



Rocky Mountain Research Station Grassland, Shrubland and Desert Ecosystems Science Program



Restoration on the Range: Healing America's Iconic Landscapes

Western rangelands provide the wide-open spaces that are integral to the identity of the American West. Seen as the backdrop to countless western films, these landscapes provide sustenance to the region's people and its iconic flora and fauna, such as sagebrush, cactus, antelope and roadrunners. But native rangelands have disappeared at an alarming rate over the past century. At least 272 million acres of rangelands that greeted early European settlers have vanished, converted to croplands, forests, urban developments, industrial sites, roads and reservoirs. The USDA Forest Service estimates that housing development will alter 57 million more acres of rangeland by 2030.

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*Pronghorn antelope have returned
to the newly restored Bonita
Grasslands, Arizona.*

Photo: Natural Resources
Conservation Service [NRCS]

"The challenges are mounting across the landscapes we share," said Forest Service Chief Tom Tidwell during a speech to the Western States Land Commissioners Association in Little Rock, Arkansas in January 2010. Forest Service leaders have identified multiple pressing threats to public lands, including fire, invasive species, loss of open space, climate change, water shortages, and pressure from human uses, such as recreation, energy development, and urban expansion.

These challenges threaten more than just the West's legendary scenic vistas. Healthy rangelands contribute to America's economy and its citizens' wellbeing. Rangelands produce a diversity of important commodities such as forage, wildlife habitat, game and fish, water, minerals, energy, plant and animal gene pools, recreational opportunities, and wood products. Rangeland watersheds provide water to municipalities, irrigators and industry. Ranching and subsistence farming are traditional lifestyles associated with rangelands.

The availability of beautiful vistas such as those viewed on the Wyoming Centennial Scenic Byway is a measure of how well landscapes have been managed or restored. Photo: Mindi Crabb

With so much rangeland already lost, restoring what's left on public lands is crucial for preserving native plant and animal species, conserving biological diversity and species gene pools, providing for traditional lifestyles, supporting tribal needs, and enabling economic and recreational uses.





Streams and riparian zones can be damaged by flood events, drought, invasive species, overgrazing, and recreation, and are frequently selected for restoration actions. Near Jackson, Wyoming.

Photo: Tim McCabe, NRCS

"I believe that Americans who love their public lands can coalesce around the common goal of ecological restoration"

Researchers at the USDA Forest Service Rocky Mountain Research Station (RMRS) are working on a variety of restoration projects that aim to restore the functions of healthy rangeland ecosystems so that they remain resilient and capable of delivering the ecosystem services on which Americans depend. Their results will help researchers create better methods, tools and native plant materials for restoring ecosystems, for evaluating the risks and effectiveness of various restoration treatments and for monitoring changes.

RMRS programs like the Great Basin Native Plant Selection and Increase Project (see next page) aim to provide plant materials of key restoration species that are adapted to local environments and genetically diverse. Studies of plant landscape genetics (genecology) provide tools to guide conservation and restoration efforts, measure and monitor success, and ultimately minimize extinction risk by conserving species as dynamic entities capable of evolving in the face of changing conditions. "Quantitative genetics and genecology studies can help researchers determine how, or if, species and populations will adapt to changing conditions," says Forest Service National Genetics Program Leader Randy Johnson. RMRS researchers are developing approaches for selecting and increasing supplies of plant materials that can be used for restoration in an era of drought, climate change, and potential plant migrations; monitoring protocols for assessing ecosystem response to restoration, long-term community recovery, persistence, and resilience; and conducting vulnerability assessments to identify priority restoration species and sites.

Despite significant challenges, Tidwell remains hopeful about restoration. "I believe that Americans who love their public lands can coalesce around the common goal of ecological restoration," he says. Tidwell has developed an approach that emphasizes stewardship on a scale that supersedes ownership. "An all-lands approach brings landowners and stakeholders together across boundaries to decide on common goals for the landscapes they share," he says. The all-lands approach brings stakeholders together for a shared purpose — to imagine and create a sustainable future, says Tidwell. "Our collective responsibility is to work through landscape-scale conservation to meet public expectations for all the services people get from forests and grasslands."

The Great Basin Native Plant Selection and Increase Project

When wildfires burned millions of acres of U.S. public lands in 1999 and 2000, a shortage of native plant materials drastically limited rehabilitation and restoration efforts. In response to this crisis, Congress directed the Secretaries of the Interior and Agriculture to create a plan to supply native plant materials for emergency stabilization and long-term rehabilitation and restoration efforts, and the Great Basin Native Plant Selection and Increase Project (GBNPSIP) became an exemplary part of that plan.

The GBNPSIP aims to increase the availability of native plant seeds for use in restoring native plant communities across the Great Basin. The program works toward three overarching goals — to increase the variety of native plant materials, particularly native forbs, available for restoration in the Great Basin; to develop seeding technology and equipment for reestablishing native species and communities; and to transfer research results to seed growers and land managers who can put them to work on the ground.

At present, the GBNPSIP includes more than 25 partners with backgrounds in botany, restoration ecology, agriculture, horticulture, and entomology who are working together to achieve the program's goals. "Our project emphasizes collaboration and communication among researchers, public and private land managers, restorationists, and private seed and plant growers," says Nancy Shaw, Team Leader of the GBNPSIP.

Over the last decade, the program's work has focused in five main areas. First, to identify restoration species required to improve community diversity and habitat for sage-grouse and other organisms; second, to provide genetically diverse, regionally adapted plant materials of these species and tools to guide selection of materials suitable for use under future climate change scenarios; third, to solve problems related to seed production of problematic species; fourth, to devise strategies and equipment for re-establishing healthy, diverse ecosystems at the landscape scale; and finally, to facilitate science delivery to the people who need it to make restoration-related decisions.



Research Botanist Nancy Shaw evaluates variation in seedlings in Lucky Peak Nursery greenhouse.

Photo: USDA Forest Service

“Our project emphasizes collaboration and communication among researchers, public and private land managers, restorationists, and private seed and plant growers”

Conservation genetics research has become an important focus of the GBNPSIP. With Forest Service, Agricultural Research Service and university geneticists, GBNPSIP researchers are examining genetic variation across the landscape and its relationship to environmental variation. “Genetic variations that correlate with physiographic or climatic variations at the seed source locations are likely to represent adaptive traits,” says Bryce Richardson, a Research Geneticist at the RMRS Shrub Lab in Provo, UT. Results of these studies help researchers to map genetic variation across the landscape and to develop seed zones and seed transfer guidelines that can address the potential impacts of climate change and make recommendations for now and into the future. Researchers are also developing provisional seed zones based on precipitation, temperature and physiographic variables for species lacking species-specific seed zones.

By shifting away from exotic grass monocultures and increasing the use of native species where feasible, land managers can improve ecosystem diversity, structure and function. However, re-establishing communities of grasses, forbs and shrubs on semi-arid and arid lands remains challenging. As native forbs have not been widely used in Great Basin restoration efforts, GBNPSIP researchers have conducted studies on the establishment and competitive abilities of forbs that might be used in restoration projects. Program scientists have also established seeding studies at six locations in four states, primarily on Wyoming big sagebrush sites, to identify strategies for re-establishing diverse, functional communities following wildfire. Changes in planting practices, including separating species with different seed sizes, plant growth rates, and competitive abilities and modification of equipment to reduce disturbance are being examined for their effects on subsequent community development. As part of this research, scientists are conducting long-term evaluation of protocols for monitoring post-fire seedlings and the impacts of livestock grazing on native seedlings. Collaborators are also examining changes in dust emissions, soil physical and chemical characteristics, and exotic invasives in response to wildfire, seeding practices and post-seeding vegetation as well as pollinator response to fire and restoration practices.

How genetic information is used to guide large-scale native plant restoration efforts.

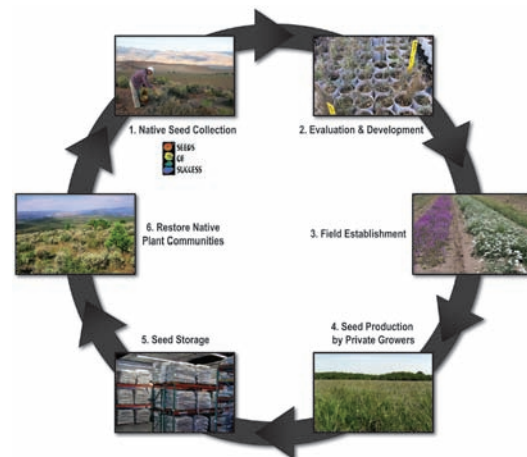


Figure 1 from Kramer, A.T. and K. Havens. 2009. Plant conservation genetics in a changing world. *Trends in Plant Science* 14: 599-607.

Step 1. Seed collection

Collection efforts take care to capture genetic variation between and within populations as well as phenotypic plasticity. Genetic sampling guidelines exist for rare species, and genetic studies can be used to guide and gauge the success of seed collection work.

Step 2. Evaluation and development

Collecting from multiple seed sources allows researchers to conduct genetic studies on collected seeds to learn more about the species' biology and underlying adaptive genetic diversity in order to identify and delineate seed transfer zones. Surprisingly little is known about most species, so this stage is often critical to guiding effective species restoration.

Step 3. Field establishment

Step 4. Seed production by private growers
During grow-out (steps 3 and 4) managers aim to maintain maximum quantitative genetic variation while limiting the potential for inappropriate inbreeding as well as inappropriate intrapopulation gene flow or interspecific hybridization. Genetics research has helped identify when and where these genetic factors are a concern.

Step 5. Seed storage

It is important to clean, dry and store seeds to ensure the storage and equal survival of genetic diversity.

Step 6. Restoration of native plant communities
Restoration practices benefit from incorporating genetic considerations, including choosing the best seed source (guided by research in stage 2), species mix, and restoration technique to maximize appropriate quantitative genetic variation and population size.



Top: Overview of the treatments at the SageSTEP Marking Corral site in eastern Nevada near Ely. The Mechanical, Chainsaw Cut Treatment is in the foreground, and the Prescribed Fire Treatment is in the background. Each treatment covered over 1,000 acres.

Bottom: Prescribed Fire at the SageSTEP South Ruby site near Elko, NV.

Photos: Robin Tausch



Research on cultural practices for seed production of native plant materials is another important research focus of GBNPSIP. “Native seed growers are primarily small businesses and are reluctant to take on new species with uncertain markets, especially when the market for native plant materials in the Great Basin fluctuates widely from year to year depending on the number of acres that burn,” says Shaw. Native forbs generally do not produce a seed crop the first year and many exhibit bottlenecks to successful seed production. Research on irrigation, weed control and stand establishment for native forb species has helped identify major differences in requirements among genera and species, and this research has increased grower interest and confidence in using these species. Additional research focuses on insect, disease, and pollinator relationships that can become paramount when wild species are grown in monocultures. As plant communities and species ranges are altered by climate change, these relationships may become more prominent and problematic in wildland settings.

As research results become available, they are shared with stakeholders via publications, workshops, field days, annual meetings, and symposia. Researchers in the project publish their results in scientific journals and present them at conferences, but their work isn’t done until they’ve delivered these results and recommendations to the land managers who can put it to use.

SageSTEP: Restoring Sagebrush Communities

Sagebrush habitats extend over 40 million hectares in the western U.S. and Canada and provide a home to more than 350 vertebrate species. Over the last century, fire suppression, inappropriate livestock grazing, expansion of conifers, and the invasion of exotic weeds like cheatgrass have contributed to the decline of sagebrush ecosystems, making sagebrush steppes among the most endangered ecosystems in western North America.

The Sagebrush Steppe Treatment Evaluation Project (SageSTEP) is a long-term study designed to evaluate the effects of land management on sagebrush communities to identify the best ways to restore and conserve these crucial habitats. The SageSTEP project is spread over a regional network of sites to allow

researchers to study the thresholds between healthy and unhealthy sagebrush communities over a broad range of conditions across the Great Basin. These studies examine the effects of various restoration treatments on plants, wildfire, soils, water runoff, erosion, birds and insects. The project also includes economic analysis to help managers select optimal management strategies, and a social science element to explore citizens’ and managers’ views about the various treatments.

The SageSTEP project involves two main experiments. The first focuses on cheatgrass invasion, and identifies sagebrush sites threatened by cheatgrass invasion to study the effects of four land management options; no management action, prescribed fire, mechanical thinning of sagebrush by mowing, and herbicide application to thin old, unproductive sagebrush plants and encourage growth of young sagebrush and native understory grasses. Researchers hope the study will help them identify the optimal amount of native perennial bunchgrasses needed in the understory to allow managers to improve land health without conducting expensive restoration, such as reseeded of native grasses.

The second SageSTEP experiment involves the RMRS Reno Lab and focuses on woodland encroachment. For this experiment, researchers are studying sagebrush communities threatened by woodland encroachment to study the effects of no management action, prescribed fire, and mechanical removal of trees (chainsaw cutting). The objective “”, says Robin Tausch, Research Range Scientist, “is to find out how much native sagebrush/bunchgrass community is necessary for managers to improve land health without expensive restoration efforts.

The results of the SageSTEP project should provide resource managers with information they need to make restoration management decisions with the least amount of risk and uncertainty. Several years have passed since the application of fuels treatments to the SageSTEP study sites, and some preliminary trends have begun to emerge, but these early results require long-term monitoring to ensure that they represent lasting trends. One important strength of the SageSTEP project is that it monitors trends over the long term and should yield durable results that can help land managers make management decisions that will promote sustainable results.



Trained US Forest Service fire management personnel apply fire treatments to RMRS study sites on the Kiowa National Grassland, near Clayton, New Mexico.

Photo: USDA Forest Service



Research Ecologist Paulette Ford oversees fire application efforts on her grassland study sites.

Photo: USDA Forest Service

Fire's Role in the Ecology of the Shortgrass Steppe

Fire is a natural disturbance in the shortgrass steppe of the southern Great Plains and the southwestern U.S. Decades of fire suppression in these areas has altered these grassland ecosystems. Given the uncertainty of future scenarios for climate change and climate variability we need to know now how fire seasonality, and over the long-term fire frequency, along with climate variability and climate change will affect ecosystem function. The reestablishment of periodic fire is fundamental to the ecological restoration of grasslands in the southern Great Plains of the United States. However, prior to reintroducing large-scale fire as a management tool, the appropriate fire season, frequency, and fire effects on ecosystem components need to be determined.

Research ecologist Paulette Ford from the RMRS's Albuquerque lab is leading a long-term, 18-year research project on the Kiowa National Grassland in northeastern New Mexico to examine the effects of fire in the growing season versus the dormant season in shortgrass steppe. The study, in its 15th year, examines effects of fire in the growing versus dormant season on shortgrass steppe at return intervals of three, six and nine years. The research includes analysis of the responses of multiple ecosystem components to disturbance by fire under prolonged drought conditions. Responses measured include soil and vegetation nutrient cycling response, biotic soil crust response, small mammal and invertebrate response, and black-tailed prairie dog colony response.

The research addresses the questions: What is the optimal amount and type of fuel treatment to apply to a landscape? Can restoring fire to a landscape reduce adverse impacts from climate change? How does fire impact climate change mitigation strategies such as the use of vegetation management as a carbon sequestration tool? In addition, the Kiowa and Rita Blanca National Grasslands are receiving consideration as a proposed release site for the black-footed ferret once their populations are extensive enough to support a release. Research on the effects of season and frequency of prescribed fire on black-tailed prairie dog colonies will assist site managers to plot

strategies to use prescribed fire as a tool to increase populations. Long term, landscape scale strategies for the shortgrass steppe ecosystem will be greatly enhanced by the knowledge of how fire sustains prairie dog towns as a vital component of that ecosystem. These towns provide habitat for mountain plover and other dependent species and are a source of prey base for many species of hawks. The research will also be helping to return an endangered species, the black-footed ferret, to a part of its historic range by providing data needed to make informed management decisions and aid in the development of site specific recovery plans for both the ferret and the prairie dog.

Ford's research thus far has demonstrated that shorter fire return intervals, i.e., burned three times in nine years may lead to potentially higher erosion and lower soil fertility in semiarid grasslands. However, longer fire return intervals, i.e., burned once or twice in nine years leads to lower erosion and higher soil fertility. Her research additionally demonstrates the differential effects of fire on various ecosystem components, that it may not be possible to maximize all ecosystem responses to fire at one time, with the choice depending on the management goal, that conclusions about resilience of shortgrass steppe to disturbance by fire will vary with both temporal and spatial scales, and that vegetation response to fire depends mainly on levels of precipitation.

Results of Ford's experiment also suggest that shortgrass steppe has the ability to recover from fire relatively quickly, i.e., three to 30 months; that even in the short-term, plant and animal communities on burned and unburned grasslands are relatively similar; all ecosystem components that measured are generally, but not equally resilient; season of fire does affect response; and some fire effects can be immediately obvious, while other effects have a lag time between treatments and results, or are overshadowed by environmental variation.

The results of Ford's grassland fire research are currently being used by the USDA Forest Service Cibola National Forest, Kiowa and Rita Blanca National Grasslands to develop a prescribed burning plan to benefit wildlife habitat, reduce fuel loading, and to better align the timing and intensity of fire to increase benefits for the plains ecosystem.



Antelope bitterbrush, Purshia tridentata. Purshia species occur throughout the range of the interior west and are an important shrub for habitat, wildlife browse, successional development, and erosion control.

Photo: Kas Dumroese



Mexican cliffrose, Purshia mexicana. Purshia mexicana seedlings grown in a greenhouse study that investigates seedling physiological differences relative to drought adaptation and tolerance.

Photo: Kas Dumroese

Teasing out the different ways that plant and animal species respond to fire will help managers more effectively use fire to restore these grasslands. “If we can understand and predict grassland community responses to fire, then we can use fire as a management tool to create desirable landscape patterns for managing populations of plant and animal species,” Ford says.

Stocktype Trials: Boosting Outplanting Performance

Seedlings for reforestation and restoration come in a wide range of shapes and sizes. These traits are often referred to as “stocktypes,” a term that describes a seedling’s age and its method of production. When restoration managers embark on a new project, they face a question: which stocktype will perform the best for the project at hand?

Answering this age-old question isn’t as straightforward as it might sound. Many factors influence outplanting success, including how a seedling is produced, its genetics, and the characteristics of the site where it will be planted. In this age of tight budgets and short planning cycles, managers need to know that their limited resources will produce the best possible results. Stocktype trials can help managers determine the best planting stock for a given site, but these trials require careful planning and design to ensure that the results are realistic. “The results of any stocktype trial and the relevance of the conclusions are only as good as the study design,” says Jeremiah R. Pinto, a plant physiologist at the Forestry Sciences Laboratory Rocky Mountain Research Station in Moscow, ID.

Pinto and RMRS plant physiologist R. Kasten Dumroese are studying ways of improving stocktype trials to ensure that their results are applicable to the real world. Nursery practices influence the results of outplanting projects in ways that are easily missed. “It sounds so basic, but nursery managers and even researchers are constantly overlooking this issue and making decisions with flawed data,” says Dumroese. “For example, we could be wasting a lot of money growing big seedlings when smaller seedlings would do just as well, simply because smaller stocktypes weren’t produced well in the nursery. A more correct set of cultural practices

designed especially for the smaller stocktypes may have resulted in an opposite result.”

Pinto’s work has shown that the results of many stocktype trials inadvertently end up reflecting the cultural practices used to produce the stocktype rather than the intrinsic nature of the planting stock. “We suspect that most nursery plants are pampered — even when we think they aren’t — and a better understanding of the dynamics between irrigation frequency and subsequent plant quality can help us produce seedlings that are better able to survive and grow on outplanting sites,” says Dumroese. “In light of climate change, and the potential changes in outplanting conditions — for example, hotter and drier conditions earlier in the growing season — it will be imperative that seedlings are grown to withstand those increasingly difficult conditions during their establishment.”

Dumroese and Pinto are investigating physiological differences as they relate to drought adaptation and tolerance among three bitterbrush species, *Purshia glandulosa*, *P. mexicana*, and *P. tridentata*, by looking at water movement through plant stems (hydraulic conductivity) under nursery scenarios. These species span the range from New Mexico northward to Washington. “We are giving them different nursery cultural practices to see what the effect is on conductivity and what happens when that conductivity is disrupted (xylem cavitation),” says Pinto. “To a large degree, the resistance to cavitation is species specific and under genetic control, but we hypothesize that nursery practices can affect cavitation events after outplanting, thereby influencing seedling survival and growth. We are also interested in what happens after cavitation — do species recover or is outplanting performance permanently compromised?”

These native bitterbrush species are used in restoration efforts, but success with direct seeding efforts is often low. Pinto and Dumroese are studying key physiological and ecophysiological components in these species as they relate to nursery culture, successful outplanting, and potential climate change mitigation efforts through assisted migration. The results should help restoration and nursery managers improve the success of restoration projects and alter, favorably, the trajectories of the restoration goals.



A message from the Program Manager

Restoration is one of five focal areas of the Grassland, Shrubland and Desert Ecosystems Science Program (GSD). Our program mission is to develop and deliver knowledge and tools that will help to sustain and restore grasslands, shrublands and deserts threatened by invasive species, disturbances, urban pressures and climate change. Scientists in our program develop methods for restoring ecosystems with native plants, assess genetic variation and resilience among plant subspecies, and design and test restoration treatments to determine best restoration treatment practices. Studies focus on restoring ecosystems damaged by disturbances such as wild fire, exotic plant invasions, human uses, drought, and climate change. Our research also evaluates the capacity for species to adapt to environmental changes. We provide decision support to managers by developing new plant materials for use in restoring ecosystems. We also develop approaches for restoring habitats required by rare, threatened and endangered plant and animal species.

—Dr. Deborah Finch,
Science Program Manager

Meet some GSD Scientists



Dr. R. Kasten Dumroese is a plant physiologist at the RMRS's Forestry Sciences Laboratory in Moscow, ID, and the national nursery specialist on the National Restoration, Nurseries and Genetic Resources team.

His research involves improving propagation techniques for native plants, and applied nursery research to remove bottlenecks to production efficiency and plant quality. He transfers technology to nursery managers and professionals engaged in reforestation and restoration of degraded ecosystems. Dumroese publishes the *National Nursery Proceedings* and the *Forest Nursery Notes* newsletter and serves as the editor-in-chief of the *Native Plants Journal*, a publication about the growing and outplanting of North America's native flora. He's also involved in the Native Plant Network, which hosts a searchable database of more than 2500 protocols for growing native plants.



Dr. Paulette Ford is a Research Ecologist stationed at the RMRS Lab in Albuquerque, New Mexico. Her research interests include the roles of disturbance (i.e. fire, drought, infestations, pathogens) and

climate change in structuring desert, grassland, and woodland communities, and methods for restoring degraded ecosystems. She is currently studying the effects of season and frequency of fire in shortgrass steppe of the southern Great Plains and she is working with university colleagues on the relationships between climate change and other stressors in southwestern US ecosystems.



Dr. Jeremiah R. Pinto is a plant physiologist at the RMRS Forestry Sciences Laboratory in Moscow, ID, and the tribal nursery coordinator on the National Restoration, Nurseries and Genetic Resources

team. He chairs the Intertribal Nursery Council, and has won numerous awards for his work, including the Two Chiefs' Partnership Award from USDA Forest Service & NRCS in 2006 and the Intertribal Timber Council Earl Wilcox Memorial Individual Achievement Award for outstanding service to Indian Forestry in 2007. His research focuses on forest and native plant nursery propagation, outplanting, and establishment

including biophysical and physiological limitations and adaptations within each system. He stays connected to his Native American background by working as a technical nursery liaison to Indigenous peoples across the U.S.



Dr. Bryce Richardson is a Research Geneticist stationed at the RMRS Shrub Lab in Provo, UT. His research interests are focused on population genomics, genecology, and phylogenetics of plants and

plant pathogens. He is currently studying the genetic capacity of big sagebrush, blackbrush, aspen and other plants to adapt to changing climates and environments using common garden studies. He is the regional contact for the Western Forest Transcriptome Survey, a collaboration to identify climate-related genes from diverse species.



Dr. Nancy Shaw is a Research Botanist at the RMRS Aquatic Sciences Laboratory in Boise, ID. Her research focuses on ecological restoration in the Great Basin, and she serves as Team Leader of the Great Basin Native Plant Selection

and Increase Project, a program sponsored by the USDI Bureau of Land Management. She conducts collaborative research with geneticists, agronomists, and restoration ecologists to increase the availability of genetically diverse, regionally adapted plant materials, and she evaluates strategies for restoring damaged communities and provides venues for science delivery.



Dr. Robin Tausch is a supervisory range scientist and plant ecologist at the RMRS Great Basin Ecology Lab at the University of Nevada, Reno. He is currently studying the paleoecology of Great Basin upland

ecosystems to determine how plant communities have changed in response to Holocene climate change. His work also focuses on more recent vegetation changes to explore how the spatial and temporal patterns of the expansion of pinyon-juniper woodlands are influencing the community dynamics and fire patterns of the affected sagebrush ecosystems. Finally, he's studying how current spatial and temporal patterns in vegetation and fire are likely to change in response to climate change.



Restoration of disturbed sites in New Mexico will likely benefit Gunnison's prairie dog, a candidate-listed species, through effects on plague transmission.

Photo: Megan Friggens



Sagebrush habitat restoration is needed to sustain populations of sage grouse, a candidate-listed species.

Photo: US Fish and Wildlife Service

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Program Manager

Grassland, Shrubland and
Desert Ecosystems Science

Deborah Finch, Ph.D.

USDA Forest Service
Rocky Mountain Research Station

333 Broadway SE, Suite 115
Albuquerque, NM 87102

voice 505-724-3671
fax 505-724-3688
cell 505-401-0580

www.fs.fed.us/rm/grassland-shrubland-desert/

www.fs.fed.us/rm/albuq/dfinch.php

Writer/Editor

Christie Aschwanden
christie.asch@gmail.com
www.christieaschwanden.com

Design/Layout

Andrew Schlabach
andrew@alloneplanet.com

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