1972

Effect of SO2 Emission on Populations of Four Lichen Species

Avery Glen Peoples
Northern Michigan University

THE EFFECT OF SO_2 EMISSION ON POPULATIONS OF FOUR LICHEN SPECIES

by

Avery Glenn Peoples

This thesis is recommended for approval by the student's thesis committee.

Chairman

Approved by , Dean of Graduate Studies.

August 11, 1972

Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Arts.

Northern Michigan University
Marquette, Michigan
August 3, 1972

THE EFFECT OF SO_2 EMISSION ON POPULATIONS OF FOUR LICHEN SPECIES

by

Avery Glenn Peoples

B.S., The Defiance College

A Thesis
Submitted in Partial Fulfillment of the
Requirements for the Degree of
Master of Arts in Biology

School of Graduate Studies
Northern Michigan University
Marquette
August 1972

ABSTRACT

Populations of *Cladonia chlorophaea*, *C. squamosa*, *Stereocaulon evolutoides*, and *S. tomentosum* in the major paths of windblown emissions are assayed for SO_2 damage and compared to lichens not exposed. Lowered levels of chlorophyll and lichen products, as well as altered age distributions, indicate damage due to SO_2.

ACKNOWLEDGMENT

To Dr. Warren J. Vande Berg, for his aid, advice, and counsel; to the Drs. Merry and Wagner, for their assistance; and to the Drs. Ruffer, Mikula, and Speaks, the first two for showing me how to learn and the latter for making sure I damned well knew what to do with what I learned: I extend my thanks.

TABLE OF CONTENTS

I. INTRODUCTION 1

II. EXPERIMENTAL 3

Calculation of SO_2 Exposure
Extraction and Determination of Chlorophyll
Analysis of Chlorophyll Sulfur
Extraction Methods for Lichen Products
Methods of Soil Analysis
Listing of Species Present
Age Analysis Method

III. RESULTS 9

IV. DISCUSSION 22

V. SUMMARY 25

LITERATURE CITED 26

APPENDIXES

I. RAISANEN COMMUNICATION 28

II. LICHEN PRODUCTS 30

III. STATISTICAL RESULTS 32

LIST OF TABLES

Table		Page
1.	Wind data	9
2.	Rates of sulfur emission	11
3.	Sulfur exposure	12
4.	Comparison of soils from collection sites	14
5.	Plant index	15
6.	Chlorophyll per gram of thallus	16
7.	Lichen products: *Stereocaulon evolutoides* . . .	17
8.	Lichen products: *Stereocaulon tomentosum*	18
9.	Lichen products: *Cladonia squamosa*	19
10.	Lichen products: *Cladonia chlorophaea*	20
11.	Population age distribution	21

LIST OF ILLUSTRATIONS

Figure | Page

1. Thallus size versus age 8

2. Relative numbers of lichens reproduced annually versus coal consumption 24

3a. Some typical lichen products 31

3b. Typical lichen synthesis 31

Map

1. Major wind vanes and wind rose for McClure Dam and Presque Isle Park 10

2. Intensity of sulfur exposure 13

LIST OF APPENDIXES

Appendix		Page
I.	Raisanen communication	28
II.	Lichen products	30
III.	Statistical results	32

I.

INTRODUCTION

Since Father Louis Andre spent the winter of 1671 eating "tripe de roche, a species of lichen, which, being boiled, resolved itself into a black glue, nauseous, but not void of nourishment," (Parkman,1879) the Upper Peninsula of Michigan has been a known site of copious lichen growth. Today, throughout Marquette County, Alectoria and Usnea, shields of Parmelia, Xanthoria, and Umbellaria, and fields of Cladonia and Stereocaulon are common occurrences, pointing to the unsullied nature of the environment. However, a particular area has, in the more recent years, experienced a gradual but persistent decline in lichen populations.

The outlet of the Dead River near the northern boundary of the city of Marquette is an area once populated heavily with lichens (Dachnowski,1907; Hedrick,1940). The construction of a generating plant, coupled with an ever increasing demand for electric power, appears to have occurred at the same time as the decline in lichen populations. The scope of this study is to determine if emissions from the power plant are contributing to the lowering of the lichen populations.

Several investigators have studied the effects of variable environmental interactions on lichens. Brodo (1964) studied the effects of general factory emissions on lichens. Heavy metal tolerances were studied by Lamb (1951a,1951b) and Huneck et al. (1968), while Ahmann and Mathey (1967) looked into the effects of elevated nitrate, carbon monoxide, and carbon dioxide levels. Sulfur di and tri oxide effects have been studied by Neelaxathan et al. (1962) and Scotter (1965). Sulfur oxides in general effect the chlorophylls of all green plants by displacing the magnesium in an electrophilic way and thus deactivating the molecule. The reaction is essentially irreversible, and the chlorophyll is no longer able to function in photosynthesis.

Four species of lichen from two genera were chosen for physical and chemical evaluation to determine if the presence of the generating plant is a contributing factor to the declining population of the lichens. Cladonia chlorophaea, Cladonia squamosa, Stereocaulon evolutoides and Stereocaulon tomentosum are inhabitants both of the area surrounding the generating plant and the site chosen as an area similar in all respects save the presence of the power plant--McClure Dam on the Dead River.

II.

EXPERIMENTAL

Calculation of SO_2 Exposure (Geiger, 1965)

Calculation of SO_2 fallout per square meter at some distance may be made for a point source by using this formula.

$$SO_2 \text{ (in g/m}^3)^* = \frac{2Q}{\pi c^2 \bar{u} x^{2-n}} \qquad \frac{y^2+h^2}{c^2 x^{2-n}}$$

Where h = height of stacks in meters
- Q = quantity of pollutant in g/sec emitted
- x = distance from source in meters
- $\bar{u}$ = mean wind velocity
- y = distance from main path to x
- c^2 = 0.015 (from adiabatic lapse rate constant)
- n = 0.2 (from humidity constant)

*in surface layer of air

Extraction and Determination of Chlorophyll (Dunn and Arditti, 1968)

One gram (dry weight) of lichen thallus is placed in four volumes (50 ml) of 80 per cent ethanol and homogenized in a Waring blender on high speed for 2 minutes. The solution is then centrifuged at 800xg for 10 minutes to remove the cellular debris. The supernatant is decanted and acetone is added to make it 80 per cent of the mixture.

The resultant solution is then assayed spectrophotometrically, and the results recorded as a function of the absorbance. To determine the chlorophyll content, optical density at 650 nm is multiplied by 5.8 to determine milligrams per milliliter of the final solution. Since chlorophyll determination was based on 10 g of lichen, the determination to give milligrams of chlorophyll per gram of lichen is $\frac{OD \times 5.8}{10}$ = mg/g lichen.

<u>Analysis of Chlorophyll Sulfur</u> (Allenstein,1972)

Chlorophyll is extracted as before. Following the extraction the chlorophyll is hydrolyzed with 6 <u>M</u> HCl for 4 hours at 150 C. $BaSO_4$ was added in aqueous acid solution, followed by gentle heating. The presence of sulfoxy compounds or sulfur was proven by precipitate.

<u>Extraction Methods for Lichen Products</u> (Asahina and Shibata, 1954)

Atranorin

One weight of lichen thallus is boiled for 2 hours in ether. The solvent is removed by distillation and the residue extracted for 2 hours in boiling chloroform. The chloroform mixture is filtered and the residue discarded. The remaining liquid is distilled dry and the resultant residue is resuspended in one weight ether followed by adding one weight of warm chloroform. The solution is shaken gently while at 35 C, followed by cooling with two weights of cold absolute ethanol and an ice bath. The crystals are cold suction filter recovered.

Baeomycesic Acid

Four weights of thallus are extracted with an equal volume of ether and filtered after 5 hours. The ether fraction is then shaken with sodium bicarbonate in excess and refiltered. Eighty per cent acetone (1 volume) is added to the filtered residue and 0.2 volumes of 6 <u>M</u> HCl are added. After gentle mixing and standing overnight, the resultant crystals may be filtered out.

Squamatic Acid

One weight of lichen is extracted with two weights of ether for 3 days. The solution is distilled off and the residue resuspended in a minimum volume of chloroform. The residue is filtered, and the liquid portion shaken with two volumes of glacial acetic acid. The crystals are then filtered and dried.

Lobaric Acid

Five volumes of ether and one volume of lichen are extracted for 10 hours. The solution is allowed to cool after filtration. The solution is then refiltered and shaken with bicarbonate and 0.5 volumes of 6 <u>M</u> HCl. The crystals are then filtered out and dissolved in absolute ethanol and recrystallized.

Stictic Acid

One weight of thallus (dry) is extracted with an equal weight of ether for 2 hours. The solvent is distilled off and the lichen extracted with acetone for 15 hours. The hot extract is cooled and filtered and the solvent distilled off. The crystals remaining are the product.

Norstictic Acid

One weight of thallus is extracted in hot ether for 3 days and hot filtered. The solvent is then distilled off and the crystals resuspended in 1:1::acetone:absolute ETOH. One volume of aniline is slowly added. The yellow crystals are then filtered out.

Fumarprotocetraric Acid

One weight of thallus is extracted with ether for 2 days, then hot filtered, and the residue resuspended in hot acetone and gently stirred for 4 hours. The solution is then hot filtered, and the hot liquid is ice bath cooled. After cooling to 0 C, the crystals may be filtered out.

Grayanic Acid

One weight of thallus is extracted with ether for 6 days and shaken with 5 per cent bicarbonate. The precipitate is then boiled in one volume 6 M HCl for 2 hours, cooled, and filtered. The precipitate is then redissolved in ether, and the ether distilled off. The crystals are then redissolved in hot 1:1::pet. ether:benzene and stirred for 6 hours. The solvent is then hot filtered and cooled to 0°. The crystals are then filtered out.

Methods of Soil Analysis (Black,1969)

Soil pH

Twenty g of soil are stirred into 20 ml of distilled H_2O and the pH read on a pH meter.

Available Phosphate

One g of soil is stirred into 7 ml of extracting solution composed of 15 ml of 1 N NH_3F, 25 ml of 0.5 N HCl, and 460 ml of H_2O. The solution is shaken 1 minute, then filtered, and 2 ml of a solution composed of 15 g $(NH_4)_6$ Mo_1 $4H_2O$ in 350 ml H_2O and 350 ml 1 M HCl is added. One ml $SnCl_2$ solution (10 g $SnCl_2$ $2H_2O$ in 25 ml conc HCl), diluted with 333 ml H_2O is added and shaken well. After standing for 10 minutes, the OD is measured at 660 nm. Phosphate in soil in ppm is calculated by OD at 660 x 35.

Total Nitrogen

Kjeldahl.

Listing of Species Present

The following information is recorded: (1) predominant growth type, (2) grass and sedge types, (3) predominant herbaceous growth, and (4) bryophyte and fungal growth.

Age Analysis Method (Hale, 1972; Danielson, 1968)

The average annual growth rate is estimable for cladonias in general as 2.3-2.6 mm/year, while for stereocaulons, the rate is 1.8-2.1 mm/year. However, a more accurate method of determining age is given by using the following graphs.

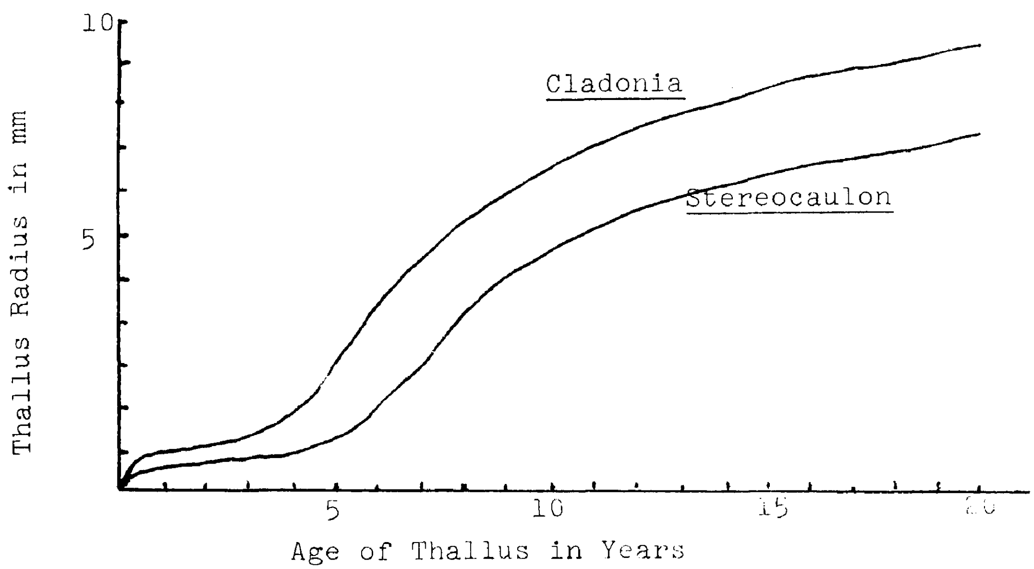


Fig. 1.--Thallus size versus age.

Statistical Methods (Standard)

Standard T tests were applied to the population means for the following sections: (1) chlorophyll content, (2) lichen product content, (3) soil factors. Also, a standard F test was applied to the data from the age triangles (Appendix 3).

III.

RESULTS

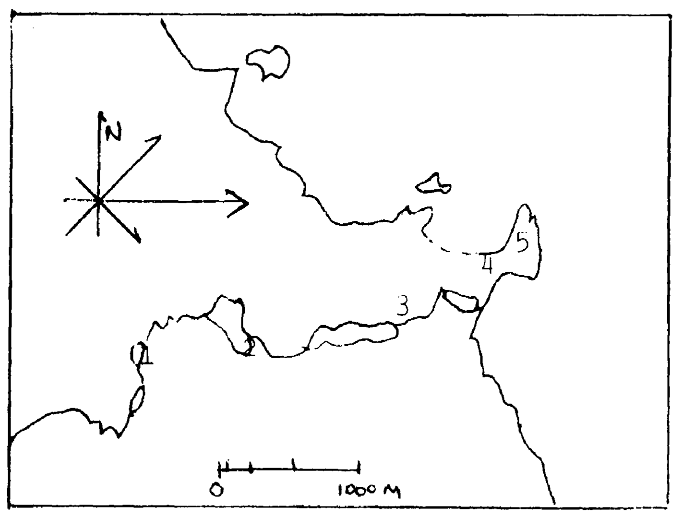
Wind data for the ten years preceding the study were analyzed for velocity and direction. From these data a wind rose (Map 1) representing time spent and velocity for the eight major compass points was constructed. The average velocity and percentage of time spent blowing in those directions is represented in Table 1.

TABLE 1

WIND DATA

Direction of Wind	Mean Wind Velocity (mph)	% time
0°	4.0	2.6
45°	3.5	0.7
90°	4.0	1.2
135°	5.4	8.0
180°	4.1	6.0
225°	4.3	9.7
270°	4.0	2.7
315°	6.0	1.6

These data indicate that the major wind flow is to the East (90°), with the second high direction being to the NE (45°). By superimposing the wind rose on maps it is possible to determine the relative values of the wind blowing past that point. Map 1 shows major wind vanes for McClure Dam and the Presque Isle generating plant.



1. McClure Dam
2. Forestville Dam
3. Marquette Tourist Park
4. Generating plant
5. Presque Isle Park

Map 1.--Major wind vanes and wind rose for McClure Dam and Presque Isle Park.

Calculations of SO_2 from coal consumption (Appendix 1) are represented in Table 2. These data indicate the average quantity of SO_2 being emitted per second when the plant is in operation.

TABLE 2

RATES OF SULFUR EMISSION *

Year	Tonnage of Coal Consumed	Tonnage of SO_2 Emitted	Mean SO_2 Emission in g/sec
1961	72,900	2,920	8.6
1962	122,400	4,896	13.6
1963	181,900	7,276	29.0
1964	297,000	11,880	34.3
1965	325,000	13,000	37.2
1966	362,500	14,500	41.8
1967	454,200	17,160	48.4
1968	465,900	18,636	53.7
1969	507,600	20,304	58.5
1970	487,700	19,408	55.9

*Raisanen, Personal Communication (Appendix 1)

Emission data, when substituted into the formula for calculating SO_2 exposure per area, gives the data represented in Table 3.

TABLE 3

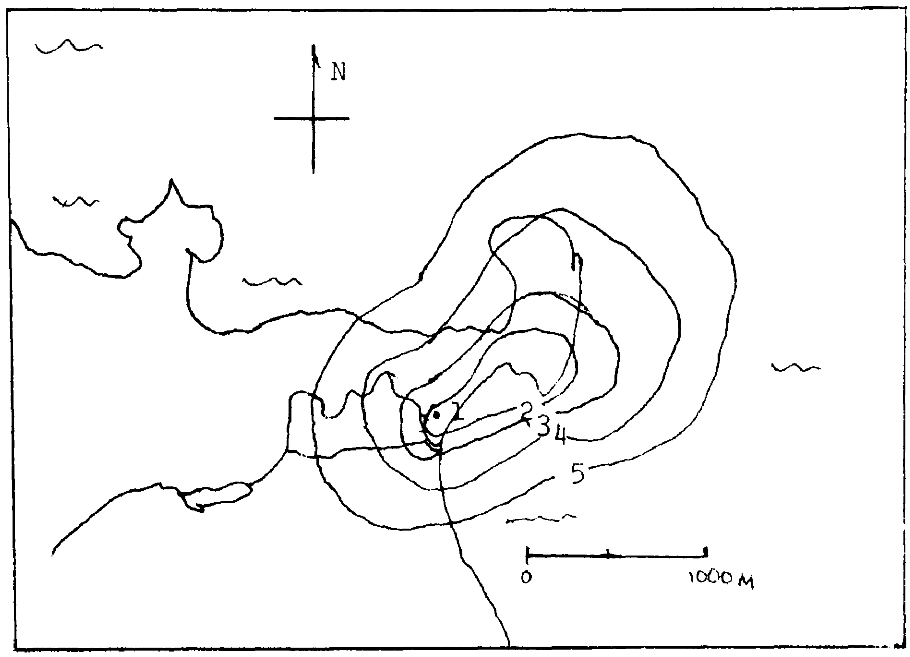
SULFUR EXPOSURE

$g/m^3/sec$*

Direction	ū	500m	1000m	1500m
0°	4.0	.728	.0050	.0010
45°	3.5	.973	.0052	.0012
135°	5.4	.631	.0037	.0007
180°	4.1	.831	.0048	.0010
225°	3.5	.973	.0052	.0012
270°	4.0	.728	.0050	.0010
315°	6.0	.568	.0033	.0007

*In surface layer above ground.

These data, when superimposed on the map of the area surrounding Presque Isle Park (Map 2), show the park to be the land mass receiving most of the SO_2.



1. Generating plant
2. Area exposed to 20 kg SO_2 per meter^2 annually
3. Area exposed to 15 kg SO_2 per meter^2 annually
4. Area exposed to 10 kg SO_2 per meter^2 annually
5. Area exposed to 5 kg SO_2 per meter^2 annually

Map 2.--Intensity of sulfur exposure.

The soils of Presque Isle Park and McClure Dam were then compared. These data are represented in Table 4.

TABLE 4

COMPARISON OF SOILS FROM COLLECTION SITES *

Distance	$\bar{x}$ pH	$\bar{x}$ P %	$\bar{x}$ tot. Nit. %	$\bar{x}$ Carbon %
McClure Dam				
500m	6.0	.036	.003	.43
1000m	6.1	.049	.006	.49
1500m	6.1	.031	.005	.76
Presque Isle				
500m	6.1	.030	.007	.52
1000m	6.0	.031	.004	.59
1500m	6.1	.037	.004	.49

*Soils sampled in a random manner at all sites and averaged.

According to these data the soils of the two areas do not differ significantly (Appendix 3). At the same time, the major species of plants in the areas were compared, and these data are shown in Table 5.

The collected lichens were then assayed chemically for chlorophyll, and the milligrams of chlorophyll per gram of thallus were calculated. These data are shown in Table 6. The chlorophyll data indicates that the lichens at McClure Dam have significantly more chlorophyll per gram than those at Presque Isle Park (Appendix 3). Lichen products were assayed for and calculated in milligrams per gram of thallus. These data are shown in Tables 7-10. These data indicate that the lichens from Presque Isle Park and surrounding area have less lichen products per gram of thallus than do the lichens from the McClure Dam area.

TABLE 5

PLANT INDEX

Plants common at both Presque Isle and McClure Dam:

Pinus banksiana	Vaccinium sp.
Populus tremuloides	Arctostaphylos uva-ursi
P. grandidentata	Rubus parviflorus
Acer saccharinum	
A. rubrum	Hydnum sp.
A. pennsylvanicum	Amanita vulgaris
A. spicatum	Polyporus betulina
Cornus florida	
	Parmelia sp.
Lycopodium sp.	Cladonia sp.
	Umbelaria sp.
Mnium sp.	
Polytrichum sp.	
Ceratodon purpurea	

The chlorophyll was then tested for sulfur. The tests showed that those lichens on Presque Isle and the surrounding areas contain sulfur in the chlorophyll fraction while all of those from McClure Dam do not.

The age pyramids, Table 11, were constructed to determine the age differences at the sites and the relative

TABLE 6

CHLOROPHYLL PER GRAM OF THALLUS

	S. evolutoides		*S. tomentosum*		*C. chlorophaea*		*C. squamosa*	
500m	OD 650	mg/g	OD 650	mg/g	OD 650	mg/g	OD 650	mg/g
North	.056	.0325	.060	.0348	.112	.0650	.103	.0597
NE	.038	.0220	.041	.0238	.076	.0441	.068	.0394
South	.109	.0632	.117	.0679	.212	.1230	.183	.1061
SW	.075	.0435	.074	.0426	.176	.0441	.074	.0429
West	.045	.0261	.045	.0261	.097	.0523	.084	.0487
NW	.050	.0290	.056	.0325	.101	.0586	.091	.0528
1000m								
North	.093	.0539	.142	.0824	.173	.1003	.148	.0858
NE	.070	.0406	.103	.0597	.141	.0818	.131	.0760
South	.150	.0870	.179	.1038	.270	.1566	.249	.1444
SW	.134	.0777	.164	.0951	.212	.1230	.186	.1079
West	.100	.0580	.120	.0696	.189	.1096	.171	.0992
NW	.100	.0580	.126	.0731	.192	.1114	.176	.1021
1500m								
North	.123	.0714	.154	.0898	.214	.1241	.182	.1056
NE	.103	.0597	.136	.0789	.191	.1108	.175	.1015
South	.142	.0824	.199	.1154	.301	.1746	.268	.1554
SW	.127	.0737	.185	.1073	.251	.1456	.231	.1340
West	.121	.0702	.126	.0731	.233	.1351	.200	.1160
NW	.120	.0696	.129	.0748	.237	.1375	.203	.1177

TABLE 7

LICHEN PRODUCTS: STEREOCAULON EVOLUTOIDES

mg per g of thallus

	500m	1000m	1500m	McClure Dam
Atranorin				
North	.129	.195	.239	.629 $\bar{x}$
NE	.087	.184	.216	
South	.229	.313	.417	
SW	.088	.239	.286	
West	.109	.220	.259	
NW	.099	.216	.263	
Norstictic Acid				
North	.084	.122	.146	.477 $\bar{x}$
NE	.051	.091	.130	
South	.142	.187	.259	
SW	.056	.144	.167	
West	.071	.140	.169	
NW	.074	.151	.165	
Lobaric Acid				
North	.084	.121	.149	.495 $\bar{x}$
NE	.055	.093	.132	
South	.160	.187	.258	
SW	.048	.144	.168	
West	.072	.140	.192	
NW	.073	.151	.160	

TABLE 8

LICHEN PRODUCTS: STEREOCAULON TOMENTOSUM

mg per g of thallus

	500m	1000m	1500m	McClure Dam
Atranorin				
North	.139	.211	.262	.630 $\bar{x}$
NE	.084	.159	.229	
South	.261	.340	.363	
SW	.083	.257	.302	
West	.129	.231	.272	
NW	.191	.231	.279	
Norstictic Acid				
North	.113	.152	.191	.460 $\bar{x}$
NE	.068	.123	.172	
South	.213	.251	.338	
SW	.069	.154	.172	
West	.087	.172	.213	
NW	.089	.177	.217	
Lobaric Acid				
North	.051	.075	.092	.260 $\bar{x}$
NE	.033	.058	.084	
South	.092	.121	.159	
SW	.034	.092	.117	
West	.042	.081	.160	
NW	.046	.089	.170	

TABLE 9

LICHEN PRODUCTS: CLADONIA SQUAMOSA

mg per g of thallus

	500m	1000m	1500m	McClure Dam
Squamatic Acid				
North	.140	.212	.167	.641 $\bar{x}$
NE	.087	.161	.227	
South	.261	.340	.367	
SW	.079	.262	.309	
West	.127	.224	.272	
NW	.191	.231	.279	
Baeomycesic Acid				
North	.041	.060	.074	.190 $\bar{x}$
NE	.026	.046	.067	
South	.074	.046	.128	
SW	.026	.074	.088	
West	.035	.071	.082	
NW	.037	.068	.081	

TABLE 10

LICHEN PRODUCTS: CLADONIA CHLOROPHAEA

mg per g of thallus

	500m	1000m	1500m	McClure Dam
Fumarprotocetraric Acid				
North	.109	.148	.192	.480 $\bar{\bar{x}}$
NE	.071	.124	.170	
South	.213	.251	.338	
SW	.069	.153	.172	
West	.086	.173	.213	
NW	.087	.175	.220	
Grayanic Acid				
North	.127	.197	.243	.670 $\bar{\bar{x}}$
NE	.089	.192	.214	
South	.239	.311	.419	
SW	.094	.233	.280	
West	.109	.221	.273	
NW	.106	.216	.264	

amounts of total growth at the sites. Data from these calculations show a drastically reduced percentage of younger lichens in the Presque Isle Park area.

TABLE 11

POPULATION AGE DISTRIBUTION

Age	1 yr	1-2	2-4	4-10	10-20	20+
			500 m			
North	3.0	3.0	4.2	8.7	49.1	32.2
NE	2.8	3.0	4.1	10.2	51.6	28.3
South	4.6	5.2	6.6	12.4	46.1	25.1
SW	5.1	5.9	5.0	10.4	38.0	35.6
West	6.2	6.8	7.2	10.6	34.2	30.0
NW	6.4	6.3	7.8	12.2	37.5	32.8
			1000 m			
North	4.4	5.1	6.6	10.3	43.4	31.2
NE	4.7	4.9	7.3	10.4	46.3	26.5
South	5.9	6.3	7.1	12.3	42.4	26.6
SW	6.1	6.6	7.4	11.9	40.1	27.9
West	7.3	7.4	9.1	12.9	38.4	22.9
NW	6.9	7.4	10.3	12.1	36.7	16.6
			1500 m			
NE	4.5	5.1	7.8	12.3	27.4	44.9
SW	8.4	9.3	11.6	23.4	27.6	29.7
West	7.9	8.4	13.2	18.6	29.2	22.9
NW	6.8	7.3	12.0	12.4	29.4	31.9
			McClure Dam			
$\bar{x}$	10.2	11.6	12.3	25.1	29.4	11.4

IV.

DISCUSSION

The results indicate that the populations of the four lichen species studied are significantly different. The levels of chlorophyll in the thallus are lower per weight in the lichens from the area surrounding the generating plant. Chlorophyll from the lichens near the power plant contains sulfur, implying that in some manner, the chlorophyll is being deactivated. Those lichens from the sites around the generating plant also exhibit significantly lower levels of lichen products. The populations near the power plant exhibit different percentages of specific age groups. The predominant age lichen in the area of the generating plant is an older lichen, while those of the McClure Dam area are young to middle aged.

The weather for the two areas studied is similar, though not exactly the same. Average temperatures vary by four and five degrees Fahrenheit. However, since temperature is generally recognized as an insignificant factor in lichen growth (Hale,1956), temperature is probably not a factor. Land usage is also nearly the same, as both areas are used for recreation. Hale (1972) has shown that lichens within 3 meters of a roadway may be effected by carbon monoxide emission. Only one collection site, at 1000 meters Southwest of the generating plant, is within 3 meters of a roadway. Both sites exhibit the same predominant plant types. Soils of the two areas are similar in all assays. The areas are similar in all respects excepting the generating plant at the sites near the mouth of the Dead River.

The chlorophyll levels correlate inversely to the amounts of SO_2 being deposited at the sites. The same phenomenon is observable both in the levels of lichen products and in the age data. That is, the numbers of younger lichens increase as the distance from the generating plant increases. A strict parallelism is not always observed (note southern and southwestern sites). The collecting site at 1000 meters southwest of the generating plant is within 3 meters of Lakeshore Drive and is possibly effected by carbon monoxide emissions as mentioned earlier. All of the levels of chlorophyll and lichen products are lower than those found in the lichens near McClure Dam. This information would indicate that the SO_2 is absorbed into the algal layer, where it deactivates the chlorophyll in the lichens.

The altered age pyramids indicate that the greatest damage is done when the lichens are younger. This seems reasonable since the lichens of these genera are essentially ecorticate when young and would have little protection from the SO_2 at that point in the life cycle.

Drawing on the coal consumption, SO_2 generation data, and the age data, and extrapolating back to time "0" for the lichens in the area of the power plant, it is possible to draw a graph representing quantity of SO_2 emitted versus the relative numbers of lichens being produced on an annual basis (Fig. 2). The data at the present time indicate that as the demand for power rises, the coal consumption, and therefore SO_2 generation, will also increase. These data also indicate that as the quantity of SO_2 emitted continues to increase, the number of lichens in the area surrounding the generating plant will decrease.

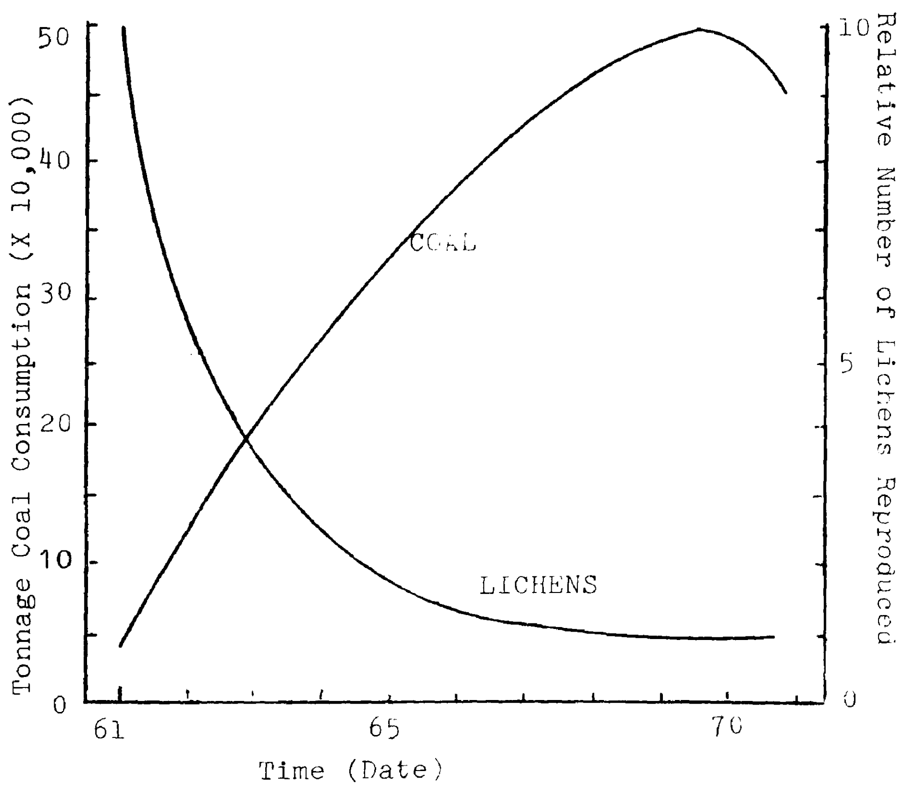


Fig. 2.--Relative numbers of lichens reproduced annually versus coal consumption.

V.

SUMMARY

The results of this study indicate that the lichens growing near the Presque Isle generating plant have significantly lower levels of chlorophyll and lichen products than do lichens growing near McClure Dam. The age distribution of the lichens is also different at the two sites, with significantly fewer young lichens at the Presque Isle collection sites. The factor which is believed to be responsible for these observations is the SO_2 emission of the Presque Isle generating plant.

LITERATURE CITED

Ahmann, G., and A. Mathey. 1967. Bryologist 70:93-97.

Asahiny, Y., and S. Shibata. 1954. Chemistry of Lichen Products. 227 p. Univ. Microfilms. Ann Arbor, Mich.

Black, C. 1965. Methods of Soil Analysis. American Soc. Agron., Madison, Wis. 2 vol.

Brodo, I. 1964. Bryologist 67:76-87.

Culberson, C.F. 1965. Phytochem 4:951-961.

Culberson, C.F. 1966. Phytochem 5:815-818.

Culberson, C.F. 1967a. Bryologist 70:70-75.

Culberson, C.F. 1967b. Phytochem 2:335-341.

Culberson, W.L. 1961. Am. J. Bot. 48:164-178.

Curd, W., et al. 1933. J. Chem. Soc. 1933:130-133.

Dachnowski, A. 1907. Rep. Mich. Acad. Sci. 9:88-103.

Danielson, V. 1968. Studies in Population Analysis Methods. Academic Press, New York. 418 p.

Dunn, A. and J. Arditti. 1968. Experimental Physiology. Holt, Rinehart, and Winston, New York. 312 p.

Geiger, R. 1965. The Climate Near the Ground. Harvard University Press, Cambridge, Mass. 1107 p.

Hale, M. 1956. Castanea 21:30-32.

Hale, M. 1965. Lichen Handbook. Smithsonian Press, Washington D.C. 154 p.

Hale, M. 1972. The Biology of Lichens. Arnold Publishing House, New York. 176 p.

Hedrick, J. 1940. Papers, Mich. Acad. Sci.,Arts,Let. 25:47-65.

Hess, D. 1958. Planta 52:65-72.

Huneck, S., et al. 1968. Tetrahedron 24:2707-2755.

Lamb, M. 1951a. Can. J. Bot. 29:522-584.

Lamb, M. 1951b. Nature 168:38-64.

Mazingo, H. 1961. Bryologist 64:325-335.

Neelakathan, S., et al. 1962. Tetrahedron Letters 1962:3531-3536.

Roberts, M. 1938. J. Org. Chem. 22:168-173.

Scotter, G. 1963. Can. J. Bot. 41:1199-1262.

Shibata, S., and H. Chiang. 1965. Phytochem 4:133-134.

APPENDIX 1

Upper Peninsula Power Company
GENERAL OFFICES
616 Shelden Avenue
Houghton, Michigan 49931

January 5, 1971

Mr. Glen Peoples, Graduate Assistant
Department of Biology
Northern Michigan University
Marquette, Michigan 49855

Dear Mr. Peoples:

We wish to acknowledge your letter of December 22, 1970 requesting information on the amounts of fuel consumed at the Presque Isle Station and also the height of the stacks at the plant.

The records on fuel consumption are not readily available on a month to month basis but this data can be provided as a total for each year for the past ten years with a monthly average then derived from this yearly volume. Nevertheless, we appreciate your offer to assist in the detail of looking up this information as we are totally involved in the job of operating a utility on an economic basis and with providing the best possible service to the people, who expect and deserve such service.

Enclosed are the coal volumes as described. The only other fuel consumed at the station is fuel oil which is a relatively small amount used for the purpose of starting the boilers.

We hope that this information will be helpful to you.

Very truly yours,

R. R. Raisanen

R. R. Raisanen, Manager
Environmental Quality

Enclosure

PRESQUE ISLE STATION

Year	Tons of Bituminous Coal
1960	57,000
1961	72,900
1962	122,400
1963	181,900
1964	297,000
1965	325,000
1966	362,500
1967	454,200
1968	465,900
1969	507,600
1970	487,700

STACK HEIGHTS

Unit	Height*
1	147'6"
2	147'6"
3	194'0"
4	194'0"

*Feet above ground elevation - 606.0' above sea level.

RRR:me
1-5-71

APPENDIX II

LICHEN PRODUCTS

Lichen products, the unique by-products of the phycobiont-mycobiont symbiosis, are generally understood to be indicators of general health of the thallus. Depsides and depsidones are the two classes of lichen products found in the four species studied (Fig. 3b). These products may be isolated and synthesized in the laboratory via the reaction route shown (Fig. 3a) (Roberts,1938). However, the mechanism of <u>in vivo</u> synthesis is unknown.

By the same token, the function of these metabolic enigmas is also unknown. It has been suggested (Hale, 1969) that the lichen products may function as light absorbing pigments that protect the symbiosis from being damaged by ultraviolet light. Others have suggested that the products are acetate storage molecules (Curd <u>et al.</u>,1933), that the molecules are a waste carbon atom storage (Mazingo,1961), and that the lichen products are a protective device to keep the lichens from being eaten (Hale,1972). In any case, the mechanism for synthesis and metabolic role of lichen products is unknown.

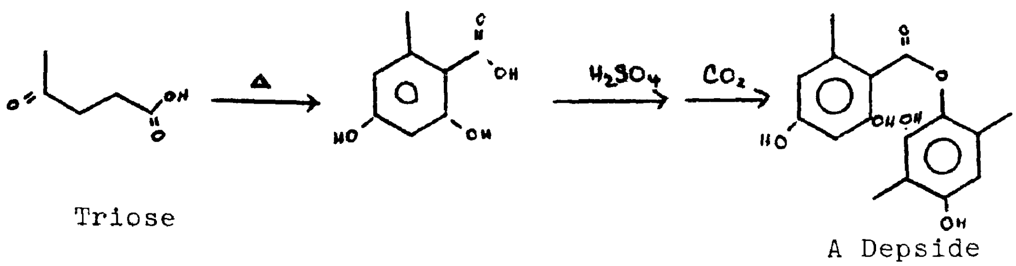


Fig 3a. Lichen Product Synthesis

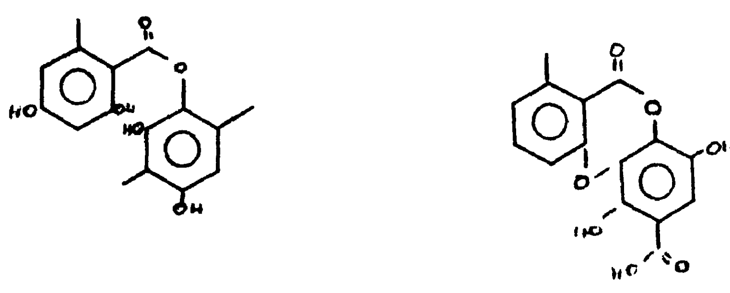


Fig 3b. Typical Lichen Products

APPENDIX III

STATISTICAL RESULTS

T Test *

	Significance Levels for Population Means					
	Chlorophyll	Lichen Products	Soils			
			pH	P	N	C
C. chlorophaea	.001	.001	R	R	R	R
C. squamosa	.001	.001	R	R	R	R
S. evolutoides	.001	.001	R	R	R	R
S. tomentosum	.001	.001	R	R	R	R

* Assuming the null hypothesis.

R = null hypothesis rejected, that is, there is no difference in the population means.

F Test

The means of the age data were analyzed by a standard F test and found to be significant at the .001 level.