Effects of Prescribed Fire and Thinning on Wildfire Severity: The Cone Fire, Blacks Mountain Experimental Forest

Carl N. Skinner, Martin W. Ritchie, Todd Hamilton
USDA Forest Service, Pacific Southwest Research Station, Redding, CA 96002

Julie Symons
Geography Department, California State University, Chico, CA

Introduction

The severity and extent of wildfires in recent years (e.g., 1987, 1988, 1990, 1992, 1994, 1996, 1999, 2000, 2002, 2003) have increased public awareness of a widespread fuels problem throughout much of the western United States. The 2002 and 2003 fire seasons appear to have served to accentuate the magnitude of the fuels problem in the minds of many. Yet, trends of increasing dead and live biomass (fuel) have been noted for many years (e.g. Cooper 1960; Parsons and DeBenedetti 1979; Biswell 1989). The increasing accumulations of fuels have been attributed to the altering of fire regimes by several factors, most notably nearly a century of attempted fire exclusion by various land management agencies (McKelvey et al. 1996, Skinner and Chang 1996). Both the Legislative and Executive branches of the Federal Government have responded by directing land management agencies to greatly expand fuel treatment programs including the recent Healthy Forests Restoration Act. While little information exists on the effectiveness of fuel treatments for reducing the severity of wildfires, even less information exists from wildfires that have burned into existing research projects designed to study effects of manipulating stand structure and other fuel treatments.

Though fuels management has long been advocated (Show and Kotok 1925, 1929; Weaver 1943; Biswell 1989), implementation has been inconsistent both spatially and temporally. Additionally, few treated sites have collected data prior to being burned in a wildfire to allow for more than anecdotal description of the affect of fuels treatment on subsequent fire effects (SNEP 1996; Omi and Martinson 2002). While even less information exists documenting the effects of wildfires that have burned into existing research projects designed to study effects of manipulating stand structure and other fuel treatments.

In September of 2002, during north wind conditions with very low humidity, the Cone Fire burned over 2000 acres, mostly on the Blacks Mountain Experimental Forest where a large project was underway to study ecological responses to contrasting stand structures (Oliver 2000). Treatments implemented before the fire included mechanical thinning with and without slash reduction through prescribed fire. All treatments were accomplished less than 6 years prior to the wildfire occurrence. The historic fire regime of this ecosystem was of the frequent/low-moderate severity type of interior ponderosa pine in the southern Cascade Range of northern California (Norman 2002; Norman and Taylor 2003).

Initial observations indicate that treated stands experienced lower fire severity than untreated stands. Additionally, stands thinned without follow-up prescribed fire appear to have experienced higher fire severity than those where thinning was followed by prescribed fire. However, in the case of both treatments the fire dropped quickly out of the crowns to become either a surface fire or die out upon entering the treated areas. The rapidity of apparent change from a high-intensity crown fire to a much lower-intensity surface fire may have significant implications for management of wildland/urban interface zones as well as wildlands in general.

We investigated patterns of severity from the Cone fire that burned into the existing treatment areas. Our objective was to describe fire effects on trees and compare the fire effects in treated areas to those in untreated areas.

Study Area

The 10,300-acre BMEF was established in 1934. The forest of this area is generally of the inland ponderosa pine type (Eyre 1980) composed of the following tree species: ponderosa pine (*Pinus ponderosa*), Jeffrey pine (*P. jeffreyi*), incense cedar (*Calocedrus decurrens*), and white fir (*Abies concolor*) with minor amounts of western juniper (*Juniperus occidentalis*) and curl-leaf mountain-mahogany (*Cercocarpus ledifolius*) (nomenclature follows Hickman 1993). The fire regime of these forests generally is of the frequent, low-moderate severity type (Taylor 2000; Norman 2002). Few fires larger than a few acres have occurred since the beginning of fire suppression early in the 20th Century, with the last fire of significant acres occurring in 1910 (Skinner unpublished data).

Blacks Mountain Ecological Research Project

The Blacks Mountain Ecological Research Project (BMERP), a long-term, large-scale, interdisciplinary research project, was initiated in 1991 at the Blacks Mountain Experimental Forest (BMEF) in the southern Cascades of northern California. This study was designed to increase our understanding of the effects of forest structural complexity on the health and vigor of interior ponderosa pine ecosystems, quantify the ecosystem's resilience to natural and human-induced disturbances, and determine how these ecosystems can be managed for sustained resource values (Oliver 2000).

The research approach for the BMERP was to create, by operational scale manipulations, two distinct forest structures: late-seral stage (high structural diversity or HiD) and mid-seral stage (low structural diversity or LoD) (Table 1). Twelve units, six of each structural type, ranging from 190-350 acres in size were treated for a total area of approximately 3100 acres. Vegetational structures were created by prescribed timber harvesting. Harvested trees up to 16" DBH were removed as whole trees for either biomass (<10") or small sawlogs (10"-16"). Where trees >16" DBH were harvested (LoD), the tops and limbs were severed from the boles before removal of the logs. For post logging/thinning fuels treatment, each unit is split in half with one half receiving prescribed fire and the other half receiving only lop and scatter. Over time, the response of various ecosystem components and processes, such as fuel accumulation, decay of coarse woody debris, soil quality, nutrient cycling, soil micro-arthropods, vegetation, insects, and wildlife to these vegetational structures will be measured.

Table 1**.** Each of the following four treatments is replicated three times in a fully randomized block design with split units for prescribed fire.

Number	**Structure**	**Grazing**	**Split**	**Size**
3	HiD	Yes	Fire / No Fire	274-350 ac.
3	HiD	No	Fire / No Fire	190-279 ac.
3	LoD	Yes	Fire / No Fire	295-304 ac.
3	LoD	No	Fire / No Fire	200-276 ac.

The HiD structure was accomplished by thinning from below and retaining the larger trees. HiD treatment was designed to extend the longevity of the larger, old trees while removing most of the ladder fuels. Intense competition from smaller trees was accelerating the demise of large old trees (Dolph et al. 1995). The HiD structure was designed to simulate more historical conditions of late-successional pine forests (Oliver 2001). Basal area was reduced from an average of 120+ ft^2 to ~90 ft^2 per acre. Crown cover after treatment, measured with a vertical site tube, averages 30.3% in HiD thin + lop and scatter (HiDLS) plots and 30.5% in thin + prescribe burn plots (HiDF).

The LoD structure was created by removing the remaining larger trees from the overstory and the smaller trees (ladder fuels) from the understory, thus leaving mostly intermediate trees. The LoD treatment was designed to simulate the stand structure commonly achieved through thinning operations in previously partial cut stands of northeastern California pine forests. Basal area was reduced from an average of 120+ ft^2 to ~40 ft^2 per acre. Crown cover after treatment averages 18.8% in LoD thin + lop and scatter (LoDLS) plots and 16.3% in thin + prescribe fire plots (LoDF).

Although the design does not include untreated controls per se, four Research Natural Areas (RNAs), each about 100 acres in size and well distributed within BMEF, are being studied to provide quantitative and qualitative information on untreated systems (Figure 1). Crown cover in the RNAs averages 55.1% in unburned units and 43.5 % in burned units. More detail on experimental design is available in Oliver (2000).

Surface fuels
Pre-treatment fuel quantities were estimated using the protocols given in Blonski and Schramel (1981) and Maxwell and Ward (1980). The quantities of woody fuels added due to harvesting large trees in LoD areas are estimated using unpublished biomass equations supplied by R.F. Powers (PSW Redding Silviculture Lab) adjusted using charts in Harrell (1978). Fuels quantities existing outside of experimental plots are assumed to be similar to fuel quantities that existed in experimental plots before treatments were applied.

Pre-treatment fuel quantities were quite variable. Mean quantity of 0-3" material before treatment in experimental plots affected by the Cone Fire was estimated to be 4.2 (range

1.6-9.3) tons/acre while the mean of 3"+ material was 10.8 (.5-38.7) tons/acre. Following treatment, surface fuel quantities increased by an average of 3.5 (range 0-13.6) tons/acre in LoD from the tops and limbs of the large trees that were cut. This increase was predominantly highly flammable 0-3" material. Little surface fuel was added to HiD treatment areas since only whole trees harvested by machine were removed. Thus, the LoDLS treatment generally had greater surface fuel quantities following treatment than before treatment.

Where treatments were followed by prescribed fire, the 0-3" material was essentially eliminated except in unburned islands. The 3"+ material was considerably reduced primarily through decreasing diameters by 4 to 6 inches (Mares 2003).

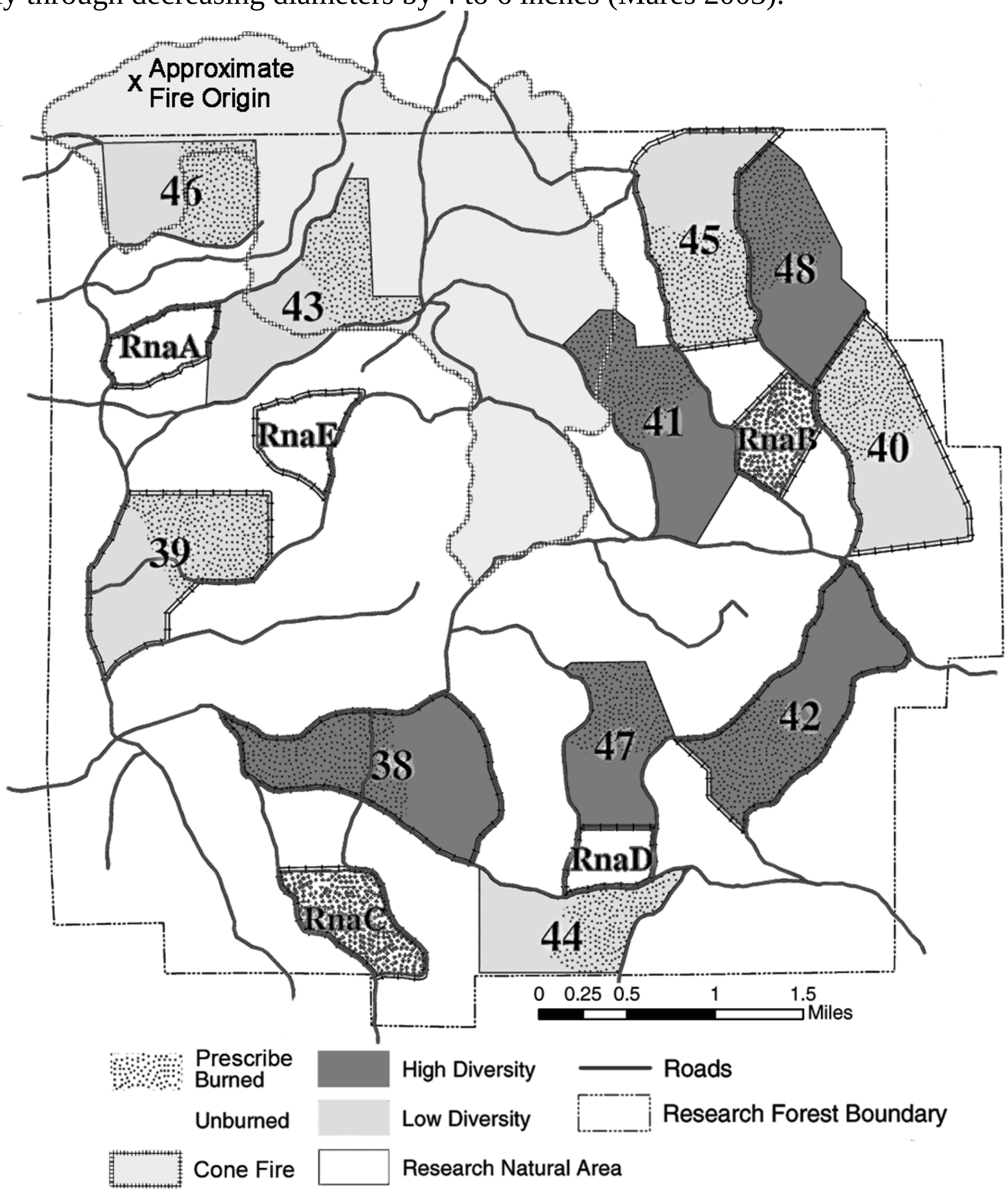


Figure 1. Extent of Cone Fire within the Blacks Mountain Experimental Forest. Bold block numbers and letters indicate BMERP treatment units.

Cone Fire Effects
This study was conducted in the portion of the Blacks Mountain Experimental Forest affected by the Cone Fire of September 26-28, 2002. The fire started accidentally outside of the BMEF around 1:30 pm on September 26 on the south slopes of Blacks Mountain in a dense stand of mostly young ponderosa pine and white fir. Weather conditions during the fire are summarized in Table 2. Under these stand and weather conditions the fire quickly became a high-intensity surface fire with torching common except in previously thinned areas and spotting up to 1.25 miles ahead of the main front. The fire initially moved south easterly until it entered the saddle between Blacks Mountain and Patterson Mountain. North winds coming through the saddle combined with down slope nighttime winds to cause the fire to turn and burn in a southerly direction. The fire continued as an intense surface fire with continuous torching outside of the thinned areas until it reached the more open, grassy areas south of Patterson Flat the following morning. It then became a moderate intensity surface fire with occasional torching (USDA Forest Service 2002).

The Cone Fire affected three BMERP treatment units – Two LoD treatments units (43 and 46), and one HiD treatment unit (41). All three treatment units were grazed. None of the treatment units where grazing is excluded were affected by the fire. Similarly, none of the RNA units were affected by the fire (Figure 1).

Table 2. Local weather conditions on days burned by the Cone fire (USDA Forest Service 2002).

Day	Wind speed Mph	Wind Gusts Mph	Max. Temp. ^oF	Min. Temp. ^oF	Relative Humidity Min / Max (%)
09/26/02	4-10	9-21	76	53	4 / 31
09/27/02	5-8	9-15	64	47	21 / 43

Methods

We established 25 strip plots (33 ft x 492 ft) systematically located perpendicular to the boundaries of the treatment units affected by the Cone Fire to characterize the pattern of fire damage to trees as the fire approached and entered the unit (Figure 2). Initial observations of surface burn, crown scorch, and bole char indicate that 164 ft outside and 328 ft inside of treatment units is sufficient to characterize change in fire effects and intensity. The 328 ft inside the treatment units was further divided into two 164 ft sections to characterize the fire effects in the edge zone and further into the treated area.

The centerline of each strip plot was marked. Surface characteristics were noted as surface cover and conditions at each 3.28ft distance along the centerline.

Table 3. Within the strip plot, all trees >4" were tagged and the following data recorded:

a.	Species
b.	Distance from treatment unit boundary
c.	Diameter class (1 inch classes)
d.	Live or Dead
e.	Height
f.	Height of bole scorch in each of four quadrants
g.	Height of crown scorch in each of four quadrants
h.	Estimate of height to live crown prior to Cone fire
i.	Calculate surface area of bole scorch and crown surface area damage from the above measurements.

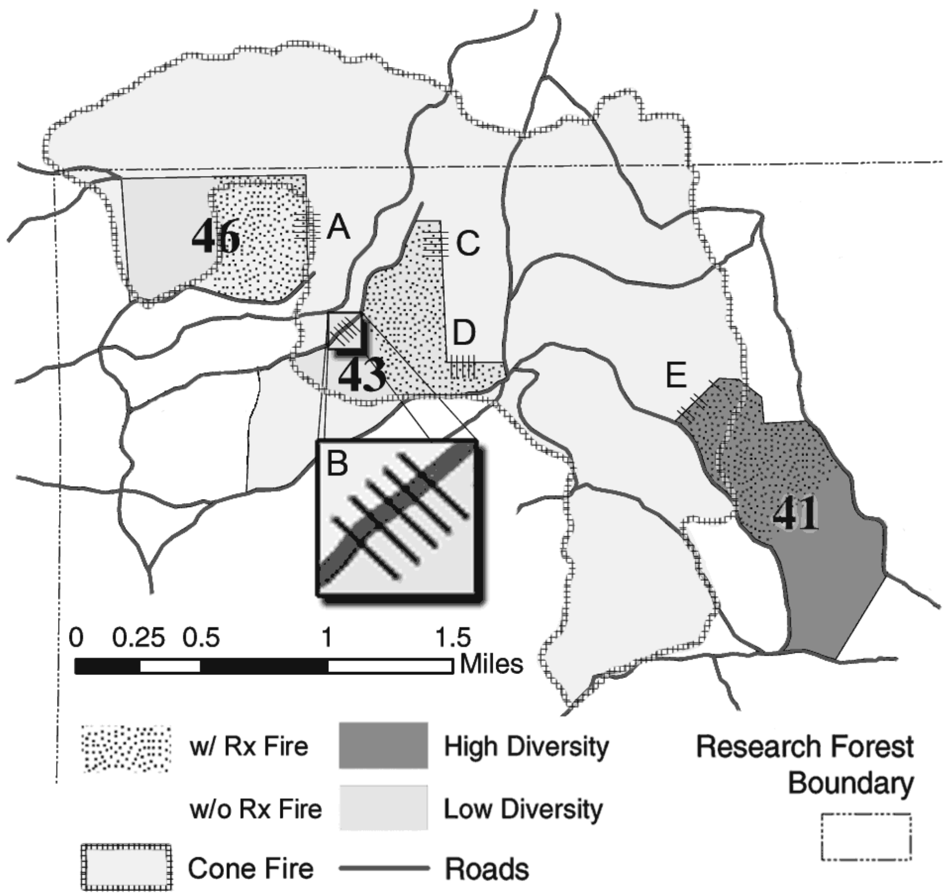


Figure 2. Location of strip plots. See Table 4 for explanation of letter code.

Within the strip plot, all trees <4" were tallied within each 3.28 ft distance and the same data recorded for each as for the larger trees.

Table 4. Total number of strip plots was as follows (Figure 2):

a.	Treatment Unit 46 (LoDF): 5 on east edge of half with prescribed fire
b.	Treatment Unit 43 (LoDLS): 5 on north edge of half w/o prescribed fire
c.	Treatment Unit 43 (LoDF): 5 on northeast edge of half with prescribed fire
d.	Treatment Unit 43 (LoDF): 5 on southeast edge of half with prescribed fire
e.	Treatment Unit 41 (HiDF): 5 plots on north edge

Results

The data for the strip plots are grouped based upon the type of treatments that had been implemented before the Cone Fire. The three groups are a) high diversity structure - thinning with prescribed fire (HiDF), b) low diversity structure - thinning with prescribed fire (LoDF), and c) low diversity structure - thinning with lop and scatter (LoDLS).

Tree Density

The number of trees per acre varied greatly between the untreated and treated areas in the HiDF and LoDF treatments (Figure 3). This was especially true of the small sized trees since they had been removed in the treated areas. LoDLS does not exhibit this dramatic difference since the area adjacent to the LoDLS treatment had been thinned in the early 1980s. Additionally, this area did not receive a treatment of the surface fuels following thinning.

Basal Area

Basal area differed little between the untreated areas and the adjacent HiDF areas. Basal area was reduced in both the LoD and LoDF treatments compared to the adjacent untreated areas.

Quadratic Mean Diameter

Again, we see differences between treated and untreated areas in HiDF and LoDF. However, little difference is seen in LoDLS when compared to the adjacent untreated area.

Mortality

There are differences in percent mortality between treated and untreated and proximity to edge of treatment in HiDF and LoDF. Little difference is seen in the LoD between the adjacent area and the BMERP treatments (Figure 4).

Discussion

The charts (Figure 3) display clear differences in pre-fire stand conditions between the areas treated with thinning and prescribed fire in the BMERP study (HiDF, LoDF) and those in adjacent, unthinned, unburned stands. Differences are also clear in subsequent fire effects between the areas of different pre-fire stand conditions (Figure 4). In each case, there was a higher percent of mortality in the untreated stands than in the areas treated in the BMERP study.

Figure 3. Trees/acre, basal area/acre, and quadratic mean diameter for trees in the 25 strip plots. The bar in the middle of the boxes denotes the median value, area within the boxes depict the 25th to 75th percentiles, the whiskers represent the 5th and 95th percentiles, and the dots represent outliers.

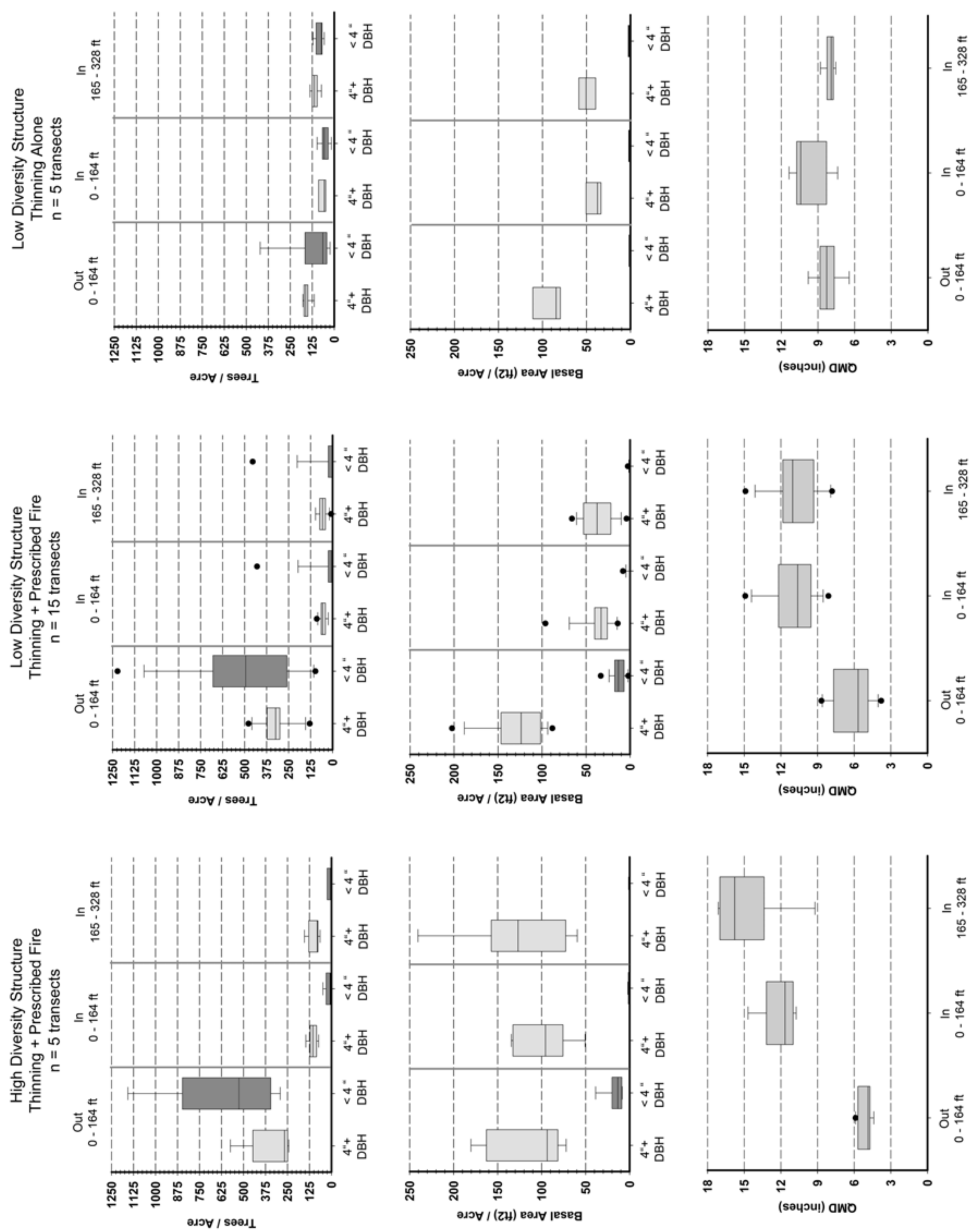
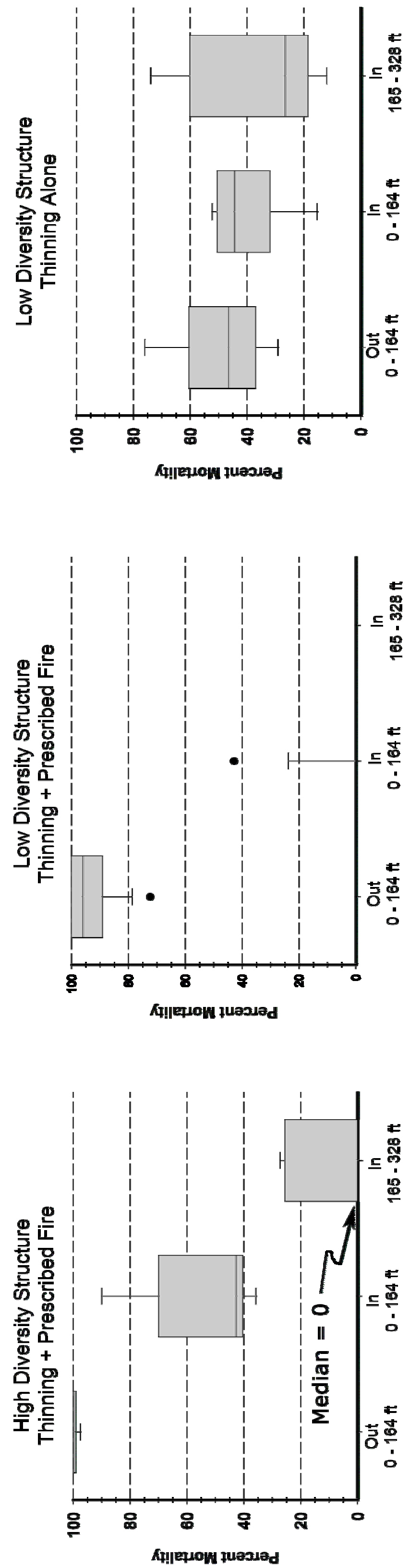


Figure 4. Percent mortality of trees in the 25 strip plots



Differences in fire severity follow current knowledge of how stand structures and fuel treatments contribute to fire behavior (Weatherspoon 1996, Stephens 1998, Scott and Reinhardt 2001, Omi and Martinson 2002, Graham et al. 2004). Generally, ladder and surface fuels had been sufficiently reduced in LoDF and HiDF treatment areas to preclude crown fire. The prescribed fires that were conducted following thinning sufficiently reduced surface fuels to exclude surface fire in the LoDF treatments. Surface fire was still possible in the HiDF treatment, but was a very low-intensity, surface fire. The mortality shown in Figure 4 in the first 164 ft of the strip plots within these treatment areas was primarily due to radiant heat from the fire burning in the adjacent area and not from the fire burning within the treated area.

The effects in the LoDLS treatment area appear quite different from the others. This area did not receive a prescribed burn following thinning. Additionally, the area adjacent to the LoDLS unit was thinned approximately 20 years before the Cone Fire. Surface fuels were not treated following harvest except for lop and scatter in the LoDLS unit and conditions were similar between the adjacent area and the LoDLS treatment area (Figure 3). Thus, there was very little difference in the proportion of mortality in these areas (Figure 4).

When the strip plots are considered together, there appears to be a gradient of fire related tree mortality that follows a gradient of pre-fire stand conditions. This gradient displays the highest mortality where no pre-fire stand thinning had occurred. Generally, where there had been no thinning treatments, mortality exceeded 90% of the stand. Where thinning had not been followed by prescribed fire and surface fuel treatments were limited to lop and scatter, mortality was generally around 40-60 % of the stand.

Where thinning had been followed by prescribed fire 2 – 4 years before the Cone Fire, fire related mortality was less than thinning alone. On the LoDF transects, fire related mortality was negligible. In the HiDF transects, there was a gradient of mortality with many trees close to the edge of the treatment area killed, apparently due to radiant heat from outside the unit, since there was little fuel and only a very low intensity fire within the unit that died out quickly.

Conclusion

Though we are describing preliminary results here, clearly differing levels of treatments were associated with dramatic differences in levels of fire-related tree mortality. It should be noted that these data describe the effects of a single fire under a narrow window of weather conditions within the interior ponderosa pine forest type. Therefore, it is a case study and one should be cautious about extrapolating the results to other forest types and to fires occurring under different weather conditions.

Acknowledgements

We thank our cooperators, the Lassen National Forest and the California State University, Chico, for help with this project. A grant from the USDA/USDI Joint Fire Science Program helped fund this work. We thank S. L. Stephens and R. F. Powers for helpful comments on an earlier version of this paper.

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