Dan Bolnick
ES 102, 1993
May 14,1993

Bioindicators and Air Pollution:

They just aren't Lichen it.

INTRODUCTION AND BACKGROUND:

Biologists often use populations of bioindicator species to monitor trends in environmental quality. Lichens and bryophytes, for example, are commonly used indicators for air quality. Large areas of Europe and America were observed to have become lichen "deserts" as the industrial revolution progressed, mainly in urban and industrial centers. Since then gradual declines in populations have been observed even in rural areas. Is this trend occuring in the rural Berkshires? The purpose of this study was to characterize and identify the lichen populations present in the Williamstown area, in order to see if this decline has reached our area. It was hoped that the resulting data would yield two forms of information: how the town appears to be affecting lichens, and what the present status of the population is. The latter is the more useful and reliable set of results. It sets up a background for later surveys to be compared to, to see what changes are occurring in the population. These trends might be able to be attributed, with some reservations, to air pollution trends.

Lichens provide excellent study species for monitoring air quality due to several special physiological traits. The lack of any protective cuticle, coupled with a high cation exchange capacity (Hutchinson,1980) and an inability to excrete toxic elements, contributes to a fast buildup of toxins. Similarly, anions such as O_3, NOx, NHx, SO2- may easily enter the thallus (leaf) of the lichen. In high concentrations, sulfates and nitrate acids may do direct damage to the cells. A single peak exposure may disturb a community of lichens (Bates,Farmer,1992). More often, low level sulfuric acid from precipitation and cloud deposition (sulfates being the most destructive of the pollutants) reacts with chlorophyll-a to remove a magnesium to form phaeophytin-a (Hale,1967). The low concentration of chlorophyll in lichens makes this damage to photosynthesis all the more serious. Acid deposition also poses a more indirect threat. Lichens are very specific as to their substrate, or growing area. Slight changes in porosity or pH of the substrate from acid deposition may result in lichen death (Hale,1967). However, it should be noted that very low-level deposition may actually favor acidophilic species, and nitrate deposition has been shown to stimulate growth through fertilization (again, only at extremely low levels) (Bates,Farmer,1992).

Coupled with heavy metals in lichen thalli (from small particulate absorption), the sulfates do far more damage. Airborne particulate metals such as zinc, lead, copper, and nickel are absorbed and stored in the cell walls of the thalli (McCarthy, Shugart,1990). These harmful heavy metals originate from automobile emissions, incinerators, generator facilities, smelters, and refineries. Studies have shown marked correlation between lead and lichen gradients along roadways (Lepp,1981). The high cation exchange capacity of thalli walls provides an excellent opportunity for pollution monitoring, as thalli may be analyzed for heavy metal contents. Comparing this data to the contents of pollution-free, or old specimens, the increase in airborne metals may be extrapolated. Lichens from this survey were stored for future analysis, if needed. Information on methodology for such analysis should be available in the text <u>Lichens, Bryophytes, and Air Quality</u>, by Nash and Wirth, published by J.Connor, Berlin and Stuttgart, 1988.

Another human-induced environmental factor that affects lichen populations is land use. Secondary forests tend to be far less rich, as microclimates affecting vital moisture content may be easily changed (Hale,1967). Light intensity, moisture, and available substrates are all dominated by forest composition. These factors change even on a single tree. Shade-tolerant Cladonia, Leptogium, Peltigera are all common at the tree base, while the canopy is dominated by Cetraria, Parmelia, Ramalina, and Usnea (Hale,1967). The very base of a tree is called the "canine zone", ← why? and provides another stratum due to its eutrophic higher pH.

Thus, there are many factors that contribute to lichen populations. Acid deposition, heavy metals, land use, microclimate, and even vertical stratification on a single tree, all affect the species and numbers present in an area. Separating these factors out is nearly impossible, thus the scarcity of field experiments that can reliably attribute lichen depletion to any specific variable. The general purpose of this survey, then, is to provide a base for comparison. Combined with the monitoring of forest states and acid precipitation by the college, some relationships may be identifiable in the long run. However, any trends observable within this single sample time, such as trends in population as a function of distance from town, may be hypothesized to be caused by one factor, but no reliable conclusions may be drawn.

METHODS

In order to collect the data on the character of the local lichen populations, a transect was run up the Taconic Crest from was the purpose to go from Low to high elevation or from polluted to less polluted sites?

Williamstown. The transect actually started on Bee Hill Road and ascended the Triple R Trail. In retrospect, this was a poor choice of trails, as it ascends close to Route 2, which sees a lot of traffic and may thus affect populations. It also contained a large area of fields, whose perimeter would have very different microclimates and thus different lichens. Finally, the character of the forest itself is quite variable (the old and young stands, and the hemlock stand), making plots along the transect harder to compare. A plot was surveyed every quarter mile along this transect, skipping the second would-be point due to topography. Another two plots were set on the top of the crest, one with a west exposure, the other east. A plot in town (HR1) was surveyed, as well as two plots on Pine Cobble adjacent to eachother. In the plots, each tree was noted (its species and circumference, which is relative to age), as was its lichen load. Lichens were counted only on tree trunks, and only to a height of 1.5 meters from the base. This keeps a control on substrate and vertical stratum. Lichen presence was noted not by number of individuals, which is often hard to count, but by area, approximating the number of 15 cm^2 unit areas (actually 5 cm diameter, but this was approximate). Thus a number stating that there were 5 units of crustose lichen on a tree implies that there was the equivalent of 5X15=75 square cm of lichen. The end result was a total of the lichen numbers and species present, and what tree species and ages they preferred. Specimens were collected from most plots representing what lichens were present. Notable lichens not seen in the plots were collected whenever found. This entire process is expedited by a map of the

along most of the transect -

- above or below the canine zone?

area, a compass, measuring tape to mark off the 10 meter radius plots, a knife for collecting specimens, and envelopes for storage.

Once all the plots were surveyed, the lichen samples were brought back to the lab. With a stereoscopic microscope, a razor and tweezers, potassium hydroxide, and bleach, tests were run on the samples to identify them. Hale,1979 is an outstanding key to North American lichens, and was used here. Chemical tests and other identification tricks are outlined in the book. Identified specimens were packed and stored for analysis in future years, or general reference.

Note: many lichens are difficult to identify, even for an expert. While I feel I have a good grip on the genera and many of the species, not all the identifications are necessarily correct or perfect.

Note: the term "lichen density" as used in the data below refers to the total coverage of lichens in a plot divided by an approximation of the area of substrate avaliable. This should give an approximation as to the suitability of a given plot to carry a large lichen load. The calculation is:

Density = (total#lichens)/(150 cm height)(mean circumference,cm)(total # of trees)

the units, thus, are square cm lichens/square cm substrate.

Note: plot numbers were rearranged to represent their order in relation to distance from town. Thus, HR1, number 1, is closest to town, while tacR1, #12, is furthest.

DATA:

PLOT LIST

NUMBER: (referring to order of distance from town)	PLOT NAME:	LOCATION:
1	HR1	In old Red Maple stand on the banks of the Hoosic River behind the landfill at Cole Field. Near a gravel bar in the river.
2	pc1	About 1/4 mile from the trail head of the Pine Cobble trail, perhaps a little more. In an open oak dominated forest. Many raspberry bushes-sign of recent clearing or interference?
3	pc2	Directly across the trail from pc1, on the North side. Similar habitat/forest.
4	tac7	Triple R Trail., near trailhead, about 60' from Bee Hill Road, and about 3-400' from Route 2.
	tac7*	Lichens collected from area near stream crossing about 1/4 mile up from tac7. Area not suitable for plot.
5	tac6	Triple R Trail in a hemlock grove about 1/2 mile up from tac7. Steep north facing slope, dark understory.
6	tac5	Triple R Trail, 1/4 mile up from tac6. Gentle slope, just west of small stream crossing.
7	tac4	Triple R Trail, 1/4 mi up from tac5, past main stream crossing.
8	tac3	Triple R Trail, 1/4 mi up from tac4. In young stand on the edge of a large field. Route 2 is a few hundred feet away
9	tac2	Triple R Trail, 1/4 mile up from tac3.
10	tac1	Top of small shoulder on Triple R Trail, 1/4 mile up from tac2. Mature forest in appearance.
11	tacR2	1/2 mile from Petersburg Pass, north along Taconic Crest Trail. Slightly to the east/below the actual crest.
12	tacR1	<1/2 mile from Pass, on the west facing flanks of the crest.
	tac0	Lichens collected from along Taconic Crest Trail near tacR2.

lichens also collected from summit of Pine Cobble.


VERMONT
MASS
Northwest Hill 1215
White Oaks
Sand Spring
HOPKINS MEMORIAL FOREST
BIRCH BROOK TRAIL
East Hollow
Petersburg Pass 2090
ABANDONED SKI AREA
PETERSBURG RD.
BULKLEY ST.
Williamstown
COLLEGE
MAIN ST.
SOUTH ST.
WILLIAMS
PINE COBBLE
Bear Spring
POWER LINE
HOOSAC RD.
Blackinton
Eph's Lookout 2354
APPALACHIAN TRAIL
East Mtn.
Spring
TACONIC TR. (HWY)
TACONIC TRAIL
Berlin Pass 2220
BERLIN PASS TRAIL
Townsend Williams Col. Ski Area
Haskin Farm
DEE HILL ROAD
Berlin Mtn. 2798
BERLIN MTN TRAIL
Torrey Woods Rd.
Sheep Hill
COLD SPRING RD.
Stone Hill 1140
Cluett Hill
GALE RD.
Green River
STRATTON RD.
LUCE RD.
Greylock
N. Adams Airport
PATTISON RD.
Williamstown Reservoir
Mt. Williams Reservoir
Sweet Brook
Sweets Corner
Blair Rd.
Mt. Hope Farm
HOPPER ROAD
Wilbur Clearing Shelter
NOTCH ROAD
Mt. Williams 2951
MONEY BROOK CUT-OFF
Mt. Prospect 2690
MT. PROSPECT TRAIL
MONEY BROOK
Money Brook Falls
Mt. Fitch 3110
BELLOWS PIPE TRAIL
SLOAN RD.
OBLONG ROAD
S. Williamstown
Steele's Corner
The Cobble 1281
Deer Ridge
Hopper Brook
Haley's Farm
HOPPER TRAIL
Mills Hollow
TACONIC
Stony Ledge 2580
Shelter
STONY LEDGE TR.
SPERRY RD.
Robinson's Point
Bellows Pipe Ski Trail
The Bellows Pipe Shelter
THUNDERBOLT SKI TR.
OVERLOOK TRAIL
Roaring Brook
ROARING BROOK
Sperry Camp Ground
Goodell Hollow
Deer Hill Shelter
Mt. Greylock 3491
GOULD RD.
2168
West Branch Green River
Mitchell Brook
Thompson Brook
ROCKWELL RD.
APPALACHIAN TRAIL
Saddle Ball Mtn.
CHESHIRE HARBOR TRAIL
2454
2388
Mountain
W. MOUNTAIN RD.
New Ashford
GREYLOCK RD.
INGRAHAM
Jones Nose
OLD ADAMS RD.
Fire Tower 2613
BRODIE MT. SKI AREA
Sugar Loaf 2030
Rounds Rock
FRED MASON RD.
42°40'

Plot #1

PLOT: HR1					
Hoosic River		Phaeophyscia	Pseudoparmelia	Candelaria	Unknown
Host species:	Size:	rubropulchra	caperata, etc *	concolor	crustose
Acer rubrum	55	0	1	0	0
	180	55	11	0	4
	350	315	14	0	5
	30	0	16	0.5	0
	85	0	7	11	0
	30	0	6	3	0
	40	0	1	0.5	0
	65	12	12	14	0
	70	0	4	9	0
	180	0	5	1	0
	70	0	0.5	0	0
	85	0	1	7	0
	95	150	3	0	0
	20	0	5	0	0
	275	105	11	0	5
	115	70	2	0	0
	80	54	7	0	0
	60	0	0	10	0
	40	0	0	0	0
	25	0	4	16	0
	50	0	0.5	0.5	0
	95	15	4	0	0
	25	0	0	0	0
	320	205	28	0	8
	90	95	5	0	0
	55	70	16	0	0
	25	0	10	0	0
	40	0	0.5	0	0
	70	125	12	0.5	0
	55	18	8	27	0
	50	0	0	11	0
	70	85	17	4	0
	125	65	9		4
	60	0	0.5	0	0
	40	0	3	0	0
	70	0	0.5	0.5	0
	65	0	14	0	0
	75	0	0.5	0	0
	390	185	7	0	0
	60	32	12	0	0
	50	0	0	0	0
	105	45	0	0.5	0
	50	0	0	0	0

Plot #1

	205	145	10	0	0
	345	46	52	0	3
	45	0	0	0	0
	35	0	8	10	0
	160	0.5	5	0	0
	70	35	14	4	0
	55	0	0.5	8	0
	45	0.5	0	0.5	0
mean:	96.96	37.80[redacted]	6.81[redacted]	2.77	0.56[redacted]
stdev	89.84	65.73[redacted]	8.88[redacted]	5.49[redacted]	1.66[redacted]
total # lichens	2443				
species totals:					
Acer rubrum	51	1928	347.5	138.5	29
lichen density	3.33	X10(-3)			
Acer rubrum	:%	78.9	14.2	5.7	1.2
notes;	Many l	ichen species	were present in	this plot, incl	uding many
that are diffic	ult to d	istinguish in t	he field, particul	arly for an am	eture. The
grouping in wh	ich I co	unted Phaeoph	yscia rubropulch	ra included sev	eral other
species. The sa	me is tr	ue for Pseudop	armelia caperata.	While I feel P.	rubropulchra
is accurately	repres	ented, I canno	vouch for P. cape	rata.	
Species presen	t but n	t counted due	o identification	difficulties inc	lude:
Physconia dete	sa				
Parmelina galb	ina				
Heterodermia	squamu	losa			
Physcia aipola					
Physciopsis	syncoll	a			
Parmelia sulca	ta				
Parmeliopsis	hypero	pta			
This entire are	was inh	abited by map	les with remarka	bly rough, une	ven bark.
As in TAC7., th	ere we	re many trees	with a light scatt	ered covering	of lichens,
making them	imposs	ible to count	using my methods		

Plot #2

PLOT: PC1							
		Cladonia	Cladonia	Physconia	Phaeophyscia	Candelaria	Unknown
Host species:	Size:	strepsilis	coniocraea	detersa	rubropulchra	concolor	green crustose
Quercus rubrum	40	0	3	3	0	0	0
	50	0	4	3	0	0	0
	80	1	2	8	0	0	0
	55	0	1	4	0	0	0
	70	0	0	0	0	0	0
	80	0	0	1	0	0	0
	75	4	0	0	0	0	0
	50	0	0	0	0	0	0
	55	0	0	0	0	0	0
	50	1	0	0	0	0	0
	140	0	0	0	0	0	0
	130	0	0	0	0	0	0
	90	0	0	3	0	0	4
	150	0	0	7	0	0	0
	145	0	27	0	0	0	0
	80	64	0	0	0	0	0
	80	0	0	0	0	0	0
	210	0	0	0	0	0	0
	250	5	0	0	0	0	0
	90	0	0	0	0	0	0
	75	0	0	0	0	0	0
	130	16	0	0	0	0	0
	55	0	0	0	0	0	0
	290	5	0	0	0	0	0
	240	74	0	0	0	0	0
	70	0	0	0	0	0	0
Prunus serotina	65	0	0	0	0	0	0
	25	0	0	0	0	0	0
	60	3	0	0	0	0	0
	50	0	0	0	0	0	0
	40	0	0	4	0	0	0
	30	0	0	7	0	0	0
	45	0	0	4	0	0	0
	50	0	0	0	0	0	0
	30	0	0	0	0	0	0
	45	0	0	0	0	0	0
	65	3	0	0	0	0	0
	40	0	0	2	0	0	0
	50	0	0	0	0	0	0
Acer rubrum	105	0	6	0	0	3	0
	70	0	4	0	0	0	0
	50	0	0	0	0	0	0
Fraxinus americana	35	0	0	5	25	9	0
	30	0	0	4	0	0	0
Carya ovata	165	0	0	0	0	0	0
mean:	86.2	3.91[redacted]	1.04[redacted]	1.22[redacted]	0.55[redacted]	0.26[redacted]	
stdev	61.9	14.48[redacted]	4.16[redacted]	2.21[redacted]	3.72[redacted]	1.40[redacted]	0.59[redacted]
species totals:							
Quercus rubrum	26	170	37	29	0	0	4
Prunus serotina	13	6	0	17	0	0	0
Acer rubrum	3	0	10	0	0	3	0
Fraxinus americana	2	0	0	9	25	9	0
Carya ovata	1	0	0	0	0	0	0
Overall totals:	45	176	47	55	25	12	
lichen density:	5.43	X10(-4)					
Lichens by percent	total#	Cladonia s	Cladonia c	Physconia	Phaeophyscia	Candelaria	Crustose
Quercus rubrum	240	70.8	15.4	12.1	0	0	1.7
Prunus serotina	23	26.1	0	73.9	0	0	0
Acer rubrum	13	0	76.9	0	0	23.1	0
Fraxinus americana	43	0	0	20.9	58.2	20.9	0
Carya ovata	0	0	0	0	0	0	0

Plot #3

PLOT: PC2						
		Cladonia	Physconia	Phaeophyscia	Candelaria	Unknown
Host Species:	Size:	strepsilis	detersa	rubropulchra	concolor	crustose
Quercus rubrum	135	0	0	0	0	0
	65	0	0	0	0	0
	55	0	0	0	0	0
	45	0	0	0	0	0
	300	0	0	0	0	0
	220	6	0	0	0	0
	50	2	0	0	0	12
	40	0	0	0	0	0
	40	0	0	0	0	0
	70	3	5	0	0	0
	50	0	0	0	0	0
	220	0	0	0	0	0
	45	17	0	0	0	0
	50	0	0	0	0	0
	50	0	0	0	0	0
	45	0	2	0	0	0
	60	1	0	0	0	0
	55	0	0	0	0	0
	25	2	3	0	0	0
	35	0	0	0	0	0
	80	0	0	0	0	0
	60	0	0	0	0	0
	65	0	0	0	0	0
	50	0	0	0	0	0
Fraxinus americana	25	0	0	0	0	0
	20	0	0	0	0	0
	30	0	0	2	1	0
	30	0	6	0	2	0
	40	0	5	22	3	0
	40	0	19	3	2	0
	45	0	9	20	5	0
	30	0	6	0	1	0
Acer rubrum	60	0	4	0	0	0
	60	3	5	0	0	0
	30	0	0	20	1	0
	80	0	0	5	0	0
	40	0	0	0	0	0
	60	0	0	0	0	0
Fagus grandifolia	20	0	0	0	0	0
	65	0	0	0	0	0
Prunus serotina	40	0	0	0	0	0
mean:	64	1.38	2.36	3.00	0.61	0.57

Plot #3

stdev:	56.7	2.85	3.60	5.47	0.99	1.87
species totals:						
Quercus rubrum	24	31	10	0	0	12
Fraxinus americana	8	0	45	47	14	0
Acer rubrum	6	3	9	25	1	0
Fagus grandifolia	2	0	0	0	0	0
Prunus serotina	1	0	0	0	0	0
Overall totals:	41	34	64	72	15	12
Lichen density:	5	X10(-4)				
Lichens by percent	total#	Cladonia s	Physconia	Phaeophyscia	Candelaria	Crustose
Quercus rubrum	53	58.5	18.9	0	0	22.6
Fraxinus americana	106	0	42.5	44.3	13.2	0
Acer rubrum	38	7.9	23.7	65.8	2.6	0
Fagus grandifolia	0	0	0	0	0	0
Prunus serotina	0	0	0	0	0	0

Plot # 4

PLOT TAC7		Cladonia sp.				
		(coniocraea)	Phaeophyscia	This plot is loc	ated about 80	from Beehill
Host Species:	Size:	(chlorophaea)	rubropulchra	Road, and abou	t 3-400' from	route 7/2/
Acer rubrum	50	0	0	It should also	be noted that,	as always,
	55	0	0	Cladonia sp. is	found only at t	he very base
	85	0	0	of the trees.		
	85	0	0			
	55	0	25			
	65	0	0			
	50	0	0			
	60	0	0			
	55	0	0			
	50	0	0			
	60	0	0			
	40	0	0			
	65	0	0			
	50	0	0			
Tsuga canadensis	150	16	0			
	25	0	0			
	50	0	0			
	45	0	0			
	45	0	0			
	140	8	0			
	100	1	0			
Populus sp.	130	0	2			
	70	0	0			
	65	0	0			
	100	0	0			
	85	0	0			
	70	0	1			
	100	0	0			
	85	0	0			
	40	0	0			
	45	0	0			
	90	0	0			
	115	0	0			
Fagus grandifolia	30	0	0			
	40	0	0			
	35	0	0			
	30	0	0			
Acer saccharum	65	0	0			
	40	0	0			
Prunus serotina	45	0	0			
	60	0	0			
mean:	66.34	0.60[redacted]	0.68[redacted]			
species totals:	trees:					
Acer rubrum	14	0	25			
Tsuga canadensis	7	24	0			
Populus sp.	12	0	3			
Fagus grandifolia	4	0	0			
Acer saccharum	2	0	0			
Prunus serotina	2	0	0			
Overall totals:	41	24	28			
lichen density:	1.28	X10(-4)				
Lichens (%)	total#	Cladonia	Phaeophyscia			
Acer rubrum	25	0	100			
Tsuga canadensis	24	100	0			
Populus sp.	3	0	100			
Fagus grandifolia	0	0	0			
Acer saccharum	0	0	0			
Prunus serotina	0	0	0			

Plot # 5

PLOT : TAC6			
steep N slope, hemlocks		Unknown	Unknown
Host Species:	Size:	green crustose	grey crustose
Tsuga canadensis	125	20	15
	130	0	0
	85	0	0
	90	0	6
	170	0	20
	40	0	0
	40	0	0
	45	0	0
	50	0	0
	40	0	0
	60	0	0
	40	0	0
	20	0	0
	20	0	0
	25	0	0
	20	0	0
	15	0	0
	60	0	0
	45	0	0
	140	0	6
	105	0	11
	170	0	0
	180	0	0
	65	0	0
	80	0	0
Acer rubrum	40	5	0
	40	0	0
	20	0	0
mean:	70	0.89	2.07
species totals:			
Tsuga canadensis:	25	20	58
Acer rubrum	3	5	0
Overall totals:	28	25	58
lichen density	2.8	X10(-4)	
lichens (%)	total#	Green crustose	Grey crustose
Tsuga canadensis	78	25.6	74.4
Acer rubrum	5	100	0

Plot #6

PLOT: TAC5					
		Pseudoparmelia	Phaeophyscia	Cladonia	Unknown
Host Species	Size:	caperata	rubropulchra	coniocraea	crustose
Populus sp.	125	0	0	0	15
	120	0	0	6	9
Tsuga canadensis	95	0	0	0	18
	30	0	0	0	0
Betula papyrifera	25	0	0	0	0
	35	0	0	0	0
	30	0	0	0	0
	30	0	0	0	0
	60	0	0	0	0
	50	0	0	0	0
	90	0	0	5	0
	65	0	0	0	0
	40	0	0	0	0
Fraxinus americana	20	2	25	0	4
	110	0	0	6	9
	20	0	0	0	14
Betula lutea	20	0	0	0	0
	90	0	0	10	12
Betula lenta	25	0	0	0	0
Carya ovata	25	0	0	0	34
Fagus grandifolia	20	0	0	0	0
	20	0	0	0	60
	30	0	0	0	0
Acer rubrum	20	0	0	0	0
	140	0	0	0	6
	35	0	0	0	0
	40	0	0	0	0
mean:	52.22	0.07[redacted]	0.92[redacted]	1	6.70[redacted]
species totals:	trees:				
Populus sp.	2	0	0	6	24
Tsuga canadensis	2	0	0	0	18
Betula papyrifera	9	0	0	5	0
Fraxinus americana	3	2	25	6	27
Betula lutea	2	0	0	10	12
Betula lenta	1	0	0	0	0
Carya ovata	1	0	0	0	34
Fagus grandifolia	3	0	0	0	0
Acer rubrum	4	0	0	0	6
overall totals:	27	2	25	27	121
lichen density:	8.3	X10(-4)			
Lichens (%)	total#	Pseudoparmelia	Phaeophyscia	C. coniocrae	Crustose
Populus sp.	30	0	0	20	80
Tsuga canadensis	18	0	0	0	100
Betula papyrifera	5	0	0	100	0
Fraxinus americana	60	3.3	41.7	10	45
Betula lutea	22	0	0	45.5	54.5
Betula lenta	0	0	0	0	0
Carya ovata	34	0	0	0	100
Fagus grandifolia	0	0	0	0	0
Acer rubrum	6	0	0	0	100

Plot #7

PLOT TAC4							
		Pseudoparmelia	Cladonia	Cladonia	Unknown grey		
Host Species:	Size:	caperata	coniocraea	chlorophaea	crustose		
Acer rubrum	35	0	0	0	0		
	55	0	29	0	0		
	50	0	11	0	4		
	40	0	6	0	0		
	50	0	4	0	0		
	30	0	0	0	0		
	40	3	5	0	0		
	106	0	22	0	0		
	25	0	0	0	1		
	130	0	0	0	0		
	60	0	0	0	0		
	40	0	0	0	0		
	25	0	0	0	0		
	30	0	0	0	0		
	30	2	0	0	0		
	45	0	4	0	0		
	35	0	0	0	0		
Betula papyrifera	80	0	20	2	0		
	100	0	42	0	0		
	20	0	0	0	0		
	40	0	15	0	0		
	85	0	0	0	0		
Populus sp.	40	0	12	0	0		
	55	0	0	0	0		
	45	0	6	0	0		
	55	0	0	0	0		
Fagus grandifolia	30	0	0	0	0		
	40	7	6	0	0		
	70	3	0	0	0		
	80	0	8	0	0		
Betula lenta	25	0	0	0	0		
mean:	51.32	0.48[redacted]	6.12[redacted]	0.06[redacted]			
Species Totals:	trees:						
Acer rubrum	17	5	81	0	5		
Betual papyrifera	5	0	77	2	0		
Populus sp.	4	0	18	0	0		
Fagus grandifolia	4	10	14	0	0		
Betula lenta	1	0	0	0	0		
Overall totals:	31	15	190	2	5		
Lichen Density:	8.94	X10(-4)					
lichens (%)	total#	Pseudoparmelia	C. coniocr	C. chloroph	Crustose		
Acer rubrum	91	5.5	89	0	5.5		
Betula papyrifera	79	0	97.5	2.5	0		
Populus sp.	18	0	100	0	0		
Fagus grandifolia	24	41.7	58.3	0	0		
Betula lenta	0	0	0	0	0		

Plot #8

TAC3					
		Phaeophyscia	Candelaria	Heterodermia	unknown
Host Species:	size:	rubropulchra	concolor	squamulosa	crustose
Betula lutea	30	0	0	0	0
	35	0	0	0	0
	30	0	0	0	0
	25	0	0	0	0
	20	0	0	0	0
	35	0	0	0	0
	40	0	0	0	0
	20	0	0	0	0
	20	0	0	0	0
	30	0	0	0	0
	20	0	0	0	0
	25	0	0	0	0
	30	0	0	0	0
Betula lenta	45	0	0	0	0
	20	0	0	0	0
	20	0	0	0	0
	25	0	0	0	0
	40	0	0	0	0
	35	0	0	0	0
	25	0	0	0	0
	20	0	0	0	0
	30	0	0	0	0
Populus sp.	100	0	0	0	0
	65	0	0	0	0
	20	0	0	0	0
	30	0	0	0	0
	20	0	0	0	0
Acer rubrum	60	0	0	0	0
	20	0	0	0	0
	30	0	0	0	0
	40	0	0	0	0
	35	0	0	0	0
	120	0	0	0	0
	30	0	0	0	0
Prunus serotina	20	0	0	0	0
Quercus grandifolia	20	0	0	0	0
	35	0	0	0	0
	25	0	0	0	0
	25	0	0	0	0
	20	0	0	0	0
Fraxinus americana	20	0	0	5	0
	30	0	0	0	0
	30	0	0	0	0

Plot #5

	35	0	0	0	0
	40	0	0	0	0
	130	scattered,10(	present in	0	0
	100	scattered,15(	crowns	0	79
species totals	trees				
Betula lutea	13	0	0	0	0
Betula lenta	9	0	0	0	0
Acer rubrum	7	0	0	0	0
Populus sp.	5	0	0	0	0
Prunus serotina	1	0	0	0	0
Fagus grandifolia	5	0	0	0	0
Fraxinus americana	7	present on 2	present	5	79
Overall totals:	47	250	present	5	79
the lichen density	n/a				
calculation comes out to		Notes:	fallen ash, <5	years ago.	
exactly 7, yet this			bottom five	feet were sc	ered thin
obviously does not reflect		coverage of Pl	aeophyscia sp	qual to a cour	of 4 or 5.
the true density of		Upper branch	es were cover	d with all fou	species fou
lichens present.		nd to be prese	t. No large fo	ose were note	anywhere.
		Rocks near th	streambed we	e covered wit	lichens.
lichens (%)	total #	Phaeophyscia	Candelaria	Heterodermia	crustose
Fraxinus americana	334	79.4	0	1.5	23.6

Plot #9

Tac2					
		Parmelia	Platismata	Cladonia	unknown
Host Species:	size:	halei	glauca	coniocraea	crustose
Picea rubra	95	0	0	0	0
Betula papyifera	120	0	0	29	0
	80	0	0	11	0
	70	0	0	0	0
	95	0	0	0	0
	75	0	0	14	0
	55	0	0	9	0
	70	0	0	0	0
	60	0	0	14	0
	55	0	0	8	0
	45	0	0	32	0
Acer rubrum	65	0	0	0	4
	30	0	0	0	0
	105	0	5	2	0
	45	0	0	0	0
	40	0	0	0	4
	110	0	0	0	0
	95	0	0	0	0
	80	0	0	0	0
	40	0	0	0	0
	60	0	0	0	4
	35	0	0	0	5
	35	0	0	0	0
	55	0	0	0	8
	45	0	0	8	0
	100	0	0	0	2
	120	0	0	18	0
	30	0	0	0	0
	55	0	0	0	0
Acer pensylvanium	30	0	0	0	0
Acer saccharum	35	0	0	0	0
Carya ovata	30	14	0	0	0
Fagus Grandifolia	55	0	0	0	0
species totals:	trees:				
Picea rubra	1	0	0	0	0
Betula papyifera	10	0	0	117	0
Acer rubrum	18	0	7	32	25
Acer pensylvaticum	1	0	0	0	0
Acer saccharum	1	0	0	0	0
Carya ovata	1	14	0	0	0
Fagus grandifolia	1	0	0	0	0
Overall totals:	33	14	7	149	25
Lichen density:	6.15	X10(-4)			
mean:	64.09	0.42	0.15	4.39	0.82
stdev	27.82	2.44	0.87	8.44	1.93
lichens by percent	total#	Parmelia h.	Platismata g.	C. coniocraea	crustose
Picea rubra	0	0	0		0
Betula papyrifera	117	0	0	100	0
Acer rubrum	64	0	10.9	50	39.1
Acer pensylvaticum	0	0	0	0	0
Acer saccharum	0	0	0	0	0
Carya ovata	14	100	0	0	0
Fagus grandifolia	0	0	0	0	0

Plot #10

PLOT TAC1				
		Pseudoparmelia	Parmelia	Cladonia
Host Species	Size:	caperata	rudecta	coniocraea
Quercus rubrum	95	133	15	40
	75	85	0	27
	90	25	0	31
	100	37	0	31
	65	45	0	14
	60	16	0	10
	75	9	0	11
	105	20	3	9
	115	63	0	34
	85	76	0	41
	45	18	0	32
	35	0	0	0
	50	5	0	9
	80	61	0	13
	35	4	0	0
	50	0	0	3
	80	21	0	11
	100	15	0	9
	40	4	0	11
	55	35	9	0
	50	9	0	29
	40	7	0	32
	45	4	0	14
Acer rubrum	20	0	0	0
	35	0	0	0
	30	0	0	0
	40	35	0	9
	45	24	0	14
	35	5	0	8
	60	13	0	0
	30	0	0	0
Fagus grandifolia	35	0	0	0
	30	0	0	0
	40	0	0	0
	40	0	0	0
	35	0	0	0
	30	0	0	0
lichen density:	3.967	X 10 (-3)		
species totals	trees			
Quercus rubrum	23	692	27	411
Acer rubrum	8	72	0	31
Fagus grandifolia	6	0	0	0
Overall totals:	37	764	27	442
mean:	56.08	20.78	0.73	11.95
stdev	25.63	29.61	2.86	13.24
lichen (%)	total#	P. caperata	P.rudecta	C. coniocraea
Quercus rubrum	1130	61.2	2.4	36.4
Acer rubrum	103	69.9	0	30.1
Fagus grandifolia	0	0	0	0

Plot #11

PLOT TAC-R2					
		Cladonia	Cladonia	Parmelia	Unknown
Host Species:	Size:	strepsilis	coniocraea	rudecta	crustose
Acer rubrum	65	1	0	0	4
	30	4	0	0	0
	80	8	0	0	0
	35	0	0	0	0
	35	0	0	0	0
	45	0	0	0	0
	65	19	0	0	0
	40	13	0	0	0
	40	0	0	0	0
	105	0	0	0	8
	65	4	0	0	2
	80	3	0	0	0
	30	0	0	0	0
	65	0	0	0	0
	70	8	0	0	0
	95	0	0	0	0
	75	9	0	0	0
	90	0	0	0	0
	65	1	0	0	0
	100	6	3	10	0
	40	0	0	0	0
	140	6	0	0	21
Fagus grandifolia	30	0	0	0	0
	65	0	0	0	1
	30	0	0	0	0
	50	0	0	0	0
	65	0	0	0	0
	55	0	0	0	0
	40	0	0	0	0
	55	0	0	0	0
	70	0	0	0	0
	85	2	0	0	0
	100	0	0	0	0
	40	0	0	0	0
	30	0	0	0	0
	60	0	0	0	0
	38	0	0	0	0
Betula papyrifera	80	13	0	0	0
	135	0	0	0	0
	65	14	0	0	0
Acer pensylvaticum	25	0	0	0	0
mean:	62.76	2.70[redacted]	0.07[redacted]	0.24[redacted]	0.87[redacted]
standard deviation:	27.99	4.80[redacted]	0.46[redacted]	1.56[redacted]	3.51[redacted]
species totals					
Acer rubrum	22	82	3	10	35
Fagus grandifolia	15	2	0	0	1
Betula papyrifera	3	27	0	0	0
Acer pensylvaticum	1	0	0	0	0
Overall totals	41	111	3	10	36
lichen density	4.15	X10(-4)			
Lichens (%)	Total#	Cladonia s.	Cladonia c.	Parmelia	Crustose
Acer rubrum	130	63.1	2.3	7.7	26.9
Fagus grandifolia	3	66.7	0	0	33.3
Betula papyrifera	27	100	0	0	0
Acer pensylvaticum	0	0	0	0	0

Plot #12

PLOT: TAC R1					
Host Species:	Size:	Physcia hyperopta	Cladonia coniocraea	Phaeophyscia rubropulchra	Cladonia strepsilis
Acer rubrum	40	1	0	0	0
	85	0	0	0	0
	40	0	0	0	0
	40	0	0	0	0
	60	0	0	0	0
	45	0	0	0	0
	40	0	0	0	0
	40	0	0	0	0
	45	0	0	0	0
	45	0	0	0	0
	50	0	0	0	0
	50	0	0	0	0
	65	0	0	0	0
	45	0	0	0	0
	40	0	9	0	0
	45	0	0	0	0
	80	0	0	0	0
	80	0	0	0	0
	40	0	0	0	0
	60	0	0	0	0
	60	0	0	2	0
	50	0	0	11	0
	30	0	0	0	0
	35	0	0	0	0
	45	0	0	0	0
	40	0	0	0	0
	250	0	0	0	0
Fagus grandifolia	25	0	0	0	39
	30	0	0	0	0
	40	0	0	0	0
	40	0	0	0	0
	35	0	0	0	0
	40	0	0	0	0
	70	0	.0	0	0
Betula lutea	70	0	0	0	0
	60	0	0	0	0
	50	0	0	0	0
	30	0	0	0	0
Ostria virginiana	45	0	0	0	0
Populus sp.	60	0	0	0	0
Fraxinus americana	30	0	0	0	0
Prunus serotina	45	0	0	0	0
Quercus rubra	45	0	0	0	0

Plot #12

mean	52.56	0.02[redacted]	0.20[redacted]	0.30[redacted]	0.90[redacted]
(it is recognized that					
these means mean very					
little due to the skewed					
nature of the data					
species totals:	trees:				
Acer rubrum	27	1	9	13	39
Fagus grandifolia	7	0	0	0	0
Betula lutea	4	0	0	0	0
Ostria virginiana	1	0	0	0	0
Populus sp.	1	0	0	0	0
Fraxinus americana	1	0	0	0	0
Prunus serotina	1	0	0	0	0
Quercus rubra	1	0	0	0	0
Overall totals:	43	1	9	13	39
lichen density:	1.83	X10(-4)			
st dev	33.9	0.152499	1.372487	1.69782611	5.94744
lichens (%)	total#	Physcia	Cladonia c.	Phaeophyscia	Cladonia s.
Acer rubrum	62	1.6	14.5	21	62.9
Fagus grandifolia	0	0	0	0	0
Betula lenta	0	0	0	0	0
Ostria virginiana	0	0	0	0	0
Populus sp	0	0	0	0	0
Fraxinus americana	0	0	0	0	0
Prunus serotina	0	0	0	0	0
Quercus rubra	0	0	0	0	0

	species:	tacR1	tacR2	tac1	tac2	tac3	tac4	tac5	tac6	tac7	HR1	pc1	pc2	Totals:
1	Candelaria concolor										138	12	15	165
2	Cladonia coniocraea	9	3	442	149		190	27		24		47		891
3	Cladonia strepsilis	39	111									176	34	360
4	Cladonia chlorophaea						2							2
5	Crustose		36		25	79	5	121	82		29		12	389
6	Heterodermia squamul					5								5
7	Parmelia halei				14									14
8	Parmelia rudecta		10	27										37
9	Phaeophyscia rubropu	13				250		25		28	1928	25	72	2391
10	Physcia hyperopta	1												1
11	Physconia detersa											55	64	119
12	Platismata glauca				7									7
13	Pseudoparmelia caper			764			15	2			347			1128

Epiphytic corticolous species:

Candelaria concolor	(tac3;HR;PC1;PC2)
Cetraria oakesiana	(tac0)
Cetraria pinastri	(tac4)
Cladonia coniocraea	(tac0;R1;R2;1;2;4;5;7;PC1)
Cladonia chlorophaea	(tac4;7)
Cladonia strepsilis	(tacR1;R2;4;PC1;PC2)
Crustose	(tac0;R1;R;2;3;4;5;6;7*;HR;PC1;PC2)
Heterodermia squamulosa	(tac3;HR)
Hypogymnia krogii	(tac7*)
Parmelia halei	(tac2)
Parmelia rudecta	(tac0;R2;1)
Parmelia squarrosa	(tac7*)
Parmelia sulcata	(HR)
Parmelina galbina	(tac7*;HR)
Parmeliopsis aleurites	(tac0)
Parmeliopsis hyperopta	(HR)
Phaeophyscia rubropulchra	(tacR1;3;5;7*;7;HR;PC1;PC2)
Physcia aipolia	(tac7*;HR)
Physcia americana	(tac0)
Physcia hyperopta	(tacR1)
Physciopsis syncolla	(HR)
Physconia detersa	(tac7*;HR;PC1;PC2)
Plastismata glauca	(tac2)
Pseudoparmelia rudecta	(tac0)
Pseudoparmelia caperata	(tac1;4;5;HR)
Ramalina farinacea	(tac7*)
Ramalina intermedia	(tac0)

Saxicolous species- all collected near Pine Cobble summit (Dolomitic limestone?).

Cladina amaurocraea
Cladina rangifera
Cladonia squamulosa
Ramelina intermedia
Umbilicata hyperborea
Umbilicata mammulata

X^2 Test							
PC1 vs. PC2							
Null Hypothes	is: There is	difference	he frequenc	of the lichen	pupulations		
between the t	o plots.						
	Cladonia	Cladonia	Physconia	Phaeophyscia	Candelaria	Crustose	Totals
Plot:	strepsilis	coniocraea	detersa	rubropulchrum	concolor		
PC1- observed	176	47	55	25	12	0	315
expected	129.2	28.9	73.2	59.7	16.6	7.4	
PC2-observed	34	0	64	72	15	12	197
expected	80.8	18.1	45.8	37.3	10.4	4.6	
Totals	210	47	119	97	27	12	512
X^2 =	160.32						
d.t =	12.6						
We may reject	the null h	ypothesis.	This implie	s that there is a	statistical	ly	
important diff	erencebet	ween the	lichen popu	lations of the tw	o plots.		

X^2 Test:							
PC1 (oaks) vs	PC2 (oaks	)					
Now knowing t	hat test pl	ots PC1 ar	d PC2 are	statistically diss	imilar, it	may be	
useful to see w	hether thi	s differenc	e is attribut	able to differenc	es in habit	at (i.e.	
tree species p	resent),	or may be	from enviro	nmental factors	or even ju	st	
variation. This	is done he	re by comp	aring lichen	populations on a	constant	tree host.	
NULL HYPOTH	ESIS:						
There is no diff	erence bet	ween the	lichen popu	lations on Red O	aks in the	plots	
PC1 and PC2.							
	Cladonia	Cladonia	Physconia	Crustose	Total.		
Plot:	strepsilis	coniocraea	detersa				
PC1-observed	170	37	29	4	240		
expected	146.8	51.5	22	12.1			
PC2-observed	24	31	10	12	77		
expected	47.1	16.5	9.5	3.9			
Totals	194	68	39	16	317		
X^2 =	58.08						
d.t.=	7.81						
We may reject	the null	hypothesis					

X^2 Test							
PC1 vs PC2:	Tree populatio	ns.					
To verify that	PC1 and PC2 a	re compa	for lichen	tat, this	attempts to		
demonstrate	that there is n	significa	ference in	populati	host trees		
between the t	o plots.						
NULL HYPOTH	ESIS:						
There is no dif	ference betwe	n the tre	lations of F	and PC2.			
PLOT:	Quercus	Prunus	Fraxinus	Carya	Acer	Fagus	Total
	rubrum	serotina	americana	ovata	rubrum	grandifolia	
PC1-observed	26	13	2	1	3	0	45
expected	26.16	7.32	5.23	0.52	4.71	1.05	
PC2-observed	24	1	8	0	6	2	41
expected	23.84	6.67	4.77	0.48	4.29	0.85	
Total:	50	14	10	1	9	2	86
X^2=	18.36						
d.t.=	11.1						
We may reject	the null hypoth	esis.	However,	this rej	ection is	within 0.05	
alpha level of	certainty. I wo	uld quest	ion whethe	r this l	evel of ac	curacy is	
necessary for a	characterizati	on of the	basic tree	populat	ions.		

X^2 Test:						
Oaks vs.Maples	TAC1					
Null hypothesis						
There is no difference between the epiphytic lichen populations on Oaks and Red Maples.						
Species:	Pseudoparmelia concolor	Parmelia rudecta	Cladonia coniocraea	Totals:		
Q.rubrum-ob	692	27	411	1130		
Expected	700.2	24.7	405.1			
A.rubrum-ob	72	0	312	103		
expected	63.8	2.3	36.9			
Totals:	764	27	443	1233		
d.t=	5.99					
X^2=	4.69					
We cannot reject the null hypothesis that red oaks and red maples carry the same lichen populations.						

X^2 Test:						
Oak vs Maple	recheck from	PC2				
NULL HYPOTHESIS:						
There is no difference between the epiphytic lichen populations on Oaks and Red Maples.						
Species:	Cladonia strepsilis	Physconia detersa	Phaeophyscia rubropulchra	Candelaria concolor	Crustose	Totals:
Q.rubrum-ob	31	10	0	0	12	53
expected	19.8	11.06	14.56	0.58	7	
A.rubrum-ob	3	9	25	1	0	38
expected	14.2	7.93	10.44	0.42	5.01	
Totals:	34	19	25	1	12	91
d.t=	9.49					
X^2=	55.23					
We may reject the null hypothesis, which you should note i the same as the null that was rejected in the last test.						

X^2 TEST					
Acer rubrum	: all plots with	5 or more ind	ividuals.		
Null hypothesis					
There is no dif	ference in the	epiphytic liche	n populations	on red maples	in all the plots.
(note: only the	three most fre	quent species	were used to m	ke this questio	usable with a
				chi	squared test
Species/Plot	Cladonia	Phaeophyscia	Pseudoparmelia		
	coniocraea	rubropulchra	caperata	Totals:	
tac1-observed	31	0	72	103	
expected	6.25	79.8	17		
tac2-observed	32	0	0	0	
expected	1.94	24.78	5.28		
tac3-observed	0	0	0	0	
expected	0	0	0	0	
tac4-observed	81	0	5	86	
expected	5.22	66.6	14.18		
tac7-observed	0	25	0	25	
expected	1.52	19.36	4.122		
tacr1-obs	9	13	0	22	
expected	1.33	17.04	3.63		
tacr2-obs	3	0	0	3	
expected	0.18	2.32	0.49		
HR1-observed	0	1928	347	2275	
expected	138.04	1761.77	375.18		
pc2-observed	0	25	0	25	
expected	1.52	19.36	4.122		
Totals:	156	1991	424	2571	
d.t.=	26.3				
X^2=	2290.24				
We may reject	the null hypoth	esis.			

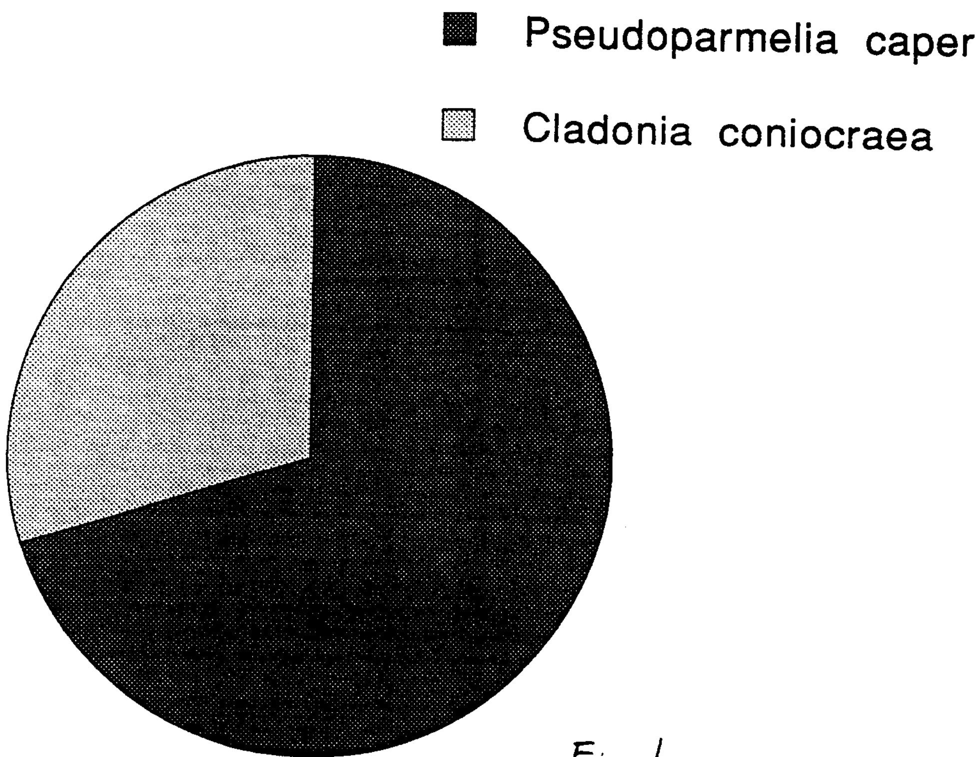


Fig 1

tac1.redmaple

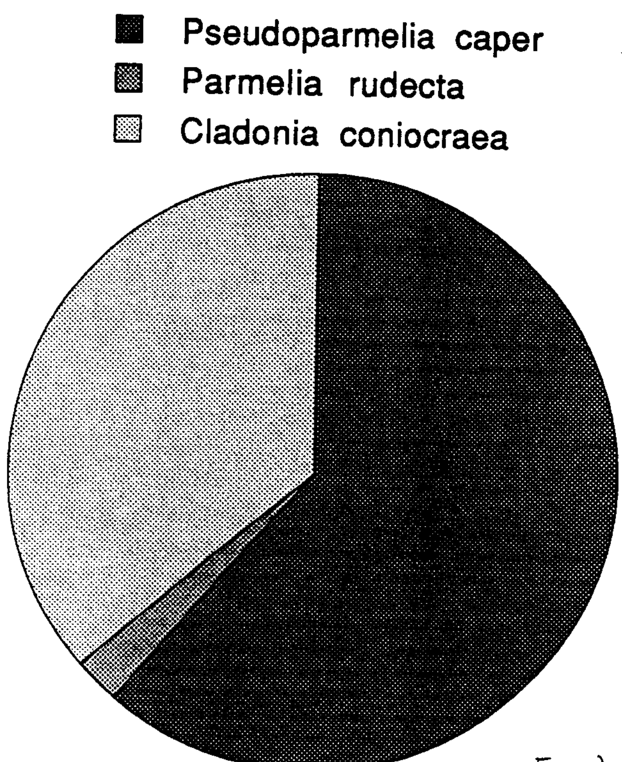


Fig 2

tac1.oak

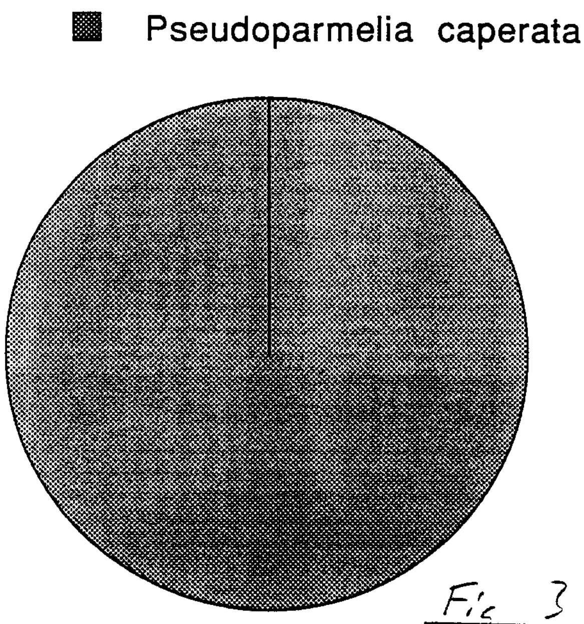


Fig 3

tac4.aspen

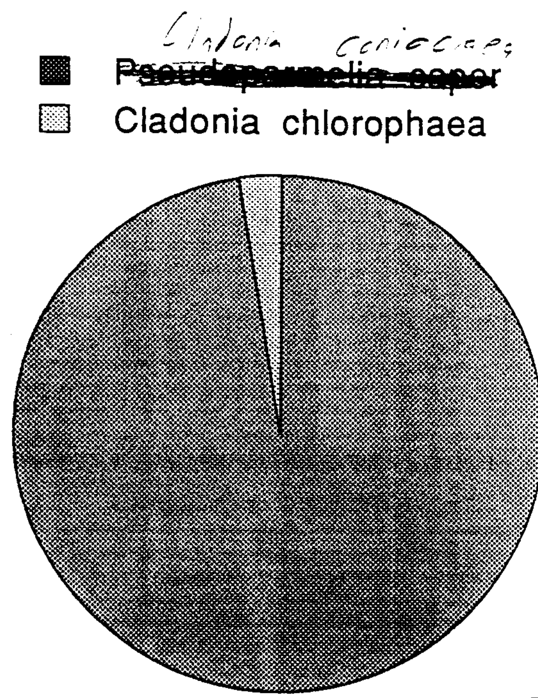


Fig 4

tac4.pbirch

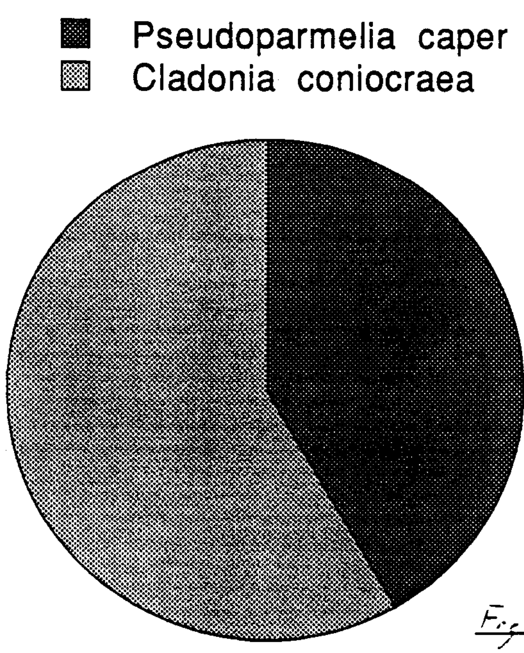


Fig 5

tac4.beech

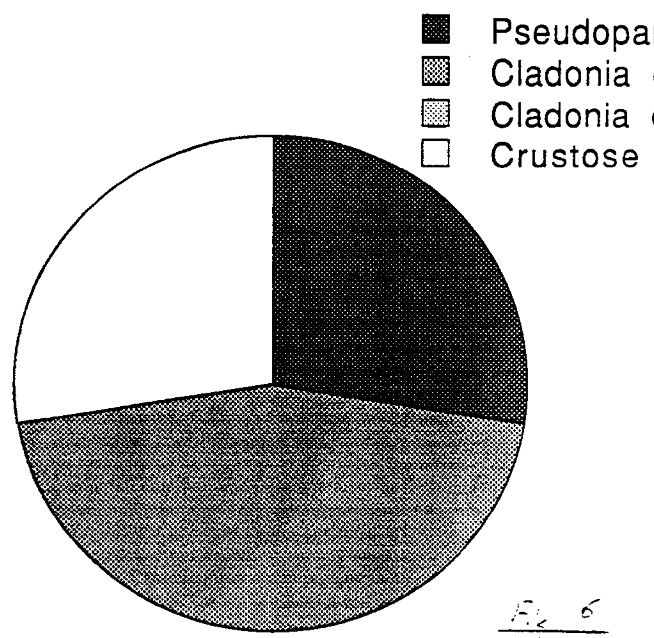


Fig 6

tac4.maple

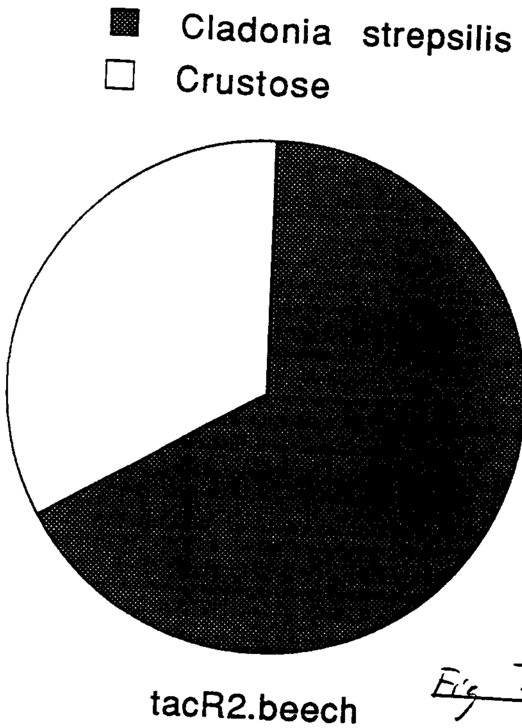


Fig 7

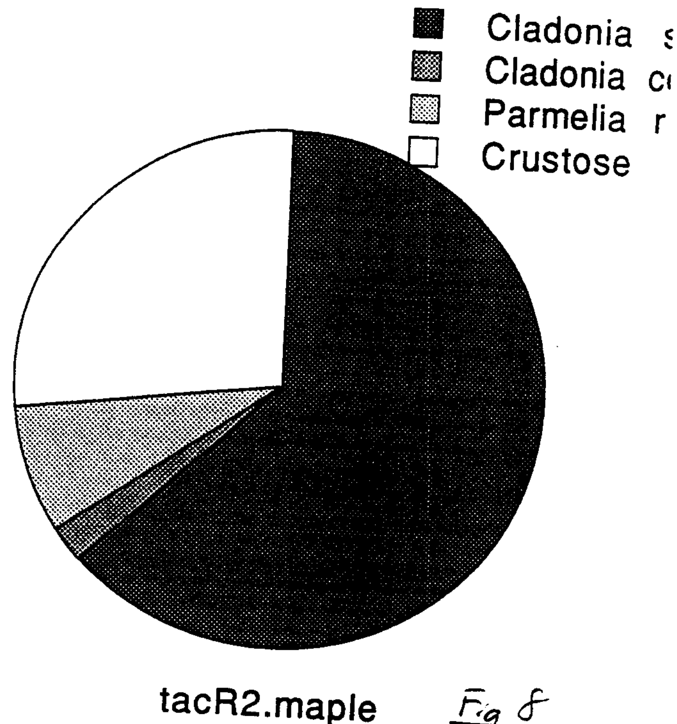


Fig 8

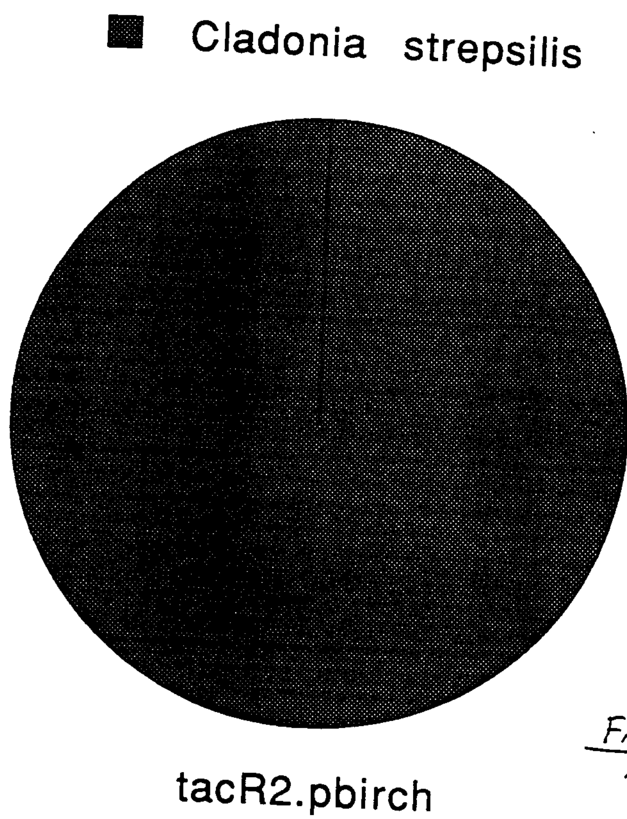
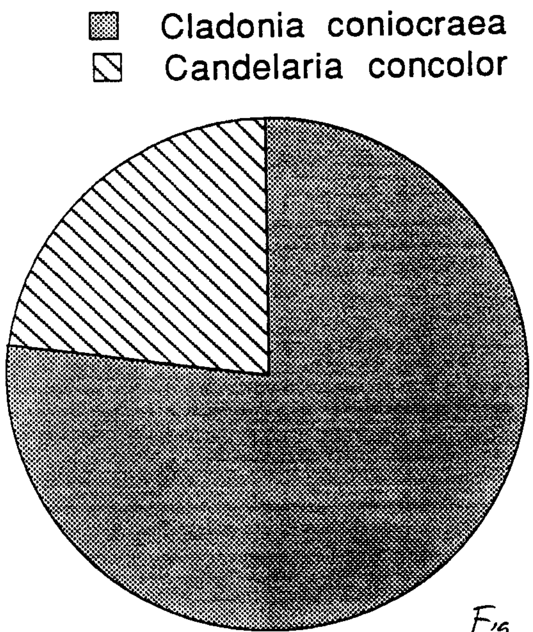
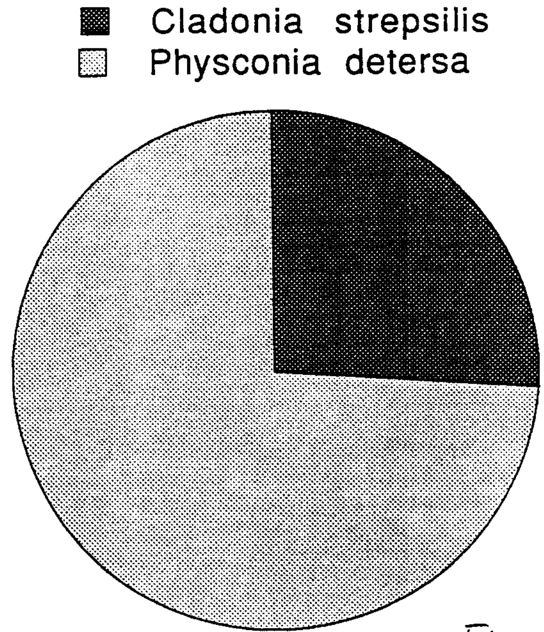


Fig 9



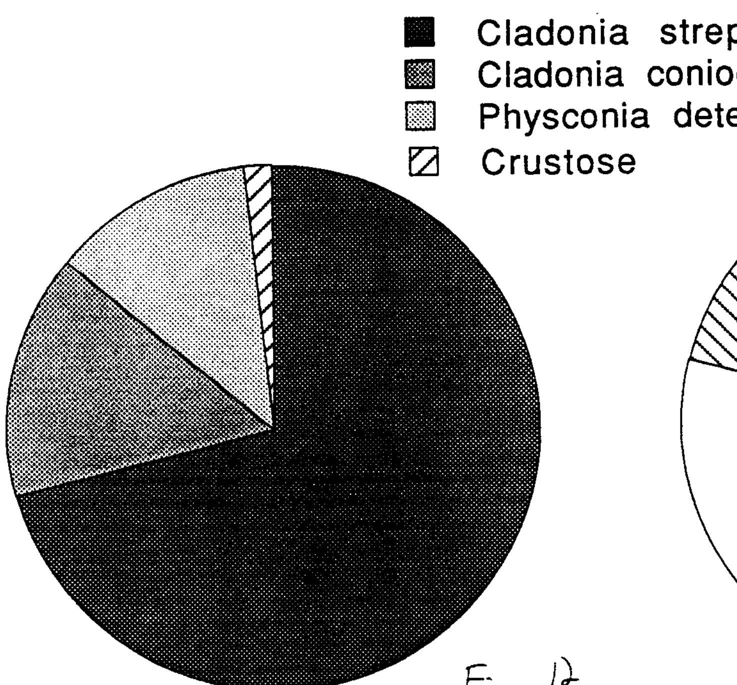
pc1.maple

Fig 10



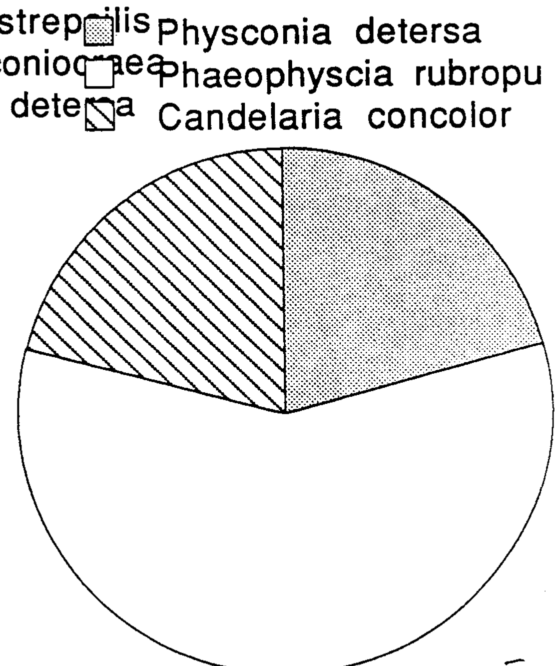
pc1.cherry

Fig 11



pc1.oak

Fig 12



pc1.ash

Fig 13

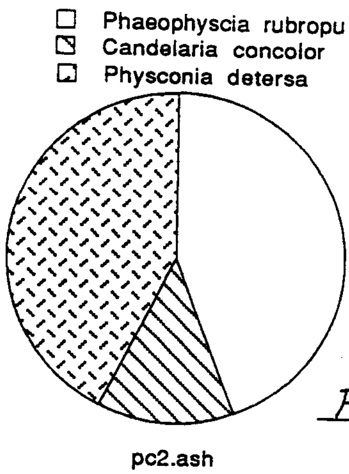


Fig 14

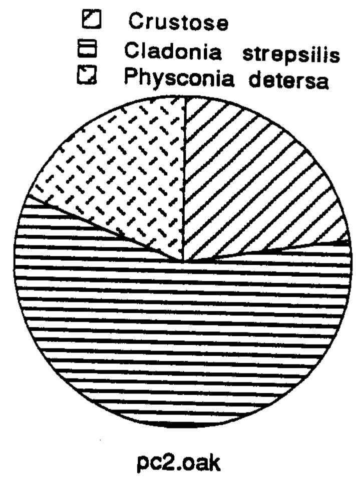


Fig 15

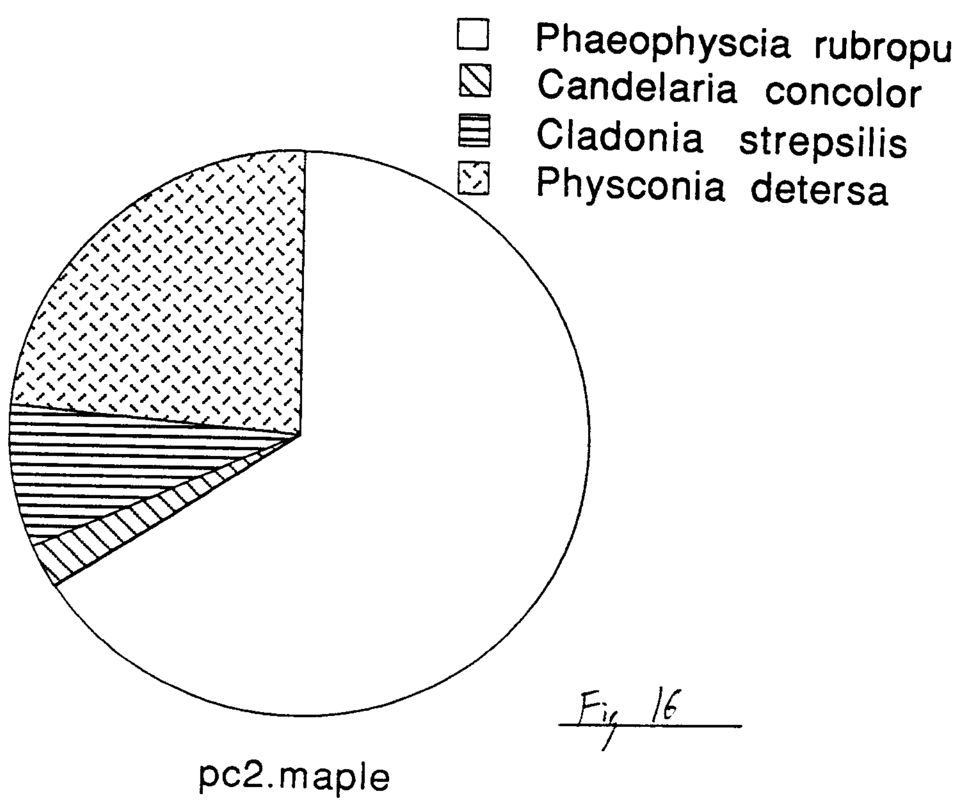
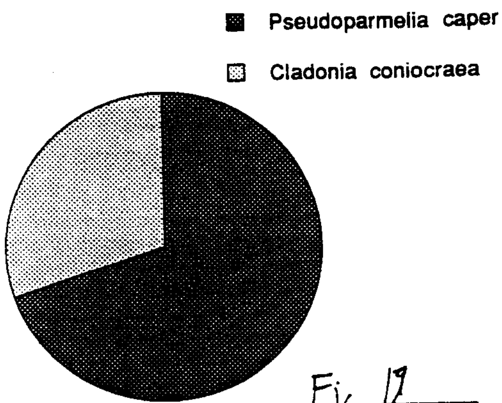
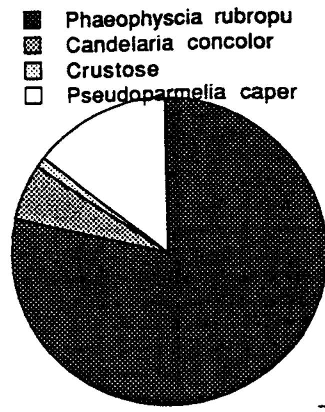


Fig 16



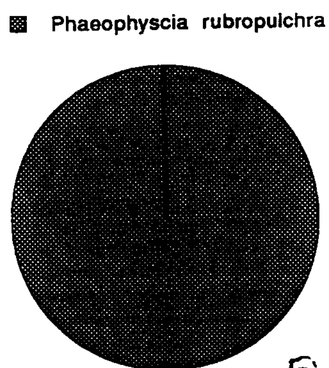
tac1.redmaple

Fig 17



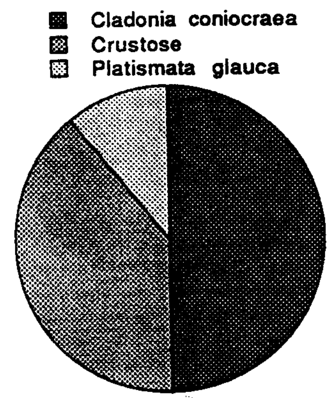
HR1.maple

Fig 18



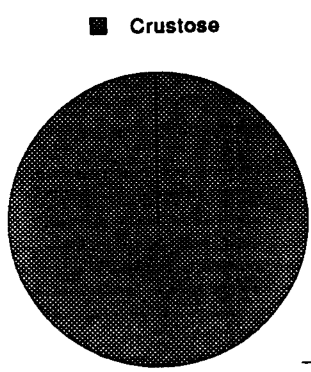
tac7.maple

Fig 19



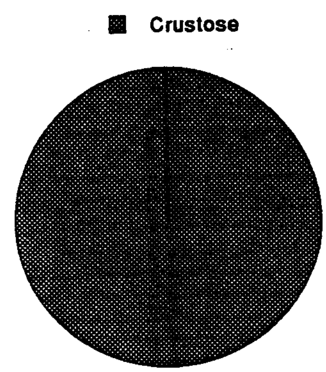
tac2.maple

Fig. 20



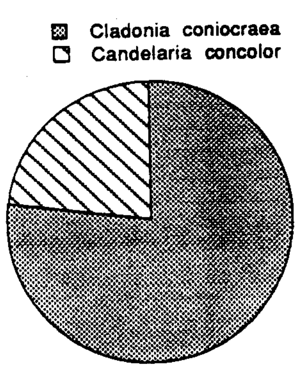
tac6.maple

Fig 21



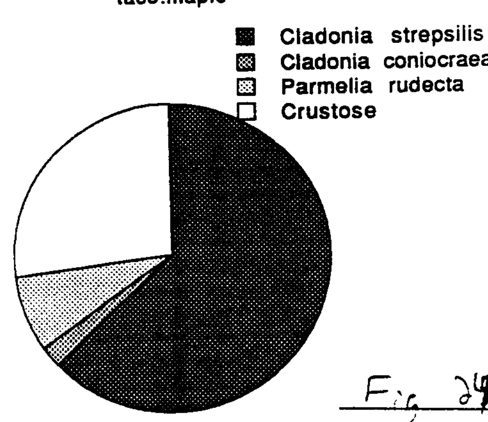
tac5.maple

Fig 22



pc1.maple

Fig 23



tacR2.maple

Fig 24

Total Lichen Population: species composition

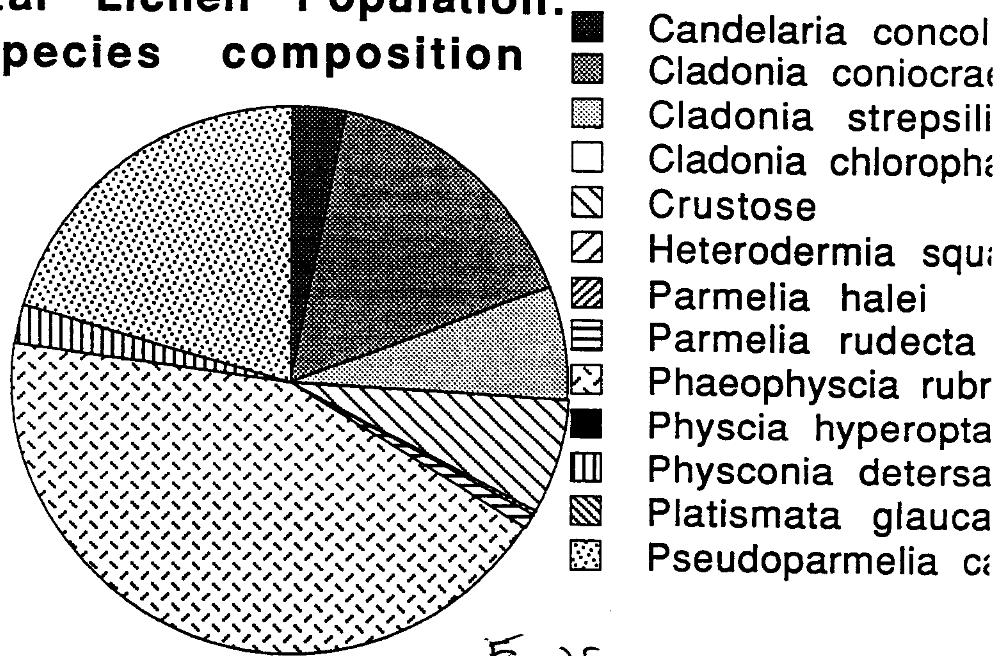
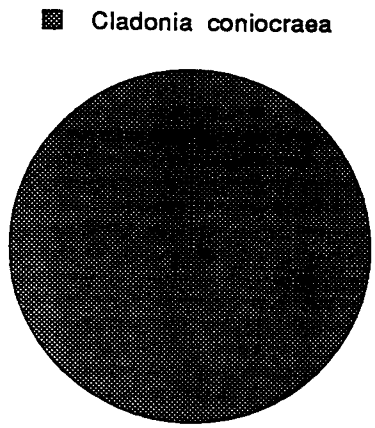


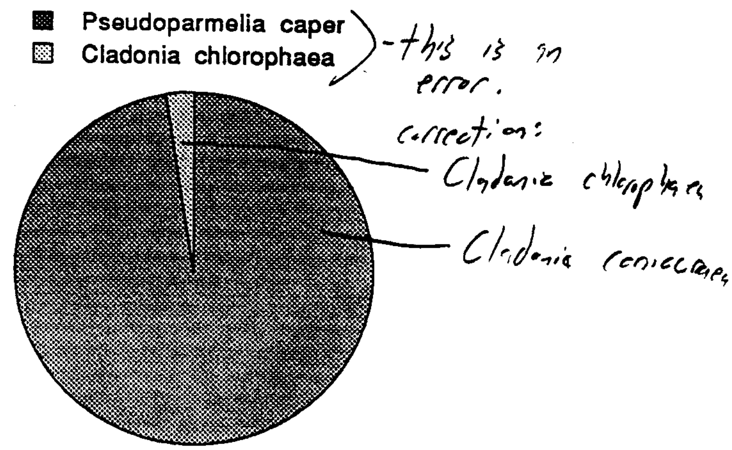
Fig 25

Totals:



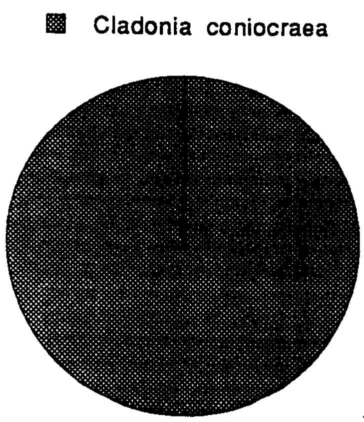
tac2.pbirch

Fig 26



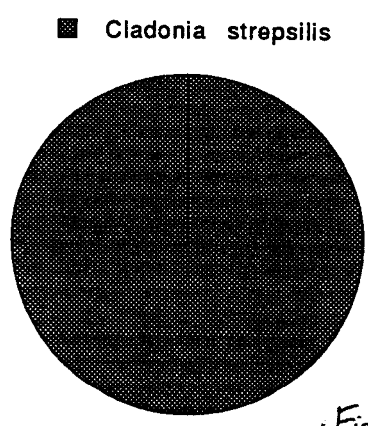
tac4.pbirch

Fig 27



tac5.pbirch

Fig 28



tacR2.pbirch

Fig 29

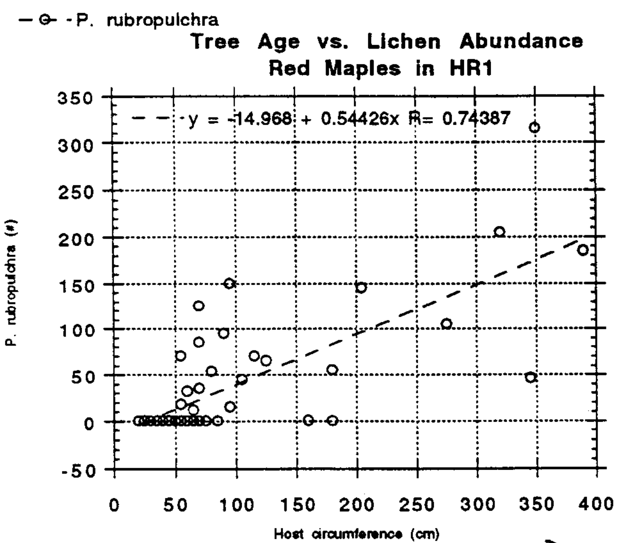


Fig 30

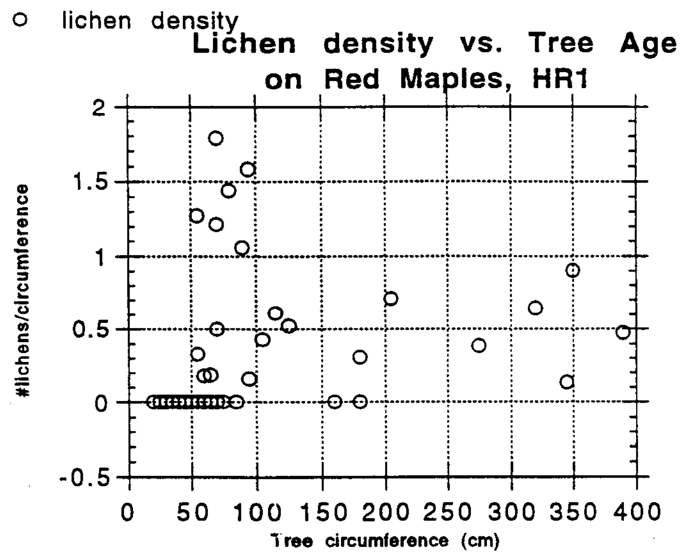


Fig 31

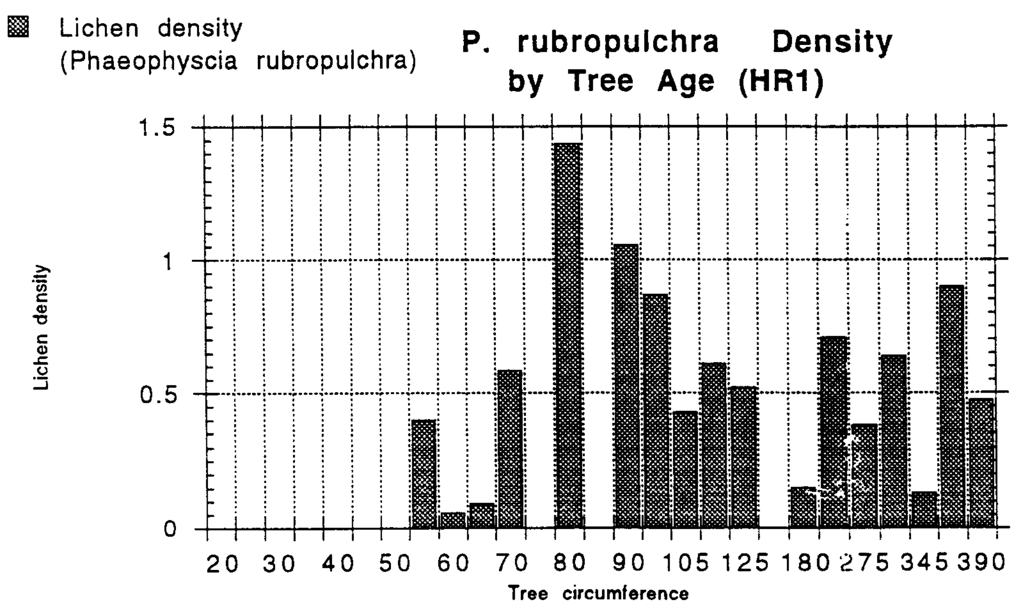


Fig 32

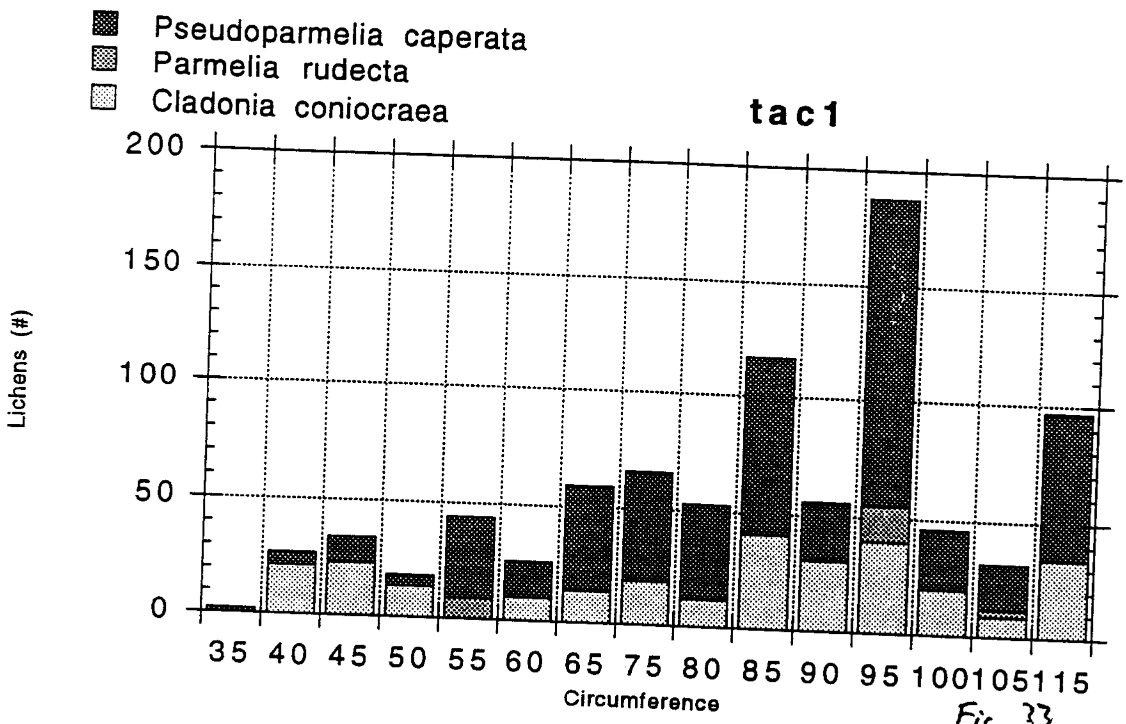


Fig 33

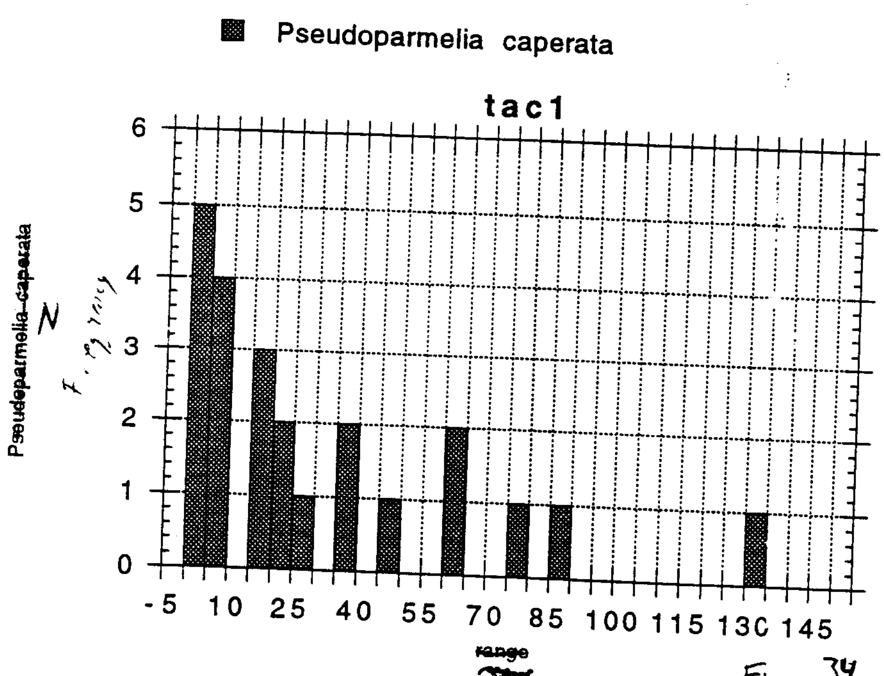


Fig 34

Pseudoparmelia caperata

Variation in Lichen Populations as a function of distance from town

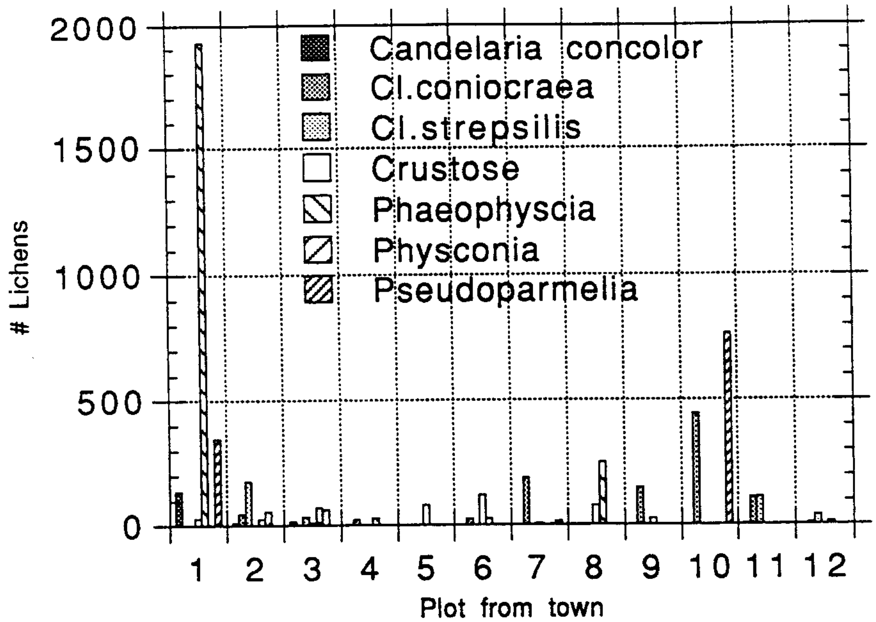


Fig 35

Inverse relationship between Cladonia and Phaeophyscia

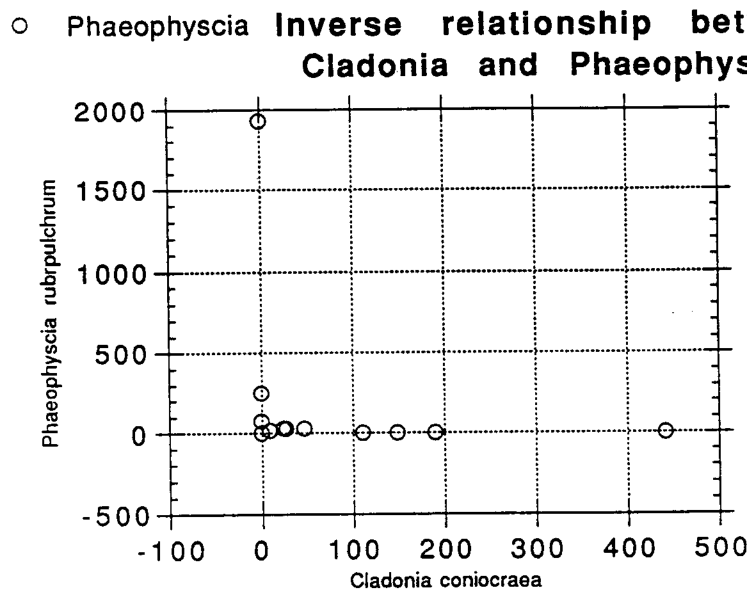


Fig 36

Cladonia sp. variation by distance from town

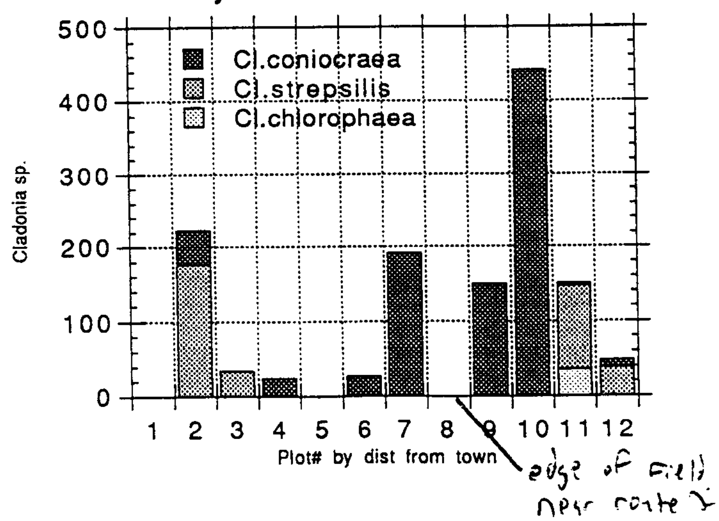


Fig 37

Lichen population of Taconic Transec
 # as a function of distance from towr

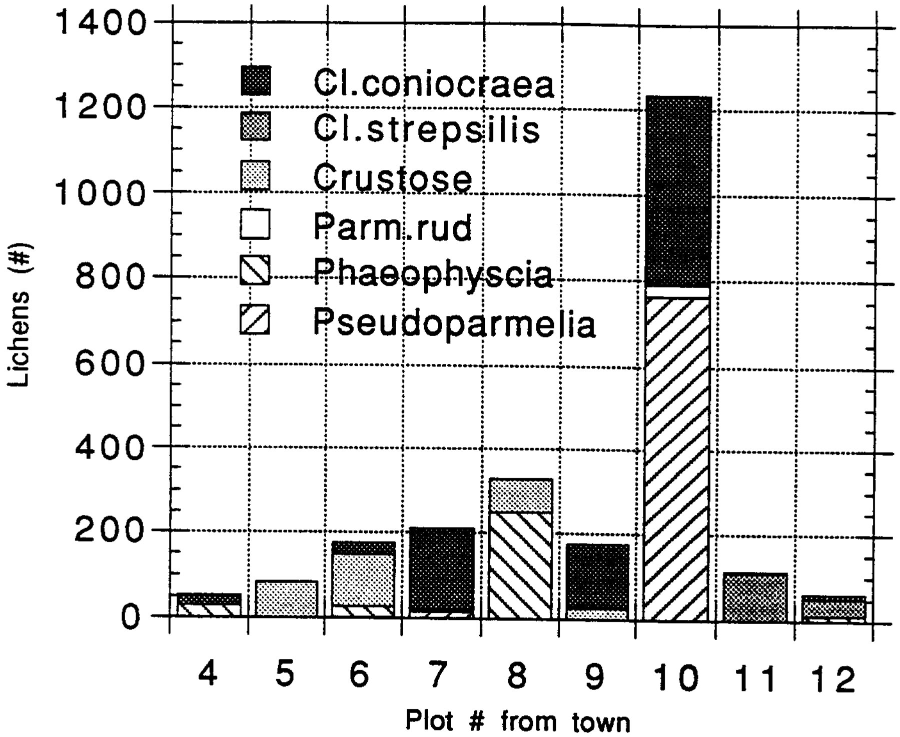
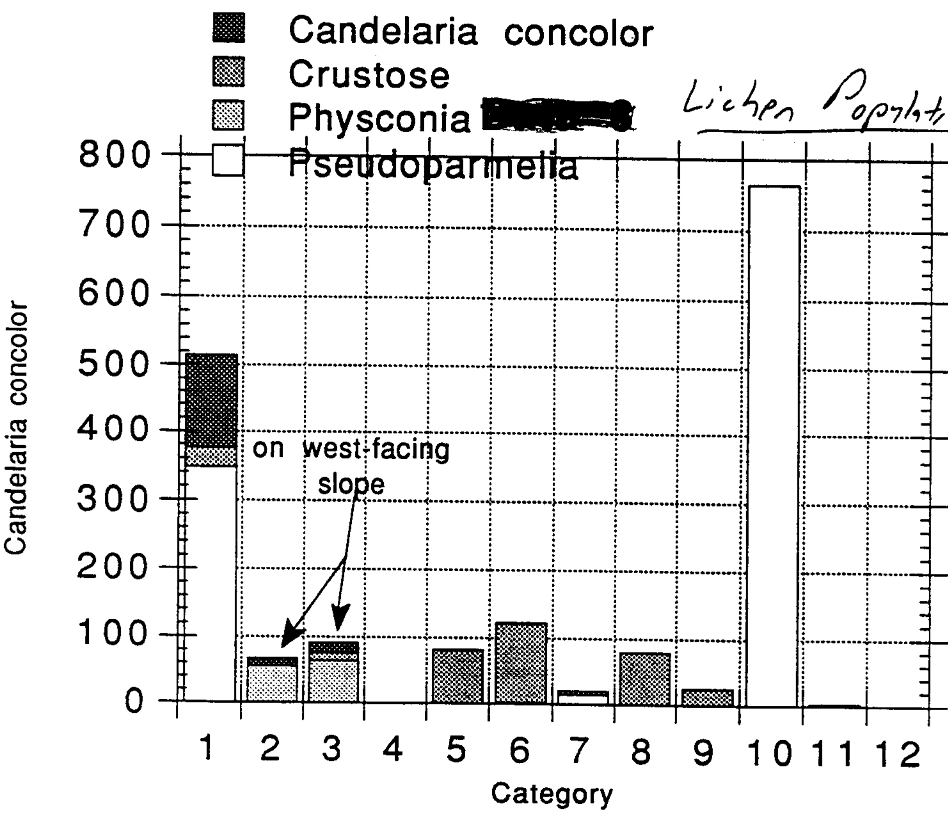


Figure 38



Lichen Population

Figure 39

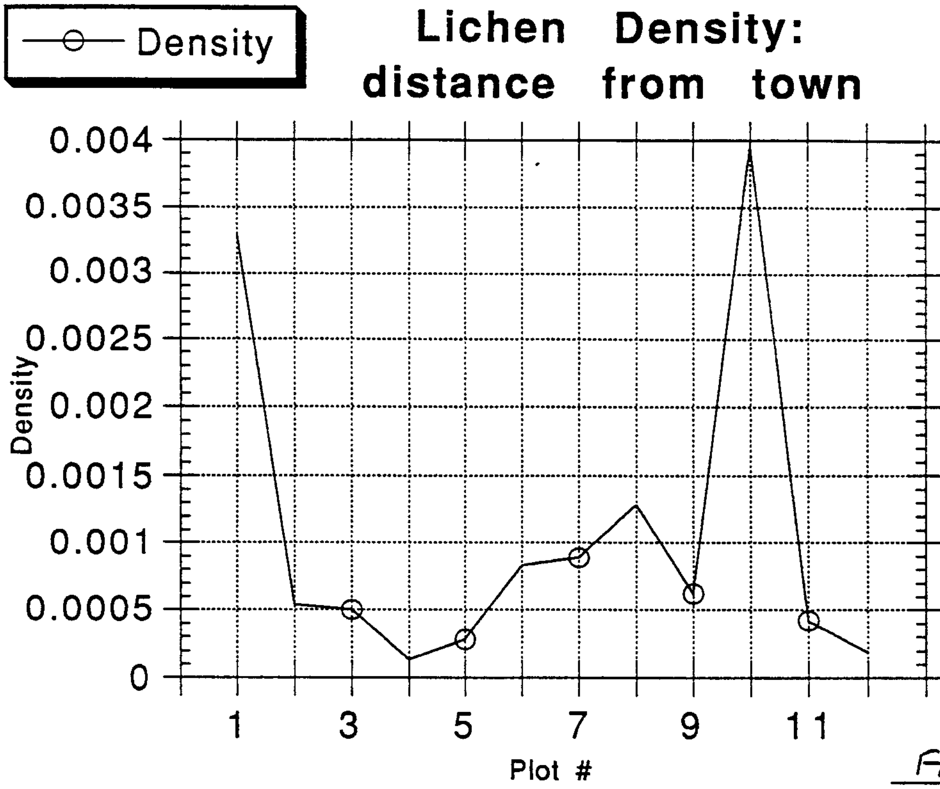

Density
Lichen Density:
distance from town
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
Density
1
3
5
7
9
11
Plot #

Figure 40

OBSERVATIONS AND RESULTS:

The primary significance of this study was to provide base information about the general lichen populations present in the valley. The most important results, therefore, are simply the data themselves. The species present and their relative quantities in each plot, are presented at the base of each plot's data sheet. The species list on page 25 presents an overall list of what species are present, while figure 25,pg 36, shows their relative frequencies overall. More specifically, Figures 1-16 show the relative frequencies of lichens on different host species in various plots. All this data is most useful when compared to similar data sets in the future.

While definite immediate conclusions cannot be drawn from this study, it is worthwhile to attempt to point out some trends and possible factors influencing the populations. One of the first questions that occurs is whether or not the 10 meter radius plots are able to accurately represent the area around them. Perhaps lichen populations are so variable as to make any one plot no more than a random sample of an extremely diverse population structure. To test the representative reliability of the plot system, I did a comparison between two adjacent plots on Pine Cobble: pc1 and pc2. The chi squared tests on page 26 tested the independence of the total lichen populations in the two plots. The result allowed us to reject the null hypothesis that the two plots were the same. Thus, it would seem that, statistically, these plots are not good representations of the entire area around them, as these two adjacent plots were so different. On the hypothesis that the two plots had a different forest structure (supported by the chi squared test on page 27), I tested the independence of lichen populations on a single substrate species between the two plots (PC1(Oaks) vs PC2(oaks), pg 26). This should eliminate the variable presented by a differing forest community. Again the chi squared value was higher than the degrees of freedom value, so the null hypothesis that the populations were the same was again rejected. This would seem to throw substantial doubt on the idea of comparing locational trends in the plots if the plots are not statistically representative of their overall area. However, the species compositions of pc1 and pc2 were quite similar. This would seem to indicate some relationship. It may be safe to say, then, that species presence is more meaningful than actual abundance, though the latter may still have its significance.

not clearly stated —

could there be environ. differences between the 2 plots

Having demonstrated the unreliability of the plot system, there are several other questions that present themselves. How do substrates affect the lichen populations? By analyzing only one plot at a time, location and environment can be kept constant. To begin with I analyzed the independence of populations on red maples and red oaks in Tac1. The chi squared test (page 28, top) results demonstrated that we could not reject the null hypothesis that the two species hold the same lichen load. This is reflected in the two pie graphs on page 30. The two species appear to hold the same species in essentially the same proportions. It would seem, then, that host species has very little to do with lichen population. To recheck this I redid the same test between oaks and maples for a different plot, pc2 (pg28, bottom). Here the test demonstrated that the populations did vary from species to species. This is easily seen in plots tac4 (see pg 31 figures 3-6), tacR2 (pg 32 fig7-9), pc1 (pg 33, fig 10-13), and pc2 (pg 34, fig 14-16). In all of these there are great differences between the species present on different hosts and their relative frequencies. In tac4 and tacR2 the dominant lichens remain the same. On the other had, pc1 and pc2 show very different species between different hosts. This inconsistency may be partly resolved by environmental factors. I would suspect that in marginal environments the nature of the substrate becomes far more vital, while better environments allow more competition and a wider range of habitats. The actual answer to this question must remain up in the air due to the variety of factor involved, and the possibility that these data are all simply statistical aberrations. However, it is worth considering.

So we have seen that the substrate species appears to have some effects on what populations of lichens are present, but that sometimes very little difference between substrates can be noticed. This leaves open the question of how variable populations are on a single substrate. The chi squared test on page 29 demonstrated that we could reject the null hypothesis that there is no difference between populations in different plots, given a constant host species, in this case red maple. There was a great deal of variation in population on red maples across the different plots (pg 35). This is no surprise, considering the environmental differences across all the plots. What is surprising is the relative uniformity of lichen species on paper birch (pg36, fig 26-29). All the paper birch were populated by Cladonia sp.. This uniformity may be attributable to the nature of paper birch bark, which may be hard for lichens to tolerate. The canine zone, where Cladonia sp. is always found, may be easier to colonize. Whatever the reason, it appears that some uniformity based on substrate is possible.

Another influence on lichen populations may be age of the host. It is obvious that the larger the tree (thus the older), the more lichens should be present, as the total area available for lichen cover would be larger than a smaller tree. The main question is whether the actual density of lichens would increase, as older trees have had more time for colonization. To answer this set of questions, I looked at HR1, which contained a wide diversity of tree ages, and many lichens (pg 37). There seemed to be a reasonable correlation between tree circumference and total number of lichens (fig 30). This is also seen in figure 33, page 38, where there seems to be a strong correspondence between circumference and epiphytic population. Pseudoparmelia caperata appears to have a strong correlation with age. Cladonia coniocraea, on the other hand, appears to remain at fairly constant levels across the age groups. However, the greater number of lichens with increasing age was not reflected in the graph of lichen density versus age (fig 31). Here, it would seem that the youngest trees, oddly enough, have the highest density. The first explanation is to say that the trees grow faster than the lichens grow or colonize, so they become less dense with age. An alternative tentative explanation hinges on the concept of recolonization. Recent declines in atmospheric SO_2 concentrations in urban areas has been matched by a slower decline in rural pollution levels (Bates, Farmer,1992). This has set the stage for lichen re-invasion in many areas. If re-invasion is occurring in HR1, then one would expect to see a more equal density of lichens on old and young trees, as populations would have had an equal period of time to colonize. Older trees may retain damage to the bark substrate, depressing lichen growth, while younger trees are more healthy. The re-colonization theory, well-confirmed in many areas, may explain the prevalence of Cladonia in the canine zone. This zone is generally felt to be a good zone for recolonization due to its higher pH. Well established Cladonia populations in canine zones may show a re-established population, led at first by Cladonia in the lower areas of the trunk, and followed by other species.

Having established the unpredictable and variable influence of substrate, substrate age, location, and the statistical unreliability of the plots, it would seem unlikely that any locational trends would present themselves. However, some do begin to appear with some analysis. By analyzing the total number of lichens, and the various species represented, with relation to the plot's distance from town, some trends do appear. Figure 38 shows the number of lichens in each plot progressing up the Triple R Trail. With the aberration of HR1 removed, there does appear to be a gradual increase in the total lichen count as you proceed away from town. This could be a coincidence, the result of air pollution, or the result of another factor such as a microclimate created by the farming fields and town which is less favorable to lichen growth. Nevertheless, this trend does appear. It is also obvious in figure 37, looking more specifically at Cladonia, and in figure 35, which also shows the extreme aberration of HR1. It is notable that plots 11 and 12, the furthest from town, drop off from this trend. Being at the top of the Taconic Crest, it is possible that these two plots get far more acid deposition (from clouds), than any other plots. Though they may be furthest from town, they are more exposed to atmospheric pollutants carried in from the west. In support of this idea is the fact that there are several species which do particularly well in the town and crest plots (2,3,11,and 12 to be specific), which are not found elsewhere. Cladonia strepsilis replaces its close relative in both these areas that one would suspect to be more pollution-prone (fig 37). Candelaria concolor and Physconia detersa are both most frequent in plots 1,2,3, which are closest to town. This fact may be a good demonstration of the differences in pollution tolerances of different lichen species. While it is possible that these are simply statistical aberrations and normal variation, the fact that Candelaria concolor, Cladonia strepsilis, and Physconia detersa are all found only in pollution-related areas makes it seem probable that there is a relationship. Of course another variable such as microclimate, slope face, or an unknown, may contribute, I would suspect that pollution levels do have an affect. This may also be reflected in figure 40, which shows lichen density as a function of distance from town. The results are quite variable, so no strong trend may be established, but it does appear that lichen density increases with distance from town, if only slightly.

It might have been interesting to collect rain samples at these sites.

What are relative & absolute levels of pollutants at the sites?

Ecological differences between lichens contribute to our understanding of pollution levels, as in the similarities between the Pine Cobble area and the Taconic Crest. The fact that three species are found in a similar zone, which is theoretically distinct (as far as air quality) from other plots, demonstrates that they have different ecological needs and roles from their relatives. Cladonia coniocraea does not appear to co-exist with Cladonia strepsilis. Nor does it appear to co-exist with Phaeophyscia rubropulchra. These relationships may be coincidental, but more likely they are indications of specific preferences. These species are the ones that should be most closely monitored in the future.

how do we really know this?

CONCLUSION:

This project yielded large amounts of data, which could be extremely useful in future years as a monitoring base survey. However, this information is useless unless followed up on. Similar transects in other areas of the valley, particularly up Mt. Greylock would be handy, as would repeating transects done here. I would urge future environmental studies students to conduct further analysis, either of populations or of the trace pollutants stored in thalli.

true!

– not entirely

Despite the high level of uncertainty due to the abundance of uncontrolled variables, some specific trends were observable. The increase in lichen abundance appears to be significant, as does the presence of what may be good indicator species present in some of the plots. Equally important is the demonstration as to how uncertain the influence of substrate, host age, plot location, and plot accuracy is. To increase the certainty involved in plot location, larger plots could be used. To remove the variable of local microclimates and make it easier to find locational trends more plots could be taken. However, both collection and identification are time consuming, and the scope of this project is limited. For future reference, it may be desirable to focus on only a few lichen and/or host species, allowing faster processing of plots. Location of roads should be taken into account more carefully (Triple R Trail was a bad choice). Some more research into study techniques is suggested. According to Treshaw, 1984, standard field techniques include: counting the number of species on a controlled substrate, and the frequency of one lichen species within a community; density. He adds that as many controls as possible should be applied (not done much at all in my project). He also suggests using some form of population index, citing a lichen-based Index of Atmospheric Purity designed by LeBlanc and Rao in the 1972 Canadian Journal of Botany (Treshaw,1984). Another factor that must be considered in a study such as this one is stemflow. Acid precipitation is often neutralized by flowing down the bark of a tree. Thus, lichens at the base of the tree, where this study was conducted, may not reflect air quality as well as canopy species.

Despite being primarily an urban problem, lichen depletion may still be affecting rural areas such as Williamstown. Car exhaust alone may contribute substantially (plot tac3, near route 2, was impoverished as far as lichens). On the other hand, lichens may be staging a re-invasion. Thus it is safe to say that the overall status of lichen populations, and their future, is unknown even as to its direction. However, its appears that some factor, probably air pollution, is affecting the lichen populations around Williamstown, creating a gradient around town, with more diverse and larger lichen populations further away from town. The job for future students lies in confirming this, and in attempting to discover whether population depletion or re-invasion is occuring in our area.

Dan -
Indeed this will serve as the basis for future works, but I wish you had spent a little more time on discussing what was there rather than short comings and difficulties — Nice job of accumulating an impressive set of data!

A-

BIBLIOGRAPHY:

Ahmadjian, Vernon, The Lichen Symbiosis, Blaisdell Publishing Company, Waltham Massachusetts, 1967.

Bates, Jeffery; Farmer, Andrew, Bryophytes and Lichens in a Changing Environment, Clarendon Press, Oxford, 1992.

Dwelley, Marilyn, Trees and Shrubs of New England, Down East Books, Camden ME., 1980.

Hale, Mason, How to Know the Lichens, Wm. C. Brown Company Publishers, Deburque IO, 1979.

Hale, Mason, The Biology of Lichens, Edward Arnold Publishers Ltd., London, 1967.

Hutchinson, TC. (ed), Effects of Acid Precipitation on Terrestrial Ecosystems, Plenum Press, NY., 1980.

Lepp, N.W. (ed.), Effect of Heavy Metal Pollutants on Plants, Applied Science Publishers, New Jersey, 1981.

Treshaw, Micheal (ed.), Air Pollution and Plant Life, John Wiley+ Sons, New York, 1984.

Thanks to Leo P. Kenney, Reading Memorial High School, for advice on lichen identification and references, as well as for providing Hale, 1979, which is out of print.

Thanks to Donald Pfister at the Farlow Herbarium, Harvard University, for advice on references.

Thanks to Hank Art, Biology Department, Williams College, for advice on statistical analysis, and general technique.