Restoration of dry, montane meadows through prescribed fire, vegetation and fuels management: A program of research and adaptive management in western Oregon

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Final Report to the Joint Fire Science Program

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Executive Summary

Mountain meadows in the Pacific Northwest, as in much of western North America, have experienced recent and rapid invasion by conifers. Changes in climate, cessation of sheep grazing, and long-term suppression of wildfire likely contribute to the observed replacement of meadow by forest. Faced by gradual loss of these habitats, land managers in the western Cascades of Oregon are using tree removal and prescribed burning as tools for restoration. However, these efforts have been undertaken with limited understanding of the historical role of fire in these meadow ecosystems, of the range of current vegetation conditions, and of the potential for restoration.

Through a collaborative effort of the research community and the Willamette National Forest in western Oregon, we have developed a program of research, education, and outreach at Bunchgrass Ridge — a complex of dry, montane meadows and coniferous forests of varying age and structure.

We have designed our research as an integrated series of observational field studies and experiments. Through retrospective analyses we explore the history of conifer encroachment — covering nearly two centuries of invasion — and its consequences for vegetation change. These provide the historical and ecological contexts for a large-scale experiment that addresses the following questions: (1) Is restoration of dry, montane meadows possible with tree removal and prescribed burning? (2) Is fire necessary for restoration or is tree removal sufficient? (3) Does the potential for restoration depend on the stage of conifer encroachment? (4) How do our experimental results bear on operational alternatives?

Retrospective Studies: Ecology and Dynamics of Montane Meadows

Detailed reconstructions of forest age structures at Bunchgrass Ridge provide insight into the timing and spatial patterning of invasion, the importance of facilitation and positive feedbacks in driving this process, and the consequences of tree encroachment for loss of meadow diversity and extent.

- Lodgepole pine and grand fir have established in meadows at Bunchgrass Ridge during two broad intervals that span nearly two centuries. Most invasion has occurred adjacent to existing edges, but occasional establishment in open meadow has led to new foci for expansion. Spatial-pattern analysis suggests that facilitation may drive the conversion of meadow to forest as early recruits (often lodgepole pine) modify the local environment for subsequent establishment (typically grand fir). This result underscores the importance of biological processes — in addition to the well-appreciated roles of climate and fire — in the dynamics of these systems. It also suggests that positive feedbacks can allow for invasion of meadow at times when climate might otherwise be unfavorable for tree establishment.
- Tree establishment is accompanied by rapid changes in ground vegetation. These reflect two simultaneous processes: displacement of meadow species and colonization by forest herbs. Both occur rapidly: within 60-80 yr of initial tree establishment, the understory is dominated by forest plants.
- Lodgepole pine and grand fir differ markedly in their facilitation of forest herbs. Under grand fir, abundance and richness of forest herbs are positively related to tree age (and

size). Under pine, there is no direct effect of age. Instead the effect of pine on understory vegetation appears to be indirect, i.e., through its facilitation of grand fir.

- Rapid replacement of meadow by forest species, as well as modification of soil chemical and biological properties by conifers, may pose barriers to restoration of these systems. Our results suggest that removing grand fir (of any age) should be a higher priority than removing pine. Clearly, however, removing trees during the earliest stages of encroachment is the most effective strategy for maintaining these systems.
- Studies of the soil seed bank suggest a limited potential for reintroduction or recovery of most meadow species via buried, viable seed. Nearly three-quarters of the species that characterize these meadows are absent from the seed bank. As a consequence, without further intervention, reestablishment of meadow species will require dispersal of seed, or gradual vegetative spread from adjacent openings. At the same time, seed banks are dominated by ruderal (early successional) grasses and herbs that may compete with target species during restoration efforts.

Experimental Studies: Restoration of Meadows by Tree Removal and Prescribed Burning

The experiment includes three replicates of three 1-ha (2.5 ac) treatments: (1) a control (no harvest), (2) tree removal with slash piled and burned (leaving most of the ground surface unburned), and (3) tree removal with the slash broadcast burned. Tree removal was conducted in winter on deep, compacted snow. Broadcast and pile burning were completed the following fall.

Replication and the untreated control enable us to make strong inferences about the effects of the restoration treatments across the backdrop of natural variation in vegetation composition in space and time. Treatments 2 and 3 allow us to test whether tree removal is sufficient to achieve restoration goals, or whether fire is also necessary. Within experimental units, a range of habitats, including areas with few trees, recent invasion (<75 yr), and older forest (95-200 yr) allows us to test whether potential for restoration depends on the stage of encroachment.

Delays in implementation of the experiment have limited initial post-treatment sampling to a single growing season. Nevertheless early results point to some striking differences in response among treatments, and to how these may be conditioned by pre-treatment forest structure. They also bear on some of the operational limitations and ecological consequences of alternative approaches to fuel reduction.

- Broadcast burning led to significant exposure of mineral soil and to increases N availability. In contrast, in the absence of fire, harvest over snow resulted in minimal soil disturbance. Similar outcomes would not have been possible if snow cover had not been present during yarding.
- Greater soil disturbance and short-term increases in N availability in broadcast burned treatments should promote greater establishment of ruderals. Surprisingly, however, in the first growing season, ruderals contributed minimally to the vegetation in either treatment, despite their prominence in the seed bank.
- Disposal of slash through pile burning represents a tradeoff between the extent and intensity of disturbance. Although burn scars covered only 10% of the ground surface their centers were characterized by significant exposure of mineral soil and

concentrations of NH_4^+-N, greatly exceeding those in broadcast burned treatments. Vegetation recovery may be problematic within burn scars; these intensely disturbed sites may also serve as foci for future invasion of weedy species.

- Gathering of slash in piles can be effective at reducing ground fuels, but hand piling can be labor intensive. At the same time, piles can be burned during late fall or early winter at a time when fire risk, as well as cost and effort associated with containment, is low. By comparison, weather conditions for broadcast burning are more restrictive, and fire containment requires greater effort and cost.
- In the short term, tree removal, with or without burning, appears to benefit meadow species at the expense of forest herbs. Changes in the abundance and diversity of meadow taxa were small relative to forested controls. In contrast, forest herbs declined significantly, particularly after burning, potentially allowing for future recruitment or spread of meadow species.
- Meadow species show potential for recovery across a wide range of forest structures. Even in old forest, where abundance and diversity of meadow species were low, responses to overstory removal and burning were neutral or positive. Persistence through disturbance, dramatic reductions in the abundance of forest herbs, and limited recruitment of ruderal species suggest potential for meadow recovery across a broad range of forest ages and structures.
- For taxa that have been lost from the system, long-term recovery will require reintroduction through seed dispersal or vegetative expansion from adjacent edges. In our system, these processes may be aided by the mosaic of residual meadow openings that occur among areas of encroachment. Focusing future restoration efforts along ecotonal areas or on small tree islands will maximize the potential for seed dispersal or vegetative spread.

Clearly, longer term observations are needed to determine whether tree removal and fire can be used to reverse the effects of encroachment, and the conditions under which restoration is possible. They may also suggest possible alternative approaches.

We see great potential for existing and future studies at Bunchgrass Ridge to inform the management and restoration of western Cascade meadows. We have invested heavily in education and outreach and expect these activities to expand as we learn more from these and additional studies.

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