Bulletin of the California Lichen Society

VOLUME 9 NO. 2 WINTER 2002

Air Quality in California Forests: current efforts to initiate bio-monitoring with lichens

Sarah Jovan
Department of Botany and Plant Pathology,
Oregon State University, Corvallis, OR 97331
jovans@science.oregonstate.edu

Abstract. The primary objective of the Forest Health Monitoring Indicator Project is to develop models that use the composition of epiphytic lichen communities to detect and monitor air quality in forests. The designs of existing air quality monitoring networks in California do not provide adequate representation of rural areas to assess impacts to forests. This article is designed to provide readers with a brief synopsis of air quality monitoring in north-central California, an overview of current air quality issues in the area, and an introduction to plans for monitoring air quality in forests with lichens.

INTRODUCTION

Air quality in California has been a hot topic since the population explosion of the 1940s. Known for its overcrowding and smog, the Los Angeles area is most frequently cited in discussions of air pollution. While less infamous, air quality in parts of the north-central region of the state (area North of Santa Barbara) are also poor and have the potential to affect forests regionally. At the present time, however, there is surprisingly little means in California to monitor air pollution in forests.

Our best estimates of air quality in forests come from two complementary air quality networks: the California Air Resources Board (CARB) dry deposition network and the National Atmospheric Deposition Program (NADP) wet deposition network. Monitoring in north-central California is subdivided into 9 districts or "air basins" (Figure 1). The design of the CARB network consists of over 100 monitors and allows efficient monitoring in many urban centers. However, few of the monitors occur in rural areas, which is necessary to detect the displacement of pollutants to forests. Most NADP monitors are rural, although there are only 11 total active sites for all of California.

The purpose of the Lichen Indicator Project is to provide a medium that is better suited for monitoring forest air quality. The premise is to use epiphytic lichen community structure to indicate air quality, a strategy that has been effectively implemented elsewhere in the United

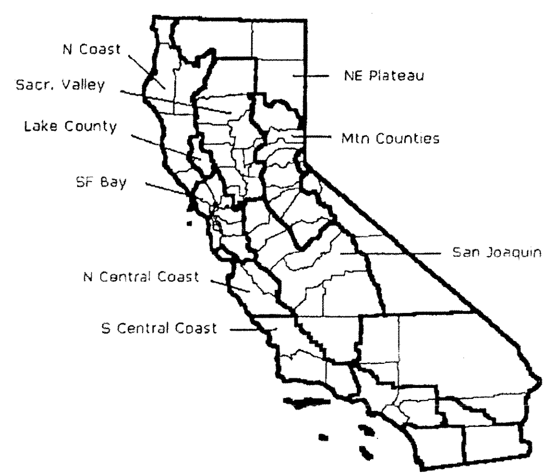

Figure 1: Map depicting air basins

States (see McCune et al, 1997, McCune et al, 1988). Sampling lichens is inexpensive compared to the costs associated with CARB and NADP monitors. Thus, sampling intensity in rural areas can be improved and sites will be better distributed across the landscape. After a brief overview of air quality concerns in the study area, a description of the scope and mechanics of the lichen project is presented.

AIR QUALITY IN NORTH-CENTRAL CALIFORNIA

Despite their shortcomings, NADP and CARB data do provide a broad perspective on air quality in the state. According to CARB data, ozone (O_3) levels consistently exceed state and federal standards in many air basins in north-central California (Table 1). High ozone is known to damage plants and possibly lichens at high concentrations (Nash & Sigal, 1979; Sigal & Nash, 1983). Compared to many cities in the Eastern U.S., ambient levels of sulfur dioxide (SO_2) are relatively low in this region although the effects on human and forest health in the state remain unclear (Table 2). There is a large body of research documenting the detrimental effects of acidic deposition on lichens (i.e. Gilbert, 1970; Hawksworth & Rose, 1970), which includes the extirpation of the most acid-sensitive species.

Table 1: Number of days ozone level exceeded state and federal standards in 2001; ozone statistic is the daily maximum 1-hour value

Air Basin	State (.09 ppm)	National (.12 ppm)
Lake Counties	0	0
North Coast	0	0
Northeast Plateau	0	0
North Central Coast	3	0
San Francisco	15	1
South Central Coast	34	2
Sacramento Valley	46	2
Mountain Counties	49	1
San Joaquin Valley	123	32

Data extracted from CARB database

Table 2: Annual arithmetic means of SO_2 concentrations for 2001

Site	ppm	µg/m³
Sacramento	0.0019	4.96
Stockton	0.0024	6.29
Nipomo	0.0025	6.46
Bakersfield	0.0026	6.72
Fresno	0.0027	7.01
Cleveland, OH	0.0060	15.72
Pittsburgh, PA	0.0080	20.96
Erie, PA	0.0100	26.20
New York, NY	0.0140	36.68
Indianapolis, IN	0.0160	41.92

Data extracted from EPA AIRS data base

Deposition rates of ammonia (NH_3) and ammonium (NH_{4+}), pollutants implicated in the eutrophication (nutrient-enrichment) of both terrestrial and aquatic ecosystems, are high in the agricultural areas of the Central Valley. Deposition is probably comparable to some agricultural areas of the Midwest although there is little data for this pollutant in California (Table 3). Elevated nitrogen levels in forests from

Table 3: Wet deposition of ammonium in 2001; based upon precipitation-weighted means

Site	mg/L
Sequoia NP	0.10
Yosemite NP	0.14
Davis	0.60
Wooster, OH	0.46
Clayton County, IA	0.61
Lake Scott Park, KS	0.74

Data extracted from NADP database

compounds like ammonium are thought to promote the establishment of nitrophilous (nitrogen-loving) lichens such as species in the genera Xanthoria, Physcia, Candelaria, and Physconia.

Emissions of a second nitrogen-based compound, nitrogen oxide (NO_x), are exceptionally high in California compared to most of the U.S. In cities in north-central California, atmospheric levels of a particular nitrogen oxide, nitrogen dioxide (NO_2), are similar to highly populated cities elsewhere (Table 4). Depending upon atmospheric conditions, nitrogen oxides can detrimentally impact forests by three main mechanisms: they are chemical

Table 4: Annual arithmetic means of NO_2 concentrations for 2001

Site	ppm	µg/m^3
Clovis	0.014	26.32
San Francisco	0.019	35.72
Bakersfield	0.023	43.24
San Jose	0.024	45.12
Atlanta, GA	0.022	41.36
New York, NY	0.031	58.28
Chicago, IL	0.032	60.16
Denver, CO	0.035	65.80

Data extracted from EPA AIRS database

precursors to O_3 formation in the atmosphere, they can contribute to acid rain, and they can cause eutrophication.

Countrywide isopleth (line maps of pollutant concentrations) and emission distribution maps for all pollutants discussed above are available on the web through the National Atmospheric Deposition Program and the Environmental Protection Agency:

1. http://www.epa.gov/air/data/nonat.html?us~USA~United%20States; maps of non-attainment areas (where pollution concentrations consistently exceed the federal standard); includes maps of ozone and others;
2. http://nadp.sws.uiuc.edu/isopleths/maps2001/; isopleth maps for wet deposition of sulfate, ammonium, nitrate, and others;
3. http://www.epa.gov/air/data/repsus.html?us~USA~United%20States; access to data and maps, including maps of emission distributions.

MECHANICS OF THE LICHEN INDICATOR PROJECT

It is still unclear to what extent these pollutants are impacting forest and lichen communities in the region. To facilitate monitoring in forests, the primary goal of the Lichen Indicator Project is to develop multivariate models that relate information on lichen community structure (such as species diversity and the relative abundances of each species) to pollution gradients. Using an ordination technique such as non-metric multidimensional scaling (NMS; Kruskal, 1964), prominent gradients in community composition can be extracted from the dataset and evaluated for correlations with environmental variables relating to climate, stand structure, and air pollution.

The sampling design for this lichen indicator project and others affiliated with the USDA Forest Health Monitoring/Forest Inventory and Analysis Programs follow a standardized protocol. Community data is obtained by surveying lichen communities within circular, .4 hectare plots. The plots are located on a permanent, 27km by 27km sampling grid established by the EPA that covers the entire United States. The California air quality models will be based upon data collected from 1998-2001 from over 200 of these plots. Sampled plots are randomly chosen from the grid.

Field crews visit each plot once and conduct surveys of the epiphytic lichen community wherein the presence and relative abundance of all epiphytic lichen species is estimated. Sampling plots again in the future will help us to track changes in pollution levels and distributions. The crews are expected to be able to differentiate between species but not to necessarily identify them. Previous experience with lichens varies between and among field workers although participants undergo a three day intensive training course and must pass a certification exam before conducting surveys. For the exam, a faux plot is surveyed by both crew-members and a professional lichenologist. Crew-members are required to capture 65% of the epiphytic lichen species collected by the lichenologist to pass. After the field season begins, crews are periodically audited by a professional lichenologist to ensure that species capture rates remain high.

For each community survey, a collection is made of each species encountered in the plot, which are later sent to a specialist for identification. Past specialists working for the California lichen indicator project include CALS member Doug Glavich (2000-2001), Daphne Stone (2000), Trevor Goward (1999), and Peter Neitlich (1998). Most of the collections currently reside at the McCune lab at Oregon State University and will soon be deposited in the OSU herbarium.

Vegetation crews collect data on stand structure (such as basal area estimates and tree species diversity), which is made available for the lichen community analysis. That plus data from climate models allow us to extract the influence of these factors on lichen communities and isolate the effect of pollution. For similar reasons, north-central California has been divided into three model areas: the greater Central Valley, the NW Coast, and the Sierra Nevada range. Creating models for the subdivisions enhances our ability to detect the effect of pollution by minimizing variability in environmental conditions since the Californian landscape is topographically and climatically diverse.

CENTRAL VALLEY MODEL

The first model will apply to the greater Central Valley model area, which includes the Bay area and adjacent coast south to Santa Barbara. Additional surveys were conducted in 33 urban parks this summer (Figure 2) near CARB air quality monitors to allow us to calibrate lichen community structure with direct pollution measurements. We did encounter several compromised lichen communities in our urban plots in the greater Central Valley model area. Typical telltale signs of pollution impact are low species diversity despite an abundance of suitable substrate (i.e. San Jose, at Guadaloupe River Park; Bakersfield, at Yokuts River Park), and unusually small thalli that are contorted and bleached (i.e. Goleta, at Lake Los Carneros and Nipomo at Nipomo Regional Park). In many plots only nitrophilous species were found (i.e. Modesto, at 1000 Oaks Park and Stockton, Oak Park). Without an intact gradient model, it's unclear which pollutants are affecting these sites and how other environmental factors are involved. However, completion of this first model is anticipated for January 2003, whereupon we can more confidently describe the effects of pollution in the study area.

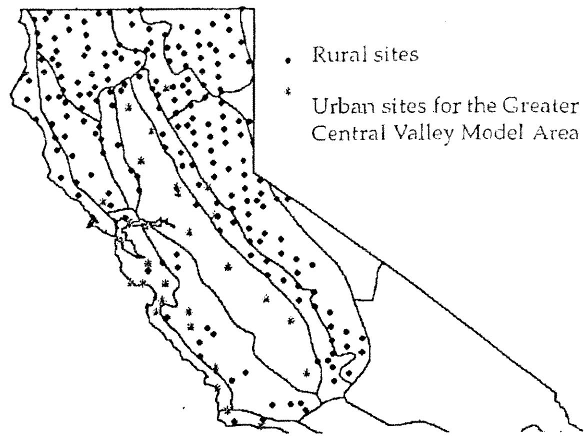

Figure 2: Map of lichen community plots

The CARB and NADP data present us with a big picture of air quality in north-central California. With additional bio-monitoring in forests, the magnitude and sophistication of air quality monitoring in California will be truly unsurpassed. We will be able to describe pollution gradients and thus identify ecosystems at risk. Likewise, we will also be able to estimate local air quality for all sites in the bio-monitoring dataset and make estimates for new sites if lichen community data is available. Hopefully these resources will greatly inform the land use and management decisions of California residents and agencies alike.

ACKNOWLEDGEMENTS

I'd like to thank Shirley Tucker for an insightful review of this essay. Ken Brotherton also helped with proofreading. Lichen data for all California plots are available online via the Forest Inventory and Analysis website at: http://www.wmrs.edu/lichen/

Literature Cited

Gilbert, O.L. 1970. A biological scale for the estimation of sulfur dioxide pollution. New Phytologist 69: 629-634.

Hawksworth, D.L. & Rose, F. 1970. Qualitative scale for estimating sulfur dioxide air pollution in England and Wales using epiphytic lichens. Nature 227: 145-148.

Kruskal, J.B. 1964. Nonmetric multidimensional scaling: a numerical method. Psychometrika 29: 115-129.

McCune, B., Rogers, P. Ruchty, A. & Ryan, B. 1988. Lichen Communities for Forest Health Monitoring in Colorado. A Report to the USDA Forest Service.

McCune, B., Dey, J., Peck, J., Heiman, K., & Will-Wolf, S. 1997. Regional gradients in lichen communities of the Southeast United States. Bryologist 100: 145-158.

Nash, T.H., III & Sigal, L.L. 1979. Gross photosynthetic response of lichens to short-term ozone fumigations. Bryologist 82: 280-285.

Sigal, L.L. & Nash, T.H., III.. 1983. Lichen communities on conifers in southern California mountains: an ecological survey relative to. oxidant air pollution. Ecology 64: 1343-1354.