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# Science

## FINDINGS

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*“Science affects the way we think together.”*

Lewis Thomas

## MOUNTAIN MEADOWS—HERE TODAY, GONE TOMORROW? MEADOW SCIENCE AND RESTORATION



James A. Lutz

*Conifer invasions into meadows sometimes take the form of tree islands.*

*“How does the meadow flower  
its bloom unfold? Because  
the lovely little flower is  
free down to its root, and  
in that freedom bold.”*

—William Wordsworth

If you’ve spent any time hiking in Oregon’s western Cascades, there’s a good chance that you’ve found your way up to a mountain meadow. In total area, meadows occupy a fraction of the landscape. But their beauty and stark contrast with the surrounding forest make them favorite destinations. One only needs to step from a tunnel of dense conifers to a bright oasis of grasses and wildflowers to know that

mountain meadows are precious patches of diversity, havens of distinction.

Ecologists are quick to confirm that instinct: Cascade meadows are biological hotspots. They are home to unique communities of plants that cannot survive under the forest canopy. Deer and elk depend on them for forage. Predatory birds, unimpeded by trees, use meadows as hunting grounds. And a diversity of butterflies, moths, and insects rely on meadow flowers for pollen and nectar.

The trouble is, through much of the Northwest, montane meadows—those at elevations where snowpack is not deep or persistent—are slowly giving way to forest in a phenomenon referred to as “conifer

## IN SUMMARY

*Mountain meadows in the Pacific Northwest 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. Recent encroachment by conifers has reduced the extent and ecological integrity of meadows, with consequences for their biota, scenic values, and recreational use. Using a diversity of approaches, researchers and managers are attempting to unravel the causes and consequences of encroachment and the potential for maintaining or restoring these important habitats.*

*Using historical aerial photography, researchers at the PNW Research Station laboratory in Corvallis, Oregon, performed retrospective analyses of meadow extent in a portion of the western Cascades. They found that half of the nonforested areas present in 1946 now support conifers, particularly where fire occurred in adjacent forest during the previous century. Counts of annual growth rings from trees in similar meadows of the Three Sisters Wilderness revealed that the timing of meadow contraction was closely tied to removal of grazing sheep and to the onset of wetter summers during the mid-1900s. A large-scale experiment at Bunchgrass Ridge in the Willamette National Forest is testing different methods of meadow restoration to understand whether fire is necessary and the conditions under which restoration is possible.*

encroachment.” Increasingly, meadows that were open throughout recent memory are filling with conifers. Trees are either marching in waves from the forest edge or are forming tree islands that gradually coalesce.

“In some cases, we see mature or old-growth forest that abuts a meadow. Here we assume the edge has been stable for centuries and that one or more processes are prohibiting encroachment,” says Fred Swanson, a researcher at the PNW Laboratory in Corvallis, Oregon. “Elsewhere, younger trees are found along an edge, suggesting that conditions have changed to allow for encroachment. We know that forests and meadows have formed a shifting mosaic over the centuries. However, recent encroachment appears more extensive and rapid than had occurred historically,” says Swanson.

This trend is troubling to natural resource managers.

In response to the gradual loss of this critical habitat, Swanson has been collaborating on several projects to study meadow ecology and to find ways to conserve or restore the meadows that remain. The work has begun to shed light on a scientifically neglected part of the landscape. “Nonforested systems have received much less study than have forests in this region,” says Swanson, who is in a position to know, having spent much of his career studying the ecology and dynamics of Cascade forests.

Charlie Halpern, a professor at the University of Washington, is one of Swanson’s primary collaborators. Together, they have taken a multi-pronged approach to attack different parts of the meadow-loss question.

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## KEY FINDINGS

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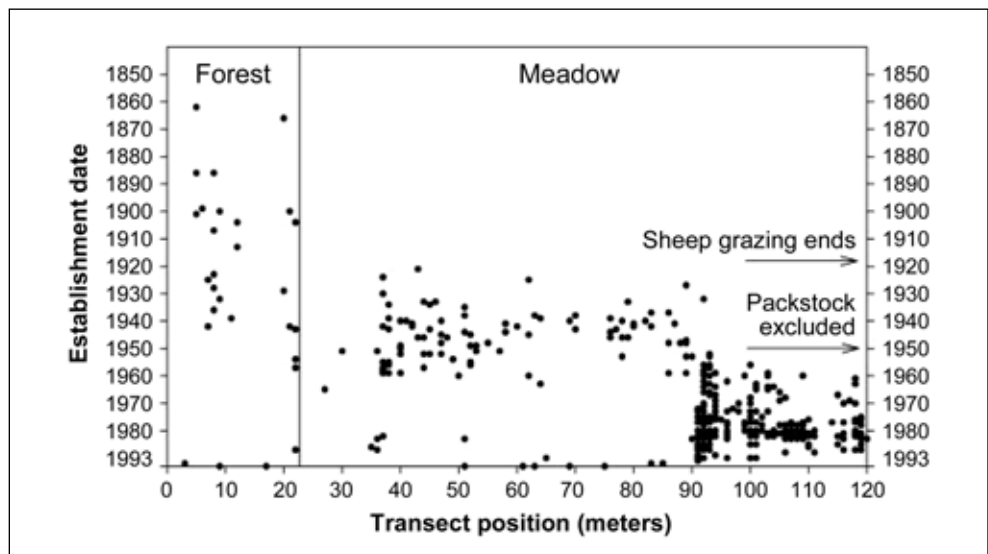
- From 1946 to 2000, meadows dominated by forbs had greater tendency to contract than did those dominated by shrubs. Furthermore, moist meadows were more likely to contract than were dry meadows. Contraction was also more common where meadow openings were adjacent to forest that experienced stand-replacing fire in the previous 150 years; it appears that fire can create forest openings that may take centuries to close.

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- In meadows of the Three Sisters Wilderness, conifer invasion was synchronous with the cessation of sheep grazing, and with the onset of cooler and wetter summers, suggesting that multiple factors may limit or promote tree establishment.

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- Within decades of conifer establishment, meadow species are largely replaced by herbs characteristic of the surrounding forest. Soil chemical and biological properties change rapidly as well, suggesting strong positive feedbacks between conifers and the below-ground ecosystem, facilitating further encroachment of trees.



Researchers measured the dates of tree establishment along a forest-to-meadow transect in the Three Sisters Wilderness, Oregon. Note the strong correspondence between timing of establishment and grazing history. Sheep grazing began about 1872, but the resulting damage to soils and vegetation led to closure of the allotment in about 1918. In 1910, the center of the meadow was fenced, and packstock associated with a backcountry guard station were allowed to graze until the station was abandoned in about 1950.

## THE WHERE AND WHY OF MEADOWS

In its most casual use, the term “meadow” is applied to all vegetated, but treeless, portions of an otherwise forested landscape. Given this loose definition, it is easy to imagine that meadows take many different forms and have diverse origins. Often, they occur where soils are too thin and dry to support trees—along ridgetops—or, where soils are permanently saturated—in poorly drained depressions, such as those found on landslide deposits and glacial landforms. These types of meadows are at low risk to conifer encroachment.

Meadows also occur in less extreme environments—on mesic or moist slopes, where soils are productive and well drained—conditions that typically support

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an abundance of trees. Understanding the processes that have maintained these types of meadows is a greater challenge.

Some may have originated with severe fire. And, it is commonly assumed that repeated burning, either through natural ignitions or the activities of Native Americans or sheepherders, kept them free of trees. “There is an assumption that fire burned through these

meadows periodically, killing any trees that had established, and maintaining open conditions indefinitely,” says Halpern. “Then, as this theory has it, once we began to suppress fire in the larger landscape, meadows lost ground to conifers.”

The idea that fire-suppression is the primary driver of meadow loss is widely held. But according to Halpern and Swanson, there are

limited data to support this conclusion. Adjacent forests burned infrequently—on the order of centuries—and the extent to which Native and early Euro-Americans used fire in these meadows is unknown. Moreover, fire may be intertwined with changes in climate and grazing history, making it difficult to identify specific causes of encroachment retrospectively.

## EVIDENCE OF CHANGE

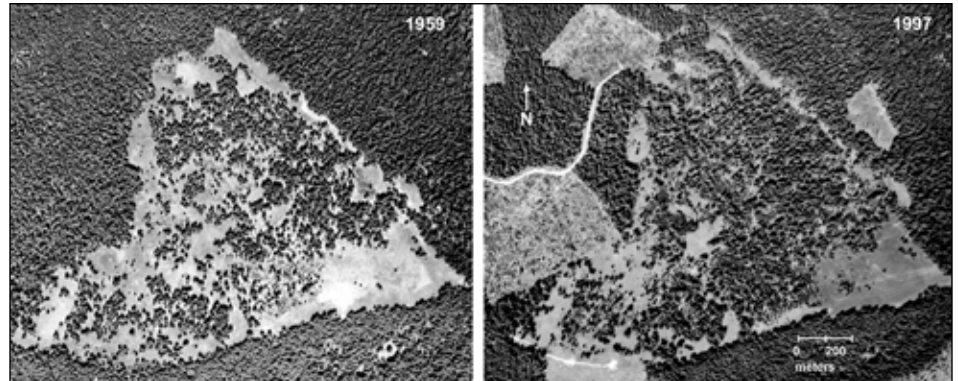
**A**ncedotal evidence of meadow loss in the Cascades abounds. But Swanson and Sadao Takaoka from Senshu University in Japan set out to quantify the extent and potential causes of change. They completed a retrospective study of meadow loss spanning five decades in a portion of the western Cascades east of Eugene, Oregon. At the time, Takaoka was a visiting scholar at the PNW lab in Corvallis.

“We used historical aerial photographs to examine effects of disturbance, especially wildfire and sheep grazing, on the dynamics of over 500 meadows distributed over a 135-square-mile area, including the Andrews Experimental Forest,” explains Swanson.

They began by mapping the locations of all nonforest patches visible in photos taken in 1946. When they overlaid these locations onto photos from 2000, they found that more than 20 percent of the patches had contracted owing to conifer invasion. Overall, natural openings made up 5.5 percent of the study area in 1946, but less than half of that, only 2.5 percent, in 2000.

In contrast, “we found only three cases of meadow expansion,” says Swanson.

“Meadows showed complex patterns of change,” he explains. “Those dominated by forbs had greater tendency to contract than did meadows dominated by shrubs. In addition, drier meadows were quite stable over



*There was a massive invasion of lodgepole pine and grand fir at Bunchgrass Ridge between 1959 and 1997. Several clearcuts appear adjacent to the study area in the 1997 photo.*

the study period, but about half of the moister, more fertile, meadows contracted. This suggests that both environment and meadow composition can affect long-term stability.”

In trying to clarify why some meadows contracted while other did not, Swanson and Takaoka capitalized on previous studies of fire history in the western Cascades. They found that meadows in areas that had burned between 1800 and 1946 tended to contract in subsequent years. They hypothesized that fires may have created and maintained these openings, but now, in the absence of fire, they are returning to forest.

However, other factors may also influence the stability of mountain meadows. Sheep were brought into the Cascade Range for summer

pasturage in the late 1800s, and grazing of mountain meadows was widespread well into the mid-1900s. Although Swanson and Takaoka were unable to relate meadow contraction to cessation of grazing, Halpern and a graduate student, Eric Miller, did find evidence of this effect in similar meadows of the nearby Three Sisters Wilderness. Based on age structures of invading trees, grazing records, and climate data, they found strong correlations between closure of Forest Service grazing allotments in the mid-1900s and the establishment of trees. However, the onset of invasion also coincided with cooler, wetter summers that are conducive to seedling establishment. Again, it seems that there are not simple explanations to the maintenance or loss of meadows.

## CONSEQUENCES FOR MEADOW ECOSYSTEMS

**W**hen first delving into the issue of meadow loss, Halpern was surprised to find that no one had documented how the ground vegetation changes as meadows are replaced by forest. “Although numerous studies have explored the causes of conifer encroachment, none has explicitly addressed its consequences for plant diversity and composition. We didn’t understand how quickly meadow species were lost from these systems or at what point forest herbs were able to establish,” he says. “This information is critical to understanding the potential for restoration.”

Halpern worked with a graduate student, Ryan Haugo, to reconstruct the changes in vegetation that occur as meadow is gradually replaced by forest. They used a “chronosequence” approach (at Bunchgrass Ridge, Willamette National Forest), sampling ground vegetation in forest patches of increasing age to infer temporal changes in the abundance and diversity of species.

“We first mapped and aged all of the trees over a 10-acre area, allowing us to describe the timing and spatial pattern of encroachment. We observed two broad periods of

forest expansion: the first between 1815 and 1905, the second, a massive invasion between 1925 and 1985. “During both periods, lodgepole pine preceded grand fir, often facilitating its establishment” says Halpern. “This process is clearly evident in the clumped distribution of grand fir (a species that can regenerate in shade) around individuals of pine (a species that requires full sun for regeneration).”

Then, using knowledge of the ages of forest patches, Haugo and Halpern traced the progressive loss of meadow species and the gradual colonization of forest herbs. They

found that most meadow species were highly sensitive to tree establishment and the resulting reductions in available light, which they also measured.

“We were more surprised at how quickly forest herbs were able to disperse from adjacent forests and to dominate the understory,” says Halpern. “Within several decades of the initial establishment of trees, forest herbs were as diverse and abundant as the residual meadow species. This is an interesting and unique type of succession: forest herbs arrive after trees, and the understory community assembles, de novo, on meadow soils that have been modified biologically and chemically by the presence of trees.”

Another graduate student examined changes in the belowground community across the same meadow-to-forest gradient. Nicki Lang was looking at the diversity of species that exist in soil as seeds. She was interested in whether meadow species maintain viable seeds in the soil, and by implication, whether the seed bank can contribute to meadow restoration if conifers are removed. Her work also offered some surprises.

Lang collected soil samples from the same patches of meadow and forest studied by Haugo. She then brought them into a greenhouse at the University of Washington where they were allowed to germinate. Over the subsequent weeks, 44 species emerged, compared with 140 species in the aboveground vegetation. Interestingly, nearly three-fourths of the species that composed the meadow flora were absent from the seed bank, and the vast majority of meadow germinants were of a single species. Most species that germinated were not even found on site; they were weedy species.

“The fact that most meadow species were not present in the soil suggests that we cannot look to the seed bank as a source for meadow restoration,” says Halpern.

These results, combined with the loss of abundance and diversity of meadow species in the aboveground vegetation point to obvious challenges to restoration, even if conifers are removed.

Sam Sweetland



*The Bunchgrass Ridge study area after tree removal and broadcast burning of three of the nine experimental plots; slash piles in three plots had not been burned at the time of this photo.*

Charlie Halpern



*Broadcast burning is one of the fuel reduction treatments at Bunchgrass Ridge.*

## A RESTORATION EXPERIMENT

**T**he vegetation and seed bank studies at Bunchgrass Ridge represent the beginning of a long-term experiment designed with resource managers from the Willamette National Forest. The 215-acre study site had previously been identified by the Forest Service as a Special Habitat Area with the primary management goal “to protect and enhance wildlife habitat and botanical sites.”

“Bunchgrass Ridge is a large, gently sloping plateau that supports a mosaic of meadow and forests of varying age. The diversity of vegetation conditions arrayed over a broad area of similar soils and topography provides an ideal setting for research and for experimenting with restoration,” says Swanson.

“We are now in the initial stages of a large, replicated experiment that examines vegetation responses to several types of

meadow restoration treatments,” he explains. “These include: complete tree removal with the resulting slash piled and burned, leaving much of the ground surface unburned; tree removal followed by broadcast burning; and control sites where no action is taken.”

“These comparisons will allow us to test whether fire is necessary to meet restoration goals or whether removal of overstory trees is sufficient,” says Halpern. “Imposed across

a broad range of forest age classes, the experiment will also allow us to identify at what point succession to forest may limit the potential for restoration.”

“These studies provide an opportunity to address both the operational issues facing managers and the requirements of experimental science,” says Swanson. “However, carrying out the experimental treatments has posed some interesting challenges. For example, it was necessary to fell and yard trees on snow to protect meadow soils from the impacts of logging equipment. Unfortunately, the plan to harvest in 2005 was foiled by the virtual absence of snow that winter. Mother Nature was more cooperative in 2006.”

Now, with logging and subsequent burning completed, field crews will be measuring first-year responses of vegetation and soils.

“Our goal is to develop an ecological basis for restoration of meadows in the western Cascades, using Bunchgrass Ridge as a center for research, adaptive management, and outreach,” says Swanson.

*“Even the fires of the  
Indians and the fierce  
shattering lightning seemed  
to work together only for the  
good in clearing spots here  
and there for smooth garden  
prairies, and openings for  
sunflowers seeking the light.”*

— John Muir

## FOR FURTHER READING

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Researchers are experimenting with pile burning of logging slash as part of meadow restoration treatments.

Sam Sweetland



## LAND MANAGEMENT IMPLICATIONS



- Mountain meadows have been susceptible to conifer encroachment during the past century. In some instances, this may reflect a process of contraction following a disturbance such as wildfire. Elsewhere, it may reflect a change in land use, such as cessation of sheep grazing, or a shift in climate. That meadow types vary in their susceptibility to encroachment provides a basis for prioritizing current restoration efforts and anticipating future maintenance needs.
- The most effective strategy for conservation and maintenance of meadow habitats is one that targets tree removal during the early stages of encroachment. At later stages, restoration is likely to be hindered by a variety of factors: loss of meadow species from the vegetation, absence of a soil seed bank for most meadow species, and changes in soil properties that facilitate further recruitment of tree seedlings. Restoration efforts should target forest-meadow edges or small tree islands to maximize the potential for dispersal of meadow species.
- Studies of a chronosequence of open meadow to old forest indicate that soil seed banks are dominated by early-successional herbs. Management activities that disturb or heat the soil may facilitate germination and growth of weedy species that can compete with species targeted for restoration.

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## WRITER'S PROFILE

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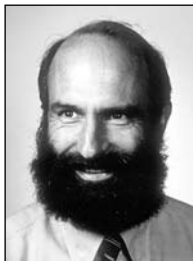
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