Evidence of climate trend effects on vegetation patterns in the US Pacific Northwest— Response of epiphytic lichens from 1993-2009

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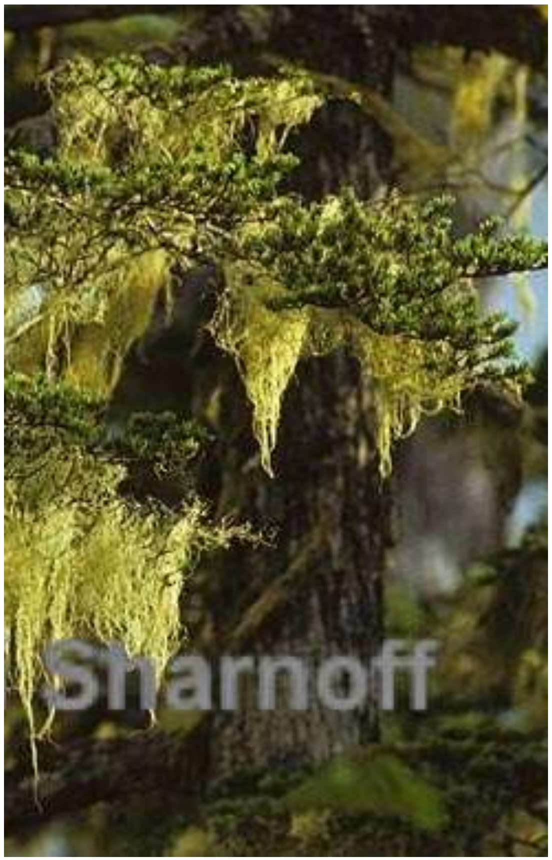
Introduction

- **The FIA Air Quality and Climate Indicator is designed to assess status and trends in air pollution and climate** affecting the nation's forests and to provide evidence of ecological effects from these trends.
- **Uses lichen community composition**
- **Which shifts** as different species reach their tolerance limits.
- Shows response **before effects on less sensitive flora can be detected.**

Lichens are symbiotic organisms consisting of a fungus and a photosynthetic green algal +/or blue-green bacterial partner.

Unique morphology and physiology underlies special sensitivity of lichens



- Epiphytes are little influenced by soil nutrition –**no roots,** aerial location. Rely on atmospheric deposition for nutrients and moisture.
- **No barrier cuticle or guard cells…**moisture, nutrients, *and* pollutants are absorbed passively over entire surface of the lichen.
- Dehydration concentrates pollutants
- Precipitation, if clean, leaches pollutants
- **Dynamic equilibrium , fast response**.
- **Require wetting and drying** for nutrient exchange between symbionts.
- **Species are differentially adapted to** hot, dry vs. cool, wet **climate regimes** and to **atmospheric deposition** of nutrients and acidity.

Every lichen is adapted to specific atmospheric deposition levels & chemistry

Lichens of low fertility, acidic environments.

Lichens of high nutrient, more alkaline environments

… so lichen species composition can be used to pinpoint a site along regional air pollution gradients.

In Oregon's Willamette Valley, oligo-trophic species thrive in clean air.

And eutrophic species thrive where nutrient availability is greater

Every lichen is also adapted to a specific range of climatic conditions…

As climate becomes warmer the composition of coastal epiphytes changes dramatically

…therefore lichen community composition can be used to pin-point a site along regional climate gradients.

Data collection

- 0.4 ha plot on the systematic national P3 grid (1 plot/96,000ac)
- Surveys up to 2 hours
- Collect sample of each species detected
- And rate abundance:

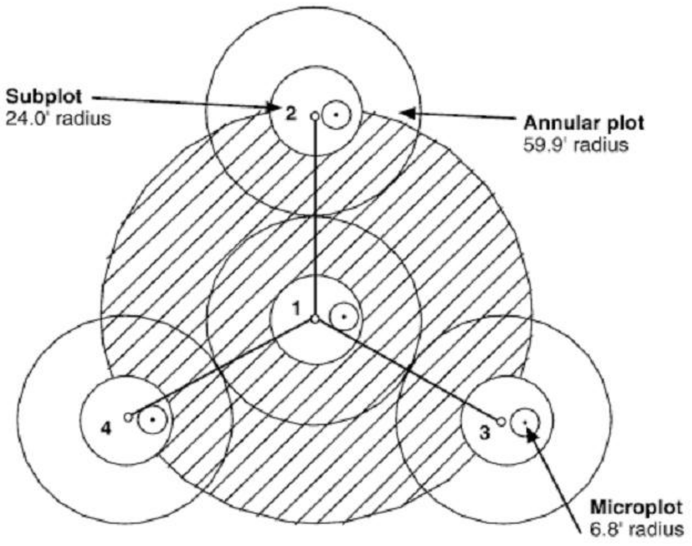
  1 = **Infrequent** (< 3 thalli)

  2 = **Uncommon** (4-10 thalli)

  3 = **Common** (>10 thalli; covers < 50% of all boles and branches)

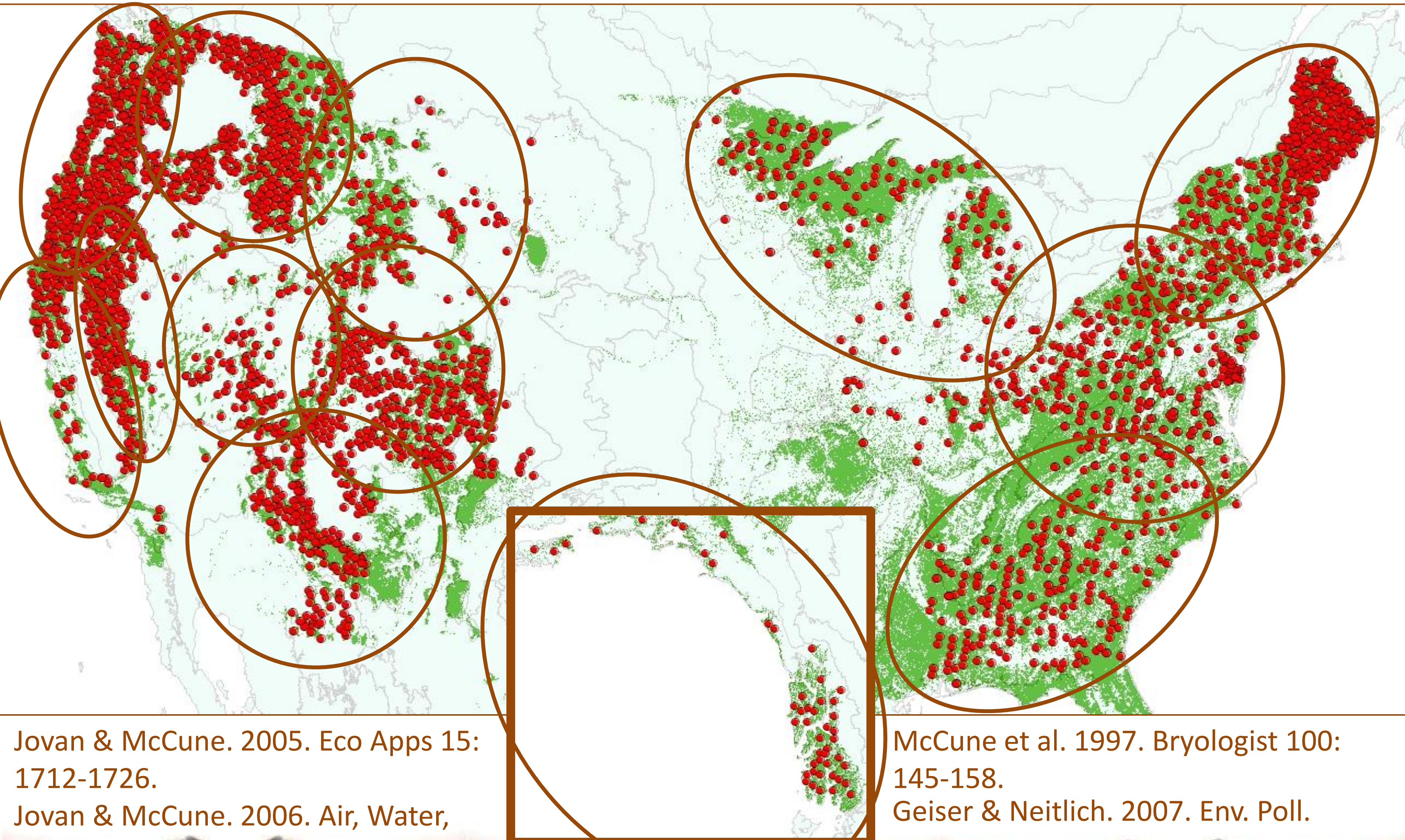
  4 = **Abundant** (>10 thalli covers > 50% of all boles and branches)

- ID by regional taxonomic expert

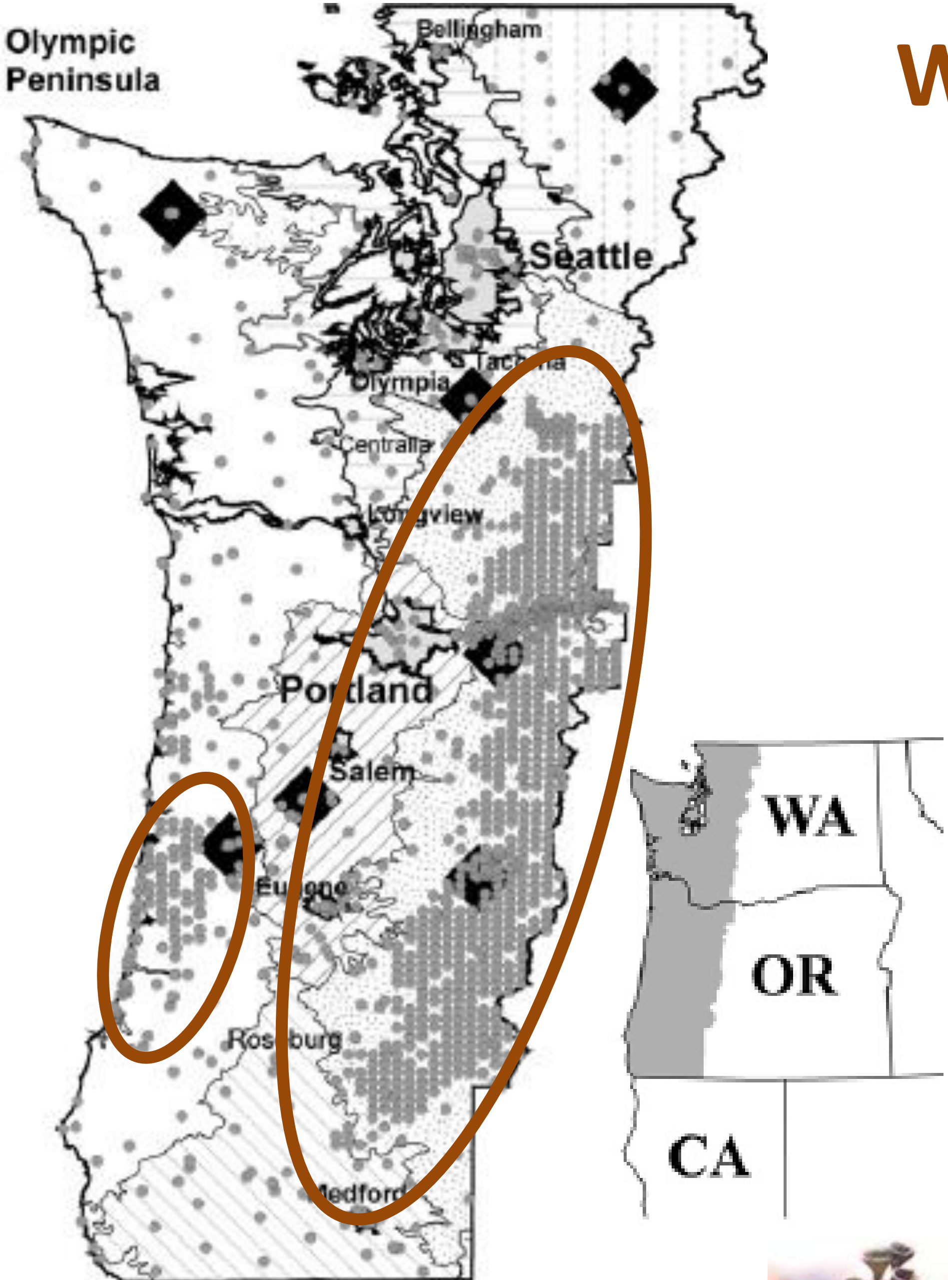


Lichens sampled in shaded area

The FIA AQ & Climate Network



Jovan & McCune. 2005. Eco Apps 15: 1712-1726.
Jovan & McCune. 2006. Air, Water, Soil Poll. 170:69-93.
McCune et al. 1997. Bryologist 100: 145-158.
Geiser & Neitlich. 2007. Env. Poll. 145:203-218.



Western PNW model

Round 1: 1993-2001

1416 plots were surveyed by:

- FIA (23 km grid)
- USFS PNW regional Air Program (5.4 km grid)

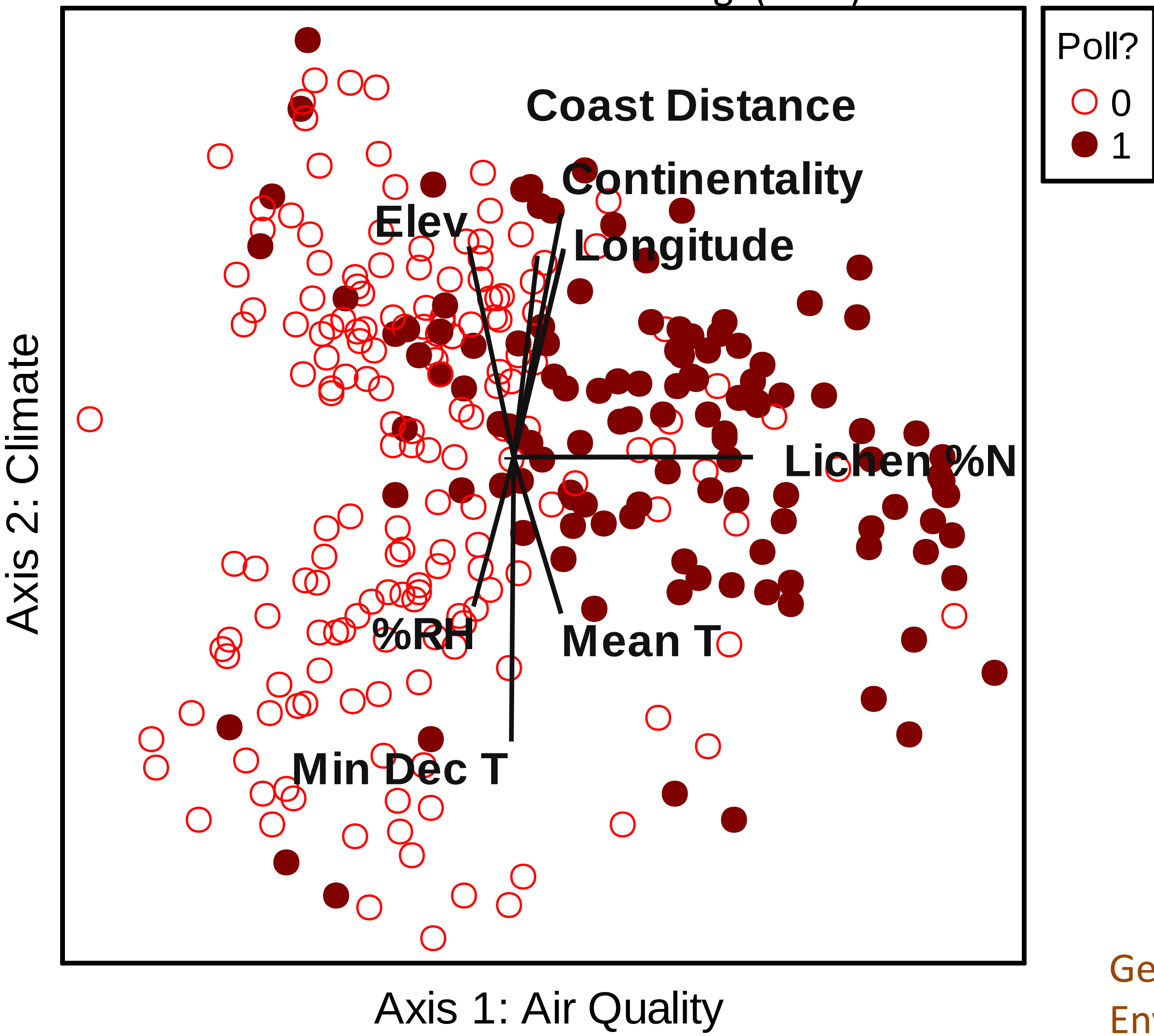
Round 2: 2003-2009

350 Air program plots were **re-**surveyed

- Providing data for this trends analysis

Geiser, L.H.; Neitlich, P.N. 2007. Env Poll145: 203-218.

Non-metric multi-dimensional scaling (NMS) ordination



Western PNW model

Two major influences :

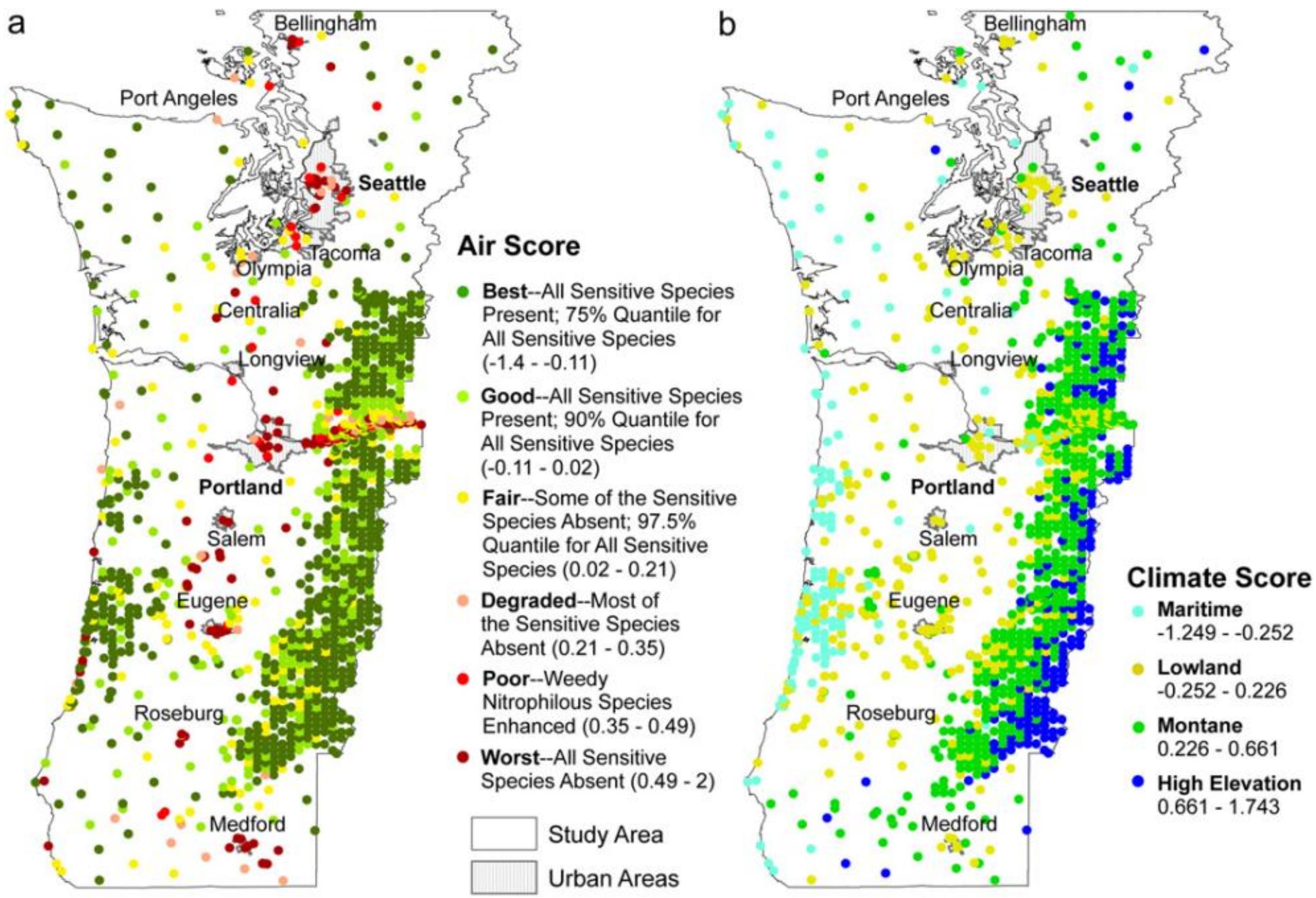
- air quality
- climate

scored as distance along Axes 1 & 2

Geiser & Neitlich. 2007. Env. Poll. 145: 203-218.

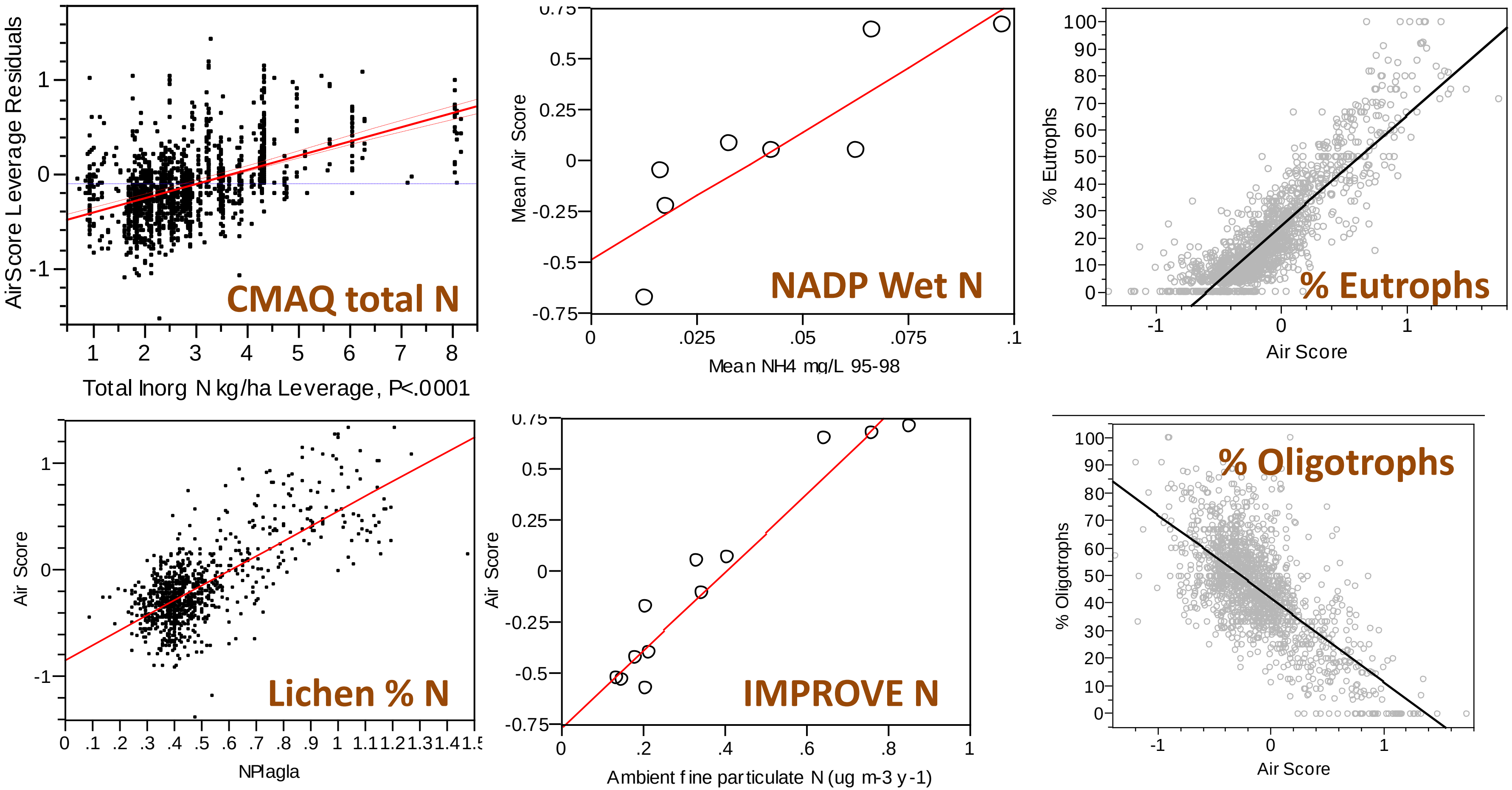
Air Quality and Climate scores

Round 1: 1993-2001



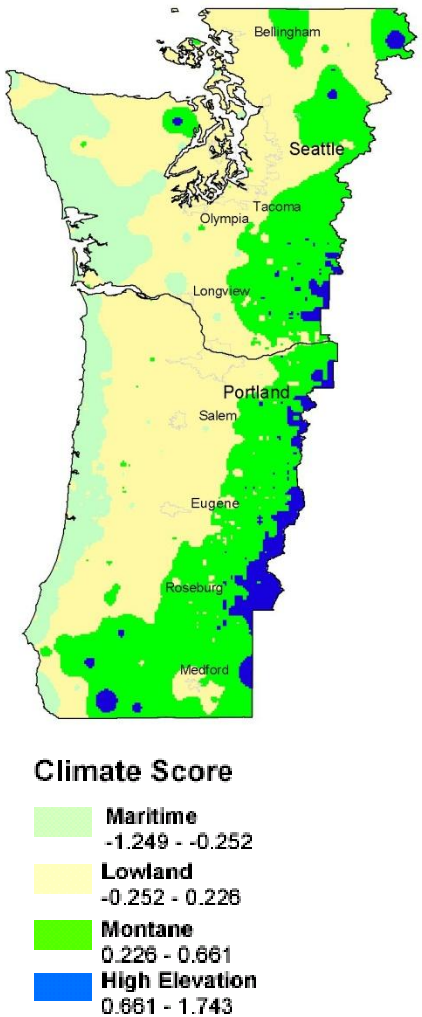
Geiser, L.H.; Neitlich, P.N. 2007. Air pollution and climate gradients in western Oregon and Washington indicated by epiphytic macrolichens. Environmental Pollution 145: 203-218.

Air scores and all available measures of atmospheric N deposition are correlated



Geiser et al. 2010. Lichen-based critical loads for atmospheric nitrogen deposition in western Oregon and Washington forests, USA. Env. Poll. 158: 2412-2421.

Climate Change Anticipated effects



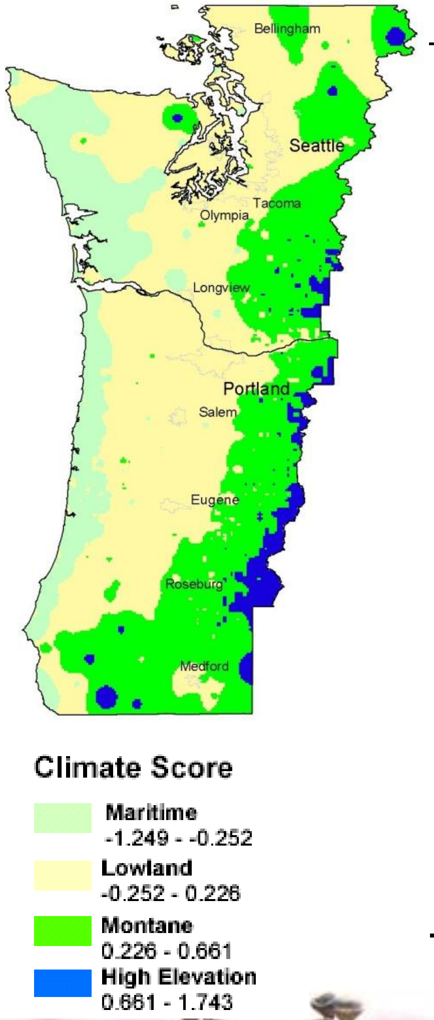
PREDICTED CHANGE:

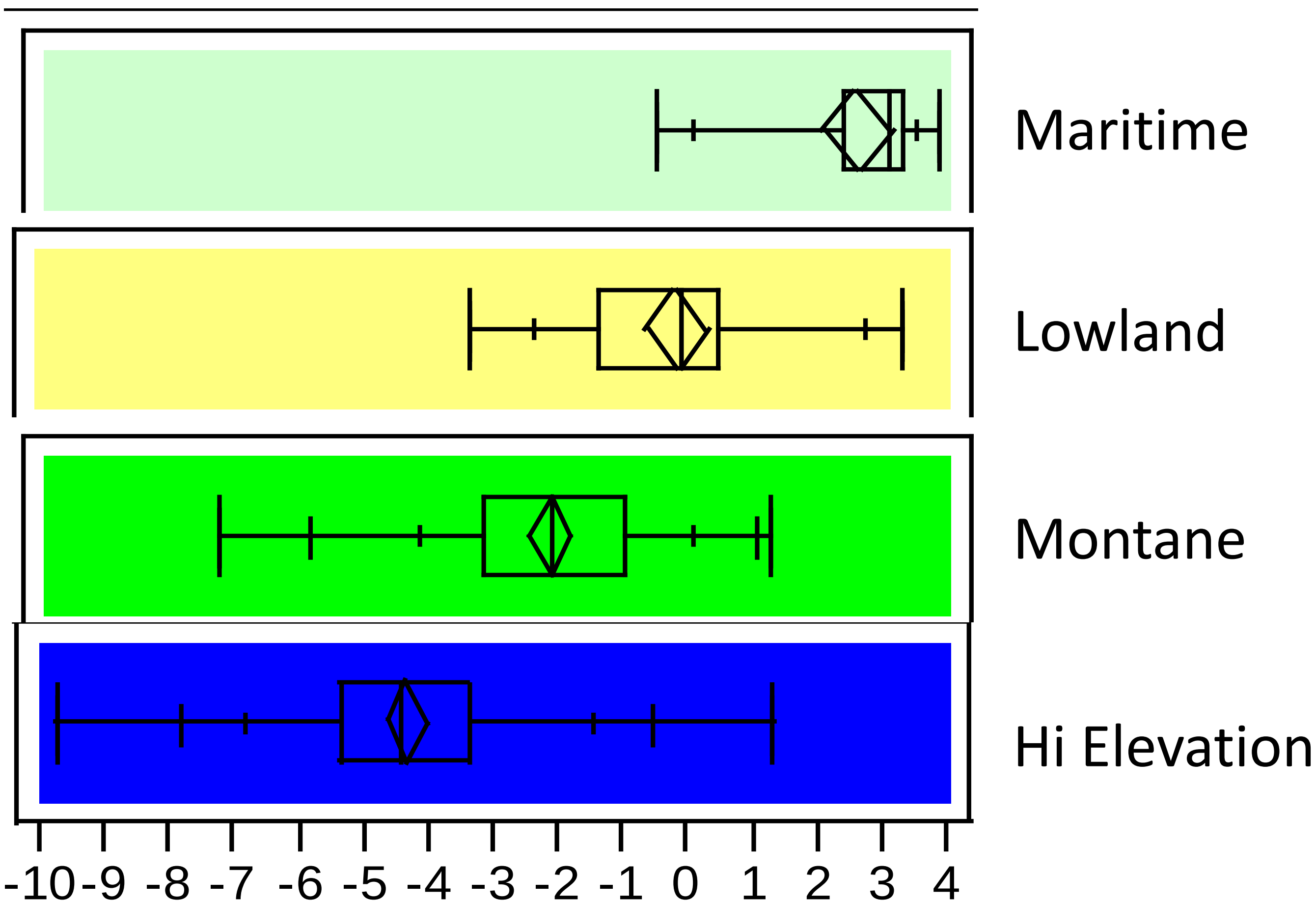
- Mean annual temperature to ↑1.5 to 3.2° C by 2040.

POTENTIAL RESPONSES:

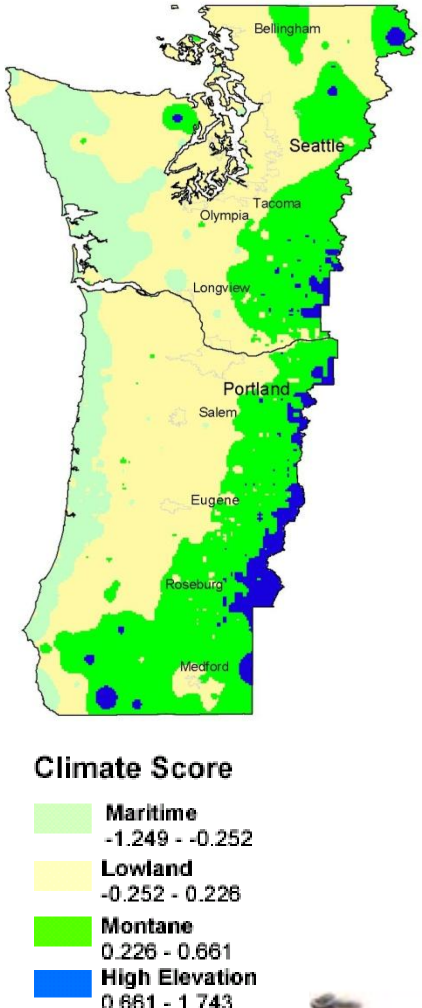
- A 1° C temp Δ ↓probability of finding some lichens 2-10 fold.
- Most biodiversity contributed by rare species →Concern for local/regional extirpations → Especially coastal (maritime) and subalpine (high elevation) species.

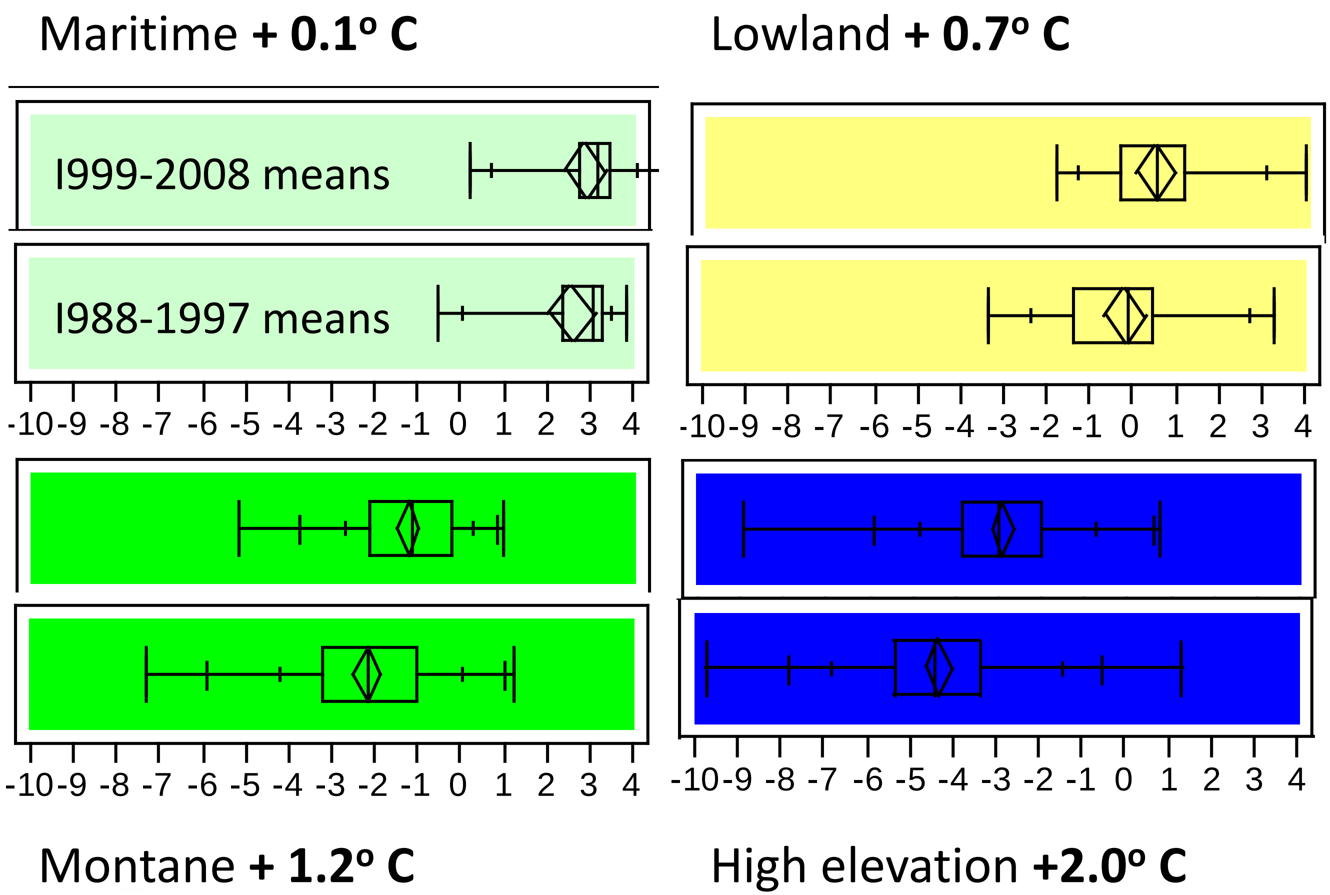
Mean min Dec Temp º C at round 1 lichen plots (1988-1998)



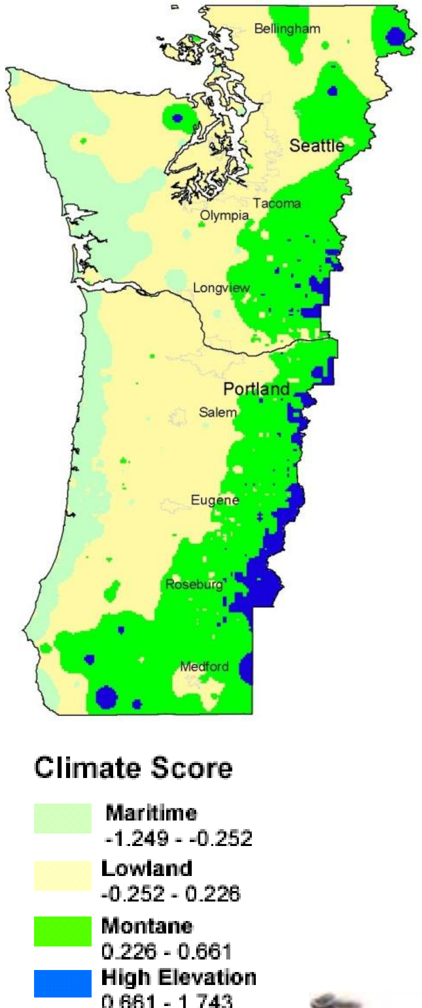


Change in mean annual min Dec T (C) at lichen plots, 1988-98 vs. 1999-2008

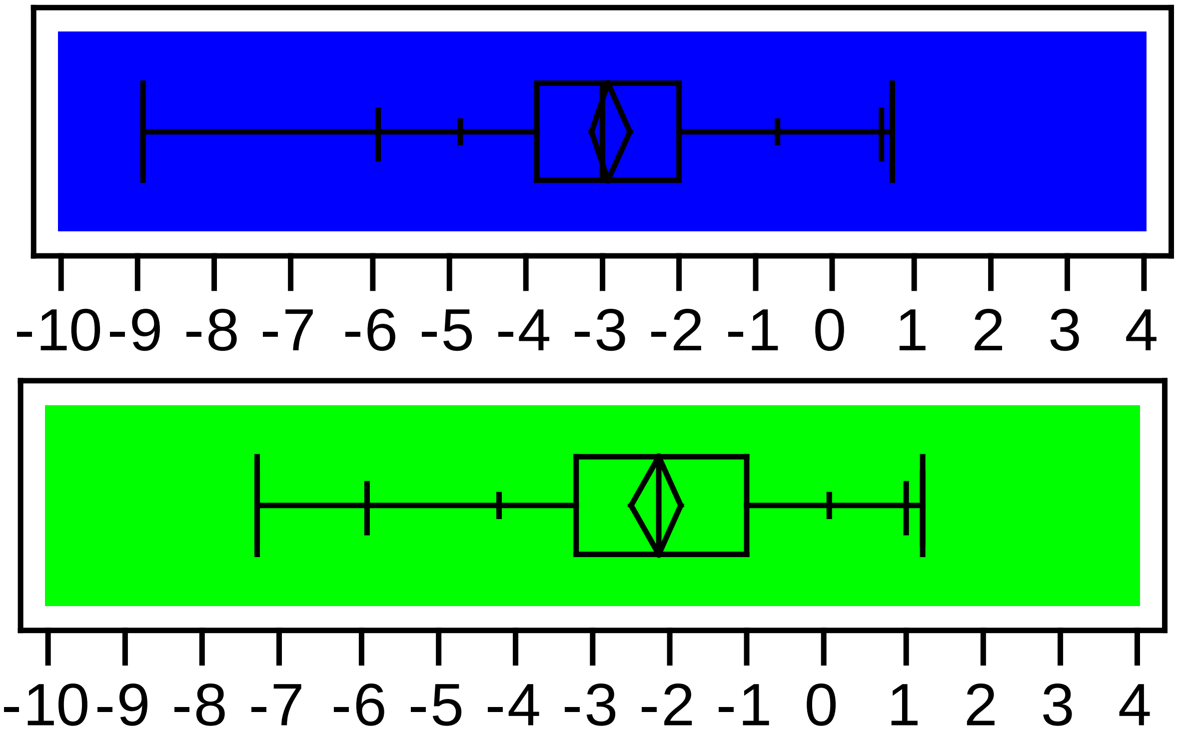




Change in mean annual min Dec T (C) at lichen plots, by climate zone, 1988-2008

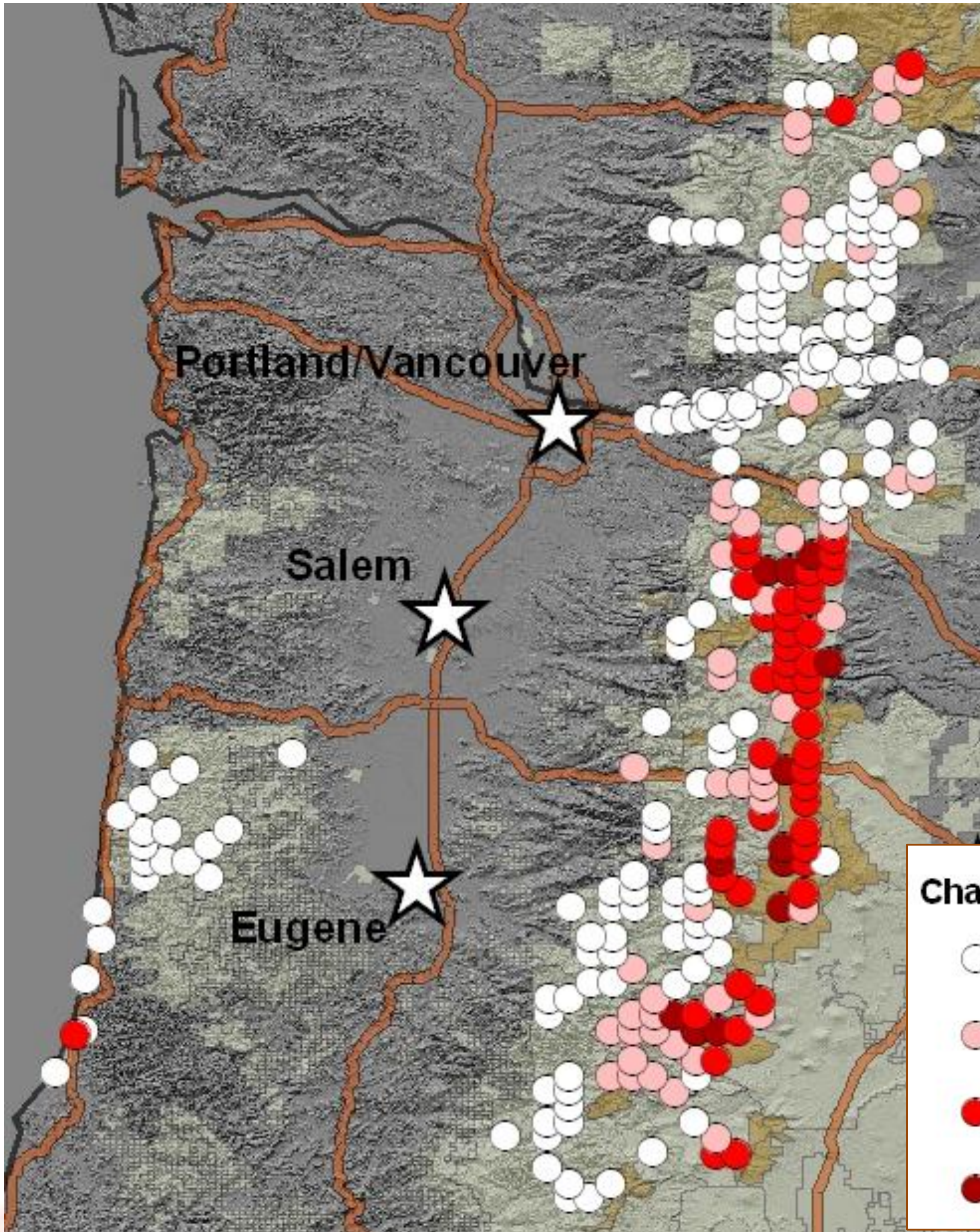


I998-2008 means for R2 High Elevation plots



I988-1997 means for R1 Montane Plots

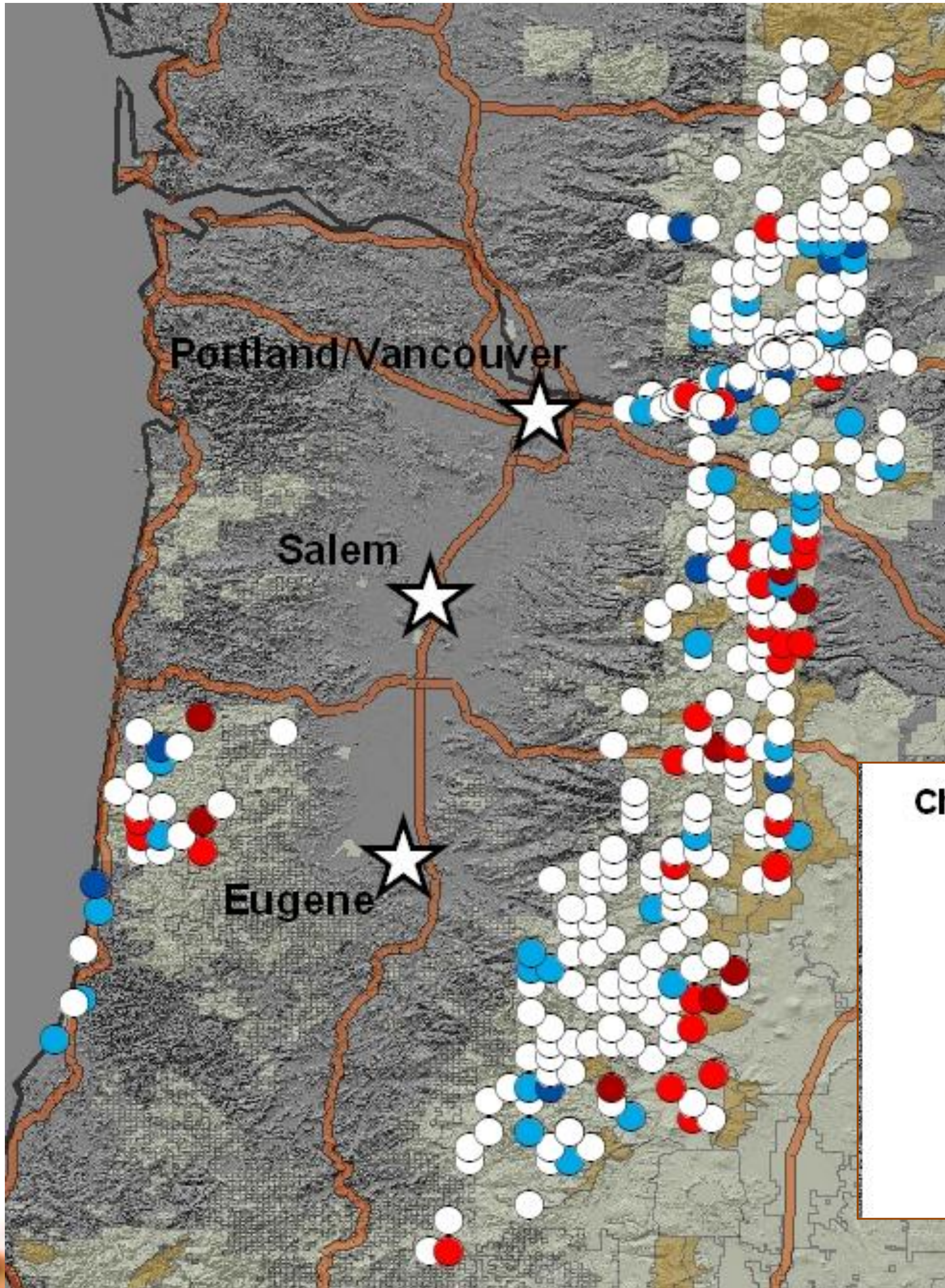
What actually happened: PRISM temperatures 1988-2008



- Warming rates ↑ with elevation
- Low elevations, valleys and the coast range did not warm
- No sites became cooler

Change in Mean Min. Dec. Temp (C)	Trend
-1.4 to 1.7	no change
1.7 to 2.6	slightly warmer
2.6 to 3.5	warmer
3.5 to 4.4	much warmer

What actually happened: Lichens 1993-97 vs. 2003-07



Lichen community based climate scores also showed greatest increases at highest elevations.

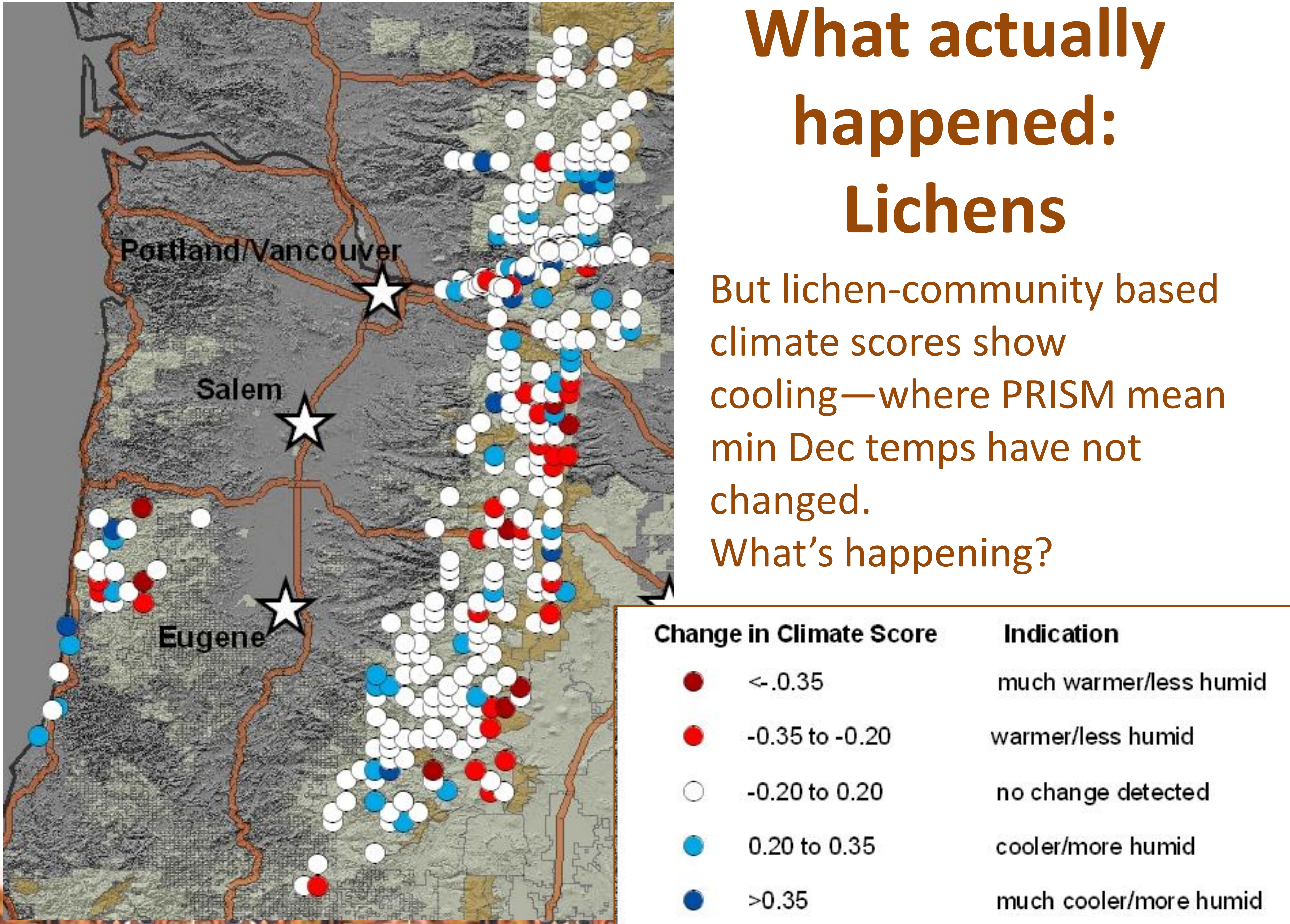
	Change in Climate Score	Indication
● (dark red)	<-.0.35	much warmer/less humid
● (red)	-0.35 to -0.20	warmer/less humid
○ (white)	-0.20 to 0.20	no change detected
● (light blue)	0.20 to 0.35	cooler/more humid
● (dark blue)	>0.35	much cooler/more humid

Like temperature, lichen-indicated warming increased with elevation

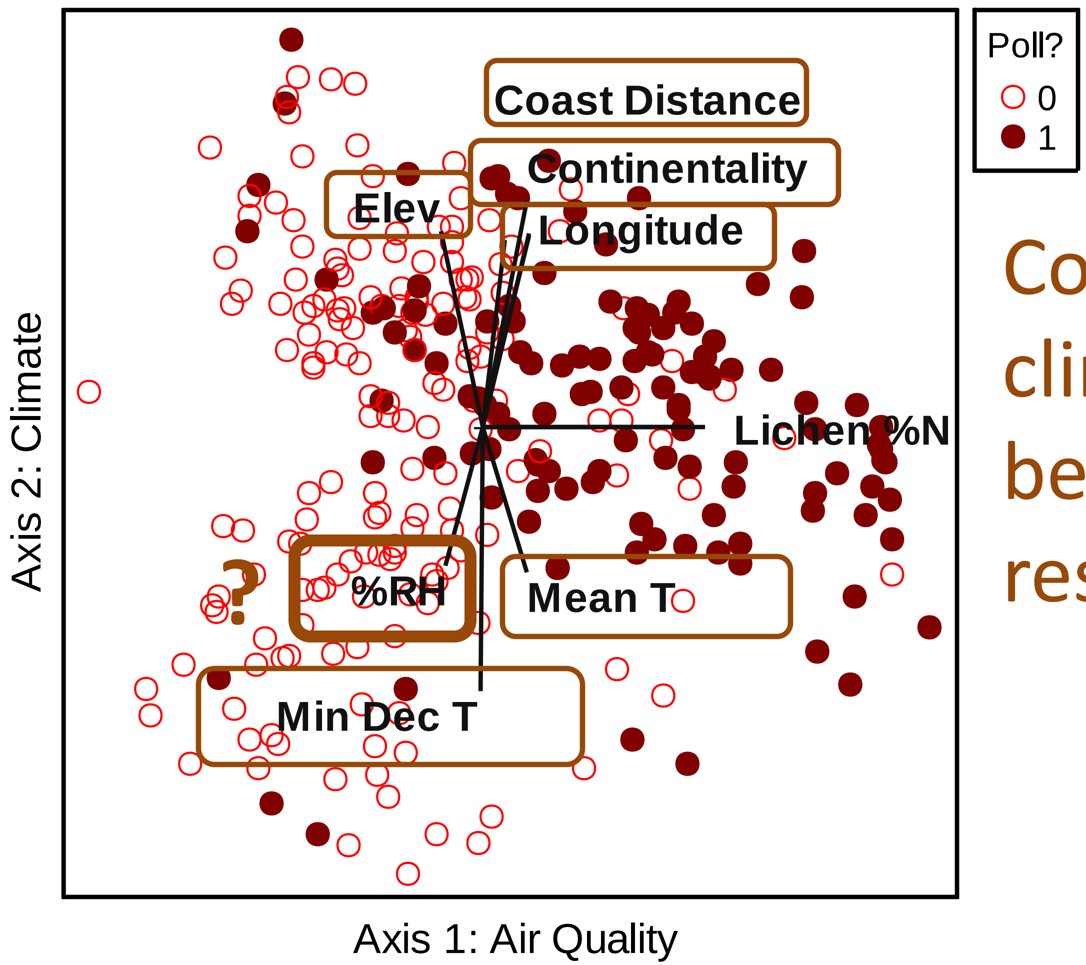
Climate change direction indicated by lichen communities (1993-2009)	N	Mean elevation (m)
much warmer	5	813
warmer	34	705
no change detected	248	583
cooler	37	539
much cooler	12	470

What actually happened: Lichens

But lichen-community based climate scores show cooling—where PRISM mean min Dec temps have not changed.
What's happening?



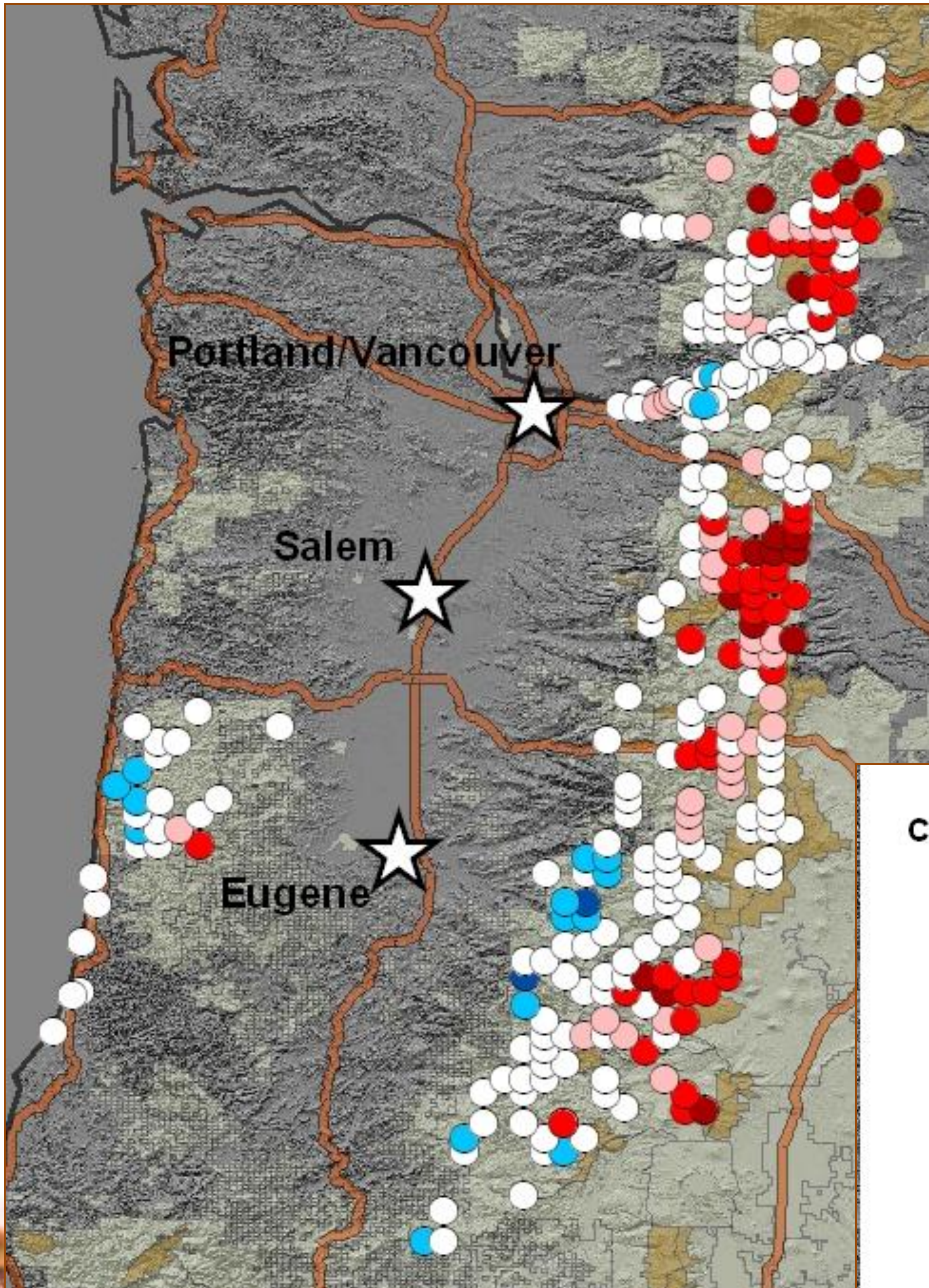
But what actually happened?



Could shifts in other climate-axis variables be influencing lichen response?

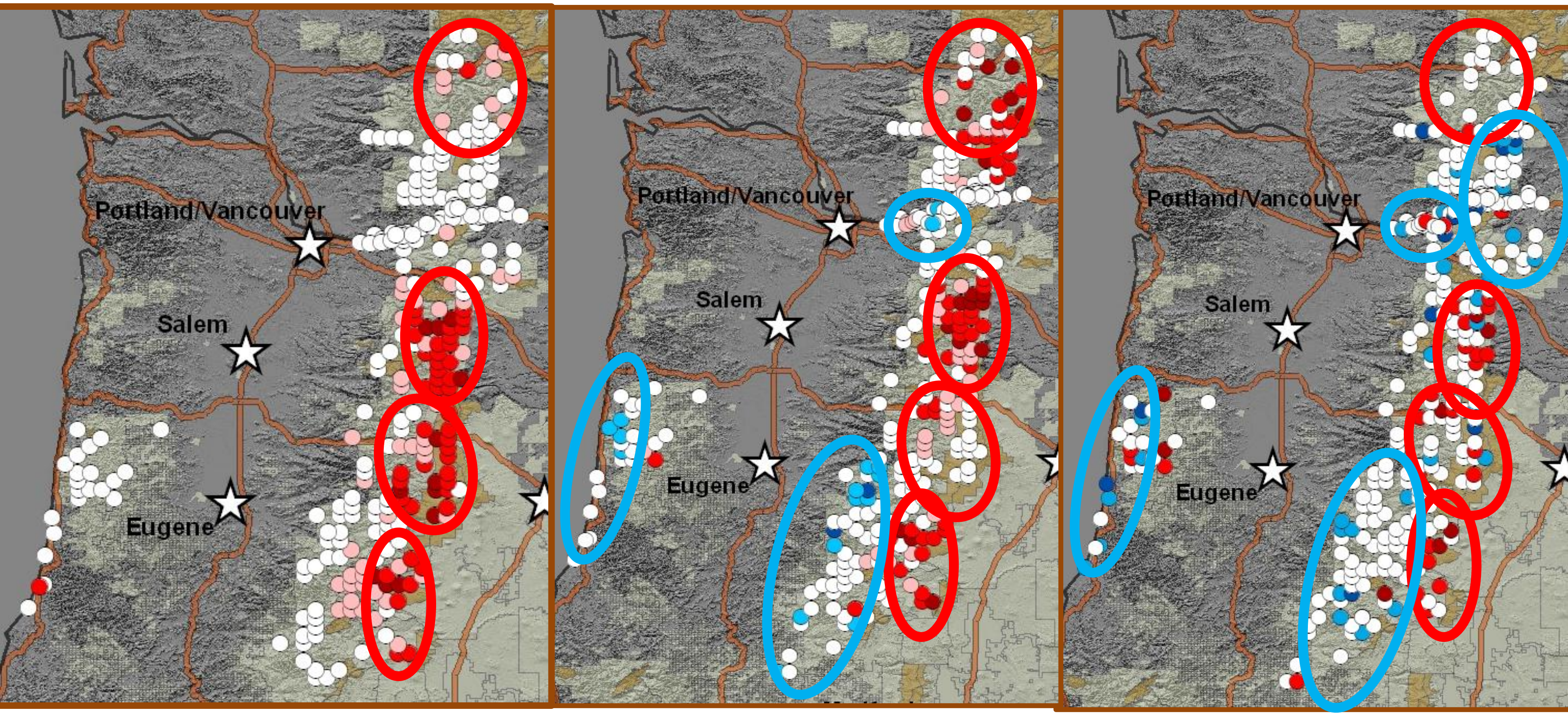
What actually happened: % RH 1988-2009

- Humidity ↓ in the high elevation Cascades
- Humidity ↑ in the lower elevation Cascades & Coast Ranges



	Change in % RH	Trend
● (dark red)	-0.88 to -0.50	Much less humid
● (red)	-0.49 to -0.31	Less humid
● (pink)	-0.30 to -0.21	Slightly less humid
○ (white)	-0.20 to 0.20	No change
● (light blue)	0.21 to 0.30	More humid
● (dark blue)	0.31 to 0.42	Much more humid

Comparing climate & lichen responses



Mean Min Dec Temp

- warmer temps

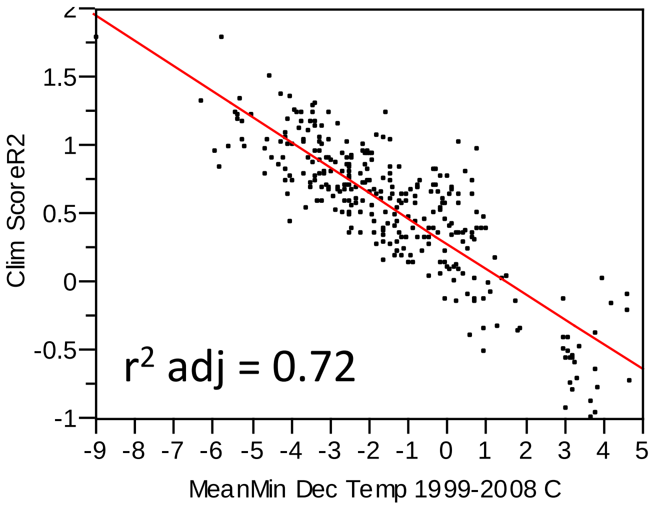
% Relative humidity

- less humidity

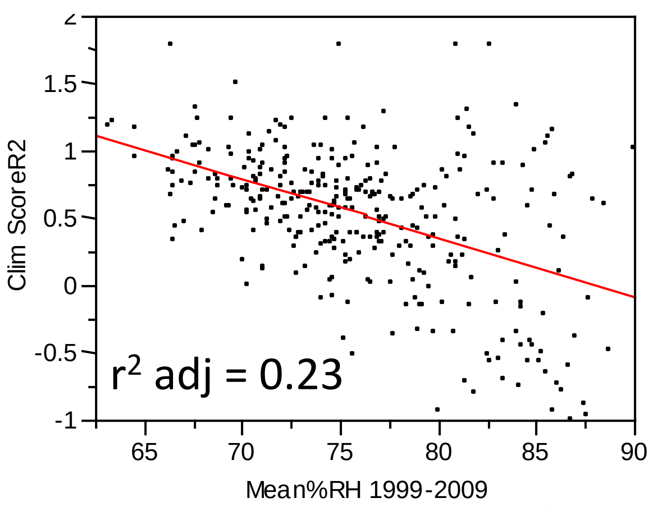
Lichen-based climate scores

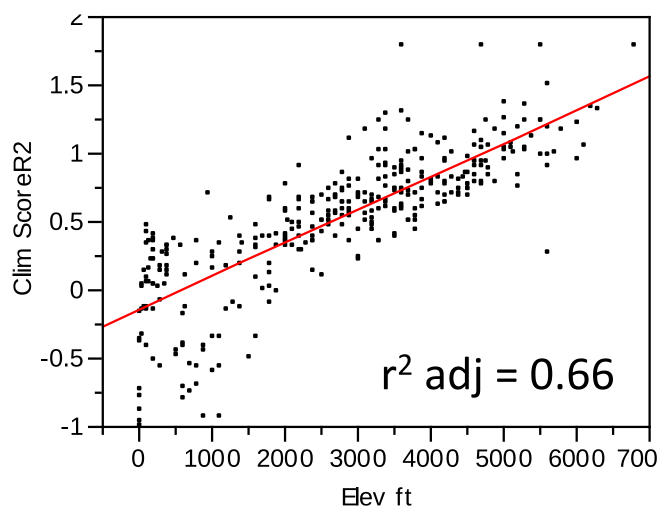
- warmer and less humid

R2 climate scores were correlated with climate variables



- Data from Round 2 (2003-2009).
- Low climate scores → low elevations with warm, humid climates,
- High climate scores → high elevations with cool, dry, climates.





What actually happened: α-Diversity

Climate Score Shift Category	N	R1 α-diversity	R2 α-diversity	Δ in α-diversity	% Δ in α-diversity
much cooler	14	20	19	-1	**-3**
cooler	42	20	19	-1	**-3**
no change	270	22	26	4	**18**
warmer	38	19	24	5	**27**
much warmer	5	14	21	7	**53**

α-diversity = mean species richness per survey site

N = number of sites

Conclusions

1. The composition of epiphytic lichen communities are highly sensitive to climate and are used by FIA to indicate climate.
2. A preliminary analysis of 10-year trends in lichen community composition provides initial evidence of climate-driven effects on species composition & diversity of PNW lichens.
3. Since lichen monitoring began in 1993, mean min Dec temperatures have clearly increased in the mid and upper elevation Cascades, but not in the Coast Range, major river valleys or other low elevation sites.
4. Trends in lichen-community based climate scores are consistent with temperature trends data: species composition shifts indicate greatest warming effects at the highest elevations.

Conclusions

5. 'Cooler' lichen-based climate scores in the Coast Range and low elevation Cascades, where temperature has not decreased, may be related to increases in relative humidity.
6. Both mean species richness at survey sites and landscape level diversity increased with warming temperatures and decreased with cooling temperatures.
7. With regard to other plant communities, these results imply that managers can expect different responses and different response rates across the landscape with differing directions and rates of change in climate variables.

Acknowledgements

We thank!—

- Our many dedicated field biologists who tramped through the brush and surveyed lichens
- The lichenologists who assisted with identifications, especially Jim Riley and Pekka Halonen.
- Our office staff for digitizing our data, especially Anne Ingersoll and Larissa Lasselle
- Our cooperators on the Gifford Pinchot, Mt. Hood, Willamette, Umpqua, and Siuslaw national forests and the Columbia River Gorge National Scenic Area who helped with logistics, field support, and funding
- The USFS PNW Region Air Resource Management Program and USFS PNW Research Station/FIA Program for major funding and support of this work.