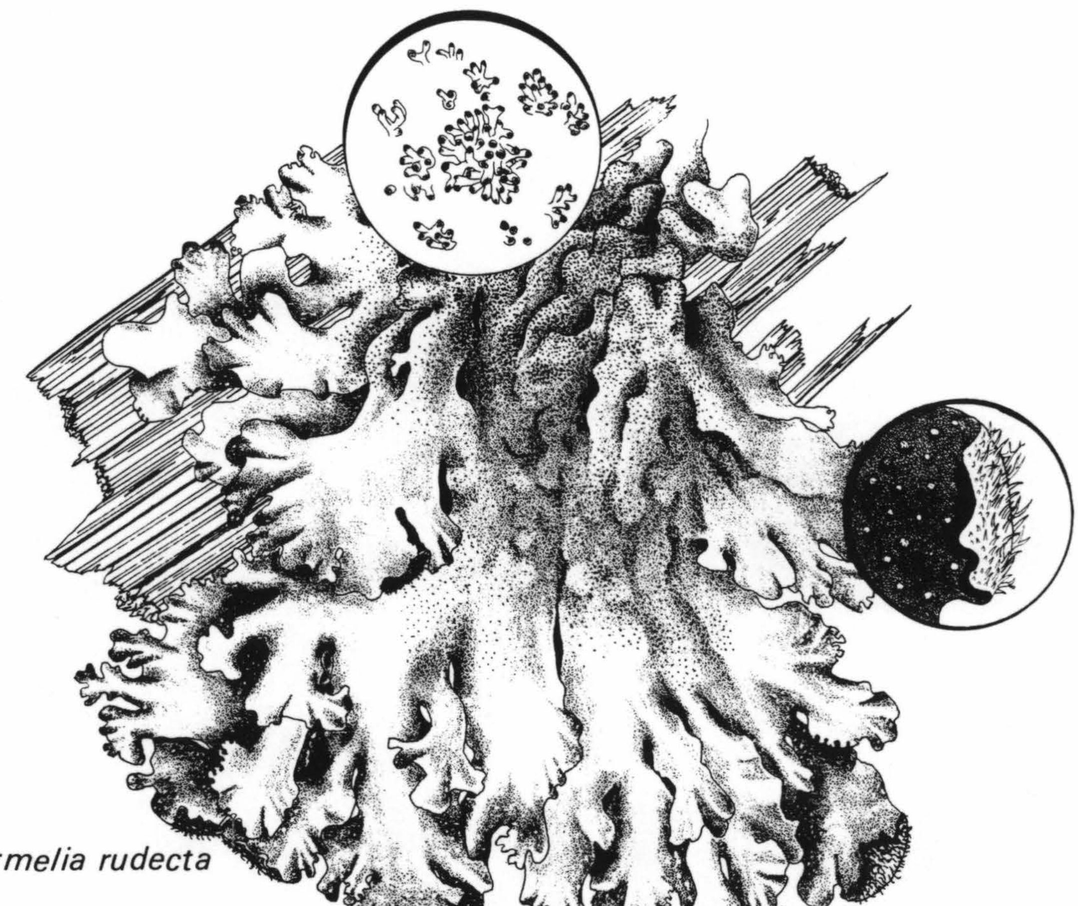
LICHENS AND AIR QUALITY IN

GEORGE WASHINGTON CARVER NATIONAL MONUMENT

FINAL REPORT

Supported by
National Park Service
Contract USDA 42-649



Parmelia rudecta

CLIFFORD M. WETMORE
PLANT BIOLOGY DEPARTMENT
UNIVERSITY OF MINNESOTA
ST. PAUL, MN 55108

OCTOBER 1992

LICHENS AND AIR QUALITY

IN

GEORGE WASHINGTON CARVER NATIONAL MONUMENT

Final Report

Prepared for

National Park Service
Midwest Regional Office
1709 Jackson St.
Omaha, Neb. 68102

USDA/42-649

by

Clifford M. Wetmore
Botany Department
University of Minnesota
St. Paul, Minnesota

June, 1992

TABLE OF CONTENTS

LICHENS OF GEORGE WASHINGTON CARVER NATIONAL MONUMENT

ABSTRACT

This study was to establish a base line lichen flora and elemental analysis figures for George Washington Carver National Monument. Lichen collections were made throughout the forested area of the park (considered one locality) and samples of one lichen were collected for elemental analysis.

There were 38 taxa of lichens found. Only a few species known to be most sensitive to sulfur dioxide grow in this region and few were found in the park. The health and fertility of the lichens were normal. The elemental analysis showed no abnormally high levels of elements. There was no indication of an air quality problem in the park now.

It is recommended that if new pollution sources are established nearby a restudy should be done.

PREFACE

Under a contract with the National Park Service through the U. S. Forest Service (USDA/42-649) a lichen study was to be performed in George Washington Carver National Monument. This study was to survey the lichens of the park, produce a lichen flora, collect and analyze lichens for chemical contents and evaluate the lichen flora with reference to the air quality. This study was to establish baseline data for future restudy and determine the presence of any air quality problems that might be shown by the lichens at the time of the study. All work was done at the University of Minnesota with frequent consultation with Dr. James Bennett, Great Lakes CPSU, Madison, Wisc. and with personnel in the park.

The park personnel have been very helpful during the field work in providing local information which has contributed significantly to the success of the project. The study was made possible by funds from the National Park Service. The assistance of all of these is gratefully acknowledged.

INTRODUCTION

Lichens are composite plants composed of two different types of organisms. The lichen plant body (thallus) is made of fungi and algae living together in a symbiotic arrangement in which both partners are benefited and the composite plant body can grow in places where neither component could live alone. The thallus has no protective layer on the outside, such as the epidermis of a leaf, so the air in the thallus has free exchange with the atmosphere. Lichens are slow growing (a few millimeters per year) and remain alive for many years and so must have a habitat that is relatively undisturbed in order to survive. Lichens vary greatly in their ecological requirements but almost all of them can grow in places that only receive periodic moisture. When moisture is lacking they go dormant until the next rain or dew-fall. Some species can grow in habitats with very infrequent occurrences of moisture while others need high humidity and frequent wetting in order to survive. This difference in moisture requirements is very important in the distribution of lichens.

Lichens are known to be very sensitive to low levels of many atmospheric pollutants. Many are damaged or killed by levels of sulfur dioxide, nitrogen oxides, fluorides or ozone alone or in various combinations. Levels of sulfur dioxide as low as 13 ug/cubic meter (annual average) will cause the death of some lichens (LeBlanc et al., 1972). Other lichens are less sensitive and a few can tolerate levels of sulfur dioxide over

300 ug/cubic meter (Laundon, 1967, Trass, 1973). The algae of the thallus are the first to be damaged in areas with air pollution and the first indication of damage is discoloring and death of the algae causing bleached lobes, which quickly leads to the death of the lichen. After the lichen dies it disappears from the substrate within a few months to a year as it disintegrates and decomposes (Wetmore, 1982).

Lichens are more sensitive to air pollution when they are wet and physiologically active and are least sensitive when dry (Nash, 1973, Marsh & Nash, 1979) and are more sensitive when growing on acid substrates.

Contrary to some published reports (Medlin, 1985) there is little evidence that most lichens are good indicators of acid precipitation. However, Sigal & Johnston (1986) have reported that one species of Umbilicaria shows visible damage due to artificial acid rain. They also report that similar symptoms were found in collections from various localities in North America. Lechowicz (1987) reported that acid rain only slightly reduced growth of Cladina stellaris but Hutchinson et al. (1986) reported that extremely acid precipitation killed or damaged some mosses and lichens. Scott & Hutchinson (1987) showed temporary reduction of photosynthesis in Cladina stellaris and C. rangiferina after artificial acid rain.

Lichens are able to accumulate chemical elements in excess of their metabolic needs depending on the levels in the substrate and the air and, since lichens are slow growing and long lived, they serve as good summarizers of the environmental conditions in which they are growing. Chemical analysis of the thallis of lichens growing in areas of high fallout of certain elements will show elevated levels in the thallus. Toxic substances (such as sulfur) are also accumulated and determination of the levels of these toxic elements can provide indications of the sub-lethal but elevated levels in the air.

George Washington Carver National Monument (GWCA) is located in Newton County, Missouri, 10 miles southeast of Joplin in the southwestern corner of the state and was established in 1943. It comprises a small area around the historic home of George Washington Carver. The park is only 210 acres, partly in forests and fields and partly in mowed lawn with scattered trees. There are also three small streams and a small pond in the park. Because of the small size of the park, collections were made throughout most of the park in all suitable habitats. The area known as Harkins Grove was not visited. Some of the agricultural areas were checked for lichens but no lichens were found there.

Most of the area within the park boundaries has been managed or disturbed. The only rocks are on the bases of some of the monuments and on a recently reconstructed stone wall around the cemetery. The most comon trees are hackberry (*Celtis occidentalis*), green ash (*Fraxinus pennsylvanica*) and walnut (*Juglans* spp.).

There have been no previous lichen collections from within the park boundaries and only a few collections in the region, however, a study done parallel to the GWCA study was done in the Hercules Glades Wilderness of the Mark Twain National Forest and most of the species in GWCA are aslo in the Hercules Glades Wilderness.

METHODS

Field work was done during September, 1991 when 55 collections were made within the park (considered one locality). There are several agricultural fields in the park but no lichens were found in them. Collections were made both in the woods and in the yard. While collecting observations were made about the general health of the lichens.

Identifications were carried out at the University of Minnesota with the aid of comparison material in the herbarium and using thin layer chromatography for identification of the lichen substances where necessary. The original packet of each collection has been deposited in the University of Minnesota Herbarium and a representative set of duplicates has been sent to the park. All specimens deposited at the University of Minnesota have been entered into the herbarium computerized data base maintained there.

LICHEN FLORA

The following list of lichens is based on my collections. In the first columns the letters indicate the sensitivity to sulfur dioxide, if known, according to the categories proposed by Wetmore (1983): S=Sensitive, I=Intermediate, T=Tolerant. S-I is intermediate between Sensitive and Intermediate and I-T is intermediate between Intermediate and Tolerant. Species in the Sensitive category are absent when annual average levels of sulfur dioxide are above 50ug per cubic meter. The Intermediate category includes those species present between 50 and 100ug and those in the Tolerant category are present at over 100ug per cubic meter.

SPECIES LIST

Acarospora fuscata (Nyl.) Arn.
Acarospora schleicheri (Ach.) Mass.
Arthonia caesia (Flot.) Körb.
Bacidia circumspecta (Nyl. ex Vain.) Malme
Bacidia rubella (Hoffm.) Mass.
Buellia stigmaea Tuck.
S-I Caloplaca cerina (Ehrh.) Th. Fr.
Caloplaca cinnabarina (Ach.) Zahlbr.
Caloplaca flavovirescens (Wulf.) Dalla Torre & Sarnth.
Caloplaca sideritis (Tuck.) Zahlbr.
Caloplaca ulmorum (Fink) Fink
S-I Candelaria concolor (Dicks.) B. Stein
Candelaria fibrosa (Fr.) Müll. Arg.
Candelariella vitellina (Hoffm.) Müll. Arg.
Dimelaena oreina (Ach.) Norm.
Eopyrenula leucoplaca (Wallr.) R. Harris
Hyperphyscia syncolla (Tuck. ex Nyl.) Kalb
Lecanora hybocarpa (Tuck.) Brodo
Lecanora strobilina (Spreng.) Kieff.
Lecidella carpathica Körb.
1 unidentified species of Lepraria
Opegrapha varia Pers.
Parmelia bolliana Müll. Arg.
I Parmelia caperata (L.) Ach.
Parmelia cumberlandia (Gyeln.) Hale
Parmelia margaritata Hue
I Parmelia rudecta Ach.
I Parmelia subrudecta Nyl.
1 unidentified species of Pertusaria
Phaeophyscia ciliata (Hoffm.) Moberg
Phaeophyscia hirsuta (Meresch.) Essl.
I Physcia aipolia (Ehrh. ex Humb.) Fürnr.
Physcia americana G. K. Merr. in Evans & Meyrow.
T Physcia dubia (Hoffm.) Lett.
I Physcia millegrana Degel.
I Physconia detersa (Nyl.) Poelt
1 unidentified species of Pyxine
S Ramalina americana Hale
1 unidentified species of Rinodina
Sarcogyne regularis Körb.
Teloschistes chrysophthalmus (L.) Th. Fr.
S-I Xanthoria fallax (Hepp in Arn.) Arn.

DISCUSSION OF FLORA

This list includes 38 species collected for this study. There are also and additional 4 unidentified species, some of which are undescribed. The most common species are Candelaria concolor, Hyperphyscia syncolla, Parmelia bolliana, Parmelia rudecta, and Physcia aipolia. Caloplaca ulmorum was abundant on one tree in the yard but was not found in Hercules Glades. All other species in GWCA were also found in Hercules Glades. The number of species in the park is typical for such a small, disturbed area with limited kinds of substrates. The scarcity of rocks greatly reduces the number of species. There are no historical records of lichens from the park so no historical comparison can be made.

The lichen flora is reasonable diverse for such a small area. There were no cases where lichens sensitive to sulfur dioxide were observed to be damaged or killed. All species normally found fertile were also fertile in the park. These observations indicate that there is no air quality degradation in the park due to sulfur dioxide that causes observable damage to the lichen flora.

ELEMENTAL ANALYSIS

An important method of assessing the effects of air quality is by examining the elemental content of the lichens (Nieboer et al, 1972, 1977, 1978; Erdman & Gough, 1977; Puckett & Finegan, 1980; Nash & Sommerfeld, 1981). Elevated but sublethal levels of sulfur or other elements might indicate incipient damaging conditions.

One species of lichen was collected for elemental analysis.

METHODS

Parmelia rudecta was collected from hardwoods in spunbound olefin bags for laboratory analysis. This species was the only one abundant enough for analysis.

The lichens were air dried and cleaned of all bark and detritis under a dissecting microscope but thalli were not washed. Three replicates were submitted for analysis.

Analysis was done for sulfur and multi-element analysis by the Research Analytical Laboratory at the University of Minnesota. In the sulfur analysis a ground and pelleted 100-150 mg sample was prepared for total sulfur by dry combustion and measurement of evolved sulfur dioxide on a LECO Sulfur Determinator, model no. SC-132, by infra red absorption. Multi-element determination for Ca, Mg, Na, K, P, Fe, Mn, Al, Cu, Zn, Cd, Cr, Ni, Pb, and B were determined simultaneously by Inductively Coupled Plasma (ICP) Atomic Emission Spectrometry. For the ICP one gram of dried plant material was dry ashed in a 20 ml high form silica crucible at 485 degrees Celsius for 10-12 hrs. Crucibles were covered during the ashing as a precaution against contamination. The dry ash was boiled in 2N HCl to improve the recovery of Fe, Al and Cr and followed by transfer of the supernatant to 7 ml plastic disposable tubes for direct determination by ICP.

RESULTS AND DISCUSSION

Table 1 gives the results of the analyses for all three

Table 1. Analysis of George Washington Carver Lichens
Values in ppm of thallus

Species	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
Parmelia rudecta	1128	2824	102005	571	542	347	35.17	14.07	30.67	9.80	1.83	18.41	1.88	1.35	0.73	1080	GWCA
Parmelia rudecta	1152	3035	90974	609	480	318	36.81	13.91	31.09	10.04	1.80	21.41	1.69	1.41	0.78	1250	GWCA
Parmelia rudecta	1169	3070	96351	569	497	305	28.26	14.24	28.97	9.29	1.71	18.09	1.69	1.04	0.65	1110	GWCA
NBS-P	1154	3680	4135	1128	479	160	16.23	665.36	64.83	3.18	16.92	12.77	2.63	2.44	0.15		NBS-P
Cladina stand.	200	688	246	267	441	573	83.34	20.51	18.38	2.81	1.75	15.45	0.88	1.03	0.23	428	C. stand.

Table 2. Summary of Analysis of George Washington Carver Lichens
Values in ppm of thallus

Parmelia rudecta	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
Mean	1150	2976	96443	583	506	323	33.4	14.1	30.2	9.7	1.8	19.3	1.8	1.3	0.7	1147	GWCA
Std. dev.	21	133	5516	23	32	21	4.5	0.2	1.1	0.4	0.1	1.8	0.1	0.2	0.1	91	GWCA

replicates. Table 2 gives the mean and standard deviations for the set of replicates. The values for the National Bureau of Standards peach leaves and also the my own lichen standard (*Cladina stellaris*) are also included in the tables. None of the reported values are below the lower detection limits of the instruments.

All of the levels found in the GWCA lichen are within typical limits for similar lichens and are similar to those for the same species in Hercules Glades Wilderness. The sulfur levels in the lichen range from 1080 to 1250 ppm for all replicates and these values are near background levels as cited by Solberg (1967) Erdman & Gough (1977), Nieboer et al (1977) and Puckett & Finegan (1980) for other species of lichens. Levels may be as low as 200-300 in the arctic (Tomassini et al, 1976) while levels in polluted areas are 4300-5200 ppm (Seaward, 1973) or higher. Different species may accumulate different amounts of elements and this is evident when comparing sulfur levels of different species. Sulfur levels in *Parmelia rudecta* from Hercules Glades also ranged from 720 to 1220 ppm and these levels are similar to those found in Minnesota and Wisconsin (Wetmore, 1991).

All of the other elements show normal levels with slightly higher levels of phosphorus, potassium, magnesium, zinc and copper. These slightly elevated levels may be due to fertilizers or soil conditions in the area and probably do not reflect air quality problems.

These tables indicate that there are no air pollution problems in the park that can be detected with lichen elemental analysis.

CONCLUSIONS

There is no indication that the lichens of GWCA are being damaged by air quality. The lichen flora is fairly diverse for such a small area. There are only a few species in the most sensitive categories to sulfur dioxide in the park. This rarity seems to be due more to ecological and climatic conditions than pollution because all species were healthy. There is no evidence of damaged or dead lichens in any area where healthy ones are not also present. The elemental analyses do not show abnormal accumulations of polluting elements.

RECOMMENDATIONS

Because of the concern about increased air pollution in the Joplin area this study provides an important base line for monitoring the effects of any new sources in the future. It is recommended that a restudy be done when new major pollution sources are established. This should be by elemental analysis since it is the most sensitive of the techniques use in this study.

LITERATURE CITED

Erdman, J. A. & L. P. Gough. 1977. Variation in the element content of Parmelia chlorochroa from the Powder River Basin of Wyoming and Montana. Bryologist 80:292-303.

Hutchinson, T. C., M. Dixon & M. Scott. 1986. The effect of simulated acid rain on feather mosses and lichens of the boreal forest. Water, Air, and Soil Pollution 31: 409-416.

Laundon, J. R. 1967. A study of the lichen flora of London. Lichenologist 3:277-327.

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

Lechowicz, M. J. 1987. Resistance of the caribou lichen Cladina stellaris (Opiz.) Brodo to growth reduction by simulated acidic rain. Water, Air, and Soil Pollution 34:71-77.

Marsh, J. E. & T. H. Nash III. 1979. Lichens in relation to the Four Corners power plant in New Mexico. The Bryologist 82: 20-28.

Medlin, J. 1985. Using lichens to monitor acid rain in Michigan. Mich. Bot. 24:71-75.

Nash, T. H., III. 1973. Sensitivity of lichens to sulfur dioxide. The Bryologist 76:333-339.

Nash, T. H. & M. R. Sommerfeld. 1981. Elemental concentrations in lichens in the area of the Four Corners Power Plant, New Mexico. Envir. and Exp. Botany 21:153-162.

Nieboer, E., H. M. Ahmed, K. J. Puckett & D. H. S. Richardson. 1972. Heavy metal content of lichens in relation to distance from a nickel smelter in Sudbury, Ontario. Lichenologist 5:292-304.

Nieboer, E., K. J. Puckett, D. H. S. Richardson, F. D. Tomassini & B. Grace. 1977. Ecological and physiochemical aspects of the accumulation of heavy metals and sulphur in lichens. International Conference on Heavy Metals in the Environment, Symposium Proceedings 2(1):331-352.

Nieboer, E., D. H. S. Richardson & F. D. Tomassini. 1978. Mineral uptake and release by lichens: An Overview. Bryologist 81:226-246.

Puckett, K. J. & E. J. Finegan. 1980. An analysis of the element content of lichens from the Northwest Territories, Canada. Can. Jour. Bot. 58:2073-2089.

Scott, M. G. & T. C. Hutchinson. 1987. Effects of a simulated acid rain episode on photosynthesis and recovery in the caribou-forage lichens, Cladina stellaris (Opiz.) Brodo and Cladina rangiferina (L.) Wigg. New Phytol. 107:567-575.

Seaward, M. R. D. 1973. Lichen ecology of the Scunthorpe heathlands I. Mineral accumulation. Lichenol. 5:423-433.

Sigal, L. & J. Johnston. 1986. The effects of simulated acid rain on one species each of Pseudoparmelia, Usnea, and Umbilicaria. Water, Air, and Soil Pollution 27:315-322.

Solberg, Y. J. 1967. Studies on the chemistry of lichens. IV. The chemical composition of some Norwegian lichen species. Ann. Bot. Fenn. 4:29-34.

Tomassini, F. D., K. J. Puckett, E. Nieboer, D. H. S. Richardson & B. Grace. 1976. Determination of copper, iron, nickel, and sulpur by X-ray fluorescence in lichens from the Mackenzie Valley, Northwest Territories, and the Sudbury District, Ontario. Can. Jour. Bot. 54:1591-1603.

Trass, H. 1973. Lichen sensitivity to air pollution and index of poleotolerance (I.P.). Folia Cryptogamica Estonica, Tartu, 3:19-22.

Wetmore, C. M. 1982. Lichen decomposition in a black spruce bog. Lichenologist 14:267-271.

Wetmore, C. M. 1983. Lichens of the Air Quality Class 1 National Parks. Final Report, submitted to National Park Service, Air Quality Division, Denver, Colo.

Wetmore, C. M. 1991. Lichens and Air Quality in St. Croix ational Scenic Riverway. Final Report, submitted to National Park Service, Midwest Regional Office, Omaha, Neb.