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OCCURRENCE OF CORTICOLOUS LICHENS IN A RURAL LOCALITY PRIOR TO OPERATION OF A NEW COAL FIRED POWER PLANT

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ABSTRACT

A survey of native lichen flora in the vicinity of a major coal-fired power plant was conducted in the summer of 1971 to identify potential bioindicators for air quality studies. The steam plant, located in the non-industrial area of Middle Tennessee, began commercial operation a year and a half later. Eighty-three species in thirty genera were identified and rated according to their abundance. Photographic records were collected of selected colonies to be compared with future photographs to be made during resurveys scheduled for two and five years after plant operation begins. This study is an intricate part of a complex surveillance effort to determine what, if any, effect a major power plant has on surrounding environment.

INTRODUCTION

One of the world's largest coal burning power plants has been constructed by the Tennessee Valley Authority (TVA) at Cumberland City in Stewart County, Tennessee. The plant has a generating capacity of 2,600 megawatts. Situated on the bank of the Cumberland River, approximately 50 miles northwest of Nashville, it is located in a rural, non-industrial area. The first of its two 1,300 megawatt units began commercial operation in the winter of 1972-73.

The TVA is concerned about the effect of its installations on the environment. Several studies concerned primarily with the effect of power plant operations on adjoining timber stands have been conducted since 1954. The most recent investigation started in the Cumberland area in 1968. It differs from the others in two major respects. First, surveillance began early enough to allow approximately four years for collection of baseline data. Second, rather than limit observations to a single resource, or at best to a few of particular interest as in the past, the collection of baseline data during the construction phase of this plant encompassed more overall information on atmospheric, biological, and related conditions. The Cumberland project affords an excellent opportunity to assess the effect of plant operations (stack gases in particular) on timber growth and survival and other forest and wildland resources in the area.

In the summer of 1971, during the preoperational period, a study of lichens also was begun. While lichens have no commercial value in this area, they are known to be very sensitive to air pollutants. Since there has been little industrial activity in the vicinity of the Cumberland power plant, many lichen species are still present that normally may be lacking in older industrial areas. If they sustain no injury now that plant operations have begun, this will be a good indication that other living organisms are equally unaffected. If some injury occurs, this will provide an opportunity to observe how individual species vary in sensitivity and to determine which are best suited for bioindicator use.

The Cumberland survey was limited to tree inhabiting or corticolous lichen species. They were recorded and photographed on 30 forestry surveillance test plots established in 1968. The plots are located at varying distances and directions from the power plant in areas containing numerous tree species (predominantly red oaks). Resurveys of lichens identified in 1971 will be conducted in the summer of 1974 and again in the summer of 1977 to determine any changes that may have occurred in species composition and condition.

PREVIOUS STUDIES

The effect of air pollutants on lichens have been noted for more than a century (Nylander, 1866). During recent years, botanists have attempted to analyze lichen populations in polluted areas to find out how and why they are affected and determine the possibility of using lichens as air pollution bioindicators. Aside from the North American studies in Canada (LeBlanc, 1961; LeBlanc and DeSloover, 1970; LeBlanc, Rao and Comeau, 1972; Rao and LeBlanc, 1967); and Brodo's work in the Long Island, New York area (Brodo, 1961 and 1966), most of the studies pertaining to air pollution effects on lichens have been conducted in Europe (Barkman, 1969; Beschel, 1958; Brightman, 1959; Fenton, 1960, 1964; Gilbert, 1965, 1970a, 1970b; Hawksworth and Rose, 1970; Skye, 1958, 1968; Skye and Hallberg, 1969; and others). Based on many of these studies, lichens have shown greater sensitivity to air pollution than have higher plants. At the same time, sensitivity also varies a great deal among different lichen species. *Lecanora dispersa* is known to be tolerant to air pollution and often is found in the center of cities. *Parmelia rudecta* and *Physcia orbicularis* (both of interest in this study) were found to be relatively sensitive to air pollution in Ontario (LeBlanc, Rao, and Comeau, 1972).

It has long been known that the growth of a city can have a detrimental influence on lichen populations. City-induced drought (Rydzak, 1958; Rydzak and Krysiak, 1970), as well as increased levels of air pollution (Skye, 1958; Brightman, 1959; Fenton, 1960, 1964; LeBlanc, 1961; Gilbert, 1965; Pearson and Skye, 1965; and others), have been cited as the culprits of this "city effect." An unresolved controversy exists as to which of these factors is the most pronounced. The drought conditions of cities caused by comparatively higher temperature and lower humidity will not, however, be a factor in the Cumberland study. Should a decline of the lichen populations be noted in this area after the calibration period, it would seem reasonable to investigate potential air pollution injury as well as other possible site factors to determine the cause.

In some previous studies lichens were observed at numerous stations around and at various distances from an existing factory or city. Maps were then prepared showing species occurrence, abundance, and vigor. The present study is an attempt to determine what, if any, effect a major power plant has on the surrounding environment. This opportunity exists because lichen populations will be studied before and after initiation of plant operations. In this study, as in most air pollution studies, only corticolous lichens were surveyed. These populations have a greater exposure to wind and, as a group, are more sensitive to air pollutants than soil and rock inhabitating lichens (Brodo, 1966).

Information compiled from previous lichen studies will be of little use in this study because the lichen flora is quite different from that of other areas investigated. Fruticose lichens, for example, are most sensitive to air pollution, but the only fruticose genera in the area are *Usnea* and *Ramalina*, and they are rare. In this study foliose lichens of the genera *Parmelia, Physcia, Pyxine,* and *Heterodermia* should be the best bioindicators. Also, observations on the less sensitive crustose lichens are included.

PROGRESS OF THE CUMBERLAND STUDY

Atmospheric sulfation monitoring instrumentation and a network of 30 forestry surveillance plots were established in 1968 and early 1969 at varying distances and in different directions from the power plant site (Figure 1). Eight of these forestry surveillance plots were located in the area which is expected to experience the highest frequency of ground level exposure to SO_2, i.e., in the prevailing downwind direction (northeast) from the steam plant between 3 and 8 miles. Fourteen plots were systematically distributed throughout the area within a 30-mile radius of the steam plant and eight other plots were located within TVA's Land Between The Lakes area which is expected to experience the lowest levels of SO_2 exposure. This latter area is located approximately 30 miles northwest of the steam plant on the Tennessee-Kentucky state line between Kentucky and Barkley Lakes.

Establishment Procedure

Corticolous lichens in predominantly red oak stands were identified and photographed on or near the 30 forestry surveillance plots during the summer of 1971. The plot locations used are similar in topography, stand composition, and site conditions. For the most part, the paired 1/5-acre plots are located on dry upland sites supporting natural stands of upland hardwoods with red oaks, white oaks, and hickories constituting the bulk of species present. Most stands are well-stocked with pulpwood and/or sawtimber-size trees. The average slope gradient is about 15 percent. Density of the canopies varies; therefore, light conditions, which play an important part in lichen development, necessitated the sampling of some trees near the edge of the woods in the vicinity but not always on the surveillance plot.

Each plot is being monitored for sulfur dioxide concentrations by a lead peroxide disc in a plastic container (Huey plate) which is mounted upside down in a clip holder fastened to a 2-inch diameter aluminum pipe at a height of approximately 7 feet. The exposure period is one month, which is the standard interval used by TVA at other locations and by other agencies in collecting this type of data.

Collecting and recording. Lichen flora was surveyed on an average of 6 trees per plot. Only lichens on living trees with a diameter at breast height of at least 4 inches were included. The sample trees were given a reference number by use of a small aluminum tag attached at a point 6 feet from the ground by an aluminum nail, and the location of each tree was recorded to facilitate the followup surveys. The presence and abundance of all species of lichens on each sample tree were observed and recorded on a field record sheet. When chemical analysis in the laboratory was required for positive identification, fragmented samples were collected and subsequently recorded on the field sheets. Observations and collections were taken from two sections of the bole of each tree: (1) the base from ground level to a height of one foot; (2) the trunk from a height of one foot to a height of 6 feet. The abundance of each species was recorded using a rating system from 1-4 as follows: (1) very abundant thalli, covering at least 40 percent of the section of a bole being surveyed; (2) numerous scattered thalli; (3) a few scattered thalli; (4) very scarce.

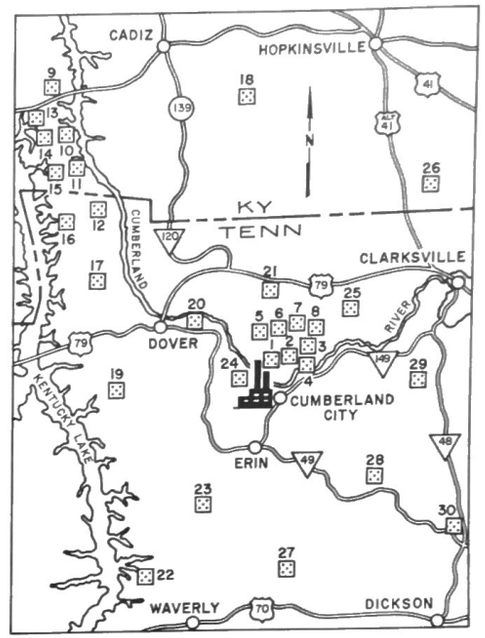

FIG. 1:

Location of Forestry Surveillance Plots in Cumberland Power Plant Area.

Photographing. For determination of possible changes in the lichen flora over the period of the study, selected colonies were photographed on one or more trees at each station or sample plot. To ensure validity of the study, it was important to photograph only healthy plants—those that appeared to show vigorous growth and those showing no symptoms of decline. The declension of a lichen is often indicated by an abnormal coloration such as pink, red, brown, or white. The thallus will begin to break apart and fall from the substrate. The center of the thallus (oldest part) falls away first leaving a ring formed by the outer lobes. Hawksworth (1971b) noted these stages in a study which reported the death of lichens in less than two years after transplanting to polluted areas.

The area of the tree photographed was marked by an aluminum tag which appeared in the lower left corner of each photograph. An aluminum nail was placed 1.5 inches to the

right of the tag. This serves as an aid to comparison of future photographs. Distance of the tag from the ground was recorded. To avoid confusion, a white card with the number of the test plot was pinned to the tree, included in each photograph,

TABLE 1: *Corticolous Lichens found in the Cumberland study area*

Species	Abundance[1]	Location of Plots: Near Plant	Control Area	Other
Allarthonia caesia	Scarce	8	-	29
Bacidia fuscorubella	Abundant	-	-	25
	Scarce	1	-	-
schweinitzii	Abundant	-	12	24,27
suffusa	Abundant	1	-	20,23,25
	Scarce	2	-	18
sp.[2]	Abundant	7	-	19,27,28
	Scarce	5,8	9-12,16	17,21,24,30
Blastenia pollinii	Scarce	4,6	-	29
Buellia punctata	Abundant	2	-	-
	Scarce	-	9	-
sp.[2]	Abundant	3,5	10-13,15	17,19,30
	Scarce	7,8	16	18,28
Caloplaca camptidia	Scarce	7	12	-
cerina	Scarce	-	-	19
holocarpa	Abundant	7	-	-
Candelaria concolor	Abundant	4,6	16	29
	Scarce	2,8	9,10-12,15	17,18,21,26
Cetraria viridis	Scarce	8	11,15,16	17,19
Cladonia spodocarpa	Scarce	-	-	17
caespiticia	Abundant	2,6	9,10,13,15,16	21,23,29
	Scarce	5	-	25,26,28
capitata	Abundant	-	12,15	17,27
	Scarce	4	10,11,13	-
chlorophaea	Abundant	2	-	-
	Scarce	-	12	-
coniocraea	Abundant	-	-	27
cristatella	Scarce	8	-	17
cylindrica	Abundant	2	-	-
	Scarce	-	10	-
decorticata	Scarce	-	15	-
grayi	Abundant	-	-	17
pyxidata	Abundant	-	11	17
subgariosa	Abundant	4	-	-
sp.[2]	Abundant	8	11,14,15	17,18,29
	Scarce	5,7	9,16	19,24,27
Coccocarpia cronia	Scarce	-	14	-
Collema conglomeratum	Scarce	-	9	-
furfuraceum	Abundant	-	-	18
subfurvum	Abundant	2	-	-
	Scarce	5	11,14	22,24,30
Dermatocarpon tuckermanii	Scarce	-	9	22
Graphis scripta	Abundant	-	11,16	-
	Scarce	-	9	18
sp.[2]	Scarce	5	-	28
Haematomma sp.[2]	Abundant	-	9	-
	Scarce	2	-	-
Heterodermia hypoleuca	Abundant	-	-	27
	Scarce	2	21	-
granulifera	Scarce	2	-	-
obscurata	Abundant	2	13	27
	Scarce	5-8	9-11,16	17,19,24-26,28-30
tremulans	Abundant	2,6	9	21,24,27
	Scarce	5,7,8	10-16	17,18,22,23,26,29,30
sp.[2]	Scarce	-	-	17
Lecanora cassiorubella	Abundant	3,5	11	19
	Scarce	2,7,8	9,12,13,15,16	17
chlarotera	Abundant	2-5,7	10-12	19,25,28-30
	Scarce	6,8	14-16	17,18,23,24,27
comizaea	Abundant	3,7,8	11	19,29
	Scarce	4,6	10,12-15	24,28
Lepraria membranacea	Scarce	2	-	-
sp.[2]	Abundant	2	-	21-23
	Scarce	5-8	9-12,16	17,18,25,27,28,30
Leptogium austroamericanum	Abundant	2	16	-
	Scarce	4	11	17,22
cyanescens	Abundant	6	-	30
	Scarce	1,2,5	9,11,13,15	19,23,24

TABLE 1 *(continued)*

Species	Abundance[1]	Location of Plots: Near Plant	Control Area	Other
Ochrolechia parella	Scarce	2	11,12,15	19,28
sp.[2]	Scarce	-	10,13	-
Opegrapha cinerea	Scarce	-	-	25
lichenoides	Abundant	-	10	18,23
sp.[2]	Abundant	-	13	18,24,25,28
	Scarce	-	11-13,16	17,20,25
Parmelia aurulenta	Abundant	1,2,4,5,7,8	13,14	18,21,23-25,27-30
	Scarce	6	9,10,12,15,16	17,19,26
bolliana	Abundant	5	-	17,30
	Scarce	-	-	19,25
caperata	Abundant	2	10,16	19,21,26,27
	Scarce	4,5,7,8	9,12,13,15	17,18,23,24,29
cetrata	Abundant	-	-	17
	Scarce	4	-	-
crinita	Abundant	-	-	19
crozalsiana	Abundant	5	-	-
	Scarce	3	12	21,29
dilatata	Scarce	-	-	27
dissecta	Scarce	2	-	17
galbina	Abundant	7	-	29
	Scarce	1	11,12	17,28
hypotropa	Abundant	1,2	-	19,24,29
	Scarce	4,5,7	10,12,13,15	21,27,28
livida	Abundant	2,4,5	9,14,15	19,21,27
	Scarce	3,8	10,12,13	17,18,24,29
madagascariacea	Abundant	2	-	-
michauxiana	Abundant	2	9	30
	Scarce	5	8	
perforata	Scarce	-	-	27
reticulata	Abundant	2	9,10	19,27
	Scarce	-	-	17,21,24,26,29
rudecta	Abundant	1,2,4,5,7,8	10,12-15	17-19,21,24,25,27-30
	Scarce	3,6	9,11,16	23,26
subrudecta	Scarce	8	-	21,24,30
subtinctoria	Scarce	2,5	-	27
texana	Scarce	-	-	21
tingtorum	Scarce	2	-	-
sp.[2]	Scarce	-	-	29
Pertusaria amara	Abundant	-	9	-
multipuncta	Abundant	2	14	-
	Scarce	-	9,12,13	17,21
pustulata	Abundant	5	10	-
	Scarce	3,7	11-13,15	23-25,28,29
tuberculifera	Scarce	2	-	-
velata	Scarce	-	11,14	23
sp.[2]	Abundant	-	9	27,30
	Scarce	2,5	10-16	17,19,21,24,26,28,29
Physcia ciliata	Scarce	6	-	18
grisea	Scarce	-	10	21,29
laciniulata	Abundant	-	10	22,30
	Scarce	-	9	24
millegrana	Abundant	1,4,7	12	18,25,29
	Scarce	5,6,8	10,11,13-16	17,19,28,30
orbicularis	Abundant	1,2,5-8	14	19,23-25,27,30
	Scarce	3,4	9-13,16	17,18,20-22,26,28,29
stellaris	Abundant	4,7	-	19,29
	Scarce	3,5,6,8	12-15	17,18,21,26,27
tribacoides	Abundant	2,6	9,13	25-28,30
	Scarce	1,4,7,8	10-12,14-16	17-19,24,29
Polychidium umbausense	Scarce	-	9	17,18,30
Porina cestrensis	Scarce	6	-	-
Pyrenula nitida	Abundant	5	11	-
	Scarce	1,7	9,10	20,25
sp.[2]	Scarce	7	-	-
Pyxine cassiopruinosa	Abundant	5-7	-	19,29,30
	Scarce	1,8	9,11-15	17,18,21,24,25,27,28
sorediata	Abundant	2,4	-	21,29
	Scarce	5,6,8	9,10,13,15,16	18,19,24,27,28,30
Ramalina fastigiata	Scarce	-	9	24
Rinodina sp.[2]	Scarce	7	12	25,27
Usnea mutabilis	Scarce	4	-	-
rubicunda	Scarce	2	-	-
strigosa	Abundant	2	-	-
sp.[2]	Scarce	-	-	19,27
Xanthoria fallax	Scarce	2	-	-

1. Abundant: Where at least one species on one or more sample trees possess numerous scattered or larger continuous patches of thalli. Scarce: Where individual lichen species are present but only in limited concentrations of a few scattered thalli.
2. Exact species unknown due to the absence of certain essential diagnostic characteristics.

and then removed. When additional groups of lichens were photographed at a given plot, they were designated by the addition of letters; i.e., 6A, 6B, 6C, etc. A Kodak Instamatic 304 camera was used with two Ektagraphic Visual-maker copy stands to choose from, depending on the desired area to be photographed. These stands have special close-up lens for exceptionally sharp focus. Use of the stands ensured that future photographs will be taken from the same distance. Kodachrome-X film was used for color slides, and a regular clear flash cube was used as the light source. A rough field drawing was made of the lichens if several species occur in one photographed section of the tree. These were labeled with a field identification. In some cases, a mark made by a knife was placed above a given lichen. The distance from the edge of the mark nearest the lichen and the edge of the lichen was recorded. The diameter of a few lichens was measured. A few trees with well developed lichen populations were photographed from a distance of several feet. Future photography will be taken at the same positions on the individual sample trees at periodic intervals.

The areas of selected lichen colonies will be determined by measuring 1971 photographs with a programmable calculator-digitizing system. Subsequent measurements of new imagery, which will be rephotographed during resurveys of the lichen flora will be compared with the initial measurements for determination of trends, if any, in lichen development in the area.

Description of Lichen Flora

The corticolous lichen flora of the Cumberland power plant area is composed mainly of foliose and crustose species. Common crustose genera in this area are *Buellia, Lecanora, Pertusaria,* and *Bacidia. Parmelia, Physcia, Pyxine,* and *Heterodermia* are common foliose genera. A total of 83 known species in 30 genera were observed in the area. The most common lichen is *Parmelia rudecta,* which was found on most of the trees examined. *Parmelia* is the dominant genus as well as the largest genus in the area. Twenty of the 83 identifiable species found in this survey are parmelias (Table 1).

Lichens were sampled on 166 trees comprising 20 species (Table 2). The most commonly used host species were scarlet oak (*Quercus coccinea*), southern red oak (*Q. falcata*), white oak (*Q. alba*), black oak (*Q. velutina*), sugar maple (*Acer saccharum*), and various hickories (*Carya* spp.). White oak proved to be the poorest for lichens in the Cumberland area. Typical species found on white oak were *Candelaria concolor* and *Physcia tribacoides.* In contrast, trees of the red oak group usually support a larger and more varied flora. Crustose lichens were most often found on the smooth bark of American beech, young hickories, and young maples.

Most of the lichens observed in the study area appear to be in good condition. As expected, the lichens show definite preferences for certain habitats. There was a difference in the lichen community at the base of a tree as opposed to the higher sections of the bole; hence, the base was examined separately from the remainder of the first six feet. The number of species per plot varied considerably. Some plots naturally were better than others. Plots that are only one or two miles apart may have a different species composition and a different development of individual lichens. Additional information about individual plots located within the three principal zones surrounding the plant is presented below.

Zone of Maximum Concentration. Plots 1-8 are located just north of the Cumberland power plant site in an area of greatest expected exposure to stack gases. Dictated by known prevailing wind direction and plume characteristics, the plots were established in a zone between azimuth readings of 345° and 33° and distances of 3 miles and 7 miles from the plant site. Lichen development on these plots ranged from good (Plots 2, 4, and 5) to fair (Plots 1, 7, and 8) and poor (Plots 3 and 6). The criteria used to judge good, fair, and poor plots were the number of different species present and the abundance of the predominant species. Survey highlights and impressions of the eight plots in this zone are mentioned below:

Plot 2 was the best study area in this zone and contained a large number of well-developed species. Within the entire 30-plot network, it was one of two locations for *Xanthoria,* and the only plot where *Usnea* was abundant enough to be of interest to the study. Although there were not many species at Plot 4, they were robust and mostly in good condition. The most notable development was in *Parmelia livida.* There were many lichens on plot 5.

Plot 1 is of interest mainly because of the unusual crustose species and the abundance of *Bacidia.* Plot 7 is unique because of the great abundance of *Caloplaca holocarpa*—an orange crustose species. This lichen was rare or absent in other parts of the major study area, but was prominent with

TABLE 2: *Lichen Flora on Sample Trees at each Sample Plot Location During Summer 1971 in Cumberland Power Plant Area*

Plot No.	Direction And Distance From Power Plant: Azimuth, Degrees	Miles	Sample Trees: No.	Kind	Lichens On Sample Trees: Condition & Development	Genera And Relative Abundance [a]	No. Species
1	345	3	3	Maple	Fair	Abundant—Bacidia, Parmelia, Physics	11
						Scarce—Leptogium, Pyrenula, Pyxine	3
2	7	4	6	Ash, Cherry, Hickory, Maple, Oak	Good	Abundant—Buellia, Cladonia, Collema, Heterodermia, Lecanora, Lepraria, Leptogium, Parmelia, Pertusaria, Physcia, Pyxine, Usnea	32
						Ecarce—Bacidia, Candelaria, Haematomma Ochrolechia, Xanthoria	5
3	23	5	2	Hickory, Oak	Poor	Abundant—Buellia, Lecanora	4
						Scarce—Parmelia, Pertusaria, Physcia	6
4	26	4	4	Oak	Good	Abundant—Candelaria, Cladonia, Lecanora, Parmelia, Physcia, Pyxine	16
						Scarce—Blastenia, Leptogium, Usnea	3
5	357	7	8	Hickory, Oak, Tuliptree	Good	Abundant—Buellia, Lecanora, Parmelia, Pertusaria, Physcia, Pyrenula, Pyxine	21
						Scarce—Bacidia, Cladonia, Collema, Graphis, Heterodermia, Lepraria, Leptogium	9
6	9	7	5	Hickory, Oak	Poor	Abundant—Candelaria, Cladonia, Heterodermia, Leptogium, Physcia, Pyxine	12
						Scarce—Blastenia, Lecanora, Lepraria, Parmelia, Porina	7

[a] Abundant: Where at least one species on one or more sample trees possess numerous scattered or larger continuous patches of thalli. Scarce: Where individual lichen species are present but only in limited concentrations of a few scattered thalli.

TABLE 2: *Lichen Flora on Sample Trees at each Sample Plot Location During Summer 1971 in Cumberland Power Plant Area (Continued)*

Direction And Distance From Power Plant			Sample Trees		Lichens On Sample Trees		
Plot No.	Azimuth, Degrees	Miles	No.	Kind	Condition & Development	Genera And Relative Abundance *	No. Species
7	25	7	5	Hickory, Oak, Tuliptree	Fair	Abundant—Bacidia, Caloplaca, Lecanora, Parmelia, Physcia, Pyxine	17
						Scarce—Buellia, Cladonia, Heterodermia, Lepraria, Pertusaria, Pyrenula, Rinodina	8
8	33	6	6	Hickory, Oak, Redbud, Sourwood, Tuliptree	Fair	Abundant—Cladonia, Lecanora, Parmelia, Physcia	15
						Scarce—Allarthonia, Bacidia, Buellia, Candelaria, Cetraria, Heterodermia, Lepraria, Pyxine	10
9	325	34	10	Hickory, Oak	Good	Abundant—Cladonia, Haematomma, Heterodermis, Parmelia, Pertusaria, Physcia	15
						Scarce—Bacidia, Buellia, Candelaria, Collema, Dermatocarpon, Graphis, Lecanora, Lepraria, Leptogium, Polychidium, Pyrenula, Pyxine, Ramalina	14
10	322	31	5	Oak	Poor	Abundant—Buellia, Cladonia, Lecanora, Opegrapha, Parmelia, Pertusaria, Physcia	19
						Scarce—Bacidia, Candelaria, Heterodermia, Lepraria, Ochrolechia, Pyrenula, Pyxine	8
11	320	28	9	Hickory, Oak	Good	Abundant—Buellia, Cladonia, Graphis, Lecanora, Pyrenula	8
						Scarce—Bacidia, Candelaria, Cetraria, Collema, Heterodrmia, Lepraria, Leptogium, Ochrolechia, Opegrapha, Parmelia, Pertusaria, Physcia, Pyxine	19
12	318	25	8	Elm, Oak, Sourwood	Good	Abundant—Bacidia, Buellia, Cladonia, Lecanora, Parmelia, Physcia	19
						Scarce—Caloplaca, Candelaria, Heterodermia, Lepraria, Ochrolechia, Opegrapha, Pertusaria, Pyxine Rinodina	10
13	319	35	4	Hickory, Oak	Poor	Abundant—Buellia, Cladonia, Heterodermia, Opegrapha, Parmelia, Physcia	15
						Scarce—Lecanora, Leptogium, Ochrolechia, Pertusaria, Pyxine	8
14	317	33	5	Hickory, Oak	Fair	Abundant—Cladonia, Parmelia, Pertusaria, Physcia	10
						Scarce—Coccocarpia, Collema, Heterodermia, Lecanora, Pyxine	6
15	315	30	5	Oak	Fair	Abundant—Buellia, Cladonia, Parmelia	9
						Scarce—Candelaria, Cetraria, Heterodermia, Lecanora, Leptogium, Ochrolechia, Pertusaria, Physcia, Pyxine	14
16	311	26	5	Oak	Poor	Abundant—Candelaria, Cladonia, Graphis, Leptogium, Parmelia	7
						Scarce—Bacidia, Buellia, Cetraria, Heterodermia, Lecanora, Lepraria, Opegrapha, Pertusaria, Pyxine	14
17	308	22	8	Oak	Poor	Abundant—Buellia, Cladonia, Parmelia	15
						Scarce—Bacidia, Candelaria, Cetraria, Heterodermia, Lecanora, Lepraria, Leptogium, Opegrapha, Pertusaria, Physcia, Polychidium, Pyxine	17
18	354	29	5	Hickory, Oak, Tuliptree	Poor	Abundant—Cladonia, Collema, Opegrapha, Parmelia, Physcia	12
						Scarce—Bacidia, Buellia, Candelaria, Graphis, Heterodermia, Lecanora, Lepraria, Polychidium, Pyxine	10
19	263	14	5	Beech, Hickory, Oak, Sassafras	Good	Abundant—Bacidia, Buellia, Lecanora, Parmelia, Physcia, Pyxine	19
						Scarce—Caloplaca, Cetraria, Cladonia, Heterodermia, Leptogium, Ochrolechia, Pertusaria, Usnea	8
20	319	10	3	Hickory	Poor	Abundant—Bacidia	1
						Scarce—Opegrapha, Physcia, Pyrenula	3
21	357	10	4	Ash, Oak	Good	Abundant—Cladonia, Heterodermia, Lepraria, Parmelia, Pyxine	15
						Scarce—Bacidia, Candelaria, Pertusaria, Physcia	6
22	215	18	2	Elm, Oak	Poor	Abundant—Lepraria, Physcia	3
						Scarce—Collema, Dermatocarpon, Heterodermia, Leptogium	4

* Abundant: Where at least one species on one or more sample trees possess numerous scattered or larger continuous patches of thalli. Scarce: Where individual lichen species are present but only in limited concentrations of a few scattered thalli.

TABLE 2: *Lichen Flora on Sample Trees at each Sample Plot Location During Summer 1971 in Cumberland Power Plant Area (Continued)*

Direction And Distance From Power Plant			Sample Trees		Lichens On Sample Trees		
Plot No.	Azimuth, Degrees	Miles	No.	Kind	Condition & Development	Genera And Relative Abundance *	No. Species
23	217	11	7	Maple, Oak	Poor	Abundant—Bacidia, Cladonia, Lepraria, Opegrapha, Parmelia, Physcia	8
						Scarce—Heterodermia, Lecanora, Leptogium, Pertusaria	5
24	304	3	4	Hickory, Oak	Good	Abundant—Bacidia, Heterodermia, Opegrapha, Parmelia, Physcia	14
						Scarce—Cladonia, Collema, Lecanora, Leptogium, Pertusaria, Pyxine, Ramalina	9
25	35	9	4	Ash, Maple, Oak	Poor	Abundant—Bacidia, Lecanora, Opegrapha, Parmelia, Physcia	10
						Scarce—Cladonia, Heterodermia, Lepraria, Pertusaria, Pyrenula, Pyxine, Rinodina	7
26	37	24	1	Oak	Poor	Abundant—Parmelia, Physcia	7
						Scarce—Candelaria, Cladonia, Heterodermia, Pertusaria	5
27	172	15	8	Hickory, Oak	Good	Abundant—Bacidia, Cladonia, Heterodermia, Parmelia, Pertusaria, Physcia	19
						Scarce—Lecanora, Lepraria, Pyxine, Rinodina, Usnea	6
28	124	11	7	Hickory, Oak, Sweetgum	Poor	Abundant—Bacidia, Lecanora, Opegrapha, Parmelia, Physcia	11
						Scarce—Buellia, Cladonia, Graphis, Heterodermia, Lepraria, Ochrolechia, Pertusaria, Pyxine	9
						Parmelia, Physcia, Pyxine	19
29	85	14	11	Hickory, Oak, Sassafras, Tuliptree	Good	Abundant—Candelaria, Cladonia, Lecanora,	
						Scarce—Allarthonia, Blastenia, Heterodermia, Pertusaria	5
30	129	21	5	Hickory, Oak	Poor	Abundant—Buellia, Lecanora, Leptogium, Parmelia, Pertusaria, Physcia, Pyxine	15
						Scarce—Bacidia, Collema, Heterodermia, Lepraria Polychidium	6

* Abundant: Where at least one species on one or more sample trees possess numerous scattered or larger continuous patches of thalli. Scarce: Where individual lichen species are present but only in limited concentrations of a few scattered thalli.

Lecanora chlarotera on hickories at this location. Plot 8 is an average plot with not too many species, but it is one of the few plots in the network at which *Cetraria viridis* was found.

Plot 3 is of little use because of a recent fire; however, it will be of interest if lichens return to the bare bark of some of the trees. Few lichens are present on Plot 6 in sharp contrast to Plot 5 which is only a mile away. One reason could be the more mature mixed woods at Plot 5. The trees at Plot 6 are mostly young oaks.

Control Area. The control plots (numbers 9-16) are located 25-35 miles northwest of the Cumberland Steam Plant in the Land Between The Lakes recreation area. The forests in the area are chiefly dry, upland hardwoods. Such areas form a favorable habitat for lichens, and many species are present. *Pertusaria* spp., *Parmelia livida, P. aurulenta,* and *P. rudecta* are especially abundant. Lichen development on this group of plots ranges from good (Plots 9, 11, and 12), to fair (Plots 14 and 15), and poor (Plots 10, 13, and 16). Survey highlights and impressions of the eight control plots from the standpoint of their lichen flora are as follows:

Plot 9 was notable for some unusual or rare species including *Dermatocarpon tuckermanii, Collema conglomeratum, Physicia lacinulata, Polychidium umhausense,* and *Ramalina fastigiata.* Species of *Heterodermia, Haematomma* and *Pertusaria* are quite abundant and well developed. Plots 11 and 12 were quite similar. Both support the somewhat rare *Rinodina* spp. and *Ochrolechia parella.* Individual lichens were numerous on most trees and in good condition, especially at Plot 11.

Several acres of forest were cleared in the summer of 1971, adjacent to Plot 14. The resulting increase in light, wind, and dust could alter the condition or species composition of the lichens. Plot 15 was average, but notable for relatively large amounts of *Lecanora* spp. and for the presence (although rare) of *Cetraria viridis.*

Plots 10, 13, and 16 were poor. The lichens that are present were only partly developed.

Intermediate Zone. Plots 17-30 are widely scattered in all directions from the Cumberland site. Plot 24 is within three miles of the power plant; the remaining plots from 9 to 29 miles away. Plots 17, 18, 19, 22, 26, 27, 29, and 30 are the most distant and some or all of these may prove suitable for use as controls. Ranked according to abundance of lichen flora and anticipated utility in the study, plots in the intermediate zone, on the whole, either were classed as good (Plots 19, 21, 24, 27, and 29) or poor (Plots 17, 18, 20, 22, 23, 25, 26, 28, and 30).

Optimum conditions for lichens seemed to exist on Plot 19. There are not a large number of species, but the individual plants were robust and in perfect condition. *Parmelia rudecta* had well-developed apothecia, which is rare and which reflects the good conditions of the area. The presence of *Parmelia bolliana, Caloplaca cerina, Cetraria viridis,* and *Usnea* spp. also is noteworthy. A supplementary Plot 19 was set up at a nearby location because of the presence of *Parmelia crinita,* the only place where this species was observed. Plot 21 was one of the best plots. The number of species was not great, but some rarely encountered species were present, and the individuals were robust and in good condition. *Heterodermia hypoleuca* with numerous apothecia was best developed here. Also notable were *Parmelia texana, P. subrudecta, P. crozalsiana,* and *Physcia grisea.* The rare *Ramalina fastigiata* was present on Plot 24, but not abundant. Most trees on this plot

support a large number of lichens. Plot 27 had a rich lichen flora. The many large parmelias including *P. subrudecta* (rare in the study area), *P. hypoleuca*, *P. rudecta*, *P. dilatata*, *P. sorediata*, and *P. perforata* were impressive. *Bacidia schweinitzii* was well developed on some of the trees. The presence of *Ramalina* and *Usnea* are also indicators of a rich flora. Species found on Plot 29 were very common with the exception of *Parmelia conspersa*.

Plots 17 and 18 are poor locations for lichens, but a rare species (*Lobaria pulmonaria*) happened to be better developed on Plot 18 than anywhere else. Plot 20 is in a river bottom forest and only *Physcia* and some crustose species were present. The remaining six plots (22, 23, 25, 26, 28, and 30) are relatively poor in terms of lichen development and condition; although some of these plots had peculiarities which may or may not be significant in future surveys.

Bark pH Determination

The bark pH of certain species of host trees was determined for some of the plots. Subsequent changes and the effect of these changes on common lichen species if any will be noted if such a situation occurs. Bark samples from 1-3 of the most commonly used host species supporting 2 or 3 predominant lichen species found throughout the Cumberland area was collected and analyzed and this procedure will be repeated at different intervals in the future.

Future Plans

In future years, more field data collection, analysis, and reporting will be done. Present scheduling calls for a resurvey of all plots after the power plant has been in operation for two and five years. Data analysis will be geared toward determining relative susceptibility of lichen species in the area, correlating the degree to which lichens are injured with atmospheric and forest tree observations made at each forest surveillance plot location, and determining the extent to which selected species of lichens can be used as bioindicators of air pollution. At the end of the five-year period a comprehensive report will be prepared evaluating the results of the study.

SUMMARY

Lichens are known to be one of the most intolerant groups of plants to air pollutants. The Cumberland power plant is coal fired with a generating capacity of 2,600 megawatts and is located in a non-industrial rural area. In summer 1971 a survey of corticolous lichen flora was conducted in the Cumberland power plant area before the plant began operation. A total of 83 known species in 30 genera were observed on 20 tree species throughout the area. The most common lichen genera were *Parmelia*, *Physcia*, *Pyxine*, and *Heterodermia*, of the foliose group, and *Buellia*, *Lecanora*, *Pertusaria*, and *Bacidia* of the crustose group. Fruticose genera were rare.

Resurveys scheduled in two and five years after the plant has been in operation will provide information on the effect of stack gases on the lichen flora, and possibly indicate which lichen species are best suited for bioindicator plant use in future air pollution studies.

LITERATURE REVIEW

Barkman, J. J. 1969. The influence of air pollution on bryophytes and lichens. *In* Air Pollution. Proceedings of the First European Congress on the Influence of Air Pollution on Plants and Animals. Wageningen. 1968. pp. 197-209.

Beschel, R. 1958. Flechtenvereine der Städte, Stadtflechten und ihr Wachstum. Berlin Naturwiss.-Med. Ver. Innsbruck 52:1-158.

Brightman, F. H. 1959. Some factors influencing lichen growth in towns. Lichenologist 1:104.

Brodo, I. M. 1961. Transplant experiments with corticolous lichens using a new technique. Ecology 42:838-841.

_____. 1966. Lichen growth and cities: a study on Long Island, New York. Bryologist 69:427-449.

Fenton, A. F. 1960. Lichens as indicators of atmospheric pollution. Irish Nat. Jour. 13:153-159.

_____. 1964. Atmospheric pollution of Belfast and its relationship to lichen flora. Irish Nat. Jour. 14:237-245.

Gilbert, O. L. 1965. Lichens as indicators of air pollution in the Tyne Valley. *In* Ecology and the Industrial Society. Oxford. pp. 35-47.

_____. 1970a. Further studies on the effect of sulfur dioxide on lichens and bryophytes. New Phytol. 69:605-627.

_____. 1970b. A biological scale for the estimation of sulfur dioxide pollution. New Phytol. 69:629-634.

Hawksworth, D. L. 1971. *Lobaria pulmonaria* (L.) Hoffm. transplanted into Dovedale, Derbyshire. Naturalist 1971:127-128.

Hawksworth, D. L. and F. Rose. 1970. Qualitative scale for estimating sulphur dioxide air pollution in England and Wales using epiphytic lichens. Nature 227:145-148.

LeBlanc, F. 1961. Inkuence de l'atmosphère polluée des grandes agglomérations urbaines sur les epiphytes corticoles. Rev. Canad. Biol. 20:823-827.

LeBlanc, F. and De Sloover. 1970. Relation between industrialibation and the distribution and growth of epiphytic lichens and mosses in Montreal. Can. Jour. Bot. 48:1485-1496.

LeBlanc, F., D. N. Rao, and G. Comeau. 1972. The epiphytic vegetation of *Populus balsamifera* and its significance as an air pollution indicator in Sudbury, Ontario. Can. Jour. Bot. 50:519-528.

Nylander, W. 1866. Les Lichens du Jardin du Luxembourg. Bull. Soc. Bot. Fr. 13:364-372.

Pearson, L. and E. Skye. 1965. Air pollution affects pattern of photosynthesis in *Parmelia sulcata*, a corticolous lichen. Science 148:1600-1602.

Rao, D. N. and F. LeBlanc. 1967. Influence of an iron-sintering plant on the epiphytic vegetation in Wawa, Ontario, Bryologist 70:141-157.

Rydzak, J. 1958. Influence of small towns on the lichen vegetation Part VII. Discussion and general conclusions. Ann. Univ. Mariae Curie-Sklodowska. Sect. C, 13:275-323.

Rydzak, J. and K. Krysiak. 1970. Lichen flora of Tomaszow Mazowiecki. Vegetatio 21:375-397.

Skye, E. 1958. Luftfororeningars inverkan på busk- och bladlavfloran kring skifferoljeverket i närkes Kvarntorp. Svensk Bot. Tidsk. 52:133-190.

_____. 1968. Lichens and air pollution. Acta Phytgeogr. Suec. 52:1-123.

Skye, E. and I. Hallberg. 1969. Changes in the lichen flora following air pollution. Oikos 20:547-552.