The Pacific Madrone: An Analysis of Resprout Characteristics after Disturbance in the Ashland, Oregon Watershed, Final Report

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Abstract:

The pacific madrone (*Arbutus menziesii*) is a broadleaf evergreen hardwood species that is very resilient to disturbance from fire and mechanical thinning by quickly resprouting near its base. The entire canopy can die back from large disturbances, allowing more of an individual's energy to go into resprouting. The Ashland Forest Resiliency Stewardship Project (AFR) is an attempt at reversing years of fire suppression in the Ashland Watershed by slowly integrating prescribed fire and thinning practices to improve the health of the local forest ecosystem. Many of the designated units within AFR have been thinned and/or burned while some have remained untreated. This project assesses the resprout characteristics of selected, variously treated, pacific madrone within the Ashland Watershed and determines if multiple treatments act as a catalyst or as a suppressor to the degree of sprouting within the species. Before accounting for resprout rate, the data collected revealed more smaller resprouts, fewer large resprouts, and shorter resprouts in units that had been both thinned and burned than those only thinned. Other results showed relationships between canopy cover and three resprout variables as well as several relationships with improved condition. Further analysis of resprout rate showed more resprouts per year after treatment among those that had seen prescribed fire, and a greater resprout response in all individuals whose exterior condition appeared healthier.

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I. Introduction and Background:

Pacific madrone (*Arbutus menziesii*) is a landmark species on the west coast of North America. Ranging from southwest British Columbia, Canada to San Diego County in California, the pacific madrone provides berries, foliage, and important habitat to many woodland creatures (Reeves, 2007). Madrone are easily distinguished by their seasonally-peeling bark and are known for rapid resprout after disturbance and drought tolerance. However, they have a relatively low tolerance to frost and shade. A hardwood evergreen, these trees are a prevalent ingredient in Douglas-fir-tanoak-pacific madrone (mixed-conifer, mixed-evergreen) forests such as those in the Klamath-Siskiyou forests, including the Ashland Watershed. Pacific madrone are a particularly vulnerable species because they require large amounts of sunlight for reproduction and resprouting, and require more sunlight as they grow older (Reeves, 2007). Over one hundred years of fire exclusion has made the forests of Southern Oregon dense with small- and medium-sized trees that shade out many species including madrone, leading to their decline.

As an attempt to manage the brand new Yellowstone, Yosemite, and Sequoia National Parks in the late 1880s, the United States Army began to implement policies of total fire suppression. Assisting policies to suppress fire on federal lands, large-scale forest reserves were also established at this time (Sugihara, et al, 2006). However, it is important to note that the thinking at the time involved systematically eliminating wildfire in attempt to produce higher timber yields. After destructive fires in 1910 that killed 78 firefighters and burned over one million hectares of national forest lands, the Forest Service chief was more adamant than ever to eradicate forest fires. In 1924, the federal Clarke-McNary Act allocated federal provisions in a way that essentially created a fire suppression policy that spread across the nation. Throughout the 1900s, agencies attempted to make fire suppression more efficient by enacting the "10 A.M." policy, in which the agencies involved were to put out any forest fire by 10 A.M. the day after it began. Among other ineffective approaches, considerable resources were used to attempt to contain wildfires. Since World War II, extensive research has been done in the fields of biology, plant ecology, and dendrology that has led to the forest management techniques accepted and used today.

In 2009, The Nature Conservancy, Lomakatsi Restoration Project, and the city of Ashland, Oregon, along with the U.S. Forest Service and other stakeholders embarked on a new approach to forest management. The Ashland Forest Resiliency Stewardship Project (AFR) and its corresponding monitoring plan were designed with four key objectives: 1) reduce the risk of large wildfires, 2) increase vigor of large old trees to help protect them from insects, disease, and future fires, 3) restore a healthy forest ecosystem, and 4) protect watershed values such as wildlife habitat and clean drinking water for the city of Ashland (Ashland Forest Resiliency Stewardship Project, 2009; ashlandwatershed.org). Thinning techniques, or treatments, used by AFR include prescribed burns to reduce surface fuel, commercial thinning to reduce overall mass and competition, and select thinning of overgrown individuals or stands to reduce ladder fuels.

Treatments within the AFR Project reduce both surface and ladder fuels in the watershed, leaving less material for forest fires and assisting the reintroduction of historic frequent, low-severity fires back into the landscape. Theoretically, reducing the return interval for low-severity fires and allowing less fuel development on the forest floor and in the canopy will correspond to less severe forest fires, bringing the forest closer to a historic fire regime. Because of their thin and seasonally-peeling bark, pacific madrone are fire-intolerant, as their bark provides poor protection from radiant heat. However, they depend on frequent, low-severity fires to reduce overstory of nearby species, allowing them access to more sunlight (Reeves, 2007). Madrone are, however, very resilient to physical harm as they are known to quickly sprout from dormant buds on the burl after damage by mechanical cutting, fire, or disease. Continuous damage from fire promotes burl development, essentially further improving species longevity (provided there is ample sunlight for optimal resprouting). Adversely, even low severity fire can cause the species to die back to the point of the burl, regardless of size or age, while higher severity fires also cause fire scars at the burl.

Pacific madrone are susceptible to disease and insect leaching during the period shortly after disturbance, which can lead to fatality. As studied in Mendocino County, California, prevention and suppression of fire in an area that historically had frequent fire has shown to be detrimental to the pacific madrone. Overgrown and abundant tanoak species had dominated and shaded out madrone, causing their decline (Reeves, 2007). In a subsequent study on species' response to fire in a dominant-coastal redwood forest, pacific madrone had the lowest mean canopy retention and highest fire char height of all species surveyed. However, madrone had one of the highest average canopy regenerations and the largest basal sprout density of all other species. They also had the lowest mortality rate, despite 86 percent of plots containing madrone displaying no crown retention. Mortality rate was decreased after fire despite total loss of canopy in many of the observed individuals (Lazzeri-Aerts, 2014). It is with this information that careful design of this project was created to look further into resprout factors that have not yet been thoroughly studied.

II. Project Objectives:

This project addresses the treatment techniques used in the AFR project and how they affect pacific madrone resprout characteristics. Treatments of certain trees in the Ashland Watershed were compared between two different restoration techniques to assess pacific madrone vigor response. The research approaches how prescribed burns, stem removal, and selective thinning affect certain resprout characteristics and resprout rate of individuals representing this species within the test parameters. The project was intended to assess whether or not the pacific madrone can continue their rapid resprout rate over time when multiple stressors (treatments) are placed on an individual, or if there is a point in which they do not perform as quickly, or produce as many sprouts, reaching a stage of diminishing returns. Alternatively, multiple treatments over time may cause an increase in the period of susceptibility to disease and insects, leaving madrone less healthy overall. This study serves as support for overall AFR goals and adds to a collection of data used by The Nature Conservancy and other AFR partners to assess forest management techniques with goals of efficiency.

In accordance with the Ashland Forest Resiliency Project's goals, this project provides a specialized account of resprout characteristics of the pacific madrone, a species that is known to be resilient to the treatments used in the Ashland Watershed. The ultimate goal of reducing surface and ladder fuels is hindered by the adaptable resprouting madrone in heavily populated areas. The outcome of this analysis could provide more efficient forms of treatment for this species and increased understanding of treatment maintenance needs. The research directly compares a specific series of treatments that have been well documented and mapped by AFR project managers in the White Rabbit public trail area in Ashland, Oregon.

As one of the goals of the Ashland Forest Resiliency Stewardship Project, undergoing and monitoring select treatment types is well underway. Multiparty monitoring of AFR techniques provide pre- and post-treatment characteristics for different species found in the Ashland Watershed. The ultimate objective for this project is to determine the most successful form of treatment for pacific madrone with regard to overall forest health and other AFR goals. In this context, effectiveness of treatment is determined by individual resprout characteristics, stand growth patterns, and future fire regimes. Here, it would be most beneficial for the madrone to have fewer small resprouts over time in order to aid in a continued healthier landscape and lower the risk of a high severity fire. It is important to note that "effectiveness" of treatment can differ slightly between projects and plots.

Questions influencing this project's design include how does the pacific madrone respond to treatments like prescribed burning and selective thinning? Is one treatment more practical over the other for future management of madrone? Does a combination of these treatments affect resprout characteristics like growth rate and comprehensive tree health over time? And is there a point at which resprout characteristics slow or diminish due to multiple years of treatments?

III. Methodology:

Before sampling and research could be conducted, a specific area within AFR was found with the help of Geographic Information Systems (ArcGIS Pro). The chosen areas were subunits 12a, 13a, and 13b (see Figure 1 and 2), which is 79 acres in total and previously denoted within the AFR Project. These locations encompass enough land and species to complete research, with a large portion of subunit 12a and part of 13a providing all of the mechanical thinning data, and the remaining area providing all of the underburned data. The three subunits were chosen based on specific parameters that were entered into GIS. A Bare Earth Digital Elevation Model (DEM) was provided by Kerry Metlen of The Nature Conservancy to create the majority of the map, in addition to Figure 3, which denotes the subunits and their treatment types. First, slope and aspect were analyzed, and then reclassified so that only slopes above 8 and below 90 degrees and aspects between south and northwest (180 - 315°) were considered. Hillshade was also analyzed to ensure that only areas that receive a high amount of sun were examined. In this case, autumn sunshine data was used, specifically 4 P.M. on September 1st, 2018 for the basis of this geoprocessing tool. Hillshade of the area's specific azimuth and altitude were calculated as well for more precise sunshine data (Astronomical Applications Department, 2019), which were then also reclassified to keep only the sunny areas and not the more shaded zones. Next, the geoprocessing tool Raster Calculator was used to combine the desired elements from all three and reject the rest so that only areas with a similar slope, aspect, and fall hillshade were studied to simulate a common field of potential growth. Finally, the applicable areas were clipped to make the map more easily readable (see Figure 1 and 2).

To complete the map, 60 random points were chosen on the selected areas; 30 on the areas that were mechanically thinned twice, and 30 on the areas that were mechanically thinned followed by a prescribed burn. The points were then given a buffer of minimum 80 feet (~24.4 meters) between each point. However, this presents one problem: there was not always a suitable individual within that point, since the point-making function was purposefully completely random. To combat this, individuals were found and chosen *as closely as possible* from the radius of the random point in the field and then remarked, as shown in Figure 2. In some cases, like the westernmost parts of the map, individual madrone were scarce, so the points are farther from their original locations. This is most likely because those areas had the least amount of sunshine required in the mapping process to be considered. Points that were randomized too close to the edges of different treatments or non-treated zones altogether were also moved slightly to avoid possible skewed data along the edges of different treatments.

With an effective map showing areas of similar slope, aspect, canopy cover, and treatment, data collection was underway. Upon procurement of individual madrone trees close to randomized points, several characteristics were measured, shown in Table 1. For each sample tree, treatment type, number of stems removed, height of stump (if multiple stems were cut at different heights, the *lowest* and *largest* stem was chosen and measured), number of resprouted stems and separated by size classes (measurements are as follows: under 1 cm, 1.00 - 2.99 cm, 3.00 - 4.99 cm, and 5 cm and above), height of tallest resprouted stem (any number up to 300 cm, anything above was noted as "over 300 cm"), root collar diameter (an average of two measurements), condition of individual (number from one to four in overall tree health, one being best condition and four being worst condition), and competition measurements were recorded.

The competition measurements include a densiometer reading as well as an estimated basal area of the average acre based on trees within the 1/10th acre plot (37.2 feet) centered around the sample tree. Measurements of plots for large ring form individuals were taken from the center of the ring form. For the competition index, every tree within the plot was measured by diameter at breast height (DBH, which is measured at four feet above the ground; an uphill measurement) to find its basal area. The densiometer readings were taken once around the sample individual in each cardinal direction, and then averaged for a single measurement. More about the densiometer tool and process can be found in Appendix E. Individual trees for basal area analysis were specifically measured with a DBH of two inches and above (circumference of at least 6.5 in); trees under this minimum requirement were ignored. This study chose also to ignore shrubs, saplings, and snags (dead but standing trees) in order to receive a more accurate representation of competitive tree density and sunlight availability for sampled individuals. Additional information on data collection is provided in Table 1.

After data collection, careful consideration was given to data entry and organization of new information and results. Then, analysis of completed data using univariate analysis, cross tabulations, and ANOVA tests were used to determine relationships and statistical significance. Univariate analysis is used to determine characteristics of each treatment technique as well as statistical significance of the responses. Bivariate correlation and ANOVA tests establish relationships between significant treatments and evaluate the differences in responses between each technique. Some limitations with the data collection methods include: a relatively small sample size, potential sampling bias, the resprout height measurement cap "over 300 cm" does not provide a true resprout height for individuals taller than 300 cm, and while this project has been concise and thorough with the specific area of interest, it may not be representative of all of AFR's work, or all pacific madrone.

IV. Results and Discussion:

Refer to Table 1 for all sampling parameters, Table 2 for resprout averages, Table 3 for ANOVA results, and Figure 5 for resprout rate box plot.

A cross-tabulation analysis of the treatment type and condition variables showed that the most common condition of the individuals within the thinned areas was "live and lush" whereas most of the individuals within the burned units were reported "live with some damage" (p=0.028). Further analysis through one-way ANOVA tests revealed relationships between treatment type and number of resprouts less than one centimeter in diameter (p=0.002), number of resprouts between three and 4.9 centimeters (p=0.044), number of resprouts over five centimeters (p=0.010), height of tallest resprout (p=0.035), canopy cover (p=0.001), and plot basal area (p=0.035). No relationship was observed between treatment type and resprouts between one and 2.9 centimeters or the number of dead resprouts.

Similarly, ANOVA tests between growth variables and the number of stems removed during selective thinning show some relationships but do not explain every case. The number of stems removed has suggested relationships between the number of resprouts less than one centimeter (p=0.000), the number of resprouts between three and 4.9 centimeters (p=0.000), and the number of dead resprouts (p=0.001). There were no relationships observed between the number of stems removed and the number of resprouts between one and 2.9 centimeters, the number of stems over five centimeters, or resprout height.

Next, analysis was conducted for possible relationships between canopy cover and resprout variables. The number of resprouts between one and 2.9 centimeters, over five centimeters, and resprout height did not have sufficient evidence to suggest a relationship. However, the full sample does propose a relationship between incoming sunlight and the number of resprouts less than one centimeter in diameter (p=0.015), resprouts between three and 4.9 centimeters (p=0.000), and the number of dead resprouts (p=0.010).

The significant relationships seen from these data suggest that there is a difference in growth after the two observed disturbances. The mean number of resprouts less than one centimeter in diameter was significantly higher in the individuals that had been burned (7.30) than those that had only been thinned (2.63). Conversely, the mean number of larger resprouts (3 - 4.9 cm and >5 cm) were lower in the burned areas than in the thinned areas (0.23 compared to 0.83 and 0.07 compared to 0.60, respectively). Lastly, the mean height of the tallest resprout was shorter in the burned areas than in the thinned areas (137.87 and 187.23 cm, respectively). All height averages between resprout class size and treatments can be found in Table 2.

Additional descriptive statistics from the one-way ANOVA tests showed relationships between an individual's condition and the number of resprouts between one and 2.9 centimeters (p=0.039), the number of resprouts over five centimeters (p=0.008), and the height of the tallest resprout (p=0.004). The mean number of resprouts between one and 2.9 centimeters in diameter increased with improved condition from 0.50 to 4.21. Similarly, the mean number of resprouts over five centimeters increased from 0.00 to 0.84 with better condition. Finally, the mean height of the tallest resprout also increased as condition improved from 94.75 to 217.37 centimeters (see Table 3).

Further analysis of resprout changes over time showed differences in resprout rate between the two treatment types. All 60 individuals have been mechanically thinned and were treated in 2013, while the 30 individuals which were also burned had seen a prescribed underburn event in 2016. Therefore, the resprout rate of thinned individuals is measured as a yearly interval with six years in total, while individuals that have been thinned and burned have been measured as a yearly interval with three years in total. Test areas that had only been thinned displayed a median of 0.915 resprouts per year after treatment and those that had been both thinned and burned presented a median of three resprouts every year, shown in Figure 5 as a box plot. While this analysis would be improved and refined with annual data collection, the initial results show increased resprouts among pacific madrone in the Ashland Watershed with multiple treatments as opposed to just one. That being said, the cause of increased resprouts seems more likely because of prescribed fire, not simply from being submitted to multiple treatments.

V. Conclusion:

The data collected provides and contributes to a broader perspective of the pacific madrone relationship with fire and thinning methods, of which there is a limited understanding with few published or peer-reviewed resources. The location of the AFR Project in the Ashland Watershed provides a great example of a diverse forest with historic mixed-severity fire regime characteristics with hope that it will produce a deeper understanding of the species and its relationship with fire.

Cross tabulations and ANOVA tests revealed several relationships that show sufficient evidence to support differences in growth based on treatment type. As seen in Table 3, there are also several combinations of data that do not show significant relationships (represented as X). Numbers in Table 3 represent p-values of each test, illustrating where relationships appear among the data set. After examination of relationships with statistical significance, this analysis indicates that the individuals within areas treated with both thinning and burning had more smaller resprouts, fewer large resprouts, and the tallest resprouts were shorter than individuals that had only been thinned. Accordingly, the goals of AFR to promote a healthier forest landscape are better achieved in individuals that were thinned only. In this sample, underburned individuals posed more future fire risk to its surrounding area. However, if historic frequent low-severity fires will be successfully reintroduced, this resprouting which would cause more fuels seems unavoidable.

Improvements to condition across both treatments increased all growth variables; that is to say, any particular individual that was in better condition than another had more resprouts of several class sizes, taller resprouts, and a larger root crown. Therefore, visible exterior condition directly relates to madrone energy and ability to bounce back from physical harm. Individuals that looked worse (more insect herbivory, less resprouts altogether or more dead resprouts, etc.) also responded poorer. After accounting for time since treatment, observed resprout rates differed between treatments. The median number of resprouts per year since treatment in the individuals that had only been thinned was less than one, while those that had been thinned and burned had a median of three resprouts per year. Based on very few found sources and further confirmed with this research, while any physical harm will promote new growth on an individual, prescribed fire acts as a stronger catalyst for madrone growth rate and speed, as it promotes bud development on the burl, improving species longevity.

Potential further analysis could include additional madrone plots elsewhere in the treated area, possibly in an area with a different aspect for comparison, or updated resprout analyses of the plots assessed for this project. This analysis provides a better understanding of how pacific madrone react to different types and frequencies of disturbance in the Ashland, Oregon Watershed through the work of the Ashland Forest Resiliency Stewardship Project.

VI. Appendices:

A. Project Partners:

Name	Address	Phone	Email
Kerry Metlen, Ph.D. Forest Ecologist, The Nature Conservancy	647 Washington St Ashland, OR 97520	(541) 770-7933	kmetlen@tnc.org

Name	Address	Phone	Email
John Gutrich, Ph.D. Southern Oregon University Professor of Environmental Science and Policy	1250 Siskiyou Blvd Ashland, OR 97520	(541) 552-6482	gutrichj@sou.edu
E. Jamie Trammell, Ph.D. Southern Oregon University Professor of Environmental Science and Policy	1250 Siskiyou Blvd Ashland, OR 97520	(541) 552-6496	trammelle@sou.edu

B. Additional Stakeholders:

Don Boucher, AFR Project Manager, United States Forest Service	Rogue River-Siskiyou National Forest 3040 Biddle Rd Medford, OR 97504	(541) 552-2913	dboucher@fs.fed.us
Chris Chambers, City of Ashland	20 East Main St Ashland, OR 97520	(541) 552-2066	chris.chamber@ashland.or.us
Marko Bey, Lomakatsi Restoration Project	P.O. Box 3084 Ashland, OR 97520	(541) 488-0208	marko@lomakatsi.org
Brett Brown Fire Ecologist, Siskiyou Mountains Ranger District	Rogue River-Siskiyou National Forest 6941 Upper Applegate Rd Jacksonville, Oregon 97530	(541) 899-3800	
Jaime Stephens, Klamath Bird Observatory	1497 E Main St, Ashland, OR 97520	(541) 201-0866	jlh@klamathbird.org
Students from Southern Oregon University:	1250 Siskiyou Blvd Ashland, OR 97520		
Emily Newbury, Environmental Science and Policy Alumni		(925) 301-6549	emrosenewb@gmail.com
Angela Powell, Environmental Science and Policy Alumni		(541) 326-2352	angelap1024@gmail.com

Citizens from the Ashland Community	Ashland, OR

C. Timeline:

Proposal Presentation	November 9, 2018
Formal Proposal	November 30, 2018
Formal Outline	January 18, 2019
Written Report First Draft	March 1, 2019
Data Collection Completed	May 5, 2019
Data Analysis Completed	May 2019
Public Presentation	May 24, 2019
Final Written Report	June 7, 2019

D. Maps:

Figure 1. Specific Study Area and Random Points (Newbury, 2019, ArcGIS Pro):

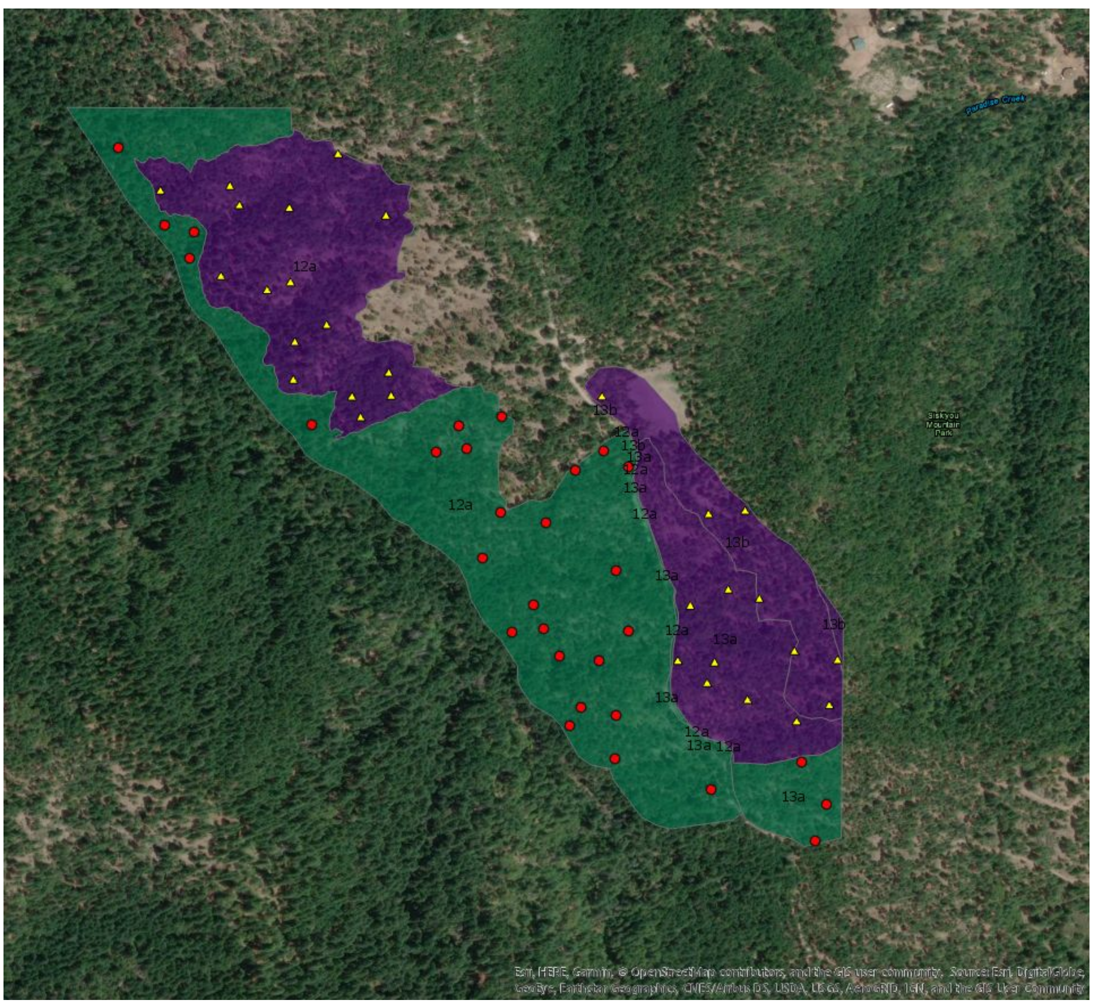


Figure 2. Study Area with Updated/Final Points (Newbury, 2019, ArcGIS Pro):

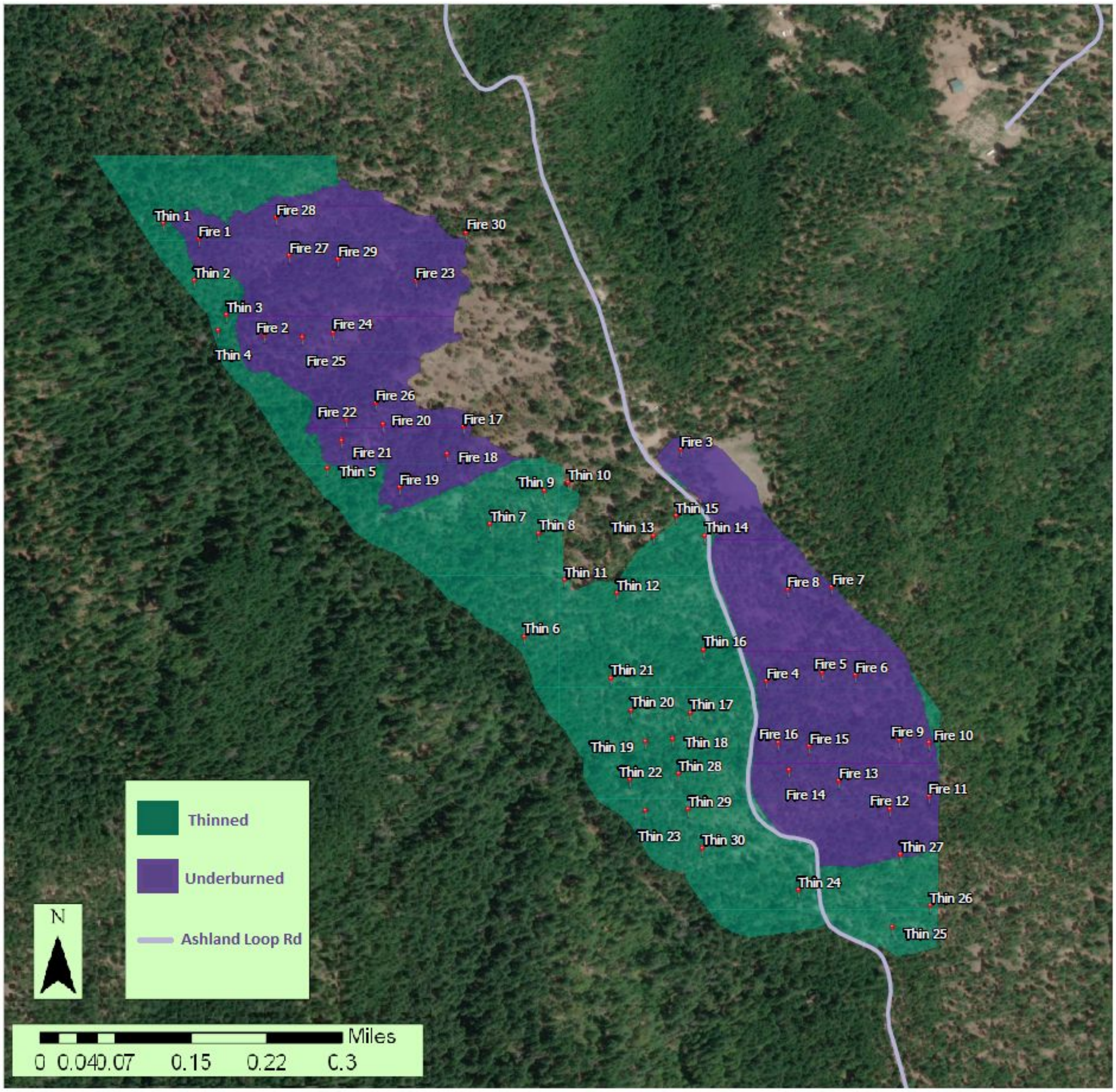


Figure 3. Ashland Watershed and AFR Management Area (AFR, ArcGIS Pro):

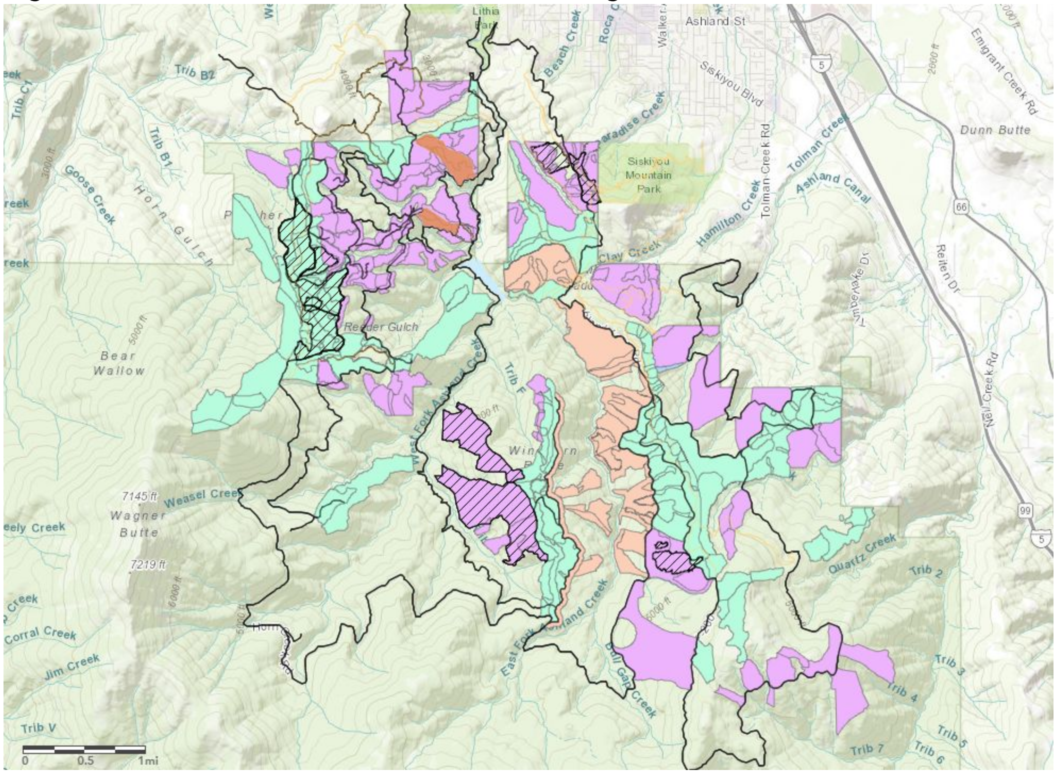


Figure 4. AFR Monitoring Plots (Metlen, 2014):

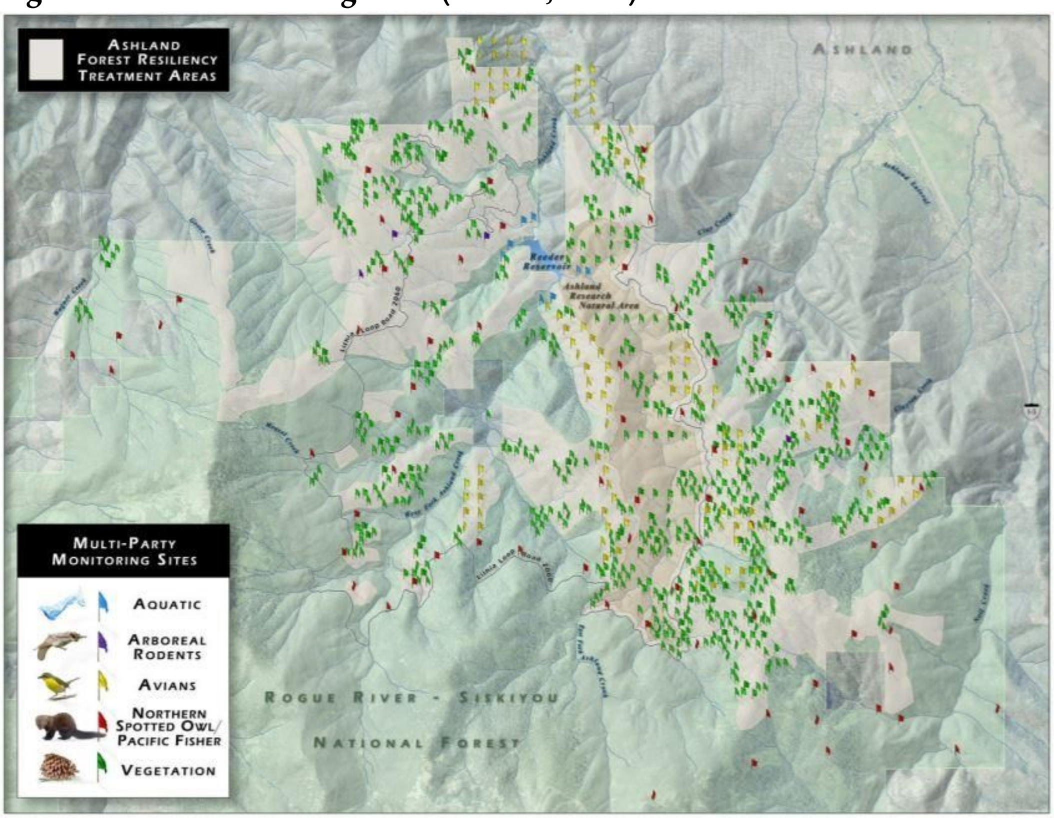
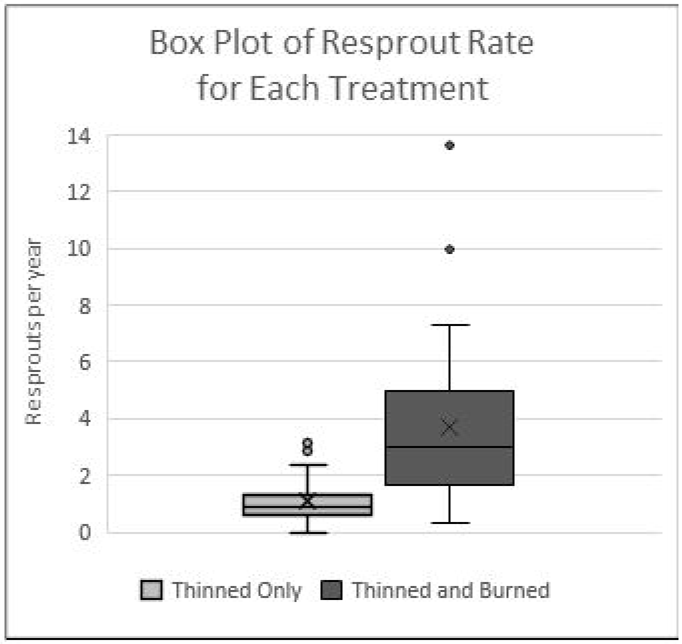


Figure 5: Resprout Rate Box Plot (Newbury, 2019):



Thinned Only

Sample size: 30
Median: 0.915
Minimum: 0.00
Maximum: 3.17
First quartile: 0.6275
Third quartile: 1.33
Interquartile Range: 0.7025
Outliers: 3.17 2.83

Thinned and Burned

Sample size: 30
Median: 3
Minimum: 0.33
Maximum: 13.67
First quartile: 1.67
Third quartile: 5
Interquartile Range: 3.33
Outliers: 13.67 10.00

E. Data Gathering Instruments:

Physical data collection instruments:

Global Positioning System (GPS), Avenza Maps smartphone application, densiometer (a competitive tree density measurement taken at an individual in each of the four cardinal directions facing away from the trunk, averaged into one number out of a total of 50 squares, and then multiplied by two for a percentage of total foliage cover). More information about densiometer readings provided by The Nature Conservancy (Duwal & Perchemlides, 2018).

Data accumulation and analysis software:

Geographic Informations System (ArcGIS Pro), Statistical Package for Social Sciences (SPSS), Google online collaboration apps (Docs, Sheets, and Slides). The public online Google Drive folder for this research can be viewed and accessed here:
https://drive.google.com/drive/folders/15wDzjtDLiHAXfHGi7Miw4CNYqanHJg8A?usp=sharing

F. Table 1: Data Dictionary (Powell, 2019):

Tree Characteristics		
Field	**Description**	**Codes**
TRTM	Treatment: Mechanical thinning with or without prescribed burning.	MT=Mechanically thinned; PB= Prescribed burns.
STRM	Number of stems removed in treatment.	Count
STHT	Stump height after thinning.	Measured in centimeters
STID	Stem ID: Number of regrown stems after treatment. Stems are counted and tallied by size classes of <1 cm or 1 - 3 cm.	Count
RPHT	Resprout height (for tallest stem)	Measured in centimeters
RCDM	Root collar diameter: Average of two perpendicular measurements. Note if ring form.	Measured in centimeters
COND	Condition: Description of tree status. Note damage.	1= Live and lush; 2= Live but with some damage; 3= Live but with significant damage; 4= Dying/dead.
COMP	Competition: Densiometer reading averaged from four cardinal directions. Species composition and plot basal area within 1/10th acre around individual.	Canopy cover and basal area

Table 2: Height Averages by Resprout Class and Treatment Type (Powell, 2019):

Results	Resprouts <1 cm (count)	Resprouts 3 - 5 cm (count)	Resprouts >5 cm (count)	Tallest Resprout Height (cm) (excludes heights >300 cm)
Burned Average	4.65	1.92	1.80	130.85
Thinned Average	8.42	1.75	2.00	112.92

Table 3: ANOVA Results (Powell, 2019):

ANOVA p-values	Resprouts <1 cm	Resprouts 1 - 3 cm	Resprouts 3 - 5 cm	Resprouts >5 cm	Height	Dead Resprouts
Treatment	0.002	X	0.044	0.010	0.035	X
Stems Removed	0.000	X	0.000	X	X	0.001
Canopy Cover	0.015	X	0.000	X	X	0.010
Condition	X	0.039	X	0.008	0.004	X

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