LAVEN/GALLUP
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Preliminary Report on

Prescribed Fire & the Restoration of the Ponderosa Pine - Grassland Ecotone

report for May, 1995 - December, 1995

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Abstract: This study evaluates the effects of prescribed fires on understory species composition and on canopy tree mortality in two ponderosa pine stands near the grassland ecotone in Boulder, Colorado. Project activity in the first funding year involved collection data before, during, and shortly after the two fires. All understory species in a systematic grid were sampled, and fire-related characteristics of selected individual trees were measured. During the fire, intensity measurements were taken. Some preliminary summary data are available for individual trees and for fire intensity. Anticipated project activities in the second and third year are post-fire data collection and data analysis.

Introduction

The City of Boulder Open Space Department and Colorado State University's Department of Forest Sciences are jointly undertaking a study of some ecological effects of fire at the ponderosa-grassland ecotone on Boulder Open Space Land. The study is designed to test alternative hypotheses about the effect of fire on understory composition, and about tree characteristics as they relate to fire-caused mortality:

understory composition:

- H_0 The fires had no effect on the species composition of the understory.
- H_{a1} The fires will favor some understory species over others.
- H_{a2} The fires will favor native understory species over exotics.

tree mortality:

H_o Tree characteristics that were measured before a fire will not effectively help predict which trees have a higher probability of surviving a prescribed fire
H_a The size and shape of a tree is a partial determinant of how much fire it will sustain and also of its likelihood of surviving a fire.

Better understanding about tree mortality and understory composition in Boulder will help managers who must make fire management choices for stands where a fire regime unaffected by people is not a viable option. Characteristics of trees and understory before the fires are being compared to the post-burn forest and to unburned control areas. Project data collection before, during, and immediately after the prescribed fires is the focus of first-year efforts for the study and is complete. More detail about transect layout is included in the appendix.

Description of Methods and Preliminary Observations

Sampling Configuration

Two sites were selected to represent different degrees of tree cover within the ponderosa - grassland ecosystem. At Lindsay, canopy closure is nearly complete. At Stengel II, few tree crowns touch any other. No ecological gradients were visible at either site that would be apt to affect sampling, except one draw at Stengel II. No transects were located in the draw.

Sample areas were selected on a systematic grid. A baseline was set across a portion of each site with similar tree and forb density. All ten transects at the more open Stengel II site are along a single baseline. At Lindsay there was not enough similar forest cover contiguous with the burn area for all control transects to be along the same north-south baseline as was used within the burn, so an additional control baseline was laid about 300 meters (m) east of the burn. Study transects 50 m in length were placed 50 m apart on each baseline.

Site Characteristics

site descriptor	Stengel II	Lindsay
state plane coordinates	T1S, R70W, sec.32	T1S, R70W, sec.31
elevation	1890 m	1920 m
site slope	5 % (1 %)[a]	12 % (1 %)
transect slope	1.2 % (0.7 %)	10 % (0.7 %)
transect aspect	north[b]	east[b]
densiometer, percent of reflected area with tree canopy	20 (4.5)	75 (2.3)[c]

a - standard errors of means are in parentheses. All slopes are calculated from absolute values.
b - mode of ten transects per site
c - sample size on Lindsay twice that of Stengel II

Photographs were taken for use with public outreach efforts and to assist with field work. They do not provide quantitative data nor will they be used in any analysis, but they are a communication vehicle that conveys more intuitive impressions.

- Each transect end cap was photographed from about five meters interior to the cap along the transect. These will aid in subsequent location of study transects if necessary.
- The procedure used to measure most variables was photographed.
- Photographs of fire behavior were taken during each prescribed fire.
- Photographs facing plot center were taken from each end cap both before and immediately after the fire. Repeat photographs from the same locations will be taken next summer.

Indicators of Change in Understory Composition

Understory vegetation was sampled in a 30 cm x 60 cm plots laid south of the transect line every 2 m. Total percent cover was recorded, as were the percent of ground surface occupied by basal plant material, litter, bare soil, rock, etc. To study individual plant species, the percent cover of each within the plots was recorded. The number of non-rhizomatous individuals was counted up to five. The appendix describes in detail how each study variable (understory, tree, transect, and fire intensity) was measured, and known limitations on the quality of data collected.

When species could not readily be identified in the field, a plant believed to be of the same species but not within the immediate area was collected. Because much of this identification work remains to be done and all understory data need to be computerized, initial results are not yet available.

Indicators of Individual Tree Mortality

On Lindsay, circles of 7 m radius were laid out at the 15 m and the 35 m points on each transect. Every tree within the study circle that is at least 30 cm tall was measured. On Stengel, 25 m circles centered on transects' 25 m points were used, and gave only about two-thirds as many study trees as the much smaller pairs of circles gave for Lindsay as a whole.

Numbers of Trees Sampled

count of	Stengel II	Lindsay
total study trees	266	397
study trees within burn	200	279

control trees	66	118

The distance and compass direction of each tree relative to its plot center were recorded. It will therefore be possible to plot individual trees within study circles. Exploratory data analysis will include evaluation of spatial autocorrelation of fire effects at the scale of individual trees.

To evaluate tree mortality, characteristics of each tree that might help predict its ability to resist fire damage were measured before the fire. The following average values across each site are preliminary.

Pre-fire Characteristics of Study Trees

characteristic	unit of measure	Stengel II	Lindsay
diameter at breast height[a]	mm	287 (8)[b]	166 (6
total height	cm	791 (35)	806 (30)
height to lowest foliage (height of base of live crown)	cm	59 (7)	270 (14)
height of the lowest ladder fuel	cm	15 (2)	95 (5)
number of neighbors whose canopies touch	count	.6 (.1)	2.2 (.1)
crown class indicating height relative to the surrounding stand (selected classes)	% in 'below' class	14 %	54 %
	% in 'open' class	46 %	1 %
number of quadrants of the upper canopy that are shaded	count	1.2 (.1)	3.3 (0.04)
depth of duff	cm	3.3 (0.2)	5.0 (0.1)

a - Shows only single largest stem, and includes data for trees whose diameter at breast height is at least 25 mm
b - standard errors of means are in parentheses

There was too little variation on either site in tree species or obvious tree healthiness, and too few standing dead trees to make meaningful measurements of these otherwise logical characteristics.

Post-fire measurements of study trees relate to the amount of heat they received during the fire, the extent to which the heat may damaged them, or both:

Post-fire Characteristics of Study Trees

characteristic	unit of measure	Stengel II	Lindsay
existence of torching within the tree	% of trees	23 %	18 %
height of stem char	cm	173 (20)[a]	357 (24)
height of highest scorched foliage	cm	363 (32)	679 (31)
height of lowest unconsumed foliage	cm	87 (9)	279 (18)
crown scorch	% of tree	21 (2)	89 (1)
prevalence of classes of ground char in a mini-plot under each tree (selected classes)	% with some area unburned	30 %	4 %
	% with some area 'moderate'	56 %	76 %
whether the tree's aluminum number tag melted and needed replacement	% of trees	9 %	19 %

a- standard errors of means are in parentheses

Fire Intensity Measurements

Treatment transects and trees were fully within the fire area. On each site, at least three of ten transects, and comparable numbers of trees, were left unburned as controls. To allow fire to build to a steady intensity before reaching the transects, buffers were left between the edge of the fire and transects. At Stengel II, with lower intensity fire, buffers were 10 m, while on Lindsay they were at least 50 m. A considerable effort was made to minimize grazing on Stengel II so that grasses and forbs would be left standing to burn, but one difficulty after another occurred and the electric fence was ineffective. One-hour fuel loads were therefore low.

Fuel loads were measured before the fires. Dead wood on the forest floor was measured and calculated using standard Forest Service procedures (Brown 1974). Understory and litter were clipped or gathered, dried, and weighed for half a Daubenmire square per transect in mid-July, or after most grazing was complete. The height of the understory was measured at point intercepts every two meters along understory transects.

Fuel Loads

fuel category	Stengel II tons/acre	kilos/ hectare	Lindsay tons/acre	kilos/ hectare	BEHAVE fuel model 2 (timber with grass): t/a, kg/hec
down woody:					
1-hour	less than .1	3	less than .1	13	
10-hour	0.2	356	0.5	1,028	1, 2242
100-hour	0.3	629	0.9	1,988	0.5, 1121
1000-hour sound	0.1	245	less than .1	75	
1000-hour rotten	0	0	1.3	2,930	
total down woody	0.5	1,232	2.7	6,034	
litter	3.3 (.08)	7504 (187)	6.6 (.15)	14,816 (325)	
understory (grasses and forbs)	.7 (.01)	1461 (19)	.4 (.02)	931 (41)	2, 4484
height of understory	12 cm (.6)		3 cm (.3)		30 cm

a - standard errors of means are in parentheses

Fuel loads are generally lower than used in the fire behavior computer simulation program BEHAVE for the most comparable fuel model, particularly in the down woody component. Woody fuel accumulations were variable as well as light. Especially at Stengel II, there were so few dead or diseased trees that very few limbs had fallen since selective logging about a dozen years prior. Most of the wood on the site was the few remains of very small slash piles from the logging.

Fuel moistures were measured for 10-hour dead woody fuel (1/4 - 1" diameter), 1000-hour sound dead wood (3-8" diameter), and live pine needles.

- A 10-hour fuel stick was set out at each site in a tree canopy and weighed to determine moisture. The sticks were taken down during final burn preparations so they would not be consumed. This probably compromised measurements, since the last readings were taken in mid-evening and around sunrise rather than during the midday burn period.
- Thousand-hour moisture sampling logs were cut at each site, skinned and elevated the week of July 4. Logs were standing dead trees on site, or sound dead and down that was naturally elevated. They were sampled within a day prior to each fire, and measured both with an electronic wood moisture probe (protimeter) and by drying and weighing. The two measurement methods yielded virtually the same results. On each site one log

was judged unsuitable because it was either punky or still somewhat green when sampled.

- At least eight soil can samples of live conifer needles were sampled at the same time at each site, and their moisture measured by drying and weighing.

Fuel Moistures

fuel category	Stengel II	Lindsay
10-hour	6 %	5 %
1000-hour	15 %	17 %
live needles	115 % (2 %)[a]	113 % (34 %)

a - standard errors of means are in parentheses

Both fires spread for the most part as head fires. Several methods were used to track their above-ground intensity. The methods work best for surface fires. At Stengel, the measurements are generally consistent with observations. At Lindsay, tree torching was the most ecologically significant characteristic of the fire. Even heat at ground-level was probably generated primarily by torching trees. The measuring methods used do not capture the effects of torching well, and in general even passive crown fires are difficult to measure at a scale as fine as the transects used.

- Flame lengths and depth of flaming front were estimated visually. If a surface fire with limited torching advanced from transect to transect, this could be done for each transect. Actual fire behavior did not conform to these limiting requirements. At Stengel, fire spread was slow and uneven enough that it had to be lit repeatedly and in many places at once throughout the site with torches, so measurements for individual transects are not available.
- BEHAVE computer simulations were made prior to the fire and will be refined from weather data collected on fire days. BEHAVE models surface burning of the understory but does not provide information about tree torching and passive crowning. Weather data were collected by an automated weather station (Lindsay) or by hand (Stengel II).
- Rates of spread were measured by throwing tagged metal bars at the flaming front at timed intervals. Again, Lindsay was generally too intense for effective measurements with this method. The measurements obtained for Lindsay were for areas of the fire with minimal torching, and for those limited areas are accurate. The data from Stengel II are much more representative of the whole fire.
- Cans with fixed volumes of water were placed on each transect. Where the fire was hottest, the extent of water evaporation provides relative indications of higher intensity locations within the burn. Water cans do not measure absolute intensity.
- A record was kept of aluminum tree tags melted in each fire. While done in order to track study trees, it will also indicate some areas that reached the melting point of aluminum during the fires.

- Finally, tree scorch can be translated into minimum estimates of flame length or energy released in the flaming front. When trees torched (including individuals at Stengel II or groups at Lindsay), scorch will overestimate surface intensities. When heat is high enough to scorch a very tall tree all the way to the top, but the actual tree is of only medium height, for example, measuring scorch will underestimate intensity. Height of foliage consumption and tree char provide relative but not absolute indicators as well.

Fire Behavior

fire or weather attribute	Stengel II	Lindsay
date of fire	Oct. 11, 1995	August 29, 1995
time of flaming front passage	11:10 - 12:30	11:45 - 14:30
firing devices	drip torch	drip torch and terratorch
firing pattern	strip head	modified (U-shaped) ring
clouds	none	broken
temperature	75 - 89°F	RAWS records not yet evaluated
relative humidity		
winds - sustained	0 - 3 mph	"
- gusts	3 - 10 mph	"
- direction	SSE	"
flame length	16 cm (1.7)[a]	8 cm (0.9)
depth of flaming front	15 cm (2.8)	n/a
rate of spread	51 cm/min (8.3), or 1.5 ch/hr (.25)	34 cm/min (15), or 1.0 ch/hr (.5)
water cans - contents' evaporation in excess of control cans' evaporation	0.15 % (.06)	6.5 % (3.5)
- temperature increase in excess of control can's increase[b]	9°F (3)	37°F (9)
depth of litter and duff in fire transects - before fire (cm)	1.6 (.3)	2.5 (.4)
- after fire (cm)	1.2 (.2)	1.1 (.4)

percent of tree tags melted	8 %	13 %

a - standard errors of means are in parentheses
b - not yet adjusted for variations in measurement times

For a fire that burns only on the surface, scorch heights can corroborate BEHAVE prediction and observations of flame length. For evaluating fire effects on the understory at Stengel, scorch heights of trees that did not torch are an additional source of data about burning surface fuels. (Data analysis of the subset of trees that torched will be undertaken in 1996.) At Lindsay, scorch heights suggest a much hotter fire than indicated in the chart above, and are more accurate a representation of actual fire effects for most of the fire's area. Even scorch underestimates the fire's heat, however, because it is limited to the height of the tree.

The indicator used to measure ground char is more robust than any of the individual measures of intensity. Ground char is an indicator of below-ground intensity. It was categorized using a classification developed by Ryan and Noste (1983).

Char plots were placed downhill of each tree midway between the trunk and the dripline for the mortality portion of the study. For the understory composition portion of the study, char plots were placed across the transect line (south) from each understory plot. Duff was excavated to determine relative depth of char and the percent of the area within a frame falling in each of Ryan and Noste's categories was estimated to the closest 10%. Char was not sampled directly within understory plots because measuring involved stirring the char to find its depth. This might change seed arrangement or other determinants of understory regrowth.

Ground Char Severity
Percent of Total Surface Area Sampled

site	location	unburned	light	moderate	other[a]	overall rating[b]
Stengel II	understory	41	49	5	5	light
	trees	14	55	28	3	moderate
Lindsay	understory	12	49	30	9	moderate
	trees	3	40	52	5	moderate

a - rock (primarily), basal area of trees, bare soil, and at Lindsay a single stump hole which was the only severe ground char observed.
b - using Ryan and Noste's classifications

Char was more severe directly under trees than along transects. It is logical that more duff and litter would accumulate under trees both because they fall there, and because trees create wind eddies. The deeper duff and litter provides more fuel to generate higher intensities. Most of the longer flame lengths observed on Stengel were within tree driplines. Overall ground char of most individual understory transects at Lindsay was moderate (4 of 6) and at Stengel was light (6 of 7).

Fire intensity and ground char together constitute severity. They will be used in regression analyses to evaluate the apparent effect of severity on observed vegetation changes.

Work to be Completed in Summer, 1996

Understory composition: In summer, 1996, the same vegetation sampling locations and procedures will be used so that direct pre-fire to post-fire comparisons can be made. Plant phenology was recorded for each week of understory sampling, so that repeat evaluations can be made when the plants are at the same stage of growth.

Data analysis will depend on how similar the understory in the second year is to the first year. It is anticipated that ANOVA and chi-square tests comparing the two years will be most appropriate. Individual species may be compared year-to-year if they are abundant enough. Comparisons of groups that will be explored include exotics v. native species, grasses v. forbs, and plants that overwinter as seed v. underground storage organs. Regression analysis will also be used to evaluate the effect of fire severity on the larger changes in understory composition.

Tree mortality: Toward the end of the 1996 growing season, when delayed mortality still caused by the fire is becoming evident, study trees will be inspected to see which are alive. During the data analysis phase of the project, multiple regression will be used to evaluate which group of morphological characteristics best predict damage and mortality, and what damage indicators predict mortality.

Literature Cited

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Ryan, Kevin C. and Nonan V. Noste. 1983. Evaluating prescribed fires. Proceedings of the Wilderness Fire Symposium, Missoula MT, Nov. 15-18 1983, pp. 230-237.

Weber, William A. 1990. Colorado Flora: Eastern Slope. University Press of Colorado, Niwot, CO.

Appendix: Description of Study Variables

Transects

- The transect baseline of the Flatirons Mesa transect is due north-south for the northernmost 4 transects, then bends 5° (compass 355°) so the fire would not come too close to a stock tank which has wooden supports. Transect baselines were shot with a hand-held compass, and are only approximately straight.
- The transect baseline at Lindsay crosses much of the closed canopy portion of the site, because that is the part that is noticeably different from Flatirons Mesa. It follows a 120° (SE to NW) line for about 180 m south of the north road close to the center of the site on that edge, and continues about 110 m across the road where it will anchor unburned control transects. At its north end the baseline stops at a fairly steep drainage, where the understory visibly changes. At the south end, the baseline continues slightly closer to due north-south so it stays well away from the forest edge along the canal bank. The baseline continues just over 200 m, and ends within sight of the more open trees that closely resemble Flatirons Mesa. There is not a closed canopy area at the south end of the transect to be used for additional unburned control.
- Permanent plot markers are driven to soil level at each end of each transect. The markers are capped short pieces of 3/8" steel reinforcing rod. The aluminum caps are stamped 'CSU FIRE 1995' and also indicate that they mark an Open Space research plot.

Understory Sampling

- Twenty-five plots are sampled on each transect. A metal tape is stretched between each pair of transect endpoints. A 30 x 60 cm Daubenmire frame is then laid perpendicularly at 0m and each 2 m increment on the south side of the tape.
- Within each plot, ocular estimates of percent of plot area are made for:
  - rock
  - bare soil
  - basal plant area
  - litter
    (Totals add to within 5% of 100%. Explicit estimates of basal plant area started on transect 4 on Flatirons Mesa, when we realized it was implicit and should be cross-checked.)
  - total understory cover. Of this list, total cover is the most difficult and probably least accurate.
  - cover by species
- Cover is generally estimated to the closest five percent. Where cover is light, more accurate estimates can be made, and estimates of 7%, 3%, 2%, 1%, and 'trace' were also made.

- Observers generally trade jobs regularly through a day. This helps with attentiveness and prevents systematically bias due to unrecognized differences in people's estimates. Observers also occasionally make independent estimates and compare them.
- Plants are considered live and not litter as long as any of the plant is still partly green.
- Plants are counted by species through a count of 5. Over 5, only 'many' is recorded. The count is limited to five because for dense, young plants and some grasses, higher counts are very slow and of marginal accuracy. Clumps are counted when plants have multiple stems from one root system, but undoubtedly errors are made here.
- No effort is made to count above-ground stems of species known to be rhizomatous, because stem counts are not an accurate measure of the number of plant individuals. For other plants found to be rhizomatous, stem counts will not be used in analysis of the number of individuals.
- Only plants at least 2.5 cm tall are surveyed or identified. Smaller plants generally consisted of only a first pair of leaves, and were too immature for reliable identification. A few exceptions are made for plants known to stay very small, like low, tight basal rosettes. This standard involves overlooking very few plants, and rarely even 1% of total cover.
- There are very few shrubs on either site. They are included in plots, as are tree seedlings less than three feet high.
- Low-hanging branches of larger ponderosa are not measured in the plots except that to note whether each plot is directly under tree foliage.
- The above-ground portions of plants rooted outside the plot that hung over the plot edges were included in estimates of cover. By contrast, stem counts included only plants rooted inside the plot.

Species Identification

- When unfamiliar species are in a plot, a code is recorded and a plant that appears to be of the same species is pressed. Collections are made only outside the transect width (tape plus one Daubenmire) in order to prevent bias in second-year sampling. This is accurate for most specimens, but is sometimes uncertain when, for example, only the first few leaves of a plant have appeared.
- Pressed plants are compared with herbarium specimens (CU, Open Space and CSU) as needed. Because pressed plants are not actual samples from within plots and species identified in the field are not pressed, the collection of pressed specimens is not a voucher collection. Also, so the pressings can be used for comparisons in the field, they are mounted between double sheets of clear Contact paper. The Contact obscures microscopic features. Extra pressed specimens are left for the Open Space herbarium.
- In summer, 1995, no matching plant could be found for fewer than two dozen individuals. In each instance the plant was very small (less that 8 cm tall), and the single example within the plot covered less than 1% of total area. The plant is marked with a temporary flag until the transect is completed, in case a similar plants is found later to compare. When none was found, the missing datum was noted.

- A much larger source of missing data will be plants that cannot ever be identified. They are virtually all vegetative, some are quite young, and many are grasses. All samples have been retained. Several skilled and extremely generous botanists have helped with many of these plants, which generally cannot be keyed.
- Finally, the field identifications improve with experience but are not perfect. For example, a group of plants with similar basal leaves, including Erigeron vitensis, Liatris punctata, and some yet to be identified, is hard to tell apart and is not in all cases correctly identified. Poa pratensis is not reliably differentiated from P. agassiziensis in this study. One, or perhaps both, are very prevalent. One is native while the other is exotic. The differences were too subtle for the data collectors to pick comparable plants.
- The calendar date of each survey is recorded. Each week, observers record indicators of plant phenology, so that plots can be resampled in summer, 1996, when plants are at their same developmental stages.
- Species names and classifications follow Weber (1990).

Tree Sampling

- Each sampled tree has a numbered metal tag. Generally, tags are attached at breast height and facing plot center. Most are attached with non-toxic nails. Tags are attached to the smallest tree with loose wires, and a record was kept of which trees have wires. The wires should be removed within three growing season so that no trees are girdled.
- Before the prescribed fires, the following measurements were made:
  - diameter at breast height. The diameter of very short trees was measured instead at the base of the crown. A cutoff for measuring at the crown was chosen of less than 25 cm at breast height, so that individual leader twigs would not be measured as the tree's diameter.
  - total height
  - height to lowest foliage. Base of live crown was generally measured at its lowest point. However, a rule was developed to prevent measuring very short branches growing alone at the base of large trees. If a single, clearly subordinate branch near the base of the tree was more than a meter below the next branch above it and its foliage was an entirely separate vertical plane, the upper branch was considered to be the base of the live crown instead of the lower branch.
  - height of the lowest ladder fuel. Ladder fuel was defined to be any wholly dead branch at least 40 cm long (20 cm for trees less than 3 m tall), no more than 2.54 cm in diameter at its remaining extremity, and no lower than 30 cm below any part of any other dead or alive branch. The 1" diameter cut-off was chosen to correspond with size classifications used in measuring time-lag fuel moistures. One- and ten-hour fuels but not larger branches are generally considered to be responsible for fire spread, including in a vertical direction.
  - number of neighbors whose canopies touch, or, if none, distance to nearest canopy. Because neighbors were often closest high in the crown, an observer stood as directly under each tree's closest branches as possible, and the distance between observers was measured. No effort was made to compensate for vertical distance, except that trees

were considered touching only if one had branches both above and below the other, or the total distance in three dimensions between the trees' needles appeared to be less than one meter.

- crown class indicating height relative to the surrounding stand. Categories adapted[1] for the relatively open structure of the ponderosa study sites are:

  open grown - no more than a quarter of the tree at its base shaded at a 60° angle from the trunk by other trees

  above - top quarter of the tree above the adjacent dominant canopy

  below - three-fourths or less the height of the adjacent dominant canopy

  even - remaining trees

- depth of duff. This was measured at a point estimated visually to be half-way between the trunk and the dripline at the point around the tree where the dripline was farthest from the trunk. Initially individual excavations were made, but on this generally dry site it was found that mineral soil could as accurately and more quickly be located by wiggling the ruler into the duff.
- number of quadrants of the top half of the live crown that is shaded. A quadrant was considered not shaded if sun could reach it at a 60° angle from the trunk.

- Some variables that might logically help predict fire susceptibility were not measured.
  - Bark thickness was measured with a commercially-available stabbing tool. Four observers tried for some time to learn to use it on the same trees and branches. Each read markedly different bark thicknesses, none of which was correct when a small part of bark was removed to check.
  - vigor, including disease and damage, was evaluated for about a third of the study trees on each site following USFS Stage 2 survey standard specifications (op. cit.) Fewer than three trees per site had enough reduction in vigor to even be noted by this scale. Results with so few trees would not be sound statistically, so the measuring was discontinued.
  - Dead trees were not tallied before the fire, even though standing dead trees can in some situations be a significant fuel component. Only a single dead tree more than 3" (7.6 cm) in diameter was found on all of Table Mesa during a search for potential 1000-hour fuel indicators, and it was not within the study area. Dead trees on Lindsay existed, but there were only two or three within all twenty tree study circles. Therefore whether a tree was dead or alive was not tallied
  - Tree species was not recorded individually. In some ponderosa forests, successional Douglas-fir is an important ladder fuel. In this study, every tree is Pinus ponderosa. At Lindsay, there were fewer than ten Douglas-fir or Rocky Mountain junipers within tree study circles, or too few to create a statistically valid sample for the species. They were noted but not measured . None was taller than about three meters, and each sustained very heavy fire damage.
- After the prescribed fires, the following measures of tree damage were made:
  - height of bark char, at the maximum place it reached on any aspect of the bole
  - percent of live crown scorched, estimated visually

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1 adapted from pp. 48 - 49 of USFS Rocky Mountain Region. Standard Specifications: Stage II Inventory. No further bibliographic information. 101 pp.

- scorch height, at the maximum place it reached on any aspect
- base of crown, measured in the same way that live crown was, except that scorched but not consumed needles were included
- existence of torching. A tree was considered to have torched if at 183 cm or above, all the needles on at least some twigs were consumed. The 6' cut-off was chosen to correspond with the definition of surface fuels incorporated into BEHAVE. If a tree torched, the highest twig on the tree that torched was measured. Trees shorter than 183 cm could not torch by definition
- whether the study tree's aluminum tag had melted enough that the number was no longer readable

- In summer, 1996, mortality will be judged from cambial kill. When the vitality of a core taken just through the live wood is not obvious, it will be checked chemically. Since fire-induced mortality rates may stay near their peak well in to the second growing season after a fire, mortality will be measured late in the season.