Chapter 5 - Ecological Monitoring Tools and Methods

General features of an ecological sampling design

The general design for ecological field sampling falls into two categories, 1) point sampling at a series of *points* along transect lines, and 2) plots sampling in a series of *points* along transects.

A *transect* is a line, laid on the forest floor, that is used to make sure the points or plots are distributed evenly throughout the forest stand. The length of *the* transect is specified, and usually measured with a tape, for example, a 50-meter fiberglass tapes. A compass bearing is often used to allow the transects to be parallel with one another. If feasible, the starting and ending points of a transects would be permanently marked so that the same points can be sampled before and after treatment. Points are marked at regular intervals along the transect and measurements are taken. If plots are used, whether circular or square, they are marked out at intervals along a transect or at a permanent point.

Efficient sampling protocols can be ensured with a careful field design that incorporates simultaneous collection of indicator measurements. For example, snags and tree density can be sampled simultaneously. Within one plot, data about the trees, understory, wildlife, and soil can be collected at the same time. Surface fuels, understory native and non-native plant cover, and percent bare soil can all be sampled at the same time in one-square-meter plots. The number, length, and locations of transects will necessarily vary, depending on size of the stand and heterogeneity of the forest.

Sampling should be distributed throughout the forest stand. For example, consider a square stand of 20 hectares (50 acres) of homogeneous ponderosa pine forest. Half the stand is on a south-facing slope and half is on a north-facing slope. Monitoring crews might establish three 100-meter transects in the south-facing portion and three 100-meter transects in the north-facing portion of the stand, for a total of six transects. Transects should be parallel to one another, which can be accomplished by following a compass bearing. Transects could be spaced approximately 60-75 meters apart. The starting points for each transect would be selected randomly, for example, by throwing a branch over one’s shoulder. Measurements could then be taken at 10-meter intervals along each transect, at the 5 m point, the 15 m point, the 25 m point, etc. for a total of 60 sampling points distributed throughout the stand (10 points along each of 6 transects).

It is essential to establish baseline measures before starting treatments. A minimum of 30 points should be sampled in each area both before and after treatments.

Table 2. Summary of Indicators and Sampling Requirements

Indicator	Goal	Sampling Method	Sampling Frequency	Timing of Sampling	Minimum Data
Stem density and area (live and dead trees)	1	Fixed or variable radius plots	Before, After, +5 years	Any	10 to 30 plots
Canopy closure	1	Densiometer or vertical projections	Before, After, +5 years	Conifer-any Deciduous-growing season	10 to 30 plots
Height to tree crown	1	Average and minimum height per plot	Before, After, +5 years	Any	10 to 30 plots
Surface fuels cover and depth throughout	1	Photo series	Before, After, +5 years	Any	10 points
Landscape Openings	1	*			
Density of live old and large trees	2, 4	Derive from tree data above	Before, After, +5 years	Any	10 points
Density of dead old and large trees	2, 4	Derive from tree data above	Before, After, +5 years	Any	10 points
Understory plant species cover	3	1 square meter subplots	Annual	Peak growing season	30 subplots
Understory plant species richness	3	1 square meter subplots	Annual	Peak growing season	30 subplots
Bird relative abundance and species richness	4	Point count	3 times during breeding season; 5 times during the non-breeding season	for breeding season: May-June; non-breeding season: October-February	30 independent points per unit (treated and untreated) collected yearly
Wildlife presence indices	4	Strip transect	Once during breeding season; once during the non-breeding season	Breeding season: May-June; non-breeding season: October-February	Ten 200m X 2m strip transects per unit (treated and untreated) sampled yearly for 5 years
Bare soil cover	5	1 square meter subplots	Annual	Peak growing season	30 subplots
Soil loss	5	Check dams in micro watersheds	Before, After, +5 years	Any	4 micro watersheds
Soil compaction	5	Points on transects	Before and After treatments	Any	30 points
Riparian Community Health	6	Photo series	Annual	Peak growing season	10 points

* Consult with local resource managers or academic scientists for methodology.

Control sites

One way monitoring can be greatly strengthened is by establishing a control site. A control site is a location where no treatments are done, but which is sampled in the same way that the treated site is sampled. Controls allow comparison between treated and untreated areas. Data from control sites show changes that occur in natural communities without treatment. For example, a 10-year drought may cause the understory plant cover to be significantly reduced. If we only look at a treated site before and after treatments, we would not know whether the climate was affecting understory plant change, or the restoration treatments. Controls allow us to understand the effects of the treatment and not confuse them with changes that come from climate or other causes (Savage 2002).

Creating a sampling design

To create a sampling design, first decide what you are trying to learn and divide your study/work area into areas of similar forest type, elevation, and other features. If, for example, your objective is to determine the effects of pre-fire forest thinning on understory vegetation composition and cover, then, at a minimum, you will have to sample enough to quantify what the vegetation was like before the thinning and what it is like at some period after the thinning. If there is variation in the stand (e.g., in slope, aspect, moisture, pre-thinning structure), then you may need to divide that stand into separate areas to sample. In other words, recognize the natural or pre-existing variation in the stand that may be causing differences in the understory vegetation regardless of what treatment you apply or when you sample.

Second, collect the best quality and most specific data possible. For example, if you need to quantify species richness, then you will have to be able to identify species (or have them identified by someone else after you collect them and assign your own specific codes to them). It will be especially important to be able to accurately identify non-native species. If you are going to quantify species cover then you must learn to accurately and consistently estimate cover.

Creating a set of data sheet for all of the indicators to be sampled will help you collect good data. Taking copies of the data sheets on a clipboard into the field will make recording and storing data easier.

No multiparty monitoring program will have the funding to measure everything, so your selection of what and how to monitor should balance your monitoring needs and the available resources to get data that is scientifically credible. Involving public agencies, non-profit organizations, and people from the general public can help the multiparty monitoring team select what to monitor.

Sampling

Overstory sampling

The overstory traits that can be measured include canopy closure, tree-stem density and tree-stem area, height to tree crown, density of large, old-tree density, snag density, clumps of large and old trees, clumps of young and small trees, and mast-producing plant species. Sampling can be conducted using either a plot method or a transect-based method. In the sampling protocol outlined below, we identify plot-based or a transect-based method for measuring each variable. Before being used in the field, a standard sampling protocol should be designed. Other resources, listed at the end of this section, can help in the design of a sampling protocol.

Plot-based sampling. Plots are circular or square areas laid out at regular distances from one another, every 20 meters for example. Square plots are usually created using stakes and fiberglass tapes. Circular plots are created using a fixed point in the center (e.g., a stake) and extending a rope or tape to a specific length from the stake in all directions to determine the area of the plot. The size of the plot will vary depending on the indicator being sampled. For example, tree density requires a larger plot, for example a 10-by-10 meter square plot, while understory cover requires a smaller plot, a 1-by-1 meter plot, for example. A 12.62-meter-radius circle makes a .05 hectare plot.

Transect-based sampling. For transect-based sampling, points are located at specific distances along a transect. Sampling is then done at the point itself. The point-centered-quarter method is a transect-based sampling approach. It requires imagining a line perpendicular to the transect, thus forming a cross with four quarters. In each of the four quarters, the nearest tree to the transect point is chosen. For each tree sampled, the distance from the point to the tree is recorded. The diameter of the tree at breast height of the tree can also be measured. Diameter can be used to construct size class distributions. Diameter at breast height can also be converted into basal area, a useful measure for describing the tree stand. Sampling points must be spaced along the transect such that individual trees are not recorded twice. Small plots, one meter square for example, can also be located at regular intervals along a transect. Recommended sampling approaches are based on efficiency and ease of measurement.

Measures of the following indicators can be sampled in plot-based sampling.

Tree stem density and tree stem area
Height to tree crown
Surface fuels cover and depth
Density of old and larger trees, both living and dead
Understory native plant richness [1 square meter subplots]
Understory native plant frequency [1 square meter subplots]

The following indicators can be sampled in point-based sampling along transects:

Percent canopy closure
Tree-stem density, using the point-centered-quarter method
Tree-stem area, using the point-centered-quarter method
Height to tree crown, using point-center-quarter method
Surface-fuels cover and depth
Density of old and larger trees, both living and dead, using point-center-quarter method
Understory native plant-species richness and cover [1 square meter subplots]
Understory non-native plant-species richness and cover [1 square meter subplots]

The clumpiness of trees is an indicator that provides useful information about wildlife habitat and other ecological features. It is not, however, as simple a measure as some of the others described here and interpretation would probably require assistance from a specialist. One approach would be to analyze the variability in spacing between trees. The data would already be collected when sampling for density using the point-center-quarter method. Similar distances between trees on average, or low variability, would mean a spatially more homogenous forest. Dissimilar distances between trees on average, or high variability, would mean a clumpy stand.

The spatial distribution of openings in the canopy, such as meadows, can also be sampled using transects, but this involves more intensive sampling. This method requires a fairly large grid sample, with many transects and points. At each point, the observer records whether there is meadow or forest onto a map. If the points are dense enough, then the boundary of meadows can be demarcated on the map. Further information on this kind of method can be found in *Landscape Ecology*, by Forman and Godron (1986).

Equipment needed for overstory sampling

Compass
Meter tape or metric loggers tape
Metal stake or rebar to fix at center point or ends of transects
Diameter at breast height measuring tape
Data sheets
Tools for data collection (electronic or paper)
Increment borer [optional]

Understory Sampling

Locations of one-square-meter plots located along transects for sampling understory plants can be used with other sampling approaches, such as the transect method. The following Web site gives examples: http://www.nrel.colostate.edu/projects/stohlgren/stohlgrensamplingmw.html

First, record the species name and aerial cover (as a percent of the whole plot) for each understory plant that is rooted within the 1 square meter subplot. Aerial cover is a measure of the amount of ground shaded by the entire plants, including leaves and stems. Then estimate the total aerial cover of that species in the plot. Record whether the plant is native or non-native.

Aerial cover can be estimated in several different ways:

Clumped and matted species: Start by training your eye to recognize 1% cover (a 10 cm x 10 cm portion of a 100 cm x 100 cm [1 x 1 meter] subplot - roughly the size of a person's palm). Once you can visually recognize a 1% area (and you can use your palm as a guide by holding it over different species) you can count the cover of a species in 1% increments as you gaze over the whole plot. This method works best for species that tend to grow in clumps or mats and take up a larger proportion of the plot.

Scattered plants that do not form a dense cover: For plants with very sparse growth forms, aerial cover needs to be imagined by bunching the plant parts together in your mind. For example, imagine pushing all the blue grama grass together and measuring how much of the plot it would take up. This method works well for plants that do not form a dense cover and with individuals that are scattered throughout the plot.

These methods for estimating understory vegetation cover can also be used to measure bare ground (e.g., for soil erosion potential) and surface litter (e.g., for understory fuel quantification, and measures of fuel depth and type may be collected in addition to the cover value).

The following webpage also has useful tips for making a sampling design to measure understory plants: http://www.nrel.colostate.edu/projects/stohlgren/stohlgrensamplingmwnotes.html#Tips

Equipment for understory sampling

Compass (for sighting a straight transect and describing how to relocate that transect in the future)
Appropriate tapes (e.g., 100 m for transects or smaller for circular plots)
Subplot frame (1 m x 1 m; can be constructed from PVC, meter sticks, or even marked cord with stakes to anchor the corners)
Tools for plant identification (hand lens, field guides)
Tools for plant collection, labeling, and pressing (digging tool, ziplock bags, labels, plant press)
Data sheets
Tools for data collection (electronic or paper)
GPS unit and digital (or regular) camera

Wildlife Sampling

Wildlife monitoring by multiparty assessment groups should focus on indirect or observational methods to monitor restoration effects on wildlife. Following is a description of measures for the wildlife indicators discussed in this text.

Bird point counts

Birds should be sampled at counting stations (also called points) that have been systematically placed within treated and untreated areas. A minimum of 30 stations should be sampled within each area. Stations should be spaced at least 200 meters apart to minimize the chance of recording the same bird at multiple points. An efficient way of placing count stations is to array them along randomly placed transects. The location of the first station would be a random distance (between 50 and 200 m) along the transect, with subsequent points spaced at equal intervals. These wildlife-sampling stations may coincide with vegetation sample plots.

Stations can be marked in a number of ways. One suggestion is to nail cattle ear tags to trees with a number or code identifying that station written on the tag. The tags are bright (usually red or yellow) and are easily found. Flagging could be used to mark the path from one point to the next. Randomization will minimize potential for bias in placement of sampling stations. Stations should be no closer than 100 m from the area boundary to minimize edge effects.

Each station should be sampled 3 times during the breeding and 5 times during the non-breeding season to account for changes in bird behavior and delectability within the season. More visits are needed in the non-breeding season because birds are more patchily distributed, often found in flocks of one or more species. Observers should count birds at 10-15 stations each day.

Counts should start within ½ hour after sunrise, and be completed no later than 4 hours after sunrise. If possible, have a different person count each station on repeat visits to help mask observer-based bias. Upon reaching a station, observers should wait 1-2 minutes to orient themselves, get data sheets ready, and to allow birds to return to "normal" activities after being disturbed by the person(s) walking to the station. Thereafter, observers should record the species, age, sex, and mode of detection (song, call, visual, other) of all birds seen or heard within a 50-m radius of the station. (To help estimate distance from the counting station, place flagging tape, a different color from that used to mark transects, 50 m from the counting station.) The information should be recorded at 5-minute intervals. .

All observers must go though training to ensure that they have the skills and physical capability of doing this work. Local chapters of the Audubon Society may be able to provide volunteers and training.

Strip transects for sampling wildlife sign

Mark the transect connecting count stations using a rope. This can be done at 50-m intervals. Walk along the transect or rope with a meter stick. When you encounter wildlife signs (deer, elk, rabbit pellets; rodent burrow; squirrel cone; squirrel midden, etc) verify that it is within 1 meter of the transect. Sign that occurs in groups (e.g., pellets) should be lumped as one observation. Keep a tally of all sign found within the belt transect.

Equipment needed for wildlife sampling

Compass
Meter tape or metric loggers tape
Metal stake or rebar to fix at center point or ends of transects
Flagging
Cattle ear tags
Rope
Meter stick
Aluminum nails
Binoculars
Field guide
Data sheets
Clipboard
Tools for data collection (electronic or paper)
Reference guide (pictures, drawing, descriptions

Soil Conditions Sampling

Soil erosion

Measurements should be taken in treated areas and also in untreated, control sites. Percent surface bare soil can be sampled in one meter square plots at intervals along transects, at the same time that understory plant measurements are taken. As noted previously, percent of bare soil can be used as an indicator of soil erosion.

More direct methods of measuring soil erosion require more effort, and will only work for projects areas that include a small basin or are located at the head (top) of a basin. The method of measuring soil erosion described here involves measuring sediment yield in small watersheds as it collects behind small check dams. Measurements should be taken in treated areas and also in untreated, control sites. Multiple sub-basins can be identified, both within and outside of the treatment area, to provide ample choice of replicating sub-basins along similar aspect with similar soils and duplicating the location characteristics in the adjacent watershed, or control.

Each micro-watershed should be delineated using pin flags from the ridge down to an outlet with visible drainage topography or gully system. Each micro-watershed can vary in area, but should be approximately less than or equal to 0.1 acres. A checkdam must be constructed at each outlet to trap sediment.

Sampling procedure: Begin at a point in the watershed that facilitates sampling all sediment traps in a reasonable time frame.

1. (1) Record any observations that you see (i.e. unusual, extreme, no change from last time).
2. (2) Take pictures (i.e. sediment in trap, rill/interrill erosion, gully, new channels).
3. (3) If check dam is overtopped, measure the height of the high water mark in centimeters above spillway (usually indicated by a fine line of sediment adhered to silt fence).
4. (4) Excavate all sediment into buckets, sweeping up the final sediment from the collecting basin fabric floor.
5. (5) Record total sediment volume to nearest 0.1 liter.
6. (6) Examine sediment trap, make any necessary repairs, improvements-document these on field form under comments.

(Modified from Hastings, B. 2002.)

Soil compaction

Soil compaction can be measured by using devices called penetrometers. Each devise comes with a set of direction on its use. Read these instructions before beginning sampling. The soil compaction tester is used at a series of sample points along a transect line. The soil should not be rocky or difficult to penetrate. It is best if the soil is about the same level of moistness down to about 10 inches. Establish a transect line with the 50 meter tape and secure both ends with metal stakes. At 5 meter intervals along the tape, test soil compaction one meter away from the tape in a perpendicular line. All sampled points should be on the same side of the tape. There will be 10 soil compaction sample points for each transect. Establish 3 to 5 transects.

Equipment for sampling soils

Increment borer [optional]
Meter tape or metric loggers tape
Metal stake or pin to fix at center point or ends of transects
Diameter tape
Data sheet, pencils
10 liter bucket
1 liter bucket, graduated to tenths of liters
Dust pan and hand broom
Nalgene plastic beakers (small and large)
Measure stick
Penetrometer

Watershed Values Sampling

Riparian community health

Photographs of the riparian community taken at permanent points before treatments and at intervals after treatments can give a visual impression of well the ecosystem is doing. The method for repeat photography can also be used for a visual assessment of overstory, understory, and soil erosion in the ponderosa pine forest. Photos should be taken before and immediately after treatments, and at intervals in time after restoration work. They can be easily be taken at the same time that other sampling is done. Repeat photographs are not only valuable, but are one of the easiest and fastest methods of monitoring.

Repeat photographs are taken of a forest scene from the same place at intervals in time -- from a permanently marked point, at a rebar stake for example, and looking in exactly the same direction. Film that is specifically for low light conditions may work best. Record the place and time of each photograph. Ensure correct identification of the site by including a card with the ID number in the photo. Notes on each permanent point can be helpful later, for example, whether grazing animals were seen, time of day, and so on. Archiving of photographs should be done with care. A loose-leaf notebook, with plastic sleeves for photo prints, can be used to store the photographs.

Collecting ecological data: How often and how long?

The frequency of monitoring (how often the treated and control sites should be measured) and the duration of monitoring (how many years measurements should continue) may vary depending on the important questions and funding available for monitoring in any particular project. At a minimum, multiparty assessments groups should monitor:

1. before treatment,
2. shortly after treatment completion, and
3. 3-5 years after treatments. Photographs and historical data will provide an excellent reference for longer-term assessment.

As the first step of monitoring, baselines conditions must be documented. . These types of data allow comparison of before and after variables. Without baseline data, it is impossible to understand the changes in the forest that result from restoration.

Vegetation probably does not need to be measured more than once per year, unless specific variables require multiple or different seasons. Whenever possible, vegetation measurements should taken in the same season each year. The best estimates of *herbaceous vegetation* (non-woody plants, e.g., grasses and forbs) will be made toward the end of the growing season, in August and September. At a minimum, herbaceous vegetation should be measured before and after the treatments and again after a few years.

The immediate post-treatment environment is not a good basis for assessing the ecological results of the project. The impacts of delayed tree mortality, plant succession, scorch, soil disturbance, and invasive plants cannot be evaluated until at least a few years pass. This uncertainty should be built into the project's monitoring / evaluation plan.

Analyzing collected data

Once ecological monitoring has produced a set of information from before and after the restoration treatments, this information will need to be analyzed and interpreted to provide insight into the changes in the ecosystem that treatments have produced. Some information, such as a series of photographs taken over time in the project area, can be compared fairly easily by visual comparison. Other information, such as numerical data on changes in canopy cover or density of trees, must be compared more carefully. Local colleges and universities, county extension agents, USDA-Forest Service ranger stations, and other natural resource managers may be able to provide useful assistance in understanding how to interpret the data collected for ecological monitoring.

One approach to interpreting monitoring data is to establish targets before the implementation of the restoration project. Such targets must be built into the project from the beginning. Ecological monitoring data can then be used to see if the target has been achieved. Using target values or a range of values is helpful because it is clear when a target has been met. We may not know if in the long run restoration will achieve success, but we can know if we have begun to move forest conditions in the right direction.

The data from ecological monitoring should be summarized and analyzed at regular intervals, every year at least. This way, any problem that arises from the monitoring can be addressed right away and changes to current management activities can be adapted to remedy trends. Multiparty monitoring groups often learn to know the forest and the restoration project very well, and may stay interested and involved in the forest area far longer than agency personnel and researchers. Good records will help keep information available to community members.

Managing ecological data

If the records of data collected in monitoring are carefully kept, they can be useful long after the restoration project is complete. Data from notes taken in the field should be transferred to a clean copy soon after the sampling is done. Copies should then be made of all records and a set of the copied data stored separately. Information kept on computers should be copied onto disk or CDs and stored separately. A paper copy of all data that resides on computers should also be stored separately. Loose-leaf notebooks are good places to keep a complete record of all information and photographs from the project.

Monitoring information is chiefly useful to the people who are contributing to an managing the restoration project, by helping them to understand the forest changes resulting from treatments and informing them that the restoration treatments may need to be adjusted. But some types of ecological variables, such as the forest conditions that support cool ground fires, are best monitored at a regional scale, for example, across the Southwest. For this and other large-scale variables, it would be helpful to archive the monitoring data in a permanent storage site, for future analysis of ecological change in the region.

Data storage and archiving

A commitment to using the finding of monitoring efforts is an essential part of restoration monitoring. Once the data are collected, they should be used to determine future management activity. For example, if thinning in moist areas with a high non-native species component results in an increase in that non-native species, then more control efforts may need to be focused in those types of areas before and after thinning. This last commitment also includes maintaining the ability to relocate plots for future sampling.

Likewise, a commitment to data management and careful storage and archiving of monitoring findings is an essential part of restoration monitoring. Data sheets should be carefully labeled and placed in notebooks. Electronic data, including electronic spreadsheets, can be archived with local professional resource managers, such as the USDA-Forest Service.

Resources

In creating a monitoring program, community members should consult with local professional resource managers such as County Extension Agents, non-profit groups such as The Nature Conservancy or the Audubon Society, the academic community at local colleges or universities, and the literature cited below. For example, these resources can suggest minimum data sets that should be collected, advice on laying out the sampling design, and advice on the analysis of the data collected.