Project Title: Effects of Prescribed Burn Regime and Grazing on Eastern Oregon Ponderosa Pine Vegetation and Fuels: The Season and Interval of Burn Study

JFSP project ID number: 12_01_01_10

Principal Investigator:

Dr. Becky K. Kerns, Research Ecologist, USDA Forest Service, Pacific Northwest Research Station, 3200 Jefferson Way, Corvallis, OR 97331; 541.750.7497; bkerns@fs.fed.us

Co-Principal Investigators:

Douglas Westlind, USDA Forest Service, Pacific Northwest Research Station, Corvallis, OR
Michelle Day (formerly Buonopane), Oregon State University, Corvallis, OR
Dr. Jeff Hatten, Oregon State University, Corvallis, OR

I. Abstract

In the western United States, the Season and Interval of Burn study (SIB) represents a unique long-term permanent plot study platform that was developed on the Malheur National Forest in 1997. Established at the request of local land managers to investigate the influence of spring and fall prescribed fire treatments on black stain root disease and its potential insect vectors, the original study was significantly expanded in 2002 to include 5 and 15 year burn intervals, a grazing component and the addition of an array of ecosystem response variables—tree growth and mortality, interactions with insect and diseases, fuels, understory vegetation and exotic plant species, and soil organic matter and biota—all largely funded by JFSP and the National Fire Plan over the following decade. Funding from this RFP provided the opportunity to all plots for vegetation, fuels, and soil response 2012-2015.

Frequent fall burning (15-year) provided some resource benefits such as increased tree growth for surviving trees, reduction of some finer fuels (1-hr, litter and duff), and some regeneration reduction. Frequent fall burning had little impact on the understory plant community, although some species typically associated with increasing after fire did benefit, including the invasive annual grass cheatgrass. However, the reintroduction of fire did not increase understory productivity and diversity, a common goal related to prescribed fire use. We documented few benefits associated with very frequent (five year frequency) reburning, except that it was more effective in reducing conifer regeneration. However, very frequent reburning resulted in increases in invasive plant cover, trends in decreasing cover for some plant functional groups, and decreases in total plant richness. Therefore very frequent re-burning is meeting few management objectives associated with the reintroduction of fire and the restoration of fire prone ponderosa pine forests in these Southern Blue Mountain Ecoregion stands.

In our fire treatments, grazing exclusion did impact total plant cover, although the magnitude of the grazing exclusion response may depend on climactic patterns. However it is difficult to decipher these patterns without even longer term data sets. Management goals related to increasing understory productivity and vigor after fires may consider grazing exclusion as an option. However our results also suggest that grazing exclusion alone in the absence of fire can also increase understory productivity.

II. Background and Purpose

Ponderosa pine forests are a major forest type in western North America and their ecological history has served as a textbook example for the reintroduction of fire and the use of prescribed fire to restore forest structure and function (Allen et al. 2002, Hessburg and Agee 2003). Repeat burning or "maintenance burning" is critical for the establishment of historical fire regimes and more than one burn may be necessary to reduce fuels adequately and minimize fire-caused tree mortality. But knowledge about prescribed fire effects generally comes from single-burn, single season studies. Thus there is little data regarding the impacts of repeat burning and different prescribed fire regimes.

Prescribed fire regimes, including fire frequency, fire intensity, and season of burning, can strongly influence overstory tree growth and mortality, insect and disease dynamics, fuels, and understory vegetation composition and dynamics. Fire suppression efforts during the last century have led to fuel levels well outside the historical range of variability (Agee 2003). As fire is reintroduced to western ponderosa pine stands, it is unclear if they can sustain unwanted mortality, initially from the heat effects of fire (Ryan and Frandsen 1991, Swezy and Agee 1991) and subsequently to insects and insect vectored disease. The largest trees of highest value are especially susceptible (Kolb et al. 2007). To keep fuel loads within target ranges and minimize mortality, managers will burn them repeatedly. However, the effects of season and interval of prescribed burning regimes on ecosystem structure and function are poorly understood.

Managers are also concerned about how the timing of stand treatments affects the efficiency of fuels reduction, understory abundance and diversity, and second order fire effects such as the spread and impact of insects and diseases, and how grazing and fire interact and impact understory vegetation composition and dynamics. Few studies have examined the interaction of fire and cattle grazing together in western US forests. Yet livestock grazing commonly occurs in dry and low elevation forested areas. Many of these lands are also the focus of extensive restoration efforts involving the reintroduction of fire. Ungulates can exert important influences on ecosystem processes and have profound direct and indirect effects on vegetation development and species composition (Hobbs 1996, Weisberg and Bugmann 2003, Wisdom et al. 2006).

In the late 1990s, Walter Thies, Christine Niwa, and Douglas Westlind (USFS, Pacific Northwest Research Station) developed a study at the request of local land managers to investigate the influence of spring and fall prescribed fire treatments on black stain root disease and its potential insect vectors (Thies et al. 2001, Thies and Westlind 2005). Becky Kerns joined the team in 2000 and the team sought funding to significantly expand the study with support from JFSP. The expanded study includes 5- and 15-yr burn intervals, a grazing component and the addition of an array of ecosystem response variables—tree growth and mortality, interactions with insect and diseases, fuels, understory vegetation and exotic plant species, and soil organic matter and biota – the Season and Interval of Burn Study (SIB).

The burn intervals of five and fifteen years were chosen by local fire managers based on knowledge available at the time about historical fire frequencies (Bork (1984) reported mean fire return intervals in the area at 4-11 years; Soeriaatmadja (1966) reported 3-36 years), the desire to control fuel conditions using very frequent fires, and reports from the southwest that the most effective repeated burn interval was 4 years (Sackett et al. 1996). Thus 5 years was chosen as a low end “extreme” and 15 years as a more moderate burn cycle. Spring and fall burning were tested because although most historical fires burned in the summer or fall, spring fire, weather, and fuel conditions allow fuel consumption and fire behavior to be more easily controlled in the shoulder seasons. In nearly all cases, spring and fall prescribed fire regimes are the only ones available to land managers. But managers are often particularly concerned about potential deleterious effects owing to spring burning because it is outside the natural range of variability for these systems.

To our knowledge, ours is the only study examining seasonal and interval prescribed fire effects and the interaction of livestock grazing in ponderosa pine forests. In the western United States, the SIB represents a unique long-term permanent plot study platform — all largely funded by JFSP (01B-3-3-16, 03-3-3-28, 06-2-1-10) and the National Fire Plan. The present project was funded by JFSP in order to continue this critical long-term permanent plot and to remeasure all plots pre- and post- burning for vegetation, fuels, and soil response. The objectives of the study were multidisciplinary and included:

1) Examine the impact of season of burn (fall, spring and control) at two intervals (5 year and 15 year) to determine the response of:
   - Ponderosa pine tree growth: as measured by height and diameter.
   - Ponderosa pine mortality: as influenced by fire, insects, and disease.
   - Fuels: Litter, duff, woody fuels, and tree live crown height.
   - Understory vegetation: abundance and richness by life-form and function group, species composition, grass reproductive capacity, and conifer regeneration and as influenced by environmental variables (soil, light, other disturbance).
   - Soil components: total carbon, total nitrogen, pH, and fungal composition as measured by molecular techniques.
2) Examine the impact of season of burn (fall, spring and control), 5-yr interval reburning, and cattle grazing, and determine understory vegetation response: abundance and richness by life-form and functional group, species composition, grass reproductive capacity, and conifer regeneration, as influenced by grazing intensity, fire severity and environmental variables (soil, light, other disturbance).

III. Study Description and Location

The study encompasses six upland ponderosa pine forested stands located at the southern end of the Blue Mountains, Emigrant Creek Ranger District, Malheur National Forest, Oregon (Fig. 1). Stands range in size from 40 – 56 ha, with individual treatment units ranging from 4.5 – 24.5 ha. The stands were identified and delineated by US Forest Service district staff in 1995 and are part of a larger, relatively continuous ponderosa pine and mixed-conifer forested landscape. Four stands are located in the southeastern part of the district (Driveway Stands, Fig. 1). The other two stands (Trout and Kidd Flat) are located 18 km to the west. Each stand received a thinning prescription in 1994 or 1995 (consistent within each stand), including areas later delineated in this study as controls. Parent materials consist of basalt, andesite, rhyolite, tuffaceous interflow, altered tuffs, and breccia (Carlson 1974). The soils received ash from pre-historical eruptions of ancient Mount Mazama and other volcanoes in the Cascade Mountains to the west. Soils are generally dominated by Mollisols, but Inceptisols and Alfisols are also present (Hatten et al. 2008).

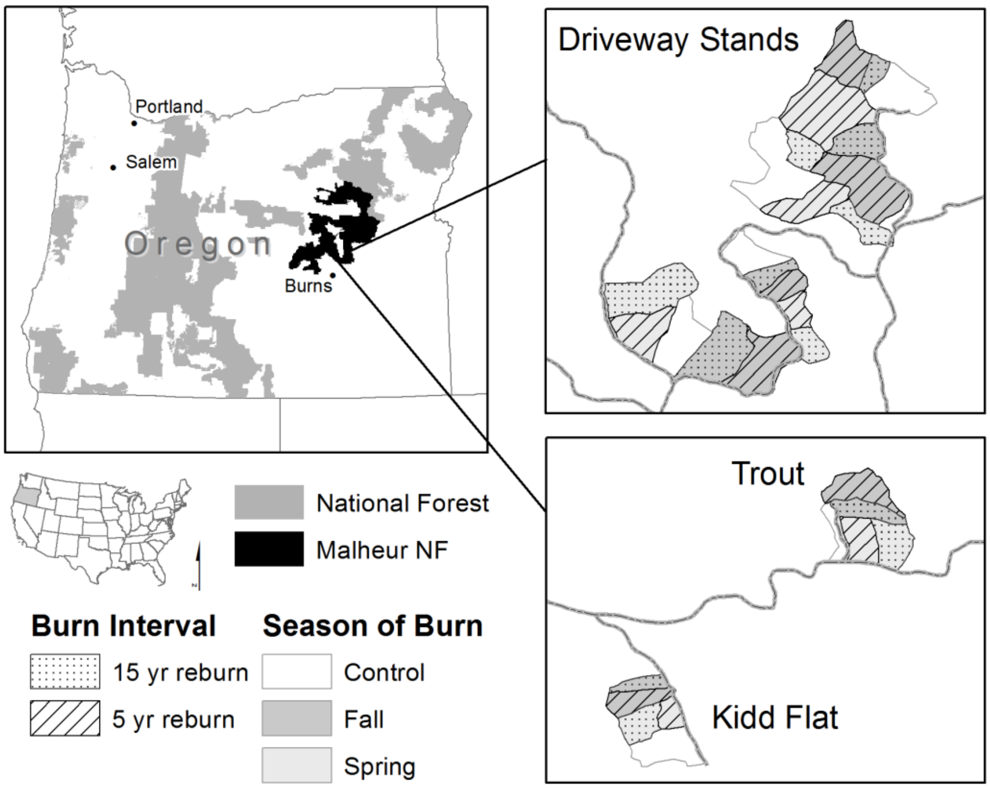

Fig. 1. The study area showing the location of the Malheur National Forest and orientation of the stands.

The stands are dominated by mixed-aged ponderosa pine (mostly about 100-120 years old, with a few individual trees about 200 years old) but *Juniperus occidentalis* and *Cercocarpus ledifolius* also occur. The Driveway stands are characterized by the *Pinus ponderosa*/*Pseudoroegneria spicata* plant association. The western stands are largely representative of the *Pinus ponderosa*/*Carex geyeri* plant association.

In 2010-2014, the area started to be impacted by a large and somewhat unprecedented pine butterfly (*Neophasia menapia*) outbreak. Defoliation in the study area is significant, but our rapid qualitative assessment conducted in fall 2011 indicated that defoliation is uniform across the sites and treatments. Because the outbreak is consistent and uniform across our sites and treatments, and no significant mortality is expected, the experiment is not in jeopardy.

The main study is a split-plot randomized complete block design with two factors: season of burn and interval of burn (n=6). Season of burn is the whole plot treatment with three factor levels that appear one time in each block: control, fall, spring. The split-plot treatment is for interval of burn: 5-yr, 15-yr. Prior to burning in 1997, each stand was divided into three units with boundaries established along roads and topographic features to control prescribed burns. Control, fall, and spring burn treatments were then randomly assigned. In 1998, six 0.2-ha (0.5-ac) circular plots were established to evaluate responses to the first burns. Plots were located at least 100 m (330 ft) apart, and plot centers were permanently marked and mapped. In 2002, each burned experimental unit was bisected and one randomly selected subunit of each pair was assigned to either the 5- or

15-yr burn interval. Implementation of the burn schedule is shown in Fig. 2. Note that in 2012, only two stands were burned due to adverse burn conditions initially, and then closure of the burn window. The other four stands were burned in the fall of 2013 and spring of 2014. This change resulted in an extension request for this study and all plots were remeasured in 2015 rather than 2014.

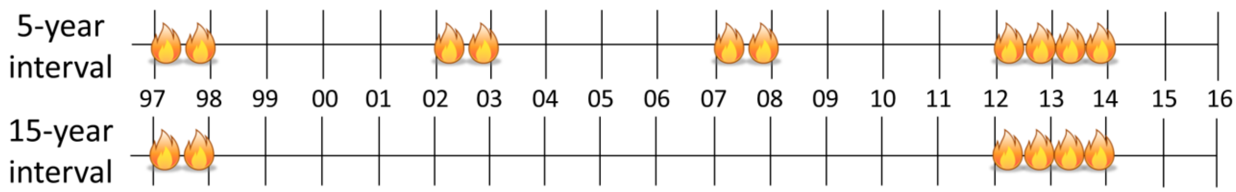

Fig. 2. Fall and spring burn schedule for the study. In 2012 due to adverse burn conditions only two stands were burned. The other four stands were burned in the fall of 2013 and spring of 2014.

The grazing study was established only on the 5-yr interval treatments on four of the stands, two in the Driveway area, and Trout and Kidd Flat. This study is also a split-plot randomized complete block with two factors: 5-yr reburning and grazing (n=4) (Fig. 3). Reburning at 5-yr intervals was the whole plot treatment. Fenced exclosures for the grazing treatment enclosed a single 10-m radius subplot within each exclosure. Exclosure plots were located along a random bearing a minimum distance of 50 m from the preexisting subplots using a compass and tape. During the duration of the study, each stand has been grazed by cattle from late June/early July through early to mid-August (except in the no grazing exclosures). Cattle use is operational in nature and the fenced exclosures only excluded cattle. Native ungulates (deer, elk, and antelope) and other herbivores can enter by jumping over or going under the barbed wire. Documentation of native ungulate access is provided by noting utilization and fresh dung. In addition, fences are closed only when cattle are present in the area.

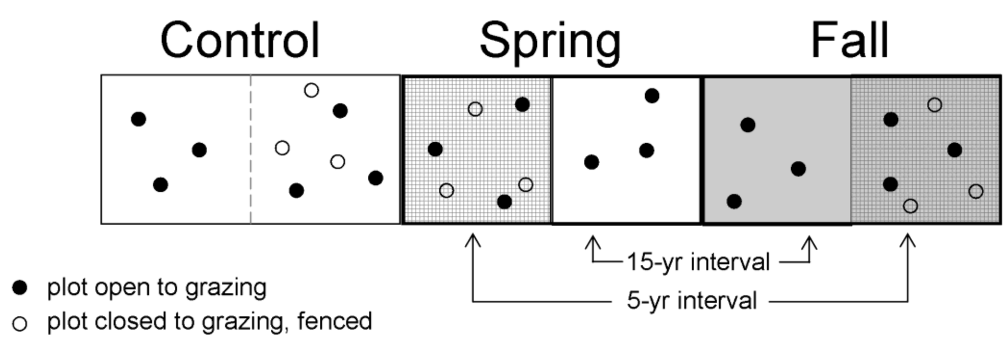

Fig. 3. Schematic of a single experimental block (stand). The study includes 6 such stands, although only 4 of the stands have the grazing component.

IV. Key Findings

Impacts of season and interval of burn

A. Ponderosa pine tree growth

Ponderosa pine growth data were collected in 2013, 15 years following the initial treatments and reflect the results of the initial burn followed by two repeated burns at 5-yr intervals for the 5-yr treatments versus a single burn in the case of the 15-yr re-burn treatments. Fall 15-yr burning resulted in diameter growth increases of 32, 21, and 19% over that of the spring 15-yr, spring 5-yr and control (marginally significant) treatments respectively, while fall 5-yr diameter growth was 29% higher than the spring 15-yr treatment. No other diameter growth comparisons were significantly different. There were no statistically significant differences in tree height growth for any of the treatments. A paper fully describing growth and mortality differences will be prepared for publication in late 2017.

B. Ponderosa pine mortality

Due to the one year delay in burning some of the stands, the final mortality data will be collected during the summer of 2017 and reported at a later date, as tree mortality cannot be effectively assessed immediately following burning.

C. Fuels

Four years following the initial burns of 1997/1998 we compared seasonal burning effects (spring, fall, and a no-burn control) on litter and duff, woody surface fuel, and seedling density at the six previously thinned ponderosa pine stands. Air temperature during the burns was higher for spring than fall, but humidity, wind speed and flame lengths were similar for both seasons yet fall burn severity was higher. We document marginally significant reductions of 1h fuel with both burn seasons of approximately 40%, but no significant reductions in 10 through 1000 h fuel with either burn season. Fall burning reduced the combined litter and duff depth by approximately 65% but spring burning only resulted in 14% reduction when compared to the unburned controls. There were reductions in pine seedling density (less than 1.37 m tall) from the controls of 42% and 83% for spring and fall burning respectively, but the effect was only significant for fall.

Initial burns followed with either three re-burns at 5-yr intervals, or one 15 years later all reduced combined litter and duff depth to approximately 50% from areas that were not burned (controls). Fall burning resulted in the highest 1000 hour fuel load primarily owing to higher overstory mortality and subsequent snag and branch fall resulting from the initial burns. All burn treatments limited seedling regeneration survival, but fall burning and the 5-yr interval burns were the most effective. Neither burn season nor interval effectively reduced 1- to 1000-hour woody fuels from that of the controls.

D. Understory vegetation

The first fall burns in 1997 created a weak pulse in total plant cover compared to spring burns and controls in some cases (as detected in 2002), but this trend disappeared in the single burn treatment by 2007. Reburning initially reduced plant cover for 1-2 growing seasons, but cover tended to recover after 5 years, although trends are dependent on annual climatic trends. In 2012, after 15 years and three reburns, total plant cover was not significantly different as compared to a single burn (although cover was higher in the fall single burn unit, it was not significant). In 2015, two growing seasons after four 5-yr reburns and one 15-yr reburn, few differences were detected among the treatments (the fall 15-yr reburn had significantly greater cover as compared only to the spring 15-yr reburn). Plant richness was initially higher after the first fall burns, but this trend did not hold. Reburning appears to lower richness. Richness increased from 2002 to 2015 in all treatments (including controls) except the fall 5- and 15-yr treatments.

The plant community appears to be on the one hand fairly resilient to reburning, but also does not respond strongly positively to either 5- or 15-yr reburning. Initially fall burning and 5-yr repeat burning increased native annual forbs, but this trend disappeared by 2015. We did not detect that spring burning, even at 5-yr intervals, was particularly detrimental to the plant community, which was a concern expressed by mangers at the outset of this study. However, the exotic annual grass cheatgrass (*Bromus tectorum*) has responded positively to fall burning and reburning. Although fall 5-yr reburning is not exacerbating this trend, which appears to be largely in response to the first burns. Cheatgrass is responding positively to spring reburning, but this response was not detected until the third 5-yr reburn. Native plant functional groups that responded more positively to both burn treatments include open tufted perennial bunchgrasses, rhizomatous grasses, annual forbs, and the resprouting nitrogen-fixing shrub *Ceanothus velutnius*. Native perennial sedges tended to respond less positively to reburning. The effects of reburning tended to diminish with time, a result that might be related to the fact that finer fuels were limited in the reburns, and reburning did not impact larger fuel or create much fuel heterogeneity (fuel limitation, less fire spread and impact).

E. Soil components

Fifteen years following the initial burn treatments, 5-yr interval burning (three burns) resulted in lower nitrogen soil content in spring compared with fall, although there were no differences with unburned controls or treatments burned a single time. A single spring burn reduced the stable N isotope ratio ($\delta^{15}N$) of the top 15 cm of soil when compared with 5-yr interval burning in the spring. Carbon soil content was higher in all treatments compared with 5-yr interval burning in the spring (including unburned controls), except in comparison to a single fall burn. A single spring burn increased the stable carbon isotope ratio ($\delta^{13}C$) in comparison to a single fall burn. Five-year interval burning in the fall resulted in less acidic soils compared with no burning, but no other differences in pH were detected.

Impacts of season of burn, 5-yr interval reburning and cattle grazing

D. Understory vegetation

Grazing exclosures were built in 2002, five growing seasons after the initial entry burns. Exclosures were only built on the 5-yr interval treatments (fall and spring) and in the controls. Differences in total cover due to grazing emerged in both 2007 and 2012, in the maximum post-fire recovery years. Grazing exclusion increased total cover about 6-10%. Note that plant cover is measured prior to utilization, so differences do not reflect material cattle have consumed, but reflect overall plant vigor, productivity and response to prior years grazing. Total plant cover response to grazing is not detected in the second growing season after the fire (2004, 2009, 2015). The resprouting nitrogen-fixing shrub, *Ceanothus velutinus*, had slightly higher cover in areas that were ungrazed. Other plant functional group responses were not significant for the grazing treatment. Most plant functional groups had trends of higher cover for areas not grazed, resulting in the documented differences for total cover.

V. Management Implications (one-two paragraph discussion of each)

Frequent fall burning (15-year) provided some resource benefits such as increased tree growth for surviving trees, reduction of some finer fuels (1-hr, litter and duff), and some regeneration reduction. Frequent fall burning had little impact on the understory plant community, although some species typically associated with increasing after fire did benefit. However, the reintroduction of fire did not increase understory productivity and diversity, a common goal related to prescribed fire use. On the one other hand burning did not appear to be detrimental to the plant community, including spring burning.

We documented few benefits associated with very frequent (five year frequency) reburning, except that it was more effective in reducing conifer regeneration. However, very frequent reburning resulted increases in invasive plant cover, trends in decreasing cover for some plant functional groups, and decreases in total plant richness. Therefore very frequent re-burning is meeting few management objectives associated with the reintroduction of fire and the restoration of fire prone ponderosa pine forests in these Southern Blue Mountain Ecoregion stands.

In our fire treatments, grazing exclusion did impact total plant cover, although the magnitude of the grazing exclusion response may depend on climactic patterns. However it is difficult to decipher these patterns without even longer term data sets. Management goals related to increasing understory productivity and vigor after fires may consider grazing exclusion as an option. However our results also suggest that grazing exclusion alone in the absence of fire can also increase understory productivity.

It is possible that many of our results are related to the fact that prescribed fires are conducted under such conservative conditions that significant changes in many ecosystem properties should not be expected. Fires conducted under drier fuel moisture conditions and more historically typical time periods may lead to quite different outcomes. For example, Varner et al. (2007) suggested that a potential strategy for increasing fuel consumption would involve timing prescribed fires to periods when fuel moisture contents are appropriately low. It is possible that conducting managed fires under recommended prescriptions is at odds with achieving certain resource goals.

VI. Relationship to other recent findings and ongoing work on this topic (one to two pages)

Our results on fuels are somewhat consistent with results in the literature. Prescribed burns do not reliably lead to large reductions in fuels (e.g., Fonda and Binney 2011, Price et al. 2015). Vaillant et al. (2009) found that 100-hr fuels were reduced 10-50% while 1-hr fuels were reduced 90-98% in California fire and pine stands of firs and pines, but results were short lived. However, our result that mortality resulting from the intial burns, especially in the fall, followed by snag and limb fall can lead to increases in 1000 hr fuels that are not subsequently consumed by low intensity reburns has not been reported in the literature. A few studies found fall burns were better at reducing fuels compared to spring burns (Knapp et al. 2005, Perrakis and Agee 2006, Fettig et al.

2010). However, fuel moisture content most likely drives this, and spring burns may be effective if fuel moisture is low enough. Kauffman and Martin (1989) found late spring burns reduced litter and duff more so than late fall burns, demonstrating fuels are not always drier in the fall compared to the spring. Measuring and predicting fuel moisture content at the time of burning is challenging (Engber et al. 2013, Varner et al. 2016). Our results that reburning during the drier fall season and at shorter intervals is more effective at controlling excessive conifer regeneration is consistent with studies from the Black Hills of South Dakota and Wyoming (Battaglia et al. 2008).

Numerous studies have documented that wildfire and prescribed burning can enhance understory abundance or diversity in the absence of cattle grazing, as noted in a recent syntheses (Bartuszevige and Kennedy 2009, Abella and Springer 2015). Few studies have examined the interaction of fire and cattle grazing together in western US forests. Much of the research on herbaceous community response to grazing after fire from the western US has been conducted in big sagebrush steppe. Yet livestock grazing commonly occurs in dry and low elevation forested areas. Many of these lands are also the focus of extensive restoration efforts involving the reintroduction of fire. Thus our work is an important contribution to the literature.

VII. Future work needed (one to two pages)

Understanding the impacts of different prescribed fire regimes will require long-term remeasurement of these stands through time. With one of our burn regimes at a 15-yr frequency it is impossible to know the longer-term impacts at this point in time. In addition, deciphering patterns in vegetation response to treatments is confounded by annual climactic variability. Examination of longer-term trends may allow a better understanding of vegetation response to climactic trends, which is becoming increasingly important due to changes in climate.

We would also like to include more precise measurement of fuel moisture, fire intensity, heat, heat transfer, etc. at the time of burning, particularly in terms of overstory tree mortality. Future work could include such measurements if we are able to obtain funding to do so.

In addition, synthesis of our current work in a manager friendly format such as a general technical report would allow more in-depth analysis and assessment of trends and patterns. For example, resource managers frequently desire information about prescribed fire regimes and individual plant species. Such information is difficult to assess statistically as required for a peer-reviewed publication but charts and graphs related to trends could potentially be informative for managers. Comparison of our prescribed fire regime work to other longleaf pine systems in the US is also needed. Developing more conceptual understanding of resource response to prescribed fire regimes may be achievable with a larger synthetic effort.

Owing to the novel and unique nature of this study in the western US, replication of this study at additional sites would provide more powerful inference. This is particularly true for the grazing portion of the study. We are not aware of any other studies in ponderosa pine forests in the West that examine the interaction of re-burning and post-fire cattle grazing. In addition other grazing systems and management options could be tested. For example could similar results to what we obtained in relation to grazing exclusion be demonstrated with a 1 to 2 year rest after burning? Our study only examines grazing versus no grazing thus offering managers few options as total grazing exclusion is unlikely for managers.

VIII. Deliverables Crosswalk

Proposed	Delivered	Status

Master's Thesis†	Kerns and Day. The influence of fire and grazing on AMF communities in a ponderosa pine dominant ecosystem.	In progress
Refereed Publications (3-4)	(1) Westlind and Kerns. Effect of repeated seasonal burning at 5 and 15 year intervals on fuels and conifer seedlings in a ponderosa pine forest of the Blue Mountains of Oregon, USA. Fire Ecology; (2) understory vegetation response to 5-yr interval seasonal reburning and grazing; (3) understory vegetation response to a single seasonal prescribed burn versus three 5-yr interval burns; (4) Zald et al. Understory species composition and richness patterns in relation to different seasons and intervals of prescribed burning. Forest Ecology and Management; and (5) tree growth, mortality, insect and disease	(1-5) In progress
Unanticipated Publications	(1) Oliver, Kerns and Buonopane 2012. A closer look: Decoupling the effects of prescribed fire and grazing on vegetation in a ponderosa pine forest. Science Findings (2) Kerns and Westlind 2013. Effect of season and interval of prescribed burn on ponderosa pine butterfly defoliation patterns. Canadian Journal of Forest Research (3) Kerns 2014. Fire, forests and invasive annual grasses. Douglasia (4) Kerns 2014. Disturbance is a key factor in plant invasion. Western Forester (5) Kerns and Day. The importance of disturbance by fire and other abiotic and biotic factors in driving cheatgrass invasion varies based on invasion stage. Biological Invasions	(1) Published (2) Published (3) Published (4) Published (5) In press
Conference Presentations	(1) Kerns et al. 2012. Post-fire cattle grazing in ponderosa pine forests. (2) Kerns et al. 2012. Effects of prescribed burn regime and grazing on eastern Oregon ponderosa pine vegetation and fuels: The Season and Interval of Burn Study.	(1) June, 2012 (2) December, 2012 (3) May, 2014

	(3) Kerns and Day. 2014. Effects of prescribed burn regime on understory vegetation: a fifteen year response. (4) Kerns et al. 2015. Effects of prescribed burn regime and grazing on eastern Oregon ponderosa pine vegetation and fuels: The Season and Interval of Burn Study. (5) Westlind et al. 2015. Prescribed fire effects on fuel structure in an eastern Oregon ponderosa pine forest. (6) Kerns and Day 2016. Burn season and interval effects on understory vegetation in an eastern Oregon ponderosa pine forest. (7) Westlind et al. 2016. Repeated spring and fall prescribed burning may not achieve desired fuel structures for ponderosa pine forests in the Blue Mountains of Oregon. (8) Zald et al. 2016. Understory vegetation changes with different seasons and intervals of prescribed burning.	(4) February, 2015 (5) November, 2015 (6) March 2016 (7) March 2016 (8) April 2016
Unanticipated Conference Presentations	(1) Kerns and Day 2015. Exotic species dynamics in dry coniferous forests: insights into invasion theory from long-term data. (2) Kerns and Day 2015. Cheatgrass dynamics in coniferous forests.	(1) June, 2015; (2) September, 2015
Field Demonstration Tour	A tour of the study sites and discussion of results will be scheduled once manuscript preparation is complete. Prior field demonstrations in 2014 and 2015 were cancelled due to travel caps.	Anticipated Fall 2017

†The graduate student working on this project withdrew after almost 2 years due to personal issues. Data collection and most analyses are complete. Kerns and Day are working to get these data published and have completed DNA analysis and have a paper in preparation.

IX. Literature Cited

Abella, S. R. and J. D. Springer. 2015. Effects of tree cutting and fire on understory vegetation in mixed conifer forests. Forest Ecology and Management 335:281-299.

Agee, J. K. 2003. Historical range of variability in eastern Cascades forests, Washington, USA. Landscape Ecology 18:725-740.

Allen, C. D., M. Savage, D. A. Falk, K. F. Suckling, T. W. Swetnam, T. Schulke, P. B. Stacey, P. Morgan, M. Hoffman, and J. T. Klingel. 2002. Ecological restoration of southwestern ponderosa pine ecosystems: a broad perspective. Ecological Applications 12:1418-1433.

Bartuszevige, A. M. and P. L. Kennedy. 2009. Synthesis of knowledge on the effects of fire and thinning treatments on understory vegetation in U.S. dry forests. Special Report 1095, Oregon State University. Agricultural Experiment Station Corvallis, OR.

Battaglia, M. A., F. W. Smith, and W. D. Shepperd. 2008. Can prescribed fire be used to maintain fuel treatment effectiveness over time in Black Hills ponderosa pine forests? Forest Ecology and Management 256:2029-2038.

Bork, J. L. 1984. Fire history in three vegetation types on the eastern side of the Oregon Cascades Oregon State University, Corvallis, OR.

Carlson, G. 1974. Soil resource inventory basic soil information and interpretive tables: Malheur National Forest. USDA Forest Service, Pacific Northwest Region, Portland, OR.

Engber, E. A., J. M. Varner, C. J. Dugaw, L. N. Quinn-Davidson, and J. K. Hiers. 2013. Utility of an instantaneous moisture meter for duff moisture prediction in long-unburned longleaf pine forests. Southern Journal of Applied Forestry 37:13-17.

Fettig, C. J., S. R. McKelveya, D. R. Cluck, S. L. Smith, and W. J. Otrosinac. 2010. Effects of prescribed fire and season of burn on direct and indirect levels of tree mortality in Ponderosa and Jeffrey Pine Forests in California, USA. Forest Ecology and Management 260:207-218.

Fonda, R. W. and E. P. Binney. 2011. Vegetation response to prescribed fire in Douglas-fir forests, Olympic National Park. Northwest Science 85:30-40.

Hatten, J. A., D. Zabowski, A. Ogden, and W. Thies. 2008. Soil organic matter in a ponderosa pine forest with varying seasons and intervals of prescribed burn. Forest Ecology and Management 255:2555-2565.

Hessburg, P. F. and J. K. Agee. 2003. An environmental narrative of Inland Northwest United States forests 1800-2000. Forest Ecology and Management 78:23-59.

Hobbs, N. T. 1996. Modification of ecosystems by ungulates. Journal of Wildlife Management 60:695-713.

Kauffman, J. B. and R. Martin. 1989. Fire behavior, fuel consumption, and forest-floor changes following prescribed understory fires in Sierra Nevada mixed conifer forests. Canadian Journal of Forest Research 19:455-462.

Knapp, E. E., J. E. Keeley, E. A. Ballenger, and T. J. Brennan. 2005. Fuel reduction and coarse woody debris dynamics with early season and late season prescribed fire in a Sierra Nevada mixed conifer forest. Forest Ecology and Management 208:383-397.

Kolb, T. E., J. Agee, P. Z. Fule, N. McDowell, K. Pearson, A. Sala, and R. Waring. 2007. Perpetuating old ponderosa pine. Forest Ecology and Management 249:141-157.

Perrakis, D. D. B. and J. K. Agee. 2006. Seasonal fire effects on mixed-conifer forest structure and ponderosa pine resin properties. Canadian Journal of Forest Research 36:238-254.

Price, O. F., J. G. Pausas, N. Govender, M. Flannigan, P. M. Fernandes, M. L. Brooks, and R. B. Bird. 2015. Global patterns in fire leverage: the response of annual area burnt to previous fire. International Journal of Wildland Fire 24:297-306.

Ryan, K. C. and W. H. Frandsen. 1991. Basal injury from smoldering fires in mature *Pinus ponderosa* Laws. International Journal of Wildland Fire 1:107-118.

Sackett, S. S., S. M. Haase, and M. G. Harrington. 1996. Lessons learned from fire use for restoring southwestern ponderosa pine ecosystems. Pages 54-61 *in* W. W. Covington and P. K. Wagner, editors. Conference on Adaptive Ecosystem Restoration and Management: Restoration of Cordilleran Conifer Landscapes of North America. Gen. Tech. Rep. RM-GTR-278 USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Soeriaatmadja, R. E. 1966. Fire history of the ponderosa pine forests of the Warm Springs Indian Reservation, Oregon. Ph.D. Dissertation. Oregon State University, Corvallis, OR.
Swezy, D. M. and J. K. Agee. 1991. Prescribed-fire effects on fine-root and tree mortality in old-growth ponderosa pine. Canadian Journal of Forest Research 21:626-634.
Thies, W. G., C. G. Niwa, and D. J. Westlind. 2001. Impact of prescribed fire in ponderosa pine stands in the southern Blue Mountains on various components of the ecosystem-- three years post fire. Pages 108-112 *in* K. Marshall, editor. Proceedings of the 49th Annual Western International Forest Disease Work Conference, September 16-20, Carmel, CA. USDA Forest Service, Central Point, OR.
Thies, W. G. and D. J. Westlind. 2005. Root disease research in support of forest management: some recent examples. Pages 115-120 *in* J. Guyon, editor. Proceedings of the 53rd Annual Western International Forest Disease Work Conference, September 26-30, 2005, Jackson, WY. USDA Forest Service, Forest Health Protection, Ogden, UT.
Vaillant, N. M., J. Fites-Kaufman, A. L. Reiner, E. K. Noonan-Wright, and S. N. Dailey. 2009. Effect of fuel treatments on fuels and potential fire behavior in California, USA, National Forests. Fire Ecology 5:14-29.
Varner, J. M., J. K. Hiers, R. D. Ottmar, D. R. Gordon, F. E. Putz, and D. D. Wade. 2007. Overstory tree mortality resulting from reintroducing fire to long-unburned longleaf pine forests: the importance of duff moisture. Canadian Journal of Forest Research 37:1349-1358.
Varner, J. M., J. K. Kreye, J. K. Hiers, and J. J. O'Brien. 2016. Recent advances in understanding duff consumption and post-fire longleaf pine mortality. Page 614 *in* C. J. Schweitzer, W. K. Clatterbuck, and C. M. Oswalt, editors. Proceedings of the 18th Biennial Southern Silvicultural Research Conference. e-Gen. Tech. Rep. SRS-212. UDA Forest Service, Southern Research Station, Asheville, NC.
Weisberg, P. J. and H. Bugmann. 2003. Forest dynamics and ungulate herbivory: from leaf to landscape. Forest Ecology and Management 181:1-12.
Wisdom, M. J., M. Vavra, J. M. Boyd, M. A. Hemstrom, A. A. Ager, and B. K. Johnson. 2006. Understanding ungulate herbivory-episodic disturbance effects on vegetation dynamics: knowledge gaps and management needs. Wildlife Society Bulletin 34:283-292.

Presentations and Invited Talks

Kerns, B.K., M. Buonopane, W. Thies, and C. Niwa. 2012. Post-fire cattle grazing in ponderosa pine forests. Invited oral presentation and published abstract, 65th Annual Meeting of the Society for Range Management, June 30, Spokane, Washington.
Kerns, B.K., D. Westlind, and M. Day. 2012. Effects of prescribed burn regime and grazing on eastern Oregon ponderosa pine vegetation and fuels: The Season and Interval of Burn Study. Oral presentation, Fifth International Fire Ecology and Management Congress, December 3-7, Portland, Oregon.
Kerns, B.K. and M. Day. 2014. Effects of prescribed burn regime on understory vegetation: a fifteen year response. Oral presentation, Large Wildland Fires: Social, Political and Ecological Effects Conference, May 19-23, Missoula, Montana.
Kerns, B.K., M.A. Day, and D. Westlind. 2015. Effects of prescribed burn regime and grazing on eastern Oregon ponderosa pine vegetation and fuels: The Season and Interval of Burn

Study. Oral presentation, 68th Annual Society of Range Management Meeting: Managing Diversity, February 2, 2015, Sacramento, California.

Kerns, B.K. and M.A. Day. 2015. Exotic species dynamics in dry coniferous forests: insights into invasion theory from long-term data. Oral presentation, 10th North American Forest Ecology Workshop: Sustainable Landscapes: From Boreal to Tropical Ecosystems, June 14-18, 2015, Veracruz, Mexico.

Kerns, B. K. and M. Day. 2015. Cheatgrass dynamics in coniferous forests. Oral presentation, International Ecology and Management of Alien Plant Invasions Conference, September20-24, Waikoloa Beach, Hawaii.

Westlind, D.J., B.K. Kerns, and W.G. Thies. 2015. Prescribed fire regime effects on fuel structure in an eastern Oregon ponderosa pine forest. 6th International Fire Ecology and Management Congress, November 16-20, San Antonio, Texas.

Kerns, B.K. and M.A. Day. 2016. Burn season and interval effects on understory vegetation in an eastern Oregon ponderosa pine forest. Oral presentation, 87th Annual Northwest Scientific Association Meeting, March 23-26, 2016, Bend, Oregon.

Westlind, D.J., B.K. Kerns, and W.G. Thies. 2016. Repeated spring and fall prescribed burning may not achieve desired fuel structures for ponderosa pine forests in the Blue Mountains of Oregon. Poster presentation, 87th Annual Northwest Scientific Association Meeting, March 23-26, 2016, Bend, Oregon.

Zald, H.S.J., B. Kerns, and M. Day. 2016. Understory vegetation changes with different seasons and intervals of prescribed burning. Poster presentation, 5th International Fire Behavior and Fuels Conference, April 11-15, 2016, Portland, Oregon.

Publications in Print

Kerns, B.K. 2014. Fire, forests and invasive annual grasses. Douglasia 38, Winter (invited contribution).

Kerns, B.K. 2014. Disturbance is a key factor in plant invasion. Western Forester 59:6-7,18 (invited contribution).

Kerns, B.K. and M.A. Day. In press. The importance of disturbance by fire and other abiotic and biotic factors in driving cheatgrass invasion varies based on invasion stage. Biological Invasions.

Kerns, B.K. and D.J. Westlind. 2013. Effect of season and interval of prescribed burn on ponderosa pine butterfly defoliation patterns. Canadian Journal of Forest Research 43:979-983.

Oliver, M., B.K. Kerns and M. Buonopane. 2012. A closer look: Decoupling the effects of prescribed fire and grazing on vegetation in a ponderosa pine forest. Science Findings 141. Portland, OR: U.S. Department of Agriculture Forest Service, Pacific Northwest Research Station. 5 p.

Publications in Preparation

Kerns, B.K. and M.A. Day. In prep. Prescribed fire regimes and understory vegetation: the influence of season and interval of burn.

Kerns, B.K. and M.A. Day. In prep. The influence of fire and grazing on AMF communities in a ponderosa pine dominant ecosystem.

Kerns, B.K. and M.A. Day. In prep. Fire and grazing interactions in a ponderosa pine forest.

Westlind, D.J. and B.K. Kerns. In prep. Effect of repeated seasonal burning at 5 and 15 year intervals on fuels and conifer seedlings in a ponderosa pine forest of the Blue Mountains of Oregon, USA. Fire Ecology

Zald, H.S.J., Kerns, B.K. and M.A. Day. In prep. Understory species composition and richness patterns in relation to different seasons and intervals of prescribed burning. Forest Ecology and Management