Understory Response Four Years Following Treatment at Beaver Ranch:

Jefferson County Open Space Small Research Grant Final Report

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COLORADO FOREST RESTORATION INSTITUTE - 2201

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Document Development: Ecological monitoring of forest management and restoration treatments at Beaver Ranch was collaboratively developed by the Upper South Platte Partnership (USPP). Beaver Ranch provided an excellent opportunity for USPP partners to establish long-term monitoring to evaluate treatment effectiveness and partnership goals. Through the Jefferson County Open Space (JCOS) small research grants program, CFRI staff and field crews revisited long-term monitoring plots in the summer of 2021 to collect data four years post-treatment. In the call for proposals, JCOS staff expressed interest in understanding regeneration responses following forest thinning treatments. CFRI and JCOS staff worked together to broaden the data analysis for this report to include additional information surface fuel conditions, potential fire behavior, and understory plant communities. Previous ecological monitoring reports for forest management projects at Beaver Ranch can be found in the Upper South Platte Watershed Monitoring Report (Slack et al., 2021).

Acknowledgements: Special thanks to the dozens of students, field technicians, and crew leaders that participated in collecting field data at Beaver Ranch from 2016-2021. Thank you to the JCOS natural resources staff for providing review of earlier drafts.

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CSU Land Acknowledgment

Colorado State University acknowledges, with respect, that the land we are on today is the traditional and ancestral homelands of the Arapaho, Cheyenne, and Ute Nations and peoples. This was also a site of trade, gathering, and healing for numerous other Native tribes. We recognize the Indigenous peoples as original stewards of this land and all the relatives within it. As these words of acknowledgment are spoken and heard, the ties Nations have to their traditional homelands are renewed and reaffirmed.

CSU is founded as a land-grant institution, and we accept that our mission must encompass access to education and inclusion. And, significantly, that our founding came at a dire cost to Native Nations and peoples whose land this University was built upon. This acknowledgment is the education and inclusion we must practice in recognizing our institutional history, responsibility, and commitment.

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Cover photo: An open ponderosa pine stand on top of a ridge at Beaver Ranch Park. Photo credit: Andrew Slack, 2021.

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Introduction

Mechanical forest treatments are an essential tool for many western U.S. forest managers. These actions are often done to mitigate the effect of century of fire suppression (Sherriff & Veblen, 2006) and reduce the potential fire behavior and fire hazards in natural areas, especially areas within the wildland urban interface. The Upper South Platte Partnership (USPP) was formed with the goal to increase cross-boundary collaborative efforts across forested areas of the Upper South Platte watershed to enhance ecological resilience and reduce wildfire risk (Slack et al., 2021). As a part of the USPP, Jefferson County Open Space's (JCOS) has implemented multiple mechanical thinning projects.

JCOS Small Research Grant allowed the Colorado Forest Restoration Institute (CFRI) to extend monitoring at Beaver Ranch. Beaver Ranch is a community park located within the wildland urban interface surrounding the town of Conifer, Colorado (Figure 1). The park is within the Upper South Platte watershed, and treatments were collaboratively planned and funded through the USPP. Beaver Ranch treatment outcomes are of particular interest to the USPP and others due to the longevity of the ecological monitoring at the site. Additionally, the treated area is a mixed conifer forest on a cooler, wetter, and northwest-facing slope, which offers particular interest in regards to treatment effectiveness and treatment longevity especially compared to less productive sites. Thus, this monitoring on Beaver Ranch treatment impacts and outcomes provides valuable learning opportunities about forest restoration in these complex areas. Extending ecological monitoring at Beaver Ranch to four years following treatment has provided information about tree regeneration, surface fuels, and understory vegetation which require more time to recover from treatments. Data collection and analysis sought to answer the following research questions:

1. How has tree regeneration responded to forest thinning?
2. How have surface fuel conditions and modeled fire behavior changed overtime following treatment?
3. How does understory vegetation respond to thinning four years following treatment?

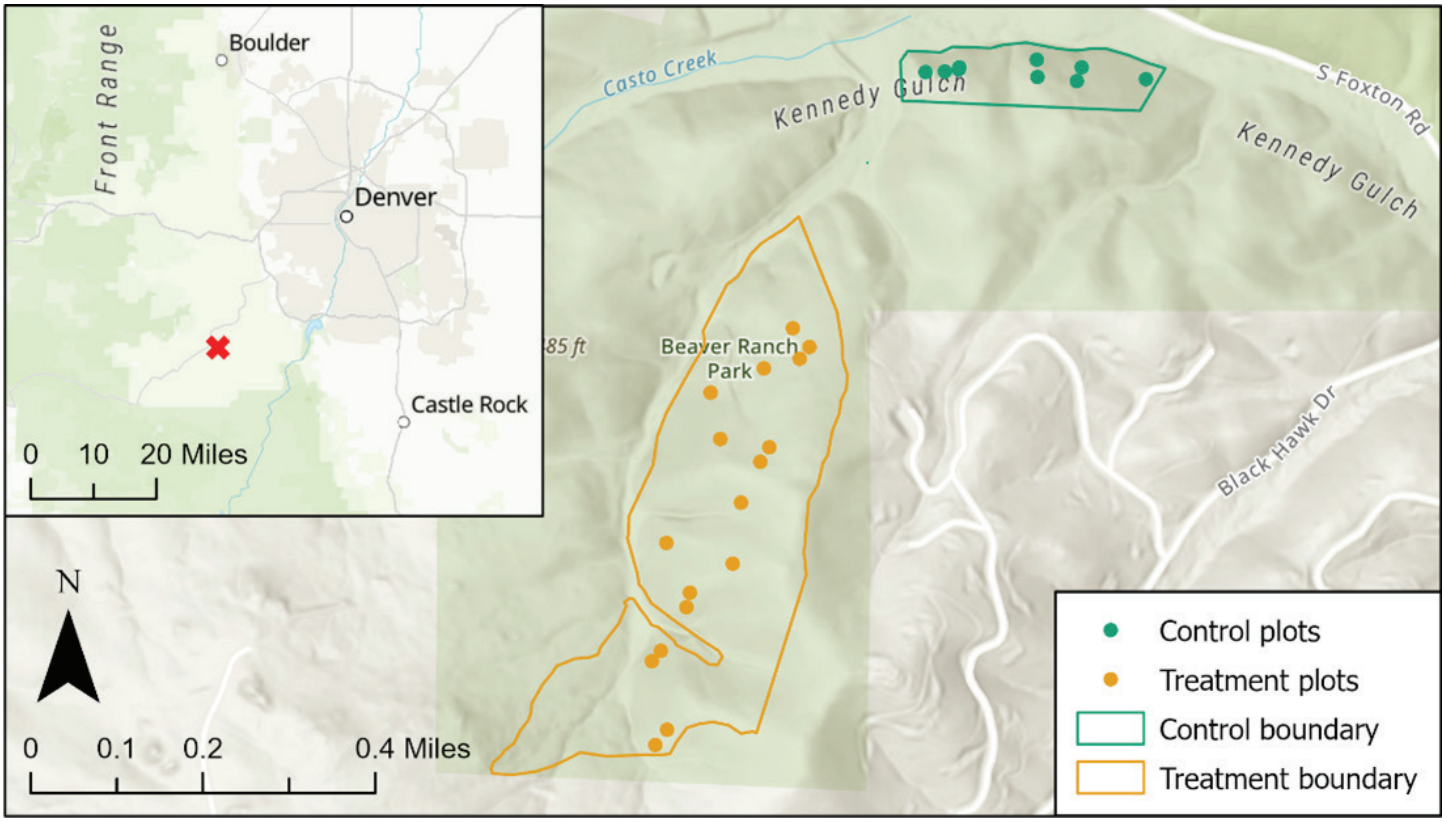

Figure 1. Map of Beaver Ranch's location, unit boundaries, and monitoring plots.

Treatment Background

Treatments were designed to: retain ponderosa pine and aspen while reducing Douglas-fir and lodgepole pine; create more forest openings; increase age diversity; and reduce the potential for high severity wildfire. The landscape resilience management objectives for the USPP include: reducing mean canopy cover; maintaining a complex mosaic of forest canopy; increasing the ratio of ponderosa pine to other conifers; and creating conditions that support the future use of prescribed fire. More information on the project and adaptive management can be found here –www.cfri.colostate.edu.

Table 1. Project Information.

Implementation Agency	Coalition for the Upper South Platte
Ownership	Jefferson County Open Space
Year Completed	2017
Acres Treated & Monitored	72.5
Forest Type	Mixed Conifer
Implementation Method	Mechanical Thinning
Slash Treatment	Product Removal, Mastication, Pile Burning
Years Monitored	2016, 2018, 2021

Methods

In 2016, CFRI installed 20 long-term monitoring plots in the Beaver Ranch Phase 2 treatment area, coupled with 10 plots in a control area. Most plots were remeasured in 2018, one year following treatment. Three treatment plots could not be relocated, as treatments removed plot markers and nearby landmarks. This grant allowed CFRI to visit the 17 treatment and 10 control plots again, four years post-treatment, to gather information about the mid- to long-term impacts of forest restoration (Figure 1).

At each monitoring plot, a series of plot pictures are taken (Figure 2), and topographical information is recorded. 10 BAF variable radius plots are used to measure overstory trees. Each tree's species, diameter, height, canopy base height, and decay class, if dead, are recorded. 1/10th acre fixed radius plots are used to measure tree regeneration. Woody surface fuel loading is estimated in tons/acre. All pieces of coarse wood within the plot are measured; three $1m^2$ quadrats are used to assess fine wood. Shrubs and herbaceous vegetation are measured with line-point intercepts with a total of 200 points. At each point, plants at all strata are identified to species, shrub heights are recorded, and the substrate is identified. Litter and duff depths are measured at 12 of these points. Lastly, every plant species within the plot is identified (Colorado Forest Restoration Institute, 2018).

CFRI puts field data through a series of quality control checks and analyzes it using R (R Development Core Team, 2021) and the Forest and Vegetation Simulator Fire and Fuels Extension (Reinhardt & Crookston, 2003). Some data, which did not meet quality expectations, was excluded from analysis. All 17 treatment plots were used to assess changes in seedling structure and composition. Data from only 16 and 13 plots could be used to assess the changes to saplings and the overstory respectively. Data from all 17 treatment plots was incorporated in the fire and fuels analysis, although data for one measurement type for five plots was excluded. Since plant composition naturally changes over time, control plots are included in understory analyses to provide a baseline. Data from all 17 treatment plots and 9 control plots was used to assess changes in understory plants and ground cover. Statistical differences between pre-, 1 year post-, and 4 years post-treatment are analyzed using one-way repeated measures analysis of variance, and post-hoc comparisons use pairwise t-test. All data mets the assumption for equal variance, and only the seedling dataset does not meet the assumption for a normal distribution. One-way analysis of variance is shown to be robust against type I error when the normality assumption is not met (Blanca Mena et al., 2017); therefore, data transformations and nonparametric test options are not used.

Figure 4. Photo series of a control plot (left) and a treatment plot (right) thats shows some of the changes observed from pre-trestement in 2016 (top), 1 year post-treatment in 2018 (middle), and 4 years post-treatment in 2021 (bottom).

Results and Discussion

Forest Structure, Composition, and Regeneration

Phase two treatments had negligible impacts on tree regeneration (Figure 3). Douglas-fir seedlings per acre was significantly lower immediately following treatment (P=0.0300), but recruitment by 4 years following treatment returned Douglas-fir seedlings to pre-treatment levels. Total seedlings per acre decreased by over 40% from pre-treatment to one year post, and increased again to pre-treatment densities. There was a slight increase in aspen regeneration immediately following treatment, but the increase was not statistically significant (Figure 3). Lastly, forest thinning had no impact ponderosa pine regeneration, and ponderosa pine seedlings per acre remained relatively low through pre- and post-treatment visits (Figure 3).

The response of tree regeneration to treatment was as expected based on other long-term studies on regeneration following thinning on north-facing aspects in other areas of Colorado (Ertl, 2015). All sites on north-facing aspects, including Beaver Ranch, have dense regeneration of Douglas-fir and other conifers regardless of treatment due to cool and wet conditions (Ertl, 2015; Figure 3). The Beaver Ranch treatment left many Douglas-fir in the overstory, so the return of Douglas-fir regeneration to pre-treatment levels is expected (Figure 3). This is consistent with Fialko et al. (2020) who found dense Douglas-fir regeneration in areas with a considerable amount of Douglas-fir in the overstory to provide seeds. At Beaver Ranch the ratio of ponderosa pine to other conifers did not change following treatment, which is in contrast to other research across Front Range treatments (Barrett et al., 2021). In these studies, the percent of ponderosa pine regeneration compared to Douglas-fir is much higher post-treatment, however treatments were more intense than at Beaver Ranch (Ertl, 2015; Fialko et al., 2020). The Beaver Ranch treatment left a relatively dense overstory, reducing canopy cover from 52% to 41%, compared to other USPP sites where canopy cover was often halved (Slack et al. 2021). A canopy cover of 41% does not leave as much area for the shade-intolerant ponderosa pines to regenerate compared to neighboring, stronger treatments (Fialko et al., 2020; Slack et al., 2021). The light thinning here did not promote ponderosa pine regeneration, thus future forest composition is likely to be unchanged. Shifting long-term forest composition towards ponderosa pine will require additional, more intense treatment. Alone, the phase two treatment has not met the goal of promoting ponderosa pine.

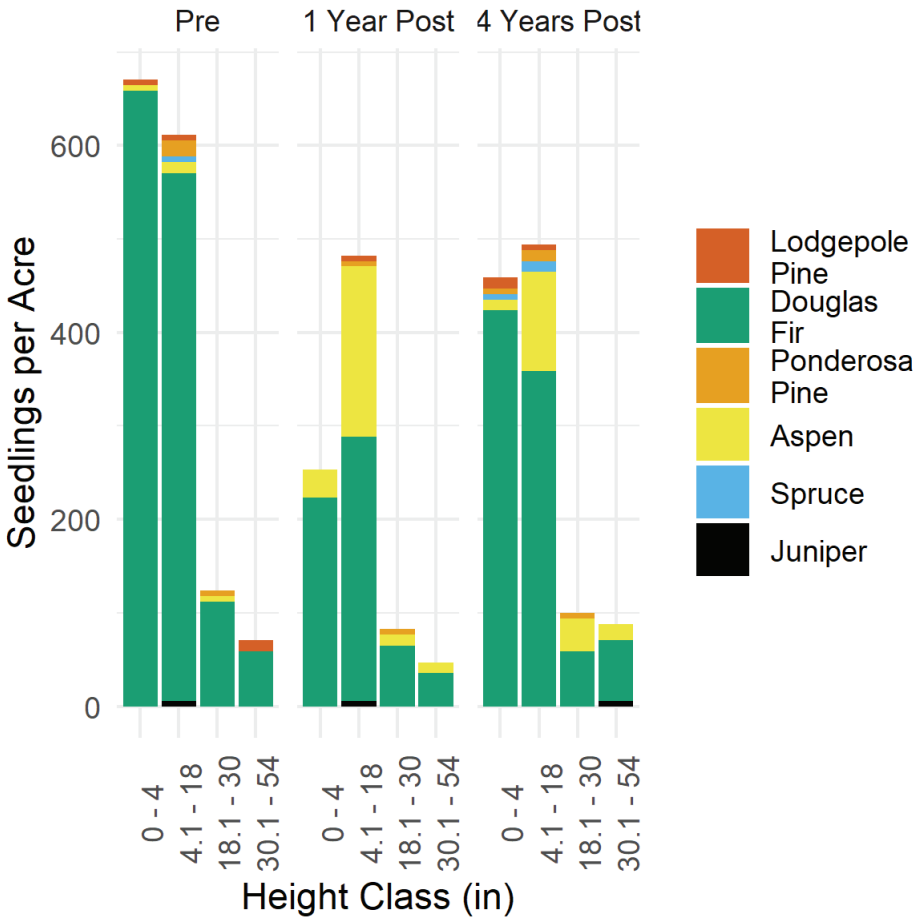

Figure 3. Number of seedlings per acre by species and height class. Douglas-fir seedlings decrease from pre-treatment (left) to 1 year post-treatment (middle), and recover 4 years post-treatment (right).

Fuels and Fire Behavior

Four years post-treatment, most surface fuels were at their highest levels. Fine woody fuel loading slightly decreased immediately following treatment, but then significantly increased by 46% 4 years following treatment (P=0.0293). Coarse woody debris increased by 30% after treatment, and remained higher 4 years following treatment, but the increase was not statistically significant (P>0.05). Litter and duff depths and shrub cover were unchanged following treatment (P>0.05). (Table 2) Treatment had no impact on most types of ground cover, such as coarse woody fuel, soil and gravel, and rock. There was a minor increase in the cover of litter and duff.

Given the low intensity of treatment at Beaver Ranch, it is not surprising that shrub cover and litter and duff depths were unchanged. Treatment impact on fine and coarse woody fuel loadings is consistent with or better than impacts from nearby treatments. The non-significant changes to coarse wood at Beaver Ranch follows findings from Briggs et al. (2016). The changes to fine woody fuel loadings at Beaver Ranch match the impacts from other USPP treatments. Of the sites included in the 2021 USPP monitoring report, roughly half of the treatments had minimal changes to fine wood while the other half experienced a large increase in fine woody fuel loading following treatment (Slack et al., 2021).

Increases in woody fuel loading for treatments outside of the USPP but in other mixed conifer forests along the Front Range, are even greater. By contrast, Battaglia et al. (2010) showed mean woody fuel loading more than tripled after mulching on some sites. The reason Beaver Ranch did not see increases on this scale is due to slash management following thinning. Slash management was so effective that fine woody fuel loading significantly decreased one-year post-treatment (Table 2). Natural fine wood accumulation is the most likely explanation for the significant increase at the four-year post-treatment visit. Although the increase in fine wood fuel loading is significant when comparing one to four years post-treatment, the increase only returned fuels loads to pre-treatment levels and does not increase fuels to a level of high concern from a fire behavior perspective.

Surface fire behavior remained relatively unchanged through our study period. Although flame length for passive crown fire decreased following treatment, this only increased the surviving tree basal area by one percent (Table 3). Based on the modeled fire behavior, torching index, the wind speed needed to initiate crown fire activity, continues to increase slightly following treatment (Figure 4). Crowning index, the wind speed needed to carry an active crown fire, is marginally higher than it was pre-treatment (Figure 4).

Table 2. Surface fuel conditions. Asterisks denote a statistically significant difference.

Visit	Fine Woody Fuel Loading (tons/acre)	Coarse Woody Fuel Loading (tons/acre)	Litter Depth (in)	Duff Depth (in)	Shrub Cover (%)
Pre	1.51 ± 0.26	3.06 ± 0.59	0.76 ± 0.06	0.99 ± 0.10	7.50 ± 1.71
1 Year Post	*1.40 ± 0.16	3.98 ± 0.62	0.97 ± 0.14	0.88 ± 0.13	4.32 ± 1.57
4 Years Post	*2.04 ± 0.23	4.33 ± 0.63	0.85 ± 0.06	1.05 ± 0.14	5.41 ± 1.92

Table 3. Modeled fire behavior.

Visit	Pre		1 Year Post		4 Years Post	
Fire Weather Conditions	Moderate	Severe	Moderate	Severe	Moderate	Severe
Fire Type	Surface	Passive	Surface	Passive	Surface	Passive
Total Flame Length (feet)	2.3	21.4	2.4	15.4	2.4	15.5
Surviving Tree Basal Area (%)	58	1	54	1	57	2

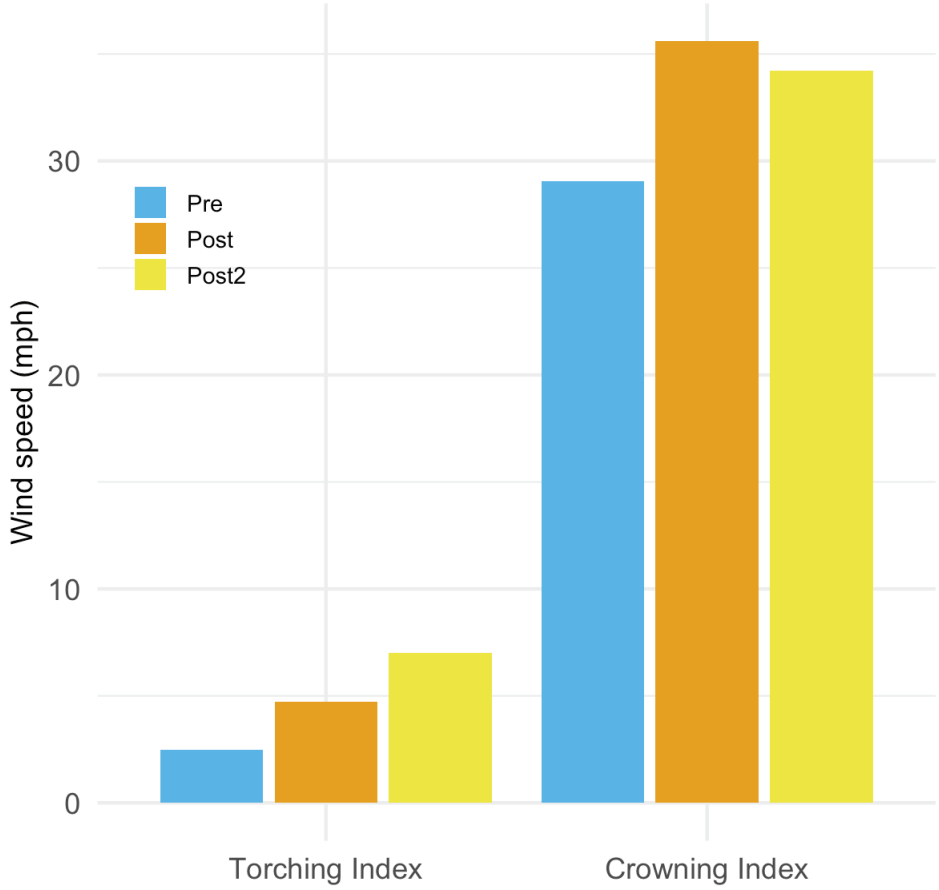

Figure 4. Torching and crowning indices. Torching and crowning index represent the windspeed needed to initiate torching and crown fire behavior, respectively. A higher value indicates lower wildfire hazard.

Fire behavior metrics at Beaver Ranch were unchanged following treatment, which is inconsistent with other research. While torching and crowning indices have increased following treatment at Beaver Ranch, the increases are less than expected (Figure 4). In a review of published literature, Fulé et al. (2012) found an average increase in these indices following similar thinning treatments of 1.5 to 4 times higher than pre-treatment values. Most other USPP treatments have increases between 0.5 and 1.5 times pre-treatment values, although there are a few sites where changes were similar to Beaver Ranch (Slack et al., 2021).

The similar flame lengths and surviving tree basal areas at Beaver Ranch suggest that this treatment was not as effective as most others at reducing canopy fuels (Table 3). The Fulé et al. (2012) literature review of treated areas similar to Beaver Ranch found most sites with different fire behavior had changes to canopy fuels following treatment. Since canopy cover at Beaver Ranch only decreased by 11%, it follows that fire behavior should be unchanged (Slack et al., 2021). Beaver Ranch's fire behavior did not sufficiently change to make prescribed burning more feasible than it was pre-treatment. Additionally, given the more productive nature of these sites, increases in sapling and basal area through time contributed to the lack of change in fire behavior following thinning activities. As mentioned previously there was not a significant decrease in the total number of seedlings post-treatment, therefore seedlings that recruit into saplings could act as ladder fuels. Beaver Ranch should be watched closely, as these ladder fuels have the potential to increase fire behavior in the future.

Understory Plant Communities

Understory plant diversity significantly decreased in both the control (P=0.0003) and the treatment (P=0.0016) from pre-treatment to one year following thinning; however, four years following thinning diversity remained lower in the control (P=0.0005) and recovered in the treatment (Figure 5). Furthermore, species richness in the control significantly increased four years following thinning (P=0.0007). In the treatment species richness was unchanged during all three monitoring visits (P>0.05; Figure 6). Changes in understory vegetation were expected as plant communities shift in response to interannual changes in environmental conditions such as climate. Decreasing diversity and increasing species richness in the control suggested that while there were more individual species, the plant cover shifted to be dominated by fewer species. Specifically, graminoid cover in the control significantly increased following treatment (P=0.0092), and forb cover decreased (P=0.0111). In the treatment, graminoid cover also increased (P=0.0072), but forb cover was unchanged (P>0.05). The shift in the understory plant communities that occurred in the control, where the relative abundance of forbs decreased and species richness increased, was mitigated in the treatment unit. Furthermore, four years following treatment thinning maintained forb cover and species richness, and aided in the recovery of species diversity. Percent plant cover decreased in both the control (P=0.0174) and treatment (P=0.0042), and thinning had no impact on overall plant cover (Figure 7). Lastly, very few non-native species were recorded during any monitoring visit (e.g. noxious weeds were present in only two treatment plots with a maximum cover of ~1% four years following treatment), and thinning had no impact on the relative abundance of non-native plant species (Figure 6).

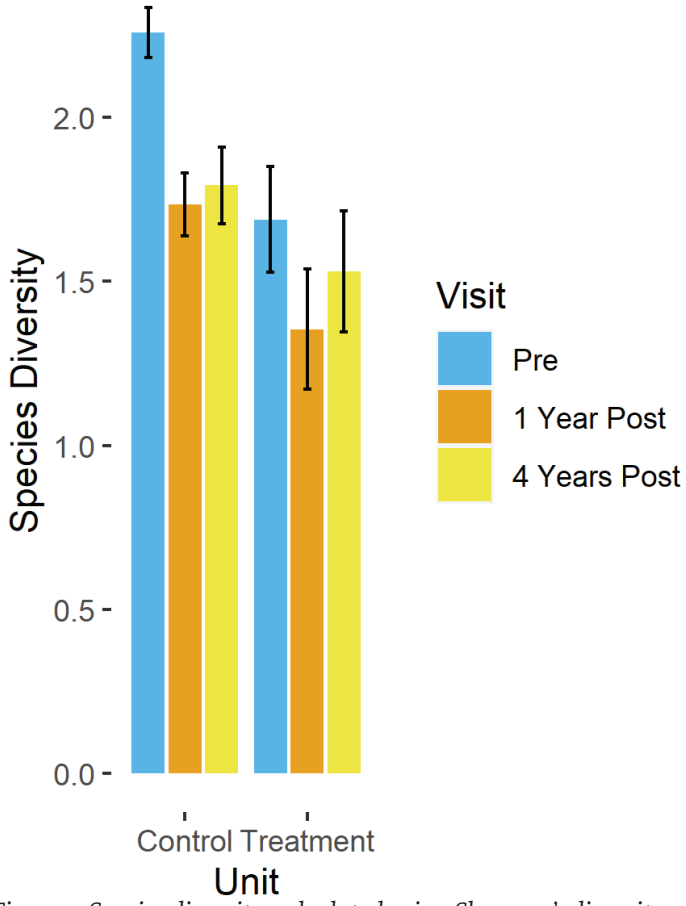

Figure 5. Species diversity, calculated using Shannon's diversity index.

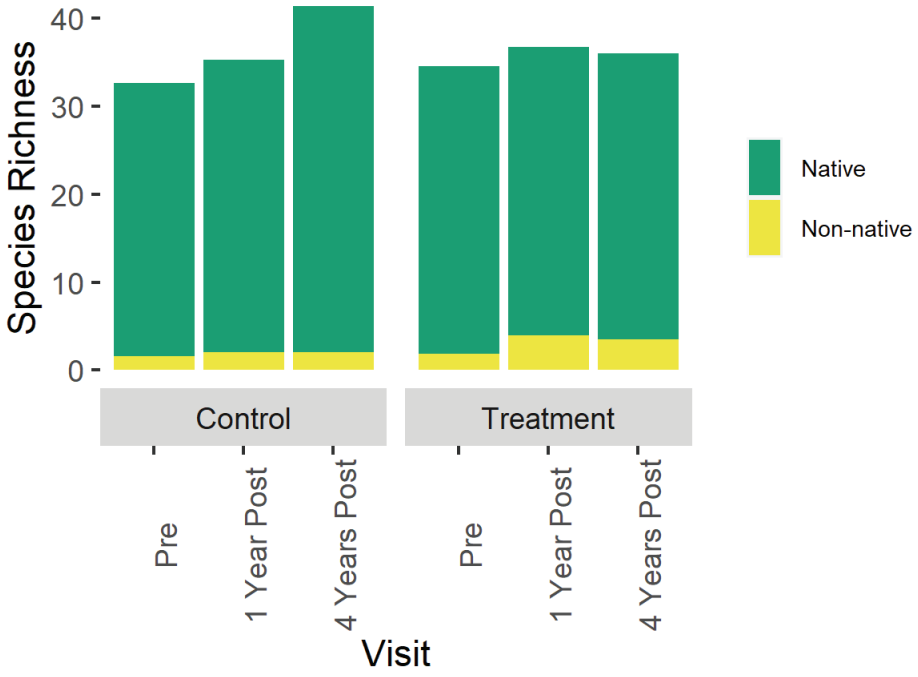

Figure 6. Species richness by native status.

The recovery in diversity following thinning in treatment areas is consistent with other research done near Beaver Ranch which show understory plants benefit from forest restoration treatments (Ertl, 2015; Briggs et al., 2017; Fornwalt et al., 2017). Unlike at Beaver Ranch, other treatments had significantly increased plant richness and cover; however, these sites were visited close to a decade after treatment (Ertl, 2015; Fornwalt et al., 2017), thus a further increase in diversity at Beaver Ranch may occur in the coming years. Additionally, the low treatment intensity at Beaver Ranch may have been insufficient to increase richness and cover through time. Although continued monitoring will be necessary to determine the full impact of treatment on understory plants at Beaver Ranch, understory species are not responding negatively four years post-treatment.

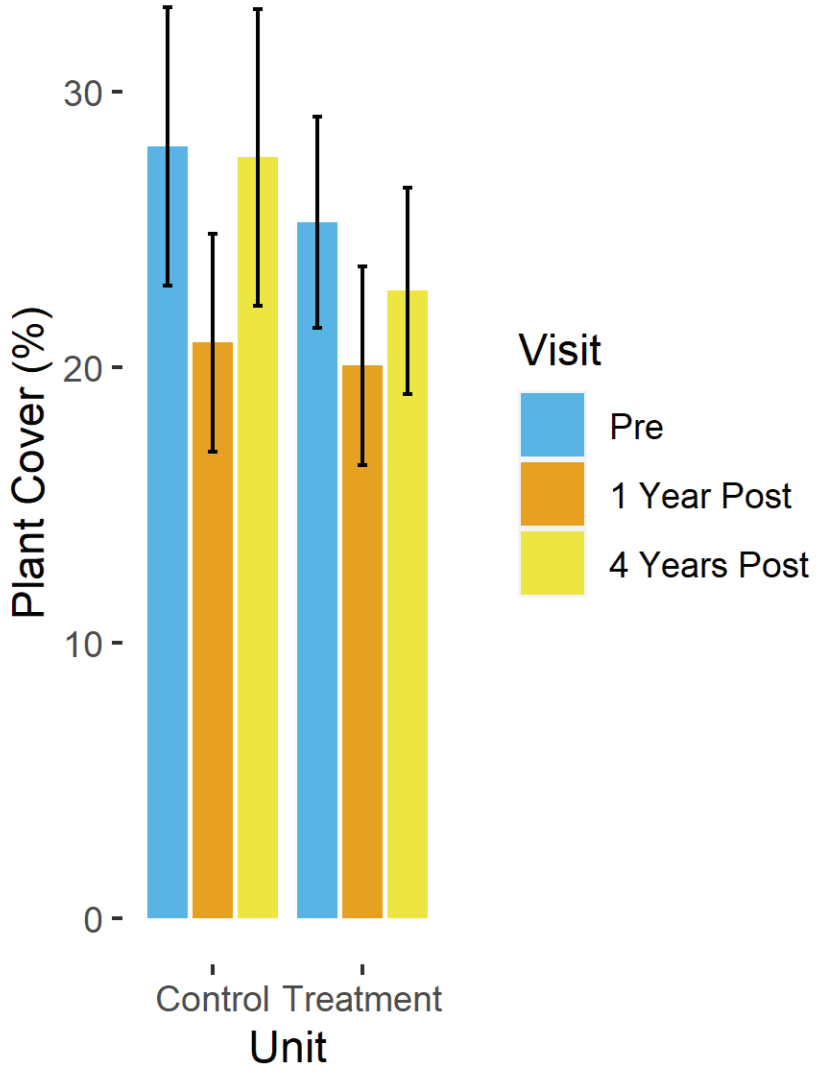

Figure 7. Percent cover of understory plants.

Conclusion

Monitoring four years following treatment at Beaver Ranch has broadened our understanding of the impacts of treatments on forest structure, surface fuels, and understory plant communities. Although treatment initially reduced the number of Douglas-fir seedlings, the number of seedlings four years post-treatment and pre-treatment are similar, and ponderosa pine specifically was not promoted. The USPP objective to increase the ratio of ponderosa pine compared to other conifers is unlikely to be met at Beaver Ranch without additional treatments. Given that predicted fire behavior metrics were unchanged, the treatment goal of reducing the potential for high severity wildfire and the USPP objective of creating conditions which promote the use of prescribed fire were not met. Understory plants were not negatively impacted by treatments, as treated areas did not experience a loss of diversity or proliferation of non-native plants following treatment. Furthermore, thinning aided the recovery of species diversity that may have been impacted by environmental conditions such as climate immediately following treatment.

Even though this forest restoration treatment did not fully achieve desired impacts on regeneration and fire behavior, it provides valuable lessons to help improve future treatments. These lessons highlight a low intensity thinning on a north facing slope, and foster discussion around desired conditions and appropriate prescriptions at more productive sites.

Literature Cited

Barrett, K.J., Cannon J.B., Schuetter A.M., Cheng A.S. (2021). Effects of collaborative monitoring and adaptive management on restoration outcomes in dry conifer forests. Forest Ecology and Management, 488, Article 119018. https://doi.org/10.1016/j.foreco.2021.119018

Battaglia, M. A., Rocca, M. E., Rhoades, C. C., & Ryan, M. G. (2010). Surface fuel loadings within mulching treatments in Colorado coniferous forests. Forest Ecology and Management, 260(9), 1557-1566. https://doi.org/10.1016/j.foreco.2010.08.004

Blanca Mena, M. J., Alarcón Postigo, R., Arnau Gras, J., Bono Cabré, R., & Bendayan, R. (2017). Non-normal data: Is ANOVA still a valid option?. Psicothema, 2017, vol. 29, num. 4, p. 552-557. https://doi.org/10.7334/psicothema2016.383

Briggs, J. S., Fornwalt, P. J., & Feinstein, J. A. (2017). Short-term ecological consequences of collaborative restoration treatments in ponderosa pine forests of Colorado. Forest ecology and management, 395, 69-80. https://doi.org/10.1016/j.foreco.2017.03.008

Colorado Forest Restoration Institute. (2018). Mothership Plot Protocol. CFRI-1810. https://cfri.colostate.edu/wp-content/uploads/sites/22/2018/10/2018-Mothership-Protocol.pdf

Ertl, E. (2015). Restoration impacts on understory plant species in a Colorado Front Range ponderosa pine and Douglas-fir forest. Master of science thesis, Colorado State University, Fort Collins, Colorado. https://www.proquest.com/docview/1727112858?pq-origsite=gscholar&fromopenview=true

Fialko, K., Ex, S., & Wolk, B. H. (2020). Ecological niches of tree species drive variability in conifer regeneration abundance following fuels treatments. Forest Ecology and Management 476. https://doi.org/10.1016/j.foreco.2020.118475

Fornwalt, P. J., Rocca, M. E., Battaglia, M. A., Rhoades, C. C., & Ryan, M. G. (2017). Mulching fuels treatments promote understory plant communities in three Colorado, USA, coniferous forest types. Forest Ecology and Management, 385, 214-224. https://doi.org/10.1016/j.foreco.2016.11.047

Fulé, P. Z., Crouse, J. E., Roccaforte, J. P., & Kalies, E. L. (2012). Do thinning and/or burning treatments in western USA ponderosa or Jeffrey pine-dominated forests help restore natural fire behavior? Forest Ecology and Management, 269, 68-81. https://doi.org/10.1016/j.foreco.2011.12.025

R Development Core Team. (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.r-project.org/

Reinhardt, E. & Crookston, N. L. (2003). The Fire and Fuels Extension to the Forest Vegetation Simulator. Gen. Tech. Rep. RMRS-GTR-116. Ogden, UT: US Department of Agriculture, Forest Service, Rocky Mountain Research Station. 209, 116. https://doi.org/10.2737/RMRS-GTR-116

Slack, A. W., Wolk, B. H., Stevens-Rumann, C. S., Brown, H. L. C., Barrett, K. J., Mueller, S. E., Hunter, T. M., Morici, K. E., & Warnick, K. J. (2021). Upper South Platte Watershed Monitoring Report: Learning from forest restoration projects to advance landscape resilience and collaboration. CFRI 2103. https://cfri.colostate.edu/wp-content/uploads/sites/22/2021/04/Upper-South-Platte-Monitoring-Report-2021_Web.pdf

Sherriff, R. L., & Veblen, T. T. (2006) Ecological effects of changes in fire regimes in Pinus ponderosa ecosystems in the Colorado Front Range. Journal of Vegetation Science, 17: 705-718. https://doi.org/10.1111/j.1654-1103.2006.tb02494.x