Chapter 12: The Variable-Density Thinning Study at Stanislaus-Tuolumne Experimental Forest

E. Knapp,[1] M. North,[2] M. Benech,[3] and B. Estes[4]

Introduction

Prior to historical logging and fire suppression, forests of the Sierra Nevada were extremely heterogeneous. Frequent low- to moderate-intensity fire was partly responsible for this heterogeneity, which in turn helped make forests resilient to high-severity stand-replacing events. Early observers of forests on the west slope of the Sierra Nevada noted the arrangement of large trees as grouped or clustered (Dunning 1923, Show and Kotok 1924) (fig. 12-1). Show and Kotok (1924) described the mixed-conifer forest as "uneven aged, or at best even-aged by small groups, and is patchy and broken; hence it is fairly immune from extensive devastating crown fire."

A major emphasis in forest management today is improving the resilience of stands to large-scale crown fires. To put forests on the path toward resilience after a long period of fire exclusion, stands are often first mechanically thinned, typically using some variation of thinning from below, which targets the smaller trees and retains the larger and more fire-resistant dominant and codominant individuals. With thinning from below, crowns of individual trees are typically separated from each other, which can lead to a relatively even forest structure. This evenness has sometimes been perceived to be in conflict with management of habitat for wildlife and other forest species. Thinning that produces a more

Duncan Dunning

Figure 12-1—Mixed-conifer forest structure in 1929, within "methods-of-cutting" study units prior to cutting. These plots are located in what today is the Stanislaus-Tuolumne Experimental Forest within the Stanislaus National Forest. Note the relatively even age/size within groups but uneven age/size among groups, along with gaps containing robust understory vegetation.

[1] Research ecologist, U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 3644 Avtech Parkway, Redding, CA 96002.

[2] Research ecologist, U.S. Department of Agriculture, Pacific Southwest Research Station, 1731 Research Park Dr., Davis, CA 95618.

[3] Resource management program area leader, U.S. Department of Agriculture, Forest Service, Stanislaus National Forest, No. 1 Pinecrest Lake Rd., Pinecrest, CA 95364.

[4] Province ecologist, U.S. Department of Agriculture, Forest Service, Pacific Southwest Region, Eldorado National Forest, 100 Forni Rd., Placerville, CA 95667.

Summary of Findings

1. **The high-variability thinning treatment was designed to produce similar spatial heterogeneity** to what was noted on detailed maps of unlogged stands on the Stanislaus-Tuolumne Experimental Forest in 1929. These historical maps show trees arranged in distinct groups of varying density, intermixed with small gaps averaging about 0.25 ac (0.1 ha) in size (range: 0.1 to 0.5 ac) (0.04 to 0.2 ha).
2. **Marking prescriptions initially were difficult to write**, but crews in the field quickly adopted the approach of first identifying gaps and then tree groups using a combination of relative density, average tree size, and dominant species.
3. **The flexibility of the high-variability thinning treatment made it easier to respond to differing topography and forest conditions.** In addition, after some practice, the rate of marking crew progress began to approach the usual rate for more traditional prescriptions.

grouped arrangement of trees may be one means of creating heterogeneity at a scale beneficial for wildlife species that prefer different forest structures for nesting, roosting, and foraging, and understory plant species that thrive in different light environments, while simultaneously increasing resilience to wildfire.

The high-variability thinning prescription described in this chapter is part of a new variable-density thinning study on the Stanislaus-Tuolumne Experimental Forest (STEF) designed to investigate the ecological effects of structural variability retained during forest thinning operations (Stanislaus National Forest 2010). Three forest structure treatments (high variability, low variability, and an unthinned control), all with or without prescribed burning as a followup treatment, are being compared. The objective of the high-variability thinning treatment is to produce an arrangement of trees and degree of spatial complexity similar to what was once found in historical forests prior to logging and fire suppression. The study planning predates publication of U.S. Forest Service General Technical Report GTR 220 (North et al. 2009) and is therefore not among the projects designed specifically to implement principles therein. We include it here because the objective of the high-variability treatment is similar to a core concept in GTR 220 of increasing spatial heterogeneity and thus provides a useful illustration.

Context

The STEF is located near Pinecrest, California, at elevations ranging from 5,200 to 6,200 ft (1585 to 1890 m). Precipitation averages about 40 in (102 cm) per year with about half falling as snow. January minimum temperatures average 19 °F (-7.2 °C), and July maximum temperatures average 81 °F (27.2 °C). The vegetation is representative of much of the mid-elevation mixed-conifer forest on high-quality soils throughout the western slopes of the Sierra Nevada. Based on historical data and stem maps produced in 1929, dominant conifer species at that time were white fir (*Abies concolor* (Gordon & Glend.) Lindl. ex Hildebr.), sugar pine (*Pinus lambertiana* Douglas), incense cedar (*Calocedrus decurrens* Torr. Florin), ponderosa pine (*P. ponderosa* Laws), and Jeffrey pine (*Pinus jeffreyi* Balf.), in order of abundance. Some of the more important shrubs included bearclover (*Chamaebatia foliolosa* Benth), manzanita (*Arctostaphylos patula* Greene), and several species of Ceanothus (*C. cordulatus* Kellogg, *C. integerrimus* Hook & Arn, *C. parvifolius* (S. Watson) Trel.). A recently completed fire history study indicates that the historical fire-return interval was between 5 and 8 years, but that the last widespread fire occurred in 1889 (Skinner 2011). Therefore, about 15 to 22 cycles of fire have been missed.

The high-variability thinning prescription was applied to stands that were originally cut in the 1920s. At that time, most trees of merchantable size were removed. The forest that emerged in the years since logging and under a regime of fire exclusion contains a greater abundance of fir and incense cedar, and less pine than the historical forest (details below).

Information Used

Data about the historical forest structure that was used to develop the high-variability prescription were obtained from stand maps produced as part of a "methods-of-cutting" (MOC) study installed in 1929, under the direction of Duncan Dunning, an early U.S. Forest Service scientist. The study evaluated natural regeneration and growth of the residual stand after three different logging treatments that were representative of logging in the Sierra Nevada at the time. The MOC studies were established at other locations in the Western United States, including other sites in the Sierra Nevada, but only at STEF were data for ecological variables other than trees collected. In addition, the STEF MOC plots are the only ones known to remain intact and undisturbed from additional management activities.

For each of the three 10-ac (4 ha) plots, the well-known surveyor, E.A. Wieslander, drew extremely detailed stand maps based on data collected in 1929 (before and after logging). These maps show the location, species, and diameter of

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all trees >3.6 in (9.1 cm), in addition to the spatial extent of shrubs by species and regeneration patches by species, snags, and downed logs. The maps were recently digitized and data associated with individual trees were discovered at the National Archives in San Bruno, California. All trees within plots were remapped in 2007 and 2008, using modern survey equipment (laser rangefinder with compass module mounted on a tripod and connected to a global positioning system unit). Preliminary analyses show that the number of trees >4 in (10.2 cm) in diameter at breast height (d.b.h.), which averaged 142 trees per acre (351 trees per hectare) in 1929 prior to logging (Hasel et al. 1934), has more than doubled today. The basal area in the MOC plots increased from 242 ft^2/ac (55.6 m^2/ha) in 1929 to 308 ft^2/ac (70.8 m^2/ha) today. Lack of light on the forest floor has resulted in shrubs declining from about 30 percent cover in 1929 to about 2 percent today. The proportion of basal area composed of pine species has declined while white fir and incense cedar have increased.

The 1929 prelogging data provide a model for forest structure that the high-variability thinning prescription is based on. These data show that trees were arranged in groups of varying density, basal area, and canopy cover, interspersed with gaps (fig. 12-2). Some groups consisted of widely spaced large trees, while others contained a much higher tree density with interlocking crowns. The historical data allowed us to describe some of the variability among tree groups, and also to quantify the spatial scale of the groups and gaps. Within these 10-ac (4-ha) plots, gaps averaged slightly less than a quarter of an acre (range 0.08 to 0.51 ac) (0.03 to 0.21 ha), with one gap occurring approximately every 2 acres (0.81 ha).

This gap size is similar to what has been reported in other forests in the Western United States with a history of frequent low- to moderate-intensity fire. Gaps in giant sequoia/mixed-conifer forest after numerous prescribed burns were found to average 0.25 ac (0.1 ha) (Demetry, unpublished data, cited in Stephenson [1999]), and a different survey of similar forests showed a large range of gap sizes between 0.16 and 2.89 ac (0.06 to 1.17 ha) (Demetry 1995). Most other studies have focused on the size of tree groups rather than gaps. Assuming groups of trees became established in gaps, group size should be less than the gap size (Stephenson 1999), because gaps have an edge effect with more light and other resources for tree growth in the center of the gap. Bonnickson and Stone (1981) found significant clustering of large living and dead trees (together approximating the historical stand) in mixed-conifer/giant sequoia forest in Kings Canyon National Park, and reported aggregations of trees ranging between 0.07 to 0.40 ac (0.03 to 0.16 ha).

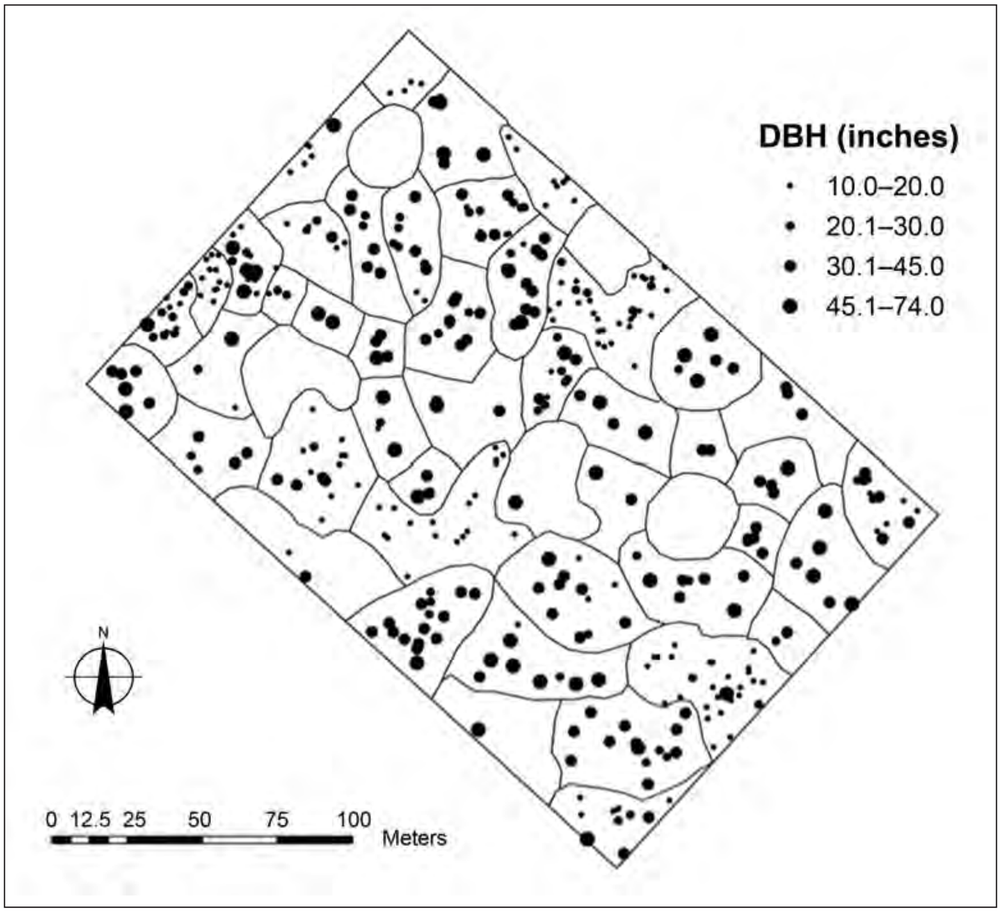

Figure 12-2—Stem map from 1929 showing trees >10 in (25.4 cm) diameter in an uncut stand, "methods-of-cutting" plot No.10, Stanislaus-Tuolumne Experimental Forest. Gaps and approximate groupings of trees of similar size, spatially separated from other groups, were drawn in for illustration. DBH = diameter at breast height.

Using a 1938 stand map from unlogged east-side ponderosa pine at Blacks Mountain (Lassen National Forest), Youngblood et al. (2004) found a random distribution of trees at smaller scales (<28 ft) (<8.5 m), but clustering at larger scales up to 79 ft (24.1 m). Assuming a circular shape, this would equate to tree group size of 0.11 ac (0.04 ha). In a stand reconstruction from old stumps and logs, North et al. (2007) determined clustering to occur at a scale up to 197 ft (60 m) [if circular, this would be a 0.69-ac area (0.28 ha)] in mixed-conifer forest. These patterns are not limited to forests in California. In ponderosa pine forests of Arizona, Cooper (Cooper 1960, 1961) reported that the size of tree groups ranged between 0.15 and 0.32 ac (0.06 and 0.13 ha), while White (1985) found a somewhat broader range of group sizes (0.05 to 0.72 ac) (0.02 to 0.29 ha), but a very similar average of 0.25 ac (0.1 ha). A reconstruction of a ponderosa pine forest in Washington indicated an average group size of 0.01 ac (0.004 ha) in more mesic plots to 0.49 ac (0.2 ha) in the driest plots

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(Harrod et al. 1999). Graham and Jain (2005) noted the existence of tree groups averaging 0.01 to 0.10 ac (0.004 to 0.04 ha) in ponderosa pine forests of southern Idaho. An analysis of all western North America studies of tree spatial patterns in fire-dependent forests found a common mosaic of three elements usually manifest at scales <1 ac (0.4 ha): openings, single trees, and clumps of trees with interlocking crowns (Larson and Churchill 2012).

Implementation

In developing the high-variability thinning prescription, we first examined existing published prescriptions designed to increase spatial variability. Graham and Jain (2005) introduced a silvicultural concept called "free selection" with the similar goal of increasing forest complexity. Free selection is described as a hybrid between even-age and uneven-age management, similar in concept to applying an even-age system in a fine-scale mosaic. One component of free selection is to include openings to regenerate early successional species. A prescription developed by Harrod et al. (1999) helps to define the scale of patchiness. Based on historical forest structure data, Harrod et al. (1999) visualized the forest as a series of approximately 98-ft diameter (0.17 ac) (0.07 ha) circles, each thinned to a varying extent—areas with smaller diameter trees thinned to 39 percent to 72 percent of maximum stand density index (SDI), depending on average tree diameter, to areas with larger trees thinned to 150 percent of maximum SDI. The Harrod et al. (1999) prescription also called for leaving the best trees, based on crown form, regardless of spacing. For the high-variability prescription at STEF, we used some of the same concepts and ideas outlined by Harrod et al. (1999) and Graham and Jain (2005), but refined our marking guidelines using data from the nearby 1929 MOC plots.

The first step in marking the stands was to walk through the entire unit and identify locations where gaps would be created. These gaps averaged one quarter of an acre (range 0.1 to 0.5 ac) (0.04 to 0.2 ha) and one was placed approximately every 2 ac (0.81 ha). Gaps varied in shape with dimensions taking into consideration shading from adjacent trees so that higher light conditions were produced. Priorities for gaps were areas currently lacking pine, and fir groups with evidence of root disease. Some gaps were designed to enlarge existing gaps (e.g., centered around remnant black oaks (*Quercus kelloggii* Newberry)), while others were located in more productive areas of the stand to ensure opportunities to grow groups of large trees, including pines, in the future. Gap edges were marked with flagging. Gaps occasionally included one large pine to provide a seed source. If a tree was left in the gap, preference was given to trees located near the northern edge of the opening where they would not interfere with the amount of light hitting the forest floor.

To better visualize the future stand, we used a leave-tree mark. This allowed us to also mark to retain patches of regeneration observed during this first walk through of the stand. We identified regeneration patches as saplings and young trees less than 10 in d.b.h. (25.4 cm), of good health (long crowns) or desired species composition (greater than 25 percent of the trees being pine). These regeneration patches would normally be removed during the biomass portion of the thinning operation. In some cases, the entire regeneration patch was marked for no entry. In other cases, just the most desirable young trees were retained at wider spacing. This latter situation may eventually lead to portions of the stand with a more open grown structure, which may provide important habitat for some wildlife species.

The second step was to view the portion of the stand not in gaps or regeneration patches as a series of continuous groups (similar to methods outlined in Harrod et al. 1999), each about a quarter acre, but varying from 0.1 to 0.5 ac (0.04 to 0.2 ha). The size and shape of groups depended on obvious breaks in composition or size of trees in the existing stand. Each group was then marked for thinning to either the median basal area target for treed areas (220 ft^2/ac; range 170 to 270 ft^2/ac) (50.5 m^2/ha; range 39.0 to 62.0 m^2/ha), or to low basal area (120 ft^2/ac; range 70 to 170 ft^2/ac) (27.5 m^2/ha; range 16.1 to 39.0 m^2/ha), or high basal area (320 ft^2/ac; range 270 to 370 ft^2/ac) (73.5 m^2/ha; range 62.0 to 85.0 m^2/ha). We chose basal area as our thinning metric, rather than the SDI proposed by Harrod et al. (1999), because we thought it would be easier for a marking crew to visualize. Because the historical data suggests that areas of the stand with a higher proportion of pine were generally of lower density, fir and cedar were thinned more heavily in groups where the largest trees were predominantly pine. In these cases, the existence of larger pines within the group determined the basal area category. For the high basal area groups, the existing stand was sometimes already at or near the basal area target, which resulted in no or few trees being marked for removal. In high basal area groups, care was taken in marking so that cut trees were ones that could be removed without damaging the residual trees. Each unit within the project ended up containing about the same number of each thinning level. However, some parts of the unit ended up with more high basal area groups and some parts more low basal area groups because the thinning target for each group was dictated by existing conditions in the stand rather than being systematically employed.

Within groups, the best trees (generally the largest trees and/or trees with the best crown form) were retained regardless of crown spacing. This led to cases where leave trees were in closer proximity or farther apart from each other than might otherwise occur under standard marking guidelines. Some trees with long (deep) crowns were also left to increase canopy cover for wildlife. Because of the current lack of pine compared with historical conditions, leave-tree priority among conifers was sugar pine > ponderosa/Jeffrey pine > incense cedar > white fir. An exception to selection based on size was sometimes made if the group contained smaller individuals of the favored pine species mixed with larger firs or cedars. No black oaks were cut, but all conifers within the drip line of black oaks were removed where damage to the oak could be avoided. Because leave-tree selection was based foremost on size and species and secondarily on crown form, some trees with relatively poor vigor (higher probability of mortality in the short term) and other characteristics important for wildlife were maintained. All snags larger than 15 in (38 cm) in diameter were retained whenever possible (i.e., when not a safety issue). From a starting studywide basal area of approximately 290 ft^2/ac (66.6 m^2/ha) (300 ft^2/ac (68.9 m^2/ha) in the high-variability units), the marking guidelines were designed to produce an average postthinning basal area of 200 ft^2/ac (45.9 m^2/ha) (range 150 to 250 ft^2/ac (34.4 to 57.4 m^2/ha)) over the unit (including gaps).

The environmental assessment (EA) for the project was completed by the Stanislaus National Forest with the interdisciplinary team consisting of district staff and U.S. Forest Service Pacific Southwest Research Station scientists. The decision notice was signed in August 2010. Two years of outreach, which became increasingly focused as the research plan and prescriptions evolved, preceded the writing of the EA and included tours of the study area by groups representing environmental as well as timber industry interests. Thinning commenced in July 2011 (fig. 12-3).

Eric Knapp

Figure 12-3—Portion of a unit within the “variable-density thinning” study on the Stanislaus-Tuolumne Experimental Forest thinned using the high-variability prescription. Photo was taken September 14, 2011, shortly after treatment.

Lessons Learned

Importance of Outreach

One of the challenges with writing a prescription to generate a high degree of structural variability is describing exactly what will be cut. As noted by Graham et al. (2007), complex forest structure defies easy description. Our objective with the high-variability prescription was to work with and accentuate residual structure that already exists within these second-growth stands. We were interested in what the stands will look like after thinning, not what will be removed. Having only stand exam data and lacking more detailed information such as complete stand maps, it was not possible to accurately describe what will be removed beforehand. We purposefully did not include diameter limits in the prescription because diameter limits can restrict opportunities for generating structural complexity. However, we were also aware of stakeholder concern about the lack of detail provided in metrics, such as diameter limits, that are typically stated in thinning prescriptions. Without diameter limits, it will be necessary to develop other descriptors that provide a sense of accountability to stakeholders.

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We hope that experiments like this one, in which what is removed can be quantified after thinning, will provide stakeholders one example of the thinning effort required, given the starting conditions, to produce a highly variable structure approximating historical stands. Currently, examples are limited. Lacking such information, we used historical data and maps to define desired posttreatment stand conditions. Field visits with various stakeholder groups were also critical for developing an understanding of objectives and generating some amount of trust. Field visits often included walking into the nearby methods-of-cutting plots that were established in 1929. Seeing what the stem density, tree arrangement, and understory vegetation look like today compared with the 1929 maps provided a powerful visual guide. Field visits also included a walk into representative stands targeted for thinning, and discussion about what to cut at different places in the stand to produce the desired highly variable structure. On one field visit, tree-marking paint was given to participants and, after discussions about objectives, we collectively marked approximately 3 ac (1.2 ha) of a stand. Participants with widely varying backgrounds and perspectives came to surprisingly similar conclusions about what trees to leave and what trees to remove.

Training a Marking Crew to Visualize Tree Groups

In standard thinning-from-below prescriptions, marking crews typically make decisions about whether to leave or cut a tree by looking at the health of individual trees in relation to immediate neighboring trees. The high-variability prescription takes

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a broader view, requiring marking crews to consider a larger patch size (average of a quarter-acre group (0.1 ha)), and make decisions not only about how to mark the group, but how this group fits with other groups in the stand that are marked differently. This means few black and white decisions and no right or wrong answers, which was initially frustrating for some. We found that walking through the stand first and finding obvious structures that could be used as anchors helped. These included areas with thin soils, root disease pockets, remnant black oaks, and groups of larger legacy trees.

On the Stanislaus National Forest, we benefited by having discussions in the field and several iterations of sample marks with the district marking crew and other forest staff over the course of 3 years as the prescription evolved. In addition to members of existing marking crews, the marking crews for the variable-density thinning study included personnel with expertise in wildlife, botany, fuels, planning, and silviculture. We spent the first part of the initial days looking over illustrations of stand structure from the 1929 methods-of-cutting plots, which show the different types of stand conditions and tree arrangements that once existed. Walking through the stands together and discussing possible structures that could be created also helped. Finally, by following the lead of those with the most experience implementing this new prescription, those with less experience were able to develop a feel for what we were trying to accomplish. Many who helped noted that marking stands in this way was a challenge, requiring much more thought than the average prescription. However, frequently altering the mark to produce different postthinning structures also encouraged creativity, which was very satisfying to many of those involved.

Metrics for Describing Variability When Marking

We quickly realized that quantifying basal area within each tree group was tedious and impractical. In addition, basal area, while easier to visualize and mentally calibrate in the field than a percentage of maximum SDI (Harrod et al. 1999), was still an imperfect descriptor of the variability created with the prescription. For example, a low basal area group could consist of a medium to high density of small trees or very widely spaced large trees. In addition, a prism—the common field method for estimating basal area—does not cover a defined area and is thus not ideal for measurements within discrete tree groups. Therefore, we ended up marking more by "feel" rather than strictly adhering to the basal area targets/ranges for each group. We also began to describe groups using a combination of relative density (high/medium/low), average tree size (large, medium, small), and dominant species (pine, fir, incense cedar), rather than basal area. High-density areas were characterized by leave trees with interlocking or closely spaced crowns, while trees in low-density areas generally were relatively widely spaced (though not at a regular spacing, in most cases). Medium-density areas were intermediate, approximating densities used in standard thinning prescriptions for this forest type. (Note: while the tree densities within high, medium, and low groups generally also resulted in basal areas within the ranges listed in the prescription, some additional work still needs to be done to quantify these structural differences within the marked stands, using metrics most relevant to marking crews in the field.) For tree size, large was assumed to be leave trees averaging >24 in, (61 cm) medium = 14 to 24 in (36 to 61 cm), and small = <14 in (36 cm). These tree size categories can readily be tailored to the stand conditions at a site.

Spatial Scale

While we attempted to vary the mark in groups averaging about a quarter acre, the actual size of the groups ended up exceeding this value more often than not. Perhaps having a larger number of marking crew members working together caused the collective broader view. However, obvious boundaries within the stand such as changes in tree density, average tree size, or species composition also tend to occur at larger spatial scales today. Sometimes crews would continue to mark in one type of stand structure until a different type of stand structure was reached rather than breaking up areas that are relatively homogeneous today. To mark to produce discontinuities at the scale historical forests were structured may therefore require frequent recalibration of spatial-scale targets.

Time/Effort Required

One of the concerns voiced was the extra time, effort, and expertise marking such complex prescriptions might require if implemented on a broader scale. Several observations suggest that this may not be as big of an obstacle as initially feared. In our case, we were more rigid in implementing some aspects of the prescription (e.g., requiring five gaps in each 10-ac [4-ha] unit) than needs to be the case outside of research. While progress was initially slow until the marking crew became comfortable visualizing the forest in this new way, speed quickly increased throughout the 2-week marking period. By the time we finished, a marking crew of three (only two carrying paint, while the third produced a hand-drawn map recording what was done throughout the stand) was able to mark about 13 to 15 ac (5.3 to 6.1 ha) in a day. While still less than a seasoned marking crew can accomplish for simpler prescriptions, it is not unreasonable to expect that speed would continue to improve with additional experience. This prescription may not lend itself to the traditional format of a marking crew of five working in unison and each member taking an adjacent strip—a team of two working on a unit together may ultimately be the most efficient.

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