# QUALITY ASSURANCE PLAN

***Forest Inventory and Analysis Program/Forest Health Monitoring Program***

## Lichen Communities Indicator

by B. McCune (1994)
Revision 5 – March 11, 2001 (Peter Neitlich)

## 1. PROJECT DESCRIPTION

### 1.1 Problem Definition and Background

Lichen communities are being implemented as indicators for detection monitoring within the Forest Inventory and Analysis (FIA) program of the U.S. Forest Service. The FIA lichen indicator assesses first the initial condition of lichen communities in a region (completed for SE USA, McCune et al. 1997b), then over time monitors change in response to climate and air quality gradients.

A lichen community is an assemblage of species of lichenized fungi. For the purposes of the FIA program, flora is restricted to macrolichens occurring on living or standing dead woody substrates, including both trunks and branches, trees and shrubs. Microlichens (i.e., crustose lichens) are excluded because they are poorly known taxonomically and are difficult to differentiate. Only standing and recently fallen woody substrates are included, thereby standardizing the measurements to a class of substrates that can be found on all forested sites. For example, although lichens commonly are abundant and diverse on rocks, many FIA plots will not have exposed rock as an available substrate.

### 1.2 Assessment Questions

Lichen communities as an indicator address several key assessment questions, particularly those concerning contamination of natural resources, biodiversity, and sustainability of timber production.

- Are changes in regional air quality affecting our forests? If so, is it improving or deteriorating? In what areas is it changing?

Sulfur and nitrogen air pollutants are stressors that clearly affects lichen communities, even when effects on higher plants are difficult to detect in the field. Lichen communities may be used to indicate air quality and indicate *potential* impacts of these pollutants on other components of the ecosystem.

Hundreds of papers worldwide (chronicled in the series "Literature on air pollution and lichens" in *the Lichenologist*) and dozens of review papers and books (e.g., Hawksworth and Rose 1976, Smith et al. 1993, van Dobben 1993) published during the last century, have

documented the close relationship between lichen communities and air pollution, especially $SO_2$, $NO_2$, and acidifying or fertilizing nitrogen and sulfur-based pollutants. In a comparison of biological responses between nearby and remote areas surrounding a coal-fired power plant, lichens gave a much clearer response (diversity, total abundance, and community composition) than either foliar symptoms or tree growth (Muir and McCune 1988). The lack of ambiguity partly results from standardizing the substrate (e.g., bark or bark of a particular group of species). Much of the sensitivity of epiphytic lichens apparently results from their lack of a cuticle and their total reliance on atmospheric sources of nutrition. Although trees may respond to moderate, chronic levels of air pollution deposits, all of the other influences on tree growth, such as complex variation in soils, make the response to pollutants difficult to measure. Lichens provide, therefore, a clear indication of air pollution impacts, not only directly upon lichens, but also upon total forest productivity.

- Is the lichen component of biodiversity changing through time?

Because air pollution affects long-term forest sustainability and biodiversity, lichens also indicate trends in assessing those ecosystem properties. In addition, lichens themselves form a large portion of the macrophytic species of many forests. For example, in *Abies grandis* forests in western Montana, the number of macrolichen species in a stand is comparable to the number of vascular species (Lesica et al. 1991). In a typical stand in the southeastern U.S., 20-40 lichen species are found in a single FIA plot. ( These lichens are not merely decoration on the trees; numerous functional roles of lichens in temperate forest ecosystems are known. In many forests lichens have key roles in nutrient cycling (esp. nitrogen fixation in moist forests; Pike 1978) and food webs. [Examples: A main component of the diet of northern spotted owls is flying squirrels (Dawson et al. 1987), and flying squirrels eat epiphytic lichens during the winter (Maser et al. 1986, Z. Maser et al. 1985). Epiphytic lichens are also important forage for deer, elk, and a primary food for the endangered mountain caribou in Idaho (Rominger and Oldemeyer 1989, Servheen and Lyon 1989).]

## 1.3 Description of Measurements

Lichen community field activity will concentrate on determining the presence and abundance of macrolichen species on trees at each FIA plot (120-foot radius core of the plot). The field crew will collect samples which will be mailed to a lichen expert. The field methods are described in detail in the Field Methods Guide (USDA Forest Service 1998).

The method has two concurrent parts. (1) Collect voucher specimens for specialist identification. The collection should represent macrolichens species diversity as fully as possible. The sampled population consists of all macrolichens occurring on woody plants, excluding the 0.5 m basal portions of trees and shrubs. (2) Estimate the abundance of each species. Note that the crew member responsible for this task need not be able to accurately identify specific lichen species (that is the responsibility of the specialist). The sampler must be able to make distinctions between species.

Species identification and determining abundance rating are critical to achieving project objectives. All data being collected is critical for proper assessment of the lichen community indicator.

For each sampling location, the following data are collected:

Total number of samples
Type of sample: Lichen
Measurements planned for each sample: Species ID, Abundance class

Personnel and equipment to collect these data are described in the Field Methods Guide (USDA Forest Service 1998).

### 1.4 2001 Activities

Lichen communities are scheduled for inclusion as an indicator in the following regions: southeast, northeast, midatlantic, west coast region, interior west region.

May-June 2001: Training of field crews
June 2001: Field work begins
June 2001: Hot Checks (audit of crews by experts)
July 2001: Lab identification of samples begins
Aug 2001: Cold checks (blind remeasurements of crew plots) by experts
Sept 2001: Field work completed
Dec 2001: Lab identification of samples completed. Data entry begins
Jan. 2002: Data entry and error checking completed

## 2. PROJECT ORGANIZATION AND RESPONSIBILITIES

### 2.1 Key Personnel

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Field crew: At least one person per crew who has received lichen community training.

Other lichen specialists, trainers, and auditors are participating in each region.

2.2 Organizational Chart

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Program managers
        |
Indicator advisors
|       |
|       Lichen specialist & trainers
|       |
Field crew
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## 3. QUALITY ASSURANCE OBJECTIVES

### 3.1 Measurement Quality Objectives and Samples

Data must be collected within certain standards of quality (Table 1). Remeasurements and audits will be conducted during the field season as one way to evaluate data quality. Corrective action (retraining and retesting) will be taken if standards are not met.

In all cases the index scores are calculated from unitless numbers representing relative abundance (see field method). The algorithm for calculating index scores is an iterative procedure (program NMSCORE) that finds an index score for best fit, using a multivariate model of lichen community gradients based on non-metric multidimensional scaling.

Lichen community gradients are extracted from the data matrix of plots by lichen species, using multivariate methods for data reduction. The most generally-effective technique for generating scores on compositional gradients, when faced with heterogeneous community data sets, is non-metric multidimensional scaling (NMS; Kruskal 1964, Mather 1976; implemented in McCune 1993). NMS has proved one of the most robust and effective methods for multivariate data reduction, especially with species *x* sample data and city-block distance measures (Beals 1984; Faith et al. 1987). NMS is well-suited to data that are non-normal or are on arbitrary or discontinuous scales (Mather 1976). NMS can be used both as an ordination method and as a technique for assessing the dimensionality of a data set.

Table 1 Measurement quality objectives and their method of assessment.

| | MQO | Method of Assessment |
|---|---|---|
| Precision | 12% | Deviation between index scores from repeat measurements of the same plot |
| Bias | 12% | Signed deviation from "true" index scores, as determined from expert data. In practice, obtaining 65% or more of the expert's species will yield index scores that meet this MQO |
| Accuracy | 12% | Absolute deviation from "true" index scores, as determined from expert data. In practice, obtaining 65% or more of the expert's species will yield index scores that meet this MQO |
| Completeness | 90% | Percentage of forested plots with lichen data |

### 3.1.2 Precision

Precision is estimated from remeasurements by the same or different crews on the same plot. Each region is handling this QA task in different ways. "Reference crews" resample selected plots done by the regular field crews. Alternatively "reference plots" are sampled by multiple crews and/or by a single crew on multiple dates. The particular type of remeasurement error addressed (within-crew or between-crew) varies depending on how these methods are implemented are implemented in each region.

For example, the lichen community indicator within-crew precision is assessed with the percent deviation between index scores, calculated as

100*(trainee's 1st score - trainee's 2nd score)/length of the gradient,

where index scores are calculated by applying the regional gradient model. Revisits should occur at least one week after initial visit if possible. No more than one month should pass between the initial visit and revisit. The MQO for precision is 12%, representing the disagreement between index scores calculated on the basis of multiple visits.

### 3.1.3 Accuracy and Bias

Accuracy can be expressed in terms of the percent deviation between index scores of two independent samples of the same lichen plot, one of which is collected by a lichen specialist and is considered the true species composition. "Index scores" in this case tell where a plot falls on a climatic gradient and on an air quality gradient. This percent deviation is calculated as:

100*(expert's score - trainee's score)/length of the gradient.

The signed deviation expresses bias. The absolute deviation expresses accuracy. These calculations are possible only for those regions that are in the "application phase" of the lichen community indicator, meaning that a gradient model of lichen communities has already been constructed. For 1998 data analysis, models are available for the southeastern USA and the northeastern USA, and we have shown for southeastern USA that the FIA lichen community indicator achieves the set goals for precision, accuracy and bias (McCune et al. 1997a).

We have found that if the trainee obtains 65% or better of the specialist's species list, that the index scores will mostly fall within 10% of the expert's. Therefore, this 65% figure is used as an operational goal for training, certification, and audits. It is referred to below as our "field MQO," and is used as a readily calculated basis for providing rapid feedback to the crew.

### 3.1.4 Representativeness

The representativeness of the sample is not controlled by this specific project, since the national FIA sampling design has been fixed by other previous work. It appears, however, that the quarter-interpenetrating design works very well for the lichen community indicator. Because the plot is not subsampled in the lichen community work, there is no question of representativeness at the plot level.

### 3.1.5 Completeness

Completeness is defined as the proportion of plots that will yield useable data. The MQO for completeness is 90%. The three main areas we need to watch to promote completeness are:

1. The crew has adequate time to complete the lichen sampling.
2. The lichen community samples are adequate, not decomposed, and are received by the lichen specialist. The lichen specialist should promote good specimen quality by checking shipments as they are received and providing feedback to the crews, if necessary.
3. The crew remembers to record abundance codes on the bags.

### 3.1.6 Comparability

There have not been large-scale regional studies of lichen communities in North America, therefore comparability can only be addressed through time and in subregion comparisons. If the preceding QA objectives are met, comparability within the FIA project will be assured. Comparability is obtained by standard methods, consistently trained individuals, and a QA program that maintains comparability among crews.

### 3.2 Sources of Measurement Error

The greatest potential sources of error in the lichen community data are (1) inadequate scrutiny of the site due to lack of time, and (2) failure to discriminate between species.

Adequate scrutiny depends on adequate time. If other field activities dominate and lichen assessment activities are restricted, measurement error may incur. Accuracy also depends on the crew capabilities in seeking out the full range of microsites present in the lichen plot.

The ability to discriminate different species will depend largely on the attitude and abilities of the trainees. Almost anyone can be trained to discriminate among lichens. Like most new tasks, however, it requires concentration and a willingness to learn on the part of the trainee. Although some trainees are strongly self motivated, most trainees need to feel that the lichen work is important as reflected in the attitude of the crew leader and program managers. Training and adequate instruction in higher plant taxonomy can be helpful, but lichen identification is very different from higher plant identification. Training in invertebrate animal identification also develops observational skills useful for learning to discriminate lichen species in the field.

Species determinations by appropriately trained lichen specialists should present few problems. Still the lichen specialist may have difficulty identifying specimens that are very small or poorly developed. This problem can be minimized by open communications between the lichen specialist and the field crew.

## 4. SITE SELECTION AND SAMPLING PROCEDURES

### 4.1 Sampling Process or Experimental Design

The sampling network design and site selection procedures are addressed elsewhere in the QA plan for on-frame studies. Lichen community data will be recorded on the 1-ha plots. The actual area to be sampled (the "lichen plot") is a circular area with 120-foot radius centered in the 1-ha plot (see Field Methods Guide; USDA Forest Service 1998).

### 4.2 Sampling Methods Requirements

The field sampling procedure is fully described in the Field Methods Guide (USDA Forest Service 1998).

### 4.3 Sample Handling and Procurement

Sample handling and procurement are described in detail in the Field Methods Guide (USDA Forest Service 1998).

## 4.4 Sample Custody

The data consists of the collection of a voucher specimen and the associated abundance score, which will be recorded on the voucher sample bag. Each bag is labeled with the plot number. The field crew has custody of the data until the specimens are mailed to the regional lichen specialist. Samples are tracked by (1) express mail receipts, (2) the lichen community mailing form, which lists the contents of each shipment, and (3) a plot packing slip, which identifies each plot's bag of smaller bags. The mailing form and plot packing slip are shown in the Field Methods Guide (USDA Forest Service 1998).

The samples will be stored by the regional specialist for one year. Eventually voucher specimens will be permanently stored at a major herbarium having a significant lichen collection. In the past, voucher specimens from the southeast have been deposited in the lichen herbarium at Duke University, Durham, North Carolina (DUKE). Vouchers from the west have been stored at Oregon State University (OSC). Vouchers from the Northeast and Lake States have been stored at the University of Wisconsin, Madison (WIS).

# 5. ANALYTICAL PROCEDURES

## 5.1 Field Methods

Only one field "measurement" (actually an observational score) is made per sample: the abundance score for each species recognized, but not necessarily identified, in the field. The method is described in the Field Methods Guide (USDA Forest Service 1998).

## 5.2 Analytical Methods

### 5.2.1 Sample Receipt

Specimens should be transported via express mail or some other mailing method that facilitates tracking. On receipt, boxes should be opened immediately and checked for damp lichens. Damp specimens should be thoroughly air-dried. Record the date received and contents (list of plots included, with sample dates) of each shipment.

### 5.2.2 Sample Analysis

The lichen specialist identifies the contents of each bag. In the case of mixed collections or multiple collections of the same species, see the special instructions below (5.2.4).

### 5.2.3 Special instructions for multiple collections of the same species

Because the field crew is instructed to make a species distinction even when they are unsure whether two organisms belong to the same species, it is expected that in many cases two or more collections from a given plot will be of the same species. This should be noted on the data sheet by recording multiple specimen numbers on a given line.

After all bags from the plot have been recorded, a combined abundance value should be recorded using the following rules for combining abundance values: 1 = rare ($\leq$ 3 individuals seen), 2 = occasional (4-10 individuals seen), 3 = common (> 10 individuals seen), 4 = abundant (more than half of the stems and branches seen have this species).

| Recorded values | Result |
|---|---|
| 1 + 1 | 2 |
| 1 + 2 | 2 |
| 2 + 2 | 2 |
| 1 + 1 + 1 | 2 |
| 1 + 1 + 2 | 2 |
| 1 + 2 + 2 | 3 |
| 3 + any others | 3 |
| 4 + any others | 4 |

### 5.2.4 Special Instructions for Recording Species Not Recognized by the Field Crew

Despite the field crew's best efforts, the lichen specialist will occasionally encounter species that were not identified during plot audits. Although the species can easily be recorded for the plot by the specialist, those species will not have an abundance value assigned by the field crew. Therefore, the specialist should identify each species that is not represented by a voucher in any of the other bags from that plot. In these cases, the species should be recorded on the data sheet and a missing value indicator (0) recorded in the abundance column. On the right side of the data sheet, missing value indicators (0's) are recorded under "field number" and "abundance".

### 5.2.5 Data Entry and Reporting

Record species name(s) on the bag and on the data sheet and return the contents to the bag. Make a backup copy of the list of species identification and file this copy. Mail the list of species identifications, along with plot and species numbers for each identification, to the indicator lead. Complete the "Lichen Identification Data Sheet" (Figure 1) in addition to a list of species codes.

### 5.2.6 Voucher Specimens

The lichen specialist will select individual species for herbarium specimens, therefore each species should be represented by no less that three specimens at all plots. These specimens should be stored in standard lichen packets identified by completed herbarium labels. The label data must include the plot ID number. Basic plot data (locational information) will be provided by the logistics coordinator or the indicator lead.

### 5.2.7 Sample Storage

Store bags and lichens for future reference. At the end of the field season, the herbarium specimens should be mailed to the indicator lead.

### 5.2.8 Communications

The lichen specialist will maintain a list of comments/suggestions initiated for and by the field crew. Questions concerning sample processing should be addressed to the field crew or indicator lead, as appropriate.

### 5.2.9 Documentation

See "Lichen Identification Data Sheet" (Figure 1).

## Lichen Identification Data Sheet

Hex ID #_____ Plot #_____ Field Date: _____
Lichen specialist _____ County, State:_____
Collector_____Crew #____ ID Date: _____

**#** = Coll. No. **A** = Abundance on packet. **Abun** = Sum Abundance (see rules). **Sp. Code** – See Epiphyte Codes List

| | **FINAL DATA** | | | | **DATA FROM PACKETS** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Species Name** | | | | | | | | | |
| | **Sp. Code** | **Abun.** | **#** | **A** | **#** | **A** | **#** | **A** | **#** | **A** | **Comments** |
| 1 | | | | | | | | | | | |
| 2 | | | | | | | | | | | |
| 3 | | | | | | | | | | | |
| 4 | | | | | | | | | | | |
| 5 | | | | | | | | | | | |
| 6 | | | | | | | | | | | |
| 7 | | | | | | | | | | | |
| 8 | | | | | | | | | | | |
| 9 | | | | | | | | | | | |
| 10 | | | | | | | | | | | |

Etc…

Abundance codes used by field crews: 1 = rare ($\leq$ 3 individuals seen), 2 = occasional (4-10 individuals seen), 3 = common ( > 10 individuals seen), 4 = abundant (more than half of the branches and trunks seen have this species).

Species codes: Refer to master list for 6-character lichen species code names.

Figure 1 Lichen identification data sheet.

## 5.3 Calibration Procedures and Frequency

No measurement devices are being used, therefore calibration procedures are not required.

## 6. DATA REDUCTION, VERIFICATION, VALIDATION, AND REPORTING

All data entry, verification, validation, and initial reporting is the responsibility of the lichen community indicator lead. Details are provided below.

### 6.1 Data Entry, Verification, and Validation

Field data are recorded on the outside of the specimen collection paper bags. These data are entered in PC-ORD compact format (McCune 1993) from the "Lichen Identification Data Sheet" (above) on an IBM PC-compatible computer in ASCII files at the laboratory, following species determinations (Figure 1). A three-disk backup system will be used, and a backup copy must be made after each data entry or modification session. Data will be checked for errors by two people, one reading from a printed copy of the entered data while the other person checking against the original data sheets. Data values will be screened against acceptable ranges. Missing data or data of unacceptable quality (field crew's opinion) are flagged by recording a "0" for the abundance value. For data analysis, these values have the least impact if they are converted to abundance=3, because that is by far the most common abundance level. Thus, when we know that a species was present in a plot, abundance=3 is the default level and has less impact on the analysis than not using that species in that plot (setting abundance=0). If more than 10% of the species are flagged with a zero, that plot should be removed from the analysis.

After species lists and abundances are verified and validated, electronic files are sent to the information management coordinator in Las Vegas. Files that are archived in Las Vegas are indicated by darkened corners in Figures 3 and 4.

The compact format data files are expanded to a full plot *x* species matrix in standard PC-ORD format using program SUMMARY in PC-ORD. Data reduction and analysis will be run on these data files.

### 6.2 Data Reduction

Various community parameters at the plot level can be calculated from lichen species abundance data (also collected at the plot level, but the data are aggregated from individual species to the community). The most commonly used are:

1. **Species richness** -- the total number of species recorded in the sampling unit (plot).
2. **Total abundance** -- the sum of the abundance classes across species.
3. **Score on compositional gradient** -- the score is calculated by finding the best fit of a given plot on a gradient in air quality. Non-metric multidimensional scaling is used to define that gradient and to find the position of best fit for each plot.

### 14.6.3 Data Flow and Reporting

The lichen community indicator is implemented in two phases (Figure 2): (1) construction and calibration of a gradient model of lichen communities to isolate and describe an air quality gradient and (2) application of the model to calculate air pollution impact scores for on-frame plots, which are then used to answer resource assessment questions. These questions concern the spatial pattern and trend of the condition of our forest resources, as described above. At this time only the southeast region is in the application phase. The other regions will be in the calibration phase until gradient models for those regions are completed.

The flow of data and kinds of data analyses differ for these two phases. Data flow for the calibration phase is shown in Figure 3, while the application phase is shown in Figure 4. In the calibration phase reporting is the responsibility of the indicator lead. However assessment reports in the application phase will eventually revert to the regions. Reports are planned for various audiences with lag times from one year (basic statistical summaries) to several years (peer-reviewed publications).

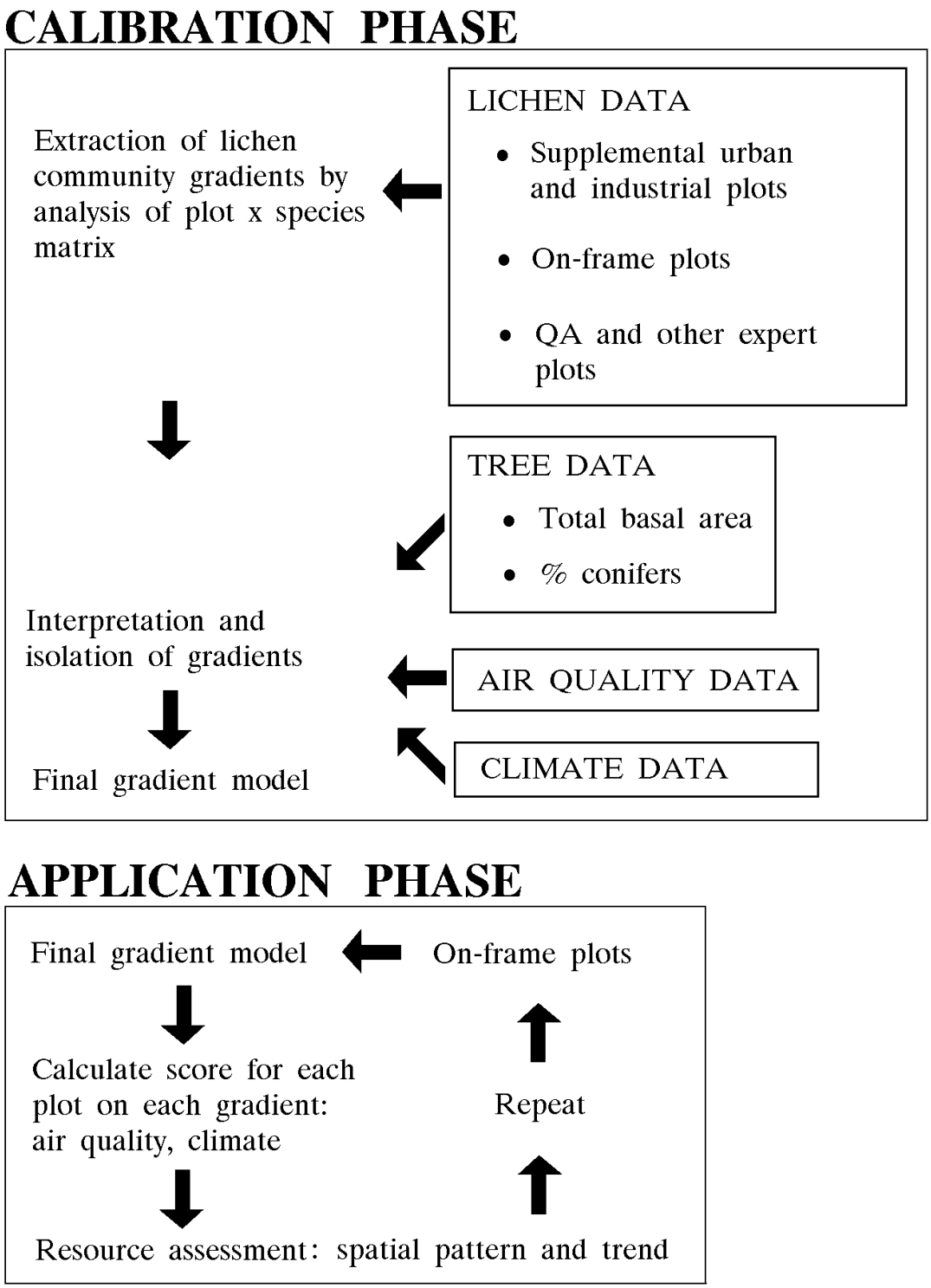


Figure 2. Overview of development and application of the lichen community indicator.

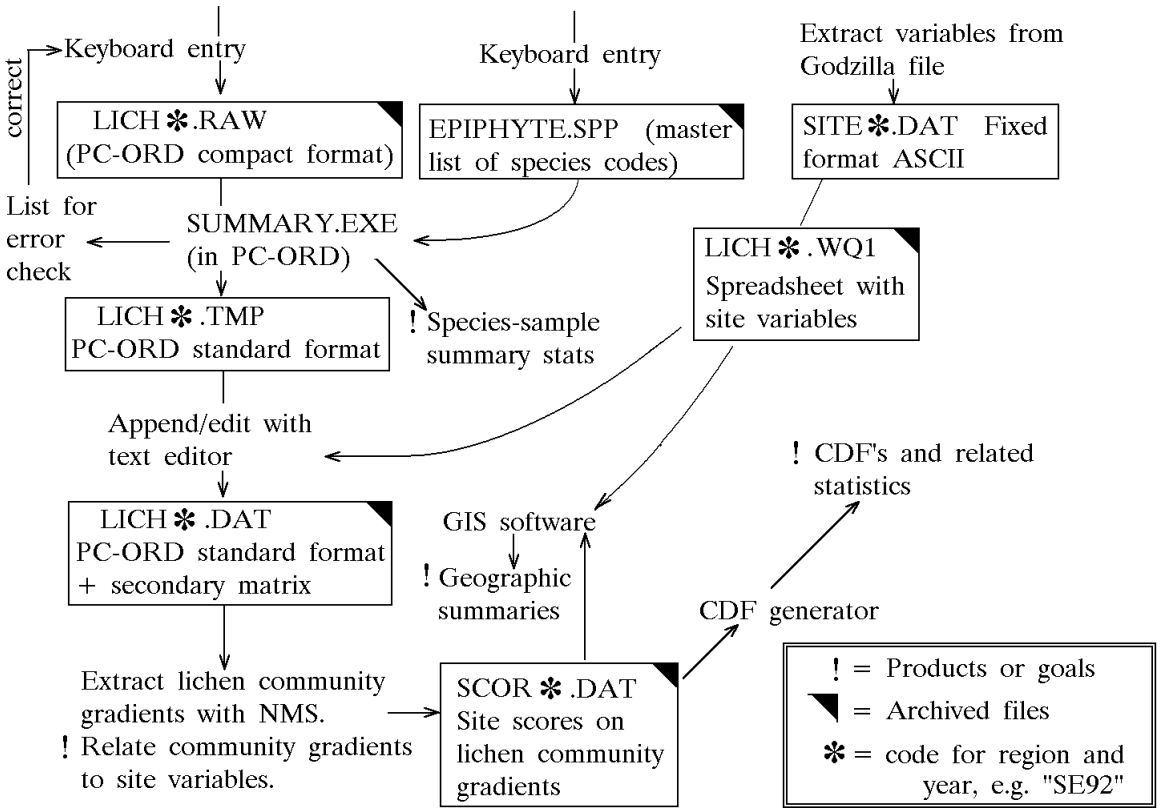


Figure 3. Flow of lichen community data -- CALIBRATION PHASE. Data files are indicated by boxes. Each region in each year is assigned a unique four-character code to replace the asterisks (*) in file names (CA94= California, 1994; CO94 = Colorado, 1994, NE94 = Northeast, 1994; SE94 = Southeast, 1994); Products or goals are indicated with exclamation points

(!).

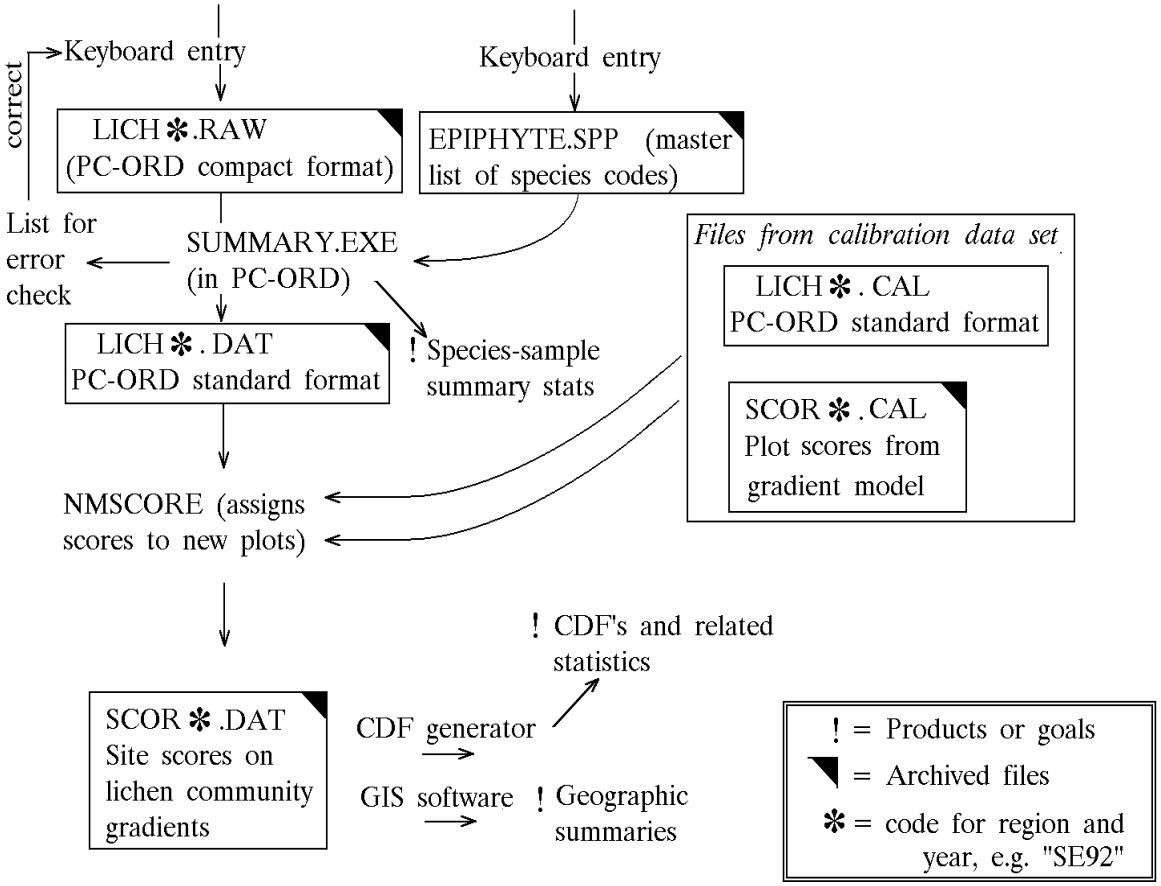


Figure 4. Flow of lichen community data -- APPLICATION PHASE. Data files are indicated by boxes. Each region in each year is assigned a unique four-character code to replace the asterisks (*) in file names (CA94= California, 1994; CO94 = Colorado, 1994, NE94 = Northeast, 1994; SE94 = Southeast, 1994)

### 6.4 Data Analysis

Data analysis (Figures 3 and 4) will consist of:

1. Analysis of data quality by using data from audit and remeasurement plots. Data will be compared between the field personnel and the auditors (lichen specialists).

2. Derivation of a regional model of variation in lichen communities (performed only in Calibration Phase). The model consists of gradients representing the major components of variation in lichen communities. This multivariate analysis will be done within bioclimatic regions.

3. Description of regional patterns of lichen community parameters (listed in 6.2).

4. Establishment of nominal/subnominal boundaries (Calibration Phase only) for indications of air quality by comparison of known polluted areas with otherwise similar but remote areas. Because locally-polluted areas occur in essentially all forested ecosystems of North America, the nominal/subnominal boundary can be varied and calibrated throughout the continent.

5. Analysis of the relationship between lichen community parameters and various off-frame spatial data (e.g., pollutant emission data), to the extent that data availability and funds permit.

## 7. INTERNAL QUALITY CONTROL CHECKS

### 7.1 Quality Control Requirements

Data must be collected within certain standards of quality (Table 1). Remeasurements and audits will be conducted during the field season as one way to evaluate data quality. Corrective action (retraining and retesting) will be taken if standards are not met (discussed further below). Data quality will be measured at (1) post-training certification, (2) early- to mid-season field audit, and (3) plot remeasurements. Each of these is discussed below.

Data quality will be measured by certification and field audits. A second aspect of quality control is ensuring that the voucher specimens are adequate, not decomposed, and received by the lichen specialist. The lichen specialist should promote good specimen quality by checking shipments as they are received and providing feedback to the crews, if necessary. If problems are perceived either by the field crew or the lichen specialist, they should contact each other and/or the indicator lead.

## 7.2 Pretraining

Pretraining is used to certify trainers. It is held shortly before the training. Trainers are lichen specialists, so pretraining does not consist of lichen training. Rather, the trainers are familiarized with the FIA lichen methodology, QA procedures, training curriculum, and are brought up to date on the overall status of the indicator. Trainers are certified with the same procedure as for trainees and using the standard form for lichen community certifications and audits (Figure 5).

## 7.3 Training and Certification

Only people who have successfully comple`ted lichen training and certification should collect the lichen community data. The trainee is certified by performing the lichen community method on a test plot and meeting the field MQO (65% of the expert's species list). The trainer completes a form (Figure 5) that records the trainee's score and certification. The trainee receives supplemental training and retesting if they fail the initial test.

Training occurs at the beginning of the field season. A key training objectives is to maximize the ability of the field crew to discriminate among lichen species in the field. The ability to assign reliable names to the species is not an objective of training. That will be the responsibility of the Lichen Specialist.

Training materials, specifically a compilation of training documents and related background information on lichens, will be distributed to the appropriate field crew members no less than one week before training.

There will be a training sessions which consists of the following:

1. Study of the appropriate section of the Field Methods Guide (Halsell 1994).
2. Study of handouts on basic lichen taxonomy.
3. Tutorial on how to discriminate among species.
4. Preparation of a small personal reference collection of common lichen species.
5. Practice plots with the assistance of the trainer.
6. Practice plots without the assistance of the trainer.
7. Data quality check (certification) at the end of the training session.

For 1998 training will be held at three eastern sites and one western site.

## 7.4 Remeasurements (see MQOs, section 3)

## 7.5 Debriefing

We schedule time at the end of the field season us to learn from the trainees. This will happen via a questionnaire (Figure 6). In some cases a lichen specialist or their representative will solicit feedback from the trainee in person. The trainees' comments during debriefing are

collated and summarized by the indicator lead and become part of the basis for improving the method for next year.

## 8. QA AUDITS

### 8.1 Hot Checks

Hot checks serve two primary purposes: (1) check in with the field crew to see if they are having any difficulties with the method, and (2) documenting the data quality. The first objective is achieved by talking with the crew, observing the method in progress, and providing immediate feedback. The second objective is met by calculating numerical scores (comparing results to those of the lichen specialist) based on the field crew sampling a plot without interference from the auditor. One or more plots will be examined per audit. The lichen community audit proceeds in five steps. Note that the early steps provide immediate feedback to the crew, but the later steps quantify the data quality with increasing rigor.

1. The auditor asks the crew member if they have questions concerning the method before the sampling begins, then discusses those problems with the crew member. (If time allows the auditor to be present for two plots, the first plot should be done more interactively, with the specialist helping the crew rather than as a test plot).

2. The auditor then allows the crew member to sample on their own, but observing at a distance the manner in which the crew member covers the plot. At the end of the plot, the lichen specialist then quickly assesses the number and quality of specimens and provides immediate feedback on the specimens and other aspects of technique (for example, if the person camps out on one tree and doesn't see a lot of the plot). Normally it is fairly easy for a specialist to judge how well someone is doing, even before the final scores are in. The specialist then samples the plot independently.

3. The specialist identifies the lichens, then evaluates the number of species obtained by the crew member as a percentage of the specialist's. These values are reported by the specialist to the indicator lead and crew member as soon as possible. Occasionally this can be reported to the crew member in the field, but usually those figures are reported within a week. In the past we have found that if trainees obtain 65% or better of the number of species obtained by the specialist, that the plot index scores (item 4 below) will mostly fall within 10% of the specialist's.

4. After the data are delivered from the specialist to the indicator lead, the species scores for both the crews and the specialists are entered into data files. The indicator lead then calculates plot index scores for each QA plot for both the crews and the specialists. This requires application of the multivariate lichen gradient model for that specific region. Until those models are built for each region, the results cannot be delivered during the field season. The crew's score is then expressed as a deviation from the expert's. This is the most important numerical descriptor of the data quality, because it takes into account the mix and abundance of species.

Corrective actions cannot include alterations in the basic method. Any suggested changes in methodology should be reported to the indicator lead.

Results of the audit are communicated to the QA indicator advisor in a summary QA report prepared at the end of the field season, or earlier if requested by program managers.

8.2 Cold checks

Cold checks are remeasurement of crew plots by experts within 2 months of crew sampling. Plots to remeasure are chosen at random by experts, and crews have no knowledge of which plots will be cold checked.

## 9. CALCULATION OF DATA QUALITY INDICATORS

The data assessment procedures are described above under section 3.1.

## 10. CORRECTIVE ACTION

Corrective actions, as appropriate and feasible, are initiated via communications between field crew, lichen specialist, and indicator lead. Follow-up audits may be made if the problem is perceived as seriously affecting data quality. Corrective actions can be initiated by anyone, but approval for substantive changes in the method must be obtained from the indicator lead. Any such changes must be reported in writing to the Deputy Program Manager for Research or the Program Manager.

## 11. QUALITY ASSURANCE REPORTS TO MANAGEMENT

The "QA Report Form" (Figure 5) or a comparable substitute will be used during pretraining, training, and audit procedures and will be made available to the Project Manager and QA specialist.

A summary of training, audits, remeasurements, and debriefings and QA results will be reported by the indicator lead following the end of field activities. Also, significant QA problems and recommended solutions will be provided.

Data Quality Evaluation -- Lichen Communities
Used for Certification and Audits

Name _____ Region/study _____

Date _____

Plot _____

Trainer/auditor_____

Evaluation

_____ Percent of species detected

Comments

Figure 5. Data quality evaluation form for Lichen Communities.

DEBRIEFING QUESTIONS -- LICHEN COMMUNITIES --1998

Study area (circle): PNW / Calif / Colo / SE /Midatlantic/ New England / Lake states

Your name:_____ (optional)

Position (circle): Botanist / Forester I / Forester II / Forester III / Logistician / Aid / Tech

TRAINING

Did you participate in the lichen training session at the beginning of the field season? Yes / No

If YES, then how much training did you receive the first week? half days / full days

If NO, then how were you trained to do the lichen community sampling?

Did you prepare a personal reference collection? Yes / No

If YES above, did you find this helpful? Yes / No

Did you receive sufficient training to effectively collect the lichen data? Yes / No

What areas were covered well in the training?

What areas need improvement in the training?

Other comments or suggestions on training:

FIELD WORK

In what percentage of the lichen community sampling did you participate? 100 / 90 / 75 / 50 / 25 / 10%

How much time did the lichen communities take in the field, on average?

What was the range in field time per plot for the lichen work?

Did you have enough time to complete the task to your satisfaction? Yes / No

If "NO" above, then how much time should be allocated for lichen communities?

Figure 6. Debriefing questionnaire for Lichen Communities (cont. on next page)

DESIGN:

Are there any changes you would suggest in the field methods, to make it more efficient or repeatable?

Was the equipment provided satisfactory to complete the task? Yes / No

If "NO", please be specific about any problems.

In what proportion of the plots did you use the lichen community worksheet? _____

MANUAL:

Did you use the Lichen Community training notebook? Yes / No

If "YES", did you find it helpful? Yes / No

Is it worthwhile to produce this in future years? Yes / No

Suggestions for changes in the Lichen Community notebook (for example, other things that should be included or parts that were not useful)?

Did you use your copy of the published lichen manual? Yes / No

Is it worthwhile to provide this to the field crews in future years? Yes / No

OTHER COMMENTS/SUGGESTIONS:

Figure 6, cont. Debriefing questionnaire continued.

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