Predicting Nitrogen Deposition to Forests in the Los Angeles Basin using Lichen Communities

STATUS: MS in prep

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Use of lichen communities in air quality biomonitoring:

→ Allows inexpensive mapping of pollution deposition patterns across the landscape

thus, enhancing geographic scope/density of information from instrumented networks

→Provides evidence of an ecological effect

lichens are ”canaries in the coalmine,” often used to develop critical loads for N and S (e.g. Fenn et al. 2008, Fenn et al. in press; Geiser et al. 2010)

Sensitivity to pollution:

Lichens

- Are poikilohydric (e.g. lack mechanisms for storing water)
- Have moisture-activated metabolism
- Lack a protective cuticle and so absorb water over their entire surface
- Chemicals scavenged by precip and washed from surrounding surfaces are readily internalized

Morphological changes in a moderately pollution tolerant species from the L.A. Basin

Hypogymnia imshaugii
at a clean site

H. imshaugii
At polluted sites

N indicator groups

Oligotrophs

Highly sensitive

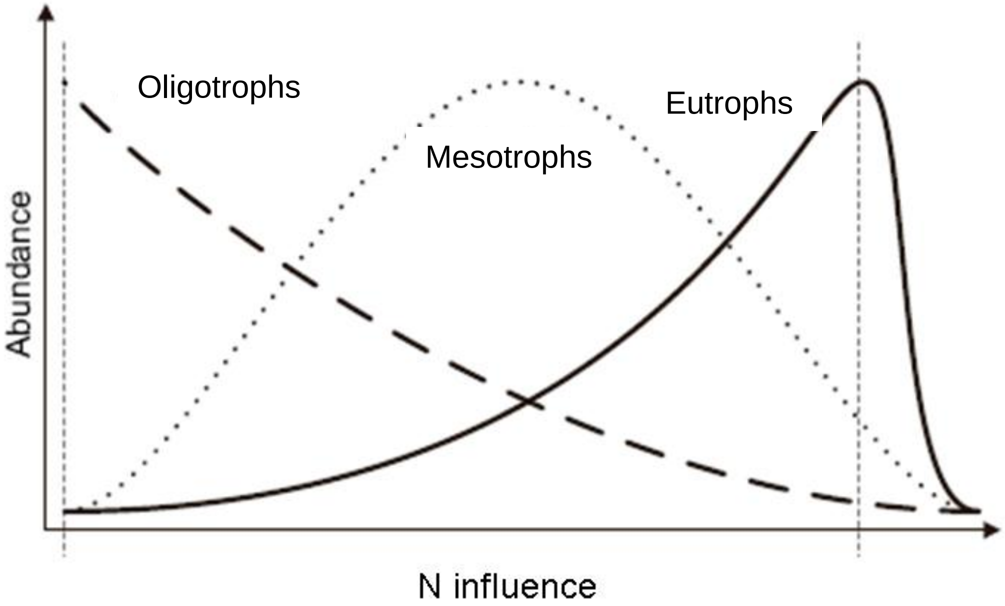
Mesotrophs

Moderately sensitive

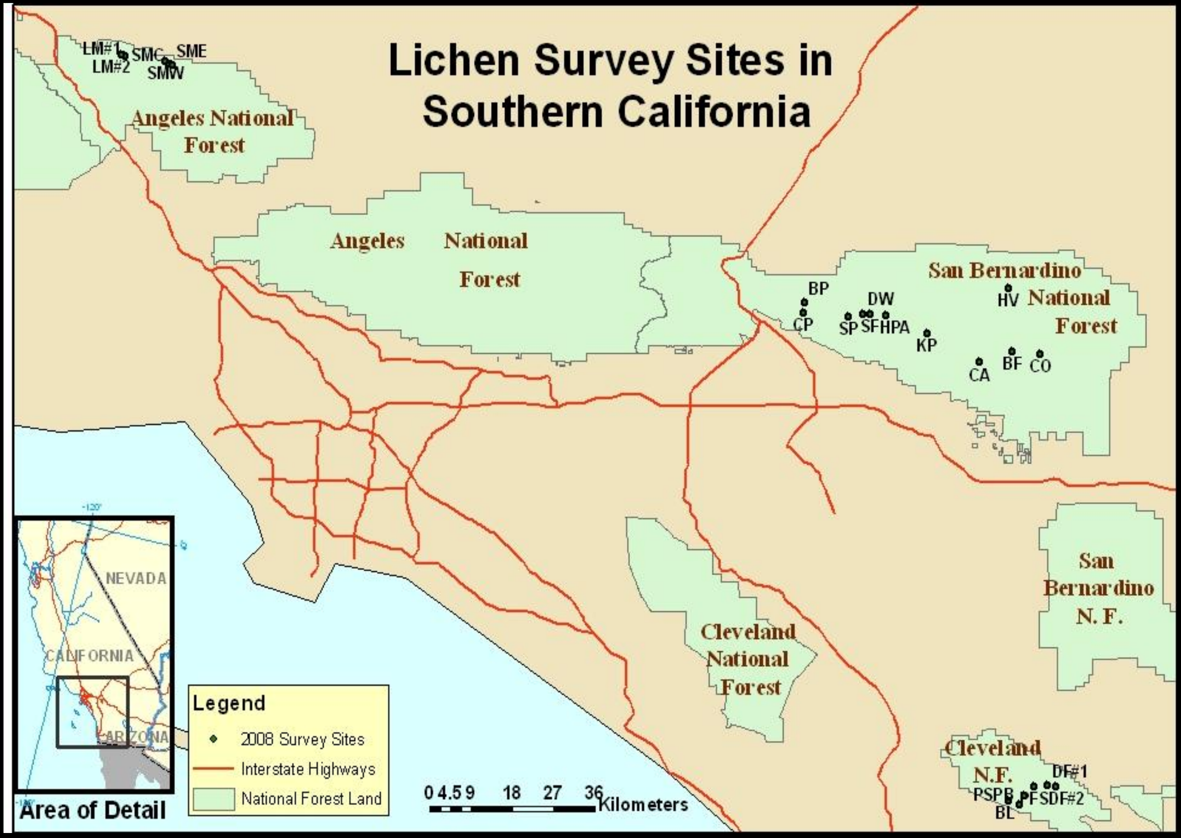
Eutrophs

N-loving “weeds”

N optima



Study area: South Coast Air Quality Management District (SCAQMD)



- Surveyed lichens at 22 plots co-located with long-term monitoring sites:
    - All plots have historical lichen data (1976-77)
    - Most plots have air quality monitors
    - *Quercus-kelloggii* stands
    - Elevation band: 1500-2000m
    - 118-312 trees per ha

Study area history:

- Hasse (1913)
    - Collected extensively in the basin
    - Published the *Lichen Flora of Southern California*
- Sigal and Nash (1983)
    - ~ 50% montane lichen spp. extirpated since Hasse (1913)
    - Spp. loss mistakenly correlated with O_3 gradient (experimental evidence by *Riddell et al. (2010)* and the current study confirm it was probably N…)

Objectives

We re-surveyed Sigal and Nash's sites in 2008 to:

1) Determine if/how lichen community composition has changed since the late 70s (*Riddell and Jovan et al., in press*)

2) Determine which pollutants are likely affecting current lichen communities in the SCAQMD.

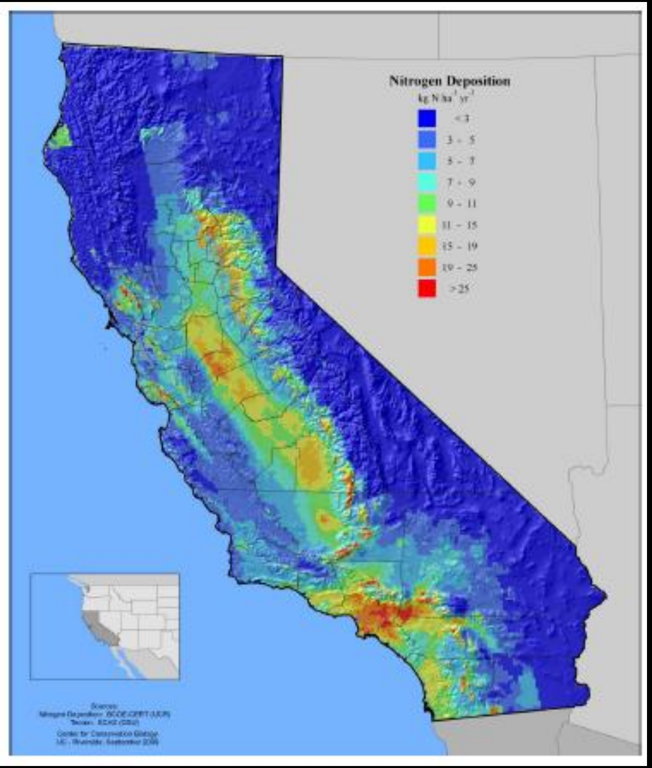
Data:

N deposition estimates from CMAQ (n = 22)

Wet oxidized N, Dry oxidized N
Wet reduced N, Dry reduced N

Definition: Communities Multi-scale Air Quality model. Emissions-based at 4 x 4 km resolution.

Data Source: http://www.epa.gov/asmdnerl/CMAQ/CMAQscienceDoc.html



CMAQ modeled total N dep $kg^{-1} ha\ yr^{-1}$

Data:

Air concentrations of gases (n = 10)

Ammonia (NH_3)
Nitric acid (HNO_3)
Ozone (O_3)
Nitrogen dioxide (NO_2)

Definition: seasonal averages and sums from passive monitoring, summer 2006

Data Source: *Bytnerowicz, unpublished data*

Ogawa passive samplers

Data:

Twig nitrate (NO_3^-; n = 22)

Serves as an additional measure of N deposition

Collected15 twigs per site, all within a 10 day period (Aug. 2008)

Soaked in 0.25 KCL for 1 hr

Measured pH and nitrate (NO_3^-) concentration of sample solution

Quercus kelloggii leaf

Data:

Throughfall N (n = 8)

Definition: The hydrologic flux of N from the canopy to the forest floor (*Fenn and Poth 2004*).

-this flux captures both wet and dry N deposition

Data Source: *Fenn et al. 2008*

ion resin exchange column with snow tube

Data Collection:

2 methods:

1. Transects of 10 *Quercus kelloggii* boles
    Measured % cover of each lichen species at each cardinal direction using a 5x16 cm mesh grid of 0.5cm^2 squares

2. FIA survey protocol

Forest Inventory and Analysis Lichen Communities Indicator

- Lichens are sampled on a national grid of permanent plots for monitoring air quality and climate change effects on forest health.
- We currently track the status of lichen communities at over 4000 sites in the continental U.S.
- When fully implemented, we'll track at over 6,800 sites

Data collection:

- Timed surveys lasting up to 2 hours
- 0.4 ha plot centered on the *Quercus* transect
- Abundance of each epiphytic macrolichen is estimated:

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)

Data:

Environmental variables

- Climate (from PRISM data by *Daly et al, 1994, 2001, 2002*):
  - precipitation, mean temperature, maximum temperature, minimum temperature
- Geographic variables:
  - longitude, latitude, distance from the coast, elevation
- Stand structure variables:
  - total basal area (BA), % BA in hardwoods, hardwood species richness, total tree species richness
- Substrate characterization:

  -- bark pH, twig surface pH, twig nitrate

Gradient analysis:

- Major patterns in community composition are distilled by comparing species assemblages between all possible pairs of plots using a distance measure.

- Sørensen distance (syn. Bray & Curtis; Czekanowski 1913)

$$\text{Distance}_{A,B} = 2w/(a+b)$$

where *w* = species in common, *a* = species in plot *A*, *b* = species in plot *B*.

≈ shared species / total species

- A matrix of distances (i.e. “differences”) among plots is generated.

- This info is used to arrange plots along gradients in lichen community composition

- Each plot gets score on each gradient, depending on its species assemblage.

Gradient analysis:

Non-metric multidimensional scaling (NMS)

Definition: **“**an iterative search for the best positions of n entities on k dimensions (axes) that minimizes the stress of the k-dimensional configuration.” (*McCune and Grace 2002*)

Original Citation: *Kruskal 1964*

Software: PC-ORD (*McCune and Mefford 2008*)

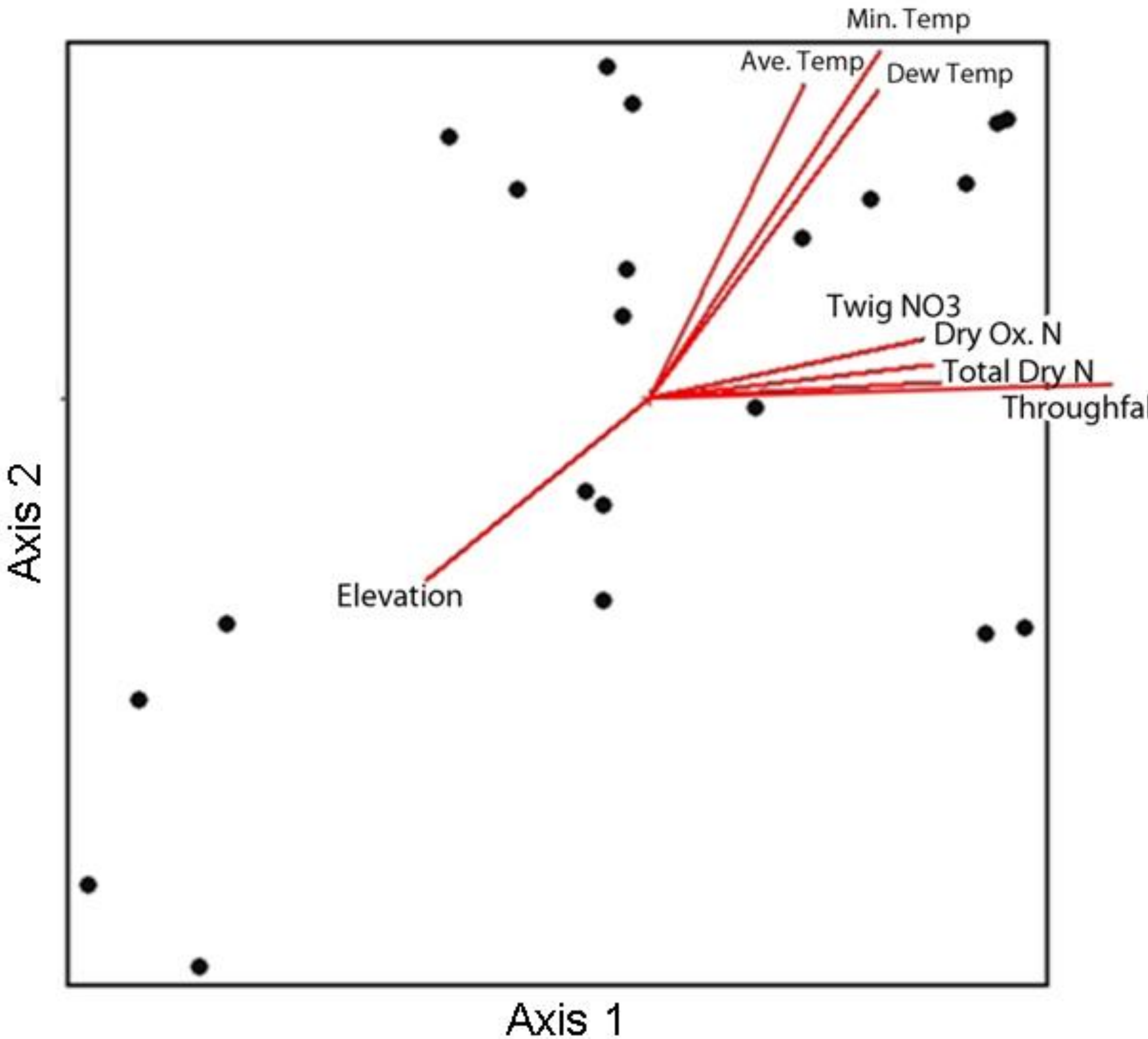
Results:

- NMS resolved 3 statistically significant axes explaining 88% of the variability in lichen community composition.

	r^2
Axis 1	0.48
Axis 2	0.24
Axis 3	0.16

*Results are presented for the % cover data, which are more precise

Results:



r² values for axis 1

Only variables with correlation >.50 to one or both axes are shown

Throughfall = 0.94

Total Dry N = 0.62

Dry Oxidized N = 0.60

Twig NO_3 = 0.58

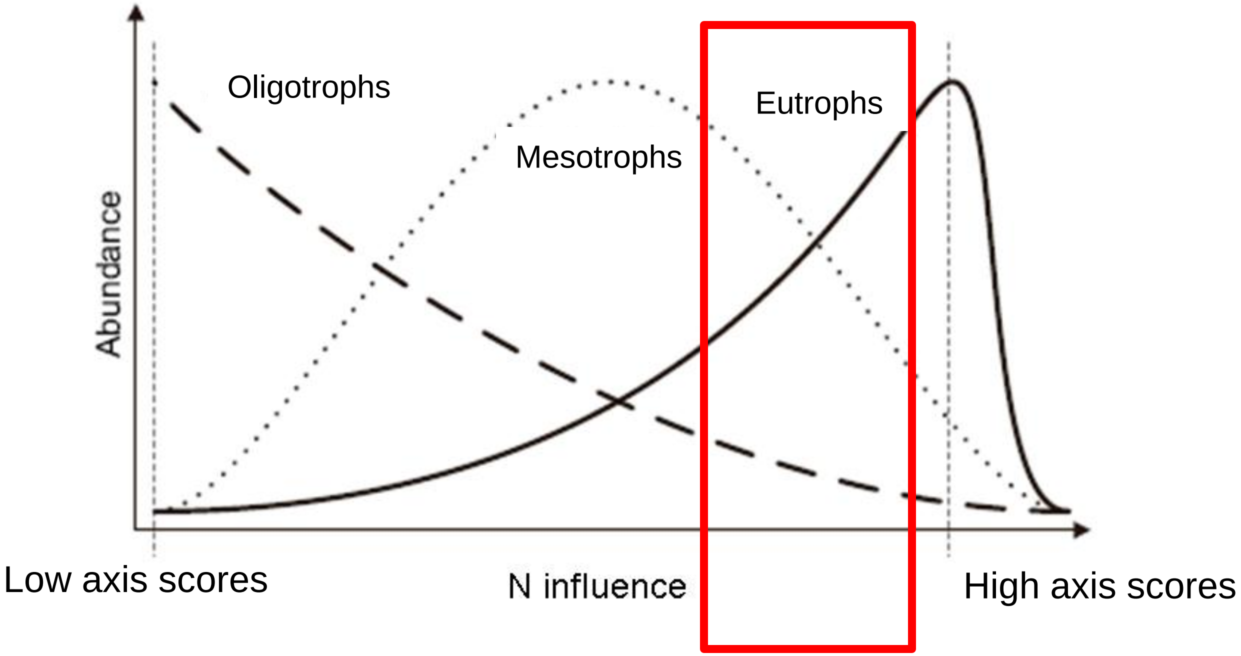
Temp = 0.49

Elevation = 0.48

Correlation of best environmental predictors to axis 1 scores

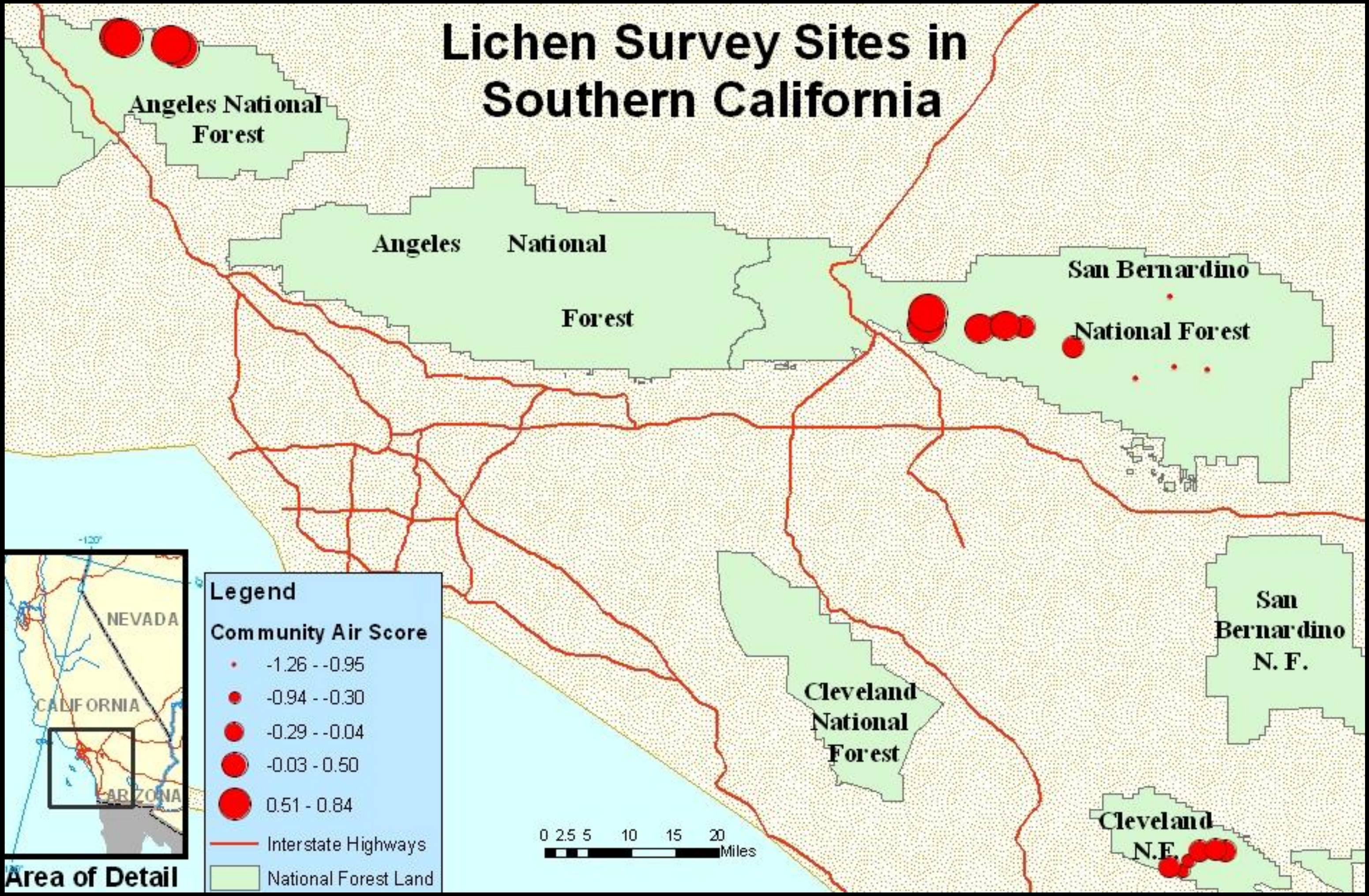
	% cover on oaks		FIA protocol	
	r^2	p	r^2	p
Throughfall N	**0.94**	**<.0001**	**0.74**	**0.007**
Total Dry N	0.62	<.0001	0.35	0.004
Dry Oxidized N	0.6	<.0001	0.42	0.001
Twig NO_3^-	0.58	<.0001	0.38	0.002

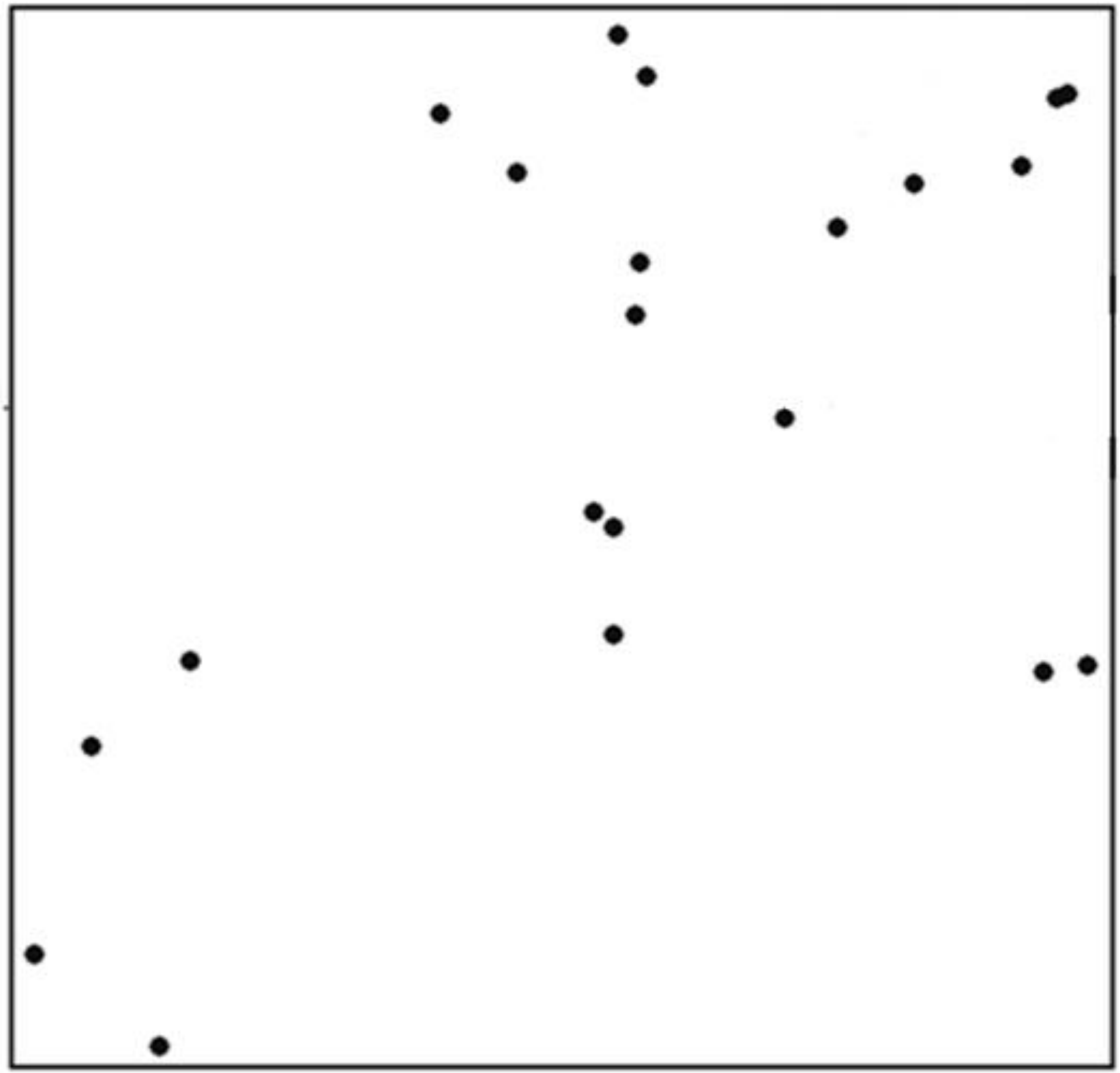
N optima

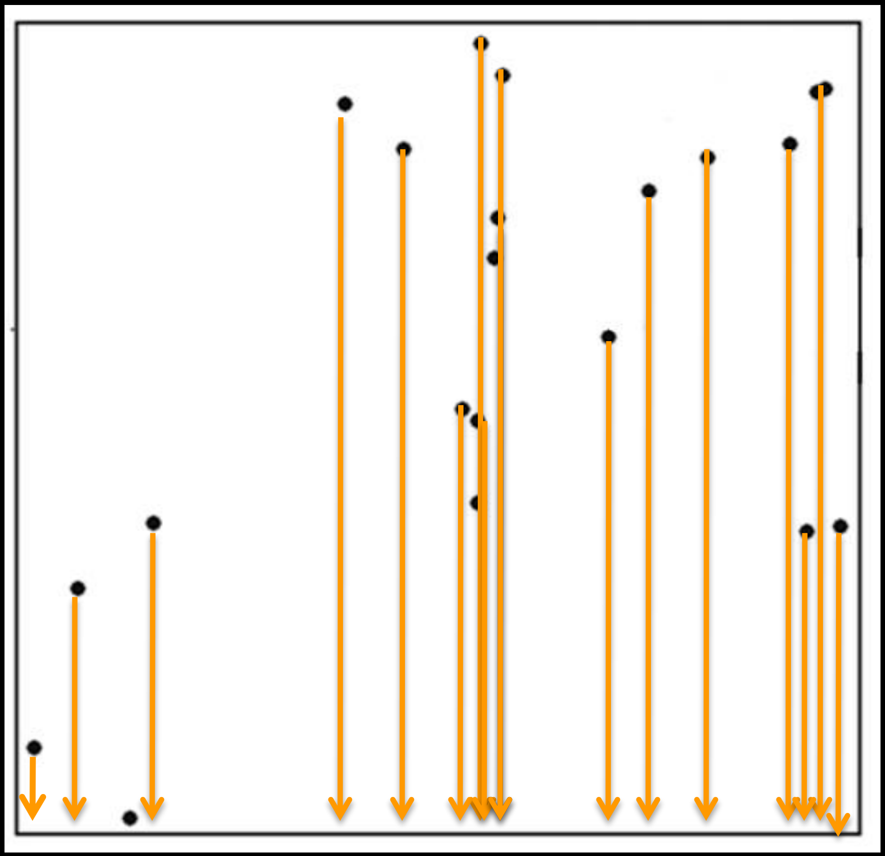


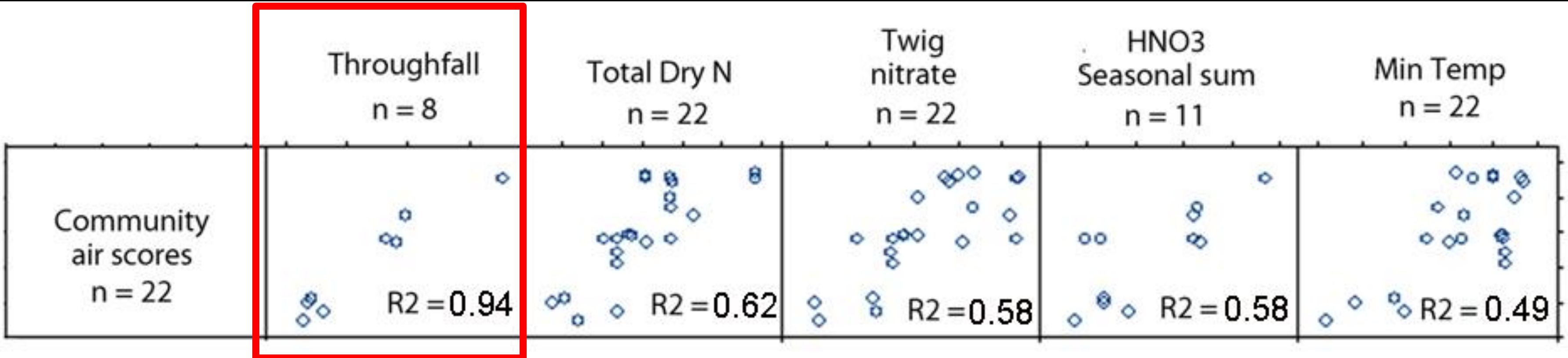
Oligotrophs
Eutrophs
Mesotrophs
Abundance
Low axis scores
N influence
High axis scores

Results: Relative N impact at study sites





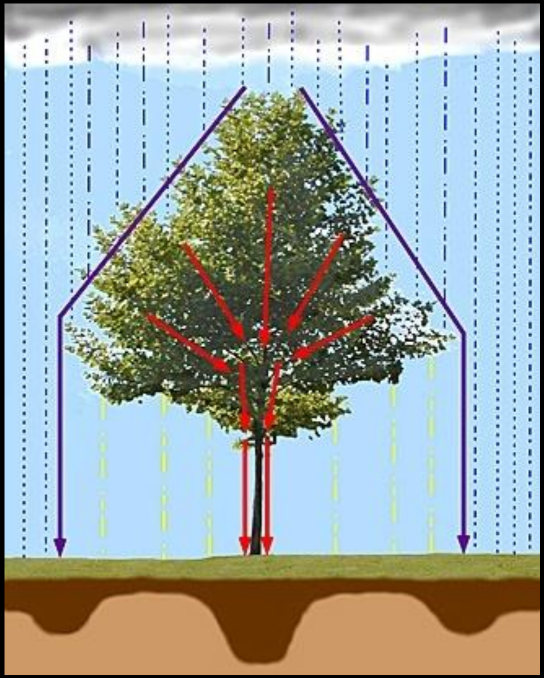



Throughfall
n = 8
Total Dry N
n = 22
Twig
nitrate
n = 22
HNO3
Seasonal sum
n = 11
Min Temp
n = 22
Community
air scores
n = 22
R2 = 0.94
R2 = 0.62
R2 = 0.58
R2 = 0.58
R2 = 0.49

Throughfall measures NH_4^+ and NO_3^- dissolved in precipitation and in stemflow.

→integrates wet and dry deposited N
→accounts for canopy enhancement of dry deposition

Tufted *Usnea* (beard lichen) hangs from a hawthorn branch. Walnut Park, Corvallis, Oregon.



N deposition estimated for all sites

Lichen-based predictions of throughfall were off an average of ± 4.57 kg N ha^{-1} yr^{-1}

Region	Average deposition	95% C.I.
Western San Bern.	48 kg	39.0 – 57.0 kg
Eastern San Bern.	8 kg	3.8 – 12.2 kg
Angeles NF	61 kg	57.8 – 64.1 kg
Cleveland NF	35 kg	31.2 – 38.9 kg

Actual versus lichen-predicted throughfall for San Bernardino sites

Site	Actual	Predicted	95% C.I.
Barton Flat	**8.8**	**12.3**	5.8 - 18.8
Breezy Point	---	**65.1**	54.0- 76.3
Camp Angelus	**12.8**	**6.4**	0 - 13.9
Camp Osceola	**7.5**	**10.4**	3.7 - 17.2
Camp Paivika	**71.1**	**62.6**	52.0- 73.2
Dogwood	**33.4**	**37.2**	31.3- 43.1
Heaps Peak Arboretum	**36.4**	**36.1**	30.3- 41.9
Holcomb Valley	**6.1**	**3.1**	0 - 11.2
Keller Peak	---	**37.2**	31.3- 43.1
Sky Forest Ranger Station	---	**50.4**	42.4- 58.4
Strawberry Peak	**39.3**	**47.3**	39.9- 54.8

Background N deposition in the west ~1kg

N deposition at 21/22 sites exceeds the critical load for lichens

Critical load (CL): the highest amount of N that does not cause harm to lichen communities (i.e. a shift in community composition).

→Throughfall predictions ranged from 3.1 to 65.1 kg N ha^{-1} yr^{-1}

→N CL for Oak forests: 5.5 kg N ha^{-1} yr^{-1} (*Fenn et al in press*)

Conclusions

- Nitrogen is clearly a key driver of lichen community composition in S. California.
  - In 1976-77 Sigal likely witnessed a flora compromised by N, not O_3
- If N inputs increase, communities are expected to shift further towards total domination by eutrophic species.
- New sites can be sampled, scored by the gradient model, and used to predict throughfall
- Air Q measurements are expensive! Lichen predictions can help us focus our monitoring efforts and prioritize where to install new instruments to measure N.

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