Final Report
JFSP Project No. 01B-3-3-16

Project Title: The effect of season and interval of prescribed burns in a ponderosa pine ecosystem.
Project Location: Burns, Harney County, Oregon (Malheur National Forest)
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EXECUTIVE SUMMARY:
This JFSP project contributed to the expansion and continuation of an existing study. The primary objective of the existing study was to determine the influence of season of burn (spring or fall) on the development of black stain root disease (BSRD). For that study experimental units were burned in the fall of 1997 and the spring of 1998. Funds from several sources supported the burns and collection of data on a variety of elements of the ecosystem. This project supported an expansion of the initial study to include interval of burn and to examine the influence of both season of burn and interval of burn on understory vegetation, development of disease, insect populations, and a variety of other elements of the ecosystem. Outputs from this project will utilize data collected at the initiation of the season of burn study as well as data collected during this project. Some data collected during this project may serve as the baseline for comparisons with data collected later. Outputs using data from this project that are developed after this project is officially terminated will acknowledge support by JFSP and copies of those outputs will be sent to JFSP.

This report is organized to present an overview of the study, the objectives and outputs as promised and as delivered for this project, followed by four brief summaries and statements of conclusions of the major outputs to date from this project as reported in three papers in refereed journals. A summary of the fuels assessment is included here to make it generally available. A list of outputs to date is provided at the end of this report.

INTRODUCTION

Preexisting season of burn study: historical perspective

Since the mid-1980s, USDA Forest Service, Pacific Northwest Region (R6) pathologists have been calling attention to black-stain root disease (BSRD) of ponderosa pine (*Pinus ponderosa* Dougl. ex Laws) caused by the fungus *Leptographium wageneri* var *ponderosum* (Harrington and Cobb) Harrington and Cobb in stands east of the crest of the Cascade Range in Oregon. Since initial identification of BSRD on the Emigrant Creek Ranger District, Malheur National Forest, in 1989, district personnel have been mapping locations of BSRD. BSRD and other root diseases concern resource managers because of the broad effects of tree mortality: a) on wildlife, especially related to big game winter range and hiding cover; b) on high value stands managed for fiber production on a reduced land base; and c) on increased fuel loading and risk of wildfire. As more stands with BSRD were located, managers questioned how their management practices may have affected the spread and impact of the disease. They were concerned that the increased use of prescribed burning in spring may create stressed trees and make the stands more attractive to potential insect vectors of the fungus which would likely be active in early to mid-summer. The managers in eastern Oregon have two relatively short windows of opportunity for prescribed burns: late spring and early fall. To pick the most viable option, managers needed to know how the seasonal timing of prescribed burning will affect the future development of BSRD in the stand.

A three year study of the effects of season of burn (SOB) on tree mortality was established in mixed-age ponderosa pine at the south end of the Blue Mountains near Burns, Oregon. Each of six previously thinned stands was subdivided into three 30 – 60 ac experimental units and one of three treatments was randomly assigned to each: fall 1997 burn, spring 1998 burn, and no burning (control). Burns were representative of operational prescribed burns, given weather and fuel conditions. Trees within six 0.5-ac circular plots on each experimental unit were tagged and observed to determine fire damage and to detect immediate and delayed mortality and occurrence of BSRD. The 5321 tagged ponderosa pines alive at the time of the burns were observed for three growing seasons. Observations were expanded to include: bole-infesting beetles, decomposition, lichens, primary fire effects, soil and litter arthropods, understory vegetation, and woodpeckers. Strengths of the SOB study include: burning units are operational in size, thus results are easily adapted to management needs; the study design includes replication and random assignment of treatments to experimental units including controls; because of the timing of the burns, at each examination all treatment plots will have developed without further disturbance for the same number of growing seasons; and a wide range of ecological consequences are being studied on the same experimental units and sample plots. For additional details of study and site see Thies et. al. 2005 (citation below).

JFSP Project 01B-3-3-16: an expansion and extension of the season of burn study

This project was overlaid on the SOB study as an examination of burn interval, and concurrently extended the number of seasons for observing tree mortality differences based on season of burn. To install the interval of burn study, each burned experimental unit from the SOB study was bisected and one randomly selected subunit of each pair was burned 5 years following the first burn, the other subunit is intended to be used to test a 15-year interval. Until the 15-yr interval burn those units will be observed and used to compare the effects of a single burn at two seasons. The season of the second burn was the same as used for the first burn. Thus the burns occurred in fall 2002 or spring 2003. Control units from the SOB were left undisturbed. Through this project we extended observations on the SOB study. Data collected in the summer of 2002 measured changes 5 years after a burn and also served as the starting point for observation of the effects of the second burn. The units that will be burned 15 yr after the first burn will be observed to monitor the impact of the season of burn.

The current project has served as the basis for two additional JFSP projects: 1. Project 03-3-3-28; Becky K. Kerns and Walter G. Thies, "The effects of season of prescribed fire and grazing on understory plant communities in a ponderosa pine forest." This project installed grazing exclosures and monitored the post-burn development of understory vegetation absent grazing by cows. It also provided for additional seasons of observations of the understory vegetation. 2. Project 04-2-1-85; Darlene Zabowski and Walter G. Thies, "Does season of burn and burn interval affect soil productivity and processes in a ponderosa pine ecosystem? The current project provided the study platform with replicated experimental units while this new project monitored the chemical and physical changes in the soil and evaluated soil productivity.

Project Objectives and status of completion: Objectives from the original proposal are in ***bold italic.*** To summarize; all major objectives have been met and publications are either already available or will be in the near future.

a) ***Develop and maintain the study areas to establish 5-year and longer interval burn sites for spring and fall prescribed burning.***
Fully successful. Burn interval was successfully incorporated into the SOB study using a split-plot design. Each of the 12 experimental units burned in 1997/1998 (six in the fall of 1997 and six in the spring of 1998) were bisected and one subunit of each pair was randomly selected to be burned 5 years following the first burn; the other will be burned at a longer interval, currently intended to be 15-years. The first 5-yr interval burns (second burn in the series for these study areas) were conducted in fall 2002/ 2003, each set was completed within one week, and designated sites were burned as intended and within prescription. All planned data collection and plot maintenance activities were completed.

b) ***Determine which stand and tree characteristics, fire season and severity, and fuels loading and consumption parameters best predict which fire injured trees will be killed by insects and diseases.***
Successful. Data were successfully collected on all tagged trees in the study and those trees were observed for five seasons for resulting mortality. Results have been published which define the impact of season of burn on tree survival (Thies et al. 2005) and which predict probability of tree mortality based on fire damage to individual trees (Thies et at. 2006). Fuels data could not be related to individual trees but was analyzed by experimental units by Niwa and presented in this report as a fuels assessment. BSRD-caused tree mortality was anticipated to be influenced by SOB but such was not the case, those results have been reported (Thies et al. 2005). Data concerning insects trapped and attacks on individual trees was successfully collected, analysis and reporting will be handled by Niwa.

c) ***Determine the influence of both multiple burns and the season of burn on plant community composition including exotic and invasive species.***
Fully successful: Data defining the impacts of both the first and second burns on understory vegetation, including invasives and exotics, were successfully collected. One paper has been accepted for publication (Kerns et al. 2006) and a second is in preparation. Additional funding has been secured to extend the observations by two seasons and additional papers by Kerns can be expected.

d) ***Develop management guidelines that predict tree growth and mortality due to first and second order fire effects after prescribed burning.***
Successful; all anticipated data defining first and second order fire effects was collected on each tagged tree. To date there is no indication that the prescribed burns have influenced BSRD-caused (second order fire effects) tree mortality (Thies et al. 2005) and thus management guidelines are not appropriate or necessary. Insect impacts are yet to be analyzed; publication of those analyses will be done by Niwa. First order fire effects have been reported (Thies et al. 2006); when additional model validation data is available, a General Technical Report will be prepared as a management guideline for projecting delayed mortality of ponderosa pine in the field. A publication of the impact of the burns on tree growth is being prepared and will be submitted in 2006.

e) ***Develop a probability model of post-fire insect and disease caused mortality that will be compatible with the Fire and Fuels Extension of the Forest Vegetation Simulator model.***
All data was successfully collected, disease-caused mortality does not appear to be influenced by fire (Thies et al. 2005) and insect impacts will be reported later by Niwa.

f) ***Use tree growth and mortality information to improve existing fire effects models.***
Successful: Tree growth and mortality data was successfully collected. A model has been developed and published (Thies et al. 2006) to predict delayed mortality based on fire damage symptoms for the first burns (1997/1998) and data will be made available to those working on improving existing major models. Tree mortality on burned units following the second burn (2002/2003) was not different from the mortality rates on the control units. Tree growth observed 5 years following the first burn is being prepared for publication and the data will be provided to those working on improving existing models.

Deliverables and their status: Deliverables from the original proposal are in ***bold italic.*** In summary, the goal for all major deliverables have been met and publications are either already available or will be in the near future. Presentations to pest and fire management professional organizations and to local forest managers have been made or scheduled. Additional presentations will be made to user groups as conclusions are drawn from additional data. This study complex is an ongoing effort with various sub-studies funded from a variety of sources, these additional studies are expected to amplify the results from this Project.

1) ***Annual progress reports will be submitted in FY 2002 - 2005.***
All reports and posters were delivered to JFSP on time. The PI attended all of the PI-workshops held during the active life of this project.

2) ***Fuels inventory and duff consumption: Woody fuel loading and consumption will be presented in tabular form for all units preburn but only for burned units postburn. These will be completed FY 2003.***
The fuels assessment is presented below to make it available to the reader now. This assessment will be analyzed and published with data collected before and after the third 5-year burn to improve understanding of fuels accumulation, loading, and consumption during prescribed burns.

3) ***Burn management guidelines will be prepared for bole infesting beetles and root diseases in ponderosa pine stands that are ready for prescribed burning. These will be General Technical Reports for forest resource managers; they will be produced in FY 2004/2005 (beetles) and FY 2005 (root diseases).***
Potential insect vectors of BSRD were monitored with a goal of managing the disease through managing the insect vector. Since BSRD-caused mortality does not appear to be influenced by SOB (Thies et al. 2005) the need for management guidelines has moderated. However, analysis of the bole infesting beetle data may yield management guidelines and will be handled by Niwa.

4) ***Peer-reviewed technical papers will be prepared describing the interaction of prescribed fire and insects and disease. They will be submitted to journals by FY 2004 (beetles) and FY 2005 (root diseases).***
Same as 3 above. A peer reviewed technical paper has been published (Thies et al. 2005) which addresses the relationship of prescribed fire to BSRD (other diseases were rarely detected in this study). Technical papers related to insects may have to wait for results from yet a third burn in the 5-year interval.

5) ***A probability model of post-fire beetle- and root disease-caused tree mortality in ponderosa pine type will be produced in 2005/6. A General Technical Report will describe the probability model and its relationship to the Fire and Fuels Extension of the Forest Vegetation Simulator model.***
Same as 3 above. In the absence of a disease fire interaction the original intent here will be frustrated. However, in the absence of a strong insect or disease response to the fires it was possible to better define the relationship of fire-caused damage to tree mortality (Thies et al. 2006). That data will be made available to help improve the FVS model.

6) ***Results of the understory vegetation response to seasonality and interval of burn will be submitted to peer-reviewed journals in FY 2004.***
This work has been successfully completed. One paper (Kerns et al. 2006) has been accepted to be published in June of 2006. A second paper is in process now and has not yet been submitted.

7) ***Data describing first order fire effects will be available for incorporation into the FOFEM model by FY 2004.***
First order fire effects from the first burns (SOB study 1997/98) as immediate and delayed tree mortality has been analyzed and used to develop a model (Thies et al. 2006). That paper and the field data will be made available for incorporation into the FOFEM models. The second burn supported by this project resulted in no fire-related mortality, presumably because the fuel

consumption did not support high enough fire intensity. Thus, a second set of data for first order fire effects is not available.

Technology Transfer: ***Papers directed both at managers and researchers will be published (see Deliverables above). Oral and poster presentations will be made to the fire, ecological, insect and disease conferences to transfer this technology to resource managers and Forest Health Protection specialists. In cooperation with the Forest Health Protection specialists, the Region Six fire organization, and the Oregon Department of Forestry we will develop and distribute General Technical Reports to local managers.***
Papers have been published both in refereed journals and as papers in proceedings. Oral and poster presentations have been made to both fire and health protection specialists. A listing of papers and presentations to date is provided at the end of this report as a list of outputs. In addition during the winter of 2006 Thies and Kerns are scheduled to make presentations to the Forest Leadership Teams and Fire Management Teams of five National Forests in eastern Oregon.

FINDINGS:

Findings from this project are provided in three papers in refereed journals. A summary of each paper and conclusions are provided below. In addition, a recently developed summary of fuels data is provided. This data will be used along with data collected from future burns of the same area to better understand the relationship of fuels to season and interval of burn. The summary is presented here so the reader can better understand the fuels associated with this study area and can evaluate ecosystem response with consideration of the consumption of those fuels.

1) Thies, W.G., Westlind, D.J., Loewen, M. 2005. Season of prescribed burn in ponderosa pine forests in eastern Oregon: impact on pine mortality. International Journal of Wildland Fire, 14:223-231. Note: since this paper is already available and partially described in the introduction we will provide the conclusions as bullet statements here, additional detail can be obtained from the paper.

Conclusions:

a) The percentage of ponderosa pine mortality was higher after fall prescribed burns than after those in the spring.

b) Season of prescribed burn had an effect on survival of ponderosa pine as it influenced fire intensity and burn severity.

c) Lion’s tail, a purported symptom of BSRD, was not a reliable predictor of BSRD incidence.

d) Although BSRD is present in many trees in the test stands (approximately 22%) the rate mortality caused by the disease is very low (approximately 0.5%).

2) Thies, W.G., Westlind, D.J., Loewen, M., Brenner, G. 2006. Prediction of delayed mortality of fire-damaged ponderosa pine following prescribed fires in eastern Oregon,

USA. International Journal of Wildland Fire 15(1): 19-29 Note: since this paper is already available we will provide an extended abstract here, additional detail can be obtained from the paper.

Summary

Prescribed burning is a management tool used to reduce fuel loads in western interior forests. Following a burn, managers need the ability to predict the mortality of individual trees based on easily observed characteristics. Data for this paper was collected from trees from the SOB study. A study was established in six stands of mixed-age ponderosa pine with scattered western junipers at the south end of the Blue Mountains near Burns, Oregon. Stands were thinned in either 1994 or 1995. Three treatments, a fall burn, spring burn, and unburned control, were randomly assigned to 30-ac experimental units within each stand. Prescribed burns occurred during mid-October of 1997 or mid-June of 1998 and were representative of operational burns, given weather and fuel conditions. Within each experimental unit, six 0.5 ac-plots were established to evaluate responses to the burns. Ponderosa pine plot trees (n = 3415) alive a month after the burns were evaluated for burn damage and in succeeding falls the trees were evaluated for delayed mortality. By fall 2001, four growing seasons after the fires, annual mortality on burned and unburned units were similar.

Data were collected on tree crowns, stems, and tree quadrants in fall 1998. Three criteria governed variable selection: (1) each variable provided a measure of fire damage or tree quality known or expected to influence post-fire mortality; (2) each variable was quickly and precisely measurable with nondestructive sampling procedures; and (3) variables measured were readily observable soon after fire. Measured variables and observation of the delayed mortality were used to develop models for probability of delayed mortality for individual trees. Nine fire damage and tree morphological variables were evaluated by logistic regression: A five-factor full model and a two-factor reduced model are presented for projecting probability of mortality. Significant variables in the full model included measures of crown, bole, and basal damage: live crown proportion, needle scorch proportion, bud kill proportion, proportion of the tree with severe basal char, proportion of the bole height with scorch. To provide managers with a reduced model more readily applied in the field, we selected two easily measured variables (proportion of the crown height with needle scorch and proportion of the bole with scorch) and developed a reduced model. Both the full and the reduced models had a good fit to the data.

Figure 1 is a representation of the reduced model to help the reader visualize the relationships involved between the two variables and the probabilities of mortality.

While the presented models are a good fit to the data, they are based on 3415 ponderosa pine from six stands in the southern Blue Mountain in Oregon. Care should be exercised in extrapolating results and using these models beyond the geographical area of the sampled stands or to species other than ponderosa pine until additional datasets are available to validate the models for other areas or species.

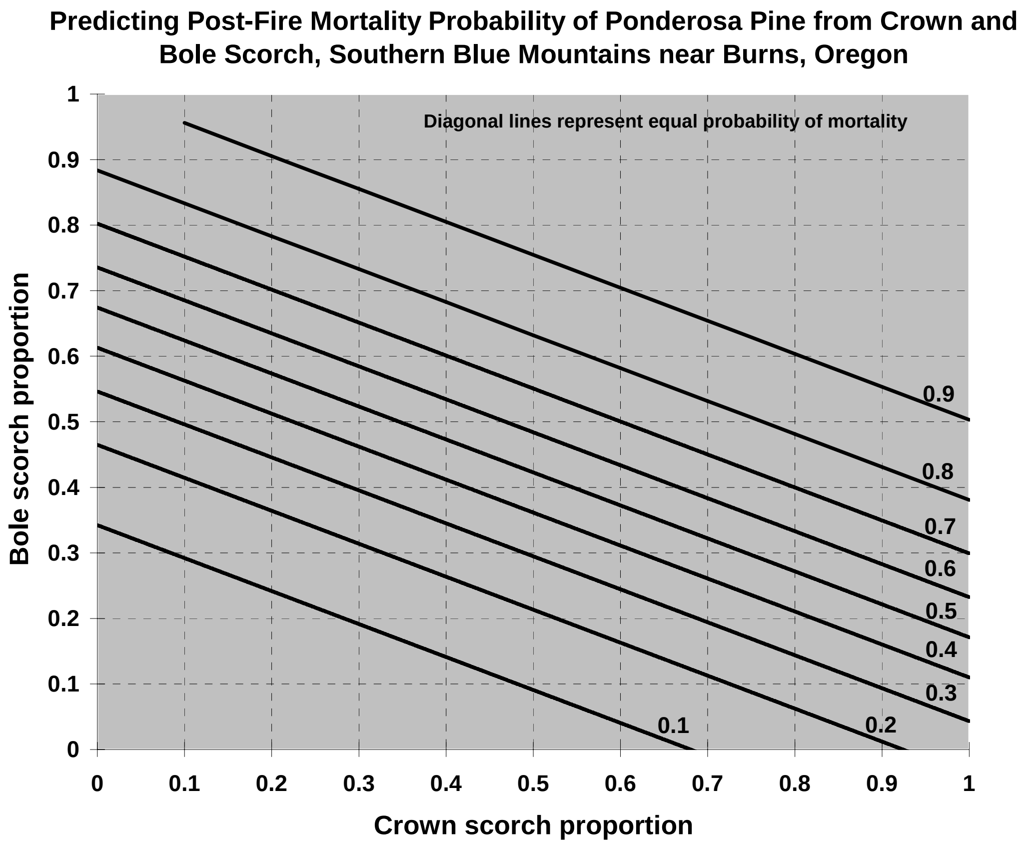


Figure 1. Probability of individual ponderosa pine delayed mortality as a function of bole and crown scorch proportion. If validation data supports the reduced model, then this chart could prove to be a very useful tool for quickly evaluating the probability that an individual tree will die based on easily observed fire damage. To use this chart measure both the bole and crown scorch proportions from the ponderosa pine of interest. Find the corresponding bole scorch proportion on the left hand vertical axis then move horizontally to the right finding the corresponding crown scorch proportion. Then interpret the probability of mortality from the diagonal lines of equal mortality probability. As an example assume a pine with 0.40 bole scorch proportion and 0.80 crown scorch proportion. The corresponding probability of mortality will be 0.7.

3) Kerns, B. K., Thies, W. G., Niwa, C.G. 2006. Season and severity of prescribed burn in ponderosa pine forests: implications for understory native and exotic plants. Écoscience 13(2): xx-xx. Note: This paper has been accepted and is projected to be published in June 2006.

Methods

Data were collected from six stands consisting of three randomly applied treatments: no burn, spring burn and fall burn. To assess vegetation patterns in relation to direct measures of fire severity, we used post-fire data recorded in the summer of 1998 on each 0.20 ha plot. These data included plot values for percent ground blackened, average tree crown scorch height, proportion of trees with crown scorch, average and maximum tree bole scorch height, proportion of trees with bole scorch, and proportion of trees and proportion of basal area that were immediately killed by the fire.

We collected understory vegetation data in the summer of 2002, five growing seasons after the prescribed fires using a series of nested plots. In each 0.20 ha circular plot, a concentric 0.03 ha circular subplot and eight 1-m^2 microplots were established. Two microplots were located five and six meters from the circular plot center in each cardinal direction. Each microplot consisted of a gridded PVC square and foliar plant cover was recorded by species to the nearest percent and other ground cover was also recorded (e.g. bare soil, rock, litter, coarse woody debris). To increase consistency in ocular estimates of plant cover, the same person recorded cover in almost all the plots throughout the field season. Species that could not be identified due to herbivory, desiccation, immaturity, etc. were assigned to a genus or life-form group such as graminoid, forb, shrub, etc. Presence of all species was recorded in the 0.03 ha subplot and cumulative species (species not found in the 0.03 ha subplot) were recorded in the 0.20 ha plot. Each site was sampled as close to the vegetative phenological maximum as possible. All unknown species were collected off the plot and identified by Richard Halse, Oregon State University Botany and Plant Pathology Department.

To assess species richness and cover patterns in relation to other potentially important variables, additional data were collected on each plot. O horizon depth was measured seven meters from the plot center in each cardinal direction. Overstory tree canopy cover was measured using a moosehorn densiometer at the plot center, and five and fifteen meters from the center in each cardinal direction (total of nine points for each plot). Ponderosa pine trees in the 0.20 ha plot were tallied and dbh (diameter at breast height, 1.4 m above mineral soil measured from the uphill side) was recorded. Slope and aspect were also recorded.

To assess how vegetation patterns varied by life-history traits, four species group categories were analyzed: exotic annuals/biennials, native annuals/biennials, forbs and graminoids. No winter annuals are present in this ecosystem and no annual native grasses were found. Perennial exotics and legumes were not distinguished as separate groups because they were uncommon, as were warm season species (C_4). For richness, species in each group category were summed using the presence data at each scale (0.03 and 0.20 ha). We chose to focus our analysis on species richness and cover, rather than diversity indices, because these metrics are straightforward, readily understood, easy to communicate to managers and policy makers, and do not obfuscate simple underlying units.

We used classification and regression tree analysis (CART, Breiman et al., 1984) to analyze relationships between burn treatments, burn severity, forest structure, substrate conditions, environmental heterogeneity and native and exotic species richness and cover. The response variables modeled were richness (0.03 ha) and cover for the four species groups. Full models were developed using default settings in S-PLUS 2000 (stopping criteria = 0.01, minimum group size = 10, minimum split = 5) and final optimum model size was selected using ten-fold cross-validation (Clark & Pregibon, 1993).

Results

- Fall burns had significantly more exotic/native annual/biennial (an/bi) species and greater cover of these species compared to spring and unburned areas (Figure 2). These patterns are likely related to indirect fire effects associated with fire severity and resource availability, rather than direct fire effects due to burn timing.

- High native and exotic an/bi richness and cover were associated with overstory gaps and higher fire severity areas, conditions common to fall burns. Exotics may be more successful at exploiting these environments.

- No treatment differences were found for native perennials. Location was important for explaining native perennial patterns, but richness and cover were also positively associated with lower fire severity, greater tree cover, and coarse woody debris.

- Expectations for increased native perennial plant diversity and abundance following prescribed fires may not necessarily be met and exotic species spread may compromise other ecosystem attributes.

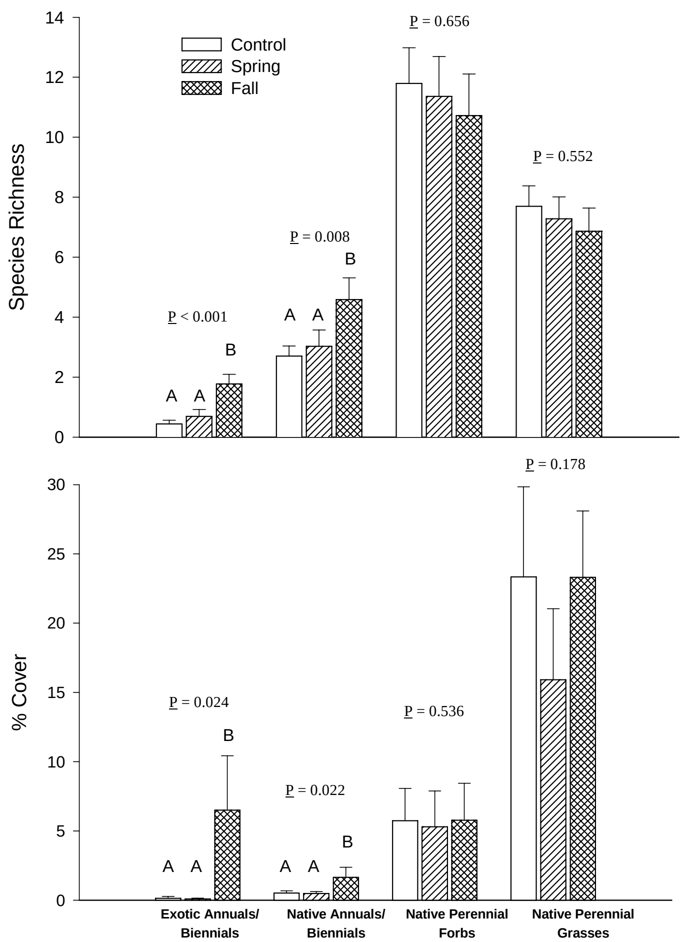
- Restoration in these forests presents a challenge as prescribed fires interact with present environmental conditions that are very different than historical conditions.

Literature Cited

Breiman, L., J.H. Friedman, R.A. Olshen, & C. Stone, 1984. Classification and regression trees. Chapmam and Hall, Boca Raton, FL.

Clark, L.A., & D. Pregibon, D., 1993. Tree-based models. Pages 377-418 in M. Chambers & T.J. Hastie (eds.). Statistical Models in S. Chapman and Hall, New York.

Figure 2. Richness (0.03 ha) and cover for each species group in relation to treatment (n = 6). Data are means ± SE. P values are listed for overall ANOVA tests. Different uppercase letters denote statistically significant differences (P < 0.05) for post-hoc pairwise Tukey's tests.



4) Fuels Assessment by C.G. Niwa

Methods and Materials

Litter, duff and woody fuels were monitored in 2002, five years after the original prescribed fires; and in 2003, the season following the reburns. Fall and spring reburn sub-units were surveyed both years. Fuels were measured in control units only in 2002, since no burning treatments were subsequently applied to these areas.

Fourteen fuels transects were established in each control unit and each fall reburn and spring reburn sub-unit. The transects were located either within a previously established fixed-radius plot, or at randomly selected points between plots. In addition to the 12 transects located in the six fixed-radius plots, control units contained two transects set up randomly between the established plots, for a total of 14 transects. Fall and spring reburn sub-units contained six transects in the three fixed-radius plots, and in addition, eight transects were set up between established plots, for a total of 14 transects. The transects that were set up between plots were 132’ from an established plot center at a random azimuth. Random azimuths were chosen by one crew member spinning the bezel of their compass and another crew member telling them when to stop.

Transects were 66’ long, at a random azimuth from the center stake of an established plot or the randomly selected point between plots. For every transect set up, a second was set up along the corresponding back azimuth. Along these transects litter and duff accumulation were measured and woody debris were tallied according to Brown (1974). The following data were collected:

1. Litter and duff were measured in tenths of inches at 20’ and at 40’ along the fuels transect using duff pins (gutter nail or welding rod). The duff-litter interface is defined as the point where fallen litter transforms from intact into decayed. In the control units, the total depth of the litter and duff combined was recorded. Litter depth was measured in the reburn sub-units from the top surface of the litter to the prefire duff-litter interface. Postfire, the distance from the top of the duff pin to the burned surface of the forest floor, and from the top of the duff pin to mineral soil was measured. Using these measurements, litter and duff consumption were calculated.

2. 1 hr fuels (diameter less than ¼”) were counted along the first 6’ of the transect from the plot center.

3. 10 hr fuels (diameter greater than or equal to ¼” and less than 1”) were counted along the first 6’ of the transect from the plot center.

4. 100 hr fuels (diameter greater than or equal to 1” and less than 3”) were counted along the entire transect.

5. 1000 hr fuels (diameter 3” and greater) were counted along the entire transect, measured for length and designated as either sound or decayed.

Data Analysis

Six fuels classes were summarized and statistically analyzed: litter and duff, 1 hr, 10 hr, 100 hr, 1000 hr and total woody fuels (the last four classes combined).

Analysis of variance was used to test for significant differences at the 0.05 level among treatment means for each of the two survey years. Due to non-normal distribution in the raw data, a rank transformation (Kruskal-Wallis test) was used (Sprent 1993). When significant treatment differences existed "least significant differences" were computed to make multiple comparisons between treatments (Sprent 1993).

Results

Fuel loadings before (2002) and after (2003) the fall and spring units were reburned are presented in Table 1. Following both fall and spring reburns, the greatest reduction was in the 1000 hr fuels class (82.8% and 53.9%, respectively). In the spring reburn sub-units, there was also high consumption of the 10 hr fuels, with a 51.9% reduction. The 10 hr fuels category had the lowest percent reduction after the fall reburn, while after the spring reburn, the 1 hr fuels were the least consumed (18.6% and 7.1%, respectively). The litter and duff layer were reduced 26.7% after the fall reburn and 37.7% following the spring reburn.

Means and standard errors by year and treatment for each the six fuels classes are presented in Table 1.

Five years after the original prescribed burns, litter and duff depths were significantly less in the fall reburn sub-units compared to the control and spring reburn treatements. Following the reburns, there were statistical differences between all of the treatments, with fall reburn the least, spring reburn intermediate and controls having the deepest litter and duff layers.

1 hr fuels were statistically greater in control units than in spring burn treatements five years after the original fires. 1 hr fuel accumulations in the fall burns were intermediate and not significantly different from either of the other treatments. After the reburns, 1 hr fuels were significantly more abundant in controls than both the fall and spring reburns, and there was no difference between the seasonal treatments.

Five years after the original prescribed burns, 10 hr fuels had the same pattern of abundance as 1 hr fuels. However, following the reburns, there were statistical differences between all of the treatments, control units had the most, fall reburns were intermediate and spring reburns had the least 10 hr fuels.

100 hr fuels were significantly more abundant in control units compared to fall treatments five years after the original burn. 100 hr fuel accumulations in the spring burns were intermediate and not significantly different from either of the other treatments. After the reburns, 100 hr fuels showed the same pattern as the litter and duff. There were statistical differences between all treatments, with fall reburn the least, spring reburn intermediate and controls having most 100 hr fuels.

1000 hr fuels showed no significantly differences between treatments five years after the original fires. However, after the reburns, 1000 hr fuel loadings had the same pattern as the litter and duff and 100 hr fuels. There were statistical differences between all treatments, with fall reburn the least, spring reburn intermediate and controls having most 1000 hr fuels.

Five years after the original burns, there were significantly heavier total woody fuel loads in control treatments than in the fall and spring burns, and there was no difference between the seasonal treatments. Following the reburns, total woody fuels reflected the pattern of the litter and duff, 100 hr and 1000 hr fuel classes. There were statistical differences between all treatments, with fall reburn the least, spring reburn intermediate and controls having highest woody fuel loadings.

Conclusions

- Fuel loadings in 2002, five years after the original burn, were generally highest in the control treatments. This was consistent over all of the fuel classes.
- Fuel loadings five years after the original burn in the fall and spring sites varied with fuel size class and may have been affected by the addition of woody material due to tree mortality caused by the fire treatments.
- Following the reburns, fuel loadings in 2003 were always statistically higher in the control treatments.
- With the exception of the 10 hr fuel class, fuels were higher in the spring reburn sub-plots than in the fall reburn treatments. This is likely because the amount of consumption of 10 hr fuels was extremely low in the fall reburn treatment (18.6%) and very high in the spring reburn (51.9%).

References Cited

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Sprent, P. 1993. Applied Nonparametric Statistical Methods. Second Edition. Chapman-Hall, London. 342 p.

Table 1. Treatment means and standard errors for 5-years after the original burn and immediately after reburning; and percent reduction in fuel classes for fall and spring reburns. Means after original burns or after reburning followed by the same letter are not significantly different (P = 0.05). [1 inch = 2.54 cm; 1 ton/ac = 2.24 metric tons/ha]

	5 – years After Original Burn			Immediately After Reburning			Percent Consumption	
	2002	2002	2002	2002	2003	2003	Fall	Spring
	Control	Fall	Spring	Control	Fall	Spring		
Litter and Duff (in)	**2.11a** *± 0.13*	**0.75b** *± 0.05*	**1.83a** *± 0.09*	**2.11a** *± 0.13*	**0.55c** *± 0.04*	**1.14b** *± 0.07*	26.7	37.7
1 hour fuels (tons/ac)	**0.08a** *± 0.01*	**0.05ab** *± 0.01*	**0.04b** *± 0.06*	**0.08a** *± 0.01*	**0.04b** *± 0.01*	**0.04b** *± 0.01*	25.0	7.1
10 hour fuels (tons/ac)	**2.41a** *± 0.21*	**1.69ab** *± 1.13*	**1.65b** *± 0.19*	**2.41a** *± 0.21*	**1.37b** *± 0.12*	**0.79c** *± 0.10*	18.6	51.9
100 hour fuels (tons/ac)	**2.82a** *± 0.22*	**2.02b** *± 0.20*	**2.41ab** *± 0.27*	**2.82a** *± 0.22*	**1.23c** *± 0.12*	**1.70b** *± 0.12*	39.0	29.4
1000 hour fuels (tons/ac)	**24.94a** *± 4.30*	**12.75a** *± 3.97*	**11.51a** *± 2.85*	**24.94a** *± 4.30*	**2.19c** *± 0.44*	**5.30b** *± 0.91*	82.8	53.9
total woody fuels (tons/ac)	**31.20a** *± 4.59*	**16.50b** *± 4.06*	**15.6b** *± 3.00*	**31.20a** *± 4.59*	**4.83c** *± 0.53*	**7.83b** *± 0.93*	70.8	49.8

Outputs from Project 01B-3-3-16 (as of 3/7/06)

Publications

Thies, W.G., Westlind, D.J., Loewen, M. 2005. Season of prescribed burn in ponderosa pine forests in eastern Oregon: impact on pine mortality. International Journal of Wildland Fire, 14:223-231.

Thies, W.G., Westlind, D.J. 2006. Root disease research in support of forest management: some recent examples. Proceedings of the fifty-third annual Western International Forest Disease Work Conference: 2005 September 26-30; Jackson, Wyoming. USDA Forest Service, Ogden, Utah. (also oral presentation)

Thies, W.G., Westlind, D.J., Loewen, M., Brenner, G. 2006. Prediction of delayed mortality of fire-damaged ponderosa pine following prescription fires in eastern Oregon, USA. International Journal of Wildland Fire 15(1): 19-29.

Kerns, B. K., Thies, W. G., Niwa, C. 2006. Season and severity of prescribed burn in ponderosa pine forests: implications for understory native and exotic plants. Écoscience 13(2): xx-xx. [publication projected for June 2006]

Oral Presentations

Kerns, B.K., W.G. Thies, and C.G. Niwa. 2003. Does season of prescribed burn influence exotic species interactions in an eastern Oregon ponderosa pine forest? Oral presentation, North American Forest Ecology Workshop, Corvallis, OR.

Kerns, B.K., W.G. Thies, and C.G. Niwa. 2003. Effect of season of prescribed fire on understory plant communities in an eastern Oregon ponderosa pine forest. Oral presentation, Society for Ecological Restoration, Northwest Chapter, Portland, OR. (Published abstract)

Thies, W.G, Niwa, C.G., Westlind, D.J. 2004. Impact of diseases, insects and fire on ponderosa pine mortality following spring and fall underburning in the southern Blue mountains of Oregon – a work in progress. Annual Meeting of Society of American Foresters and the Canadian Institute of Forestry, 2-6 October, Edmonton, Alberta, Canada. (abstract of talk provided in the program but not published)

Kerns, B. K. Thies, W. G. and Niwa, C. 2005. Prescribed burn and grazing in ponderosa pine forests: implications for the herbaceous understory. Oral presentation, Annual Meeting, Ecological Society of America, Montréal, CA. (Published abstract).

Thies, W.G., Kerns, B.K. 2006. Effect of season and interval of prescribed burns in a ponderosa pine ecosystem on root disease, tree mortality, and understory vegetation. Presentation to be made to the Forest Leadership Team Malheur National Forest and Emigrant Springs Ranger District in March 2006. A similar presentation is being planned to be given on four other National Forests in eastern Oregon winter 2006.

Dissertations

Kangas, M. 2003. Prescribed fire in a ponderosa pine stand in the Blue Mountains, Oregon: Relationships among post-fire Scolytidae incidence, delayed tree mortality, snag decay dynamics, and woodpecker snag use. M.S. Thesis, Department of Forest Science, Oregon State University, Corvallis, Oregon. 92 p.

Posters

Kerns, B.K., Thies, W.G., Niwa, C.G. 2003. Season effects of prescribed fire on understory plant communities in an eastern Oregon ponderosa pine forest. Poster presentation, National Fire Plan Convention, New Orleans, LA.

Thies, W.G., Niwa, C.G., Kerns, B.K., Westlind, D.J. 2004. Effect of season and interval of prescribed burns in a ponderosa pine ecosystem. April 5-9, 2004, Phoenix, AZ (Poster and presentation requested by JFSP).

Kerns, B.K. Thies, W.G., Niwa, C. 2004. Ponderosa pine understory plant community patterns: interactions of prescribed fire severity and season of burn. Poster presentation, Annual Meeting, Ecological Society of America, Portland, OR. (Published abstract)

Science findings (Information publication produced monthly by the PNW Research Station and mailed to 15,000 recipients.)

Kerns, B.K., Thies, W.G., Niwa, C.G, 2006 Not all prescribed fires are created equal—fire seasons and severity effects in ponderosa pine forests of the southern Blue Mountains. PNW Station Science Findings. March, 2006. 5p. Available at the following website: http://www.fs.fed.us/pnw/sciencef/scifi81.pdf

In progress:

Kangas, M, Filip, G.M, Thies, W.G. Predicting post-fire delayed ponderosa pine mortality and bark beetle incidence using stem char height. Submited to: Western Journal of applied Forestry.

Kerns, B.K., Thies, W.G., Niwa, C.G Seasonal prescribed fire and grazing effects on ponderosa pine forest understory plant communities. Being prepared for: Ecological Applications.