CENTRE FOR EVIDENCE-BASED CONSERVATION

SYSTEMATIC REVIEW No. 42

WORKING TITLE:

DO THINNING AND/OR BURNING TREATMENTS ON PONDEROSA PINE AND RELATED FORESTS IN WESTERN USA PRODUCE RESTORATION OF NATURAL FIRE BEHAVIOUR?

REVIEW PROTOCOL

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COVER SHEET

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1. BACKGROUND

Ponderosa pine (*Pinus ponderosa*) and related species (*P. jeffreyi*, *P. durangensis*) range over approximately 10,000,000 ha of western North America, forming forests of great ecological and social value. These pines are adapted to a disturbance regime of frequent surface fires (Keeley and Zedler 1998), consistent with the dry, fire-prone habitats they have occupied over evolutionary time scales. Frequent fires maintained relatively open uneven-aged forests with abundant, diverse understories over most of the landscape (Cooper 1960, Minnich et al. 1995, Brown and Cook 2006), although some areas may also have experienced infrequent severe fires (Sherriff and Veblen 2007, Pierce and Meyer 2008). From the mid-nineteenth century (California, Oregon, South Dakota) till the mid-twentieth century (northern Mexico), forest structure, composition, and disturbance patterns across the vast range of these species were affected by impacts associated with industrialized society: grazing of large herds of introduced livestock, extensive logging and conversion to even-aged forests, and extended fire exclusion. As a consequence, forest structure changed to dense stands of young trees, forest floor fuels accumulated, and fire-sensitive conifers such as *Abies* and *Pseudotsuga* expanded in pine/mixed-conifer ecotones. High-severity wildfires were first reported in ponderosa pine forests as early as 60-70 years ago (Weaver 1943, Cooper 1960). But in recent years, the presence of heavy contiguous canopy and surface fuels (Fiedler et al. 2002) has facilitated the exponential growth in the size of severe fires, especially during the droughts that have become increasingly frequent with warming global temperatures (Westerling et al. 2006). Insect herbivory on stressed trees and direct mortality from drought interact with fire to magnify disturbance severity (Breshears et al. 2005). Severe fires in these formerly fire-adapted forests have led to widespread topsoil loss (Moody and Martin 2001), tree mortality and conversion to non-forest vegetation (Savage and Mast 2005), and invasion by introduced weedy species (Keeley 2006). These issues are not confined to North America; strikingly similar patterns of larger fires resulting from higher fuel loads and warmer climate have been observed across pine forests of the Mediterranean Basin in southern Europe and northern Africa (Pausas 2004, Leone and Lovreglio 2004).

Early in the twentieth century, Aldo Leopold (1924, 1937) called attention to the problems stemming from the changing patterns of ecosystem structure and disturbance. The concept of ecological restoration was advanced by Leopold in 1949 in *A Sand County Almanac*. Early experiments in ecological restoration through reinstatement of surface fire by means of controlled burns (Weaver 1951, Lindenmuth 1960, Sweeney and Biswell 1961) were poorly received by forest managers, who preferred to rely on intensive silvicultural cuttings to control density. By the 1960s and 70s, fire policies were adjusted to admit the ecological role of fire and permit more burning (Stephens and Ruth 2005). Relatively liberal fire-use policies are credited with successful restoration of fire-resilient forests in some places, especially remote and unharvested forests such as those of the Gila Wilderness in New Mexico (Rollins et al. 2001). However, many forests have become altered to that the point where surface fires are insufficient to reverse deleterious changes (Sackett et al. 1996, Miller and Urban 2000). Impelled by the costly and damaging effects of severe fires, a number of experimental and observational research studies have focused on combined forest treatments of tree thinning, prescribed burning, and other interventions that may restore resiliency to severe burning as well as restoring structural, compositional, and functional attributes that were characteristic of these ecosystems prior to recent anthropogenic disruption (Covington et al. 1997, Stephenson 1999, Allen et al. 2002). The literature on this topic has grown rapidly but has not been synthesized in a comprehensive manner.

Our focus in this systematic review is to ask if thinning and/or burning treatments on ponderosa pine and related forests in western USA produce restoration of natural fire behaviour. The Society for Ecological Restoration International (SER) defines restoration as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed" (http://www.ser.org/content/ecological_restoration_primer.asp). Nested beneath this broad definition are a set of attributes of restored ecosystems. Key features include attention to the range of variability in reference ecosystems, either in the form of intact, preserved sites or as reconstructed from paleoecological and historical evidence (Meine et al. 2005), recovery of natural resiliency to characteristic disturbances, and evidence of sustainability—though climate change is affecting the concept of "sustainability" worldwide (Harris et al. 2006). There has been considerable debate among ecologists about the relative merits of the term "natural" vs. "historical" in describing reference ecosystems, with some authors objecting to the implication in "natural" of statis, normative value, and linear successional trajectories (a detailed discussion is available in Stephenson 1999). Resolution of this question is not within the scope of this review but here we use "natural," first because reference ecosystems are not only found in the historical past but also in modern times, such as remote or protected areas, and second because the implicit link to specific time periods in the term "historical" tends to understate the evolutionary lineage of ecological attributes. For example, the differing fire-related adaptations of surface-fire adapted *Pinus ponderosa* (thick bark, large buds, resilience to canopy scorch) vs. crown-fire adapted *Pinus contorta* (serotinous cones, thin bark) did not separate from common ancestors in the past few centuries but rather over millions of years of selection under different fuel, weather, and ignition environments (Axelrod 1986, Keeley and Zedler 1998), supporting the assertion that the respective fire regimes associated with these species can be described as natural. In any event, studies reviewed in this exercise will include restoration goals stated with either or both of these terms.

Many practical fuel treatments have been developed outside the specific framework of "ecological restoration," but still with strong consideration of reference conditions. A key example is the USA-wide research program called "Fire/Fire Surrogates" (FFS) (Youngblood et al. 2005). A "fire surrogate" is a treatment designed to reduce fuels without using fire, because of the costs, risks, and externalities of fire use. Examples include thinning-only or thinning plus fuel mastication. The other FFS treatments usually include fire-only and fire + thinning. Research from these experimental sites includes assessment of effects on fire behaviour (e.g., Stephens and Moghaddas 2005) as well as related studies on other ecological implications of the treatments (Metlen et al. 2004). Treatments to reduce fuels or alter fire behaviour have also been designed with no attention or resemblance to reference ecosystems. For example, clearcutting of broad firebreaks was a common, albeit often ineffective and ecologically damaging, forestry practice to interrupt fuel continuity (Agee et al. 2000). These sorts of treatments are now uncommon in the western USA and will not be considered in this review.

Testing treatment effectiveness in restoring natural fire behaviour is not entirely amenable to direct experimentation. Numerous studies have shown that treated sites can be burned safely and effectively with prescribed fire (e.g., Sackett et al. 1996, Stephens and Moghaddas 2005), but it is not possible to deliberately ignite severe experimental fires in treated ponderosa pine forests. Two alternative methods of research, both included in this review, are simulation modelling of fire behaviour (e.g., Scott 1998, Stephens 1998, Fiedler et al. 2002) and retrospective observational studies evaluating the behaviour of severe wildfires that burned through treated and paired untreated forests (e.g., Pollett and Omi 2002, Cram and Baker 2003, Martinson and Omi 2003, Finney et al. 2005).

Literature reviews have not kept pace with the growing body of literature in the field and there are no systematic reviews on the topic. Existing reviews have examined specific aspects of the effectiveness of forest treatments. For example, Fernandes and Botelho (2003) sought to review the effectiveness of prescribed burning treatments. Graham et al. (2004) integrated silvicultural and fire behaviour concepts to develop treatment recommendations. Agee and Skinner (2005) drew upon the literature to standardize concepts and terminology associated with fuel reduction. The most recent and thorough review was published by Hunter et al. (2007), which took a broad approach to synthesis of the literature in support of developing guidelines for forest treatments. Hunter et al. (2007) included the topics of treatment effects on fire behaviour and the relationship between ecological restoration and other fuel treatments, but these themes comprised a small fraction of the report (2 of 75 pages). The systematic review proposed here will be a useful synthesis of the literature because of the comprehensive systematic methodology, the direct focus on fire behaviour, the limitation to ponderosa pine and related species, and the explicit consideration of ecological restoration principles.

2. OBJECTIVE OF THE REVIEW

2.1 Primary question

Do thinning and/or burning treatments on ponderosa pine and related forests in western USA produce restoration of natural fire behaviour?

2.2 Secondary question *(if applicable)*

Potential secondary questions could be: What is the functional relationship between the variables and fire behaviour? How might relationships differ among pure ponderosa pine forests versus related forests (Jeffrey pine, dry mixed conifer, ecotonal ponderosa forests)? How might regional variability (Southwest, central Rockies, Black Hills, northern Rockies, Sierra Nevada, northern Mexico) affect restoration methods and outcomes?

3. METHODS

3.1 Search strategy

- Internet search engines and databases supported by Cline Library, Northern Arizona University: Ingenta, Forest Science Database (Ovid), JSTOR, Google Scholar.
- U.S. government databases (U.S. Department of Agriculture, Forest Service publications and proceedings)
- Libraries at universities with Forestry programs (M.S. and Ph.D. theses).

Search terms to include: western forests AND fuels treatments, fuels treatments AND ponderosa pine, fuels treatments AND Jeffrey pine, fuels treatments AND mixed conifer, thinning AND ponderosa pine, thinning AND Jeffrey pine, thinning AND mixed conifer, burning AND ponderosa pine, burning AND Jeffrey pine, burning AND mixed conifer, fire behaviour AND ponderosa pine, fire behaviour AND Jeffrey pine, fire behaviour AND mixed conifer. Searches will be conducted on both the common names ("ponderosa pine") and scientific names ("*Pinus ponderosa*") of the species.

3.2 Study inclusion criteria

- **Relevant subject(s):** coniferous forests dominated by ponderosa pine (*Pinus ponderosa*), Jeffrey pine (*Pinus jeffreyi*), or dry mixed conifer forests dominated by one of these pine species but also containing firs (*Abies* spp.), Douglas-fir (*Pseudotsuga menzieseii*), other pine species (e.g., *Pinus lambertiana*, *Pinus coulteri*) and aspen (*Populus tremuloides*).
- **Timeframe:** studies from 1970-present will be included, but references that appear in the literature to relevant earlier research will be tracked down.
- **Types of intervention:**
    - Thin only
    - Burn only (prescribed fire and/or wildland fire use)
    - Thin and burn
    - Season of burning
- **Types of comparator:**
    - Replicated randomized experiments
    - Before-after control-impact (BACI) studies
    - Observational studies
    - Expert opinion
- **Types of outcome:** Forest stand and fire behaviour modelling variables
    - Crowning index based on fire behaviour models
    - Torching index based on fire behaviour models
    - Canopy bulk density
    - Canopy base height
    - Tree density
    - Basal area
    - Species composition
    - Diameter distribution
    - Forest biomass
    - Actual fire behaviour
- **Types of study:**

Studies investigating actual or predicted crown fire response to actual or simulated thinning and/or burning treatments.

- **Potential reasons for heterogeneity:**

There is heterogeneity in the pine ecosystems distributed across a broad region of North America, both in terms of historic conditions prior to impacts from industrialized society and present conditions. This heterogeneity is associated with the latitudinal and elevational gradients where these forests occur and ecotones with adjacent ecosystems. There is also heterogeneity in the types of thinning and burning treatments and the characteristics of studies (experimental, observational, etc.).

3.3 Study quality assessment

Studies will be evaluated based on the types of methodology comparator, with the greatest weight given to replicated randomized experiments and less to observational and opinion studies.

3.4 Data extraction strategy

All studies included at full text will be read by two members of the review panel. We will assemble review information in a master spreadsheet, recording qualitative and quantitative aspects of the studies.

3.5 Data synthesis

Data synthesis will be done by the review panel after reading the studies. We will assemble basic data about the studies reviewed (e.g., number of studies identified in the search, number and percent deemed relevant for review, distribution of geographic locations and information type). We will focus on evidence from literature regarding the specific outcome variables. These will probably be grouped into a few categories: forest structure (density, diameter distribution, biomass, and basal area), species composition, canopy fuels (canopy bulk density and base height), predicted fire behaviour (crowning and torching indices), and actual fire behaviour. We will draw inferences about the similar and different effects of treatments and highlight areas where further research is needed.

4. POTENTIAL CONFLICTS OF INTEREST AND SOURCES OF SUPPORT

The review is led by researchers from Northern Arizona University who have contributed to the literature on this topic. We will address the possibility of conflict of interest by broadening the review panel to include scientists from other institutions and regions. Another independent check is the review process through CEBC and additional reviews solicited from scientists who are not on the review panel and not affiliated with Northern Arizona University.

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5. REFERENCES

Agee, J.K., B. Bahro, M.A. Finney, P. Omi, D.B. Sapsis, C.N. Skinner, J.W. van Wagtendonk, C.P. Weatherspoon. 2000. The use of shaded fuelbreaks in landscape fire management. Forest Ecology and Management 127:55-66.

Agee, J.K., and C.N. Skinner. 2005. Basic principles of forest fuel reduction treatments. Forest Ecology and Management 211:83-96.

Allen, C.D., D.A. Falk, M. Hoffman, J. Klingel, P. Morgan, M. Savage, T. Schulke, P. Stacey, K. Suckling, and T.W. Swetnam. 2002. Ecological restoration of southwestern ponderosa pine ecosystems: A broad framework. Ecological Applications 12:1418-1433.

Axelrod, D.I. 1986. Cenozoic history of some western American pines. Ann. Missouri Bot. Gard. 73:565-641.

Breshears, D.D., N.S. Cobb, P.M. Rich, K.P. Price, C.D. Allen, R.G. Balice, W.H. Romme, J.H. Kastens, M.L. Floyd, J. Belnap, J.J. Anderson, O.B. Myers, and C.W. Meyerd. 2005. Regional vegetation die-off in response to global-change-type drought. PNAS 102:15144-15148.

Brown, P.M., and B. Cook. 2006. Early settlement forest structure in the Black Hills ponderosa pine forests. For. Ecol. Manag. 223: 284-290.

Cooper, C.F. 1960. Changes in vegetation, structure, and growth of southwestern pine forests since white settlement. Ecology 42:493-499.

Covington, W.W., P.Z. Fulé, M.M. Moore, S.C. Hart, T.E. Kolb, J.N. Mast, S.S. Sackett, and M.R. Wagner. 1997. Restoration of ecosystem health in southwestern ponderosa pine forests. Journal of Forestry 95: 23-29.

Cram D.S., and T.T. Baker. 2003. 'Annual report: Inventory and classification of wildland fire effects in silviculturally treated vs. untreated forest stands of New Mexico and Arizona.' College of Agriculture and Home Economics, New Mexico State University. (Las Cruces, NM).

Fernandes, P.M., and H.S. Botelho. 2003. A review of prescribed burning effectiveness in fire hazard reduction. International Journal of Wildland Fire 12:117 – 128.

Fiedler, C. E., C. E. Keegan, III, S. H. Robertson, T. A. Morgan, C. W. Woodall, and J. T. Chmelik. 2002. A strategic assessment of fire hazard in New Mexico. Final report to the Joint Fire Science Program, Boise, Idaho.

Finney, M.A., C.W. McHugh, and I.C.Grenfell. 2005 Stand- and landscape-level effects of prescribed burning on two Arizona wildfires. Canadian Journal of Forest Research 35:1714-1722.

Graham, R.T., S. McCaffrey, and T.B. Jain. 2004. Science basis for changing forest structure to modify wildfire behaviour and severity. Gen. Tech. Rep. RMRS-GTR-120. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 43 p.

Harris, J.A., R. J. Hobbs, E. Higgs, and J. Aronson. 2006. Ecological restoration and global climate change. Restoration Ecology 14:170–176

Hunter, M.E., W.D. Shepperd, J.E. Lentile, J.E. Lundquist, M.G. Andreu, J.L. Butler, and F.W. Smith. 2007. A comprehensive guide to fuels treatment practices for ponderosa pine in the Black Hills, Colorado Front Range, and Southwest. Gen. Tech. Rep. RMRS-GTR-198. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 93 p.

Keeley, J.E. 2006. Fire management impacts on invasive plants in the western United States. Conservation Biology 20: 375-384.

Keeley, J.E., and P.H. Zedler. 1998. Evolution of life histories in *Pinus*. Pages 219-250 in: Ecology and biogeography of *Pinus*. Ed. D.M. Richardson. Cambridge, UK: Cambridge University Press.

Leone, V., and R. Lovreglio. 2004. Conservation of Mediterranean pine woodlands: scenarios and legislative tools. Plant Ecology 171:221-235.

Leopold, A. 1924. Grass, brush, timber, and fire in southern Arizona. Journal of Forestry 22: 1-10.

Leopold, A. 1937. Conservationist in Mexico. American Forests 37: 118-120, 146.

Lindenmuth, A.W. 1960. A survey of the effects of intentional burning on fuels and timber stands of ponderosa pine in Arizona. Sta. Pap. No. 54. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 22 p.Martinson EJ, Omi PN (2003) 'Performance of fuel treatments subjected to wildfires.' USDA Forest Service, Rocky Mountain Research Station Proceedings RMRS-P-29. (Fort Collins, CO)

Meine, C., D. Egan, and E.A. Howell (eds.). 2005. The Historical Ecology Handbook: A Restorationist's Guide to Reference Ecosystems. Island Press, Covelo, CA.

Metlen, K. L., C.E. Fiedler, and A. Youngblood. 2004. Understory response to fuel reduction treatments in the Blue Mountains of Northeastern Oregon. Northwest Science 78: 175-185.

Miller, C., and D. L. Urban. 2000. Modeling the effects of fire management alternatives on Sierra Nevada mixed-conifer forests. Ecological Applications 10:85-94.

Minnich, R.A., M.G. Barbour, J.H. Burk, and R.F. Fernau. 1995. Sixty years of change in Californian conifer forests of the San Bernadino Mountains. Conservation Biology 9:902-914.

Moody, J.A., and D.A. Martin. 2001. Initial hydrologic and geomorphic response following a wildfire in the Colorado Front Range: Earth Surface Processes and Landforms. 26: 1049-1070.

Pausas, J.G. 2004. Changes in fire and climate in the eastern Iberian Peninsula (Mediterranean Basin). Climatic Change 63:337-350.

Pierce J., and G. Meyer. 2008. Long-term fire history from alluvial fan sediments: the role of drought and climate variability, and implications for management of Rocky Mountain forests. International Journal of Wildland Fire 17:84–95.

Pollet J., and P.N. Omi. 2002. Effect of thinning and prescribed burning on crown fire severity in ponderosa pine forests. International Journal of Wildland Fire 11:1-10.

Rollins, M.G., T.W. Swetnam, and P. Morgan. 2001. Evaluating a century of fire patterns in two Rocky Mountain wilderness areas using digital fire atlases. Canadian Journal of Forest Research 31:2107-2123.

Sackett, S.S., S.M. Haase, and M.G. Harrington. 1996. Lessons learned from fire use for restoring southwestern ponderosa pine ecosystems. Pages 53-60 in W. W. Covington and P. K. Wagner, technical coordinators, USDA Forest Service General Technical Report RM-GTR-278, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Savage, M., and J.N. Mast. 2005. How resilient are southwestern ponderosa pine forests after crown fires? Canadian Journal of Forest Research 35:967-977.

Sherriff, R.L., and T.T. Veblen. 2007. A spatially-explicit reconstruction of historical fire occurrence in the ponderosa pine zone of the Colorado Front Range. Ecosystems 10:311-323.

Stephens, S.L. 1998. Evaluation of the effects of silvicultural and fuels treatment on potential fire behavior in Sierra Nevada mixed-conifer forests. Forest Ecology and Management 105:21-35.

Stephens, S.L., and J.J. Modhaddas. 2005. Experimental fuel treatment impacts on forest structure, potential fire behavior, and predicted tree mortality in a California mixed conifer forest. Forest Ecology and Management 215:21-36.

Stephens, S.L., and L.W. Ruth. 2005. Federal forest-fire policy in the United States. Ecological Applications 15:532-542.

Stephenson, N. L. 1999. Reference conditions for giant sequoia forest restoration: structure, process, and precision. Ecological Applications 9:1253-1265.

Sweeney, J.R., and H.H. Biswell. 1961. Quantitative studies of the removal of litter and duff by fire under controlled conditions. Ecology 42:572-575.

Weaver, H. 1943. Fire as an ecological and silvicultural factor in the ponderosa pine region of the Pacific Slope. Journal of Forestry 41:7-15.

Weaver, H. (1951) Fire as an ecological factor in the southwestern ponderosa pine forests. Journal of Forestry, 49, 93-98.

Westerling, A.L., H.G. Hidalgo, D.R. Cayan, and T.W. Swetnam. 2006. Warming and earlier spring increase western U.S. forest wildfire activity. Science 313:940-943.

Youngblood, A., K. L. Metlen, E.E. Knapp, K.W. Outcalt, S.L. Stephens, T.A. Waldrop, and D. Yaussy. 2005. Implementation of the Fire and Fire Surrogate study—a national research effort to evaluate the consequences of fuel reduction treatments. Balancing Ecosystem Values Proceedings, Fire and Fire Surrogates. USDA Forest Service.