



USDA Forest Service

# GSD Update

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

## Year in Review: Spotlight on 2013 Research by the Grassland, Shrubland and Desert Ecosystems Science Program

*In this issue of the GSD Update, we take a look back at selected studies of the Grassland, Shrubland and Desert Ecosystems Science Program (GSD) that depict its strengths and focus areas. Significant results of recent research and science delivery by GSD scientists are highlighted. We feature program research that lines up with the strategic research priorities of the USDA Forest Service and the Rocky Mountain Research Station (RMRS). In particular, we spotlight accomplishments in:*

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*Measuring factors that contribute to the expansion of a recently introduced plant species, sickleweed, into a native prairie.*

Photo: Jack Butler

- Assessing changes in ecosystems and landscapes caused by disturbances and stressors such as fire, invasive species, climate change and their interactions.
- Developing knowledge and approaches for managing and restoring ecosystems and landscapes to improve their resiliency.





Investigating the population genetics of a recently introduced plant species.

Photo: Jack Butler

“Invasive plant species threaten ecosystems throughout North America and around the world. However, little is known about how evolutionary processes shape these invasions. Because predictions of invasive spread are based on species characteristics, it is imperative to determine whether an invader is evolving novel traits in the invaded region.”

— Francis Kilkenny,  
RMRS Research Biologist

Figure. Final survival (A) and final biomass (B) for Japanese honeysuckle plants from the core and the margin of the North American range after three years of growth at gardens in both regions (From Kilkenny and Galloway 2012).

## Disturbance Ecology

### Investigating new emerging invasive plant threats

National Grasslands represent large tracts of native prairie that pose distinctive challenges to studying and managing invasive plants. Because newly introduced species can quickly spread unimpeded across large areas of these uninterrupted landscapes, early detection and rapid response is a critical component of invasive plant research and management in grassland ecosystems. But, studies that focus specifically on recently introduced exotic plants in the early stages of establishment are limited. Documenting the pattern of invasion before the species becomes widespread is an essential part of identifying traits that contribute to understanding the success of recent invaders while increasing knowledge of factors influencing invasibility

RMRS Research Ecologist **Jack Butler** (Rapid City, SD) partnered with national grasslands of the Forest Service Rocky Mountain Region and with South Dakota State University to investigate the biological and habitat characteristics of a rapidly expanding population of sickleweed (*Falcaria vulgaris*), an invasive plant newly introduced on the grasslands of the Northern Great Plains. The approach involved using herbarium records of the species to reconstruct the introduction history and potential pathways of spread. Using detailed field surveys, researchers described the pattern of abundance and distribution of the species and identified the factors that can predict the susceptibility of local and regional grassland communities to invasion. This work was complemented by cutting edge laboratory research on population genetics, seed germination and establishment characteristics of the species. Genetic analyses identified the number and location of potential sites of introductions while seed germination trials described the establishment and spread potential of sickleweed.

Collectively, these studies assisted managers in developing a range of management alternatives to reduce establishment of new populations and limit expansion of existing populations. The approach also provides a template for future evaluations of newly introduced species before they potentially become invasive.

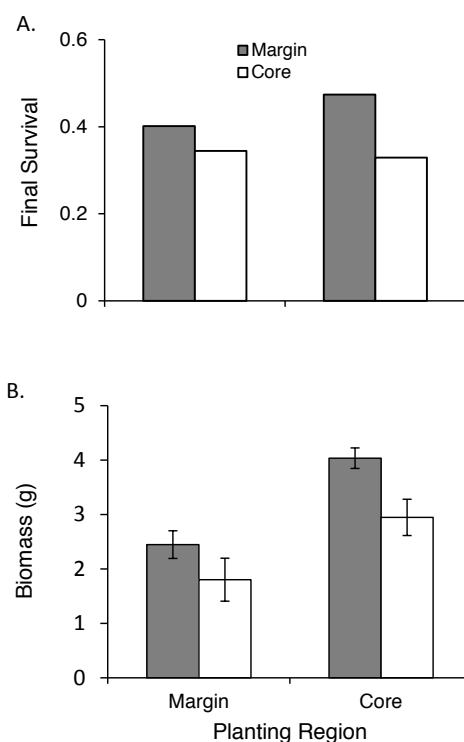
To learn more about this research, refer to the following publications:

Butler, J.L.; Wacker, S.D. 2013. Sickleweed on the Fort Pierre National Grasslands: An emerging threat. *The Prairie Nat.* 45:28-38 <http://www.treesearch.fs.fed.us/pubs/44491>

Sarbotam, P.; Nebal, M.P.; Neupane, A.; Larson, G.E.; Butler, J.L. 2012. Inferring introduction history and spread of *Falcaria vulgaris* Bernh. (Apiaceae) in the United States based on herbarium records. *Proc. South Dakota Acad. Sci.* 91:113-129. <http://www.treesearch.fs.fed.us/pubs/44493>

### Can evolution make a stronger weed?

For his dissertation research at University of Virginia, **Francis Kilkenny** (now a Research Biologist with RMRS in Boise, ID) compared the performance of eastern North American populations of Japanese honeysuckle (*Lonicera japonica*) from areas established 100–150 years ago, now the southern core of the range, to populations from the northern range margin, established within the last 65 years. Growth and survival of individuals from core and margin populations were compared in common gardens in both regions over a three-year period.





Analyzing flammable volatile terpene s from beetle-attacked trees in Montana.

Photo: Justin Runyon

Margin plants had a faster growth rate than core plants, regardless of the garden location. Margin plants also had greater survival, which was a direct result of their faster growth rate. An additional experiment showed that margin plants were stronger competitors than core plants. These results demonstrate that Japanese honeysuckle populations at the leading edge of the range expansion have evolved faster growth rates and stronger competitive ability.

To better predict invasions, researchers and managers will need to develop predictive models that take into account variation within a species and the possibility that evolution is taking place in the invaded range.

To learn more about this research, see the following publications:

Kilkenny, F.F.; Galloway, L.F. 2012. Adaptive divergence at the margin of an invaded range. *Evol.* 67(3): 722-731. <http://www.treeseearch.fs.fed.us/pubs/44359>

Evans, G.A.; Kilkenny, F.F.; Galloway, L.F. 2013. Evolution of competitive ability within *Lonicera japonica*'s invaded range. *Int. J. Plant Sci.* 174(5): 740-748. <http://www.treeseearch.fs.fed.us/pubs/44358>

## Bark beetles can affect wildfires by altering tree chemistry

Bark beetle outbreaks and wildfires are principal drivers of change in western North American forests, and both have increased in severity and extent in recent years. These two agents of disturbance interact in complex ways to shape forest structure and composition. For example, mountain pine beetle (*Dendroctonus ponderosae* Hopkins) epidemics alter forest fuels and can potentially change the frequency and intensity of wildfires. Given the great influence these processes have on forest ecosystems, a better understanding of how bark beetles and fires interact is needed to better manage forests and to predict and manage wildfires.

RMRS Research Entomologist **Justin Runyon** (Bozeman, MT) and collaborators are working to determine how bark beetle attack changes moisture and chemistry of several tree species and how these changes affect flammability. Findings from this research will allow us to

improve fire behavior and risk models to better predict and manage wildfires and protect property and human life.

Most current fire behavior prediction models assume a uniform fuel source, but bark beetle affected forests are often a mosaic of green, yellow, and red trees. These research projects explore changes in fuel moisture, terpenes, and combustibility in Rocky Mountain conifers resulting from bark beetle attack across these different stages of infestation.

Recently completed research by graduate student Wesley Page and Dr. Michael Jenkins (Utah State University) and Justin Runyon has revealed that (1) mountain pine beetle attacked lodgepole pine trees are chemically-altered and dry out rapidly to become more flammable through the red stage, (2) beetle attack increases emission rates of several highly flammable terpenes, (3) the flammability of yellow and red trees increases with regard to ignitability with shorter times to ignition, lower temps at ignition, and higher heat yields when compared with unattacked green trees, and (4) the yellow stage of Engelmann spruce attacked by spruce beetles contains less moisture and is more flammable than unattacked trees. These findings suggest that fire managers and firefighters should be aware of the possibility of increased potential for crown fire initiation in affected stands and the prospect for rapid changes in fire behavior as fires move in and out of beetle affected areas.

For more information, see the following publications:

Jenkins, M.J.; Runyon, J.B.; Fettig, C.J.; Page, W.G.; Bentz, B.J. 2014. Interactions among the mountain pine beetle, fires, and fuels. *Forest Sci.* 60. <http://www.treeseearch.fs.fed.us/pubs/44259>

Page, W.G.; Jenkins, M.J.; Runyon, J.B. 2014. Spruce beetle-induced changes to Engelmann spruce foliage flammability. *Forest Sci.* 60. [www.mendeley.com/download/public/2814061/6111861134/9bcce0789bd082c16eb93f72cba0cf6a6cd6e2c6/dl.pdf](http://www.mendeley.com/download/public/2814061/6111861134/9bcce0789bd082c16eb93f72cba0cf6a6cd6e2c6/dl.pdf)



Banded male black-backed woodpecker with transmitter adjacent to cavity currently being excavated.

Photo: Mark Rumble

## Managing forests for a disturbance dependent species

Black-backed woodpeckers (*Picoides arcticus*) depend on recently killed forests/trees for habitat where they forage for larvae of woodborers, bark beetles and other insects. However the forest conditions that create habitat are extremely ephemeral and they are only valuable for a few years. These uncommon birds are a Sensitive Species in the Rocky Mountain and Southwest Regions of the USDA Forest Service, a Species of Greatest Conservation Concern in South Dakota and a candidate species for protection under the Endangered Species Act.

Black-backed woodpeckers are well known to use recently burned forests and forested stands killed by insects such as mountain pine beetle (*Dendroctonus ponderosae*) which are infesting forests throughout the western U.S. Recently a petition was filed to protect the Black Hills population of black-backed woodpeckers as a distinct population segment in light of the low estimated populations. The current widespread mountain pine beetle infestation in the Black Hills is a significant source of potential habitat for black-backed woodpeckers, yet also is of concern to National Forest managers because of the substantial loss of timber resources associated with it.

In 2004, RMRS Research Wildlife Biologist **Mark Rumble** (Rapid City, SD) partnered with University of Missouri, Black Hills National Forest and South Dakota Department of Game, Fish and Parks to document black-backed woodpecker use of mountain pine beetle infestation and successful nesting and fledging of young in these infested forests. In 2008 following two wildfires and an ongoing mountain pine beetle infestation, they began evaluating habitat created by wildfire and habitat created by mountain pine beetle infestations. In 2010, the team also began assessing habitat created by fall prescribed fire. Results showed that the Black-backed woodpecker population growth was positive in habitat resulting from wildfire, slightly negative in the mountain pine beetle infestation, while the prescribed fire acted as a significant population sink. Post-fledging survival of juveniles influenced populations. Further research suggests that the season that fires burn affects the abundance of woodborers, the primary source of food for black-backed woodpeckers.

While the current widespread mountain pine beetle infestation in the Black Hills may provide habitat for black-backed woodpeckers, beetles also are of concern to National Forest managers because of the substantial loss of timber resources.

To learn more about this research, see the following publications:

C.T. Rota; M.A. Rumble; J.J. Millsbaugh; C.P. Lehman; D.C. Kesler. 2014. Space-use and habitat associations of Black-backed Woodpeckers (*Picoides arcticus*) occupying recently disturbed forests in the Black Hills, South Dakota. *Forest Ecol. and Mgmt.* 313: 161–168. <http://www.sciencedirect.com/science/article/pii/S0378112713007354>

## Understanding drought impacts on pinyon-juniper ecosystems

Several studies have documented the impacts of drought, increased temperatures, and bark beetle infestation on die-off in pinyon-juniper woodlands since the die-off event, but none have examined pinyon die-off along a selected precipitation gradient. RMRS Research Ecologist **Paulette Ford** (Albuquerque, NM) collaborated with researchers at Northern Arizona University and elsewhere to identify spatial gradients of die-off using an extensive network of field sites, extrapolating to the entire area using remote sensing. They asked the question: How do environmental patterns alter pinyon pine die-off dynamics over a region that experienced a gradient of mortality? The study explored precipitation relationships with a die-off event of pinyon pine (*Pinus edulis engelmannii*) in north-central New Mexico during the 2002–2003 drought. Pinyon die-off and its relationship with precipitation was quantified spatially along a precipitation gradient with standard field plot measurements of die-off combined with canopy cover derived from normalized burn ratio (NBR) from Landsat imagery.

Results of the study show a pattern of pinyon die-off along a precipitation gradient during a drought, where the most notable pattern is a strong threshold response of die-off to precipitation; sites above a 600-mm threshold of cumulative precipitation during the drought period had little to no die-off, while sites <600 mm were highly variable but included areas with high levels of die-off. Furthermore, this threshold response in die-off had a



*Pinyon mortality.*

Photo: N.S. Cobb

“An increased value for long-term experimental areas has been suggested by linking them into regional, continental or even global networks in order to address questions about ecosystem stress at broad spatial and ecological scales.”

—Stanley Kitchen, RMRS Research Botanist

distinct south to north pattern, where reduced precipitation occurred in more northerly sites.

A commentary by Hicke and Zeppel (2013) in *New Phytologist* praised the article, stating that the study was novel for several reasons. The team covered extensive spatial gradients in climate and tree mortality, using widespread field sampling in conjunction with remote sensing to examine variability along these gradients. A combination of methods including field observations of mortality and stand structure, remote sensing, and analyses of climate station and gridded climate data allowed the authors to ascertain climate influences on mortality.

These findings make significant contributions to understanding mechanisms of tree mortality and how climate influences trees. They help managers predict how forests will respond to warming and manage the impacts that will cascade through ecosystems.

Additional information on this research can be found in:

Clifford, M. J.; P.D. Royer; N.S. Cobb; D.D. Breshears; P.L. Ford. 2013. Precipitation thresholds and drought-induced tree die-off: Insights from patterns of *Pinus edulis* mortality along an environmental stress gradient. *New Phytologist* 200: 413-421. <http://www.treesearch.fs.fed.us/pubs/43777>

## Detecting ecosystem stress: The value of long-term experimental areas

The RMRS-managed Desert Experimental Range (DER) in southwestern Utah is one of 23 experimental forests and ranges that use uniform methods to census native bee populations. In his role as DER Scientist-in-charge, RMRS Research Botanist **Stanley Kitchen** (Provo, UT) arranged for the DER to be part of a networked study designed to assess

pollinator diversity and resilience across the country.

In 2013, data from the DER were used in two multi-site collaborations to assess ecosystem response to climate extremes. Partners included 4 universities, 8 USDA Agricultural Research Service Units in 7 states, and 3 USDA Forest Service Research Stations. This work produced important contributions to our understanding of how natural systems respond to change. In one study, data from 41 sites in Australia and North and South America were used to test vegetation response to variable weather with a focus on the early twenty-first century drought (2000-2009). Results demonstrate the broad-scale capacity for plant communities to match their water demand to fluctuations in water availability across a wide range of climatic conditions, suggesting resilience in biomes ranging from arid grasslands to wet forests. However, results also suggest that this resilience will be tested as climatic conditions become more extreme in the future. Study collaborators predict that, because of their sensitivity to drought, grassland biomes will act as early indicators of drought-induced losses.

A second study by this collaboration explores in greater detail the effects of extreme precipitation on plant communities. In this analysis, data from 11 USA sites (including the DER) demonstrate that precipitation patterns characterized by extreme rainfall events result in decreased sensitivity to annual precipitation, limiting ecosystems' ability to use rain efficiently to sustain plant growth. It also suggests that extremes in precipitation patterns frequently produce negative effects, and are as important as total annual precipitation in driving biome production. This means that negative consequences should be expected where changing climates result in a greater proportion of the total annual precipitation being associated with infrequent extreme events.



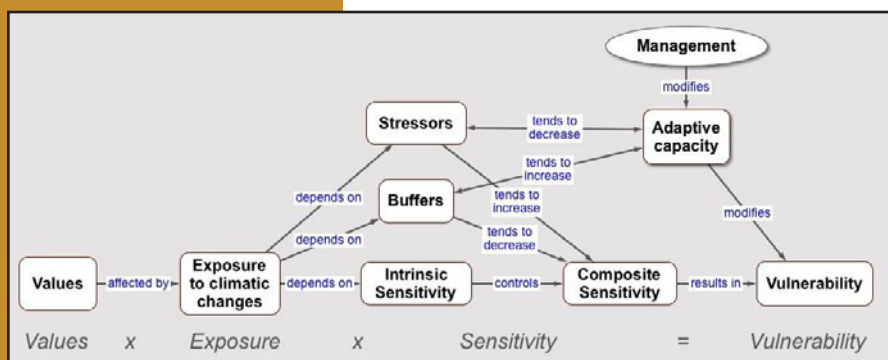
*Pinyon skeletons.*

Photo: N.S. Cobb

For additional information about this research, refer to:

Ponce-Campos, G.E.; Moran, M.S.; Huete, A.; Zhang, Y.; Bresloff, C.; Huxman, T.E.; Eamus, D.; Bosch, D.D.; Buda, A.R.; Gunter, S.A.; Scalley, T.H.; Kitchen, S.G.; McClaran, M.P.; McNab, W.H.; Montoya, D.S.; Morgan, J.A.; Peters, D.P.C.; Sadler, E.J.; Seyfried, M.S.; Starks, P.J. 2013. Ecosystem resilience despite large-scale altered hydroclimatic conditions. *Nature* 494: 349-352. <http://www.treeseearch.fs.fed.us/pubs/43187>

Zhang, Y.; Moran, M.S.; Nearing, M.A.; Campos, G.E. Ponce; Huete, A.R.; Buda, A.R.; Bosch, D.D.; Gunter, S.A.; Kitchen, S.G.; McNab, W.H.; Morgan, J.A.; McClaran, M.P.; Montoya, D.S.; Peters, D.P.C.; Starks, P.J. 2013. Extreme precipitation patterns and reductions of terrestrial ecosystem production across biomes. *J. Geophys. Res. Biogeosci.* 118: 1-10. <http://www.treeseearch.fs.fed.us/pubs/43259>



*Conceptual model for assessing vulnerability, showing linkages among exposure, values and system condition (sensitivity), and demonstrating the relationship between management and vulnerability. (From Furniss and others, 2013, Gen. Tech. Rep. PNW-GTR-884).*

## Helping managers use climate change vulnerability assessments

Climate change creates new challenges for resource managers and decision-makers, with broad and often complex effects that make it difficult to design management actions and minimize undesirable impacts. Projections for the United States indicate that the Southwest is likely to experience more extreme climate changes than other regions. These changes exacerbate existing problems associated with sustaining valued natural resources. To understand these impacts, many agencies have undertaken climate change vulnerability assessments. These assessments are a valuable way to incorporate scientific research into management planning. However, vulnerability assessments and reports are often hard to access and methods and approaches used to measure vulnerability are diverse, which hinder the ability of resource managers to incorporate this information into their management strategies.

RMRS Research Ecologist **Megan Friggens** and GSD Program Manager **Deborah Finch** (both in Albuquerque, NM) joined forces with cooperator Karen Bagne and colleagues from University of Arizona and the USDA Forest Service Southwest Region to write a general technical report (RMRS-GTR-309) that reviews pertinent information regarding methods and approaches used to conduct climate change vulnerability assessments, and provides managers with an updated summary of knowledge regarding vulnerability to climate change of species and habitats in the American Southwest. Their report summarizes and discusses considerations for each of the four stages of the vulnerability assessment process: 1) Selecting a target, scope, and scale, 2) Predicting climate change response, 3) Translating response into vulnerability, and 4) Gleaning management implications. Several common themes are found among the assessments applied to the southwestern U.S.: Vulnerability of grasslands to invasive species is likely to increase under climate change. Hydrological systems will be taxed by multiple impacts, including higher water temperatures, changes in precipitation events, and spread of invasive species in both aquatic and riparian habitats. Many studies show that temperature alone drives or is sufficient to lead to observed or predicted changes. Areas near ecotones are more vulnerable to change (e.g., Madrean habitats).

The report synthesizes important information regarding how Southwestern ecosystems may be affected by climate change. In addition, it provides background and context on vulnerability assessments to help resource managers determine the relevance of assessments for their management questions as well as develop strategies for new assessments that address gaps in our knowledge of climate change effects.

The published RMRS-GTR-309 can be found at:

Friggens, M.; Bagne, K.; Finch, D.; Falk, D.; Triepke, J.; Lynch, A. 2013. Review and recommendations for climate change vulnerability assessment approaches with examples from the Southwest. Gen. Tech. Rep. RMRS-GTR-309. Fort Collins, CO: USDA Forest Service, RMRS. 106 p. <http://www.treeseearch.fs.fed.us/pubs/44184>.

Examples of climate change vulnerability assessments in the Southwest are at: <http://www.treeseearch.fs.fed.us/pubs/43922>, <http://www.treeseearch.fs.fed.us/pubs/40418>



Yellow toadflax infestation, Hebgen Lake Ranger District, Gallatin National Forest.

Photo: Sharlene Sing



Rhinusa pilosa gall on yellow toadflax stem.

Photo: Andre Gassmann

## Managing Resilient Landscapes

### ***Rhinusa pilosa*: A new candidate biocontrol agent for the invasive weed yellow toadflax**

Making new weed biocontrol agents available to U.S. stakeholders is costly and complicated. First, foreign exploration conducted by sponsored overseas collaborators identifies potential weed biocontrol agents through literature reviews and native range surveys of herbivores associated with the target weed. A comprehensive taxonomic review of the target weed must also be completed to identify potential risks to non-target plant species closely related or with biochemical properties similar to the target weed. Review results are used to generate a test plant list. Rigorous, systematic tests of each herbivore species' fidelity to the target weed, as guided by the test plant list, help to significantly narrow the initially large pool of potential agents. Combined results of host specificity tests, climate matching assessments and biological and ecological characterizations are used to identify candidate agents. Research results associated with the species predicted to make the safest and most effective biocontrol agent are summarized in a petition submitted to USDA Animal Plant Health Inspection Service's petition (APHIS) Plant Protection and Quarantine program to solicit approval to make open field releases in North America.

Work by RMRS Research Entomologist **Sharlene Sing** (Bozeman, MT) has been critical in all steps of the process to identify, vet and solicit approval to release a new candidate biocontrol agent for the invasive weed yellow toadflax (*Linaria vulgaris*):

- developed a test plant list for invasive *Linaria* and submitted it for review to the Technical Advisory Group for Biological Control Agents of Weeds (TAG)
- summarized results from host specificity tests, developed and submitted for review to the TAG a petition for a permit to make field releases of the yellow toadflax stem galling weevil *Rhinusa pilosa*
- gained TAG's recommendation to APHIS to approve North American releases of *Rhinusa pilosa*. APHIS agreed to proceed with steps

required for issue of a release permit based on summarized petition evidence indicating that *Rhinusa pilosa* poses no obvious threat to economically or ecologically important non-target organisms

- developed multiple grant applications with collaborators and gained external funding to support foreign exploration and overseas host specificity testing
- co-authored a peer-reviewed article (in review)

The availability of a new biocontrol agent such as *Rhinusa pilosa* will increase opportunities for integrated weed management, and provide a sustainable, self-dispersing management tool to the wide range of North American stakeholders affected by yellow toadflax.

### **Cheatgrass die-off – problem or opportunity?**

On millions of acres in the Great Basin, shrub steppe vegetation has been replaced by near-monocultures of the flammable invasive annual cheatgrass (*Bromus tectorum*). Restoration of these ecosystems is virtually impossible without cheatgrass control. In recent years, however, land managers have noticed a new phenomenon in cheatgrass-infested rangeland – complete cheatgrass stand failure or 'die-off', sometimes over very extensive areas, which is not human-caused.

Die-off areas form conspicuous gray patches in the sea of spring green. They negatively impact forage production, and can potentially become highly erodible bare soil. On the other hand, die-offs are areas where cheatgrass has been effectively controlled through natural processes, and they could represent windows of opportunity for restoration seeding.

RMRS Research Ecologist **Susan Meyer** (Provo, UT) partnered with 3 Bureau of Land Management offices and 3 universities to study and understand both the causes and consequences of cheatgrass die-offs. Three different soilborne fungal pathogens interact synergistically in the context of specific environmental conditions to generate the die-off phenomenon. The first pathogen greatly reduces seed set, and also produces litter conditions



Cheatgrass die-off areas like this one near Winnemucca, NV were repeatedly observed by local land managers.

Photo: Owen Baughman

highly conducive to the success of the other two pathogens the following year. One of these seed pathogens kills germinating seeds while the other kills dormant seeds in the persistent seed bank.

Die-offs are usually transient phenomena, with cheatgrass stand recovery within a few years. Field experiments have demonstrated that native grasses can be successfully seeded into recent die-offs, showing that they may indeed represent short-term opportunities for ecological restoration. Cheatgrass die-offs have negative consequences in the short term but can potentially be managed for enhanced ecosystem stability and productivity in the long term once their ecological attributes are understood.

To learn more about this research, refer to the following:

Baughman, O.W.; Meyer, S.E. 2013. Is *Pyrenophora semeniperda* the cause of downy brome (*Bromus tectorum*) die-offs? *Invasive Plant Sci. and Manage.* 6: 105-111. <http://www.treesearch.fs.fed.us/pubs/43779>

Field planting of inoculated cheatgrass plants near Aztec, NM.

Photo: Rosemary Pendleton



## Development of a novel biocontrol method for cheatgrass: The role of fungal endophytes

Many plants are colonized by fungi that live within the stems and leaves. These fungal endophytes can affect plant growth either positively or negatively. RMRS Research Ecologist **Rosemary Pendleton** (Albuquerque, NM) partnered with the University of Idaho and others to explore the use of native fungal endophytes in combating cheatgrass expansion and growth. Using fungal endophyte strains isolated from cheatgrass stems collected in Idaho, Colorado, and New Mexico, experiments have been carried out both in the laboratory and the field to assess the impact of endophyte inoculation on cheatgrass growth and fecundity. Field experiments were conducted both in Idaho, where cheatgrass has a long history, and in New Mexico, where cheatgrass has recently arrived and populations are expanding.

Over 7,000 strains of endophytes were isolated from cheatgrass stems. Of these, one strain of *Sordaria fimicola* (CID 323), a dung fungus, has been effective at reducing growth and fecundity of cheatgrass in both lab and field tests. The life-cycle of this fungus has now been documented. A report on the field study results is in preparation by Pendleton and others. In contrast, thermotolerance of cheatgrass seeds is enhanced by inoculation with another of the isolates, a strain of *Morchella*, a fungus often associated with fire. This finding illustrates a positive cheatgrass/fungal endophyte mutualism benefiting the cheatgrass/fire cycle.

Fungal isolates of *Fusarium* have also been taken from both cheatgrass and another invasive grass, *Ventemata dubia*, that appears to be supplanting cheatgrass in some areas. *Ventemata* plants from which half of the *Fusaria* were isolated did not show signs of disease or reduced growth, while cheatgrass plants from which *Fusaria* were isolated were not as healthy as *Fusaria*-free plants. The work on fungal endophytes (and *Fusarium* endophytes and rhizosphere pathogens) will broaden the knowledge base on: why some native grass plantings fail; on how *Bromus tectorum* and *Ventemata dubia* are successfully invading native perennial grasslands and shrub-steppe;



Top: Highly flammable pinyon pine trees catch fire during a prescribed burn at the "Marking Corral" SageSteppe study site.

Photo: Robin Taush

Middle: Sagebrush biomass is reduced using a mower pulled by a tractor to release the perennial grasses and forbs in the community.

Photo: [www.sagestep.org](http://www.sagestep.org)

Bottom: Ecosystem recovery after prescribed fire.

Photo: Jeanne Chambers

and potential ways to reduce cheatgrass and *Ventennata* infestations.

Early results from this research can be found in:

Baynes, M. A.; Newcombe, G.; Dixon, L.; Castlebury, L.; O'Donnell, K. 2012. A novel plant-fungal mutualism associated with fire. *Fungal Biol.* 116:133-144. <http://www.treesearch.fs.fed.us/pubs/39872>

## SageSTEP - The Sagebrush Treatment Evaluation Project

Sagebrush ecosystems in the western United States provide ecosystem services for local communities and urban centers and essential habitat for a diversity of species. In recent decades, invasion and expansion of annual invasive grasses at low to mid elevations, especially cheatgrass, has resulted in an annual grass fire cycle and conversion of large areas to annual weed dominance. Progressive expansion and infilling of pinyon and juniper trees at mid to high elevations have resulted in depletion of understory sagebrush species and increased risk of large and severe fires. Local communities face the threat of catastrophic wildfire, and several species associated with these ecosystems are of conservation concern, including the greater sage-grouse (*Centrocercus urophasianus*) whose status warrants listing under the Endangered Species Act.

The SageSTEP Project was funded by the Joint Fire Sciences Program in 2006 to determine the most effect approaches for restoring and maintaining sagebrush ecosystems exhibiting cheatgrass invasion and/or pinyon pine and juniper encroachment. A collaborative team, including RMRS Research Ecologist **Jeanne Chambers** (Reno, NV), RMRS Scientist Emeritus **Robin Tausch** (Reno, NV), university scientists and government agencies from 6 western states implemented vegetation management treatments at 18 study sites across the Great Basin. They studied the responses to these treatments – prescribed fire, clearcutting, mastication (tree shredding), mowing, and herbicides – over a period of five years. An interdisciplinary approach was used that included vegetation, the fuel bed, soils, water, erosion, wildlife, and invertebrates.

SageSTEP scientists have already reported many results – in their newsletter, in

conferences and workshops, in tours, in scientific journals, and in General Technical Reports. Field guides have been published on how to select sites and treatments for areas exhibiting cheatgrass invasion and/or pinyon and juniper encroachment, and on how to evaluate fuel loads. A special issue of *Rangeland Ecology and Management* is in process that highlights three years of post-treatment results for the different disciplines in 13 separate articles. A long-term presence and focus on outreach have made SageSTEP a familiar name among those working in sagebrush systems, and the results are helping to guide fuels treatments and restoration activities across the region. The information on treatment effectiveness is being incorporated into both policy and planning documents.

For more information on this research, explore the website [www.sagestep.org](http://www.sagestep.org).

## Conservation and restoration of shrublands

Shrubs are the cornerstones for many arid ecosystems, providing cover and forage for wildlife, storing carbon below ground and mitigating wind erosion of soils and dust storms. Shrub dominated ecosystems such as the Great Basin and Mojave Deserts are threatened by a combination of increasing fire frequency, invasion of non-native annual grasses and climate change. Successful shrubland restoration after disturbances hinges on planting or seeding the appropriate seed sources to compete against annual grasses and weeds that can promote increased fire frequency and greatly affect wildlife, carbon sequestration process and wind erosion.

RMRS Research Geneticist **Bryce Richardson** (Provo, UT) teamed with other Station scientists, US Geological Survey and Brigham Young University to develop genetic tools and diagnostic techniques that can be used to: 1) ensure the appropriate seed sources are used in restoration, 2) conserve at risk populations and foster genetic diversity and 3) develop diagnostic techniques that allow rapid identification of shrub taxa based upon seed properties. The Great Basin Native Plant Selection and Increase Project (a Bureau of Land Management – RMRS partnership) and Great Basin Landscape

“Seed transfer guidelines and zones are used to guide the movement of plant materials, but by the end of the century, many landscapes in the U.S. will have climates that are incompatible with current vegetation.”

– Mary Williams and Kas Dumroese

Conservation Cooperative sponsored the research.

Recent research has included the development of contemporary and future seed transfer zones for blackbrush (*Coleogyne ramosissima*), and an assessment of the genetic relationships between subspecies of big sagebrush. Ongoing research is developing a rapid diagnostic test to determine subspecies of big sagebrush from seed properties.

Recent findings will aid in the identification and deployment of seed, which has been in high demand by land management agencies for the increasing number of restoration projects across our arid ecosystems.

To learn more about this research, refer to the following publications:

Richardson, B.A.; Page, J.T.; Bajgain, P.; Sanderson, S.C.; Udall, J.A. 2012. Deep sequencing of amplicons reveals widespread intraspecific hybridization and multiple origins of polyploidy in big sagebrush (*Artemisia tridentata*, Asteraceae). *Am. J. Bot.* 99: 1962-1975. <http://treesearch.fs.fed.us/pubs/42420>

Richardson, B.A.; Meyer, S.E. 2012. Paleoclimate effects and geographic barriers shape regional population genetic structure of blackbrush (*Coleogyne ramosissima*: Rosaceae). *Botany* 90: 293-299. <http://treesearch.fs.fed.us/pubs/40435>

Richardson, B.; Kitchen, S.G.; Pendleton, R.L.; B.K. Pendleton; Germino, M.J.; Rehfeldt, G.E.; Meyer S.E. 2014. Adaptive responses reveal contemporary and future ecotypes in a desert shrub. *Ecol. Appl.* 24: 413-427. <http://www.esajournals.org/doi/pdf/10.1890/13-0587.1>

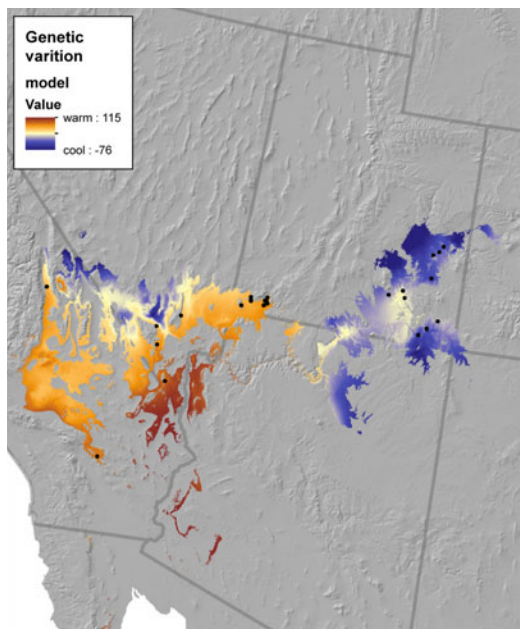


Figure: A map of the genetic variation found in blackbrush principally showing warm and cool ecotypes of the Mojave and Colorado Plateau ecoregions, respectively. This variation is the foundation for creating seed zones for restoration. The points represent seed sources used in the common garden experiment. (From Richardson et al. 2014, *Ecol. Appl.* 24: 413-427)

## Tracking climate change and assisted migration: Maintaining resilient landscapes

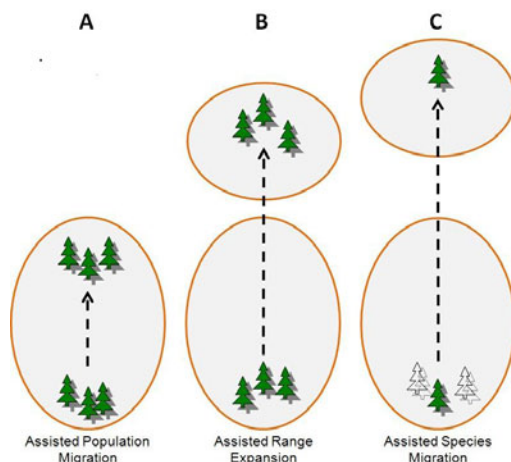
Under the current rate of climate change, migration and adaptive responses of native plants will likely fall behind. Current transfer guidelines and zones will have limited use given the dynamic changes in climate. One adaptation strategy at the nexus of native plant transfer guidelines and climate change is assisted migration, defined as the intentional movement of plants in response to climate change. Although researchers have proposed frameworks and guidelines on how to apply assisted migration of native plants, there is no consensus on implementation in the U.S. because of concern over ecological and economic risks and lack of supporting data.

To identify knowledge gaps and provide a central foundation for collaboration in generating research questions, conducting studies, transferring and acquiring data, expanding studies to key species and geographic regions, and guiding native plant transfer, RMRS Postdoctoral Scientist **Mary Williams** from Michigan Technological University and RMRS Research Plant Physiologist **Kasten Dumroese** (Moscow, ID) compiled a literary database about native plant transfer guidelines, climate change, and assisted migration. The database connects all pieces of information from peer-review journal articles to decision-support tools.

As a result of their investigative efforts, Williams and Dumroese have informed scientists, land managers, and university students about climate change and assisted migration through presentations and publications, including co-hosting a holistic-approach workshop in Portland, OR that covered the historical, biological, social, legal, and ethical aspects of assisted migration and a review article published in the *Journal of Forestry* (July/August 2013).

This research has and will continue to transfer current information to scientists, land managers, policymakers and the general public about climate change and adaptive strategies pertaining to native plant species toward maintaining resilient, functional ecosystems across the landscape.

Figure: As a management response to climate change, seed sources and populations could be moved within their current range to keep pace with changing conditions (A), from their current range to suitable areas just outside in anticipation of warmer climates (B), or far outside their current range to prevent extinction (C) (From Williams and Dumroese, *Journal of Forestry* 111:287-297).



To learn more about this research, refer to the following publications:

Williams, M.I.; Dumroese, R.K. 2013. Preparing for climate change: Forestry and assisted migration. *J. Forestry* 111: 287-297. <http://www.treeseearch.fs.fed.us/pubs/44260>

Williams, M.I.; Dumroese, R.K. 2013. Climatic change and assisted migration: Strategic options for forest and conservation nurseries. *Forest Nursery Notes* 33: 33-35. <http://www.treeseearch.fs.fed.us/pubs/43883>

## Growing better seedlings faster to withstand severe outplanting conditions

To restore ecosystems and improve their resilience to disturbance, land managers commonly outplant seedlings reared in nurseries. As budgets continue to shrink and budget timelines become shorter, land managers require high-quality planting stock that is, preferably, produced in a single year. These constraints are challenging to conventional nursery practices, and the situation is exacerbated by changing disturbance regimes such as more frequent drought conditions and droughts of more severe duration. Nursery and land managers require new techniques to produce seedlings for restoration in shorter periods of time that have improved quality to meet challenging outplanting conditions.

Results of investigations by RMRS Research Plant Physiologists **Jeremy Pinto** and **Kasten Dumroese** (Moscow, ID) and university colleagues have provided a better understanding of the outplanting window, that is, the time required for seedlings to establish and the edaphic conditions that favor establishment. Their work has provided insights into how best to compare seedlings produced under different nursery practices so that results have broader

application across a variety of restoration sites. They discovered that applications of fertilizer in the fall, especially to deciduous species immediately before they shed leaves, appreciably improve seedling nutrient reserves that foster better growth after outplanting. Pinto and Dumroese also showed that nursery managers can successfully inoculate seedlings with beneficial, symbiotic microorganisms during nursery production, even when fertilization is used, a result counter to the current paradigm. Their publications illustrate the value of testing high-quality, alternative nursery stock, coupled with aggressive site preparation, to accelerate seedling establishment and growth on sites overrun with invasive grasses. And, they identified an optimum fertilization level for longleaf pine across several different container types, which provides flexibility to restoration plans and may reduce costs.

Outplanting seedlings is one tool in the manager's toolbox for restoring degraded landscapes to regain ecosystem function and long-term resilience. Compressing the time required to produce seedlings allows land managers to better get the job done with declining budgets and shorter time frames. Improving the efficiency of growing seedlings in the nursery, and improving survival and growth on the outplanting site reduces costs and helps achieve restoration goals faster.

For additional information about this body of research, see:

Pinto J.R.; Marshall J.D.; Dumroese R.K.; Davis A.S.; Cobos D.R. 2012. Photosynthetic response, survival, and growth of three ponderosa pine stocktypes under water stress enhanced by vegetative competition. *Can. J. Forest Res.* 42:333-344. <http://www.treeseearch.fs.fed.us/pubs/40242>

Zhu Y.; Dumroese R.K.; Pinto J.R.; Li G.L.; Liu Y. 2013. Fall fertilization enhanced nitrogen storage and translocation in *Larix olgensis* seedlings. *New Forests* 44: 849-861. <http://link.springer.com/article/10.1007/s11056-013-9370-z/fulltext.html>

Dumroese R.K.; Sung S.S.; Pinto J.R.; Ross-Davis A.; Scott D.A. 2013. Morphology, gas exchange, and chlorophyll content of longleaf pine seedlings in response to rooting volume, copper root pruning, and nitrogen supply in a container nursery. *New Forests* 44: 881-897. <http://link.springer.com/article/10.1007/s11056-013-9377-5/fulltext.html>



The testing of a new, high-quality stocktype illustrates potential significant growth gains on restoration outplanting sites that help accomplish restoration goals in a shorter period of time. These *Acacia koa* seedlings exhibit extraordinary growth after one year.

Photo: Jeremy Pinto



*Robinia pseudoacacia* seedlings that were fertilized and inoculated with the symbiotic microorganism *Rhizobium* (left) show potential for the production of high-quality seedlings for outplanting, versus seedlings grown with fertilizer but without inoculation.

Photo: Jeremy Pinto.



Technician monitoring a post-fire seeding on a Wyoming big sagebrush site in north-central Utah.

Photo: Matt Fisk

## Regional assessment of post-fire native seeding strategies

Shrublands of the western U.S. have been widely impacted by livestock grazing, annual weed invasion and wildfire. In the absence of active intervention, many burned shrublands will convert to annual grasslands. Post-fire seeding provides an opportunity to stabilize and revegetate at-risk shrublands. USDA and USDI policies and regulations mandate the use of native species, but improved seeding equipment and strategies are needed to increase the success of multi-species native seedings, and improve habitat for sage-grouse and other at-risk species.

RMRS Research Botanist **Nancy Shaw** (Boise, ID; now Scientist Emeritus) and RMRS Research Geneticist **Jeff Ott** (Boise, ID) teamed up with universities in Texas, Wyoming and Utah as well as Bureau of Land Management and Natural Resources Conservation Service to apply post-fire seeding treatments on former Wyoming big sagebrush locations in Utah, Idaho and Oregon, testing the use of the standard rangeland drill and a new minimum-till drill, application methods for drilling grass species and planting small-seeded forb and shrub species, and Wyoming big sagebrush seeding rates. Research goals were to improve establishment of seeded species, reduce loss of residual native species and biological soil crusts, and increase resistance to invasion by exotic annuals.

Research Findings include:

- Post-fire establishment of native species can be enhanced through drilling and broadcast treatments, but adverse climatic conditions and cheatgrass proliferation remain problematic.
- Second year cheatgrass cover was lower in seeded minimum-till treatments relative to non-seeded controls.
- The conventional rangeland drill may provide a more favorable seedbed for aerially-broadcast species when seeded in fall.
- Establishment of drilled species (large seeds) was similar for both types of drills (conventional and minimum-till).

Results will guide selection of seeding mixes, appropriate seeding equipment to meet project goals and site conditions, and improved strategies for re-establishing shrub mixes. This will aid in placing post-fire disturbances in Wyoming big sagebrush communities on a trajectory towards recovery.

To learn more about this research, see:

Shaw, N. et al. 2011. Equipment and strategies to enhance the post-wildfire establishment and persistence of Great Basin native plants. Final Report: JFSP Project Number 07-1-3-12. Boise, ID: Joint Fire Science Program. 30 p. <http://www.treesearch.fs.fed.us/pubs/44643>.

Taylor, M. 2013. Exotic, native and seeded species and soil biotic community response to post-fire seedings in northern Utah. Laramie, WY: University of Wyoming. Thesis. 96 p. <http://www.treesearch.fs.fed.us/pubs/43734>

## Tactics for conserving unique biological resources

The Spring Mountains National Recreation Area (SMNRA), Humboldt-Toiyabe National Forest, has the unique dual challenge of providing for intense recreational use by residents and visitors while conserving endemic fauna and flora found nowhere else in the world. Management of the unique flora and fauna of the Spring Mountains NRA requires sound science-based information to minimize recreational impacts on rare plant and animal species.

To develop knowledge needed by SMNRA managers, RMRS Research Ecologist **Burt Pendleton** teamed with Management and Engineering Technologies International Inc., Northern Arizona University, University of Nevada Las Vegas and Great Basin Institute to complete a database of all available information for almost 50 rare and endemic species that was used to generate GIS based potential habitat maps for each species. The complete distribution of many of these species within the SMNRA is unknown and the maps are used to efficiently locate species populations and identify potential locations at project sites. The database also provides up to date information on conservation species which has been subsequently summarized in species fact sheets. Other accomplishments are as follows:

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[www.fs.fed.us/rm/albuq/dfinch.php](http://www.fs.fed.us/rm/albuq/dfinch.php)

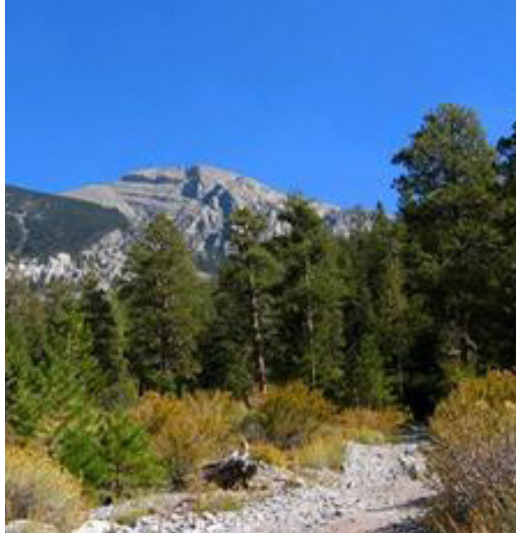
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*Mt. Charleston, in the Spring Mountains National Recreation Area is home to many species found only in southern Nevada.*

Photo: USDA Forest Service.

- Comprehensive Level II inventories have been completed for 77 springs and riparian areas. The data have been used to develop a framework and guide for springs' stewardship.
- 187 permanent FIA plots have been established and data have been collected, compiled and analyzed. The FIA data provide a superb baseline data set which will be used in coming decades to monitor changes in species composition and community structure.
- Pendleton established the Spring Mountains Science Safari series to provide science based outdoor activities for families each summer. The program has completed its fifth year.
- Genetics work on Palmers chipmunk has been published, demonstrating that Palmers chipmunk is genetically distinct from the other resident chipmunk species, has a large genetically diverse population and will likely not be significantly affected by management and recreational activities.
- Genetic and distribution studies of spring snails and rare butterflies, including the Mount Charleston Blue Butterfly, very recently listed as endangered, are ongoing.

To learn more, refer to the following reports:

Solem, S. J.; Pendleton, B. K.; Griffen, C.; Coles-Ritchie, M.; Ledbetter, J.; McKelvey, K.S.; Berg, J.; Menlove, J.; Woodlief, C.; Boehnke, L. 2013. Final Program Report 2010-2012: Monitoring and evaluation for conserving biological resources of the Spring Mountains National Recreation Area. El Paso, TX: Management and Engineering Technologies International, Inc. (METI) and Albuquerque, NM: USDA Forest Service, RMRS. 185 p. <http://www.treesearch.fs.fed.us/pubs/44827>

## Monitoring biodiversity with satellite imagery

One of the simplest and most often applied measures of biodiversity is the total number of species present in an area, community or landscape, i.e., species richness. While a seemingly simple concept, the determination of species richness on a broad scale can be challenging. Assessment of plant biodiversity at the landscape scale is often based on intensive and extensive fieldwork at great cost of time and money. RMRS Research Ecologist **Steve Warren** (Provo, Utah) recently completed a research project with collaborators from Colorado State University and the Universities of Bayreuth and Landau-Koblenz in Germany exploring the use of satellite imagery to quantify relative species richness. The project was conducted at the U.S. Army's Grafenwoehr Training Area in Germany. A 16 km<sup>2</sup> portion of the military training facility was systematically sampled by plant taxonomic experts on a grid of one hundred 1-ha plots. The diversity of disturbance types, the resulting habitat heterogeneity, and plant species richness were determined for each plot. Using an IKONOS multi-spectral satellite image, they examined 172 metrics of spectral diversity as potential indicators of those independent variables.

Across all potential relationships, a simple count of values per spectral band per plot, after compressing the data from the original 11-bit format with 2048 potential values per band into a maximum of 100 values per band, resulted in the most consistent and accurate predictor for various metrics of habitat heterogeneity and plant species richness. The count of values in the green band generally out-performed the other bands. The relationship between spectral diversity and plant species richness was stronger than for measures of habitat heterogeneity. Based on the results, researchers concluded that remotely-sensed assessment of spectral diversity, when coupled with limited ground-truthing, can provide estimates of habitat heterogeneity and plant species richness across broad areas and can be effectively and economically applied for a variety of purposes on broad landscapes. Purposes include (1) comparisons of the relative species richness within two or more areas, (2) monitoring species richness over time, and (3) the identification of plant biodiversity hotspots within landscapes.