Stand Treatment Impacts on Forest Health (STIFH): Structural Responses Associated with Silvicultural Treatments

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Abstract: A major gap currently exists in our understanding of how landscape-level operational silviculture affects ponderosa pine (*Pinus ponderosa*) forest ecosystem health in northern Arizona. More than 70% of our forested landscape is in relatively young, even-aged stands resulting from a history of grazing, fire exclusion, atypical climatic events, and large ('yellow') pine removal. This multi-year, multiple-investigator project specifically examined stands that have been thinned to improve forest ecosystem health, or similarly thinned and then treated with prescribed underburning. These two treatments were not different from one another with respect to any aboveground structural characteristic. However, every measure of living overstory density (trees and saplings) was lower in thinned treatments than in untreated stands, and mean tree size (stem and crown) was consistently greater in thinned treatments. Areas burned by stand-replacing wildfire in 1996, now without an overstory, had zero seedlings and saplings as well as greater densities of standing dead trees than treated and untreated stands. The STIFH project as a whole is examining a range of species-specific and ecosystem responses to this spectrum of stand conditions, including fungi, insect, and understory plant composition.

Key words: ponderosa pine, forest ecosystem health, silviculture, thinning, prescribed fire.

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INTRODUCTION

A major research gap currently exists in our understanding of how landscape-level operational stand treatments, like thinning and prescribed fire, affect forest development and health in northern Arizona. In 1998, Northern Arizona University's School of Forestry began to fill that gap with a multi-year, multiple-investigator research project in the ponderosa pine (*Pinus ponderosa* var. *scopulorum*) forests of the Coconino and Mogollon Plateaus. We identified treatment specifics and stands that could potentially be used for a broad forest ecosystem health study that examines aboveground forest structure, soils, and insect and fungal populations (Harvey 1994).

As many in northern Arizona are aware, a large percentage of our forested land is in relatively young, dense even-aged stands. This atypical condition has resulted from a management history that includes over-grazing, fire exclusion, uncommon climatic events, and major removal of large overstory pine (Pearson 1949, Swetnam and Betancourt 1990, Covington et al. 1994, Sampson and Adams 1994). The Stand Treatment Impacts on Forest Health (STIFH) project was designed specifically to examine stands that have been treated in the last decade with either thinning (TH) or thinning with prescribed burning (TB) to reduce fuel accumulations and stimulate tree vigor, thus improving overall stand health (Sampson and Adams 1994). In addition, we examined untreated control stands (UN), with neither thinning nor fire in the last 20-30 years, and areas burned by stand-replacing wildfire in 1996 (WF). These four broad "treatments", defined below in detail, paint a wide spectrum of stand conditions available for management (Smith et al. 1996) and a broad range of disturbances both with and without fire (Fig. 1). In the future, other stand types/ treatments (e.g., pine/oak mixes and large-scale ecological restoration treatments) will be available to include in the design to broaden its scope.

STIFH was designed to examine large (> 40 ha), mechanically-thinned stands with and without prescribed low-intensity surface fire. These are typical silvicultural approaches used by land managers to improve forest health, reduce the risk of wildfire, and improve aesthetics (Smith et al. 1996). Such treatments will remain as likely objectives for much of the western landscape, particularly for reducing the risk

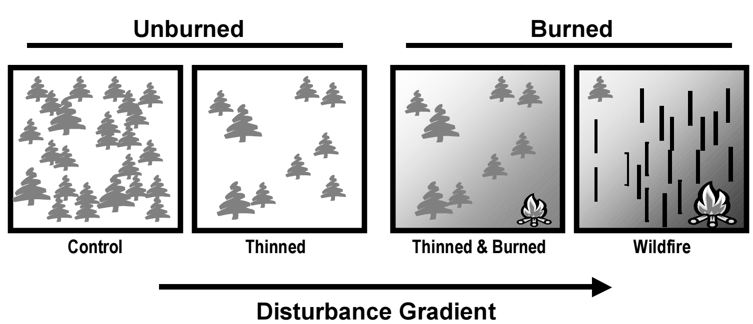

Figure 1. Conceptual representation of the four study 'treatments' arranged along a disturbance gradient, both with/without fire and with/without mechanical treatment.

of fire in the urban-wildland interface. Future treatment refinements likely will be spawned from these traditional silvicultural practices as well as new ecosystem-based management ideas and practices (including many aspects of ecological restoration). The initial four STIFH treatments represent our best first guess at two reasonable silvicultural options and two polar alternatives currently available for comparison; they are the only treatments available in large pieces across this landscape. Large land areas are necessary for evaluation of many forest ecosystem health parameters (e.g., most wildlife habitat, plant dispersion, and watershed process issues).

METHODS

Stand Selection

The first step in this project was to identify candidate stands of greater than 40 ha on the Coconino or Mogollon Plateau (within two hours of Flagstaff) in each of the four "treatments" using the following selection criteria:

Unmanaged (UN) – stands dominated by even-aged, smaller (< 40 cm diameter at breast height (DBH)) 'blackjack' ponderosa pine trees (a common name based on bark characteristics), with only a scattering of larger (> 60 cm DBH) 'yellow' ponderosa pine, Gambel oak (*Quercus gambelii*), or other tree species. Specifically, the average density of yellow pine in this treatment does not exceed 10 trees/ha, with no stand exceeding 37 trees/ha, and oak/juniper stems comprising less than 10% of tree density. These stands had not received a density-altering treatment within the last 30 years, based on USDA Forest Service records and field observations, such that the stands have a Stand Density Index (Rieneke 1933) in excess of 270 and, thus, the trees are crowded and actively self-thinning (Smith et al. 1996). These stands serve as a control treatment for examining disturbance.

Thinned stands (TH) – stands of mature, even-aged 'blackjack' ponderosa pine, similar to the unmanaged stands (i.e., a low density of 'yellow' pine, oak and/or other species), but which have had greater than 30% of their basal area removed between 1988 and 1995. At least half of the volume removal came from diameter classes < 30 cm ('pulpwood' size). Potential stands were identified from management records available from the USDA Forest Service.

Thinned and prescribed burned stands (TB) – stands like the thinned stands that also received at least one prescribed broadcast surface burn treatment within three to four years of thinning (1989 to 1997). Overstory survival, following the broadcast burn, has been greater than 90%, indicating minimal fire disturbance to overstory trees.

Wildfire areas (WF) – stands typically like the unmanaged stands prior to a stand-replacing wildfire during the summer of 1996, in which greater than 90% of the ponderosa pine basal area (blackjack and yellow pine) was killed and/or consumed by the fire. This treatment serves as the maximum disturbance.

Ten to twenty stands were identified in each of the first three treatments, from which ten stands were selected randomly for this study (Fig. 2). Due to the limited availability of wildfire stands on comparable terrain and soil, only seven wildfire areas were identified and included in the study.

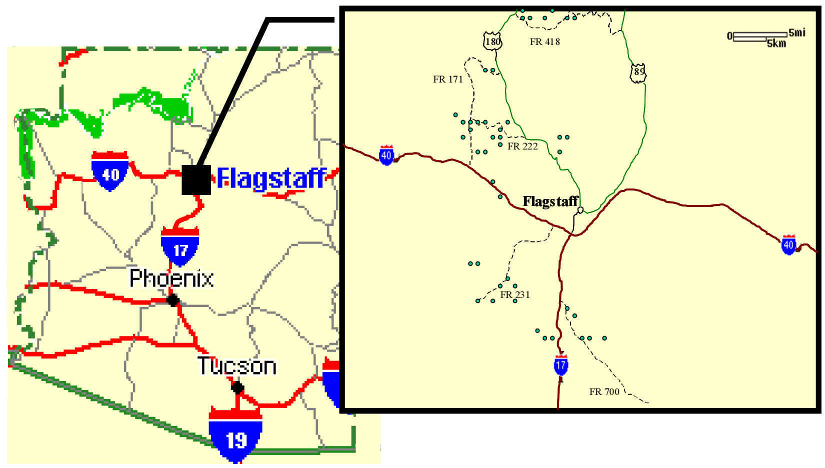

Figure 2. Location of STIFH research plots in ponderoda pine forests of northern Arizona. Circles on inset denote individual plots.

Data Collection and Analysis

Ten randomly-located (systematic following a random start), 20 m by 20 m square plots were established in each stand for sampling overstory trees, saplings (small trees between 0.1 and 7.4 cm DBH) and seedlings (Table 1) using standard forest mensurational techniques (Avery and Burkhart 1994). The intent was to augment and update existing data available for each stand, to establish permanent plot locations that can be re-measured over time, and to provide identifiable locations for sampling of other taxa (plant and animal) which may be related to tree vegetation and forest ecosystem health. Permanent plot centers were established with labeled iron pins inside painted PVC sleeves; neighboring trees were tagged with similar labels. Corners were pin-flagged for delimiting the plot and corner fuel transects.

A systematic, random sample of ten plots within stands (along a grid with a random start) allowed calculation of stand means and variances for comparisons among stands, and will allow the exploration of correlations among different taxa within stands. Comparisons among treatments were based on the 7 or 10 randomly-selected stands within each treatment. Live overstory and seedling density and structure were compared among the UN, TH, and TB treatments only; the WF treatment had no live trees. We used analysis of variance (ANOVA) to test for differences in structural characteristics among the treatments. Tukey's Honestly Significant Difference (Tukey's HSD) was used as a multiple comparison test for means that had significant ($P \leq 0.05$) ANOVA results (Zar 1996).

Results and Discussion

Unmanaged (UN) stands had significantly higher total tree density (trees/ha) and Stand Density Index (SDI) (Rieneke 1933) than their thinned (TH) and thinned/

Table 1. Aboveground stand structure variables collected at each plot in each stand on STIFH, near Flagstaff, Arizona

Trees greater than 7.6 cm (3 in) in 20 m by 20 m square plot - tagged:
- tree number: 1 - x,
- 1-letter species code: P = pipo, Y = yellow pipo, Q = quga, J = jude or jusc,
- DBH: with d-tape just above the nail,
- total height and height to live crown: with clinometer,
- crown radius in longest dimension and clockwise perpendicular to that radius: with distance tape,
- crown position (i.e., D = dominant, C = codominant, I = intermediate, or S = suppressed),
- Hawksworth dwarf mistletoe rating (0-6),
- bark beetle rating (0-2, see below), and
- Keen's crown classification.

Saplings less than 7.6 cm (3 in) within 20 m by 20 m square plot:
- direction and distance from point: with hand compass and distance tape, or laser,
- 1-letter species code (as above),
- DBH: with d-tape at 1.4 m (4.5 ft),
- total height and height to live crown (as above),
- crown radius in longest dimension and perpendicular to that radius (as above),
- Hawksworth dwarf mistletoe rating (as above), and
- bark beetle rating (as above).

Seedlings (saplings less than 1.4 m (4.5 ft) height) within 20 m by 20 m square plot:
- direction and distance from point (as above),
- 1-letter species code (as above),
- total height with tape, and
- severity of browse — number of past clippings/forks.

Stumps within 20 m by 20 m square plot:
- 1-letter species code, and
- inside bark diameter: with tape.

Snags, oak, and yellow pines within 50 m (164 ft) radius:
- landscape density rating (0-3, see below).

Bark Beetle Rating system (from USDA, FS Forest Insect and Diseases Field Guide):

0 - no attack
1 - old attacks; pitch tubes on tree bole hard and pink to reddish. Needle color from green to yellowish-green or reddish to rusty brown.
2 - fresh attack; green needles, but with soft pinkish-white pitch tubes on the bole. Dry reddish-brown boring dust in bark crevices and at the tree base.

Snag, Oak, and Yellow Pine Landscape Density Rating system:

0 - none visible within 50 m (164 ft)
1 - low density; not in plot but less than 10 individuals within 50 m
2 - medium density; 11-20 within 50 m with perhaps some in the plot
3 - high density; greater than 20 individuals with 50 m with some in the plot.

burned (TB) counterparts (Figs. 3a and 3b). This is logical given past management that removed overstory trees, and simply confirms that thinning treatments were effective. These data also show that the TB treatment, which includes prescribed surface fire, was not significantly different from the unburned, TH treatment in terms of overstory density and, as shown below, individual tree characteristics.

Differences in density across the three treatments were traceable to a higher density of small-diameter, blackjack pine trees in UN stands (Fig. 3c), which leads to notable differences in average tree stem and crown characteristics. Unmanaged stands had lower average stem diameters at breast height (DBH), which together with shading suppression and lower average live crown ratios (LCR), led to lower average

Stand Type Comparisons Among the Three Treatments with Live Trees

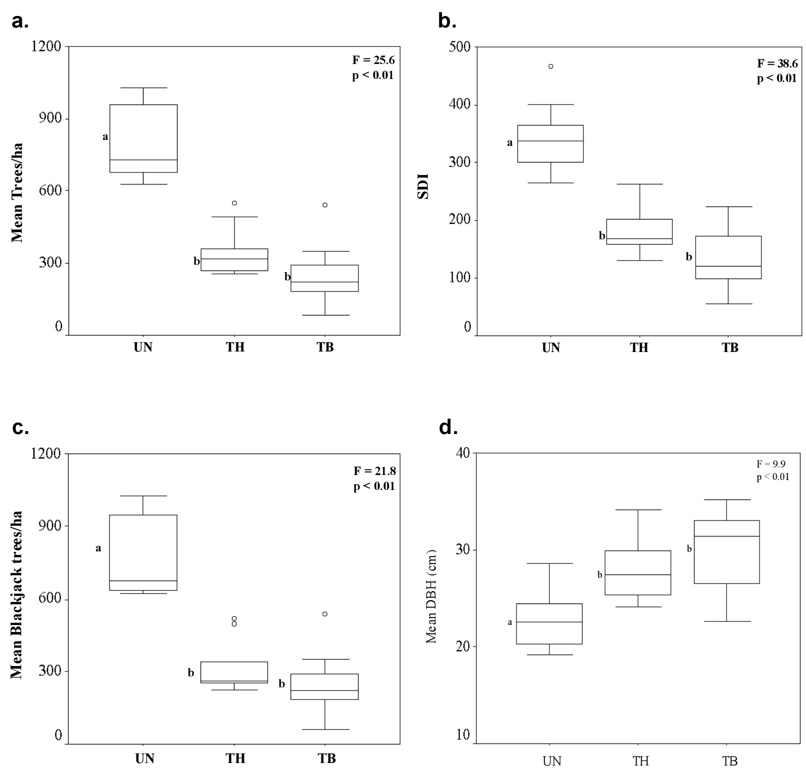

Figure 3 a-d. a. Mean overstory tree density (trees/ha); b. mean Stand Density Index; c. mean density of small-diameter 'blackjack' pine trees (stems/ha); d. mean DBH (cm). ANOVA F-statistic and observed significance (p) values are shown in the upper right corner of each graph. Significant differences among individual treatment means are denoted with letters to the left of each box plot. Each whisker represents range of values. Boxes represent interquartile range. Means are lines within boxes. Outliers (circles) represent values greater than 1.5 box lengths.

crown diameters (Figs. 3d-3f). Such differences in tree characteristics are predictable given differences in overstory stand density (Smith et al. 1996). Unmanaged stands had a higher density of saplings (Fig. 3g). These saplings, however, were predominantly suppressed individuals from the same cohort as the overstory trees, rather than younger, vigorously-growing saplings that can contribute to future stand structure (Smith et al. 1996). There were no significant differences in seedling density among treatments (Fig. 3h).

Comparisons were made across all four treatments with regard to the standing dead component. Wildfire stands had significantly higher densities of standing dead trees as a result of these stand-replacing events – an efficient way to kill trees (Fig. 4).

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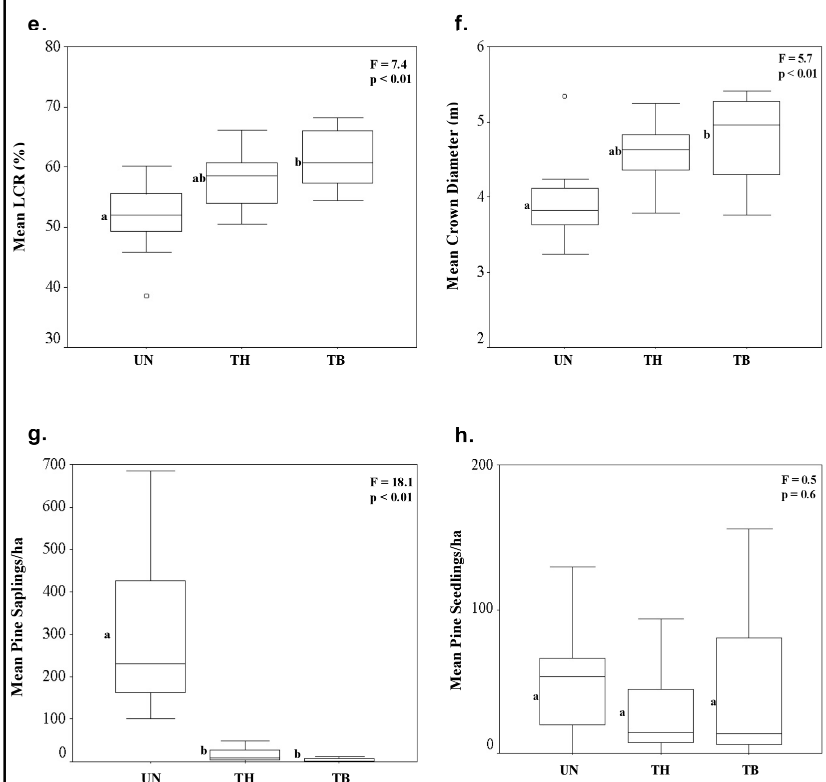

Figure 3 e-h. e. Average live crown ratio (percent); f. mean crown diameter (m); g. mean density of living saplings (stems/ha); h. mean density of living seedlings (stems/ha). ANOVA F-statistic and observed significance (p) values are shown in the upper right corner of each graph. Significant differences among individual treatment means are denoted with letters to the left of each box plot. Each whisker represents range of values. Boxes represent interquartile range. Means are lines within boxes. Outliers (circles) represent values greater than 1.5 box lengths.

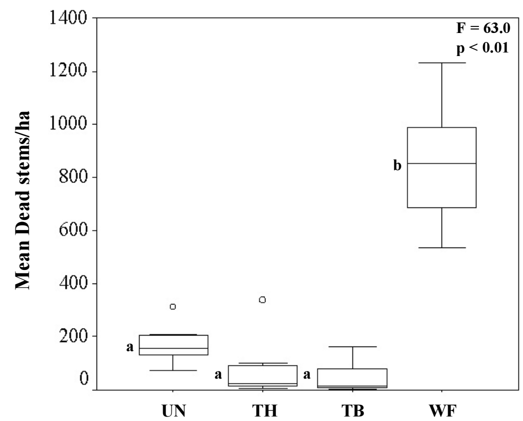

Figure 4. Mean density of standing dead trees (stems/ha). ANOVA F-statistic and observed significance (p) values are shown in the upper right corner of each graph. Significant differences among individual treatment means are denoted with letters to the left of each box plot. Each whisker represents range of values. Boxes represent interquartile range. Means are lines within boxes. Outliers (circles) represent values greater than 1.5 box lengths.

Understory prescribed burning resulted in no tree mortality, which is consistent with the fire-adapted nature of ponderosa pine (Pearson 1949, Covington et al. 1994).

MANAGEMENT IMPLICATIONS

Knowledge of aboveground structural conditions in these four treatments will develop with additional data collection and analysis to support ongoing research on various taxa associated with assessing forest ecosystem health. These first results establish that the only difference between TH and TB treatments is the prescribed underburning, which should not affect aboveground tree structure. A possible exception to this could be the impact of prescribed fire on seedling density (Bailey and Covington, in press), though these results do not show a difference in seedling density between TH and TB treatments. Analysis of fuels transect data were not available to truly characterize the TB treatment.

Unmanaged stands were high-density stands with an over-abundance of smaller diameter, suppressed ponderosa pine and associated ecosystem conditions identified by Covington et al. (1994). These stands represent a condition ripe for stand-replacing wildfire during some impending drought year similar to 1996. Indeed, one of the UN treatments became a WF treatment during the 2000 fire season. We hope to have more results from the STIFH project that can provide conclusions about the overall ecosystem health implications of having a large percentage of our forested landscape in an unmanaged condition, heading for a wildfire condition.

ACKNOWLEDGEMENTS

We would like to acknowledge financial support from the NAU School of Forestry, NAU Organized Research, and USDA Forest Service Rocky Mountain Research Station. Data collection could not have proceeded without the hard work of Noah Barstatis, Erik Brischler, Rebecca Davis, Kerry Griffis, David Huffman, Kathryn Smith, Marc Trenam and Bill Zipse.

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