×10^{-6}	5.5	3.20×10^{-6}	5.4	4.00×10^{-6}	5.4	4.00×10^{-6}
10	5.3	5.00×10^{-6}	5.3	5.00×10^{-6}	5.2	6.30×10^{-6}	5.3	5.00×10^{-6}

VITA

Carlos Ramirez Reyes was born in Temblador, Monagas State, Republic of Venezuela on August 6, 1935. His father Felix Ramirez was a butcher and his mother Eugenia Reyes de Ramirez a housewife. He began his formal education in his hometown and received his elementary education diploma from the Simon Bolivar Adult Education Center in Caracas in 1951. He entered the Normal "Miguel Jose Sanz" in Barquisimeto in 1954 and graduated from that Institution as an Elementary School Teacher in 1958. He entered the Instituto Pedagogico in Caracas in 1958 and obtained his Secondary School Teacher Certificate in Biology and Chemistry in 1963. In 1964 he was awarded his High School Diploma by equivalence from the Technical Educational Council of Venezuela. In 1965 he entered the University of Michigan at Ann Arbor as a Graduate Student under a Venezuelan Government Scholarship and attained the degree of Master of Science in Biology in 1967. After three years of college teaching in Venezuela he then came back to the University of Michigan as a Graduate Student to work for the Ph.D. degree in Botany under a C.O.N.I.C.I.T. scholarship. In 1972 he graduated with a Master of Science in Botany and entered The University of Tennessee to continue working under the guidance of Dr. A. J. Sharp on his Ph.D. in Botany which he

expects to receive during the summer of 1974.

He is married to Felicia Matilde Perez, an elementary school teacher. One son Carlos Alberto and one daughter Marielly have resulted from this union.