Legacy Tree Monitoring in the Ashland Watershed

with the Ashland Forest Resiliency Stewardship Project

Photo Credit: Sean Bagshaw

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I. Introduction

As a part of our Southern Oregon University Senior Capstone project, we worked together with the Ashland Forest Resiliency Stewardship Project (AFR) to monitor legacy trees in the Ashland watershed in Ashland, Oregon. We have gathered and analyzed data with the intention of providing needed evidence to assess how the legacy trees' vigor, growth rates, and mortality rates respond to the applied treatments.

II. Background

A. Ashland Watershed

Due to more than a century of fire-suppression and wide-spread logging in the American west, in conjunction with climate change, forest species composition has changed. Many forests now consist of high density small trees, and shade tolerant, fire intolerant species. Due to this anthropogenic interference, the Ashland watershed forests are now prone to high-intensity fires with a frequent return interval. Large shade intolerant species, such as ponderosa and sugar pine are dying at an accelerated rate. In the absence of fire, they are being replaced by small diameter trees which comprise closed-canopy forests (Metlen, 2013). In order to restore the forest to its natural pre-suppression fire regime, new forest management practices have been implemented as a part of AFR.

B. Ashland Forest Resiliency Stewardship Project

AFR is a collaborative effort between four primary partners: The United States Forest Service, the City of Ashland, The Nature Conservancy (TNC), and the Lomakatsi Restoration Project. This multiparty monitoring group is responsible for observing the application of the project in the Ashland watershed. The National Park Service, Klamath Bird Observatory, citizens from the community, and students from Southern Oregon University (SOU) are also involved in the monitoring effort. All of these entities are stakeholders in the health and well-being of the Ashland watershed. Batham and Lajoie are advised and supported by Dr. Kerry Metlen and Derek Olson of TNC, and Dr. Mark Shibley, and Dr. Gregory Jones of Southern Oregon University.

III. Legacy Tree Monitoring

A. Ashland Forest Resiliency Stewardship Project Goals

Preliminary work has been completed by Dr. Kerry Metlen, Derek Olson and others in TNC, including remote sensing the watershed to determine the location of legacy trees and data collection for each of the 163 legacy trees included in the study. Legacy trees are trees which are of remarkable landscape, nature conservation, and/or cultural value due to their age, size or condition. For the purposes of this monitoring effort, trees 150 years old or older are considered legacy trees. The primary goal of legacy tree monitoring for the AFR project is to protect *Pseudotsuga menziesii* (PSME), and *Pinus ponderosa* (PIPO) legacy trees, with a secondary goal of protecting *Arbutus menziesii* (ARME), *Quercus kelloggii* (QUKE), and *Pinus lambertiana* (PILA), legacy trees (Table 1).

Table 1. Legacy tree species code, scientific name, and common name.

Tree Species Code	Scientific Name	Common Name
PSME	*Pseudotsuga menziesii*	Douglas fir
PIPO	*Pinus ponderosa*	Ponderosa pine
ARME	*Arbutus menziesii*	Pacific madrone
QUKE	*Quercus kelloggii*	Black oak
PILA	*Pinus lambertiana*	Sugar pine

B. Our Goals

Volunteer hours were completed with TNC to aid in legacy tree monitoring within the Ashland watershed. The objective of this portion of the project was to complete all field data collection, to enter control plot and legacy tree data into a Microsoft Access database, and to summarize and analyze the data. The ultimate goals of our contribution to the legacy tree monitoring project were to help TNC establish a reference point for comparison of pre- and post-treatment fieldwork; to display initial effects of AFR treatment methods on the composition of the forest over time; and to gain experience and knowledge to prepare for a career in environmental studies. Completing these goals required several group meetings, extensive fieldwork and data analysis, and the cooperation of the AFR project, TNC, and all project advisors.

IV. Relevant Studies

The major driving question of legacy tree monitoring is: How will the vigor, growth rates, and mortality rates of legacy trees in the Ashland watershed be impacted by forest thinning and prescribed burn treatments implemented as a part of the AFR project? This question will take several years to evaluate; however, numerous studies have addressed similar questions about forest and legacy tree responses to thinning and prescribed burn treatments. Many of them have been completed in or near the Pacific Northwest and encompass a similar forest composition. A review of these studies will provide an understanding of how legacy trees and the rest of the Ashland watershed forest may respond to AFR thinning and burning techniques.

Various methods have been developed to protect legacy trees and overall forest health. One of those methods is forest thinning. According to Graham et al., there are 5 general thinning methods: Low, or thinning from below; crown, or thinning from above; selection, or diameterlimit thinning; free thinning; and mechanical thinning (1999). In a study with over 25 years of post-treatment data in the Sierra Nevada forests of California, several thinning treatments were applied, including the thinning methods listed above (Stephens & Moghaddas, 2005). Over the course of the study, thinning treatments shifted from a traditional silvicultural system to a more modern approach over time. The effectiveness of seven systems and two types of reserves used in the Sierra Nevada mixed conifer forests was evaluated in terms of vegetation structure, fuel bed characteristics, modeled fire behavior, and potential wildfire related mortality. Traditional treatments included plantation treatments, overstory removal, and individual tree selection, while modern treatment consisted of low thinning and the institution of old-growth and young-growth reserves. This broad range of methods provided an opportunity for comparison among the treatments (Stephens & Moghaddas, 2005).

The results of this study indicated that the majority of the traditional silvicultural systems did not effectively reduce potential fire behavior and its effects (2005). Average basal area per hectare (the area of land occupied by trees) was significantly higher in low thinning, old-growth reserve, young-growth reserve, and individual tree selection treatments. Overstory removal treatment areas' average basal area was similar to that of un-thinned, masticated, and pre-commercially thinned plantations. In general, thinning from below, old-growth reserves, and young-growth reserves were more effective at reducing predicted tree mortality. The authors suggest the use of a combination of mechanical treatments and prescribed fire as a management technique to reintroduce a fundamental ecosystem process into forests (Stephens & Moghaddas, 2005).

Another method for forest density management is including prescribed burn along with forest thinning. In a study by Ritchie, Skinner, & Hamilton, the authors observed fire severity among treated and untreated stands after a wildfire at Blacks Mountain Experimental Forest (2007). The treatment areas were part of a large-scale experiment designed to evaluate stand structure, grazing and prescribed fire in an interior ponderosa pine (*Pinus ponderosa*) forest. At several locations in the forest, the wildfire burned from a dense, untreated forest stand, into an area that had been recently treated with combinations of thinning and prescribed fire. Tree survival and damage data was collected and analyzed using a logistic regression model relating the probability of initial mortality to distance from treatment plot boundary, and treatment history. Fire behavior simulation was used to evaluate the effectiveness of the pre-fire stand treatments (Ritchie, Skinner, & Hamilton, 2007).

This study revealed that the combination of thinning and prescribed burn produced the highest tree survival rates and drastically reduced fire intensity. Thinned units with prescribed fire were predicted to have nearly 100% survival. Survival rates in thinned areas without prescribed fire was higher than observed in other untreated areas of the forest, but generally lower than the other treated units. The survival rate in the untreated area was nearly zero.

In another study, “Difference in Radial Growth Response to Restoration Thinning and Burning Treatments between Young and Old Ponderosa Pine in Arizona”, thinning and prescribed burn treatments were also applied (Skov, Kolb, & Wallin, 2005). The authors examined the difference in response to 4 levels of thinning treatment among old, presettlement, and young, postsettlement ponderosa pine trees over 3 years. Treatments included three levels of thinning followed by prescribed fire and an unthinned and unburned control; treatments were implemented on three different sites (Skov, Kolb, & Wallin, 2005).

The results from this study showed that thinning increased radial growth at breast height of young, post-settlement trees in all 3 years after treatment and growth response was negatively correlated with post-treatment stand basal area. In contrast, growth of old, pre-settlement trees was not affected by thinning in most years, and there was no relationship between growth and post-treatment stand basal area. Application of the same thinning prescription to stands with different management history resulted in different post-treatment basal area and consequently different growth response to thinning for post-settlement trees. These results indicate that 80-year-old, post-settlement ponderosa pines are more responsive to restoration thinning than older pre-settlement trees (Skov, Kolb, & Wallin, 2005).

Another factor to be considered when using thinning and prescribed burn techniques is the relationship between prescribed burn and mortality. In a study by Maloney et al., the authors compare the types of insect- and pathogen-mediated mortality on mixed-conifer trees in the Teakettle experimental Forest east of Fresno, California, three years after treatment (2008). They found that the number of bark beetle attacked trees and mortality was greater in burn treatments than in no-burn treatments. Attacks were most common among larger diameter trees. Treatments also increased the frequency and abundance of Ribes, an alternate host for white pine blister rust. They conclude that continued monitoring is needed (Maloney et al., 2008).

Several studies have been conducted regarding thinning and prescribed burn to reduce forest density, restore pre-fire suppression forest composition, and to protect and promote legacy trees. Although prescribed burn poses the risk of initial tree mortality due to bark beetle attacks, the combination of forest thinning and prescribed burn is shown to have the greatest positive effect on legacy tree growth. Parties involved in the AFR project took several of these studies into consideration when creating the project plan and have utilized similar techniques.

V. Methodology

A. Legacy Trees

The Environmental Impact Statement (EIS) for the AFR found that natural processes, specifically fire, are not likely to function in a manner that maintain values of interest without management intervention treatments, including fuel management and forest density reduction. Retention of large old legacy trees and their response to treatments are key factors and a critical component of AFR multiparty monitoring.

Sampling locations were selected within a 100 m buffer of the project footprint.

The Nature Conservancy developed a remotely sensed map of legacy conifer locations that was used to target sample trees, and plot centers were allocated using GIS. Figure 1 displays legacy tree plots, shown in light green.

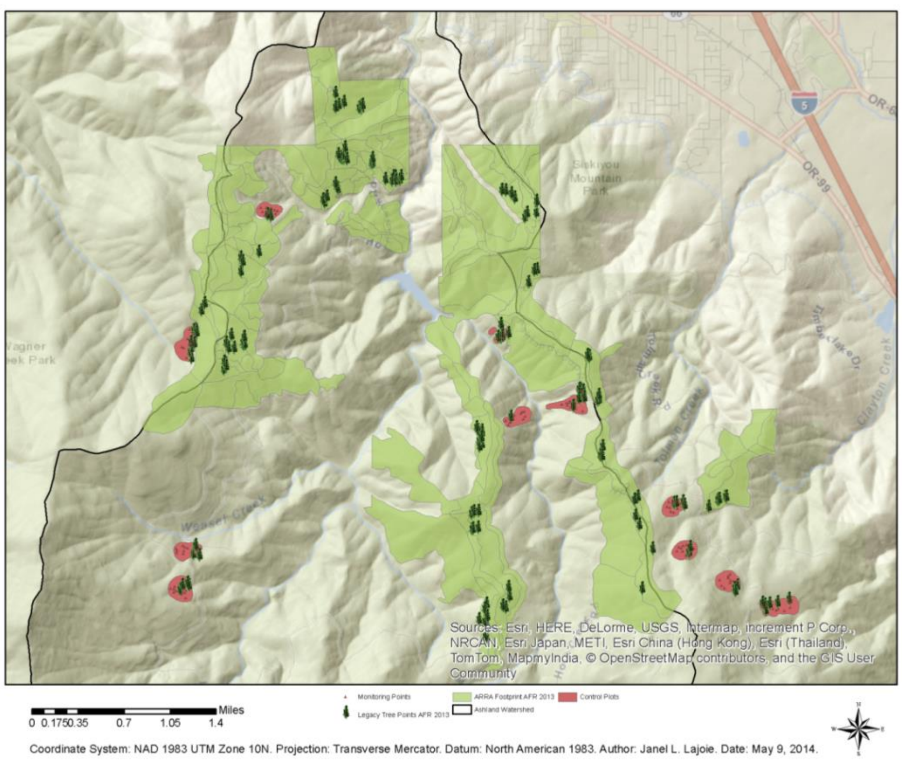


Figure 1. Legacy tree and control plots in the Ashland watershed, Ashland, Oregon.

Samples were stratified by treatment history, proposed treatment, and biophysical setting. To avoid sampling bias, the living legacy tree with live canopy >20% closest to the remotely sensed legacy tree pixel in the GIS data was measured. Legacy trees in close proximity to one another, but of different species, were monitored whenever possible. Since conifers are more easily remotely sensed than deciduous, ARME and QUKE samples were taken near conifer legacy trees whenever possible, and then a potential tree list was compiled from previous efforts in the watershed. The location of legacy trees are shown in figure 1 using small dark green tree symbols.

Throughout the watershed, 163 legacy trees have been identified, photographed, and tagged with an individual identification number, with considerable additional data collected for each tree. The data regarding each legacy tree includes, but is not limited to, diameter at breast height (DBH), species, vigor, canopy base height, crown dieback, and animal and insect damage (Shown in Appendix D). Plot characteristics were recorded in a one-tenth acre plot surrounding each legacy tree. The number and species of live trees remaining in the plot were recorded, and the stumps and species of trees were recorded according to treatment.

Three treatments have been and will continue to be performed suurounding each legacy tree, including staged neighbor removal (ST), density management neighbor removal (DM), and an untreated control group (NT). Currently, there are 25 treated tree plots consisting of 13 density management plots and 12 staged neighbor removal plots, and 10 untreated tree plots. In the staged treatment non-commercial thinning was implemented in 2005. Commercial tree harvest was implemented in 2013 in both the ST and DM only treatments.

The data for the 163 legacy tree plots and legacy tree treatment plots was entered into a Microsoft Access database, and was analyzed using Microsoft Excel and IBM SPSS software. The quadratic mean diameter (QMD) of trees was calculated to determine the average diameter of trees around each of the legacy tree species in radial plots. The average basal area per acre (BA/ac) and average trees per acre (TPA) were calculated by radial plot and sub-unit plot, around each of the legacy tree species, both pre- and post-treatment. Pre- and post-treatment data were then used to determine the magnitude of treatment around each of the legacy trees in both radial and sub-unit plots.

B. Control Plots

The control plots were created with ArcGIS software and are shown in a salmon color in both figures 1 and 2.

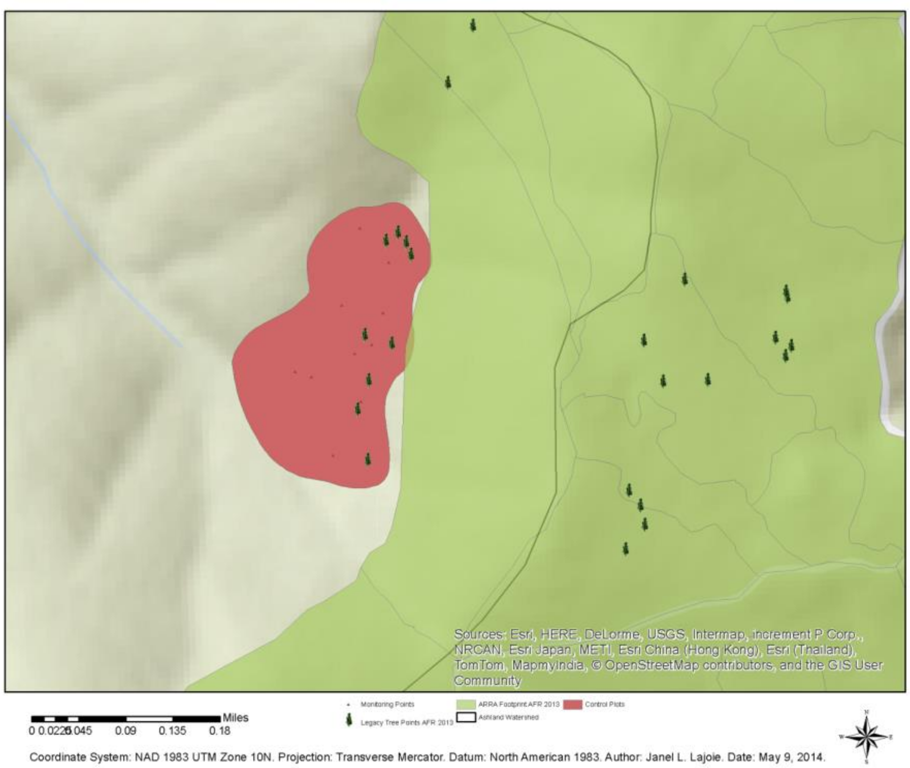


Figure 2. Control plot example in the Ashland watershed, Ashland, Oregon.

The parameters for measuring control stand density plots include:

- 5 acre minimum stands with 5 plots per stand, or if there are multiple trees within a stand, then 10 plots per stand
- Plots a minimum of 100 feet from stand edge
- Minimum of 66 feet between plots.

Each random point was evaluated with both a fixed radius plot and a variable radius plot. The fixed radius plot was a 360-degree circle with a 3.6 meter radius beginning at due north. From due north to due east, all hardwood saplings and seedlings with a diameter >5 inches diameter at breast height (4.5 feet; DBH) were recorded. For the entire plot, all conifers with DBH >5 inches height were recorded.

A variable radius plot survey for the entire 360 degree area surrounding the random point was conducted with the aid of a Spiegel Relaskop relascope and TruPulse hypsometer. The relascope was used to measure the basal area of a forest stand, and the hypsometer was used as a rangefinder to evaluate the distance of individual trees in relation to the random point in the control area. All PSME, PIPO, ARME, QUKE, PILA, *Abies concolor* (ABCO), *Calocedrus* (CADE), and *Chrysolepis chrysophylla* (CHCH) of sufficient size were included in the count. By using these tools and collecting consistent data, we are able to determine forest stand density, timber stand volume, and growth. These methods were used in all 110 random points in control areas throughout the legacy tree monitoring control area.

Data recorded in the field using data collection sheets (Appendix E) included plot number1-110, species, height or diameter at breast height and tally in fixed plots, diameter at breast height in variable plots. Additional data that was deemed important or unusual such as extensive bark beetle invasion, widespread mortality, or tagged trees was noted in the comments section of the data collection sheets.

After control plot data collection was complete, the information from the data collection sheets was entered into a Microsoft Excel worksheet, to be transferred into an Access database by TNC. After data was entered, our project goals expanded to address these reasearch questions:

- What is the forest composition in the Ashland Watershed, pre- and post-treatment?
- What is the magnitude of thinning treatments around legacy trees?

The data was analyzed using Microsoft Excel, to understand the pre-treatment forest composition in the Ashland watershed, and to determine the magnitude of thinning treatment in each of the treatment areas.

VI. Results

A. Radial Plots

Initial calculations reveal that the pre-treatment QMD of trees in the radial plots range from 9.77 to 11.27 inches in DM, 8.23 to 10.90 in NT, and 8.59 to 9.63 in ST treatment areas (Table 2). Post-treatment QMDs are higher, with a range of 11.73 to 15.17 inches in DM, 8.23 to 10.9 in NT, and 11.31 to 14.82 in ST treatment areas.

Table 2. Quadratic mean diameter of trees in legacy tree radial plots, by treatment, pre- and post-treatment.

Quadratic Mean Diameter of Trees in Legacy Tree Radial Plots

	DM		NT		ST	
Legacy Tree Species	Pre	Post	Pre	Post	Pre	Post
ARME	10.23	13.73	8.81	8.81	9.63	12.87
PILA	10.01	11.73	10.90	10.90	9.38	14.82
PIPO	9.77	14.16	8.64	8.64	8.59	11.31
PSME	10.70	15.17	8.23	8.23	8.67	14.38
QUKE	11.27	14.83	9.39	9.39	8.90	12.32

Forest density is shown as mean TPA and mean BA/ac around legacy tree species, by treatment type, in Radial plots (Table 3). Pre-treatment mean TPA values range from 327.27 to 633.64 trees per acre. Pre-treatment mean BA/ac range from 198.38 to 312.21. Post treatment values are lower in DM and ST areas with TPA values ranging from 114.55 to 173.64 trees per acre, and BA/ac values ranging from 79.87 to 169.38.

Table 3. Radial tree densities around legacy trees, pre- and post-treatment.

Radial Density of Legacy Tree Plots Pre -Treatment

	DM				NT				ST			
Legacy Tree Species	$\bar{x}$ TPA	σ	$\bar{x}$ BA/ac	σ	$\bar{x}$ TPA	σ	$\bar{x}$ BA/ac	σ	$\bar{x}$ TPA	σ	$\bar{x}$ BA/ac	σ
ARME	450.00	218.68	256.83	100.75	633.64	354.55	268.00	86.93	617.27	249.84	312.21	115.71
PILA	522.73	220.73	285.62	130.08	327.27	185.26	212.25	77.95	536.36	118.34	257.65	113.40
PIPO	464.55	183.92	241.96	78.33	529.09	439.19	215.62	94.02	591.82	156.96	238.41	71.05
PSME	454.17	84.90	283.44	70.68	536.36	322.99	198.38	59.45	612.73	301.67	251.26	114.93
QUKE	399.09	243.74	276.65	120.91	440.00	236.78	211.58	72.99	619.09	307.00	267.43	102.16

Radial Density of Legacy Tree Plots Post -Treatment

	DM				NT				ST			
Legacy Tree Species	$\bar{x}$ TPA	σ	$\bar{x}$ BA/ac	σ	$\bar{x}$ TPA	σ	$\bar{x}$ BA/ac	σ	$\bar{x}$ TPA	σ	$\bar{x}$ BA/ac	σ
ARME	155.45	107.83	159.86	71.01	633.64	354.55	268.00	86.93	173.64	186.67	156.87	95.29
PILA	157.27	200.15	118.04	84.47	327.27	185.26	212.25	77.95	124.55	83.35	149.26	97.73
PIPO	117.27	36.63	128.19	64.83	529.09	439.19	215.62	94.02	114.55	85.25	79.87	49.16
PSME	135.00	115.64	169.38	90.80	536.36	322.99	198.38	59.45	138.18	79.85	155.89	93.31
QUKE	133.64	71.59	160.25	67.80	440.00	236.78	211.58	72.99	145.45	75.41	120.40	37.26

Treatment magnitude describes the amount of thinning treatment applied around the legacy trees. A number closer to 1 implies that thinning was greater around that legacy tree species. TPA treatment magnitude values range from 0.61 to 0.73 in DM areas, and 0.72 to 0.81 in ST areas, while BA/ac treatment magnitude values range from 0.37 to 0.63 in DM areas, and 0.39 to 0.66 in ST areas. Treatment magnitude is zero in NT areas (Table 4).

Table 4. Treatment magnitude on trees per acre and basal area per acre in Radial plots, around legacy tree species, by treatment.

Treatment Magnitude in Legacy Tree Radial Plots

	DM		NT		ST	
Legacy Tree Species	$\bar{x}$ TM (TPA)	$\bar{x}$ TM (BA/ac)	$\bar{x}$ TM (TPA)	$\bar{x}$ TM (BA/ac)	$\bar{x}$ TM (TPA)	$\bar{x}$ TM (BA/ac)
ARME	0.64	0.37	0.00	0.00	0.74	0.51
PILA	0.73	0.63	0.00	0.00	0.75	0.45
PIPO	0.68	0.45	0.00	0.00	0.81	0.66
PSME	0.70	0.41	0.00	0.00	0.75	0.39
QUKE	0.61	0.42	0.00	0.00	0.72	0.51

B. Sub-Unit Plots

Forest density was also calculated by sub-unit. Thinning was applied around random points within the sub-units. Since legacy trees occurred within those sub-units, we were able to determine unit thinned tree densities around the legacy tree species. Pre-treatment mean TPA values range from 147.14 to 497.67 trees per acre. Pre-treatment mean BA/ac range from 126.86 to 228.64. Post treatment values are lower in DM and ST areas with TPA values ranging from 230.83 to 461.34 trees per acre, and BA/ac values ranging from 149.17 to 205.75 (Table 5).

Table 5. Unit tree densities by legacy tree species, pre- and post-treatment.

Unit Density of Legacy Tree Sub-Units Pre-Treatment

	DM				NT				ST			
Legacy Tree Species	x̄ TPA	σ	x̄ BA/ac	σ	x̄ TPA	σ	x̄ BA/ac	σ	x̄ TPA	σ	x̄ BA/ac	σ
ARME	497.67	179.72	221.75	31.67	231.00	76.09	188.80	53.05	293.18	118.18	220.27	27.52
PILA	435.50	159.49	223.50	49.97	193.40	48.31	194.20	23.03	255.73	67.20	211.64	37.34
PIPO	454.09	194.05	210.91	32.79	216.27	57.12	197.09	28.15	273.45	113.34	228.64	22.69
PSME	436.25	199.04	214.33	32.03	227.45	54.62	200.55	28.44	255.00	123.82	227.18	22.52
QUKE	296.09	68.18	199.09	20.42	147.14	114.92	126.86	83.39	276.64	103.27	172.64	30.48

Unit Density of Legacy Tree Sub-Units Post-Treatment

	DM				NT				ST			
Legacy Tree Species	x̄ TPA	σ	x̄ BA/ac	σ	x̄ TPA	σ	x̄ BA/ac	σ	x̄ TPA	σ	x̄ BA/ac	σ
ARME	461.34	169.57	187.15	32.55	231.00	76.09	188.80	53.05	266.37	120.44	181.78	51.85
PILA	400.24	165.18	187.12	51.15	193.40	48.31	194.20	23.03	233.17	70.60	193.95	37.40
PIPO	421.47	194.65	180.15	33.52	216.27	57.12	197.09	28.15	251.15	115.20	193.65	53.43
PSME	399.07	193.42	179.73	32.15	227.45	54.62	200.55	28.44	230.83	126.92	205.75	22.49
QUKE	270.42	65.01	175.63	15.47	147.14	114.92	126.86	83.39	246.71	98.21	149.17	18.86

TPA treatment magnitude values in sub-unit plots range from 0.07 to 0.09 in DM areas, and 0.08 to 0.11 in ST areas (Table 6). BA/ac treatment magnitude values are higher with values ranginging from 0.12 to 0.16 in DM areas, and 0.08 to 0.17 in ST areas. Treatment magnitude is zero in NT areas.

Table 6. Treatment magnitude on trees per acre and basal area per acre in Sub-unit plots, around legacy tree species, by treatment.

Treatment Magnitude in Legacy Tree Sub-Unit Plots

	DM		NT		ST	
Legacy Tree Species	x̄ TM (TPA)	x̄ TM (BA/ac)	x̄ TM (TPA)	x̄ TM (BA/ac)	x̄ TM (TPA)	x̄ TM (BA/ac)
ARME	0.07	0.16	0.00	0.00	0.09	0.17
PILA	0.08	0.16	0.00	0.00	0.09	0.08
PIPO	0.07	0.15	0.00	0.00	0.08	0.15
PSME	0.09	0.16	0.00	0.00	0.09	0.09
QUKE	0.09	0.12	0.00	0.00	0.11	0.14

VII. Discussion

A. Radial Plots

QMDs are higher Post-treatment due to thinning of smaller trees, leaving larger trees that increase QMD values. QMDs in NT areas do not change due to the fact that they are not treated. PIPO had the lowest pre-treatment QMD values in 2 of the 3 treatments; however, QMD values change significantly around PIPO legacy trees.

Mean TPA values in radial plots are significantly reduced post-treatment, while mean BA/ac values are only moderately reduced (Table 3). This is due to the fact that many smaller trees were removed, impacting trees per acre, while leaving larges trees' basal areas in tact. Figure 3 compares the TPA and BA/ac values in the DM and ST treatment areas. BA/ac values show greater variance than TPA values. Hardwoods (ARME and QUKE) tend to have highest remaining TPA and BA/ac, while PIPO has the lowest remaining TPA and BA/ac. This indicates that treatment around PIPO trees is higher than the other legacy tree species.

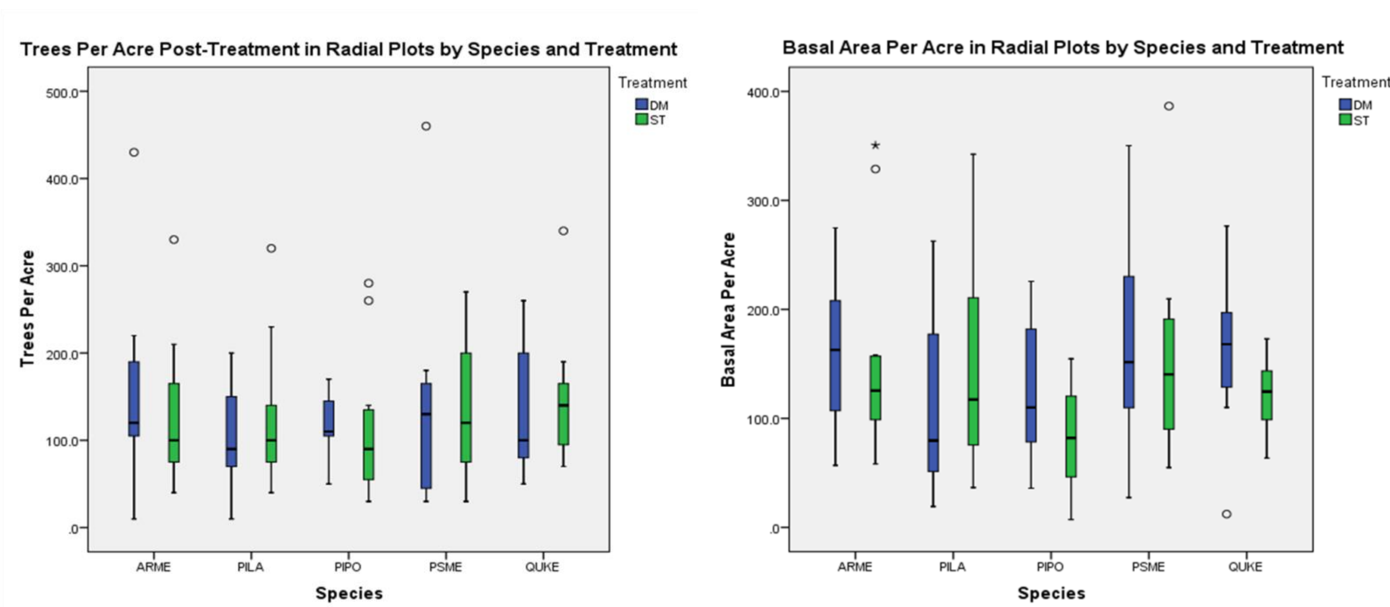


Figure 3. Box plots depicting post-treatment trees per acre and basal area per acre, by legacy tree species and treatment in Radial plots in the Ashland watershed.

TPA treatment magnitudes tended to be higher in ST treatment areas, than in DM (Figure 4). BA/ac treatment magnitudes varied among the treatments. Treatment magnitude values are highest around PIPO trees, especially in ST areas. Values tend to be lowest around hardwoods (ARME and QUKE). TPA treatment magnitude values are greater than BA/ac values due to the thinning of smaller trees, as previously mentioned.

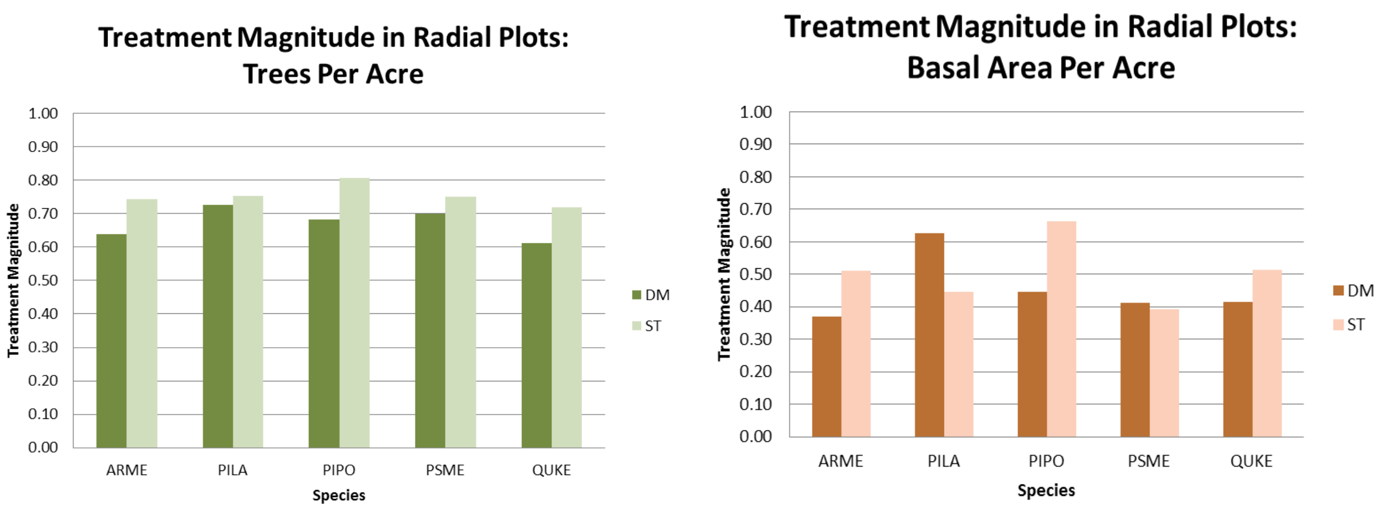
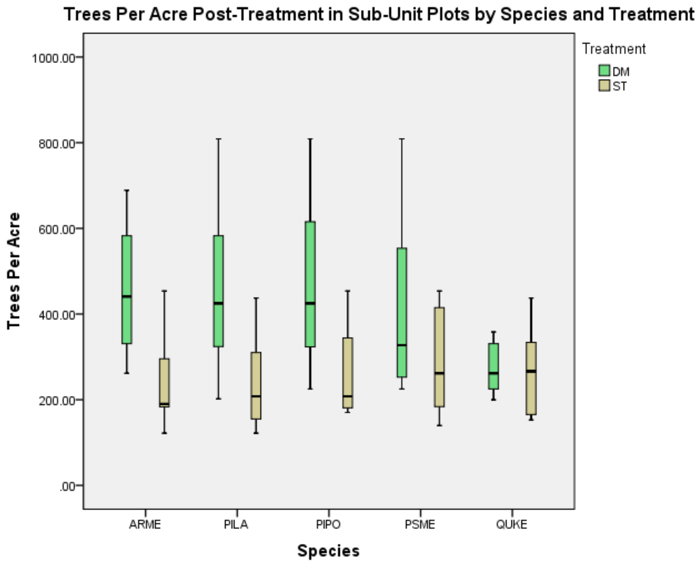


Figure 4. Treatment magnitude comparison of trees per acre and basal area per acre in Radial plots.

B. Sub-Unit Plots

Tree densities in sub-unit plots are reduced post treatment in both TPA and BA/ac values (Table 4). However, the values are not as significantly reduced as in the radial plots. Post-treatment TPA values vary among plots and are still fairly high, while BA/ac values have very little variance (Figure 5). This indicates that sub-units have a a wide range of TPA, but have similar BA/ac values.



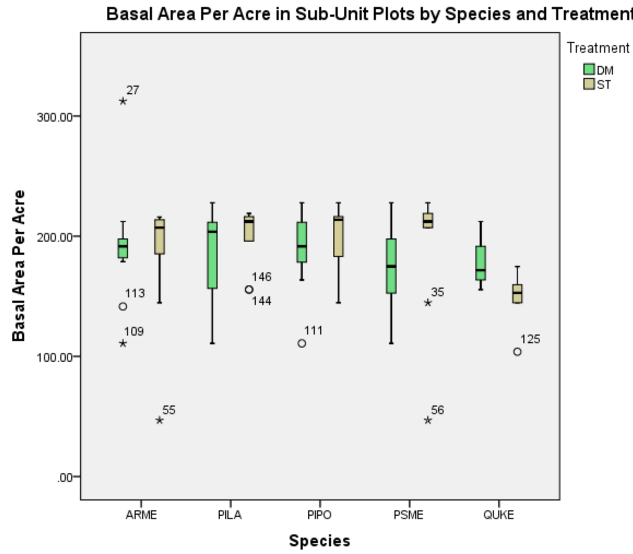
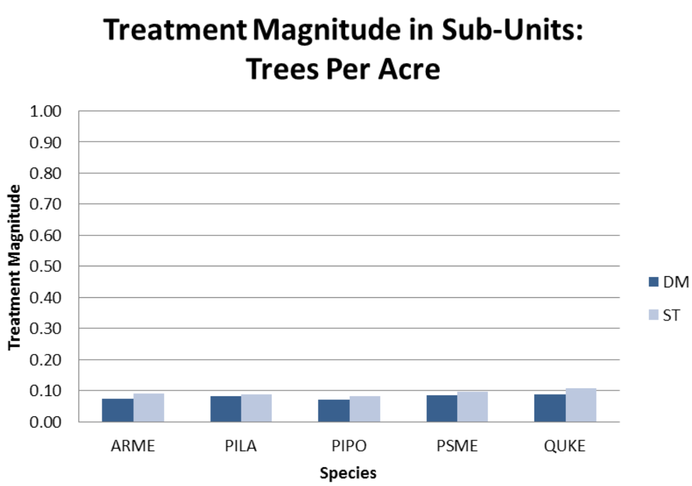


Figure 5. Box plots depicting trees per acre and basal area per acre, by legacy tree species and treatment in Sub-unit plots in the Ashland watershed.

Treatment magnitude values are much lower in sub-unit plots as compared to radial plots (Figure 6). The TPA treatment magnitude values are lower than BA/ac values, also differing from radial plots. This indicates that BA/ac is more impacted by thinning treatments than TPA. BA/ac treatment magnitude values are also more varied than TPA values, similar to radial plots.



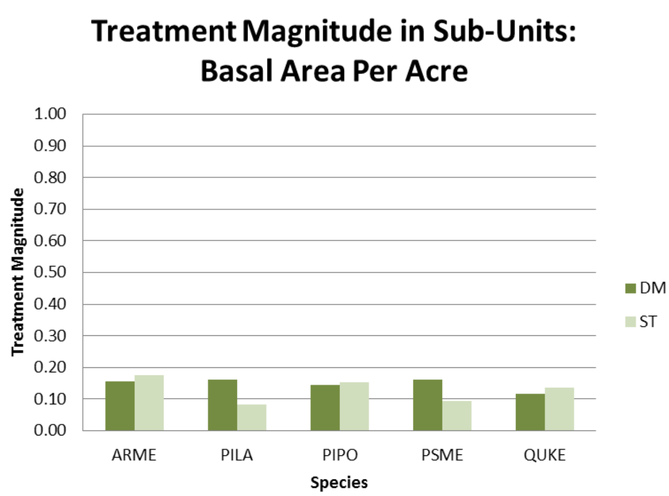


Figure 6. Treatment magnitude comparison of trees per acre and basal area per acre in Sub-unit plots.

VIII. Project Constraints

In the process of the Capstone project, there have been several project constraints. Firstly, the AFR project is a multi-year monitoring project, so this work has been a contribution to the effort, but was not intended to be concluded. The effects the thinning treatments will ultimately have on the forest composition and legacy trees are temporal in nature. A more in-depth analysis of the overall treatment effects cannot be evaluated in this capstone project, but could be useful to incoming Capstone students in subsequent years.

The second constraint is obtaining data in dangerous, difficult to reach terrain. Much of the watershed is located on fairly steep slopes; all but one of the control plots were created on traversable slopes that were relatively accessible by 4-wheel drive and hiking. When the safety of researchers is at risk, it is best not to attempt to collect the data. Due to the danger of the situation, the inaccessibility of the plot, weather constraints, and the fact that the plot contained only one legacy tree to monitor, no data was collected from one of the originally selected control plots.

IX. Project Significance

At local scales, the weather is an extremely important factor in the control and spread of fire. Topography also plays an important role, in that both south-facing and steep slopes often burn with greater severity (Alexander, 2006). In the last 50 years, the Rogue Valley has experienced increasingly dry conditions. The 2013 wildfire season was one of the most severe for the region, and 2014 is poised to be the driest year on record, which could bring another high severity fire year (Snow, 2014). Since 2010, Ashland has set several climate records including highest barometer, highest average wind speed, warmest day, warmest night, and highest heat index, which can all affect fire spread, intensity, and severity (Jones, 2014).

Climate change combined with years of fire suppression and improper forest management techniques have led to overly dense forests in the Ashland watershed. Increased fuel buildup in dense forests leads to higher intensity fires. High intensity fires are detrimental to the vegetation, specifically legacy trees, and wildlife, and are extremely dangerous to nearby civilizations. The combination of climate change and increased fuel load gives the Ashland watershed greater opportunity for ignition. Considering the Ashland watershed is directly above the city of Ashland and near the city of Talent, many human lives are at stake.

The AFR project is designed to help restore the forest to pre-fire suppression conditions with applied forest thinning treatments. The treatments are designed to reduce forest density, thereby reducing fire fuels, protecting legacy trees, and ultimately protecting human welfare. Our work with TNC and other key stakeholders will aid in monitoring the various treatments implemented in the Ashland watershed. Their involvement is crucial to establishing a reference point for future evaluation of the AFR project. The knowledge gained from legacy tree monitoring, as a part of the AFR project, will help to protect the forest and affected citizens and can be used for future forest thinning projects.

X. Appendix A: Project Timeline

Formal Proposal Completed	November 27, 2013
Proposal Presentation Completed	December 6, 2013
Report Outline Completed	January 31, 2014
Data Collection Completed	February 28, 2014
Data Entry Completed	March 7, 2014
Report First Draft Completed	March 14, 2014
Begin Power Point Presentation	March 31, 2014
Begin Poster Compilation	March 31, 2014
Complete STELLA Model	April 15, 2014
Data Analysis Completed	April 30, 2014
Public Presentation	May 14, 2014
Final Written Report	May 30, 2014

XI. Appendix B: Key AFR Monitoring Partners

Agency Name	Address	Contact	Phone	Email
The Nature Conservancy	33 N Central Ave Ste 405 Medford, OR 97501	Kerry Metlen, Ph.D.	(541) 770-7933	kmetlen@tnc.org
		Derek Olson, Field Assistant		dolson@tnc.org
Southern Oregon University	1250 Siskiyou Blvd Ashland, OR 97520	Mark Shibley, Ph.D.	(541) 552-6761	shibleym@sou.edu
		Charles Welden, Ph.D.	(541) 552-6868	welden@sou.edu
		Gregory Jones, Ph.D.	(541) 552-6758	gjones@sou.edu
United States Forest Service Rogue River-Siskiyou National Forest	3040 Biddle Rd Medford, OR 97504	Don Boucher, AFR Project Manager	(541) 552-2913	dboucher@fs.fed.us

XII. Appendix C: Additional Stakeholders

Agency Name	Address	Contact	Phone	Email
City of Ashland	20 East Main St Ashland, OR 97520	Chris Chambers	(541) 552-2066	chris.chamber@ashland.or.us
Lomakatsi Restoration Project	P.O. Box 3084 Ashland, OR 97520	Marko Bey	(541) 488-0208	marko@lomakatsi.org
National Park Service	1250 Siskiyou Blvd Ashland, OR 97520	Daniel Sarr, PhD Ecologist/Program Manager	(541) 552-8575	Dan_Sarr@nps.gov
Klamath Bird Observatory	1497 E Main St, Ashland, OR 97520	Jaime Stephens	(541) 201-0866	jlh@klamathbird.org
Students from Southern Oregon University	Ashland, OR	Amie Batham, Environmental Studies Captsone Student	(530) 351-2480	clinea@sou.edu
		Janel Lajoie, Environmental Studies Captsone Student	(541) 821-2222	lajoiej@sou.edu
Citizens from the Ashland community	Ashland, OR			

XIII. Appendix D: Legacy Tree Data Collection Sheets Sample

Obs: DO, KP
Date: 8/16/13

Legacy Tree Effectiveness Monitoring

√AC LTID

Tree Characteristics			
Field	**Value**	**Description**	**Codes**
LTID	341	Legacy Tree ID: Unique ID for centroid of the legacy tree, automatically generated 3-digit starting with 300.	300+
STID	0	Stem ID: Consecutive number ID with the largest stem being stem #1. All stems with DBH> 10 cm receive their own record. Stems of 0, 0.1-4.9 cm or 5.0-10.0 cm are tallied and receive a single record.	For single stemmed trees enter a zero, for multi-stemmed trees 1, 2, 3, etc.
TRTM	ST	No-treatment, or commercial density management with or without staged non-commercial treatment from AWPP	NT=No treatment; DM=AFR commercial unit; ST=Staged AFR commercial
TRYR	2013	Year of AFR treatment	Four number year
CNBH	6	Canopy base height for the plot	In meters
COND	1	Condition Code: Description of tree status	1 = Live, 3 = Recent dead (< five years), 4 = Older dead (> five years, loose bark), 9 = Stump (cut)
SPCD	QUKE	Species Code: 4 letter species code (Genus and Species)	ABCO; ARME; PIPO; PILA; PSME; QUKE
DBH	35.7	Diameter measured at 1.37 m (4.5 feet) from the base for all trees, at 0.33 m (1 foot) from the base for cut stumps. If the tree forks below breast height, add multiple records for multiple stems.	Diameter in centimeters to the nearest millimeter
RCDM	0.7	Root Collar Diameter: Average of two perpendicular measurements. Recorded for all individuals of ARME and QUKE. Recorded on the first (largest) stem of multi-stemmed individuals.	Measured in meters
CAPO	2	Canopy Position relative to the canopy. Open grown trees: full light from all sides with little competition. Dominants: light from above and partly from the sides. Codominants: light from above but little from the sides. Intermediates: little light from above or sides but are in the upper canopy. Suppressed: below main canopy.	0=Open Grown; 1=Dominant; 2=Codominant; 3=Intermediate; 4=Suppressed
VIGR	B	Vigor of the tree broken into 4 classes, similar to Keene's classification for ponderosa from best (A) to worst (D).	1=A, 2=B, 3=C, 4=D
CRPC	95	Percent of tree height in live crown, excluding epicormic branches	Percent
CRDB	50	Crown dieback: the percent of crown missing, dead, or dying, excluding epicormic branches	Percent
HWDB	1	Only on hardwoods, relates to dieback of major branches	0=no dieback, 1=least one, but <50% of all major limbs dead, 2= ≥50%, but not all, major limbs dead, 3=all major limbs dead; epicormic branches only.
EPBR	0	Number of epicormic branch nodes sprouting	Number
CAOF	3	Canopy offset, for hardwoods only estimate the center of the crown mass and measure distance to bole	Number
VPAC	N/A	Van Pelt (2007) age class	0=<150, 1=150-200, 2=200+ years

Obs: DO, KP
Date: 8/16/13

Legacy Tree Effectiveness Monitoring

341 LTID

BLDM	0	Bole damage related to mechanical treatments	0=None, 1=Minor, cambium disrupted on <0.25 of diameter and/or <1 m tall, 2=Major, cambium disrupted on >0.25 of diameter and/or >1 m tall
CNDM	0	Canopy damage related to mechanical treatments. Percentage of living canopy that was destroyed/removed	Percent
MSCD	0	Mistletoe severity code, dwarf mistletoe for conifers, true mistletoe for oak. Hawksworth rating based on the third of the crown infected and severity of infection.	0-6 where each third of the tree can receive a 0 (none), 1 (low), or 2 (high) and then the thirds are summed.
WNDM	0	Wind damage, from none to completely windthrown	0=None, 1=Canopy broken, 2=Bole bent, 3=Windthrown
ANDM	0	Animal damage with mild damage <20% of crown or <50% of bole damaged and severe>20% of crown or >50% of bole.	0=None, 1=Mild, 2=Severe
BLCH	0	Height of bole char	Meters and centimeters
CRSC	0	Percent of canopy killed by crown scorch	Percent
BBCD	0	Bark beetle code. Zeroes mean unsuccessful attack, 1's mean tree is fading due to the attack	00=None, 10, 11=Mountain pine beetle, 20, 21=Douglas-fir beetle, 30, 31=Turpentine beetle, 40, 41= Ips, 50, 51=Fir engraver
DFCD	0	Defoliating insect code. Zeroes mean unsuccessful attack, 1's mean tree is fading	00=None, 10, 11=Pine butterfly, 20, 21= Tussock moth, 30, 31=Spruce budworm, 40, 41= Tent caterpillar
FHFB	0	Flatheaded Fir Borer code. Zeroes mean unsuccessful attack, 1's mean tree is fading	00=None, 10=Flatheaded fir borer tree not fading, 11=Flathead fir borer tree fading
RESP	0	For madrone and oak not if this stem is a resprout from a much older root crown.	0=No, 1=Yes
PHID1	122/681	Lower horizontal photo ID	Number
PHID2	—82	Upper vertical ID	Number
PHAZ	42	Azimuth to the photo point from the tree	Degrees
PHDS	17.5	Distance to the photo point from the tree	Meters

Comments: 2ND POTENTIAL LEGACY OAK ~ 7 m DOWNSLOPE

Legacy Tree Effectiveness Monitoring

Obs: DO, KP		Plot Characteristics Data Sheet			Date: 8/16/13
LTID: 341		Plot Size: 0.04 ha (0.1 ac) – 11.3 m (37.2) foot radius			
			Stumps		Live
	DBH (cm)	DSH (cm)	AFR	AWPP	
ABCO	0-12.4	0-14			
	12.5-24.9	14-29			
	25.0-37.4	29-44			
	37.5-49.9	44-60			
	>50	>60			
PSME	0-12.4	0-14	1	2	
	12.5-24.9	14-29		9	
	25.0-37.4	29-44	4		2
	37.5-49.9	44-60	1		
	>50	>60			
PIPO	0-12.4	0-14			
	12.5-24.9	14-29			
	25.0-37.4	29-44			
	37.5-49.9	44-60			
	>50	>60			61.1 1
ARME	0-12.4	0-14	1	2	
	12.5-24.9	14-29			
	25.0-37.4	29-44			1
	37.5-49.9	44-60			1
	>50	>60			

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Legacy Tree Effectiveness Monitoring

PILA	0-12.4	0-14			
	12.5-24.9	14-29			
	25.0-37.4	29-44			
	37.5-49.9	44-60			
	>50	>60			
QUKE	0-12.4	0-14			1
	12.5-24.9	14-29			1
	25.0-37.4	29-44			
	37.5-49.9	44-60			1
	>50	>60			
CADE	0-12.4	0-14			
	12.5-24.9	14-29			
	25.0-37.4	29-44			
	37.5-49.9	44-60			
	>50	>60			
	0-12.4	0-14			
	12.5-24.9	14-29			
	25.0-37.4	29-44			
	37.5-49.9	44-60			
	>50	>60			

Comments:

XIV. Appendix E: Control Plot Data Collection Sheet Sample

Observer JL BM

Ashland Forest Resiliency
Legacy Tree Controls

Date 11-24-13 12:25

Stand	Plot	SPP	DBH	Tally	Comments
25	F	ABCO	4.5	•	lots of
25	F	CADE	1	•	dead standing ABCO
25	F	ABCO	1	• •	
25	V	ABCO	23.3		
25	V	ABCO	16.4		
25	V	ABCO	8.3		
25	V	ABCO	9.3		
25	V	ABCO	15.3		
25	V	ABCO	20.5		
25	V	PSME	25		
25	V	ABCO	28.2		
25	V	PIPO	65.5	35.7m	#391
27	F	ABCO	1	[illegible]	
27	F	PIPO	1	•	
27	V	PSME	33.7		
27	V	CADE	68	Burned out	- still alive
27	V	PSME	31.2		
27	V	ABCO	20.5	lots of	dead standing ABCO, PIPO
27	V	ABCO	18.1		
27	V	PSME	36.4		
27	V	ABCO	22.7		
27	V	PIPO	45.1		

XV. References

Alexander, J. D., Seavy, N. E., Ralph, C. J., & Hogoboom, B. (2006). Vegetation and topographical correlates of fire severity from two fires in the klamath-siskiyou region of oregon and california. *International Journal ofWildland Fire*, (15), 237-245. Retrieved from www.publish.csiro.au/journals/ijwf

Conroy, S. D. (2009). *Ashland Forest Resiliency Final Environmental Impact Statement* (Environmental Impact Statement: Record of Decision). Jackson County, Oregon. Retrieved from http://a123.g.akamai.net/7/123/11558/abc123/forestservic.download.akamai.com/11558/www/nepa/1582_FSPLT2_051645.pdf

Graham, R. T., Harvey, A. E., Jain, T. B., & Tonn, J. R. (1999). Effects of thinning and similar stand treatments on fire behavior in western forests. Retrieved from http://digitalcommons.usu.edu/barkbeetles/55/

Hood, S. M. (2010). *Mitigating old tree mortality in long-unburned, firedependent forests: a synthesis* (Gen. Tech. Rep. No. RMRS-GTR-238) (p. 71). Fort Collins, CO: U.S. Department of Agriculture,Forest Service, Rocky Mountain Research Station.

Jones, G. (2014). *Sou: Ashland weather station*. Retrieved from http://weather.sou.edu/

Latham, P., & Tappeiner, J. (2002). Response of old-growth conifers to reduction in stand density in western Oregon forests. *Tree Physiology*, *22*(2-3), 137–146.

Maloney, P. E., Smith, T. F., Jensen, C. E., Innes, J., Rizzo, D. M., & North, M. P. (2008). Initial tree mortality insect pathogen Maloney.pdf. *Canadian Journal of Forest Research*, *38*, 3011–3020.

Metlen, K. (2013). Ashland Forest Resiliency Stewardship Project Effectiveness Monitoring: Legacy Tree Protocol. Retrieved from http://ashland.or.us/Files/AFR%20Mon%20Plan%2020130910.pdf

Metlen, K., & Borgias, D. (2013). Ashland Forest Resiliency Stewardship Project Monitoring Plan. Retrieved from http://ashland.or.us/Files/AFR%20Mon%20Plan%2020130910.pdf

Metlen, K., Olson, D., & Borgias, D. (2013). *Conserving large old trees in restoring dry, fire prone forests of the Rogue Basin*. The Nature Conservancy.

Ritchie, M. W., Skinner, C. N., & Hamilton, T. A. (2007). Probability of tree survival after wildfire in an interior pine forest of northern California: Effects of thinning and prescribed fire. *Forest Ecology and Management*, *247*(1-3), 200–208. doi:10.1016/j.foreco.2007.04.044

Skov, K. R., Kolb, T. E., & Wallin, K. F. (2005). Difference in radial growth response to restoration thinning and burning treatments between young and old ponderosa pine in Arizona. *Western Journal of Applied Forestry*, *20*(1), 36–43.

Snow, S. (2014). The drought of 2013-14 and climate change as of february 2014.*Rogueclimate.org*, DOI: http://www.rogueclimate.org/the_drought_of_2013_2014

Stephens, S. L., & Moghaddas, J. J. (2005). Silvicultural and reserve impacts on potential fire behavior and forest conservation: Twenty-five years of experience from Sierra Nevada mixed conifer forests. *Biological Conservation*, *125*(3), 369–379. doi:10.1016/j.biocon.2005.04.007