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Manual for Monitoring Air Quality Using Lichens on National Forests of the Pacific Northwest

- Field protocols
- Laboratory protocols
- Individualized sampling strategies for nine national forests

Manual for Monitoring Air Quality Using Lichens on National Forests of the Pacific Northwest

Field protocols, laboratory protocols, and individual sampling strategies for the

Columbia River Gorge National Scenic Area
Deschutes National Forest
Gifford Pinchot National Forest
Mt. Hood National Forest
Siuslaw National Forest
Umpqua National Forest
Wallowa-Whitman National Forest
Willamette National Forest
and
Winema National Forest

US Department of Agriculture-Forest Service, Pacific Northwest Region, Air Resource Management, Portland, Oregon

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Cover illustration of *Nephroma laevigatum* by Alexander Mikulin.

Copies of this document can be obtained from: Program Director, Air Resource Management, USDA-Forest Service Pacific Northwest Region, 333 SW 1st Street, Portland, OR 97204. This document is also available on-line at the url < http://www.fs.fed.us/r6/aq >.

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EXECUTIVE SUMMARY

This document records the methods used to survey lichen communities and to collect lichens for chemical analysis on national forests of the Pacific Northwest during the 1990s for air quality indication. Individualized sampling strategies for nine national forests provide a synopsis of local and semi-regional emission sources with potential to adversely affect Forest ecosystems, monitoring priorities, maps of survey site locations, and rotation schedules for remeasurements. Current status of and trends in air quality, including ecological effects, can be indicated by repeat measurements using the same methodology. Data and reports from the first round of monitoring are available from the director of the USDA-Forest Service Pacific Northwest Region Air Program, or from the air program website at http://www.fs.fed.us/r6/aq. Two additional sources for data retrieval are the Forest Service Natural Resources Information System and the Northwest Alliance for Computational Science and Engineering at Oregon State University, http://airlichen.nacse.org/.

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1. INTRODUCTION

1.1 LICHEN MONITORING BY THE USFS PACIFIC NORTHWEST REGION AIR RESOURCE MANAGEMENT PROGRAM: HISTORY AND OBJECTIVES

In 1993, managers of the Willamette, Siuslaw, Deschutes and Mt. Hood National Forests pooled resources to develop a unified approach to air quality biomonitoring using non-vascular plants. Other administrative units began participating in 1994 (Gifford Pinchot National Forest and the Columbia River Gorge National Scenic Area), 1997 (Umpqua and Winema National Forests), and 1998 (Wallowa-Whitman National Forest). The program's primary objectives are to help national forest managers obey federal and state laws and to fulfill agency mandates with regard to the detection and quantification of adverse effects from air pollution on forest ecosystems and resources by:

1. Establishing a network of sites on national forest lands at which inventories of lichen communities and chemical analysis of lichen tissue for nitrogen, sulfur and metals are performed on a regular basis.
2. Monitoring lichen community composition to document and map locations where air quality has improved or deteriorated and to document adverse effects to sensitive lichens. (Lichens are highly sensitive to sulfur dioxide (SO_2), fluorine gas (F), acid rain (including sulfuric and nitric acids), and fertilizing compounds such as ammonia (NH_3) and nitrates (NO_3). Lichens are less sensitive, but still responsive if levels are sufficiently high, to nitrogen oxides (NO_x), ozone (O3) and peroxyacetylnitrate (PAN).)
3. Using chemical analysis to map areas of concern by documenting enhanced levels of sulfur- and nitrogen-containing pollutants and toxic metals in lichen and moss tissue.
4. Building a publicly accessible, unified lichen database, interfaceable with other Forest, regional and national databases.
5. Providing analysis and interpretation of biomonitoring data, including thresholds for enhancement of sulfur, nitrogen and metals in lichen tissue, sensitivities of lichens to air pollutants, and site scores for air quality based on lichen community composition.

A secondary objective is to provide current and historical information about the diversity, abundance, distribution, and habitat requirements of lichens on national forest lands.

1.2 USFS RESPONSIBILITIES FOR AIR RESOURCE MANAGEMENT

Forest responsibilities for monitoring air quality are founded in law and are described in agency and regional documents and federal legislation. Under these mandates, line officers have the responsibility to detect, describe and speak up about air pollution affecting the national forests:

1.21 Federally legislated responsibilities

The Clean Air Act (CAA) of 1970 and its amendments in 1977 established 156 Class I areas, 88 of which are managed by the USFS. Stringent air-quality standards protect these clean air regions. Federal land managers are required to participate in the Prevention of Significant Deterioration (PSD) permitting process for new or modified pollution sources. The PSD process requires that managers predict changes that would likely occur to Air Quality Related Values (resources that may be affected by a change in air quality) if the permit were granted. Forest Service managers

are required to obtain enough information to independently evaluate proposals and effects, rather than merely echo the assessment of either the proponent or the regulatory agency.

Other federal mandates include the:

1. Forest and Rangeland Renewable Resources Planning Act of 1974, recognizing the fundamental need to "protect and, where appropriate, improve the quality of the soil, water and air resources".
2. The Federal Land Management Policy Act of 1976, establishing the policy that the “US national interest will be best realized if the public lands and their resources are periodically and systematically inventoried in a manner that will protect the quality of scientific, scenic, historical, ecological and environmental, air and atmospheric, water resources and archeological values...".
3. State Implementation Plans (SIP), prepared by US states and required by the CAA. SIP is the contract between EPA and each State to attain and maintain acceptable air quality. Air quality standards can be stricter in SIPs than they are in the CAA. The Forest Service can be very influential in the preparation of the State Implementation Plans.
4. National Environmental Policy Act (NEPA) of 1976. Air is an issue common to all NEPA actions and many special use permits.
5. The Wilderness Act, the Farm Bill, the Organic Act of 1897, the Multiple Use-Sustained Yield Act and NFMA all mandate Forest Service roles in the protection of forest health and ecosystems from impairment, of which air is an intrinsic element.
6. Agenda 21, the document signed by our country in 1992 at the United Nations Conference on Environment and Development in Rio de Janeiro, Brazil, places a high value on understanding ecosystems, including atmospheric and climatological components.

1.22 USFS Air Resource Management policy

Within the US Forest Service, the Air Resources Management (ARM) program addresses issues of air quality. Although ARM originated as a PSD Class I area protection program, Class I areas comprise only 8% of the National Forest System. The main value of understanding the air resource and the effect of air pollution on other resources is to accomplish quality integrated ecosystem management. The Chief's policy is that air is a fundamental resource and shall be managed as other national forest resources such as soil and water. The ARM program is described in detail by agency documents including the Forest Service Air Resources Handbook (FSH 2509.19 Expired Interim Directive No. 1. and subsequent updates), the Forest Service Manual (2580) and individual Forest Plans.

To underscore the fundamental tenants of the US Forest Service ARM program, an agency framework document was prepared and approved in 1988 (USFS 1988). One of its three basic elements is the protection of Class I and II areas by:

1. Determining locations for high pollutant concentrations and areas of probable adverse effects using existing emission data, air quality monitoring, personal observation, modeling, and professional consultation.
2. Determining the current condition of national forest resources.
3. Establishing monitoring sites throughout national forest areas.
4. Determining adverse effects of air-pollution on national forest resources due to outside generated emissions sources, and obtaining baseline data for modeling potential impacts from proposed new emission sources.
5. Orienting air regulatory personnel to air quality conditions, trends and the significance of findings.
6. Training specialists and managers on operations and management methods.

1.23 Regional Air Resource Management guidelines

In May 1992, Region 6 published *Guidelines for Evaluating Air Pollution Impacts on Class I Wilderness Areas in the Pacific Northwest* (Peterson et al. 1992). The preface states: "Forest Service Air Resource managers in the Pacific Northwest are responsible for protecting class I wilderness areas from air pollution. To do this, they need scientifically defensible information to determine critical concentrations of air pollution having the potential to impact class I wilderness values". The guide specifically names lichens as an Air Quality Related Value, recommends the use of lichens and bryophytes as biomonitors of air quality, and states that the Forest Service should implement monitoring independent of the PSD review process.

In summary, federal laws and agency guidelines and policies mandate that managers of the national forests monitor air quality and account for adverse effects to forest ecosystems resulting from changes in air quality. Lichen monitoring was added to the current USFS Pacific Northwest Region air program to help satisfy these information needs.

1.3 LICHENS AS BIOMONITORS OF AIR QUALITY

1.31 Monitoring sulfur, nitrogen and metals via chemical analysis of lichens.

Lichens are composite organisms formed by a fungus and a green alga and/or a blue-green bacterium. Lichens lack mechanisms utilized by higher plants for water uptake (e.g. root systems, conducting tissue) and regulation of gas exchange (e.g. waxy cuticles, stomata). Surface area contact with the substrate by many lichen species is relatively low and, when lichens are hydrated, gas exchange occurs over the entire surface. Thus, compared to vascular plants, elemental content of lichens is strongly affected by atmospheric influences: gases, particulate matter and precipitation. Because of their unique biology, lichens accumulate a wide variety of air pollutants, many of which can be predictably correlated with average atmospheric deposition (Herzig et al. 1989, Ross 1990, Saeki et al. 1977, Garty 2001). Sulfur, nitrogen and metal concentrations in lichen tissue indicate air quality within a region or around a point source, providing a widely accepted monitoring method (Richardson 1992, Nash and Gries 1991, Stolte et al. 1993, Nash 2002).

Lichens accumulate elements by gas exchange, by entrapment of airborne particulates, by ion-exchange of dissolved metals and other ions to cell walls, and by active transport, particularly of sulfur and phosphorus, across cell membranes (Richardson and Nieboer 1983). Lichens undergo rapid hydration and dehydration. These processes alternately concentrate and leach pollutants, maintaining a dynamic equilibrium with atmospheric and substrate sources of these chemicals. Accumulation or depletion can be rapid as evidenced by the detection of significant changes in elemental status in short term transplant and seasonal studies (Boonpragob and Nash 1990, Gailey and Lloyd 1986, Garty 1988, Puckett 1985).

Two basic approaches to lichen biomonitoring are: 1) element analysis of lichen tissue, and 2) species presence and cover (Wetmore 1988, Will-Wolf 1988). Element analysis can detect gradual changes in tissue levels before conditions become lethal and is a more sensitive method than species mapping for pollutants to which lichens are not especially sensitive, e.g. lead. The presence of specific anthropogenic elements in lichen thalli offers direct evidence of their presence in the air. Lichen tissue concentrations can be compared to background values in the

literature, or to baseline studies, to determine whether they are elevated. If tissue data can be calibrated with direct measurements of air pollution at instrumented sites, lichens can be used to estimate annual average ambient levels, or deposition, of sulfur, nitrogen and certain metals.

1.32 Sensitivity of lichens to air pollutants.

Lichens have species-specific response patterns to increasing levels of atmospheric pollutants, ranging from relative resistance to high sensitivity. Sensitive species are damaged or killed by annual average levels of sulfur dioxide as low as 8-30 µg/ m^3 (Johnson 1979, DeWit 1976, Hawksworth and Rose 1970, LeBlanc et al. 1972), by short term exposure to nitrogen oxides as low as 564 ug/m^3 (Holopainen and Kärenlampi 1985) and by peak ozone concentrations as low as 20- 60 ug/m^3 (Egger et al. 1994, Eversman and Sigal 1987). With regard to ozone, most reports of adverse effects on lichens have been in areas where peak ozone concentrations were at least 180-240 µg/m^3 (Scheidegger and Schroeter 1995, Ross and Nash 1983, Sigal and Nash 1983, Zambrano and Nash 2000). Ruoss et al. (1995) found no adverse effects on lichens in areas of Switzerland with daily summer peaks of 180-200 µg/m^3. They attributed lack of response to low lichen metabolic activity caused by low humidity at times of the day when ozone was highest; ozone concentrations never rose above 120 µg/m^3 when the relative humidity was over 75%.

In addition to gaseous pollutants, lichens are sensitive to depositional compounds, particularly sulfuric and nitric acids, hydrogen ions, sulfites and bisulfites, and other fertilizing or alkalinizing pollutants such as NH_3 and NH_4^+. While sulfites, nitrites, and bisulfites are toxic in themselves, acidic compounds affect lichens through direct toxicity of the H^+ ion, fertilization by nitrate ($NO3^-$), and acidification of bark substrates (Farmer et al. 1992). For example, in a study of northwest Britain, *Lobaria pulmonaria* was limited at nearly all sites to trees with bark pH >5 (Farmer et al. 1991). In the Netherlands, a number of studies have demonstrated that ammonia-based fertilizers alkalinize and enrich the nutritional composition of lichen substrates which in turn influences lichen community composition and element content (van Herk 1999, van Dobben et al. 2001, van Dobben and ter Braak 1999 and 1998). Finally, it is clear that pollutant mixes can have synergistic protective or adverse effects on lichens and that individual species differ in their sensitivity to these pollutants and their response to pollutant mixes (Hyvärinen et al. 1992, Gilbert 1986, Farmer et al. 1992).

The ability of lichens to absorb and concentrate sulfur from oxidized sulfur sources is well established, as is their sensitivity to SO_2 gas. The first indications of air pollution damage from these sources are inhibition of nitrogen fixation, increased electrolyte leakage, decreased photosynthesis and respiration followed by discoloration and death of the algae (Fields 1988). More resistant species tolerate regions with higher concentrations of these pollutants, but may exhibit changes in internal and/or external morphology (Nash and Gries 1991, Will-Wolf 1980).

A preliminary air quality assessment can be made by studying the lichens present in an area with reference to their sensitivities to sulfur dioxide or other pollutants. If many or all of the more sensitive species are absent from an area where they would be expected to occur, there is a high probability that the air quality has been degraded. If all of the expected sensitive species are present, air pollution is unlikely to be adversely affecting other organisms. Denison (1987) cautions: 1) lichen community dynamics are complex and a missing species can also be due to gradual climatological and environmental changes during natural succession, and 2) variation in the skill and meticulousness of the individual researchers who measure and identify the lichens can affect results as much as pollution effects. The most accurate results from this method are achieved where historical records (Wetmore 1988) and good quality control and quality assurance programs to assess and minimize observer error are available (Stolte et al. 1993).

1.33 Lichen monitoring guidelines for US federal land managers

In the past decade, several documents have become available to guide federal land managers in the design, implementation and use of lichen monitoring (Stolte et al. 1993, Geiser and Williams 2002, Blett et al. 2003). These documents offer useful advice to novice and expert alike that can enhance the quality and utility of lichen monitoring data in decision-making and regulatory arenas. In addition, a working group of federal land managers, lichenologists, and computer specialists has been formed that offers support for lichen monitoring efforts on public lands (http://ocid.nacse.org/research/airlichen/workgroup).

2. METHODS

2.1 SUMMARY

2.11 Field protocols and training procedures

Methodology and training procedures follow the protocols of the Lichen Indicator section of the Forest Health Monitoring (FHM) program (Tallent-Hassell 1994) [see http://fia.fs.fed.us/library.htm#Manuals for an electronic copy of the current manual]. FHM was developed in cooperation with the US Environmental Protection Agency to monitor the condition of the nation's forests; the lichen indicator assesses the status of and trends in air quality and climate and has been closely scrutinized for repeatability (McCune et al. 1997). FHM is a component of EMAP (Environmental Monitoring and Assessment Program), and is currently administered by the USFS Forest Inventory and Analysis program. All FHM lichen indicator data are archived with the Information Management group for FHM at the EPA office in Las Vegas, Nevada. The methods in this manual produce data for managers of Pacific Northwest regional national forests that are comparable with data produced by the FHM lichen indicator.

In the basic plan, like the FHM lichen indicator, specially trained field crews perform a complete survey of epiphytic macrolichens, including ocular abundance estimates. In addition, and different from the FHM lichen indicator, target lichens and mosses are collected for tissue analysis at all plots. Twenty grams dry weights of two target lichens or mosses are collected at each plot. These samples are used to establish site baselines for toxic elements and to determine sub-regional element profiles. Target lichens are regionally abundant and easy to collect and prepare for analysis.

2.12 Quality assurance and quality control

The methodology described herein emphasizes quality control and minimizes specialized knowledge required by field personnel. The program coordinator trains and certifies field personnel, spot checks crews during the summer for quality control, inspects and aids sample preparation for tissue analysis, verifies identities of lichens collected in the field, supervises database entry, and provides data analyses. Forests share a common database from which statistical analyses are performed.

2.13 Selection of plot locations

Plot locations were selected from the USFS Pacific Northwest Region Current Vegetation Survey (http://www.fs.fed.us/r6/survey/) 5.5 km (3.4 mile) grid, now the Phase 2 (P2) grid of the Forest Inventory and Analysis program (http://fia.fs.fed.us/). All the plots are field-marked and co-ordinates are recorded digitally in the USFS regional geographic information system. The grid is overlaid without regard to where the plots fall; some plot centers fall in streams, lakes or alpine areas and were not installed. The EMAP-FHM program was initiated on a separate hexagonal grid. Recently FIA has taken over administration of both programs and the CVS and FHM plots are now integrated with the FIA grid into a single plot network.

Managers of individual national forests select priority areas for monitoring or more intensive sampling depending on proximity of the national forest to local and regional sources of air pollution, Forest priorities, and availability of funding. The default monitoring area and intensity is the entire Forest at the P2 scale. This is an intensification of the FIA/FHM grid. FHM monitors 1/16 of the P2 plots for lichens (i.e. plots are 28 km apart) and provides regional assessments, whereas managers of Pacific Northwest national forests are usually seeking watershed level assessments, especially in Class I areas. Also, because good air quality is prerequisite to ecosystem health, managers need to understand the status and trends in air quality on all national forest lands.

2.15 Monitoring frequency

One quarter of monitored plots are measured each year over a four-year period to complete one round of sampling. A ten-year monitoring interval is recommended between rounds. For example, if a monitoring round began in 1993, it would be completed in 1996. The next round would then begin in 2003.

2.16 Reporting

Reports are generated on demand, to summarize trends in, and current status of, air quality and to quantify ecosystem effects of air pollution via its effects on the Air Quality Related Value, lichen communities. Reports and publications resulting from this program are available from the Pacific Northwest Region Air Resource Management website (http://fs.fed.us/r6/aq).

2.17 Supplemental monitoring and other uses of lichen information

Supplements to the basic plan include expanded tissue analysis for elements of local, but not Forest-wide or regional concern, more intensive sampling in Class I Wilderness or areas of special concern, and the addition of transects to answer specific questions regarding point sources. Photo-documentation, growth studies, fumigations, transplants, or more quantitative measurements of lichen abundance may be added as needed to the basic monitoring strategy. These are not detailed here but can be developed by individual Forests or districts with the assistance of the program coordinator. Crustose and non-epiphytic macrolichens may be collected to inventory and establish habitat requirements of poorly known species.

In the 1990's lichen data from the air quality program was used extensively to meet information needs of the Survey and Manage component of the Northwest Forest Plan, i.e. to assess rarity, distribution, habitat requirements, and to write management recommendations. Lichen survey information also aids forest inventory efforts and the documentation of biodiversity, assists in the identification of biologically rich hotspots or habitat types, and can be used to identify old-growth associated lichens. It may help answer other management questions, such as amount of fuel

loading or availability of winter forage, and can aid planning decisions regarding old-growth management and protection of forest health.

2.2 TISSUE COLLECTION AND ELEMENT ANALYSIS METHODS

Element content refers to the concentration (percent or ppm dry weight) of selected elements. Elements are selected for analysis based on the likelihood of detectable enrichment from anthropogenic sources. ICP-AES, or preferably ICP-MS, analysis provides a suite of elements for a set cost. Typically, this includes aluminum (Al), boron (B), barium (Ba), calcium (Ca), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), potassium (K), magnesium (Mg), manganese (Mn), sodium (Na), nickel (Ni), phosphorus (P), lead (Pb), silica (Si), strontium (Sr), titanium (Ti), vanadium (V) and zinc (Zn). Total sulfur (S) and nitrogen (N) are measured by separate methods, and concentrations of these elements provide the best estimate of the exposure of lichens to harmful pollutants. Because of their environmental toxicity, mercury (Hg) and arsenic (As) are important elements to monitor, but they are much more expensive to analyze, and extra care must be taken in the field and laboratory to avoid volatilization leading to low recovery.

Each sample for element analysis must contain only one lichen species and be free of visible dirt, bark and other surface grit. Because lichen species differ in their ability to accumulate elements and because measurements must be comparable across national forest boundaries, only a few regionally common species are used for tissue analysis.

The elemental content of selected lichen species establishes site baselines for toxic elements and determines regional toxic profiles. Lichen elemental content is clearly indicative of key assessment questions, especially those concerning contamination of natural resources. Because a suite of elements is measured, it is sometimes possible to identify the different sources of contamination such as fossil fuels, saltwater aerosols and agricultural dusts (e.g. Sloof 1995, Reis et al. 1996).

Elemental content is determined by various methods. Typically, a 10 g, cleaned and dried, composite sample can adequately represent the mean element content at a plot. Samples are hand-cleaned of debris, oven dried, then ground. A bulk collection of thoroughly dried and ground material, if stored in the dark, can be used to assess laboratory precision over a period of about ten years. Because lichens hydrate readily, and hydrated material can decompose, storage of the bulk collection in the freezer is preferable to storage at room temperature. Recently, it has become possible to acquire standardized lichen materials (SRMs) (see section 2.38). Lichen SRMs are highly desirable because some important elements, such as sulfur and nitrogen, can be considerably lower in lichen samples than in plant SRMs.

2.21 Sample collection procedure

What to collect
Collect $\geq$ 20 grams each of two target lichens, dry weight. Dusty, gritty, discolored, or decaying material should be avoided. Collect replicate samples as described in the quality control section below.

Where to collect
The target species should be collected from a minimum of 6 different locations near or within the plot. Lichens attached to tree branches, shrubs or tree boles, in the litter, or on fallen branches, may be used. Exceptions are target species in the genera *Alectoria*, *Bryoria* and *Usnea.* These deteriorate quickly on the forest floor and should not be collected from litter or fallen branches. In non-forested areas, *Xanthoparmelia cumberlandia* may be collected from rocks. Replicates and repeat collections should be made from the same host species and types of substrate locations, in roughly the same proportions.

Collections should be made near or on the plot but not more than 1 km (.65 miles) away from the plot perimeter—approximately 20% of the distance to the next plot. Lichens should not be collected within 35 m of any road. Off-plot collecting will increase the probability of finding a given target species at each collection site.

How to collect
Most samples can and should be collected with the fingers. Non-powdered vinyl gloves are worn to prevent contamination of the samples. While wearing gloves the field crew should not touch anything brought with them onto the plot except the Kapak bag. Unused Kapak bags should be stored in a clean zip-loc plastic bag. New gloves will be used at each plot and replaced if they become torn or contaminated. A clean, stainless steel knife may be used to collect target species, e.g. *Xanthoparmelia*, that are tightly adhered to the substrate. Keep the designated collecting knife in a separate, clean, plastic bag and wash it after several uses with soap and water. Snow and ice remove lichens from tree boles and in some areas, particularly high elevations in the Cascades, lichens may be above arm's reach. In these cases, it may be a good idea to carry a pole length tree pruner to saw off small branches with high target lichen cover.

The samples should be collected as clean and free from bark and other foreign surface material as is practical and will be cleaned carefully later in the office. Place samples in metalized polyester Kapak bags and weigh on a 100 g Pesola spring scale. If the lichens are dry, the sample and bag together should weigh $\geq$ 28 g. If the lichens are wet, the bag should weigh more than 100 g and adequacy of the sample size should be judged by volume rather than weight. After enough material has been collected, press out excess air, fold the open edge of the bag over three times, and carefully seal with waterproof, removable, laboratory tape. The bag should be airtight.

What to record
The following information should be recorded directly on the Kapak bag, and also on the field data card. Write on the bag with an indelible marker:

1. Plot number
2. Date
3. Substrate(s): Host species name and substrate location in order by the amount of sample in the bag from that substrate. E.g. "*Pinus contorta* branches, *Pinus ponderosa* branches and boles" would indicate that the sample weight collected primarily from *P. contorta* branches and in lesser amounts from *P. ponderosa* branches and boles.
4. Target species acronym
5. Collector's initials
6. Moisture status of sample at the time of collection: dry, damp or wet.

Target Species
Two species will be collected at each monitoring site from the following list of target species. Whenever possible, one of the target species should be *Platismatia glauca*. Target species are grouped below by desirability. Target species acronyms are given in parentheses.

Most Preferred
Platismatia glauca (Plagla), collect whenever possible

Preferred
Alectoria sarmentosa (Alesar)
Evernia prunastri (Evepru)
Hypogymnia enteromorpha (Hypent)
Hypogymnia imshaugii (Hypims)
Hypogymnia inactiva (Hypina)
Letharia vulpina (Letvul)

Good
Bryoria fremontii (Bryfre)
Letharia columbiana (Letcol)
Sphaerophorus globosus (Sphglo)

Acceptable if no other target species are present
Isothecium myosuroides (Isomyo)—moss, do not collect from litter
Lobaria oregana (Lobore)
Lobaria pulmonaria (Lobpul)
Neckera douglasii (Necdou)—moss, do not collect from litter
Usnea (Usnea)--shrubby species only
If a moss is collected, the second target species must be a lichen.

2.22 Sample preservation and storage

On the plot, sealed, airtight, sample bags should be placed in a shady location or inside a daypack so they do not overheat while the remaining work on the plot is performed. Damp or wet samples should be air dried as quickly as possible, preferably the same day, by spreading onto clean 100% acid free blotter paper laid over a flat surface covered with clean plastic wrap. Label blotters so that sample identity is retained. Lichens and mosses should not be air-dried in areas subject to contamination (e.g. near cooking areas, roads, or in rooms where organic solvents are used, dust levels are high, or smoking is permitted). Kapak bags can be dried by crimping them open and leaving them upright, or by hanging them open on a line with a clothespin. As soon as they are dry, place the lichens back in the dried Kapak bags and carefully reseal. Sealed bags should be airtight. Dry lichens make a crunchy sound when the Kapak bag is squeezed; if the contents feel soft, they are probably damp. *Specimens must be thoroughly air dried to avoid fungal decay.* Store dry, samples in a clean, dry, dark place (bags are not opaque).

2.23 Sample delivery

After the first two plots are completed, specimens will be mailed or brought to the lichen specialist to allow immediate feedback to the field crews concerning specimen quality and quantity. Thereafter, the bags will be delivered biweekly or monthly to the program coordinator. Bags should be packed closely, but without excessive crushing, in a sturdy cardboard box. Bags from several plots can be mailed in the same box. A packing list should be kept by the field crew specifying the plot number, Forest, species, field replicate number, and mailing date of each sample (see “Forms” section).

2.24 Common problems and solutions

Problem: None, or only one, of the target species is present in sufficient quantities for collection, even if the sampling area is expanded to the 1 km maximum sampling radius.
Solution: In this case, no samples, or only one sample should be collected. Do not substitute non-target species.

Problem: *Platismatia glauca* is present, but it would be faster to collect other target species.
*Solution***:** Limit collection time to 1.5 hours and collect other target species while looking for *P. glauca*. Although 20 grams is the desired sample size, if the material is clean, dry, and in good condition, field sample size as low as 12 grams may be useable. Samples that weigh < 8 grams after cleaning in the office are not usually sent to the analytical laboratory.

Problem: More than 1 hour has been spent collecting but sample weight is still very low.
Solution: Get help from other crew members or switch to a more easily collected target species. Usually it's a good idea to stop collecting after two hours and process the collection that has been made. The decision to send the sample to the laboratory will be made in the office after the sample is cleaned.

Problem: All the sample material came from one or two trees.
Solution: This is not acceptable. The material must evenly represent at least six locations. Expand the area of collection up to the maximum size allowed. If material is still too scarce, collect a different species or collect nothing.

Problem: Lichens were collected wet, it is still raining by evening, and the field crew is camping.
Solution: Drying the lichens is still important to prevent fungal decay. If the distance is reasonable, go to the nearest district office to dry the lichens. Alternatively, store the samples in a cooler with ice up to two days, then air dry the lichens in a tent or in clean mesh bags on a clothes line as soon as conditions improve. Avoid use of heating devices to dry samples.

2.25 Equipment and supplies

Non-Consumable

1. Pesola spring scale, 100 g.
2. Reference samples of target species (provided or approved by the lichen specialist).
3. Locking-blade (ca. 4" blade), cleaned regularly with soap and water and stored in a new Ziploc bag after washing.
4. Poled tree pruner, useful for high elevation plots where deep snows create a high "lichen line".

Consumable

1. Black waterproof markers, such as "Sharpies", for writing on specimen bags.
2. 4 x 7" metalized polyester bags (sold by Kapak Corp., 5305 Parkdale Drive, Minneapolis, MN 55416, 1-800-527-2557 Product #60-4B-IM)). Two bags are needed for most plots, one for each species. Bring extra bags for field replicates.
3. Rolls of laboratory tape, ¾" or 1" wide. Tape should adhere to wet surfaces and be removable. Masking tape and cellophane tapes are difficult to remove and are not recommended.
4. Disposable vinyl gloves, not powdered, one pair of gloves per plot.

5. New, gallon size Ziploc bags. Store gloves and Kapak bags in separate Ziploc bags, placed inside a third Ziploc bag with the sharpie, scale and laboratory tape.
6. Roll of clear plastic wrap.
7. 100% cotton herbarium blotter sheets (11.5 X 16”), folded in half and stored in a clean Ziploc bag. Replace as they become visibly stained or smudged.

2.26 Interferences

This method may be used in any season or weather condition. Normally, the tissue collection season is May 15-Oct 15, that is, after the winter rains have ceased and before autumn rains have begun. Lichens collected during the rainy season typically have lower concentrations of mobile elements like S, N, K, Na, therefore mid to late summer is the ideal time to capture maximum pollutant loading. The method requires careful discrimination among species in the field and should not be performed in poor light. If the field crew observes or smells smoke from forest fire, field burning, or other types of combustion during collection, this should be noted on the field data card. Because of the potential for lead and other heavy metal contamination, no smoking is allowed on the plot or in the vicinity of the plot during the visit.

2.27 Safety

Only minor hazards are associated with the method. Care should be used when removing lichen specimens with a knife. A locking-blade or fixed-blade knife is best. Trees should not be climbed to procure specimens.

2.28 Quality control and performance standards

Only people who have successfully completed lichen training should collect the lichen elemental samples. Data quality will be measured at several times:

1. A post-training evaluation based on sampling a test plot.
2. A mid-season evaluation of field technique and sample quality by the lichen specialist.
3. Analysis of field and laboratory replicates and standard reference materials by the laboratory to evaluate accuracy, precision, and apportion variance.

The following components of data quality will be evaluated:

Precision

Precision, or repeat measurement error, is determined in several ways:

1. Revisits by the field crews who re-sample one plot within one month of its initial sampling. Collections are made for the same target species sampled in the previous visit.
2. Field replicates are made at every fifth plot for each species. After collection for the first bag is completed, collection should be made into a second bag. The purpose of the field replicate is to assess variability in elemental content on the site due to the collection method. If each collection contains a representative selection of lichens on the plot, and both samples are in good condition, there should be little variability in element content between the two collections. Field replicates should only be collected at sites where material is plentiful to avoid creating a bias in which the first bag contains samples that are in better condition than the second bag.
3. Other components of precision are determined during lab analysis, by using various kinds of quality control samples (standards, splits, blanks—see section 2.4). The data quality objective (DQO) for precision is a coefficient of variation of 15%.

Accuracy
Accuracy is determined in the laboratory by analyzing reference samples with known elemental content. The DQO for precision is a coefficient of variation of 15%.

Completeness
Completeness is the proportion of plots that will yield usable data. The DQO for completeness is 90%. The most important aspect of quality control for completeness is ensuring that the lichen elemental samples are adequate, not decomposed, and being received by the program coordinator. The field crew should ensure specimen quality by periodically calling the program coordinator to verify shipments and soliciting comments and suggestions on the quality of the specimens.

2.29 Specialist procedures

The samples will be processed first by the field crew who air-dry any samples that were damp or wet at the time of collection. The dry samples are then mailed or hand-carried to the program coordinator. The program coordinator processes all samples by 1) checking to see that each sample is thoroughly air dried, 2) verifying the identity of the species contained in the sample, 3) cleaning the sample so that it contains only one species, and 4) assigning a unique sample number to each sample bag. Data from sample bags are entered in a computerized database. The samples are then randomized, and assigned a consecutive laboratory ID number. The coordinator mails the samples to the analytical laboratory where they are processed and analyzed in order by laboratory ID number. Between 1993 and 2001 this laboratory was the Research Analytical Laboratory, Dept. of Soil Science, 135 Crops Research Bldg., University of Minnesota, St. Paul, MN 55108, Attn.: Roger Eliason, (612) 625-9211.

2.3 LABORATORY ANALYSIS

At the laboratory, air-dried samples are first passed through a stainless steel grinder with a 20-mesh sieve and mixed thoroughly. Ground samples are dried at 65^{o}C for 2 hours and cooled in a desiccator before weighing for analysis. The following analyses are made:

2.31 Sulfur

Total sulfur is determined by combusting 200 mg of sample mixed with 500 mg of V_2O_5 in an oxygen atmosphere at 1370 ^{o} C in a Leco Corp. SC-132 Sulfur Analyzer. The SO_2 evolved from the sample is determined by a nondispersive infrared detector empirically calibrated with LECO plant reference materials (LECO Corporation, 3000 Lakeview Dr., St. Joseph, MI 49085). Reference materials used for sulfur analysis in the 1990s were commercially prepared Peach leaves (Alpha Resources, Stevensville, MI), NIST 1575 Pine needles and NIST 1572 Citrus leaves.

2.32 Nitrogen

Between 1993 and 1997, total nitrogen concentration in lichen samples was measured using a semi-micro Kjeldahl digestion method (Horneck and Miller 1998). Since 1997, total nitrogen has been determined by combustion (Matejovic 1995). The combustion method yields slightly higher results because nitrates are determined (Simone et al. 1994 and empirical testing of duplicate lichen material). The standard reference material for nitrogen in the 1990s was NIST 1575 Pine Needles.

Total Kjeldahl nitrogen is determined by converting the various forms of nitrogen to NH_4^+, measuring NH_4^+ concentration, and subtracting the weight of hydrogen. To accomplish this, 0.150 g of dry, ground plant material is digested in 3.5 ml concentrated H_2SO_4 with 1.5 mg K_2SO_4 and 7.5 mg selenium. This mixture is placed in an electrically heated aluminum block at 400°C and digested for 1 hour. The NH_4^+ formed is reacted with salicylate in the presence of hypochlorite and nitro-prusside to form an emerald-green complex. Color intensity is measured spectrophotometrically on a Technicon AutoAnalyzer at 660 nm. The method converts only partial amounts of nitrate, thus samples containing high concentrations of nitrates must be pretreated with salicylic acid to ensure complete conversion. The nitrate reduction step is not necessary for lichen samples. Nitrates comprised less than 0.01% of the total nitrogen in a randomized subset of regional lichen samples.

The combustion method for total nitrogen uses a LECO FP-528 Nitrogen Analyzer. A 150-500 mg sample is weighed into a gel capsule and dropped into an 850° C furnace purged with O_2 gas. The combustion products (CO_2, H_2O and NO_x) are filtered, cooled by a thermoelectric cooler to condense most of the water, and collected into a large ballast. A 3 cc aliquot of the ballast combustion product is integrated into a helium carrier stream. The stream first passes through a hot copper column to remove O_2 and convert NO_x to N_2. A reagent tube then scrubs the remaining CO_2 and H_2O from the stream. N_2 content is measured by a thermal conductivity cell against a helium background and the result is displayed as a weight percentage of nitrogen.

2.33 Aluminum, boron, cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, nickel, phosphorus, potassium, sodium, and zinc.

These elements are determined using simultaneous inductively coupled-atomic emission spectrometry (ICP-AES) (Dahlquist and Knoll 1978). Reporting limits during the 1990s are listed in **Table 1**. For this analysis, one gram of sample is weighed into a 20 ml high form silica crucible, covered, and dry-ashed at 485° C for 10-12 hours in a circulating air muffle furnace (Munter and Grande 1981). After ashing, 5 ml of 20% HCl is added and the mixture is boiled under reflux for about 3 hours for improved recovery of aluminum, chromium and iron. After cooling, 5 ml of deionized water is added. This digest solution is gently swirled and allowed to settle for 3 hours. The supernatant is decanted and transferred to 15 ml plastic disposable tubes for direct determination. During ICP-AES analysis, measurement of a sample is repeated three times with 10-s gas flow between each measurement.

The procedure is a partial digestion of the sample that is designed to solubilize the less refractory components of plant material. Silicate matrices that may be present as contaminants of the sample are not as completely solubilized in this procedure as the plant tissue.

2.34 Barium, beryllium, cobalt, lithium, molybdenum, rubidium, silicon, strontium, titanium, and vanadium

Resources permitting, tissue samples are analyzed for these trace elements by the same ICP procedures described above. During the 1990s, concentrations of beryllium, cobalt, lithium and rubidium in Pacific Northwest lichens from background “clean” areas were below laboratory detection limits.

2.35 Ash

The percentage ash yield is determined by combusting 1 g of the oven-dried sample at 485 °C for 12 hours in a circulating air muffle furnace.

Table 1. University of Minnesota Research Analytical Laboratory Determination and Reporting Limits for ICP-AES analysis of lichen tissues.

Element	Determination Limit	Units (dry wt)	Analytical Method	Wavelength	Reporting Limit µg/l
Ash	0.5	%	Ash		
N	0.01	%	LECO		
S	0.01	%	LECO		
Al	3.6	µg/g	ICP-AES	308.215	180
As	0.78	µg/g	ICP-AES	193.696	40
B	0.46	µg/g	ICP-AES	249.773	24
Ba	0.12	µg/g	ICP-AES	455.403	7
Be	0.04	µg/g	ICP-AES	313.042	3
Ca	4.36	µg/g	ICP-AES	317.933	42
Cd	0.12	µg/g	ICP-AES	226.502	7
Co	0.24	µg/g	ICP-AES	228.616	13
Cr	0.28	µg/g	ICP-AES	205.552	15
Cu	0.52	µg/g	ICP-AES	324.754	27
Fe	0.96	µg/g	ICP-AES	259.940	18
K	14	µg/g	ICP-AES	766.491	708
Li	0.4	µg/g	ICP-AES	670.781	21
Mg	3.8	µg/g	ICP-AES	279.079	191
Mn	0.06	µg/g	ICP-AES	257.610	4
Mo	0.22	µg/g	ICP-AES	202.030	12
Na	3.6	µg/g	ICP-AES	588.995	181
Ni	0.44	µg/g	ICP-AES	231.604	23
P	0.7	µg/g	ICP-AES	214.914	36
Pb	1.7	µg/g	ICP-AES	220.353	85
Rb	53	µg/g	ICP-AES	780.020	2650
Si	1	µg/g	ICP-AES	251.611	85
Sr	0.06	µg/g	ICP-AES	421.552	4
Ti	0.3	µg/g	ICP-AES	334.941	16
V	0.36	µg/g	ICP-AES	292.402	19
Zn	0.4	µg/g	ICP-AES	213.856	8

Reporting limits are based on the concept of the Lowest Quantitatively Determinable Concentration (LQDC) and are 5 times the instrument detection limit. Precision at the LQDC is approximately ± 10% and analytical results are quantitative. The instrument detection limit is 2 times the standard deviation of eleven replicates of a reagent water sample.

2.36 Fluoride

One g of dried sample is added to 20 ml of 0.05 M H_2SO_4 and shaken 15 minutes. Twenty ml of 0.01 M NaOH is added, followed by another 15 minute shaking period. The solution is then buffered by 5 ml of 3 M sodium acetate and 10 ml of 0.5 M sodium citrate to reduce interference from Al, Si, and Fe. Fluoride is measured with a fluoride ion selective electrode under constant stirring and temperature (Jacobson and Heller 1972).

2.37 Mercury

Mercury is analyzed by digesting a 0.50 g sample with 2 ml H_2O_2 and 0.5 ml HNO_3 in a microwave digestion vessel for four minutes at 296 watts and 8 minutes at 565 watts, followed by a 2 hour digestion in a 95^{o}C hot water bath with 0.25 M sulfuric acid, 5% potassium permanganate and 5% potassium persulfate. After reduction with stannous chloride, total mercury is quantified by the cold vapor technique using atomic absorption spectrophotometry on a Monitor Elemental Mercury Detector.

2.38 Reference materials and blanks

National Institute of Standards and Technology (NIST) standard reference materials (SRMs)
At least 1-2 NIST SRMs are analyzed with each batch. NIST SRMs have concentration ranges established by the National Institute of Standards and Technology. They are purchased directly from NIST and submitted as blind samples to the testing laboratory. Analysis results are used to assess laboratory accuracy.

Lichen standard reference materials
The use of a standardized lichen material in addition to or in lieu of a NIST SRM is highly desirable because concentrations of some elements are lower in lichens than in plant materials and it is easier for the laboratory to achieve precise, accurate results for these elements for the NIST SRM than for the lichen samples. The lichen, *Pseudevernia furfuracea* is available as CRM 482 from IRMM (Institute for Reference Materials and Measurements) Reference Materials Unit: Technical and Sales Information, Retieseweg, 2440 Geel, Belgium, http://www.irmm.jrc.be. This material is certified for Al, As, Cd, Cr, Cu, Hg, Ni, Pb and Zn (Quevauviller et al. 1996). A second reference material, IAEA-336, *Evernia prunastri* (Heller-Zeisler et al.1999, Stone et al. 1995) is certified for more elements Al, As, Ba, Br, Cd, Ce, Cl, Co, Cr, Cs, Cu, Eu, Fe, Hg, K, La Lu, Mn, Na, Nd, P, Pb, Rb, Sb Sc, Se Sm, Sr, Tb, Th, V, Yb, Zn. It can be ordered from Analytical Quality Control Serives Agency's Laboratories, Seibersdorf A-2444, Seibersdorf, Austria or from the IAEA website at http://www.iaea.org/programmes/aqcs/main_database.htm.

Alectoria sarmentosa Reference Material
A sample of the lichen check, *Alectoria sarmentosa* from the Mt. Hood National Forest (submitted in large volume to the lab in 1993) is analyzed every 20-30 samples (1-2 for each sulfur batch, 2 for each nitrogen batch, 4 for each ICP-AES batch). This check is used to compare laboratory precision between batches and years. A new *Alectoria sarmentosa* check was collected in winter 2002 from Willamette Pass, Willamette National Forest, in the central Oregon Cascades, and submitted to the UMN Research Analytical Laboratory in spring 2003.

Duplicates
Duplicate analyses of the digests are run every 10 samples for all elements. This determines the laboratory precision within a batch.

Acid blanks
One or two acid blanks are analyzed with each analytical batch (batch size varies between ICP-AES, nitrogen, and sulfur analyses. These blanks pass through all digestion/analytical procedures for the nitrogen, sulfur, and ICP-AES analyses and are identical, as far as possible, to the samples. They are used to detect and quantify contamination of the samples from the analytical reagents.

2.39 Receipt and storage of analytical results

Results are received from the laboratory in electronic spreadsheet form and hard copy as % sulfur, % nitrogen and ppm (dry weight) of the remaining elements. Individual sample dilution-factors and direct instrument readings for ICP results are also provided. Upon receipt, the data is checked for inconsistencies and, if necessary, arrangements are made to rerun samples with anomalous values. Currently the lichens and air quality databases are stored at the Siuslaw National Forest Corvallis Supervisor's Office and at NACSE (Northwest Alliance for Computational Science and Engineering) in the Computer Science department of Oregon State University. Eventually, a copy of the database will be archived by the USFS Natural Resources Information System, updated annually. The lichen module is scheduled for development in 2003-2004. Currently the database can be queried from http://www.fs.fed.us/r6/aq/lichen.

2.4 LICHEN COMMUNITY METHODS

The purpose of the lichen community indicator is to use lichen species and communities as biomonitors of change in air quality, climate change, and/or change in the structure of the forest community. Lichen communities are good indicators of air quality, particularly long-term averages of sulfur dioxide concentrations. Other pollutants that alter natural lichen communities include sulfur and nitrogen-based acid deposition, nitrogen fertilizers, fluorine and, possibly, ozone and other oxidants (see Section 1.32).

The following lichen community survey methods employed by our program were developed under the auspices of the USDA-Forest Service Forest Health Monitoring Program and are described in the FIA Field Methods Guide (http://fia.fs.fed.us/library.htm#Manuals). A few differences exist between the protocol that follows and the FIA Field Methods Guide. Our abundance rating has more categories than FHM, but can be collapsed to FHM ratings; substrates are recorded; and it is permissible to collect lichens below 0.5 meter on woody substrates east of the Cascade crest as long as they are tree and shrub-dwelling epiphytes and not terricolous or rotting wood species.

The objectives of this task are to determine the presence and abundance of macrolichen species on woody plants (using a 34.7 m [114 ft] radius plot) and to collect samples to be mailed to the lichen specialist(s). The method has three parts, performed at the same time:

1. Make a collection of voucher specimens for identification by a specialist, the collection representing the species diversity of macrolichens on the plot as fully as possible. The population to be sampled consists of all macrolichens occurring on woody plants, excluding the 0.5 m basal portions of trees and shrubs (west side of the Cascade crest only). Fallen branches are included in the sampling.
2. Estimate the abundance of each species. Note that the crew member responsible for this task need not be able to accurately assign species names to the lichens (that is done later by a specialist), but must be able to make distinctions among species.
3. Record the substrate from which the lichen was collected. For woody substrates, record the species and location (i.e., branches, bole, limbs, etc.).

2.41 Procedure

1. The area to be sampled (henceforth the "lichen plot") is a circular area with 34.7 m (114 ft) radius. The area of the lichen plot is 3782 m^2 = 0.378 ha = 0.935 acres.

2. Sampling continues for a maximum of two hours or until 10 minutes elapse with no additional species recorded. At least 30 minutes must be spent searching the plot, even if very few lichens are present.
3. A reconnaissance walk through the lichen plot should be taken to locate lichen epiphytes on woody plants, collect voucher samples and assign abundances. The following method is suggested: Begin at approximately 30 m (100 ft) due north from plot center, measuring with the eye to the limiting boundary of 114 ft. and continue to the right in a sinuous manner 90^{o}. (The plot should be flagged every 90^{o} along the perimeter). The same procedure is followed around the rest of the plot. If time allows, a second circuit of the plot can be made, searching for spots which were not visited in the first pass.
4. Lichen species with fruticose and foliose (i.e. macrolichen) growth forms will be collected.
5. Woody plants (all trees and shrubs $\geq$0.5 m tall) within the lichen plot will be inspected for lichen species. Fallen and reachable branches will also be inspected.
6. Care should be taken to inspect the full range of substrates and microhabitats available: shaded and exposed, conifers and hardwoods, fallen upper branches and lower branches, large shrubs and trees in particular topographic positions (for example, checking in draws or ravines of an otherwise uniform slope, so long as it occurs within the lichen plot). Rotten logs, stumps, or other semi-permanent features of the forest floor should NOT be sampled.
7. Abundance ratings. Relative abundance within the lichen plot will be recorded. Relative abundance for each species is estimated as follows. Choose the highest rating that is true in **Table 2**.
8. A sample of each putative species will be collected and placed in a paper packet labeled with plot number, collector's initials, forest acronym, substrate and relative abundance. The abundance rating can be revised as collection proceeds or given at the end of the collection period. Any relevant comments are recorded on the outside of the packet under "Remarks". For more details, see section 2.52 below. Before leaving the plot all packets should be checked to make sure that, as a minimum, plot number, abundance and substrate has been recorded on every packet. They should then be alphabetized by genus and species (if known) and sequential packet numbers assigned, beginning with "1".
9. How to handle uncertainties: The field crew will frequently have uncertainties about the classification of an organism. The following rules for the field crew are designed to put the onus of the responsibility for classification on the specialist, not the field crew.
    a. When in doubt, assume it is a lichen.
    b. When the growth form is in doubt, assume it is a macrolichen.
    c. When species distinctions are in doubt, assume that two different forms are different species.

The purpose of these rules is to encourage the field crew to make as many distinctions in the field as possible. The specialist can later adjust the data by excluding specimens that are not macrolichens and by combining forms that were considered separately by the field crew but are actually the same species.

2.42 Sample collection, preservation, and storage

Optimally, palm-sized (about 5 cm in diameter) samples of fruticose and foliose growth forms are collected. These growth forms include all species that are three-dimensional or flat and lobed. Even minute fruticose and lobate forms should be included. Squamulose species and *Cladonia* squamules lacking upright stalks should not be included.

Table 2. Abundance ratings for lichen community surveys

Code	Abundance	Description
1	Rare	< 3 individuals/colonies in area
2	Uncommon	4-10 individuals or colonies in area
3	Common	10-40 individuals or colonies in area
4	Very Common	>40 individuals or colonies in area but less than half of the boles and branches are covered by the species. Choose one:
	4-1	Individuals/colonies are few (between 40-80) and widely scattered around the area
	4-2	The lichen is restricted to one or two small areas in the area, usually on just a handful of trees or shrubs. The total number of individuals or colonies is >40.
	4-3	Many trees or shrubs have up to 20 individuals or colonies.
	4-4	Many trees or shrubs have more than 20 individuals or colonies.
	4-5	More than half the trees or shrubs have up to 20 individuals or colonies.
	4-6	More than half the trees or shrubs have more than 20 individuals or colonies.
5	Abundant	More than half of the available substrate is covered by the subject species.

These codes correspond to the FHM lichen indicator codes as follows: 1 = FHM 1; 2 and 3 = FHM 2; 3 to 4-4 = FHM 3; 4-5 to 5 = FHM 4.

In some cases, a small sample should be obtained because of the scarcity of the species. However, if the abundance rating is $\geq$ 3, the sample should be generous. Large samples containing multiple individuals simplify the identification process and demonstrate that the collector was able to distinguish the species from look-alikes, improving confidence in the assigned abundance code. Collecting large samples also improves the likelihood of picking up inconspicuous species that may not be distinguishable in the field. These can be recorded by the lichen specialist in the office.

Species in the genera *Usnea* and *Bryoria* are most difficult to distinguish in the field and large samples nearly always contain a mix of species within a packet. If species are present in equal amounts, the abundance code may unusable. For these genera, the best strategy is to carefully learn characters that differentiate species and collect smaller samples in multiple packets.

Before leaving the plot, each specimen will be placed in a separate folded paper packet and labeled as follows:

1. Plot number (use FIA Plot ID code for on-frame plots).
2. Ocular abundance code (can be revised as collection proceeds and the observer becomes more familiar with the plot).
3. Substrate.
4. Occasionally there will be more than one species on a given bark sample. If there is any chance of ambiguity about which species in the packet corresponds with the abundance rating, a descriptive clarifying phrase, such as "the white one" or "the sorediate one", will be written on the packet.

Packets will be labeled with an indelible marker. If the packets are damp, a soft pencil (No. 2 or softer) can be used.

The lichen worksheet and all of the specimen packets from a given plot will be placed into a paper or Ziploc bag with the plot number, collectors initials, and date recorded on the outside of the bag and the top folded down or sealed.

The bags should be stored in a dry place until delivery to the specialist. Specimens must be thoroughly air dried to avoid fungal decay. If specimens were wet when collected, the individual packets should be spread out and dried inside or in the sun as soon as possible. If temperatures are above room temperature, wet lichens are likely to mold within 2-3 days.

2.43 Sample delivery

After the first two plots are completed, the specimens will be mailed or brought to the program coordinator. This allows the coordinator to provide immediate feedback to the field crews concerning specimen quality and quantity. Thereafter, the packets can be delivered biweekly or monthly. Packets should be packed closely, but without excessive crushing, in sturdy cardboard boxes. Packets from several plots can be mailed in the same box. The field crew should save a running packing list (see "Forms" section) specifying the CVS plot numbers, Forest, and date mailed. Any notes of possible use to the lichen specialist should be sent with the packets.

2.44 Equipment and supplies

Consumable

1. Folded labeled paper packets (can be made by recycling one-sided office paper). Carry 40 packets per plot west of the Cascade crest, and 25-30 packets for plots east of the Cascade crest.
2. Black waterproof markers for writing plot numbers and abundance data on paper or plastic bags.
3. Larger brown paper bags (16.5 x 9.5 " or similar size), or gallon-sized re-sealable clear plastic bags, one per plot.
4. Soft pencils (No. 2 or softer) and indelible pens.
5. 6 mailing forms
6. 60 field data cards per Forest.

Non-Consumable

1. Locking-blade or fixed-blade knife (ca. 4" blade) with belt sheath.
2. 14-20x hand lens (Bausch and Lomb Hastings Triplet is recommended).
3. Guides for lichen identification:
    a. Brodo, I., S. D. Sharnoff and S. Sharnoff. 2001. Lichens of North America. Yale University Press, New Haven, CT.
    b. Goward, T. 1999. *The Lichens of British Columbia. Part 2. Fruticose Species*. British Columbia Ministry of Forests Research Program.
    c. Goward, T. McCune, B. and Meidinger, T. 1994. *Lichens of British Columbia. Part 1. Foliose lichens*. British Columbia Ministry of Forests Research Program.
    d. McCune, B. and L. Geiser. 1997. *Macrolichens of the Pacific Northwest*. Oregon State University Press. See Bruce McCune's website for updated keys: http://oregonstate.edu/~mccuneb/getkeys.htm.
    e. McCune, B. and T. Goward. 1995. *Macrolichens of the Northern Rocky Mountains*. Mad River Press, Eureka, CA.
4. Hand pruners (useful for collecting small branch segments).
5. 1" wide chisel (useful for collecting samples from tough-barked hardwoods, a sheath can be made from a piece of cardboard and strapping tape).

6. Clipboard (for field data forms).

2.45 Interferences and safety

This method may be used in any season or weather condition. Because careful discrimination among species in the field is required, the method should not be performed within an hour of sunset or sunrise, or during dark, rainy conditions.

Only minor hazards are associated with the method. Care should be used when removing lichen specimens with a knife or chisel. A locking-blade or fixed-blade knife is best. Trees should not be climbed to procure specimens.

2.46 Quality control and performance standards

Only people who have completed lichen training and have been certified should collect the lichen community data. Data quality will be measured using a post-training audit and a mid-season field audit. Field audits compare the results of a lichenologist with the field-crew member. One or more plots will be examined per audit.

The field crew will be audited within 2-4 weeks after the conclusion of training by the lichen specialist. Results of the audit will be included in a summary QA report prepared at the end of the field season. Corrective action by the auditor will be correction of any misunderstandings and provision of additional on-the-spot training so that the crew can better complete its task. Corrective actions cannot include alterations in the basic method.

A second aspect of quality control is ensuring that the voucher specimens are adequate, not decomposed, and being received by the lichen specialist. The field crew should ensure specimen quality by periodically calling the lichen specialist to verify shipments and solicit comments and suggestions on the quality of the specimens.

The performance of the method is assessed by evaluating data quality objectives (DQOs) for detectability, precision, accuracy, and completeness. Each of these is evaluated below, based on the FHM program experience with this method in 1992.

Detectability
Detection capabilities of field crews are determined by the percentage of the specialist's species that is represented in the field crew's data. The DQO for this statistic is 80%.

Precision
Precision, or repeat measurement error, is determined by the field crews revisiting and re-sampling one plot sometime during the same field season. The DQO for precision is 85%. Scores are compared as described in the accuracy section, below.

Accuracy
Accuracy can be expressed in terms of the percent agreement between species composition 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. This agreement is calculated as the concordance in abundance scores. The abundance scores have six possible levels (0, 1, 2, 3, 4, and 5). Concordance between two investigators for a single plot will be calculated as the percent similarity between the scores for the two investigators, calculated using the sum of the shared

species abundance sores divided by the total of all scores from both investigators. The DQO is 80%.

Completeness
Completeness is the percentage of fields on the packet labels (see Section 5.8) of all the samples collected on a plot that have been recorded and are legible (excluding the species identification). The DQO of completeness is 90%.

2.47 Lichen specialist procedures

Purpose
The program coordinator has five roles:

1. Conduct or assist with training of field crews.
2. Verify or supervise verification of lichens collected and identified by the field crew.
3. Conduct or assist with field audits.
4. Supervise database entry.
5. Write or assist with data analysis and annual reports.

Procedure for processing specimens

1. Receive boxes of specimens in the mail or directly from the field crew.
2. Open the boxes immediately and check for damp lichens. If some are damp, thoroughly air-dry them.
3. Identify the contents of each bag by species. In the case of mixed collections or multiple collections of the same species, see the special instructions below.
4. Enter the list of species identifications, along with plot numbers, substrates and abundances for all identifications in a computerized spreadsheet.
5. Prepare voucher specimens. Select individuals for herbarium specimens such that, ideally, each species is represented by about three specimens from each national forest. These specimens should be stored in standard, labeled herbarium packets. In all cases, the label data should include the plot number and the date of collection. Vouchers are currently stored in the Siuslaw National Forest herbarium.
6. Store packets (with lichens!) for future reference. Packets are currently stored in the Siuslaw National Forest Supervisor's Office storeroom.
7. Keep a list of comments/suggestions for the field crew. They will call you periodically for feedback.

Handling multiple collections of the same species
Because the field crew is instructed to err on the side of making a species distinction 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. Each collection will be entered separately in the database.

For data analysis purposes, a combined abundance value can be calculated for those species collected more than once on a plot using the rules in **Table 3** for combining abundance values.

Recording species mixed with vouchers but not recognized by the field crew
Despite the best efforts of the field crew, the lichen specialist will occasionally encounter species that were not recognized in the field. Although these lichens can easily be recorded by the specialist, they will not have abundance values assigned by the field crew. In these cases, the species should be recorded on the data sheet, and a missing value indicator (0) recorded for

abundance and packet number. For data analysis purposes, zeroes are usually converted to the most common abundance rating, 3.

Table 3. Combining abundance values for multiple collections of a single species on one plot.

Recorded Values	Result
1 + 1	2
1+ 2	2
1 + 3	3
2 + 2	2
2 + 3	3
4 + any others	4 (Use highest rating recorded)
5 + any others	5
1 + 1 + 1	2
1 + 1 + 2	2
1 + 1 + 3	3
1 + 2 + 2	3
1 + 2 + 3	3
1 + 3 + 3	3
2 + 2 + 3	3
2 + 3 + 3	3
3 + 3	3
3 + 3 + 3	4

Quality Assurance Reports to management
A QA report form will be used during training and audit procedures, and can be made available to the air resource management staff officers and program managers. A summary of QA results from the training, audits, re-measurements, and debriefings will be compiled by the program coordinator along with a description of any significant QA problems and recommended solutions.

2.48 Data entry and analysis

Data entry
Field data are recorded on the packets used for collecting specimens. These data are later entered in the office, following determinations of species. Data will be entered onto a computer spreadsheet and backed up on a Forest Service network drive. Currently the lichens and air quality databases are stored on networked personal computers (backed up on shared unit space) at the Siuslaw National Forest Corvallis Supervisor's Office and at NACSE (Northwest Alliance for Computational Science and Engineering) in the Computer Science department of Oregon State University. Data values will be screened against acceptable ranges.

Data analysis
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 computations 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 as a weighted average across species for a given sample unit, the species weights being derived from a measure of sensitivity to air pollution or any other gradient or scores derived from equations based on

ordination of samples varying in the quantity to be indicated (i.e. an "assessment endpoint", e.g. air pollution).

Data analysis will consist of:

1. Analysis of data quality by using data from audited plots. Data will be compared between the field personnel and the auditors (lichen specialists).
2. Derivation of synthetic composite variables 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.
4. Establishment of nominal/subnominal boundaries for indications of air quality by comparison of known polluted areas with otherwise similar, but remote areas.
5. Analysis of the relationship between lichen community parameters and various spatial data (e.g. emissions, NADP, IMPROVE, lichen tissue chemistry), to the extent possible by data availability and funds.

2.5 COLLECTION OF OTHER FIELD DATA

The collection of site data is integral to differentiating lichen community responses to air pollution from responses to other environmental influences. Site data also provides critical information with regard to the distribution and associated habitats of lichens detected in community surveys. For surveys that are co-located with CVS or FIA plots, most of the site data can be obtained directly from these programs and only the on-frame field data card (Form 5.2. Field Data Sheet for Lichen Monitoring Plots) need be completed. When an off-frame plot is surveyed, then both the on-frame field data card (Form 5.2) and an off-frame data card (Form 5.3 Additional Information For Off-Grid Plots) should be completed.

2.51 Completing the Field Data Form 5.2.

Note that use of metric units is preferred. However older equipment may provide only feet and inch measures. To avoid time consuming calculations in the field, both metric and British system equivalents are provided on data forms 5.2 and 5.3.

Plot number
Record the CVS or FIA number or, if the plot is off-frame, then give the plot an alpha-numeric name of no more than 8 digits, with no spaces. Usually the site is named for a nearby feature or city, e.g. “SilverCk”. If several sites are surveyed in the same area, use sequential numbers, e.g. “SilverC1”, “SilverC2”.

Lichen surveyor
Write the first and last name of the person who surveyed the lichens. During an audit or on a plot used for training, more than one person will be making a lichen survey. In these cases, write the names of both surveyors.

Lichen tissue collector
Write the first name and last name of the person(s) who collected lichens for tissue analysis.

Date
Write the date during which the plot was surveyed.

Other observers
If any other persons were present on the plot, even if they did not participate in data collection, record their names here.

Plot type
Circle "FIA/CVS" if the plot is a numbered plot on the FIA or CVS grid. Circle "Rep" if the plot has been previously surveyed for lichen communities or if samples for tissue analysis have been previously collected at the site. Circle "Audit" if the plot was audited simultaneously by a certified field person and the lichen specialist. Circle "Training" if the plot was surveyed by someone who was not certified. Circle all that apply.

Stand location
Record the National Forest (if applicable), Ranger District (if applicable), County and State on the appropriate lines. Write a brief description of the location in words that would allow someone to find the approximate location of the site on a map, and provide sufficient information for a herbarium label. Give the approximate distance and direction from the nearest town, or other landmark, e.g. "On the western footslopes of Blanket Mtn, 8 km ne of Creighton". Do not copy the detailed directions from the CVS plot card. These are already available in electronic form.

Stand age
This section should only be completed when tree age data is available (i.e. from tree cores obtained on the site, from clean-cut stumps, or from CVS data) or when the surveyor understands the plant community well enough to recognize the seral species.

Stand structure
Check the largest size category that applies, considering only the dominant and co-dominant trees on the site. If the plot is partially disturbed, e.g. half is clear-cut, rate the least disturbed portion and describe the structural heterogeneity in the "Notes" section.

Vegetation cover
The purpose of this section is to provide a visual synopsis of the plant community. Write the scientific name or FS acronym of each plant in the box that most closely describes the percent of ground or canopy covered by that species. It is not necessary to make an exhaustive list of all plants on the plot; indicator species are sufficient. Ground cover of the various bryophyte species can be summed and recorded as a single value, as can that of lichens. A notable cover of epiphytic lichens or bryophytes should be described in the "Notes" section, providing species names, if known.

Lichen chemistry
Record the six-letter acronym of the target lichens or mosses collected for chemical analysis, and the substrates from which the target species were collected. Substrates and substrate locations should be recorded in order of importance, as directed in Section 2.21. Also record the weight of the sample, after subtracting the weight of the bag. Note the moisture status of the sample, dry (no further drying needed, lichens feel crisp and crunchy through the bag), damp or wet (the sample needs to be dried to prevent decay). Spatial extent: Describe where the sample was collected, e.g. "over the entire plot", "on the lower half of the plot", "in a stand of .5 ha about 1 km s of the plot west of Rd 104", etc.

Notes
This is the place to make notes about any deviations from the protocols that were made, to provide a verbal description of the habitat (suitable for a herbarium label), to note any outstanding

features of the plot, and to describe the lichen community composition and condition. This is one of the most important sections of the field data card.

Plot audit
The purpose of the audit is to help field crews remember to do the most important tasks before leaving the plot—it is primarily a self-check. If two persons are working, either crew member may complete the audit. The auditor signs and dates the card when all the tasks have been completed.

2.52 Completing the Off-Grid Field Data Form 5.3

Plot number and date
Follow the directions provided in Section 2.51, above.

Location
Measure latitude and longitude in decimal degrees (XX.XXXXX^{o}) and UTMs in meters in the field using a hand held GPS. Set the mapping datum to NAD27 CONUS. Units of measurement can be toggled between meters and decimal degrees in the field. Record values for both units of measurement, and the UTM zone, while on the plot. Township, Range and Section is determined from a map and recorded to the nearest ¼ section, e.g. "T120S R30E S24 SE ¼". The map name and size/scale are recorded, e.g. "Alsea USGS quadrangle". If a multi-page atlas is used, such as the *Oregon Atlas and Gazetteer*, then record the name of the atlas, the year or edition, and the page number. Record the number of the aerial photo, if one was available.

Physiography
Topographic position is determined from a topographic map. Aspect and slope are measured using a compass and clinometer, respectively. Aspect is the steepest downhill direction. Slope is determined by standing at plot center and averaging the uphill and down hill slopes along the aspect. Elevation can be obtained from a topographic map or from a handheld GPS.

Trees/shrubs
Record the plant association if a plant association guide for the area is available. (Check with ecology or botany program specialists to obtain the most recent plant community guides). Follow the key to determine the plant association and record the code and the full name.

Determine the largest size class containing at least eight trees. All live trees, including remnants, on the plot may be included in the size class tally.

Dbh measurements
The purpose of these measurements is to gather tree data that are roughly comparable to summarized tree data available from the CVS/FIA program. Usually, the most efficient procedure is to flag a subplot of 15.6 m (51.1') radius, measured from plot center, while laying out the larger plot for the lichen community survey. If the plot center area is not generally representative of the vegetation on the site, then the subplot should be established in a more representative area.

Record the actual radius of the subplot(s) used. The minimum size that can be used is listed in the column, "Minimum radius". Larger subplots are permissible. The maximum radius for all size classes is 56.4 m (185.1'). Subplots smaller than 15.6 m are primarily used to save time when there are many small trees on the plot.

The number of trees in each size class is tallied by recording an "H" for each hardwood tree (do not include tall shrubs), and a "C" for each conifer, in the "Tally of Trees" space. Circle or otherwise clearly indicate which trees are dominants or codominants to separate overstory and understory. For example, the line for size class 13-24.9 cm might look like: 13-24.9 cm, 8 m, 15.6 m, HHHH CCCCC.

Age of oldest tree cohort
To estimate the age of the oldest trees on the plot, core 2-3 trees of different species that appear to be the largest trees on the site, including remnants. Record the tree species acronym, the dbh, and the length of the core. If possible, record the number of rings in the core (this is often best accomplished at a later time, using a dissecting microscope with a good light). Estimate the age using the formula, age in years = [(# rings/core length)* dbh] +5. Store tree cores in straws, labeled with plot number and tree number, and sealed at both ends using lab tape.

3. INDIVIDUALIZED SAMPLING STRATEGIES NATIONAL FORESTS

The following sections describe local and regional emission sources with potential to adversely affect forest ecosystems (especially lichens), monitoring priorities for lichen sampling, and potential and on-going interfaces with other monitoring efforts. The pollutants of main concern are those that alter or degrade species composition of plants, fungi and microbes through acidification of the environment (e.g., nitric and sulfuric acid from acid rain), those that artificially enhance the fertility of the forest, (e.g. anthropogenic sources of ammonia, nitrates, nitric acid, sulfates, sulfuric acid), and reactive gases that directly harm vegetation through adverse effects on physiology or structural integrity (e.g. sulfur dioxide, nitrogen oxides, ozone, fluorine, peroxyacetylnitrate). Toxic metals and accumulated persistent, semi-volatile, organic pollutants are also a perceived threat and developing methods for evaluating effects of these pollutants on Pacific Northwest forests may be an important future goal.

As large industrial point sources are controlled, pollutants resulting from individual actions and increasing population size—that is pollution due to higher energy and food production needs, higher rates of transportation of people and goods, and increasing numbers of, small, unpermitted point sources, comprise an increasing percentage of the acidifying, fertilizing, and oxidizing pollutants in the US Pacific Northwest. In addition, trans-Pacific transport of pollutants from Asia and Europe occurs and are expected to continue increasing as population size, energy use, and standard of living increases in these continents. Currently, this source is estimated to contribute 5-25% of ambient NO_x levels in western Oregon and Washington (Fenn et al. 2003).

Figures and **Maps** referenced in sections 3.1 to 3.9 can be found immediately after Section 3.9 and in Appendix I, respectively.

3.1 COLUMBIA RIVER GORGE NATIONAL SCENIC AREA

3.11 Emissions sources

The Columbia River Gorge National Scenic Area (CRGNSA) (**Fig. 1**) is a major transportation corridor. High traffic density from the Portland area Interstate Highway 84 follows the Oregon side of the river and State Highway 14 follows the Washington side. There is also frequent rail traffic on both sides of the river and active barge and recreational boating activity in the river itself. Diurnal winds carry pollutants up and down the river valley from the Portland-Vancouver metropolitan area and from industries and agriculture within or in close vicinity to the Scenic Area. In 1996, the two counties with the highest combined emissions of nitrogen oxides, sulfur dioxide and ammonia in Oregon were Multnomah and Morrow (**Figs. 3** and **5**); they border the Scenic Area to the west and east, respectively. Multnomah, Clackamas, and Washington counties, comprising the Portland metropolitan area, have been the three fastest growing counties in Oregon over the past 50 years (**Fig. 7**). The Portland metropolitan area, together with the Vancouver and Kelso/Longview urban-industrial areas in Washington's Clark and Cowlitz Counties, respectively (**Figs. 4, 6** and **8**), are likely to continue to be important sources of increasing emissions in the future, especially of NO_x and ozone, which are strongly correlated to population size.

3.12 Monitoring priorities

Monitoring priorities include sites with high visitor use and federally owned lands within the Scenic Area. There are no Class I areas in the Columbia River Gorge National Scenic Area (**Fig. 2**).

3.13 Sampling strategy

There are FIA/FHM but no CVS plots in the CRGNSA. Lichen surveys have been made in north-south river valleys and along an east-west transect on the valley floor (See **Maps A** and **B**). Lichens were sampled for tissue analysis approximately every 4.8 km (3 miles) on alternating sides of the Columbia River. In treeless areas, the epilithic lichen, *Xanthoparmelia cumberlandia*, was collected for tissue analysis. No lichen community surveys were made in treeless parts of the Scenic Area. Coordinates and relocation directions have been recorded for the initial monitoring round, but no permanent markers were installed. Nineteen FIA plots were surveyed for lichens.

3.14 Potential interfaces

There are two IMPROVE sites in the CRGNSA, one in the west at Mt. Zion and the other in the east, near Wishram. Visibility and chemistry of fine particulates are monitored on a weekly basis. A passive monitoring station at Horsethief State Park was installed to estimate ambient levels of SO_2, H_2S, NH_3, NO, NO_2, and NO_x (biweekly averages in summer, monthly averages in winter) from July 2002-June 2003. IMPROVE and passive monitoring data are available from the USFS PNW Regional Air Resource Management Program website at http://www.fs.fed.us/r6/aq. The nearest National Acid Deposition Program (NADP) monitor is in the Bull Run Watershed of Mt. Hood National Forest. NADP monitors wet deposition chemistry, including concentrations of hydrogen, sulfate, nitrate, ammonium, calcium, magnesium, and sodium ions in precipitation, rain volume and total seasonal and annual deposition. Data from this program are accessible via the NADP website at http://nadp.sws.uiuc.edu/.

3.2 DESCHUTES NATIONAL FOREST

3.21 Emissions sources

Other than forest fire, the Deschutes National Forest (**Fig. 1**), in Jefferson, Deschutes, Lake and Klamath Counties, has historically been remote from large emission sources (**Figs. 3** and **5**). However, human population in the city of Bend and in surrounding Deschutes County is growing rapidly. From 1960 to 2000, Deschutes County grew from 20,000 to nearly 120,000 people, and nearly half that growth occurred between 1990 and 2000 (**Fig. 7**). Baseline monitoring in the 1990s should provide a good benchmark against which future measurements of air quality can be compared.

3.22 Monitoring priorities

There are two Class I areas in the Deschutes National Forest: Three Sisters Wilderness and Mt. Washington Wilderness (**Fig. 2**). The Newberry National Volcanic Monument (**Fig. 1**) is a high priority area because of the potential for geothermal development. Other areas of special concern are the Mt. Jefferson Wilderness and the Research Natural Areas.

3.23 Sampling strategy

Baseline monitoring has been completed for the entire Forest. At the 5.5 km (3.4 mile) grid level, there are 211 plots (See **Map C**). A special baseline study for the Newberry National Volcanic Monument included an additional 12 plots.

3.24 Potential interfaces

There is an IMPROVE site for Three Sisters Wilderness located on the west side of the Cascades near the crest at Carmen. IMPROVE monitors visibility and chemistry of fine particulates on a weekly basis. The nearest NADP monitor is behind the Silver Lake Ranger District office of the Fremont National Forest in Silver Lake. Data from these sites can be accessed via the USFS PNW air resource management website: http://www.fs.fed.us/r6/aq.

3.3 GIFFORD PINCHOT NATIONAL FOREST

3.31 Emissions sources

Pollution sources with potential to affect the Gifford Pinchot National Forest (**Fig. 1**) lie primarily in Lewis County and in the densely populated, fast growing counties of western Washington between Seattle and Vancouver (i.e. King, Pierce, and Clark) (**Figs. 4** and **8**). The Centralia coal-fired power plant in Lewis County was the single largest source of sulfur oxides in the Pacific Northwest during the 1990s. In 1999, combined annual emissions of SO_2, NO_x and NH_3 from Lewis County were greater than those of Seattle's King County (45 vs. 32 thousand tons, respectively) (**Fig. 6**). Efforts to control emissions at this site should result in significant reductions of NO_x and SO_2 by the next round of monitoring. There are eight counties in Washington with emissions exceeding 20,000 tons per year (King, Pierce, Snohomish, Whatcom and Skagit Counties comprising the Tacoma-Seattle-Bellingham Metropolitan Area; Lewis County; Spokane County in northeastern Washington; and Vancouver's Clark County) (**Fig. 6**). In contrast, there are only two counties in Oregon with emissions over 20,000 tons per year (**Fig.**

5), Portland's Multnomah County, and Morrow County in central Oregon where the Boardman power plant is located. The difference is primarily due to a significantly higher human population in Washington compared to Oregon (**Fig. 9**) and concentrated industry in the Puget Sound area.

3.32 Monitoring priorities

The two Class I areas on the Gifford Pinchot National Forest are Goat Rocks Wilderness and Mt. Adams Wilderness (**Fig. 2**). Other priority areas include Indian Heaven, Trapper Creek, William O. Douglas, and Tatoosh Wildernesses and the Mt. St. Helens National Volcanic Monument. An air-quality monitoring plan for the Goat Rocks Wilderness was prepared in 1993 (Horner and Peterson).

3.33 Sampling strategy

Baseline monitoring has been completed. At the 5.5 km (3.4 mile) grid level, there are 183 plots Forest-wide (See **Maps D** and **E**). The Northern Skill Area of the Forest (formerly Packwood and Randle Ranger Districts) was first surveyed from 1995-1996, and the Southern Skill Area (formerly Mt. St. Helens and Mt. Adams Ranger Districts) was surveyed in 1997-1998, completing the first round of monitoring.

3.34 Potential interfaces

The NADP monitor in closest vicinity to the Gifford Pinchot National Forest is in University of Washington's Pack Experimental Forest near Eatonville. This monitor is used to measure precipitation and wet deposition of sulfates, nitrates, ammonia and other ionic components of acidic precipitation. Six lichen plots were installed within 4 km (2.5 miles) of each of these monitors in 1998, and an additional 36 plots were installed within 7.2 km (4.5 miles) of each monitor between 1999 and 2000. Lichens were collected for chemical analysis at all 42 plots; lichen communities were surveyed in 1998 only. Data from the NADP site and lichen plots can be accessed via the USFS PNW air resource management website: http://www.fs.fed.us/r6/aq.

3.4 MT. HOOD NATIONAL FOREST

3.41 Emissions sources

The Mt. Hood National Forest (**Fig. 1**) has the highest visitor use and is the closest to high-density centers of industry and population of the national forests in this program. The Columbia River/Portland area is the site of several major point sources and many additional smaller industrial pollution sources, high traffic density from the Portland area and also within the Forest, and multiple smaller home heating wood stove and incineration sources. In addition, the east flank of Mt. Hood and northeastern parts of the Forest are potentially exposed to local and Columbia Basin agricultural and industrial emissions. Mt. Hood National Forest is downwind of four of the fastest growing counties in Oregon: Multnomah, Washington, Clackamas, and Marion (**Figs. 3, 5** and **7**). Continuing increases in population are a likely source of additional emissions in the future.

3.42 Monitoring priorities

The Mt. Hood Wilderness is the only Class I area on the Mt. Hood National Forest (**Fig. 2**) and has the highest priority for monitoring. Other areas of special concern are the Columbia Wilderness and Bull Run watershed (source of drinking water for the Portland area), both located in the Columbia Ranger District; the Salmon-Huckleberry, Badger Creek and Bull of the Woods Wildernesses; Resource Natural Areas; and the northwestern and northeastern parts of the Forest closest to urban, industrial, and agricultural areas and major transportation corridors.

3.43 Sampling strategy

Baseline monitoring was completed from 1994-1997. At the 5.5 km (3.4 mile) grid level, there are 152 plots (See **Maps F** and **G**).

3.44 Potential interfaces

Air quality monitors
The nearest IMPROVE sites are in the Columbia River Gorge National Scenic Area near Mt. Zion and Wishram. There is an NADP monitor near the west end of Bull Run Reservoir #2. These monitors offer opportunities for calibrating instrument and biological data using transplants or by establishing lichen monitoring plots nearby. In 1993, one monitoring plot was established near the Wishram IMPROVE station. Six lichen plots were installed within 4 km (2.5 miles) of the NADP monitor in 1998, and an additional 36 plots were installed within 7.2 km (4.5 miles) of the NADP monitor between 1999 and 2000. Lichen tissue data were collected at all plots; lichen communities were surveyed in 1998 and 1993.

Water quality monitoring
There is a water-quality monitoring program for Bull Run Watershed.

3.5 SIUSLAW NATIONAL FOREST

3.51 Emissions sources

Remote and upwind from major population centers, the Siuslaw National Forest (**Fig. 1**) is less affected by regional urban and transportation emissions than the Columbia River Gorge National Scenic Area or Mt. Hood National Forest. Its location in the central Oregon Coast Range means that much of the weather originates over the relatively clean Pacific Ocean. There are large, permitted stationary point sources in Toledo, Gardiner and North Bend/Coos Bay. Other important emission sources are smaller industries, motorized vehicles, agriculture, and forestry activities. The Tillamook vicinity is a local source of ammonia emissions from dairy farming. Rapidly growing human population in the Willamette Valley (Lane, Douglas, Marion counties) (**Figs. 3, 6** and **7**) and trans-Pacific pollutants are a likely source of increased emissions in the future.

3.52 Monitoring priorities

There are no Class I areas on the Siuslaw National Forest (**Fig. 2**). Areas of special concern are the Oregon Dunes National Recreation Area, Sutton Creek Recreation Area, the Research Natural Areas and the Drift Creek, Cummins Creek and Rock Creek Wildernesses. The immediate coastline is habitat for a rich and unique lichen flora, not found elsewhere in the region.

3.53 Sampling strategy

The Siuslaw has no Class I areas and therefore the default plan, a Forest wide monitoring strategy using the 5.5 km (3.4 mile) grid, has been implemented. There are 78 plots on this grid (see **Maps H** and **I**). 10 additional off-frame plots were installed in the Oregon Dunes National Recreation Area. Baseline monitoring occurred from 1994 through 1997.

3.54 Potential interfaces

An NADP monitor is located on the Siuslaw National Forest, near the town of Alsea. The monitor is used to measure concentrations and deposition of sulfates, nitrates, ammonia and other ionic components of acidic precipitation. Six lichen plots were installed within 4 km (2.5 miles) of this monitor in 1998, and an additional 36 plots were installed within 7.2 km (4.5 miles) of the monitor between 1999 and 2000. Lichen tissue data were collected at all plots; lichen communities were surveyed in 1998 only. Data from the NADP monitor and lichen plots can be accessed via the USFS PNW air resource management website, http://www.fs.fed.us/r6/aq.

3.6 UMPQUA NATIONAL FOREST

3.61 Emissions sources

Emission sources are primarily located to the west of the Umpqua National Forest (**Fig. 1**) in Lane, Douglas and Jackson Counties (**Figs. 3** and **5**). They include stationary and mobile sources in the Eugene/Springfield metropolitan areas, the southern end of the Willamette valley and the I-5 corridor including Cottage Grove, Roseburg, Grants Pass and Medford. State Route 138 is the main traffic route through the Forest. It leads to the northern entrance of Crater Lake National Park. Rapidly growing human population in Land, Douglas and Jackson counties (**Fig. 7**) and transpacific pollutants are likely sources of increased emissions in the future.

3.62 Monitoring priorities

Mt. Thielsen, Rogue-Umpqua Divide and Boulder Creek Wildernesses have boundaries within the Umpqua National Forest. None are Class I areas. Wildernesses and Botanical Special Interest Areas are the highest priorities for air quality monitoring.

3.63 Sampling strategy

Initial Forest-wide monitoring was completed from 1997 to 2000. There are 135 plots on the 5.5 km (3.4 mile) grid (See **Maps J** and **K**), about 34 per year on a four-year rotation.

3.7 WALLOWA-WHITMAN NATIONAL FOREST

3.71 Emissions sources

Local sources of air pollution with potential to affect the Wallowa-Whitman National Forest (**Fig. 1**) are primarily related to agriculture. The nearest notable stationary source of emissions is a power plant approximately 144 km (90 miles) northwest of Eagle Cap Wilderness at Boardman in Morrow County. No major highways traverse the Wallowa-Whitman National Forest. Compared

to national forests west of the Cascade crest, ammonia comprises a high percentage of emissions from counties surrounding the Wallowa-Whitman National Forest (Wallowa, Umatilla, Union, Baker) (**Figs. 3** and **5**). Human population is low and fairly stable; only Umatilla County has grown significantly since the 1950s (**Fig. 7**).

3.72 Monitoring priorities

There are two Class I areas on the Wallowa-Whitman: Eagle Cap Wilderness and Hells Canyon Wilderness (**Fig. 2**). Part of the North Fork John Day and Monument Rock Wildernesses are also in the Wallowa-Whitman National Forest. The Class I Wildernesses have the highest priority for air quality monitoring.

3.73 Sampling strategy

Monitoring to date has been limited to the Eagle Cap Wilderness, Hell's Canyon National Recreation Area and Hells Canyon Wilderness. There are 43 plots in the 5.54 km (3.4 mile) CVS grid within the boundaries of Eagle Cap Wilderness (See **Map L**), about 11 plots per year in a four-year rotation. The initial round of monitoring was completed from 1998 through 2001. In 1999, lichen-monitoring sites were established in Hell's Canyon National Recreation Area and Wilderness along the Snake and Imnaha Rivers, and five tributaries of these rivers. At the Hell's Canyon plots, *Xanthoparmelia cumberlandia* was collected for tissue analysis and lichen communities were surveyed in *Celtis occidentalis* plant communities only.

3.74 Potential interfaces

Data from the following programs can be accessed from the USFS PNW Regional Air Resource Management website at http://www.fs.fed.us/r6/aq.

An NADP monitor is located in Starkey Experimental Forest and Rangeland. The monitor is used to measure precipitation and wet deposition of sulfates, nitrates, ammonia and other ionic components of precipitation. Six lichen plots were installed within 4 km (2.5 miles) of this monitor in 1998 and an additional 36 plots were installed within 7.2 km (4.5 miles) of the monitor between 1999 and 2000. Tissue data were collected at all sites; lichen communities were surveyed in 1998 only.

There are two IMPROVE sites, one near the south end of Hell's Canyon National Recreation Area in Oxbow, OR and the other at Wallowa Lake, near the northeastern boundary of Eagle Cap Wilderness. Hourly ozone means were recorded using a 2Btechnologies field monitor from July to October 2002 at the Oxbow site.

At Hell's Canyon NRA, passive sampling stations were maintained for one year at Cache Creek Ranch, Pittsburg Creek Ranch, Dug Bar, Kirkwood Creek Ranch, and Hell's Canyon Dam Visitor's Center. Mean ambient concentrations of NO_x, NO_2, NO, NH_3, H_2S and SO_2 were collected on a biweekly (summer) and monthly (winter) basis from July 2002 through June 2003.

3.8 WILLAMETTE NATIONAL FOREST

3.81 Emissions sources

Emissions with potential to affect the Willamette National Forest (**Fig. 1**) originate primarily in the Willamette Valley, especially in Lane County. The largest industrial point sources are in Springfield, Cottage Grove, and Albany. In addition there are multiple smaller stationary sources concentrated along the I-5 corridor between Albany and Cottage Grove. The Willamette NF is adjacent to prime agricultural areas of the Willamette Valley and could be affected by volatilized fertilizers, pesticides and manures. Other important emissions are from mobile sources, forest fires and field burning. Future emissions increases are most likely to arise from continued rapid population increases in Lane, Linn and Douglas Counties (**Figs. 3, 5,** and **7**) and from increases in trans-Pacific pollutants.

3.82 Monitoring priorities

The Willamette National Forest has two Class I areas. They are Three Sisters Wilderness and Mt. Washington Wilderness (**Fig. 2**). Under federal law, these areas have more stringent protection requirements and information needs are therefore greatest. There are five Class II Wildernesses: Mt. Jefferson, Middle Santiam, Menagerie, Waldo Lake, and Diamond Peak. Other special interest areas are the H. J. Andrews Experimental Forest, and the Research Natural Areas.

3.83 Sampling strategy

Baseline monitoring was completed for the entire Forest from 1995 through 1997. There are 237 5.5 km (3.4 mile) grid plots on the Willamette National Forest (see **Maps M** and **N**).

3.84 Potential interfaces

Instrumented monitors
An IMPROVE site close to the Three Sisters Wilderness monitors visibility and particulate chemistry. A National Atmospheric Deposition Program monitor at the H. J. Andrews Experimental Forest headquarters monitors precipitation and wet deposition chemistry. These sites offer opportunities for calibrating instrument and biological data using transplants or by monitoring existing lichens near these monitors. In 1993, one monitoring plot was established near the IMPROVE station at Carmen. Six lichen plots were installed within 4 km (2.5 miles) of the NADP monitor in 1998, and an additional 36 plots were installed within 4.8 km (3 miles) of the NADP monitor between 1999 and 2000. Lichen tissue data were collected at all sites; lichen communities were surveyed at the 1993 and 1998 plots only. Data from the NADP monitor, IMPROVE, and lichen plots can be accessed via the USFS PNW air resource management website, http://www.fs.fed.us/r6/aq.

Air Toxics Study
Samples of lichens and mosses were collected from the Three Sisters and Mt. Washington Wildernesses as part of an international air toxics study in 1993. These samples were analyzed for persistent organochlorines and metals. An international standard was included with the metals analysis. Metal and organochlorines concentrations in lichens were compared to sites in southeast and south central Alaska, the Russian Far East south to the Primorsky Region, arctic Alaska, Siberia (Taimyr Peninsula) and Scandinavia/Northern Europe.

Water quality monitoring
The Willamette National Forest has sponsored a number of water quality and snow chemistry assessments.

USFS Forest Sciences Laboratory, Corvallis, Research.
Potential exists for collaborating with research scientists at H. J. Andrews Experimental Forest, a LTER (Long Term Ecological Research) site.

3.9 WINEMA NATIONAL FOREST

3.91 Emissions sources

The Winema National Forest (**Fig. 1**), in Klamath County (**Fig. 3**), is remote from the largest urban and industrial areas of Oregon. Local emissions are primarily from stationary point sources in Klamath Falls and Medford, mobile sources and agriculture. State Route 97 bisects the Winema National Forest. It is the main transportation artery along the east side of the Cascade Mountains between Bend and Klamath Falls, and connects to State Routes 138 and 62 to Crater Lake National Park. Nearly half of the combined emissions of NO_x, NH_3 and SO_2 in Klamath County are from ammonia, a consequence of intensive agriculture in and around the Klamath basin (**Fig. 5**). The growing human population in neighboring Josephine County, to the west, is a potential source of increased emissions in the future. The population of Klamath County has been fairly stable over the past 30 years (**Fig. 7**).

3.92 Monitoring priorities

Mountain Lakes Wilderness is the only Class I area in the Winema National Forest (**Fig. 2**). There are two other Wildernesses: Sky Lakes and Mt. Thielsen. Monitoring the Class I area and other Wildernesses is the highest priority for this national forest.

3.93 Sampling strategy

There are approximately 145 5.5 km (3.4 mile) CVS plots on the Winema National Forest (see **Maps O** and **P**). The first round of forest-wide monitoring occurred from 1997 through 2000.

3.94 Potential Interfaces

The closest NADP monitor is in the Fremont National Forest in the Silver Lake Ranger District compound. The monitor is used to measure concentrations and wet deposition of sulfates, nitrates, ammonia, hydrogen ions and other ionic components of precipitation. Six lichen plots were installed within 4 km (2.5 miles) of this monitor in 1998. Lichen community and tissue data were collected at these sites. Data from the NADP monitor and lichen plots can be accessed via the USFS PNW air resource management website, http://www.fs.fed.us/r6/aq.

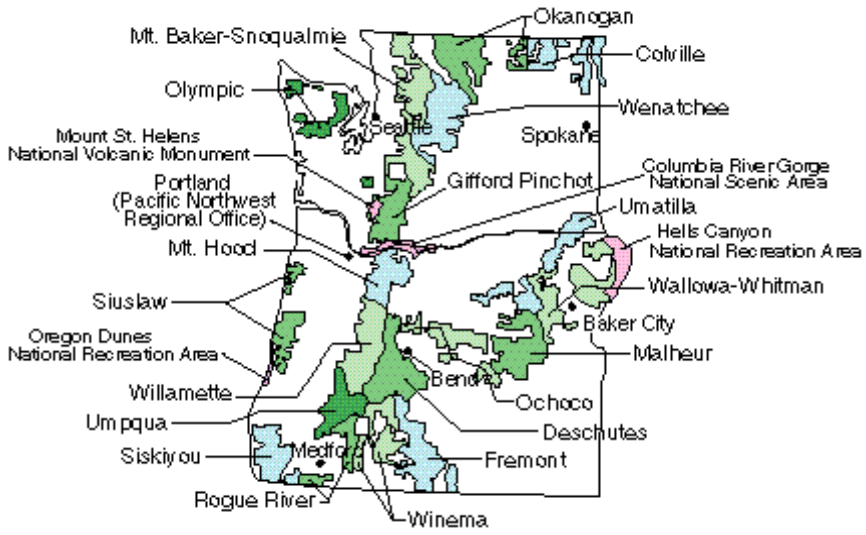

Figure 1. Federal lands in Oregon and Washington managed by the USDA Forest Service.

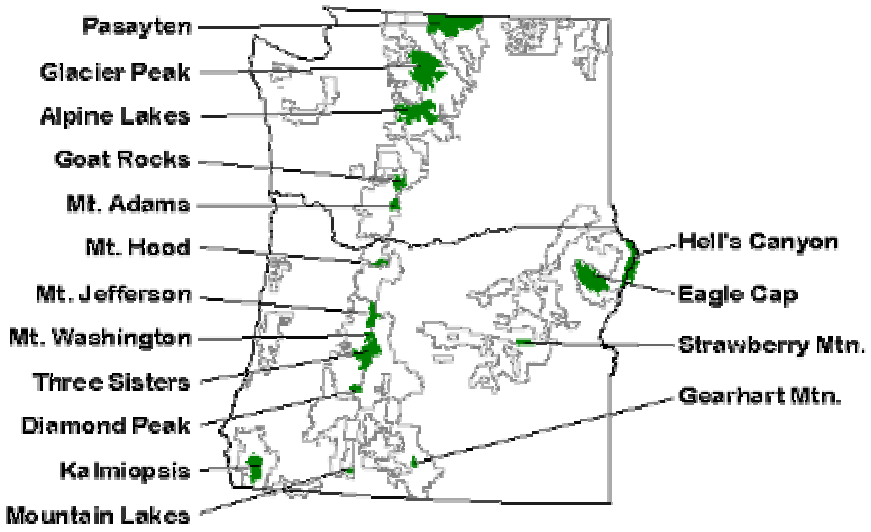

Figure 2. Class I Wildernesses of Oregon and Washington managed by the USDA Forest Service.

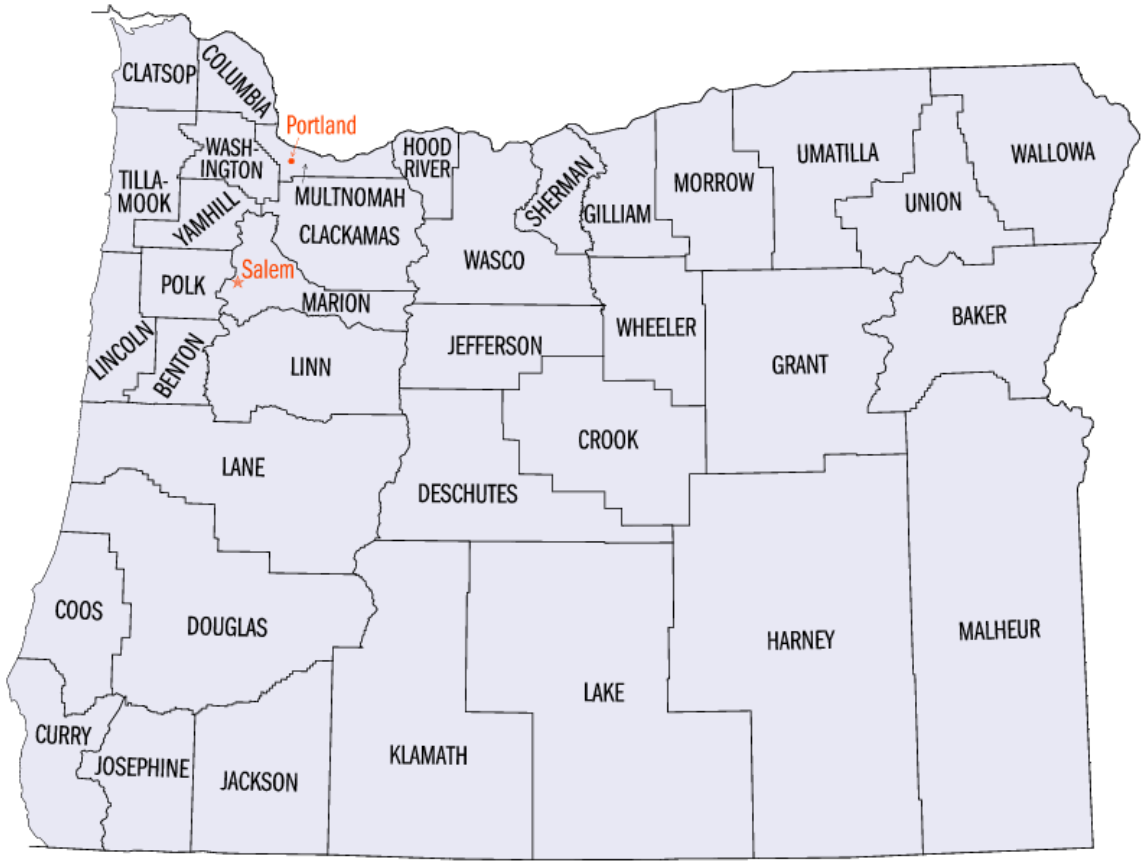

Figure 3. Counties of Oregon.

Figure 4. Counties of Washington.

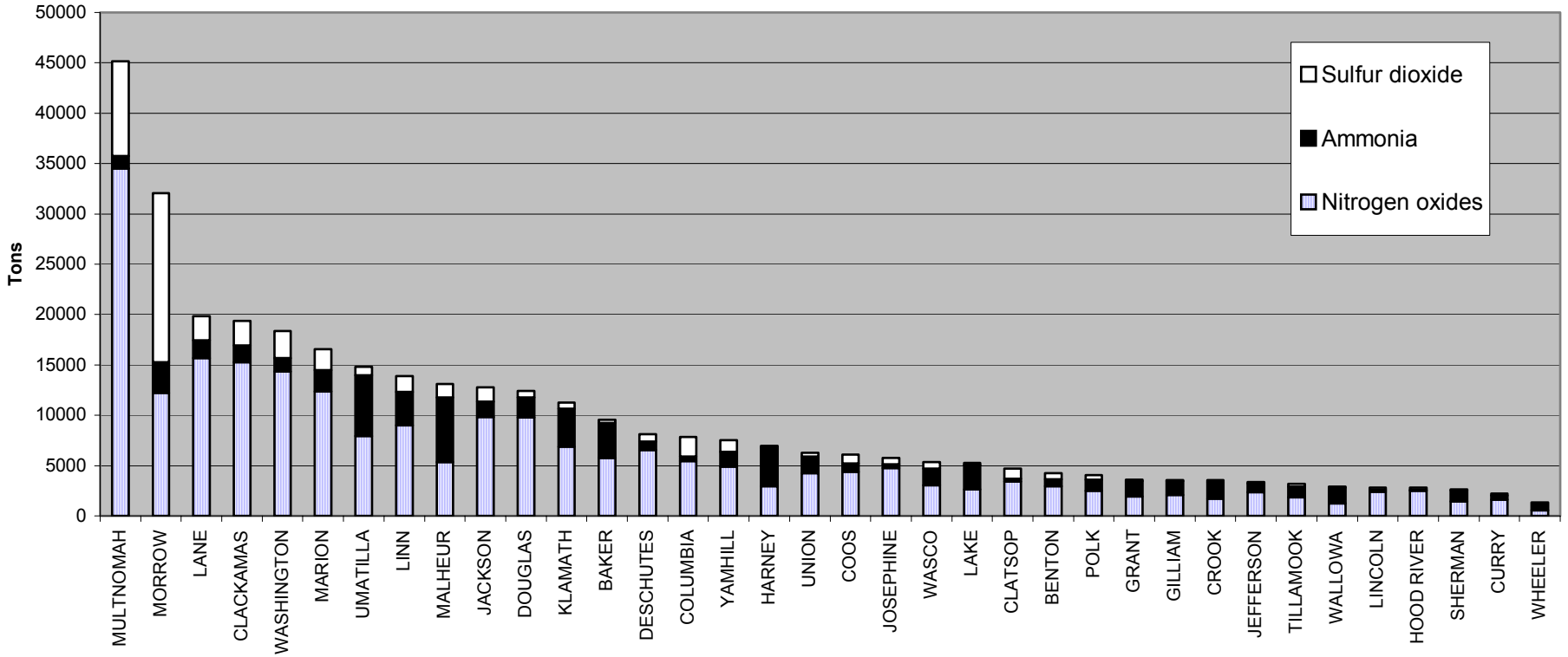

Figure 5. 1999 Oregon emissions of nitrogen oxides, ammonia, and sulfur dioxide from all sources by pollutant and county. Source: US EPA 1999.

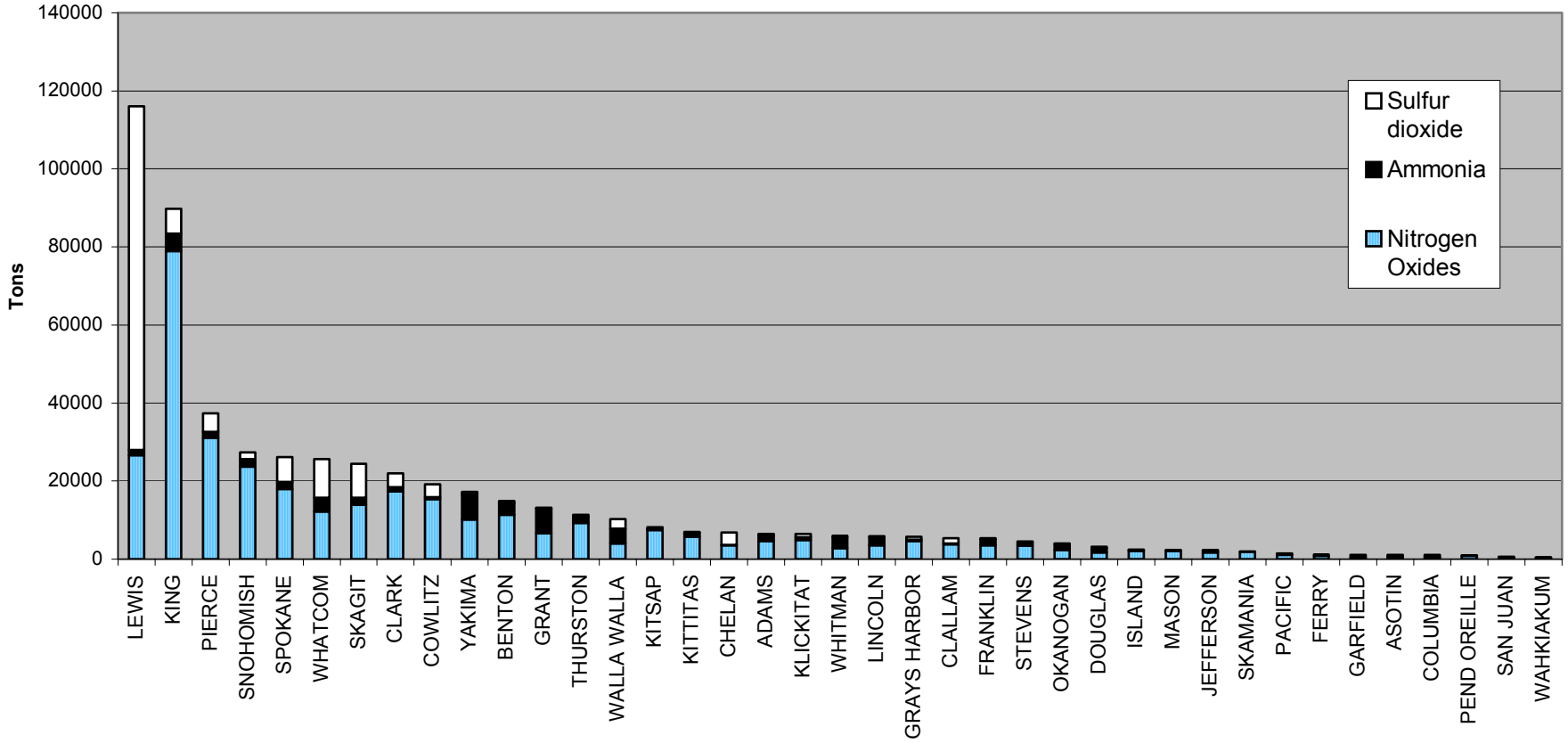

Figure 6. Washington 1999 emissions of nitrogen oxides, ammonia, and sulfur dioxide from all sources by pollutant and county. Source: US EPA 1999.

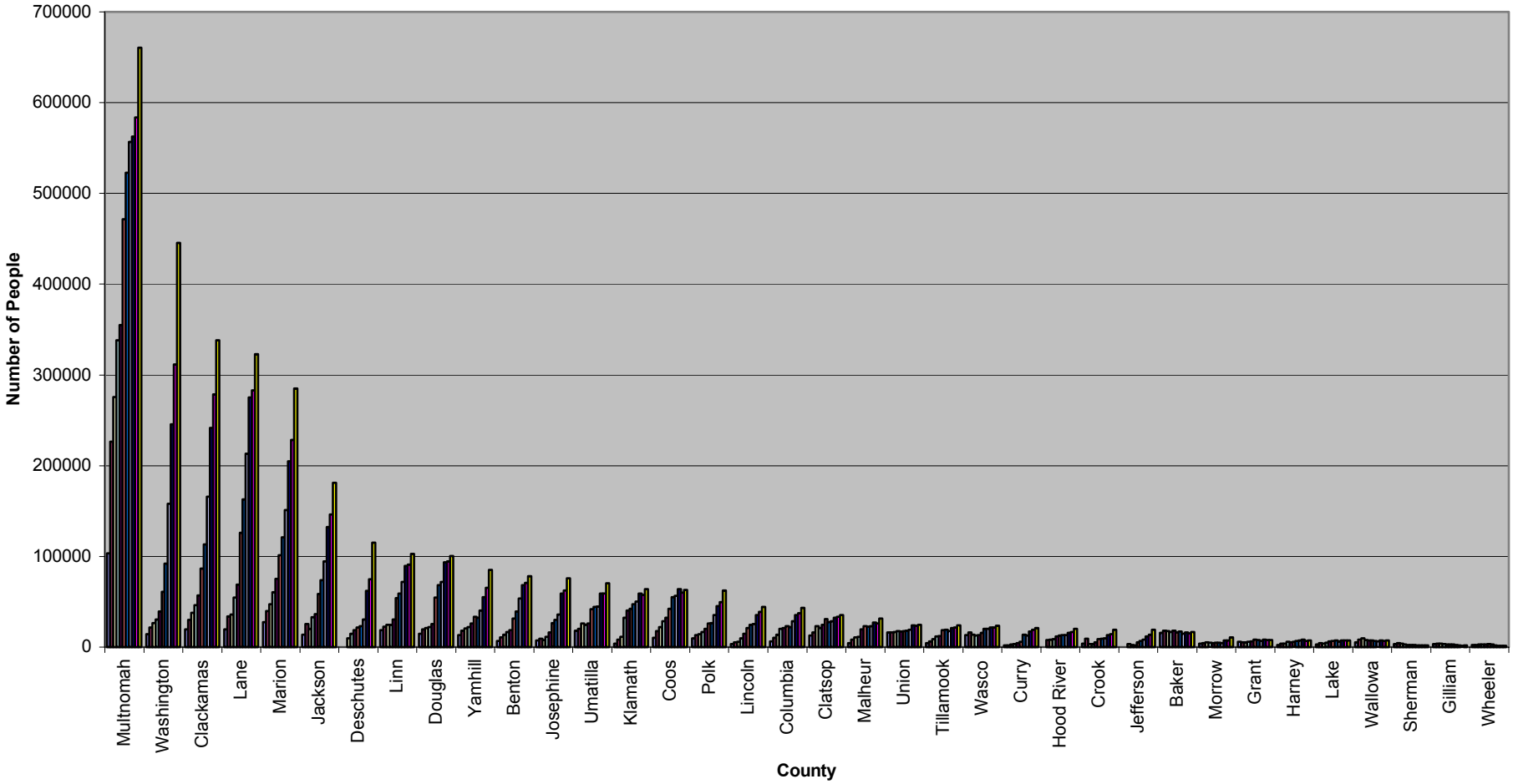

Figure 7. Human population size in Oregon counties from 1900 to 2000, in ten-year intervals. Sources: Forstall 1995a, US Census Bureau 2003.

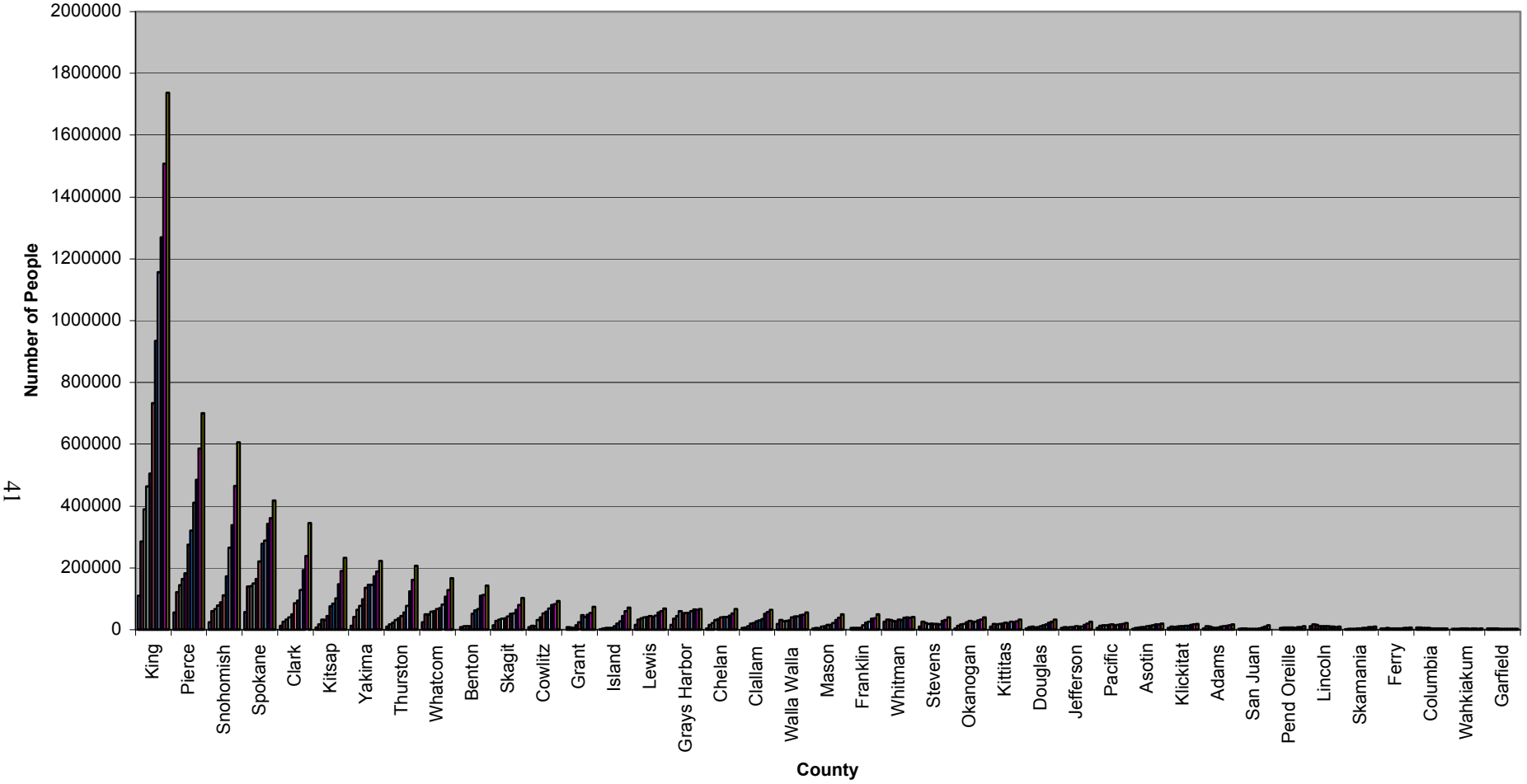

Figure 8. Human population size in Washington counties from 1900 to 2000, in ten-year intervals. Sources: Forstall 1995b, US Census Bureau 2003.

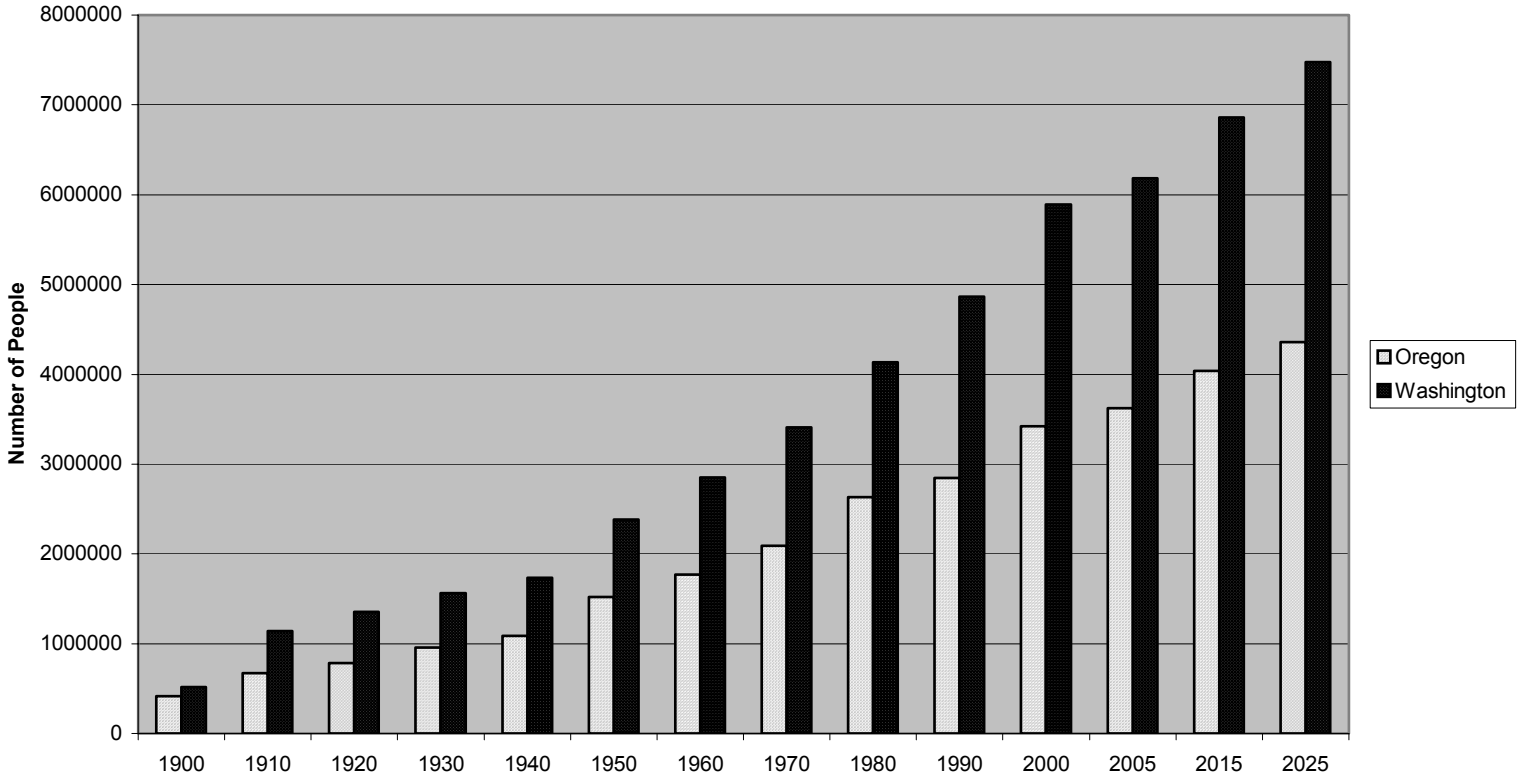

Figure 9. Actual and projected human population growth in Oregon and Washington, 1900 to 2025. Sources: Campbell 1997, Forstall 1995 a and b.

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5. FORMS

5.1 FIELD EQUIPMENT LIST

Community survey
Collecting packets
Pens
Pencils
Knife
Hand lens
Clippers
Rubber bands
Zip-loc bags
Watch
Large paper or plastic bags

Tissue analysis
Kapak bags
Tape
Sharpie marker
Gloves
Spring scale

Plot documentation
Field data sheet
Clipboard with codes, acronyms
Plant indicator species guide
Plant association book
Off-frame plot card
Methods summaries

Finding and measuring plot
Aerial photos
Plot description (1st page of CVS field card)
Topographic map (with resource orthoquad overlay)
Compass
Clinometer
Altimeter
Calculator
Paper
Hip chain
District map
Field vest/backpack
Dbh tape
36 m (120') tape measure
Flagging
Increment borer
Straws
Lubricant (WD-40)
Rag/paper towels
Handheld global positioning system

Safety/Personal
First aid kit
Extra clothes
Water
Lunch
Rain gear
Radio and/or cell phone (maintain twice daily communications)
Extra radio and gps batteries
Adaptor to charge cell phone in vehicle
Matches in waterproof case
Whistle
Hard hat
Insect repellent
Sunscreen
Garbage sack (bright orange)
Leave copy of itinerary with supervisor and dispatch
Wear steel toed boots, long pants and longsleeve shirt

5.2 FIELD DATA SHEET FOR LICHEN MONITORING PLOTS

USFS PACIFIC NORTHWEST REGION AIR RESOURCE MANAGEMENT

Plot #_____ Date_____
Lichen surveyor_____ Other observers_____
Lichen tissue collector _____

1. Plot type (circle all that apply): CVS/FIA, Rep, Audit, Training, Off-Grid

2. Stand location
National Forest _____ County _____
District _____ State _____
Location in words _____
_____

3. Stand age (check one)
_____ Shrub/forb (very early seral & pioneer vegetation, 1-30 yrs)
_____ Seedling/sapling (early seral, 30-100 years)
_____ Pole timber (mid-seral, 100-200 years)
_____ Mature (late-seral, 200 years until seral species are gone from the overstory)
_____ Old-growth (climax vegetation, late seral species absent in the overstory)

4. Stand structure (check one, consider dbh of dominants and codominants only)
_____ 1. Open sapling-pole, < 30 cm (11") ave. dbh, open canopy
_____ 2. Closed sapling-pole, < 30 cm (11") ave. dbh, closed canopy
_____ 3. Small saw timber, 30- 53 cm (11-20.9") ave. dbh
_____ 4. Large saw timber > 53 cm (21") ave. dbh
_____ 5. Old growth

5. Vegetation cover by species (write indicator species—acronyms OK—in appropriate box)

Cover:	0-5%	6-25%	26-50%	51-75%	76-100%
trees and shrubs					
forbs and grasses					
mosses lichens					

Plot # _____ Date _____

7. Lichen chemistry

Lichen species collected	Substrate(s): Record plant acronym and location (e.g. bole, branch, litter, d/d)	# Grams (- bag)	Moisture status (dry, damp, wet)

Describe spatial extent of sampling area for lichen chemistry _____
_____

8. Notes. Briefly describe any **deviations from standard operating procedures**, describe the **habitat** (stand age and structure, surrounding landscape, plant community and ecozone, e.g. riparian area, beach) and **outstanding features of the plot** (clear-cut, two different stand ages, stream lake or road through plot, etc.) and the **lichens** (overall abundance, dominant and unusual species).

_____
_____
_____
_____
_____
_____
_____
_____

9. Plot audit (complete before leaving the plot).

Was the lichen community surveyed? _____
How much time was spent on the lichen community survey? _____
Are community packets completely labeled? (Check!) _____
Are community packets alphabetized? _____
Were lichens collected for chemical analysis? _____
Are the Kapak bags correctly labeled (plot #, target species, substrate, acronyms and locations in order by sample volume, collectors initials, collection date, forest acronym, moisture status)? _____
Do the field data card and Kapak bags have the same information? _____
Is the field data card complete? _____
If off-grid, was the plot location marked on a map? _____

Signature of Auditor _____ **Date** _____

5.3 ADDITIONAL INFORMATION FOR OFF-GRID PLOTS

USFS PACIFIC NORTHWEST REGION AIR RESOURCE MANAGEMENT

Plot # _____ Date_____

1. Location (use mapping datum NAD27 CONUS)
a. Latitude _____N Longitude _____W
b. UTM Zone _____ UTM Northing _____ UTM Easting _____
c. Township/Range/1/4 section _____
d. Map name and scale _____
e. Aerial photo number (optional) _____

2. Physiography (use topographic map)

a. Topographic position (Circle one):

Flat or rounded ridgetop or peak > 37 m wide
Narrow ridge top or peak < 37 m wide
Sidehill, upper 1/3
Sidehill, middle 1/3
Sidehill, lower 1/3
Canyon bottom < 200 m wide
Bench or terrace
Broad flat 200 m or more wide
Other, describe _____

b. Slope _____%
c. Aspect _____ degrees
d. Elevation _____ meters

3. Trees/shrubs

a. Plant association _____
b. Largest size class with 8 or more trees (Circle one):
pole 13-22.9 cm (5-9") dbh
small 23-52.9 cm (9.1-20.9") dbh
medium 53-80.9 cm (21-31.9") dbh
large 81-121.9 cm (32-47.9") dbh
giant ≥ 122 cm (48") dbh

Plot #_____ Date_____

4. Dbh measurements

Center subplots on plot center if center is roughly representative of the plot; otherwise choose the most representative area. Subplot sizes should be large enough to represent the entire plot. Minimum allowable subplot radius varies with size class (see chart below); maximum radius for any class is 185.1'. Record subplot radius used under "Actual radius". Tally number of trees in each size class, recording an H for a hardwood, C for a conifer. Circle C's or H's that represent dominant or codominant trees.

Size class	Minimum radius	Actual radius **and units**	Tally of trees
2.5-12.0 cm (1-4.9")	3.6 m (11.8')		
13-24.9 cm (5-9.9")	8 m (26.3')		
25-37.9 cm (10-14.9")	15.6 m (51.1')		
38-49.9 cm (15-19.9")	15.6 m (51.1')		
50-74.9 cm (20-29.9")	15.6 m (51.1')		
75-99.7 cm (30-39.9")	15.6 m (51.1')		
100-122 cm (40-47.9")	15.6 m (51.1')		
>122 cm (>48")	56.4 m (185.1')		

5. **Age of oldest tree cohort.** Collect tree core samples from 2-3 of the oldest trees, including remnants.

Tree #	Tree Species	Dbh (cm)	# Rings in core	Length of core (cm)	Estimated age ([# Rings/ Length * Dbh] + 5)
1					
2					
3					

5.4 LICHEN SPECIMEN MAILING FORM—Lichen Surveys

Please enclose a copy of this form whenever specimens for the community analysis section are mailed. Keep a copy for your records.

FIELD CREW TO LICHEN SPECIALIST:

Sent by: _____ to: _____ Date: _____

Sender's comments: _____

_____

Received by: _____ Date: _____

Receiver's comments: _____

_____

CONTENTS

Plot #	National Forest or Administrative Unit	Notes

5.5 LICHEN SPECIMEN MAILING FORM—Element Analysis

Enclose this form whenever specimens for tissue analysis are mailed. Keep a copy for your records.

FIELD CREW TO LICHEN SPECIALIST:
Sent by: _____ to: _____ Date: _____

Sender's comments: _____

Received by: _____ Date: _____

Receiver's comments: _____

CONTENTS

FIELD USE					LAB USE ONLY
Plot #	Forest	Target Species	Rep #*	Notes	Lab species ID

* Number replicates sequentially WITHIN the plot (start with #1 for first sample in each plot).

5.6 DATA QUALITY EVALUATION: LICHEN COMMUNITIES CERTIFICATION AND FIELD AUDITS

Name _____

Date _____

Plot _____

Trainer/auditor _____

Evaluation

____ Percent of species detected

____ Percent of agreement in species composition

____ Percent agreement in abundance ratings for species also rated by auditor

____ Percent of packets in which all fields were completed and legible

Comments

5.7 FEEDBACK FORM

To the field crews: To help us improve the lichen procedures, logistics, and training, please send comments to the lichen specialist. After the training or at any time during or after the field season, please write down your comments and send them to the program coordinator.

Date _____ Your trainer _____

Your Name _____

Training

Did you receive sufficient raining to effectively collect the lichen data?

What areas were covered well in the training?

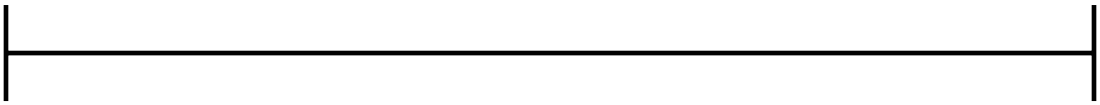
What areas need improvement in the training?

Other comments on the training:

Field work

Comments and suggestions:

5.8 PACKET FORM



Plot No.:	**For/Dist:**	**Date:**	**Packet No:**
Species:			**Collector:**
Substrate:	**Abund:**	**Chemistry:**	
Remarks:			

6.0 FIELD TRAINING

6.1 TRAINING OBJECTIVES

Training usually takes place over five days and consists of the following:

1. Study of the field methods manual and lichen community survey protocols.
2. Study of characteristics used to differentiate lichen species.
3. Study of common lichens: recognizing and naming species.
4. Tutorial on collection of lichens for chemical analysis.
5. Field practice in locating FIA plots, orientation and use of aerial photos.
6. Field practice in lichen community survey, tissue collection, other field measurements, and completing field data cards.
7. Discussion of equipment, logistics, organization, sample handling and processing.
8. Training in defensive driving, first aid, CPR, personal safety, radio communications and check-in safety procedures.
9. Certification.

Training will be followed within 2-5 weeks by a field visit and audit by the program coordinator.

6.2 SAMPLE TRAINING AGENDA

Day 1
8:00-12:00 AM
Introduction to lichen biology—work stations to learn to differentiate lichens based on color, size, morphology and reproductive structures.
Learn to recognize common lichens.
Slide show of common lichens.

1:00-5:00 PM
Driver safety training.
Short field trip to practice finding lichens.
Collecting lichens for tissue analysis.
Practice recognizing genera.
Slide show quiz of common genera.

Day 2
8:00-12:00
Summer logistics, field schedule.
Review of procedures, datacards, forms.
Review forest lichens.
Slide show on air resource management program: issues, monitoring results.

1:00-5:00
Field practice, in groups.

Day 3
8:00-12:00, 12:30-6:30
Safety session.
Two field sites. Work in pairs.

Day 4
8:00-12:00, 12:30-6:30
Two field sites. Work as individuals.

Day 5
8:00- 12:00
Certification plot.
Written test.

Bring suitable clothing for work in the woods each day, including field vest, boots, rain-gear, hard hats, long pants and long-sleeved shirts and a daypack. For lichen work, bring a hand lens, knife and field guides. Bring water and a bag lunch.

Lichen community certification is achieved when the trainee meets the data quality objectives for the training, including a score of 80% or better relative to the trainer in both categories listed in **Table 4**. This is documented in writing by recording the trainee's score on the Data Quality Evaluation sheet. The trainer(s) should clearly indicate that the evaluation was done for the certification process.

Table 4. Scoring certification plots

Category	Score	Evaluation
% of species detected	<80 %	Need more practice
	> 80 %	Certified
Number of species detected	<80 %	Need more practice
	> 80 %	Certified

Consideration is also given to the kinds of species missed, to whether collection sizes were adequate, and to the legibility and completeness of handwritten fields on packets. Individual arrangements can be made for non-certified personnel to begin fieldwork with certified field crew and to re-take the certification test after a few weeks additional practice.

6.3 TRAINING DOCUMENTS

6.31 What is a lichen?

Lichens are symbiotic organisms
Lichens are made of symbiotic relationships between fungi and a photobiont. The photobiont can be either a green alga or cyanobacteria ("blue-green algae"). The fungus is almost always an Ascomycete (sac or cup fungus).

Differentiating lichens from algae, fungi and mosses
Lichens can be confused with algae, fungi and mosses. You can usually tell them apart by the following characteristics:

1. Terrestrial algae tend to have little differentiation into macroscopic structures and they never produce disc-like reproductive structures. The most common algae that might be confused with lichens are: powdery green algae on tree trunks (*Protococcus*-like algae), orange, velvety growth on tree trunks (often *Trentepohlia*), and blackish, amorphous growths on soil or rock (often *Nostoc*, a cyanobacterium).
2. Non-lichenized fungi do not have a photosynthetic partner. In most cases, if it looks like a fungus and you can't find the green of blue-green pigmented partner, it is a fungus.
3. Mosses and leafy liverworts have a distinct stem and leaf structure and are usually bright green (occasionally purplish or brownish). Thalloid liverworts are strap-shaped, bright green to purplish or brownish green. Break these open and they are greenish inside. Break a lichen open and it will either be partly whitish inside or completely black inside (use a hand lens).

Protocol: When in doubt, assume it is a lichen.

Growth Forms
The basic growth forms for the thallus (the body of the lichen) are...

Fruticose: 3-D forms. The most common forms are shrubby, pendulous-stringy, or upright stalks.

Foliose: Flat to ascending thallus with definite lobes.

Squamulose: Clusters of small dabs of lichens. These may be ear-shaped, convex, or concave.

Crustose: Tightly attached crusts, often appearing like they were painted on the substrate.

Macrolichens include foliose and fruticose forms.

Protocol: When in doubt, assume it is a macrolichen.

Species Distinctions
1. *Color* is important. However, most species show color variation depending on light levels. In general individuals of a given species will be more deeply colored, often with a brownish tinge, when growing in strong light. Shade forms tend to be paler and often more greenish than the sun forms.

2. Reproductive structures are important.

Asexual structures (have both the algal and fungal components):

a. *Soredia* have the consistency of flour and have a dull appearance. Soredia usually occur in patches called soralia.
b. *Isidia* are shiny, slender bumps that occur scattered or in clusters. They are shiny because they are covered by a cortex, like the rest of the upper surface of the lichen.

Sexual structures are produced by the fungus:
a. *Apothecia* are disk-like fruiting bodies of the fungi (Ascomycetes).
b. *Perithecia* are flask-shaped fruiting bodies of the fungi, but these are usually immersed in the thallus, so that all that can be seen with a hand lens is a black dot where the tip of the flask reaches the surface.

Note that two lichens that look alike, except that one has apothecia and the other soredia, are different species. Likewise, isidia vs. soredia on otherwise similar lichens will indicate different species.

3. *Position of reproductive structures* is important. For example, do the soredia occur on the lobe tips, the margins, or on the lobe surface?

4. *Habit* is important. Some species are drooping, others erect, others are tightly appressed.

5. The *lower surface* is important. Look at the color. Look for rhizines, feltiness, white spots and veins.

6. *Chemistry* is important, but is not used very often in the field. Lichenologists routinely use several specific reagents in the lab to make "spot tests". A spot test is made by applying a small drop of a reagent to the lichen and looking for a color reaction.

Protocol: When in doubt, assume it is a different species.

6.32 Look-alike lichens, over-looked lichens, difficult genera, newly described species.

Keys, additional field recognition characters, and habitat and range descriptions for lichens in Oregon and Washington can be found in McCune and Geiser (1996) and other references listed in section 2.44. Updated regional keys can be found at the Northwest Lichenologists webpage at http://www.nwlichens.org .

Alectoria

Problem: Because everyone collects only a small voucher of the more abundant species, ***A. sarmentosa***, *A. vancouverensis* is rarely detected. The best habitat for *A. vancouverensis* is the transition between valley forests and mountain forests (below 2100', 700 m) usually dropping below the elevation of highest dominance by *Alectoria*; it may be most frequent on the immediate coast.

Remedy: When in the range of *A. vancouverensis*, collect many individuals of *Alectoria* per packet.

1. ***A. vancouverensis*** is morphologically indistinguishable from *A. sarmentosa*—they can be distinguished in the office by the C+ medulla.
2. ***A. lata*** looks like ***A. imshaugii*** without isidia. Typically, it has ascocarps but so far all the collections made in our region have been sterile. It is rare in the PNW and easily overlooked. Study herbarium examples to develop a search image for this species.

Bryoria

Problem: Bryoria species often grow intermixed, and therefore collection packets often contain species mixes, making it difficult to apportion abundance ratings.

Remedy: Try to collect single species. Examine material with a hand lens before placing in a packet. *Bryoria* can be differentiated by color, branching pattern and angles, filament diameter, thallus habit (erect or pendent) and presence of soralia, apothecia, or pseudocyphellae.

Also, there are some rare bryorioid lichens. Please learn these so you can spot them in the field:

1. ***Bryoria tortuosa*** is found in the Willamette Valley, Puget Trough, eastern Cascades. It has a brown, foveolate thallus with yellow pseudocyphellae.
2. ***Bryoria subcana*** is found at low to mid elevation west of Cascade Crest. Pale with abundant, broad soredia.
3. ***Sulcaria badia*** is found at low to mid elevations west of Cascade Crest; it is pale chestnut to yellowish brown in color and has deep, long, fissural pseudocyphellae.
4. ***Bryoria pseudocapillaris*** is known only from the immediate coast. Pale with long pseudocyphellae.
5. ***Bryoria spiralifera*** is known only from the immediate coast. Brown to reddish brown with long spiraling pseudocyphellae.

Candelaria concolor and Chrysothrix chorina/candelaris

These are rather small but brightly colored lichens that appear to be good indicators of nitrogen deposition; collect them if they occur on the plot. Study herbarium examples to develop a search image. *C. chlorina* and *C. candelaris* are distinguished by the diameter of the soredia (0.1 and 0.01 mm respectively). *Chrysothrix* species may be hard to distinguish in the field, but are easily separated in the office.

Cetrelia/Esslingeriana

Problem: These may be under-collected because they look like *Platismatia glauca*. *P. glauca* is often found at the same sites, usually in greater abundance.

Remedy: Learn to recognize these species by looking at examples in the herbarium.

1. ***Cetrelia cetrariodes*** can be confused with *Parmotrema* (but lacks cilia) or a very broad lobed *Parmelia* (but lacks abundant rhizines) or with *Platismatia glauca*. It is distinguished by its pseudocyphellae on the upper surface and the elongate marginal soredia, often following the edge of a lobe for 5-10 mm or more. It is most common on the Siuslaw NF (i.e. in the Coast range) and is not known east of the Cascade crest. It occurs in moist riparian and valley bottom forests, especially on older *Alnus rubra*.
2. ***Esslingeriana idahoensis*** differs from small individuals of *P. glauca* by its lack of soredia or isidia and a pored black lower surface. It is most common east of the Cascade crest but is occasionally found in low to mid elevation forests on the west side.

Cladonia

Problem: These tend to be under-collected and, when they are collected, packets frequently contain a mixture of species.

Remedy: Make a point to look for *Cladonia* species (at heights > 1/2 meter) on tree boles. Continue to collect only colonies with at least 10 podetia. Learn to differentiate species. *Cladonia* are differentiated by color (yellow green vs. gray green), presence or absence of cups, color of apothecia and pycnidia, presence and distribution of soredia, and size, shape and distribution of squamules.

Dendriscocaulon spp.

Resembling a tiny, highly-branched, gray *Leptogium* with a fuzzy appearance to the naked eye. Easily overlooked, this species is associated with oak woodlands and with cyanolichen-rich coniferous forest. *Dendriscocaulon* species are thought to be escaped, independently-living cephalodia of *Sticta* and *Lobaria* spp. Be on the look-out for the very rare, examples of *Sticta* or *Lobaria* in which the dominant, green algal phototype and the dendriscocauloid form can be found on the same individual.

Hypogymnia

Problems: Although we are finding a lot of species diversity, it is easy to mix different species mixes in the same packet—making it difficult to apportion the abundance rating recorded on the packet many times packets with high abundance ratings are incorrectly labeled. If only one individual is in the packet, it is not possible to know if the field person incorrectly identified the lichen, or happened to collect an example of a different species even though most of what s/he saw was the labeled species.

Remedies: Learn to differentiate species better. Collect more material. Put more *Hypogymnia* in the packets and/or collect more packets if you are not sure it is the same.

Species that are easy to confuse with one another:

1. ***Hypogymnia enteromorpha* and *appinata***. Separated definitively by a P test though generally *H. appinata* lacks the small side buds and can have a more appressed, "melted" look. Study examples in the herbarium and in the original *Bryologist* report by Goward and McCune (1993).
2. ***H. occidentalis, enteromorpha* and *metaphysodes***: *H. occidentalis* is narrower lobed and more appressed than *H. enteromorpha*. The upper surface of *H. occidentalis* usually has a dark, continuous margin and older parts are more rugose than *H. enteromorpha*. *H. occidentalis* and *enteromorpha* must be separated in the office with a P test. *Metaphysodes* forms circular *colonies like H. physodes but without soredia. Small individuals of occidentalis can look like metaphysodes*. But the lobes of *H. occidentalis* always have a black ceiling inside, whereas those of *H. metaphysodes* have a white ceiling.
3. ***H. inactiva* and *H. imshaugii***. These species are easily confused. Check insides of lobes in several places. *H. imshaugii* is white inside throughout, inactiva has a black floor.
4. ***H. occidentalis* and *H. rugosa*.** *H. rugosa* is rare. Most rugose *Hypogymnia* will be *H. occidentalis*. *H. rugosa* differs from *H. occidentalis* in having regularly dichotomous branching,

no bud-like side lobes, and a papery (rather than cartilaginous) texture. H. rugosa typically occurs at high elevations at passes in the Cascade crest and in a narrow band on the east side of the crest.

Leptogium and Collema

These genera are often overlooked because they are darkly colored, and are associated with dark, moist microsites. *Leptogium* and *Collema* species often grow mixed with mosses on trunks of deciduous trees and on shrub stems. They are cyanolichens and have a gelatinous texture when moistened

Melanelia

Problem: Packets often contain more than one species and some species are under-collected. The most frequently collected *Melanelia* are ***M. exasperatula*** and ***M. subaurifera***. The dominance and high abundance of a few species seems to camouflage the more rare but similar-looking species.

Remedy: Examine species with a hand lens before collecting to note distinguishing features. Shape and size of isidia is especially important. Collect more material. Learn some of the less common species by examining herbarium specimens under a dissecting microscope.

Under-collected but common epiphytic *Melanelia*:

1. ***M. fuliginosa*** is most easily confused with *M. subaurifera* but has longer, often acutely branched, cylindrical isidia and no soredia. Erumpent and eroded isidia may be mistaken for soredia.
2. ***M. elegantula*** has long, fine, vertical isidia that branch at right angles, originating from conical shaped papillae
3. ***M. subelegantula*** is similar to *M. elegantula* but the isidia tend to become flattened and lobulate
4. ***M. multispora*** is the most common *Melanelia* with abundant apothecia and no isidia or soredia on hardwoods west of the Cascade crest. Separated from *M. subolivacea* in the office by the higher number of spores per ascus.
5. ***M. subolivacea*** is the most common *Melanelia* with abundant apothecia and no isidia or soredia (except see *M. multispora* above). The surface of some individuals may look warty and these warts can be mistaken for poorly formed isidia.

Under-collected and rare epiphytic *Melanelia*:

1. ***M. subargentifera*** has laminal and marginal granular to isidioid soredia, the laminal ones mainly arising from small, hemispherical pustules. Cortical hairs generally present on some lobe ends. Upper surface is brown but often has a yellowish or reddish cast.
2. ***M. disjuncta*** is widespread on rock but rare on bark or wood. With laminal and submarginal punctiform to strongly capitate and stipitate soredia, arising in part from pseudocyphellae (check submargins); lobes often shiny.
3. ***M. sorediata*** is widespread on rock but rare on bark or wood. With mainly terminal soredia located on the primary lobes or small, more or less erect, lateral branches, arising by gradual disintegration of the cortex; lobes generally dull and lacking pseudocyphellae.
4. ***M. glabra*** occurs in CA and ID. Lobe tips have tiny hyaline cortical hairs; thallus is thick, large, and olive to brown or dark brown, commonly with apothecia.

Pannaria/Fuscopannaria/Psoroma

Problem: All the species in these genera are easy to overlook and have been under-collected. These lichens are difficult to spot because of their small size and their dark color, especially when moist.

Remedy: Study herbarium specimens to learn to recognize the species. Study lichen guide to learn their preferred habitats and substrate. Make a point to look for them on the plots. See Jørgensen (2000) for an updated key to this genus.

Epiphytic species to learn:

1. ***Psoroma hypnorum*** separates from *Pannaria* because the photobiont is a green alga.
2. ***Pannaria rubiginosa*** and ***Pannaria malmei*** form neat little rosettes with elongated lobes. The upper surface is light blue-gray to brownish. Apothecia are common, reddish brown, and have an even, persistent thalline rim. Margins of the apothecia are not white felted tomentose. The two species are distinguished in the office by a P test of the medulla.
3. ***Fuscopannaria saubinetii***. From a distance, looks like a dark or greyish crust. Minutely incised lobes can be observed with a hand lens. The apothecia are pale to orangish-brown and lack a thalline margin.
4. ***Fuscopannaria leucostictoides*** has bluish-gray tinged lobes. The apothecia have thick, thalline, white felted-tomentose margins**.**

Parmelia

Problem: Mixed species in packets, several species under-collected. (See *Melanelia*). ***Parmelia sulcata*** is usually much more abundant than other *Parmelia* species.

Remedy: Learn to differentiate species better. Collect more material in packets and/or collect more packets.

Under-represented species to learn:

1. ***P. squarrosa*** has shiny isidia and squarrose rhizines.
2. ***P. hygrophila*** has dull isidia and forked rhizines.
3. ***P. pseudosulcata*** has shiny isidia and simple rhizines.
4. ***P. saxatilis***, occurs on trees but the most common substrate is rock. *P. saxatilis* looks like *P. pseudosulcata* but has a K^+ y medulla. In the absence of a K test, the best field guess for *Parmelia* with shiny isidia is *P. pseudosulcata.*

Physcia/Physconia

Problem: Some people have trouble recognizing or separating these genera.

Remedy: Study examples in the herbarium. Goward and McCune's "Lichens of BC" has a good key. Study species distinctions in the key.

Pseudocyphellaria

The three most common *Pseudocyphellaria* species are ***P. anomola***, ***P. anthraspis***, and ***P. crocata***. Two new, rare species to the PNW are *P. perpetua (*Miadlikowska 2002) and *P. mallota* (Tønsberg 1999). ***P. perpetua*** is known primarily from the immediate coast. It resembles *P. crocata* but has narrower lobes, primarily marginal pseudocyphellae, and a yellow medulla. ***P. mallota*** is thumbnail sized, has tiny hairs on the upper surface, and yellow pseudocyphellae below. ***P. rainierensis*** is another rare species of old growth forests, recognized by its lobulate marginal isidia and blue- to gray-colored thallus.

Ramalina/Niebla

Problem: A few species appear to be under-collected.

Remedy: Learn to differentiate under-collected species from more common ones.

1. ***Ramalina thrausta*** occurs sporadically on the east side of the Cascades in low elevation moist forest, especially riparian spruce or fir. Occurs in low-elevation old-growth Douglas fir forests west of the Cascades. It is most common in conifer forests of the immediate coast. *R. thrausta* is most easily confused with *Alectoria sarmentosa*. It is separated from that species by an absence of raised pseudocyphellae and a slightly flattened thallus with hooked tips, sometimes with minute terminal soredia.
2. ***Niebla cephalota*** looks like *Ramalina farinacea* in poor condition, and may be overlooked for this reason. The thallus has black spots throughout, and has slightly larger and rounder (vs. elliptical)

soralia than *R. farinacea*. Known only from the immediate coast. Collect sparingly as this is a rare lichen.

3. ***Ramalina subleptocarpha*** looks like a wide-lobed *R. farinacea*. Primarily a low elevation lichen of the Willamette Valley.

Usnea

Problem: mixed species in packets, some species probably under-collected.
Remedy: learn to differentiate species better

Characters separating species:

1. Color of axis or cortex
2. Pendant vs. shrubby
3. With or without papillae
4. With or without colored cortex or axis
5. Foveolate vs. smooth branches
6. Isidia and soredia: Do they occur together? Are soredia concave or convex? Do soredia erode the cortex so much that the central cylinder shows? How large are they relative to the branch diameter. Look for isidio-soredia and soredio-isidia.
7. Branching patterns and stiffness/softness of thallus
8. Blackening or not of holdfast (always collect the holdfast)
9. Ratio of medulla to central axis (make longitudinal section with knife). Is the medulla dense or cobwebby?
10. Presence or absence of articulations (annular rings)
11. Distribution and frequency of fibrils

Distinguishing species of** Usnea **in the field

(References: 15 Mar 2000 key by B. McCune and distribution data in Air Quality database)
Boldfaced species are most common in our area.

Pendant Usnea (> 11 cm long).

Usnea cavernosa. Main branches strongly pitted and ridged, no papillae, isidia, or soredia; fibrils lacking or sparse (*Alectoria*-like). Willamette Valley, Umpqua NF.

Usnea chaetophora. Base slightly to distinctly blackened; papillae usually present but may be sparse and low; soralia absent to scattered, usually minute and borne on small tubercles; isidia occasionally present, *Alectoria*-like. Wide distribution: Coast Range, western and eastern Cascades.

Usnea filipendula. Similar to *U. longissima* but with more main branches. Papillae are tall, cylindrical and abundant; tuberculate isidio-soralia often arise from scars of detached fibrils; base blackened or not. Widely distributed from the Coast Range to the eastern Cascades.

Usnea hesperina. Main branches smooth, no papillae, annular cracks common, sometimes *Alectoria*-like, sometimes fibrillose. Soralia absent to abundant. Isdia absent to sparse, soon abraded. Immediate coast.

Usnea longissima. Very long, rarely dividing main branches with many short branches perpendicular to the cylindrical main axis. No papillae or isidia. Soralia occasionally present. Coast Range and low elevation, western Cascades.

Usnea madeirensis (= *silesiaca*). Base blackened; thallus with annular cracks especially at the base; soralia > ½ branch diameter; isidiate at least when young. Immediate coast, Coast Range and Puget Trough.

***Usnea scabrata*.** Main branches are wrinkled and ridged; isidia are abundant; papillae may be weakly developed; few annular cracks. Widely distributed from the Coast Range to the eastern Cascades.

Shrubby Usnea (< 11 cm long)

1. With cigar-shaped branches (pinched at the nodes and slightly to distinctly expanded in the internodes):

Usnea wirthii. Pale lemon yellow central axis; cortex often with red spots. Isidia absent; base pale; branch apices recurved; branches usually with annular cracks; soralia plane to slightly concave, sometimes confluent; papillae distinct and numerous; fibrils usually abundant. Widely distributed.

Usnea cornuta. White central axis, thallus large (5-15 cm), papillae limited to main branches or absent. Isidia usually small, <1/2 branch diameter, sometimes coalescing into larger patches. Base pale or blackened. Widely distributed, especially in Coast Range.

Usnea glabrata. White central axis, thallus small (<5 cm). Papillae sparse or absent, no isidia but soralia may become large and wrap around the branches. Base is pale or slightly blackened. Branch apices are straight to recurved. Soralia occurring mostly near the apices, usually large and tuberculate, and often confluent and wrapping around the branches when mature. Isidia lacking but spinules may be present around the soralia. Papillae limited to main branches or absent. Widely distributed.

Usnea fragilescens var. mollis. Similar to *U. cornuta* but soralia are usually > ½ branch diameter. Base distinctly blackened; thallus subpendent to 20 cm long and sparsely branched; isidia present; soralia present arising from slow tubercles; papillae low, numerous, sometimes indistinct; fibrils sparse to abundant. Coast Range.

Usnea esperantiana. Central axis white, isidia absent. Thallus to 8 cm long. Base pale; branch apices recurved; soralia plane to slightly concave, sometimes confluent; papillae distinct and numerous. Fibrils are usually present and abundant. Limited to Coast Range?

2. With cylindrical branch segments

Usnea diplotypus. Soralia are raised, not exposing central axis, becoming isidiate. Short to cylindrical papillae; terminal branches more or less similar in diameter, tapering only toward tips. Widely distributed, most common east of the Cascade crest.

Usnea glabrescens (=fulvoreagens). Base blackened; with concave soredia; no isidia. Soralia similar to *U. lapponica*; branches cylindrical, branching isotomic dichotomous; base conspicuously blackened. Fibrils and lateral branches divergent (as opposed to the rare species *U. wasmuthii*, with narrow, ascending fibrils and black base splitting into right angled segments). Widely distributed.

Usnea lapponica. Branches are often deformed with foveoles or irregularly swollen; base pale or blackened; soralia becoming strongly concave, exposing the central axis, the edges of the ruptured cortex flexed outward, eventually the soralia wrapping around the branches. Most common east of the Cascade crest.

Usnea nidulans. Cortex translucent; fibrils often in fascicles of two to four; soralia tuberculate when present. Papillae low. Rare. Immediate coast and Coast Range.

U. subfloridana. Annular cracks few to scattered; soralia tuberculate to slightly excavate, mature soralia often rounded; papillae warty to cylindrical; fibrils often abundant near the base. Widely distributed.

Usnea substerilis. Soralia initially raised, becoming concave, not exposing central axis. Usually isidiate; base pale or blackened; papillae low to cylindrical, usually numerous. Willamette Valley and eastern Cascades, Columbia River Gorge.

Usnea pacificana. Papillae warty, terminal branches tapering; soralia punctiform and tuberculate; thallus initially erect, becoming pendent to 20 cm; base slightly to distinctly blackened; annular cracks common near the bases with white, everted, medullary rings common on the main branches; soredia usually sparse; isidia short to long, occurring on young soralia but easily abraded. Occurring west of the Cascade crest.

Colored Axis or Cortex (red, yellow, brown or black)

Usnea rubicunda. Thallus reddish brown, immediate coast.

Usnea wirthii. See entry under cigar-shaped shrubby *Usnea*.

Usnea ceratina. Central axis reddish, pinkish brown or rose; raised tubercles commonly bearing isidia and coarse soredia. Annular cracks often abundant and conspicuous; tubercles sometimes coalescing into ridges. Cortex thick and glossy; base pale to rarely blackened. Pendent to 30 cm. Rare. Coastal.

Usnea sphacelata. Cortex blackening toward branch tips; thallus tufts to 2 cm; branches often black spotted or banded. Rare. On rock in subalpine to alpine.

Xanthoria
Problem: Some new species have been described that are difficult to distinguish in the field.
Remedy: Learn and look for distinguishing field characters, put collections in separate packets if two specimens look slightly different.

Distinguishing Field Characters
Presence or absence of soredia
Color of soredia compared to the upper cortex
Shape and location of soralia
Thallus size and color
Lobe width and degree to which lobes are appressed to, or raised above, the substrate
Presence and color, relative to upper cortex, of pycnidia
Attachment by hapters vs. rhizines

The following information is from an updated key by Bruce McCune, from 26 Mar 2000, based largely on Lindblom (1997). **Bold-faced** species are most common in our area.

Esorediate species

1. *X. parietina*. Thallus is relatively large, to 10 cm, and lobes 1-3 mm broad. Apothecia usually present. Most common along river bottoms (Willamette Valley, Columbia River Gorge), usually on hardwoods, in nutrient enriched environments.
2. ***X. polycarpa.*** Thallus small, to 2.5 cm; lobes <1 mm broad; abundantly apotheciate; thallus attached with short hapters; no rhizines.
3. ***X. hasseana***. Similar to *X. polycarpa* but with rhizines and lacking hapters; color is yellow to orange; pycnidia are darker than the thallus. Occurring in semi-open to open, nutrient rich habitats on hardwoods.
4. *X. montana*. Similar to *X. hasseana* but color is light to dark orange and occurring in open, dry habitats on hardwoods and conifers.
5. *X. tenax.* No lower cortex; look for this lichen in SW Oregon.

Sorediate species

1. ***X. candelaria***. Dwarf fruticose thallus, lobes steeply ascending to erect; thalline margin of apothecia often with lobules and soredia.
2. ***X. fallax***. Soredia in marginal, crescent-shaped slits border by upper and lower cortex, usually yellowier or greener than the upper surface; soralia broadening to half moons or nearly circular "bird nests; marginal lobes appressed, often down-curved, 7 to 1.5 mm broad; margins of older apothecia occasionally breaking open into soralia. Rhizines usually abundant. On bark, esp. of hardwoods, in dry, nutrient enriched habitats.
3. ***X. fulva***. Soralia apical, on lower side of lobes; lobes narrow, 0.2-0.6 mm wide, ascending to erect with orange to red pycnidia; rhizines sparse to abundant. Most common east of the Cascade crest.
4. *X. ulophyllodes*. Soredia marginal or just below the lobe tips, or laminal on well-developed thalli, similar in color to the upper surface; lobes horizontal to suberect; rhizines frequently visible from above. On bark or wood.
5. *X. sorediata.* Soredia laminal; usually on rock, rarely on bark.
6. ***X. oregana***. Variable morphology ranges from appressed yellow thalli with wrinkled lobes and marginal-submarginal soredia to orange thalli with semi-erect to erect, wrinkled or smooth lobes and soredia produced from almost helmet-shaped lobe apices. Rhizines rarely visible from above; lobes usually 0.4-1.0 mm wide; soralia not laminal on the upper surface; apothecia are rare. Usually on bark and wood, widespread coastal and inland.

6.33 Summary of lichen survey procedures

Above all:

WRITE NEATLY!!!!
PUT PLENTY OF MATERIAL IN LICHEN SURVEY PACKETS

Sampling area
The area to be sampled is a 35 m (114 ft.) r circular plot centered on sampling point #1 of the CVS plot.

Sampling time
Sampling continues for a maximum of two hours or until 10 minutes elapse with no additional species recorded and all sectors of the plot have been covered. At least 30 minutes must be spent searching the plot, even if very few lichens are present.

Reconnaissance walk
Walk through the entire lichen plot to locate lichen epiphytes on woody plants, collect voucher samples and assign abundances.

Lichens to collect
Collect epiphytic fruticose and foliose lichens.

Substrates for collections
Woody plants (must be > 0.5 m tall west of the Cascade crest to avoid ground lichens creeping up over moss on bases of trees and shrubs) within the lichen plot will be inspected for lichens species. Fallen and reachable branches will also be inspected. Rotten logs, stumps, and branches overgrown with ground mosses on the forest floor should not be sampled.

Where to look
Carefully inspect the full range of substrates and microhabitats available: shaded and exposed, conifers and hardwoods, fallen upper branches and lower branches, large shrubs and trees in particular topographic positions (e.g. checking in draws or ravines of an otherwise uniform slope).

Abundance ratings
Record abundance within the lichen plot on each packet. Use the highest rating that is true, estimated as follows:

Code	Abundance
1	Rare (≤3 individuals on the plot)
2	Uncommon (4-10 individuals on the plot)
3	Common (10-40 individuals on the plot)
4	Very common (>40 individuals observed but covering less than half the available substrate. Choose one: 4-1 individuals are few (close to 40) and widely scattered around the plot 4-2 most of the individuals are restricted to one or two small areas on the plot 4-3 many trees have ≤ 20 individuals 4-4 many trees have >20 individuals 4-5 > 50% of the trees have ≤ 20 individuals 4-6 > 50% of the trees have >20 individuals
5	Abundant (the lichen physically covers more than half of the available substrate)

Recording substrate
Record substrate species (4 letter acronym OK). If species cannot be determined use the most specific term that is certain, e.g. "conifer branch" or "hardwood snag". Also record the location of the lichen on the substrate, e.g. branches, boles, fine branches, fallen, over moss on branch, base of boles over moss. If the collection is on wood rather than bark, write "on wood". If the lichen is collected as free-fall litter and is not attached to a branch, specify "litterfall". If collecting non-epiphytic species, describe the substrate as specifically as possible—on limestone rock, on duff and decayed organic mater, in mineral soil, etc.

Packet labeling
A sample of each putative species will be collected and placed in a paper packet labeled with the CVS/FIA plot number. If it is not a CVS or FIA plot, assign a unique number or letter code no more than 8 digits in length, e.g. Eugene1. Number packets sequentially (these numbers are used with plot number to track individual collections in the database), and record abundance, collector's initials, forest acronym, and collection date.

How to handle uncertainties
Field observers will frequently have uncertainties about the classification of an organism. The following rules are designed to put the onus of the responsibility for classification on the specialist, not the field crew:

1. When in doubt, assume it is a lichen.
2. When the growth form is in doubt, assume it is a macrolichen.
3. When the species distinction is in doubt, assume two different forms are two different species.

Sample collection
Optimally, a palm-size sample of fruticose and foliose growth forms is collected. Even minute fruticose and lobate forms should be included. *Cladonia* squamules lacking upright stalks should not be included. Collecting large samples improves the likelihood of picking up inconspicuous species that may not have been noticed in the field. These additional species can be recorded in the office.

Packaging samples, preservation and storage.
Each specimen will be placed in a separate folded and labeled paper packet. Often there will be more than one species on a bark sample. If there is any ambiguity about which species in the packet corresponds with which abundance rating, a clarifying phrase, such as "the white one" or the "sorediate one" should be written on the packet. *Air-dry samples thoroughly to avoid decay*. Packets should be stored in a dry place until delivery to the program coordinator.

Quality control
Only those who have completed certified personnel may collect the lichen community data.

Mailing packets
Periodically send or deliver packets to the program coordinator. Bind packets from a single plot with rubber bands, in alphabetical order by genus and species, and place in a separate paper or Ziploc bag with the corresponding field data card. Place bags in a box with a completed mailing form (Form 5.4).

6.34 Summary of tissue collection procedures

What to collect
Collect ≥ 20 g each of 2 target lichens, dry weight. Avoid dusty, gritty, discolored, or decaying material.

Target species

MOST PREFERRED
Platismatia glauca (collect whenever possible)

PREFERRED
Alectoria sarmentosa (Alesar)
Evernia prunastri (Evepru)
Hypogymnia enteromorpha (Hypent)
Hypogymnia imshaugii (Hypims)
Hypogymnia inactiva (Hypina)
Letharia vulpina (Letvul)

GOOD
Bryoria fremontii (Bryfre)
Letharia columbiana (Letcol)
Lobaria oregana (Lobore)
Sphaerophorus globosus (Sphglo)
Xanthoparmelia cumberlandia (Xancum)

ACCEPTABLE if no other target species are present. If a moss is collected, collect a lichen for the second target species.
Isothecium myosuroides (Isomyo)--moss
Lobaria pulmonaria (Lobpul)
Neckera douglasii (Necdou)--moss
Usnea (Usnea)--shrubby species only

Replicates
For each species, make one replicate collection for every five collections, i.e. at one out of five plots where that species was collected. To save time and improve repeatability, collect replicates at sites where the species is plentiful rather than waiting until the fifth plot or until later in the field season.

Repeat visits
Revisit one plot per Forest during the field season and sample the same species again.

Where to collect
Make collections within 1 km (0.65 miles) of plot center. Collect ≥ 35 m away from roads. Collect from ≥6 locations per sample. Lichens on tree branches, shrubs or tree boles, in the litter, or on fallen branches, may be used. Collect *Alectoria*, *Bryoria* and *Usnea* spp only from live or standing substrates. Collect replicates and repeats from the same host species and types of substrate locations.

How to collect
While collecting wear unpowdered vinyl gloves and avoid crew touching anything brought onto the plot. Store unused Kapak bags in clean zip-loc plastic bags. Wear new gloves at each plot and replace if they become torn or contaminated. Place clean samples in Kapak bags and weigh on a 50 g Pesola scale. If the lichens are dry, the sample and bag together should weigh ≥ 28 g. If the lichens are wet, the bag should weigh more than 100 g and adequacy of the sample size should be judged by volume rather than weight. Fold the edge of the bag over three times and seal with waterproof, removable, laboratory tape.

What to record
Write on the bag with an indelible marker: plot number, date, substrate(s), target species acronym, collector's initials, and moisture status of sample, i.e. dry, damp or wet. List host species name and substrate location in order by the amount of sample in the bag from that substrate. E.g. "*Pinus contorta* branches, *Pinus ponderosa* branches and boles" would indicate that the sample weight collected from *P. contorta* branches> *P. ponderosa* branches> *P. ponderosa* boles.

Drying samples
Dry any damp or wet samples within two days of collection. If samples are kept wet more than one day, store them on ice in a cooler. Dry lichens in mesh bags attached to a clothesline, or on clean 100% cotton herbarium sheets on a clean desk or other flat surface, preferably covered by glass or plastic wrap.

7.0 APPENDICES

APPENDIX I. MAPS OF PLOT LOCATIONS

The following maps show the general location of the CVS plots comprising the 5.5 km grid, by national forest, and of additional off-frame plots established during the first round of monitoring. Plot numbers correspond to plot numbers in the master database and to the plot rotation schedules in Appendix 2.

APPENDIX II. PLOT ROTATION SCHEDULE

The following tables are lists of the plots surveyed in the first round of monitoring by year and national forest.

Table B1. Columbia River Gorge National Scenic Area plot rotation schedule.

Columbia River Gorge National Scenic Area							
1993		**1994**		**1998**		**1999**	**2000**
CRG03	CRG526	ARM101	ARM138	ARM166	CRG56	CRG11	FIA014
CRG04	CRG528	ARM102	ARM139	ARM167	CRG57	CRG201	FIA015
CRG07	CRG529	ARM103	ARM140	ARM170	CRG58	CRG517	FIA016
CRG08	CRG531	ARM104	ARM141	ARM171	CRG59	CRG518	FIA018
CRG09	CRG532	ARM105	ARM142	ARM172	CRG60	CRG530	FIA020
CRG10	CRG534	ARM106	ARM143	ARM174	CRG62	CRG539	FIA022
CRG12	CRG535	ARM107	ARM144	ARM175	CRG70	CRG540	FIA024
CRG15	CRG536	ARM108	ARM145	CRG01	CRG71	CRG541	FIA025
CRG19	CRG537	ARM109	ARM146	CRG02	CRG72	FIA001	FIA026
CRG202	CRG538	ARM110	ARM147	CRG06	CRG73	FIA003	FIA027
CRG22	CRG61	ARM111	ARM148	CRG11B	CRG75	FIA004	FIA032
CRG23	CRG63	ARM112	ARM149	CRG13	CRG76	FIA006	FIA033
CRG24	CRG67	ARM113	ARM150	CRG14	CRG77		FIA044
CRG25	CRG68	ARM114	ARM151	CRG16	CRG78		FIA134
CRG27	CRG74	ARM115	ARM152	CRG18	CRG81		FIA-DNR
CRG31	CRG79	ARM116	ARM153	CRG20	CRG82		
CRG37	CRG84	ARM117	ARM154	CRG21	CRG89		
CRG40	CRG86	ARM118	ARM155	CRG27B	Miller Island		
CRG46	CRG87	ARM119	ARM156	CRG28			
CRG48	CRG88	ARM120	ARM157	CRG29			
CRG50	Sandy Rv Delta	ARM121	ARM158	CRG30			
CRG503	Spr. Cr. Hatch.	ARM122	ARM159	CRG32			
CRG504	Tillatson	ARM123	ARM160	CRG33			
CRG505		ARM124	ARM161	CRG34			
CRG508		ARM125	ARM162	CRG35			
CRG509		ARM126	ARM163	CRG36			
CRG510		ARM127	CRG519	CRG38			
CRG511		ARM128		CRG44			
CRG513		ARM129		CRG45			
CRG514		ARM130		CRG47			
CRG515		ARM131		CRG49			
CRG520		ARM132		CRG507			
CRG521		ARM133		CRG51			
CRG522		ARM134		CRG52			
CRG523		ARM135		CRG53			
CRG524		ARM136		CRG54			
CRG525		ARM137		CRG55			

Table B2. Deschutes National Forest Plot rotation schedule.

Deschutes National Forest			
1994	**1995**	**1996**	**1997**
1058168	1102184	1060172	1088188	1058160	1110188	1058164	1106172
1060168	1104172	1062164	1090172	1058172		1060164	1112168
1062176	1106168	1062204	1094180	1060160		1062156	1112172
1064200	1108172	1064156	1096180	1062160		1062172	
1066156	1110172	1064164	1098172	1064152		1066160	
1066164	1110184	1064204	1104168	1064160		1066192	
1066196	1112184	1066152	1104176	1064180		1066204	
1068160		1066200	1108168	1066208		1068172	
1068164		1068204	1108180	1068152		1070160	
1068208		1070164	1110176	1068156		1070168	
1070204		1070192	1110180	1068168		1070200	
1070220		1070216	1112180	1068196		1070208	
1072164		1070228		1068200		1070224	
1072200		1072160		1068212		1072212	
1072216		1072168		1070172		1072220	
1072224		1072172		1070196		1074160	
1074180		1072192		1070212		1074164	
1074196		1072208		1072204		1074200	
1076164		1072228		1074192		1074204	
1076176		1074168		1074208		1074216	
1076208		1074176		1074212		1076160	
1076224		1074220		1074224		1078160	
1078180		1076168		1076196		1078164	
1078192		1076172		1076216		1078200	
1078216		1076180		1076220		1080164	
1080160		1076212		1078196		1080168	
1080204		1078172		1078204		1080196	
1082188		1078176		1080180		1082168	
1082204		1078208		1080192		1082172	
1082208		1078212		1080208		1082180	
1084180		1078220		1082160		1084172	
1084204		1080176		1082164		1084176	
1086184		1080184		1082192		1084196	
1088176		1080200		1082196		1086172	
1088192		1080212		1084168		1086200	
1092180		1080220		1086176		1088180	
1092188		1082176		1086188		1090180	
1094176		1082184		1088172		1092172	
1096176		1082200		1090184		1092176	
1096184		1084200		1102168		1094172	
1100172		1086180		1106176		1096172	
1102172		1088168		1108176		1100168	

Table B3. Gifford Pinchot National Forest plot rotation schedule.

Gifford Pinchot National Forest						
1994	**1995**		**1996**		**1997**	**1999**
1180172	1164176	1196160	1160148	1174160	1158140	2195160
1182152	1180156	1196164	1160152	1174164	1158144	2195162
1182160	1180160	1196168	1160156	1174168	1158172	2195164
1182176	1180164	1196172	1160160	1174172	1160144	2196158
1184180	1180168	1196176	1160164	1174176	1160168	2196162
1186160	1180176	1196184	1160172	1174180	1162144	2196166
1186184	1180180	1198136	1162148	1174184	1162160	2197156
1188160	1182156	1198156	1162152	1176168	1162164	2197160
1188168	1182168	1198180	1162156	1176172	1164144	2197162
1190168	1182172	1200156	1162168	1176176	1164148	2197166
1190176	1182180		1162172	1178160	1164160	2198158
1192160	1184152		1162176	1178172	1164164	2199156
1192164	1184156		1164152	1178180	1166144	2199158
1192180	1184160		1164156	1178184	1166148	
1194132	1184164		1164168	1180184	1166152	
1194164	1184168		1164172		1166160	
1194176	1184172		1166156		1166164	
1194180	1184176		1166168		1168148	
1196180	1186152		1166172		1168164	
1198164	1186156		1166176		1168168	
1198168	1186168		1168152		1170164	
1202156	1186172		1168156		1170168	
	1186176		1168160		1172140	
	1186180		1168172		1174152	
	1188156		1168176		1174156	
	1188164		1170156		1176140	
	1188172		1170160		1176152	
	1188176		1170172		1176156	
	1188180		1170176		1176160	
	1188184		1172156		1178156	
	1190172		1172160		1178164	
	1190180		1172164		1178168	
	1192168		1172168		1178176	
	1192176		1172172		1180136	
	1192184		1172176		1180152	
	1194136		1172180		1182164	
	1194160		1172184		1184144	
	1194168		1174136		1186148	
	1194184		1174140		1198184	
	1194188		1174144			
	1196136		1174148			

Table B4. Mt. Hood National Forest plot rotation schedule.

Mt. Hood National Forest			
1994	**1995**	**1996**	**1997**
1118168	1122160	1122152	1120164
1120160	1122164	1124164	1122144
1124144	1124148	1128160	1122148
1124168	1124156	1132144	1122156
1126152	1124160	1132160	1122168
1126156	1126148	1134140	1124152
1126164	1126160	1134144	1126144
1128148	1126168	1134164	1128156
1128168	1128152	1134184	1130152
1130160	1128164	1136144	1132156
1132140	1130156	1136148	1134156
1132152	1130164	1136160	1136156
1132164	1130168	1136172	1138152
1134172	1132148	1136192	1138156
1136152	1132168	1138164	1138160
1136164	1134152	1138176	1140156
1136180	1134160	1138180	1140160
1136188	1134168	1138184	1140184
1138168	1134176	1140188	1142160
1138192	1134180	1144152	1142164
1140152	1136168	1144156	1142168
1140164	1136176	1144164	1142176
1140168	1136184	1144180	1144160
1140172	1138148	1146148	1144172
1142180	1138188	1146152	1148168
1144148	1140148	1146156	1150160
1144168	1140176	1146164	1152164
1144184	1140180	1146172	1152172
1146160	1142184	1146180	1154164
1146176	1144176	1146184	1154168
1148148	1144188	1148156	
1148176	1146188	1148164	
1148184	1148152	1150156	
1150148	1148160	1150164	
1150168	1148172	1152160	
1154172	1150152	1152168	

Table B5. Siuslaw National Forest plot rotation schedule.

Siuslaw National Forest			
1994	**1995**	**1996**	**1997**
1084052	1088040	1070028	1074044
1090044	1090036	1072028	1074048
1104052	1090040	1082032	1078044
1122048	1090052	1084048	1080040
	1092040	1090048	1082044
	1092044	1098044	1082048
	1092048	1100036	1082052
	1094040	1100044	1084044
	1094052	1100048	1086040
	1096040	1102052	1086044
	1096044	1106044	1086048
	1096056	1108044	1088044
	1098036	1124044	1088052
	1098048	1126048	1092036
	1100040	1130040	1092052
	1102036	1130044	1094036
	1102044	1134052	1094044
	1104044	1136052	1094048
	1104048	1140056	1094056
	1106040		1096052
	1106068		1098040
	1108052		1102048
	1108056		1106048
	1138064		1106052
			1108040
			1108068
			1124048
			1126044
			1132048
			1136056
			1136060
			1138044
			1138048
			1138056
			1140048

Table B6. Umpqua National Forest plot rotation schedule.

Umpqua National Forest			
1997	**1998**	**1999**	**2000**
1036096	1036104	1036100	1042108
1048120	1038096	1040100	1044112
1048124	1038108	1042116	1044120
1050120	1040112	1044108	1044124
1050128	1042100	1044116	1046112
1052112	1042120	1046108	1046120
1052116	1048128	1046116	1048108
1054136	1050112	1048104	1050108
1054148	1050124	1048112	1050132
1054152	1052100	1048116	1050148
1056108	1054116	1050104	1052104
1056116	1054140	1050116	1052120
1056140	1054144	1050152	1052128
1056148	1056104	1052108	1052140
1058116	1056144	1052124	1054108
1058120	1056152	1052132	1056112
1058144	1058108	1052136	1056128
1060120	1058140	1054112	1056136
1062116	1060144	1054120	1058136
1062120	1062124	1054128	1058148
1064116	1062148	1054132	1060148
1064120	1062152	1056124	1060156
1064128	1066116	1056132	1062128
1072116	1068112	1056156	1066124
1074116	1068124	1058112	1076120
1074120	1070124	1058128	1078116
	1072120	1058132	
		1060124	
		1060132	
		1060136	
		1060152	
		1062144	
		1064124	
		1066120	
		1068116	
		1072124	
		1076116	

Table B7. Wallowa-Whitman National Forest plot rotation schedule.

Wallowa-Whitman National Forest			
1998	**1999**	**2000**	**2001**
1138436	1138416	1136428	1134428
1138440	1138420	1138424	1138428
1140408	1140416	1140424	1140436
1144420	1140428	1140432	1142428
1144424	1142412	1142408	1144408
1144432	1142424	1142436	1144416
1146424	1144412	1144404	1146404
1150400	1146408	1146412	1146416
1152404	1146420	1148416	1148420
	1148404		1150412
	1148412		

Table B8. Willamette National Forest plot rotation schedule.

Willamette National Forest							
1995		**1996**		**1997**			
1062140	1092160	1064132	1088152	1062132	1080132	1092144	1110148
1064144	1094148	1064136	1090144	1062136	1080136	1092152	1110156
1066132	1094160	1066148	1092164	1064140	1080140	1092156	1110160
1066144	1096148	1070128	1092168	1064148	1080144	1094132	1110164
1068140	1098156	1070132	1094136	1066128	1080152	1094152	1112140
1070136	1098160	1070148	1094164	1066136	1080156	1094156	1112144
1070144	1100156	1070152	1094168	1066140	1082120	1096144	1112148
1072136	1100164	1072132	1096136	1068128	1082132	1096152	1112152
1074136	1102156	1072140	1096164	1068132	1082136	1096156	1112156
1074148	1102164	1072144	1098136	1068136	1082148	1096160	1114144
1076140	1104160	1072156	1102144	1070140	1082152	1096168	1114152
1076152	1104164	1074156	1102148	1072148	1082156	1098140	1114156
1078132	1106148	1076124	1102152	1072152	1084120	1098144	1116168
1078144	1106164	1076128	1104132	1074124	1084128	1098148	1118144
1080148	1108148	1078156	1104152	1074128	1084132	1098152	1118152
1084160	1108160	1080124	1104156	1074140	1084136	1098164	1118156
1086124	1110136	1080128	1106156	1074144	1084140	1100144	1120144
1086144	1110152	1082124	1112160	1074152	1084152	1100148	1120148
1086152	1114164	1082128	1112164	1076132	1084156	1100152	1120156
1086156	1116160	1082140	1116148	1076136	1086136	1102160	
1086160	1116164	1082144	1116156	1076144	1086148	1106136	
1086164	1118148	1084124	1118160	1076148	1088124	1106144	
1088128	1120140	1084144	1118164	1076156	1088136	1106160	
1088132	1122140	1084148		1078120	1088148	1108144	
1088144		1086120		1078124	1088156	1108152	
1088164		1086128		1078128	1090152	1108156	
1090132		1086132		1078136	1090156	1108164	
1090148		1086140		1078148	1090160	1110140	
1092148		1088140		1080116	1092136	1110144	

Table B9. Winema National Forest plot rotation schedule.

Winema National Forest					
1997	**1998**	**1999**		**2000**	
1018148	1040180	1018152	1036200	1018144	1054160
1022148	1042184	1022144	1036204	1022196	1056160
1024144	1044164	1022152	1038152	1026148	1056176
1024172	1046184	1022188	1038172	1026176	1058184
1024176	1046192	1024148	1038176	1028148	1060184
1026168	1048188	1024184	1038180	1028152	
1028168	1050176	1026172	1038188	1028176	
1030152	1050184	1028172	1040164	1030168	
1032164	1052160	1028180	1040176	1030180	
1034148	1052188	1030184	1040188	1030196	
1038160	1054184	1030188	1042188	1032152	
1040160	1056164	1030192	1044188	1034152	
1042160	1056172	1032168	1044192	1034168	
1042180	1058180	1032172	1046188	1034180	
1044160	1058188	1032180	1048160	1034200	
1052156	1060176	1032184	1048184	1036172	
2019146	1060188	1032188	1048196	1036176	
	1062180	1032196	1050156	1036196	
		1034164	1050188	1038148	
		1034172	1052176	1038164	
		1034176	1052180	1038184	
		1034184	1054164	1040184	
		1034192	1054176	1044184	
		1034196	1054188	1046160	
		1036152	1056168	1046196	
		1036168	1056180	1048192	
		1036180	1056188	1050160	
		1036184	1058176	1050180	
		1036188	1062184	1052184	

APPENDIX III. FREQUENCY AND DISTRIBUTION OF EPIPHYTIC MACROLICHENS IN PACIFIC NORTHWEST NATIONAL FORESTS

The following tables contain alphabetical listings of epiphytic macrolichens, by national forest. With the exception of the Columbia River Gorge National Scenic Area, only lichen survey data from plots comprising the CVS 5.5 km (3.4 mile) grid are used in these tables. Because nearly all 5.5 km CVS plots were surveyed, frequency estimates (% of 1-acre sites in which the species has been detected) are representative of the entire area within each national forest. Note this list does not include ground dwelling, rock-dwelling, or crustose lichens. Because some lichens are more difficult to detect than others, and all lichens are difficult to detect when very few individuals are present, the frequencies provided should be considered minimums.

Table C1. Columbia River Gorge National Scenic Area lichens (151 sites surveyed).

Columbia River Gorge National Scenic Area					
Lichen species	Count of Known Sites	Frequency (% of Sites Surveyed)		Lichen species	Count of Known Sites	Frequency (% of Sites Surveyed)
Alectoria imshaugii	2	1.3		*Lobaria oregana*	2	1.3
Alectoria sarmentosa	13	8.6		*Lobaria pulmonaria*	28	18.5
Bryoria capillaris	15	9.9		*Lobaria scrobiculata*	16	10.6
Bryoria fuscescens	1	0.7		*Melanelia elegantula*	13	8.6
Bryoria tortuosa	1	0.7		*Melanelia exasperatula*	74	49.0
Candelaria concolor	27	17.9		*Melanelia fuliginosa*	7	4.6
Cavernularia hultenii	1	0.7		*Melanelia glabra*	9	6.0
Cetrelia cetrarioides	3	2.0		*Melanelia subargentifera*	3	2.0
Cladonia bellidiflora	2	1.3		*Melanelia subaurifera*	25	16.6
Cladonia chlorophaea	1	0.7		*Melanelia subelegantula*	15	9.9
Cladonia fimbriata	1	0.7		*Melanelia subolivacea*	33	21.9
Cladonia ochrochlora	3	2.0		*Menegazzia terebrata*	9	6.0
Cladonia pyxidata	3	2.0		*Nephroma helveticum*	14	9.3
Cladonia squamosa	5	3.3		*Nephroma resupinatum*	18	11.9
Cladonia transcendens	1	0.7		*Nodobryoria abbreviata*	8	5.3
Collema furfuraceum	11	7.3		*Nodobryoria oregana*	1	0.7
Collema nigrescens	1	0.7		*Normandina pulchella*	3	2.0
Esslingeriana idahoensis	2	1.3		*Parmelia hygrophila*	8	5.3
Evernia prunastri	120	79.5		*Parmelia pseudosulcata*	1	0.7
Hypogymnia austerodes	1	0.7		*Parmelia saxatilis*	11	7.3
Hypogymnia enteromorpha	43	28.5		*Parmelia sulcata*	134	88.7
Hypogymnia imshaugii	31	20.5		*Parmeliopsis hyperopta*	10	6.6
Hypogymnia inactiva	71	47.0		*Parmotrema arnoldii*	9	6.0
Hypogymnia metaphysodes	2	1.3		*Parmotrema chinense*	6	4.0
Hypogymnia occidentalis	2	1.3		*Peltigera aphthosa*	2	1.3
Hypogymnia physodes	85	56.3		*Peltigera canina*	2	1.3
Hypogymnia rugosa	4	2.6		*Peltigera collina*	46	30.5
Hypogymnia tubulosa	98	64.9		*Peltigera membranacea*	6	4.0
Hypocenomyce scalaris	1	0.7		*Peltigera neckeri*	2	1.3
Hypotrachyna sinuosa	18	11.9		*Peltigera rufescens*	3	2.0
Kaernefeltia merrillii	10	6.6		*Phaeophyscia orbicularis*	4	2.6
Leptogium corniculatum	1	0.7		*Physcia adscendens*	97	64.2
Leptogium furfuraceum	3	2.0		*Physcia aipolia*	70	46.4
Leptogium saturninum	11	7.3		*Physcia dubia*	2	1.3
Leptogium gelatinosum	6	4.0		*Physconia americana*	1	0.7
Letharia columbiana	2	1.3		*Physconia enteroxantha*	18	11.9
Letharia vulpina	29	19.2		*Physcia stellaris*	3	2.0

Table C1, Cont'd. Columbia River Gorge National Scenic Area lichens (151 sites).

Lichen species	Count of Known Sites	Frequency (% of Sites Surveyed)
Physcia tenella	4	2.6
Physconia isidiigera	47	31.1
Physconia perisidiosa	26	17.2
Platismatia glauca	103	68.2
Platismatia herrei	41	27.2
Platismatia norvegica	2	1.3
Platismatia stenophylla	65	43.0
Pseudocyphellaria anomala	14	9.3
Pseudocyphellaria crocata	1	0.7
Ramalina dilacerata	27	17.9
Ramalina farinacea	102	67.5
Ramalina subleptocarpha	1	0.7
Sphaerophorus globosus	24	15.9
Sticta fuliginosa	26	17.2
Sticta limbata	29	19.2
Tuckermannopsis chlorophylla	38	25.2
Tuckermannopsis orbata	59	39.1
Tuckermannopsis platyphylla	5	3.3
Usnea cornuta	1	0.7
Usnea filipendula	3	2.0
Usnea glabrata	3	2.0
Usnea longissima	2	1.3
Usnea scabrata	2	1.3
Usnea wirthii	9	6.0
Vulpicida canadensis	11	7.3
Xanthoria candelaria	1	0.7
Xanthoria fallax	9	6.0
Xanthoria parietina	1	0.7
Xanthoria polycarpa	98	64.9

Table C2. Deschutes National Forest lichens (187 sites surveyed).

DESCHUTES NATIONAL FOREST					
Lichen species	Count of Known Sites	Frequency (% of Sites Surveyed)	Lichen species	Count of Known Sites	Frequency (% of Sites Surveyed)
Ahtiana pallidula	7	3.7	*Hypogymnia tubulosa*	18	9.6
Ahtiana sphaerosporella	15	8.0	*Hypotrachyna sinuosa*	1	0.5
Alectoria imshaugii	124	66.3	*Kaernefeltia merrillii*	166	88.8
Alectoria lata	1	0.5	*Letharia columbiana*	134	71.7
Alectoria sarmentosa	123	65.8	*Letharia vulpina*	170	90.9
Alectoria vancouverensis	1	0.5	*Lobaria hallii*	1	0.5
Bryoria capillaris	28	15.0	*Lobaria pulmonaria*	2	1.1
Bryoria fremontii	125	66.8	*Melanelia elegantula*	14	7.5
Bryoria friabilis	2	1.1	*Melanelia exasperatula*	16	8.6
Bryoria furcellata	2	1.1	*Melanelia subaurifera*	2	1.1
Bryoria fuscescens	92	49.2	*Melanelia subelegantula*	47	25.1
Bryoria glabra	32	17.1	*Melanelia subolivacea*	33	17.6
Bryoria lanestris	14	7.5	*Nephroma helveticum*	1	0.5
Bryoria nadvornikiana	3	1.6	*Nephroma resupinatum*	1	0.5
Bryoria pseudofuscescens	108	57.8	*Nodobryoria abbreviata*	123	65.8
Bryoria tortuosa	11	5.9	*Nodobryoria oregana*	58	31.0
Bryoria trichodes	8	4.3	*Parmelia hygrophila*	22	11.8
Candelaria concolor	31	16.6	*Parmelia saxatilis*	2	1.1
Cladonia carneola	3	1.6	*Parmelia sulcata*	35	18.7
Cladonia chlorophaea	2	1.1	*Parmeliopsis ambigua*	48	25.7
Cladonia fimbriata	4	2.1	*Parmeliopsis hyperopta*	76	40.6
Cladonia furcata	1	0.5	*Peltigera collina*	2	1.1
Cladonia norvegica	1	0.5	*Physcia adscendens*	7	3.7
Cladonia ochrochlora	2	1.1	*Physcia aipolia*	2	1.1
Cladonia sulphurina	1	0.5	*Physcia biziana*	1	0.5
Cladonia transcendens	3	1.6	*Physcia caesia*	2	1.1
Esslingeriana idahoensis	24	12.8	*Physcia dimidiata*	3	1.6
Evernia prunastri	19	10.2	*Physcia dubia*	1	0.5
Hypocenomyce castaneocineria	5	2.7	*Physcia stellaris*	1	0.5
Hypocenomyce scalaris	41	21.9	*Physconia enteroxantha*	3	1.6
Hypogymnia apinnata	19	10.2	*Physconia isidiigera*	3	1.6
Hypogymnia austerodes	1	0.5	*Physconia perisidiosa*	1	0.5
Hypogymnia enteromorpha	19	10.2	*Platismatia glauca*	77	41.2
Hypocenomyce friesii	1	0.5	*Platismatia herrei*	7	3.7
Hypogymnia imshaugii	120	64.2	*Platismatia stenophylla*	13	7.0
Hypogymnia inactiva	5	2.7	*Pseudocyphellaria anomala*	3	1.6
Hypogymnia metaphysodes	48	25.7	*Pseudocyphellaria anthraspis*	2	1.1
Hypogymnia occidentalis	70	37.4	*Ramalina farinacea*	5	2.7
Hypogymnia physodes	23	12.3	*Tuckermannopsis chlorophylla*	69	36.9
Hypogymnia rugosa	9	4.8	*Tuckermannopsis orbata*	36	19.3

Table C2, Cont'd. Deschutes National Forest lichens (187 sites surveyed).

Lichen species	Count of Known Sites	Frequency (% of Sites Surveyed)
Tuckermannopsis platyphylla	82	43.9
Tuckermannopsis sepincola	1	0.5
Usnea cornuta	1	0.5
Usnea filipendula	2	1.1
Usnea glabrata	2	1.1
Usnea lapponica	2	1.1
Usnea scabrata	40	21.4
Vulpicida canadensis	107	57.2
Xanthoria candelaria	1	0.5
Xanthoria fallax	31	16.6
Xanthoria polycarpa	8	4.3

Table C3. Gifford Pinchot National Forest lichens (179 sites surveyed).

GIFFORD PINCHOT NATIONAL FOREST					
Lichen species	Count of Known Sites	Frequency (% of Sites Surveyed)	Lichen species	Count of Known Sites	Frequency (% of Sites Surveyed)
Ahtiana pallidula	20	11.2	*Hypogymnia physodes*	140	78.2
Alectoria imshaugii	16	8.9	*Hypogymnia rugosa*	6	3.4
Alectoria lata	6	3.4	*Hypogymnia tubulosa*	108	60.3
Alectoria sarmentosa	168	93.9	*Hypotrachyna sinuosa*	8	4.5
Alectoria vancouverensis	1	0.6	*Kaernefeltia merrillii*	13	7.3
Bryoria capillaris	98	54.7	*Leptogium lichenoides*	3	1.7
Bryoria fremontii	16	8.9	*Leptogium polycarpum*	7	3.9
Bryoria friabilis	55	30.7	*Letharia columbiana*	3	1.7
Bryoria fuscescens	53	29.6	*Letharia vulpina*	27	15.1
Bryoria glabra	45	25.1	*Lobaria hallii*	2	1.1
Bryoria pseudofuscescens	16	8.9	*Lobaria oregana*	31	17.3
Bryoria trichodes	52	29.1	*Lobaria pulmonaria*	28	15.6
Cavernularia hultenii	59	33.0	*Lobaria scrobiculata*	8	4.5
Cetrelia cetrarioides	2	1.1	*Melanelia exasperatula*	4	2.2
Cladonia carneola	1	0.6	*Melanelia fuliginosa*	5	2.8
Cladonia chlorophaea	3	1.7	*Melanelia subaurifera*	12	6.7
Cladonia fimbriata	8	4.5	*Melanelia subelegantula*	14	7.8
Cladonia furcata	1	0.6	*Melanelia subolivacea*	2	1.1
Cladonia macilenta	4	2.2	*Menegazzia terebrata*	1	0.6
Cladonia ochrochlora	25	14.0	*Nephroma bellum*	14	7.8
Cladonia pyxidata	1	0.6	*Nephroma helveticum*	16	8.9
Cladonia squamosa	19	10.6	*Nephroma laevigatum*	3	1.7
Cladonia sulphurina	1	0.6	*Nephroma parile*	5	2.8
Cladonia transcendens	28	15.6	*Nephroma resupinatum*	9	5.0
Cladonia umbricola	11	6.1	*Nodobryoria abbreviata*	10	5.6
Cladonia verruculosa	2	1.1	*Nodobryoria oregana*	135	75.4
Collema nigrescens	1	0.6	*Normandina pulchella*	1	0.6
Esslingeriana idahoensis	16	8.9	*Parmeliopsis ambigua*	34	19.0
Evernia prunastri	39	21.8	*Parmelia hygrophila*	119	66.5
Fuscopannaria leucostictoides	6	3.4	*Parmeliopsis hyperopta*	152	84.9
Fuscopannaria saubinetii	3	1.7	*Parmelia pseudosulcata*	15	8.4
Hypocenomyce castaneocineria	3	1.7	*Parmelia saxatilis*	1	0.6
Hypocenomyce scalaris	5	2.8	*Parmelia squarrosa*	1	0.6
Hypogymnia apinnata	107	59.8	*Parmelia sulcata*	91	50.8
Hypogymnia enteromorpha	139	77.7	*Peltigera britannica*	1	0.6
Hypogymnia imshaugii	144	80.4	*Peltigera collina*	10	5.6
Hypogymnia inactiva	151	84.4	*Peltigera membranacea*	1	0.6
Hypogymnia metaphysodes	71	39.7	*Peltigera neopolydactyla*	1	0.6
Hypogymnia occidentalis	52	29.1	*Physcia adscendens*	1	0.6
Hypogymnia oceanica	19	10.6	*Platismatia glauca*	172	96.1

Table C3, Cont'd. Gifford Pinchot National Forest lichens (179 sites surveyed).

Lichen species	Count of Known Sites	Frequency (% of Sites Surveyed)
Platismatia herrei	139	77.7
Platismatia norvegica	59	33.0
Platismatia stenophylla	115	64.2
Polychidium contortum	2	1.1
Pseudocyphellaria anomala	20	11.2
Pseudocyphellaria anthraspis	12	6.7
Pseudocyphellaria crocata	12	6.7
Pseudocyphellaria rainierensis	4	2.2
Psoroma hypnorum	2	1.1
Ramalina dilacerata	15	8.4
Ramalina farinacea	22	12.3
Sphaerophorus globosus	83	46.4
Sticta beauvoisii	5	2.8
Sticta fuliginosa	9	5.0
Sticta limbata	4	2.2
Tuckermannopsis chlorophylla	149	83.2
Tuckermannopsis orbata	96	53.6
Tuckermannopsis platyphylla	96	53.6
Tuckermannopsis subalpina	8	4.5
Usnea cornuta	3	1.7
Usnea filipendula	66	36.9
Usnea glabrata	11	6.1
Usnea glabrescens	7	3.9
Usnea lapponica	1	0.6
Usnea longissima	2	1.1
Usnea scabrata	38	21.2
Usnea subfloridana	19	10.6
Usnea wirthii	6	3.4
Vulpicida canadensis	8	4.5
Xanthoria candelaria	1	0.6
Xanthoria polycarpa	4	2.2

Table C4. Mount Hood National Forest lichens (133 sites surveyed).

MT. HOOD NATIONAL FOREST					
Lichen species	Count of Known Sites	Frequency (% of Sites Surveyed)		Lichen species	Count of Known Sites	Frequency (% of Sites Surveyed)
Ahtiana pallidula	8	6.0		*Hypogymnia inactiva*	100	75.2
Ahtiana sphaerosporella	1	0.8		*Hypogymnia metaphysodes*	46	34.6
Alectoria imshaugii	27	20.3		*Hypogymnia occidentalis*	28	21.1
Alectoria lata	1	0.8		*Hypogymnia oceanica*	6	4.5
Alectoria sarmentosa	114	85.7		*Hypogymnia physodes*	75	56.4
Bryoria capillaris	66	49.6		*Hypogymnia rugosa*	4	3.0
Bryoria fremontii	9	6.8		*Hypogymnia tubulosa*	76	57.1
Bryoria friabilis	26	19.5		*Hypotrachyna sinuosa*	12	9.0
Bryoria fuscescens	33	24.8		*Kaernefeltia merrillii*	14	10.5
Bryoria glabra	36	27.1		*Leptogium gelatinosum*	3	2.3
Bryoria pseudofuscescens	22	16.5		*Leptogium polycarpum*	2	1.5
Bryoria tortuosa	2	1.5		*Letharia columbiana*	14	10.5
Bryoria trichodes	19	14.3		*Letharia vulpina*	35	26.3
Candelaria concolor	4	3.0		*Lobaria oregana*	39	29.3
Cavernularia hultenii	14	10.5		*Lobaria pulmonaria*	18	13.5
Cavernularia lophyrea	1	0.8		*Lobaria scrobiculata*	8	6.0
Cetrelia cetrarioides	2	1.5		*Melanelia elegantula*	2	1.5
Cladonia carneola	3	2.3		*Melanelia exasperatula*	16	12.0
Cladonia chlorophaea	3	2.3		*Melanelia fuliginosa*	2	1.5
Cladonia fimbriata	2	1.5		*Melanelia subaurifera*	4	3.0
Cladonia macilenta	4	3.0		*Melanelia subelegantula*	12	9.0
Cladonia ochrochlora	10	7.5		*Melanelia subolivacea*	8	6.0
Cladonia pyxidata	1	0.8		*Menegazzia terebrata*	4	3.0
Cladonia squamosa	12	9.0		*Nephroma bellum*	10	7.5
Cladonia sulphurina	2	1.5		*Nephroma helveticum*	14	10.5
Cladonia transcendens	12	9.0		*Nephroma laevigatum*	4	3.0
Cladonia umbricola	2	1.5		*Nephroma occultum*	2	1.5
Collema furfuraceum	1	0.8		*Nephroma parile*	3	2.3
Esslingeriana idahoensis	21	15.8		*Nephroma resupinatum*	7	5.3
Evernia prunastri	13	9.8		*Nodobryoria abbreviata*	20	15.0
Fuscopannaria leucostictoides	4	3.0		*Nodobryoria oregana*	83	62.4
Fuscopannaria mediterranea	1	0.8		*Normandina pulchella*	3	2.3
Fuscopannaria saubinetii	8	6.0		*Parmeliopsis ambigua*	30	22.6
Hypocenomyce friesii	2	1.5		*Parmelia hygrophila*	25	18.8
Hypocenomyce scalaris	1	0.8		*Parmeliopsis hyperopta*	102	76.7
Hypogymnia apinnata	31	23.3		*Parmelia pseudosulcata*	5	3.8
Hypogymnia austerodes	1	0.8		*Parmelia saxatilis*	5	3.8
Hypogymnia duplicata	7	5.3		*Parmelia squarrosa*	9	6.8
Hypogymnia enteromorpha	94	70.7		*Parmelia sulcata*	88	66.2
Hypogymnia imshaugii	75	56.4		*Peltigera britannica*	4	3.0

Table C4, Cont'd. Mount Hood National Forest lichens (133 sites surveyed).

Lichen species	Count of Known Sites	Frequency (% of Sites Surveyed)
Peltigera collina	8	6.0
Peltigera membranacea	3	2.3
Peltigera pacifica	1	0.8
Peltigera rufescens	1	0.8
Physcia adscendens	4	3.0
Physcia aipolia	3	2.3
Physconia americana	4	3.0
Physconia perisidiosa	1	0.8
Platismatia glauca	127	95.5
Platismatia herrei	97	72.9
Platismatia lacunosa	1	0.8
Platismatia norvegica	27	20.3
Platismatia stenophylla	103	77.4
Polychidium contortum	1	0.8
Pseudocyphellaria anomala	14	10.5
Pseudocyphellaria anthraspis	6	4.5
Pseudocyphellaria crocata	13	9.8
Psoroma hypnorum	1	0.8
Ramalina dilacerata	8	6.0
Ramalina farinacea	16	12.0
Ramalina subleptocarpha	1	0.8
Sphaerophorus globosus	71	53.4
Sticta fuliginosa	11	8.3
Sticta limbata	2	1.5
Tuckermannopsis chlorophylla	105	78.9
Tuckermannopsis orbata	63	47.4
Tuckermannopsis platyphylla	31	23.3
Tuckermannopsis subalpina	6	4.5
Usnea cornuta	2	1.5
Usnea filipendula	35	26.3
Usnea glabrata	2	1.5
Usnea glabrescens	4	3.0
Usnea longissima	2	1.5
Usnea scabrata	27	20.3
Usnea subfloridana	12	9.0
Usnea wirthii	5	3.8
Vulpicida canadensis	9	6.8
Xanthoria fallax	1	0.8
Xanthoria polycarpa	4	3.0

Table C5. Siuslaw National Forest lichens (77 sites surveyed).

SIUSLAW NATIONAL FOREST					
Lichen species	Count of Known Sites	Frequency (% of Sites Surveyed)		Lichen species	Count of Known Sites	Frequency (% of Sites Surveyed)
Ahtiana pallidula	2	2.6		*Lobaria oregana*	36	46.8
Alectoria imshaugii	4	5.2		*Lobaria pulmonaria*	16	20.8
Alectoria sarmentosa	8	10.4		*Lobaria scrobiculata*	2	2.6
Alectoria vancouverensis	6	7.8		*Melanelia fuliginosa*	1	1.3
Bryoria capillaris	3	3.9		*Melanelia subaurifera*	7	9.1
Bryoria friabilis	1	1.3		*Menegazzia terebrata*	60	77.9
Bryoria fuscescens	3	3.9		*Nephroma bellum*	10	13.0
Bryoria glabra	2	2.6		*Nephroma helveticum*	5	6.5
Bryoria trichodes	2	2.6		*Nephroma laevigatum*	3	3.9
Cavernularia hultenii	10	13.0		*Nephroma resupinatum*	3	3.9
Cavernularia lophyrea	36	46.8		*Nodobryoria oregana*	3	3.9
Cetrelia cetrarioides	2	2.6		*Normandina pulchella*	1	1.3
Cladonia carneola	2	2.6		*Parmotrema arnoldii*	7	9.1
Cladonia fimbriata	4	5.2		*Parmotrema chinense*	15	19.5
Cladonia norvegica	1	1.3		*Parmotrema crinitum*	2	2.6
Cladonia ochrochlora	19	24.7		*Parmelia hygrophila*	18	23.4
Cladonia squamosa	18	23.4		*Parmelia pseudosulcata*	4	5.2
Cladonia transcendens	9	11.7		*Parmelia sulcata*	61	79.2
Cladonia verruculosa	3	3.9		*Parmeliopsis hyperopta*	4	5.2
Erioderma sorediatum	3	3.9		*Peltigera britannica*	1	1.3
Esslingeriana idahoensis	1	1.3		*Peltigera collina*	12	15.6
Evernia prunastri	16	20.8		*Peltigera membranacea*	7	9.1
Fuscopannaria leucostictoides	4	5.2		*Peltigera neopolydactyla*	7	9.1
Fuscopannaria mediterranea	2	2.6		*Physcia adscendens*	1	1.3
Fuscopannaria saubinetii	1	1.3		*Platismatia glauca*	39	50.6
Hypocenomyce castaneocineria	1	1.3		*Platismatia herrei*	20	26.0
Hypogymnia apinnata	57	74.0		*Platismatia lacunosa*	17	22.1
Hypogymnia enteromorpha	51	66.2		*Platismatia norvegica*	11	14.3
Hypogymnia heterophylla	3	3.9		*Platismatia stenophylla*	7	9.1
Hypogymnia imshaugii	7	9.1		*Polychidium contortum*	5	6.5
Hypogymnia inactiva	39	50.6		*Pseudocyphellaria anomala*	6	7.8
Hypogymnia occidentalis	7	9.1		*Pseudocyphellaria anthraspis*	20	26.0
Hypogymnia physodes	26	33.8		*Pseudocyphellaria crocata*	19	24.7
Hypogymnia tubulosa	11	14.3		*Ramalina dilacerata*	2	2.6
Hypotrachyna sinuosa	52	67.5		*Ramalina farinacea*	28	36.4
Kaernefeltia californica	2	2.6		*Ramalina roesleri*	2	2.6
Kaernefeltia merrillii	2	2.6		*Ramalina thrausta*	3	3.9
Leioderma sorediatum	1	1.3		*Sphaerophorus globosus*	66	85.7
Leptogium corniculatum	2	2.6		*Sticta fuliginosa*	6	7.8
Leptogium gelatinosum	1	1.3		*Sticta limbata*	18	23.4

Table C5, Cont'd. Siuslaw National Forest lichens (77 sites surveyed).

Lichen species	Count of Known Sites	Frequency (% of Sites Surveyed)
Tuckermannopsis chlorophylla	11	14.3
Tuckermannopsis orbata	44	57.1
Usnea cornuta	48	62.3
Usnea filipendula	47	61.0
Usnea glabrata	22	28.6
Usnea glabrescens	10	13.0
Usnea hesperina	5	6.5
Usnea lapponica	1	1.3
Usnea longissima	12	15.6
Usnea scabrata	8	10.4
Usnea subfloridana	11	14.3
Usnea wirthii	67	87.0
Vermilacinia cephalota	1	1.3

Table C6. Umpqua National Forest lichens (115 sites surveyed).

UMPQUA NATIONAL FOREST					
Lichen species	Count of Known Sites	Frequency (% of Sites Surveyed)	Lichen species	Count of Known Sites	Frequency (% of Sites Surveyed)
Ahtiana pallidula	36	31.3	*Kaernefeltia merrillii*	27	23.5
Ahtiana sphaerosporella	7	6.1	*Leptogium lichenoides*	2	1.7
Alectoria imshaugii	69	60.0	*Leptogium polycarpum*	2	1.7
Alectoria lata	1	0.9	*Letharia columbiana*	3	2.6
Alectoria sarmentosa	107	93.0	*Letharia vulpina*	80	69.6
Alectoria vancouverensis	1	0.9	*Lobaria hallii*	1	0.9
Bryoria capillaris	63	54.8	*Lobaria oregana*	11	9.6
Bryoria fremontii	19	16.5	*Lobaria pulmonaria*	56	48.7
Bryoria friabilis	7	6.1	*Lobaria scrobiculata*	6	5.2
Bryoria fuscescens	35	30.4	*Melanelia exasperatula*	7	6.1
Bryoria glabra	38	33.0	*Melanelia subaurifera*	9	7.8
Bryoria pseudofuscescens	18	15.7	*Melanelia subelegantula*	9	7.8
Bryoria subcana	1	0.9	*Melanelia subolivacea*	7	6.1
Bryoria trichodes	2	1.7	*Nephroma bellum*	11	9.6
Candelaria concolor	1	0.9	*Nephroma helveticum*	22	19.1
Cavernularia hultenii	2	1.7	*Nephroma laevigatum*	8	7.0
Cladonia carneola	3	2.6	*Nephroma occultum*	2	1.7
Cladonia cornuta	1	0.9	*Nephroma parile*	3	2.6
Cladonia fimbriata	5	4.3	*Nephroma resupinatum*	12	10.4
Cladonia furcata	2	1.7	*Nodobryoria abbreviata*	11	9.6
Cladonia ochrochlora	8	7.0	*Nodobryoria oregana*	75	65.2
Cladonia squamosa	8	7.0	*Normandina pulchella*	3	2.6
Cladonia transcendens	23	20.0	*Parmelia hygrophila*	79	68.7
Collema nigrescens	2	1.7	*Parmelia pseudosulcata*	9	7.8
Esslingeriana idahoensis	49	42.6	*Parmelia sulcata*	61	53.0
Evernia prunastri	38	33.0	*Parmeliopsis ambigua*	37	32.2
Fuscopannaria saubinetii	15	13.0	*Parmeliopsis hyperopta*	98	85.2
Hypocenomyce castaneocineria	10	8.7	*Peltigera aphthosa*	2	1.7
Hypocenomyce scalaris	3	2.6	*Peltigera britannica*	3	2.6
Hypogymnia apinnata	34	29.6	*Peltigera collina*	25	21.7
Hypogymnia enteromorpha	94	81.7	*Peltigera membranacea*	1	0.9
Hypogymnia imshaugii	106	92.2	*Physcia adscendens*	1	0.9
Hypogymnia inactiva	76	66.1	*Physcia aipolia*	5	4.3
Hypogymnia metaphysodes	62	53.9	*Physcia tenella*	1	0.9
Hypogymnia occidentalis	32	27.8	*Physconia americana*	2	1.7
Hypogymnia oceanica	7	6.1	*Physconia perisidiosa*	1	0.9
Hypogymnia physodes	65	56.5	*Platismatia glauca*	110	95.7
Hypogymnia rugosa	4	3.5	*Platismatia herrei*	86	74.8
Hypogymnia tubulosa	32	27.8	*Platismatia lacunosa*	1	0.9
Hypotrachyna sinuosa	4	3.5	*Platismatia stenophylla*	38	33.0

Table C6, Cont'd. Umpqua National Forest lichens (115 sites surveyed).

Lichen species	Count of Known Sites	Frequency (% of Sites Surveyed)
Pseudocyphellaria anomala	43	37.4
Pseudocyphellaria anthraspis	46	40.0
Pseudocyphellaria crocata	5	4.3
Ramalina dilacerata	6	5.2
Ramalina farinacea	26	22.6
Sphaerophorus globosus	55	47.8
Sticta fuliginosa	5	4.3
Tuckermannopsis chlorophylla	94	81.7
Tuckermannopsis orbata	74	64.3
Tuckermannopsis platyphylla	79	68.7
Usnea cavernosa	1	0.9
Usnea cornuta	1	0.9
Usnea filipendula	42	36.5
Usnea glabrata	12	10.4
Usnea glabrescens	2	1.7
Usnea hesperina	1	0.9
Usnea lapponica	2	1.7
Usnea longissima	1	0.9
Usnea scabrata	44	38.3
Usnea subfloridana	7	6.1
Usnea wirthii	2	1.7
Vulpicida canadensis	32	27.8
Xanthoria candelaria	1	0.9
Xanthoria polycarpa	4	3.5

Table C7. Wallowa-Whitman National Forest lichens (40 sites surveyed).

WALLOWA-WHITMAN NATIONAL FOREST					
Lichen species	Count of Known Sites	Frequency (% of Sites Surveyed)	Lichen species	Count of Known Sites	Frequency (% of Sites Surveyed)
Alectoria imshaugii	10	25.0	*Parmeliopsis hyperopta*	12	30.0
Alectoria sarmentosa	13	32.5	*Peltigera canina*	1	2.5
Bryoria capillaris	15	37.5	*Peltigera collina*	1	2.5
Bryoria fremontii	25	62.5	*Physcia adscendens*	2	5.0
Bryoria friabilis	1	2.5	*Physcia aipolia*	1	2.5
Bryoria fuscescens	20	50.0	*Physcia dubia*	1	2.5
Bryoria glabra	2	5.0	*Physconia perisidiosa*	2	5.0
Bryoria lanestris	3	7.5	*Platismatia glauca*	11	27.5
Bryoria pseudofuscescens	16	40.0	*Platismatia herrei*	2	5.0
Bryoria trichodes	1	2.5	*Ramalina farinacea*	1	2.5
Candelaria concolor	2	5.0	*Tuckermannopsis chlorophylla*	10	25.0
Cladonia carneola	1	2.5	*Tuckermannopsis orbata*	17	42.5
Cladonia fimbriata	1	2.5	*Tuckermannopsis platyphylla*	18	45.0
Cladonia transcendens	2	5.0	*Usnea filipendula*	6	15.0
Esslingeriana idahoensis	3	7.5	*Usnea glabrata*	3	7.5
Evernia prunastri	4	10.0	*Usnea glabrescens*	4	10.0
Hypocenomyce friesii	2	5.0	*Usnea lapponica*	6	15.0
Hypogymnia austerodes	1	2.5	*Usnea scabrata*	1	2.5
Hypocenomyce scalaris	1	2.5	*Vulpicida canadensis*	6	15.0
Hypogymnia imshaugii	38	95.0	*Xanthoria candelaria*	2	5.0
Hypogymnia inactiva	1	2.5	*Xanthoria polycarpa*	5	12.5
Hypogymnia metaphysodes	17	42.5			
Hypogymnia occidentalis	8	20.0			
Hypogymnia physodes	13	32.5			
Hypogymnia tubulosa	12	30.0			
Kaernefeltia merrillii	9	22.5			
Letharia columbiana	31	77.5			
Letharia vulpina	38	95.0			
Melanelia elegantula	4	10.0			
Melanelia exasperatula	21	52.5			
Melanelia fuliginosa	1	2.5			
Melanelia subaurifera	1	2.5			
Melanelia subelegantula	19	47.5			
Melanelia subolivacea	20	50.0			
Nephroma parile	2	5.0			
Nodobryoria abbreviata	29	72.5			
Nodobryoria oregana	11	27.5			
Parmelia hygrophila	8	20.0			
Parmelia sulcata	15	37.5			
Parmeliopsis ambigua	22	55.0			

Table C8. Willamette National Forest lichens (210 sites surveyed).

WILLAMETTE NATIONAL FOREST						
Lichen species	Count of Known Sites	Frequency (% of Sites Surveyed)		Lichen species	Count of Known Sites	Frequency (% of Sites Surveyed)
Ahtiana pallidula	43	20.5		*Hypogymnia inactiva*	159	75.7
Ahtiana sphaerosporella	3	1.4		*Hypogymnia metaphysodes*	88	41.9
Alectoria imshaugii	92	43.8		*Hypogymnia occidentalis*	61	29.0
Alectoria sarmentosa	192	91.4		*Hypogymnia oceanica*	27	12.9
Alectoria vancouverensis	15	7.1		*Hypogymnia physodes*	157	74.8
Bryoria capillaris	111	52.9		*Hypogymnia tubulosa*	122	58.1
Bryoria fremontii	14	6.7		*Hypotrachyna sinuosa*	17	8.1
Bryoria friabilis	53	25.2		*Kaernefeltia merrillii*	32	15.2
Bryoria fuscescens	65	31.0		*Leptogium gelatinosum*	1	0.5
Bryoria glabra	72	34.3		*Leptogium lichenoides*	1	0.5
Bryoria lanestris	1	0.5		*Leptogium polycarpum*	6	2.9
Bryoria pseudofuscescens	58	27.6		*Letharia columbiana*	6	2.9
Bryoria trichodes	25	11.9		*Letharia vulpina*	82	39.0
Cavernularia hultenii	44	21.0		*Lobaria hallii*	6	2.9
Cavernularia lophyrea	1	0.5		*Lobaria oregana*	75	35.7
Cetrelia cetrarioides	1	0.5		*Lobaria pulmonaria*	82	39.0
Cladonia carneola	2	1.0		*Lobaria scrobiculata*	28	13.3
Cladonia chlorophaea	2	1.0		*Melanelia elegantula*	1	0.5
Cladonia cornuta	1	0.5		*Melanelia exasperatula*	13	6.2
Cladonia fimbriata	9	4.3		*Melanelia fuliginosa*	2	1.0
Cladonia furcata	4	1.9		*Melanelia subaurifera*	23	11.0
Cladonia macilenta	1	0.5		*Melanelia subelegantula*	23	11.0
Cladonia ochrochlora	21	10.0		*Melanelia subolivacea*	6	2.9
Cladonia squamosa	9	4.3		*Menegazzia terebrata*	2	1.0
Cladonia sulphurina	1	0.5		*Nephroma bellum*	32	15.2
Cladonia transcendens	23	11.0		*Nephroma helveticum*	40	19.0
Cladonia umbricola	1	0.5		*Nephroma laevigatum*	7	3.3
Cladonia verruculosa	2	1.0		*Nephroma occultum*	10	4.8
Dendriscocaulon intricatulum	1	0.5		*Nephroma parile*	19	9.0
Esslingeriana idahoensis	48	22.9		*Nephroma resupinatum*	18	8.6
Evernia prunastri	36	17.1		*Nodobryoria abbreviata*	7	3.3
Fuscopannaria leucostictoides	14	6.7		*Nodobryoria oregana*	125	59.5
Fuscopannaria saubinetii	7	3.3		*Normandina pulchella*	3	1.4
Hypocenomyce castaneocinereia	9	4.3		*Parmelia hygrophila*	156	74.3
Hypocenomyce friesii	1	0.5		*Parmelia pseudosulcata*	22	10.5
Hypocenomyce scalaris	3	1.4		*Parmelia squarrosa*	1	0.5
Hypocenomyce sorophora	1	0.5		*Parmelia sulcata*	104	49.5
Hypogymnia apinnata	103	49.0		*Parmeliopsis ambigua*	54	25.7
Hypogymnia enteromorpha	187	89.0		*Parmeliopsis hyperopta*	180	85.7
Hypogymnia imshaugii	176	83.8		*Peltigera britannica*	5	2.4

Table C8, Cont'd. Willamette National Forest lichens (210 sites surveyed).

Lichen species	Count of Known Sites	Frequency (% of Sites Surveyed)
Peltigera collina	30	14.3
Peltigera membranacea	2	1.0
Peltigera neckeri	1	0.5
Peltigera neopolydactyla	3	1.4
Peltigera pacifica	1	0.5
Physcia adscendens	6	2.9
Physcia aipolia	12	5.7
Physconia americana	1	0.5
Physconia perisidiosa	1	0.5
Physcia tenella	5	2.4
Platismatia glauca	205	97.6
Platismatia herrei	166	79.0
Platismatia norvegica	7	3.3
Platismatia stenophylla	137	65.2
Polychidium contortum	1	0.5
Pseudocyphellaria anomala	74	35.2
Pseudocyphellaria anthraspis	44	21.0
Pseudocyphellaria crocata	32	15.2
Pseudocyphellaria rainierensis	5	2.4
Psoroma hypnorum	1	0.5
Ramalina dilacerata	17	8.1
Ramalina farinacea	41	19.5
Ramalina thrausta	2	1.0
Sphaerophorus globosus	120	57.1
Sticta fuliginosa	25	11.9
Sticta limbata	9	4.3
Tuckermannopsis chlorophylla	157	74.8
Tuckermannopsis orbata	110	52.4
Tuckermannopsis platyphylla	141	67.1
Tuckermannopsis subalpina	5	2.4
Usnea cornuta	3	1.4
Usnea filipendula	107	51.0
Usnea glabrata	15	7.1
Usnea glabrescens	8	3.8
Usnea lapponica	2	1.0
Usnea longissima	1	0.5
Usnea scabrata	91	43.3
Usnea subfloridana	24	11.4
Usnea wirthii	5	2.4
Vulpicida canadensis	24	11.4
Xanthoria polycarpa	10	4.8

Table C9. Winema National Forest lichens (122 sites surveyed).

WINEMA NATIONAL FOREST					
Lichen species	Count of Known Sites	Frequency (% of Sites Surveyed)	Lichen species	Count of Known Sites	Frequency (% of Sites Surveyed)
Ahtiana pallidula	13	10.7	*Platismatia glauca*	26	21.3
Ahtiana sphaerosporella	14	11.5	*Ramalina farinacea*	2	1.6
Alectoria imshaugii	57	46.7	*Tuckermannopsis chlorophylla*	31	25.4
Alectoria sarmentosa	59	48.4	*Tuckermannopsis orbata*	17	13.9
Bryoria capillaris	25	20.5	*Tuckermannopsis platyphylla*	48	39.3
Bryoria fremontii	95	77.9	*Usnea filipendula*	4	3.3
Bryoria friabilis	1	0.8	*Usnea glabrata*	2	1.6
Bryoria fuscescens	22	18.0	*Usnea scabrata*	16	13.1
Bryoria glabra	1	0.8	*Usnea subfloridana*	1	0.8
Bryoria implexa	1	0.8	*Vulpicida canadensis*	85	69.7
Bryoria pseudofuscescens	61	50.0	*Xanthoria candelaria*	8	6.6
Bryoria tortuosa	2	1.6	*Xanthoria fallax*	1	0.8
Bryoria trichodes	1	0.8	*Xanthoria polycarpa*	10	8.2
Candelaria concolor	8	6.6			
Esslingeriana idahoensis	7	5.7			
Evernia prunastri	20	16.4			
Hypocenomyce scalaris	9	7.4			
Hypogymnia apinnata	2	1.6			
Hypogymnia enteromorpha	1	0.8			
Hypogymnia imshaugii	83	68.0			
Hypogymnia metaphysodes	24	19.7			
Hypogymnia occidentalis	29	23.8			
Hypogymnia physodes	3	2.5			
Hypogymnia rugosa	1	0.8			
Hypogymnia tubulosa	4	3.3			
Kaernefeltia merrillii	102	83.6			
Letharia columbiana	108	88.5			
Letharia vulpina	118	96.7			
Melanelia elegantula	9	7.4			
Melanelia exasperatula	9	7.4			
Melanelia subelegantula	20	16.4			
Melanelia subolivacea	23	18.9			
Nodobryoria abbreviata	106	86.9			
Nodobryoria oregana	25	20.5			
Parmelia hygrophila	9	7.4			
Parmelia sulcata	16	13.1			
Parmeliopsis ambigua	28	23.0			
Parmeliopsis hyperopta	32	26.2			
Physcia adscendens	2	1.6			
Physcia aipolia	1	0.8			
Physconia enteroxantha	1	0.8			

APPENDIX IV. THE MOST COMMON EPIPHYTIC MACROLICHENS OF PACIFIC NORTHWEST NATIONAL FORESTS

The following tables list the most common epiphytic macrolichens, by national forest, ordered by frequency. Familiarity with these species should help field crews readily recognize most of the species they are likely to encounter during a survey and improve their ability to detect and differentiate less common species.

Table D1. Common lichens of the Columbia River Gorge National Scenic Area.

Columbia River Gorge National Scenic Area						
Lichen Species	No. of Detec-tions	Frequency (% of Sites Surveyed)		Lichen Species	No. of Detec-tions	Frequency (% of Sites Surveyed)
Parmelia sulcata	134	88.7		*Melanelia subolivacea*	33	21.9
Evernia prunastri	120	79.5		*Hypogymnia imshaugii*	31	20.5
Platismatia glauca	103	68.2		*Letharia vulpina*	29	19.2
Ramalina farinacea	102	67.5		*Sticta limbata*	29	19.2
Hypogymnia tubulosa	98	64.9		*Lobaria pulmonaria*	28	18.5
Xanthoria polycarpa	98	64.9		*Candelaria concolor*	27	17.9
Physcia adscendens	97	64.2		*Ramalina dilacerata*	27	17.9
Hypogymnia physodes	85	56.3		*Physconia perisidiosa*	26	17.2
Melanelia exasperatula	74	49.0		*Sticta fuliginosa*	26	17.2
Hypogymnia inactiva	71	47.0		*Melanelia subaurifera*	25	16.6
Physcia aipolia	70	46.4		*Sphaerophorus globosus*	24	15.9
Platismatia stenophylla	65	43.0		*Hypotrachyna sinuosa*	18	11.9
Tuckermannopsis orbata	59	39.1		*Nephroma resupinatum*	18	11.9
Physconia isidiigera	47	31.1		*Physconia enteroxantha*	18	11.9
Peltigera collina	46	30.5		*Lobaria scrobiculata*	16	10.6
Hypogymnia enteromorpha	43	28.5		*Bryoria capillaris*	15	9.9
Tuckermannopsis chlorophylla	38	25.2		*Melanelia subelegantula*	15	9.9
Platismatia herrei	41	27.2				

Table D2. Common lichens of the Deschutes National Forest.

Deschutes National Forest						
Lichen Species	No. of Detec-tions	Frequency (% of Sites Surveyed)		Lichen Species	No. of Detec-tions	Frequency (% of Sites Surveyed)
Letharia vulpina	170	90.9		*Parmeliopsis ambigua*	48	25.7
Kaernefeltia merrillii	166	88.8		*Melanelia subelegantula*	47	25.1
Letharia columbiana	134	71.7		*Hypocenomyce scalaris*	41	21.9
Bryoria fremontii	125	66.8		*Usnea scabrata*	40	21.4
Alectoria imshaugii	124	66.3		*Tuckermannopsis orbata*	36	19.3
Alectoria sarmentosa	123	65.8		*Parmelia sulcata*	35	18.7
Nodobryoria abbreviata	123	65.8		*Melanelia subolivacea*	33	17.6
Hypogymnia imshaugii	120	64.2		*Bryoria glabra*	32	17.1
Bryoria pseudofuscescens	108	57.8		*Candelaria concolor*	31	16.6
Vulpicida canadensis	107	57.2		*Xanthoria fallax*	31	16.6
Bryoria fuscescens	92	49.2		*Bryoria capillaris*	28	15.0
Tuckermannopsis platyphylla	82	43.9		*Esslingeriana idahoensis*	24	12.8
Platismatia glauca	77	41.2		*Hypogymnia physodes*	23	12.3
Parmeliopsis hyperopta	76	40.6		*Parmelia hygrophila*	22	11.8
Hypogymnia occidentalis	70	37.4		*Evernia prunastri*	19	10.2
Tuckermannopsis chlorophylla	69	36.9		*Hypogymnia apinnata*	19	10.2
Nodobryoria oregana	58	31.0		*Hypogymnia enteromorpha*	19	10.2
Hypogymnia metaphysodes	48	25.7				

Table D3. Common lichens of the Gifford Pinchot National Forest.

Gifford Pinchot National Forest						
Lichen Species	No. of Detec-tions	Frequency (% of Sites Surveyed)		Lichen Species	No. of Detec-tions	Frequency (% of Sites Surveyed)
Platismatia glauca	172	96.1		*Cavernularia hultenii*	59	33.0
Alectoria sarmentosa	168	93.9		*Platismatia norvegica*	59	33.0
Parmeliopsis hyperopta	152	84.9		*Bryoria friabilis*	55	30.7
Hypogymnia inactiva	151	84.4		*Bryoria fuscescens*	53	29.6
Tuckermannopsis chlorophylla	149	83.2		*Bryoria trichodes*	52	29.1
Hypogymnia imshaugii	144	80.4		*Hypogymnia occidentalis*	52	29.1
Hypogymnia physodes	140	78.2		*Bryoria glabra*	45	25.1
Hypogymnia enteromorpha	139	77.7		*Evernia prunastri*	39	21.8
Platismatia herrei	139	77.7		*Usnea scabrata*	38	21.2
Nodobryoria oregana	135	75.4		*Parmeliopsis ambigua*	34	19.0
Parmelia hygrophila	119	66.5		*Lobaria oregana*	31	17.3
Platismatia stenophylla	115	64.2		*Cladonia transcendens*	28	15.6
Hypogymnia tubulosa	108	60.3		*Lobaria pulmonaria*	28	15.6
Hypogymnia apinnata	107	59.8		*Letharia vulpina*	27	15.1
Bryoria capillaris	98	54.7		*Cladonia ochrochlora*	25	14.0
Tuckermannopsis orbata	96	53.6		*Ramalina farinacea*	22	12.3
Tuckermannopsis platyphylla	96	53.6		*Ahtiana pallidula*	20	11.2
Parmelia sulcata	91	50.8		*Pseudocyphellaria anomala*	20	11.2
Sphaerophorus globosus	83	46.4		*Cladonia squamosa*	19	10.6
Hypogymnia metaphysodes	71	39.7		*Hypogymnia oceanica*	19	10.6
Usnea filipendula	66	36.9		*Usnea subfloridana*	19	10.6

Table D4. Common lichens of the Mt. Hood National Forest.

Mt. Hood National Forest						
Lichen Species	No. of Detec-tions	Frequency (% of Sites Surveyed)		Lichen Species	No. of Detec-tions	Frequency (% of Sites Surveyed)
Platismatia glauca	127	95.5		*Hypogymnia apinnata*	31	23.3
Alectoria sarmentosa	114	85.7		*Tuckermannopsis platyphylla*	31	23.3
Tuckermannopsis chlorophylla	105	78.9		*Parmeliopsis ambigua*	30	22.6
Platismatia stenophylla	103	77.4		*Hypogymnia occidentalis*	28	21.1
Parmeliopsis hyperopta	102	76.7		*Alectoria imshaugii*	27	20.3
Hypogymnia inactiva	100	75.2		*Platismatia norvegica*	27	20.3
Platismatia herrei	97	72.9		*Usnea scabrata*	27	20.3
Hypogymnia enteromorpha	94	70.7		*Bryoria friabilis*	26	19.5
Parmelia sulcata	88	66.2		*Parmelia hygrophila*	25	18.8
Nodobryoria oregana	83	62.4		*Bryoria pseudofuscescens*	22	16.5
Hypogymnia tubulosa	76	57.1		*Esslingeriana idahoensis*	21	15.8
Hypogymnia imshaugii	75	56.4		*Nodobryoria abbreviata*	20	15.0
Hypogymnia physodes	75	56.4		*Bryoria trichodes*	19	14.3
Sphaerophorus globosus	71	53.4		*Lobaria pulmonaria*	18	13.5
Bryoria capillaris	66	49.6		*Melanelia exasperatula*	16	12.0
Tuckermannopsis orbata	63	47.4		*Ramalina farinacea*	16	12.0
Hypogymnia metaphysodes	46	34.6		*Cavernularia hultenii*	14	10.5
Lobaria oregana	39	29.3		*Kaernefeltia merrillii*	14	10.5
Bryoria glabra	36	27.1		*Letharia columbiana*	14	10.5
Letharia vulpina	35	26.3		*Nephroma helveticum*	14	10.5
Usnea filipendula	35	26.3		*Pseudocyphellaria anomala*	14	10.5
Bryoria fuscescens	33	24.8				

Table D5. Common lichens of the Siuslaw National Forest.

Siuslaw National Forest						
Lichen Species	No. of Detec-tions	Frequency (% of Sites Surveyed)		Lichen Species	No. of Detec-tions	Frequency (% of Sites Surveyed)
Usnea wirthii	67	87.0		*Pseudocyphellaria crocata*	19	24.7
Sphaerophorus globosus	66	85.7		*Cladonia squamosa*	18	23.4
Parmelia sulcata	61	79.2		*Parmelia hygrophila*	18	23.4
Menegazzia terebrata	60	77.9		*Sticta limbata*	18	23.4
Hypogymnia apinnata	57	74.0		*Platismatia lacunosa*	17	22.1
Hypotrachyna sinuosa	52	67.5		*Evernia prunastri*	16	20.8
Hypogymnia enteromorpha	51	66.2		*Lobaria pulmonaria*	16	20.8
Usnea cornuta	48	62.3		*Parmotrema chinense*	15	19.5
Usnea filipendula	47	61.0		*Peltigera collina*	12	15.6
Tuckermannopsis orbata	44	57.1		*Usnea longissima*	12	15.6
Hypogymnia inactiva	39	50.6		*Hypogymnia tubulosa*	11	14.3
Platismatia glauca	39	50.6		*Platismatia norvegica*	11	14.3
Cavernularia lophyrea	36	46.8		*Tuckermannopsis chlorophylla*	11	14.3
Lobaria oregana	36	46.8		*Usnea subfloridana*	11	14.3
Ramalina farinacea	28	36.4		*Cavernularia hultenii*	10	13.0
Hypogymnia physodes	26	33.8		*Nephroma bellum*	10	13.0
Usnea glabrata	22	28.6		*Usnea glabrescens*	10	13.0
Platismatia herrei	20	26.0		*Cladonia transcendens*	9	11.7
Pseudocyphellaria anthraspis	20	26.0		*Alectoria sarmentosa*	8	10.4
Cladonia ochrochlora	19	24.7		*Usnea scabrata*	8	10.4

Table D6. Common lichens of the Umpqua National Forest.

Umpqua National Forest					
Lichen Species	No. of Detec-tions	Frequency (% of Sites Surveyed)	Lichen Species	No. of Detec-tions	Frequency (% of Sites Surveyed)
Platismatia glauca	110	95.7	*Pseudocyphellaria anomala*	43	37.4
Alectoria sarmentosa	107	93.0	*Usnea filipendula*	42	36.5
Hypogymnia imshaugii	106	92.2	*Bryoria glabra*	38	33.0
Parmeliopsis hyperopta	98	85.2	*Evernia prunastri*	38	33.0
Hypogymnia enteromorpha	94	81.7	*Platismatia stenophylla*	38	33.0
Tuckermannopsis chlorophylla	94	81.7	*Parmeliopsis ambigua*	37	32.2
Platismatia herrei	86	74.8	*Ahtiana pallidula*	36	31.3
Letharia vulpina	80	69.6	*Bryoria fuscescens*	35	30.4
Parmelia hygrophila	79	68.7	*Hypogymnia apinnata*	34	29.6
Tuckermannopsis platyphylla	79	68.7	*Hypogymnia occidentalis*	32	27.8
Hypogymnia inactiva	76	66.1	*Hypogymnia tubulosa*	32	27.8
Nodobryoria oregana	75	65.2	*Vulpicida canadensis*	32	27.8
Tuckermannopsis orbata	74	64.3	*Kaernefeltia merrillii*	27	23.5
Alectoria imshaugii	69	60.0	*Ramalina farinacea*	26	22.6
Hypogymnia physodes	65	56.5	*Peltigera collina*	25	21.7
Bryoria capillaris	63	54.8	*Cladonia transcendens*	23	20.0
Hypogymnia metaphysodes	62	53.9	*Nephroma helveticum*	22	19.1
Parmelia sulcata	61	53.0	*Bryoria fremontii*	19	16.5
Lobaria pulmonaria	56	48.7	*Bryoria pseudofuscescens*	18	15.7
Sphaerophorus globosus	55	47.8	*Fuscopannaria saubinetii*	15	13.0
Esslingeriana idahoensis	49	42.6	*Nephroma resupinatum*	12	10.4
Pseudocyphellaria anthraspis	46	40.0	*Usnea glabrata*	12	10.4
Usnea scabrata	44	38.3			

Table D7. Common lichens of the Wallowa-Whitman National Forest.

Wallowa-Whitman National Forest						
Lichen Species	No. of Detec-tions	Frequency (% of Sites Surveyed)		Lichen Species	No. of Detec-tions	Frequency (% of Sites Surveyed)
Hypogymnia imshaugii	38	95.0		*Hypogymnia tubulosa*	12	30.0
Letharia vulpina	38	95.0		*Parmeliopsis hyperopta*	12	30.0
Letharia columbiana	31	77.5		*Nodobryoria oregana*	11	27.5
Nodobryoria abbreviata	29	72.5		*Platismatia glauca*	11	27.5
Bryoria fremontii	25	62.5		*Alectoria imshaugii*	10	25.0
Parmeliopsis ambigua	22	55.0		*Tuckermannopsis chlorophylla*	10	25.0
Melanelia exasperatula	21	52.5		*Kaernefeltia merrillii*	9	22.5
Bryoria fuscescens	20	50.0		*Hypogymnia occidentalis*	8	20.0
Melanelia subolivacea	20	50.0		*Parmelia hygrophila*	8	20.0
Melanelia subelegantula	19	47.5		*Usnea filipendula*	6	15.0
Tuckermannopsis platyphylla	18	45.0		*Usnea lapponica*	6	15.0
Hypogymnia metaphysodes	17	42.5		*Vulpicida canadensis*	6	15.0
Tuckermannopsis orbata	17	42.5		*Xanthoria polycarpa*	5	12.5
Bryoria pseudofuscescens	16	40.0		*Bryoria simplicior*	4	10.0
Bryoria capillaris	15	37.5		*Evernia prunastri*	4	10.0
Parmelia sulcata	15	37.5		*Melanelia elegantula*	4	10.0
Alectoria sarmentosa	13	32.5		*Usnea glabrescens*	4	10.0
Hypogymnia physodes	13	32.5				

Table D8. Common lichens of the Willamette National Forest.

Willamette National Forest						
Lichen Species	No. of Detec-tions	Frequency (% of Sites Surveyed)		Lichen Species	No. of Detec-tions	Frequency (% of Sites Surveyed)
Platismatia glauca	205	97.6		*Bryoria fuscescens*	65	31.0
Alectoria sarmentosa	192	91.4		*Hypogymnia occidentalis*	61	29.0
Hypogymnia enteromorpha	187	89.0		*Bryoria pseudofuscescens*	58	27.6
Parmeliopsis hyperopta	180	85.7		*Parmeliopsis ambigua*	54	25.7
Hypogymnia imshaugii	176	83.8		*Bryoria friabilis*	53	25.2
Platismatia herrei	166	79.0		*Esslingeriana idahoensis*	48	22.9
Hypogymnia inactiva	159	75.7		*Cavernularia hultenii*	44	21.0
Hypogymnia physodes	157	74.8		*Pseudocyphellaria anthraspis*	44	21.0
Tuckermannopsis chlorophylla	157	74.8		*Ahtiana pallidula*	43	20.5
Parmelia hygrophila	156	74.3		*Ramalina farinacea*	41	19.5
Tuckermannopsis platyphylla	141	67.1		*Nephroma helveticum*	40	19.0
Platismatia stenophylla	137	65.2		*Evernia prunastri*	36	17.1
Nodobryoria oregana	125	59.5		*Kaernefeltia merrillii*	32	15.2
Hypogymnia tubulosa	122	58.1		*Nephroma bellum*	32	15.2
Sphaerophorus globosus	120	57.1		*Pseudocyphellaria crocata*	32	15.2
Bryoria capillaris	111	52.9		*Peltigera collina*	30	14.3
Tuckermannopsis orbata	110	52.4		*Lobaria scrobiculata*	28	13.3
Usnea filipendula	107	51.0		*Hypogymnia oceanica*	27	12.9
Parmelia sulcata	104	49.5		*Bryoria trichodes*	25	11.9
Hypogymnia apinnata	103	49.0		*Sticta fuliginosa*	25	11.9
Alectoria imshaugii	92	43.8		*Usnea subfloridana*	24	11.4
Usnea scabrata	91	43.3		*Vulpicida canadensis*	24	11.4
Hypogymnia metaphysodes	88	41.9		*Cladonia transcendens*	23	11.0
Letharia vulpina	82	39.0		*Melanelia subaurifera*	23	11.0
Lobaria pulmonaria	82	39.0		*Melanelia subelegantula*	23	11.0
Lobaria oregana	75	35.7		*Parmelia pseudosulcata*	22	10.5
Pseudocyphellaria anomala	74	35.2		*Cladonia ochrochlora*	21	10.0
Bryoria glabra	72	34.3				

Table D9. Common lichens of the Winema National Forest.

Winema National Forest						
Lichen Species	No. of Detec-tions	Frequency (% of Sites Surveyed)		Lichen Species	No. of Detec-tions	Frequency (% of Sites Surveyed)
Letharia vulpina	118	96.7		*Parmeliopsis ambigua*	28	23.0
Letharia columbiana	108	88.5		*Platismatia glauca*	26	21.3
Nodobryoria abbreviata	106	86.9		*Bryoria capillaris*	25	20.5
Kaernefeltia merrillii	102	83.6		*Nodobryoria oregana*	25	20.5
Bryoria fremontii	95	77.9		*Hypogymnia metaphysodes*	24	19.7
Vulpicida canadensis	85	69.7		*Melanelia subolivacea*	23	18.9
Hypogymnia imshaugii	83	68.0		*Bryoria fuscescens*	22	18.0
Bryoria pseudofuscescens	61	50.0		*Evernia prunastri*	20	16.4
Alectoria sarmentosa	59	48.4		*Melanelia subelegantula*	20	16.4
Alectoria imshaugii	57	46.7		*Tuckermannopsis orbata*	17	13.9
Tuckermannopsis platyphylla	48	39.3		*Parmelia sulcata*	16	13.1
Parmeliopsis hyperopta	32	26.2		*Usnea scabrata*	16	13.1
Tuckermannopsis chlorophylla	31	25.4		*Ahtiana sphaerosporella*	14	11.5
Hypogymnia occidentalis	29	23.8		*Ahtiana pallidula*	13	10.7