1993

Lichen Communities on White Oaks in East-Central Illinois

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LICHEN COMMUNITIES ON WHITE OAKS IN EAST-CENTRAL ILLINOIS

(TITLE)

BY

Michael R. Thon

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

MASTER OF SCIENCE

IN THE GRADUATE SCHOOL, EASTERN ILLINOIS UNIVERSITY
CHARLESTON, ILLINOIS

1993
YEAR

I HEREBY RECOMMEND THIS THESIS BE ACCEPTED AS FULFILLING
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ABSTRACT

This study was conducted as a survey of epiphytic lichen communities occurring on white oak trees at Walnut Point State Park (Douglas Co.) and Fox Ridge State Park (Coles Co.). Using a system of cover classes to estimate lichen cover, quantitative data on the distribution and abundance of epiphytic lichens was obtained. These data were used to calculate summary statistics of each community including total cover, species richness, and Shannon diversity. A total of ten taxa representing six genera were found. The foliose lichen *Physcia millegrana* had the highest cover in the open canopy habitats while all other taxa had average coverages of less than one percent. Open canopy habitats had consistantly higher cover than the closed canopy habitats although the Fox Ridge open and closed canopy habitats and the Walnut Point open canopy habitats were similar in species richness and Shannon diversity. The Walnut Point closed canopy habitat was almost completely devoid of lichen cover with only *Candelaria concolor* occuring on ten percent of white oaks sampled.

ACKNOWLEDGMENTS

I would like to thank Dr. Pederson and Dr. Ebinger for their review of this manuscript. I would also like to thank Dr. Wilhelm at the Morton Arboretum for his assistance in the identification of the lichen specimens. Above all, I must thank my parents for their continued support throughout my education, and Dr. Methven for his support and guidance throughout this whole project.

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INTRODUCTION

Previous studies of the lichens of Illinois and Indiana (Williams, 1980; Skorepa, 1973; Mertz, 1972; Wiedman, 1971) have resulted in the publication of surveys and checklists which include detailed habitat descriptions and information on lichen species abundance. Mertz (1972) completed a survey of lichens occurring at Turkey Run State Park, Parke County, Indiana which included habitat descriptions for each collecting location. The descriptions were useful in establishing general habitat preferences for each taxon. Williams' (1980) study described the occurrence of lichens in four different types of habitats at "Rocks Park" in Coles County, Illinois. For each habitat an estimate of the relative abundance of each species was made based on three general classes: rare, medium, and abundant. Williams also included an in depth study of each habitat and reported ecological parameters such as tree density and relative dominance. A taxonomic and ecological study of the lichens of southern Illinois completed by Skorepa (1973) also included measures of the abundance of each taxon and paid particular attention to corticolous lichens.

These studies have concentrated on characterizing species/community associations with minimal investigation into variation in epiphyte distribution resulting from microclimate variables. Although each of these studies described the geographical distribution of lichens with

respect to habitat ecology (vegetation type, climate, etc.) lichen distribution is affected on a scale much smaller than that obtained by systematic surveys (Yarranton, 1972; Hale, 1952). Investigations by Yarranton (1972), Barkman (1958) and Hale (1952) have shown that the distribution of corticolous lichens may be affected by many microclimate variables. Barkman (1958) described bark pH, bark moisture, and bark roughness as potential influences on lichen distribution. Since measurement of microclimate variables is often difficult, Yarranton (1972) chose to use orientation (eg., north vs. south, etc.) and height above ground as indirect measures of microclimate variability.

Lichen morphology and identification

Lichens form as a result of symbiotic associations between a fungus and an alga or a cyanobacterium (Hale, 1979). The resulting growth form or thallus is unlike either of the two constituent organisms. Fungal hyphae make up the majority of the thallus and are often differentiated into three distinct layers, the upper cortex, medulla, and lower cortex. The algal cells are usually confined to a distinct layer within the medulla.

Lichens are classified into three general groups based on growth form, foliose (lobed or leaf-like), fruticose (stalked or shrubby) and crustose (crust-like) (Hale, 1979). Foliose lichens have a lobed, dorsiventral growth form which is usually composed of a well developed upper cortex,

medulla, and lower cortex. The thallus may be closely appressed or loosely attached to the substrate. Rhizines, root-like hyphal outgrowths of the lower cortex, are present in some foliose lichens and serve to anchor the thallus to the substrate. They may also aid in nutrient uptake. Fruticose lichens have an erect thallus that projects away from the substrate. Due to the three-dimensional nature of the thallus, there is no lower cortex and no observable lower surface. Crustose lichens have a reduced thallus that has no lower cortex and a medulla which is closely adherent to the substrate.

Asexual reproduction is believed to be the primary means for dispersal and establishment in lichens. Specialized structures for asexual reproduction include soredia and isidia. Soredia are granular outgrowths of the medulla composed of tightly interwoven fungal hyphae interspersed with algal cells. Soredia may be produced over the entire surface of the lichen or within defined patches called soralia. Isidia are outgrowths of the upper cortex and medulla and are usually elongated, finger-like and may be branched. Sexual reproduction is believed to be limited to the fungal component. Some lichens produce specialized ascomata (apothecia or perithecia) which bear asci and ascospores. No lichen algae or cyanobacteria have been observed to undergo sexual reproduction while incorporated into the symbiotic association.

As with most groups of organisms, lichen identification relies heavily on morphological features. Alternative methods must be used for lichens which lack distinctive morphological features. Most lichens produce a group of distinctive chemical compounds, usually weak phenolic compounds or fatty acids (Hale, 1979), called lichen products or secondary metabolites. Several types of chemical tests have been devised to determine the presence or absence of these compounds in lichen thalli (Brodo, 1988; Hale, 1979).

The chemical spot tests involve the application of three different reagents, calcium hypochlorite (C), potassium hydroxide (K), and paraphenylenediamine (P or PD), to the cortex or medulla of a lichen thallus. Color changes of the tissue indicate the presence of certain lichen products or groups of products. A lichen thallus containing atranorin, for example, will turn yellow in K. Chemical spot tests are convenient, relatively easy to use and are commonly included in dichotomous keys (Brodo, 1988; Hale, 1979). The drawback with these tests is that they do not allow the identification of specific lichen products.

A more precise method for detecting lichen products involves microchemical crystallization. Lichen products are extracted from the thallus with an appropriate solvent and crystallized on a clean glass slide. The type of solvent system used and the morphology of the crystals when examined

under a microscope are used to identify the substance and the lichen. The main disadvantages with this technique are that some lichen products do not form crystals or do not form distinctive crystals. Also, other substances present may interfere with crystal formation. Despite these problems, crystal tests have been used effectively by Wilcer (1984), Mertz (1972) and Thompson (1967)

High pressure liquid chromatography (HPLC) and thin layer chromatography (TLC) have also been used to identify lichen products. These techniques are particularly useful when it is necessary to identify substances that are not identifiable using crystal tests (Hale, 1979). High pressure liquid chromatography is commonly used today although thin layer chromatography (TLC) is still used where equipment for HPLC is unavailable. A standardized method for TLC developed by Culberson and Kristinsson (1970) and Culberson (1972) utilizes cover classes rather than strict R_f values since R_f values can change slightly from one plate to the next. Micro-extractions of lichen thalli are applied to three separate chromatography plates. Each plate is developed in a different solvent system each of which provide different results. Since the R_f values of lichen products vary with the type of solvent used, more definitive identifications may be obtained (Culberson, 1969). Purified lichen products or extracts of lichens with known products

can be processed along side unknowns to aid in the identification of lichen products.

Sampling methods used for corticolous epiphytes

McCune and Lesica (1992) evaluated techniques used to sample corticolous cryptogams. Several different techniques have been used, including point sampling and whole plot visual estimations of epiphyte cover.

Point sampling consists of recording the presence of species at points arranged within a sample area or quadrat. McCune and Antos (1982) and Yarranton (1972) used points located at regular intervals along a measuring tape wrapped around the tree bole while Kershaw (1964) used points arranged within a pin frame placed on the bole. Point samples have the advantage of allowing for a quantitative estimate of epiphyte cover while minimizing the possibility for sampling bias. The disadvantage of point sampling is that it is time-consuming and requires a large number of points in order to allow for an adequate sample size (McCune and Lesica, 1992).

Whole plot visual sampling involves visual inspection of a plot and recording estimates of species cover. This can be done within either a single large plot or sub-samples of the plot. Despite certain problems in overestimating true cover, cover classes are often used when collecting this type of data (Floyd and Anderson, 1987). Cover class data can be gathered efficiently and gives similar results

to non-classed estimates of percent cover, providing the classes are not too broad (McCune and Lesica, 1992). Lesica *et al.* (1991) and Nimis (1985) used this sampling method successfully in studying corticolous lichens and bryophytes in several different forest types.

The present study was conducted as a survey of epiphytic lichen communities occurring on white oak trees in east central Illinois. The objectives of the study are: 1) to obtain quantitative data on lichen distribution on white oaks in order to provide an accurate description of lichen community composition, and; 2) to determine if variation in species composition and distribution on white oaks occurs.

METHODS

Study sites

The study sites selected for this project are two state parks in east-central Illinois. Fox Ridge State Park, Coles County, lies south of Charleston along the Embarras River on the Shelbyville Moraine, the terminal moraine of the Wisconsin glaciation (Ebinger, 1985). Its topography is highly dissected with deep, narrow valleys between which lie well drained ridge tops. Representatives of upland forest (Ebinger, 1985) dominated by white and black oak are limited largely to the ridge tops and gentle slopes. Ebinger (1985) reported the density of arborescent species in these areas to be 330 stems per ha (134 stems per acre).

Walnut Point State Park, Douglas County, is situated northeast of Charleston. The topography of Walnut Point is much flatter than that of Fox Ridge and contains the best remaining example of an upland, streamside forest in the upper part of the Embarras River watershed (Ebinger *et al.*, 1977). Although dominant canopy trees are also white oak and black oak, density of arborescent species are slightly less than at Fox Ridge with an average of 259 stems per ha (105 stems per acre).

Within the upland forests of both state parks corticolous epiphytes of white oak were chosen for study due to the abundance of that tree species. Both sites also contain white oaks in open canopy conditions found within

picnic areas and along roads. Trees in these open areas appeared to be more widely spaced and had little surrounding understory. After preliminary field observations it was decided that the open canopy trees would be included as a separate habitat type since the trees appeared to host a notably different lichen community. Thus, four habitats were examined: Walnut Point State Park closed canopy, Walnut Point State Park open canopy, Fox Ridge State Park closed canopy, and Fox Ridge State Park open canopy.

Closed canopy areas selected for study had relatively homogeneous topography and forest composition (Figure 1). Open canopy trees that were selected for sampling were in low density areas with little surrounding understory vegetation although some variation in these parameters was

Figure 1. Upland forest area at Fox Ridge State Park, Coles County.

Figure 2. Open canopy area of Fox Ridge State Park, Coles County.

allowed to permit adequate sampling (Figure 2). A map of both parks indicates areas sampled (Figure 3). Whenever possible, trees were selected randomly using a technique modified from Eversman (1982). A topographic map was used to plot a line through the center of each site. Using the topographic map and a compass, this line was followed through the site and at ten meter intervals (estimated by pacing) the nearest white oak tree was sampled.

During the course of this study three different epiphyte sampling techniques were utilized and their effectiveness assessed. The first two methods undertaken were point sampling methods, selected for their apparent ease of application and minimization of bias from the researcher. The first method was a technique used by

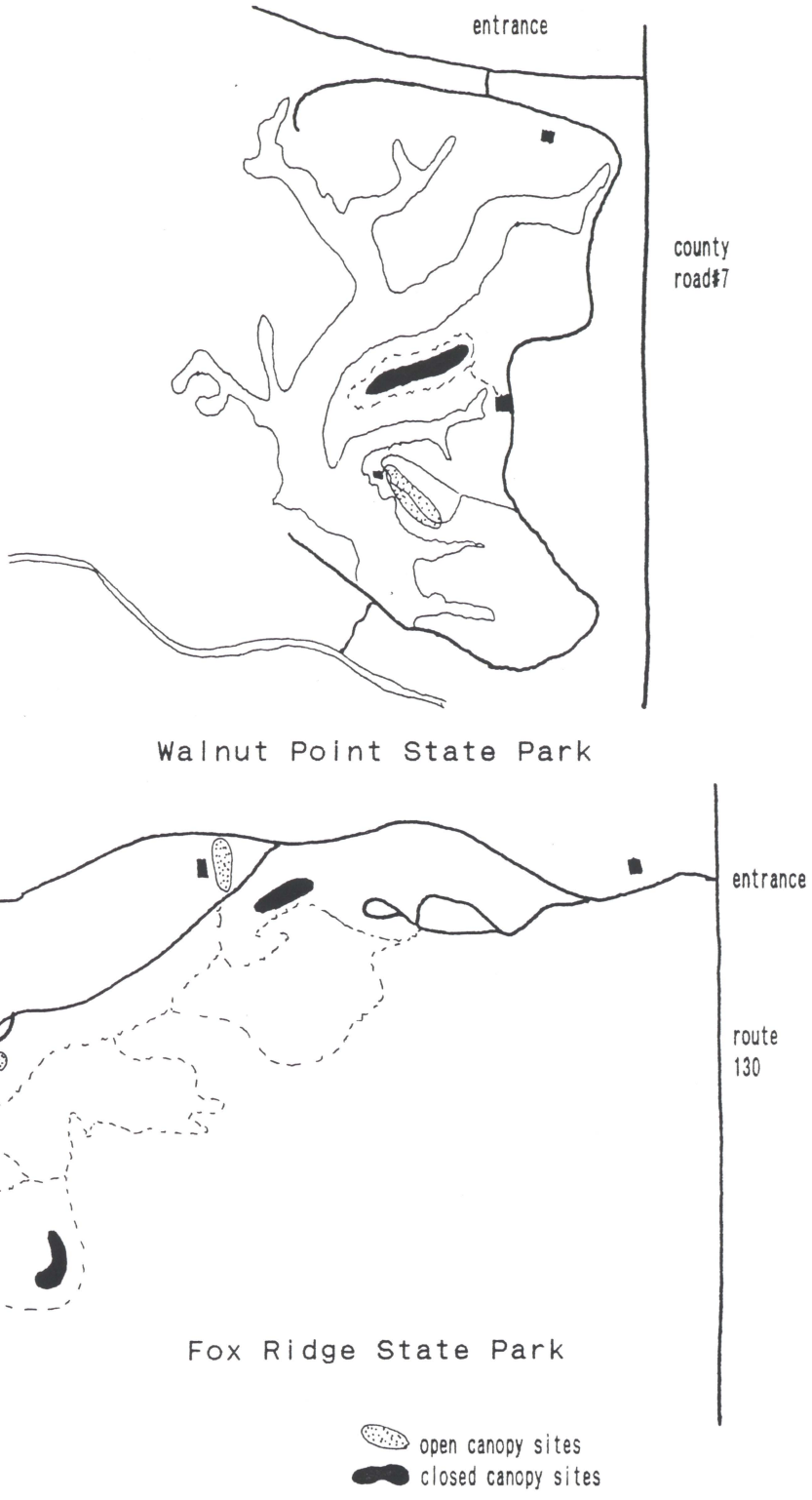

Figure 3. Sampling locations at Fox Ridge State Park, Coles County and Walnut Point State Park, Douglas County.

Yarranton (1972) and McCune and Antos (1982). A measuring tape was wrapped around a tree bole at four different heights and the presence of lichen species at the intersection of one centimeter marks and the tape edge were recorded. The second method utilized a 10 cm x 10 cm quadrat (McCune and Lesica, 1992) drawn on clear plastic with 100 points arranged regularly at one centimeter intervals (Yarranton, 1972; Kershaw, 1964). The quadrat was placed at sixteen different locations about the tree trunk and the presence of lichen species at each point was recorded. The drawbacks of point sampling methods described by McCune and Lesica (1992) were confirmed in this study. It was quickly determined that a large sample size would be necessary for adequate sample size and species capture. More specifically, the relatively low cover exhibited by corticolous lichens in the study sites prevented the inclusion of certain species in the point samples. It is important to note, however, that these techniques have been used successfully in other studies, in part because the lichens in other studies had a much higher cover.

The technique used for this study involved an estimation of the cover of each species using cover classes. In order to determine differences in lichen communities due to height and orientation each tree selected for study was divided into four sub-samples. The east and west sides of each tree were identified with a compass and marked with

tacks at 1 and 2 m heights above ground using a meter stick. Each tree was thus divided into the following four quadrants: north 0-1 m, north 1-2 m, south 0-1 m, and south 1-2 m. Percent cover of each lichen species occurring in each quadrant was recorded according to the following cover classes: 0%, 0-1%, 1-5%, 5-15%, 15-25%, 25-35%, 35-45%, 45-55%, 55-65%, 65-75%, 75-85%, 85-95%, 95-100%. These cover classes were previously used by McCune and Lesica (1992) and Lesica *et al.* (1991) and seemed narrow enough to give a relatively accurate estimate of lichen cover. Ten trees were sampled in each habitat (Eversman, 1982). The trunk diameter at breast height was also recorded for each tree sampled. Voucher specimens of all lichens described herein have been deposited in the E. L. Stover Herbarium, Eastern Illinois University.

Data analysis

To study variation in community structure with respect to height and orientation, each of the four quadrants in each habitat were treated as a separate community. Summary statistics calculated for the lichen species in each quadrant included: percent cover of each lichen species, frequency of each species, total cover, Shannon diversity index, species richness and evenness. Percent cover of each lichen species was calculated by adding the arithmetic means of the cover classes and dividing by the total number of trees sampled in the habitat. Frequency was calculated as

the number of times a species occurred in a quadrant divided by the total number of that quadrant sampled within the habitat. Total cover was the sum of the percent cover of each species in each quadrant.

Species diversity within each quadrant was measured using the Shannon diversity index, H′, (Brower and Zar, 1984) calculated with the following equation:

$$H' = -\Sigma p_i \log p_i$$

where p_i is the proportion of the total number of individuals of species i. In this study, as suggested by Brower and Zar (1984), p_i is used to represent percent cover. The Shannon diversity index is a measure of uncertainty, that is, the difficulty in predicting the identity of an individual picked randomly from the community. Therefore, a high H' indicates high diversity and a high uncertainty in predicting the identity of one randomly picked individual. H' takes into account two other community variables: species richness and species evenness which were also calculated for each quadrant. Species richness is expressed as the number of species that occur in each community and species evenness is a measure of the relative proportions of those species. Evenness (J') can be expressed using the following equation:

$$J' = \frac{H'}{H_{max}'}$$

H_{max}' is the maximum value that H' can have for the given community and is calculated as:

$$H_{max}' = \log s$$

and changes with the number of species in the community (s).

The Student's t-test (Zar, 1984) was used to compare the Shannon diversities of the quadrants.

The variance for each sample is first calculated as:

$$s^2 = \frac{\Sigma f_i \log^2 f_i - (\Sigma f_i \log f_i)^2 / n}{n^2}$$

The t statistic is calculated as:

$$t = \frac{H_1' - H_1'}{\sqrt{s_1^2 + s_1^2}}$$

Degrees of freedom is calculated as:

$$DF = \frac{(s_{H_1'}^2 + s_{H_2'}^2)^2}{\frac{(s_{H_1'}^2)^2}{n_1} + \frac{(s_{H_2'}^2)^2}{n_2}}$$

Critical values for t (α= 0.05) were found using the tables published in Schefler (1988).

Using a two-tailed test and the null hypothesis that there is no difference between the diversities of two quadrants, the following comparisons were made within each habitat: north < 1 m vs. south < 1 m; north 1-2 m vs. south

1-2 m; north < 1 m vs. north 1-2 m and; south < 1 m vs. south 1-2 M. When two different habitats were compared four separate t-tests were conducted in order to compare the four corresponding quadrants (eg., the north < 1 m quadrant of habitat A was only compared to the north < 1 m quadrant of habitat B and so on).

Mean DBHs for each habitat were compared using an Analysis of Variance using the null hypothesis that all means are equal. Critical value of *F* (α= 0.05) were found using tables published in Schefler (1988).

Lichen identification

The solvent systems and extraction techniques used for TLC analyses of lichen products follow those of Culberson (1972) and Culberson and Kristinsson (1970). Lichen extracts were prepared by placing small (3-4 mm^2) fragments of the lichen thallus into 0.5 dram screwcap vials. Three extractions, using three to five drops of acetone each, were carried out at room temperature. The extracts were evaporated on a glass slide with the aid of a slide warmer at a low heat setting. Heat facilitated evaporation of the acetone and crystallization of the lichen products onto the slide where they were stored until the chromatography plates could be prepared. A 10 cm x 20 cm Merck silica gel 60 F_{254} plate, stored in a desiccator prior to use, was utilized. A row of nine spots was applied along the short side of the plate 2 cm from the edge. One or two drops of acetone were

applied to the surface of a slide to dissolve the crystallized lichen products. The solution was collected in a micropipette and applied as a spot to the plate. Extracts of *Parmelia perforata* (Jacq.) Ach., which contains both atranorin and norstictic acid, were applied at locations one and nine of every plate. The plates were developed either in solvent system A (benzene-dioxane-acetic acid; 180:45:5 ml) or solvent system C (toluene-acetic acid; 200:30 ml) (Culberson, 1972). Since the lichens investigated in this study contained substances that separated in these two solvent systems, solvent system B was not utilized. Chromatograms run in solvent C were pre-treated for five minutes in an atmosphere of glacial acetic acid as described by Culberson (1974). A standard Brinkman chromatography tank was lined on three sides with chromatography paper and filled with the appropriate solvent to a depth of 1 cm. Chromatograms were developed at room temperature for forty-five minutes or until the front ran approximately 10 cm up the plate. The plates were air dried, and examined under UV light (254 nm and 366 nm) to identify spots that fluoresce. The plates were sprayed with a solution of 10% H_2SO_4, then placed in a 110°C oven for twenty minutes to visualize the spots.

Atranorin and norstictic acid were run along with unknowns on each plate. After developing the plates the spots of these two compounds were used to divide the plate

into eight R_f classes (Figure 4). All unknown spots were placed into R_f classes. Extracts of lichens containing known substances were also run along with unknowns on each plate to aid in identification.

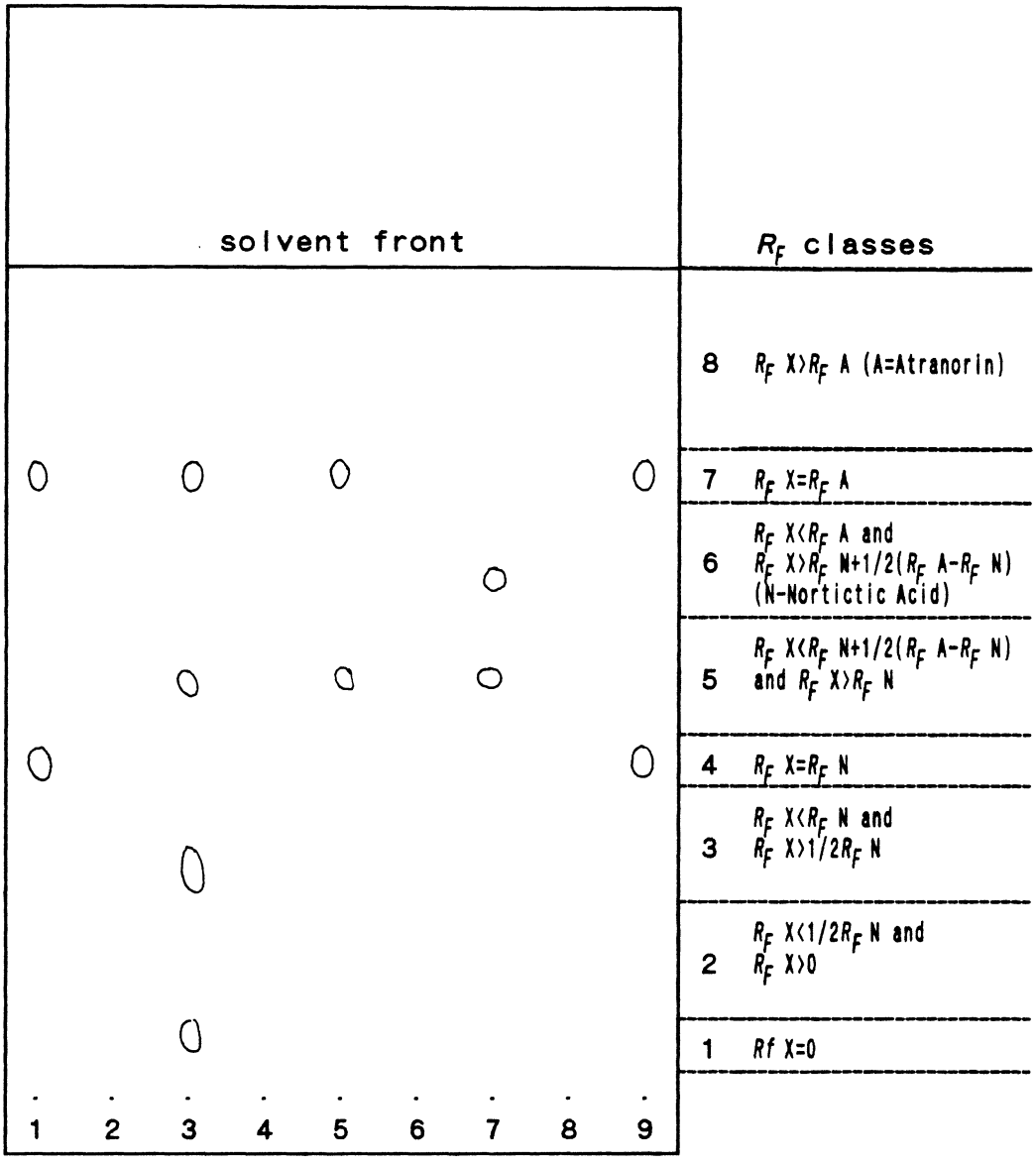

Figure 4. Diagram of a plate developed in solvent C including R_F classes used in the thin-layer chromatography method. Atranorin and norstictic acid are run as controls at positions 1 and 9. Other spots are as follows with R_F classes in brackets: Position 3; *Lepraria lobificans*: constictic acid [1-2], stictic acid [3], zeorin [5], atranorin [7]. Position 5; *Lepraria* sp#1: zeorin [5], atranorin [7]. Position 7; *Lecidea* sp#4: zeorin [5], usnic acid [6].

RESULTS AND DISCUSSION

Description of taxa

Descriptions of taxonomically important characteristics based on personal observations as well as pertinent literature references (in brackets) are included. Nomenclature follows that of Egan (1987).

Candelaria concolor (Dickson) B. Stein.

Thallus foliose, lemon yellow to greenish-yellow, lobes finely branched, 0.2 mm wide; soredia scattered; lower surface white, sparsely rhizinate. Medulla and cortex K-. [Hale, 1979]

Graphis scripta (L.) Ach.

Thallus crustose, superficial, white to ash grey; apothecia common, lirelliform fissures imbedded in thallus with raised black walls. [Wilhelm, 1993; Brodo, 1988]

Lepraria lobificans Nyl.

Thallus crustose, sterile, pale bluish-green; covered with fine, granular, pale bluish-green soredia. K+ yellow, P+ orange. Stictic acid, constictic acid, atranorin and zeorin. [Wilhelm, 1993]

Lepraria sp#1

Thallus crustose, superficial, sterile, green to pale grayish-green, covered with fine, granular soredia pale grayish-green. Cortex K+ yellow, C-. [Wilhelm, 1993]

Lecidea sp#4 *sensu* Harris

Thallus crustose, areolate, green to yellowish-green; covered with fine yellowish-green soredia. Cortex K+ yellow, C-, P-. [Wilhelm, 1993; Harris, 1978]

Phaeophyscia orbicularis (Necker) Moberg

Thallus foliose, brownish grey, lobes 0.5 mm wide; dark brown, soralia; lower surface black with black rhizines. [Wilhelm, 1993; Hale, 1979]

Phaeophyscia rubropulchra (Degel.) Moberg

≡ *Physcia orbicularis* f. *rubropulchra* Degel.

≡ *Physcia rubropulchra* (Degel.) Moberg

= *Physcia endochrysea* (Hampe) Nyl.

Thallus foliose, brownish green, lobes 0.5 mm wide; laminal soralia dark brown; lower surface black, densely rhizinate. Medulla orange-red, K+ purple. [Hale, 1979]

Physcia americana G. K. Merr.

= *P. tribacoides* auct. *non* Nyl.

Foliose, mineral grey, lobes 1-2 mm wide; soredia in laminal soralia; lower surface white, with rhizines. K+ yellow, C-. Atranorin. [Wilhelm, 1993; Hale, 1979]

Physcia millegrana Degel.

Foliose, lobes finely divided, less than 0.5 mm wide; soredia common; apothecia 0.5-1 mm diam., brown, pruinose. Cortex K+ yellow. Atranorin. [Hale, 1979]

Punctelia rudecta (Ach.) Krog

≡ *Parmelia rudecta* Ach.

Foliose, lobes broad 5 mm or more wide, upper surface bluish-gray to gray; pseudocyphellae present; laminal isidia present; apothecia lacking; lower surface tan, rhizinate. [Hale, 1979]

Chromatography results

A TLC plate developed in solvent C illustrates spots produced from several lichen extracts (Figure 4). The identity of two crustose lichens were confirmed using the TLC technique. An extract of *Lepraria lobificans*, position three, was confirmed by the presence of stictic acid, constictic acid, zeorin, and atranorin. *Lepraria* sp#1, position five, was confirmed by the presence of spots of zeorin and atranorin. The identity of *Lecidea* sp#4 *sensu* Harris was confirmed by the production of usnic acid and zeorin.

Community structure

Average DBH for sampled trees are reported in Table 1. When mean tree diameters were compared using an analysis of variance, no significant differences were found.

Community variables and species lists for each of the four habitats are summarized in Tables 2-5. Observed percent cover and frequency of occurrence for each species are included, as are the richness, evenness and the Shannon index of each quadrant of each habitat.

Only one species was sampled in the north quadrants of the Walnut Point closed canopy habitat. For this reason, Shannon diversity indices could not be calculated and the quadrants could not be included in any of the *t*-tests. When Shannon indices were compared using the *t*-test, no significant differences were found either within habitats of between different habitats.

Table 1. Mean diameter at breast height (cm) of trees sampled in each habitat.

	open canopy	closed canopy
Walnut Point	48.4	46.3
Fox Ridge	44.8	39.4

The open canopy habitats have considerably higher total cover than the closed canopy habitats. This difference is primarily due to the presence of *Physcia millegrana* in the open canopy habitats. *Physcia millegrana* is common on open canopy trees but was encountered only once in the closed canopy habitats. All other lichens reported here were found to occur less frequently than expected and had coverages of less than one percent.

Conclusions

The field and laboratory techniques used in this study are intended to be used for similar studies in the future. The use of cover classes is a highly effective technique for the estimation of lichen cover. However, the narrow cover classes used in this study are probably not necessary for most studies. A system using broader cover classes, such as

a geometric Scandinavian type (Oksanen, 1976) would probably provide sufficient accuracy in future studies. Although the use of ten tree samples has proven adequate in other studies (Eversman, 1982), larger samples may be required where lichens occur with lower cover.

The field methods used in this study were effective in obtaining quantitative data on lichen distribution. Some variation in corticolous lichen communities occurs, as shown by the Walnut Point closed canopy habitat. Much less variation was found than expected, however, indicating that site variables originally thought to be important in lichen distribution may not be. A study of microclimate variables affecting corticolous communities would provide much insight into ecological conditions important in lichen distribution.

Table 2. Summary data for open canopy white oaks at Walnut Point State Park.

	North < 1 M	North 1-2 M	South < 1 M	South 1-2 M
Richness	9	6	6	5
Evenness (*J'*)	0.67	0.38	0.53	0.21
Shannon diversity (*H'*)	0.64	0.29	0.41	0.15
Total % cover	3.6	3.3	7.1	8.1
		Percent cover		
		Frequency		
	North < 1 M	North 1-2 M	South < 1 M	South 1-2 M
Candelaria concolor	0.15	0.10	0.25	0.15
	0.3	0.2	0.5	0.5
Physcia millegrana	2.05	2.80	5.25	7.50
	0.6	0.6	0.5	0.6
Lepraria sp#1	0.45	0.10	0.40	0.05
	0.5	0.2	0.4	0.1
Lepraria lobificans	0.05	--	--	--
	0.1	--	--	--
Phaeophyscia rubropulchra	0.30	0.10	0.60	0.05
	0.2	0.2	0.4	0.1
Punctelia rudecta	0.10	--	--	--
	0.1	--	--	--
Graphis scripta	0.15	0.10	0.10	--
	0.3	0.2	0.2	--
Physcia americana	0.05	0.10	0.55	0.25
	0.1	0.2	0.3	0.1
Lecidea sp#4	0.25	--	--	--
	0.1	--	--	--

Note. Species with percent cover and frequency marked with a "--" did not occur in that quadrant.

Table 3. Summary data for closed canopy white oak trees at Walnut Point State Park.

	North < 1 M	North 1-2 M	South < 1 M	South 1-2 M
Richness	0	0	1	1
Evenness (J')	*	*	*	*
Shannon diversity (H')	*	*	*	*
Total % cover	0	0	0.05	0.05
		Percent cover		
		Frequency		
	North < 1 M	North 1-2 M	South < 1 M	South 1-2 M
Candelaria concolor	--	--	0.05	0.05
	--	--	0.1	0.1

Note. Because the quadrants had none or only one species, Shannon index and richness are marked as "*".

Table 4. Summary data for open canopy white oaks at Fox Ridge State Park.

	North < 1 M	North 1-2 M	South < 1 M	South 1-2 M
Richness	4	3	6	5
Evenness (*J'*)	0.22	0.32	0.30	0.47
Shannon diversity (*H'*)	0.13	0.15	0.23	0.33
Total % cover	3.9	4.0	3.1	2.5

	Percent cover			
	Frequency			
	North < 1 M	North 1-2 M	South < 1 M	South 1-2 M
Candelaria concolor	0.05	0.25	0.10	0.10
	0.1	0.5	0.2	0.2
Physcia millegrana	3.60	3.60	2.70	1.90
	0.7	0.7	0.8	0.8
Lepraria sp#1	0.15	0.10	0.05	0.10
	0.3	0.2	0.1	0.2
Phaeophyscia rubropulchra	--	--	0.05	0.25
	--	--	0.1	0.1
Punctelia rudecta	0.05	--	0.05	--
	0.1	--	0.1	--
Physcia americana	--	--	0.10	0.05
	--	--	0.2	0.1

Table 5. Summary data for closed canopy white oaks Fox Ridge State Park.

	North < 1 M	North 1-2 M	South < 1 M	South 1-2 M
Richness	6	6	4	5
Evenness (*J'*)	0.92	0.91	0.97	0.89
Shannon diversity (*H'*)	0.71	0.71	0.58	0.62
Total % cover	0.6	0.8	0.55	0.5
		Percent cover		
		Frequency		
	North < 1 M	North 1-2 M	South < 1 M	South 1-2 M
Candelaria concolor	0.20	0.20	0.15	0.20
	0.4	0.4	0.3	0.4
Lepraria sp#1	0.10	0.05	0.10	0.05
	0.2	0.1	0.2	0.1
Lecidea sp#4	0.05	--	--	--
	0.1	--	--	--
Punctelia rudecta	0.05	0.05	0.10	--
	0.1	0.1	0.2	--
Phaeophyscia orbicularis	0.05	0.15	--	0.05
	0.1	0.3	--	0.1
Phaeophyscia rubropulchra	0.10	0.10	0.20	0.10
	0.2	0.2	0.4	0.2
Physcia millegrana	--	0.25	--	0.05
	--	0.1	--	0.1

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