Interpretation of the

Crater Lake Fuel Demonstration Project

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Introduction

The National Park Service initiated a formal policy of using fire as a management tool in 1968. The California national parks were the pioneers of the use of natural and prescribed fires (Agee 1974) but it was not long before other national parks implemented the policy with fire management plans that went beyond fire suppression. This new policy recognized that fire was as much a natural process as glacier movements, volcanoes, windstorms, and floods, and that maintenance of natural areas would require a new and radically different approach than simply suppression of all fires (Leopold et al. 1963). Fire programs across multiple Federal agencies have blossomed since that time. Across the West, the paradox of successful fire suppression has been recognized: the more successful we have been in suppressing fires, the worse the wildfire problem has become (Biswell 1989). In 1998, Congress established the Joint Fire Sciences Program to provide information critical to implementing landscape-level fuel treatments designed to reduce the spread and severity of wildfires.

Crater Lake Fire Research and Management History

Crater Lake began its new approach to fire by funding a fire history study in the panhandle area of the park in 1975, where a low-severity fire regime historically had existed in ponderosa pine–dominated forest. The work was completed in 1976, and showed a historic fire return interval of 9-42 years, using clusters of trees that contained multiple, small fire scars (McNeil and Zobel 1980). In 1976, the first research burn in the Panhandle area was ignited, and in 1978 the first “prescribed natural fire” was allowed to burn with monitoring on Crater Peak (the Goodbye Fire).

The management program was active until 1988, when all Federal fire management plans were suspended after the large Yellowstone fires. During and after that time, research in ponderosa pine forests (Agee and Thomas 1982, Thomas and Agee 1986, R. Mastrogiuseppe, unpublished data) and higher elevation forests in the park (Zeigler 1978, Agee 1981, Stuart 1983, Chappell and Agee, Agee 2003) helped to define the ecological effects of the program. After 1988, the fire program at Crater Lake was slow to recover, but by the late 1990’s commitments were made to revive the program (USDI, NPS 1999). Major findings from studies of management-ignited fires in the ponderosa pine zone were:

- Most small trees (< 2 in dbh) were killed
- Ponderosa pine needed to be planted in areas that had been logged before being included in the park
- Increased mortality of large pines occurred 2-5 years after fire
- 20% of large pines (> 9 in dbh) were dead on 13 burns from 650 acres over 10 years
- Mortality of pines was higher from June-July fires than from those in September
- Mortality of very large trees (>44 in dbh) reached 45%
- Duff was completely removed when duff moisture was < 30% and lethal temperatures were recorded in the fine root zone
- Raking around large trees immediately before burns did not significantly reduce duff consumption, lethal temperatures, or root mortality

History of the Fuel Demonstration Project

At the time the Crater Lake fire management program was becoming active again, the Joint Fire Sciences Program was funded to provide research and demonstration related to fuel reduction. A project was submitted for the panhandle area of the park by Dr. Mark Huff of the Forest Service, working in coordination with the park staff. The proposal was submitted under the “demonstration area” group of requests for proposals, and was funded in 2000. Dr. Huff planned to look at the ecological effects of the proposed burns, but he transferred from research to management in the Forest Service, and Dr. James Agee at the University of Washington, who had a substantial history of fire research at the park, assumed research responsibility for the project. In the final revised proposal, the park retained the “demonstration” responsibility, to display the results for practioners and visitors:

- Place signage at the demonstration site and ensure that one or more of the treatments is viewable from a primary road used by park visitors
- Post demonstration project activities and results on public accessible websites managed by the National Park Service
- Provide information about the project at a visitor information enter
- Provide field tours for private organizations and public agencies

Study Objectives and Methods

The objectives of this study were to quantify the effects of spring versus fall burning on standard fire response variables such as fuel consumption and forest structure, and also to quantify the effects of such fires on vigor and mortality of large ponderosa pine, the most important structural element in these mixed conifer forests. Specific methods are described in the Master of Science thesis of Dan Perrakis (2004).

A 150-acre study area was identified in the southern portion of Crater Lake National Park. It has a ponderosa pine overstory with a multi-layered white fir (*Abies concolor*) understory and occasional presence of other species (sugar pine [*Pinus lambertiana*], red fir [*Abies magnifica*], and lodgepole pine [*Pinus contorta*]). The area was divided into 24, 8-acre experimental units, with 8 units being burned in Spring, 8 in Fall, and 8 controls. Prescribed fires were implemented in Spring 2002 and Fall 2002. Response variables included the following:

- **Fuel Reduction**: Fuels that were measured included litter and duff, 1-, 10-, 100-, 1000- and >1000-hr timelag fuels.
- **Vegetation Structure**: Crown base height, canopy closure, size class distribution of trees, seedling and understory cover
- **Vigor and Mortality**: focused on large (>20 cm diameter) ponderosa pine

Study Findings

As outlined above, the purpose of this study was to evaluate the effects of spring and fall restoration burning on several forest health variables in a ponderosa pine/mixed-conifer stand suffering from the effects of fire exclusion. While ponderosa pine was the dominant canopy tree, that species was absent from younger age-classes, and white fir and other species appeared to be replacing the large pines. Thus, the structure of these stands is considered to have departed considerably from its pre-fire-exclusion status, with increased tree density, reduced height to live crown, and reduced openness relative to historic conditions noted throughout the study area. Forest fuels were another component of obvious interest because of their role in affecting fireline intensity, and therefore crown fire hazard.

Survival of the large pine population was also of great interest to park managers. As previously mentioned, restoration burns in these forests have often been followed by significant mortality within the large pine component, much of this apparently related to post-fire bark beetle attacks. This study sought to further examine the fire-bark beetle interaction, by measuring the beetle resistance of select trees before and after burning, in both burn and control units. In addition, the entire population of large ponderosa pines was inventoried for long-term survivorship monitoring.

Study results at this time reflect the effects of burning up to one year after treatment. Since fire effects appear to persist for several years after burning, the current analysis should not be considered final, but simply represents a report on the initial fire effects. We hope to continue monitoring and research with further funding.

Fire behavior observations

Spring burns were ignited between June 20th and 28th, 2002. Due to high fuel moistures on the site (from recent snowpack), ignition was achieved only with difficulty. Burn coverage in individual units was estimated by comparing the relative numbers of charred vs. "green" paces. Based on this rough estimate, the spring burns affected between 19 and 57% of the area of various units, with a mean value of 37%. Fire behavior was generally of low intensity, other than some occasional flare-ups in sunnier fuel "jackpots". Spring burns smoldered for 7 days before being extinguished using water.

Fall burns were lit on October 9th and 10th, 2002. Compared with spring burns, fire behavior was more intense during the fall burns, with longer estimated flame lengths and some torching of sub-canopy trees. Fall burns also covered more of the units – between 64 and 86%, with a mean of 76% of the unit area affected by burning. Fall burns smoldered until fall rains naturally extinguished them, but most fuel consumption took place during the 3-4 days immediately following ignition.

Fuels

Dead woody fuels were measured before and after burning using the common line-intersect method of Brown (1974), with ten 20-meter long transects per experimental unit. Before burning, fuel weights between treatment groups (spring burning, fall burning, controls) were similar, averaging 151 Mg/ha. On average, we measured a fuel reduction of 27.0 Mg/ha following spring burning, a reduction of 72.8 Mg/ha following fall burning, and an increase of 16.8 Mg/ha in controls (the latter is interpreted as measurement error, primarily in litter and duff biomass). When modeled relative to pre-burn fuel weights, burning treatments reduced fuels by an average of 18% in spring burns, and 52% in fall burns, both values statistically different from controls, where a fuel weight increase of 14% was calculated.

Forest structure

To evaluate the effects of spring and fall burning on forest structure, three vegetation plots were established in each experimental unit where crown base height (CBH) was measured on all trees taller than 1.37m (4.5 feet), and canopy closure was measured from one corner of the plot. Small trees (<1.37 m) and seedlings of each species were also counted in smaller subplots.

Burning significantly increased height to live crown by an average of 0.8 m in spring burn units and 2.7 m in fall burn units. Control units (again, indicative of measurement error) showed a measured decrease in CBH of 0.3 m. Out of the two burn seasons, only fall burns had a significant effect on canopy closure, where an average decrease of 2.1% in canopy closure was measured, indicating slightly more light reaching the ground after fall burning. Finally, before burning, no ponderosa pine seedlings were present in any plots. One season after treatment, one spring burn unit and 3 fall burn units had new ponderosa pine seedlings, while there were still none in any control units.

Ponderosa pine population

A total of 1725 large pines were identified, tagged and measured for DBH and crown vigor class. Average diameter was 94.4 cm, and size-classes were normally distributed, reflecting an almost complete lack of recruitment of younger trees. One year after the burning treatments, 54 ponderosa pines (3.1%) had died. Ultimate causes of mortality include fire alone (19 trees), insects alone (5 trees), fire and insects (26 trees), and windthrow or other causes (4 trees). Logistic regression modeling on the pine population revealed that overall, mortality was higher in burn units than controls, and higher in fall burns than spring burns. In addition, mortality increased with decreasing crown vigor: the combination of fall burning and very low crown vigor was particularly lethal, killing over 20% of the trees in that group. Most previous studies have reported higher large-pine mortality following spring burns than fall burns. In this case, however, the opposite effect was observed, probably as a result of the much higher intensity of the fall burns compared with spring burns – as was also noted by other researchers in a recent study (Ganz et al. 2001).

Ponderosa pine bark beetle resistance

Previous studies have shown that oleoresin exudation flow volume (OEF) and exudation pressure (OEP) can be indicative of a tree’s resistance to bark beetle attacks. This study sought to monitor the effect of fire on beetle resistance by measuring both OEP and OEF on several occasions after burning (and preferably at least once before). While study findings and entomologists’ opinions vary on the pros and cons of (and relationship between) OEP and OEF, higher values of each metric (resin volume or resin pressure) are generally believed to indicate higher beetle resistance.

Due to constraints in timing and logistics, we were able to take unbiased pre-burn OEF and OEP measurements only in fall burn units, where there were no significant differences in OEF or OEP between treatment groups. After burning, resin measurements were successfully taken in 2002 (twice in spring burn units, once in fall burn units), and again in 2003 (twice in both spring and fall burn units). Immediately after burning (July 2002 for spring burns, October 2002 for fall burns), OEP and OEF were not significantly different between burn units and controls. However, at other measurement times, resin pressure and flow were higher on trees in burned units than in controls. Values were not always statistically different between treatment groups, however, or between trees in spring burn and fall burn units. Nevertheless, a clear pattern emerged that resin volume and pressure were higher in burned trees than in unburned (control) trees in the immediate months following treatment. This most likely reflects the effects of physical injury from the fires on the trees' boles, as wounding has been documented to cause increased resin production in a number of pine species.

The hypothesized reduction in tree defenses following burning was therefore not observed, at least in the short term; other mechanisms than reduced defenses must therefore explain the increased presence of bark beetles in these stands. Over the next few years, however, we do anticipate that resin defenses in these trees will show a measured decline. Further monitoring will be ongoing to confirm or refute this mechanism over the long-term.

Study conclusions

This study showed some clear differences in fire effects between spring and fall burning. Overall, fall burns were more effective at meeting the burning objectives with respect to changes in fuel loads, forest structure, and promoting ponderosa pine regeneration. However, fall burns did result in considerably higher mortality of large pines, apparently both from immediate fire effects as well as from bark beetle attacks in the months following the burns. This was probably a result of the much higher intensity of the fall burns compared with the spring burns. Despite higher beetle presence in burned units, and especially fall burns, we did not find resin defenses to be lower in burned trees compared with controls; on the contrary, resin pressure and flow were generally higher in burned trees, probably because of the resin-inducing effect of bole injury. Since we cannot explain the short-term increases in beetle attacks following fire from the resin-defense hypothesis, it seems likely that beetles are being attracted to the burned trees by some sort of chemical cues (Primary Attraction, in entomology terms), a mechanism that is not yet confirmed or understood in ponderosa pine.

With respect to the burn seasons, this study ended up comparing a cool and moist spring burn with a fairly hot fall burn. While some might consider the difference in fuel moistures confounding, it may also be intrinsic to the burn seasons. For instance, to achieve a hotter "spring burn" in a typical season at Crater Lake, burning would have to occur in July. From a management perspective, this is very problematic since resources and permission would be hard to come by at this time of year. Furthermore, previous studies have shown that hot burns during the growing season resulted in the highest large pine mortality of any burning treatment. Managers should therefore look towards fall burns – perhaps of slightly lower intensity than the burns in this study – as the better tool for restoration of these stands. In addition, other management activities that promote improved vigor among the large pine population should be explored. For example, manual removal of small trees around the large old pines, and some raking of debris, might allow fire into these areas without as much effect on the larger trees. While an earlier study (Swezy and Agee 1991) showed no positive effect of raking, it was done immediately before burning, and we would suggest raking with delay of burning for 1 or 2 years. Monitoring of such activities, as has begun in our study, is essential to understanding the value of such treatments. Finding the ideal conditions for burning to achieve all the desired restoration objectives is obviously a great challenge, and it is not clear that prescribed burning alone is the most effective tool for these purposes.

Possible Themes of Demonstration Project

In the ponderosa pine forest that has been burned, there are three recurring themes that could be interpreted for Spring and Fall burns:

Fuel Reduction: Fires have consumed dead fuels, but new dead fuels have been created in the short-term. Presenting this dynamic could utilize not only the current project, but past burn projects, and any pile-burn operations that have occurred lower in the panhandle.

Vegetation Structure and Composition: Tree species composition, size class distribution of trees, shrub and herb cover, height to live crown, canopy closure. Much of the previous research and monitoring has provided a good database. The NPS fire monitoring system could be interpreted as well.

Vigor and Mortality: The work done by Swezy and Agee (1991) as well as Perrakis (2004) would focus on the large tree component: growth after burning, any problems with mortality from spring or fall burns, and could include other species such as white fir and lodgepole pine.

Alternative Implementations

In addition to what should be interpreted, where it should be interpreted is another important issue. The current experimental units front a major Oregon Highway (Highway 62), which provides some opportunities and challenges as noted below.

1. No Action. Lack of action is always an option in environmental assessments, and is presented here for that reason. Given that the funding of the project was contingent on somehow demonstrating the results of the project to others, the no action alternative seems to negate the commitment to effectively interpret the findings of the project.

2. Interpret from Highway. The burn units are visible from the highway, and could be interpreted from that vantage point. There is an existing pullout on the east side of the highway near the top (north end) of the burn units. Displays could be mounted in this area. Additionally large signs could be erected along the western edge of the highway illustrating differences between spring burns, fall burns, and control units. In the longer run, if these units were again burned in the same season, more significant differences might be evident. For all units, as the surface fuels at the time of the burn were very sparse along the highway, some manual clearing of the roadside vegetation would be needed to expose the interior of the units and eliminate the roadside buffer effect.

3. Interpret on Site. An on-site interpretation would require traffic control sufficient to allow visitors to cross the highway to actually enter the units. Signs to slow traffic and a crosswalk of sorts might be required (such as occurs further up the road where the concessions staff are required to cross the highway to get to their quarters. A trail could be constructed along the firelines of the units to highlight several of the plots (a spring burn, fall burn, and control) and displays could highlight the contrasts between the units.

Action Plan

The Action Plan will be the responsibility of the Crater Lake National Park staff, as noted in the Introduction. We stand prepared to help with ideas, further development of themes, and associated tasks, but will need an appropriate context to make our input most relevant. We have suggested some ideas on "what" and "where" concerning interpretation of the fuel demonstration project, and hope that these are reasonably inclusive of actions that could be implemented. We do not, however, claim that this is exhaustive or all-inclusive, and are willing to work with park staff at their request to assist them in more detailed planning. Please feel free to contact us at any time.

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