Southwest Ecological Restoration Institutes (SWERI) Biophysical Monitoring Workshop Report

NORTHERN ARIZONA UNIVERSITY

Ecological Restoration Institute

The Ecological Restoration Institute at Northern Arizona University is a pioneer in researching, implementing, and monitoring ecological restoration of southwestern ponderosa pine forests. These forests have been significantly altered over the last century, with decreased ecological and recreational values, near-elimination of natural low-intensity fire regimes, and greatly increased risk of large-scale fires. The ERI is working with public agencies and other partners to restore these forests to a more ecologically healthy condition and trajectory—in the process helping to significantly reduce the threat of catastrophic wildfire and its effects on human, animal, and plant communities.

Cover photo: Workshop participants met in both subject-specific groups (Botany, Fire and Fuels, Trees and Forest Structure, Wildlife) and, as in this photo, as a whole group to determine the biophysical variables that work best when monitoring restoration-treated forests. Photo courtesy of the Ecological Restoration Institute

NORTHERN ARIZONA UNIVERSITY

Ecological Restoration Institute

Table of Contents

Executive Summary

On October 15-16, 2009, the Southwest Ecological Restoration Institutes (SWERI) hosted a workshop in which the participants would 1) build a common understanding of the types of monitoring that are occurring in forested ecosystems of the Southwest; 2) analyze and agree on an efficient, yet robust set of biophysical variables that can be used by land mangers and scientists to monitor the effectiveness of restoration/land treatments; and 3) discuss and develop strategies to overcome common challenges to effective forest monitoring and its integration into land management decision making. An invited group of individuals representing federal and state agencies, environmental non-profits, academic institutions, and consulting firms brought their knowledge and expertise to bear on the three goals of the workshop. Working in specialty groups (Botany, Fire and Fuels, Trees and Forest Structure, Wildlife) as well as in the aggregate, workshop participants used the two days to identify the key monitoring measures for restored southwestern forests and to make recommendations about the future steps needed to ensure that effectiveness monitoring (i.e., determining whether the project goals were attained) is an integral part of the total restoration process.

The specialty groups made a focused study of the monitoring variables (i.e., measurable data about a particular physiological feature) they felt were important to their particular area, and judged them against a wide range of criteria including scientific, practical, and policy and adaptive management standards. The Botany Group, for example, identified the variables of grazing intensity, understory cover, exotic species/threatened and endangered species, and understory composition as the best measures of whether an understory had been restored. Meanwhile, the Fire and Fuels Group recognized surface fuels, tree characteristics, crown-base height, canopy cover, and understory cover and composition as the most effective variables for determining whether restoration treatments had decreased fuel loads. Perhaps not surprisingly, the Trees and Forest Structure Group found some of the same variables effective as they named tree density, size, composition, and height; surface fuels, age class, crown-base height, and forest type/plant association the most effective measures of whether treatments had restored the desired trees and forest structure. The Wildlife Group focused on two known wildlife monitoring procedures—the Multiple Species Inventory and Monitoring protocol and monitoring three or four species believed to be sensitive to restoration treatments, and doing so at three spatial scales: forest stand, landscape, and regional. This group decided that the MISM protocol was the best metric followed by sensitive species monitoring at the stand and/or landscape level.

Working in the aggregate, the group chose measurements of tree characteristics, understory cover and composition, overall visual appearance, soil integrity, wildlife, and surface fuels as the most important metrics at the project level. At the landscape level, they selected landscape characteristics (e.g., patch size and shape, connectivity), Multiple Species Inventory Monitoring, diversity of plant associations, regional characteristics (e.g., spatial modeling, frequency/acreage of characteristic fire), tree characteristics, and insects and pathogens as the most essential monitoring variables for that scale.

These results suggest that when monitoring restoration treatments, land managers might collect the most important data at the most reasonable expense if they monitor the following:

Project level
- Wildlife (Multiple Species Inventory Monitoring protocols)
- Understory (cover and composition, presence/absence of exotic/invasive species,)
- Surface fuels (understory cover and composition, coarse woody debris)
- Tree characteristics (size, height, crown-base height, species, composition)
- Visual appearance (understory cover and composition, presence/absence of exotic/invasive species, tree density, tree composition, tree age classes, surface fuels)

<u>Landscape level</u>
- Wildlife (Multiple Species Inventory Monitoring protocols)
- Tree characteristics (density, composition, age class, composition, species)
- Landscape characteristics (e.g., patch size and shape, connectivity)
- Regional characteristics (e.g., spatial modeling, frequency/acreage of characteristic fire)
- Insects and pathogens (type, spatial extent, severity of infestation)
- Plant associations (type, diversity)

It should be noted that the participants rated these metrics to work most effectively in ponderosa pine and mixed conifer forests, and less so in pinyon-juniper woodlands. In addition, the cost of monitoring at the landscape scale is likely to be greater than the project scale due to the greater spatial area being covered and the need to hire professionals to work at this scale doing GIS-related tasks, aerial photography, and ground-truthing.

To close the workshop, participants discussed how to overcome obstacles to monitoring restoration-treated forests. They met as a group and focused on 1) collaboration issues, 2) sampling and methodological challenges, and 3) implementation strategies.

There was consensus that collaborative monitoring efforts had many positive benefits including an ability to garner greater political support and resources for projects, an increased capacity to reach larger audiences, and the facility to describe whether a forest is successfully restored or on the path to restoration, and whether land managers are efficiently using funds, breaking down resistance to doing the job. There were, however, words of caution, namely, planning and implementing collaborative monitoring projects with universities need to have established protocols that ensure that projects can be sustained and not fall prey to the high attrition rate of students and faculty. The group also noted that while using a collaborative approach to monitoring can increase a project's cost effectiveness and efficiency, it should not take precedent over the collection of scientifically valid information.

In terms of methodological challenges, the group was especially concerned about data collection, storage, and sharing methods and protocols. Suggestions to overcome these challenges included 1) standardization of monitoring techniques across agencies, 2) development of guidelines for data sharing between agencies and between universities and agencies, 3) having a strong leadership team to promote and oversee a monitoring program, and 4) the establishment of more than one control plot in order to improve the validity of restoration treatments.

The group discussed three ideas designed to advance the implementation of monitoring.

- Having SWERI (and similar organizations) lead monitoring efforts on public lands, which would allow federal agencies to focus on treatment implementation.
- Creating a shared database where federal and state agencies, tribal governments, universities, nonprofits, and concerned stakeholders could store and share monitoring information was proposed as a possible solution to increasing the effectiveness and efficiency of monitoring restoration treatments.
- Making a concerted effort to advocate for increased funding support for monitoring programs as well as adopting strategies that increase their ability to effectively treat and monitor restoration activities.

While there has been a clear call by numerous stakeholders for the restoration of the forested ecosystems of the southwestern United States, the path to success has not been fully realized. As we move forward in achieving this goal, it is essential that the effects of land treatments are thoroughly monitored and used to inform an adaptive management framework and policy development. The results of this workshop indicate that there are potentially useful protocols and metrics for monitoring restoration treatments in the forested ecosystems of the southwestern United States. In many cases, however, the success of monitoring projects will require federal agencies, universities, nonprofit organizations, and other concerned stakeholders to pool their resources and work collaboratively to ensure goals are achieved.

The Southwest Ecological Restoration Institutes

In October 2004, Congress authorized The Southwest Forest Health and Wildfire Prevention Act, which established three, state-level academic institutions to demonstrate and implement science-based techniques that would reduce the risk of wildfires and restore the fire-adapted ecosystems of the interior West. A core principle of the institutes is to work collaboratively on research, education, and outreach to address the needs of land managers and stakeholders concerned with restoring the ecological and economic health of the West's frequent-fire forested ecosystems. The institutes, known collectively as the Southwest Ecological Restoration Institutes (SWERI), include the Ecological Restoration Institute at Northern Arizona University, New Mexico Forest and Watershed Restoration Institute at New Mexico Highlands University, and Colorado Forest Restoration Institute at Colorado State University.

Ecological Restoration

According to the Society for Ecological Restoration International, ecological restoration is "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed" (SER 2004). While traditional land management approaches (e.g., pre-commercial and commercial timber stand improvement harvests, fuels reduction projects) play a part in aiding ecosystem recovery, they fall short of being truly restorative because they only address changes in forest structure. Ecological restoration treatments, on the other hand, provide the potential for long-term solutions by correcting forest structure as well as reintroducing key forest processes, such as the return of frequent, low-intensity fire (Covington 2003).

Monitoring Ecological Restoration Treatments

Effectiveness monitoring (i.e., an intermittent [regular or irregular] series of reliable observations using scientifically accepted methodologies, carried out to show the degree of deviation from an expected goal or objective) is critical to the short- and long-term success of restoration treatments because it provides data to land managers and stakeholders to help them determine whether treatments are achieving their desired goals--reducing the threat of high-intensity wildfires, preserving old-growth trees, enhancing native plant and animal habitats and populations, or creating stand structure that emphasizes clumps and openings. This information can then be used to adjust ineffective or unsuccessful treatments, refine successful treatments, and/or inform practitioners and stakeholders of progress--a process known as adaptive management (Fulé 2003).

Monitoring ecological restoration treatments typically involves the targeted and repeated measurement of biophysical or social variables during a given period of time. Because restoration projects are tailored to meet the specific needs and characteristics of a given landscape, each project can and should have its own unique set of variables. Deciding which variables to monitor depends on the goals of a given restoration treatment. For example, if the project goal is to restore native plant populations, appropriate variables might include understory cover and understory plant species composition (Derr et al. 2005a).

Once a collection of appropriate variables has been identified, target values or desired levels of change must be assigned to each variable or checked against existing variables and target values already specified in an agency's planning guidelines. For example, a project to restore a native plant population may stipulate that invasive plant species should not make up more than 5 percent of the landscape. Again, to accommodate for the dynamic nature of different landscapes and the human communities that use them, each restoration treatment may have different target values (Derr et al. 2005a).

After establishing the project goals, variables and target values, a sampling design is created. The sampling design will provide detailed instructions for gathering data about a selected set of variables. This might include topics such as methods to measure each variable, the spacing and number of measurements throughout a project site, when and how often to take measurements, and where and how the data will be stored for retrieval and future use (Derr et al. 2005b).

Unfortunately, very little monitoring is done due to a lack of clearly defined, time-specific, measurable objectives in project plans, and the lack of human and financial resources. To avoid this situation, project plans should have clear monitoring goals and objectives, and strive to produce data that has professionally defensible statistical accuracy. In addition, land managers and stakeholders must be thoroughly committed to a) implementing the monitoring plan and b) using the results in adapting or informing their management actions (Elzinga et al. 2001).

The Purpose and Need for this Workshop

Because of some of the difficulties encountered when monitoring a project, there is a common understanding among agency personnel that monitoring has to be expensive and exhaustive to be credible. Since this perception is an obstacle to undertaking future restoration treatments, the Institutes convened a panel of scientists and land managers to develop a simple, yet robust, set of biophysical monitoring variables that can be simply measured by practitioners to adaptively inform management practices. Although not the goal of this workshop, it is important to note that a comprehensive monitoring program also measures the socio-economic effects of restoration treatments.

Workshop Participants

Participants for the workshop were selected according to their experience and/or knowledge of monitoring the biophysical response of land management treatments in the Southwestern United States. Invitations were sent to recognized employees working at federal and state land management offices, tribes, universities, and nonprofit organizations throughout the states of Arizona, Colorado, and New Mexico. While the planning committee made every effort to have balanced representation among the different stakeholders, the majority of the 38 attendees were from the United States Forest Service and academia.

Workshop Design and Goals

In preparation for the workshop, a planning committee was formed consisting of members from each SWERI group, The Nature Conservancy in Arizona, and several private consultants that specialize in environmental facilitation.
Using the knowledge gained from ten years of monitoring research conducted by the ERI across the West and previous research by the Community Forest Restoration Program as well as the results of surveys sent to workshop participants prior to workshop, the planning committee agreed upon the following goals as the framework of the workshop:
1. Build a common understanding of the types of monitoring that are occurring in forested ecosystems of the Southwest.
2. Analyze and agree on a robust set of biophysical variables that can be used by land mangers and scientists to monitor the effectiveness of restoration/land treatments.
3. Discuss and develop strategies to overcome common challenges to effective forest monitoring and its integration into land management decision making.

Goal 1: Building a Common Understanding of Monitoring Types Used in Southwest Forests

The first goal of the workshop was to build a common understanding about the types of monitoring occurring in southwestern forested ecosystem, and provide context and content for the collaborative development of variables for monitoring the effectiveness of restoration treatments in Goal 2. To help workshop attendees in this effort, four presenters discussed monitoring-related issues: project goals, the variables used to track the effectiveness of projects, sampling design techniques, obstacles encountered, and final outcomes of monitoring results.

The titles and authors of the presentations were: (see Appendix 1 for a synopsis of their discussions):

- Reflections on monitoring in the Colorado Front Range by Merrill Kaufmann, research plant physiologist (retired), U.S. Forest Service Rocky Mountain Research Station
- Monitoring the White Mountains Stewardship Contract by Sue Sitko, White Mountains program manager, The Nature Conservancy of Arizona
- Setting the Stage: Forest monitoring overview and case studies monitoring the effects of ecosystem restoration on northern goshawk by Christina Vojta, wildlife ecologist, U.S. Forest Service Rocky Mountain Research Station
- Monitoring large-scale forest restoration treatments: Integrating multi-disciplinary science and management by Pete Fulé, ERI director of operations and NAU School of Forestry associate professor

Goal 2: Identify the Most Effective Monitoring Variables

To achieve Goal 2, workshop attendees were asked to identify the most robust variables for monitoring the effectiveness of restoration treatments. In order to accomplish this and pool participant expertise, the attendees divided into one the following working groups: Botany, Fire and Fuels, Trees and Forest Structure, and Wildlife. Initially, the planning committee had also created a watershed working group, but dropped it due to a lack of participant interest as identified in a pre-workshop survey.

A facilitator and note taker were assigned to each working group to ensure effective and collaborative working group discussions. Each individual was provided with a list of biophysical variables (Appendix 2) that had been identified by the planning committee and through the survey sent to participants prior to the workshop. Participants were asked to review the variable list and identify and discuss any missing variables. Participants were then instructed to select five variables they believed were essential to the monitoring of their chosen working group theme. Individual votes were then tallied to identify the top five variables within each working group.

Next, the facilitators guided their group through a ranking exercise (Appendix 3) that evaluated each of the identified variables against 15 different criteria composed of four different dimensions: scientific, implementation requirements, policy and adaptive management, and ecosystems. The criteria were adopted from a comprehensive literature review of publications detailing the development and selection of environmental variables (Niemeijer 2008). Using Niemeijer's study, the workshop planning committee then further refined these criteria.

While this ranking exercise assigned each variable with a quantifiable value, the main benefit derived from the exercise were the in-depth discussions among working group participants. The following details the findings from each of the four working groups.

Identifying the Most Effective Monitoring Variables: Botany Group

Listed below are the five top variables selected by the Botany Group. After discussing the factors listed in the matrix tool, we ranked the variables. Our reasoning for these ranking is detailed below.

Grazing intensity (score of 12)
The number of livestock and season of use, in conjunction with native wildlife needs, affect the intensity or utilization of plant use (i.e., how much of the plant is consumed), which ultimately enhances or reduces the ecological health of a site. Increased grazing intensity is normally the result of too many domestic livestock or wild ungulates, poor management, or a combination of all three. These influences are exacerbated during drought conditions. Normally, grazing utilization is considered light when actual use is between 0 and 20 percent, moderate between 20 and 40 percent, high between 40 and 60 percent, and extreme when greater than 60 percent. Most allowable use values assigned to grazing allotments on USFS-administered lands are generally between 20 and 40 percent. Grazing intensity can have a significant effect on restoration projects, so monitoring those impacts through measurements of plant cover and species richness as well as animal unit use percentages is critical for meeting management objectives. Appropriate grazing thresholds have been identified and are available either through Freedom of Information requests to the appropriate agency or from Forest Service national forest web sites (i.e., National Forest web site > Projects and Plans > Grazing AOIs).

Depending on the agency (state or federal), there may be general stocking records (livestock numbers) and season of use information on most allotments that can go back to the 1950s, although such a continuous record is rare. Information on grazing intensity may be found in monitoring reports, production/utilization studies (used in determining overall livestock capacity of an allotment), and range condition and trend studies. Historical information, in conjunction with recent information related to grazing intensity and plant composition changes, can be used to determine trends and whether desired conditions are being met on an allotment.

Measuring utilization is easily repeatable and reproducible, and a multi-party monitoring team can easily collect utilization data. It is also simple to measure and record. Reliability depends on the personnel taking the measurements. Analyses are very simple and data are easily obtained when resources are limited.

Understory plant cover (score of 11)
This variable could have multiple meanings, and could include a number of factors. Although plant cover alone may be measured, data are more useful if substrate cover estimates (e.g., bare soil, litter, scat, water, rock) are also obtained. Effective ground cover is probably a more appropriate term for studies designed to examine erosion. As in the grazing intensity variable, we have a somewhat general understanding of the historical record, but site-specific data are typically lacking.

Cover measurements are very sensitive to any changes occurring in an ecosystem. However, methods that accurately capture these changes are problematic for several reasons. Many methods currently available were developed in grasslands and may not be applicable to forested or low-elevation ecosystems in the Southwest. Results may be highly variable depending on personnel and timing of data collection, and they may also be quite sensitive to precipitation. Although methods may be repeatable and reproducible, the data obtained may not be precise for many reasons, including those listed above.

Simplicity of measurements is dependent on the selected method and whether data are collected to functional group (e.g., C3, C4, N-fixing) or species level. Multi-party monitoring teams can quite easily obtain cover estimates of substrates and functional groups, and a reasonably large amount of data can be gathered with limited resources. Cover estimates of functional groups may be easily obtained with minimal training, and use of a digital camera may give a more accurate estimate than visual estimates. While photographs are useful for capturing images of plant species, training in plant identification is still required to obtain accurate results when data about composition or species richness is required.

Understory plant cover thresholds can be difficult to determine, but the data that are collected are very valuable in determining targets, goals, and objectives of restoration. The information obtained is very effectively applied to adaptive management decisions.

Exotic species/T&E species (score of 10)
There is a strong scientific, conceptual, and legal basis for monitoring exotic and threatened/endangered (T&E) species. Although the term T&E is used here, rare species, such as USFS sensitive species and narrow endemics, may be included in this category, depending on management goals and objectives. T&E and rare species are particularly vulnerable to ecosystem changes, such as climate fluctuations, while exotic species may be very useful indicators of unhealthy conditions and disturbances.

Historical information about herbaceous species is very sparse in the Southwest and is not consistent (i.e., it varies by types of records that are available, how much information is readily available, and whether that information is reliable). However, data gathered from these plant groups are repeatable and reproducible through time, and many of the same methods can be used across different ecosystems. Valid data collection requires personnel with training in plant identification, use of the appropriate methods, and monitoring the quality of the data. Thus, the reliability of data may vary, depending on experience levels of the personnel, the chosen methods, and the quality and care taken while collecting the data. For these reasons, composition of the data-collection team is critical. Multi-party monitoring teams may not be able to collect reliable data unless personnel are available with the appropriate level of experience.

Information on presence of T&E species and exotics is vital to ecosystem restoration efforts and can be effectively applied toward adaptive management decisions. Thresholds may be based on ecology or management goals and objectives. They may depend on density, numbers or acres, and are species-dependent.

As mentioned earlier, monitoring T&E and exotic species may be legally required of land management agencies. However, monitoring becomes difficult at large scales, particularly if resources are limited (which they currently are for most T&E species and for most agencies). Research efforts are generally inadequate across much of the Southwest. The main reason may be that research and monitoring efforts are not a priority with land management agencies, and thus inadequate resources are allocated to monitoring efforts.

Understory plant composition (score of 10)
As in the two previous variables, historical information is sparse, so it is challenging to use it to determine contemporary thresholds and targets for species composition. Data can be collected either on a functional group or individual species basis. Since data are already being collected on an individual species level for T&E species and for exotics, it might be easiest to include the entire suite of species in the plant community in those data collection efforts. Or, if resources are limited, the goal may be to collect composition only on a functional group level. Definition of a functional group may vary greatly, and is left open to interpretation, depending on management goals and objectives.

Understory species composition should ideally be gathered at a species level for the most inclusive data, but that might require additional resources, especially people with experience and training in plant identification. Repeatability may also vary from year to year, depending on such factors as timing of the observation and

CHARACTERISTICS	VARIABLES			
	Grazing Intensity (12)	Understory cover (11)	Exotic species/ T&E species (10)	Understory composition (10)
Strong scientific and conceptual basis	Yes	Yes	Yes	Yes
Existing historical record of comparative data	Undecided	Undecided	Undecided	Undecided
Sensitive to system changes	Yes	Yes	Yes	Yes
Repeatable and reproducible	Undecided	Undecided	Yes	Undecided
Manageable data Undecided collection requirements	Undecided	Undecided	Undecided	
Data can be collected by multi-party teams	Yes	Yes	Undecided	Yes
Requires simple and standardized analysis	Yes	Yes	Yes	Yes
Reasonable in terms of costs	Yes	Yes	Yes	Yes
Relevant to target audience	Yes	Yes	Yes	Yes
Meets mgt. objectives	Yes	Yes	Yes	Yes
Easy to establish thresholds	Yes	Undecided	No	No
Responses can be applied to adaptive mgt. decisions	Yes	Yes	Yes	Yes
Effective in pinyon-juniper	Yes	Yes	Yes	Yes
Effective in ponderosa pine	Yes	Yes	Yes	Yes
Effective in mixed conifer	Yes	Yes	Yes	Yes

Table 1: The Botany Working Group's top four variables for monitoring understory vegetation and the group's consensus as to how the variables met various characteristics. The voting totals for each variable are in parentheses after each variable name. Voting scoring: Yes = 1, Undecided = 0, No = -1.

precipitation. Repeat measurements should occur during the same season to minimize the effect of these factors. A multi-party monitoring group could easily manage collecting data about functional groups. Monitoring the plant community is very important for ecological restoration or conservation biology efforts, but it is usually not a high priority. Thus, resources are rarely allocated to collect large amounts of useful data.

Additional Notes
- All three ecosystems evaluated (pinyon-juniper, ponderosa pine and mixed-conifer) received the same score for all the variables. We noted that T&E and endemic species may be more vulnerable in pinyon-juniper than in other ecosystems due to the relatively low number of these species in pinyon-juniper. We also would recommend that riparian ecosystems be included in future discussions.
- Future discussions will need to involve some fine tuning, such as distinguishing between accuracy and precision, and defining the difference between targets and objectives.
- If the resources are available, then identify to species; otherwise identification to the level of functional group should be sufficient.
- The method used to measure the variables could affect, and therefore change, the outcomes of our rankings.
- Our group also had the goal of evaluating watershed/soil erosion variables, but we ran out of time. We feel these are important variables to determine and should be included in a future discussion.
- Other variables important to our group that did not make it in to the top five were: vertical stratification, biological crusts, soil quality including compaction and erodibility (may be watershed variable), landscape patch characteristics, and the availability of light.

Identifying the Most Effective Monitoring Variables: Fire and Fuels Group

Members of the Fire and Fuels Group identified eight variables as useful for fire and fuels analyses. Our group discussed the pro and cons of various sampling methods and the usefulness of the variables in analysis.

Surface Fuels on a Planar Transect (score of 13)
The Fire and Fuels Group considers this variable essential, useful, and relatively easy to monitor. The amount, structure, and continuity of surface fuels influence how fire moves across the landscape. The amount of surface fuel ties directly to how fuel models are used and to the Rothermel fire spread model. Surface fuel amount and structure is easily sampled using a Brown's planar transect methodology (1974).

Monitoring this variable is relatively easy and reliable because the sampling methods are easy to learn and understand, and are repeatable. Moreover, the methods and calculations used in a Brown's planar transect methodology are: 1) scientific, 2) well tested in various fuel types, and 3) will detect changes in fuels over time and space. In addition, the calculations used to determine fuel loading are easy and well established, and tie directly to fuel models for scenario development and analysis.

The constraints and concerns with this variable include: 1) the Brown planar transect method has not been well tested in pinyon-juniper woodlands; 2) Brown planar transects do not capture fuel continuity very well; and 3) while Brown planar transects are less time consuming than other methods, they still require field time and many transects in order to represent the fuels properly.

Tree Characteristics (Forest/Tree plot) (score of 13)
The Fire and Fuels Group concluded that all tree characteristics are important in predicting fire behavior and in planning and monitoring fuels-related treatments. These variables include tree species, diameter at breast height, and tree density (basal area and/or trees per area), crown-to-base height, and canopy cover (these last two items the group decided to address separately; see below). The Fire and Fuels Group summarized these elements as essential and useful.

The Fire and Fuels Group found that monitoring for tree characteristic variables was possible and fruitful because 1) detailed, scientifically based sampling protocols exist and have been widely used in many different forest types; 2) the data these protocols capture is repeatable across space and time, and can easily detect changes to forest structure and

composition due to treatments; 3) data collection is simple to sample and record, and can be analyzed in many useful ways; and 4) the collected data can be used to set desired conditions and gauge treatment success.

There are, however, constraints and concerns which include 1) the time and expertise required to perform a common stand exam; 2) smaller trees are often missed, depending on the methodology used; and 3) monitoring is often dismissed in favor of implementation, due to time constraints (even when it shouldn't).

Crown-Base Height (score of 13)
The Fire and Fuels Group felt that crown-to-base height should be part of a standard tree plot because it is important in assessing the risk of fire moving from the forest floor to the forest canopy.

Monitoring this variable produces data that 1) provide direct information about the risk of crown torching; 2) is used in many databases as an attribute to help model fire behavior; 3) detects changes over space and time; 4) is easily measured, recorded, and analyzed; and 5) can be used as a measure of desired conditions and to gauge treatment effectiveness.

The group identified the following constraints and concerns: 1) there is little or no comparative historical data, and 2) this variable is less applicable in pinyon/juniper woodlands.

Canopy Cover (score of 11)
The Fire and Fuels Group found this variable important because it helps determine how well a fire will move from one tree crown to another. In addition, more canopy cover corresponds to fewer surface fuels due to the positive interaction between the amount of light and the amount herbaceous growth. In turn, fewer surface fuels means more dead-and-down accumulation due to a lack of surface fire. The group found that monitoring for this variable produces data that are manageable, easy to record, and sensitive to changes in the system. However, they concluded that this variable is difficult to measure, analyze, and use due to the huge variation in results obtained from different sampling methods. The group agreed that it would be useful to have a standardized methodology.

The Fire and Fuels Group did note that this variable can be calculated using other tree-related variables (e.g., basal area), but the accuracy of these calculations has not been validated.

Understory Cover and Composition (quadrat) (score of 8)
The need to have data on understory cover and composition is important due to concerns with exotic and invasive plants, and pre- and post-treatment erosion. The summary of this variable was: "Species identification is difficult for lay persons, effectiveness depends on specificity."
The Fire and Fuels Group found that monitoring for understory cover and composition 1) has a strong scientific and conceptual basis; 2) requires relatively simple and standardized analyses; 3) produces data and results that are sensitive changes to the ecosystem; 4) can be used as a measure of desired conditions and a gauge of treatment success; and 5) works in all forest types as well as non-forested (i.e., grassland) areas.
The notable concerns and constraints for this variable are: 1) measuring percent cover can be subjective; 2) species identification typically requires training and expertise, and is not suited for lay persons; 3) identifying all plants to the species level is time consuming; and 4) monitoring for species composition depends on specificity.

Snags and logs (ran out of time, did not score)
Snags and logs are fuel and will affect how a fire spreads across a landscape. The Fire and Fuels Group did not have time to score this variable, but felt that the number and types of snags and logs should be included in stand exams.

CHARACTERISTICS	VARIABLES				
	Surface fuels (13)	Tree characteristics (13)	Crown-base height (13)	Canopy cover (12)	Understory cover and composition (8)
Strong scientific and conceptual basis	Yes	Yes	Yes	Undecided	Yes
Existing historical record of comparative data	Yes	Yes	Undecided	Undecided	Undecided
Sensitive to system changes	Yes	Yes	Yes	Yes	Yes
Repeatable and reproducible	Yes	Yes	Yes	Undecided	Undecided
Manageable data collection requirements	Yes	Yes	Yes	Yes	Undecided
Data can be collected by multi-party teams	Yes	Undecided	Yes	Yes	No
Requires simple and standardized analysis	Yes	Yes	Yes	Yes	Yes
Reasonable in terms of costs	Undecided	Undecided	Yes	Yes	Undecided
Relevant to target audience	Yes	Yes	Yes	Yes	Yes
Meets mgt. objectives	Yes	Yes	Yes	Yes	Yes
Easy to establish thresholds	Yes	Yes	Yes	Yes	Undecided
Responses can be applied to adaptive mgt. decisions	Yes	Yes	Yes	Yes	Yes
Effective in pinyon-juniper	Undecided	Yes	Undecided	Yes	Yes
Effective in ponderosa pine	Yes	Yes	Yes	Yes	Yes
Effective in mixed conifer	Yes	Yes	Yes	Yes	Yes

Table 2: The Fire and Fuels Working Group's top five variables for monitoring fuel loading and its effects on fire potential, and the group's consensus as to how the variables met various characteristics. The voting totals for each variable are in parentheses after each variable name. Voting scoring: Yes = 1, Undecided = 0, No = -1.

Identifying the Most Effective Monitoring Variables: Trees and Forest Structure Group

The Trees and Forest Structure Group identified and ranked several variables that could be used to monitor forests following restoration treatments.

Tree Characteristics (score of 15)

The Trees and Forest Structure Group identified several variables that are relevant to tree characteristics. These variables include 1) tree density (basal area or trees per unit area), 2) tree diameter at breast height, 3) tree species, and 4) tree height. Each of the variables within the tree characteristics category has a strong scientific and conceptual basis, and existing historical records for comparison. However, it should be noted that young or small-diameter trees are often missed in historical tree characteristic reconstruction due to the lack of physical evidence because of decomposition over time. Measurement of these variables characterizes changes in the system due to land management activities and can be repeated to determine change over time. The data collection of tree characteristics is very manageable and is simple to measure and record. The simplicity and standardized protocols for data collection and analysis ensures multi-party monitoring team success. The benefits of tree characteristic measurement data outweigh the collection costs due to the numerous uses this data can provide. Measurements of tree characteristics provide relevant data that allows managers to determine if objectives were met and if more action is needed. The variables included in the tree characteristic category are useful data to assess if the restoration/land treatment objective were met in pinyon-juniper, ponderosa pine, and mixed conifer forests.

Surface Fuels: Live and Dead (score of 14)
Surface fuels consist of live or dead herbaceous plants, shrubs, litter, and woody material located on the ground surface. The measurement of surface fuels has a strong scientific and conceptual basis, and is easily repeatable and reproducible in different contexts if similar protocols are followed. Comparisons of historical surface fuel loadings are hindered by the lack of physical evidence due to decomposition over time. This is especially true for herbaceous plants, shrubs, litter, and small woody material. Historical photographs and contemporary relationships between overstory density and surface fuels can provide some insight into surface fuel characteristics of past forest structures.

Surface fuel loadings are very sensitive to management activities. For instance, whole-tree harvesting can reduce woody surface fuel loadings while lop-and-scatter activities can increase them. Reducing overstory density often promotes an increase in herbaceous plant and shrub production.

Data collection of surface fuels is very manageable and simple to measure and record. The simplicity and standardized protocols for data collection and analysis ensures multi-party monitoring team success. The low cost of data collection and the usefulness of the data to determine potential surface fire behavior makes this type of data an excellent candidate. Surface fuel data could be useful to assess whether the restoration/land treatment objectives were met in pinyon-juniper, ponderosa pine, and mixed conifer forests.

Age Class (score of 12)
Tree regeneration often occurs after a disturbance or during a growing season with favorable climatic conditions. When an aggregation of trees originates due to a single event that generation of trees is known as a cohort. If the range of ages within the cohort is small, then the cohort is often referred to as an age class. There are three types of age-class structures: even-aged, stands with two age classes, and uneven-aged. An even-aged stand has trees that are all the same age or within the same cohort. Two-aged stands have two distinct cohorts, typically as a result of a regeneration cut or low-intensity fire. Uneven-aged stands have multiple cohorts occupying the same area (Smith et al. 1997).

Age-class structure has a strong scientific and conceptual basis, and existing historical records for comparison. However, it should be noted that young or small-diameter trees are often missed in historical age class reconstruction due to lack of physical evidence because of decomposition over time. Measurement of age class characterizes changes in the system due to land management activities and can be repeated to determine change over time. The data collection of tree characteristics is very manageable and is simple to measure and record. The simplicity and standardized protocols for data collection and analysis ensures multi-party monitoring team success. However, age-class structure is scale dependent, so monitoring teams should specify the scale they are measuring. The benefits of age-class measurement data outweigh the collection costs due to the numerous uses this data can provide. Age-class structure could be useful to assess if the restoration/land treatment objectives were met in ponderosa pine and mixed conifer forests. However, in pinyon-juniper woodlands, the group was undecided if age-class structure was a good indicator of restoration/land treatment objectives.

Crown-Base Height (score of 11)
Crown-base height is the distance between the ground and the lowest live branch whorl in the tree crown. Individual tree crown-base height values are used to calculate stand canopy base height, which is the lowest height above the ground where there is sufficient canopy fuel to initiate a passive crown fire (Van Wagner 1993). An increase in canopy-base height often results in a lower probability of starting a passive crown fire. Generally, measurements of crown-base height are repeatable, if the same methodology is used. Comparisons of crown-base height between contemporary and historical forests are difficult due to the lack of historical data. Therefore, comparisons of crown-base height for restoration purposes are based on inference. However, the use of crown-base height to assess success in fire hazard reduction treatments is appropriate.

The collection of crown-base height data is manageable and simple to measure and record. If protocols and analysis techniques are standardized, multi-party monitoring team success can be achieved and the cost is relatively low. However, there are different ways to measure crown-base height and calculate canopy-base height. For instance, when crowns are uneven in length, one can measure the compacted or uncompacted crown-base height. The

compacted crown-base height method requires the person doing the monitoring to visually "transfer" the lower branches to fill holes in the upper portions of the crown, until a full even crown is created. The uncompacted crown-base height method just measures the lowest live branch whorl. Therefore, when reporting crown-base height values, one should always identify the method used.

There are several methods to calculate canopy-base height at the stand level--each gives different estimates and will affect fire modeling results. One method averages the individual crown-base height for the stand. Another method uses the lowest crown-base height in the stand. While these two methods are simple, neither are accurate estimates of the canopy-base height (Scott and Reinhardt 2001). Another method uses the lowest 20th percentile crown-base height for the stand. Fulé and his colleagues (2001) suggest that accounting for the variability of crown-base heights instead of the "average" condition could simulate more realistic fire behavior since a crown fire can begin and be sustained in stands that are less than 50% susceptible to crown fire.

Fire behavior models, such as the Fire and Fuels Extension to the Forest Vegetation Simulator (FFE-FVS) and the Fuels Management Analysis (FMA), estimate canopy-base height by calculating the height at which a minimum defined bulk density of fine fuels is found. Although the FFE-FVS software is free and outputs data intended for the fire behavior models, proper use of the model requires some training. An additional benefit of FFE-FVS is that you can simulate forest growth and examine changes in fire behavior over time. The FMA is easy to use, but requires the user to purchase the software. Finally, allometric equations that predict canopy-base height according to stand height and basal area are currently available for Douglas-fir, ponderosa pine, mixed conifer, and lodgepole pine forests of the western United States (Cruz et al. 2003). However, these equations do not account for differences in foliage biomass based on stand age, stocking, or site quality. Cruz and colleagues (2003) also commented that due to the nature of the data they used to develop the equations, they only describe the canopy fuels and not the vertical contribution of the ladder fuels. Since the estimate of canopy-base height will differ for each of these methods, one should identify the method used.

Measurements of crown-base height provide relevant data that allows managers to determine if objectives were met, and if more action is needed. Crown-base height is useful data to assess if the restoration/land treatment objectives were met in ponderosa pine and mixed conifer forests. However, crown-base height is not deemed a good indicator of restoration/land treatment objectives in pinyon-juniper woodlands because the crowns in these woodlands often reach the ground and fire spread risk is determined by horizontal crown continuity.

Forest Habitat Type/Plant Association (score of 11)

A forest habitat type is the mapped unit that identifies a forest according to a known plant association. Plant associations are plant communities that represent stands occurring in places where environments are so closely similar that there is a high degree of floristic, soils, and landform uniformity (Daubenmire 1968). These plant associations are based on the potential climax vegetation that would exist in the absence of disturbance. These associations are named for the most shade-tolerant tree successfully regenerating and for an understory species (herb or shrub) that is indicative of the site. The first two letters of the genus and the first two letters of the species typically designate plant associations. For instance, the ponderosa pine/Gambel oak (*Pinus ponderosa/Quercus gambelii*) plant association is assigned the following code: PIPO/QUGA. A field guide, Plant associations of Arizona and New Mexico Volume 1: Forests, Edition 3, is available at www.nm.nrcs.usda.gov/technical/tech-notes/range/range99-publication-forests.pdf to help determine a forested stand's plant association.

Knowledge of plant associations provide managers with information about potential tree productivity, disease and insect susceptibility, herbaceous production, soil moisture, and tree regeneration. Although plant associations are based on climax conditions, most stands are often in early or mid-successional stages and the field guide key may not lead the user directly to the correct plant association. Instead, the user must infer the association from site factors, indicator species, tree successional relationships, or from known successional stages. This requires knowledgeable and trained personnel in forest ecology, which can increase the cost, time, and personnel requirements. Nevertheless, the data required to identify a plant association is manageable, reliable, and there is existing data available. The U.S. Forest Service has used the nomenclature of plant associations for decades, so the effects of management activities

and natural disturbances on the plant associations can be discerned. Comparisons of current plant associations with past (more than 50 years) plant associations are often obtained from dendrochronological studies, early explorer descriptions, and historical photographs. These comparisons can help managers determine if structural and species composition restoration objectives were met. If the objectives were not met, then managers can to adaptive measures to correct the situation.

Our group was undecided about how easily thresholds could be established and whether a plant association was sensitive to changes to the system. In some cases, a severe wildfire or management action could result in a species type conversion (e.g., forest to shrubland or grassland). However, others suggested that eventually the area would result in the original trajectory of the climax condition. Overall, plant associations are useful to assess if the restoration/land treatment objective were met in pinyon-juniper, ponderosa pine, and mixed conifer forests.

Insects/Forest Pathogens (score of 8)

Forest pathogens include insects, diseases, dwarf mistletoe, and other agents that decrease tree growth or result in tree death. The role that forest pathogens play in ecosystem function has a strong scientific and conceptual basis. Because epidemic levels of forest pathogens are often linked with tree stress, management activities that reduce tree stress often result in lower susceptibility to pathogens. Historical records of forest pathogen distribution are dependent on the pathogen and the time period. For most of the twentieth and twenty-first centuries, foresters have recorded the effects of various forest pathogens on forest health. However, pathogen distribution before European settlement (typically 1880) is less certain. Classification of forest pathogens in the forested ecosystem is repeatable and reproducible in different context, as long as trained personnel are present for the analysis.

A variety of pathogens affect the forest and each influence the forest on a variety of scales. People could be trained to perform stand-level inventories of insect and/or pathogen outbreaks. However, the practical dimensions of collecting data about forest pathogens at a landscape scale make this variable difficult to measure due to the need for trained personnel, aerial photography, and the associated expenses. Moreover, because many pathogens exhibit similar symptoms when viewed from the air, ground surveys by trained personnel are needed to differentiate the cause of tree mortality or decline. Because of the complexity of forest pathogen measurements, each multi-party monitoring team would need a trained person, which makes collecting data costly.

Although the practical dimensions of forest pathogens make this variable less appealing, the information is very relevant to forest managers. Monitoring forest pathogens allows managers to determine if restoration management objectives are being met and provides information for adaptive management decisions. However, it is still difficult for managers to determine thresholds that necessitate relevant action. While forest pathogens are complex and difficult to measure, data about this variable could be useful to assess whether the restoration/land treatment objectives were met in pinyon-juniper, ponderosa pine, and mixed conifer forests. Managers should also remember that dwarf mistletoe, a common forest pathogen, provides habitat for some wildlife species.

Landscape Patch Characteristics (score of 7)

Our group defined landscape patch characteristics in terms of openings and tree clumps on the landscape. Openings are areas with no to very few trees and crown closure of less than 10%. Tree clumps are patches with variable tree densities, which include areas of relatively high densities. The distribution of the openings and tree clumps should range from random to clustered on the landscape.

The concept of landscape patch characteristics has a strong scientific and conceptual basis, but it is often difficult and/or costly to discern the historical distribution of these variables. Management practices can alter the distribution of openings and clumps, but the group was undecided as to whether creating such a patchy distribution could be repeated in different landscape contexts. The group identified and discussed the problem of creating tree clumps with various densities and tree sizes when a specific tree size no longer exists in the landscape.

The practical dimensions of openings and tree clumps make this variable difficult to measure and monitor on a large scale. On a landscape level, data collection requires remote sensing techniques to measure these variables, which requires technical expertise. While remote sensing will provide information about the distribution of openings and clumps, it will not provide clump tree density or tree size information. Instead, data collection of tree clump data would require on the ground measurements, which would require considerable effort for a landscape-level analysis. Because of these reasons, multi-party monitoring teams would have difficulty collecting the data.

Quantifying landscape distribution of openings and tree clumps would be relevant to land managers and easily applied toward adaptive management decisions. Creating openings and tree clumps would meet a restoration management objective, but the group was undecided whether thresholds could be easily established to determine relevant action. The variables included in the landscape patch category are useful data to assess if the restoration/land treatment objective were met in pinyon-juniper, ponderosa pine, and mixed conifer forests.

Vegetation Structural Stage (VSS) (score of 6)
Vegetation structural stage (VSS) is a system of describing the growth stage of a forested stand. The VSS system is based on tree diameter distribution (diameter at breast height; dbh) and canopy cover. In Region 3 of the U.S. Forest Service, stands are classified into six separate vegetative stages: 1) grass/forb/shrub (dbh = 0 to 1 inch), 2) seedling/sapling (dbh = 1 to 5 inch), 3) young forest (dbh = 5 to 12 inch), 4) mid-aged forest (dbh = 12 to 18 inch), 5) mature forest (dbh = 18 to 24 inch), and 6) old forest (dbh >24 inch). If a stand has a wide range of diameters, the majority of the stems of a stand (based on basal area) in a specific diameter class would determine the vegetative stage. Canopy cover is classified into three categories: A) 0 to 40%, B) 40 to 60%, and C) more than 60% (Reynolds et al. 1992).

The concept of VSS has a strong scientific and conceptual basis, but it is often difficult to discern the historical distribution. Management practices can alter VSS, with some changes producing more immediate effects than others. For instance, a forest that is classified as a 4C could easily be changed to a 4A by thinning some of the overstory trees. However, to increase canopy cover, one must wait for the trees to grow. Classification of VSS can be repeatable and reproducible in different contexts.

The practical dimensions of VSS make this variable difficult to implement. First, VSS is scale sensitive. For example, an assessment of VSS at the stand-level and landscape-level would yield very different answers. Besides the scale issue, there are different techniques used to quantify canopy cover. Another difficulty with VSS is the lack of standardized protocols, which makes it hard for multi-party monitoring teams to easily collect data. Because of these reasons, VSS is not a reasonable and practical measurement when resources are limited.

If a standardized protocol were adopted, quantifying VSS would be relevant to land managers and easily applied toward adaptive management decisions. Creating various VSS on the landscape would meet a restoration management goal, but the group was undecided whether thresholds could be easily established to determine relevant action. VSS could be useful to assess if the restoration/land treatment objectives were met in ponderosa pine and mixed conifer forests. The group was undecided if VSS was a good indicator of restoration/land treatment objectives in pinyon-juniper woodlands.

CHARACTERISTICS	VARIABLES				
	Tree density, size, composition, height (15)	Surface fuels, live and dead (14)	Age class (12)	Crown-base height (11)	Forest type/ plant association (11)
Strong scientific and conceptual basis	Yes	Yes	Yes	Yes	Yes
Existing historical record of comparative data	Yes	Undecided	Yes	No	Yes
Sensitive to system changes	Yes	Yes	Yes	Yes	Undecided
Repeatable and reproducible	Yes	Yes	Yes	Yes	Yes
Manageable data collection requirements	Yes	Yes	Yes	Yes	Yes
Data can be collected by multi-party teams	Yes	Yes	Yes	Yes	Undecided
Requires simple and standardized analysis	Yes	Yes	Yes	Yes	Yes
Reasonable in terms of costs	Yes	Yes	No	Yes	Undecided
Relevant to target audience	Yes	Yes	Yes	Yes	Yes
Meets mgt. objectives	Yes	Yes	Yes	Yes	Yes
Easy to establish thresholds	Yes	Yes	Yes	Yes	Undecided
Responses can be applied to adaptive mgt. decisions	Yes	Yes	Yes	Yes	Yes
Effective in pinyon-juniper	Yes	Yes	Undecided	No	Yes
Effective in ponderosa pine	Yes	Yes	Yes	Yes	Yes
Effective in mixed conifer	Yes	Yes	Yes	Yes	Yes

Table 3: The Trees and Forest Structure Working Group's top five variables for monitoring overstory vegetation following restoration treatments and the group's consensus as to how the variables met various characteristics. The voting totals for each variable are in parentheses after each variable name. Voting scoring: Yes = 1, Undecided = 0, No = -1.

Identifying the Most Effective Monitoring Variables: Wildlife Group

The Wildlife Group selected two approaches for monitoring wildlife and habitat. The first is to use the Multiple Species Inventory and Monitoring protocol (Manley et al. 2006) to collect data on all taxonomic groups of vertebrates. This method uses field protocols that are capable of detecting multiple species per taxonomic group and a systematic sampling design that encompasses both treated and untreated areas. The second approach is to monitor three or four species that are believed to be fairly sensitive to thinning or burning treatments, and monitor their populations and/or special habitat features at three spatial scales: forest stand (shown in the table as "Vegetation Characteristics" at the patch scale), landscape (such as a watershed), and regional (entire area encompassing all restoration projects). This report describes how group members ranked each of these approaches from the standpoint of scientific merit, practicality of implementation, and applicability to policy and adaptive management.

Multiple Species Inventory and Monitoring (MSIM): Scientific Dimensions
The MSIM is a peer-reviewed, published protocol with a strong scientific, statistical, and conceptual basis. It uses a grid-based design similar to that of the Forest Service Inventory and Analysis program to detect as many species as possible with the least amount of sampling, for the purpose of estimating species' presence, distribution, habitat associations, and (for commonly-detected species) an estimate of population size or population density for the area of inference. The field protocols use multiple visits to estimate detection probabilities because species are often not detected during a survey, even though they are present.

16

The MSIM sampling design is not specifically tailored to monitor population responses to restoration treatments. However, it can be efficiently used for that purpose by using characteristics of restoration treatments (or simply treated vs. non-treated) as covariates in the analysis of species presence or species population estimates.

The Wildlife Group supported the MSIM for restoration monitoring because it targets entire terrestrial communities rather than a single species, making it possible to observe community responses to restoration. Moreover, since it surveys multiple species, it is well-suited to detect unforeseen responses in some species that would otherwise go undetected if the responding species was not selected for a monitoring program.

The MSIM does not have historical records because it is a fairly new design that has not been adopted in the Colorado Plateau.

Multiple Species Inventory and Monitoring (MSIM): Practical Dimensions
The MSIM uses established field protocols, but implementing all of them can become expensive. This is the greatest detriment to full implementation. Multi-party monitoring teams can, however, be engaged in collecting the data, so costs can be shared.

Multiple Species Inventory and Monitoring (MSIM): Policy and Adaptive Management Dimensions
The MSIM yields estimates of distribution and abundance that are relevant to target audiences, and would provide information about wildife responses to restoration treatments that could be used for adaptive management. It is possible to set thresholds for individual species, even though data are collected about multiple species.

Monitoring of Vegetation Characteristics, Landscape Characteristics, and Regional Characteristics for Targeted Species
The Wildlife Group selected eight terrestrial species and species groups for which targeted monitoring could be conducted. These species and groups are:

- Abert's squirrel (*Sciurus aberti*)
- Black bear (*Ursus americanus*)
- Northern goshawk (*Accipiter gentilis*)
- Mexican spotted owl (*Strix occidentalis lucida*)
- Mogollon vole (*Microtus mogollonensis*)
- Snag-roosting bats
- Ground-nesting birds
- Cavity-nesting birds

Rather than evaluate the scientific dimensions, practical dimensions, and adaptive management dimensions of the individual species and groups, the Wildlife Group evaluated the ability to monitor the habitats of these species and groups at three spatial scales: stand, landscape, and region.

Vegetation Characteristics: Scientific Dimensions
The Wildlife Group identified seven vegetation characteristics that could be monitored for all of the species and groups listed above. These attributes were selected from a strong scientific and conceptual basis from wildlife habitat relationships models for these species. In terms of historical records for comparative purposes, there is a wealth of data that have already been collected for each of these species. In particular, there is abundant information about the effects of thinning, prescribed burning, and other restoration treatments for Abert's squirrel, northern goshawk, Mexican spotted owl, and many snag-roosting bats and cavity-nesting birds. All of these characteristics have the potential to change with restoration treatments. All can be monitored using protocols that are repeatable and reproducible.

The attributes are as follows:

- basal area
- trees per acre
- interlocking crowns/canopy cover
- snag density
- snag diameter classification/distribution
- down logs/debris
- VSS Classification

Vegetation Characteristics: Practical Dimensions
It makes practical sense to monitor the vegetation characteristics listed above because they are standard variables for any type of forest vegetation mensuration. Standard protocols exist for measuring these variables, and they can be easily monitored by multi-party teams. Using these variables would be a good use of limited resources because these variables need to be monitored for other purposes besides wildlife habitat (see reports from other groups).

Vegetation Characteristics: Policy and Adaptive Management Dimensions
The public and managers are interested in how vegetation characteristics might change after restoration treatments, so these variables are highly relevant and can be effectively applied toward adaptive management decisions. A threshold could easily be established for each variable.

Landscape Characteristics: Scientific Dimensions
Most species require certain elements of landscape pattern, such as a minimum size of habitat patches, juxtaposition between different resource patch types, and connectivity between patches. Therefore, it is essential to monitor changes in landscape pattern in order to monitor the response of wildlife habitat to restoration treatments. For some species, such as Mexican spotted owl, Abert's squirrel and northern goshawk, the required characteristics of landscape pattern are fairly well understood from recent research studies. However, this information is less available or sometimes unknown for other species that the Wildlife Group selected. Therefore, additional work would be needed prior to monitoring to understand which characteristics of landscape pattern are important, and to establish minimum thresholds for each characteristic for each species.

Landscape Characteristics: Practical Dimensions
Landscape characteristics are fairly easy to measure from map images in GIS using Fragstats, a spatial pattern analysis program. The greater challenge is in monitoring changes in landscape pattern over time, partly because restoration projects are likely to make minute changes in landscape pattern over the short term that will be difficult to detect. Secondly, map images have a great deal of error caused by a variety of factors, beginning with the limitations of satellite sensors and including the limitations of interpretation and modeling. It could be difficult to distinguish real changes in landscape pattern from pseudo changes that are caused by map error.

Monitoring of landscape characteristics would likely be done by a group of specialists who are familiar with GIS and Fragstats rather than multi-party monitoring teams. However, it is possible that a group of specialists from one agency or university might contribute the maps and another agency or university might contribute the Fragstats landscape pattern analysis.

Landscape Characteristics: Policy and Adaptive Management Dimensions
Landscape pattern is extremely important to wildlife, but it is difficult to set thresholds (e.g., minimum patch size) because there is insufficient information to do this for many species. It is also difficult to apply landscape characteristics to adaptive management on the short-term because these characteristics usually reveal small changes for any given restoration project. However, landscape characteristic should not be dismissed from monitoring programs because of these challenges.

Regional Characteristics: Scientific Dimensions

A set of regional characteristics is needed in order to monitor changes in habitat that could affect dispersal, gene flow, metapopulation dynamics, and long-term sustainability of the targeted species. Historic distribution maps could be compared to existing distributions to determine whether the ranges of some species are contracting or expanding as a result of restoration treatments. Specific outcomes from each restoration treatment could be rolled into a regional analysis.

Regional Characteristics: Practical Dimensions

There are currently no known protocols for monitoring wildlife habitat at a regional scale. This is not because it is impossible to monitor at a regional scale, but rather because managers are typically funded to monitor only at the scale of their projects, so there are few precedents for doing this. It is unlikely that regional-scale monitoring would be performed by multi-party monitoring teams. Specific funding would be needed to employ someone with GIS and analytical skills. However, it is reasonable to use limited funds for this purpose, because the broad perspective of regional characteristics could help in interpretation of vegetation and landscape pattern responses.

Regional Characteristics: Policy and Adaptive Management Dimensions

Regional characteristics (e.g., species distribution and ability to disperse) are characteristics that should be monitored because they indicate whether a species is likely to persist. Contractions in distribution or loss of gene flow are indicative of a species in trouble. These characteristics are not evident by simply monitoring changes in vegetation structure or landscape pattern. Many members of the public are more concerned about the overall persistence of a species rather than the response of a species to a small-scale restoration project. Thresholds are easily established at the regional scale, as evident in recovery plans of federally listed species. Although these thresholds cannot be readily applied to short-term adaptive management projects, they provide the basis for long-term adaptive management.

CHARACTERISTICS	VARIABLES			
	Multiple Species Inventory and Monitoring (11)	Vegetation characteristics (9)	Regional characteristics (9)	Landscape characteristics (5)
Strong scientific and conceptual basis	Yes	Undecided	Yes	Undecided
Existing historical record of comparative data	No	Yes	Yes	Undecided
Sensitive to system changes	Yes	Yes	Yes	Yes
Repeatable and reproducible	Yes	Yes	Yes	Yes
Manageable data collection requirements	Yes	Yes	Undecided	Undecided
Data can be collected by multi-party teams	No	Yes	No	No
Requires simple and standardized analysis	Yes	Undecided	No	Yes
Reasonable in terms of costs	Yes	Yes	Yes	Undecided
Relevant to target audience	Yes	Yes	Yes	Yes
Meets mgt. objectives	Yes	Yes	Yes	Yes
Easy to establish thresholds	Yes	No	Yes	No
Responses can be applied to adaptive mgt. decisions	Yes	Yes	Yes	Yes
Effective in pinyon-juniper	Yes	Undecided	Undecided	Undecided
Effective in ponderosa pine	Yes	Yes	Yes	Yes
Effective in mixed conifer	Yes	Undecided	Yes	Undecided

Table 4: The Wildlife Working Group's top four variables for monitoring wildlife following restoration treatments and the group's consensus as to how the variables met various characteristics. The voting totals for each variable are in parentheses after each variable name. Voting scoring: Yes = 1, Undecided = 0, No = -1.

Additional Notes
- Due to lack of time and inadequate discussion, none of these variables were brought forward to the larger group in a meaningful way. The concept of the MSIM approach and the concept of monitoring target species at different scales were never discussed. Rather, the moderator asked that the larger group choose indicators from a pre-set list that included T&E species. The larger group concluded that T&E species should be a primary focus of wildlife monitoring--a conclusion that was never reached by the Wildlife Working Group. The Wildlife Working Group discussed using T&E species, but determined that many T&E species are not the best choice for monitoring responses to restoration treatments because they are either difficult to monitor, are not primarily found in ponderosa pine cover types, or are not sensitive to restoration projects.

Identifying the Most Essential Monitoring Variables: Plenary Session

Following the variable identification exercise, working groups reconvened into a plenary session to discuss the results of their working group deliberations. This was followed by a voting activity, in which each participant was given an opportunity to select the top five variables they believed were essential to monitoring at both the project and landscape scale. The following table details the results of the final voting exercise:

Project Level	Votes	Landscape Level	Votes
Tree Characteristics	33	Landscape Characteristics*	31
Understory Cover and Composition	21	Multiple Species Inventory Monitoring (MSIM)**	18
Overall Visual Appearance	15	Diversity of Plant Association	18
Soil Integrity	15	Regional Characteristics***	16
Select Wildlife Species Monitoring****	14	Tree Characteristics	14
Surface Fuels	12	Insects and Forest Pathogens	13
Snags and Logs	8	Exotic/T&E/Rare Species	7
Canopy Cover	9	Surface Fuels	7
Exotic/T&E/Rare Species	8		

Table 5: Results of voting on essential monitoring variables during plenary session.
     * Patch size, patch shape, connectivity, patch vegetative diversity
    ** Collected at project level, aggregated at landscape level
   *** Spatial modeling, FRCC, frequency/acreage of characteristic fire
 **** Abundance/density or presence/absence of selected wildlife species (was voted on as MSIM, but changed afterwards because MSIM is more applicable at the landscape level)

The following are additional comments made by participants during the variable selection plenary:
- If no monitoring took place, could we still determine whether land treatments were effective?
- There is a threshold level of information that allows us to determine whether we are meeting our management goals and objectives. By using this threshold to establish a "bare-bones set of variables," we can limit the amount of resources needed to implement a monitoring program.
- The variables used to monitor restoration treatments are also dependent on the location of treatments (e.g., high alpine compared to Wildland Urban Interface).
- It is also critical to examine the relationship between variables when developing monitoring frameworks.
- Methodology, information systems, and who uses the data and for what purposes need to be addressed when considering variable identification.
- While photo points are technically not monitoring variables, they can be effective for showing change over time.
- While stand exams are notoriously expensive and not universally used across the various land management agencies, they are crucial in validating LandSat imaging models; a useful tool in understanding the effects of restoration treatments. By developing an affordable and standardized format for conducting stand exams, managers can have increased capacity to track changes across forest boundaries. This can be furthered enhanced by developing incentives that encourage private land participation.

Goal 3: Develop Strategies to Overcome Common Challenges to Effective Forest Monitoring and its Integration into Land Management Decisionmaking

During the second day of the workshop, participants focused on developing strategies for overcoming large-scale obstacles to forest monitoring. Four presentations intended to contextualize some of the obstacles and possible solutions to implementing monitoring programs on public lands prefaced the discussions. The presenters were: Walter Dunn-U.S. Forest Service Regional Office (R3), Carmine Lockwood-U.S. Forest Service, Grand Mesa, Uncompahgre and Gunnison National Forests (R2), Clay Speas-U.S. Forest Service, Grand Mesa, Uncompahgre and Gunnison National Forests (R2), and Sam Amato-U.S. Forest Service Regional Office (R3) and Tessa Nicolet-U.S. Forest Service Lincoln National Forest (R3). A short synopsis of each presentation can be found in Appendix 4.

Given the wide array of such obstacles, participants choose to focus on collaboration issues, sampling and methodological challenges, and implementation strategies. The participants decided to convene as one group, in contrast to working group sessions. Topics were facilitated in a round-robin format in which participants broadly discussed issues and offered solutions without any formal agreement or consensus about final recommendations.

Monitoring and Collaboration

There are a variety of reasons and potential benefits for using a collaborative approach to monitor the effects of restoration treatments on public lands. For one, conflicts about how to respond to monitoring results can be avoided by discussing contentious issues and reaching consensus on management actions. Collaboration also allows stakeholders to share intellectual and physical capital, which promotes innovation, shared learning, and problem solving in addressing land management goals. The following ideas and conversations were shared among workshop participants:

- Collaborative groups that work together and develop a clear and cogent message have an increased ability to reach larger audiences, which builds increased support for restoration activity on public lands.
- Collaboration can create a coherent way to describe whether a forest is successfully restored or on the path to restoration, and whether land managers are efficiently using funds, breaking down resistance to doing the job, etc.
- To accomplish goals of restoration on a landscape level, we must cross administrative boundaries. This includes working pro-actively and in a mutually beneficial manner with tribal governments and private landowners.
- While in-depth research is essential to understanding the full effects of restoration treatments on ecosystems, it should be distinguished from activities that can be deployed without significant investment, while still informing adaptive management.
- Monitoring in the National Park Service is effective and well-funded. This may be correlated to their focus on preservation and their high level of accountability to the public.
- The Bureau of Land Management doesn't have the same organizational structure as the Forest Service, although the two agencies are conceptually similar at the district level. In addition, the BLM has a similar plan/act/review cycle as the Forest Service, and resource management plans are done at a district level. This suggests that each agency faces similar opportunities and challenges, and could benefit from working collaboratively to monitor landscape-scale projects.
- Planning and implementing collaborative monitoring projects with universities can be complicated by the high attrition rate of students and faculty. Protocols need to be established that ensure projects can be sustained throughout their entirety.
- Federal land management agencies that use a collaborative approach to restoration treatments are more likely to gain political support and increased resource assistance.
- While using a collaborative approach to monitoring can increase a project's cost effectiveness and efficiency, it should not take precedent over the collection of scientifically valid information.

Methodological Challenges

A successful monitoring program must ensure that the data collection process produces robust, accurate, and consistent information. However, accomplishing this feat can be quite complex when attempting to coordinate activities across multiple agencies and ownership boundaries. The issue is further complicated when agencies involve broad collaborative groups that may not have the technical knowledge or skill to conduct biophysical monitoring.

The following ideas and conversations were shared among workshop participants:

- Standardization of monitoring techniques across agencies will limit variation in data.
- Guidelines for inter-agency data sharing should be established to ensure effective communication and use of monitoring results.
- The establishment of more than one control plot is needed to improve the interpretation and validity of restoration treatments.
- The most pressing questions regarding land treatments should receive the most resources.
- Sampling design is dependent on how available money is prioritized.
- There needs to be clear mechanisms for compiling and reporting on monitoring data gathered by academia to ensure it is used effectively by land management agencies.
- Having a strong leadership team in place to promote and oversee a monitoring program is paramount to its overall success.
    - Example: Region 8 of the USFS handed out "standardized" monitoring protocol with no clear leadership specified and ended up with an incoherent mess.
    - Example: It took a leader to prioritize and pool funds to support the success of the northern goshawk monitoring program.

Two groups identified repeat photographs as quite useful when monitoring changes in an ecosystem. However, useful collected photos depend on the quality of the photos and the method by which they were taken. Photopoints are repeatable and reproducible if previous photographs are available with which to match up new photos, and if the photographer can replicate the same photopoint. Storage of photographs and images can be problematic, and it is difficult keeping pace with the latest technology. Tools (lens, etc.) used must also be consistent from year to year. A major advantage of this technique is that multi-party monitoring groups can easily take the photographs. A fuel model can often be derived from a photo as well. However, analyses can't really be conducted other than rough visual assessments. Thresholds are also difficult to determine with a photograph, and, perhaps, are not really applicable. Photos are unlikely to dictate management decisions directly, but they could be used on a supplemental basis.

One group identified fuel models as an important methodology in fire and fuels modeling and analysis. Fire behavior is based on the parameters within each fuel model. The fuel model can also be derived from other variables such as, surface fuels, tree characteristics, understory cover and photo points. The group summarized their thoughts about fuel models in these terms: "subjective, useful in many cases, more of a communication tool."

Implementation Strategies

Once a group has established their monitoring goals, variables and sampling design, they must then turn to actually getting work done on the ground. Again, overcoming many of the obstacles that have limited the amount of monitoring occurring on public lands requires adaptive strategies and innovative approaches. The following ideas and conversations were shared among workshop participants:
- A major goal of SWERI is to test and judge the success of ecological restoration treatments. Workshop participants discussed the possibility of having SWERI (and similar organizations) lead all monitoring efforts on public lands, which would allow federal agencies to focus on treatment implementation.
- The creation of a shared database where federal and state agencies, tribal governments, universities, nonprofits, and concerned stakeholders could store and share monitoring information was proposed as a possible solution to increasing the effectiveness and efficiency of monitoring restoration treatments.
    - A formal adaptive management feedback loop is essential for this system to work.
    - Such a system could help eliminate the possibility of duplicate data.
    - The Tree-Ring Laboratory Depository at the University of Arizona is a good example of data compilation and synthesis.

- A concerted effort should be made to advocate for increased funding support for monitoring programs. However, because agencies are unlikely to receive sufficient dollars, they also need to adopt strategies that increase their ability to effectively treat and monitor restoration activities. Such strategies might include the allocation of budget dollars for monitoring at the beginning of the year, programs that allow funding to be shared across agencies, community and student monitoring programs, and contracting devices like stewardship projects.

<u>Conclusion</u>

The results of the workshop suggest that when monitoring restoration treatments, land managers might collect the most important data at the most reasonable expense if they monitor the following:

Project level
- Wildlife (Multiple Species Inventory Monitoring protocols)
- Understory (cover and composition, presence/absence of exotic/invasive species,)
- Surface fuels (understory cover and composition, coarse woody debris)
- Tree characteristics (size, height, crown-base height, species, composition)
- Visual appearance (understory cover and composition, presence/absence of exotic/invasive species, tree density, tree composition, tree age classes, surface fuels)

Landscape level
- Wildlife (Multiple Species Inventory Monitoring protocols)
- Tree characteristics (density, composition, age class, composition, species)
- Landscape characteristics (e.g., patch size and shape, connectivity)
- Regional characteristics (e.g., spatial modeling, frequency/acreage of characteristic fire)
- Insects and pathogens (type, spatial extent, severity of infestation)
- Plant associations (type, diversity)

It should be noted that the participants rated these metrics to work most effectively in ponderosa pine and mixed conifer forests, and less so in pinyon-juniper woodlands. In addition, the cost of monitoring at the landscape scale is likely to be greater than the project scale due to the greater spatial area being covered and the need to hire professionals to work at this scale doing GIS-related tasks, aerial photography, and ground-truthing.

These results indicate that there are potentially useful protocols and metrics for monitoring restoration treatments in the forested ecosystems of the southwestern United States. The disciplinary groups assembled identified several methods that can provide solid, defensible information that is relatively easy to collect and store, and can be done within the constraints of existing budget and personnel. However, other methods, while capable of providing usable information, could not presently be accomplished without increases in budgets, personnel levels, and/or collaborative efforts. The group made several suggestions and recommendations about how to overcome these obstacles and what steps should be taken to promote monitoring of restoration-treated forests.

While there has been a clear call by numerous stakeholders for the restoration of the forested ecosystems of the southwestern United States, the path to success has not been fully realized. As we move forward in achieving this goal, it is essential that the effects of land treatments are thoroughly monitored and used to inform an adaptive management framework and policy development. Although federal resource dollars dedicated to monitoring will most likely be constrained, valuable information about the effects of restoration treatments can still be identified by using a combination of variables identified in this document. In many cases, however, the success of monitoring projects will require federal agencies, universities, nonprofit organizations, and other concerned stakeholders to pool their resources and work collaboratively to ensure goals are achieved.

General References

Covington, W.W. 2003. The evolutionary and historical context. Pp. 26–47 *in* P. Friederici (ed.), Ecological restoration of Southwestern ponderosa pine forests. Washington, D.C.: Island Press.

Community Forest Restoration Program. Online: http://www.fs.fed.us/r3/spf/cfrp/

Derr, T., A. Moote, M. Savage, M. Schumann, J. Abrams, L. McCarthy, and K. Lowe. 2005a. Monitoring ecological effects. Pp. 4, 9, 11, 15 *in* Monitoring handbook 4. Flagstaff, AZ: Ecological Restoration Institute.

___. 2005b. What is multiparty monitoring? Pp. 4-7 *in* Monitoring handbook 1. Flagstaff, AZ: Ecological Restoration Institute.

Elzinga, C.L., D.W. Salzer, J.W. Willoughby, J.P. and Gibbs. 2001. *Monitoring plant and animal populations*. Malden, MA: Blackwell Science, Massachusetts.

Fulé, P. 2003. Monitoring. Pp. 402–416 in P. Friederici (ed.), Ecological restoration of Southwestern ponderosa pine forests. Washington, D.C.: Island Press.

Society for Ecological Restoration. 2004. The SER International Primer on Ecological Restoration. Available online at: http://www.ser.org/content/ecological_restoration_ primer.asp.

References: Botany Group

Elzinga, C., D.W. Salzer, J.W. Willoughby, and J.P. Gibbs. 2001. *Monitoring plant and animal populations*. Malden, MA: Blackwell Science.

Hastings, J.R. and R.M. Turner. 1965. *The changing mile: An ecological study of vegetation change with time in the lower mile of an arid and semiarid region*. Tucson: University of Arizona Press.

Miller, M.E., D.L. Witwicki, R.K. Mann, and N.J. Tancreto. 2007. Field evaluations of sampling methods for long-term monitoring of upland ecosystems on the Colorado Plateau. U.S. Geological Survey Open-File Report 2007-1243, Version 1.0 in cooperation with the National Park Service. Available online at: http://pubs.usgs.gov/of/2007/1243/

Sheley, R.L. and J.K. Petroff. 1999. *Biology and management of noxious rangeland weeds*. Corvallis: Oregon State University Press.

USDI National Park Service. 2003. Fire monitoring handbook. Boise, ID: Fire Management Program Center, National Interagency Fire Center.

United States Geological Survey and National Park Service. In review. Early detection of invasive plant species handbook. Drafts available online at: http://www.pwrc.usgs.gov/brd/invasiveHandbook.cfm.

References: Trees and Forest Structure Group

Cruz, M.G., M.E. Alexander, and R.H. Wakimoto, R.H. 2003. Assessing canopy fuel stratum characteristics in crown fire-prone fuel types of western North America. *International Journal of Wildland Fire* 12:39-50.

Daubenmire, R. 1968. *Plant communities: A textbook of plant synecology*. New York: Harper and Row.

Fulé, P.Z., C. McHugh, T.A. Heinlein, and W.W. Covington. 2001. Potential fire behavior is reduced following forest restoration treatments. Pages 28-35 in Vance, G.K., C.B. Edminster, W.W. Covington, and J.A. Blake (compilers), Ponderosa pine ecosystems restoration and conservation: Steps toward stewardship. Proceedings RMRS-P-22. Ogden, UT: USDA Forest Service, Rocky Mountain Research Station.

Reynolds, R.T., R.T. Graham, M.H. Reiser, R.L.Bassett, P.L. Kennedy, D.A. Boyce, Jr., G. Goodwin, R. Smith, and E.L. Fisher. 1992. Management recommendations for the northern goshawk in the southwestern United States. General Technical Report RM-217. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station.

Scott, J.H. and E.D. Reinhardt. 2001. Assessing crown potential by linking models of surface and crown fire behavior. USDA Forest Service Research Paper RMRS-RP-29. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station.

Smith, D.M., B.C. Larson, M.J. Kelty, and P.M.S. Ashton. 1997. *The practice of silviculture: Applied forest ecology*. New York: John Wiley & Sons.

Van Wagner, C.E. 1993. Prediction of crown fire behavior in two stands of jack pine. *Canadian Journal of Forest Research* 23:442-449.

Reference: Wildlife Group

Manley, P.N., B. Van Horne, J.K. Roth, W.J. Zielinski, M.M. McKenzie, T.J. Weller, F.W. Weckerly, and C. Vojta. 2006. Multiple Species Inventory and Monitoring Technical Guide. General Technical Report WO-73. Washington, DC: U.S. Department of Agriculture, Forest Service, Washington Office.

Appendix 1

Case Presentation Summaries

REFLECTIONS ON MONITORING IN THE COLORADO FRONT RANGE
Merrill Kaufmann, Rocky Mountain Research Station

Project goals:
- Protect water quality
- Reduce the risks of catastrophic fire
- Reduce risks to human life and property
- Create sustainable forest conditions across the landscape
- Integrate research, monitoring, and management

Measured indicators:
- Tree and shrub density
- # of openings
- Crown cover
- Size class distribution of trees
- Cover < 8 feet
- Cover by species
- Cover by layer
- Ground fuels
- Precipitation
- Ground cover
- Soil particle-size distribution
- Soil water repellency
- Sediment production
- Particle size distribution of eroded sediment
- Bare soil
- Stream channel morphology
- Runoff flows and water chemistry
- Northern goshawk and other raptor nest sites (occupied/unoccupied)
- Abert's squirrel nesting and feeding trees
- Adult Pawnee montane skipper density and food plant densities
- Road characteristics, traffic, and sediment production

Indicators considered but not used:
- Water yield
- Suspended sediment and turbidity

Data collection and sampling design:
- Vegetation monitoring; plot points spaced every 5 acres
- Measured BA/acre (< 12" DBH, and total)
- Tree density class (trees, partial opening, opening)
- Slash depth
- Fuel loading (low, medium, and high)
- Plot frequency - one every 5 acres
- Common Stand Exam Protocols (CSE)
- Sediment production
- Channel morphology
- Water chemistry
- Northern goshawk
- Abert's squirrels – Presence/absence of squirrels and nest/feed trees
- Pawnee montane skipper – Adult butterfly and feed plant density measured along 400-m transects within thinned areas

Monitoring results have been used to:
- Prepare and administer thinning contracts
- Verify thinning activities are not increasing hill slope and road erosion
- Identify and protect northern goshawk nesting areas
- Prepare burn plans
- Verify thinning is having (+) effects on Pawnee montane skippers
- Identify and protect Abert's squirrel nesting and feeding areas

Comments:
For vegetation monitoring I recommend using CSE & Exams PC/PDR software for collecting data, then use FSveg under NRIS for storing and generating summary/analysis reports. We increased our monitoring efficiency substantially using this software and the Personal Data Recorders for collecting vegetation and wildlife data. After uploading data stored in the PDR to the central database, we can quickly generate ≤ 30 reports to summarize and analyze the vegetation data.

MONITORING THE WHITE MOUNTAINS STEWARDSHIP CONTRACT
Sue Sitko, The Nature Conservancy

Project goals:
- Fuels reduction
- Fire hazard risk reduction
- Improved wildlife habitat

Measured indicators:
- Vegetation changes (basal area, canopy cover, herbaceous ground cover, TPA, etc) to model changes in potential fire behavior
- Vegetation data will also be used to interpret potential effects to wildlife species of interest
- Wildlife monitoring includes squirrels, songbirds, and black bears
- Best management practices
- Soil compaction studies
- Economic and social measurements

Indicator considered but not used:
- Watershed impact
- Springs/water quantity changes
- Wider range of wildlife species

Data collection and sampling design:
- Songbird point count protocol selected due to its use in Coconino/Kaibab forests
- Squirrel sign indexing under Dodd's protocol
- Black bear radio-tracking and vegetation sampling
- Vegetation sampling using Brown/Daubenmire
- Standardized data collection methods to fit into existing models

Monitoring results have been used to:
- Establish pre-treatment baselines

Comments:
- Results of restoration work will be based on collecting and interpreting post-treatment data

MONITORING THE EFFECTS OF ECOSYSTEM RESTORATION ON NORTHERN GOSHAWKS
Christina Vojta, Rocky Mountain Research Station

Project goals:
- Monitor changes in northern goshawk presence at a scale that is relevant to this wide-ranging species

Measured indicators:
- Occupancy rates (the proportion of available goshawk habitat that is likely to be occupied by goshawks)
- Modeling is then used to correlate occupied habitat with environmental factors such as the amount of thinning, burning, the representation of late seral forest, and the juxtaposition of vegetation types and structural stages

Indicators considered but not used:
- Monitoring goshawk reproduction and recruitment

Data collection and sampling design:
- A grid of sampling units that approximately the size of a goshawk breeding territory, covering all available habitats in the area of interest
- Data collection: broadcast acoustical sampling at 120 evenly-spaced call stations within each sampling unit. Each sampling unit is surveyed twice in order to estimate the goshawk detection rate

Monitoring results have been used to:
- Provide a one year estimate of goshawk habitat occupancy rates. The regions are still collecting the environmental data needed for modeling.

Comments:
The results have been satisfactory in every region where the design has been applied. We would not change the sampling design or data collection method, but we are finding that the environmental data are harder to acquire than we thought. The USFS is currently improving their database of management actions so hopefully, information on restoration treatments will be easier to obtain in the future.

**MONITORING LARGE-SCALE FOREST RESTORATION TREATMENTS:
INTEGRATING MULTI-DISCIPLINARY SCIENCE AND MANAGEMENT**
Pete Fulé, Ecological Restoration Institute

Project goals:
- Comprehensive ecological restoration on a large ponderosa pine forest landscape
- Utilize info on the natural structure, composition, and process of the ecosystem to inform restoration goals
- Maintain public access and multiple uses such as livestock grazing and hunting

Measured indicators:
- Vegetation and fuels: Permanent plots (20 x 50 m) on a 300-m grid across the treated and control landscapes to measure trees (species, condition, diameter, height, crown base height), fuels, canopy cover, understory plants and shrubs, and photo points
- Tree-ring data: reconstruct historical conditions of forest structure and fire regime
- Tracking deer and monitoring squirrels and passerine bird
- Nested within the larger landscape were small experimental blocks, providing a replicated data set with improved statistical power for detecting changes
- Herpetofaunal and butterfly responses
- Cheatgrass performance and seeding trials
- Fire behavior and effects variables (rate of spread, flame length, crown scorch, bole char)
- Utilized the restoration/control design to gain information about habitat fragmentation, turkey roost use, and slash compression treatments

Indicators considered but not used:
- Soil data (texture, organic matter, erosion loss, etc.)

Data collection and sampling:
- Basic vegetation plot design was adopted from a standard DOI/NPS fire monitoring plot. Originally, this had the benefit that free NPS software could be used to store the data, though as the effort became more complex it was necessary to develop specific software applications.

Monitoring results have been used to:
- At the local level, early monitoring information was used to adjust subsequent treatment procedures.
- At the regional level, information and studies from Mt. Trumbull have contributed greatly to discussions about forest restoration in the Southwest.
- At the national/international level, a variety of peer-reviewed publications based on the work at Mt. Trumbull have appeared, influencing the overall status of knowledge about restoration of frequent-fire adapted pine ecosystems

Comments:
The project has proven to be highly satisfactory from a monitoring perspective. The use of permanent plots and treatment records permits remeasurement will be beneficial for future managers as well. The sampling design was robust. The main challenge for continuing this work or for initiating similar projects is cost. Substantial resources and motivation are needed to bring together the management and scientific communities for a sustained partnership of this magnitude. Re-measurement will be beneficial for future managers as well. The sampling design was robust. The main challenge for continuing this work or for initiating similar projects is cost. Substantial resources and motivation are needed to bring together the management and scientific communities for a sustained partnership of this magnitude.

Appendix 2

Goal: Evaluate and prioritize biophysical monitoring variables, from the perspective of your working group, for ecosystem level monitoring by land managers.

Outcome: Bring top five variables to plenary for interdisciplinary, ecosystem discussion, and prioritization to select the top variables that will be recommended by this workshop.

Variable List:
Please, choose the top five variables that you believe are the most suited for land management monitoring of restoration/land treatments, from the perspective of your working group.

-Photo point

-Basal area

-Tree density, size, species composition, height

-Density and size of snags

-Canopy cover

-Landscape patch characteristics (openings; tree clumps)

-Vegetation Structural Stage (VSS)

-Forest pathogens (insects, diseases, mistletoe, other damaging agents)

-Crown-base height (CBH)

-Fire Regime Condition Class (FRCC)

-Surface fuels live and dead (litter, duff, and woody debris)

-Fuel model (1-13)

-Soil compaction

-Road density

-Water quality of forest streams (physical and biological)

-Soil erosion

-Soil quality

-Water quantity

-Management Indicator Species (MIS) Abundance

-Wildlife abundance and species composition

-Wildlife cover values

-Threatened & endangered species

-Exotic species

-Understory cover, composition, and substrate cover (ex: ground cover, understory basal cover, % bare soil).

-Grazing intensity

-Biological soil crusts

-Pollinators

-Other(s)_____

Variable selection was developed by the SWERI planning team after reviewing survey results from workshop participants.

Appendix 3

Criteria for evaluating variables: Does X variable meet the following criteria?								
Ranking Scale: No (-1) Undecided (0) Yes (1)								
Scientific dimensions								
Has a strong scientific and conceptual basis?								
Has existing historical record of comparative data?								
Sensitive to changes on the system?								
Is repeatable and reproducible in different contexts?								
Sub Total:	0	0	0	0	0	0	0	0
Practical dimensions								
Has manageable data collection requirements and/or has reliable and available existing data; is it simple to measure and record?								
Can multi-party monitoring teams easily collect the data?								
Requires simple and standardized analysis?								
Reasonable to measure in terms of limited resources (time/personnel/$$$)?								
Sub Total:	0	0	0	0	0	0	0	0
Policy and adaptive management dimensions								
Is it relevant to target audiences?								
Meets management objectives (restoration of ecosystems)?								
Can thresholds be easily established to determine relevant action?								
Can be effectively applied towards adaptive management decisions?								
Sub Total:	0	0	0	0	0	0	0	0
How well does the following variable indicate the effectiveness of a restoration/land treatment within the following ecosystems?								
Ranking Scale: Poor (-1) Moderate (0) Excellent (1)								
PJ								
PIPO								
Mixed-Conf								
Sub Total:	0	0	0	0	0	0	0	0
Overall Total:	0	0	0	0	0	0	0	0

Final Recommendations:

Appendix 4

Walter Dunn-U.S. Forest Service Regional Office (R3)
Walter Dunn provided participants with an overview of the Community Forest Restoration Program (CFRP) established in New Mexico. The CFRP provides cost-share grants for forest restoration programs on public lands that have been designed through a collaborative process. A main focus of the program is fostering enhanced communication and problem solving among diverse stakeholders in building sustainable communities and forests. This includes stakeholder involvement through all aspects of restoration projects--from project design through monitoring. The CFRP has also produced a series of multiparty monitoring handbooks that serve as how-to-guides for tracking the effectiveness of restoration treatments (CFRP 2008).

Carmine Lockwood-U.S. Forest Service, Grand Mesa, Uncompahgre and Gunnison National Forests (R2)
Carmine Lockwood gave a middle manager's perspective about what an effective and efficient monitoring program needs to address in the operating environment of today's Forest Service. Specifically, his presentation outlined national "mega trends," such as declining budgets, fewer personnel, increasing management reporting and accountability requirements/systems, and a greater propensity for top-down decision-making. All these factors, Lockwood argued, suggest that field personnel must strive to make monitoring as integrated, collaborative, and elegant (i.e., focused and simple) as possible. Integrated multiple systems include performance accountability targets from the Government Performance and Results Act, planning rule assessment and evaluation requirements, nationally standardized monitoring framework/format, and environmental management system mandate. Collaborative needs include incorporation of best- available science and cooperative work with research and academia. There is also a need to achieve public understanding and buy-in about the need for a highly focused monitoring plan and the critical elements that should be included.

Clay Speas-U.S. Forest Service, Grand Mesa, Uncompahgre and Gunnison National Forests (R2)
The third presentation provided participants with insights into the approaches used at the Grand Mesa, Uncompahgre and Gunnison National Forests where Forest Service personnel are developing a monitoring framework for addressing policy recommendations and requirements issued by senior offices in Washington, D.C. Specifically, Speas focused on the question: How can land management agencies fulfill their given responsibilities using an integrated system approach, while maintaining enough flexibility to adapt to resource and social condition change? The process used first identified conditions and trends for a given location. Next, managers determined how ground activities can be refined or maintained to achieve directives from Washington offices. Finally, appropriate modifications are implemented as new information (science, technology, policy, public opinion) becomes available.

Sam Amato-U.S. Forest Service Regional Office (R3) and Tessa Nicolet-U.S. Forest Service Lincoln National Forest (R3)
Sam Amato introduced participants to a proposed USFS Southwestern Region open-source database that would enhance monitoring capabilities on public lands. Specifically, this system would provide a mechanism for centralizing data that could support fire and fuels monitoring across agency boundaries using software such as Wildland Fire Decision Support System (WFDSS), INFORMS & PHYGROW, and Fire Program Analysis (FPA). This system would also provide stakeholders with increased data access, which results in an increased ability to track the effects of vegetation treatments at broader scales. Finally, this system would provide a forum for agencies to simplify the complexity of data by adopting basic standards and formatting that would streamline the analysis process.

Ecological restoration is a practice that seeks to heal degraded ecosystems by reestablishing native species, structural characteristics, and ecological processes. The Society for Ecological Restoration International defines ecological restoration as "an intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability...Restoration attempts to return an ecosystem to its historic trajectory" (Society for Ecological Restoration International Science & Policy Working Group 2004).

In the southwestern United States, most ponderosa pine forests have been degraded during the last 150 years. Many ponderosa pine areas are now dominated by dense thickets of small trees, and lack their once diverse understory of grasses, sedges, and forbs. Forests in this condition are highly susceptible to damaging, stand-replacing fires and increased insect and disease epidemics. Restoration of these forests centers on reintroducing frequent, low-intensity surface fires—often after thinning dense stands—and reestablishing productive understory plant communities.

The Ecological Restoration Institute at Northern Arizona University is a pioneer in researching, implementing, and monitoring ecological restoration of southwestern ponderosa pine forests. By allowing natural processes, such as fire, to resume self-sustaining patterns, we hope to reestablish healthy forests that provide ecosystem services, wildlife habitat, and recreational opportunities.

The ERI White Papers series provides overviews and policy recommendations derived from research and observations by the ERI and its partner organizations. While the ERI staff recognizes that every forest restoration is site specific, we feel that the information provided in the ERI White Papers may help decisionmakers elsewhere.

ERI White Papers: Issues in Forest Restoration
1. Forestlands Health and Carbon Sequestration: Strengthening the Case for Western Forest Restoration
2. Smoke from Prescribed Burning: Issues on Public Forestlands of the Western United States
3. Public Perceptions of Forest Restoration in the Southwest: A Synthesis of Selected Literature and Surveys
4. Integrating Ecological Restoration and Conservation Biology: A Case Study from Southwestern Ponderosa Pine Forests
5. Communications Between Forest Managers and Property Owners in Pine Flat, Arizona: A Case Study of Community Interactions in a High Fire Hazard Area
6. Wilderness Management and the Restoration of Fire: An Analysis of Laws and Regulations in Northern Arizona
7. Navigating the Motives and Mandates of Multiparty Monitoring
8. Forest Service Contracting: A Basic Guide for Restoration Practitioners
9. Case Study of Community Stewardship Success: The White Mountain Stewardship Contract
10. What to Expect from Collaboration in Natural Resource Management: A Research Synthesis for Practitioners

sustainable forests, communities, and economies for Arizona, Colorado, New Mexico

SWERI
Southwestern Ecological Restoration Institutes