

**ESTABLISHMENT OF A LICHEN BIOMONITORING PROGRAM AND AIR
QUALITY BASELINE IN CHIRICAHUA NATIONAL MONUMENT AND FORT
BOWIE NATIONAL HISTORIC SITE, ARIZONA**

A LAY REPORT

**PREPARED BY
LARRY L. ST. CLAIR
PROFESSOR OF BOTANY AND
CURATOR OF NONVASCULAR CRYPTOGRAMS
AND
KIM T. ANDERSON, RESEARCH ASSOCIATE
193 MLBM
BRIGHAM YOUNG UNIVERSITY
PROVO, UTAH 84602**

PROJECT SUMMARY

Lichens are composite organisms consisting of a fungus, usually an Ascomycete, living symbiotically with either an alga or a cyanobacterium. Lichen associations are complicated and dynamic symbiotic relationships. Lichens occur on a variety of substrates (e.g. rock, bark and soil), and have a world wide distribution. Lichens lack true roots, stems and leaves and obtain most of their material resources from the atmosphere. Basically, lichens accumulate any form of matter which occurs in the atmosphere and can be removed by some type of precipitation. Between 1993 and 1995 a total of 11 lichen air quality biomonitoring reference sites were established in Chiricahua National Monument. Two additional reference sites were set up at Fort Bowie National Historic Site in 1995. A total of 148 lichen species in 56 genera from four basic substrates were identified during the course of this study. An average of 5.2 sensitive indicator species were collected per reference site (range: 3-7 species per reference site). Lichen tissues (at least one sample per reference site) were analyzed for 21 potential pollutant elements. Thallus concentrations of lead, copper, arsenic, nickel and to a lesser extent chromium consistently exceeded background levels typical of other sites in the western United States. Some lichen samples (5 out of 21) also showed marginally high concentrations of sulfur. Overall, the low average number of sensitive indicator species per reference site along with the elevated levels of several pollutant elements suggests that lichen communities in Chiricahua National Monument and Fort Bowie National Historic Site have experienced some air pollution-related impact. In order to maintain the integrity of the air quality baseline it is strongly recommended that elemental analyses be performed for at least one sensitive indicator species at each reference site every three to five years. In addition, we further recommend that one to several metabolic parameters (e.g. membrane leakage, photosynthetic rates or respiration rate) be evaluated for at least two sensitive indicator species from each reference site. These type of data will serve to fine tune the sensitivity of the existing air quality baseline.

INTRODUCTION

The term lichen was first used by the Greek botanist Theophrastus in about 300 BC. He used the term to describe "outgrowths" from the bark of olive trees. In the mid 1700s the Swedish botanist Carl Linnaeus described more than 80 lichen species; placing all of them in the

genus *Lichen*. It was not until 1867 that the symbiotic nature of lichens was first recognized. Lichenologists today interpret the lichen symbiosis to be a form of controlled parasitism, where the fungus exploits the algal cells in a significant yet controlled fashion. Regardless, under most conditions lichen associations are very stable and may persist for thousands of years.

The major functional roles of the lichen symbionts are understood. The fungal component provides structural support, some mineral nutrients, and a suitable microenvironment for the algal partner. On the other hand, the alga, through photosynthesis, is able to fix atmospheric carbon and subsequently synthesize various organic molecules including a variety of carbohydrates, amino acids, and vitamins. At least some of these organic nutrients are then transferred to the fungus and subsequently used to meet its material and energy needs.

Lichens have a thallus type of plant body, lacking true roots, stems and leaves. However, some lichens produce structures which superficially resemble roots, stems and leaves. Lichen thalli are variously developed, but generally fall into three basic growth form categories: crustose, foliose, and fruticose. Crustose species adhere tightly to their substrate and in some cases may become partially or wholly embedded in the upper surface of the substrate. Foliose lichens are generally larger, more structurally complex, and dorsiventrally flattened. While fruticose lichens are extensively branched and often have a shrub-like form. Some lichens reproduce strictly by sexual spores produced by the fungal symbiont; while other lichens reproduce by means of various types of detachable asexual fragments.

The sensitivity of lichens to a wide range of air pollutants has been documented by both field and laboratory studies. Air pollution impact on lichens is directly related to the fact that lichens obtain most of their material resources from the atmosphere. Lichen thalli are able to effectively absorb and accumulate various types of airborne materials washed from the air by any form of precipitation. Overall, because lichens obtain most of their nutrients from the atmosphere, have inherently slow growth rates, and demonstrate high surface to mass ratios they are ideal bioaccumulators and bioindicators of air pollution. Depending on general habitat conditions as well as the nature and intensity of the air pollution impact, reproduction, thallus morphology, community structure and/or metabolism may be adversely affected.

RESULTS AND CONCLUSIONS

Between 1993 and 1995 a lichen air quality biomonitoring program was established at Chiricahua National Monument and Fort Bowie National Historic Site. This baseline program consists of 11 air quality biomonitoring reference sites evenly distributed over the monument; with two additional reference sites at Fort Bowie (Figure 1). Lichen species and elemental analysis samples were collected at each reference site. Basic components of the air quality baseline program include: 1) a checklist of lichen species for each reference site; 2) a list of sensitive indicator species for each site; and 3) elemental analysis data for at least one tissue sample per reference site.

The lichen flora of Chiricahua National Monument and Fort Bowie National Historic Site is diverse and generally well developed. Thus far we have identified a total of 148 species in 56 genera. All growth forms are well represented. The flora is dominated by foliose species (51%, or 76 species), followed in order of abundance by crustose, squamulose and fruticose species. This growth form pattern is similar to the Chiricahua Wilderness Area, the San Juan Mountains (southwestern Colorado) and the Gila Wilderness Area (west central New Mexico). The abundance of macrolichens (foliose and fruticose species) in the region is probably related to three basic factors: 1) minimal human-related activity and development in the region; 2) the occurrence

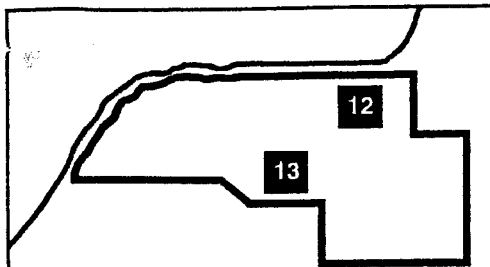
of many unique and productive microhabitats and substrates in the area; and 3) the summer monsoonal storms and unique weather patterns typical of the region.

Elemental analysis data indicate several areas of concern. Specifically, tissue concentrations of lead, copper, arsenic, nickel and to a lesser extent chromium significantly exceed background levels reported for most other sites in the western United States. Copper to zinc ratios are of particular interest. Ordinarily, at clean air sites copper to zinc ratios range between 1/3 and 1/10. However, copper to zinc ratios for lichen samples collected at Chiricahua National Monument and Fort Bowie National Historic Site consistently range between 1/1 and 2/1. This pattern of copper accumulation by lichen thalli is most likely caused by local air quality problems associated with regional copper smelting activity. Sulfur levels in 5 out of 21 samples were also marginally high.

RECOMMENDATIONS

In light of elevated pollutant levels in lichen samples from Chiricahua National Monument and Fort Bowie National Historic Site we recommend that samples of at least one sensitive indicator species from each reference site be analyzed every 3 to 5 years. We further recommend that two additional reference sites be established at Coronado National Historic Site. Finally, in order to more critically assess air pollution-related impact on the lichen communities in Chiricahua National Monument and Fort Bowie National Historic Site, we recommend that some combination of metabolic processes, such as membrane leakage, photosynthetic activity or respiration rates be evaluated in at least two sensitive indicator species from each reference site.

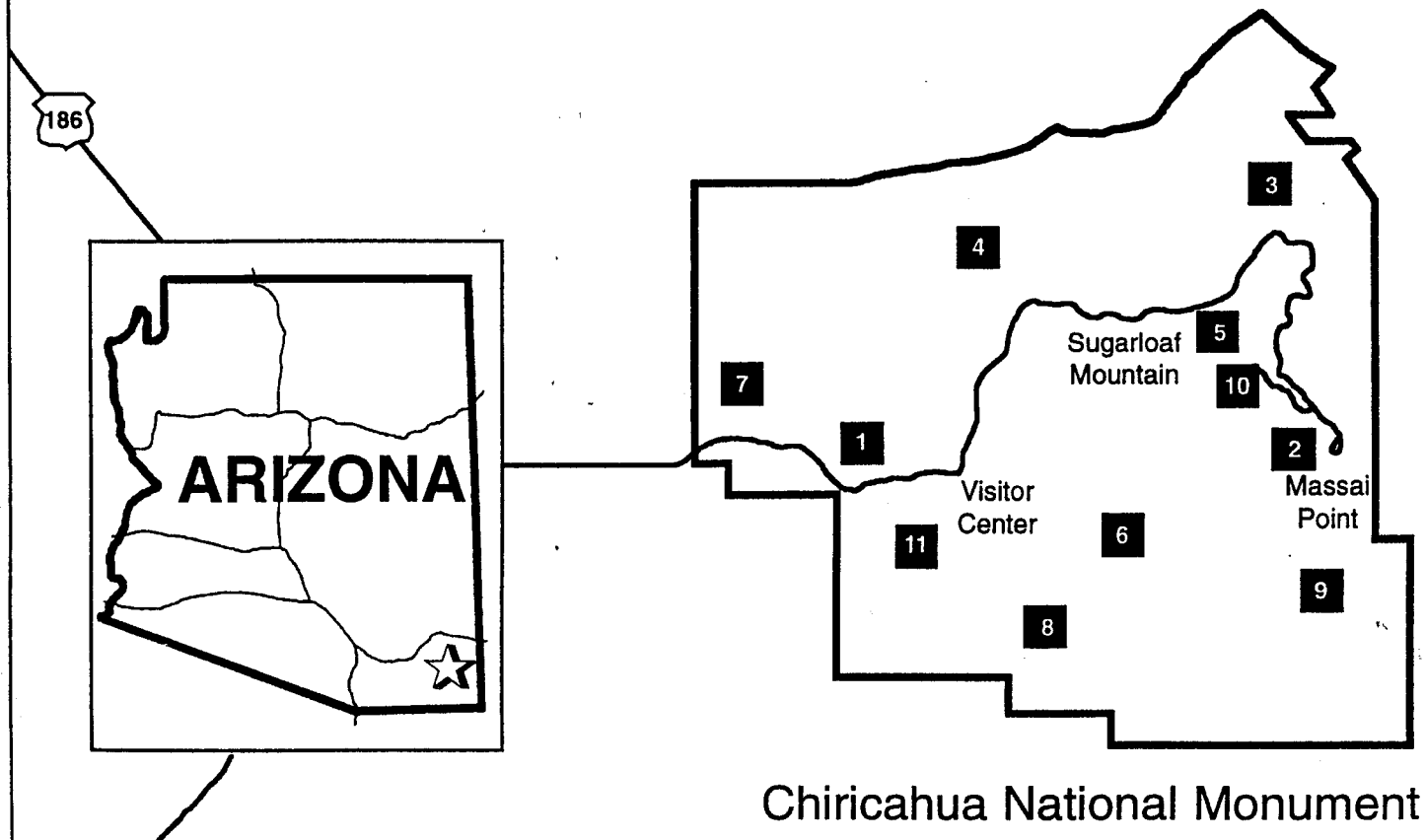
CHIRICAHUA NATIONAL MONUMENT



Fort Bowie National
Historic Site

■ = Biomonitoring reference sites
(numbers correspond with site
descriptions in report)

Figure 1



Chiricahua National Monument