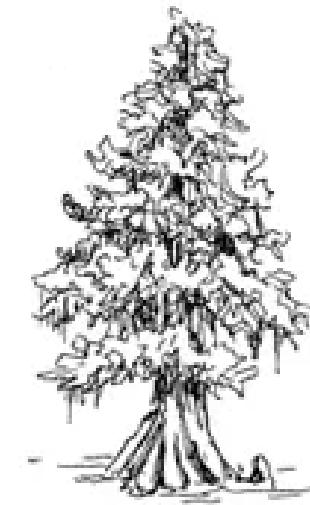
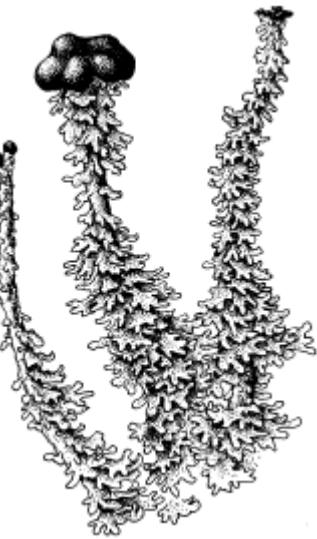


Lichen Biomonitoring in the USFS



2024

Amanda Hardman National FS Lichen Biomonitoring Coordinator
Linda Geiser National Air Resource Program Lead

Air Quality Monitoring and more



1970 Clean Air Act & 1977 amended

“prevent significant deterioration” of air quality in class 1 wilderness

1974 National Forest Management Act &
1976 Federal Land Management Policy Act

*Chief's 10year Wilderness Stewardship Challenge

*Wilderness Character Monitoring

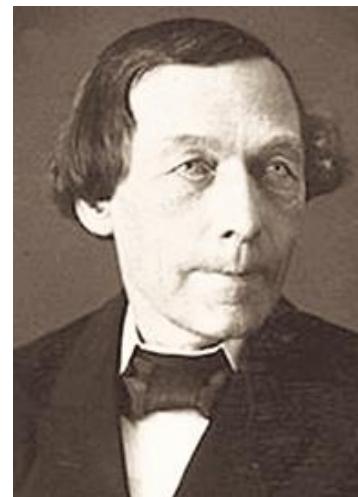
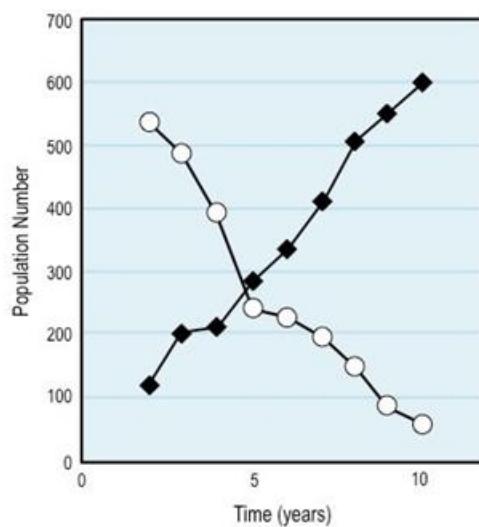
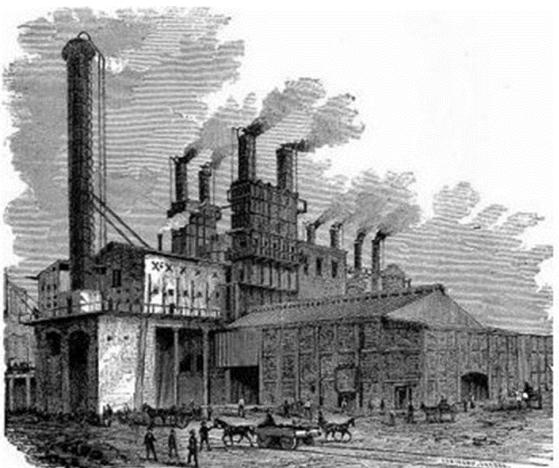
Agency Mission = sustain biodiversity

Forest and Project planning under NEPA (critical load exceedances)

Climate Change



Early observations



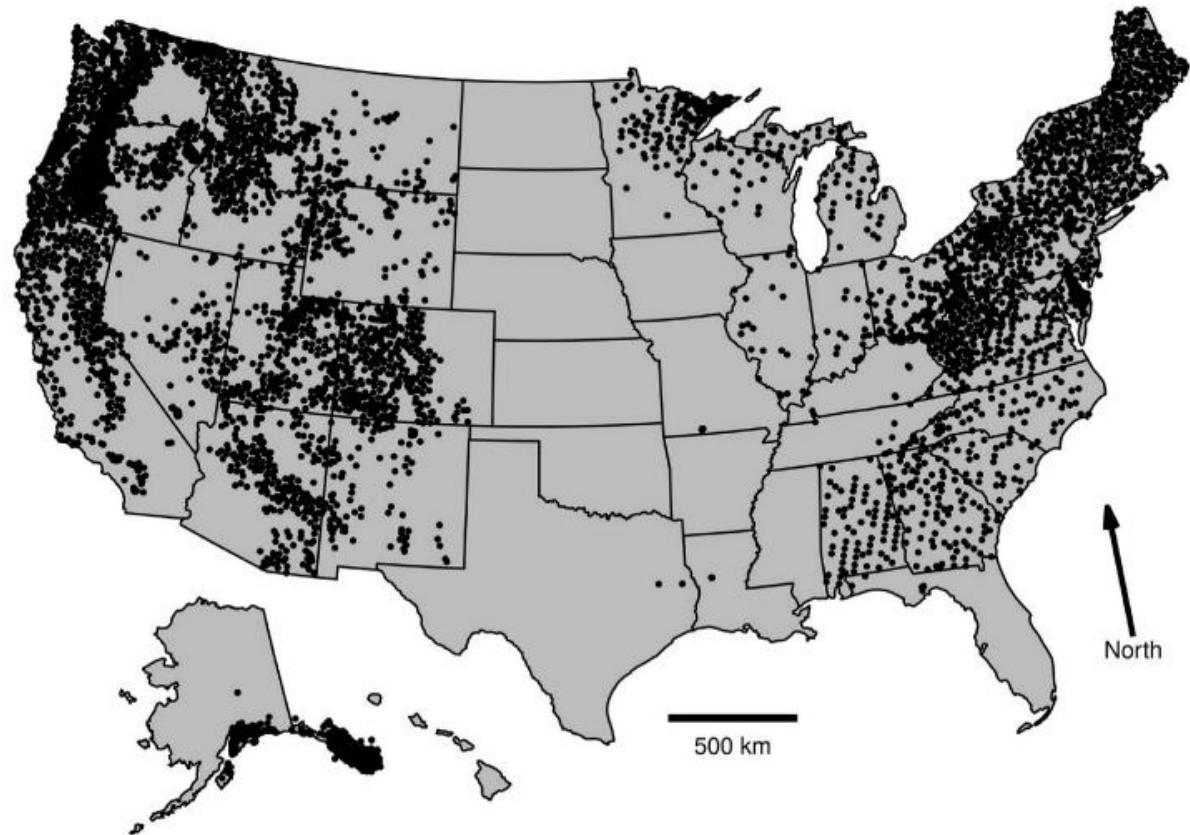
William Nylander
Early Lichenologist

Lichen Surveys Federal Land Nationwide

1973- 2023

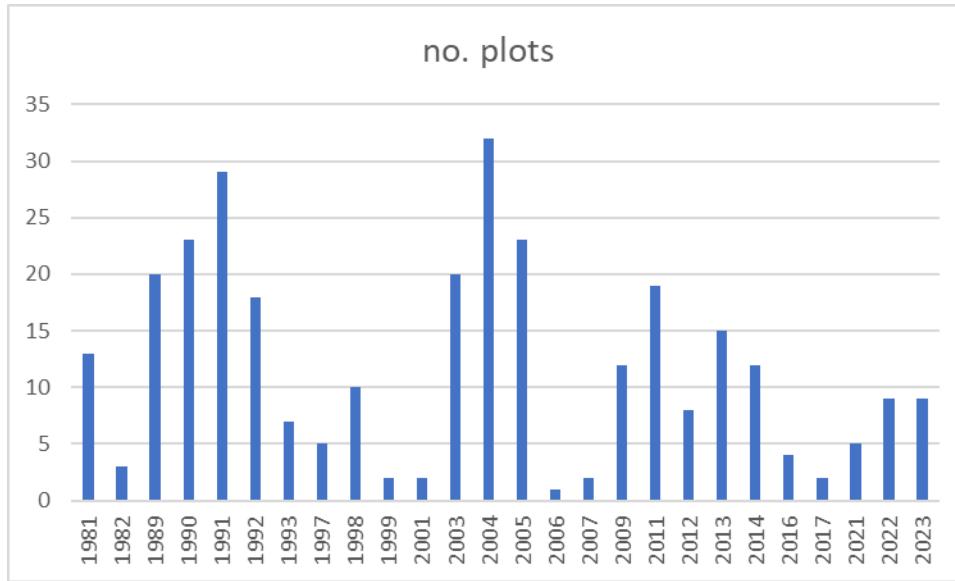
- 42 states
- **127 National Forests**
- **277 FS Wilderness areas**
- 9,000 baseline surveys, 4,000 with trends
 - NPS = 45
 - USFWS = 21
 - BLM = 327
- 200,000 species records
- 18,000 elemental analysis records

Efforts most notably accomplished by the Air Resource Management and FIA programs.



Alaska Biomonitoring

- **1989** First lichen biomonitoring installed Tongass
- **1993-1994** Chugach plots installed
- **2004** Chief's 10-year Wilderness Challenge



Plots	Chugach	Tongass
Baseline	815	109
Trends	63	13
Wilderness	215	8
		203

United States
Department of
Agriculture
Forest Service
Alaska Region
R10-TB-46
September, 1994



Air Quality Monitoring on the Tongass National Forest

Methods and Baselines Using Lichens

September 1994

Linda H. Geiser, Chiska C. Derr, and Karen L. Dillman

USDA-Forest Service
Tongass National Forest/ Stikine Area
P.O. Box 309
Petersburg, Alaska 99833



**AIR QUALITY BIO-MONITORING WITH LICHENS
THE TONGASS NATIONAL FOREST**

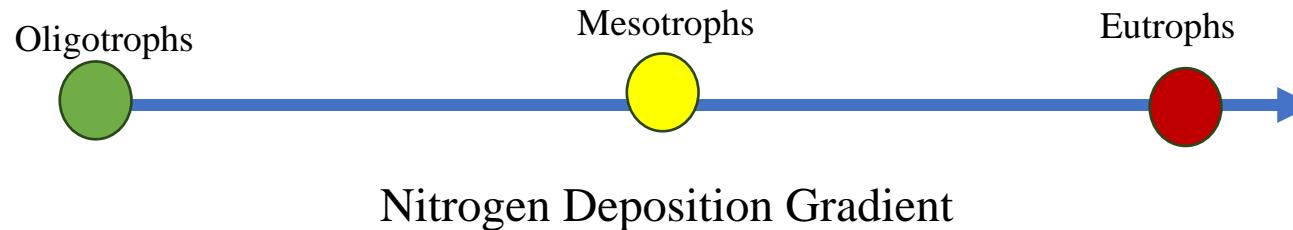


Epiphytic lichens used in air quality monitoring from Ketchikan Cove, Misty Fjords

Karen L. Dillman*, Linda H. Geiser ** and Gregory Brenner**
USDA Forest Service, Tongass National Forest, PO Box 309, Petersburg Alaska 99833
USDA Forest Service, Siuslaw National Forest, PO Box 1148, Corvallis, Oregon 97339
Pacific Analytics LLC, PO Box 1064, Corvallis, Oregon 97339

Why Lichens?

- Sensitive absorb chemicals at proportions that reflect composition in the air through wet and dry deposition



- Inexpensive
- Common and diverse in most forested ecosystems
- Infrastructure, protocols, and baseline plots ~30 years

What else do lichens tell us:

- biodiversity
- Climate shifts



Sample Method 1: Elemental analysis

Measure pollution content in lichen tissues

1. Collect



2. Clean



3. Analyze

Sample Method 1: Elemental analysis

- Potential to measure SVOC, and persistent air pollutants (PFAS), and microplastics
- We track 27 elements: sulfur, nitrogen, lead, cadmium, chromium, lead, zinc and mercury



Periodic Table of the Elements

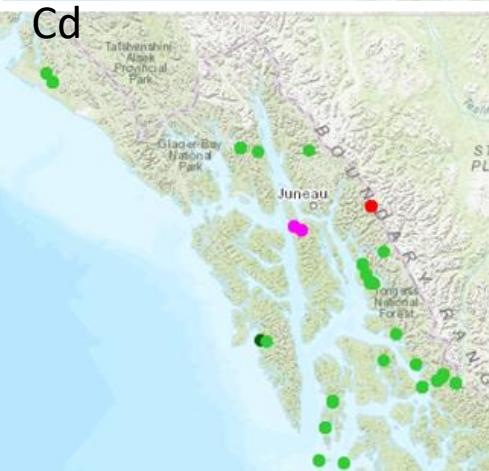
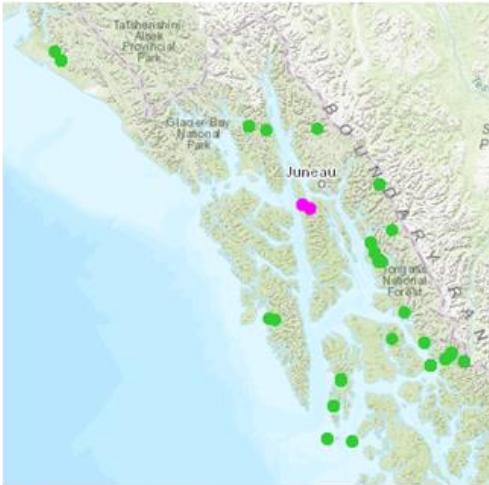
KEY

- Atomic Mass → 12.011
- Symbol → C
- Atomic Number → 6
- Electron Configuration → 2-4
- Selected Oxidation States → -4, +2, +4
- Relative atomic masses are based on $^{12}\text{C} = 12.000$
- Note: Mass numbers in parentheses are mass numbers of the most stable or common isotopes.

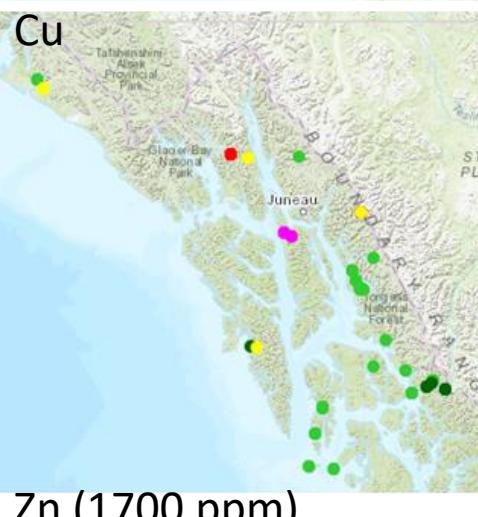
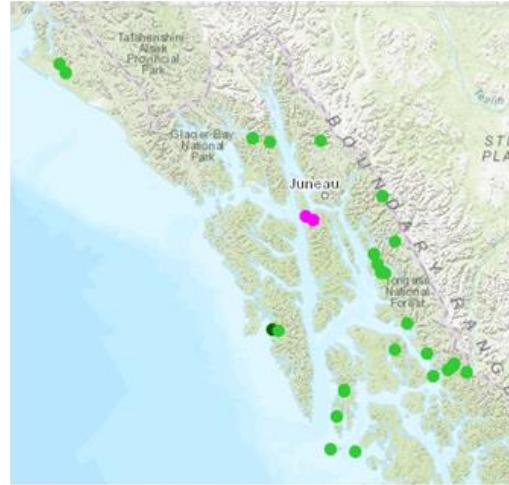
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
H												B	C	N	O	F	Ne
Li	Be											Al	Si	P	S	Cl	Ar
Na	Mg																
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub		Uuq				
Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu				
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr				

Green's Ck Mine The Tailings Disposal Facility Fugitive Dust Mitigation and Monitoring Plan

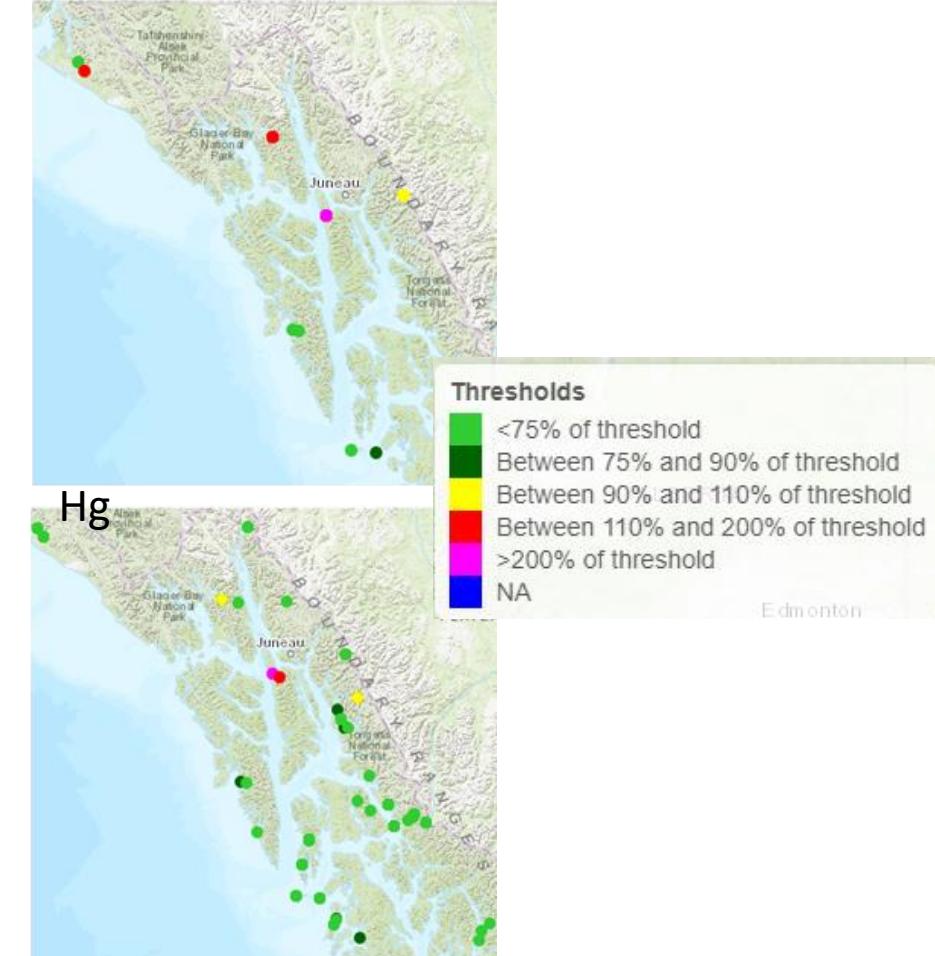
*Metal and sulfur levels in the lichen *Platismatia glauca* sampled near the tailings were more than 200% above national thresholds, and in some cases, orders of magnitude higher than thresholds (Cd 30x, Pb 100x, Zn 37x), warranting additional monitoring and monitoring sites to demonstrate effectiveness of best practices to be implemented.*



Pb (800 ppm)



Zn (1700 ppm)



S

Thresholds
<75% of threshold
Between 75% and 90% of threshold
Between 90% and 110% of threshold
Between 110% and 200% of threshold
>200% of threshold
NA

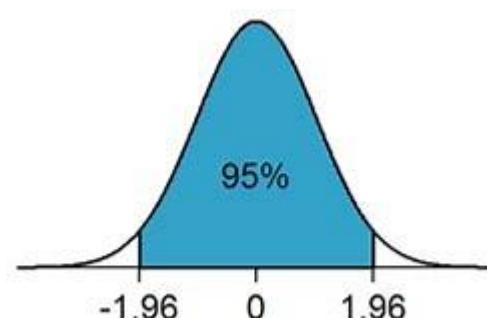
Edmonton

Sample Method 1: Elemental analysis

Determining National Thresholds



	Cd ppm	Cr ppm	Cu ppm	Hg ppb	N %	Ni ppm	Pb ppm	S %	Zn ppm
<i>Platismatia glauca</i>									
Regional Threshold	0.5	3	27.8	n/a	0.79	4.4	10	0.115	49.6
Mean									
Round 1 (n= 14)	0.2	1.3	8.6	n/a	0.61	1.8	5.6	0.072	32.6
Round 2 (n= 4)	0.2	1.4	3.6	144	0.84	1.3	3.8	0.074	31.9
Standard deviation									
Round 1 (n= 14)	0.1	0.4	5.8		0.21	0.6	1.9	0.01	6
Round 2 (n= 4)		0.6	1.3		0.54	0.6	0.5	0.045	2.2
Minimum									
Round 1 (n= 14)	0.1	0.9	3.6		0.25	0.9	3.6	0.06	26.7
Round 2 (n= 4)	0.2	0.6	2.9	144	0.5	0.6	3.5	0.037	29.6
Maximum									
Round 1 (n= 14)	0.6	1.9	19.8		0.97	3.3	9.6	0.09	47.2
Round 2 (n= 4)	0.2	2.1	5.5	144	1.64	2.1	4.6	0.14	33.7



Sample Method 1: Elemental analysis

- Benefit: least amount of training
- Challenges: no climate change, high humidity, low biomass, can take up to a year for results

The image shows the Periodic Table of the Elements. At the top left is a small inset for Carbon (C) with the following details:

- Atomic Mass:** 12.011
- Symbol:** C
- Atomic Number:** 6
- Electron Configuration:** 2-4
- Selected Oxidation States:** +2, +4
- Relative atomic mass (masses are based on $^{12}\text{C} = 12.000$)**
- Note:** Mass numbers in parentheses are mass numbers of the most stable or common isotopes.

The main periodic table is organized into groups and periods. Groups are numbered 1 through 18 across the top. Periods are numbered 1 through 7 down the left side. The table includes element symbols, atomic numbers, and atomic masses. A legend at the bottom right defines symbols for elements 72 and above: (2-8) for elements 72-80, (8-18) for elements 81-86, (18-36) for elements 87-102, and (36-54) for elements 103-122.

Sample Method 2: Community analysis

- Can also detect climate change
- Relative proportion of sensitive vs. tolerant species indicates air quality
- Assessing community composition as a whole produces a robust Air Score



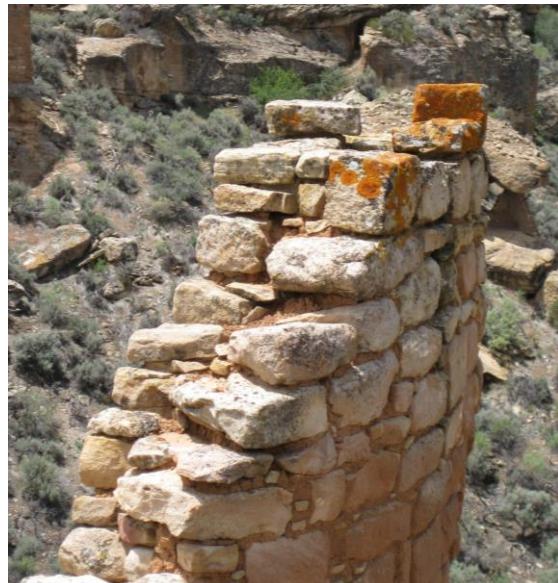
Acid rain



Oligotrophic (sensitive) species



Eutrophic (*N* tolerant) species

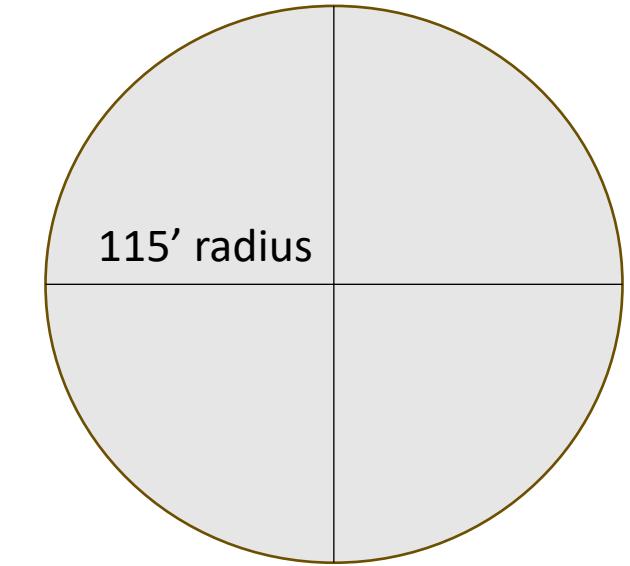


Sample Method 2 Community analysis

FIA “Lichen Indicator”

- ✓ 0.4 ha circular plots
- ✓ Time limited survey
- ✓ Epiphytic macrolichens
- ✓ Collect sample of each species
- ✓ Ocular estimates of abundance
- ✓ Quality assurance met through certification
- ✓ Revisits made every 10 years

- 1 = **Infrequent**
- 2 = **Uncommon**
- 3 = **Common**
- 4 = **Abundant**

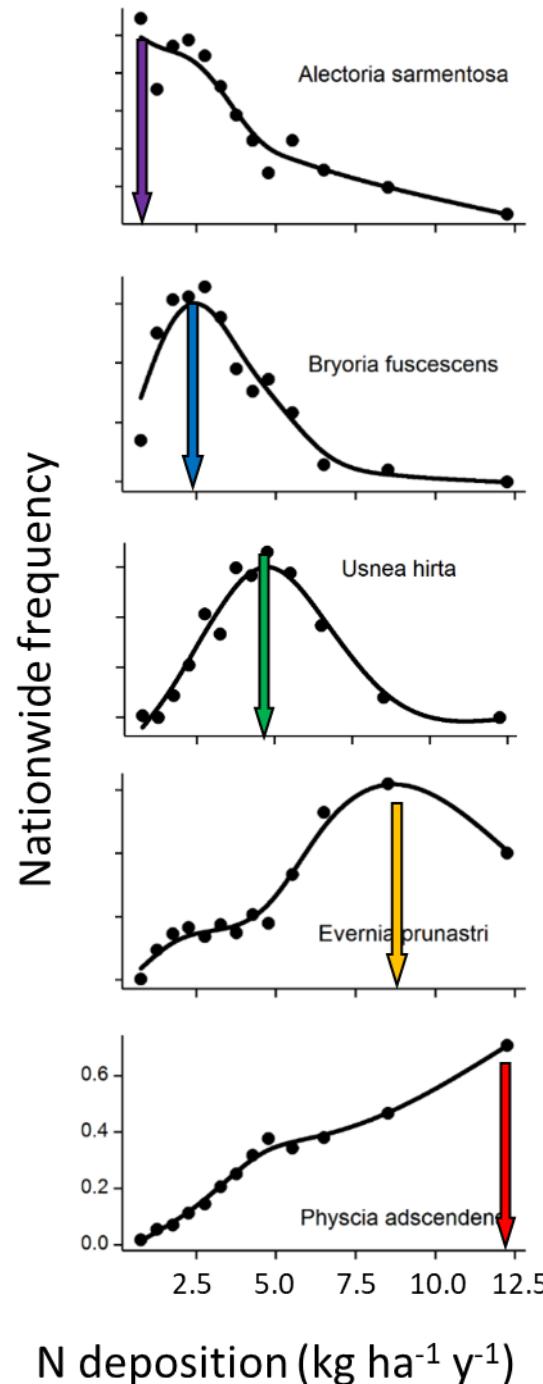


- ✓ Method requires some skill and training
- ✓ An understanding of where species grow
- ✓ Ability to see and collect the full diversity of lichen species
- ✓ Physical fitness-endurance, backpacking
- ✓ Navigation off
- ✓ Tolerance for challenges of field work



Relating peak frequency of species to deposition

the deposition value at which each species reached its peak detection frequency



Environmental Pollution
Volume 291, 15 December 2021, 118187

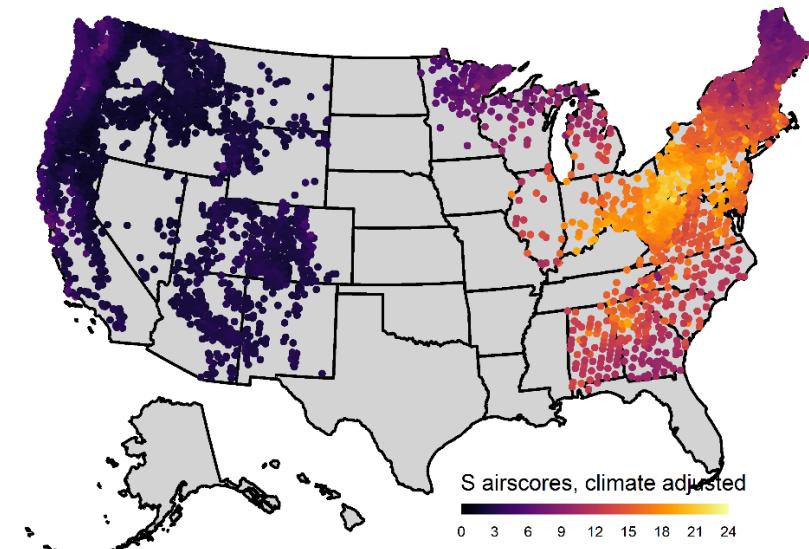
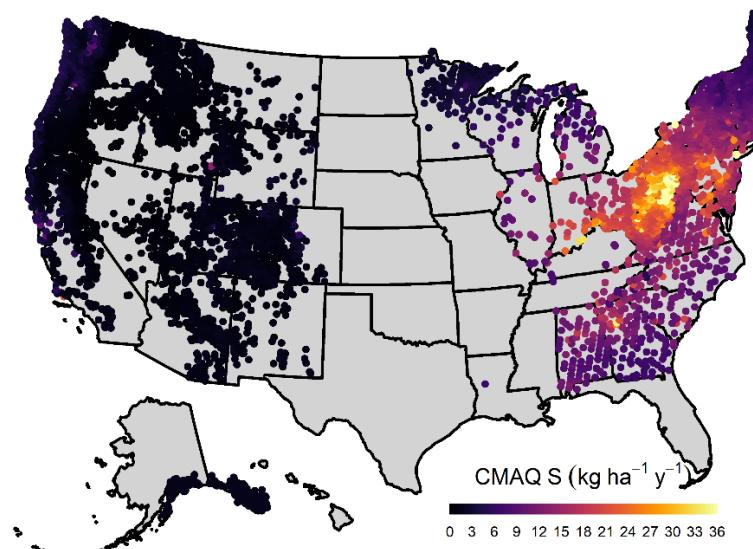
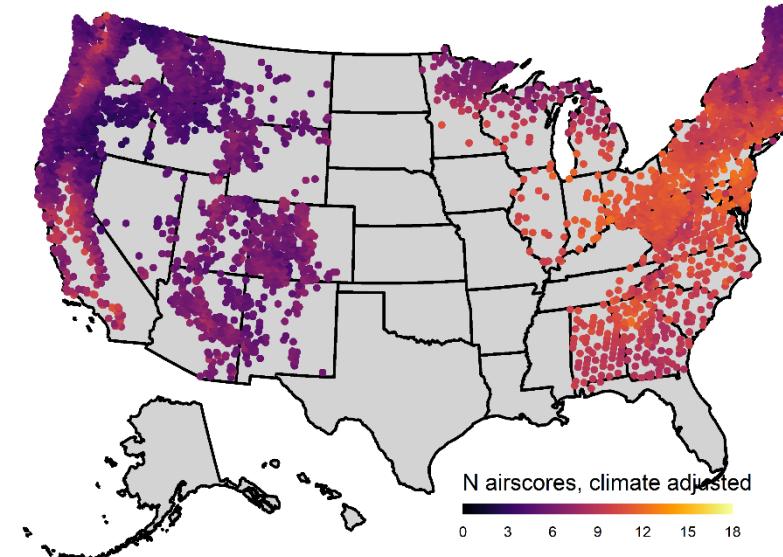
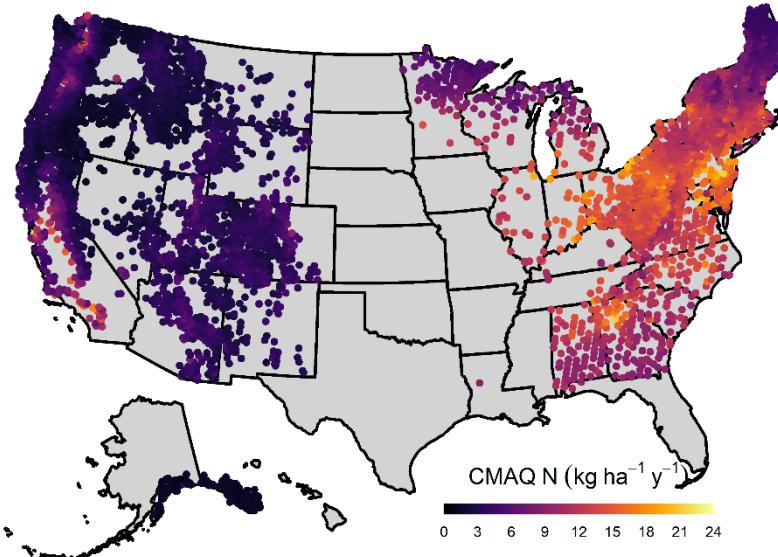


Lichen-based critical loads for deposition of nitrogen and sulfur in US forests ☆

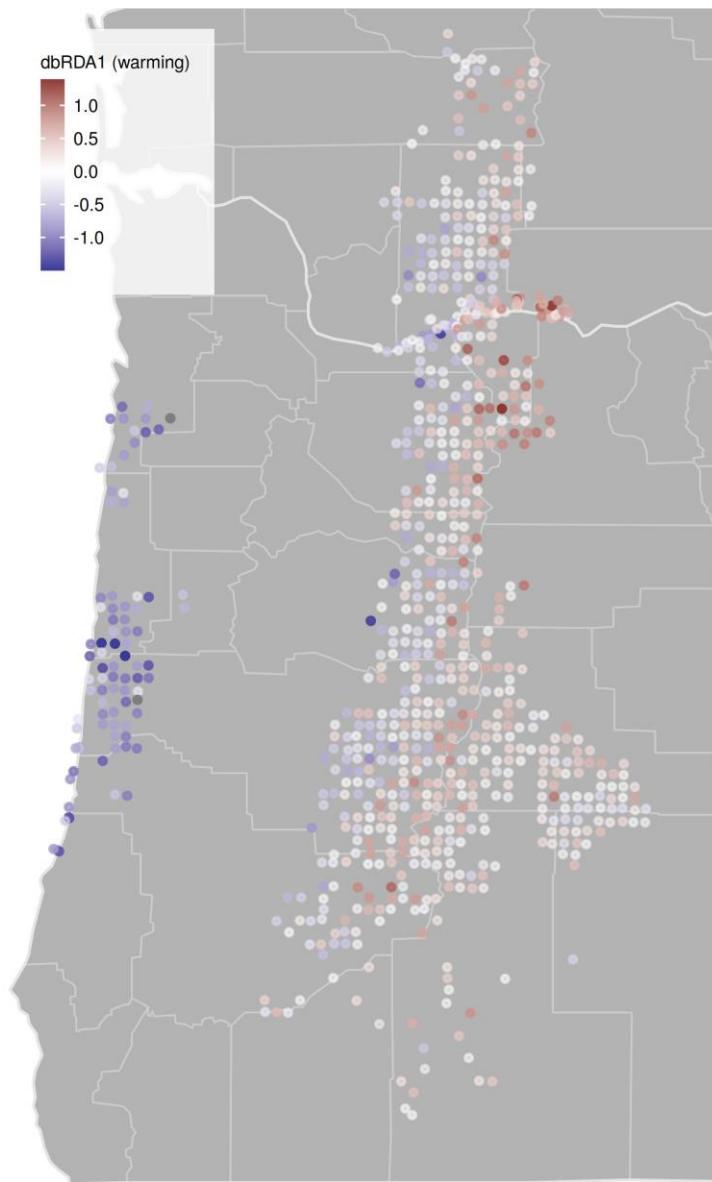
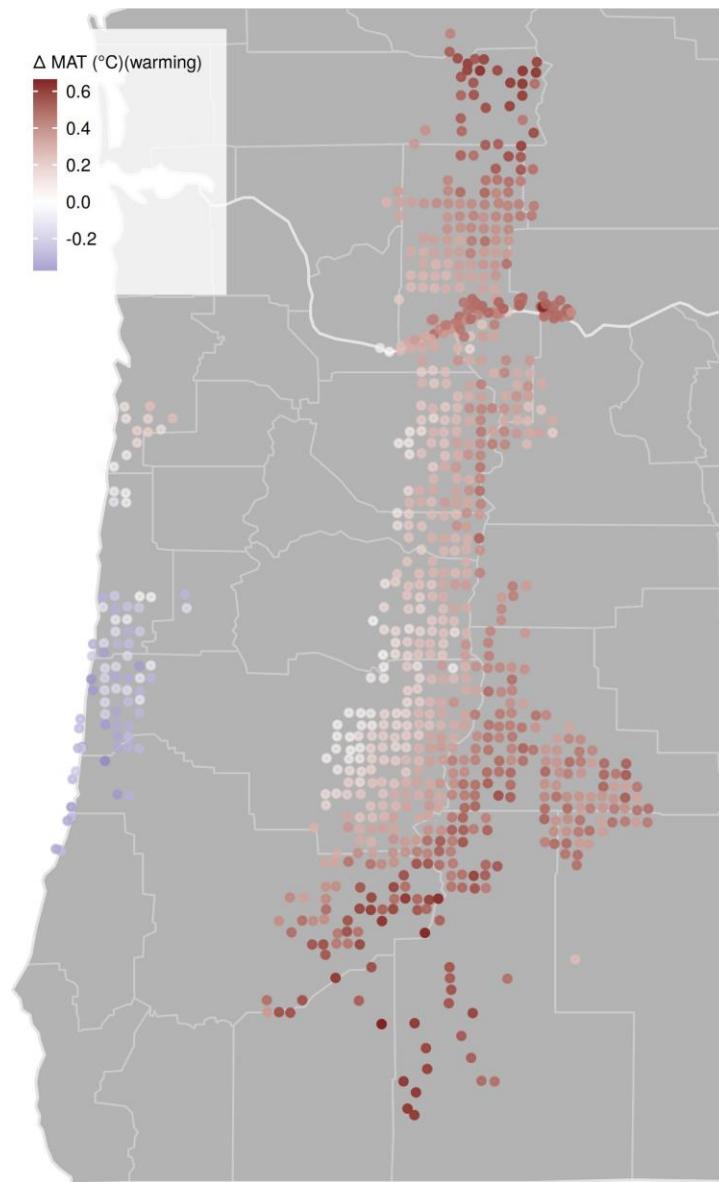
Linda H. Geiser ^a, Heather Root ^b, Robert J. Smith ^a , Sarah E. Jovan ^c, Larry St Clair ^d, Karen L. Dillman ^a

Mapping site scores

Lichen climate-adjusted ‘airscores’ track deposition at monitoring sites

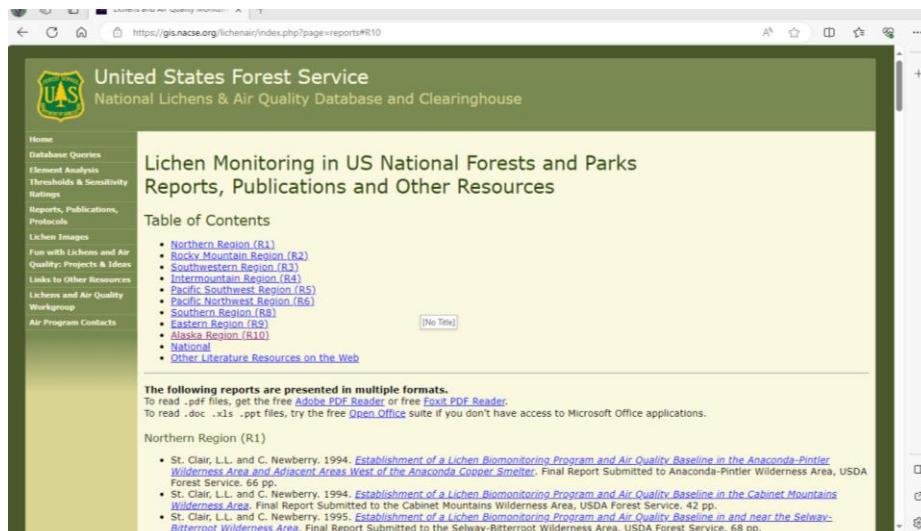


Climate changes mirrored by compositional shifts



Available Resources

- Many publications
- New Website is Forthcoming
- New tools to improve databasing



United States Forest Service
National Lichens & Air Quality Database and Clearinghouse

Home
Database Queries
Element Analysis
Thresholds & Sensitivity Ratings
Reports, Publications, Protocols
Lichen Images
Fun with Lichens and Air Quality: Projects & Ideas
Links to Other Resources
Lichens and Air Quality Workgroup
Air Program Contacts

Lichen Monitoring in US National Forests and Parks
Reports, Publications and Other Resources

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- Northern Region (R1)
- Rocky Mountain Region (R2)
- Southwestern Region (R3)
- Intermountain Region (R4)
- Pacific Southwest Region (R5)
- Eastern Region (R6)
- Southern Region (R8)
- Eastern Region (R9)
- Alaska Region (R10)
- National
- Other Literature Resources on the Web

The following reports are presented in multiple formats.
To read .pdf files, get the free [Adobe PDF Reader](#) or free [Foxit PDF Reader](#).
To read .doc .xsl .ppt files, try the free [OpenOffice](#) suite if you don't have access to Microsoft Office applications.

Northern Region (R1)
• St. Clair, L.L. and C. Newberry. 1994. *Establishment of a Lichen Biomonitoring Program and Air Quality Baseline in the Anaconda-Pintler Wilderness Area and Adjacent Areas West of the Anaconda Copper Smelter*. Final Report Submitted to Anaconda-Pintler Wilderness Area, USDA Forest Service, 66 pp.
• St. Clair, L.L. and C. Newberry. 1994. *Establishment of a Lichen Biomonitoring Program and Air Quality Baseline in the Cabinet Mountains Wilderness Area*. Final Report Submitted to the Cabinet Mountains Wilderness Area, USDA Forest Service, 42 pp.
• St. Clair, L.L. and C. Newberry. 1995. *Establishment of a Lichen Biomonitoring Program and Air Quality Baseline in and near the Selway-Bitterroot Wilderness Area*. Final Report Submitted to the Selway-Bitterroot Wilderness Area, USDA Forest Service, 68 pp.

Lichen communities and species indicate climate thresholds in southeast and south-central Alaska, USA

Heather T. Root^{1,3}, Bruce McCune¹ and Sarah Jovan²

¹ Department of Botany and Plant Pathology, Oregon State University, 2082 Cordley Hall, Corvallis, OR, 97331, U.S.A.;



Environmental Pollution

Volume 291, 15 December 2021, 118187



Recommended articles

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Help

Lichen-based critical loads for deposition of nitrogen and sulfur in US forests ☆

Linda H. Geiser^a, Heather Root^b, Robert J. Smith^a   , Sarah E. Jovan^c,
Larry St Clair^d, Karen L. Dillman^a

Lichen bioindicators of nitrogen and sulfur deposition in dry forests of Utah and New Mexico, USA

Heather T. Root^a   , Sarah Jovan^b, Mark Fenn^c, Michael Amacher^d, Josh Hall^e,
John D. Shaw^f

Wilderness Stewardship

lichenlab.shinyapps.io/shinyapp/

Lichen Data Query and Mapping Tool

Data:
 Elemental
 Lichen
 Plot

National Forest

Wilderness
 No Selection

Select the Round Years
 Show Data Table

Wilderness Stewardship Lichen Report:
<https://ecol.shinyapps.io/wildstew/>

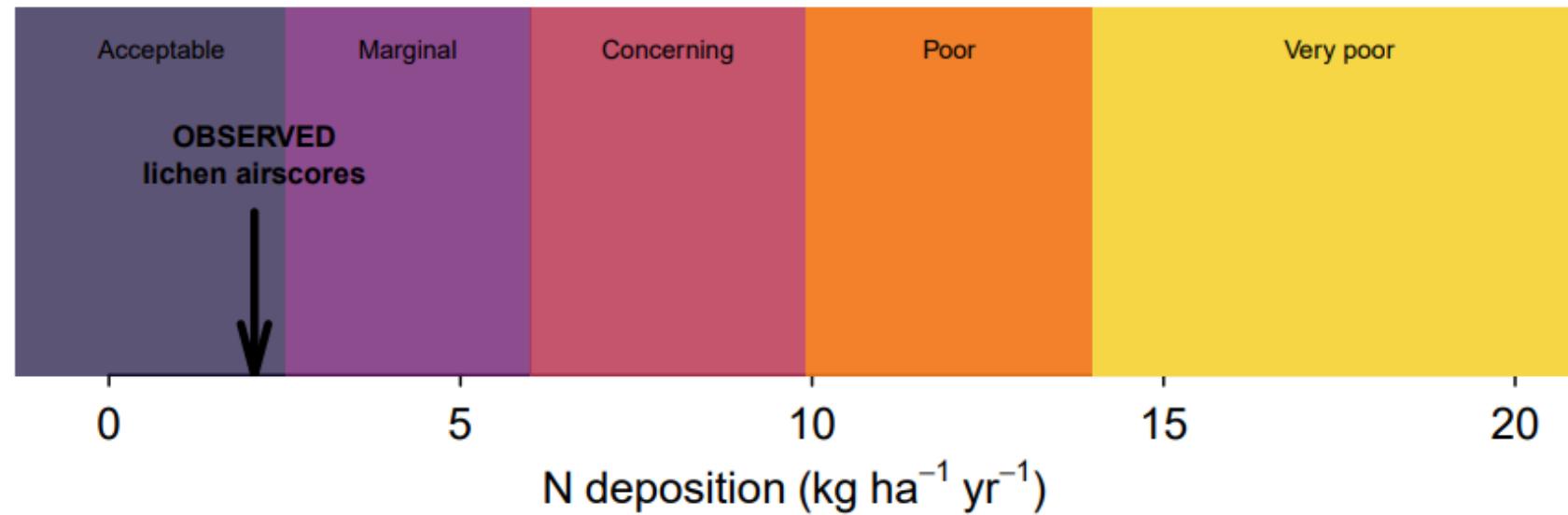
Wilderness Air Quality Values for Mount Hood Wilderness

Report prepared: 22 February 2021

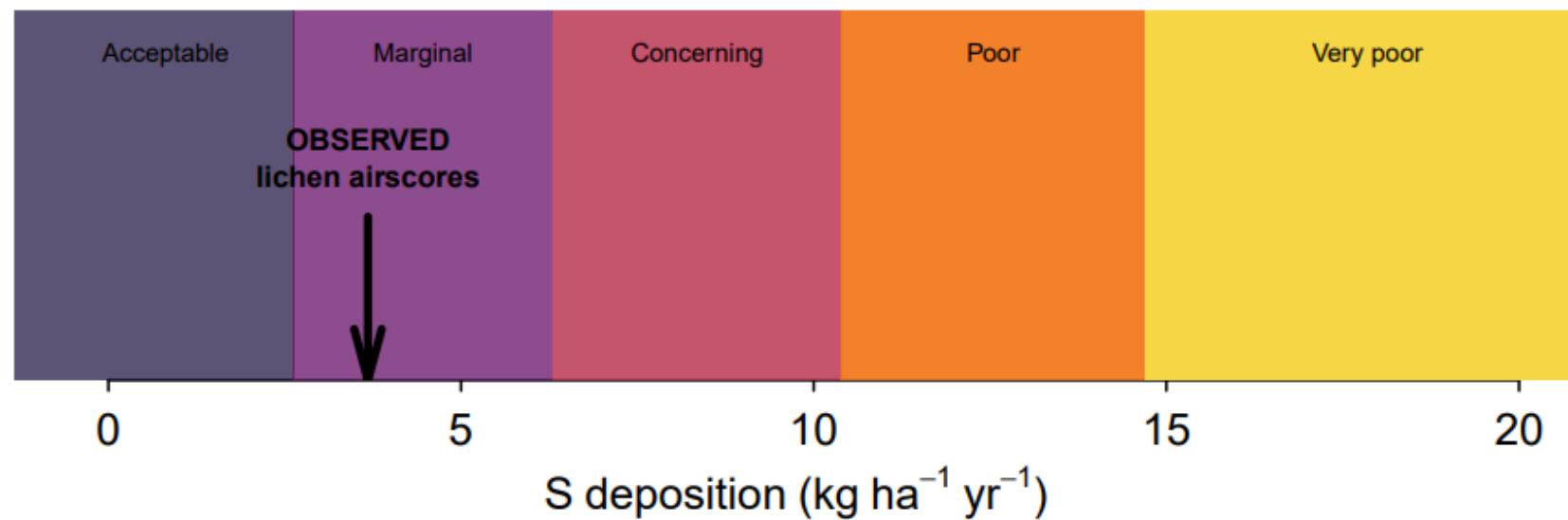
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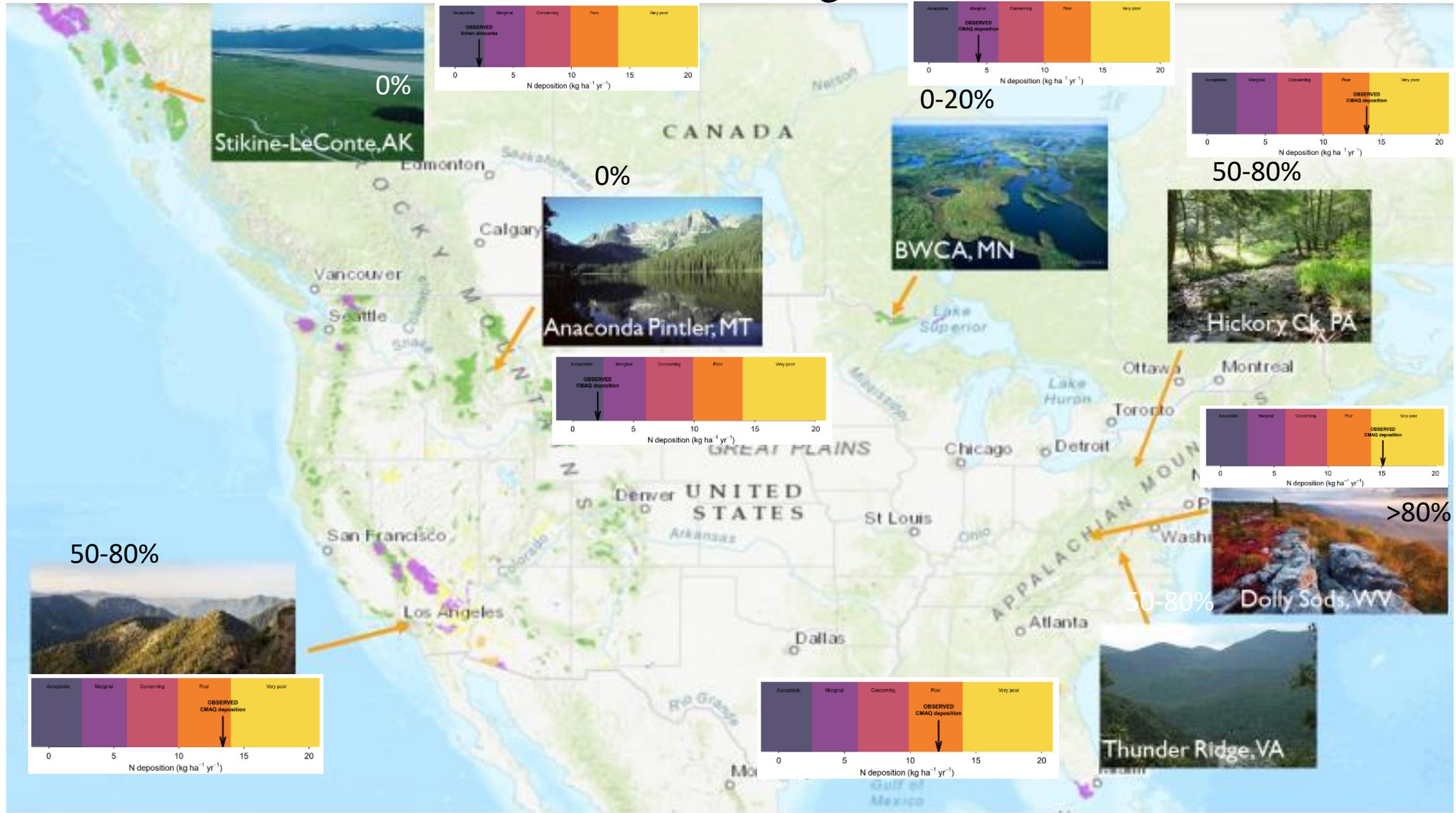
2.1 Nitrogen snapshot



2.2 Sulfur snapshot



Risk lichen richness decline with increasing



Challenges



- Budget Modernization
- Increased catastrophic fire
- Limited funding
- Data and Lab can be slow



Benefits

- Lichens don't lie
- Many tools have been developed for analyzing Forest Health
- Proven repeatable protocols
- Baseline and trends data going back 33 years
- Much less expensive for making initial detections



Thank you to Linda Geiser, Bruce McCune, Sarah Jovan, Karen Dillman, Doug Glavich, Heather Root, Rob Smith, Rick Graw and many, many more people who have been a part of this program's history, especially all the Forest Service staff, wilderness program managers, partners, volunteers, and contractors that have contributed over the years!