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Between a Rock and a Hard Place: Understanding and Managing Pinyon and Juniper Woodlands in a Changing Climate

From behind the wheel on a road trip through Nevada, Utah, or Colorado, we see pinyon and juniper woodlands that often appear homogenous and unchanging. After all, they're composed mostly of trees, which are stationary. But these woodlands embody much more than meets the eye. Pinyon and juniper trees thrive in areas with as little as 8 and as much as 20 inches of rain, and at both low and high elevations. The woodlands occupy more than 70,000 square miles of the Great Basin and Colorado Plateau and have fluctuated greatly over the past 20,000 years. They have expanded and contracted across landscapes, moved up and down in elevation, and shifted in composition and structure. In short, they are dynamic.

Today, changes since the late 20th century in pinyon and

Pinyon and juniper woodlands may appear homogenous but they vary in stand structure and composition and intermingle with other plant communities across diverse topography, soils, and microclimates. Schell Creek Mountains, Nevada. Courtesy photo by Richard Miller.

SUMMARY

Across the western United States, pinyon and juniper woodlands are undergoing significant changes that are of concern to land managers and the communities who depend on them. In some areas, the woodlands are expanding, resulting in increased fuel loads, risk of more severe fires, and loss of high value habitat for species such as greater sage grouse. In other areas, these woodlands are contracting due to human development, more severe droughts, and larger wildfires. RMRS scientists and their partners synthesized over 1,000 research and management papers on pinyon and juniper woodlands in order to help land managers, researchers, and the interested public understand and address these concerns. The resulting publication, The Ecology, History, Ecohydrology, and Management of Pinyon and Juniper Woodlands in the Great Basin and Northern Colorado Plateau of the Western United States (RMRS-GTR-403), is designed to help managers quickly reference the current state of knowledge of these semiarid woodland ecosystems, prioritize areas where conservation and restoration efforts will have the greatest benefits, and identify appropriate management actions. The synthesis covers the ecology, history, and hydrology of these semiarid woodland ecosystems as well as the history of and responses to restoration and other management treatments.

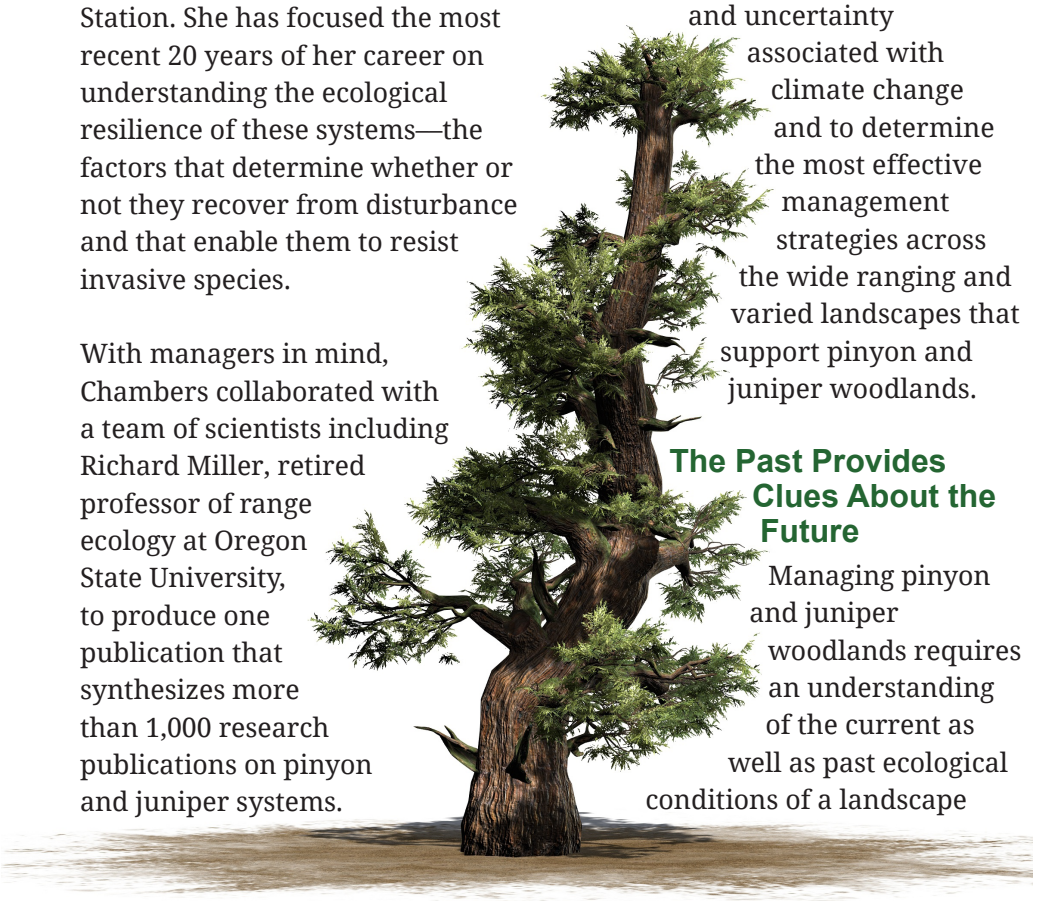
juniper woodlands present a host of challenges to land managers who are concerned with habitat conservation, invasive species, fire management, livestock grazing, and watershed protection. The list of changes varies across the landscape, but includes not only drought-induced die-offs of pinyon and juniper, increased fire severity, reduced understory vegetation and thus forage for livestock, but also changes in wildlife habitat and altered hydrologic processes.

"Effective management of these valuable ecosystems requires understanding the nature of these changes and how they differ across the landscape," says Jeanne Chambers, research ecologist with the Rocky Mountain Research Station. She has focused the most recent 20 years of her career on understanding the ecological resilience of these systems—the factors that determine whether or not they recover from disturbance and that enable them to resist invasive species.

With managers in mind, Chambers collaborated with a team of scientists including Richard Miller, retired professor of range ecology at Oregon State University, to produce one publication that synthesizes more than 1,000 research publications on pinyon and juniper systems.

"There's so much out there—so much has been written on pinyon juniper that it can be overwhelming," says Miller, the lead author who spent the better part of his career studying pinyon and juniper woodlands in the Intermountain West. "I wanted to pull it all together to tell the story of these woodlands. My hope is that this document makes the scientific literature more accessible and will save time for managers."

The resulting report, "The Ecology, History, Ecohydrology, and Management of Pinyon and Juniper Woodlands in the Great Basin and Northern Colorado Plateau of the Western United States" (RMRS-GTR-403), is intended to help managers navigate the complexity and uncertainty associated with climate change and to determine the most effective management strategies across the wide ranging and varied landscapes that support pinyon and juniper woodlands.



The Past Provides Clues About the Future

Managing pinyon and juniper woodlands requires an understanding of the current as well as past ecological conditions of a landscape or a particular site—the soils, topography, and perhaps most importantly, climate.

"Climate is the primary driver of vegetation dynamics in both time and space—through its effects on seed production, plant establishment, mortality, persistence, and the long-term and pervasive influence on disturbance regimes"

"Climate is the primary driver of vegetation dynamics in both time and space—through its effects on seed production, plant establishment, mortality, persistence, and the long-term and pervasive influence on disturbance regimes," the report authors state.

Dramatic changes in climate have occurred across the Intermountain Region over the past 100,000 years. The most significant changes occurred between the late Pleistocene 20,000 years ago, when ice sheets covered most of the land, and 6,000 years ago at the peak of the Holocene Thermal Maximum, the warmest and driest periods. The changes in temperature and precipitation during this transition affected woodland and shrubland communities across the region, but many tree species persisted.

Singleleaf pinyon arrived in the very north end of Owens Valley near the California and Nevada border around 9,000 years ago. The species slowly moved north more than 200 miles, reaching its northwestern most boundary near Pyramid Lake, Nevada, 300 years ago. Courtesy photo by Richard Miller.

Thanks to the highly variable topography and orientation of mountain ranges, some species remained within their moisture and temperature ranges by migrating up or down in elevation or moving north and south. Some shifted as much as 3,000 feet in elevation, and others migrated hundreds of miles northward.

"Studying the past increases our understanding about how current and future variations in temperature and precipitation influence woodland and shrubland migration and local extinction," Chambers says. "Knowing how a species has responded in the past to climate change can provide important insights into how it's likely to respond in the future."

Consider the singleleaf pinyon. At the end of the last ice age, this species occurred near Las Vegas, Nevada. But Chambers notes that over the past 10,000 years, as temperatures have increased, the species has migrated more than 400 miles north all the way to Reno. "So with continued climate change and the right conditions for seed dispersal, we would expect that species to continue to move to more northern areas," she says.

The Last Two Centuries

By looking to the more recent past, scientists and managers can better understand the primary drivers of woodland expansion and infill, as well as contraction, and anticipate changes in the future.

"Knowing how a species has responded in the past to climate change can provide important insights into how it's likely to respond in the future"

–Jeanne Chambers

"The past history has a huge impact on what's currently growing on a site," Miller says. "What kind of disturbance has occurred. Has it burned? Has it been overgrazed? Has there been significant drought?"

In the Intermountain West, some of the most significant changes in pinyon and juniper woodlands have occurred in the last 200 years. The 1850s are considered the decade that divides presettlement and postsettlement pinyon-juniper woodlands. Studies show that since 1860, a period which marks a distinct rise in human impacts, the area occupied by the woodlands has increased about two to six times. Evidence from packrat middens (they contain well-preserved fragments of vegetation that can be carbon dated), pinyon and juniper pollen analysis, and tree-ring studies suggest that rate of expansion and infill (increased density) between the mid-1800s to the mid-1900s was unprecedented. Postsettlement, newly established woodlands accounted for well over half of the more than 20 million acres of woodlands that currently

Pinyon-Juniper Woodland Expansion and Contraction: What's at stake?

Nutrient-rich pine nuts have been a staple food source for Native Americans for thousands of years, and pinyon and juniper woodlands continue to be important for Native peoples for their subsistence and economic, cultural, and spiritual values. Today, these ecosystems are important to people across the Great Basin and Colorado Plateau for a variety of reasons: recreation, hunting, wildlife conservation, livestock grazing, aesthetics, and watershed protection to name a few. Although pinyon and juniper woodlands are expanding into sagebrush and other ecosystems in some areas, severe droughts are resulting in increased tree mortality and woodland contraction in other areas. Whether expanding or contracting, much is at stake as these ecosystems continue to change.

Duncan Leao, forest fuels and vegetation program manager at the Humboldt-Toiyabe National Forest, tracks many management activities across Nevada and eastern California.

"As we plan projects, we're trying to meet multiple objectives," he says. "So, for example, in one area where expansion is limited, we may be doing a lop and scatter type treatment with hand crews to promote sagebrush health. But then in another area, we may be doing landscape-scale thinning to promote the health and resiliency of the pinyon and juniper woodland."

In addition to improving tree and soil health, thinning can increase species and structural diversity.

Habitat Changes

Changes in woodland structure via succession and tree removal may impact wildlife, depending on the species. Restricting the expansion of the pinyon and juniper is important for the greater sage grouse, which requires large contiguous areas of sagebrush and has declined considerably in the last 100 years.

"Even small amounts of the woodlands prevent the grouse from using the areas because of increased predation risk," says Jeanne Chambers, research ecologist with the Rocky Mountain Research Station.

Expansion may also reduce forage for native wildlife and livestock as understory species lose out to trees in competition for water.

On the other hand, a reduction of the woodlands—whether intentional or due to disturbances like wildfire and drought—can be detrimental to species that depend on them. One such species is the pinyon jay, an at-risk species which relies on the woodlands for nesting and whose diet consists primarily of pinyon-pine seeds.

Hydrology

Too many trees in the wrong place can wreak havoc on hydrology of an ecosystem not only by reducing understory vegetation, but also by exposing more bare ground and increasing surface runoff and erosion.

"Expansion has the potential to change the whole hydrologic system, especially in areas with low precipitation," Chambers says. "Due to interception of precipitation and uptake of soil water by the trees, you may have less available groundwater in a system than you would where you have sagebrush, and as a consequence you might see reduced streamflow or dryer meadows."

At the same time, if not done carefully, tree reduction can also negatively affect hydrology and increase soil erosion.

Fire and Invasive Species

Fuels managers share concerns about how expansion in sagebrush ecosystems affects fire behavior and the ability of a system to recover. As trees mature and become denser, woody fuel loads increase along with the risk of crown fires that can sweep through large stands of trees including old growth.

Infill also depletes understory species including sagebrush, shrubs, perennial grasses, and forbs.

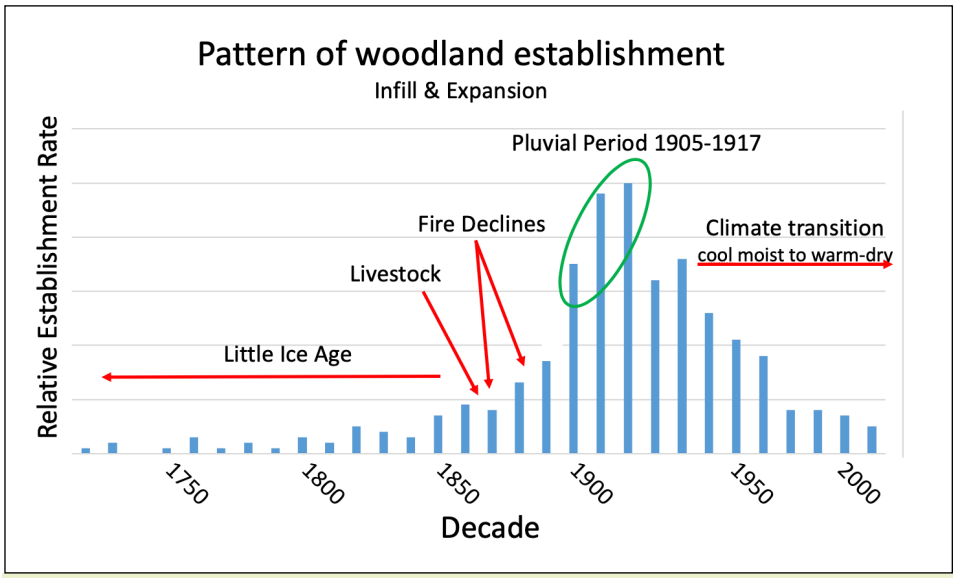
"One of the key things to understand about sagebrush and pinyon-juniper ecosystems is that postfire recovery potential is dependent upon those species that survive and regrow after fire," Chambers says. "Once you've lost the understory vegetation, restoration is more difficult and areas may need to be seeded to help them recover."

As the ecological resilience of an area diminishes, the risk of invasion by annual grasses goes up.

"If you have a site that is very vulnerable to cheatgrass, the only thing that's going to keep it out is what happens to be growing on that site," says Richard Miller, retired professor of range ecology at Oregon State University. "If it's locked up with really good herbaceous vegetation, especially perennial grasses with a fibrous root system, that really has a big impact on limiting cheatgrass."

Climate Change

Warming temperatures and more severe droughts may reduce native plant species, including pinyon and juniper, and give invasive annual grasses a stronger foothold. In drier sagebrush areas that didn't burn very often in the past, an increase in invasive species creates greater potential for fire and development of invasive grass-fire cycles. In addition, several studies report that increased concentrations of atmospheric CO_2 result in increased cheatgrass biomass, and thus more fine, contiguous fuel. As climate changes, managing the effects of expansion and contraction requires careful consideration of both the risk of wildfire and annual grass invasion and the high value resources that many pinyon and juniper woodlands support.



Typical pattern of establishment of pinyon and juniper woodlands throughout the Great Basin and Colorado Plateau from the 1700s through the early 2000s.

KEY FINDINGS

- Pinyon and juniper woodlands are highly dynamic—over the last 20,000 years their distribution has shifted more than 3,000 feet in elevation and they have migrated hundreds of miles.
- In the Intermountain West, some of the most significant changes in pinyon-juniper woodlands have occurred in the last 200 years following a distinct rise in human effects.
- In the Great Basin, woodlands are expanding into sagebrush ecosystems and have increased 125 to 625 percent, while in the Colorado Plateau, severe drought has resulted in tree mortality and woodland contraction.
- The rapid expansion of pinyon-juniper woodlands in the Great Basin is attributed to a number of factors, including both direct and indirect effects of climate, historic overgrazing, and altered fire regimes.
- Tree expansion and infilling results in progressive increases in woody fuels and increased risk of high severity fires. It also depletes native understory species, decreasing the ecological resilience of the area and increasing the risk of invasive annual grasses, like cheatgrass.
- Management goals have evolved since World War II from an emphasis on producing livestock forage, improving big game habitat, and preventing flooding to restoring and maintaining ecosystem function and managing for diversity and resilience to disturbance.

exist in eastern Oregon, eastern California, Nevada, and Utah.

Evidence suggests that most young woodlands are "not the result of tree replacement across millions of acres of persistent woodlands after stand-replacing events, but instead represent widespread expansion through new tree establishment in recent centuries," the report authors write.

The rapid expansion of pinyon and juniper woodlands is attributed to a number of factors including both direct and indirect effects of climate, historic overgrazing, and altered fire regimes. Climate directly affects seed production, seedling establishment, tree growth, and tree mortality. It also affects disturbances including fire, competition, insects, and disease. The wet period in the late 1800s and early 1900s created favorable conditions for cone production and tree-seedling establishment. The same conditions would have also resulted in the production and accumulation of fine fuels, which has been closely linked to widespread large fires. Yet studies indicate that fire occurrence during this period declined dramatically. So what happened to those fine fuels? The elimination of burning by Native Americans coincided with this decline in fires, but the primary driver of the reduction of fine fuels, including perennial grass cover, was heavy grazing. Prior to settlement, perennial grass cover had limited tree-seedling establishment; the reduction from grazing helped set the stage for woodland expansion.

Management and Restoration: Then and Now

Prior to World War II, pinyon and juniper trees were harvested by hand for fenceposts, firewood, and conversion into charcoal for mining. Vegetation management on public

Left: An old-growth woodland on the Kaibab Plateau where tree density has increased significantly since the 1900s. Many postsettlement trees seen today across the Colorado Plateau and Great Basin were established during a wet period between 1890 and 1920. Right: Mature trees on a site in central Oregon established during the first part of the 20th century expanding into mountain big sagebrush and Idaho fescue. Courtesy photos by Richard Miller.

lands didn't begin to take shape until low fuel prices and a surplus of heavy mechanical equipment and chemicals were ushered in after the war. During the next 3 decades, woodlands were largely managed with an eye toward producing forage for livestock, improving big game habitat, and preventing flooding in downstream towns. By the late 1970s, management goals shifted to include watershed improvement, fuel reduction, and wildlife habitat conservation.

Today, restoring and maintaining ecosystem function has shifted again.

"We need to manage for diversity and design treatments using the concept of resiliency," says Duncan Leao, Humboldt-Toiyabe National Forest, forest fuels and vegetation program manager. "Our goal postfire is to retain pinyon and juniper woodlands. We would rather have that than a cheatgrass monoculture."

However, restoring ecosystems with levels of pinyon and juniper that are similar to presettlement conditions in order to maintain resilience and biodiversity into the future is a notion that is increasingly challenged by climate change, the introduction of new species, and changing disturbance patterns.

"Our frame of reference is from the past," says Leao, "yet we're working into a future with more extremes, both dry and wet, with really nothing in the middle, and it's going to be warmer. We may not want to manage for those historical conditions or those reference conditions, but it gives us a good guide for what things could look like into the future."

Reigning in Woodland Expansion

The prevailing method of restricting pinyon and juniper woodland expansion is tree removal and has been since the 1950s and 1960s. Removing trees whether by cutting, shredding, chaining, or prescribed burning reduces the risk of severe fire caused by abundant woody fuels. Miller says it is extremely important to document the characteristics of a site to be treated in order to interpret and predict posttreatment responses over time. The variables to track include: climate, soils, topography, vegetation composition at the time of treatment, and weather, as well as posttreatment disturbances and how the treatments were applied.

"We should be able to explain why the treatments that were successful, were successful, and why the ones that failed, failed—possibly because

the treatments shouldn't have been implemented on those sites to begin with, or the wrong treatments were used."

Take chaining, for example, which involves pulling out woody plants by dragging a ship anchor chain secured between two bulldozers across the ground. The technique was popular until the 1970s when fuel prices rose and poor practices that resulted in high levels of soil disturbance raised public concern.

"It's an old technique and some people think that it's damaging, but the information in RMRS-GTR-403–the photos and the descriptions–show how responsive and successful chaining can be if you do it in the right spot and you do it correctly," says Cody Coombs, BLM fuels program manager with the Ely District in Nevada. "It can greatly improve understory species, and that's beneficial for wildlife as well as livestock."

Chaining is still used today and is less expensive than cutting or shredding. It causes less disturbance in warm and dry areas than prescribed fire, but areas may need to be retreated following growth of tree seedlings. Modern techniques, in combination with seeding native plants, can be a useful rehabilitation tool.

In order to decide when and where to apply treatments, from chaining and shredding to cutting and prescribed fire, managers need to consider the multiple factors that drive plant succession (see the next callout box), and their decisions need to be backed by scientific evidence.

"The report provides the scientific basis for the treatments we choose, for example if we're thinning or proposing mastication," says Coombs. "With all the different

Pinyon-juniper stand in eastern Nevada showing recent mastication in the foreground and a 5-year-old chaining and seeding in the background. Tree removal methods need to be carefully considered and should fit with ecological site characteristics, including the option to do nothing. Courtesy photo by Richard Miller.

MANAGEMENT IMPLICATIONS

- The goal of restoring ecosystems that support pinyon and juniper in order to maintain resilience and biodiversity is challenged by climate change, the introduction of new species, and changing disturbance patterns.
- In areas where trees are increasing, tree removal treatments, including mechanical removal (e.g., chaining, shredding, cutting) and prescribed fire, have been widely implemented to reduce woody fuels and improve wildlife habitat for sagebrush-dependent species such as the greater sage grouse.
- Properly implemented treatments that preserve or increase perennial understory species enhance ecological resilience and resistance to plant invasions. The recovery potential of understory plant communities after wildfire or prescribed fire depends on those species that survive and regrow.
- One of the most important skills that natural resource managers need in order to select the best treatments for a particular location is the ability to predict outcomes following natural disturbances or vegetation treatments.
- The synthesis report (RMRS-GTR-403) can be used in a shared stewardship context to prioritize areas for management of pinyon and juniper woodlands in locations that will provide the greatest ecological benefits and to identify effective management strategies for prioritized areas that will meet local needs.

Ecology Detectives: How to Identify Treatment Strategies for Managing Pinyon and Juniper Woodlands

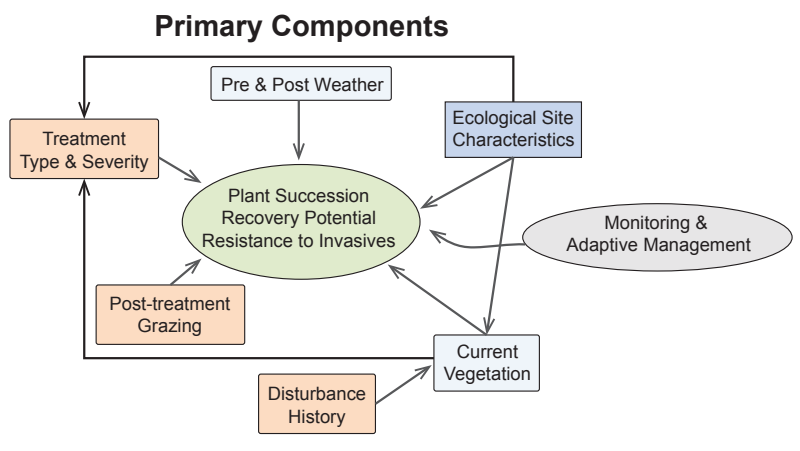
One of the most important skills for natural resource managers is the ability to predict outcomes following natural disturbances or vegetation treatments.

"I always thought Sherlock Holmes would have been a great ecologist because he was so observant and he could look at the facts and put things together," says Richard Miller, lead author of RMRS-GTR-403 that synthesizes more than 1,000 scientific studies on pinyon and juniper woodlands. "A good ecologist or a good resource manager needs to be a good detective, where they look at all the facts and then are able to put a story together and make the best possible decisions they can."

Acting as detectives, vegetation managers need to know what questions to ask, where to search for clues, and how to conceptualize the factors that influence succession.

In addition to describing the advantages and disadvantages of different types of treatments, RMRS-GTR- 403 includes a set of guiding questions to help managers choose the best options for a given site.

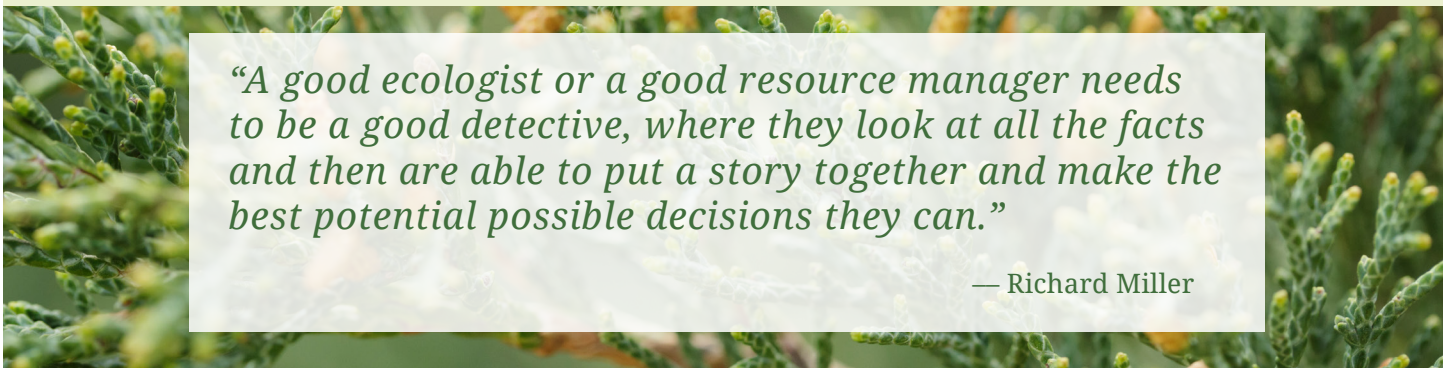
(1) What are the ecological site characteristics of the area to be treated that will influence resistance to invasive annuals?
(2) What is the current vegetation on the site?
(3) How will different treatment methods influence posttreatment succession and invasive annuals?
(4) What are the nonsprouting shrubs on the site?
(5) What is the erosion potential if plant cover is temporarily reduced?
(6) Will the density of small trees require followup treatments?
(7) Are surface fuels adequate to carry fire under moderate weather conditions if the treatment is prescibed fire? Or is pretreatment required?
(8) Will posttreatment fuel loads be acceptable?



A conceptual model of the primary components that drive succession following vegetation management treatment. Consideration of key characteristics of these components increases the ability to predict outcomes following disturbance and vegetation management (Miller and others 2013, 2014a).

The synthesis also provides a conceptual framework for understanding the factors that influence succession in pinyon and juniper woodlands, including current conditions (vegetation, ecological characteristics of a site, and weather conditions) as well as pre- and postdisturbance history (type, frequency, and severity).

Much of the information managers need can be gathered through field observations. Miller recommends two RMRS field guides (RMRS-GTR-322 and RMRS-GTR-338) that include tools to help evaluate fire severity based on evidence left on the landscape after fire, and to determine if a site is (or was) an old-growth woodland or an expansion woodland. A fourth reference (RMRS-GTR-308), provides a state-of-the-knowledge review about the effects of fire on vegetation and soils in the Great Basin Region.



references in it, it's kind of a one-stop shop."

A substantial section of RMRS-GTR-403 documents how vegetation and soils respond to different treatments (including how native and invasive species respond to fire).

"I'm really impressed with the way the report is put together," Coombs says. "It includes examples of what's worked and what hasn't, which shows where you get the best bang for your buck."

Leao agrees and also values the report as a reference for deciding the location of treatments.

"Knowing the difference between persistent woodlands, areas with old-growth characteristics that are important to manage for, and what's migrating really helps us focus where to apply our treatments," he says.

He plans to use the report when it's time to update his forest's plans. He also values it as "a common frame of reference, in language that we can speak to—not just within the Forest Service, but also as a public communication tool for explaining why we're doing what we're doing."

The threat of invasive annuals following fire treatment in pinyon-juniper woodlands is of major concern. The vegetation that is present prior to treatment influences fire severity, resilience or recovery potential, and resistance to invasive plants. Egan Range, Nevada. Courtesy photo by Richard Miller.

The Way Forward

With more than 75 years of science, and more than 2,000 papers on the subject of pinyon and juniper woodlands, scientists' and managers' knowledge of these systems has grown substantially. Soils and ecological site types across the Great Basin and the Colorado Plateau have been mapped and powerful technology has been developed to measure and model processes and project future conditions. But the challenges of managing these ecosystems—warming temperatures, droughts, more severe fires, and invasive species—seem to keep growing.

"What none of us are good at right now is truly understanding how climate warming is going to play out in these systems," Chambers says. "For example, we tend to focus our treatments on those lower elevation slopes that are likely to become warmer and drier; but maybe we should be focusing on the higher elevation areas, where we are most likely to have refugia in the future."

Given that the future is impossible to predict with any certainty and as management goals continue to evolve, frameworks for making decisions backed by scientific information will continue to guide the way forward.

SCIENTIST AND MANAGER PROFILES

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

JEANNE CHAMBERS is an emeritus senior scientist with the Rocky Mountain Research Station located in Reno, Nevada. Her research focuses on factors that determine resistance to invasive species and affect ecological resilience to disturbances like wildfire in arid and semiarid shrublands, woodlands, and riparian ecosystems.

RICHARD F. MILLER is an emeritus professor with the Eastern Oregon Agricultural Research Center at Oregon State University in Corvallis, Oregon. His research focuses on range ecology, specifically the spatial and temporal dynamics of sagebrush and juniper woodlands in the Intermountain Region with an emphasis in fire.

DUNCAN LEAO is the Humboldt-Toiyabe National Forest forest fuels and vegetation program manager.

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FURTHER READING

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About the

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The purpose of SYCU is to provide scientific information to people who make and influence decisions about managing land.

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