



Fire exclusion and changes in climate and grazing pressure have led to rapid encroachment of mountain meadows by conifers throughout the Pacific Northwest. Faced by gradual loss of these unique habitats, land managers have begun to experiment with tree removal and prescribed fire as potential tools for restoration. Credit: James Lutz.

Restoring Mountain Meadows: Using Fire, Vegetation, and Fuel Management in Western Oregon

Summary

Meadows occupy a small percentage of the western Cascade landscape. Yet they sustain an abundance of species that do not exist in adjacent forests. These biologically rich habitats have been shrinking for more than a century as a result of conifer encroachment. Charlie Halpern, at the University of Washington, and his colleagues combined retrospective and experimental research to understand the consequences of encroachment for these ecosystems, and whether, and under what conditions, it was possible to restore meadows through tree removal and prescribed burning. Their initial results indicate that meadow species are replaced by forest herbs within decades of tree establishment and that early intervention may greatly aid restoration. However, they also found that tree removal, with or without burning, benefits meadow species at the expense of forest herbs, suggesting strong potential for restoration where meadow species still persist.

Key Findings

- Retrospective studies revealed that tree encroachment leads to rapid replacement of meadow species by forest herbs.
- Seventy-five percent of the species that characterize these meadows are absent from the soil seed bank (the pool of buried, viable seeds), even in areas of open meadow.
- In the short term, tree removal, with or without burning, appears to benefit meadow species at the expense of forest herbs. Changes in the diversity and abundance of meadow taxa were no greater one year after tree removal (with or without burning) than in untreated plots. However, forest herbs showed significant declines, particularly after burning, potentially facilitating future recruitment or spread of meadow species.
- Broadcast burning of logging slash led to significant exposure of mineral soil and to increased nitrogen availability—changes that may promote greater establishment of weedy species. In contrast, pile burning of slash resulted in minimal disturbance and only localized effects on soil properties.

Introduction

When considering the densely forested Cascade Mountains, open patchy meadows and other non-forested openings are not necessarily the first images that spring to mind. Yet this mountain landscape has its share of meadows enjoyed for their biological diversity, scenic vistas, and complex histories of human use. Montane meadows, embedded within the forest, are of particular interest and value as they harbor a diverse flora and fauna that would otherwise not exist in this landscape. In the Pacific Northwest, writes Jonathan Thompson, these meadows "...are patches of remarkable biological diversity. Lush, forb-, grass-, and shrub-dominated communities attract rich assemblages of arthropods, support diverse communities of birds, and provide habitat for small mammals and other wildlife." But meadows in many areas of the western United States are also shrinking with the expansion of forests, and as they do, so are the habitats that support this diversity.

Charlie Halpern is a plant ecologist at the University of Washington. He notes, "considerable research has been devoted to the causes of tree encroachment into meadows in this region: changes in climate, cessation of sheep grazing, and long-term fire exclusion have contributed to loss of meadows. In contrast, little is known about the *consequences* of tree invasion for meadow composition and structure. By understanding the time course over which these changes occur, we hope to provide managers with information that can be used to assess the potential for restoration or maintenance of these unique habitats."

He says, "Managers are interested in slowing or reversing these trends, but there is great uncertainty about the potential for restoration and what management tools might best achieve that goal."

Halpern and his colleagues, Fred Swanson (with the Pacific Northwest [PNW] Research Station, Corvallis), and John Cissel (originally with the Willamette National Forest, now with the Joint Fire Science Program, Boise), joined with staff of the McKenzie River Ranger District, Willamette National Forest to focus their efforts at Bunchgrass Ridge, a system of grass- and forb-dominated meadows that has been invaded by lodgepole pine and grand fir for nearly two centuries.

The team undertook a series of retrospective studies and an experiment designed to unravel the history of encroachment, its consequences for biological diversity, and the potential for restoration of meadow habitats. Their goals according to their Joint Fire Science Program (JFSP) final report were, "to improve understanding of the ecology and dynamics of mountain meadows in this region, and to assist land managers in designing strategies for meadow restoration and maintenance."

The experiment, outlined in the report, was designed to address 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?"

Meadows across time: A landscape perspective

Fred Swanson is a co-author on the JFSP final report. He and visiting Japanese scientist, Sadao Takaoka, have studied the tendencies for meadows in this region to remain stable over time or to experience encroachment. They examined a 135-square mile portion of the western Cascade landscape using aerial photographs from 1946 and 2000, and combined this with tree-ring analysis to delve deeper into the past to document changes in the extent of open areas of several types. They found that the proportion of "non-forested" areas declined from 5.5 percent of the study area in 1946 to only 2.5 percent in 2000. Swanson says, "Our most important insight is that some types of openings—xeric meadows in particular—are very stable, while others—the moister, more fertile types—are more prone to encroachment." Takaoka and Swanson suggest that this information can be useful to managers in setting priorities for meadow restoration or maintenance.

In hindsight: Looking back while moving ahead

The study site, Bunchgrass Ridge, forms a broad, gently sloping plateau and is designated a Special Habitat

Area by the Willamette National Forest targeted as a high priority for restoration. A mosaic of montane meadows and coniferous forests of varying age distributed over an area of 250 acres makes Bunchgrass an ideal system for studying the history and dynamics of tree encroachment and for testing methods of restoration.

Halpern says, “There are two components to our work: retrospective studies of vegetation change and the experiment itself. We began by looking back in time to reconstruct the timing and spatial patterning of conifer encroachment and how these have led to changes in the vegetation. Within this context, we could then design an experiment that explored the potential for restoration.”

“Our retrospective studies are based on a ‘chronosequence’ approach, allowing us to infer from forests of differing age, the changes in structure and composition that have occurred over long periods of time. We sampled hundreds of plots in which all trees were measured, spatially mapped, and aged. From these plots we were able to reconstruct nearly two centuries of encroachment.”

Ryan Haugo, a Masters student working with Halpern, took advantage of this chronosequence to study changes in the ground vegetation as meadows are gradually replaced by forest. In each of more than 350 plots, he and his assistants sampled the abundance and diversity of meadow and forest species.



Examples from the chronosequence: (left) recent invasion, (middle) young (less than 90 years old) forest, and (right) old (greater than 90 years old) forest. Credit: Charlie Halpern.

Meanwhile, Nicki Lang, another Masters student, used the same chronosequence to study changes in the below-ground community of buried, viable seeds. She was interested in whether meadow species retain a seed bank despite being lost from the above-ground vegetation. The answer to this question would have important implications for restoration. Lang removed hundreds of soil samples from different stages of the chronosequence, spread them in germination flats in the greenhouse, watered them, and recorded what emerged over the next 7 months. Halpern says, “It was a like a treasure hunt, seeing what emerged from those flats and wondering whether this might be a viable route to restoration.”

By comparing forest age and structural characteristics with vegetation composition, Haugo was able to document remarkably strong and consistent trends in the ground vegetation with forest encroachment. He observed rapid

declines in the abundance and diversity of meadow species and synchronous establishment of forest herbs that dispersed from adjacent stands and flourished beneath the developing canopy. This occurred within decades. “Haugo’s work has clear implications for managers,” says Halpern. “The most effective strategy for maintaining or restoring these meadows is one that targets tree removal early in the process of encroachment, before meadow species are lost from the system. At later stages, managers may be faced by a number of challenges.”

Lang’s studies of the seed bank point to two of those challenges. Nearly 75 percent of the species that characterize these dry, montane meadows were absent from the soil seed bank—even in areas of open meadow. However, this is not uncommon in grassland ecosystems; typically the seed bank differs considerably from the vegetation above ground. And, similar to seed banks in many ecosystems, those at Bunchgrass were dominated by weedy species typical of disturbed sites. “Lang’s findings point to two potential barriers to restoration,” says Halpern. “We can’t expect the vast majority of meadow species to reemerge from the soil after tree removal—seed dispersal from adjacent meadows will be necessary. And, restoration activities that expose or heat the mineral soil may stimulate a flush of weedy forbs that can compete with the species of interest.”

Playing with fire: To burn or not to burn

Was it feasible to restore meadows simply by removing trees? Or would application of fire also be necessary? Would responses to tree removal and fire depend on the length of time that forest had been present, and thus the degree to which trees had modified the vegetation and soils?

Halpern points out that “at these elevations in the western Cascades, fire is not a frequent agent of disturbance. Historically, fires may have occurred every 100 years or more, although it is not clear to what extent Native Americans used fire to maintain these open habitats.”

Three treatments, replicated three times each on 2.5 acre plots, included (1) a control (no harvest), (2) trees removed with the resulting slash piled and burned (leaving most of the ground surface unburned), and (3) trees removed with the slash broadcast burned.



Aerial view of Bunchgrass Ridge one day after broadcast burning. Slash piles visible in adjacent pile and burn units were treated subsequently. Credit: Sam Swetland.

Each experimental unit included the variety of vegetation structures (open meadows to old forests) examined in the chronosequence. Thus, according to the report, “a range of habitats (were present) including areas with few trees, recent invasion (less than 75 years), and older forest (95–200 years) (that) allow(ed) us to test whether potential for restoration depends on the stage of encroachment.”

“An important management goal was to minimize soil disturbance during harvest,” says Halpern. “At higher elevations in the montane zone it is possible to yard trees on snow provided that depth and compaction are sufficient. Unfortunately, plans to harvest in winter 2005 were thwarted by lack of a snowpack. Winter was more cooperative in 2006 and trees were felled and yarded on a deep, compacted layer of snow.”



Felling and yarding were done on snow to minimize soil disturbance. Credit: Tevia White.

Residual slash settled to the ground as snow melted that spring. It was either left in place in the broadcast burn treatments or hand piled. After a summer of curing, fuels were broadcast burned in late September, aided by a system of fire lines and hoses. Slash piles were burned in November at the onset of fall rains, when risk of fire spread was low. “For both treatments, fuel and weather conditions were ideal and implementation was excellent,” says Halpern. “We owe much to the skills and dedication of our collaborators on the Willamette National Forest.”



The two fuel-reduction treatments: (left) broadcast burn and (right) pile and burn. Credit: (left) Charlie Halpern and (right) Sam Swetland.

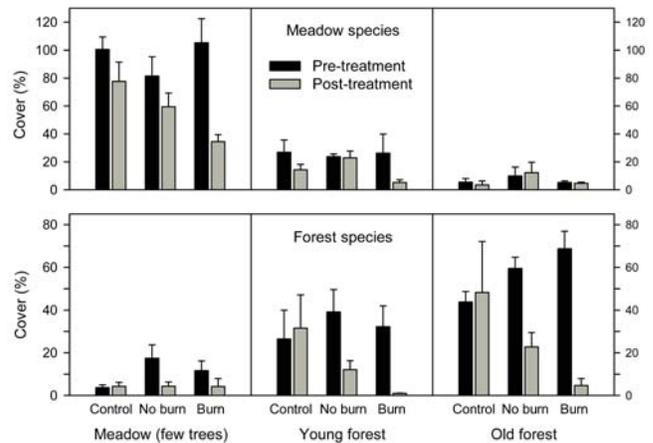
Can you remove trees, add fire, and restore meadow?

“We completed our first set of post-treatment measurements in 2007,” says Halpern. “Naturally, longer term observations are needed to answer our questions, but even in the short term we have seen some very interesting and potentially promising results.”

“The short story is that broadcast burning resulted in significant exposure of mineral soil, elevated levels of nitrogen, and greater colonization of tree seedlings,” says Halpern. “In contrast, the pile and burn treatments experienced little soil disturbance and no detectable effect on soil chemistry, except for small areas within the burn scars.”

“In comparing the responses of meadow and forest understory species, tree removal, whether or not it is followed by burning, appears to benefit meadow species at the expense of forest herbs,” says Halpern.

This last result is potentially good news for managers. Forest understory plants, which prefer shaded environments, are at a disadvantage after tree removal, while sun-loving meadow species can capitalize on increased light, if they have not been lost from the system.



Changes in abundance of meadow and forest species in plots representing different stages of encroachment: meadow, young forest, and old forest.

Despite significant alteration of soil properties in the broadcast burned treatments (and in the burn piles), the team was surprised to find that weedy species were uncommon. This was unexpected given their prominence in the seed bank. This, too, may be good news for managers, although continued monitoring is needed to determine what role these wind-dispersed species will play in the future. The scars left by burn piles in particular, may serve as foci for future invasion and subsequent spread into the adjacent vegetation.



A burn-pile scar one growing season after treatment. Credit: Charlie Halpern.

Clearly, there are tradeoffs in disposing of slash via broadcast versus pile burning. Creating slash piles is labor intensive, hence expensive, but burning can occur when the risk of fire spread is low. Broadcast burning does not require redistribution of fuels, but conditions for successful burning are more restrictive and less predictable. Yet, an important take-home message from the early results of this experiment is that, regardless of the type of fuel treatment, meadow species preferentially benefit from removal of trees.

Western Cascade meadows possess an ecological vitality and a unique flora and fauna that are at risk to the pressures of forest expansion.

Western Cascade meadows possess an ecological vitality and a unique flora and fauna that are at risk to the pressures of forest expansion. Even during the earliest stages of encroachment, meadow species begin to lose ground to the forest.

However, the results of this study suggest that restoration efforts may yield positive results. According to the JFSP final report, “Meadow species show potential for recovery across a wide range of forest structures. Even in older forest where abundance and diversity of meadow species were low, responses to overstory removal and burning were neutral or positive.” The report goes on to say that, “Persistence through disturbance, dramatic reductions in the abundance of forest herbs, and limited recruitment of (weedy) species suggest potential for meadow recovery across a broad range of forest ages and structures.”

Still, says Halpern, “These systems have inertia. Once conifers have been present for several decades—long enough to modify vegetation and soils—there is high likelihood of continued recruitment of seedlings, even after the overstory is removed. This may require that managers are prepared to make repeated entries to remove seedlings.”

The team’s work has also led to a broader program of research, education, and outreach centered at Bunchgrass Ridge and extending to other meadows in the western Cascades. “Through these associations, we have been able to undertake a much larger program of research, training, and education than would have been possible with JFSP funding alone,” notes Halpern (see project website: <http://depts.washington.edu/bgridge/>).

Research at Bunchgrass Ridge has, and will continue to provide novel insights into the ecology, dynamics, and restoration of mountain meadows in the Pacific Northwest. Halpern concludes, “We see tremendous potential for studies at Bunchgrass to inform the management of these highly valued ecosystems—similar experiments have not been attempted elsewhere. Future observations may confirm the results of our initial measurements...or they may lead to new surprises.”

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Management Implications

- The most effective strategy for conservation and maintenance of montane meadow habitats is one that targets tree removal during the earliest stages of encroachment. At later stages, restoration may be hindered by a variety of factors: loss of meadow species from the vegetation, absence of meadow species from the soil seed bank, and changes in soil properties that facilitate recruitment of tree seedlings.
- In the short term, meadow species show the potential for recovery across a wide range of pre-treatment forest structures, with or without the use of fire.
- For meadow taxa that have been lost from these systems, long-term recovery will require reintroduction through seed dispersal or vegetative expansion from adjacent edges. Focusing restoration efforts along forest-meadow boundaries or on small tree islands will maximize the potential for dispersal or vegetative spread.

Further Information: Publications and Web Resources

- Bunchgrass Ridge: Restoration of montane meadows in western Oregon: A center for research and adaptive management. Project website: <http://depts.washington.edu/bgridge/>
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Scientist Profiles

Charlie Halpern is a Research Professor at the School of Forest Resources, College of the Environment, University of Washington. His research interests include the successional development of forest communities, vegetation responses to forest management, and the ecology and dynamics of montane and subalpine meadows. He has been conducting long-term studies at the H.J. Andrews Experimental Forest Long-term Ecological Research (LTER) Site since 1980, and is a Principal Investigator in the Demonstration of Ecosystems Management Options (DEMO) experiment, a regional study of structural-retention harvest in the Pacific Northwest (<http://www.fs.fed.us/pnw/rmp/demo/>). He received his Ph.D. from Oregon State University (1987) and his B.S. from Cornell University (1980).



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The information in this Brief is written from JFSP Project Number 01C-3-3-10, which is available at www.firescience.gov.

An Interagency Research, Development, and Applications Partnership



JFSP *Fire Science Brief*
is published monthly.
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