LICK CREEK: LESSONS LEARNED AFTER 20+ YEARS OF FUEL TREATMENTS IN PONDEROSA PINE

NORTHERN ROCKIES FIRE SCIENCE NETWORK

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Fuel reduction projects are designed to reduce wildfire hazard, but goals can also include ecological restoration, wildlife habitat enhancement, and forest health improvement. In the U.S. northern Rocky Mountains, ponderosa pine/Douglas-fir forests cover over eight million hectares (≈20 million acres). Before European settlement, these forests burned very frequently (3-30 years) mostly as low-intensity fires. A century of fire suppression policies has converted many open, seral ponderosa pine forests to dense stands with abundant Douglas-fir regeneration, resulting in reduced tree vigor, increased susceptibility to insect infestations, and increased fire hazard, even for older, traditionally more fire-resistant trees.

The USDA Forest Service began harvesting timber from the Lick Creek drainage on western Montana's Bitterroot National Forest in the early 1900s. This early work was documented in photographs, which have been replicated for over 100 years. The photographs show changes in forest stand structure in the absence of disturbance, such as fire and harvesting, and helped demonstrate the need for restoration research in northern Rocky Mountain

Key Management Findings

- **Fuel reduction and restoration treatments are most effective at reducing fuels with a combination of thinning and prescribed burning.**
- **Single-entry fuel treatments in low-elevation dry forests likely will not remain effective for longer than the historic mean fire return interval, therefore maintenance/re-entry treatments are needed to maintain low fuel levels.**
- **Shorter maintenance intervals may exacerbate non-native understory species invasion , depending on timing of treatments.**
- **Results suggest that without future disturbance, tree species dominance across the study area will shift from a shade-intolerant pine to shade-tolerant Douglas-fir forest. The exception to this is in units that were thinned followed by a prescribed fall burn. In these units, ponderosa pine still outnumbers Douglas-fir trees across all size classes over 20 years post-treatment.**

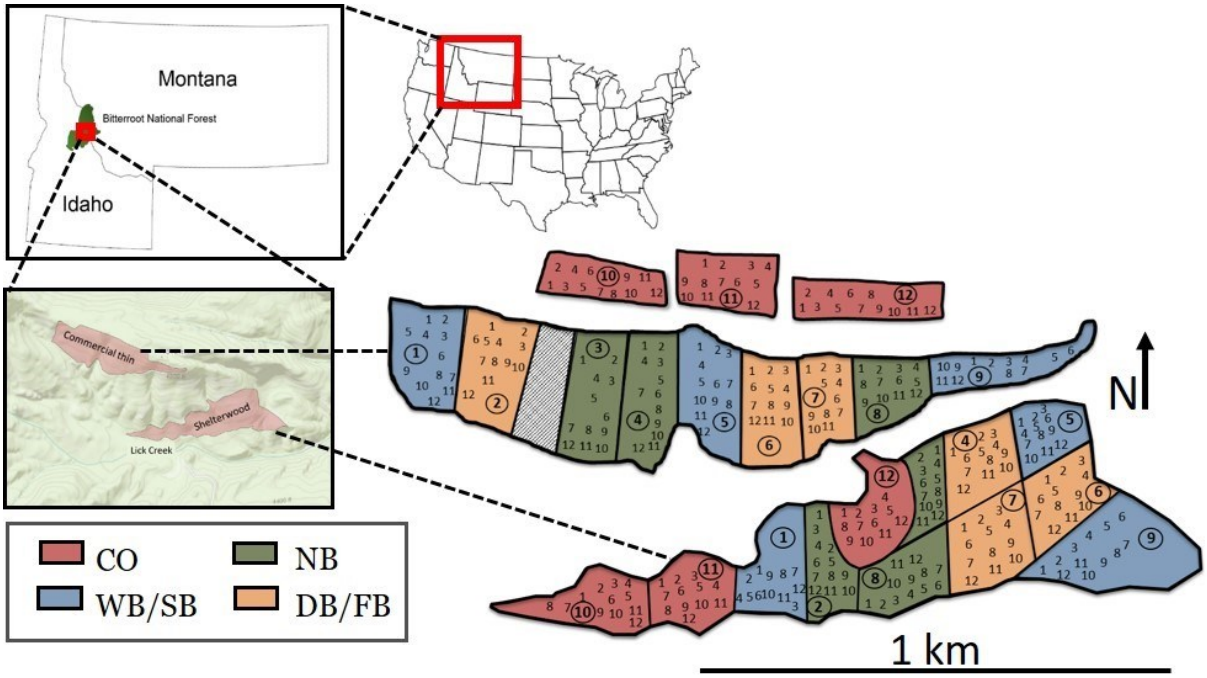

Figure 1. Location of Lick Creek Demonstration—Research Forest and the Thinning and Retention Shelterwood studies by treatment and unit on the Bitterroot National Forest in western Montana. Treatments: CO = Control, NB = Cut, No Burn, SB = Cut+Spring Burn (thinning only), FB = Cut+Fall Burn (thinning only), WB = Cut+Wet Burn (retention shelterwood only), and DB = Cut+Dry Burn (retention shelterwood only). Units are 1-2 hectares (2.5-5 acres).

ponderosa pine forests. Thus, the Lick Creek Demonstration–Research Forest studies were established in 1991 to evaluate tradeoffs among alternative cutting and burning strategies aimed at reducing fuels and moderating forest fire behavior while restoring historical stand structures and species compositions. The experiment consisted of two separate studies of thinning and retention shelterwood cuttings with and without prescribed burning treatments (Figure 1). Treated units were harvested in 1992; half of the units were prescribed burned 1 to 2 years later. Throughout the 23 years since treatment, effects on the forest ecosystem have been studied, including: fuels, forest structure and composition, understory species responses, tree physiology, resistance to bark beetles, carbon storage, and fire hazard. Permanent photo points established in each study also visually document forest and fuel change over time.

Fuels and Fire Hazard

There were very few differences in fuel loads between the treated units and controls 22-23 years post-treatment, and all units had more ladder fuels in the form of live saplings and seedlings. Canopy fuel loads were lower in treated units compared to untreated control units; however, no other canopy fuel metric differed between any treatment and the control. The only persistent difference in surface fuels was in the retention shelterwood, where 1-hour fuels were lower in the treated units compared to control units.

Crown fire hazard varied greatly within the units, but means were similar between treatments. The increased hazard was driven by increases in live surface fuels from seedlings and saplings in the retention shelterwood, which increased canopy bulk density and reduced canopy base height.

Key Research Findings

23 years post-treatment, treated units showed:

- **increased tree growth, even during drought conditions**
- **reduced tree mortality from mountain pine beetle**
- **non-native understory species cover similar to pretreatment levels (<5% cover), despite a large spike 3-5 years post-treatment**
- **aboveground tree biomass (i.e., carbon storage) recovered to pre-harvest levels**
- **increased ladder fuels from saplings and seedlings**
- **surface and canopy fuel characteristics and crowning and torching indices similar to untreated units.**

Forest Structure and Composition

The overstory was still dominated by ponderosa pine 23 years post-treatment, but the smaller size classes were primarily dominated by Douglas-fir, suggesting that without future disturbance, these forests will increasingly shift from ponderosa pine to Douglas-fir. The exception to this was the cut+fall burn treatment in the thinning unit, where ponderosa pine outnumbered Douglas-fir trees across all size classes. The treatments that included a broadcast prescribed burn killed many existing seedlings and saplings. For more information on fuels and forest changes, see Hood et al. 2020.

Tree Growth and Physiology

All treatments led to an overstory tree growth release that persisted through the time of resampling, 22-23 years post -treatment, when growth was still higher than trees in the

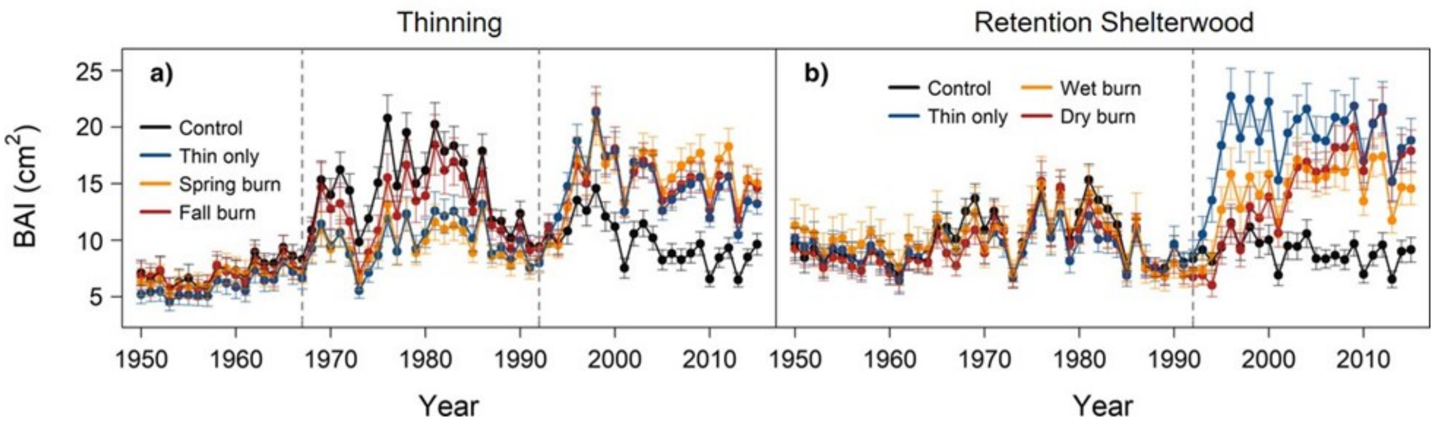

Figure 2. Growth responses to the 1992 harvesting, with and without prescribed burning (1993 and 1994) relative to the untreated control by study (control = black, thin only = blue, spring or wet burn = yellow, fall or dry burn = red). BAI is basal area increment. Values are means ± SE. Dashed vertical lines represent the year of cutting (1992) plus the year of an earlier thinning treatment (1967)conducted in portions of the current thinning study.

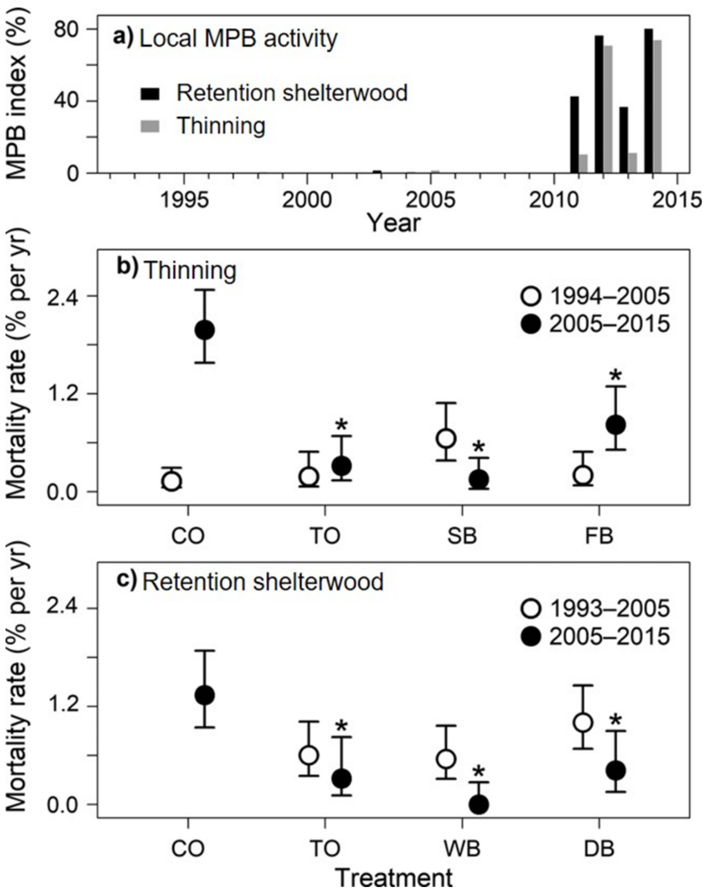

Figure 3. Comparison of (a) trends in local mountain pine beetle (MPB) activity, and (b, c) tree mortality rates in thinning and retention shelterwood studies. The MPB index represents the proportion of the area within a 500-m radius surrounding the experimental units in which MPB activity was recorded in Aerial Detection Surveys. Mortality rates for the control of the retention shelterwood experiment were not calculated because trees were not tagged until after the initial sampling. Asterisks above the error bars for the treatment represent a significantly lower mortality rate ($P < 0.05$) than the control for the respective time period. Treatments are abbreviated as CO, control; TO, thin only; SB, spring burn; FB, fall burn; WB, wet burn; and DB, dry burn.

controls (Figure 2). Carbon isotope analysis of the annual growth rings gave researchers insight into when trees experienced stress from drought on a seasonally annual basis. The retention shelterwood treatments had little effect on climate–growth relationships, but they markedly altered seasonal carbon isotope signals and their relationship to climate, indicating that reduced competition enabled the remaining trees to continue to fix carbon for longer periods during the late summer. This led to higher stem growth even when drought stopped carbon assimilation in the slower-growing trees in the untreated units. Carbon isotope analysis was not performed in the thinned units.

Tree Mortality and Resistance to Bark Beetles

The number of trees that died annually was low (≤1% per yr) in both treated units and controls during the first 12 years post-treatment (1993 or 1994 through 2005; Figure 4). Mountain pine beetle activity in the study area increased over the next decade (2005-2015), with aerial surveys documenting beetle-caused mortality in more than 70% of the area between 2011 and 2014 (Figure 3a). Over this time period, mortality rates in the control units increased by up to 1.98% per yr. Mortality was significantly greater in the controls than in the treatments, where the mortality rates (thinning: ≤0.82% per yr and retention shelterwood: ≤0.42% per yr) remained similar to those found during the previous decade when pressure from mountain pine beetle was lower (Figure 3).

Carbon Storage

Across all treatments in both the thinning and retention shelterwood studies, tree biomass had recovered to pre-harvest levels by 2015, or 23 years post-treatment. In the thinning study, total aboveground and live-tree biomass were greatest in the control and did not differ among the three thinned treatments. Forest floor biomass was lower in the two burned treatments compared to the two unburned treatments. Seedling, vegetation, stump, and snag biomass did not differ among the four treatments. In the retention shelterwood, total aboveground and live tree biomass were both greater in the unburned treatments relative to the burned treatments. Forest floor and snag biomass also tended to be lower in the burned treatments. Seedling, vegetation, and stump biomass were similar across all treatments.

Understory Species Responses

Native grasses and shrubs declined immediately after treatments (43% and 40% reduction, respectively), but then increased, peaked about five years after treatment (74% greater than pre-treatment) and then generally declined to levels similar to pre-treatment. The magnitude of these patterns was related to the treatment or disturbance intensity (i.e., cut-and-dry-burn > cut-and-wet-burn > cut-and-no-burn > control) with tree basal area explaining remaining variation in cover for native plant groups.

Non-native grasses and forbs followed similar overall trajectories, but cover of these groups increased immediately after treatment and rose more steeply to their peak five years post-treatment (12 times greater than pre-treatment), with differences persisting through year 23. While long-term non-native plant cover decreased as tree basal area increased, overstory conditions alone did not fully account for treatment differences. This suggests that the different effects of burning associated with more intensive treatments favored non-natives. Nonetheless, increases in non-native plant cover were modest in the last sampling year, suggesting that after 23 years understory responses in this forest type were resilient to restoration treatments. However, because forest structure was becoming denser and more dominated by Douglas-fir, retreatment may be necessary at intervals of less than 23-years, which could exacerbate non-native plant responses. These results provide insight into how forest restoration treatments and their timing may affect understory susceptibility to non-native plant invasion.

Management Implications

Our research shows that fuel treatments aimed at reducing potential wildfire severity can also have the added benefits of sequestering carbon, increasing resistance to mountain pine beetle outbreaks, and improving resilience to drought stress.

Our findings support other studies showing fuel reduction and restoration treatments are most successful with a combination of cutting and burning strategies, but also show that fuel treatments in low-elevation dry forests will likely not remain effective for much longer than historic mean fire return intervals. Retreatment may be necessary at shorter intervals and would make it easier to control regeneration through prescribed burning, rather than relying on mechanical treatments such as slashing or mastication prior to burning. The size of the regeneration in many of the units after 23 years makes it hard to safely conduct a prescribed burn that would eliminate some of the regeneration (especially Douglas-fir), while minimizing overstory tree mortality. An additional concern is that re-treatment could exacerbate non-native species responses. This highlights the importance of continued treatment and monitoring of this long-term study to determine appropriate management strategies in ponderosa pine forests of the Northern Rockies.

Additional Information

For more information on the Lick Creek Demonstration Site including other ongoing research and references:

https://www.nrfirescience.org/lick-creek-demonstration-site

Data archive including photo-points of same areas over time:

Lutes, D.C.; Hood, S.M.; Keyes, C.R.; Harrington, M.G.; Pearson, D.E.; Ortega, Y.K.; Sala, A. 2020. Lick Creek Demonstration-Research Forest: Data and photo archive of 25-year fire and cutting effects on vegetation and fuels. Fort Collins, CO: Forest Service Research Data Archive. https://doi.org/10.2737/RDS-2020-0008

Related Publications

Bowen, K.; Keyes, C.R.; Hood, S.; Seielstad, C.; Lutes, D. 2020. Comparison of three methods for quantifying coarse surface fuel loading. In: Hood, et al., eds. Proceedings of the Fire Continuum – preparing for the future of wildland fire; 2018 May 21-24; Missoula, MT. Proceedings RMRS-P-78. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Pages 22-30. https://www.fs.usda.gov/treesearch/pubs/62322

Clyatt, K.A.; Keyes, C.R.; Hood, S.M. 2017. Long-term effects of fuel treatments on aboveground biomass accumulation in ponderosa pine forests of the northern Rocky Mountains. Forest Ecology and Management 400: 587-599. https://www.fs.usda.gov/treesearch/pubs/54505

Crotteau, J. S.; Hood, S.M.; Lutes, D.C.; Keyes, C.R.; Sala, A.; Harrington, M.G. 2018. Management and Succession at the Lick Creek Demonstration/Research Forest, Montana. Journal of Forestry 116:481-486. https://www.fs.usda.gov/treesearch/pubs/56719

Hood, S.M.; Keyes, C.R.; Bowen, K.J.; Lutes, D.C.; Seielstad, C. 2020. Fuel treatment longevity in ponderosa pine-dominated forest 24 years after cutting and prescribed burning. Frontiers in Forests and Global Change 3: Article 78. https://www.fs.usda.gov/treesearch/pubs/60461

Jang, W.; Crotteau, J; Ortega, Y.K.; Hood, S.M.; Keyes, C.R.; Pearson, D.E.; Lutes, D.; Sala, A. 2021. Native and Non-native Understory Vegetation Responses to Restoration Treatments in a Dry Conifer Forest over 23 Years. Forest Ecology and Management 481:118684. https://www.fs.usda.gov/treesearch/pubs/61684

Peters, G.; Sala, A. 2008. Reproductive output of ponderosa pine in response to thinning and prescribed burning in western Montana. Canadian Journal of Forest Research 38(4): 844-850.

Sala, A.; Peters, G.D.; McIntyre, L.R.; Harrington, M.G. 2005. Physiological responses of ponderosa pine in western Montana to thinning, prescribed fire and burning season. Tree Physiology 25: 339-348.

Smith, H.Y.; Arno, S.F. 1999. Eighty-eight years of change in a managed ponderosa pine forest. Gen. Tech. Rep. RMRS-GTR-23. Ogden, UT: U.S. Department of Agriculture, Rocky Mountain Research Station. 55 p. https://www.fs.usda.gov/treesearch/pubs/28424

Tepley, A.J.; Hood, S.M.; Keyes, C.R.; Sala, A. 2020a. Forest restoration treatments in a ponderosa pine forest enhance physiological activity and growth under climatic stress. Ecological Applications 30(8): e2188. https://www.fs.usda.gov/treesearch/pubs/60159

Tepley, A.J.; Hood, S.M.; Keyes, C.R.; Sala, A. 2020b. Forest Restoration Treatments in a Ponderosa Pine Forest Enhance Physiological Activity and Growth Under Climatic Stress. The Bulletin of the Ecological Society of America 101: e01772. https://www.fs.usda.gov/treesearch/pubs/61693

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The Northern Rockies Fire Science Network (NRFSN) serves as a go-to resource for managers and scientists involved in fire and fuels management in the Northern Rockies. The NRFSN facilitates knowledge exchange by bringing people together to strengthen collaborations, synthesize science, and enhance science application around critical management issues.