Biomonitoring with Lichen Communities in Southern California.

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Introduction

Lichen species respond differentially to pollution. For over a century scientists have utilized lichen communities for air quality biomonitoring in more remote regions where measuring pollution directly can be expensive and technically challenging. Some of the worst air quality in the nation occurs in the South Coast Air Quality Management District (SCAQMD) as a result of topography, climate, and a dense human population driving almost 11 million vehicles. Historical lichen data from 55 montane sites show a flora highly degraded by pollution in the late 1970's (Nash and Sigal 1998) in montane regions of the SCAQMD. We re-sampled 19 of these sites and used species composition to model forest health effects. The lichen model was calibrated with pre-existing air quality measurements, allowing us to predict pollution levels for regions lacking direct measurements.

Objectives

1. Compare two lichen assessment methods (an intensive percent cover transect method (Fig. 3) vs. timed surveys used by the FIA Program (Fig. 2).
2. Develop a model to predict pollution impact using current lichen community composition.

Methods

We used two methods for surveying epiphytic lichen communities at 21 sites (Fig. 1) : The Forest Inventory and Analysis (FIA) method (Fig. 2), and an intensive percent cover transect method (Fig. 3). Community-level lichen responses to pollution were investigated for both datasets using Non-metric multidimensional scaling ordination (NMS, Kruskal citation). Nitrogen (N) deposition was estimated for all sites using the EPA's Community Multi-scale Air Quality model (CMAQ; 4km^2 resolution; Tonnesen et al. 2007). Throughfall N, concentrations of N gases , and ozone were measured at 8-10 sites. Rinses of nitrate (NO_3^-) from twigs provided an estimate of dry N deposition to each site.

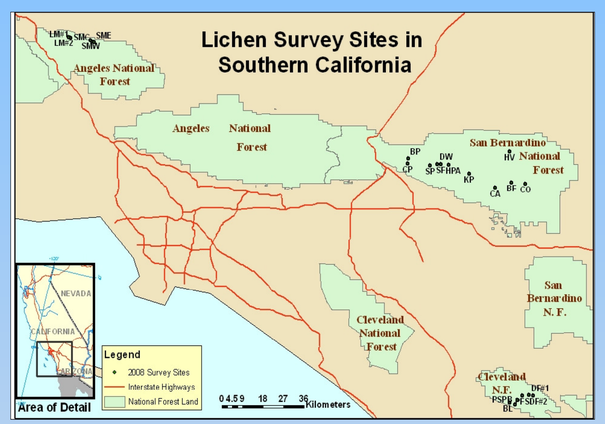

Fig. 1. Map of study area with sites from 2008 surveys.
Codes: Barton Flat (BF), Boucher Lookout (BL), Breezy Point (BP), Camp Angelus (CA), Camp Osceola (CO), Camp Paivika (CP), Deer Flat #1 (DF#1), Deer Flat #2, (DF#2), Dogwood (DW), Fry Creek West (FCW), Heaps Peak Arboretum (HPA), Holcomb Valley (HV), Keller Peak (KP), Liebre Mt. #1 (LM#1), Liebre Mt. #2 (LM#2), Palomar Fire Station (PFS), Palomar State Park Boundary (PSPB), Sawmill Mt. Campground (SMC), Sawmill Mt. East (SME), Sawmill Mt. West (SMW), Sky Forest (SF), and Strawberry Peak (SP).

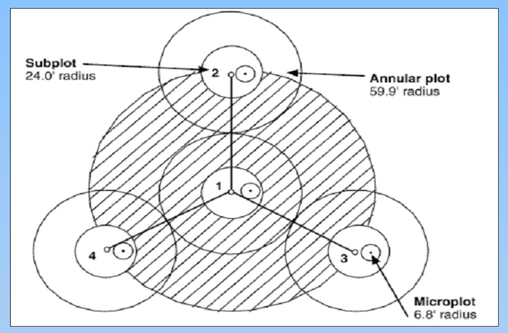

Fig. 2. FIA plot diagram method is a timed survey where each species' abundance is estimated across all woody substrates within a 0.4 Ha plot

Fig. 3. Percent cover transect method measured percent cover of each lichen species on 10 black oak boles (*Quercus kelloggii*) using 5 x 16cm grids in 4 cardinal directions on each oak.

Results and Conclusions

Table 1. Pearson coefficients of correlation for community air scores of the percent cover of lichen communities on oaks and the FIA survey methods from NMS analyses with site environmental variables. Variables with $r^2 > 0.5$ for either air score are in **boldface.**

		Community air score from percent lichen cover on oaks		Community air score from FIA Survey	
		r^2	p	r^2	p
Air scores	Percent cover on oaks	1	0.0006	0.45	0.0006
	Air Score from FIA Survey	0.45	0.0003	1	0.0003
Throughfall N	**Throughfall N**	**0.94**	<.0001	**0.74**	0.007
Twig N	**Twig surface NO_3^-**	**0.58**	<.0001	0.38	0.002
CMAQ modeled N deposition values	**Total Dry N deposition**	**0.62**	<.0001	0.35	0.004
	Dry Oxidized N	**0.60**	<.0001	0.42	0.001
	All N dep	0.49	0.0003	0.22	0.03
	Dry NH_x	0.48	0.0004	0.15	0.08
	Dry atmospheric NH_4	0.38	0.002	0.04	0.37
	Dry atmospheric NO_3^-	0.36	0.003	0.03	0.47
Passive monitor values for summer 2006	**HNO_3savg**	**0.59**	0.006	**0.50**	0.02
	HNO_3sum	**0.59**	0.006	**0.50**	0.02
	Total N season average	**0.50**	0.02	0.40	0.04
	NH_3 seasonal sum	0.48	0.02	0.38	0.04
	NH_3 seasonal average	0.47	0.02	0.37	0.05
	NO_2 seasonal average	0.42	0.03	0.33	0.06
	NO_2 seasonal sum	0.42	0.03	0.32	0.07
Environmental Variables	**Minimum Temp.**	0.49	0.0003	**0.60**	<.0001
	Dewpoint	0.49	0.0003	**0.75**	<.0001
	Elevation	0.48	0.0004	0.43	0.0009
	pH of oak bark	0.41	0.001	0.10	0.16
	Average Temp.	0.33	0.01	**0.56**	<.0001
	pH of fir bark	0.25	0.02	0.23	0.02
	Hardwood basal area	0.15	0.52	0.29	0.40
	Hardwood % cover	0.14	0.35	0.39	0.18
	% Hardwood basal area	0.11		0.27	

Table 2. Throughfall N (TF N) deposition estimates in kg ha^{-1} yr^{-1} based on lichen oak community air scores and twig surface NO_3^- for all sites where lichen communities of *Quercus kelloggii* were surveyed. Lower CI and Upper CI are confidence interval bounds for 95% confidence intervals.

Site	Actual TF N	Estimate TF N based on air scores
Palomar Mt. area - Cleveland National Forest		
Boucher Lookout		**39.2 ± 6.2**
Deer Flat #1		**38.8 ± 6.1**
Deer Flat #2		**38.6 ± 6.1**
Fry Creek West		**31.6 ± 5.4**
Palomar Fire Sta.		**37.4 ± 5.9**
Palomar S.P. B.		**27.1 ± 5.3**
San Bernardino National Forest		
Barton Flat	**8.8**	**12.3 ± 6.5**
Breezy Point		**65.1 ± 11.1**
Camp Angelus	**12.8**	**6.4 ± 7.5**
Camp Osceola	**7.5**	**10.4 ± 6.7**
Camp Paivika	**71.1**	**62.6 ± 10.6**
Dogwood	**33.4**	**37.2 ± 5.9**
Heaps Peak Arboretum	**36.4**	**36.1 ± 5.8**
Holcomb Valley	**6.1**	**3.1 ± 8.1**
Keller Peak		**37.2 ± 5.9**
Sky Forest R.S.		**50.4 ± 8**
Strawberry Peak	**39.3**	**47.3 ± 7.4**
Sawmill Mt. Area - Angeles National Forest		
Liebre Mt. #1		**64 ± 10.9**
Liebre Mt. #2		**63.3 ± 10.8**
Sawmill Campground		**55 ± 8.9**
Sawmill Mt. East		**61.2 ± 10.3**
Sawmill Mt. West		**62.8 ± 10.6**

1) Lichen communities in the SCAQMD remain highly N-impacted. Throughfall N was a remarkably strong predictor in both the Sigal and FIA models (Table 1).

2) The FIA model compared well to the more precise Sigal model, resolving the same fundamental pollution pattern (Table 1, Fig. 4). The FIA P3 lichen monitoring programs provide valuable data for assessing environmental conditions.

3) Accuracy of throughfall N predictions from the more extensive survey method (Table 2) tentatively suggests managers may obtain a reasonable estimate of N deposition simply by surveying lichen communities, especially when comparing communities in areas with similar environmental conditions and plant communities.

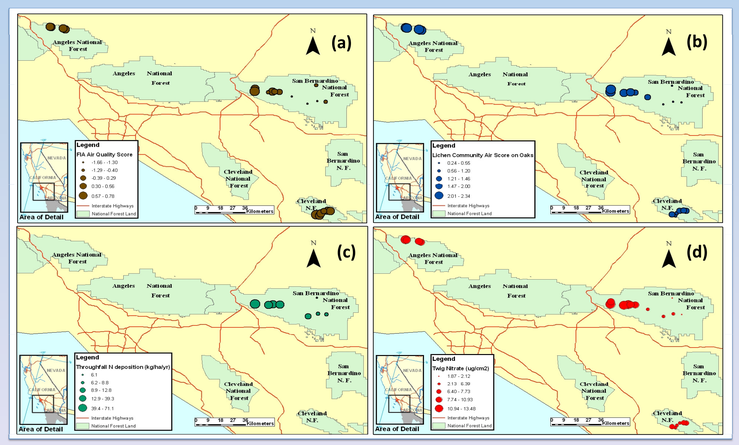

Fig. 4. Maps depicting the relative values of **(a)** FIA air quality (AQ) scores, **(b)** lichen percent cover on oaks AQ scores, **(c)** measured throughfall N deposition, and **(d)** nitrate deposition to twigs at each site.

References:

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2. Tonnesen, G., Z. Wang, M. Omary, and C. J. Chien. 2007. Assessment of Nitrogen Deposition: Modeling and Habitat Assessment. California Energy Commission, PIER Energy-Related Environmental Research, Sacramento CA. www.energy.ca.gov/2006publications/CEC-500-2006-032.

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