

# A SUMMARY OF STUDIES RELEVANT TO FIRE, INSECT OUTBREAKS, AND FOREST MANAGEMENT ISSUES IN THE COLORADO FRONT RANGE

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The list below describes some of our publications and primary datasets relevant to current discussions of forest management in Colorado but with an emphasis on Boulder County.

1. Veblen, T.T., T. Kitzberger and J. Donnegan. 1996. Fire Ecology in the Wildland Urban Interface of Boulder County: A research report to the City of Boulder Open Space.

This report includes site-specific fire histories for 41 sites in the montane zone of Boulder County. Latitudes and longitudes and data for these fire history sites (and many other sites in Boulder County subsequently sampled by our research group) can be downloaded from NOAA's International Multiproxy Paleofire Database (IMPD;

<http://www.ncdc.noaa.gov/paleo/impd/>). Access the Report online at:

[https://www.researchgate.net/publication/358397854\\_Fire\\_History\\_Report\\_City\\_of\\_Boulder\\_Open\\_Space](https://www.researchgate.net/publication/358397854_Fire_History_Report_City_of_Boulder_Open_Space)

2. Veblen, T.T. and D.C. Lorenz. 1991. *The Colorado Front Range: A Century of Ecological Change*. Univ. Utah Press.

This book includes many matched historical and modern landscape photos in Boulder and Larimer Counties. A scan of this book can be downloaded either from the following ResearchGate link or from the CU Library link.

[https://www.researchgate.net/publication/234017704\\_The\\_Colorado\\_Front\\_Range\\_A\\_Century\\_of\\_EcologicalChange](https://www.researchgate.net/publication/234017704_The_Colorado_Front_Range_A_Century_of_EcologicalChange) or [https://scholar.colorado.edu/geog\\_facpapers/43/](https://scholar.colorado.edu/geog_facpapers/43/).

3. Veblen, T.T. and J.A. Donnegan. 2006. *Historical Range of Variability of Forest Vegetation of the National Forests of the Colorado Front Range*. USDA Forest Service, Rocky Mountain Region and the Colorado Forest Restoration Institute, Fort Collins. 151 pages. [https://sites.warnercnr.colostate.edu/wp-content/uploads/sites/32/2016/05/2005\\_HRVFrontRangeForests.pdf](https://sites.warnercnr.colostate.edu/wp-content/uploads/sites/32/2016/05/2005_HRVFrontRangeForests.pdf)

This report was completed under a Cooperative Agreement between the Regional Office of the Forest Service and the University of Colorado initiated in 1999. The draft of the Report was peer-reviewed by personnel of the Forest Service and by anonymous reviewers selected by the Ecological Society of America.

4. Sherriff, R.L. and T.T. Veblen. 2006. Ecological effects of changes in fire regimes in *Pinus ponderosa* ecosystems in the Colorado Front Range. *Journal of Vegetation Science* 17:705-718.

This paper presents fire history and tree age data on 24 sites from the lower through the upper montane zone of the northern Front Range. The tree age data reveal if the stand structure is due to recovery following a 19<sup>th</sup> century fire or if it indicates tree encroachment during 20<sup>th</sup> century fire exclusion. Those two contrasting patterns are often conflated in the public messaging from land managers. Access it at:

[https://www.researchgate.net/publication/227636245\\_Ecological\\_effects\\_of\\_changes\\_in\\_fire\\_regimes\\_in\\_Pinus\\_ponderosa\\_ecosystems\\_in\\_the\\_Colorado\\_Front\\_Range](https://www.researchgate.net/publication/227636245_Ecological_effects_of_changes_in_fire_regimes_in_Pinus_ponderosa_ecosystems_in_the_Colorado_Front_Range)

5. Schoennagel, T., R.L. Sherriff, and T.T. Veblen. 2011. Fire history and tree recruitment in the upper montane zone of the Colorado Front Range: implications for forest restoration. *Ecological Applications* 21:2210-2222.

This large dataset on tree ages in the upper montane zone (i.e. mixed conifer forests) shows that a large majority of the trees established directly following widespread forest burning in the second half of 19<sup>th</sup> century. Only a small proportion of tree ages indicate establishment of trees during the modern fire suppression period of the 20<sup>th</sup> century (i.e. woody encroachment). Dense stands of trees (sometimes described by the non-scientific term "as overgrown") in the mixed conifer zone today primarily reflect natural regeneration following widespread fires in the 19<sup>th</sup> century associated with both drought and increased ignitions by white settlers. Messaging from land managers sometimes recognizes the

importance of 19<sup>th</sup> century logging triggering the development of dense post-logging stands of ponderosa pine and Douglas fir but the messaging usually fails to recognize the importance of 19<sup>th</sup> century higher severity fires (i.e. killing > 70% of canopy trees over patch sizes of many acres) in promoting dense even-aged stands in today's landscape.

The appendix presents fire history and tree age data on 31 stands in the upper montane zone mostly in Boulder County showing that they originated following moderate to higher severity burns in the 19<sup>th</sup> century and earlier. Access it at: [https://www.researchgate.net/publication/51662600\\_Fire\\_history\\_and\\_tree\\_recruitment\\_in\\_the\\_Colorado\\_Front\\_Range\\_upper\\_montane\\_zone\\_Implications\\_for\\_forest\\_restoration](https://www.researchgate.net/publication/51662600_Fire_history_and_tree_recruitment_in_the_Colorado_Front_Range_upper_montane_zone_Implications_for_forest_restoration)

6. Sherriff, R.L., Platt R.V., Veblen T.T., Schoennagel T.L., Gartner M.H. 2014 Historical, observed, and modeled wildfire severity in montane forests of the Colorado Front Range. PLoS ONE. 9(9) pages 1-17: e106971. doi:10.1371/journal.pone.0106971

The first page of this paper describes how to access data for over 200 sites sampled for fire history primarily in Boulder County. We used forest structure and tree-ring fire history in lower and upper montane forests to characterize historical fire severity at 232 sites and then spatially modeled historical fire-severity across the entire study area using biophysical variables. Only 16% of the study area recorded a shift from historical low severity to a higher potential for crown fire today. An historical fire regime of more frequent and low-severity fires at low elevations (< 2260 m) supports a convergence of management goals of ecological restoration and fire hazard mitigation in those habitats. In contrast, at higher elevations mixed-severity fires were predominant historically and continue to be so today. Thus, for most of the upper montane zone, thinning treatments should not be viewed as ecological restoration. Access the article at:

[https://www.researchgate.net/publication/266022549\\_Historical\\_Observed\\_and\\_Modeled\\_Wildfire\\_Severity\\_in\\_Montane\\_Forests\\_of\\_the\\_Colorado\\_Front\\_Range](https://www.researchgate.net/publication/266022549_Historical_Observed_and_Modeled_Wildfire_Severity_in_Montane_Forests_of_the_Colorado_Front_Range)

7. Hart, S.J., T.T. Veblen, K.S. Eisenhart, D. Jarvis, D. Kulakowski. 2014. Drought induces spruce beetle (*Dendroctonus rufipennis*) outbreaks across northwestern Colorado. *Ecology* 95:930–939. <http://dx.doi.org/10.1890/13-0230.1>

Using tree rings, we document that spruce beetle outbreaks were widespread and severe during the 19<sup>th</sup> century, long before any possible effects of modern fire suppression. Land managers sometimes falsely assert that recent regional-scale beetle outbreaks reflect “unhealthy forests” because of modern fire suppression impacts on forest structure. Our work and that of Forest Service scientists show that regional-scale bark beetle outbreaks were widespread long before modern fire suppression and that they are driven primarily by climate variability. For example, see: Negron JF, Huckaby L. Reconstructing historical outbreaks of mountain pine beetle in lodgepole pine forests in the Colorado Front Range. *Forest ecology and management*. 2020 Oct 1;473:118270. <https://doi.org/10.1016/j.foreco.2020.118270>

8. Rodman, Kyle; Fornwalt, Paula; Chapman, Teresa; Coop, Jonathan; Edwards, Gloria; Stevens, Jens; Veblen, Thomas. 2022. SRRT: A decision support tool to inform postfire reforestation of ponderosa pine and Douglas-fir in the southern Rocky Mountains. Res. Note RMRS-RN-95. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 12 p. <https://doi.org/10.2737/RMRS-RN-95>.

This describes how to use an online tool that allows a user to assess the suitability of current climate and future predicted climate for planting ponderosa pine and Douglas fir at recently burned sites. For example, a user can select the year 2010 and delimit the approximate area of the Fourmile Canyon fire to determine locations where the current climate or projected future climate (2031-2060) are suitable for tree seedling survival.

9. Chapman, TB, T Schoennagel, TT Veblen, KC Rodman. 2020. Still standing: recent patterns of post-fire conifer refugia in ponderosa pine forests of the Colorado Front Range. *PLoS ONE* 15(1): e0226926. <https://doi.org/10.1371/journal.pone.0226926>

This study examined 23 Front Range fires (1996-2013) for burn severity and conifer survival in the Ponderosa pine zone. A key finding was that pre-fire forest canopy cover was not strongly associated with post-fire conifer survival. Instead, conifer survival was more strongly associated with abiotic landscape variables such as moister soils, proximity to streams, and topographic positions. The study did not specifically examine potential effects of mechanical thinning and prescribed fires which affected only 3% of the burned area. However, the findings call into question reliance on solely tree canopy cover (and its modification through mechanical thinning) as the best predictor of where trees are likely to survive fires due to reduced burn severity. Although I have observed some discomfort among land managers with the finding that tree cover is not the best predictor of burn severity, the results showing the importance of abiotic factors on wildfire patterns appear to be consistent with the current emphasis on PODs (Potential Operational Delineations) in planning strategic responses to potential wildfires.

**10.** Hart, S.J., T. Schoennagel, T.T. Veblen, and T.B. Chapman. 2015. Area burned in the western United States is unaffected by recent mountain pine beetle outbreaks. *Proceedings of the National Academy of Sciences*. [www.pnas.org/cgi/doi/10.1073/pnas.1424037112](http://www.pnas.org/cgi/doi/10.1073/pnas.1424037112) Significance copied from the article:

“Across western North America, abundant susceptible pine hosts and a suitable climate during the early 21st century have promoted widespread mountain pine beetle (MPB) outbreaks, leading to concern that dead fuels may increase wildfire risk. The assumption that outbreaks raise fire risk is driving far reaching policy decisions involving expenditures of hundreds of millions of dollars. Contrary to the expectation that an MPB outbreak increases fire risk, spatial overlay analysis shows no effect of outbreaks on subsequent area burned during years of extreme burning across the West. These results refute the assumption that increased bark beetle activity has increased area burned; therefore, policy discussions should focus on societal adaptation to the effects of the underlying drivers: warmer temperatures and increased drought.”

Acknowledging that this was a macroscale study, we also wrote: “...Although tree removal to reduce tree-fall risks to homes, recreational sites, and communication and power infrastructures is clearly justified, MPB infestation has not fundamentally altered the risk of burning. Nevertheless, we note that the effects of beetle outbreaks on other measures of fire behavior, most importantly, fire intensity and crowning behavior, may be important and clearly warrant caution from a fire-fighter safety perspective. Recognition of the potential for unanticipated fire behavior at a stand scale due to MPB-induced tree mortality is essential for firefighter safety.”

**11.** Hart, S, O Santiago, JD Carrell, TT Veblen. 2025. Drought may initiate western spruce budworm outbreaks, but multi-year periods of increased moisture availability promote widespread defoliation. *Forest Ecology and Management*. <https://doi.org/10.1016/j.foreco.2025.122932>

Using tree rings, we reconstructed outbreaks of western spruce budworm on Douglas fir since the mid-1600s for the Colorado Front Range. We show that budworm outbreaks have not increased in frequency or severity during the 20<sup>th</sup> – 21<sup>st</sup> century period of fire exclusion. Assertions that modern fire exclusion has resulted in an increase in budworm outbreaks, mountain pine beetle outbreaks, and spruce beetle outbreaks are contradicted by the evidence of tree-ring reconstructions conducted by our research group and by USDA Forest Service scientists.

**12.** Rodman, KC, RA Andrus, AR Carlson, TA Carter, TB Chapman, JD Coop, PJ Fornwalt, NS Gill, BJ Harvey, AE Hoffman, KC Kelsey, D Kulakowski, DC Laughlin, JE Morris, JF Negrón, KM Nigro, GS Pappas, MD Redmond, CC Rhoades, ME Rocca, ZH Schapira, JS Sibold, CS Stevens-Rumann, TT Veblen, J Wang, X Zhang, SJ Hart. Rocky Mountain forests are poised to recover following bark beetle outbreaks, but with altered composition. *Journal of Ecology* 110:2929–2949. <https://doi.org/10.1111/1365-2745.13999>

The key finding of this metadata analysis is that following the bark beetle outbreaks of the early 2000s, forests in Colorado are experiencing changes in tree species dominance and composition but there has been no significant conversion from forest to non-forest vegetation.

It is important to note that the current and projected MPB outbreak may include areas where Pipo is near its distributional limit in the foothills ecotone. Consequently, following projected tree mortality of Pipo it is logical to expect some conversion from forest or woodlands to non-forest vegetation. Modeling tools similar to the Rodman et al. 2022 tool cited above will be useful for projecting areas that are more likely to convert from forest to non-forest.

**13.** Rodman, KC, MA Battaglia, ME Chambers, PJ Fornwalt, ZA Holden, TE Kolb, MT Rother, JR Ouzts, TT Veblen. A changing climate is snuffing out post-fire forest recovery in montane forests of the Southern Rocky Mountains. *Global Ecology and Biogeography* 29:2039–2051. <https://DOI.org/10.1111/geb.13174>

As the title indicates, this study demonstrates widespread lack of tree regeneration following recent fires in Pipo and Psme forests in Colorado. This is justification for devoting more resources to post-fire tree planting at the limited sites now climatically suitable for those tree species. Among the various ecosystem services needing protection by replanting trees is the carbon sequestration function of forests to reduce the positive feedback of carbon emissions to the atmosphere.

**14.** Rodman, KC, TT Veblen, S Saraceni, TB Chapman. 2019. Wildfire Activity and Land Use Drove 20th Century Changes in Forest Cover in the Colorado Front Range. *Ecosphere* 10(2):e02594. 10.1002/ecs2.2594. <https://doi.org/10.1002/ecs2.2594>

We used aerial imagery from 1938-1940 and 2015 to quantify changes in forest cover for a 2932-km<sup>2</sup> study area in the northern Front Range (NFR) of Colorado covering most of the period of modern fire suppression. We linked the observed changes to historical land use and fire history. In the NFR overall forest cover increased 7.8%, but there was notable spatial variability and many sites also experienced Forest Loss. Recent (1978–2015) wildfire was the largest single driver of Forest Loss, with fires burning 14.3% of the total study area. Reasons for Forest Gain were more complex, with elevation, past mining density, fire history, and topographic heat load index being the strongest predictors of increases in forest cover. In the montane zone, fire-excluded stands with a history of frequent, low-severity surface fire showed a greater increase in cover than did stands with a history of mixed-severity fire (15.7% vs 11.7%). Historical mining activity is one of the dominant anthropogenic impacts in ecosystems in the NFR and it had a complex, non-linear relationship with 20th-century changes in forest cover. Subalpine stands originating after stand replacing fires circa mid-1800s to early 1900s showed some of the greatest gains in forest cover, indicative of slow and continuous post-fire recovery through the 20th century.

**15.** Chapman, T.B., T.T. Veblen, T. Schoennagel. 2012. Spatio-temporal patterns of mountain pine beetle activity in the southern Rocky Mountains. *Ecology* 93: 2175-2185. <https://doi.org/10.1890/11-1055.1>

We compared broadscale spatiotemporal patterns of MPB activity in lodgepole pine and ponderosa pine from 1996 to 2010 in Colorado with regional weather fluctuations and then tracked the annual meso-scale progression of the epidemic in lodgepole pine with respect to weather, topography, and forest stand attributes. Warm temperatures and low annual precipitation (i.e. drought) favorable to MPB activity showed high regional synchrony across areas of both pine species. For lodgepole pine, development of the outbreak was also associated with lower elevations, greater dominance by lodgepole pine, stands of larger tree size, and stands with higher percentage canopy cover. After extreme epidemic levels of MPB activity were attained, MPB activity was less strongly associated with stand and weather variables.

**16.** Moritz, MA, C Topik, CD Allen, PF Hessburg, P Morgan, D. Odion, TT Veblen, IM McCullough. 2018. A Statement of Common Ground Regarding the Role of Wildfire in Forested Landscapes of the Western United States. Fire Research Consensus Working Group Final Report. Published by Science for Nature and People and the Wilburforce Foundation.: <https://www.nceas.ucsb.edu/featured/fire-research-consensus>.

A quick look at the Executive Summary will give you an idea of where several of us with quite divergent viewpoints on wildfire management were able to identify some areas of common ground for moving forward on challenging issues.

For a video of an outreach talk on some of these themes, see: [CoNPS Annual Conference 2022 - Tom Veblen - YouTube](#) *The Challenge of Shifting from the Forest Restoration Narrative to an Evidence-based Climate Adaptation Paradigm in Colorado*.