














URBAN LICHENS:
Environmental Bioindicators

Gary B. Perlmutter & Eimy Rivas Plata

Lunchtime Discovery Series

November 18, 2015

NC STATE UNIVERSITY

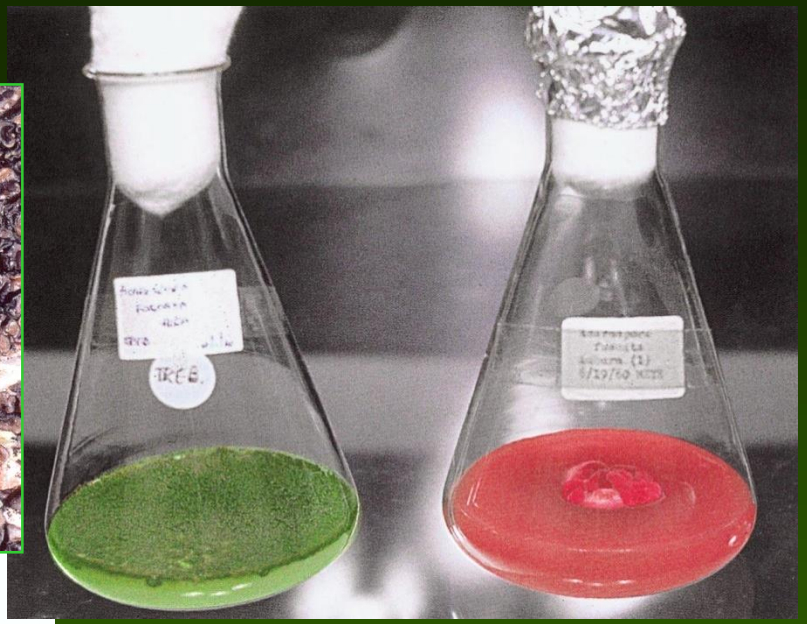
The Field Museum

What is a lichen?

- Organism or ecosystem?
- Mycobiont (fungus)
  - Ascomycota ~95% lichens
  - Bacidiomycota ~5% lichens
- Photobiont (photosynthetic partner)
  - Green alga (Chlorophyta)
  - Cyanobacterium (“blue-green alga”)
  - Both
- Endolichenic fungal and bacterial colonies
- Systematic classification based on the mycobiont

The symbiosis...

Acarospora fuscata thallus and components in culture



Xanthoria parietina thallus and mycobiont in culture

Lichens look very different from their individual components and produce unique morphological and anatomical structures

Why are lichens interesting?

Pioneer organisms in the succession of ecosystems

Indispensable elements in the water and nutrient cycle: lichens store water up to 800% of their dry weight and cyanobacterial lichens fix atmospheric nitrogen

Chemical properties that are useful in the pharmaceutical and perfume industry

We can eat lichens...
(although they don't taste so good)

Bioindicators of environmental pollution and ecological continuity

What do lichens look like?

crustose
(*Arthonia*)

foliose
(*Leptogium*)

squamulose
(*Cladonia*)

fruticose
(*Ramalina*)

dimorphic
(*Cladonia*)

pendulous
(*Usnea*)

Where do lichens live?

soil
= terricolous
(*Dibaeis*)

bark
= corticolous
(*Haematomma*)

rock
= saxicolous
(*Porpidia*)

moss
= muscicolous
(*Gomphillus*)

wood
= lignicolous
(*Canoparmelia*)

leaf
= foliicolous
(*Mazosia*)

Lichen diversity!

- 5400 species in the US and Canada (Esslinger 2014)
- 1000 taxa reported in North Carolina
- 470 taxa reported in NC Piedmont
- 15 counties adequately sampled – tally could be much higher

A Cumulative Checklist for the Lichen-forming, Lichenicolous and Allied Fungi of the Continental United States and Canada

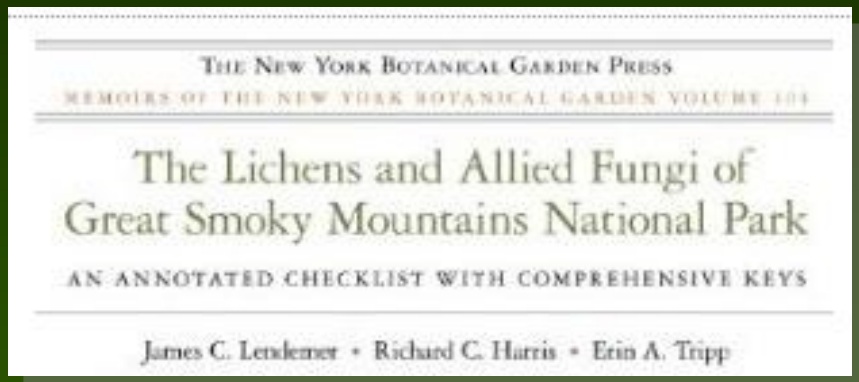
Vers. 20

The count for this current online version (#20) is 5,388 total species in 720 genera, with an additional 43 subspecies, 47 varieties, and 3 forms. The total species number includes 586 lichenicolous fungi (*), 79 saprophytic fungi related to lichens/lichenicolous fungi (+), and another 55 species of varying and/or uncertain biological status (#).

http://www.ndsu.edu/pubweb/~esslinge/chcklst/chcklst7.htm

Lichen diversity in North Carolina

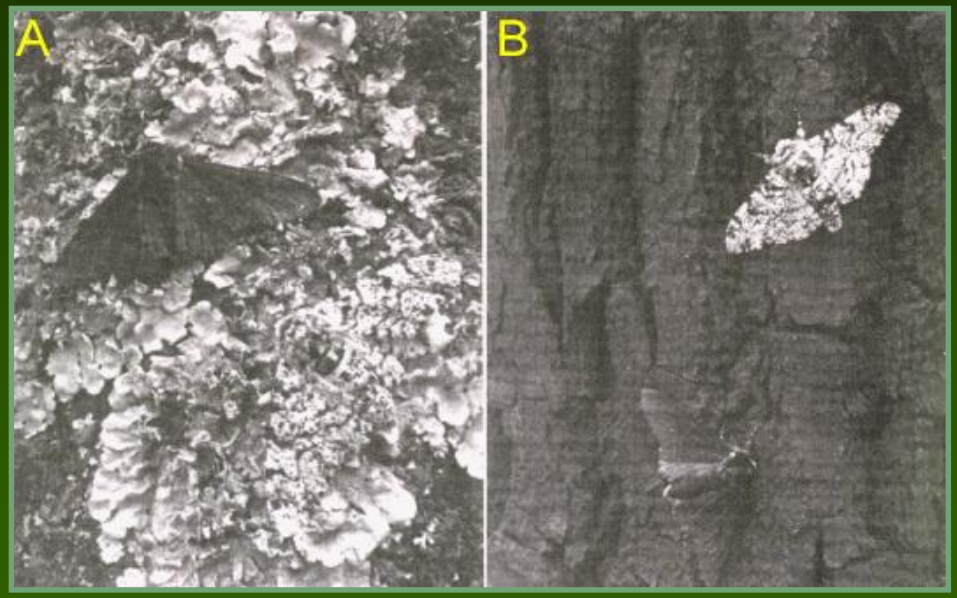
Over 1000 species!



Dare Regional Biodiversity Hotspot

Lichen Air Pollution Sensitivity

- Receive nutrients from air, susceptible to air pollutants: SO_2, NO_x, metals
- Lichen health been linked to air pollution >100 yrs
- Affects include element bioaccumulation, tissue damage, and reduction in populations & communities



Lichens as Bioindicators

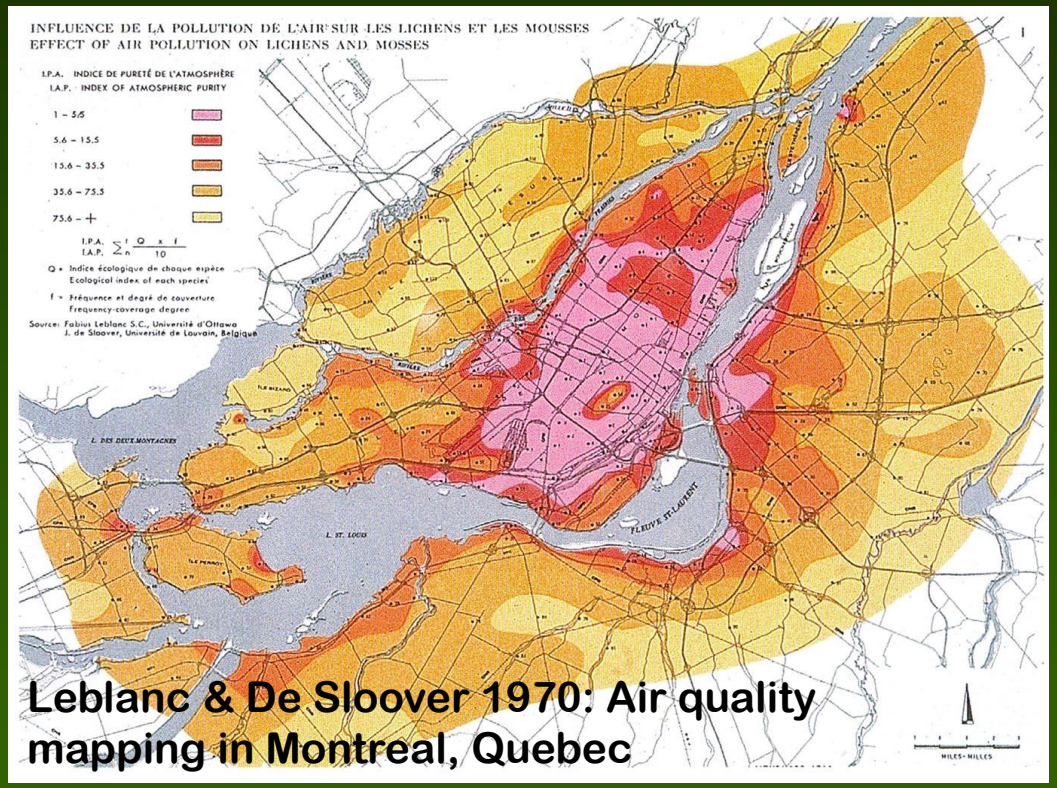
- Many reports worldwide document correlation of air quality with lichen health, species richness and abundance
- Urban and industrial surveys conducted in Europe, Asia and the Americas

Lung lichen (*Lobaria pulmonaria*)

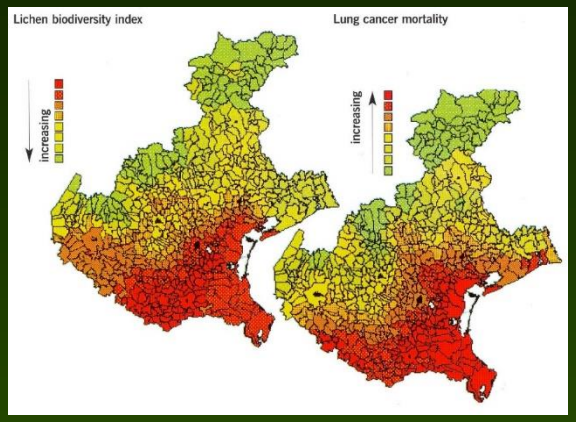
Lichen Biomonitoring Methods

- Lichen community mapping – assessment of an area's air quality
- Tissue analysis – evidence of bioaccumulation of pollutants
  - *In situ*
  - Transplant studies
- Long term studies (repeat at 5-8 yr intervals)

Air Quality Mapping



Leblanc & De Sloover 1970: Air quality mapping in Montreal, Quebec



Cislaghi & Nimis 1997 (Nature): Lichen diversity correlated with lung cancer mortality in Veneto and Venice (Italy)

Guatemala City

Example: Southeast USA (McCune et al.1997)

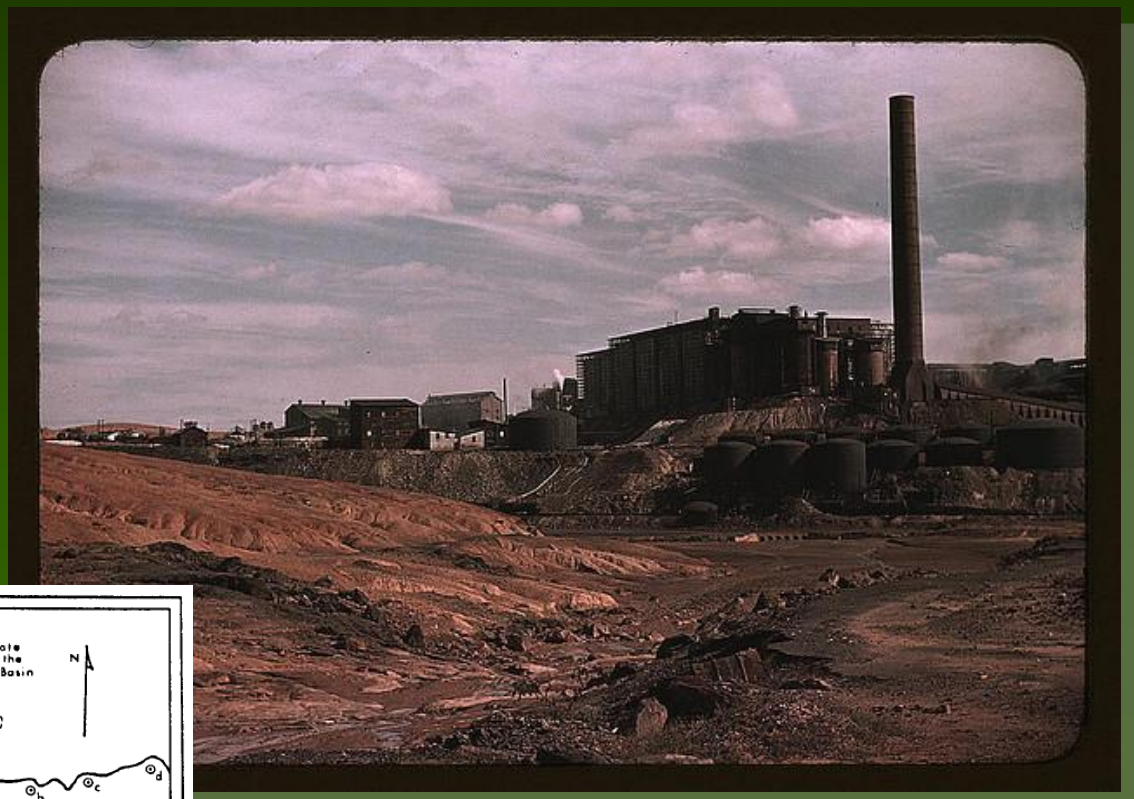
- Part of USFS Forest Health Monitoring (FHM) Program
- Epiphytic macrolichens (no crusts) sampled in 203 circular plots across Southeast (VA, NC, SC, TN & GA) conducted in 1992-1993
- Species diversity analyzed against air quality (SO_2 & NO_x) categorized broadly as
  - 1) urban/industrial
  - 2) rural
- Results: Pollutant-tolerant spp. and lower species richness in urban/industrial areas

Example: Copperhill, TN (Mather 1978)

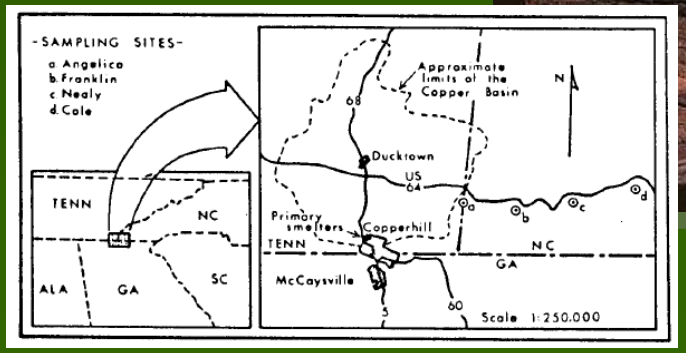
- Industrial emissions and waste decimated local environment
- Transect study in western NC
- Greater macrolichen abundance & diversity further away from copper mine & smelter (SO_2 source)
- Beard lichens (*Usnea*) best indicator.

LICHENS AS INDICATORS OF AIR POLLUTION IN THE VICINITY OF COPPERHILL, TENNESSEE

Thomas C. Mather
Department of Botany
University of Georgia
Athens, 30602



Copper mine and sulfuric acid plant, 1939



Example: N pollution impact - UK (Leith et al. 2005)

- Lichen floras on oak trunks & twigs sampled along transects from N point sources
  - Mixed deciduous woodland adjacent to poultry farm (ag source)
  - Mixed conifer-deciduous woodland abutting major highway (vehicle source)
- Categorized lichens as acidophytes, nitrophytes per van Herk in Netherlands (1999, 2002)

UK study – lichen categories

Acidophytes (acid-loving lichens)

Cladonia

Lepraria

Nitrophytes (N-loving lichens)

Candelaria

Xanthomendoza

UK study - Results

- Twig communities more strongly correlated with [NH_3] than trunk communities
- Loss of acidophyte communities at lower [NH_3] than invasion of nitrophytes
- Application of macrolichens as [NH_3] indicators is appropriate among acid-bark trees of same species in areas of habitat homogeneity
  - Negative bark pH (acidity) correlates with [NH_3]
- Negative correlation of acidophytes on twigs with all forms of N deposition (NH_3, NO_2 & Total N) suggest combined effect of N pollution

Coal-fired powerplant study, Wyoming (Gouch & Erdman 1977)

- 35 elements analyzed in thalli of soil lichen *Xanthoparmelia chlorochroa* along upwind & downwind transects from powerplant

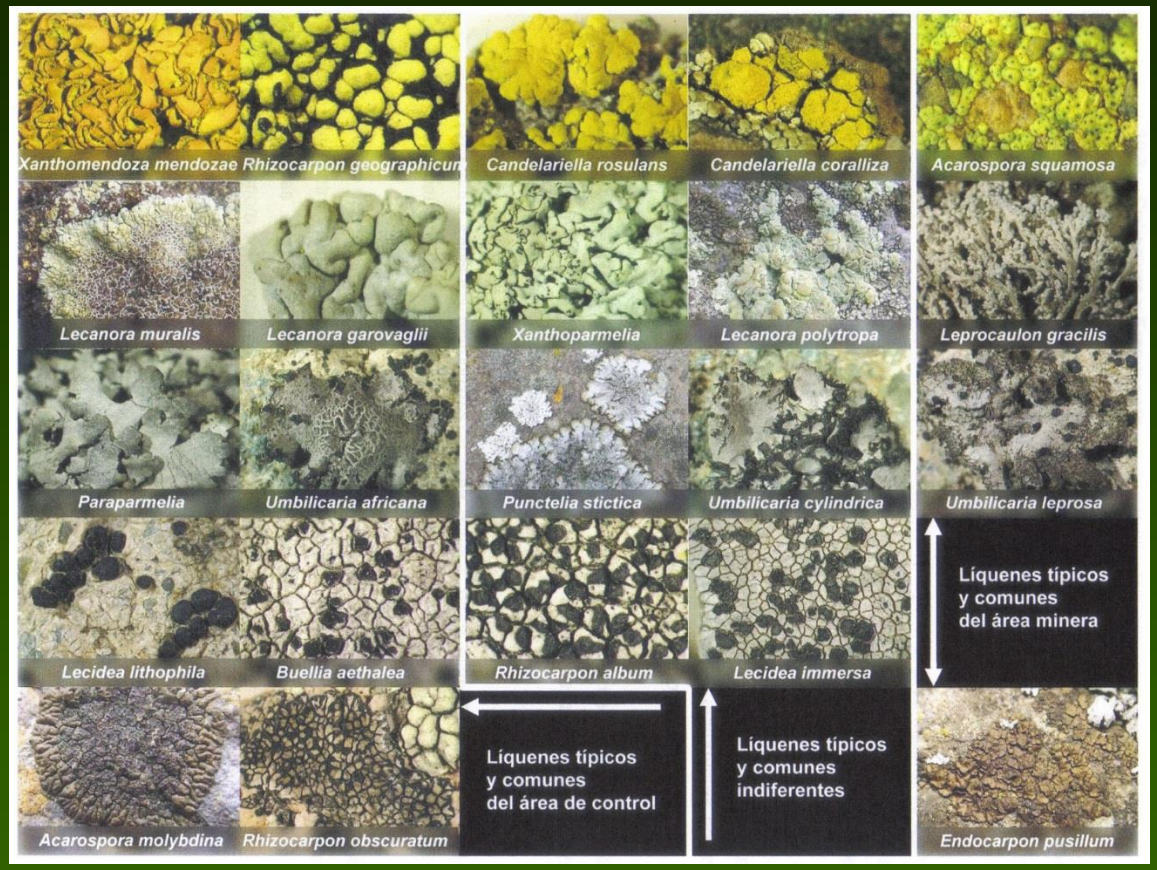
Pollutant	Coeff. of Determin.
Ash yield[a]	0.58**
Ca[a]	0.77**
F	0.56**
Li	0.61**
Se	0.61**
Sr	0.91**
U	0.52**

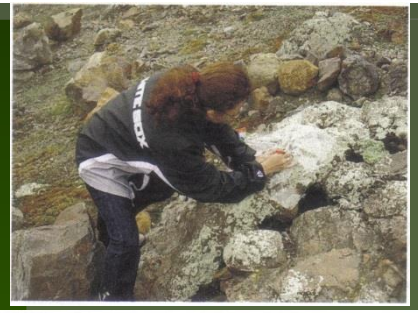
[a]Percent dry wt

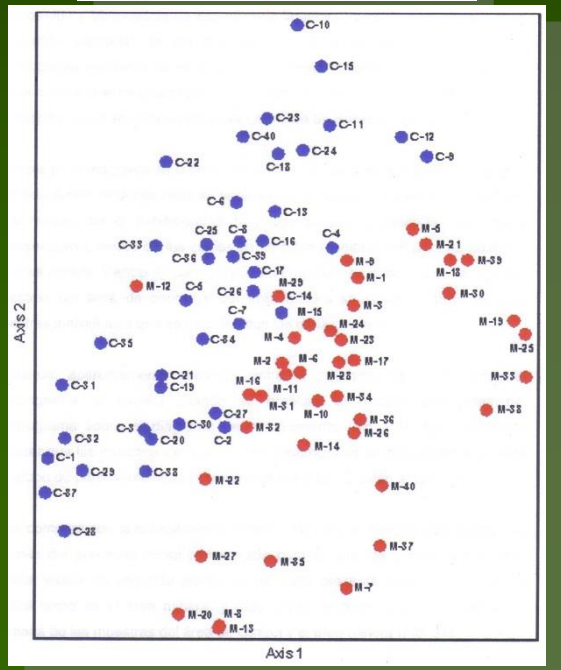
Significance: *P <0.05; **P <0.01

Element	r
Al	0.88*
Ca	**0.93****
Cr	0.96**
F	**0.92****
Ga	0.91*
Fe	0.85*
Li	**0.99****
Mg	0.89*
Mn	0.86*
Ti	0.93**
U	**0.95****
V	0.95**
Yb	0.89**
Y	0.91**

Example: Heavy Metal Pollution - Peru (Rivas Plata)







Lichen community composition correlated with heavy metal pollution in the Peruvian Andes

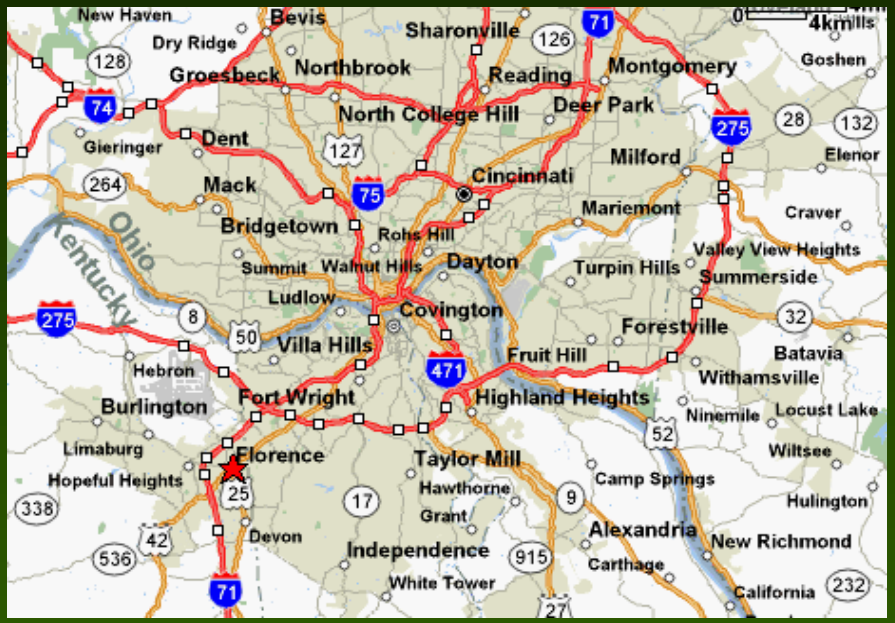
Temporal Studies: Washington DC area (Lawrey 1993)

- Long term study of elements S, N and 7 metals (Al, Cd, Cr, Cu, Ni, Pb, Zn) in *Flavoparmelia baltimorensis* in three sites (MD & VA)
- Demonstrates limited signs of improvement in air quality

Plummers Island, MD			
	1983	1988	1992
Sulfur (% dry wt)	0.205	0.186	0.156
Element (ug/g dry wt)	1979	1988	1992
Pb	1131.00	418.30	136.80
N		18800.00	17200.00
Al		1497.00	2782.50
Cd		1.49	<0.20
Cr		20.00	20.00
Co		25.90	31.80
Ni		16.44	7.36
Zn		106.00	102.50

Example: Cincinnati urban study (Washburn 2006)

- Epithytic macrolichens examined in 7 urban & 4 non-urban sites in the metropolitan area for effects of NO_X, NH_3, SO_2 & O_3



RESULTS

- NO_X, NH_3 & O_3 but not SO_2 were found to impact lichen abundance.

- SO_2 effects appear to be overwhelmed by those of the other pollutants.

Raleigh Urban Lichen Study (Perlmutter 2010)

Bioassessing air pollution effects with epiphytic lichens in Raleigh, North Carolina, U.S.A.

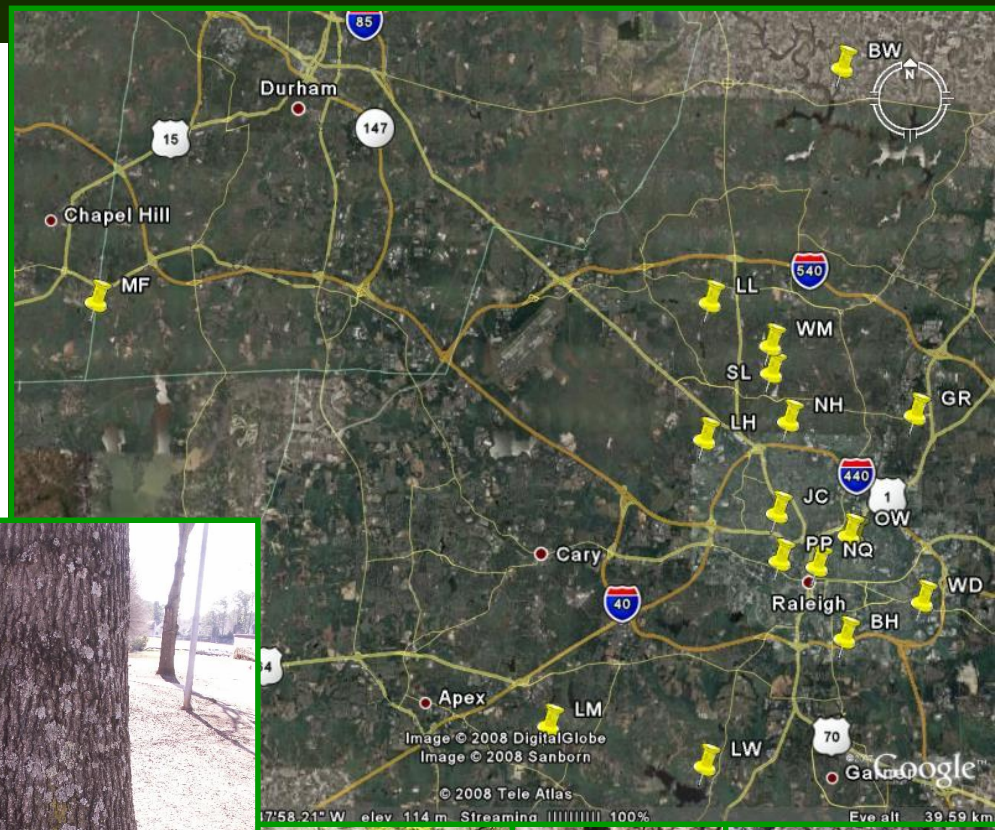
Gary B. Perlmutter[1]

North Carolina Department of Environment and Natural Resources, Division of Air Quality, Raleigh Regional Office, 3800 Barrett Drive, Raleigh, NC 27609, U.S.A.

ABSTRACT. Lichen diversity and coverage on willow oaks were measured in 16 parks in the Raleigh area of North Carolina, plus one natural area in nearby Orange County (control), as a pilot study for a potential statewide lichen biomonitoring project. This study's objectives were to assess the air pollution effects of the Raleigh urban airshed on these lichen communities, and determine what methods are best for this bioassessment. Thirty-one macrolichens and 24 crustose lichens were detected with average trunk floras of 4–20 taxa per site. Lichen communities were do... *Buellia curtisii, Candelaria concolor, Candelariella reflexa, Lecanora strobilina, L. hybocarpa millegrana, Pyxine subcinerea* and *Punctelia rudecta*, of which the macrolichen species ar... be pollution-tolerant, including *Py. subcinerea*, which is here described as such. The ...

Table 5. Correlation test results of lichen diversity variables and urban variables.

Test	r	P
Macrolichen LDV vs. Population	−0.26	0.314
Macrolichen LDV vs. Traffic	−0.35	0.168
Macrolichen % Cover vs. Population	−0.31	0.226
Macrolichen % Cover vs. Traffic	−0.45	0.070
Macrolichen Species Richness vs. Population	−0.48	0.051
Macrolichen Species Richness vs. Traffic	−0.46	0.063
Crustose Lichen Species Richness vs. Population	−0.53	0.029
Crustose Lichen Species Richness vs. Traffic	−0.28	0.276
Total Lichen Species Richness vs. Population	−0.64	0.006
Total Lichen Species Richness vs. Traffic	−0.51	0.036



Quercus phellos

Shade tolerance = pollution sensitivity?

Preference of lichens for shady habitats is correlated with intolerance to high nitrogen levels (Hauck & Wirth 2010, *Lichenologist* 42(4): 475-484)

- "We tested this hypothesis using published ecological indicator values (estimates of eutrophication tolerance and light preferences on an ordinal scale) for more than 500 central European lichen species. Our results show that shade-adapted lichens are indeed at the same time intolerant to eutrophication."

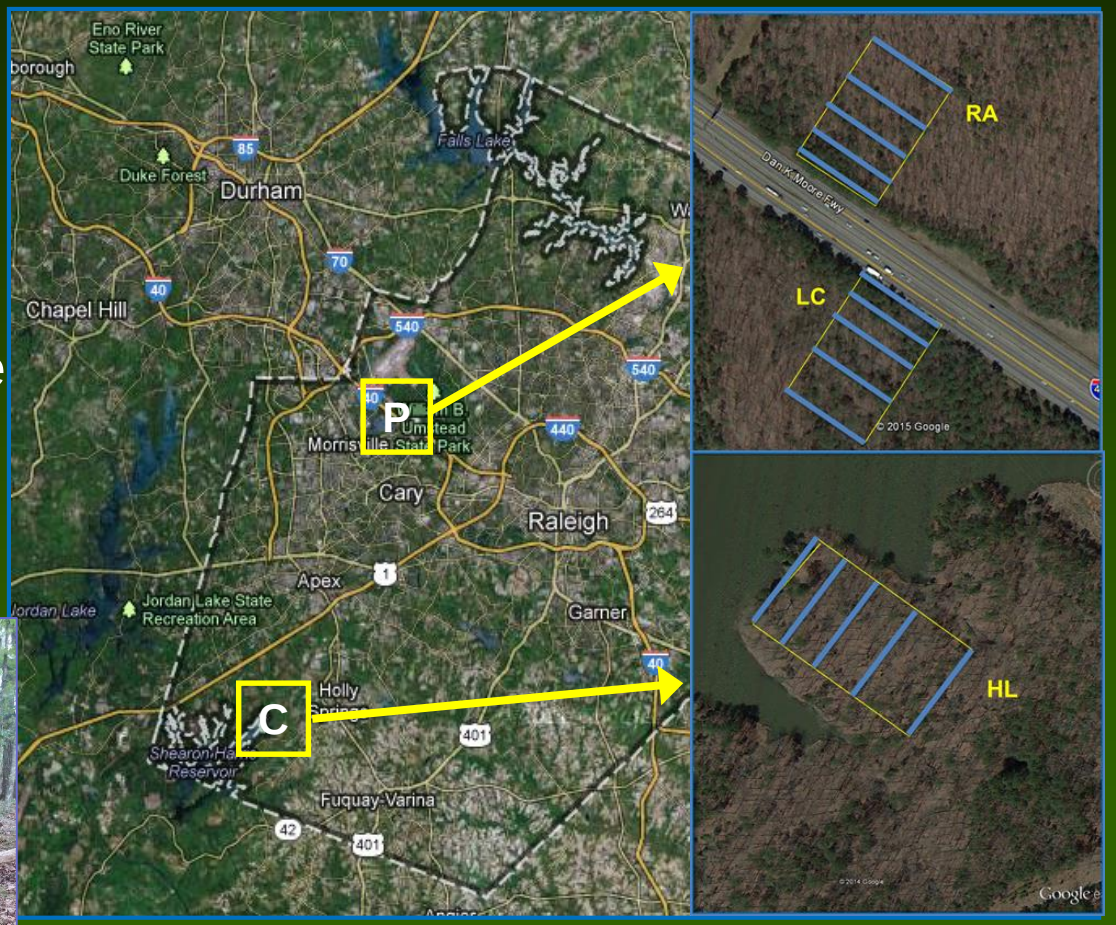
Arthonia

Pyrenula

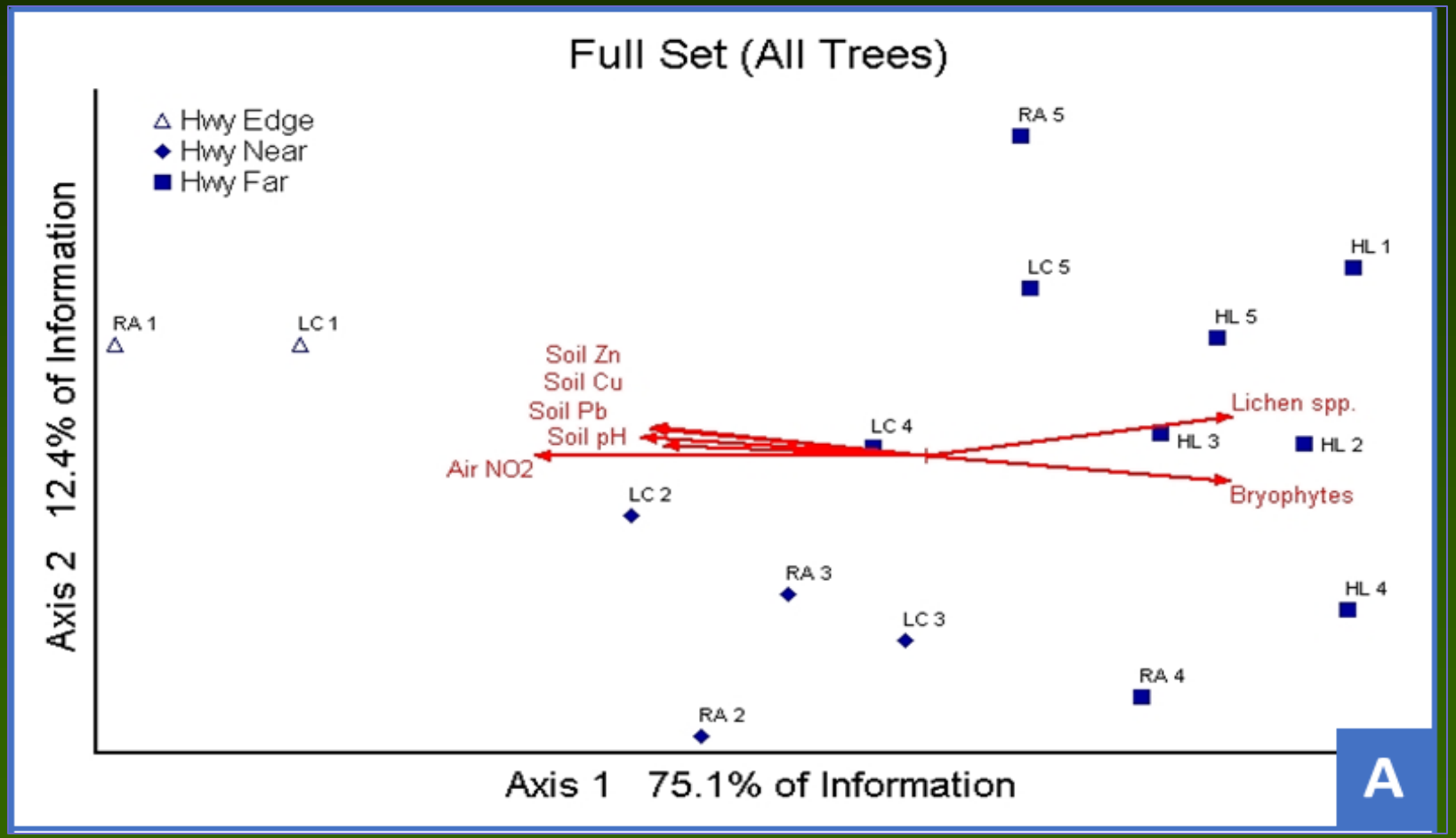
Graphis

Highway Pollution Effects

- Transects from I-40 (polluted) and Harris Lake (control)
- Are lichen communities different by site?
- Do communities change across gradient with distance from road?
- What environmental factors are related?

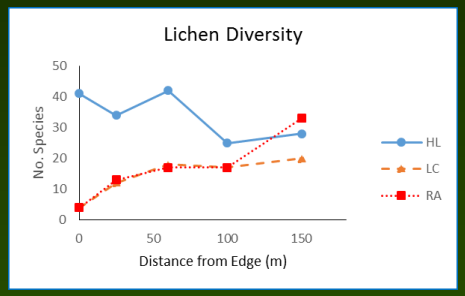


Results


Full Set (All Trees)
Hwy Edge
Hwy Near
Hwy Far
Axis 2 12.4% of Information
Axis 1 75.1% of Information
RA 1
LC 1
RA 5
LC 5
HL 1
HL 5
Soil Zn
Soil Cu
Soil Pb
Soil pH
Air NO2
LC 4
Lichen spp.
HL 3
HL 2
Bryophytes
LC 2
RA 3
HL 4
LC 3
RA 4
RA 2
A

Results

Lichen diversity as a response to ambient NO_2 concentration



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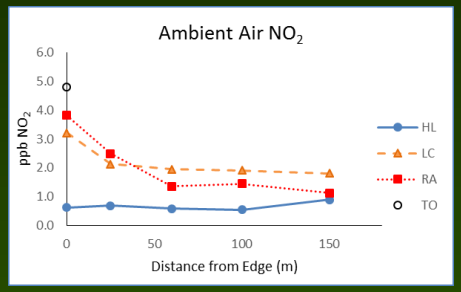
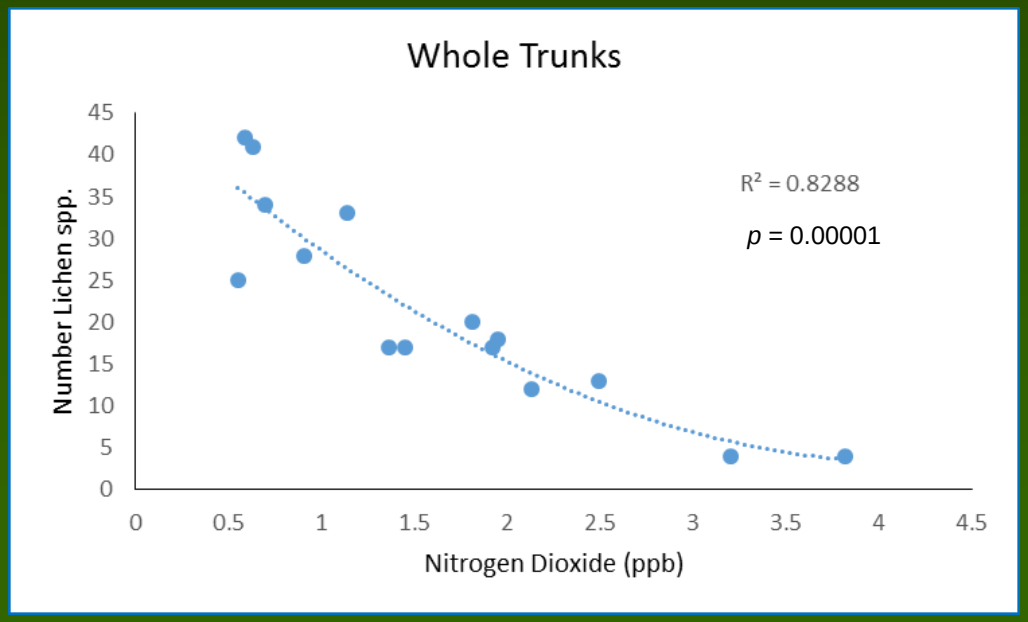




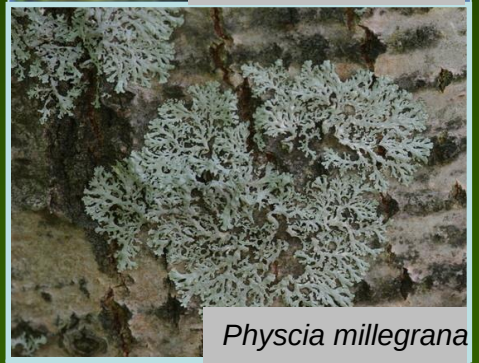
Linear relationships:

NO_2 vs. lichens (this study)
$r^2 = 0.786$, $p = 0.0002$

Traffic vs. lichens (Perlmutter 2010)
$r^2 = 0.260$, $p = 0.036$

Nitrophilous, exposed urban

Candelaria concolor



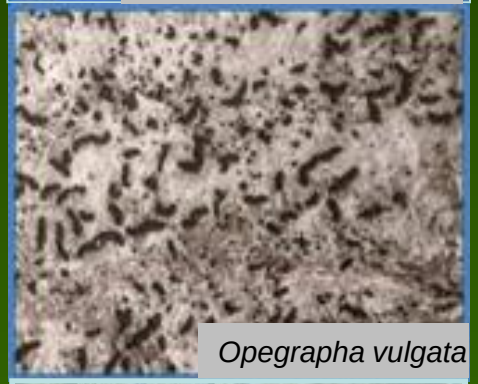
Physcia millegrana

Pyxine subcinerea

Image by V. Charney

Pollution tolerant, shaded forest

Pseudosagedia cestrensis



Opegrapha vulgata

Cladonia ravenelii

Image by R. Rittmaster

Pollution sensitive, shaded forest

Lobaria quercizans

Brigantiaea leucoxantha

Leptogium corticola

Image by J. Hollinger

lichenportal.org

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NORTH AMERICAN LICHEN HERBARIA

Home > North and South Carolina > North Carolina

North Carolina *Games*

Authors: Gary B. Perlmutter
Publication: Perlmutter, G.B. 2005. Lichen checklist for North Carolina, USA. Evansia 22(2): 51-77.
More Details

Families: 87
Genera: 270
Species: 976 (species rank)
Total Taxa: 977 (including ssp. and var.)

Page **1** of 2: **1** | 2

Family Incertae Sedis
Abrothallus hypotrachynae

ACAROSPORACEAE
Acarospora chrysops
Acarospora dispersa
Acarospora fuscata
Acarospora janae
Acarospora obpallens
Acarospora tuckerae
Polysporina simplex
Polysporina subfuscescens
Sarcogyne privigna
Sarcogyne similis

AMPHISPHAERIACEAE
Amphisphaeria bufonia

ARTHONIACEAE
Arthonia sp.
Arthonia albovirescens
Arthonia anglica
Arthonia bisepta
Arthonia diffusa
Arthonia kermesina
Arthonia quintaria

Options
Search:
Synonyms
Filter:
Original Checklist
Display as Images
Notes & Vouchers
Taxon Authors
Rebuild List

Photos by F.Bungartz

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Candelaria fibrosa (Fr.) Mull. Arg.
Go to Encyclopedia of Life...
Family: Candelariaceae

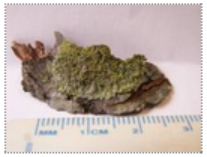
Stephen Sharnoff

Greater Sonoran Desert Lichen Flora

Nash, T.H., Ryan, B.D., Gries, C., Bugartz, F., (eds.) 2001. Lichen Flora of the Greater Sonoran Desert Region. Vol 1. Tempe, AZ

Thallus: small foliose, up to 4 cm wide, adnate, lobate **lobes**: dorsiventral, imbricate, c. 0.5-2 mm wide, often with secondary lobes, margin ± crenulate **upper surface**: lemon yellow to mustard yellow, smooth to somewhat wrinkled; soredia and isidia: absent **upper cortex**: c. 5-20 µm thick **medulla**: white, thin **lower cortex**: c. 10-35 µm thick **lower surface**: white to pinkish, white; rhizines: abundant, simple **Apothecia**: common, laminal, sessile, up 2 mm diam.; margin: smooth, often with white or yellow cilia; disc: darker yellow than the thallus; epithecium: c. 10 µm thick; hymenium: c. 60-90 µm tall; paraphyses: simple or branched near the tips, cylindrical to submoniliform with up to 5 µm wide tips; hypothecium: 30-45 µm thick **asci**: clavate, >30-spored **ascospores**: uni- or biguttulate, colorless, 7-11 x 4-6 µm **Pycnidia**: common, immersed, concolorous with upper surface or slightly darker **conidia**: ellipsoid, to narrowly ellipsoid 2-3.5 x 1.5 µm **Spot tests**: upper surface K- (or




Thank you!

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