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Forest Structure and Landscape Patterns in the Subalpine Lodgepole Pine Type: A Procedure for Quantifying Past and Present Conditions

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INTRODUCTION

In the lodgepole pine/subalpine fir forests of the Northern Rocky Mountains, fires and mountain pine beetle outbreaks have recurred for thousands of years. Each disturbance began a new cycle of succession and new landscape patterns (Lotan and others 1985). Recently, National Forest managers have attempted to assess the effects of fire suppression and logging on landscape patterns and wildlife habitat in these forests. Lodgepole pine forests have experienced a diverse history of disturbance, and succession has occurred over different time scales (Arno 1980; Barrett and others 1991; Hawkes 1979; Romme and Despain 1989; Tande 1979). Thus, site-specific information is necessary to describe landscape patterns and change. Preliminary maps of stand mosaics can be prepared from aerial photographs. However, field inspections and inventories are needed to refine these maps and to accurately characterize a stand's structure and its history of disturbance.

We have developed a method for documenting forest structure and landscape patterns. To test the method, we conducted a pilot study of a 500-acre tract of lodgepole pine/subalpine fir forest on a broad, subalpine ridge in the Bitterroot National Forest southwest of Hamilton, MT. We used this experience to develop a procedure for quantifying forest structure and landscape patterns—both past and present—in other subalpine lodgepole pine forests. Along with the proposed sampling procedure, we offer suggestions for analyzing and interpreting data. We began with the procedures presented in Arno and Sneck (1977) and Barrett and Arno (1988), refining and expanding them to characterize the landscape mosaic quantitatively. A three- to four-person crew spent 5 days sampling during our pilot study. We laid out a grid of transects, systematically sampling 35 different 0.1-acre plots spaced 800 feet apart. The data revealed a surprisingly complex mosaic of forests stands linked to disturbance history as well as a pronounced successional advance toward climax forest conditions during this century.

RECOMMENDED FIELD METHODS

This technique is best suited to continuously forested areas from about 500 to 2,000 acres in size, with moderate, rather than steep and broken, terrain. If landscape patterns are being defined over larger areas, this technique might be used to sample representative portions of the areas. The technique was designed for and tested in the subalpine lodgepole pine zone, although it might be useful in some other disturbance-related (seral) forest types. Often, aerial photographs are used to look for mosaic patterns based on the structure of forest stands. But if moderate-intensity fires have occurred, the stand mosaic is probably more intricate than it might appear from the photographs. Timber type maps or other stand maps may also give a general overview of the most obvious stand mosaic patterns in the area. A 4-inch-per-mile topographic map (such as a 150 percent photocopier enlargement from a 7-1/2 minute U.S. Geological Survey quadrangle) is convenient for delineating the study area.

The next step is to determine the distance between plots, and the corresponding number of plots. We recommend setting up a grid in which the distance between plots along a transect is the same as the distance between transects (fig. 1). The plot grid should be fine enough to allow mapping at the desired level of resolution. Plot spacings between 500 and 1,000 feet will probably be appropriate for characterizing stand mosaic patterns. A grid should contain at least 35 to 40 plots to depict and quantify a landscape mosaic for a small area. To determine a useful spacing for the systematic grid, divide the total area by a proposed number of plots. This will indicate the number of acres represented by each plot. For example, 500 acres divided by 34 plots equals 14.7 acres/plot, which corresponds to a square spacing of 800 feet—the square

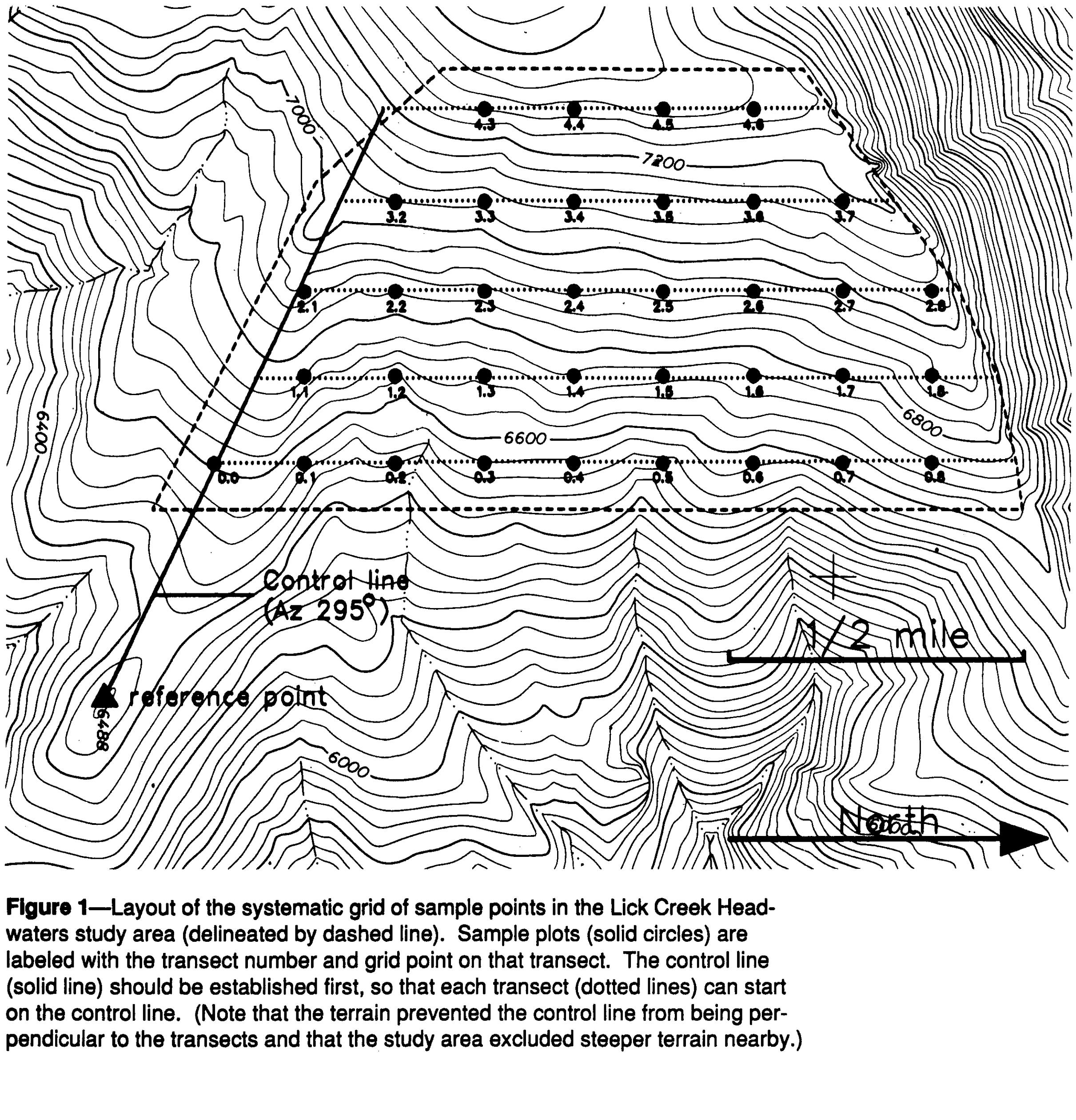

Figure 1—Layout of the systematic grid of sample points in the Lick Creek Headwaters study area (delineated by dashed line). Sample plots (solid circles) are labeled with the transect number and grid point on that transect. The control line (solid line) should be established first, so that each transect (dotted lines) can start on the control line. (Note that the terrain prevented the control line from being perpendicular to the transects and that the study area excluded steeper terrain nearby.)

root of the quantity 14.7 acres times 43,560 square feet per acre. On a 4-inch-per-mile base map this ground distance is represented by 0.61-inch map distance (800 feet/5,280 feet/mile x 4 inches/mile = 0.61 inch). A three- to-four-person crew will take about an hour to sample each plot, including the time to lay out the transect to the next plot.

When the proposed number and spacing of plots has been selected, the plot grid can be overlaid on the study area base map (see fig. 1). The plot locations are found by measuring the predetermined distances between plots. Accurate information on stand boundaries is gathered by recording the points on each transect where stand boundaries are crossed. Transects can be laid along the topographic contours so the sample points are at roughly the same elevation. The study area's shape and topography will influence the grid's design and position. The actual number of plots may differ slightly from the proposed number.

Laying Out a Grid

The procedure for establishing a grid of sample points is similar to that used in the line-plot method of timber cruising (see Dilworth 1989 or Society of American Foresters 1984). An important difference for this procedure is that the location of each sample point must be determined and mapped by reference to a landmark near the area to be sampled.

Begin by locating a geographic feature that can be located both on a map and on the ground, such as a rock outcrop, road junction, or section corner (fig. 1). On the map, draw a primary control line starting at this reference point. If possible, run this line perpendicular to the desired transect orientation. Systematically draw the transect lines (secondary control lines in a line-plot timber cruise) at the predetermined horizontal distance between transects. For uniform sampling coverage, locate the first transect line one-half the distance between transects inside the study area boundary. Each succeeding transect is drawn parallel to the first at the prescribed distance until the sample area is fully covered.

Next, draw markers on the map indicating sample point locations. Locate the first plot at the intersection of the control line and the first transect, provided this plot falls within the study area. Locate each successive plot on the transect at the predetermined distance, the same as the distance between transects. After you have located all the plots, you will have drawn an aligned grid (fig. 1).

Figure 1 shows a grid layout that runs along the contours of an east-facing watershed. In this case, an east-west control line could not be established perpendicular to the transects due to the steep, broken terrain, and the lack of reference points. Instead, the control line was started at the monument on peak 6488 and drawn along the ridge near the study area's southern boundary. The resulting line had a map-measured true azimuth of 295 degrees, forming an angle of 65 degrees with the north-south transect lines. The prescribed transect interval was 800 feet, so the distance between transects along the control line was 800 feet divided by the sine of 65 degrees (0.906), or 883 feet. The corresponding map distance is 0.69 inch on a 4-inch-per-mile map.

When you are working in the field, you can use a compass, clinometer, and 300-foot surveyor's tape to measure from the reference point to the intersection of the control line and the first transect. All measurements and calculations are for horizontal distance, so take care to hold the tape horizontal or to correct for slope while taping by using a table of slope correction factors or a similar method. Establish the entire control line, placing a wire flag at the start of each transect (every 883 feet in fig. 1). Write the transect number on the flag with a permanent marker. Sample the first plot at the intersection of the control line and the first transect (fig. 1). After sampling this plot, continue measuring along the first transect to successive predetermined sample points.

Sample succeeding transects in the same manner. However, unless the control line is perpendicular to the transects, you will need to determine the distance from the flag at the start of the transect to the location of the first plot. To make the calculation in the example (fig. 1), determine the distance traveled north by dividing 800 feet by the tangent of 65 degrees (2.145) to get 373 feet. That is, in traveling 883 feet at an azimuth of 295 degrees, you moved 373 feet north. Therefore, you only need to travel 800 – 373 or 427 feet to arrive at the first plot north of the flag on the second transect. Depending on the shape of the area, plots might be located on both sides of the control line. By the fourth transect you will have traveled 373 x 4 or 1,119 feet north of the first plot established. Since you will now be north of the second plot of the grid, the distance to the next plot on the transect is 1,600 – 1,119 or 481 feet.

Plot Sampling Procedure

At each predetermined point, place a wire flag in the ground, labeled with the transect and plot number. This flag will be the center of the 0.1-acre circular plot (37.2-foot radius). Use an inventory form (appendix B) to record site characteristics, including elevation, aspect, and percent slope. Examine the vegetation in the plot and determine the habitat type and phase in the applicable classification—in Montana, Pfister and others (1977).

Tally all living trees in the plot by species and diameter-size classes (appendix B). The plot can be tallied in pie-shaped segments using 37.2-foot cables or ropes staked at the plot's center, extending out like spokes on a wheel.

Examine the plot for evidence of the previous stand. Describe any previous overstory layer that is now dead, listing the major species and the diameter of these trees. Try to determine whether this layer was the dominant overstory, or was scattered. This former overstory may be standing or lying on the forest floor. Try to determine why and roughly when the overstory trees died. For example, lodgepole pine stands often have a major component of large lodgepole or whitebark pine trees that were killed by beetles in the early 1900's. You may find galleries where the beetles lived etched in the trunks of dead trees. Or you may find evidence of a fire intense enough to destroy the stand. The previous stand may still be evident as dead trees, either down or standing. The dead trees may have remnants of charred bark, but the wood itself will not be charred. Other stands may have arisen after a double burn, which consumed most remnants of the previous stand; still, you should be able to find charred stumps from the trees killed by the first burn. Note how this information is recorded in appendix B.

Record fire history evidence in and adjacent to the plot. For instance, identify trees with single, double, or multiple fire scars, and determine the best scars to sample by cutting out a section with a saw, as described in Arno and Sneck (1977). You should saw fire scar sections while sampling plots, for greatest efficiency and to aid field interpretation.

We have found that a light-weight 2.7-cubic-inch chain saw with a 16-inch bar (weight 12 pounds without fuel) is usually adequate for fire scar sampling in most lodgepole pine stands. A 3.5-cubic-inch saw with a 20-inch bar is usually adequate for sectioning larger fire-scarred trees, such as Douglas-fir. Where sawing is not allowed, increment borers can be used to sample fire scars (Barrett and Arno 1988), although this method is less precise and takes more time.

The final step in sampling is to obtain accurate age-class data to characterize stand structure. For example, lodgepole pine forests generally have even-aged classes of the shade-intolerant (seral) species—lodgepole pine, western larch, and perhaps whitebark pine. These species usually became established soon after fires. In contrast, shade-tolerant species such as spruce, subalpine fir, and interior Douglas-fir, regenerate successfully without disturbances such as fires. Accurately identifying the age-classes of seral species helps determine the influence past fires have had on forest composition and stand structure. If the stand has living trees with single fire scars and the fire was severe enough to kill some trees and open the stand, the stand should have a postfire age class along with one or more age classes of the fire's survivors. If the stand does not have living fire-scarred trees, there is likely to be just one age class of seral trees—the class that began growing after the last stand-replacement fire.

To learn the stand's fire history, use an increment borer to age four to six seral trees representing the old, or fire-scarred, generation. Similarly, sample a few seral dominant trees that appear to be from the postfire generation. In each case, bore the tree within a foot of ground line. You need to continue boring until you obtain a sample that intersects or passes very near the pith. Large trees can be bored higher on the bole, if necessary to avoid rot; then a correction factor must be developed to account for the years the tree took to grow to the height at which the core was taken. These and other age-class sampling procedures are described in more detail in Barrett and Arno (1988).

Make a preliminary growth-ring count of all sample trees while you are in the field so you will know when you have adequately sampled all age-classes. You may find individual rings difficult to distinguish during slow-growth periods. Wetting the core with water and using a 10-power hand lens when reading it may help. Some segments with extremely slow growth, where rings are close together, may have to be sliced with a single-edged razor blade before you can read them.

Five or more seral trees with similar ages constitute good evidence of a disturbance-induced regeneration age class. Data from nearby plots can help confirm age classes. If fire records are unavailable, or fire scars are not found, the establishment date of the oldest tree in a fire-initiated age class provides the best indicator of the fire year. Even so, the fire may have occurred several years earlier.

A few borings should be taken from the largest shade-tolerant trees in the plot (for example, spruce or subalpine fir) to augment the information on age-class structure. Spruce occasionally survive light fires. Subalpine fir seldom do unless they were in a patch of unburned trees. Large Douglas-firs often survive fires and have healed-over fire scars as evidence (Arno and Sneck 1977; Barrett and Arno 1988).

Since field counts are imprecise, you should label and store the cores in straws or mount them in grooved boards so you can make the final determinations of age in the office or laboratory (Barrett and Arno 1988). When measuring along the transect to the next plot, record the boundary of habitat-type changes and stand-type changes. In most cases, you will sample the newly encountered stand type at the next plot.

DATA SYNTHESIS

Our method allows a landscape mosaic grid to be developed. Each grid point is a mosaic element, helping to define the stand's history of disturbance, and its composition and structure. The data can be used to reconstruct presettlement stand conditions, allowing the current landscape to be compared with a primeval landscape.

After you have collected the field data and determined tree ages, record the disturbance history at each sample plot, using the data form in appendix C. Use the fire scar dates and age classes of seral trees (lodgepole pine in this case) to characterize the stand history in each plot. Additional disturbances that did not result in seral age classes, such as underburns or beetle epidemics, should also be recorded.

The tree diameter data associated with each age class indicate the presence and abundance of a given age class in each sample plot. You should try to link each age class to a diameter class at each plot. Sometimes diameters associated with two different age classes overlap. Trees in the older age class will often have a visible fire scar or crown form typical of older (overmature) trees. In sample plots where such overlaps are a serious problem, you can use fire scars, crown form, or even increment borings from individual trees to determine the age class of each seral tree in the sample plot. Some stands may not have enough evidence to date fires or other major disturbances—for example see figure 2, third sample from the left in the lower row. In other stands, several minor disturbances may have given rise to mixed age classes—for example, figure 2, lower right sample.

For each sample plot, the age-class structure of the seral stand components can be described for the current stand and also estimated for the stand as it existed in the past. In this study we used 1900 as a comparison year. We felt that it would have been difficult to speculate about stand conditions before then, and that 1900 was early enough to represent an essentially unmanaged landscape. In other study areas, a different comparison year might be chosen. We noted the presence in the two time periods of any structural classes of seral tree species, represented as seedlings, saplings, poles, mature or overmature trees, based on their ages. The age class criteria we used are listed in figure 3; modifications might be needed for other sites.

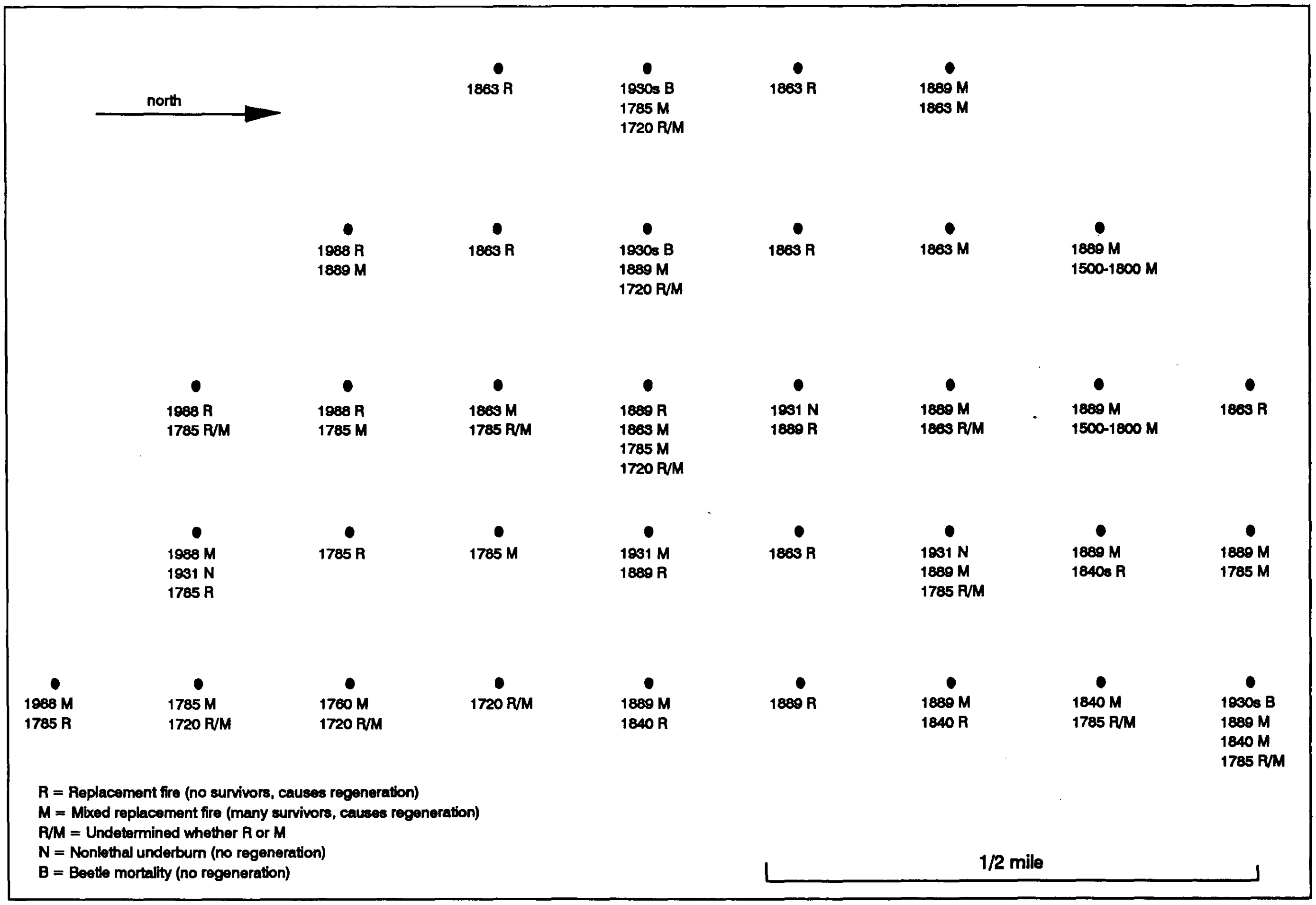

Figure 2—Disturbance history at each sample plot in the Lick Creek Headwaters study area.

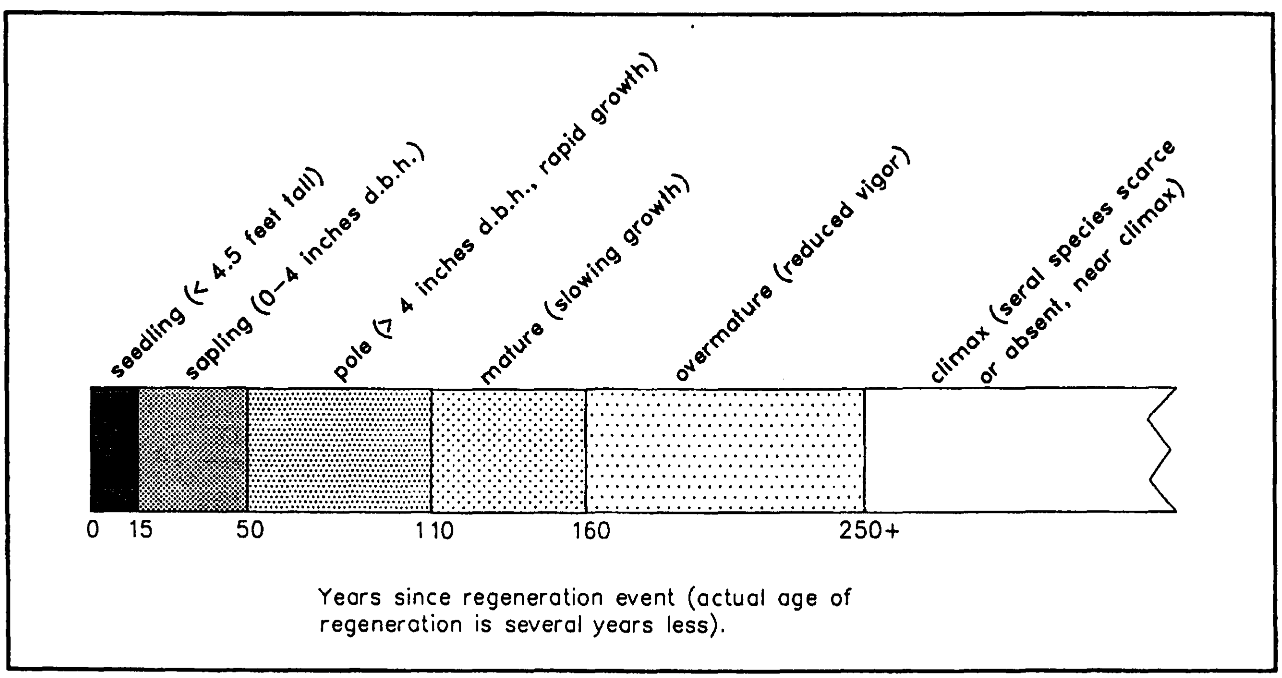

Figure 3—Definitions of structural classes of seral species used in the Lick Creek Headwaters study area.

The species composition at each sample plot should be described for the two time periods. For example, we classified the stands in our study area as either primarily (1) lodgepole pine, (2) whitebark pine, (3) subalpine fir, or (4) mixed, not dominated by a single species. A stand was considered primarily lodgepole pine, for instance, if lodgepole made up more than 50 percent of the stand basal area. Other categories might be useful for other sites. For the historic stands, we estimated stand composition based on a general assessment of current diameter distributions and the growth rates that produced them, along with evidence of dead trees by species.

A stand map can be produced by starting with structural stand types identifiable on aerial photographs. Often in National Forest lands a timber type map based on interpretation of aerial photography is already available. This map can be refined by adding the stand structure and boundary information gathered in the field.

Stand structure and species composition in the two time periods can be compared by summarizing each stand type's percent coverage of the landscape.

PILOT STUDY AREA

To test our methodology we applied it to a 500-acre study area within the 1,500-acre lodgepole pine/ subalpine fir forest at the headwaters of Lick Creek, on the Bitterroot National Forest southwest of Hamilton, MT. This study area spans a broad and rather uniform (15 to 30 percent inclination) east-facing slope between elevations of 6,500 and 7,500 feet. Habitat types (Pfister and others 1977) are primarily *Abies lasiocarpa / Xerophyllum tenax* (both *Vaccinium globulare* and *V. scoparium* phases) in the lower elevations, and *Abies lasiocarpa / Luzula hitchcockii*, *V. scoparium* phase at upper elevations. A few sample points fell in the *Abies lasiocarpa-Pinus albicaulis / V. scoparium* habitat type, and one in *Abies lasiocarpa / Menziesia ferruginea*. No timber harvesting has occurred in the study area. In 1988 a portion of the area was burned by the Rock Creek wildfire. This man-caused fire was suppressed, but otherwise probably would have burned through the entire study area, based on the behavior of this fire and others nearby in 1988.

PILOT STUDY RESULTS

The disturbance history at the Lick Creek Headwaters study area is shown in figure 2. The history is synthesized in figure 4 and table 1. Fires burned a substantial portion of the study area in 1720, 1785, 1863, and 1889. The intervals between these major fires ranged from 26 to 78 years, but it has been 102 years since the last major fire in 1889. The interval would have been 99 years if the man-caused fire in 1988 had not been suppressed.

Most fires differed in severity from one sample point to another, giving rise to a complex mosaic of single-aged and multiple-aged stands. Figure 5 illustrates this mosaic in the two time periods. A typical fire history study (Arno and Sneck 1977) would probably not depict fire activity and postfire succession on such a small scale.

In 1900 an estimated 77 percent of the study area was dominated by lodgepole pine (table 2). By 1987, nearly a century after the area's last major disturbance, lodgepole covered just 51 percent. Coverage of lodgepole pine stands evidently will increase to 57 percent of the area after the stands burned in 1988 regenerate. The coverage of stands dominated by subalpine fir almost doubled between 1900 and 1991. In 1900, 14 percent of the stands were dominated by whitebark pine; whitebark pine dominated none of the stands in 1991. Mixed composition stands covered none of the area in 1900, but covered 26 percent in 1991.

Table 3 shows the transitions in species composition in more detail. For example, the first row of the table shows transitions for plots dominated by lodgepole pine in the year 1900. In 1991, 74 percent of these plots continued to be dominated by lodgepole, 22 percent had converted to mixed species, and 4 percent had converted to subalpine fir. All of the plots that were dominated by subalpine fir remained in that category. The first column for lodgepole pine in 1991 indicates the lack of disturbances that could have converted other stands into lodgepole stands. No stands that were previously whitebark pine or subalpine fir were converted to lodgepole pine. The column of zeros for whitebark pine in 1991 shows that stands dominated by this species were no longer found in the study area.

An even more striking indicator of the change from seral to climax species is the decrease in younger components of seral species between 1900 and 1991 (tables 4 and 5). Aside from the sample points burned in the 1988 Rock Creek fire, no stands currently have lodgepole pine seedling or sapling components. In 1900 seedling and sapling stages were well represented. In 1900, 72 percent of the study area had immature age classes of lodgepole pine (seedlings, saplings, and poles); by 1991 just 57 percent did.

Table 6 examines the transitions in stand structure. The relatively large number of zeros below the diagonal line of the table reflects the lack of disturbance over the period.

The extent of stands with significant cone-bearing whitebark pine (defined as trees >6 inches d.b.h.) was also estimated for 1900 and 1991. Whitebark pine's nutlike seeds are important for wildlife. We considered more than 20 percent of stand basal area to indicate a significant level of abundance. Although

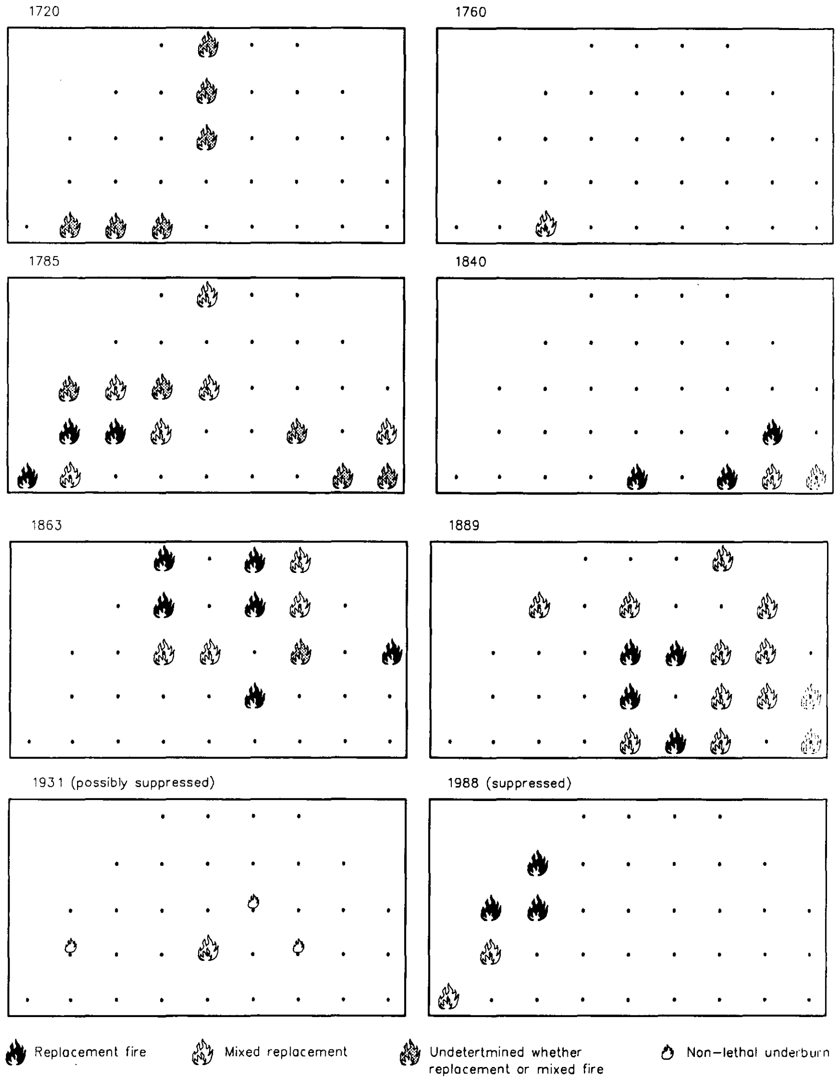

Figure 4—Spatial occurrence and severity of past fires in the Lick Creek Headwaters study area. Each dot corresponds to a sample plot.

Table 1—Extent and severity of past fires in the Lick Creek Headwaters study area. In some cases, replacement fires cannot be distinguished from mixed fires

		Fire severity[2]			
Fire year	**Extent of fire[1]**	**R**	**M**	**R/M**	**N**
1720	6/6			100	
1760	1/6		100		
[3]1785	14/17	[4]21	43	36	
1840	5/20	60	40		
1863	11/29	55	36	9	
[3]1889	16/35	25	75		
1931	4/35		25		75
[3]1988	[5]5/35	60	40		

[1]Number of plots on which a fire was detected over the number of plots where fire records extended back that far.

[2]Fire severity classes: R = replacement fire (no survivors, causes regeneration); M = mixed (many survivors, causes regeneration); R/M = undetermined whether replacement or mixed; N = non-lethal (nearly all trees survive, no regeneration).

[3]Major regional fire year.

[4]Percent of burned plots.

[5]The 1988 Rock Creek fire was suppressed within the southern edge of the study area.

Table 2—Stand composition of the study area in 1900 and 1991, based on species basal area. Sample plots were characterized as lodgepole pine if at least 50 percent of the basal area at the sample plot was lodgepole pine, and so on. Values are percent of the sample plots dominated by lodgepole pine, subalpine fir, or whitebark pine, or mixed (not dominated by a single species)

Stand composition	1900	1991
Lodgepole pine	77	57
Subalpine fir	9	17
Whitebark pine	14	0
Mixed species	0	26

Table 3—Transition matrix for species composition changes between 1900 and 1991. Values indicate the percent change from one stand type to another. Stand types are defined as in table 2

	1991			
1900	Lodgepole pine	Whitebark pine	Mixed species	Subalpine fir
Lodgepole pine	74	0	22	4
Whitebark pine	0	0	60	40
Mixed species	—	—	—	—
Subalpine fir	0	0	0	100

Table 4—Percentage of the study area covered by three stand types based on structural age classes of lodgepole pine in 1900 and 1991. Immature stands are limited to stands containing seedlings, saplings or poles; mixed stands contain at least one immature seral age class as well as a mature or overmature component; stands without an immature component have not experienced disturbance within 110 years

Stand type	1900	1991
Immature	49	20
Mixed	23	37
No immature	28	43

it may be possible to confuse individual older dead whitebark pine and lodgepole pine trees, it is possible to determine whether whitebark pine was a major overstory component based on its stoutly branched and forked snags that stand for many decades.

Stands with at least 20 percent basal area of cone-bearing whitebark pine occurred on an estimated 37 percent of the sample plots in 1900. In 1991, whitebark pine was this abundant only on 17 percent of the sample plots. Additionally, the average diameters of overstory whitebark pine were much smaller in 1991 than in 1900. The median diameter of overstory whitebark pine in 1991 was 7 inches. Much of the large-diameter whitebark pine that had been present in 1900 was killed by bark beetles in the 1930's.

Sample data collected on a regular grid lends itself to computation of indices to assess landscape pattern. For example, diversity, dominance and contagion are indices developed from information theory (O'Neill and others 1988; Turner and Ruscher 1988). These three indices were computed for the study area using individual sample points as data, as represented by the grids in figure 5.

Diversity is computed as:

$$-\sum_{k=1}^{m} (P_k) \log (P_k)$$

where P_k is the proportion of the landscape in stand type k, and m is the number of stand types present. Larger values indicate more diversity in the landscape. The largest values result when equal areas are in each stand type.

Table 5—Detailed breakdown of lodgepole pine age class representation in the study area in 1900 and 1991. Values are percentage of the area with a given class. More than one class might be present in any single stand; therefore, totals are greater than 100 percent

Structural age class	1900	1991
Seedlings	43	14
Saplings	29	0
Poles	14	43
Mature	40	49
Overmature	14	40
Lodgepole pine absent	0	6

Table 6—Transition matrix for changes in structure of lodgepole pine between 1900 and 1991. Values indicate the percent change from one stand type to another. Stand structural classes are defined in figure 3

	1991			
1900	Immature	Mixed[1]	Mature	Overmature or absent
Immature	29	29	42	0
Mixed	0	75	25	0
Mature	22	22	0	56
Overmature or absent	0	0	0	100

[1]Mixed stands include both immature and mature age classes.

Dominance is the difference between maximum possible diversity and observed diversity. It is used to indicate the extent to which the landscape is dominated by a stand type. It is computed as:

$$1 - (\text{Diversity}/\log(m))$$

where m is the number of stand types present.

Contagion is computed as:

$$2m \log(m) + \sum_{i=1}^{m} \sum_{j=1}^{m} (Q_{i,j}) \log(Q_{i,j})$$

where $Q_{i,j}$ is the proportion of sample points of stand type i that are adjacent to sample points of stand type j and m is the number of stand types present. Contagion is used as a measure of the extent to which stand types are clumped. Lower values mean that the different stand types are broken up and widely distributed over the landscape, while large values near $2m \log(m)$ mean that stand types are aggregated: a given area, or in this case sample point, is more likely to be near other similar areas than expected if stand types were randomly distributed.

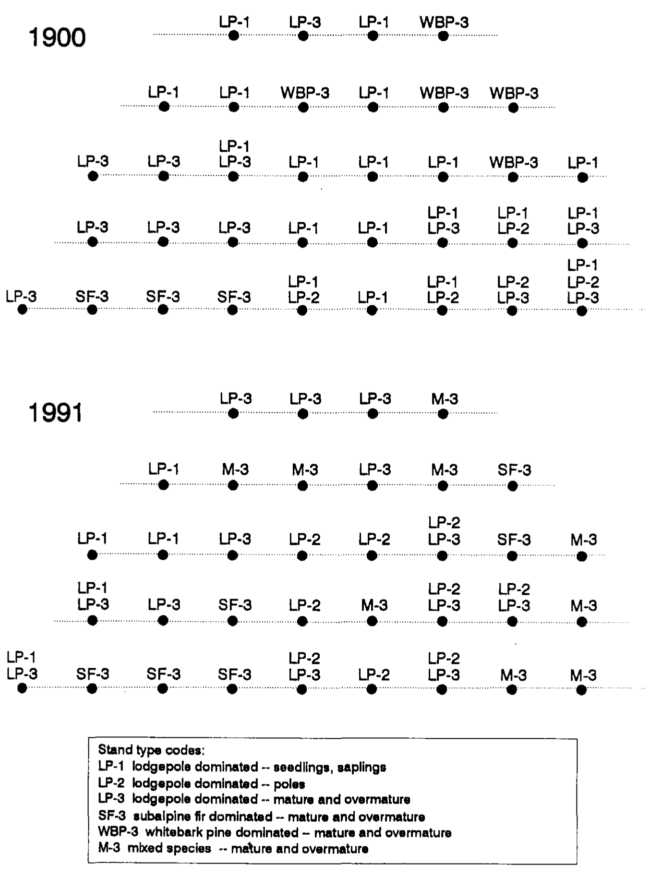

Figure 5—Stand types identified at each sample plot in 1900 and 1991. Mixed species stands (m-3) may include a mixture of lodgepole pine, subalpine fir, whitebark pine, Engelmann spruce, or Douglas-fir. See figure 3 for definitions of structural types.

Table 7—Landscape indices quantifying characteristics of the landscape mosaic in 1900 and 1991, as represented in figure 5

	Diversity	Dominance	Contagion
1900	1.80	0.22	0.85
1991	1.85	.20	.74

Landscape indices for the two time periods are reported in table 7. The sample size was rather small for computing these indices. Ten different stand types are represented in figure 5. Of these, eight were present in 1900, and seven in 1991. If all 10 types were equally represented in a landscape, its index of diversity would be 2.3; if only one type were present, diversity would be 0. The landscapes represented in figure 5 have fairly similar diversity values of 1.80 (1900), and 1.85 (1991). Dominance, which can range from 0 to 1, decreased very slightly over the time period. It was low in both time periods, indicating that the landscape was not dominated by a single stand type. Contagion was also low in both time periods, indicating that the different stand types were not contiguous blocks, but were scattered over the landscape.

These computations were applied to stand type only, and thus address the pattern of the mosaic as a whole, not biodiversity considerations such as overall species richness.

CONCLUSIONS

The data produced and synthesized with these procedures allows detailed comparison of landscape mosaics in the past, the present, and under future management scenarios. Pre-1900 disturbances and the resulting stand structure and composition and landscape mosaic can be compared directly with the current and projected disturbance patterns and the resulting stand attributes. If undesirable conditions and trends are identified, land managers will have quantitative information for better management strategies.

In our pilot study area, for example, pre-1900 fires were relatively frequent but patchy, resulting in a fine-grained mosaic of young and mixed-age lodgepole pine communities with few late-successional stands dominated by fir. Conversely, disturbances have been less frequent and succession has advanced throughout the area since 1900. A manager might use this information and data on forest fuels to consider whether a new pattern of fire frequency and severity is emerging—namely, severe stand-replacing fires occurring at long intervals (Barrett and others 1991). Another trend in this study area is the dramatic decline in overstory whitebark pine, bad news for wildlife species that depend on it.

We feel that the relatively simple procedures outlined here will provide the kind of information useful for evaluating forest landscape patterns and trends. The findings and their interpretations for land management planning will be unique for each area studied.

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APPENDIX A1—TRANSECT LOG FOR USE IN ESTABLISHING CONTROL LINE AND TRANSECTS

DATE:	CREW:
TRANSECT:	STARTING POINT:

TP	Point Description / Comment	Distance and direction to next point					
		Az	Ds	S%	SCF	Dh	TOT
		XX	XX	XX	XX	XX	XX

TP = turning point (numbered consecutively); Az = azimuth (degrees); Ds = slope distance; S% = percent slope; SCF = slope correction factor; Dh = horizontal distance (Ds*SCF); TOT = cumulative distance travelled on transect or control line.

APPENDIX A2—EXAMPLE TRANSECT LOG FOR TRANSECT 3 OF THE LICK CREEK HEADWATERS STUDY SITE

DATE: 8-21-91	CREW: M. Hartwell S. Arno E. Reinhardt
TRANSECT: 3	STARTING POINT: Control line Point C-19

TP	Point Description / Comment	Distance and direction to next point					
		Az	Ds	S%	SCF	Dh	TOT
3-0	Starting from C-19 (480.5' to first plot)*	0°	300	0	1	300	300
3-1	in 1988 fire		180.5			180.5	480.5
3-2	Plot 3.2 complete mortality in 1988 fire		200			200	680.5
3-3	1988 underburn		200			200	880.5
3-4	on 1988 dozer line		200			200	1080.5
3-5			200			200	1280.5
3-6	Plot 3.3		200			200	1480.5
3-7	Change into more open, 2-aged stand		200			200	1680.5
3-8			200			200	1880.5
3-9			200			200	2080.5
3-10	Plot 3.4		200			200	2280.5
3-11	Passed through a small patch of even-aged PICO/PIAL		200			200	2480.5
3-12			200			200	2680.5
3-13	LPP in ABLA-dominated stand w/fallen old PIAL		200			200	2880.5
3-14	Plot 3.5		200			200	3080.5
3-15			200			200	3280.5
3-16	Older PIAL-PICO 150' either side of this point		200			200	3480.5
3-17			200			200	3680.5
3-18	Plot 3.6 Younger PICO		200			200	3880.5
3-19			200			200	4080.5
3-20			200			200	4280.5
3-21			200			200	4480.5
3-22	Plot 3.7 End of transect						
		XX	XX	XX	XX	XX	XX

TP = turning point (numbered consecutively); Az = azimuth (degrees); Ds = slope distance; S% = percent slope; SCF = slope correction factor; Dh = horizontal distance (Ds*SCF); TOT = cumulative distance travelled on transect or control line.

APPENDIX B1—GENERAL PLOT AND SITE DATA FOR FOREST LANDSCAPE STRUCTURE STUDY

DATE:	TRANSECT:	PLOT:
CREW:		ELEVATION: ft
HABITAT TYPE:		
TIME: am/pm	SLOPE: %	ASPECT: deg

Live Tree Tally: Diameter at breast height (4.5′) within 1/10 acre plot (37.2 feet radius)

	1-inch class	3	5	7	9	11	13	15	17	19	21
PICO											
PIAL											
PIEN											
ABLA											

Record dead overstory trees (standing or fallen) individually by species, DBH and Years-Since-Death Class.
Class 1 = 1-10 yrs Class 2 = 11-25 yrs Class 3 = 26-90 yrs

Species																	
DBH																	
YSD																	

On-site descriptive interpretation of stand history (see text for instructions):

Age structure:

Fire history:

Other disturbances:

Evidence of previous stand:

Increment core data:

No.	SPP	DBH	CORE HT	BOARD	SLOT	FIELD COUNT	COMMENTS

APPENDIX B2—EXAMPLE GENERAL PLOT AND SITE DATA FOR FOREST LANDSCAPE STRUCTURE STUDY

DATE: 8-21-91	TRANSECT: 3	PLOT: 6
CREW: M. Hartwell S. Arno E. Reinhardt		ELEVATION: 7120 ft
HABITAT TYPE: ABLA/LUHI-VASC		
TIME: 13 am/pm	SLOPE: 18 %	ASPECT: 110 deg

Live Tree Tally: Diameter at breast height (4.5') within 1/10 acre plot (37.2 feet radius)

	1-inch class	3	5	7	9	11	13	15	17	19	21
PICO											
PIAL											
PIEN											
ABLA											

Record dead overstory trees (standing or fallen) individually by species, DBH and Years-Since-Death Class.
Class 1 = 1-10 yrs Class 2 = 11-25 yrs Class 3 = 26-90 yrs

Species	PICO	PIAL	PIAL	PIAL	PIAL	PIAL
DBH	9	5	13	15	13	17
YSD	1	1	3	3	3	3

On-site descriptive interpretation of stand history (see text for instructions):

Age structure: Appears one-aged except for PIAL understory. Possibly regen from fire ~ 130 yrs ago.

Fire history: No evidence of underburning in stand. Replacement or Partial replacement fire ~ 130 yrs ago.

Other disturbances:

Evidence of previous stand: Many large old PIAL fallen in last 90 years.

Increment core data:

No.	SPP	DBH	CORE HT	BOARD	SLOT	FIELD COUNT	COMMENTS
1	PICO	13.1	1	6	11	106	actual corr. age: 128
2	PIAL	11.0	1	6	12	95	133
3	PICO	12.6	1	6	13		116
4	PICO	13.0	1	7	1		off-center by 4 cm 183
5	PICO	9.3	1	7	2	112	115
6	PICO	9.9	1	7	3	108	110

APPENDIX C1—SAMPLE POINT SUMMARY SHEET (TO BE COMPLETED IN OFFICE)

Transect and sample point	Disturbance event date and type[1]					Species composition[2]		Whitebark component[3]		Structural class 1900[4]		Structural class 1991[4]		Habitat Type and phase
						1900	1991	1900	1991	1	2	1	2	

[1]Enter the estimated date of event followed by one of the following codes: R = regeneration-causing, stand-replacing fire; M = regeneration-causing fire with survivors (mixed); N = nonlethal underburn which causes no regeneration; R/M = undetermined whether fire was stand-replacing or mixed; and B = heavy mortality caused by bark beetle infestation. Create other codes as necessary.

[2]LP=lodgepole pine dominated, SF=subalpine fir dominated.

[3]Check box if overstory whitebark pine is at least 20% of total basal area.

[4]Se = seedling, Sa = sapling, Po = pole, Ma = mature, Ov = overmature, Cl = near climax. (See Figure 4 for definitions)

APPENDIX C2—EXAMPLE SAMPLE POINT SUMMARY SHEET FOR TRANSECT 3 OF THE LICK CREEK HEADWATERS STUDY SITE

Transect and sample point	Disturbance event date and type[1]					Species composition[2]		Whitebark component[3]		Structural class 1900[4]		Structural class 1991[4]		Habitat Type and phase
						1900	1991	1900	1991	1	2	1	2	
3.2	1889M	1988R				LP	LP			Se		Se		
3.3	1863R					LP	M			Sa		Ma		
3.4	1930sB	1889M	1720R/M			WBP	M	✓		Se	Ov	Po	Ov	
3.5	1863R					LP	LP			Sa		Ma		
3.6	1863M					WBP	M	✓		Sa		Ma		
3.7	1889M		(MISC)			WBP	SF	✓		Se	Ov	Po	Ov	

[1] Enter the estimated date of event followed by one of the following codes: R = regeneration-causing, stand-replacing fire; M = regeneration-causing fire with survivors (mixed); N = nonlethal underburn which causes no regeneration; R/M = undetermined whether fire was stand-replacing or mixed; and B = heavy mortality caused by bark beetle infestation. Create other codes as necessary.

[2] LP=lodgepole pine dominated, SF=subalpine fir dominated.

[3] Check box if overstory whitebark pine is at least 20% of total basal area.

[4] Se = seedling, Sa = sapling, Po = pole, Ma = mature, Ov = overmature, Cl = near climax. (See Figure 4 for definitions)

APPENDIX D—EQUIPMENT CHECKLIST

300-foot fiberglass surveyor's tape[1]
Tall wire flags (one per plot)
Altimeter
Azimuth compass
Clinometer
Pencils and pens
Clipboard
Plot forms (photocopy from appendixes A, B)
Diameter tapes (inches)
Wax pencil
Elmer's glue
Core sample boards
16-inch increment borers
WD-40
Beeswax
$^3/_{16}$-inch hardwood dowel
Rubber bands

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[1]We do not recommend leaving a fiberglass tape on the ground overnight between sampling days because animals will chew through the fiberglass. A 300-foot tape can be spooled onto a reel designed for storing long extension cords and suspended from a tree.

Arno, Stephen F.; Reinhardt, Elizabeth D.; Scott, Joe H. 1993. Forest structure and landscape patterns in the subalpine lodgepole pine type: a procedure for quantifying past and present conditions. Gen. Tech. Rep. INT-294. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 17 p.

Presents a method of quantitatively representing the mosaic of stand types on a small landscape in the subalpine lodgepole pine forest type. The method utilizes macroplots placed systematically on a transect grid. Structure and composition of both current and past stands are inventoried. Procedures for data analysis and interpretation are illustrated for a lodgepole pine landscape in Montana.

KEYWORDS: forest ecology, forest fires, forest succession, landscape mosaics, plant communities, plant succession, forest inventories, fire histories, Montana, Northern Rocky Mountains

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