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Resilience Test: Can Ponderosa Pine Bounce Back After High-Severity Fire?

The Cameron Peak Fire ignited in mid-August 2020 in the mountains west of Fort Collins, Colorado. Driven by high winds, the fire started in high-elevation spruce-fir forests, then moved down in elevation, burning hot and fast through thousands of acres of drought-stricken ponderosa pine forests to the north and east of Rocky Mountain National Park. The fire burned through more than 208,000 acres before it was finally contained.

Scientists and land managers observing the after-effects of wildfires like the Cameron Peak Fire fear that iconic ponderosa pine forests, which are adapted to

relatively frequent, low- to mixed-severity burning, may not regenerate in the extensive, treeless patches often left by high-severity fire.

Ponderosa pine relies on seeds from surviving trees to regenerate. And since ponderosa pine seeds only disperse a short distance from parent trees—generally only 150 to 200 feet and less commonly more than 600 feet—regeneration may be limited in large high-severity patches that are hundreds or even thousands of acres in size. Increased drought and heat due to ongoing and projected climate change may further limit regeneration.



Ponderosa pine regeneration grows along a surviving forest edge in a high-severity burn patch in the 2000 Pumpkin Fire in Arizona. USDA Forest Service photo by Pepe Iniguez.

If ponderosa pine regeneration in large high-severity patches is sparse, then the patches may change from ponderosa pine forests to grasslands, shrublands, or other forest types, such as aspen or Gambel oak.

Wildfire-Driven Change

The 2002 Hayman Fire was the largest known fire to have burned in Colorado until the Cameron Peak Fire and two other 2020 wildfires knocked it from its notorious perch. The Hayman burned a wide swath (137,600 acres) dominated by ponderosa pine in the mountains northwest of Colorado Springs. Over 50 percent of the Hayman

burned at high severity, leaving massive patches of blackened land, many thousands of acres in size, with no surviving trees to produce seed for regeneration or even groundcover to protect fragile soils.

Paula Fornwalt, a Rocky Mountain Research Station (RMRS) research ecologist, was working as an RMRS research technician in 2002 when the Hayman Fire burned through research plots on the Pike National Forest. Her research interests immediately following the fire focused on herb and shrub recovery in those plots, but as the years passed, the lack of ponderosa pine regeneration caught her attention.

“I was out in the Hayman Fire area a lot, especially the first 5 years after it burned,” Fornwalt says. “And I became acutely aware that I wasn’t seeing any ponderosa regeneration in the interior of big, high-severity patches, though I was sometimes seeing it elsewhere in the fire. So, I wanted to look at the question of why this was.”

Fornwalt’s RMRS colleagues Mike Battaglia, Carolyn Sieg, and Jose “Pepe” Iniguez were also interested in questions about post-fire ponderosa regeneration in high-severity patches. Battaglia was studying how prescribed fire affected ponderosa regeneration in the Black Hills of South Dakota, while Sieg and Iniguez had begun to look at spatial patterns of ponderosa regeneration in mixed-severity patches in Arizona.

In 2013, the four researchers teamed up to conduct a project across this broad three-state geography. Suzanne Owen also joined the team as a Ph.D. student at Northern Arizona University (NAU), while Marin Chambers joined as a M.S. student and Justin Ziegler joined as a Ph.D. student at Colorado State University (CSU). Other RMRS, NAU, and CSU researchers joined the team as well. An aim of their project was to examine (1) the influence of environmental factors, such as distance from surviving trees, elevation, and other vegetation, on ponderosa regeneration in high-severity patches, as well as (2) the spatial patterns of ponderosa regeneration in these patches.

SUMMARY

Ponderosa pine forests were historically shaped by frequent, low- to mixed-severity fires. Land managers and scientists are concerned that recent high-severity fires, which have left expansive treeless patches in their wake, may prevent ponderosa pine from successfully regenerating in much of its former area. If ponderosa pine does not reclaim these sites, these areas will become grasslands, shrublands, or other forest types, such as aspen or Gambel oak.

RMRS scientists and their NAU and CSU colleagues examined the spatial patterns of ponderosa pine regeneration following fire, as well as the influence of environmental factors, such as distance to seed source, elevation, and other vegetation, on ponderosa regeneration success. They focused on large, high-severity patches in Arizona, Colorado, and South Dakota wildfires. Their results show that ponderosa pine generally regenerated in groups or clumps, rather than in a relatively homogenous pattern, and the amount of ponderosa pine regeneration declined sharply with distance to seed source. The researchers also found that ponderosa pine regenerated more abundantly in higher-elevation sites where climate tends to be cooler and wetter. Other vegetation generally did not negatively influence ponderosa regeneration, and in many cases, had a positive effect on regeneration success, probably by mitigating harsh site conditions. Downed logs also appeared to ameliorate harsh site conditions, to the benefit of regeneration.

Overall, these results suggest that ponderosa pine may recover in high-severity patches that are close to surviving seed sources, but in large patches far from surviving trees, ponderosa pine recovery may be compromised, especially where growing conditions are harsh. These results can help managers better anticipate recovery within high-severity patches, and in turn, better determine whether tree planting treatments are needed to maintain ponderosa pine forests in the future as well as where and how to conduct them.



For Iniguez, the driving questions that spurred the project were the key to understanding resilience, or whether a forested system can recover from disturbance like high-severity wildfires.

Iniguez says: “Because ponderosa pine is a species that spreads by seed, and the seeds don’t travel very far, there was always this idea that ponderosa would not come back in these big, high-severity patches, and instead these patches would convert to another vegetation type, maybe grasslands. So, we took that idea as a hypothesis and went out to test it.”

Sieg and Iniguez were also curious to see if the natural tree clumpiness so common in old growth ponderosa pine forests would be present in the spatial patterns of tree seedling establishment in the burned areas.

Measuring Resilience

To start to understand ponderosa pine regeneration in large high-severity patches, the research team focused on fires in Arizona, Colorado, and South Dakota. First, they installed a variety of small study plots to look at the influence of environmental factors on ponderosa pine regeneration. Then, to capture the spatial variability of regeneration within these patches, they supplemented these small plots with large 10-acre plots and mapped all regeneration in them.

“We knew there was regeneration out in these big patches, but it was



This map shows the approximate distribution of ponderosa pine in the western United States, as well as the wildfires included in the ponderosa regeneration study.

really sparse and heterogeneous,” Iniguez explains. “And we knew small plots weren’t going to capture spatial patterns. So, that led to the idea of these big, 10-acre plots we could apply across the study sites.”

After they finished the task of collecting the data across many fires, the researchers had a rich dataset for exploring questions related to the regeneration of ponderosa pine after high-severity burning. The hope was that

the insights gleaned from their analyses could help managers better anticipate recovery patterns within high-severity patches, and in turn, better determine whether, where, and how to conduct post-fire management activities, such as tree planting, to maintain ponderosa pine forests into the future.

Is Ponderosa Pine Bouncing Back?

Taken together, the research led by the team suggests that there are two primary environmental

“filters” that determine natural regeneration success.

The first is the presence of a nearby seed source. While ponderosa pine regeneration was found in most high-severity patches, densities declined sharply in areas farther from surviving trees. On the Pumpkin and Rodeo-Chediski Fires in Arizona, for example, the researchers reported higher regeneration densities in edge plots located within 600 feet of surviving forest (28 stems/acre) versus interior plots located more than 600 feet from surviving forest (12 stems/acre).

Fornwalt and Battaglia report similar patterns in Colorado and South Dakota. “That’s something that all the fires we sampled have in common—that as distance from the seed source increased, regeneration decreased,” Fornwalt explains.

But their research also showed that even if there is a seed source, regeneration is not guaranteed in high-severity patches. Climate is the second critical filter. Because climate tends to be cooler and wetter at higher elevations and warmer and drier at lower elevations, researchers used elevation as a proxy for climate. They found that when surviving trees were in close proximity, regeneration density declined as elevation decreased in the Colorado study sites: at higher elevations (above approximately 8,000 feet), ponderosa regeneration

densities averaged around 380 seedlings/acre, but averaged only around 50 seedlings/acre at elevations below 8,000 feet. This suggests that regeneration is more abundant in areas that are cooler and wetter than in those that are hotter and drier.

“At the lower elevations, these big treeless patches cook in the sun,” Battaglia says. “Cooler and wetter conditions like those found at higher elevations are crucial for ponderosa pine seedlings to survive those high surface temperatures.”

Battaglia adds that localized “microsites” that are cooler and wetter, like near downed logs or near other vegetation, can still support regeneration, even at otherwise hot, dry sites. For example, their research found that, on the Pumpkin Fire in Arizona, regeneration growth increased as the cover of downed logs increased.

The spatial patterns portion of the project focused on the location and distribution of individual tree seedlings (that is, whether seedlings were in groups or clumps, or whether they were relatively randomly or uniformly spaced), and how patterns were shaped by distance to seed source and interactions with other tree species.

In all five fires where spatial patterns of regeneration were examined, the tree seedlings were generally found in small groups within high-severity patches, rather than in random or uniform distributions. However, this pattern did not generally vary with distance to seed source. Battaglia adds that understanding patterns of how regeneration occurred spatially—whether ponderosa comes back in groups or clumps or as individual trees uniformly or randomly spaced out—was an important insight from the study.

A ponderosa pine seedling is shaded by a downed log in the 2002 Hayman Fire, Colorado. The study indicated that cooler and wetter “microsites” created by downed logs can improve regeneration success in harsh post-fire environments, which are typically warmer and drier than areas with a surviving tree canopy. However, downed logs can also increase risk of reburns that can threaten young regenerating forests. USDA Forest Service photo by Paula Fornwalt.



“We found patches of regeneration—‘groupy-clumpy’ it’s sometimes called—with single trees here and there, rather than evenly spaced seedlings across high-severity areas,” Battaglia says. “And those regeneration dynamics are consistent with the patchy patterns in which ponderosa pine forests develop.”

One finding from the spatial pattern analysis that surprised researchers was that interactions with other tree species didn’t appear to hinder ponderosa pine establishment.

Sieg noted: “There was no evidence ponderosa pine seedlings were

repulsed by other regenerating tree species, which suggests that there weren’t competitive interactions limiting ponderosa pine. And in many cases, there was attraction, suggesting that it may benefit ponderosa pine to establish near other tree species or other native plants. Perhaps those other species were helping moderate the harsh growing environment by providing shade.”

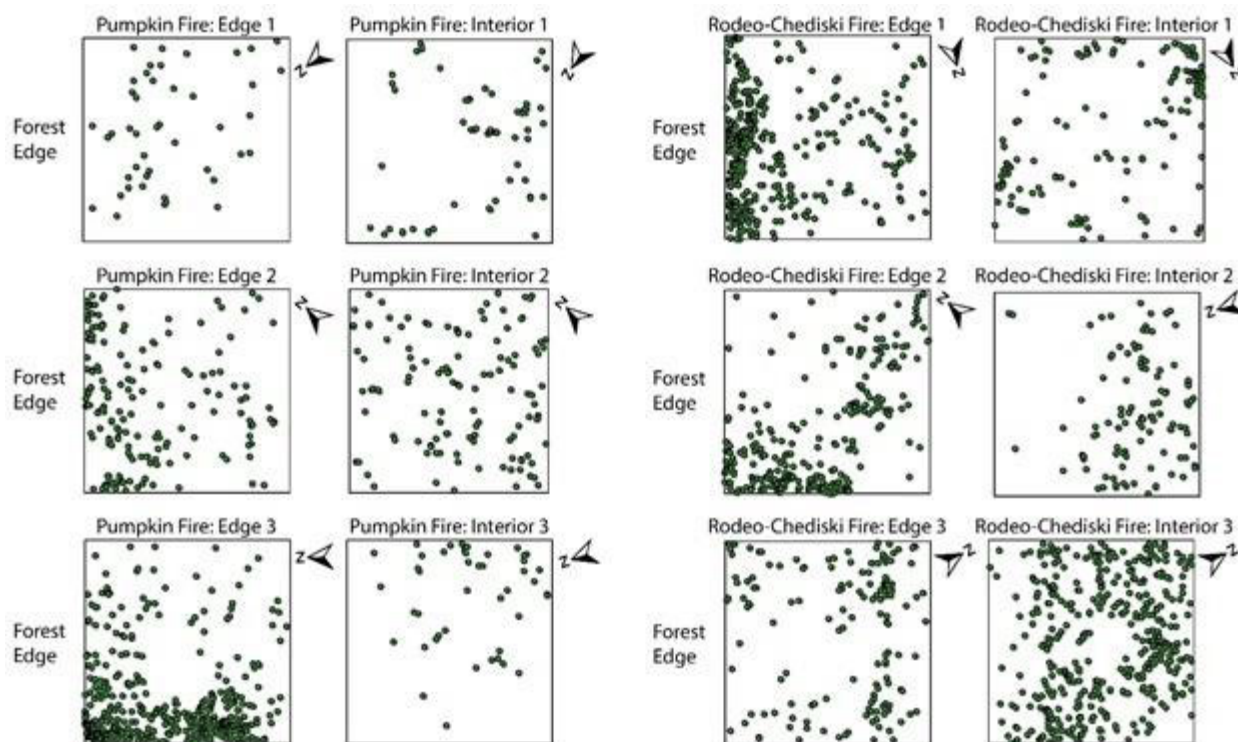
The Question of Type Conversion

Ponderosa seeds generally only disperse 150 to 200 feet. For large high-severity patches, it could well take many generations for post-

fire ponderosa pine seedlings to grow up, produce cones, and seed out repeatedly to fill that patch. That raises a practical question: If a burned site is on a trajectory to recover as a ponderosa pine forest, but recovery may take 100 years, has type conversion occurred? What about 200 years? Or 300 years?

The researchers all have slightly different outlooks on whether high-severity fire is driving ponderosa pine forests being replaced by other species.

“Most of the large patches, which are hundreds or even thousands of acres in size, are just not likely to



This figure shows stem maps of ponderosa pine regeneration 13 years after the Pumpkin Fire and 12–13 years after the Rodeo-Chediski Fire in edge plots near surviving ponderosa pine trees and in interior plots greater than 600 feet from any surviving ponderosa pine trees. Both fires burned in Arizona. (Owen et al. 2017.)

naturally recover to ponderosa pine forests in our lifetimes, or in hundreds of years, simply because the distance to seed sources is so great,” Fornwalt says. “Then you factor in the warmer and drier conditions predicted with climate change and that means even lower regeneration rates.”

Iniguez is more optimistic of the ability of the forests to recover. His mantra is “low regeneration does not mean no regeneration.”

He admits that his view is influenced by his experiences observing ponderosa regeneration after the 2002 Rodeo-Chediski Fire in Arizona, where regeneration has been observed as much as 900 to 1,200 feet from surviving seed sources. Iniguez attributes the regeneration observed in parts of the Rodeo-Chediski burned area to unique soils, and to a series of wet years in the perfect window after the fire for promoting regeneration.

“If you were a betting person, and you visited one of these sites right after the fire, you would have bet that the site would never come back as forest,” Iniguez says. “But then little by little, you see regeneration. Some people might say, ‘Well, there’s not enough regeneration.’ But to me, the fact that we found any regeneration in these sites points to the resilience and sustainability of the system.”

Sieg was amazed that all of their large 10-acre plots had some



Post-fire ponderosa pine regeneration tends to occur in a “groupy-clumpy” spatial pattern, rather than in a randomly or evenly spaced pattern, as shown here in an area burned by the 2000 Jasper Fire in South Dakota. USDA Forest Service photo by Paula Fornwalt.

ponderosa seedlings—even far from surviving trees. The densities were lower than typically found in unburned ponderosa forests, but assuming the seedlings survive, the low-density forests that will develop will be less susceptible to crown fires than dense forests.

But Sieg and Iniguez also agree that with climate change, high-severity fires in ponderosa pine are more likely to lead to the ponderosa being replaced by other plant species at warmer and drier, lower elevation sites because it is more difficult for seedlings to survive their critical first few years.

Tree Planting Considerations

Results from these studies have important implications for

management actions, such as tree planting. Fornwalt believes a take-home lesson is that there are portions of severely burned landscapes that are not regenerating naturally, and those areas may be good candidates for tree planting.

If a burned site is on a trajectory to recover as a ponderosa pine forest, but recovery may take 100 years, has type conversion occurred? What about 200 years? Or 300 years?



The interior of this large high-severity patch in the 1996 Buffalo Creek Fire, Colorado, appears to be largely devoid of ponderosa pine regeneration. USDA Forest Service photo by Paula Fornwalt.

“So, the question for managers becomes: Do they want these nonregenerating areas to become forest again? If they do, they’re going to have to be proactive and plant,” Fornwalt says. “And, if they decide to plant, then our science can provide some guidance for where and how to do it.”

For example, Battaglia recommends managers avoid planting near surviving trees, which will probably seed natural regeneration if environmental conditions remain suitable. He also recommends planting ponderosa in groups

or clumps to mimic natural regeneration.

“If you’re going to plant trees, the natural order of things would not be equal spacing every 6 or 10 or 20 feet, the typical ‘pines-in-lines’ pattern. That’s just not how those natural systems work,” Battaglia explains.

Fornwalt echoes Battaglia’s recommendations and further recommends that planting be prioritized in sites that are cooler and wetter, such as at higher elevations, as planted trees are

more likely to survive there. She also recommends that planting be conducted in cooler and wetter microsites, like near downed logs or other vegetation. However, she acknowledges that planting near these flammable “nurse objects” may increase the likelihood that the planted seedlings would die if the site were to reburn.

Land Manager Perspectives

Jeff Underhill, who was not involved with this research but is very involved in management of ponderosa forests, has a unique perspective on ponderosa pine

regeneration. Underhill worked on the Pike-San Isabel National Forest in Colorado and was involved in forest recovery efforts on the Hayman Fire. He is currently a silviculturist on the Black Hills National Forest in South Dakota and has been working to manage recovery in the area burned by the 2000 Jasper Fire, another of one of the fires selected for the regeneration study.

Agreeing with the study findings, Underhill says that former ponderosa pine forests that lost seed sources during the fires are changing to other vegetation types. He also suggests managers be strategic in assessing areas for potential planting efforts.

“It’s really an exercise in prioritizing areas for planting that have the highest likelihood of success,” says Underhill. “On the Pike [National Forest] in the Hayman burn area, we considered factors like slope, aspect, and access, and we tended to target the cooler, more northern aspect sites because we had a higher chance of seedling survival.”

Underhill explains that for fires like the Hayman in Colorado and the Jasper in South Dakota, both with extensive high-severity patches, managers are only touching a small footprint with planting operations. And while those treatments are important, the vast areas that are not being

KEY FINDINGS

- In the Arizona, Colorado, and South Dakota wildfires studied, ponderosa pine seedlings in high-severity patches grew in groups, similar to patterns seen in older forests.
- The density of ponderosa pine seedlings declined rapidly as distance from surviving trees decreased.
- Ponderosa seedlings were more abundant in cooler and wetter sites, such as at higher elevations.
- Ponderosa seedlings did not mind neighbors and even benefitted from growing near other pines, oak, aspen, and some native forbs and grasses.
- Ponderosa seedlings also were more successful near downed logs but may be at risk if the log burns.



The density of ponderosa pine regeneration declines rapidly as distance from surviving forest increases in this area burned by the 2000 Jasper Fire, South Dakota. USDA Forest Service photo by Paula Fornwalt.



planted are mostly grasslands and shrublands, and that this vegetation type change will likely last for centuries.

“We’re seeing change at a more rapid pace, and I’m not sure it’s realistic to think that we can keep up with it,” Underhill says.

Farther south, Lloyd “Randy” Fuller is the vegetation management staff officer on the Apache-Sitgreaves National Forest in Arizona and has been managing the area burned by the 2002 Rodeo-Chediski Fire. Land managers have been trying to shorten the forest recovery cycle in the Rodeo-Chediski burn area by using targeted planting, but some areas just are not coming back.

Fuller explains that high-severity patches in the Rodeo-Chediski Fire included small refugia of surviving ponderosa pines that serve as seed sources for regeneration. Those refugia produced their own flush of seedlings after the fire, many of which survived and are now approaching seed-bearing age, which could help fill in even more of the high-severity patches. He worries that reburns, either through wildfire or prescribed fire, could destroy that progress that has been made in managing natural and artificial regeneration (i.e., planting) on the landscape.

“We have lots of discussions with the prescribed fire folks about how important those seeds are, and also the advanced regeneration,” Fuller says. “We have 20 years invested in those areas, and I don’t want to set them back with fire and lose 20 years of progress.”

MANAGEMENT IMPLICATIONS

- In the absence of active management, portions of large high-severity patches may convert from ponderosa pine forests to grasslands, shrublands, or other forest types.
- However, other portions of large high-severity patches, particularly cooler and wetter areas near surviving trees, may recover to ponderosa pine forests or woodlands.
- Where ponderosa pine forests do recover, the trees may be largely distributed in heterogeneous “groupy-clumpy” spatial patterns, rather than in random or uniform patterns.
- Planting ponderosa pine may help maintain this species in large high-severity patches where it is desired but regenerating poorly.
- Planting in high-severity patches may be most successful where climate tends to be cooler and wetter, such as at higher elevations, as natural regeneration was most successful in these areas.
- Planting near downed logs or other vegetation may enhance regeneration success, though it may also increase their risk of mortality in a reburn.
- To mimic patterns of natural regeneration in ponderosa pine forests, planting can be done in groups.

FURTHER READING

Chambers, M.E.; Fornwalt, P.J.; Malone, S.L.; Battaglia, M.A. 2016. [Patterns of conifer regeneration following high severity wildfire in ponderosa pine-dominated forests of the Colorado Front Range](#). *Forest Ecology and Management*. 378: 57–67.

Owen, S.M.; Sieg, C.H.; Sánchez Meador, A.; Fulé, P.Z.; Iniguez, J.M.; Baggett, L.S.; Fornwalt, P.J.; Battaglia, M.A. 2017. [Spatial patterns of ponderosa pine regeneration in high-severity burn patches](#). *Forest Ecology and Management*. 405: 134–149.

Owen, S.M.; Sieg, C.H.; Fulé, P.Z.; Gehring, C.A.; Baggett, L.S.; Iniguez, J.M.; Fornwalt, P.J.; Battaglia, M.A. 2020. [Persistent effects of fire severity on ponderosa pine regeneration niches and seedling growth](#). *Forest Ecology and Management*. 477: 118502.

Owen, S.M.; Patterson, A.M.; Gehring, C.A.; Sieg, C.H.; Baggett, L.S.; Fulé, P.Z. 2019. [Large, high-severity burn patches limit fungal recovery 13 years after wildfire in a ponderosa pine forest](#). *Soil Biology and Biochemistry*. 139: 107616.

Ziegler J.P.; Hoffman C.M.; Fornwalt, P.J.; Sieg, C.H.; Battaglia, M.A.; Chambers, M.E.; Iniguez, J.M. 2017. [Tree regeneration spatial patterns in ponderosa pine forests following stand-replacing fire: Influence of topography and neighbors](#). *Forests*. 8: 391.



SCIENTIST AND MANAGER PROFILES

The following individuals were instrumental in the creation of this Bulletin:



Paula Fornwalt is a research ecologist with the RMRS Forest and Woodland Ecosystems program. Her research focuses on how natural and human disturbances affect plant populations and communities in Rocky Mountain forests.



Jose "Pepe" Iniguez is a research ecologist with the RMRS Wildlife and Terrestrial Ecosystems program. His research focuses on understanding how fire impacts forested ecosystems across temporal and spatial scales. He uses dendrochronological techniques that allow reconstruction of fire history and age structure patterns both in stands and across landscapes.



Mike Battaglia is a research forester with the RMRS Forest and Woodland Ecosystems program. He is interested in developing and implementing innovative management strategies to enhance forest resiliency to disturbances and evaluating the subsequent ecological impacts of these activities.



Carolyn Sieg is a research plant ecologist with the RMRS Forest and Woodland Ecosystems program. She is interested in how plant communities and fuels change through time following severe wildfires and how spatial patterns in forests and regeneration are altered by such disturbances and subsequent management actions.



Jeff Underhill is currently the forest silviculturist for the Black Hills National Forest. He also has experience as a regional silviculturist for the Forest Service's Rocky Mountain Region Mountain Region, a timber program manager, timber management assistant, district silviculturist, and pre-sale forester. He earned his M.S. in Forestry from the University of Tennessee and his M.E. in GIS from the University of Colorado at Denver.



Lloyd "Randy" Fuller is currently the timber, silviculture, and engineering staff officer on the Apache-Sitgreaves National Forests. He holds a B.S. in Forest Science from Northern Arizona University and a Ph.D. in Forest Pathology and Entomology from Oregon State University. He has over 40 years of experience in forest management and restoration in the western United States with the USDA Forest Service and the DOI Bureau of Indian Affairs.

These scientists also played a major role in this research:

Suzanne Owen is a natural resource specialist in the Resource Assessment and Monitoring program at the Pacific Northwest Research Station. Her research focuses on disturbance and land management effects on ecosystem processes and spatial patterns of post-fire regeneration.

Marin Chambers is a research associate with the Colorado Forest Restoration Institute at Colorado State University. Her primary research interests are disturbance and restoration ecology, specifically forest recovery, resilience, and adaptation in relation to forest management, natural disturbances, and climate change.

Justin Ziegler is a research associate and doctoral candidate in the Forest and Rangeland Stewardship Department at Colorado State University. His research primarily focuses on modelling of wildland fire behavior in complex burning environments, as well as investigating the causes, consequences, and management of tree spatial heterogeneity in fire-prone forests.



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Top: A ponderosa pine seedling stands alone in the interior of a high-severity patch created by the 2002 Hayman Fire, Colorado. Photo courtesy of Marin Chambers.

Bottom: Ponderosa replanting unit established inside of the Hayman Fire (Pike National Forest). USDA Forest Service photo by Alexis Neukirch.



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