2021

Sula study revisited: 20-year post-fire regeneration in the southern Bitterroot Valley, Montana.

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SULA STUDY REVISITED: 20-YEAR POST-FIRE REGENERATION IN THE SOUTHERN BITTERROOT VALLEY, MONTANA.

By

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Bachelor of Science in Forestry, The University of Montana, Missoula, Montana, 2019

Thesis

presented in partial fulfillment of the requirements

for the degree of

Master of Science
in Forestry

The University of Montana
Missoula, MT

June 2021

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Rymniak, Luke, M.S., June 2021 Forestry

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ABSTRACT

In the summer of 2000, a number of large fires burned in the southern Bitterroot Valley near Sula, Montana. Research was conducted in 2001 and 2003 in the fire-affected areas of the French Basin and Larid Creek areas in order to investigate the effects of environmental variables, fire severity, and post-fire management on vegetation regeneration. In 2020 these areas were remeasured to understand trends over time by evaluating the impact of these same factors 20 years post fire. The results showed that the effects of environmental variables, fire severity, and post-fire management on vegetation regeneration were varied. The most influential environmental variable to affect vegetation regeneration for understory species and overstory species was aspect. Fire severity was influential, with differences in overstory and understory severity impacting the distribution, presence, and percent cover of vegetation species. The most influential post-fire management activity was seedling planting. Results suggest that study areas that were affected by high severity fire are unlikely to return to pre-fire conditions without tree planting or other management activities. Further research should be conducted on the survival rate of planted seedlings in managed areas over time. Comparisons should also be made between natural seedling regeneration and planted seedling viability in burned areas over time. More research should be conducted on fire severity's long-term effects on understory vegetation as these ecosystems return to a form of equilibrium over time.

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Introduction

In the summer of 2000, a number of large fires burned approximately 350,000 acres (550 square miles) across the southern Bitterroot Valley of Montana in national and state forest lands (Republic, 2014) (Figure 1). These fires, usually referred to as the Valley Complex or the Sula Complex, were ignited by lightning on July 31st, 2000 and continued burning until mid-September (Keegan et al. 2004). By October the 4th, cool cloudy weather stopped fire growth and immediate attention fell to the task of rehabilitating the burned areas.

Figure 1. Map of Montana with the site of the 2000 fires marked. Image source: Map of Montana [Online image]. https://www.nationsonline.org/oneworld/map/USA/montana_map.htm

Approximately 307,000 acres of the fire fell in the Bitterroot National Forest (BNF) which is under the jurisdiction of the United States Forest Service (USFS 2000a). This burned acreage represented 20 percent of the BNF at the time, and while soil erosion mitigation work and watershed protection efforts had already been made by the Burned Area Emergency Rehabilitation (BAER) teams immediately after the fire, it was clear that extensive recovery work would be needed for the immediate future (USFS 2000a). The work proposed by the Forest Service included the reduction of fuels, the improvement of watersheds, revegetation, and improvements of forest health (Bitterroot 2001). While some restoration work was accomplished including extensive soil stabilization projects, seedling planting, and some salvage logging of standing dead trees, a majority of the plans were not completed due to public backlash and subsequent litigation over more extensive proposed salvage logging operations (Sienkiewicz 2006).

Over 15,000 acres of the fire fell in the Sula State Forest, which is under the jurisdiction of the Montana Department of Natural Resources and Conservation (DNRC) (Harrington 2003). Within 6 months of the fire, extensive salvage logging had taken place on 6,000 acres of the affected area and numerous fire rehabilitation projects, including erosion mitigation and culvert installation (Harrington 2003). The salvage logging conducted in this area was in response to the DNRCs explicit mandate to manage state trust lands for long-term revenue generation (Sienkiewicz 2006). Part of the rehabilitation projects involved the planting of over one million seedlings in areas that had been affected by high severity fire (Republic, 2014).

The rehabilitation work accomplished by both agencies affected large areas of the landscape. This, in combination with an unprecedented fire that occurred in a diverse forested ecosystem, raised the question of what possible long-term effects these management decisions and general fire characteristics could have on vegetative regeneration. This study will investigate these long-term effects and trends by examining the effects of environmental variables, fire severity, and post-fire management on vegetation regeneration in the southern Bitterroot Valley.

It is important to understand the impacts of disturbance on a forest ecosystem's ability to regenerate when considering climate change. In particular, overstory tree cover provides a buffer to understory vegetation and tree seedlings from climate extremes (Davis et al. 2018). This buffer protects seedlings and understory vegetation from hotter temperatures and can help retain ground level moisture (Davis et al. 2018). The removal of the overstory due to uncharacteristically severe disturbances can have direct effects on the conditions that understory vegetation could experience, and tree regeneration may no longer be possible (Davies et al 2018). This could result in conditions that could affect forest resiliency to disturbance and could result in uncharacteristic ecosystem transitions (Davis et al. 2020). By examining post-fire ecosystems, we can determine to what extent severe disturbances have altered successional pathways and if mitigation efforts are effective in countering fire impacts.

An important fire characteristic is fire severity. Fire severity is defined as what happens to the dominant vegetation during a fire (Arno et al. 2000). In this case, the effects of fire on tree mortality determines the level of severity. If a majority of the overstory trees are killed, the fire is considered "high severity"; if the fire does not kill most of the overstory trees, it is considered "low severity"; and if a combination of the two occurs, the fire is considered "mixed severity" (Arno et al. 2000). Forest ecosystems in the northern Rocky Mountains, including the southern Bitterroot valley, historically operated under a mixed severity fire regime (Brown et al. 1994). However, the combination of fire suppression, livestock grazing, and the removal of Native Americans and their burning practices has caused a shift in the fire regime of the Douglas-fir (*Pseudotusuga mienzisii)* and ponderosa pine (*Pinus ponderosa)*-dominated dry forest ecosystem types (Arno et al. 2000; Hessburg and Agee 2003). The historically low to mixed severity fires that were more frequent on this landscape have now shifted to high severity stand replacing fires that can have long-term ecological and social impacts (Arno et al. 2000). There are numerous examples of these ecological impacts, with one of them being a shift in overstory tree species composition from primarily ponderosa pine, western larch *(Larix occiedentalis)*, and whitebark pine (*Pinus Albicaulis)* to Douglas-fir dominated stands in lower elevation areas (Arno et al. 2000; Arno et al. 1995). This, combined with an increase of dead and down woody debris and ladder fuels, increases the opportunity for the occurrence of unusually severe and extensive wildfires as seen with the Valley Complex and other large fire events in the last two decades (Keane et al. 2002; Arno et al. 2000).

Fire effects on tree mortality for ponderosa pine and Douglas-fir have been attributed to crown scorch volume and direct tissue damage (Fowler and Hull, 2004). Crown scorch volume is the proportion of foliage either consumed or damaged on a tree following a fire. A greater proportion of crown scorch volume was shown by Fowler and Hull (2004) to be an effective indicator of tree mortality, with 80-95 percent scorch volume for ponderosa pine and 70 to 95 percent for Douglas-fir indicating a high probability of tree death within two to three years post-fire. It could be expected that high severity fire would result in a high proportion of fire-scorched trees and subsequent mass mortality. This increase in tree mortality can have serious effects on forest regeneration and could induce uncharacteristic changes in forest ecosystems.

In conjunction with changes in the forest ecosystem due to fire severity, tree regeneration and understory vegetation is also affected. The effects of fire on understory vegetation regeneration are shown to be variable depending on severity and soil duff consumption (Armour et al. 1984). While short-term vegetational recovery in response to fire is variable depending on severity, pre- and post-fire vegetation species composition, and overstory tree mortality, the eventual successional outcome is expected to be the same (Lyon and Stickney 1976; Armour et al. 1984). Succession generally follows the same path from herb-dominated, to shrub-dominated, to tree-dominated systems over time. However, this timeline is dependent on the severity of the disturbance and other site characteristics (Armour et al. 1984). While species richness and plant cover are shown to increase slightly post-fire, other contributing factors such as environmental variables most likely have a stronger influence on understory vegetation regeneration (Laughlin & Fule 2008). Environmental variables such as slope and aspect are important influences on vegetation regeneration due to their effects on solar and moisture availability (Laughlin & Fule 2008). Specifically, sunnier sites generally have higher soil temperature and shady sites have more soil moisture, both of which can greatly affect the species composition and percent cover of vegetation that is present (Xue et al. 2018).

Post-fire management can also have varying effects on tree regeneration and understory vegetation. In the case of the Valley Complex, the most prominent management activities for both agency-controlled areas were salvage logging and seedling planting. Studies that focused on salvage logging's effects on post-fire forest structure have found no significant long-term impacts on vegetation regeneration. Fifteen years after treatment, understory vegetation species composition and cover were not affected by logging activities when best management practices were followed (Peterson & Dodson, 2016). Salvage logging's effects were most noticeable on shrub cover, with higher salvage intensities resulting in lower cover due to the disturbance of underground rhizomes (Knapp & Ritchie, 2016). Rhizomes are characterized as horizontal underground stems that often can persist after severe disturbances. A common species that depends on rhizomes for regeneration is ninebark (*Physocarpus malvaceus*) which is known to sprout vigorously after fires (Habeck 1992). Other studies found that immediate effects from post-fire logging were variable depending on a number of factors. The type of logging system had an effect on ground compaction and erosion, with ground-based skidding causing the most direct effects. In some cases, logging residue was shown to reduce overland flow and subsequently slow erosion. Logging has been shown to significantly reduce post-fire habitat for species that depend on standing dead snags for nesting habitat. However, logging also increased habitat for species that prefer non-boreal environments resulting in a change in overall species composition, but not richness (Mciver & Starr, 2000). McGinnis et al. (2010) showed that post-fire logging practices and herbicide treatments on shrub regeneration had differing effects on dead fuel amounts and understory species composition. Salvage logged areas showed greater amounts of dead fuel, however the predicted fire behavior of that area was not different from the untreated areas due to the persistence of shrub cover in both areas. Salvage logging is not without controversy, with some studies pointing to its possible negative effects on wildlife habitat and seedling regeneration. One study suggests that salvage logged areas could reduce seedling regeneration due to soil disturbance and excess woody debris, resulting in long-term effects on forest health (Donato et al., 2006).

Other post-fire treatments such as regeneration planting have shown to achieve their goal in increasing the number of saplings present in comparison to untreated stands (Donovan, et. al., 2019). However, spatially homogeneous planting methods have been found to be non-conducive to stand resilience to future disturbances such as fire (North, et al., 2019). Ouzts et al. (2015) showed that areas that had undergone post-fire seedling planting produced target amounts of mature trees over time as compared to non-planted areas which were not able to produce the desired density. While this study highlighted that only half of the areas planted would meet desired tree densities over time, this was an improvement over non-planted areas that did not meet desired densities.

The areas affected by the fires of 2000 in the Southern Bitterroot valley display a unique combination of all of these factors. Wildland fires effects on forested ecosystems can have varied, extensive, and long-lasting consequences that need to be investigated in order to promote holistic land management in the future.

In 2001, twelve study transects were established in the fire-affected areas of the BNF and the Sula State Forest in order to document changes in vegetation recovery over time (Kolb & Thompson, 2001). Field research was conducted during the summers of 2001, 2003, and 2020 on these transects within the southern Bitterroot valley (Figure 2). The study area is split between the Larid Creek and French Basin areas located near Sula, MT. The Laird Creek study area, west of Sula, is located in the Bitterroot National Forest and managed by the US Forest Service. The French Basin area, north of Sula, is located in the Sula State Forest and is managed by the MT Department of Natural Resources and Conservation (Figure 2).

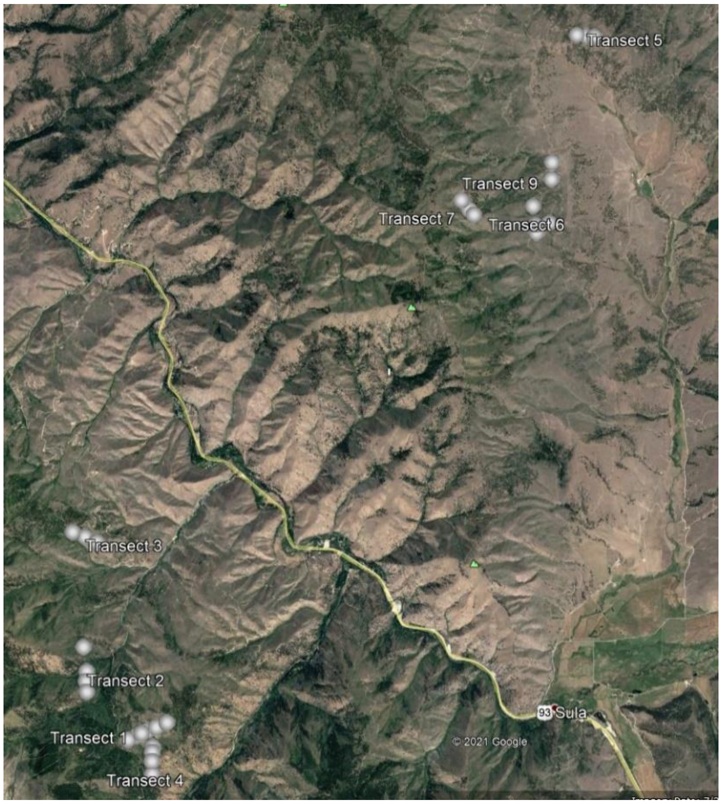

Figure 2**.** Overview map of study area. The Larid Creek study area consists of transects 1-4 in the far bottom left of the map. The French Basin area consists of transects 5-9 in the top right of the map.

These sites were sampled during the summer of 2001 and 2003 in order to investigate the influences of fire severity, environmental variables, and post-fire management on post-fire vegetation recovery. Data collected during these studies included tree counts, seedling counts, and understory vegetation cover. The results from the 2003 study indicated that the post-fire plant community was dominated by species that were resistant to fire. Salvage logged areas did not display any significant difference in vegetation as compared to non-salvage logged areas, although there was less vegetation variability in non-salvaged areas overall (Hollingsworth, 2005). Habitat type group, firegroup, understory vegetation cover, mean patch size in 2001, and overstory severity were shown to be the most influential indicators of understory cover in 2003 (Hollingsworth, 2005). In the summer of 2020, these transects were re-sampled in order to continue the research that had been previously conducted in 2001 and 2003.

The purpose of this study is to investigate the effects of environmental variables, fire severity, and post-fire management activities on vegetation regeneration in the areas affected by the fires of 2000 in the Southern Bitterroot Valley. Statistical analyses were conducted utilizing the data collected in 2001, 2003, and 2020 in order to answer the following questions:

1. What are the differences in overstory tree survival over 20 years, and what are the most significant explanatory variables that affect the number of live trees in 2020?

2. What are the changes in seedling survival between over time, and what are the most significant explanatory variables that affect the number of live seedlings in 2020?

3. What are the differences in understory vegetation patch size and composition over time, and what are the most significant explanatory variables that affect patch size, overall cover, and individual species cover over time? Additionally, what effects do overstory and understory fire severity have on the percent cover of major understory species over time?

Methods

Study Location and Transect Differences

Eight transects, which were established during the 2001 study (Figure 2), were remeasured during the summer of 2020. Four of these transects were located in the Larid Creek area (transects 1-4) and four were located in the French Basin area (transects 5-7 and 9). The topography was varied in the study area, with slopes ranging from 0 to 60 percent, with a majority of the nested plots located on 20% to 40% slopes. Study plots generally fell on east to southeastern facing aspects and were generally part of the warm/dry habitat type. The warm/dry Douglas-fir habitat type is generally found on the warmer slopes and benches in the area, and generally consists of ponderosa pine and Douglas-fir, depending on the stage of succession the stand is in (Crane and Fischer 1986). These sites are generally more productive than the cool/dry sites that were also sampled within the study area. Warm/dry habitat types were sampled at transects 3, 5, 6, 7, and 9. The cool/dry habitat type is generally found on cooler facing slopes and is characterized as a less productive, Douglas-fir dominated stand structure (Crane and Fischer 1986). Within the study area, examples of this habitat type were sampled in transects 1, 2, and 4.

Transects were established across areas that experienced three kinds of post-fire salvage logging treatments after the fires, which are classified as a no salvage treatment, a delayed salvage treatment, and an immediate salvage treatment. Transects classified as a no salvage treatment were transects 1, 2, 3 and 5 and received no post-fire salvage logging of any kind. Transects 4 and 7 were classified as a delayed salvage treatment and were salvage logged during 2002 and 2003. Transects 6 & 9 were classified as an immediate salvage treatment and were salvage logged during the winter of 2000/2001 (Figure 3). Salvage classifications, overstory and understory fire severity rankings, aspect, and percent slope of each nested plot within these transects is listed in the following table (Table 1)

Table 1. Transect and plot data.

Transect # Plot #	Aspect (degrees)	Slope (%)	Overstory Severity	Understory Severity	Salvage type
T01P01	68	32	Mixed	Mixed	No Salvage
T01P02	200	39	High	Mixed	No Salvage
T01P03	134	42	High	High	No Salvage
T01P04	94	39	High	High	No Salvage
T01P05	224	40	High	High	No Salvage
T01P06	186	40	High	High	No Salvage
T02P01	134	50	Low	Mixed	No Salvage
T02P02	50	59	Mixed	High	No Salvage
T02P03	360	65	Low	High	No Salvage
T02P04	90	30	High	High	No Salvage
T03P01	130	49	Low	High	No Salvage
T03P02	136	35	Mixed	High	No Salvage
T03P03	120	20	High	High	No Salvage
T04P01	310	48	Low	Mixed	Delayed Salvage
T04P02	296	48	Mixed	Mixed	Delayed Salvage
T04P03	286	55	High	High	Delayed Salvage
T04P04	250	55	Low	Low	Delayed Salvage
T05P01	130	25	Low	Mixed	No Salvage
T05P02	220	30	Mixed	High	No Salvage
T05P03	290	30	High	High	No Salvage
T06P01	81	2	High	High	Immediate Salvage
T06P02	77	6	Mixed	High	Immediate Salvage
T06P03	110	7.5	Low	Low	Immediate Salvage
T07P01	72	27	Low	High	Delayed Salvage
T07P02	348	50	Mixed	High	Delayed Salvage
T07P03	44	40	High	High	Delayed Salvage
T09P01	10	34	Low	High	Immediate Salvage
T09P02	85	3	Mixed	High	Immediate Salvage
T09P03	16	7	High	High	Immediate Salvage

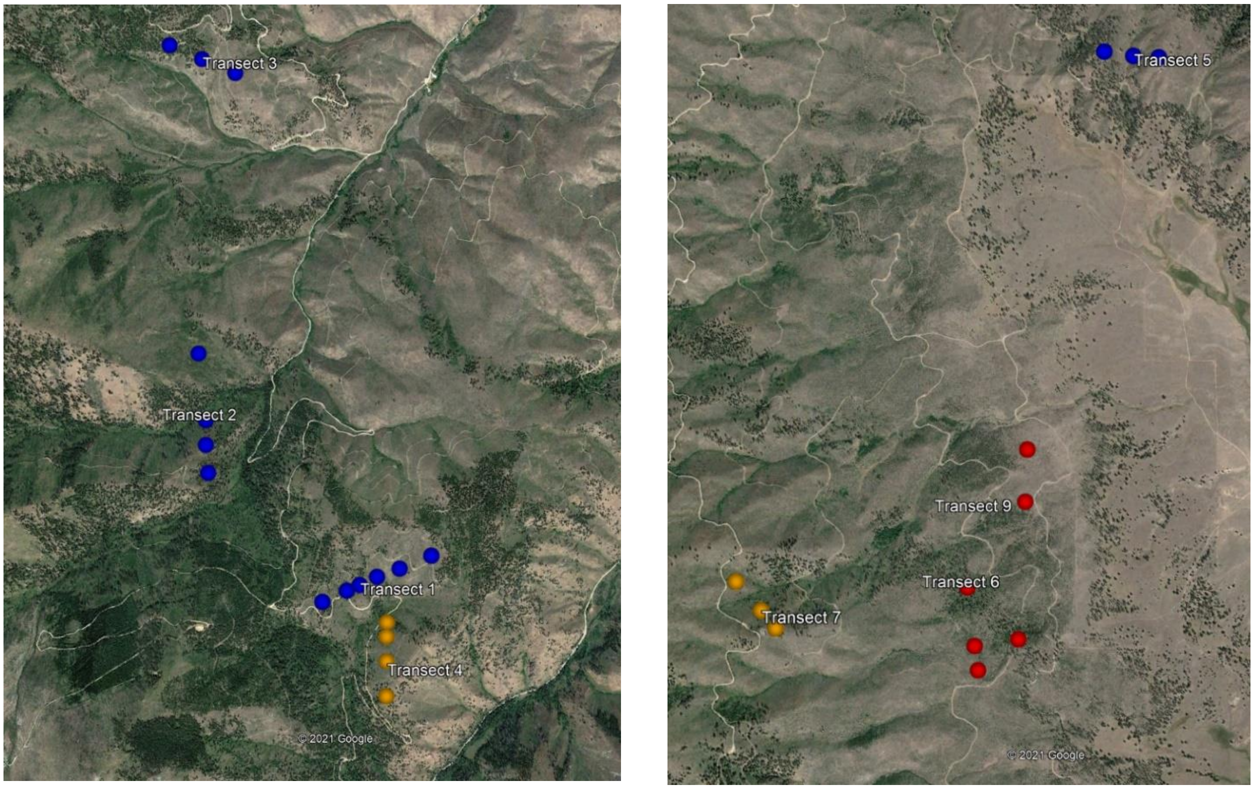

Figure 3**.** Maps of Laird creek (left) and French basin (right) study areas with transects marked with their corresponding salvage treatment. Blue indicates no salvage, orange delayed salvage, and red immediate salvage. (Retrieved from Google Earth, 4/8/2021).

Data Collection

Transects were approximately one kilometer in length and were located across areas where fire had created a mosaic of fire behavior. Transects had a minimum of three nested plots established along their length, with some transects having up to six nested plots. The fire severity of the area within the plots were classified in 2001 based on individual tree crown scorch and overstory tree mortality within the plot area (Table 2).

Table 2**.** Fire severity classes for overstory trees

Fire Severity	Observed Individual Tree Effects (2001)
Low	<50% Individual tree crown scorch <20% stand overstory tree mortality
Mixed	>50% Individual tree crown scorch 20-70% stand overstory mortality
High	>70% Stand overstory mortality

In the summer of 2020, plot centers were located using GPS data points and photo reference points that had been established in 2001. Four photos were taken from each plot center, with one photo in each cardinal direction. Photos taken in 2001 and 2003 were used to locate plot centers and to observe changes in the surrounding area over time. A combination of a handheld recreation-grade GPS and the mobile map application Avenza were used to locate plot center. While plot centers had been temporarily monumented in 2001, these were not present in 2020.

Current live overstory tree data were recorded for a 37.2 ft radius, 1/10th acre (400-m^2) circular plot (Figure 4). Overstory trees in 2020 were classified as living trees that were 6 ft tall and greater and were at least 3 inches DBH or greater. The species, an ocular estimate of diameter at breast height to the nearest inch (DBH), an ocular estimate of height in feet to the nearest 10 feet, and any types of observed defect for each tree were recorded for each stem with its pith (center) within the circular plot. Seedling counts were collected within the same 37.2 ft radius (400-m^2) circular plot. Seedlings in 2020 were classified as being less than 6-feet tall and less than 3 inches DBH and were tallied by species.

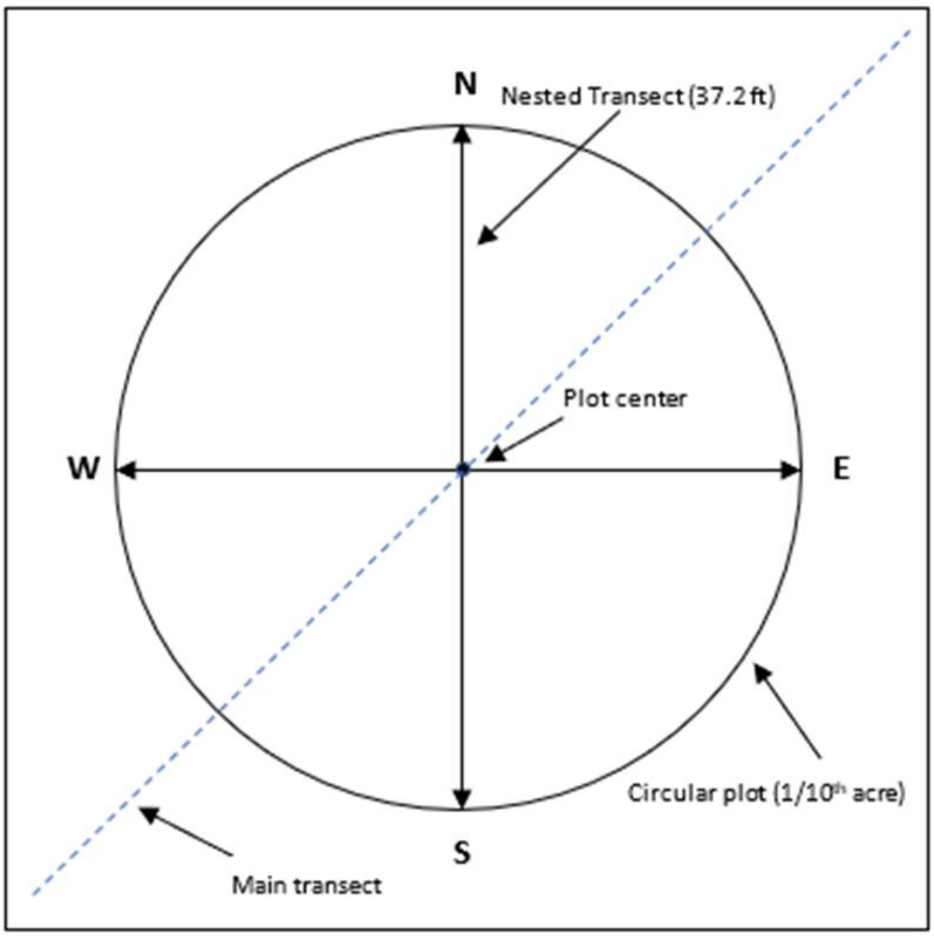

Figure 4. Diagram of plot measurements.

Each plot had four nested (37.2 ft) transects arranged in cardinal directions across the plot center (Figure 4). Vegetation data was collected along the length of each 37.2 ft nested transect within each plot. The goal of the data collection along the length of each transect was to record the length, overall percent vegetation cover, and percent individual species cover of each vegetation patch bisected by the transect. A vegetation patch was defined as a combination of understory species to include graminoids, forbs, mosses, and shrubs of a uniform density and composition. During the study conducted during 2001, direct fire effects on soil and vegetation cover were used to differentiate and identify patches. During the 2003 study, it was more difficult to differentiate these patches due to growth over time and greater reliance was placed on identifying understory vegetation cover and the presence of bare mineral soil (Hollingsworth, 2005). The data collection conventions of the 2003 remeasurements were carried over to the 2020 study.

The presence of bare ground for a minimum distance of 1 foot, a change in overall percent cover of at least 10 percent, or a change in species proportions of 10 percent would indicate the start of a new patch. The length in feet measured with a cloth tape, percent composition of individual species to the nearest 5 percent and overall percent cover of each patch to the nearest 5 percent were visually estimated and recorded along the length of each nested transect (Figure 4).

Data Analysis.

Data recorded in 2001, 2003, and 2020 was compiled in order to make statistical inferences between each of the study years. Environmental variables recorded and assigned in 2001 and 2003 to each of the nested plots were carried over to the 2020 data. These variables include the following: aspect, slope, habitat type group, position on slope, vertical slope shape, horizontal slope shape, fire group, pre-fire (2000) percent estimated tree canopy cover, post-fire (2001) estimated percent tree canopy cover, stand crown burn severity, understory burn severity, and salvage type.

Aspect is defined as the compass direction that a slope is facing. Slope is defined as the rise or fall of the land surface and is measured as a percentage. Slope in the study plots ranged from 0 percent to 60 percent. Habitat type group is defined as the potential climax vegetation that can be supported on the landscape. The study area had two Douglas-fir habitat type groups: the warm/dry group, and the cool/dry group. Position on slope refers to the location of the plot center on the hillside. Plot centers were classified as either being on the bottom, middle, or top of the slope. Vertical and horizontal slope shape refers to the profile of the slope in reference to the plot center. This was classified as linear, convex, concave, or undulating. Fire group is defined as the grouping of habitat and community types as used by the Forest Service (Crane and Fischer 1986, Fischer and Bradley 1987). There are two fire groups in the study area: fire group four and six. Fire group four is described as a warm/dry Douglas-fir dominated habitat, and fire group six is described as a moist Douglas-fir habitat (Fischer and Bradley 1987). Pre- and post- fire estimated percent tree canopy cover refers to the estimated percent canopy cover of overstory trees in the plot area and were estimated in 2001.

Field data from 2001, 2003, and 2020 was manually entered into Microsoft Excel. These Excel databases were then read into R Studio in order to conduct statistical analyses.

Dependent variables were stratified by environmental variables in various ways utilizing tables and charts to show differences over the study years. These dependent variables include mean vegetation patch size (average vegetation patch length in meters) and mean percent understory cover. Mean percent understory cover represents the average total percent cover of vegetation patches for each nested transect. Mean percent cover of individual species was also calculated to represent the average percent cover of understory vegetation for each nested transect. This was calculated by multiplying each vegetation patch length by the individual species cover for that patch. These values were summed and then divided by the total nested transect length and multiplied by 100.

Statistical analysis to test hypotheses were conducted in R Studio (v. 1.2.5033). Non-standard libraries used during analysis include doBY and MASS. Negative binomial models were used to explore the significance of variables for the presence of live seedlings and overstory tree counts in 2020. One-way ANOVA and Tukey HSD tests were used to determine the differences in the level of significance for dependent variables for mean patch size, mean percent cover, and individual species percent cover.

In order to investigate the significance of explanatory variables on the response using generalized linear modeling, the following procedure was used. The distribution of the response variables was investigated by using a paired panel R script. The distribution of the response and explanatory variables for overstory tree and seedling models can be found in Appendix A. After determining that the distributional assumptions of multiple linear regressions did not hold for the count data of live overstory trees and seedlings, a generalized linear model was chosen. Considering that the response variable is a positive count, a Poisson distribution and log link were used for each of the models. Model building procedures began with a fully saturated, additive model, and based on results from the summary tables of the fitted models, refinements were made by dropping explanatory terms that were shown to no longer be significant until a final model was reached. Overdispersion for both models was investigated by calculating and examining the Pearson residuals. After determining that all models built here had Pearson values that exceeded one and clearly displayed overdispersion, a negative binomial distribution model fit was then used. Final models were created, and the model coefficients were evaluated to determine which explanatory variables had the most influence on the dependent variable.

Results

Overstory tree and seedling responses to environmental variables over time.

Overstory tree counts recorded from each of the study years were totaled and consolidated (Table 3) . Total tree counts for each of the years consisted of trees that were greater than 3 inches DBH and greater than 6 feet tall. These counted trees consisted of Douglas-fir and ponderosa pine. Total tree counts were then divided into three categories: dead, damaged, and live. Trees were considered dead if they displayed no live crown, trees were considered damaged if they had some live crown but had visible scorch or bole marks, and trees were considered live if they had a live crown and little to no visible damage. The overall trends in overstory trees per study for each study year can be seen in Appendix B (Figures B9-B14). The overall change in live overstory trees between each of the study years was significant, with 31 trees (24%) transitioning from live and growing in 2001 to either dead or damaged in 2003. Between 2003 and 2020, 45 (46%) live and growing trees either transitioned to damaged or down woody debris. The change from damaged to dead between the study years was also significant, with almost all (99%) of the counted damaged trees in 2001 (261) transitioning to dead in 2003. All of the counted dead trees in 2003 were no longer standing in 2020 and had transitioned to dead and down woody debris. Tree counts are also broken down by species. Table

3 shows the individual differences for ponderosa pine and Douglas-fir tree counts between the study years. While the 2001 data shows that there were more Douglas-fir present in the sites as compared to ponderosa pine, that difference is no longer present in 2020, with each species having almost the same total count. It is also interesting to note the continued die-off of mature Douglas-fir trees from 2003 to 2020, with 47 trees (70%) no longer being classified as live within the study area (Figures B12-B14). Out of twenty-nine sample plots, only seven plots (24%) had live Douglas-fir within the count areas which can be seen in Figure B14. In comparison, the number of live ponderosa pine trees increased slightly over that same period (Figures B9-B11).

Table 3**.** Overstory tree counts and Trees Per Acre for each study year by status and percent change over time for each classification and each year. Individual species totals are also shown.

Mature Tree Summary Table			
Classification	**Total 2001**	**Total 2003**	**Total 2020**
All	477	412	80
Dead	88	313	0
Damaged	261	2	28
Live	128	97	52

Ponderosa Pine Tree Summary Table			
Classification	**Total 2001**	**Total 2003**	**Total 2020**
All	180	134	41
Dead	18	102	0
Damaged	131	2	9
Live	31	30	32

Douglas-fir Tree Summary Table			
Classification	**Total 2001**	**Total 2003**	**Total 2020**
All	297	278	39
Dead	70	211	0
Damaged	130	0	19
Live	97	67	20

Ponderosa Pine Trees per acre			
Classification	**Total 2001**	**Total 2003**	**Total 2020**
All	62	46	14
Dead	6	35	0
Damaged	45	1	3
Live	11	10	11

Douglas-fir Trees per acre			
Classification	Total 2001	Total 2003	Total 2020
All	102	96	13
Dead	24	73	0
Damaged	45	0	7
Live	33	23	7

Negative binomial models were fitted to these data in order to investigate the most significant explanatory variables that affected the number of live overstory trees in 2020. Models for the live presence of the two tree species, ponderosa pine and Douglas-fir, were fitted and the results were interpreted. Model results for the number of live ponderosa pine trees within the study area for 2020 indicate that an eastern facing aspect, a southeastern facing aspect, and a no salvage treatment option had significant influence. The final model fit, AIC value, and residual diagnostic plot of the model can be found in Appendix A. The model suggests that an eastern and southeastern facing aspect has a significant positive effect on the number of live trees as compared to the mean ($p = 0.27$, $p=0.29$), while a no salvage treatment option had a significantly negative effect on live tree count ($p = 0.0037$). Model results for the number of live Douglas-fir tree counts within the study area indicates that none of the of the variables had significant influence.

Seedling counts recorded from each of the study years were totaled and consolidated (Table 4). The overall trends in total seedling counts per species and plot by study year can be seen Appendix B (Figures B6-B8). The overall change in the number of live seedlings between each of the study years was significant, with Douglas-fir seedling numbers increasing by 1,241 (427 trees per acre) between 2001 and 2003 (Figures B6 and B7). Ponderosa pine seedling numbers also increased, although this may be attributed to seedling plantings that occurred in some of the study transects. Douglas-fir seedlings from 2003 to 2020 decreased by 600 (206 trees per acre) while the number of ponderosa pine seedlings increased by 148 (51 trees per acre) (Figures B7 and B8).

Table 4. Live tree seedlings counts for each study year for ponderosa pine and Douglas-fir.

Seedling Count Summary Table			
Species	**Total 2001**	**Total 2003**	**Total 2020**
Ponderosa pine	11	68	216
Douglas-fir	37	1278	678

Ponderosa Pine Seedling Count by salvage type			
Salvage Type	Total 2001	Total 2003	Total 2020
No salvage	0	8	95
Immediate Salvage	0	25	64
Delayed Salvage	11	35	57

Douglas-fir Seedling count by salvage type			
Salvage Type	Total 2001	Total 2003	Total 2020
No salvage	1	489	325
Immediate Salvage	13	736	306
Delayed Salvage	23	53	47

Ponderosa Pine Seedling count by understory severity			
Understory Severity	Total 2001	Total 2003	Total 2020
Low	0	4	3
Mixed	11	7	64
High	0	57	149

Douglas-fir Seedling count by understory severity			
Understory Severity	Total 2001	Total 2003	Total 2020
Low	9	235	90
Mixed	28	980	515
High	0	63	73

Ponderosa Pine Seedling count by overstory severity			
Overstory Severity	Total 2001	Total 2003	Total 2020
Low	0	18	12
Mixed	11	33	87
High	0	17	117

Douglas-fir Seedling count by overstory severity			
Overstory Severity	Total 2001	Total 2003	Total 2020
Low	25	1062	341
Mixed	12	198	292
High	0	18	45

Live TPA of Overstory and Understory Tree Species per year				
	Species	**2001**	**2003**	**2020**
Overstory TPA	**DF**	33	23	7
	PP	11	10	11
Seedling TPA	**DF**	13	440	233
	PP	4	23	74

Stratifying each species' total seedling count by salvage type, understory severity, and overstory severity shows the differences in seedling counts between the levels of each variable over time (Table 4). For ponderosa pine seedlings, a no salvage and immediate salvage treatment resulted in higher seedling counts from 2001 to 2020 as compared to delayed salvage. A no salvage treatment had the highest number overall, with the greatest increase occurring between 2003 and 2020. A high and mixed understory severity had the highest number of counted ponderosa pine seedlings over time, with high understory severity having the largest number of ponderosa pine seedlings overall. Mixed and high overstory severity had the highest number of counted ponderosa pine seedlings over time, with high severity plots having the largest number of seedlings by 2020.

Douglas-fir seedlings stratified by salvage type displayed a similar trend as ponderosa pine seedlings with a no salvage and immediate salvage treatment having the highest seedling counts by 2020. It should be noted that in 2003, an immediate salvage treatment had higher seedling counts as compared to a no salvage treatment but by 2020, the opposite was true. Mixed understory severity had substantially higher counts over each of the study years as compared to low and high severity. Low severity areas did have higher counts in 2003, but this was no longer the case in 2020. Douglas-fir seedlings stratified by overstory severity showed that low and mixed severity had the highest counts over time. In 2003, there were substantially more Douglas-fir seedlings in low overstory severity areas overall, but by 2020 this difference had become less dramatic.

Model results for live ponderosa pine seedlings within the study year for 2020 indicate that an eastern facing aspect and a no salvage treatment were a significant influence. The final model fit, AIC value, and residual diagnostic plot of the model can be found in Appendix A. Model results suggest that an eastern facing aspect had a significantly positive effect on the number of live seedlings ($p = 0.028$) as compared to the mean, while a no salvage treatment option had a slight negative effect ($p = 0.05$). Model results for live Douglas-fir within the study area indicate that aspect, overstory fire severity, and understory fire severity had a significant influence. The final model fit, AIC value, and residual diagnostic plot of the model can be found in Appendix A. Model coefficients suggest that different aspect facings had negative effects on the number of seedlings, with a northeast, south, west, and northwest facing being the most significant ($p = 0.027$, $p = 0.003$, $p = 0.002$, $p = 0.004$). A southeastern facing aspect is suggested to have the greatest negative effect on live seedling numbers with a p-value of 2.55e-05. Fire severity was also significant, with a high overstory severity having a significant positive effect ($p = 0.02$) and a high understory severity having a significant negative effect ($p = 0.003$). No significant correlation was found between aspect and fire severity in these data.

Mean Patch Size

Mean patch size refers to the average cross-sectional length of all patches intercepted in each nested transect. Comparisons of mean patch size were made across each of the study years stratified by independent variables and converted to meters (Table 5). In 2001, post fire tree cover, slope, and vertical slope shape were shown to be significant for mean patch size. In 2003, only post-fire tree cover and position on slope was shown to be significant (Hollingsworth 2005). In 2020, none of the variables tested were shown to be a significant influence for mean patch size. The p-values from the one-way anova tests for 2020 were included in Table 4 to show the change in significance across each of the study years.

Table 5**.** Independent variables correlated with mean patch size for each study year.

Variable	2001	2003	2020
	p	p	p
Post-fire (2001) tree cover (%)	0.001	0.001	0.669
Slope (%)	0.001	-	0.601
Vertical slope shape	0.046	-	0.623
Posistion on slope	-	0.021	0.697

Mean patch sizes stratified by each variable and category shows the shift to uniformity starting in 2003 and continuing through 2020 (Table 6).

Table 6. Mean patch length in meters stratified by variables for each study year. Numbers in bold and outlined in red were shown to be statistically significant (p<0.05).

Variable	Category	Number of obsevations	Mean Patch Size (m)		
			2001	2003	2020
Overstory severity	Low	171	4.6	2.4	6.6
	Mixed	148	4.9	1.8	6.8
	High	212	7.6	1.8	6.5
Understory severity	Low	157	4.9	2.1	6.6
	Mixed	119	5.2	1.8	6.5
	High	255	8.5	1.8	6.7
Habitat type group	Warm/dry	383	6.1	1.8	6.5
	Cool/dry	148	5.2	2.1	6.6
Aspect	North	64	7.9	1.8	6.8
	Northeast	31	5.5	2.4	7.6
	East	151	4.9	1.8	6.7
	Southeast	118	4.6	1.8	6.4
	South	35	5.5	1.5	6.7
	Southwest	38	6.4	1.8	6.7
	West	58	6.4	1.5	6.1
	Northwest	36	6.1	1.8	6.6
Slope (%)	0-20	127	**7.6**	2.1	6.8
	21-40	229	**6.1**	2.1	6.6
	41-60	175	**4.3**	1.8	6.6
Posistion on slope	Bottom	110	5.2	**2.1**	6.8
	Mid-slope	222	4.9	**1.8**	6.5
	Top	199	7.3	**1.8**	6.6
Vertical slope shape	Linear	315	**5.2**	1.8	6.6
	Convex	136	**8.5**	1.8	6.4
	Undulating	80	**4.9**	2.1	6.9
Horizontal slope shape	Linear	91	4.6	2.1	6.3
	Concave	231	5.5	1.8	6.5
	Convex	209	6.7	1.8	6.8
Firegroup	4	106	5.8	2.1	6.7
	6	425	5.8	1.8	6.6
Pre-fire (2000) tree cover %	1-30%	160	5.4	1.8	6.7
	31-45%	179	6.3	2	6.6
	>45%	192	5.9	2.1	6.5
Post-fire (2001) tre cover %	0	237	**7.1**	**1.6**	6.5
	1-25%	168	**4.9**	**2.1**	6.7
	>25%	126	**4.3**	**2.5**	6.7
Salvage Type	Delayed Salvage	135	-	-	6.5
	Immediate Salvage	102	-	-	6.9
	No Salvage	294	-	-	6.5

Understory Vegetation Cover

Understory vegetation cover refers to the mean percent cover of all understory species per transect. Comparisons of mean percent understory vegetation cover were made across each of the study years stratified by independent variables (Table 7). In 2001, post-fire tree cover, habitat type group, position on slope, and overstory severity were all shown to be significant for mean percent cover. In 2003, pre-fire tree cover, habitat type group, aspect, and fire group were shown to be significant (Hollingsworth 2005). In 2020, pre-fire tree cover, habitat type group, aspect, overstory severity, vertical slope shape, and horizontal slope shape were shown to have a significant influence on mean percent understory cover.

Table 7**.** Variables correlated with understory vegetation percent cover for each study year.

Variable	2001	2003	2020
	p	p	p
Pre-fire (2000) tree cover %	-	0.008	3.39E-05
Post fire (2001) tree cover %	0.001	-	-
Habitat type group	0.015	0.001	1.44E-07
Posistion on slope	0.001	-	-
Aspect	-	0.01	3.00E-03
Firegroup	-	0.02	-
Overstory severity	0.008	-	0.0003
Vertical slope shape	-	-	0.0004
Horizontal slope shape	-	-	0.001

In 2020, there was a significant difference in mean percent understory cover for areas of high pre-fire tree cover (greater than 45%) and medium tree cover (31-45% , $p<0.0001$). There was also a difference between high tree cover and low tree cover (1-30%, $p<0.004$). Medium tree cover to low tree cover was not found to be statistically significant.

For habitat type group, a significant difference was shown for mean percent understory cover in each of the previous study years and 2020. Aspect also influenced mean percent understory cover in 2020, with the southeast aspect displaying the lowest overall mean percent understory cover. Overstory severity was influential in 2020, with the most significant difference in mean percent understory cover existing between high overstory severity and low overstory severity fire classifications ($p<0.0001$). Vertical and horizontal slope shapes also were significant in 2020, with differences between linear and convex vertical slope shapes ($p<0.01$), undulating and convex slope shapes ($p<0.001$), and linear and concave horizontal slope shapes ($p<0.001$) displaying the most significance for mean percent understory cover.

The summary table of mean percent understory cover shows the overall changes over the study years, with a significant increase in cover from 2001 to 2003 followed by an overall decrease in mean percent understory cover from 2003 to 2020 (Table 8).

Category	Number of observations	Understory Cover (%)		
		2001	2003	2020
Low	171	**39**	41	**22**
Mixed	148	**31**	46	**27**
High	212	**26**	41	**29**
Low	157	39	45	26
Mixed	119	25	44	30
High	255	26	36	25
Warm/dry	383	**28**	**38**	**24**
Cool/dry	148	**40**	**52**	**33**
North	64	36	**51**	**28**
Northeast	31	36	**45**	**30**
East	151	38	**51**	**29**
Southeast	118	25	**30**	**21**
South	35	32	**39**	**27**
Southwest	38	40	**26**	**30**
West	58	14	**35**	**23**
Northwest	36	29	**47**	**28**
0-20	127	34	40	27
21-40	229	34	42	27
41-60	175	26	45	25
Bottom	110	**45**	41	28
Mid-slope	222	**34**	48	26
Top	199	**22**	37	25
Linear	315	31	42	**27**
Convex	136	24	36	**21**
Undulating	80	53	56	**30**
Linear	91	27	39	**32**
Concave	231	35	45	**24**
Convex	209	29	41	**27**
4	106	34	**50**	26
6	425	31	**41**	26
1-30%	160	35	**49**	**28**
31-45%	179	31	**44**	**30**
>45%	192	29	**35**	**22**
0	237	**25**	41	26
1-25%	168	**36**	43	28
>25%	126	**40**	45	25
Delayed Salvage	135	-	-	25
Immediate Salvage	102	-	-	29
No Salvage	294	-	-	26

Table 8**.** Understory percent cover stratified by variables for each study year. Numbers in bold and outlined in red were shown to be statistically significant ($p<0.05$).

Fire Severity effects on Major Understory Species

The effects of understory fire severity class was variable on mean percent cover of major understory species in 2020. Major understory species were those having greater than 5% cover in any of the severity classes in 2003 and are listed in the percent cover table (Table 9). While understory severity did not significantly influence overall mean percent vegetation cover in 2020, it did significantly influence cover of individual vegetation species, including ninebark (*Physocarpus malvaceus*), snowberry (*Symphoricarpos albus*), heartleaf arnica (*Arnica cordifolia*), spotted knapweed (*Centaurea micranthos*), and beargrass (*Xerophyllum tenax*) (Table 9) (Table 10).

Table 9**.** Percent cover of major understory vegetation species stratified by understory fire severity for each study year. A = accidental (species with mean cover <1% or species with only one occurrence)

		2001 Cover %			2003 Cover %			2020 Cover %		
Lifeform	**Species**	**Low**	**Mixed**	**High**	**Low**	**Mixed**	**High**	**Low**	**Mixed**	**High**
Shrubs	*Arctostaphylox uva-ursi*	6.0	-	A	7.4	-	2.1	5.6	1.2	2.4
	Linnaea borealis	10.8	A	-	6.4	A	A	2	-	-
	Physocarpus malvaceous	17.2	6.5	-	13.1	8.4	-	-	6.9	7
	Rubus parviflourus	-	-	-	9.6	A	-	-	-	-
	Spiraea betulifola	5	6.6	A	3.9	7.7	3.4	2.2	A	1
	Symphoricarpos albus	4.2	6.1	3.5	4.5	8	4.8	4.8	17.2	7.9
	Vaccinium caespitosum	-	-	-	5.3	-	2.9	-	-	-
	Vaccinium globulare	7.3	A	-	6.3	3.1	-	1	1	1.1
Forbs	*Arnica cordifolia*	11	1.9	6.7	10.4	A	2.2	3.6	2.4	A
	Centaurea maculosa	14.6	5.5	-	6.8	7.8	3.5	9.1	3.3	6.8
	Cirsium arvense	-	-	-	A	-	9	-	-	A
	Epilobium angustifolium	14.3	10.2	15.9	6	6.8	7.3	A	-	-
	Erigeron spp.	21.1	10.3	A	13.5	9.8	3.7	-	-	-
	Verbascum thapsus	-	-	-	3.1	-	5.5	-	-	-
	Xerophyllum tenax	12	17.2	12.4	8.1	15.5	21.4	13.6	A	5
Graminoids	*Calamagrostis rubescens*	12.1	10.7	10.8	12.4	14.5	8.1	17.2	20.2	21.8
Moss	Moss	-	-	-	7.7	8.3	9.5	-	-	A

The differences in mean percent cover for each species between the levels of severity can been seen in Figure 5, with each graph representing a different species. The species that were affected responded as expected due to their fire adaptations and no significant deviations from those trends were observed.

Table 10**.** List of understory species by common name that were significantly affected by understory severity in 2020 with corresponding p-values.

Common Name	**P-value**
ninebark	0.02
common snowberry	1.42E-05
heartleaf arnica	0.05
spotted knapweed	0.05
beargrass	0.0008

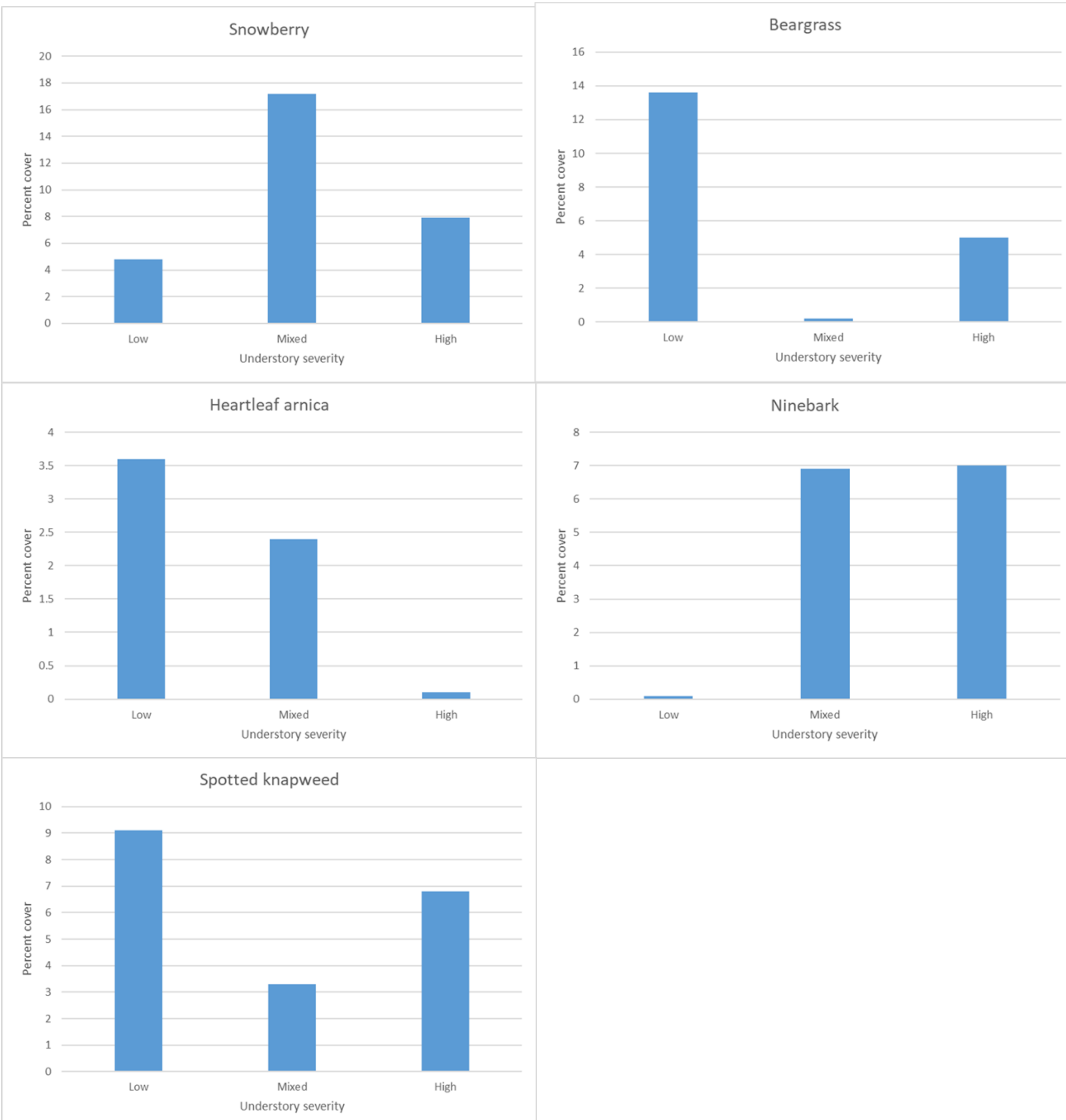

Figure 5. Mean percent cover of significantly affected understory species stratified by understory fire severity class.

The summary table of mean percent cover of major understory species for each study year stratified by understory severity class shows the overall changes in composition and the changes for each individual species by severity class. It is interesting to note the decrease in the number of major vegetation species from 17 in 2003 to 10 in 2020. This can be seen in the absence of four forbs species and two shrub species from 2003 to 2020 (Table 9).

Overstory severity influenced overall mean percent understory vegetation cover for 2020 and it also had effects on individual mean percent cover of major species. Overall differences between the overstory fire severity classes are shown for each of the major species, with heartleaf arnica, spotted knapweed, and beargrass percent cover being influenced the most in 2020 (Table 11). Heartleaf arnica was influenced by overstory severity, with the differences between mixed and low severity ($p<0.2$) and high and low severity ($p<0.2$) being the greatest. Spotted knapweed was slightly influenced by overstory severity with the greatest difference existing between mixed and low severity ($p<0.05$). Beargrass was significantly influenced by overstory severity, with the greatest difference existing between mixed and low severity ($p<0.01$). The visual trend of these differences can be seen in Figure 6. Overall differences in percent cover for each of the major understory species stratified by overstory severity class are listed below (Table 12).

Table 11. Understory species significantly affected by overstory severity in 2020.

Common Name	**P-value**
heartleaf arnica	0.01
spotted knapweed	0.06
beargrass	0.01

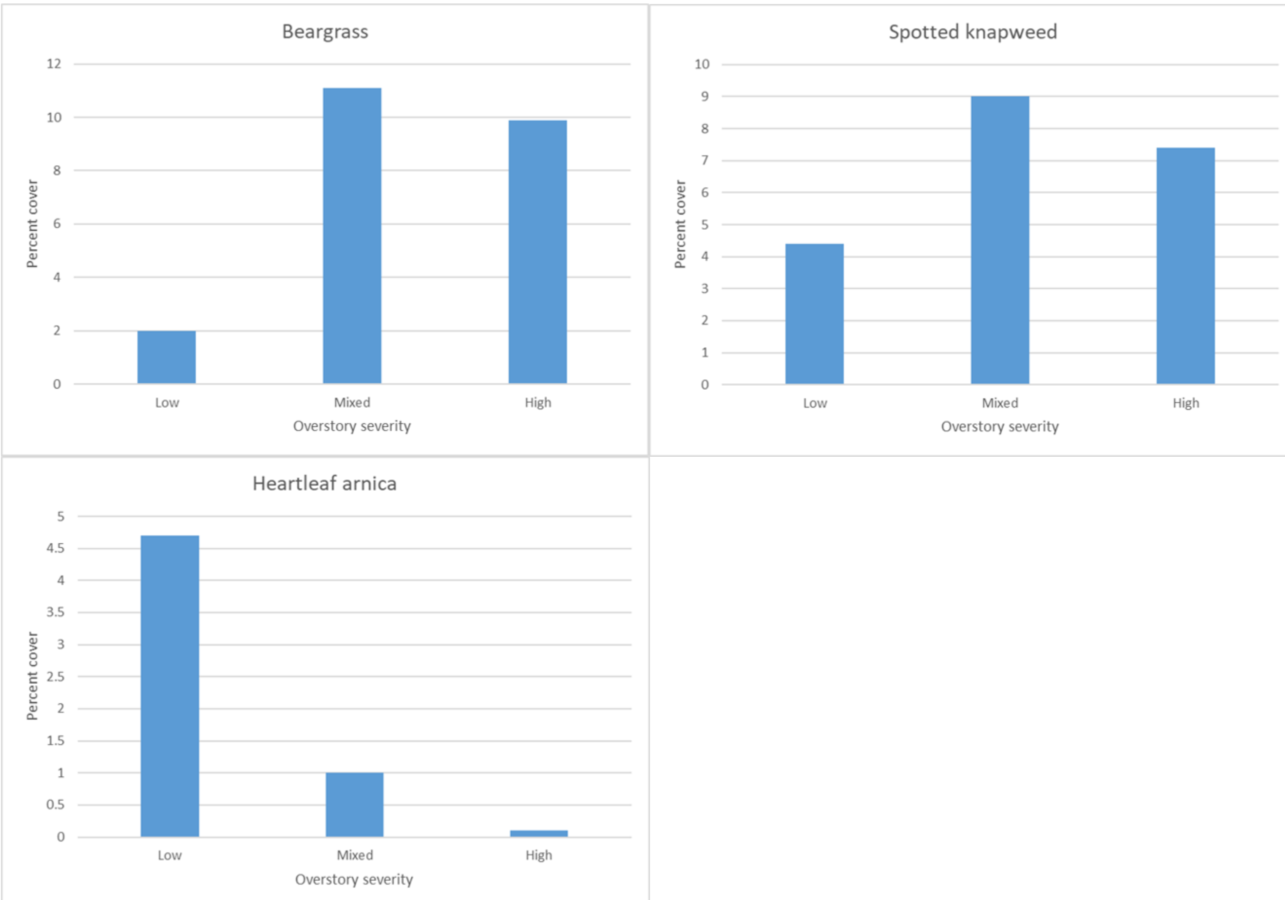

Figure 6. Mean percent cover of significantly affected understory species stratified by overstory severity class.

Table 12**.** Percent cover of major understory vegetation species stratified by overstory fire severity for 2020. A = accidental (species with mean cover <1% or species with only one occurrence)

		2020 Cover %		
Lifeform	**Species**	Low	Mixed	High
Shrubs	*Arctostaphylox uva-ursi*	4.2	3.5	2.6
	Linnaea borealis	1.41	0.9	-
	Physocarpus malvaceous	2.8	2.2	8
	Rubus parviflourus	-	-	-
	Spiraea betulifola	A	1.5	2.11
	Symphoricarpos albus	9.1	8.1	7.2
	Vaccinium caespitosum	-	-	-
	Vaccinium globulare	A	1.1	1.5
Forbs	*Arnica cordifolia*	4.7	1	A
	Centaurea maculosa	4.4	9	7.4
	Cirsium arvense	-	A	-
	Epilobium angustifolium	-	A	-
	Erigeron spp.	-	-	-
	Verbascum thapsus	-	-	-
	Xerophyllum tenax	2	11.1	9.9
Graminoids	*Calamagrostis rubescens*	15.9	21.3	21.16
Moss	Moss	-	0.1	-

Discussion

The most prominent changes for overstory tree counts for each of the study years are in the differences of dead and damaged trees between 2001 and 2003, and the differences in dead trees from 2003 to 2020. Almost all of the trees that were classified as damaged in 2001 had transitioned to standing dead by 2003, and by 2020 all of the standing dead trees within the plot areas had transitioned to down woody debris. The time it took to transition from standing dead to down woody debris is consistent with findings from other studies, with most disturbance effected areas taking between 10 and 12 years to lose half of their standing dead trees (Passovoy and Fule 2006). Another study concluded that salvaged logged areas would generally have fewer large, standing dead trees as compared to non-salvaged areas, and that dead tree persistence over time was shorter for salvaged areas (Russel et al, 2006). This would be expected given the nature of salvage logging, especially in the French Basin study area given the DNRC's mandate to manage the land for revenue purposes. Still, it is crucial to note that standing dead trees were observed in the study areas outside of the plots, indicating that some dead trees can persist well over 20 years post fire. Comparing site photographs shows the difference in standing dead numbers observed outside the study plot areas between the Larid Creek area and the French Basin area, with more standing dead being present in the Larid Creek area (Figure 7).

Figure 7. Examples of observed standing dead trees outside of plot areas. The picture on the left is located in the Larid Creek area (transect 4) and underwent a delayed salvage. The picture on the right is located in the French Basina area (transect 9) and underwent an immediate salvage.

Model results for the presence of ponderosa pine in 2020 suggest that a southeast and eastern facing aspect had a positive influence on the number of live trees in the study area. Ponderosa pine is able to persist on warm/dry sites as compared to Douglas-fir (Howard, 2003), and this is reinforced by the southeast facing aspect result of the model. Ponderosa pine is rated as a very fire-resistant species due to its thick bark and self-pruning attributes and would be more suited to survive on the more fire-prone south facing aspects in the study area (Howard, 2003). A no salvage treatment option was shown to have a significant negative effect on the number of live ponderosa pine in the study areas. This result is most likely attributed to some ponderosa pine seedlings that had been planted in 2000 that had transitioned to maturity since then, although without detailed planting data it is difficult to say how many actually did. With such low counts of ponderosa pine stems across the study area, even a few seedlings that had transitioned to maturity in non-salvaged areas over time could influence the model results. However, this model output could also be a result of the small sample size of the study and that there are more non-salvaged plots overall. Further research could be conducted in order to fine tune this model.

Model results for the presence of Douglas-fir indicated that none of the variables were influential on live overstory tree counts in 2020. While this may indicate that no single variable had a significant effect on the distribution of live trees in the study area, it is more likely that the large number of zero count plots and the small sample size of the study contributed to this result. Out of twenty-nine sample plots, only 6 (20%) had live Douglas-fir within the count areas. A larger study plot radius may yield better results in future studies.

The live seedling counts for each study year per species shows the significant changes over time in number and composition of seedlings within the study areas (Table 3). Of particular note is the large increase in Douglas-fir seedlings between 2001 and 2003 with an overall increase of 1,241 (564 trees per acre). This increase can be attributed to some plots where survivor overstory Douglas-fir trees prolifically reseeded the immediate area (Steinberg 2002). This is followed by a large decrease in seedlings from 2003 to 2020, with almost half of seedlings found in 2003 no longer being present in the plot areas in 2020. A possible explanation for this decrease could be from competition from more robust Douglas-fir seedlings or a lack of shade in the fire effected areas, although it is difficult to say without data between 2003 and 2020 (Steinberg 2002). The increase in ponderosa pine seedlings over time is significant as well, with the largest increase occurring over the 2003-2020 time period. Again, this could be attributed to replanting efforts that took place in the study areas, but natural regeneration should not be dismissed. Model output for the presence of live ponderosa pine seedlings in the study areas suggest that aspect had a positive influence and a no-salvage treatment option had significant negative influence. An eastern facing aspect was shown to be a positive influence on the number of seedlings in the study area. This may be attributed to a few plots located in the Larid Creek study area that may have been planted after the 2003 study. Reference pictures from the area show no viable seed source in the plot and in the immediate surroundings and it is assumed that they were planted (Figure 8). Other planting activities in the French Basin study area may also have influenced the model result as well. A no salvage treatment was shown to have a slightly negative affect on the number of live seedlings in the study area. This could be attributed to the lack of planting done in these areas; however, it is more likely that the lack of surviving overstory seed sources could be a contributing factor as alluded to in the overstory tree model.

Figure 8. Western facing view of transect 1, plot 5 in the Laird Creek study area. Suspected planting areas of ponderosa pine seedlings such as this could have influenced the model results for number of live seedlings in the study area. Note the lack of immediate live overstory trees within the area that could have provided a seed source.

The presence of more seedlings in treated areas vs non-treated areas does not definitively indicate that salvage logging was the most significant contributing factor to live seedling numbers in these results. Rather, assumed planting after salvage logging could be the most influential factor with logged areas more likely to have been planted. Observed natural regeneration in the study areas were present but low, which could be attributed to the die-off of overstory ponderosa pine between study years. Without a seed source, areas that underwent high severity fire would most likely be unable to return to a ponderosa pine/Douglas-fir dominated system without outside assistance. It should be noted that the number of ponderosa pine seedlings that were assumed to be planted in the French basin study area was almost identical between the 2003 and 2020. This indicates that these sites are capable of supporting tree seedlings regardless of what kind of salvage logging occurred there.

Model results for live Douglas-fir seedlings in the study area indicate that aspect, overstory, and understory fire severity had significant influence. Certain aspects were shown to have negative effects on the number of seedlings in the area. These include a northeast, northwest, west, southeast, and south facing aspect. The variability of this result could be attributed to survivor overstory trees that reseeded areas prolifically between the study years on various aspects. An example of this could be seen in transect 9 plot 1, where surviving overstory Douglas-fir in and around the plot area heavily reseeded the area (Figure 9). One study indicated that basal area was positively correlated with seedling density in that larger diameter trees resulted in more seedlings of the same species within the immediate plot area (Page et al., 2001). Future modeling should include average basal density as an explanatory variable to investigate if this relationship occurred within these study areas.

Seedlings also require partial shade on warm/dry facing aspects which further points to the importance of overstory survivors in the plot areas (Steinberg 2002). Douglas-fir seedlings in the Northern Rockies seem to prefer the cool, moist north facing aspect yet can also persist if adequate shade is provided (Steinberg 2002). The model output seems to suggest this, however it is more likely that the large number of zero count plots mixed with a small number of higher count plots on certain aspects could have influenced this result.

Figure 9. Northern and southern facing pictures of transect 9, plot 1 illustrates the ability of overstory Douglas-fir to prolifically reseed areas.

Fire severity was shown to have some influence on the number of live seedlings in the study area. In particular, high overstory fire severity was shown to have positive effect while high understory fire had a significantly negative effect. This may be attributed to plantings that took place on high overstory severity areas in both study areas, although natural regeneration from outside sources should not be discounted. Another possible explanation for this result is that areas that underwent high severity understory fire no longer had adequate shading to allow Douglas-fir seedlings to establish and persist (Steinberg 2002). Possible seed banks of Douglas-fir could also have been consumed during the fire in areas of high understory fire severity. This result could also be attributed to the small sample size of the study and the small number of high seedling count plots encountered.

Mean understory vegetation patch size was not significantly affected by any variable in 2020. Previous studies conducted in the area pointed to the significance of post-fire tree cover, slope, and slope shapes on mean patch size. However, by 2020 these were no longer significant and overall mean patch size had become more uniform than previous study years. This result is consistent with the idea that successional pathways of understory species become less variable over time after disturbance (Armour 1984), and this can be seen in the decrease in variation through the study years. This result may point to a return to pre-fire understory patch size, although without pre-fire data it is difficult to say if that is what is occurring.

Mean understory percent vegetative cover was significantly influenced by a number of factors in 2020. These variables include pre-fire tree cover, habitat type group, aspect, overstory severity, vertical slope shape, and horizontal slope shape. In the case of pre-fire tree cover, 31-45% estimated overstory cover had the highest understory vegetation cover in 2020. A possible explanation for the significant differences in understory percent cover between the three classes of pre-fire tree cover could be the differences in fire severity between each of the cover classes (Arno et al. 2000). For example, an area with 31-45 % overstory cover may be more likely to have experienced a mixed severity fire which could result in a combination of high intensity and low intensity fire. This mosaic burn pattern could result in a broader range of understory survivor species within the area as compared to an area that only experiences a high intensity or low intensity fire. While most literature focuses on overstory response to different levels of severity, it could be inferred that understory species may have a similar response and mixed severity areas could display more variety in species. More research should be conducted on this matter.

Habitat type group had a significant effect on understory percent cover, with the cool/dry group having significantly more understory vegetation cover than the warm/dry groups. The cool/dry habitat group generally has less evaporation and more available moisture which could contribute to more understory vegetation growth (Fischer et al. 1983). Aspect also had a significant effect on understory cover, with southern facing aspects generally having less overall cover than northern and eastern facing aspects. This can be attributed to more available sunlight on southern aspects which results in hotter, drier areas. Overstory severity had a significant effect on cover as well, with high severity areas having more overall understory cover than low and mixed severity areas. This can be attributed to the high overall percent cover of pinegrass (*Calamagrostis rubescens*) across all of the severity classes. Pine grass is known to be able to survive even the most severe wildfires and can sprout prolifically from its underground rhizomes (Matthews 2000). Vertical and horizontal slope shape also had an effect on vegetation cover, with an undulating vertical slope shape and a linear horizontal slope shape having the greatest percent cover overall. While there is little research done on how slope shape could affect vegetation cover, it is suspected that small variations in topography may give a small amount of cover that could allow varying levels of growth to occur and could also affect water retention.

Certain understory species were significantly affected by understory severity in 2020. The mean understory percent cover of ninebark was shown to be significantly affected by severity in that it was only present in mixed and high severity study areas. This species resprouts from underground rhizomes, surviving root crowns, and is known to be fire resistant (Habeck 1992) . It also takes time to spread after disturbance and this is seen in the transition of the species from low and mixed severity areas in 2001 and 2003 to mixed and high severity areas in 2020 (Habeck 1992).

Another species that was strongly influenced by severity was common snowberry with percent cover being significantly higher in mixed severity areas. The species is known to recolonize areas quickly post-fire that have experienced low to moderate soil disturbance (McWilliams 2000). This explains why areas of high understory fire severity do not display as much common snowberry cover due to higher soil consumption overall.

Heartleaf arnica was slightly affected by understory severity, with the greatest differences being between high and low severity areas. The species was mostly absent in high severity areas due to its small form that rarely persists above duff cover. This makes it highly susceptible to anything greater than a low severity fire, although its wind dispersed seeds allow it to easily resprout in such low severity areas or allow survivors to recolonize areas quickly as in the case of mixed-severity areas (Reed 1993).

Spotted knapweed was shown to be slightly affected by understory severity, with mixed severity sites having lower percent cover than low or high severity sites. Possible explanations for this are that the species has a perennial taproot that will survive most low severity fires which would allow it to repopulate quickly in the absence of other, more fire- susceptible species. In the study areas, it was noted that most instances of the species were in large, bare ground areas of the warm/dry habitat type areas, possibly indicating the effects of this survival mechanism (Zouhar 2001).

Beargrass was shown to be affected by understory severity with the most percent cover existing in areas of low severity. Previous study years indicated that the opposite was true, with mixed and higher severity areas displaying more percent cover of the species. While the species can repopulate areas that have been cleared by recent disturbances, it is very sensitive to competition from other shrub species and will diminish over time (Crane 1990). It should be noted that most instances of the species occurred in the warm/dry habitat areas that generally had little to no overstory or shrub presence, which again affirms the species' preference for more open areas.

Overstory severity had some effects on the percent cover of certain species in 2020. Heartleaf arnica displayed the greatest percent cover in areas of low overstory severity, which again points to its susceptibility to higher severity fires. Spotted knapweed had the greatest percent cover in areas of mixed and high overstory fire which again could point to the species ability to reseed areas quickly from survivors or offsite colonizers. Beargrass had the greatest percent cover in areas of mixed and high severity, which could be attributed to some individuals that persisted in open areas of forest canopy on the site.

Conclusions

The effects of environmental variables, fire severity, and post-fire management on vegetation regeneration in the areas affected by the 2000 fires in the Southern Bitterroot valley were varied. The most influential environmental variable to affect vegetation regeneration for understory species and overstory species was aspect. Aspect was influential on the distribution of tree seedlings, overstory trees, and understory percent vegetative cover. Fire severity was also influential, with differences in overstory and understory severity having influence on the distribution, presence, and percent cover of vegetation species across the study areas. Areas of higher understory and overstory severity influenced the presence of certain fire-resistant species while lower understory and overstory severity areas promoted more shade tolerant species. Overall, environmental variables and fire severity had the greatest long-term effects on vegetation regeneration, although as time continues to pass, these effects become less varied, especially in the understory. The most influential post-fire management activity was seedling planting. This resulted in a large increase of tree seedlings in areas that would most likely be unable to regenerate naturally. While natural regeneration was present on site, it was apparent that a majority of the study areas that had experienced high severity fire would be unable to naturally regenerate without outside influence.

These results indicate that without a targeted post-fire management plan, it will be difficult for severely affected ecosystems to return to their successional pathways over time. As more severe wildfires continue to persist on the landscape, it will be up to land managers to decide what comes back as overstory seed sources diminish. As the feedback loop of climate change and severe wildfires continue in the future, it will be extremely important to consider the implications of a delayed response when managing burned forested ecosystems.

There are some limitations of this study. The most prominent limitation is that the exact areas and times where tree seedling plantings occurred is unknown. While it was known that the DNRC study areas were planted in 2001, other study areas including some Forest Service plots displayed some evidence of plantings that occurred after 2003 and it was difficult to determine what could be considered natural regeneration or artificial. Having the planting data would significantly improve the model outputs and would help clarify the data overall.

Another limitation of this study is that in order to make comparisons across each of the study years, it was required that the study methods need to be kept uniform. However, these methods could use some expansion. It is recommended that the overstory tree count plots are expanded in size beyond a 1/10th acre radius plot to gather further data on standing dead persistence and live tree seed sources in both study areas. It was also difficult to track some overstory tree counts and individual tree status through the study years as some of the data collected in the previous studies were unclear or too general in scope. Also, it would be useful to see if any rehabilitation work had been conducted in either study area between 2003 and 2020.

Further research should be conducted on the survival rate of planted seedlings in managed areas over time. Comparisons should also be made between natural seedling regeneration and planted seedling viability in burned areas over time. More research should be conducted on fire severity’s long-term effects on understory vegetation as these ecosystems return to a form of equilibrium over time.

Overall, this research suggests that forested ecosystems that are affected by high severity wildfires will experience long-term changes to vegetation species composition and abundance. Areas that are managed immediately after fire with a clear goal in place could expect to meet their land management goals. Forested ecosystems that do not receive some form of post-fire management treatment could expect to take much longer to return to post-fire stand conditions or could possibly never return to that original state. Depending on agency goals or mandates, immediate action should take place in fire affected ecosystems if forest health and resiliency is to be maintained in the era of climate change.

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Appendix A. Raw 2020 Understory Vegetation Data

Table A1. T01P01

	Distance	% Cover	Cov G	G	Cov F	F	Cov S	S
1	N							
2	5	65	25	XETE			30	VASC
3			10	CARU				
4								
5	10	45	10	CAGE			25	VASC
6			10	CARU				
7	12	5			5	ARNCA		
8	30	70	60	CARU	<	KNAP		
9					10	LIBO		
10							<	SPRIEA
11								
12	37	25			25	KNAP	<	SPRIEA
13	E							
14	4	100	50	XETE	50	ARNICA		
15	8	40			40	ARNICA		
16			<	CARU				
17	28	85	20	XETE	35	ARNICA	5	SPIREA
18					25	LIBO		
19								
20								
21	34	10	10	CARU				
22	37	40	20	CARU	20	LIBO		
23	S							
24	9	70	40	XETE	30	HUCK		
25	13	20	5	XETE			15	SPIREA
26	19	85	50	CARU	30	HUCK	5	SPIREA
27	37	15	5	CARU	10	KNAP		
28								
29								
30	W							
31	13	75	35	XETE	40	HUCK		
32	22	100	70	CARU			30	WILLOW
33								
34	25	20			15	KNAP		
35					5	FRUI		
36	30	30	30	CARU				
37								
38	32	15	10	CARU	5	KNAP		
39								
40								
41	37	100	60	XETE	10	HUCK		
42			20	CARU				
43								
44								
45								
46								
47								

Table A2. T01P02

	Distance	% Cover	Cov G	G	Cov F	F	Cov S	S
1	N							
2	10	50	20	XETE	20	VASSI		
3			5	CARU	10	VASC		
4					5	SYAL		
5	22	25	10	CARU	5	VASSI		
6					5	ARCO		
7					5	KNAP		
8	37	50	10	XETE	10	SPRIEA		
9			15	CARU	10	VASC		
10					5	SYAL		
11	E							
12	6	20	10	CARU	10	VASC		
13					<	KNAP		
14	18	10			5	ARCO		
15					5	KNAP		
16	30	10			5	ARCO		
17					5	SPRIEA		
18					<	KNAP		
19	37	50	25	CARU	25	SPRIEA		
20	S							
21	5	5	5	CARU	<	KNAP		
22					<	VASSI		
23	13	20	10	XETE	5	SYAL		
24					5	SPRIEA		
25	24	20	10	CARU	5	SPRIEA		
26					5	SYAL		
27	37	40	5	CARU	25	VASSI		
28					10	VASC		
29	W							
30	13	50	15	XETE	25	VASSI		
31			5	CARU	5	SPRIEA		
32	18	10			5	KNAP		
33					5	SYAL		
34	27	40	15	CARU	10	VASSI		
35			5	XETE				
36			10	FEID				
37	37	40	30	XETE	10	WILLOW		
38								
39								
40								

Table A3. T01P03

	Distance	% Cover	Cov G	G	Cov F	F	Cov S	S
1	N							
2	5	20	5	XETE	5	KNAP	10	SPRIEA
3								
4	13	80					80	CEVE
5	17	30	5	XETE	5	FRUI		
6			5	CAGE	5	KNAP		
7					5	ACMIl	5	SPRIEA
8	33	95	10	CAGE	80	KNIC		
9			5	XETE				
10	37	10	5	CARU	5	FRUI		
11					<	KNAP		
12	E							
13	2	5			5	ACMIL		
14	4	20	10	XETE			10	SPIREA
15	6	5			5	KNAP		
16	11	25	15	XETE			10	SPIREA
17	37	40	10	XETE	15	KNAP		
18					5	ACMIL	5	SPIREA
19	S							
20	6	10	5	FEID	<	KNAP	<	SPIREA
21	12	30	15	CAGE			10	SPIREA
22			5	XETE				
23	15	10			5	KNAP	5	SPIREA
24	23	70	50	CAGE	10	KNAP		
25					5	ACMIL		
26					5	FRUI		
27	25	10			5	ACMIL		
28					5	KNAP		
29	37	40	30	XETE	5	ACMIL		
30					5	KNAP		
31	W							
32	16	10	5	CAGE	5	KNAP		
33	28	15			10	KNAP		
34					5	ACMIL		
35	37	30	15	CAGE	10	KNAP	5	SPIREA
36								
37								
38								
39								
40								

Table A4. T01P04

	Distance	% Cover	Cov G	G	Cov F	F	Cov S	S
1	N							
2	3	15			5	ACMI	10	VASC
3	11	5	5	CARU				
4	20	50	25	XETE			25	SHCA
5	27	10			5	KNAP	5	SYAL
6	37	20	10	CARU			5	SYAL
7							5	VASC
8	E							
9	4	5			<	KNAP	5	SPRIEA
10	14	60					50	WILLOW
11							5	ROSE
12							5	SPRIEA
13	16	10	5	XETE			5	SPRIEA
14	30	10	5	CARU			5	VASC
15	37	80	70	XETE			10	VASC
16	S							
17	3	5			5	KNAP		
18	7	95	95	XETE				
19	16	30			5	ACMI	10	VASC
20					5	KNAP	5	SPIREA
21							5	SHCA
22	28	30	10	CARU			5	SPIREA
23							15	SHCA
24	32	10					10	SHCA
25	37	80	40	XETE			40	SHCA
26	W							
27	3	50	50	XETE				
28	7	15	10	CARU			5	SHCA
29	12	5			5	KNAP		
30	25	50	40	XETE			10	SHCA
31	33	25	10	CARU			15	VASC
32	37	10	5	CARU	5	KNAP		
33								
34								
35								
36								
37								
38								
39								
40								

Table A5. T01P05

	Distance	% Cover	Cov G	G	Cov F	F	Cov S	S
1	N							
2	2	5			5	ACMI		
3					<	KNAP		
4	6	70	50	CARU				
5			15	CAGE	5	KNAP		
6	15	30	10	CARU	10	KNAP		
7					10	FRUI		
8	24	70	25	CARU	5	KNAP	15	SYAL
9			25	CAGE				
10	29	40	35	SCHA			5	SYAL
11	37	50	10	CARU	25	KNAP	10	SYAL
12			5	FEID				
13	E							
14	4	15			5	ACMI	5	SYAL
15					5	KNAP		
16	13	35	5	CARU	5	ACMI		
17					25	KNAP		
18	37	60	20	CARU	10	KNAP	15	SYAL
19			5	FEID				
20	S							
21	11	70	50	XETE	5	KNAP	5	SYAL
22			5	CARU	5	ACMI		
23	15	80					80	CEVE
24	19	20	5	CARU	5	KNAP		
25			5	FEID	5	ACMI		
26	25	40	20	XETE	5	KNAP	5	SYAL
27			5	CARU	5	ACNI		
28	36	20	5	FEID	10	KNAP	5	SYAL
29	37	80	40	XETE			40	CEVE
30	W							
31	3	20	10	CARU			10	SYAL
32	9	90	50	XETE			40	SCHA
33	20	60	15	CARU	5	KNAP	5	SYAL
34			15	CAGE	5	ACMI		
35			15	FEID				
36	26	40	10	FEID	10	KNAP	5	SYAL
37			10	XETE				
38	37	20	5	CARU	15	KNAP		
39								
40								

A6. T01P06

	Distance	% Cover	Cov G	G	Cov F	F	Cov S	S
1	N							
2	6	5			<	KNAP	<	SYAL
3	15	20					10	SYAL
4							10	VASC
5	21	20	10	XETE			10	SYAL
6	29	10			5	KNAP	5	SYAL
7	37	25	10	FEID	10	KNAP	5	SYAL
8	E							
9	6	5			5	HOLLY		
10	17	50	25	CARU			10	SYAL
11							15	SCHA
12	24	20			15	KNAP	5	SYAL
13	37	60	40	XETE	10	KNAP	10	SYAL
14	S							
15	13	15			10	KNAP	5	SYAL
16	18	20					10	SYAL
17							10	VASC
18	27	35	10	XETE	5	KNAP	10	SYAL
19			10	CAGE				
20	32	10			5	KNAP	5	SYAL
21	37	20	10	XETE	5	KNAP	5	SYAL
22	W							
23	5	10			10	KNAP		
24	14	35	10	XETE			5	SYAL
25			10	CARU				
26			10	CAGE				
27	16	10	5	CAGE	5	KNAP		
28	20	80					80	CEVE
29	25	5	5	CARU	<	KNAP		
30	37	30	20	XETE	5	KNAP	5	SYAL
31								
32								
33								
34								
35								
36								
37								
38								
39								
40								

A7. T02P01

	Distance	% Cover	Cov G	G	Cov F	F	Cov S	S
1	N							
2	3	5	5	CARU				
3	5	10					5	SPIREA
4							5	HOLLY
5	6	40	40	XETE				
6	16	15	10	CARU			5	DB
7	24	30	20	CARU	5	ARNCA	5	SPIREA
8	37	30	20	CAGE	5	LUPINE	5	SPIREA
9	E							
10	4	15	15	CAGE				
11	7	20	5	CAGE			10	CYAN
12							5	DB
13	37	35	25	CARU	5	ARNCA	5	HOLLY
14	S							
15	15	40	20	IF			15	SYAL
16							5	SPIREA
17	24	15			5	LUPINE	5	SYAL
18							5	DB
19	28	20	15	CAGE	5	LUPINE		
20	32	15			10	ACMI		
21					5	LUPINE		
22	37	10					10	SYAL
23	W							
24	16	25	15	CARU			10	DB
25	20	20	15	IF			5	DB
26	30	15			5	LUPINE	5	DB
27							5	HOLLY
28	32	20	20	IF				
29	37	20			5	LUPINE	10	SYAL
30							5	HOLLY
31								
32								
33								
34								
35								
36								
37								
38								
39								
40								

A8. T02P02

	Distance	% Cover	Cov G	G	Cov F	F	Cov S	S
1	N							
2	9	20	15	CARU			5	SYAL
3	23	35	20	CARU	5	STRAW	10	SYAL
4	34	10	5	CARU			5	SYAL
5	37	35	25	CARU			10	NINE
6	E							
7	24	40	30	CARU	10	UNK2		
8	37	60	10	CARU			40	NINE
9							10	SYAL
10	S							
11	11	30	20	CARU			10	SYAL
12	26	30	10	CARU			10	SYAL
13			10	XETE				
14	37	15	15	CARU				
15	W							
16	6	20	15	CARU			5	SYAL
17	16	25	15	CARU			10	SYAL
18	24	30	5	CARU			20	NINE
19							5	SYAL
20	29	10					10	SYAL
21	37	5	5	CARU				
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								
33								
34								
35								
36								
37								
38								
39								
40								

A9. T02P03

	Distance	% Cover	Cov G	G	Cov F	F	Cov S	S
1	N							
2	9	40	10	CAGE			30	NINE
3	17	30	25	CARU			5	SYAL
4	25	20	5	CARU			15	SYAL
5	37	40	10	CARU			20	VASSI
6			10	CAGE				
7	E							
8	12	35					30	NINE
9							5	SYAL
10	30	50	5	CARU			45	SYAL
11	37	15	10	CAGE			5	NINE
12	S							
13	8	35	5	CAGE			30	NINE
14	13	10	5	CAGE			5	NINE
15	24	40	5	CAGE			5	SYAL
16							30	NINE
17	37	20	5	CAGE			5	NINE
18							5	SYAL
19							5	SPIREA
20	W							
21	9	20					15	NINE
22							5	SYAL
23	21	30	5	CAGE			20	NINE
24							5	SYAL
25	37	25	15	CAGE			5	SYAL
26							5	NINE
27								
28								
29								
30								
31								
32								
33								
34								
35								
36								
37								
38								
39								
40								

A10. T02P04

	Distance	% Cover	Cov G	G	Cov F	F	Cov S	S
1	N							
2	6	5	5	XETE				
3	13	20	5	XETE			10	SOAP
4							5	WILLOW
5	27	30	15	XETE			15	VASC
6	37	20	5	CAGE			15	VASC
7								
8	E							
9	7	30	30	XETE				
10	15	15	5	CARU				
11			10	XETE				
12	16	5					5	VASC
13	20	5	5	CARU				
14	21	20	20	XETE				
15	37	35	15	XETE			20	VASC
16	S							
17	13	25	25	XETE				
18	29	40	5	CARU	25	KNIC	10	VASC
19	37	20	10	CARU			10	VASC
20	W							
21	11	20	15	CARU	5	ARNCA		
22								
23	37	25	10	XETE	5	KNIC	10	VASC
24								
25								
26								
27								
28								
29								
30								
31								
32								
33								
34								
35								
36								
37								
38								
39								
40								

A11. T03P01

	Distance	% Cover	Cov G	G	Cov F	F	Cov S	S
1	N							
2	8	5			5	KNAP		
3	15	15	5	ES	5	ACMI		
4					5	KNAP		
5	30	25	5	ES	5	KNAP	15	SYAL
6	37	10	5	ES			5	SYAL
7	E							
8	10	20	5	CAGE	15	KNAP		
9	32	20			20	KNAP		
10	37	20			15	KNAP	5	SYAL
11	S							
12	20	25			5	LUPINE		
13					20	KNAP		
14	26	20	5	CAGE			15	SYAL
15	37	30	5	CAGE			25	SYAL
16	W							
17	14	15			5	KNAP	15	SYAL
18	22	10			5	ACMI	5	SYAL
19	37	25	5	IF	5	KNAP	10	SYAL
20					5	LUPINE		
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								
33								
34								
35								
36								
37								
38								
39								
40								

A12. T03P02

	Distance	% Cover	Cov G	G	Cov F	F	Cov S	S
1	N							
2	4	20	5	CARU	5	DB	10	SYAL
3	7	35	5	CARU			30	CYAN
4	15	15	5	CARU			10	SYAL
5	18	25	5	CARU			20	CYAN
6	37	40	20	CARU	10	KNAP		
7					5	KNIC		
8					5	DB		
9	E							
10	4	20	15	CARU			5	SYAL
11	6	30					30	CYAN
12	14	20	5	CARU	5	DB	5	SYAL
13					5	KNAP		
14	16	30	25	CARU			5	SYAL
15	25	15	10	CARU			5	SYAL
16	34	30	5	CARU	15	KNIC	5	SYAL
17					5	DB		
18	37	30	20	CARU	5	DB	5	SYAL
19	S							
20	10	30	5	CARU	5	DB	20	SYAL
21	13	30	10	CARU			20	SYAL
22	25	30	15	CARU			15	SYAL
23	27	30					30	CYAN
24	37	40	10	CARU	5	KNAP	25	SYAL
25	W							
26	8	20	5	CARU			15	SYAL
27	12	25					5	SYAL
28							20	CYAN
29	14	5					5	SYAL
30	20	35	5	CARU	10	DB	10	SYAL
31					5	KNAP		
32	27	15	5	CARU	5	KNAP	5	SYAL
33	37	20			10	DB	5	SYAL
34					5	KNAP		
35								
36								
37								
38								
39								
40								

A13. T03P03

	Distance	% Cover	Cov G	G	Cov F	F	Cov S	S
1	N							
2	2	5			5	KNAP		
3	6	15	10	CARU	5	KNAP		
4	12	10	5	CARU	5	KNAP		
5	18	10	5	XETE	5	KNAP		
6	24	20	5	XETE	10	KNAP		
7			5	CARU				
8	30	20	5	XETE	5	KNAP		
9			10	CARU				
10	37	10	5	XETE	5	KNAP		
11	E							
12	4	10	5	CARU	5	KNAP		
13	9	15	5	CARU	5	KNAP		
14					5	KNIC		
15	37	35	10	CARU	5	ACMI		
16			10	XETE	10	KNAP		
17	S							
18	12	25	10	CARU	5	KNAP		
19			10	XETE				
20	16	30	10	XETE	20	KNIC		
21	29	20			10	KNAP		
22					10	KNIC		
23	33	10	5	CARU	<	KNAP		
24			5	XETE				
25	37	40	5	CARU	35	KNIC		
26	W							
27	9	10	5	XETE	5	KNAP		
28								
29	20	30	15	CARU	15	KNIC		
30	30	15	5	XETE	5	KNAP		
31					5	DB		
32	37	25	15	CARU	5	KNAP		
33					5	DB		
34								
35								
36								
37								
38								
39								
40								

A14. T04P01

	Distance	% Cover	Cov G	G	Cov F	F	Cov S	S
1	N							
2	8	50	45	CARU	5	ARCO		
3	12	5			5	ARCO		
4	24	50	35	CARU	15	ARCO		
5	28	5			5	ARCO		
6	32	30	10	CARU	10	ARCO		
7					10	LIBO		
8	34	5			5	LIBO		
9	37	45	5	CARU	30	LIBO		
10					10	ARCO		
11	E							
12	9	25	15	XETE	5	ARCO		
13			5	CARU				
14	13	10			5	THOC		
15					5	ARCO		
16	19	10	5	FEID	5	ARCO		
17	37	65	15	XETE	20	ARCO		
18			15	CARU			15	PHMA
19	S							
20	9	30	15	XETE	10	ARCO		
21					5	LIBO		
22	12	10	5	CARU	5	ANRA		
23	14	30	20	XETE	5	ARCO		
24	29	50	30	CARU	10	ARCO		
25					10	LIBO		
26	37	10	2	CARU	5	ANRA		
27	W							
28	10	0						
29	16	50	40	CARU	10	ARCO		
30	32	60	40	XETE	10	ARCO	10	VASC
31	37	20			20	ARCO		
32								
33								
34								
35								
36								
37								
38								
39								
40								

A15. T04P02

	Distance	% Cover	Cov G	G	Cov F	F	Cov S	S
1	N							
2	6	15	5	CARU	5	APAN		
3					5	KNAP		
4	12	25	10	XETE	5	APAN		
5			5	CARU	5	KNAP		
6	19	30	20	CARU	5	APAN		
7					5	KNAP		
8	37	60	5	XETE	50	KINIC		
9			5	CARU				
10	E							
11	11	20	5	CARU	15	APAN		
12	18	30	5	XETE	10	KNAP		
13					15	ANRA		
14	25	30					30	WILLOW
15	31	10					5	ROSE
16							5	SYAL
17	S							
18	6	20	10	CARU	10	APAN		
19					<	KNAP		
20	14	35	25	CARU	5	APAN	5	FIREWEED
21	18	30	10	CARU	5	APAN	5	SYAL
22					10	KNAP		
23	37	40	5	XETE	30	APAN		
24					5	KNAP		
25	W							
26	4	10			5	KNAP		
27					5	APAN		
28	22	50	25	CARU	25	APAN		
29	33	20	10	CARU	5	APAN		
30					5	KNAP		
31	37	40	25	CARU	10	KNAP		
32					5	APAN		
33								
34								
35								
36								
37								
38								
39								
40								

A16. T04P03

	Distance	% Cover	Cov G	G	Cov F	F	Cov S	S
1	N							
2	1	10			10	KNAP		
3	6	40	35	XETE	5	KNAP		
4	13	25	15	XETE	10	KNAP		
5	20	25			15	KNAP	5	SPIREA
6							5	SYAL
7	30	45	25	XETE	5	ACMI	5	SYAL
8					10	KNAP		
9	37	35	10	XETE	5	ARNCA	5	SYAL
10					15	KNAP		
11	E							
12	3	5			5	KNAP		
13	5	50	50	XETE				
14	13	20	5	CARU	15	KNAP		
15	23	30	20	XETE	10	KNAP		
16	25	10			5	KNAP		
17					5	ACMI		
18	37	35	5	XETE	20	KNAP	5	SYAL
19					5	ARNCA		
20	S							
21	5	5			5	KNAP		
22	37	60	10	XETE	5	KNAP	35	SYAL
23							10	SPIREA
24	W							
25	6	20			15	KNAP		
26					5	ACMI		
27	8	30	30	XETE				
28	11	10			10	KNAP		
29	23	35	10	XETE	5	KNAP	20	SYAL
30	33	70					70	CYAN
31	37	20	10	XETE			10	SYAL
32								
33								
34								
35								
36								
37								
38								
39								
40								

A17. T04P04

	Distance	% Cover	Cov G	G	Cov F	F	Cov S	S
1	N							
2	7	5			5	KNAP		
3	11	20	20	IF				
4	13	5			5	KNAP		
5	16	25	15		5	KNAP		
6					5	ACMI		
7	27	15	5	IF	5	KNAP		
8					5	LUPINE		
9	30	20	10	IF	5	LUPINE		
10					5	KNAP		
11	37	15	5	IF	5	KNAP		
12					5	LUPINE		
13	E							
14	6	10	10	IF	<	KNAP		
15	18	20	20	IG				
16	37	35	25	IF	10	KNAP		
17	S							
18	4	15	15	IF				
19	11	10			10	KNAP		
20	18	20	5	IF	15	KNAP		
21	21	20	10	XETE	10	KNAP		
22	32	35	20	IF	15	KNAP		
23	37	20	5	IF	15	KNAP		
24	W							
25	11	25	20	IF	5	KNAP		
26	17	10	5	IF	5	KNAP		
27	22	10	5	IF	5	KNAP		
28	37	20	10	IF	5	KNAP		
29					5	HOLLY		
30								
31								
32								
33								
34								
35								
36								
37								
38								
39								
40								

A18. T05P01

	Distance	% Cover	Cov G	G	Cov F	F	Cov S	S
1	N							
2	6	15	5	CAGE	5	LUP		
3					5	KNAP		
4	11	20	10	CAGE	5	ACMI		
5					5	LUP		
6					5	KNAP		
7	14	0						
8	16	20	15	CAGE	5	KNAP		
9	20	5			5	KNAP		
10	25	10	5	CAGE	5	ACMI		
11	26	5			5	KNAP		
12	30	5	5	CAGE				
13	34	10			10	ARNCA		
14	37	10	10	CAGE				
15	E							
16	4	20			10	ACMI	5	SYAL
17					5	HAWK		
18	7	10	5	CAGE			5	SYAL
19	14	10			5	ACMI		
20					5	KNAP		
21	34	40	25	CARU	5	LUP	5	SYAL
22					5	KNAP		
23	37	10			5	ACMI		
24					5	KNAP		
25	S							
26	6	5	5	CAGE				
27	10	10			5	ACMI		
28					5	KNAP		
29	19	15			10	LUP		
30					5	HOLLY		
31	29	15	10	CARU	5	KNAP		
32	37	5			5	HOLLY		
33	W							
34	9	10	5	CAGE	5	LUP		
35	14	10	10	CAGE				
36	18	5			5	KNAP		
37	22	10	10	CAGE				
38	37	20			10	STAR		
39					5	KNAP		
40					5	HOLLY		

A19. T05P02

	Distance	% Cover	Cov G	G	Cov F	F	Cov S	S
1	N							
2	5	5					5	SYAL
3	13	15	5	CAGE	5	ACMI		
4					5	KNAP		
5	19	20	10	CAGE	5	KNAP	5	SYAL
6	25	10			5	KNAP		
7					5	LUPINE		
8	33	15			5	KNAP	10	SYAL
9	37	5			5	KNAP		
10	E							
11	9	5			5	KNAP		
12	17	10	5	CAGE	5	KNAP		
13	21	10			5	LUPINE	5	SYAL
14	32	15			10	KNAP		
15					5	LUPINE		
16	37	10			5	KNAP	5	SYAL
17	S							
18	13	20	5	CAGE	15	KNAP		
19	20	10	5	CAGE	5	LUPINE		
20	37	25	5	CARU	5	LUPINE	10	SYAL
21			5	CAGE				
22	W							
23	15	5			5	KNAP		
24	31	15	5	CAGE	5	KNAP	5	SYAL
25	35	10			5	LUPINE	5	SYAL
26	37	10			10	KNAP		
27								
28								
29								
30								
31								
32								
33								
34								
35								
36								
37								
38								
39								
40								
41								

A20. T05P03

	Distance	% Cover	Cov G	G	Cov F	F	Cov S	S
1	N							
2	9	25	20	CAGE	5	KNAP		
3	14	20	5	CAGE	15	KNAP		
4	20	15	5	CAGE	10	KNAP		
5	28	5			5	HOLLY		
6	37	25	20	CAGE	5	HOLLY		
7	E							
8	7	25	15	CAGE	5	ACMI		
9					5	KNAP		
10	16	20	5	CAGE	15	KNAP		
11	23	15	5	CAGE	5	KNAP		
12					5	LUPINE		
13	28	15			15	KNAP		
14	37	20	10	CAGE	5	KNAP		
15					5	LUPINE		
16	S							
17	7	20	10	CAGE	5	KNAP		
18					5	HOLLY		
19	11	20	10	CAGE				
20	15	20	10	CAGE	5	KNAP		
21			5	IDF				
22	24	25	10	CAGE	10	KNAP		
23			5	IDF				
24	37	30	15	CAGE	5	ACMI		
25			5	IDF	5	KNAP		
26	W							
27	6	15	10	CAGE	5	KNAP		
28	26	30	10	CAGE	15	KNAP		
29					5	HOLLY		
30					5	LUPINE		
31	37	40	35	CAGE	5	KNAP		
32								
33								
34								
35								
36								
37								
38								
39								
40								

A21. T06P01

	Distance	% Cover	Cov G	G	Cov F	F	Cov S	S
1	N							
2	10	40	25	CARU			5	SYAL
3			10	CAGE				
4	19	30	20	IF				
5			10	CARU				
6	28	10	10	CARU				
7	37	35	25	CARU				
8			10	CAGE				
9	E							
10	17	45	35	CARU			10	SYAL
11	32	60	60	CARU				
12	37	50	30	CARU			20	SYAL
13	S							
14	9	40	25	CARU			15	SYAL
15	18	30	30	CARU				
16	37	50	35	CARU			15	SYAL
17	W							
18	9	25	20	CARU			5	SYAL
19	30	60	40	CARU	20	ACMI		
20	37	20	15	CARU	5	ACMI		
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								
33								
34								
35								
36								
37								
38								
39								
40								

A22. T06P02

	Distance	% Cover	Cov G	G	Cov F	F	Cov S	S
1	N							
2	5	10	5	CAGE			5	SYAL
3	19	50	10	CAGE	5	KNAP	5	SYAL
4			15	CARU	15	KNIC		
5	28	40	35	CARU			5	SYAL
6	35	20	5	CARU	10	KNAP		
7					5	HOLLY		
8	37	40	15	CARU	20	KNIC		
9			5	CAGE				
10	E							
11	2	30	20	CARU	10	KNIC		
12	7	30	10	CAGE	5	HOLLY		
13			10	CARU	5	ACMI		
14	12	20	10	CARU	5	KNAP		
15					5	HOLLY		
16	37	45	30	CARU	5	KNAP	10	SYAL
17	S							
18	15	45	30	CARU	5	KNAP	10	SYAL
19	23	20	15	CARU			5	SYAL
20	29	40	15	CARU	5	ACMI	5	SYAL
21			15	CAGE				
22	37	25	10	IF	5	ACMI	10	SYAL
23	W							
24	5	20	10	CARU	10	KNIC		
25	10	40	40	CARU				
26	19	30	10	CARU	5	HOLLY	15	SYAL
27	24	15	5	CARU	5	KNAP		
28					5	HOLLY		
29	27	5	5	CARU				
30	32	10	5	CARU			5	SYAL
31	37	20	5	CAGE	5	ACMI	5	SYAL
32			5	CARU				
33								
34								
35								
36								
37								
38								
39								
40								

A23. T06P03

	Distance	% Cover	Cov G	G	Cov F	F	Cov S	S
1	N							
2	7	30	5	CAGE	20	KNIC	5	SYAL
3	14	10	5	CARU	5	ACMI		
4	19	30	25	CARU			5	SYAL
5	23	35	10	CAGE	20	KNIC	5	SYAL
6	29	25	10	CARU			5	SYAL
7			10	CARU				
8	37	50	5	CAGE	40	KNIC		
9					5	ACMI		
10	E							
11	7	30	5	CARU	5	KNIC		
12			10	CAGE	5	ACMI		
13	12	35	15	CAGE	10	KNIC		
14			5	CARU	5	ACMI		
15	17	20	10	CARU	5	KNIC		
16					5	ACMI		
17	26	25	5	CARU	15	KNIC		
18					5	ACMI		
19	29	20	15	CARU	5	KNIC		
20	37	30	15	CARU	15	KNIC		
21	S							
22	8	15	5	CARU	5	KNIC	5	SYAL
23	18	40	15	CARU	20	KNIC	5	SYAL
24	22	10			5	KNIC		
25					5	ACMI		
26	37	45	30	CARU	5	ACMI	5	SYAL
27					5	KNIC		
28	W							
29	8	20			10	KNIC	5	SYAL
30					5	ACMI		
31	13	25	5	CARU	15	KNIC	5	SYAL
32	21	25	10	CAGE	15	KNIC		
33	28	35	5	CARU	5	ARNCA	10	SYAL
34			5	CAGE			10	SYAL
35	34	25	10	CARU	5	KNIC	5	SYAL
36			5	CAGE				
37	37	20	5	CARU	15	KNIC		
38								
39								
40								

A24. T07P01

	Distance	% Cover	Cov G	G	Cov F	F	Cov S	S
1	N							
2	8	20	15	CARU	5			
3	24	25	15	CARU	5	UNK		
4					5	LUP		
5	28	40	5	CARU			35	NINE
6	27	25	15	CARU	5	ACMI		
7					5	LUP		
8	E							
9	5	20	15	CARU			5	SYAL
10	11	15	5	IF	5	ACMI		
11					5	LUP		
12	15	15	5	CARU	5	ACMI	5	SYAL
13	18	10	5	IF	5	ACMI		
14	28	25	5	CARU	10	LUP	5	SYAL
15					5	ACMI		
16	34	20	5	CARU	5	HOLLY	5	SYAL
17					5	LUP		
18	37	15	5	CARU	5	ACMI	5	SPIREA
19	S							
20	7	15	5	CARU	5	HOLLY	5	SYAL
21	11	5			5	ACMI		
22	20	15	5	CARU	5	LUP		
23					5	UNK		
24	24	5	5	IF	<	KNAP		
25	37	30	30	IF				
26	W							
27	4	10	5	CARU	5	HOLLY		
28	7	10	5	CARU			5	SYAL
29	17	35	10	CARU	10	LUP	10	SYAL
30					5	ACMI		
31	25	20	5	CARU	5	ACMI	10	SYAL
32	31	30	5	CARU	5	ACMI	20	SYAL
33	37	20	10	CARU	5	ACMI	5	SYAL
34								
35								
36								
37								
38								
39								
40								

A25. T07P02

	Distance	% Cover	Cov G	G	Cov F	F	Cov S	S
1	N							
2	4	10	5	CARU	5	UNK		
3	6	40	5	CARU			35	NINE
4	16	25	15	CARU	5	UNK2	5	VACCI
5	18	30					30	SYAL
6	24	40	10	CARU			30	NINE
7	27	30	10	CARU	10	UNK2	10	VACCI
8	37	20	15	CARU	5	UNK2		
9	E							
10	9	20	10	CARU	5	UNK2	5	VACCI
11	18	10			5	ACMI	5	VACCI
12	20	40					40	NINE
13	33	30	25	CARU			5	VACCI
14	37	10					10	VACCI
15	S							
16	10	15	5	CARU	5	ANRO		
17					5	ANRC		
18	19	35	25	CARU	5	UNK2	5	VACCI
19	29	15	10	CARU	5	UNK2		
20	37	20	20	CARU				
21	W							
22	5	10	5	CARU	5	UNK2		
23	16	10	5	CARU	5	ANRC		
24	34	40	5	CARU	5	ANRO	25	VACCI
25					5	ANRC		
26	37	<5	<5	CARU				
27								
28								
29								
30								
31								
32								
33								
34								
35								
36								
37								
38								
39								
40								

A26. T07P03

	Distance	% Cover	Cov G	G	Cov F	F	Cov S	S
1	N							
2	4	10	5	CARU	5	ARNCA		
3	24	90					90	NINE
4	36	10	10	CARU				
5	37	15					15	ALDER
6	E							
7	4	20	10	CARU			10	NINE
8	10	25	5	CARU			20	NINE
9	34	45	35	CARU	10	UNK2		
10	37	80					80	NINE
11	S							
12	13	40	20	CARU			20	NINE
13	16	15	5	CARU			10	NINE
14	22	25					25	NINE
15	28	10	5	CARU			5	NINE
16	32	20	5	CARU			15	NINE
17	37	25	15	CARU			10	SYAL
18	W							
19	18	40	10	CARU			30	NINE
20	32	35	5	CARU			30	NINE
21	37	40	5	CARU			20	NINE
22							20	SYAL
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								
33								
34								
35								
36								
37								
38								
39								
40								

A27. T09P01

	Distance	% Cover	Cov G	G	Cov F	F	Cov S	S
1	N							
2	5	20	10	CARU	5	ANRO		
3					5	ARNCA		
4	10	10	5	CARU	5	ARNCA		
5	14	15	10	CAGE	5	ARNCA		
6	19	10	5	CARU	5	ANRO		
7	37	55	40	CARU	5	ARNCA	5	SYAL
8					5	ANRO		
9	E							
10	4	10	5	CARU	5	ARNCA		
11	13	20	10	CARU	5	ARNCA	5	SYAL
12	23	40	20	CARU	5	ARNCA	5	SPIREA
13					5	ANRO	5	SYAL
14	37	50	30	CARU	5	ANRO	5	KINIC
15					5	ARNCA	5	DB
16	S							
17	8	30	15	CARU	5	ARNCA	5	SPIREA
18					5	ANRO		
19	22	60	45	CARU	5	ANRO	5	SPIREA
20							5	SYAL
21	37	40	20	CARU	15	ARNCA	5	SYAL
22								
23	W							
24	12	40	25	CARU	10	ARNCA	5	SYAL
25	21	10			5	KNAP		
26					5	ANRO		
27	30	20	5	CARU	5	ARNCA	5	SPIREA
28					5	ANRO		
29	37	30	10	CARU	5	HOLLY	5	SYAL
30					5	ARNCA		
31					5	ANRO		
32								
33								
34								
35								
36								
37								
38								
39								
40								

A28. T09P02

	Distance	% Cover	Cov G	G	Cov F	F	Cov S	S
1	N							
2	9	20	20	CARU				
3	17	35	35	CAGE				
4	30	15	20	CAGE	5	THISTLE		
5	34	30	30	CAGE				
6	37	15	10	CARU	5	KNAP		
7	E							
8	8	25	10	CARU	5	HOLLY		
9			10	CAGE				
10	25	10	5	CAGE			5	ASPEN
11	37	20	10	CARU				
12			10	CAGE				
13	S							
14	8	15	10	CARU	5	HOLLY		
15	13	10	5	CARU	5	KNAP		
16	15	25	25	CARU				
17	25	10	10	CARU				
18	37	20	10	CARU	5	KNAP		
19					5	MOSS		
20	W							
21	10	30	25	CARU	5	KNAP		
22	19	20	15	CARU	5	HOLLY		
23	33	15	5	CAGE	5	KNAP		
24			5	CARU				
25	37	15	10	CAGE				
26			5	CARU				
27								
28								
29								
30								
31								
32								
33								
34								
35								
36								
37								
38								
39								
40								

A29. T09P03

	Distance	% Cover	Cov G	G	Cov F	F	Cov S	S
1	N							
2	7	40	20	CARU	15	KNAP	10	SYAL
3					5	ACMI		
4	23	40	25	CARU	10	KNAP	5	SYAL
5	37	30	10	CARU	10	KNAP	10	SYAL
6	E							
7	19	45	30	CARU	5	ACMI	10	SYAL
8	35	40	20	CARU			20	SYAL
9	37	25	25	XETE				
10	S							
11	4	20	20	CARU				
12	19	30	10	CARU			20	SYAL
13	30	40	35	CARU			5	SYAL
14	37	40	20	CARU			20	ASPEN
15	W							
16	15	35	5	CARU			30	SYAL
17	18	5					5	SYAL
18	27	30	25	CARU			5	SYAL
19	37	35	30	CARU			5	SYAL
20								
21								
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A30. Species key code table. (< in sheet indicates less than 5% cover).

Lifeform	Species	Code (in sheet)
Shrubs	*Arctostaphylox uva-ursi*	KNIC
	Linnaea borealis	LIBO
	Physocarpus malvaceous	NINE
	Spiraea betulifola	SPIREA
	Symphoricarpos albus	SYAL
	Vaccinium globulare	VACCI
Forbs	*Arnica cordifolia*	ARCO/ARNICA
	Centaurea maculosa	KNAP
	Cirsium arvense	THISTLE
	Epilobium angustifolium	FIREWEED
	Xerophyllum tenax	XETE
Graminoids	*Calamagrostis rubescens*	CARU
Moss	Moss	moss

Appendix B

Table B1. Matrix plot of response and explanatory variables for seedling and overstory tree models for 2020. Distribution of variables are shown in the bottom left of the matrix plot. PP20 and DF20 represent tree seedling counts of each species for 2020. PP.over20 and DF.over20 represent overstory tree counts for each species for 2020.

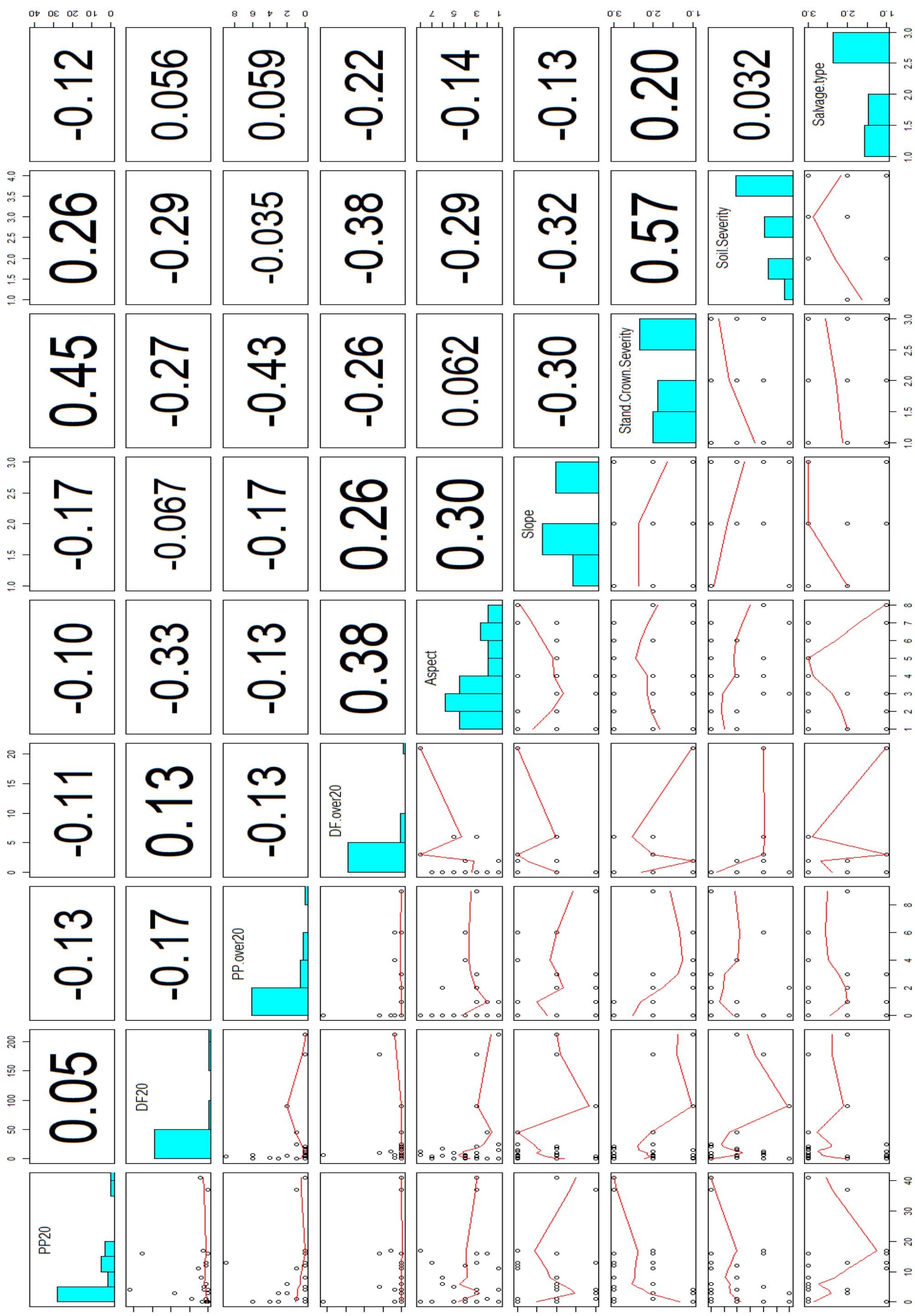

Table B2. Coefficient tables of ponderosa pine and Douglas-fir seedling models for 2020.

ponderosa pine seedling model				
Coefficient	**Estimate**	**Standard Error**	**z-value**	**p-value**
Intercept	2.39052	0.92746	2.577	0.00995
Aspect NE	0.03437	1.25666	0.027	0.97818
Aspect E	1.85111	0.84506	2.191	*0.02849*
Aspect SE	0.16289	1.0622	0.153	0.87812
Aspect S	0.23188	1.34093	0.173	0.86271
Aspect SW	1.2615	1.2921	0.976	0.3289
Aspect W	-0.80554	1.17549	-0.685	0.49317
Aspect NW	-0.25046	1.31563	-0.19	0.84902
Immediate salvage	-1.38482	0.95965	-1.443	0.14901
No salvage	-1.70612	0.88412	-1.93	*0.05364*
AIC Value	183.74			

Douglas-fir seedling model				
Coefficient	**Estimate**	**Standard Error**	**z-value**	**p-value**
Intercept	5.365476	1.223282	4.386	1.15E-05
Aspect NE	-2.43107	1.100663	-2.209	0.02719
Aspect E	-1.50977	0.84429	-1.788	0.07374
Aspect SE	-3.67561	0.873007	-4.21	*2.55E-05*
Aspect S	-3.57351	1.240993	-2.88	*0.00398*
Aspect SW	-1.85316	1.139706	-1.626	0.10395
Aspect W	-3.5596	1.169419	-3.044	*0.00234*
Aspect NW	-3.78914	1.330469	-2.848	*0.0044*
Mixed overstory severity	1.171609	0.727191	1.611	0.10715
High overstory severity	1.954928	0.861554	2.269	*0.02326*
Low understory severity	-0.00702	1.260726	-0.006	0.99556
Mixed understory severity	-0.91531	1.288121	-0.711	0.47734
High understory severity	-3.6187	1.25173	-2.891	*0.00384*

AIC Value	213.19

Table B3. Coefficient table for overstory ponderosa pine trees in 2020.

Overstory ponderosa pine model				
Coefficient	**Estimate**	**Standard Error**	**z-value**	**p-value**
Intercept	-1.06E+00	1.06E+00	-0.999	0.31786
Aspect NE	1.15E+00	1.58E+00	0.728	0.46682
Aspect E	2.44E+00	1.11E+00	2.205	*0.02747*
Aspect SE	2.42E+00	1.11E+00	2.179	*0.0293*
Aspect S	-3.28E+01	4.75E+07	0	1
Aspect SW	1.83E+00	1.41E+00	1.296	0.19484
Aspect W	-3.41E+01	3.10E+07	0	1
Aspect NW	-3.59E+01	4.75E+07	0	1
Mixed overstory severity	-1.57E-01	5.27E-01	-0.297	0.7662
High overstory severity	-3.16E+00	1.09E+00	-2.901	*0.00372*

AIC Value	80.295

Table B4. Transect and plot data.

Transect # plot #	Aspect (degrees)	Slope (%)	Stand Crown Severity	Soil Severity	Salvage type
T01P01	68	32	Mixed	Mixed	No Salvage
T01P02	200	39	High	Mixed	No Salvage
T01P03	134	42	High	High	No Salvage
T01P04	94	39	High	High	No Salvage
T01P05	224	40	High	High	No Salvage
T01P06	186	40	High	High	No Salvage
T02P01	134	50	Low	Mixed	No Salvage
T02P02	50	59	Mixed	High	No Salvage
T02P03	360	65	Low	High	No Salvage
T02P04	90	30	High	High	No Salvage
T03P01	130	49	Low	High	No Salvage
T03P02	136	35	Mixed	High	No Salvage
T03P03	120	20	High	High	No Salvage
T04P01	310	48	Low	Mixed	Delayed Salvage
T04P02	296	48	Mixed	Mixed	Delayed Salvage
T04P03	286	55	High	High	Delayed Salvage
T04P04	250	55	Low	Low	Delayed Salvage
T05P01	130	25	Low	Mixed	No Salvage
T05P02	220	30	Mixed	High	No Salvage
T05P03	290	30	High	High	No Salvage
T06P01	81	2	High	High	Immediate Salvage
T06P02	77	6	Mixed	High	Immediate Salvage
T06P03	110	7.5	Low	Low	Immediate Salvage
T07P01	72	27	Low	High	Delayed Salvage
T07P02	348	50	Mixed	High	Delayed Salvage
T07P03	44	40	High	High	Delayed Salvage
T09P01	10	34	Low	High	Immediate Salvage
T09P02	85	3	Mixed	High	Immediate Salvage
T09P03	16	7	High	High	Immediate Salvage

Table B5. Total counts of tree seedlings in each study plot for each study year by transect and plot.

Transect# Plot#	ponderosa pine seedlings 2001	Douglas-fir seedlings 2001	ponderosa pine seedlings 2003	Douglas-fir seedlings 2003	ponderosa pine seedlings 2020	Douglas-fir seedlings 2020
T01P01	0	0	1	47	16	178
T01P02	0	0	1	4	5	10
T01P03	0	0	0	0	12	5
T01P04	0	0	0	0	41	21
T01P05	0	0	0	0	8	18
T01P06	0	0	0	0	0	0
T02P01	0	1	0	32	0	6
T02P02	0	0	0	99	1	45
T02P03	0	0	1	2	0	15
T02P04	0	0	0	0	4	10
T03P01	0	0	2	292	0	2
T03P02	0	0	1	5	1	6
T03P03	0	0	1	5	1	4
T04P01	0	11	0	23	0	6
T04P02	11	12	1	4	17	12
T04P03	0	0	0	3	13	4
T04P04	0	0	0	0	0	0
T05P01	0	0	0	0	0	0
T05P02	0	0	1	3	6	5
T05P03	0	0	0	0	0	0
T06P01	0	0	1	0	37	0
T06P02	0	0	12	29	13	4
T06P03	0	9	4	235	3	90
T07P01	0	0	10	2	0	0
T07P02	0	0	10	16	11	25
T07P03	0	0	14	5	16	0
T09P01	0	4	0	472	4	212
T09P02	0	0	8	0	3	0
T09P03	0	0	0	0	4	0

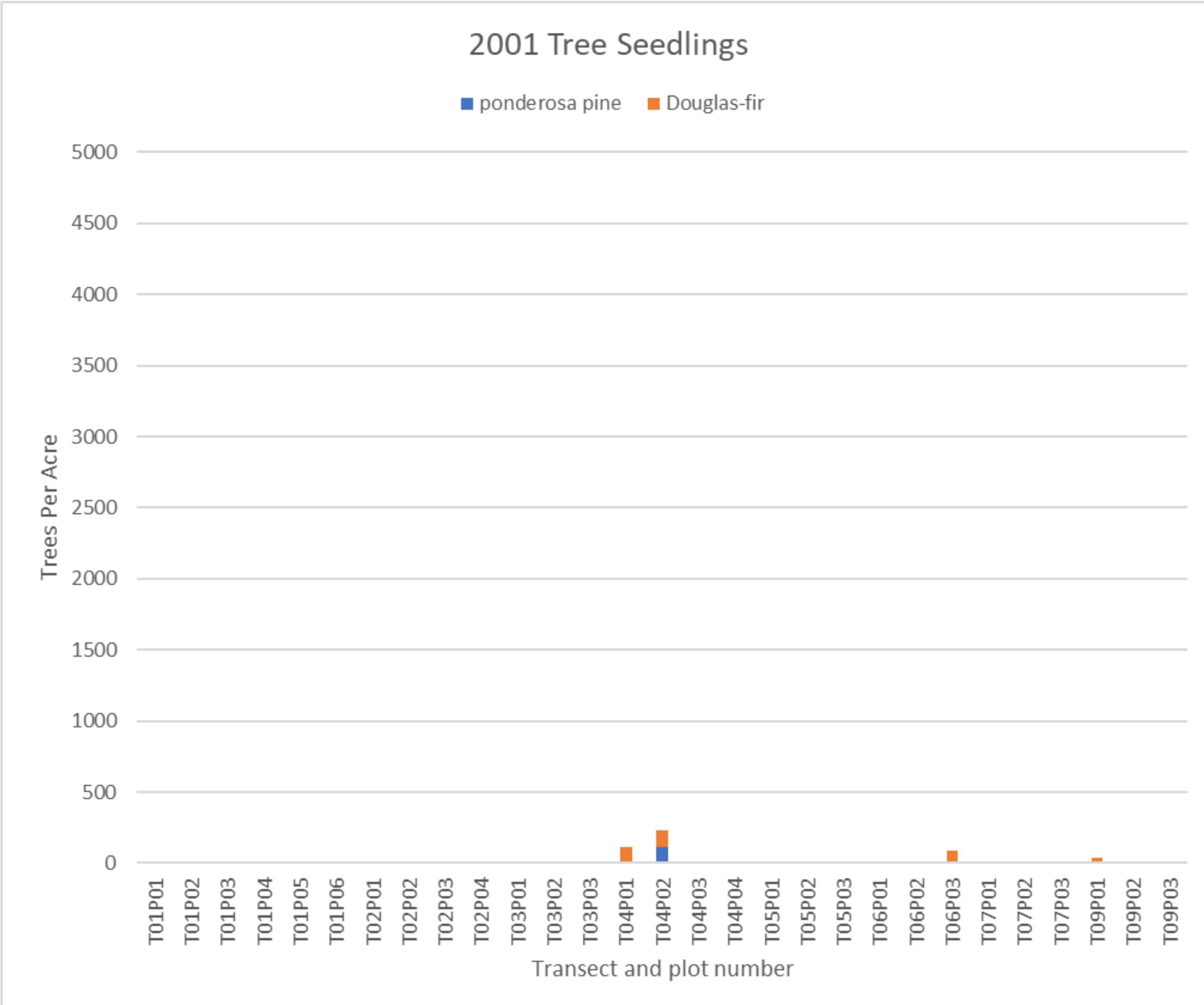

Figure B6. Number of tree seedlings per acre by species per study plot for 2001.

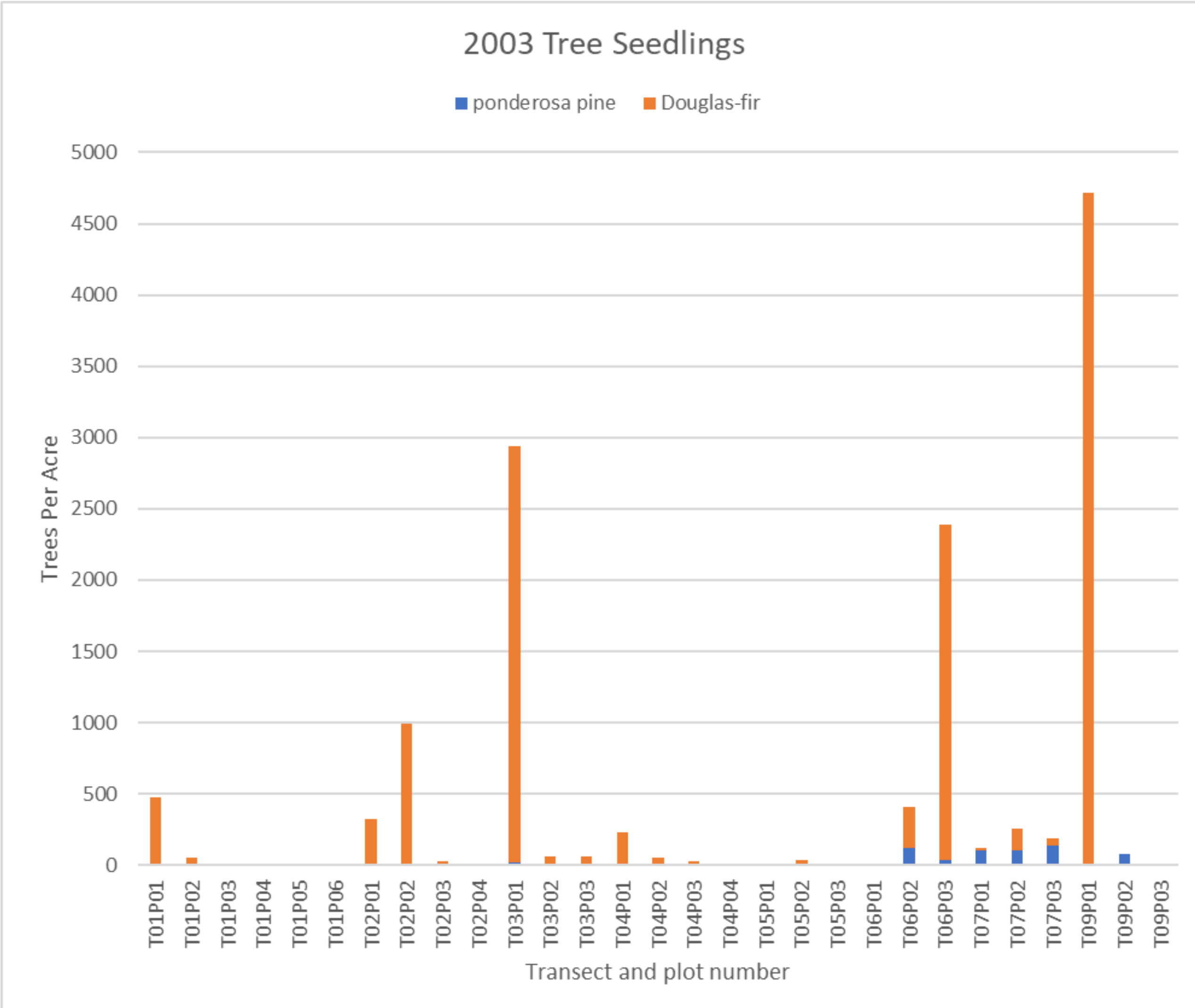

Figure B7. Number of tree seedlings per acre by species per study plot for 2003.

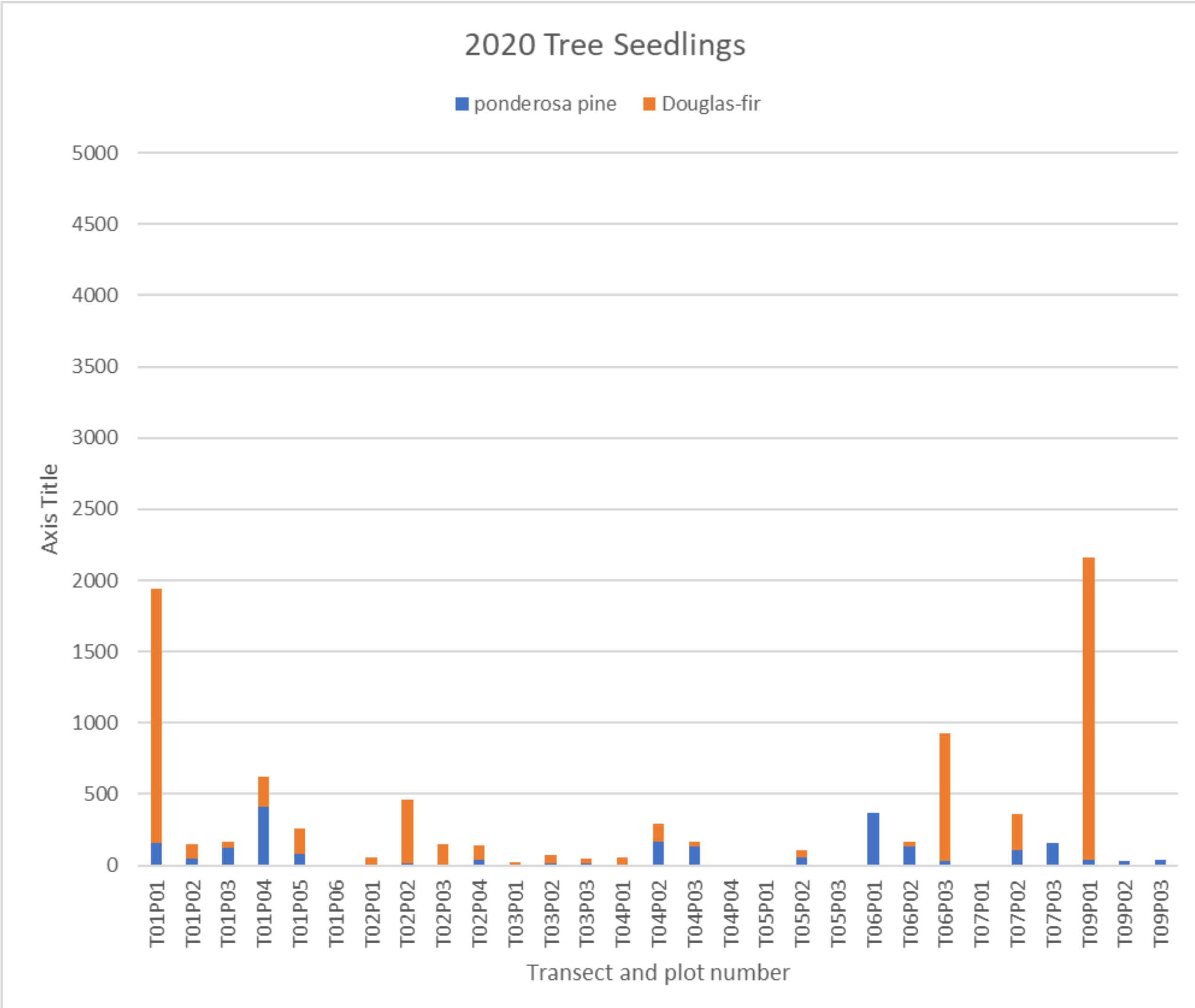

Figure B8. Number of tree seedlings per acre by species per study plot for 2020.

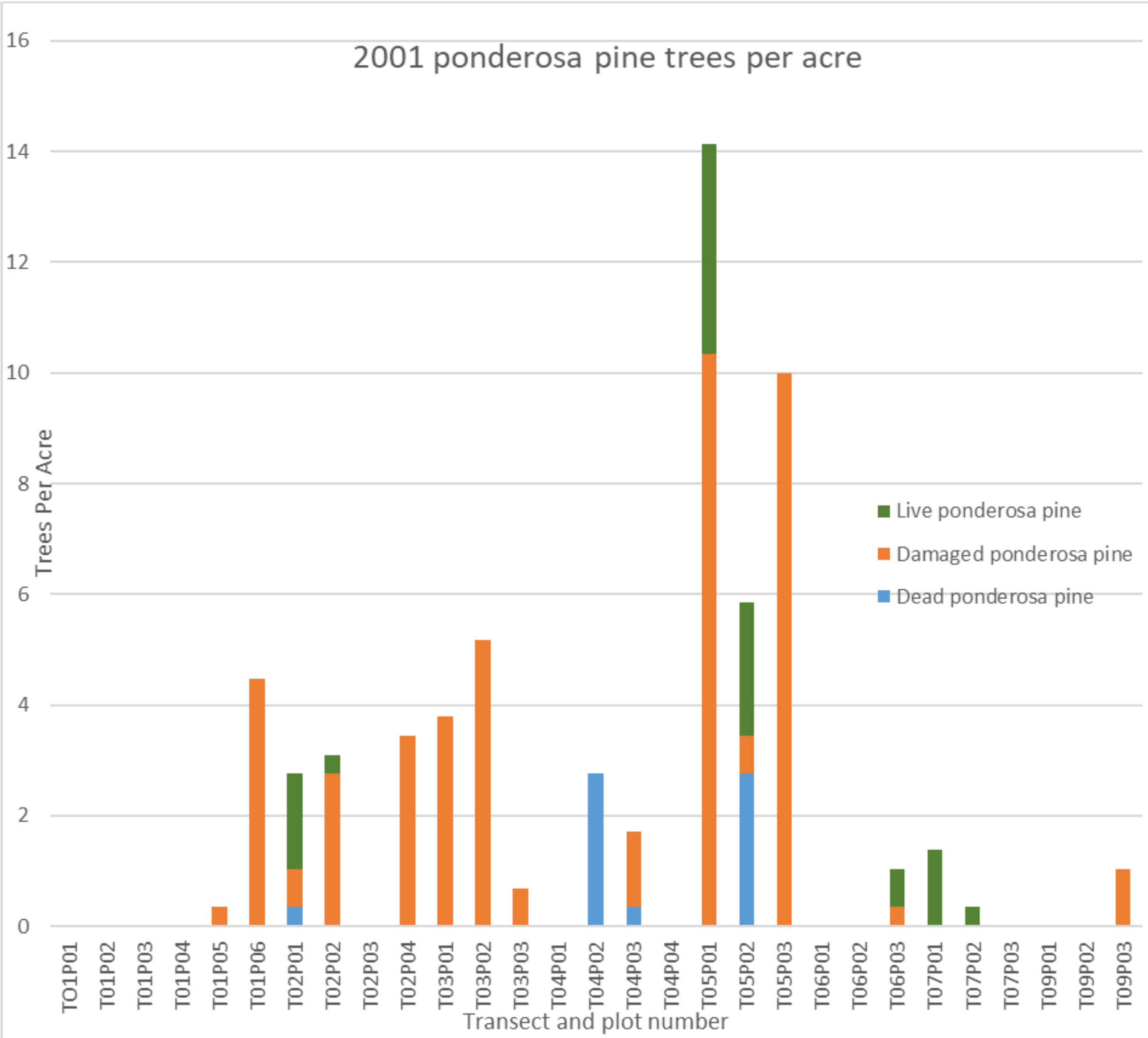

Figure B9. Number of ponderosa pine trees per acre per study plot for 2001.

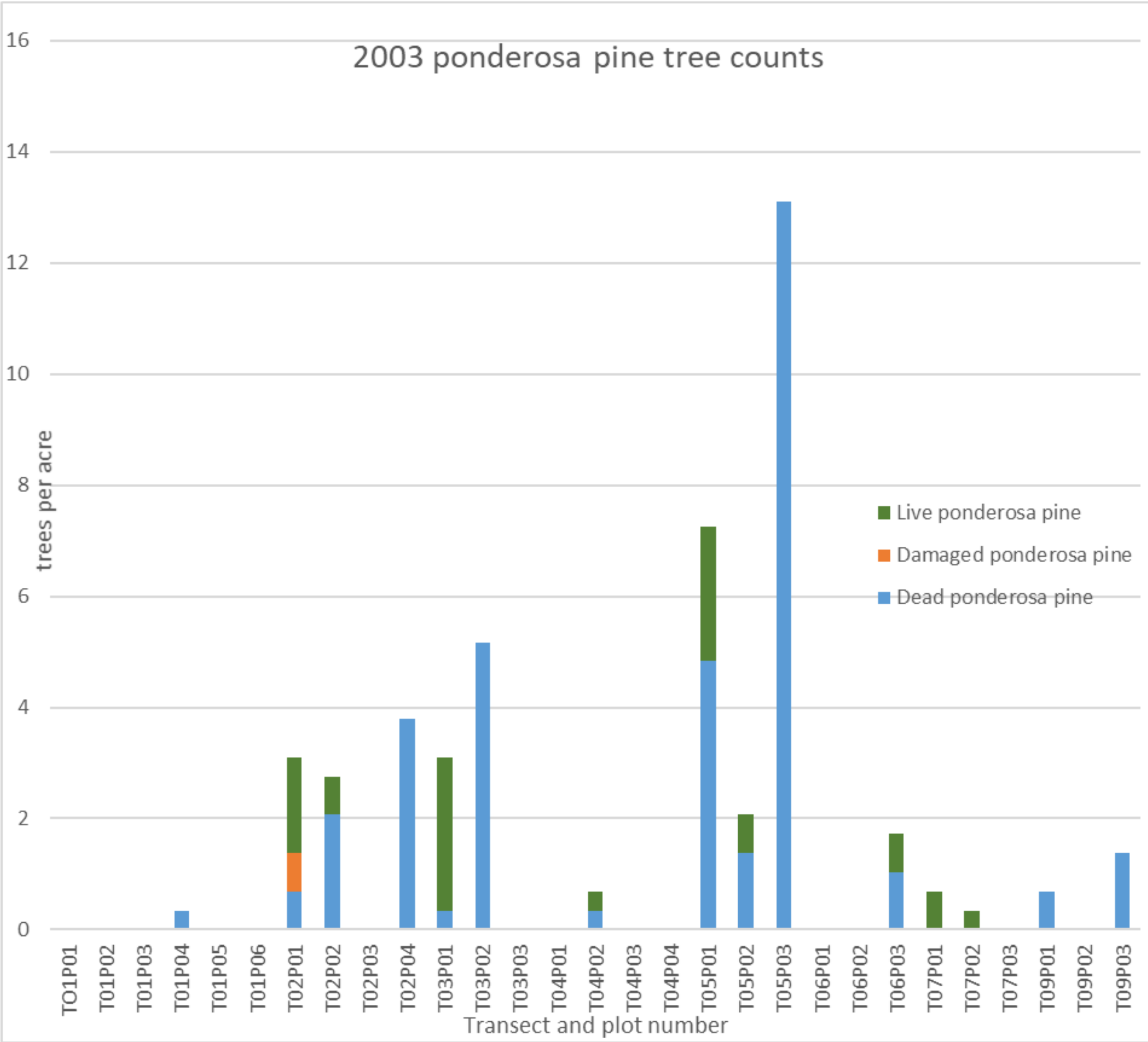

Figure B10. Number of ponderosa pine trees per acre per study plot for 2003.

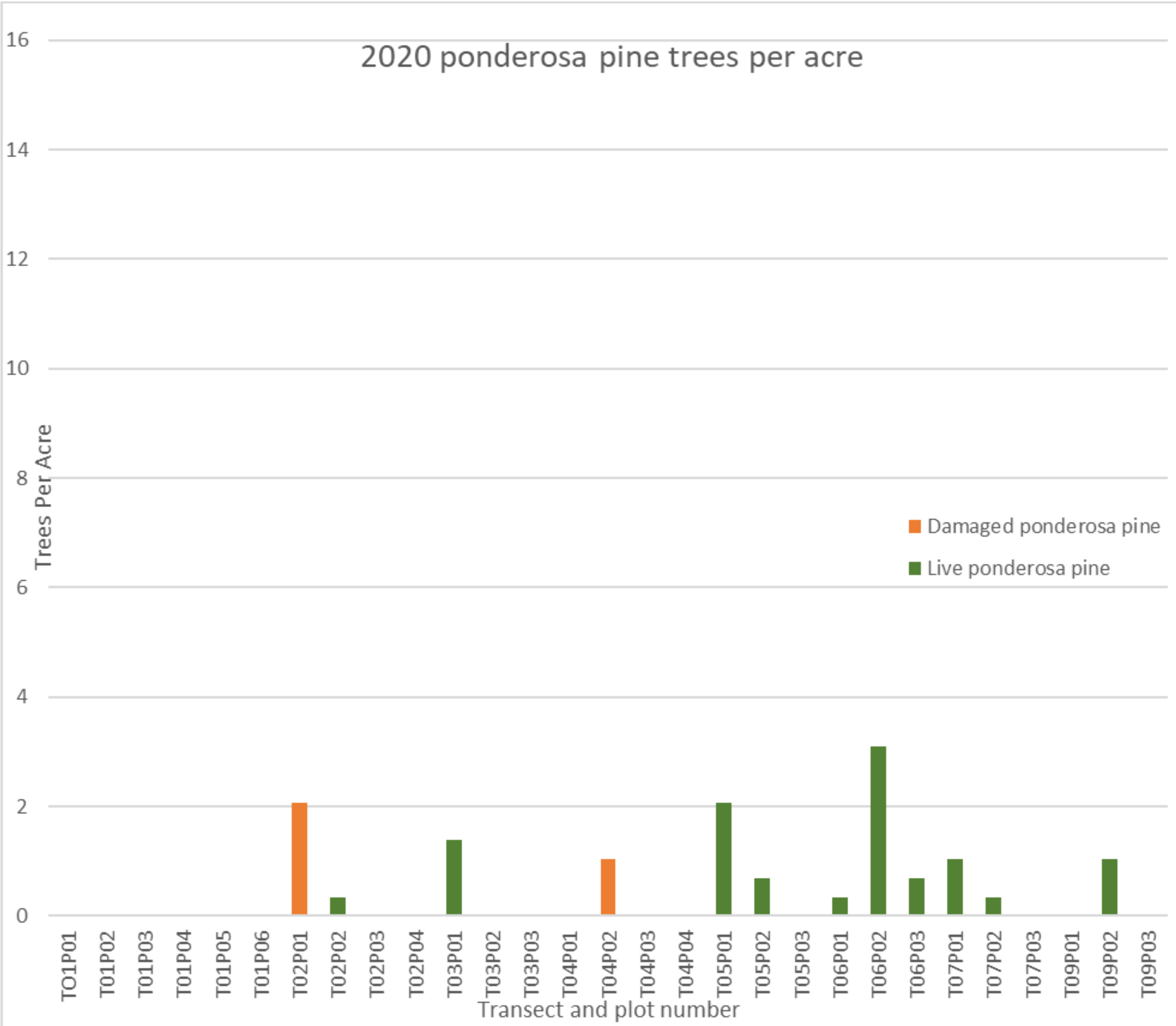

Figure B11. Number of ponderosa pine trees per acre per study plot for 2020.

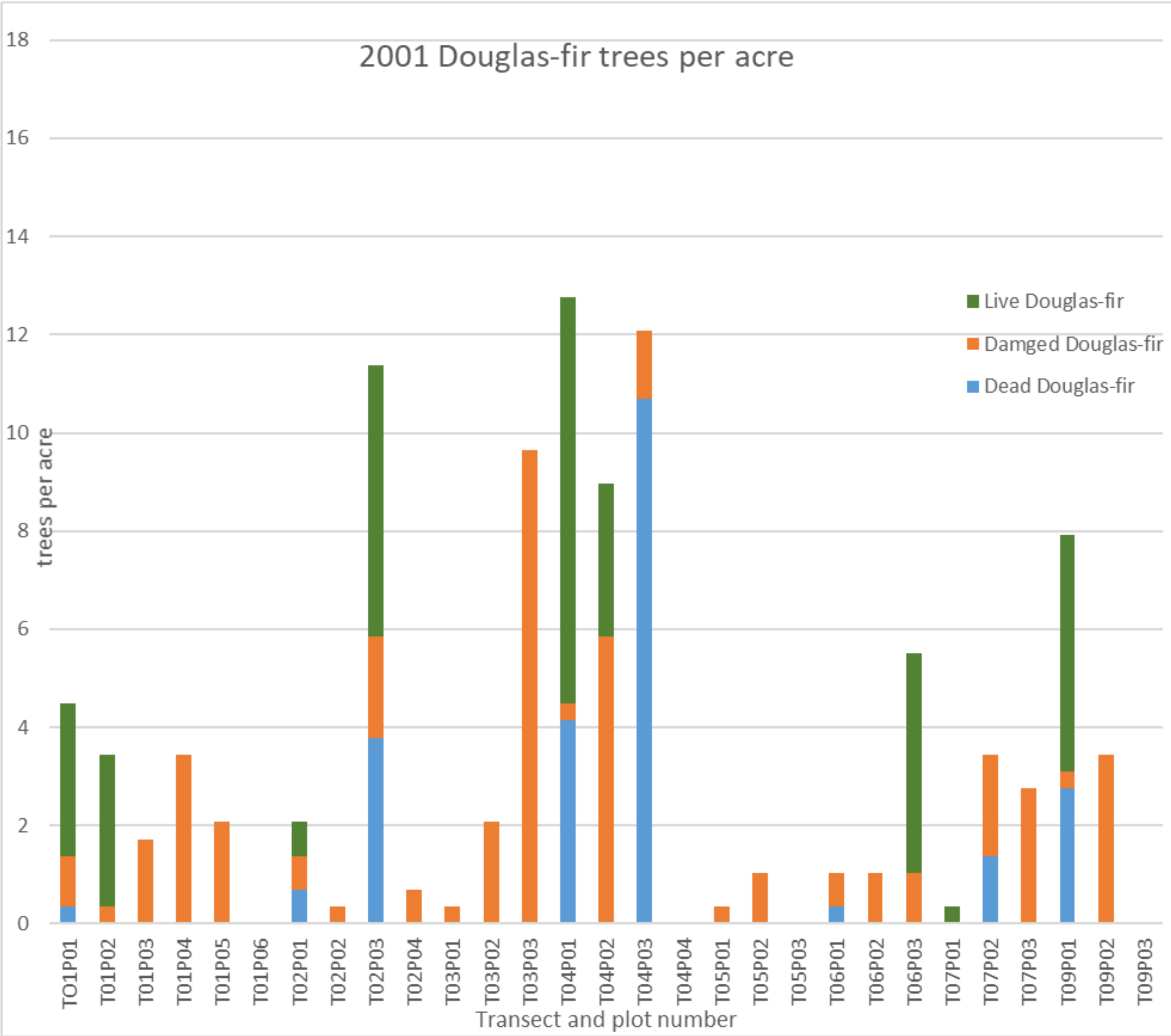

Figure B12. Number of Douglas-fir trees per acre per study plot for 2001.

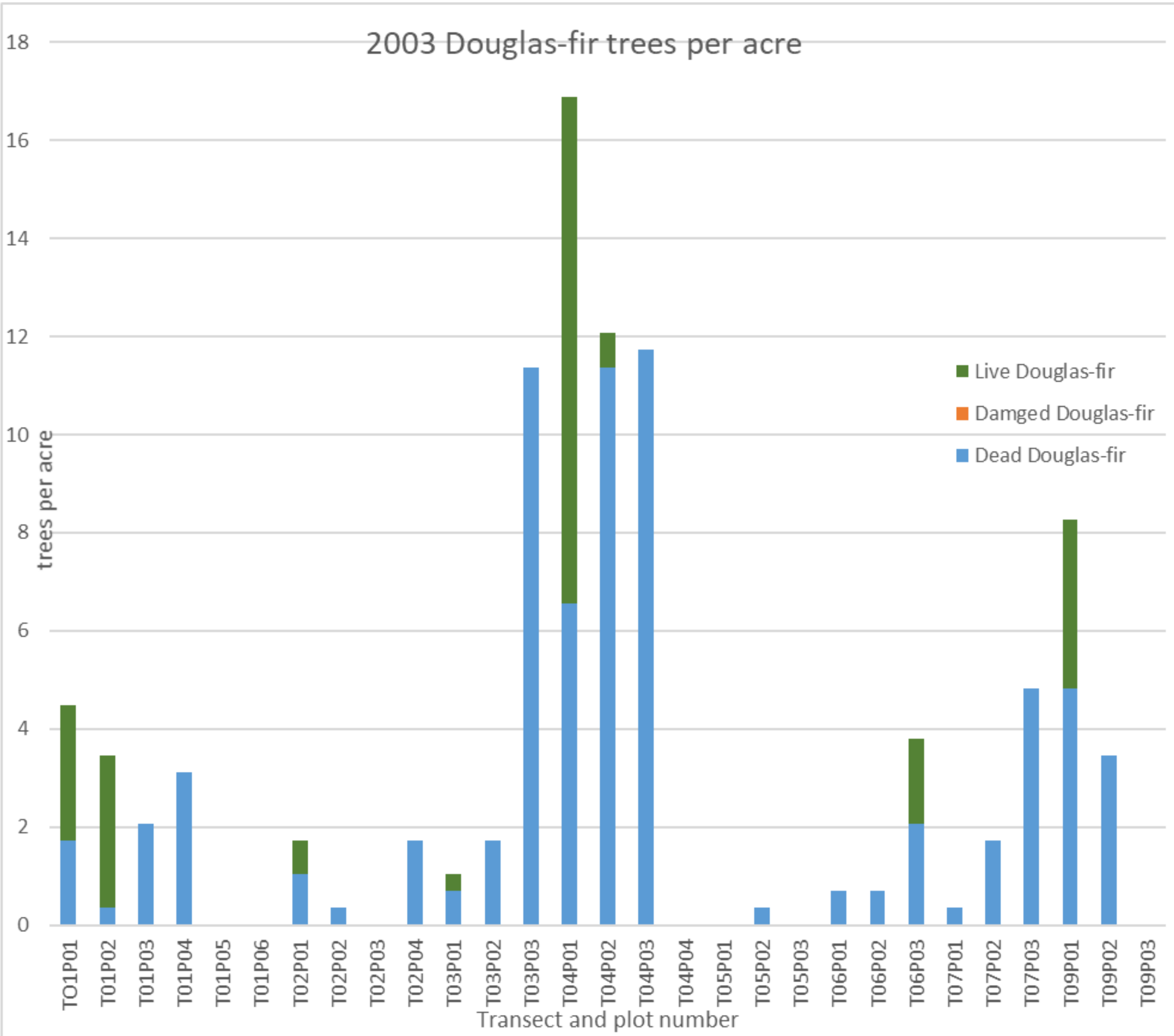

Figure B13. Number of Douglas-fir trees per acre per study plot for 2003.

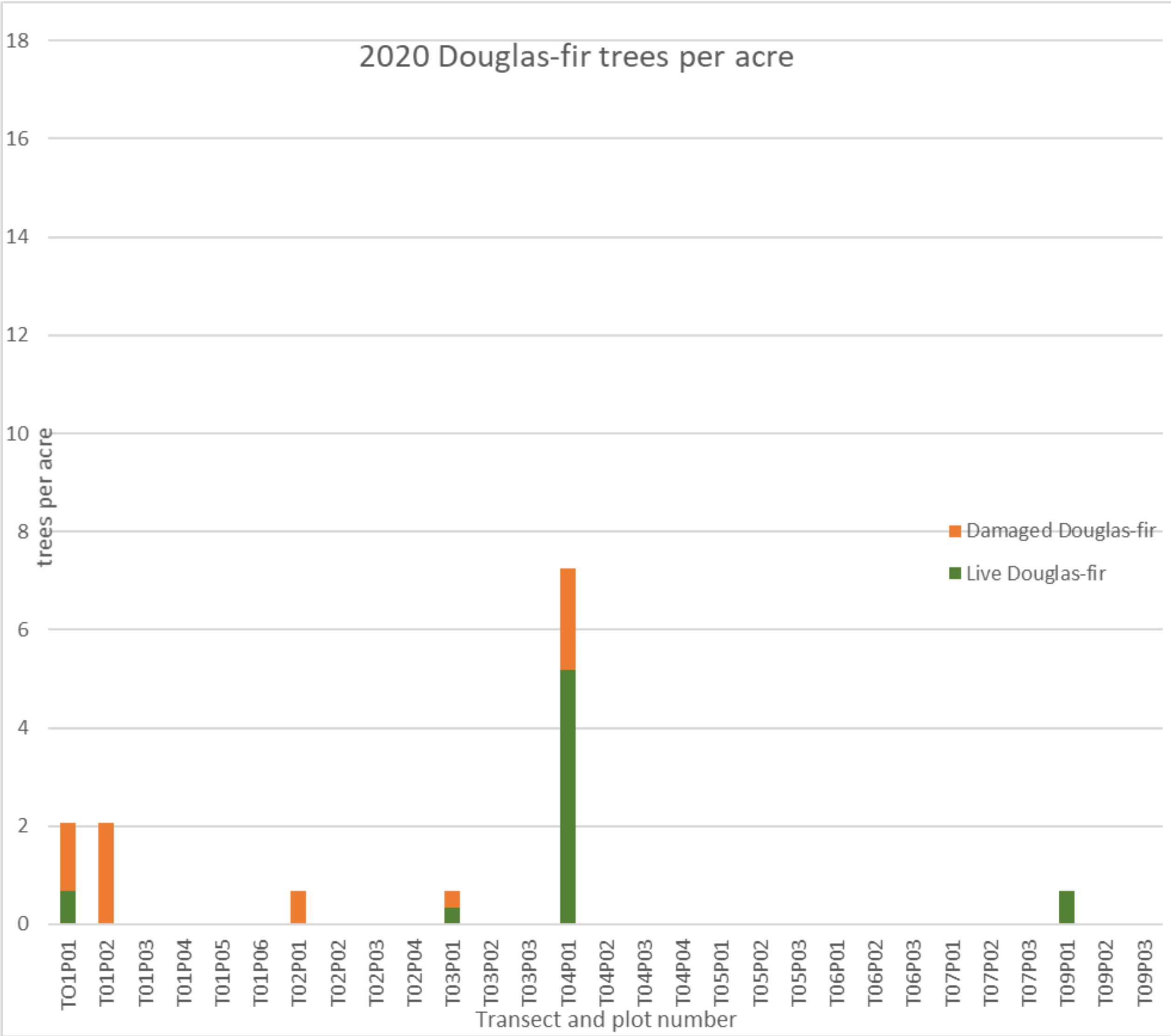

Figure B14. Number of Douglas-fir trees per acre per study plot for 2020.