United States
Department
of Agriculture

Forest Service

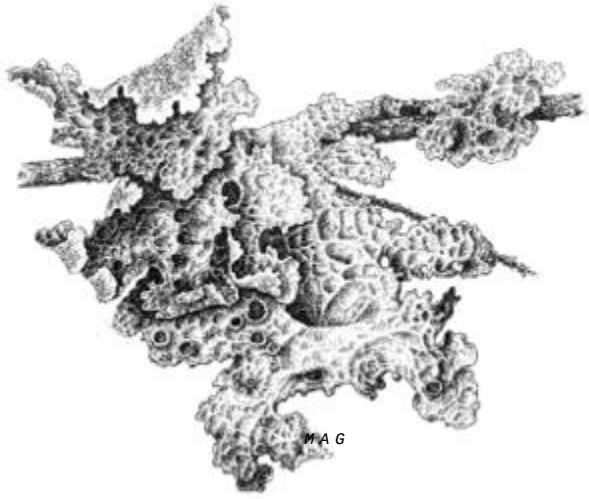
Pacific
Northwest
Region

R6-NR-AG-TP-01-02

Using Lichens as Indicators of Air Quality on Federal Lands

Workshop Report

Workshop held October 2 & 3, 2001
Arizona State University
Tempe, Arizona



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April 2002

For a list of acronyms and definitions, see glossary on pages 52-54.

This report is available on-line at the URL, http://ocid.nacse.org/research/airlichen/workgroup/

Contents

1. Executive Summary

1.1 Introduction

Prompted by plans to build a national lichen database for the US Forest Service Natural Resource Information System (NRIS), a group of Federal Air Managers and lichen monitoring specialists decided to organize a workshop on the role of lichens in air resource management on federal lands.

The goal of the workshop was to gather a diverse group of lichenologists, federal land managers and database managers to discuss ways to integrate existing data, make it more accessible to land managers dealing with air quality, and to explore ways to expand what is already being done with the data. An important additional goal of the workshop was to bring together people with common and conjoining interests, to share knowledge and develop relationships that would spawn future cooperative endeavors.

Arizona State University offered to host the gathering, and two days in October were selected. The organizing committee then developed the workshop's official objectives, as follow:

1. Gain an increased understanding of how to utilize lichen data in air resource management.
2. Understand the range of lichen information resources available, both federal and non-federal.
3. Provide input on needed analysis tools and standards for utilizing lichen data in federal air regulatory and decision-making processes.
4. Outline database needs and requirements specific to the NRIS lichen module that can accommodate or link lichen information from many sources.
5. Develop a plan for future collaboration and action.

The organizing committee decided to use a professional meeting planning and facilitation firm to assist in the design and implementation of the workshop. Rebecca Reynolds Consulting, Inc. was contracted in July 2001.

The workshop was attended by some 35 participants, mostly from the western half of the United States, and included federal land management agencies dealing with air quality as well as federal and academic representatives of programs in lichenology and data management.

1.2 Workshop Results

The workshop was organized into a sequence of plenary and smaller breakout sessions to provide participants with the opportunity to engage each other and share knowledge and information. The major findings of the five breakout sessions were gleaned from the detailed breakout group notes and summaries that make up the body of this report.

1.21 Current Uses of Lichen Information

Lichen data exists and has been used in air resource management to a limited extent in all Regions of the National Forest System. The potential uses are many, but air managers are not taking full advantage of lichen monitoring information because it is not readily accessible or easily interpreted and evaluated. Although each Region has sponsored various projects, there is a lack of integration regarding methods, interpretation, and use.

The workshop's database and technical support group identified that they were all working on separate projects, but that relevant lichen data could be integrated if needed, most efficiently through the internet. The Northwest Alliance for Computational Science and Engineering (NACSE) might be the best entity to support a multi-agency data co-op and clearinghouse. Ecological Metadata Language (EML) was the recommended metadata standard. Some of the barriers to this integration include: design and production of metadata, firewalls at NRIS, and insufficient understanding of air resource management.

The main barriers to the use of lichen monitoring data were the lack of understanding by air managers as to how to use the information and where to find it, the availability of human resources with lichenological expertise, and funding. Overall, air resource management is funded at a lower level than other resources. Outreach and enhanced understanding are key to removing or reducing these barriers (see Section 4.6).

1.22 Desired Uses of Lichen Information

Air managers must often prepare responses to Prevention of Significant Deterioration (PSD) permits in very short time periods. Because they must convince regulatory agencies and industry of their position, the information they use must be credible and reliable. Therefore, air managers need products that are clear, easily accessible, interpreted, and referenced. In light of this, air managers are most interested in working with interpreted data, published data, and standardized thresholds or limits of acceptable change, much of which needs to be prepared by experts.

The workshop breakout groups listed products that could be developed by a multi-agency, multi-academic institution data co-op and made accessible via NACSE or NRIS (see Section 4.5). These products would enhance the utilization of lichen monitoring data in PSD permits, forest planning, forest management decisions, National Environmental Protection Act (NEPA) Environmental Assessments and Environmental Impact Statements, and establishing adverse impacts to Class I Wilderness and other public lands from air pollution. These products would include a data clearinghouse, interpretation papers, annotated bibliography, and a metadatabase. They would provide regional thresholds for declaring adverse effects of air pollution on lichen health, lichen communities, and sensitive lichens; and information for detecting enhanced deposition of pollutants using lichen tissue analysis. They would also provide tools to create a spatial analysis of the extent and intensity of affected areas, to gather historical information, to find human resources, and to understand the ecological implications of exceeding regional thresholds.

1.23 Role of NRIS

NRIS would be a repository for National Forest Service (NFS) data, some National Park Service (NPS) data, and would build linkages to other databases. Optimally it would serve as the information clearing-house for air resource managers, providing the tools and data in interpreted form. NACSE could support most of these functions and provide models of how to do it until NRIS is ready. Exactly how much NRIS is able to undertake and under what time frame are still to be determined.

1.3 Next Steps/Work Plan

The following action items were developed to assure that the workshop effort is moved forward. See Section 4.7 for details.

1.31 Establish an official, on going workgroup to develop and share lichen-related information and programs to benefit air resource management on federal lands.

- **a.** Choose a name: Lichens and Air Quality Workgroup
- **b.** Create a mailing list server and website
- **c.** Develop a strategy paper (mission, goals & objectives, timeline, & core data)

1.32 Establish a core team to facilitate the workgroup's activities.

- **a.** Initially, strategy paper authors will take the lead and will recruit others as needed
- **b.** Responsible for follow-through on this Action Plan
- **c.** Responsible for planning beyond this Action Plan
  → Data Co-op, Clearing House, Schema of Databases with Standards Profile
- **d.** Prioritize the list of outputs generated by air managers (see Section 3.5) and develop a list of components for each

1.33 Produce initial products for air managers during FY2002.

- **a.** Regional Air Quality Gradient Model for Western OR & WA.
  Provide a tool to score air quality using lichen species surveys
- **b.** Intercalibrate Tissue Data in PNW Region.
  Combine USFS and NPS tissue datasets; establish regional thresholds for clean sites
- **c.** Clearinghouse and web-accessible national database.
  Compile existing lichen data and reports from the national forest system

1.4 Conclusion

The workshop was successful in gathering people with mutual interests and complimentary needs and resources, and in providing those people a forum for discussion and exploration. A baseline of information and general literacy has been achieved, as well as a new network of the participants, all of which is a foundation for future work and collaboration.

The workshop was made possible by the work of the organizing committee, the willingness of the presenters, the hospitality of Arizona State University, the financial support of NRIS and the Pacific Northwest Region of the Forest Service, and the participation of all those who attended.

This report has been compiled as a resource for future endeavor and as a record of the workshop proceedings.

2. Acknowledgements

Please see Annotated Participant List (page 58) for affiliations and addresses.

Organizing Committee

Linda Geiser, Chair
Pam Corey
Corinna Gries
Tom Nash
Peter Neitlich

Sponsors

USDA Forest Service, NRIS-Air and Pacific Northwest Region Air Program
Arizona State University

Hosts

Corinna Gries & Tom Nash, Department of Plant Biology, Arizona State University

Participants and Presenters

Suraj Ahuja	Karen Dillman	Tom Nash
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Harvey Berenberg	John Graves	Sherry Pitman
Jim Bennett	Corinna Gries	Laura Rivera
Tamara Blett	Joe Hanus	Paul Rodgers
Frank Bungartz	Bill Hill	Roger Rosentreter
Lisa Bryant	Cindy Huber	Robin Schoeninger
Bryan Cordova	Anne Ingersoll	Brad Smith
Pam Corey	Richard Martin	Larry St. Clair*
Rob Crump	Peter McCartney	Peter Stewart
Linda Davies*	Mike McCorison	Susan Will-Wolf

*not present at the workshop but submitted material included in this report

Meeting Planning/Facilitation

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3. Agenda

Day 1: Tues., Oct. 2, 2001
7:30 a.m. – 5:00 p.m.

Registration Period: 7:30 – 8:00 a.m.

I.	**Welcome** Tom Nash (ASU)	8:05-8:10 a.m.
II.	**Opening Remarks** Linda Geiser (USFS)	8:10-8:15 a.m.
III.	**Agenda Review & Group Introductions** Rebecca Reynolds, Facilitator	8:15-8:45 a.m.
IV.	**Workshop Introduction**	
	A. Role of Lichen Monitoring in Air Resource Management on Federal Lands Linda Geiser (USFS)	8:45-9:05 a.m.
	B. Overview of Resources for Monitoring with Lichens Susan Will-Wolf (FIA/FHM)	9:05-9:25 a.m.
	C. The Forest Service Natural Resource Database: NRIS-Air Pam Corey (NRIS-Air)	9:25-9:45 a.m.
V.	**Break**	9:45-10:00 a.m.
VI.	**Breakout A.** A. 1 Current and Potential Uses of Lichen Research/Data by Federal Air Managers A. 2 Electronic Networking	10:00-11:00 a.m.
VII.	**Breakout A.1. Report Back/Discussion** (Facilitated)	11:00-Noon
VIII.	**LUNCH** in the lichen herbarium	Noon- 1:00 p.m.
IX.	**Breakout A. 2. Report Back/Discussion** (Facilitated)	1:15-1:45 p.m.
X.	**Breakout B.** Information and Products Needed by Air Managers	1:45-2:45 p.m.
XI.	**Report Back/Discussion** (Facilitated)	2:45-3:45 p.m.
XII.	**Break**	3:45-4:00 p.m.
XIII.	**Demonstrations** Demo A: FIA/FHM (Peter Neitlich, FIA/FHM) Demo B: Pacific Northwest Region (Linda Geiser, USFS) Demo C: Lichen Studies on NPS Land (Jim Bennett, USGS) Demo D: NRIS (Rob Crump, NRIS)	4:00-5:30 p.m.

XIV.	**Workshop Dinner Social** Hosted by ASU (cash bar)	6:30-9:00 p.m. Tricks Restaurant

Day 2: Wed., Oct. 3, 2001
8:00 a.m. – 5:00 p.m.

I.	**Welcome Back** Corinna Gries (ASU)	8:05-8:10 a.m.
II.	**Agenda & Questions** Rebecca Reynolds, Facilitator	8:10-8:20 a.m.
III.	**Database Development**	
	A. Considerations for the Construction of Lichen Databases Corinna Gries (ASU)	8:20-8:40 a.m.
	B. Strategies for Connecting Independent Databases Peter McCartney (ASU)	8:40-9:00 a.m.
	C. Building NRIS Air's Lichen Module (Considerations & Parameters) Rob Crump/Brad Smith, (NRIS)	9:00-9:20 a.m.
IV.	**Break**	9:20-9:45 a.m.
V.	**Breakout C.** Developing the NRIS Air Lichen Module and linking to other Lichen Databases	9:45-11:00 a.m.
VI.	**Breakout C. Report Back/Discussion** (Facilitated)	11:00-Noon
VII.	**LUNCH**	Noon-1:00 p.m.
VIII.	**Demonstrations** Demo E: NACSE (Sherry Pittam, NACSE) Demo F: ASU/LIAS/ABLS (Robin Schoeninger, ASU) Demo G: On-Line Lichen Keys (Tom Nash, ASU)	1:00-2:00 p.m.
IX.	**Breakout D** D1. Summary of Products Needed by Federal Land Managers D2. Developing Resources for Lichen Monitoring D3. Plans for Continued Work	2:15-3:45 p.m.
XI.	**Break**	3:45-4:00 p.m.
XII.	**Breakout D. Report Back/Discussion** (Facilitated) Develop agreed upon Next Steps/Action Plan	4:00-5:00 p.m.
XIII.	**Adjourn**	5:00 p.m.

4. Workshop Session Results

The workshop was organized into a sequence of plenary and smaller breakout sessions to provide participants with the opportunity to engage each other and share knowledge and information. The breakout sessions were organized around a set of questions that each group answered. The major findings of the seven breakout sessions were gleaned from the detailed breakout group notes and summaries and are presented here. Acronyms in the following text may be found in the Glossary.

4.1 Current and Potential Uses of Lichens in Air Resource Management on Federal Lands. Breakout A1.

Participants: **Ahuja, Austin, Bennett, Blett, Bryant, Dillman, Geiser, Graves, Huber, Ingersoll, Martin, McCorison, Nash, Neitlich, Rogers, Rosentreter, Will-Wolf**

4.11 What data exist?

Existing lichen monitoring data sets sort into two general categories: 1) regional, standardized studies to monitor general status and trends in air quality and 2) local studies addressing specific questions, including studies in Class I areas.

FHM data and sub-regional gradient studies produce climate and air quality gradients at national, mega-regional and state levels. FIA work crosses all land ownerships of forested land in the continental US.

Anne Ingersoll (USDA-FS, PNW Region) is entering most of the data from studies sponsored by the national forests into a unified databse. The structure is modeled after the lichen database used by the USFS Pacific Northwest Region. This data will eventually reside in the corporate database being developed by NRIS. Currently it is served from NACSE in Corvallis, Oregon (www.nacse.org/lichenair). FIA/FHM data is maintained separately by Chuck Liff's group in Las Vegas, Nevada (www.wmrs.edu/lichen).

Regions 1-4 Rocky Mountains, Intermountain West, Southwest
FIA has completed evaluation monitoring at Steamboat Springs (community analysis) and statewide communities surveys in Arizona, Colorado, Idaho, Nevada and Utah. The USFS Rocky Mountain Region sponsored tissue analysis in the Mt. Zirkel area; USFS-sponsored floristics and tissue analyses by Larry St. Clair's group at Brigham Young University comprise a large electronic database. In Arizona, visibility rather than lichens has been the primary monitoring focus of the NPS Air Program.

Region 5 California
Some floristics data and element analysis exist for Class I areas. Most of the studies were sponsored by individual Forests, e.g. Bruce Ryan's floristics and modified Dobbenmeyer frame work. (A marked grid is laid over a tree bole or rock face and the grid intersections are counted to measure lichen abundance.) FIA has surveyed lichen communities of forests, region-wide.

Region 6 Oregon and Washington
Region 6 has co-located lichen surveys and tissue analysis collection at all permanently marked plots on the FIA 5.4 km grid across eight National Forests and the Columbia River Gorge National Scenic; about 1500 sites. FIA/FHM has surveyed lichen communities region-wide (28 km grid).

Regions 8-9 Eastern US

NFS sponsored work. In the East, a baseline floristic inventory of USFS Class I areas and some elemental data exist but data is patchy, and there is no data for some states. Elemental analyses of nitrogen and sulfur in lichen tissue have been done and some re-measurement at five to ten-year intervals has occurred. Cliff Wetmore at the University of Minnesota has done floristic and tissue analysis work in various National Forests and Parks. Jim Bennett also has tissue data for National Parks of the eastern US. In general, NFS sponsored studies in Regions 8 and 9 have been limited to isolated, non-randomly selected locations, and therefore more baselines are needed to be able to interpret them in a larger context.

FIA/FHM. The FHM program has the most data; lichen communities have been surveyed on a 28 km grid throughout Regions 8 and 9. A gradient model to score air quality using lichen surveys has been established for the southern States, published in *The Bryologist*, Vol. 100, 1997.

Region 10 Alaska

NFS. Floristic and element baselines have been established for the Tongass and Chugach National Forests during the early 1990s using lichen communities and tissue analysis methods. Data and reports are available online at http://www.nacse.org/lichenair.

NPS. Tissue analysis work has been conducted in a number of national parks during the 1980s through the present time including Klondike Goldrush NHP, Denali NPP, Bering Land Bridge NP, and Krusenstern NM. Floristic inventory work exists for several parks, including Gates of the Arctic, Denali, Bering Land Bridge and Kobuk River.

Other. Many species inventories by independent researchers associated with academic institutions have been conducted throughout Alaska. The herbarium and database at the University of Alaska-Fairbanks contains many collections from federal lands in Alaska. John Thomson's two volume series, *American Arctic Lichens*, contains much Arctic data. During the 1990s, the EPA sponsored *Arctic Contaminants Research Program* examined tissue concentrations of persistent organochlorines and metals in lichens and mosses. The USFWS has sponsored additional lichen inventories in southwest Alaska. FIA is scheduled to begin collecting lichen data in 2003 from coastal and southcentral areas.

4.12 How are lichen data being used?

Examples of current uses

a. Pacific Northwest, Alaska and Rocky Mountain Regions

In Oregon, Washington, Alaska and Colorado, the USFS has used lichens to show that specific pollutants are reaching a Class I area, to help to assess pollution sources, to assess air quality in specific locations within a general area for which baselines have been established, to estimate wet deposition, and to map geographic areas of concern for specific pollutants. Lichens have also been used in combination with other data to show adverse impacts of air pollution on biological diversity, and to determine whether more expensive instrumented monitors are needed.

b. Regions 8-9 Eastern US

Generally lichens have been used as an indicator of a broader AQRV, such as vegetation. Federal land managers have rarely used lichens as a primary driver for an adverse impact determination, but it is often a supporting factor, at least in the eastern US. In Theodore Roosevelt National Park a model of anticipated emissions was used in combination with the known distribution of a sensitive lichen to support a PSD case in and near the Park.

Much existing data has not been used
Basically, if information is available, air resource managers will use it. But many in the group did not know what information is currently available. For example, in California the regional guidelines contain a section specifically mentioning lichens as an AQRV. There are 21 Forests and nine National Parks in California; lichens are found in all. However, in order to use lichen data in decision-making processes, managers need to be able to reference published reports.

In some cases data has been very difficult to use. Data may consist only of species lists, and protocols and metadata are lacking. Or the data may not be spatially defined. Sometimes, data exists but federal managers are not sure how to use data in management and analysis of PSD permits.

4.13 How could lichen studies and data be used?

a. General ways Federal Land Managers can use lichen-monitoring data to address air quality questions

1. To demonstrate presence or absence of adverse effects on forest organisms, communities, and associated ecological implications of these effects:
- **Predict air pollution impacts to lichens**, and to lichen health (e.g., appearance, presence, population size).
- **Demonstrate existing impacts on lichen communities**: categorize effects of defined pollutants such as nitrogen and acid rain on lichen communities.
- S**how that a particular species is declining** and that the decline is related to air quality.
- Use as surrogates for instrumented air pollution monitors to **demonstrate patterns and trends in air pollution.**
- Use as an **early warning of air pollution effects** on forest health.
- **Use lichen data with data about other biota**, such as amphibians or aquatic plant species, as "sensitive groups" to **evaluate forest health**. Bio-indicators are often more economical than active instrumented monitors.
- **Evaluate effects of changes in air quality** using changes in abundances or population size of particular species. If abundances have decreased significantly, and it is known that the species is sensitive to a particular pollutant, then that would be useful information. Ideally, individual species could be selected for their sensitivity to particular pollutants, such as sulfur-containing acid rain or excess nitrogen.

2. To detect and monitor specific pollutants:
- Use lichens as passive monitors to **assess relative amounts of metals** in rainfall.
- Design incremental fumigation studies for nitrogen and sulfur effects. This research would connect field studies with pollutants that are being measured under controlled conditions. **Current versus anticipated pollutant levels can be attributed to a pollution source based on laboratory studies**.
- **Calibrate lichens against instrumented monitors**. For example, if five monitors provide deposition data for a large area, then lichen data from 50 samples in between the monitors could be used to **distinguish regional from localized deposition patterns**. In many cases it would not be necessary to use lichens as a measure of deposition because we have instrumented monitors available.

- **Tie element concentrations in lichen tissue to the pollutants emitted by a source**.
- **Assess multiple pollutants**. Look at accumulations of certain elements, rather than just sulfur oxides, nitrogen oxides and ozone to which lichen communities respond most readily. Need to look at metals by analyzing lichen tissue.

3. To corroborate other air quality data:
- It would be desirable to use lichen data in conjunction with other air pollution effects data when **making adverse impact determinations**.
- **Lichen data can supplement or corroborate impacts** determined using other methods. Can interpolated data from the network of monitors be used to make determinations? Deposition data could be paired with FIA data to see if that could be used to show relationships between air quality and lichens. This informtion could then be used in forest monitoring or in PSD reviews. Specific, identified pollutants could then be related to specific effects on lichen communities.
- Lichens could be used to **test the validity of model inferences**. Lichen communities respond to actual air quality, which should be similar to predicted air quality if the model works. Keep in mind that lichen communities develop over years when comparing to instrument data that may have been collected over shorter time periods.

4. To monitor conditions and compliance after a permit has been granted:
- If baseline data and air quality trends have been established for a Class I area, FLMs could **request that a new source permit applicant conduct lichen monitoring.**

b. PSD Permits

Because the federal Clean Air Act mandates FLM participation in permitting decisions affecting Class I areas, a key arena in which managers would want to use lichen data is in responses to PSD permits affecting Class I Wilderness. Although there is no legal requirement, USFS air resource managers often manage Class II Wilderness like Class I areas because of requirements stated in the Wilderness Act.

In the PSD permitting process, air managers need information to be able to answer such questions as:
- How will emissions from this project affect forest health and plant communities?
- What lichen species and what evaluation of air pollution will have an impact?
- What lichen species are to be expected?
- Is air pollution a problem?
- What are the pollution sources?

Most PSD permits' proposed emissions come in below the NAAQS, but the NAAQS were developed to protect human health. FLMs need to determine if there are effects on forest health that occur at levels below the NAAQS. Many lichens disappear at 40 mg/m^3/yr, but the NAAQS stantard for sulfur dioxide is 80 mg/m^3/yr. AQRV review guidelines for FLMs assessing PSD emissions impacts contain provisions for advising states and the EPA about potential ecosystem impacts at levels below NAAQS. States may then choose to adopt more restrictive standards or AQRV protection policies when presented with such information.

Another concern that FLMs have about PSD permits is that cumulative effects are generally not considered, only additional pollutants for each new source, but the ecosystem responds to cumulative loads. Lichens could be used to indicate current cumulative load.

An illustration of a potential use of lichen data to respond to a PSD permit application involving sulfur dioxide was described.

- Step 1. Model background pollutant levels plus additional increment from proposed PSD source.
- Step 2. Overlay predicted deposition on distribution maps of sensitive lichens with defined tolerances to the modeled pollutant. Use existing data, or new surveys, to determine if there are sensitive lichens mapped in that hotspot that could be adversely affected by additional pollution.
- Step 3. If the proposed increase plus background exceeds the tolerance of sensitive lichens, this information could be used to recommend denial or modification of a permit request. Conversely, if the increase plus background is within the tolerance level, that might support a decision to grant the permit request.

This example is predicated upon the existence of regional lichen sensitivity data. Cliff Wetmore's list for lichens of national parks (http://gaia1.ies.wisc.edu/brd/nplichen/nplichen.htm) is a start, but additional field and laboratory work is needed.

c. Responding to specific issues

Examples:

- Effects of traffic flows and motorized recreation. In Yellowstone NP, snowmobiles are the principal source of air pollution. Could lichens map pollution from this source?
- Mt. Zirkel, certifying adverse impacts to a Class I area to obtain better pollution controls protective of natural resources.
- Use lichen information to assess air quality target and to document existing information in other NEPA analyses.
- Hell's Canyon: Is nitrogen deposition enhanced? Could rock art and cultural sites be threatened?

Issues facing air managers

Because the Air Program is poorly funded within the USFS compared to other resources, air quality issues are often left out or given low priority at the Forest and District levels. If air quality is considered, the focus is usually on smoke management. Often the Clean Air Act and protection of Class I areas and the responsibilities it assigns to federal land managers are not well understood by Forest decision makers outside the air resources management program.

Now, with the fast-tracking of energy plants by the new federal administration, both NPS and USFS are being deluged with PSD permits. FLMs need "something off the shelf" that can be used rapidly and as soon as possible. Some managers are unsure how and whether lichen data could be used in addressing AQRV impacts from PSD permit emissions increases.

Precautions and concerns regarding the use of lichen studies

Some differences in data protocols between studies exist. For example, in West Virginia and Virginia, lichens were monitored by Jim Lowrey and Larry St. Clair; studies in other eastern states were done by Cliff Wetmore using different protocols. A spatial analysis of air quality would be desirable for each Class I area, but the scale of such analyses was not discussed. Spatial and temporal patterns can be determined using lichen monitoring if sampling is strictly stratified and done the same way during the different time periods.

Different regions of the US have such different lichen species and communities that developing different protocols for each region may be required. For example, FIA does not collect lichens below 0.5 m on trees, and that does not meet the needs for data collection in the SW lichen communities where normally epiphytic species grow at the base of trees and shrubs or even on the ground. Regional differences determine lichen

gradients and sensitivities. Air quality effects must be distinguished from the effects of other environmental factors that affect lichens. Therefore, use caution when generalizing to the national level; pay attention to regional differences and other differing environmental factors.

When extrapolating data between models for use in PSD review processes, provide a "margin of safety" or "wiggle room".

Another concern is the physical separation and working sphere differences between the lichen folks and the air quality folks. There is a need to increase communication and collaboration between these groups.

Lichens are living organisms. When conducting tissue analysis, it makes a difference whether the center or the edge of the lichen is sampled. Some elements accumulate in faster growing parts of the lichen, other elements accumulate to greater concentrations in older parts. The same principle applies to using different species; they have different sensitivities and element concentration profiles. Such factors require consideration when developing study protocols and field sampling methodology.

4.14 What other management needs can be addressed with lichen data?

Fire. Lichens might be used in fire management to assess fuel loading, nitrogen deposition from prescribed burns, or to evaluate habitat health. Research is needed to find out more about the sensitivity of lichens to fire and smoke and to address Forest Plan issues surrounding fire.

Forest Planning. Information about lichens could be used in documentation of biodiversity, planning old-growth management, and in protection of forest health.

Forest Management.

1. Lichen data could be used to evaluate and monitor condition of range and forest land. Examples:
    - Lichens could be used to delineate area of concern where there has been a decline in ungulate populations due to deposition of toxic metals.
    - Soil cryptogams, including lichens, can be used to monitor soil stability, grazing impacts and water run-off.
2. Data about rare lichens could be used to assess their status, habitat requirements and determine management guidelines.

NEPA. Lichen data could be used to help assess where to put conservation efforts. For example, identify areas where air quality is bad, and focus conservation efforts on areas where biodiversity is high and air quality is good.

Regional Assessments. Lichen data could be used in larger, state of the environment type of large-scale reports.

4.15 Other notes

Can NRIS store data from non-Forest Service land ownerships?

Ozone is an important pollutant and levels in the US are increasing in some areas. Not much has been done with ozone fumigation of lichens to establish their sensitivity. This could be a research need.

4.2 Information and Products Needed by Federal Land Mangers to Better Utilize Lichen Monitoring and Research Data in Air Resource Management. Breakout B.

Participants: **Ahuja, Austin, Bennett, Berenberg, Blett, Bryant, Cordova, Crump, Dillman, Geiser, Graves, Gries, Hanus, Hill, Ingersoll, Martin, McCorison, Nash, Neitlich, McCartney, Pittam, Rogers, Rosentreter, Schoeninger, Smith, Will-Wolf.**

4.21 What key information needs to be produced from lichen monitoring studies?

Key information needs are compiled data on lichen presence, abundance, and distribution (including maps), with evaluation of pollution sensitivity of the species found. Compiled element analysis data accompanied by evaluation and interpretation of that data are also needed.

The USFS PNW Region uses a standardized protocol and permanent grid for sampling and collection of both lichen community and tissue data. The key types of information produced are:

- Sensitivities of regional lichens defined by their tolerance to sulfur and nitrogen deposition levels and maximum tissue concentrations of sulfur and nitrogen, and ability to map their location.
- Sulfur, nitrogen and metal tissue levels in target lichen species, queriable by location or geographic area and comparable to regional thresholds for clean sites.
- Air pollution scores using lichen communities. Follows FHM analysis protocols; locations where sensitive species are absent receive lower scores than sites with a high biomass and diversity of sensitive species.
- Estimates of sulfur and nitrogen wet deposition using lichen data calibrated against the regional NADP network.

4.22 What thresholds, models or limits of acceptable change could be developed for lichens?

- Use FIA regional gradient models to develop acceptable ranges of air quality by region. Gradient models are developed from lichen community data spanning a range of air quality within an ecologically defined region. Scores can then be assigned to other locations within the region using new or existing community surveys. Poor scores may be unacceptable to FLMs because they indicate that air quality conditions are inadequate to support sensitive species.
- Develop regional sensitivity ratings for species. FLMs would like a sense of the pollution sensitivities of different species, perhaps via supportable, defined tolerances for each species. They need quantifiable data and well-designed studies to avoid criticism of lichen data. Which lichens occur in which Wilderness? What levels of which pollutants will prompt which changes?
- Develop a standardized rating scale for the effects of each pollutant on specific sensitive species.
- Compile literature reviews of the responses of lichens to various pollutants.
- Develop a model for anticipating effects of air pollution on lichen communities. Be able to determine both existing impacts and anticipated impacts.
- Establish regional tissue thresholds and background ranges. In particular, develop thresholds for nitrogen and sulfur-containing pollutants.

4.23 What reports would be useful? Should they be canned? Will we need to make ad hoc queries?

Desired Canned Reports and Information for General Needs
Examples:

- What are the baselines?
- What data exists to compare to baselines in a given area?
- Are thresholds being exceeded?
- Characterizations of an area, soil crusts, existing lichens, what is sensitive, endangered?
- List of threatened and endangered lichen species.
- Air quality scores.

Develop a checklist for all projects for air quality? What would be on the list?

Environmental Assessment Information Needs
Managers need answers to questions such as: which airshed is threatened, what are the current existing conditions, which lichens are present, what is their condition, are adverse effects detectable? Is air quality within expected ranges for clean sites? If not, how much pollution is present? Existing lichens and their sensitivities…will my project affect sensitivite species? For example, what would be the most likely effects of a prescribed fire?

PSD Permitting Information Needs
What are the current air pollution effects on lichen species and what are the likely effects of increased emissions? Which emissions carry the greatest threat?

PSD process needs include: lists of species, abundances, species regional sensitivity ratings, tissue elemental analysis, and affected geographical area displayed on a map. Sensitivity ratings should be driven by data.

Other desirable information would be drill-downs and advice on spatial selection, regions and forests, wildernesses, etc. and an annotated bibliography with keywords.

NEPA Information Needs
NEPA documents and reports might include available tissue analysis or community data, and provide geographic, organizational, or administrative drill-downs. Annotated bibliographies (summary, annotation, keywords) can also be included in NEPA documents.

Forest Planning Information Needs
Forest Planning information needs would include a general characterization of the airshed, its status, what AQRVs were measured and how they were measured. Maps and graphs showing extent of populations would be helpful. Pictures are also good.

4.24 What type of interpretation is needed, i.e., relationships, reports?

Managers' Issues
Managers need an additional information layer to help them interpret data and understand what it means. E.g., if there is excess lead in lichens, what should a manager do? Is it just a vegetation issue? Is it a human health issue? Otherwise misinterpretation and misuse of the data can occur.

PSD applicants must report what effects new or modified sources will have on Class I areas. Ultimately Federal Land Managers (FLMs) make the call about projected adverse effects on resources and provide formal notice of their findings to state or federal air regulators. Through this mechanism, air managers influence the ultimate amount of emissions and therefore air pollution effects on ecosystems.

Managers do not have time to review literature reports. For managers, web accessibility must go further than access to data and metadata. They need thresholds of acceptable change and acceptable ranges. They need to know if data exceeds thresholds and implications of exceedances to lichen health (growth, photosynthesis, reproduction), biodiversity, population size, and to other indicators of forest health or to other ecosystem components.

How much enhancement of tissue pollutant concentrations should trigger action by management? Any enhancement? Double the threshold for clean sites ranges? How do we separate other environmental effects or stressors that alter lichen communities or tissue concentrations? What choices do managers have when those levels are exceeded? Managers need to understand the implications of exceedance, e.g., health effects, or the potential for species loss.

What do changes in elemental data over time tell us? If we have species and elemental data, what can we conclude about the air quality? What can element concentrations in lichen tissue tell us about air pollution and/or the condition of the lichen?

Biodiversity is also a consideration; what about rare species? Common lichens are usually rated for sensitivity, whereas rare lichens are often un-rated. This is because many data points are normally needed to establish sensitivity. But managing population viability is also of concern to managers. Is there a way to connect to other information in NRIS to get at these questions, for example about the condition of the habitat? When the lichen submodule for the NRIS application is developed, tools can be developed and/or used to extract data from other modules to help managers and users make correlations between lichen and habitat data.

Sensitivities to air pollution: are there other potential stressors that could confound air quality interpretation? What other environmental factors mimic air pollution in their effects on lichens?

Important point: data must be able to withstand scrutiny by industry and regulatory agencies. Turn around time is very fast, and therefore information must be accessible very quickly. To accommodate this, information should be put in the same units used in models or by regulators, e.g., if a PSD permittee is required to report sulfur deposition, then units at the lichen data clearinghouse or in reports need to be in sulfur not sulfate.

Managers are usually aware of air pollution, but are limited in their authority to do something about it. Larger scale reports can be used when commenting on permits, but this type of information does not often make it down to the level where it will affect a land management decision. Remember also that consitituent needs and mandates change over time, and lichen data may become more or less useful with these changes.

Desired Products

Sensitivity of lichens needs to be established for each region and accessible from NRIS. This is a

research need. The USFS and NPS should cooperate with FIA/FHM to develop sensitivities for lichens from the different regions based on FHM data. Refine tables of sensitivity to a regional level. It is important to have tables of species sensitivities to air quality.

Tie tissue data to lichen sensitivity, perhaps using existing tissue data. PSD applicants must report what effects new or modified sources will have on Class I areas. Ultimately Federal Land Managers make the call about projected adverse effects on resources and provide formal notice of their findings to state or federal air regulators. Air managers influence the ultimate amount of emissions and effects on ecosystems.

NRIS, in addition to making raw data available from multiple sources, could do **data summaries on request**, and could also build a web interface to enable others to do appropriate summaries. To do this, NRIS needs a concrete set of standards with which they can design reports.

Tables of "background" levels of elements, along with guidelines on how to interpret data.

Aids to interpretation of existing data are needed so that air managers may know when existing data point to the need for more intensive sampling to address a particular air quality issue for a specific place. Air managers want some help interpreting NRIS data to be able to separate air quality response from other factors, or to know when and where interactions between air quality response and response to other environmental variables must be considered.

In addition to summaries and reports with specific information on lichens for an area, air managers need **general information** on the use of lichens to monitor air quality, to help them learn how to use lichens effectively as a tool.

Calibrations need to be made for other regions to 1) estimate sulfur and nitrogen deposition using lichens and 2) relate that to effects on sensitive species. Track incremental emissions detected by the IMPROVE network to biological changes. Take IMPROVE elemental data and compare to lichen element content.

Establish a process for using lichen data in PSD reviews. Identify attributes needing established thresholds that could then be used in the permitting process. PSD increments are a specific amount of pollution 'allowed' based on the permit application date. For example, thresholds (limits of acceptable change) were developed for visibility. During the 1980s, the NPS established a process for reviewing PSD. The Dec/Jan 2001 FLAG document is a multi-agency document providing guidance being used now for reviewing PSDs.

FIA/FHM will be producing **regional air pollution and climate gradient models based on lichen communities**. The models will then be used to score air quality at forested locations where surveys have been completed according to FHM guidelines. This system could be used to assess relative conditions over a landscape and effects of sulfur oxides and nirtrogen oxides on forest vegetation. Eco-regional analyses based on topography and precipitation are another potential product.

However, air managers do not have the time or expertise to become lichen experts. They also need a **resource person knowledgeable about lichens** who can help them with interpretation of data and data summaries, and who can, if need be, go to court with them.

Air managers and others would benefit from a **heavily distilled and annotated, searchable database of publications** and reports on lichens in National Forests and surrounding areas.

A **Clearinghouse** is needed to provide an easily accessible location for all of the above. It would be a place where anyone can get existing data, studies, protocols, etc., annotated to the degree of applicability and usability of the documents. More examples of resources a clearinghouse could provide/include:

- Comparisons of tissue data to establish whether the local levels are high or low.
- Find out which lichens to pick for tissue analysis.
- Annotated literature list and links to searchable literature database.
- Protocols.
- Monitoring locations.
- What has been done in your area. Need to know what information is available for a particular NF even before need is clear. Forest Managers want summaries for particular reporting units (one or more NFs, or Class I areas, etc.).

Do we need to do additional collecting? This would be easier to know if we could access data to find out what information is already available and if it is sufficient. A Clearinghouse could serve that need. Even if data is available, sometimes this data may not be the right kind for the current questions.

4.25 What raw data is needed to produce this information?

Raw data needed include:

- Species lists. By National Forest or subdivision, with abundances if possible.
- Sensitivity of species.
- Species richness.
- Species abundance.
- Tissue concentrations. Need to have element analysis data on species present, if available. Need summaries of existing raw data for lichens.
- Data on environmental and forest vegetation variables correlated with lichen species distributions.

Currently, FIA/FHM Regional Forest Health assessments provide:

- Species richness
- Sensitivity profile
- Biodiversity index
- Species abundance

Exposure/fumigation studies are needed to link field information about species distributions with laboratory determined sensitivities to specific pollutants and pollutant concentrations.

The difference, for element analysis data, between **passive and active monitoring** was discussed. For passive monitoring, element analysis may be done for both common and rare species, to record what is present, and to contribute to the understanding of background levels and species sensitivities. Active monitoring, on the other hand, is done with common, relatively pollution tolerant species. The goal is to use these lichens as surrogates for instrument monitoring to establish geographic patterns and track changes in air quality over time.

4.26 What metadata needs to be easily accessible for credibility?

Metadata should include:

Methods
Access to protocols is important. In regard to Region 8/9 data, dealing with protocols is difficult because each study is slightly different. Standardized metadata is needed to interpret them.

Information about data quality
Is existing data of sufficient quality to be useful? How do you rate data quality? This is a metadata issue. One of the previous breakout groups mentioned that it could be difficult to compare data if protocols are different. Therefore we need to know not only what data is available, but assess what data can be used together.

Simple summary statistics
For data summaries we need estimates of variance as appropriate, for instance for average element content.

Annotated bibliography
A bibliography would be useful to back up information obtained from website queries.

The Center for Environmental Studies (CES) has a standardized metadata format and maintains a database for metadata. For example, the metadatabase can be searched for databases that include information from a specific state, e.g., West Virginia. There may be a section for protocols.

Ecological Metadata Language (EML) is an enhancement and refinement of National Biological Information Infrastructure (NBII) and FGDC, a geospatial metadatabase that preceded EML and NBII. EML is the most preferred metadata standard for lichen monitoring data.

It is so difficult to get researchers to do metadata! Sometimes it is easier to assign someone to visit researchers and obtain the metadata from them than to expect individuals to adequately and voluntarily comply with established metadata requirements.

Question: Do managers need to be advised of minimum metadata requirements for a useful database? Or should databases be screened before they are included on a website?

4.3 Electronic Networking. Breakout A2.

Participants: **Berenberg, Bungartz, Cordova, Crump, Gries, Hanus, Hill, McCartney, Pittam, Schoeninger, Smith.**

4.31 Who has what lichen data?

There are at least two sources of lichen data: federal and academic.

NRIS
NRIS currently has no lichen data other than a link to the USDA Natural Resources Conservation Center's PLANTS database. Ancillary lichen data shows up in the AQRV sub-module as flora. This is tied to sensitive indicators. The intent is to eventually develop any other structures that are needed to house the NFS lichen data within NRIS.

NRIS uses Oracle 8, which will be deployed to most USFS units. So far NRIS is only accessible via the FS intranet and is unavailable to non-FS employees. The USFS firewall is an issue because air managers need to go outside the agency to share information from analyses. USFS employees can go out through the firewall, but others cannot come in through the firewall from the outside.

NRIS captures local data, and is updated according to local schedules. NRIS works with Access to move data from a variety of source types to an electronic format that is then pushed into Oracle. Dealing with legacy data is still an issue for NRIS. Some data are imported from other sources and are 'refreshed' according to the schedules of those sources.

NRIS is developing standard data protocols.

NACSE
NACSE helps researchers to make data available on the internet; it is not generating lichen research. Making web access simple for the research is an important component of NACSE's mission.

NACSE supports research and collections data and develops web delivery software. The background database system used by NACSE is Sybase, a relational database software program for Unix operating systems. NACSE can also support Oracle databases. Data are processed on an E450 with mapping capability (not GIS). The owner of the data maintains control of the display and access to data. Outputs: downloading of data is an option, if allowed by the owner. Current queries or entire datasets can be made downloadable.

NBII mosses and lichen data are coming into the program.

FIA/FHM
The FIA/FHM program owns data from 1994 forward. This information is available on an FTP site as comma delimited ASCII files. The user presentation layer has links to other data.
The database system used by FIA/FHM is Oracle with SAS. An Oracle web interface is planned.

ASU/Center for Environmental Studies (CES)
CES deals with a broad spectrum of data. Much consideration is given to connectivity and to other ways of making data available without too much custom code writing.

CES promotes access to data for environmental research. It is structured to integrate different types of databases: XML is used as a data exchange standard. Internet services are being programmed that make the data available in XML. SOAP messages are used for communication between services and clients. This allows access to the data regardless of the system in which they are stored (relational database, ASCII) and overcomes firewall issues. CES stores a limited number of databases, and also maintains GIS and satellite imagery files.

An attempt has been made to standardize ecological metadata using XML syntax. The EML standard has been developed in working groups and is currently in its second release (EML 2.0, http://knb.ecoinformatics.org/software/eml/ and http://caplter.asu.edu/bdi/Subjects/metadata/april2001/index.htm). The above mentioned data exchange protocols are based on this standard.

User friendly applications capture these metadata to access data via the web. Five collection databases are currently available that are integrated into one website. Two are lichen databases, integrated with animal, pollen and vascular plant data and searchable with one interface. The background database system is SQL; server programming languages are Java and JSP. The next step is to integrate other, variously structured ecological data sets.

4.32 What is needed to share and use existing lichen data?

A good data access system needs is invisible to the user, regardless of the original data structure, source, etc.

EML/XML can be used for the metadata standard.

Long Term Ecological Research (http://www.lternet.edu) sites have data managers and are a potential resource for air quality monitoring.

After information needs are defined, standard schema for lichen data for the purposes of air quality management need to be developed.

Collection data sets are somewhat easier to be made 'useable' than research data sets because they have more data fields in common.

Annie Ingersoll is compiling a lichen database for lichen monitoring data collected from national forests in the US for the USFS air program. Data within this database will be referenced to their corresponding protocols. However, there are numerous other efforts—how do we integrate them?

4.33 What are the options for connectivity between different software applications?

A base level of connectivity is achieved in a variety of ways, e.g., storage of multiple data sets on FTP sites or converting small data sets to standard structures.

Security issues exist regarding sensitive data. For example, FIA/FHM data collected on private land is private. Although the trend is to accessibility, there are some limits to this that should stay. Some of these problems can be overcome by hiding different attributes such as location or by setting up by different levels of security for different classes of users.

4.34 Discussion

Question to FLMs: Do collections from herbaria provide useful information? If so, species identification, distribution, abundance, substrate, voucher specimen are typically available from herbaria.

4.4 Developing the US Forest Service Natural Resources Information (NRIS) Air Lichen Module and Linking to Other Lichen Databases. Breakout C.

Participants: **Ahuja, Austin, Bennett, Berenberg, Blett, Bryant, Cordova, Corey, Crump, Geiser, Graves, Gries, Hanus, Huber, Ingersoll, McCartney, Nash, Neitlich, Pittam, Rivera, Rogers, Rosentreter, Schoeninger, Smith, Will-Wolf.**

4.41 What data would be in NRIS and what data linked?

How do you decide where to put data? The three most important concerns are usually preservation, persistence, and access. If those conditions can be met, the database location is adequate.

The storage location of USFS lichen data needs to be decided by the agency's biologists and air resource managers. Data collected with agency money on agency land is the most likely candidate for NRIS-Air.

There is a natural trajectory that occurs when a number of people with data in many places need simultaneous access. Often they decide to create a centralized database, but then as time passes, the data sets and data needs diverge and the centralized system becomes unwieldy. One way to avoid this is to maintain separate databases but develop a common report output.

Participants of one breakout group agreed that it could be simplest to maintain separate databases and database structures from FHM, NFS and NPS. To address information needs for PSD reviews, Forest Plans, NEPA, AQRVs, etc., the databaes would be linked by pulling together common fields using NACSE's website for the USFS Pacific Northwest Region as a starting point. This group felt that the persistence and access to the databases is more important than the longevity of any single mechanism for accessing and using it. That mechanism will evolve with the needs of the air managers and researchers and need not reside in NRIS. Under this scenario:

1) NRIS would become a repository for NFS data. NRIS-Air is a good repository for NFS data because it is corporate sponsored, is GIS referenced, and enables easy access to data in other NRIS modules. The two other breakout groups independently concluded that at a minimum, NRIS should store NFS data. Some additional advantages of storing data in NRIS include speed, availability, consistency, and access to standard look-up tables (e.g., FS uses NRCS PLANTS database for plant names and taxonomic authorities). Using NRIS as a repository simplifies or eliminates server issues, site changes, updates to data, software changes on sites, and makes the data available to push to the worldwide web. The NRIS-Air module would contain lichen community data, element analysis data, and supporting site infromation (habitat, vegetation, stand structure, stand age, location, physcial characteristics of the site, etc.).

Rob Crump indicated that it is not the intent of NRIS to compile all data from all sources. He conceptualizes NRIS as one data set of many, with NRIS providing a search tool for air managers, and developing links to other existing databases. For example, it makes sense to be able to access National Park data if it is adjacent to a national forest area of concern. Rob also thought that NRIS might just serve the database, but not provide the research reports that air managers would need. Another group suggested that NRIS could develop the Clearinghouse or, minimally, link to a Clearinghouse.

2) The FHM lichen data are part of Phase 3 FIA. In the short term, the lichen data will be stored in Las Vegas. The long term FIA solution is to incorporate the lichen data in the FIA-National Information Management System (FIA-NIMS).

FIA is committed to working with NRIS to provide the data for the various modules. The module in which the lichen data will reside is an internal NRIS decision. FIA is currently working to get the Phase 2 FIA data into NRIS-FSVeg. FIA is planning to include Phase 3 FIA data, with lichens, into FSVeg. Thus, NRIS-FSVeg will have a replicated copy of the FIA data. (Information from Chuck Liff, FIA/FHM.)

3) The Park Service may or may not maintain their own lichen monitoring data. If the agency doesn't sponsor the database…who will? Jim Bennett expressed concerned about where NPS tissue data will reside. Sherry Pittam says this problem supports the idea of a database co-op. This question needs further exploration, especially in regard to Bennett's lichen data. Bennett's database structure is very similar to the USFS National Forest system lichen database that Annie Ingersoll is creating for the Air Program, and could be accommodated in this database (with NRIS as the eventual repository).

4) Build links to external sites that provide other types of measurements of pollution, such as the National Acidic Deposition program, IMPROVE visibility network, university collections, other tissue sample data, etc. This would be a long-term goal.

4.42 How will working with a variety of databases and data formats be addressed? What does the data need to look like?

What do we want to do and what is the structure of the source databases? These questions need to be answered before designing linkages. In general:

There is a trade-off between the cost of accessing data and data cleaning. Standard data formats are desirable. Cleaning is a lot of work. Natural resources data are noisy, i.e., repeat measurements are usually a little different from each other.

Most of the lichen data are stored in relational databases, and would be accessed or brought in from a variety of sources. Addressing the various database schema, and assessing data translation are therefore important issues. Data translation methods determine the connection process by which common fields (profiles of common information) are obtained, e.g., species data, abundance, tissue, community. The needed variables, e.g., community, tissue, profiles, are then defined by, and provided back to, the user.

Or, rather than merge data from separate databases, a different strategy would entail addressing metadata issues and drawing common data from each of the databases at the time of the user query. Some translation may be needed to draw the common data. ASU-CES has a tool for discovery of data sets and on-line metadata to obtain data catalog, an index of database. The Oregon Coalition of Centralized Databases uses a similar data flow scheme.

Participants generally approved of the creation of query-able data set catalogs and data sets that would access all relevant data. And they agreed that persistence of those data needs to be guaranteed by some means.

The question arose as to how much time it would take to send a query to multiple databases at different locations. Answer: probably more than several minutes, up to 20 minutes. This seemed unacceptable. It should be possible to greatly shorten query time by making periodic temporary caches or mines of the different datasets.

4.43 What flexibility is there for the FS to use applications other than NRIS?

Natural resource data collected by field units is required by budget and accomplishment directives to be entered in NRIS and there is not much latitude in this policy. However, creating a long-term, documented Memorandum of Understanding with a host site is within the realm of possibility. So there is flexibility to use non-NRIS applications, but not carte blanche. The USFS has an approval process for 'corporate' software and hardware. These decisions must be made through official channels.

Until NRIS achieves web-capability, web accessibility and query scripts for USFS lichen data could be achieved using other software. Sherry Pittam says her group can move the interface created by NACSE to NRIS so that at some point in time, if the participating entities agreed, NRIS could take over the website query pages. Brad Smith indicated that the timeline for web access to NRIS data would be about 12-18 months.

4.44 What relationships need to be represented (technical side of shared data)? How do we go about doing this and what roadblocks exist, if any?

Is there a centralized federal database? No. NRIS is the corporate database for the US Forest Service.

Roadblocks

- USFS computer firewalls.
- Education of managers.
- Too intense a survey/analysis in some cases.
- Availability of comprehensive identification manuals and guides (some keys are available on internet, other regional and national references are listed in Section 9).
- Funding: often air quality is not a priority. How do we elevate air quality issues?
- Limited sources of data. There are not many agency lichenologists to collect data, and sometimes people do not want to share data. Money is also an issue; quality research and monitoring costs money.

Suggestion: At the next gathering like this, have State DEQ, EPA, and FWS representation so as to gain broader air quality perspective.

Question and Answer

Q. Is the goal to populate NRIS or to build a clearinghouse? How much is NRIS willing to take on?

A. The goal articulated and followed during the course of the workshop was to identify existing data, how people want to use that data, and the best vehicles for using data. NRIS could become the host of USFS National Forest system lichen data and possibly some of the NPS data. How much NRIS is willing to take on will be based on funding, priorities, and the availability of clearly defined standards for lichen data.

4.45 For what is web interface/usability key?

Data accessibility is a good idea. Availability of raw and compiled data, and of a searchable references database are important. Standard web protocols for generating data summaries are an important tool to have available on the web. Except where it would conflict with conservation of rare species, there are few situations where we would not want raw data to be accessible, along with the appropriate metadata.

Different users will need different information. Biologists may want raw data; air managers may mostly seek summaries.

4.5 Summary of Products Needed by Federal Land Managers. Breakout D1.

Participants: **Ahuja, Austin, Blett, Bryant, Ingersoll, Huber**

Task: **Brainstorm a list of products needed for FLM processes (e.g., PSD, NEPA, Planning) and the requirements of each (e.g., expertise, data, canned analysis).**

4.51 Summary of needed outputs

- Historical information — understanding what is out there: herbaria, previous inventories, etc.
- Knowledge and understanding of existing lichen communities by spatial area.
- Element analysis for those spatial areas and identification of the range of normal variability at clean sites.
- Sensitivity lists: by species, pollutant, sensitivity to that pollutant, and source of pollutant.
- Establish tissue levels that are associated with loss of species sensitive to that pollutant, especially sulfur, nitrogen and fluoride.
- Pollutant damage lists/photos — which pollutants cause what morphological changes, growth, decline, other characteristics.
- Air pollution thresholds for lichen health, lichen communities, and TES lichens.
- Assistance in what surpassing a threshold means: interpretation.

4.52 Needed products identified during previous sessions in the workshop

- Descriptions of existing lichen communities within a given geographic area and the condition of those lichen communities (structure, composition, biodiversity ratings, elemental analysis or chemistry, etc.).
- Historical information regarding lichen communities and species distribution (published reports and collections from herbaria). This is especially important for pollution affected areas such as the southeastern US. The purpose is to help managers determine the expected, desired, or potential lichen commuities and abundances.
- Sensitivities of lichens to pollutants.
- Threshold values for lichen species and communities — these may need to be developed regionally or sub-regionally or by ecological types/eco-regions.
- Where are thresholds being exceeded? By how much? What does it mean ecologically?
- Computer generated reports with tabular and geospatial capabilities.
- Overlays of lichen communities maps and instrumental analyses of air emissions, e.g., NADP, IMPROVE, AIRS, other EPA/state emissions data or point source emissions data, such as smoke stack output or the Mt. Zirkel isotope studies.
- Overlays of other geospatial/tabular data of other stressors or disturbances, such as wildfire history, timber harvest activity, grazing, etc., to help separate lichen impacts from air pollution and other environmental stressors.

- Achieve better coordination between federal agencies, and researchers to describe pollution gradients.
- Environmental gradients of lichen communities for different habitat/ecological types. The goal here is to compare what would be expected to occur in the area versus what is currently there and then coming up with explanations for differences (whether that be air pollution or some other disturbance).
- A list of clean site tissue analyses/elemental chemistry for lichen species.
- The locations of existing sources of emissions and any known proposed sources.
- A sensitivity list by lichen species and pollutant. The sensitivity list would include species names, pollutant rated, sensitivity rating, and source of rating (published report, fumigation study, someone's best guess, etc.).
- The sensitivity list could also include a list of symptoms or damage caused by air pollution and pollutants to which lichens are not sensitive.
- Damage features or symptoms augmented with pictures would be ideal for various species; this could be linked rather than stored in NRIS.
- Concern thresholds for specific species: 1) visual symptoms, 2) chemical elemental content, 3) community structure and diversity: e.g., presence/absence, damage to x% of a population (visual or other), elemental analyses above baseline values, gradients of exposure to expression of injury or growth loss (ideally we would have curves for sensitive species that defined the pollution levels at which various symptoms occur versus mortality, versus complete disappearance in order to give managers a choice in the levels of protection they may choose to enforce). A "concern threshold" is the point at which a change in a given parameter or characteristic relates to damage to the resource (AQRV = flora, indicator = lichen).

Follow-up Task: Develop a list of components for each of the above outputs in 4.51 and 4.52 and prioritize them.

4.53 Additional notes

Consider lichen sensitivity to other management activities if these are known, e.g., grazing, fire, timber harvest.

Consider Threatened & Endangered Species lichens and reports to list where, what and how many as well as lichens that may not be sensitive themselves, but are a food source for a Threatened & Endangered Species wildlife species.

4.6 Developing Resources for Lichen Monitoring and Research. Breakout D2.

Participants: **Bungartz, Cory, Dillman, Gries, Nash, Rivera, Rogers, Rosentreter, Will-Wolf**

Task: **To brainstorm ways to creatively address "roadblocks," e.g., sponsors, contacts, educational tools/needs, etc.**

Roadblocks to expanding the use of lichens in air quality monitoring can be attributed to one primary one: lack of understanding and awareness as to the value of lichens in air quality work. This results in lack of funding, lack of human resources, under use of available data, and lack of data packaged to assist air

managers using it. Therefore, the first priority for addressing this lack of understanding is the development of various communication methods targeted to specific audiences that will promote greater awareness among them.

First, however, we need to develop a "lichen mission" and set of messages that speak to each particular institution/entity (USDA-FS, ASU, NRIS, etc.). The mission needs to express the VALUE of studying lichens, and the messages address how each entity can become involved. Some of the messages may be:

- The goal is to address air quality information, and the effects on trees and forests. The strategy is to use lichens to address that issue, so as to improve forest health.
- Lichens are a useful tool for assessing how air quality relates to forest health.
- Lichen research and the products from it are valuable. Therefore, the generation of data, and its dissemination and codification are necessary to the use of lichens as forest health/air quality indicators.
- Important goals of this work include:
  - Better air quality
  - Pure research
  - Shared knowledge
  - Improved forest health

Once these messages are developed, then they can be conveyed to the various audiences, both internal and external (e.g., nature enthusiasts, users of lichen information, students, USFS staff, those who control funding within agencies, etc.). The following represents a grid of current needs, followed by proposed solutions and what would be required to act on the solution.

Need or Problem	**Solutions**	**What needed to implement? Who, how, where?**
Lichen Mission/Messages	Develop a Strategy Paper that addresses the broad value of lichens and lichen data, as well as messages specific to the audience/ institution. Use this consistently in brochures, on websites (e.g., NRIS, and R6), in workshops, etc.	Team to draft and review the Strategy Paper
Need for broader input	Include all important, related entities in future sessions, outreach, etc.	Contacts with the EPA, DEQ, FWS, Universities, and others
Lack of understanding from air quality people, general Forest Service People	1) Brochure 2) Workshops: 2-3 day workshop for air people 1-2 day workshop for environmental planners 1 day briefing 3) Internet (use as an educational tool)	* Get on the agendas of: Air Program Annual Meeting BLM FWS EPA RPOs (e.g., WRAP) National Assn. of State Foresters Congressional Staffers ABLS Meeting NSF

Need or Problem	Solutions	What needed to implement? Who, how, where?
Lack of knowledge of available lichen resources for FLMs and other managers	**Clearinghouse for Lichen Data	Website to host it; team of people to develop and maintain it
Insufficient human resources employed in the right places at the right time, with the right skills	Communicate need to lichen-ologists and to High School biology teachers	Develop recruiting message(s) Develop funding to recruit

*Entities and associated contacts that could be targets for the Workshop/Training Concept:

Air Program Annual Meeting (contact: Rich Fisher)
BLM Environmental Planners (Roger Rosentreter has contacts)
Fish & Wildlife Service
Forest Service
Regional Planning Organizations: e.g., WRAP (Rich Fisher has access, Rich Martin)
National Association of State Foresters
Congressional Staffers (Pam Corey has contacts)
ABLS (Tom Nash has contacts)
NSF

**Clearinghouse (strategy to get lichen data to FLMs in air resource management)
Need: FLMs have an issue, want to use lichens to address it, but don't know what to use, where to go, whom to talk to for expertise. To best serve the FLMs, the clearinghouse would need to address what data/reports are available, on what scale, where they are, and to whom could the FLM speak to to get more information. Therefore, the clearinghouse should include:

Regional contacts: Annotated people database
Annotated keywords, bibliography (reports)
Air collection data
Elemental data
Photos
Lichenologists
Links to all, but with an "FLM Filter" (parameters, products)

4.7 Plans for Continued Work. Breakout D3.

Participants: **Bennett, Berenberg, Geiser, Hanus, McCartney, Neitlich, Pittam**

Task: **Discuss next steps for a smaller group to carry forward the work and connections made during the workshop. Prioritize task list for this group, including clearinghouse and core data project.**

This group identified nine next steps or tasks for the coming year.

4.71 Create an organization to support, implement and share information about lichen monitoring

Choose an identity. "Lichens and Air Quality Work Group" was suggested. This work group would include all of the participants at the meeting and any others interested in lichen bioindication of air quality and practical uses of monitoring data to manage air resources.

Create a mailing list server and website. Create a mailing list server and website to support our business and communication needs as a work group.

Action Item: Sherry Pittam and Joe Hanus created a mailing list server (airlichen@nacse.org) in October, 2001 and have created our initial web page (http://ocid.nacse.org/research/airlichen/workgroup). The list server contains the names of all the workshop participants. Anyone may subscribe by visiting the website, http://www.nacse.org/mailman/listinfo/airlichen.

4.72 Write a strategy paper

The strategy paper would describe who the Lichens and Air Quality Workgroup is and what it does, its objectives, the timelines, etc.

Action Item: Strategy paper authors will be Jim Bennett (USGS), Tamara Blett (NPS), Linda Geiser & Suraj Ahuja (USFS-NFS), Peter Neitlich & Susan Will-Wolf (FIA-FHM). This team will provide a draft that will be edited by Rebecca Reynolds and sent to the rest of the workshop participants (perhaps via our new list server - see section 4.71) and other interested parties, e.g., USFWS. The team will ask Rich Fisher to review the strategy paper and provide him with a briefing from this workshop. The goal is to have the strategy paper complete by March 15, 2002.

4.73 Form a Data Co-op

One of the hoped for outcomes of the Working Group and Strategy paper would be the creation and maintenance of a Data Co-op. The Data Co-op would share data and provide access and tools to use lichen data in air resource management. The Data Co-op should contain Working Group members representing USFS-NFS, FIA-FHM, NPS, and could contain members from universities and other agencies such as BLM, USFWS and USGS.

We envisioned that The Data Co-op would benefit the data cooperators, air resource managers, and various other users of our Clearinghouse Website who may be interested in lichen monitoring.

Should NACSE be the vehicle through which The Data Co-op operates? Sherry Pittam and Joe Hanus suggested that we could investigate this option. Currently NACSE is hosting the USFS-PNW Region website, database and query pages.

NRIS-Tools can also produce tools requested from air resource managers, with access to other information available in GIS and other modules of NRIS.

Some of the first expected products of The Data Co-op would be items 4.76 and 4.77.

Action Item: Geiser will follow up by further discussion with NACSE and NRIS.

4.74 Create a Clearinghouse

Ideally the Clearinghouse would include everything that has to do with air quality monitoring using lichens: technical reports, query-able databases, website links, tools for using lichen monitoring data. It would be a place where all the studies pertinent to various regions of the US (especially federally owned lands) are identified. It would contain an annotated bibliography.

Secondarily it could include other air quality data, e.g., NADP links.

Some of the joint products from our data co-op or working group available at the Clearinghouse website would include regional and national assessment reports, sustainability reports and information and tools to use in more specific situations such as the PSD process, NEPA documents, and Forest Plan revisions.

Some non-Air Quality uses of the Clearinghouse website might relate to biodiversity, academic searches, and habitat conservation. Once people know the data is available, there may be other types of users.

The Clearinghouse will require substantial human resources to compile and metadata preparation would be a critical quality control element.

To reduce the amount of work, we may be able to use an existing clearinghouse or metadata standard. Some possibilities:

- National Spatial Data Infrastructure, uses FTGC metadata standard.
- NBII.
- EML is a good alternative too.

Another way to reduce the workload in any one year is to create the Clearinghouse gradually, perhaps starting with a regional pilot or a few, easily gathered information products, e.g., placing reports on the internet and the electronic databasing of existing data.

There is also the possibility of linking to herbarium collections data from the Clearinghouse. This is probably a project of secondary priority…collections data only tell us what is there, not what isn't there and could be difficult to combine with other types of data. But, the Species Analyst can make distribution maps from this type of data. The search system, Species Analyst, can also pull out data from many small databases that would otherwise take a long time to search individually. Consider building a link to the Species Analyst at the Clearinghouse.

Action Item: Jim Bennett can find out what we can do at NBII. Corinna Gries can recommend whether the ASU group should serve as our clearinghouse.

4.75 Identify Core Data

Core data will be expounded upon in the strategy paper. But basically, we need to figure out which data will be accessible simultaneously from all the major databases (currently FHM, NFS, NPS) during a web query. Currently we assume it would be species distribution and tissue analysis data, but the specific fields from each database and how they can be compared is a detailed task for a future committee or workshop.

Again, studies on a smaller regional scale in areas where much interagency data is available will help us understand how the process of integrating and using data from different studies could work. Examples of such initial projects are outlined in sections 4.77 and 4.78.

Shall we use herbarium data? There are some limitations inherent in collection databases because this information is not systematically collected. But it can show known species ranges and provide information about suitable habitat. ASU and the University of Kansas have both made efforts to query herbarium databases in a generic way.

4.76 Produce a regional gradient model for western Oregon and Washington

This would combine community data from FHM and USFS-PNW Region collected using FHM protocols on the FIA/Current Vegetation Survey grid. The model would make it possible to score air quality in any forested location in the study area using lichen survey information (following the FHM lichen communities indicator protocol). The study area would be western Oregon and Washington north of the Siskyou Range.

Action Item: Peter Neitlich and Linda Geiser will produce the western PNW air quality gradient model in the spring of 2002, to be published as soon thereafter as possible.

4.77 Intercalibrate tissue data in the Pacific Northwest Region

One of the environmental variables in the gradient model based on lichen communities is tissue accumulation of sulfur and nitrogen containing pollutants. There is opportunity to combine NPS data from Olympic NP, North Cascades, Mt. Rainier, Crater Lake and possibly other NPs to complement the gradient model.

Action Item: Jim Bennett and Linda Geiser will work on integrating tissue data by the end of FY 2002.

4.78 Compose the schema of databases to come up with standards profile

Group suites of variables to identify blocks of data. Then compare and contrast variables.

Action Item: Ask Peter McCartney to make a further analysis after databases are selected.

4.79 Consider holding another meeting including a wider audience

Form a team to organize our next meeting and choose a meeting date in 1-2 years. Include representation from USFWS and Park Service to improve participation by these groups. Consider international participation (Canada, UK)?

5.1 Role of Lichen Monitoring in Air Resource Management on Federal Lands

Presenter: Linda Geiser, USDA- Forest Service, Siuslaw National Forest, 4077 Research Way, Corvallis, OR 97333, lgeiser@fs.fed.us.

What characteristics make lichens useful indicators of air quality? Lichens are symbiotic organisms consisting of a fungus and an alga or a cyanobacterium. Special physiological characteristics such as high surface area, lack of roots, lack of specialized barriers to vapors and pollutants, and rapid water absorption favor the uptake and concentration of gaseous and surface-deposited pollutants in lichen tissues. Because pollutants accumulated in lichen tissues often correlate to levels in, or deposition from, the air, tissue analysis can be used to indicate air quality. The lichen symbiosis, especially the photosynthetic partner, can be disrupted by sulfur dioxide, ammonia, fluorine, and by dry or wet deposited acidic sulfur- and nitrogen-containing particulates. Because some lichens are more sensitive to these pollutants than others, the mix of species and abundances at any one site can be used to position the site along an air quality gradient, while changes in the most sensitive species provide early warning of pollution effects.

What can lichens demonstrate with regard to air quality? Lichen data can be used to:

- Map relative intensity of air pollution and identify geographic areas of concern.
- Provide a rapid assessment of air quality at specific sites within an area for which clean site ranges or a pollution gradient model have been defined.
- Document deposition of pollutants in a Class I area and help to ascertain their source.
- Cost-effectively estimate deposition where modeling or instrumented monitoring is impractical.
- Demonstrate that air pollution is causing adverse effects to the ecosystem.
- Determine whether more expensive instrument monitoring is warranted.
- Corroborate findings from visibility, deposition, camera, surface water or other measurements or "fill in" spaces in existing networks.

What kinds of data need to be collected to do this? Data from lichen community or floristic studies, tissue chemistry, transplants, fumigation, photographic and physiological response studies can be utilized, depending on monitoring objectives. Because monitoring implies a temporal element, study design, field protocols and QA/QC program critically affect repeatability and detection of changes.

What is the FS Air program doing to capture this data? Within the USFS, all regions have sponsored or undertaken lichen monitoring within the past 20 years. Various protocols have been used, and projects have had different temporal and spatial scales, depending on the information needs. Recently, larger scale FHM, Pacific Northwest and Alaska Region programs have utilized standardized protocols, training and QA/QC programs and random or design-based sampling to establish regional baselines and monitor air quality over broad spatial scales.

What is missing and what could be done to better use lichen indicators?

- Mechanisms for using lichen data in decision-making and regulatory arenas are needed.
- Standards for acceptable tissue levels and for acceptable changes in lichen species richness, distribution and abundance would help both managers and regulators.
- Managers need improved access to lichen data, data analysis tools, and assistance with study design and implementation.

5.2 Overview of Resources for Monitoring with Lichens

Presenter: Susan Will-Wolf, FIA/FHM, University of Wisconsin, Dept. of Botany, 317 Birge Hall, 430 Lincoln Drive, Madison, WI 53706-1381, swwolf@facstaff.wisc.edu.

A brief history of lichenology

1700: 'Lichens' distinguished by name as a distinct group of plants, akin to fungi and/or algae.
1800s on: Widespread scientific study of lichens.
1859: First published report of the sensitivity of lichens to air pollution (England).
1860-1900: Debate of the theory that lichens are a symbiosis between an alga and a fungus.
1870s on: Hundreds of field studies relating species decline to point sources of air pollution, mining, urbanization.
1950s on: Field studies relating lichen response to monitored/measured air pollutants. Laboratory studies of lichen physiology and mechanisms of response to pollutants.
1980s on: Increased emphasis on studies of nonpoint-source (regional) air pollution impacts and other stressors on lichens: forestry, grazing, habitat fragmentation, and loss of habitat continuity.
1990s on: Molecular studies influence lichen taxonomy, help identify lichen characters which are environmentally plastic and increase the value of lichens as ecological indicators.
Currently lichenology worldwide includes systematics, physiology, morphology, evolution, ecology, inventory and biodiversity assessment, and use as environmental indicators. The greatest concentration of lichenologists and the best-known lichen biota are in Western Europe.

Kinds of institutions studying lichens: How and why?

Entities with asterisk * are officially represented at the workshop

USA:

Federal: United States Departments of Agriculture (USDA) and the Interior (USDI)

- **Forest Inventory and Analysis (FIA) Program/ Forest Health Monitoring (FHM) Program* - Monitor forest macrolichens on a nationwide permanent grid for response to air quality, climate, other. 10-year cycle. Databased, web access.
- **National Forest System (NFS)* - Monitor forest macrolichens using FIA/FHM protocol on NF permanent plots, denser grid, for response to air quality, other. Element analysis of selected species. Additional floristic inventories and local studies using other protocols.
- **Natural Resource Information System (NRIS)* of the USFS. NRIS-Air module, under development, will be a centralized database for information on NFs.
- **National Park Service (NPS)* - Surveys of common species in NPs annotated by pollution sensitivity, element analysis of selected species. Data in spreadsheets, floristic data on web. Numerous additional local projects in various national parks.

States

- Several states have lichen bio-monitoring programs, for air quality and lichen biodiversity assessment.

Nongovernmental Organizations (NGOs)

- The Nature Conservancy (TNC), for example, collaborates with states, federal programs, inventories lichens, and identifies conservation.

USA and International: Academic and Related Resources

- Academic Institutions - train lichenologists, maintain herbaria, collaborate with other entities to conduct research on biology of lichens, applications as environmental indicators. *Arizona State (ASU), *Brigham Young, Oregon State, *Imperial College, UK, others.

- Major herbaria - see ABLS (below) web site for links. Archive lichen specimens, validate floristic data, support lichen research. Many have species lists, information on web sites.
- *Northwest Alliance for Computational Science and Engineering (NACSE): assist data owners with development and management of databases and web interfaces.
- Northwest Lichenologists, Inc.: affiliated with Oregon State (OSU), others. Outreach, training, certification of regional lichenologists. Web site with tutorials, keys, links.
- Eastern Lichen Network: based at New York Botanical Garden (NYBG), support taxonomic work by both professionals and serious amateurs.
- Professional societies - journals, web sites with links to checklists, literature databases, herbaria, many useful lichen web pages, etc.
- American Bryological and Lichenological Society (ABLS) - journal, *The Bryologist*, with feature (also online) 'Recent Literature in Lichenology.'
- British Lichen Society (BLS) - journal, *The Lichenologist*, with feature (also online) 'Literature on Lichens and Air Pollution.'

International: Several European countries have or have had lichen monitoring programs.

Human resources: Because there are fewer lichen specialists and trained non-specialists in the USA than in western Europe, human resources for conducting lichen bio-monitoring are much more limited in the USA than in western Europe. Addressing this is a significant need.

Interconnection and overlap: Current state and needs

- *FIA and FS* use same methods and have spatially overlapping coverage. FIA coverage is broader and less dense; provides context in analysis for narrower and denser coverage of FS.
- *FIA and NPS* use different methods and have overlapping coverage. FIA can provide fairly general context for interpretation of NPS data with narrower coverage.
- *FS and NPS* use similar element analysis methods with non-overlapping, but interspersed coverage. Data can be interpreted as generally complementary. They use different methods for lichen species data; are generally complementary to a limited degree.
- *FIA and BLM* coverage mostly different methods and non-overlapping; can be considered generally complementary to a limited degree.
- *FIA* can provide general context to some degree for most local/regional air quality monitoring projects for almost any other USA entity, after FIA coverage has been completed.

Ecological Perspective on Interconnections

Research has shown that cause and effect relationships in ecological systems differ at different spatial and temporal scales. The response of lichen communities to air pollution across regions seen from FIA data should be expected to be somewhat different from that seen in FS and NPS data sets. The differences can be interpreted in terms of interaction of ecologically important environment and human management variables with air quality variation. Apparent contradictions in analysis outcomes often disappear when differences in spatial and temporal scale are considered.

Sensitivity of lichens to different air pollutants is known generally across the country; there is also some evidence from monitoring programs that apparent sensitivity, and relative sensitivity, vary across the geographic range of lichen species and with respect to the state of other stressors. Data from current and future monitoring programs will refine knowledge of variation in sensitivity and vastly improve our interpretation of lichens as ecological indicators.

5.3 Considerations for the Construction of Lichen Databases

Presenter: Corinna Gries, Arizona State University, Dept. of Plant Biology, Tempe, AZ 85287, corinna@asu.edu.

Relational database platforms:
(Examples are increasing in size, scalability, efficiency, cost, and maintenance effort)
MS Access, Paradox (and many others): Desktop database systems, which do not scale well and are difficult (or impossible) to use for serving data on the internet. They serve well as a starting point for data collection. MS Access works well as a front-end application (user interface) and development tool if used in conjunction with a SQL Server. They are free or cheap and fairly "beginner friendly" with good documentation.
SQL Server: Microsoft's database engine for larger scale databases and serving live data on the web. Has Microsoft's security problems.
Oracle / Sybase: Enterprise size database systems. Highly recommended if it is provided and managed by the institution. Run on Windows and Unix.

General database design considerations:
Databases should be designed to serve the data best and not a particular question.
Avoid storing redundant information by designing several tables, linking information as necessary, but too many tables make a database difficult to handle.
Keep information as consistent as possible (spelling of collector names, description of places) by providing input masks and developing pick lists.
For any kind of descriptive information (e.g. substrate) consider developing a keyword taxonomy (e.g., bark, coniferous tree, *Juniperus*). The more thought out the keywords, the more efficient the information retrieval.
Develop a species checklist for your area (pick from an existing one) to assure highest taxonomic accuracy possible.

Database types and implications for use:
Collections databases: Data are based on collected specimens that are stored in an herbarium. These databases should provide the highest degree of taxonomic information as specimens can be studied. They do not necessarily provide precise information on small-scale distribution and certainly not on abundance.
Observation databases: Data are based on observations backed only by the occasional (representative) specimen. Emphasis is on absence/presence and sometimes abundance. Data are usually collected based on a sampling design to test a hypothesis. Especially in lichen observations the taxonomy may not be resolved as thoroughly as in collections databases.
Measurement databases: Additional data on the ecology of the species, e.g., sensitivity to certain air pollutants as measured in the laboratory, or health status in a certain area.

All of these databases are useful for the kinds of questions air managers might ask and interoperability can only be achieved through highly standardized and high quality metadata. Standards for the structure of these metadata are being developed by various groups, (ISO, FGDC, NBII, EML), and specific sets of metadata may have to be developed depending on the questions asked. We suggest XML technologies to achieve this.

5.4 Strategies for Connecting Independent Databases

Presenter: Peter McCartney, Arizona State University, Center for Environmental Studies, Tempe, AZ 85287-3211, peter.mccartney@asu.edu.

This conference seeks to develop the role of lichen databases within the broader context of environmental monitoring. This goal challenges data developers to view their data products outside the perspective of the localized research contexts in which they were derived, and to think of how they will scale across several dimensions. Minimally, we need to integrate lichen data sources from different geographic areas. In a similar vein, we want to integrate across taxonomic boundaries within similar spatial contexts. We also wish to join lichen data with other classes of information such as systematics databases for resolving taxonomic name information, character set databases for accessing behavioral data or identification keys, and field research data.

Finally, we must be more conscious of the abilities and needs of different end user groups such as research, education, and policy makers, and begin targeting applications to specific audience groups.

Guidelines for integrating collections data into scalable information systems can been seen in recent activities at Arizona State University and at Kansas Natural History Museum. Since the ultimate basis for a system is quality databases with a commitment to long-term management, ASU has invested effort into assisting collections such as the Lichen herbarium with improvements to database design, porting them to more robust server platforms with connectivity, and developing management tools. The next goal has been to make improvements that facilitate the kind of integration we wish to do. This includes improving the quality and standards for taxonomic name resolution and geo-referencing. A common taxonomic name directory and literature database have been constructed and are being cross-linked as references to all environmental databases at ASU. Work is underway to provide a similar reference for spatial locations via GIS and gazetteer databases.

While it is possible to identify many design standards that facilitate data exchange, the reality is that distributed information systems are typically built upon many individual sources that have their own unique structure, content, and software/hardware properties. To overcome these differences, we need to recognize the importance of standards for query and exchange of data. The Kansas Natural History Museum has developed the ZBIG profile for exchanging biological collections data. ASU has been participating in a group effort to define ecological metadata standards, one of which could be used for describing biological collections. Databases can then be integrated by installing local output tools for translating data into common formats.

Exchange standards permit the possibility for a common language for query. The Species Analyst is a globally integrated search system that uses the Z39.50 query standard for searching remote collections databases. ASU is working on networked solution that works in a similar way, but takes advantage of the flexible and hierarchical nature of extensible markup language (XML) to better enable searching across different kinds of data sources.

End user applications can be designed to use on these networked data access systems to address problems at new scales. A well-known example is the Biodiversity Species Workbench, a web based tool for calculating species distributions using the Species Analyst as input. To improve the quality and sophistication of such applications, we need more effort in getting existing datasets online, documented, and integrated via the types of mechanisms described here.

5.5 The Forest Service Natural Resource Database: NRIS Air. What is it?

Presenter: Pam Corey, USDA Forest Service, NRIS-Air, Mt. Hood National Forest, 16400 Champion Way, Sandy, OR 97055-7299, pcorey@fs.fed.us.

N-R-I-S stands for the "Natural Resource Information System". Organizationally, NRIS employees are part of Ecosystem Management Coordination (EMC) staff at the Washington Office of the USDA Forest Service. We focus on data from National Forest System lands. FIA (Forest Inventory and Analysis) is organizationally located within the Research and Development Deputy Area. FIA utilizes data collected across all ownerships. Overlap between the two programs currently consists of a work plan between NRIS and FIA that would lead to the ability to pass data as efficiently and as appropriately as possible from central FIA repositories to the distributed NFS NRIS database environment. This would allow NFS analysts to continue to use the tools that are being developed to operate within the NRIS environment.

NRIS is a series of databases and computer applications that link spatial and tabular data that were collected and recorded in a consistent manner. It is designed for field-level employees to support the on-the-ground work we do. NRIS enables Forest Service managers to make more informed decisions about management limitations and opportunities during assessments and analyses.

NRIS is comprised of seven modules—six database modules that store natural resource information (Air, Fauna, FSVeg, Human Dimensions, Terra and Water) and one tools module that develops computer applications and tools to be used by the other six modules. As one of these modules, the Air module is a corporate database application designed to assist air resource managers in analyzing the effects of air pollutants on natural, cultural, and social resources managed on National Forest lands.

In 1992, the Forest Service Air Program initiated an information management program that laid the groundwork for NRIS Air. Initial work focused on providing a national listing of key information for the 88 National Forest Wildernesses that have the highest degree of protection under the 1977 Clean Air Act Amendments (known as "Class I Areas"). This initial information included Air Quality Related Values. It has expanded since then to include water chemistry, visibility and ambient air data related to those Wildernesses, and in some cases, other areas on Forest Service lands.

Exchange standards permit the possibility for a common language for query. The Species Analyst is a globally integrated search system that uses the Z39.50 query standard for searching remote collections databases. ASU is working on a networked solution that works in a similar way, but takes advantage of the flexible and hierarchical nature of extensible markup language (XML) to better enable searching across different kinds of data sources.

End user applications can be designed to use these networked data access systems to address problems at new scales. A well-known example is the Biodiversity Species Workbench, a web based tool for calculating species distributions using the Species Analyst as input. To improve the quality and sophistication of such applications, we need more effort in getting existing datasets online, documented, and integrated via the types of mechanisms described here.

5.6 Building NRIS Air's Lichen Module

Presenter: Rob Crump, USDA Forest Service, NRIS-Air, Mt. Hood National Forest, 16400 Champion Way, Sandy, OR 97055, rcrump@fs.fed.us.

As with any project, defining the business requirements is a critical first step. This workshop will provide major foundational work for, not only defining the business requirements, but also in helping to determine how the lichen module should/can be built within the constraints and parameters of the NRIS-Air application.

Our intent is to build a module that meets the majority of the needs of the Federal Air Managers while providing links to other agencies and private sector lichen data resources.

The database that the Pacific NW Region Air Program has built and is hosted at Oregon State University will be used as a guide. We will work to crosswalk that database structure to the NRIS-Air structure with the intent to bring the current data across into the Air application. The proposed timeframe to accomplish this task is this fiscal year, Oct. 2001 through Sept. 2002. Of course budget constraints along with NRIS priorities may alter this plan.

The lichen module would ideally have the functionality to import lichen data from already existing datasets. A process to crosswalk the structures would need to be developed. We have the tools to assist in this task; we may or may not have the personnel to do these tasks immediately. Each external dataset would need to be reviewed and worked on individually to ensure compatibility.

Almost all of NRIS is built utilizing Oracle as the backend database. This creates some challenges but they are usually not insurmountable. Specifications of target end-user platforms and end-user capabilities will need to be assessed in the development of the database.

We do share tables with other applications and specific to the lichen module; we will look to the NRCS PLANTS table for lichen descriptions, etc. At this time NRIS-Terra is planning to steward this table for all of NRIS to use. They will coordinate with NRCS to ensure that updates are reflected in the table that NRIS Terra maintains. Other shared tables include States, Counties, USGS Quads and Organizations. These are stewarded by the Automated Lands Project (ALP) application.

The Air application developers will need to have some understanding of the business requirements of the Lichen community. As stated earlier, this workshop will be the starting point for much of what the developers need. We call this "customer representation". This customer representation will assist with the various analytical tool developments along with GIS capabilities. Again, this workshop will provide the foundation for this development.

6. Lichen Monitoring and Research Programs in the US and UK

Contacts from each of the participating entities at the workshop were asked to prepare a one-page "fact sheet" describing lichen-related program objectives and the way in which lichen information is gathered, stored and used by their agency or institution. The fact sheets are presented here.

6.1 Arizona State University

Contact Name: Thomas H. Nash III
Phone: (480) 965-3414
Entity Website: http://mgd.nacse.org/Arizona/
Email: tom.nash@asu.edu

The entity's lichen research/monitoring objective(s):

- ASU Lichen Herbarium provides a repository for over 90,000 worldwide collections, many of which are from parks and forest service lands in the Southwest.
- Conduct basic research on the effects of air pollutants (sulfur dioxide, ozone, nitrogen oxides, formaldehyde, heavy metals) on lichens, including controlled laboratory fumigations and field investigations (southern California, Mexico City, etc.).
- Conduct deposition monitoring research using lichens as surrogate receptors.

What type of lichen research/study (if any) is this entity conducting?

- Greater Sonoran Desert Lichen Flora project – supported by NSF.
- Spatial and temporal elemental deposition trends in Maricopa County, Arizona – supported by the Phoenix LTER (NSF).
- Mechanisms underlying differential sensitivity to gaseous air pollutants (formerly EPA supported).

How does this entity store and access lichen data?
Collection data are stored in SQL Server and made available for searching at http://cochise.asu.edu/collections/index.html. Over 50,000 records are currently available. Data from LTER related research project are also stored in SQL Server and are accessible through the data catalog at http://caplter.asu.edu.

How does this entity use lichen data now?
After synthesis, in the publication of scientific research papers, review articles and books. Also in the support of graduate theses and dissertations.

How would the entity envision using lichen data in the future?
Continue as above, but establish closer working relationships with federal agencies.

With what other entities does this one cooperate in relation to lichen research/data?
Instituto Mexicano del Petroleo and Universidad Nacional Autonoma de Mexico (both Mexico City).

What other information about this entity do you want to share with the Lichen Workshop participants?
This will be demonstrated at the workshop.

6.2 Brigham Young University Herbarium of Nonvascular Cryptogams

Contact Name: Larry L. St. Clair **Phone**: (801) 378-4879
Entity Website: http://bioag.byu.edu/mlbean **Email:** larry_stclair@byu.edu

The entity's lichen research/monitoring objective(s):

- Establish lichen air quality bio-monitoring baselines and programs throughout the intermountain western United States.
- Serve as a repository for lichen specimens from air quality bio-monitoring reference sites from the intermountain western United States.
- Maintain archival collection of elemental analysis samples from the intermountain western United States.

What type of lichen research/study (if any) is this entity conducting?

- Establish lichen air quality bio-monitoring baselines and programs throughout the intermountain western United States.
- Evaluate lichen-mediated bio-deterioration of prehistoric and historic rock surfaces.
- Characterize lichen communities as a component of microbiotic soil crusts in arid and semi-arid habitats.

How does this entity store and access lichen data?

- Lichen and bryophyte specimens in the Brigham Young University Herbarium of Nonvascular Cryptogams is currently being databased using Microsoft Access. The program uses a custom menu-driven data entry approach.
- Lichen collections and elemental analysis data from more than 350 air quality bio-monitoring reference sites in the intermountain western United States have been databased, using funds from the USDA Forest Service using Paradox.

How does this entity use lichen data now?

Lichen collections in the BYU Herbarium of Nonvascular Cryptogams are used:

- To document species distribution patterns in the western United States.
- To prepare various types of systematic surveys and monographs. Currently, a worldwide monograph of the lichen genus *Lobothallia* is in process.

How would the entity envision using lichen data in the future? N/A

With what other entities does this one cooperate in relation to lichen research/data?

We collaborate and have exchange programs with lichen herbaria throughout the world.

6.3 Bureau of Land Management

Contact Name: Roger Rosentreter **Phone:** (208) 373-3824
Entity Website: http://www.id.blm.gov **Email:** roger_rosentreter@blm.gov
http://www.soilcrust.org

The entity's lichen research/monitoring objective(s):
Evaluation of air quality and the determination of the rarity or status of the lichens present on Bureau of Land Management administered lands.

What type of lichen research/study (if any) is this entity conducting?

- Coordination with the USFS Forest Health Monitoring Program.
- Distribution, ecology and management of uncommon-rare Lichen species.
- Ecology and Management of biological soil crusts in rangelands of western North America.

How does this entity store and access lichen data?

- Data on Forest Health Monitoring is stored with the USFS FHM program.
- Biological soil crust data is not centrally located or coordinated.
- Rangeland data on biological soil crusts is kept by each individual field office.

How does this entity use lichen data now?

- Evaluation of Forest Health.
- Determining the rarity or status of lichen taxa.
- Evaluation of rangeland health.

How would the entity envision using lichen data in the future?

- Evaluation of air quality in Bureau wilderness areas and National monuments.
- Determine lichen taxa status for other eco-regions.
- Evaluate biological soil crust cover by vegetation type by eco-regions.

With what other entities does this one cooperate in relation to lichen research/data?
USGS, USFWS, and academia.

What other information about this entity do you want to share with the Lichen Workshop participants?
Bureau publications on biological soil crust and on rare lichen taxa are available at the Idaho BLM web site: http://www.id.blm.gov.

6.4 Forest Inventory and Analysis (FIA)/Forest Health Monitoring (FHM) Lichen Communities Indicator

Contact Name I: Peter Neitlich (West)
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Contact Name II: Susan Will-Wolf (East)
Phone: (608) 262-2754
Entity Website: http://www.wmrs.edu/lichen
Email: swwolf@facstaff.wisc.edu

The entity's lichen research/monitoring objective(s):

- To provide early detection and quantification of potential air pollution impacts on forest biodiversity, productivity and timber production.
- To monitor spatial and temporal trends in air quality and climate response.
- To provide standardized, nationwide information on lichen biodiversity in forested ecosystems.
- To document changes in lichen communities themselves related to air quality deterioration or improvement, as well as to climate change, over long time periods.

What type of lichen research/study (if any) is this entity conducting?
This is a national-scale effort utilizing a 28 x 28 km sampling grid covering all forested lands in the country and including approximately 7800 plots. FIA gathers data on macro-lichens growing on woody substrates on 0.38 ha (1 ac) plots. Community data is used to construct gradient models to score each plot on climatic and air quality gradients. Scores can be tracked spatially and temporally.

How does this entity store and access lichen data?
Data are archived in an oracle database along with the complete set of forest mensuration data at the FIA-Las Vegas Information Management Group center. Distilled datasets are accessible via FTP at ftp://fhm-server.lv-hrc.nevada.edu/pub/web_data/. Complete datasets of community data are also available from the indicator advisors.

How does this entity use lichen data now?
The program uses lichen data for assessing trends in air quality and climate across regions with gradient models, for construction of gradient models in other regions, and for biodiversity information.

How would the entity envision using lichen data in the future?
We envision completed gradient models for Lichen Community monitoring in all 50 states, augmented by tissue data collection and intensive studies on air quality, forest management and forest health**.**

With what other entities does this one cooperate in relation to lichen research/data?
We share basic protocols with the USDA/FS Lichen Air Quality Program and share data with all users included in the FHM and FIA networks.

What other information about this entity do you want to share with the Lichen Workshop participants?
We welcome the opportunity to find out how we might package and/or analyze our data to meet the needs of a more diverse pool of potential users. Our Information Management teams and Analysis teams are most interested in cooperative uses for our data.

6.5 Imperial College, London University, England

Contact Name: Linda Davies
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Email: linda.davies@ic.ac.uk

The entity's lichen research/monitoring objectives:
To evaluate the role of bio-monitoring in air quality management and environmental protection both from a policy and scientific perspective.

What type of lichen/research study (if any) is this entity conducting?
The impact of nitrogenous compounds from vehicle emissions on lichen distribution and vitality is being studied to identify tolerant and sensitive species and establish. The research is supervised by Professor J.N.B.Bell, Professor of Environmental Pollution at Imperial College, Dr. J.W. Bates (Imperial College and British Lichen Society Council) and Dr. O.W. Purvis (Natural History Museum, London and British Lichen Society Council).

How does this entity store and access lichen data?
Lichen survey data in the UK is coordinated by the British Lichen Society (http://www.theBLS.org.uk) and uses Biobase and Recorder.

How does this entity use lichen data now?
There are no regulatory systems using lichen data at the present time nor accredited survey techniques. A proposed European methodology for bio-monitoring of gaseous pollutants will be tested in 2002.

How would the entity envision using lichen data in the future?
Air quality in the UK has changed dramatically over the past fifty years with very high concentrations of sulfur dioxide being reduced to a current annual average of 20 ugm^3 (the European Standard to protect sensitive vegetation and ecosystems) at many locations. The main pollutants of concern now are nitrogen dioxide, particulate matter (PM10) and ozone. Lichen distribution is still disturbed by a legacy of acidified substrates, slow re-invasion and colonization rates and the impact of transport emissions and new industrial processes on distribution. The challenge is to establish causality in sensitive species leading to the development of a biological monitoring program of appropriate robustness for environmental protection and regulatory regimes. Accumulation potential and responses to gaseous compounds and particles including metals are of interest. Confounding variables such as temperature and humidity require quantification.

With what other entities does this one cooperate in relation to lichen research/data?
I coordinate the Air Pollution Research in London Network (APRIL: http://www.ic.ac.uk) from Imperial College where links to the European Association for the Science of Air Pollution (www.meteo.bg/EURASAP) and other European biological monitoring networks have been established. Cross-disciplinary research projects addressing London's air quality problems are developed through this network including research into the impact of pollution on flora and fauna. The contact is a member of the BLS Education and Publicity Committee and is Head of Research & Development at the National Society for Clean Air (www.NSCA.org.uk), who provides the secretariat to the International Union of Air Pollution Prevention Associations (IUAPPA). NSCA are working closely with the regulatory authorities to develop Technical Guidance for Industrial practitioners to meet their statutory obligations under the European Integrated Pollution Prevention and Control (IPPC) regime.

6.6 National Park Service Lichen Biomonitoring Project

Contact Name: James P. Bennett, USGS **Phone:** (608) 262 5489
Entity Website: http://www.ies.wisc.edu/brd **Email:** jpbennet@facstaff.wisc.edu

The entity's lichen research/monitoring objective(s):

- Determine presence/absence of common, rare, and sensitive species in parks.
- Determine elemental baselines and trends of chemical elements in parks.
- Conduct lichen elemental chemistry research as needed.

What type of lichen research/study (if any) is this entity conducting?
Common and/or targeted species are collected in many habitats and the geographic extent of a park. Sample numbers vary from one up to hundreds depending on the size of the park. Parks are re-sampled every five years if possible. Related research studies are often included in the biomonitoring design.

How does this entity store and access lichen data?
Data are quality assured, then made available to parks in hard copy form (report) as well as electronic. All files are stored on various computer hard disks and floppy disks in *Excel* spreadsheet format. Elemental data are not yet available on a website, but floristic data are. A typical data file will contain fields for year, park, locality, species, latitude, longitude, date, and chemistry fields for up to 25 elements, including ash content. No metadata are available, although USGS NBII metadata are required.

How does this entity use lichen data now?
Analysis of spatial and temporal trends in lichen chemistry in parks; studies of large-scale elemental patterns; studies of differences between species; establishment of baseline levels for common species; determinations of possible sources in and around parks.

How would the entity envision using lichen data in the future?
Continue as above, but include wider area datasets from other sources if compatibility is assured. Further studies coupling presence/absence of species with elemental data. Determine ecological factors affecting lichen chemistry.

With what other entities does this one cooperate in relation to lichen research/data?
None right now, but would like to cooperate with others doing similar work.

What other information about this entity do you want to share with the Lichen Workshop participants?
This will be provided at the workshop.

6.7 Northwest Alliance for Computational Science

Contact Name: Joe Hanus or Sherry Pittam **Phone:** (541) 737-6606
Entity Website: http://www.nacse.org/databases/ **Email:** hanusj@nacse.org or pittams@nacse.org

The entity's lichen research/monitoring objective(s):
N.A.

What type of lichen research/study (if any) is this entity conducting?
N.A.

How does this entity store and access lichen data?
N.A.

How does this entity use lichen data now?
Assist data owners with problems related to making data available to the world wide web, and with data storage and retrieval problems in general.

Consultant to data owners, specializing in usability of web interfaces, design of web interfaces, database design, software development for research scientists.

How would the entity envision using lichen data in the future?
Same as above

With what other entities does this one cooperate in relation to lichen research/data?
Academic, Federal, State and Industrial Researchers

What other information about this entity do you want to share with the Lichen Workshop articipants?
Our organization (Northwest Alliance for Computational Science and Engineering) specializes in database management and web interface and software design. Several of us with our research team, including Joe Hanus and Sherry Pittam, have formal training in research science; we work with computer scientists to build software and web sites for the scientific community.

6.8 USDA-Forest Service Pacific Northwest Region Air Resource Management Program

Contact Name: Linda Geiser **Phone:** (541)-750-7058
Entity Website: http://www.nacse.org/lichenair **Email:** lgeiser@fs.fed.us

Lichen research/monitoring objective(s):
The overall objective is to help Forests fulfill federal and agency responsibilities for the detection and description of air pollution effects and the protection of Forest air resources. Lichen data are used to identify geographic areas of concern and assess changes in air quality over time. To do this, we:

- Identify and assess air pollution sensitivity of common, regional lichen species and map their distribution within the Region.
- Establish background ranges for element concentrations in lichen tissue, define enhanced levels of sulfur, nitrogen and metals, produce regional baseline maps, and track changes.
- Map wet deposition of sulfur and nitrogen using calibrating lichen tissue data.
- Establish a regional gradient model and map air quality using lichen communities.

Type of lichen research/study being conducted:
The backbone of the program is monitoring conducted at 1500 permanently marked sites on the 3.4 mile Forest Inventory and Assessment (FIA) grid across nine national forests in OR and WA. Field crews visit all 3.4-mile plots on each Forest over a four-year period, repeating the four-year round every ten years. At each site, two of ten regional target species are collected for tissue analysis of S, N, metals and other elements. Composition and abundance of epiphytic macrolichens are surveyed using the FHM protocol. Physical and vegetation data from the FIA database are accessed and used in analysis of lichen community data. Specially-designed studies are carried out to answer specific questions, address different pollutants, or produce higher intensity maps where new or existing emission sources may adversely affect condition of forest resources or ecosystems.

How does this entity store and access lichen data?
The data are currently stored in Paradox on a PC at the Siuslaw NF with backups on the Forest network server. The database consists of four tables, linked by site number, containing QC and site-specific information about the lichens collected; element concentrations of target species; physical attributes, climate, and habitat at the sites; and composition, structure and age of the forest stand. Lookup tables ensure correct and uniform spelling for lichen, plant and place names. Once or twice annually the Paradox tables are copied to Sybase at NACSE, from which the database is web-accessible. Field names are linked to a data dictionary on the website. Monitoring protocols and reports are being made available from the website in pdf format. The data is also in the Interagency Species Management System (ISMS), an Oracle-based, regional, interagency database that tracks rare and old growth associated species. Eventually the PNW region lichen data, along with other national forest lichen data will be part of the Forest Service NRIS-Air corporate database.

How does this entity use lichen data now?
Data is used to:

- Identify geographic areas of concern.
- Demonstrate adverse affects to biological communities.
- Corroborate other types of measurements.
- And are used with other data from regional/national visibility, camera, ozone, surface water chemistry and deposition networks to aid decision-making in management and regulatory arenas.

How would the entity envision using lichen data in the future?
Similar to present, but we would like to see a wider familiarity with and acceptance of lichen data among the regulatory community, more interaction across federal agencies in areas where there are multiple federal ownerships to map and monitor air quality, and better integration of biological monitoring with instrumented monitoring by the air resource management community.

With what other entities does this one cooperate with in relation to lichen research/data?
On-going cooperation with 1) NACSE for web-accessibility, 2) FIA/FHM for crew training and development of a regional air pollution gradient model and air quality map based on lichen communities, 3) other FS Regions to create a national lichen database. Have also collaborated on joint projects with the Alaska and Rocky Mountain Regions of the USFS, the National Park Service in the PNW and Alaska, and Environment Canada in British Columbia and Alberta.

What other information about this entity do you want to share with the Lichen Workshop participants?
Visit our website!

7.3 Accessing Monitoring Information

7.31 Strategies for Connecting Independent Databases

Peter McCartney, ASU. Introduces, for the computer literate, the mechanics of connecting related, but independent databases.

7.32 Northwest Alliance for Computational Science

Joe Hanus and Sherry Pittam, OSU-NACSE. How NACSE helps biologists make their information web-accessible. Introduces the Data Pool concept.

7.33 ASU/LIAS/ABLS

Robin Schoeninger, ASU. A review of the ASU Herbarium website and other lichen-related websites.

7.34 On-Line Lichen Keys

Tom Nash III, ASU. A prototype of an interactive lichen key based on 570 species appearing in Vol. I of *Lichen Flora of the Greater Sonoran Desert* was demonstrated. Interactive keys do not follow the strict dichotomous format of traditional keys, but rather utilize multiple character sets, from which one chooses whatever is readily observable. It can be a very powerful tool, in that most species can be keyed in relatively few steps. Potentially it will be very useful for groups utilizing lichens as bioindicators of air pollution, in that it will reduce the need for extensive prior training before one can correctly identify lichens of a target area. The prototype is based on approximately 50 character sets from the over 700 available through LIAS (LIchenized AScomycetes, http://www.lias.net/index.cfm) and utilizes INKEY, which is part of the CSIRO Delta program package. Funds are being sought to expand coverage to other species both in North America and elsewhere, and to develop a mechanism to have it available over the web or as an independent system (CD or otherwise).

8. Glossary of Terms and Acronyms

ABLS - **American Bryological & Lichenological Society**.

Access - relational database systems for personal computers.

Apothecium (pl. apothecia) - fruiting bodies of the ascomycete fungi, about half of which are lichenized.

Application - a computer program; software.

AQRV - **Air Quality Related Value,** a scenic, cultural, physical, biological, ecological, or recreational resource which may be affected by a change in air quality as defined by the Federal Land Manager (FLM) for federal lands.

Background - as it pertains to air quality, a dataset describing conditions in clean areas.

Baseline - a dataset describing conditions at the onset of a study.

Cell - location in a table, e.g., column 4, row 3.

Community analysis - the analysis of lichen communities, i.e. species composition, richness and abundance to assess air quality. Used to document direct effects of air pollution on the ecosystem. Sensitive species decline as pollution increases.

Cortex - The outer "skin" of lichens, generally more or less smooth, often glossy, composed of closely packed fungal cells.

Crustose - a lichen growth form that is crust-like, i.e. closely adhered to the substrate, like paint, lacking a lower cortex, and not separable from the substrate.

Database (a.k.a. table space) - a collection of tables, relationships between tables, stored procedures, queries, and sometimes input and management applications.

EML - **Ecological Metadata Language.**

Epiphytic lichen - a lichen that grows on other plants, usually trees or shrubs. Epiphytic lichens have good exposure to the air and are less influenced by soil or mineral chemistry than ground or rock-dwelling lichens and are often used to monitor air quality in forests.

Exposure or fumigation studies - in air quality biomonitoring, exposure and fumigation studies expose lichens to controlled levels of pollutants and study their response. They are can be used to define the sensitivity of a lichen to specific pollutants.

Federal Class I Area - geographic area designated for the most stringent degree of protection from future degradation of air quality. National Parks over 6,000 acres and National Wildernesses over 5,000 acres that existed as of August 7, 1977.

FGDC - **Federal Geographic Data Committee.**

FHM - **Forest Health Monitoring.**

FIA - **Forest Inventory and Assessment.**

Field - a column in a table containing one kind of information, e.g., location, abundance, or elevation.

FLAG - **Federal Land Managers' Air Quality Related Values Workgroup.**

Flat file - single table with all the fields across the columns (like a single page spreadsheet).

FLM - **Federal Land Manager.**

Floristic study - a study of lichens species present in an area. In air quality biomonitoring, floristic studies are used to document the number of species present, their abundance, and to determine whether sensitive species are present.

Foliose - a lichen growth form that is leaf-like, i.e. two dimensional with a distinct upper and lower cortex, loosely to tightly appressed, but separable from the substrate.

Fruticose - a lichen growth form that is shrubby or string-like, upright or pendulous, i.e. three dimensional, easily separated from the substrate, surrounded by cortex but not forming different upper and lower surfaces.

FSVeg - Field Sampled Vegetation. Legacy vegetation inventory data belonging to the US Forest Service.

GIS - Geographic Information Systems.

HTML - Hypertext Mark-up Language.

IMPROVE - Interagency Monitoring of Protected Visual Environments, a long-term monitoring program developed to establish the current visibility conditions, track changes in visibility, and determine causal mechanism for the visibility impairment in National Parks and Wilderness Areas.

Isidium (pl. isidia) - a minute, asexual lichen reproductive structure that is finger-like or globular, branched or unbranched, but covered by cortex and containing both the fungal and photosynthetic partner.

ISO - International Standards Organization.

LAC - Limits of Acceptable Change, the amount of change that could occur without significantly altering an AQRV or sensitive receptor.

LIAS - Lichenized Ascomycetes website.

Lichen - a fungus with an intimate, symbiotic association with a photosynthetic green alga or a cyanobacterium. There are about 3500 species in the continental United States and Canada.

Lichen bio-monitoring - monitoring lichens to indicate the condition or changes in a resource. For example lichens have been used to assess air quality, forest health, deposition monitoring, climate change, and forest continuity.

Linux - a computer operating System; a free version of Unix.

Macrolichens - foliose & fruticose lichen growth forms. Macrolichens are easier to collect and identify than crustose lichens, and are good target species for tissue collection and community analysis.

Metadata - 1) information about the database, e.g., definition of the table structure the data is stored in, or a description of all the fields in a database and information about what is stored in each field. 2) Data about data. Detailed description of the database structure, access to the database, responsible people and the data in the database. That is, methods for sampling, analysis, quality assurance and control, etc.

Metadata Standard - e.g., NBII standards and Ecological Metadata Language (EML) – defines what kinds of fields should be in database and what they should do, plus what other parameters are necessary to describe the data, so that other people can use them without further instruction from the author.

NAAQS - National Ambient Air Quality Standards, legal limits of atmospheric pollution established by the EPA, as the concentration limits needed to protect the public against adverse effects on public health and welfare.

NACSE - Northwest Alliance for Computational Science and Engineering.

NBII - National Biological Information Infrastructure.

Non-attainment Area - an area that does not meet one or more of the National Ambient Air Quality Standards.

NRCS - Natural Resources Conservation Service.

NRIS - Natural Resource Information System.

Oracle - relational database systems for larger applications, industrial strength databases

Paradox - relational database systems for personal computers.

Place location - UTM (Universal Transverse Mercator), Lat/Long, County, Township Range or verbal description of the location.

PSD - Prevention of Significant Deterioration, a permitting process that requires emissions limitations for certain new or modified sources of air pollution. The Forest Service has input into this process by providing comment to air regulatory agencies on potential source impacts to air quality related values.

QA/QC - Quality Assurance/Quality Control; quality assurance is the set of procedures or protocols that ensure the data will be able to meet a defined, minimum standard. Quality control is the set of standard reference materials, blanks, replicates and other data collected to demonstrate that QA standards have beenmet.

QML - Query Mark-up Language.

Relational database - a database consisting of multiple tables linked through common fields.

Sensitive Receptor - an attribute of an AQRV that is most receptive to, or first affected by, air pollution, e.g., lichen communities.

Sensitive Receptor Indicator - a measurable, physical, chemical, biological, or social characteristic of a sensitive receptor, e.g., lichen tissue chemistry.

Server - a central computer serving as a repository for files, of applications, or services

SOAP - Simple Object Access Protocol, a protocol for using XML on the internet.

Soredium (pl. soredia) - an asexual lichen reproductive structure that is powdery to granular, not covered with a cortex, and contains both the fungus and photosynthetic partner.

SQL - structured query language, a language for retrieving data from a database.

Substrate - the surface upon which a lichen is growing.

Sybase - relational database systems for larger applications, industrial strength databases

Table - set of columns and rows containing data.

TES - Threatened and Endangered Species a program created by the US Endangered Species Act to protect endangered species in the US.

Thallus (thalli) - the body of the lichen.

Tissue analysis - the chemical analysis of lichen tissue concentrations of specific pollutants such as nitrogen, sulfur, metals, fluoride, organochlorines, PCBs, or radioisotopes. Tissue concentrations of individual pollutants within a species can be compared over time, over geographic areas. Some pollutants concentrate in lichens in proportion to atmospheric deposition or ambient air concentrations and may be calibrated to instrument readings.

Transplant study - lichen transplants are used to assess pollution in areas where no lichens occur, or where it is desirable to use the same starting material (i.e. specific lichen from a specific location) at all study sites.

Unix - a computer operating system

URL - universal resource locator (website address, not email).

USFS - US Forest Service.

USFWS - US Fish and Wildlife Service.

XML - markup language. Similar to HTML, extensible and more structured. Industry standard, becoming the general data exchange standard.

Wilderness - areas formally protected by the 1964 Wilderness Act, defined "...as an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain."

9. Website References & Selected Bibliography

9.1 Participating Entities

ASU: http://cochise.asu.edu/collections/index.html
Brigham Young: http://bioag.byu.edu/mlbean
BLM: http://www.id.blm.gov and http://www.soilcrust.org
FHM: http://www.na.fs.fed.us/spfo/fhm/ and http://www.wmrs.edu/lichen/
FIA: http://www.fia.fs.fed.us
FS Air Program: http://www.fs.fed.us/r6/aq/natarm
USFS Air Lichen Data: http://www.nacse.org/lichenair
Midwest National Parks Project: http://www.ies.wisc.edu/brd
Imperial College: http://www.ic.ac.uk

9.2 Computer Websites

ISO (International Standards Org.): http://www.iso.ch/iso/en/ISOOnline.openerpage
EML (Ecological Metadata Language): http://knb.ecoinformatics.org/
FGDC (Federal Geographic Data Committee): http://fgdc.er.usgs.gov/
NACSE: http://www.nacse.org
NBII: National Biological Information Infrastructure http://www.nbii.gov/index.html
NRIS: http://www.fs.fed.us/emc/nris/air

9.3 Lichenological Organizations

American Bryological & Lichenological Society: http://www.abls.org
Lichenological Information System: http://lis.freeweb.supereva.it/index.htm?p
LIAS: http://www.mycology.net/lias/index.html
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British Lichen Society: http://www.argonet.co.uk/users/jmgray/

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9.51 Alaska

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9.52 Pacific Northwest

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9.54 Rocky Mountains

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McCune, B., T. Goward. 1995. *Macrolichens of the Northern Rocky Mountains*. Mad River Press, Eureka, California. 208 pp.
St. Clair, L.L. 1999. *A Color Guidebook to Common Rocky Mountain Lichens*. M.L. Bean Life Science Museum of Brigham Young University, Provo, Utah. 242 pp.

9.55 Eastern US

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Medlin, J.J. 1996. *Michigan Lichens*. Bulletin 60, Cranbrook Institute of Science, Bloomfield Hills, Michigan. 98 pp. Includes a brief introduction and color photographs of 88 common species.

9.56 Southwest US

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