



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

GSD Update

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Year in Review: Spotlight on 2014 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 (USDA-FS) and the Rocky Mountain Research Station (RMRS). In particular, we spotlight accomplishments in:

- Research that supports ecosystem resiliency, and native and invasive species management.
- The role of climate in species adaptation, restoration and management.



Greater Sage-Grouse (female) using high elevation sagebrush habitat on the Inyo National Forest, California.

Photo: Chris Balzotti, USDA Forest Service cooperator



Research that supports ecosystem resiliency, and native and invasive species management

New research on resilience of sagebrush ecosystems used for improving sage-grouse habitat

By Dr. Jeanne Chambers

Conservation efforts are underway across the western U.S. to reduce threats to Greater Sage-grouse (*Centrocercus urophasianus*) and the sagebrush ecosystems on which they depend. The 2010 determination that sage-grouse warrant protection under the Federal Endangered Species Act has accelerated such work, including a multi-agency effort to provide a strategy for conserving sagebrush ecosystems and Greater Sage-grouse populations. The strategy, provided in a USDA-FS Rocky Mountain Research Station scientific report, focuses on mitigating the threats posed by invasive annual grasses and altered fire regimes. Recent research shows that resilience to wildfire and resistance to invasive annual grass differ across sage-

grouse habitat. Resilience and resistance of sagebrush ecosystems typically increase as environmental conditions become more favorable for plant growth and reproduction. Also, sage-grouse are more likely to be resilient if they exist in large populations across large landscapes that have continuous sagebrush cover. Thus, the strategy is based on

those factors that influence (1) sagebrush ecosystem resilience to disturbance and resistance to invasive annual grasses, and (2) the distribution, relative abundance, and persistence of sage-grouse. A sage-grouse habitat matrix links relative resilience and resistance of sagebrush ecosystems

with sage-grouse habitat requirements for landscape cover of sagebrush. The matrix is used to help decision makers assess risks and determine appropriate management strategies at large landscape scales. Focal areas for management are further defined by assessing sage-grouse Priority Areas for Conservation (PACs), breeding bird densities, and specific habitat threats. The report concludes with decision tools to help managers determine both the suitability of focal areas for treatment and the most appropriate management treatments. Emphasis is placed on fire operations, fuels management, post-fire rehabilitation, and habitat restoration activities.

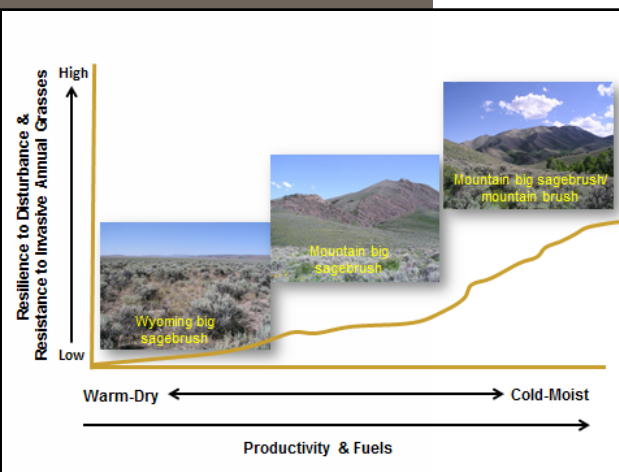
To learn more about this research, refer to the following publication:

Chambers, J. C.; Pyke, D.A.; Maestas, J.D.; Pellant, M.; Boyd, C.S.; Campbell, S.B.; Espinosa, S.; Havlina, D.W.; Mayer, K.E.; Wuenschel, A. 2014. Using resistance and resilience concepts to reduce impacts of invasive annual grasses and altered fire regimes on the sagebrush ecosystem and greater sage-grouse: A strategic multi-scale approach. Gen. Tech. Rep. RMRS-GTR-326. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station. 73 p. http://www.fs.fed.us/rm/pubs/rmrs_gtr326.html

Chambers, J.C., B.A. Bradley, C.S. Brown, C. D'Antonio, M.J. Germino, J.B. Grace, S.P. Hardegree, R.F. Miller, and D.A. Pyke. 2014. Resilience to stress and disturbance, and resistance to *Bromus tectorum* L. invasion in the cold desert shrublands of western North America. *Ecosystems* 7:360-375. doi 10.1007/s10021-013-9725-5. <http://www.treeseearch.fs.fed.us/pubs/46762>

“Resilience and resistance of sagebrush ecosystems typically increase as environmental conditions become more favorable for plant growth and reproduction.”

– Dr. Jeanne Chambers
RMRS Research Ecologist,
Reno, NV



Sagebrush ecological types that occur along ecological gradients. Modified from Chambers et al. 2014, RMRS-GTR-326.





Female Black-backed Woodpecker feeds young at a tree cavity.

Photo: Mark Rumble, USDA Forest Service

Population estimate for black-backed woodpeckers

By Dr. Mark Rumble

The Black-backed Woodpecker (*Picoides arcticus*) in the Black Hills, SD has been petitioned for listing as a distinct population segment. This petition suggested that population viability necessitated about 2000 pairs and that there were only about 411 pairs currently. Researchers at the Rocky Mountain Research Station and the University of Wyoming conducted surveys to estimate the population in 2000 and 2001. We analyzed these data to estimate the population using the most recent version of Distance Program. This population estimate was made following a period of relatively low disturbance to the forest from fire and mountain pine beetles. This species depends on recently killed forests/trees for larvae of woodborers, bark beetles and other insects which comprise their diet.

Station scientists estimated that during this period of relatively low forest disturbance, there were between 456 and 641 breeding pairs of blackbacked woodpeckers. While this estimate is less than the projected population necessary to ensure population viability, it was a conservative estimate following a period of low forest disturbance. Since then there have been a number of wildfires and a major mountain pine beetle epidemic that may have increased the population. In spring 2015 scientists will initiate a follow-up study to estimate the population following a period of relative high levels of forest disturbance. This information will help formulate an informed decision regarding the petition to list this species.

Rota, C.T., J.T. Millsbaugh, M.A. Rumble, C.P. Lehman, and D.C. Kesler. 2014. The role of wildfire, prescribed fire, and mountain pine beetle infestations on the population dynamics of Black-Backed Woodpeckers in the Black Hills, South Dakota. *PLoS ONE* 9(8): e106390. doi: 10.1371/journal.pone.0106390. <http://www.treesearch.fs.fed.us/pubs/46849>

Seeding techniques for restoring sagebrush ecosystems following wildfire

By Dr. Jeffrey Ott

Thousands of acres of public land have been seeded following wildfire in recent years for the purpose of mitigating wildfire impacts. Post-fire seeding is especially important in sagebrush ecosystems where grazing disturbance has often depleted native perennial plants while favoring invasive annuals such as cheatgrass. Although techniques for seeding non-native forage plants are well established, these techniques are not always effective for seeding the native plants that are increasingly sought by land management agencies. Innovative modifications of conventional seeding equipment and strategies have the potential to increase success when seeding mixtures of native species with different germination requirements. Newer models of rangeland drills, for example, are able to handle seeds of different sizes, planting larger seeds at precise depths in furrows and pressing smaller seeds onto the soil between furrow rows. Many newer drill models are minimum-till drills that have the potential to reduce soil disturbance compared to conventional models. Experiments have been replicated at multiple sites in the northern Great Basin to compare the





Burned sagebrush sites can be seeded using rangeland drills to re-establish native perennial plants.

Photo: Matt Fisk,
USDA Forest Service

effectiveness of these different drill types for seeding mixtures of native grasses, forbs and shrubs following fire. The minimum-till drill was found to be especially effective for small-seeded species such as Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*), an important ecosystem component that is otherwise slow to re-establish following fire. Other experimental comparisons highlight effects of seeding in different seasons, different seed quantities, and differences due to site-specific conditions and weather patterns. This research will assist managers in making informed decisions about when, what and how to seed to enhance post-fire recovery in sagebrush ecosystems.

Evaluating the resiliency of understory vegetation to timber harvest in ponderosa pine forests

By Dr. Jack Butler

Creating wood products through logging has gone on for as long as humans have inhabited forested areas. Logging can also be a valuable management tool for maintaining a healthy population of trees that can resist insects and diseases. The Black Hills has a long history of timber harvest. Indeed, in 1899 the first timber sale occurred in what is now known as the Black Hills National Forest. Since then, all of the land suitable for timber harvest has been logged 1 to 4 times. Although much of the post-harvest focus is usually on trees, the understory vegetation is largely responsible for providing ecosystem services such as cycling nutrients and maintaining biological diversity. RMRS scientists and partners are investigating the short- and long-term resiliency of the understory vegetation of ponderosa pine forests of the Black Hills to a variety of disturbances associated with timber harvest. Study sites were established in active timber cutting units. Comparing 1, 2, 3 and 7 years post-harvest data with pre-harvest information indicates that the understory vegetation is very resilient, often approaching to pre-harvest condition within a few years. Further, expansion of invasive plant species appears to be restricted to a few heavily disturbed sites.



Left: Permanent study plot, Black Hills National Forest, in 2007 immediately prior to timber harvest.

Right: Permanent study plot, Black Hills National Forest, in 2010 three years following timber harvest.

Photos: Jack Butler, USDA Forest Service





*Above: In the dry tropical forest zone of Ghana, a combination of extractive logging without adequate regeneration, fire, and invasion by *Chromolaena odorata* resulted in severely degraded forests.*

Below: Community based restoration using taungya (intercropping with food plants until shaded by the developing tree seedlings) gave rise to forest-like conditions after 10 years.

*Photos: John A. Stanturf,
USDA Forest Service*

Restoring forest landscapes

By Dr. Kasten Dumroese

The estimated billion acres globally of degraded forests presents a formidable challenge to scientists, managers, and policymakers. Where to restore? What methods are appropriate? The complexity of the challenge is compounded by the prospect of a global change and altered climate, including near term increase in the frequency of extreme events. Crafting a response to the forest restoration challenge is further complicated by the lack of consensus on what constitutes degradation and appropriate restoration goals. To provide managers with an understanding of the many factors to be considered in planning and undertaking forest restoration, the Deputy Chief for Research and Development requested a synthesis of contemporary approaches to forest restoration. Our response was to synthesize the science underpinning contemporary forest restoration. In two publications and an expert workshop (that in itself resulted in a special issue of the *Journal of Sustainable Forestry*), we explored the several paradigms underlying contemporary approaches (revegetation, ecological restoration, forest landscape restoration, and functional restoration). These were examined in terms of a degraded starting point and an ending point of an idealized natural forest. We presented a consistent terminology for restoration as viewed through the lens of the goals of the restoration activity. These restoration strategies organize the methods used: reclamation, reconstruction, rehabilitation, and replacement. Available tools for restoration include appropriate plant material and their deployment and

methods for manipulating vegetation that depend on extent of initial overstory present, area to be restored, complexity of the planting design, and site conditions. Global change, climate variability, biotechnology, and synthetic biology are emerging issues forcing a re-conceptualization of forest restoration goals, underscoring the importance of clearly defined goals focused on functional ecosystems. Long-term monitoring and evaluation embedded in adaptive management are needed to ensure restoration is successful and sustainable. No restoration project is undertaken in a social vacuum and social factors can trump biophysical considerations.

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

Stanturf, J., Palik, B.J., Williams, M.I., Dumroese, R. K. 2014. Forest restoration paradigms. *Journal of Sustainable Forestry* 33: S161-S194 <http://www.srs.fs.usda.gov/pubs/45775>

Dey, D.C., Schweitzer, C.J. 2014. Restoration for the future: endpoints, targets, and indicators of progress and success. *Journal of Sustainable Forestry*. 33(sup1): S43-S65. <http://www.treearch.fs.fed.us/pubs/45780>

Stanturf, J.A., Palik, B.J., Dumroese, R. K. 2014. Contemporary forest restoration: A review emphasizing function. *Forest Ecology and Management* 331: 292-323. <http://www.treearch.fs.fed.us/pubs/46976>





New *Larix occidentalis* stocktypes are being drought tested using new methods that reduce confounding variables commonly found in past research.

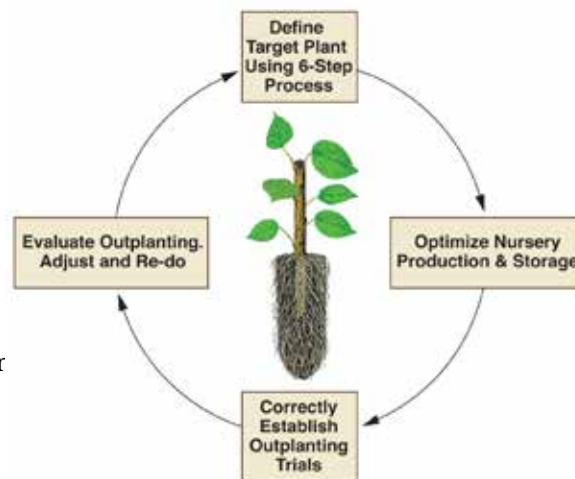
Photo: Matthew Aghai, University of Idaho.

Ensuring quality testing of nursery stocktypes

By Dr. Jeremiah Pinto

A seedling's size, shape, and age (termed stocktype) can have a significant impact on how a seedling establishes and overcomes the limiting factors on the outplanting site. Choosing the right stocktype for a restoration or reforestation project can mean the difference between a successful project and a failed one. Previously, nursery stock options were limited and availability was based on what nurseries provided. Currently, many new stocktypes are being developed to meet the needs of land managers who are carrying out restoration on highly disturbed and very challenging sites. With so many choices available, however, land managers commonly ask which stocktype will best meet their management objectives.

For years, studies have been initiated in the quest to answer the question of which plant material type is best for a particular management objective. While these studies have the best intentions, few have actually been done without some degree of confounding. Past studies often confound seed sources, nurseries, and culturing regimes, and/or have failed to address differences in initial seeding quality, which can lead to inappropriate conclusions. It is, in fact, quite hard to carry out a bona fide stocktype trial from start to finish without some degree of confounding. Using methods developed by RMRS Research Plant Physiologist Jeremy Pinto, new stocktype research is being conducted with fewer confounding variables. Improved studies produce viable and confident conclusions for making stocktype recommendations to the restoration or reforestation practitioner.



Testing new stocktypes for restoration and reforestation is an iterative process.

Graphic: James Marin, Marin Graphic Service.

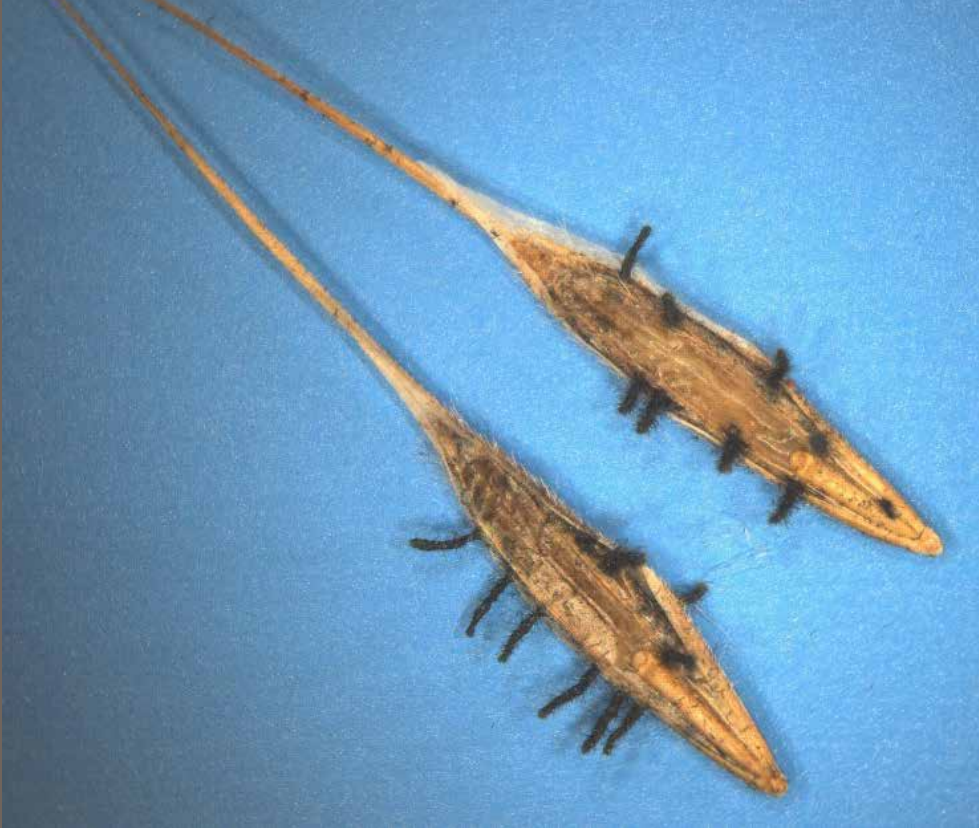
To learn more about this research, refer to the following publications:

Aghai M.M., Pinto J.R., Davis A.S. 2014. Container volume and growing density influence western larch (*Larix occidentalis* Nutt.) seedling development during nursery culture and establishment. *New Forests* 45:199-213. <http://link.springer.com/article/10.1007%2Fs11056-013-9402-8#page-1>

Pinto, J.R., Marshall, J.D., Dumroese, R.K., Davis, A.S., Cobos, D.R. 2011. Establishment and growth of container seedlings for reforestation: a function of stocktype and edaphic conditions. *Forest Ecology and Management* 261:1876-1884. <http://www.treearch.fs.fed.us/pubs/37966>

Pinto, J.R., Dumroese, R.K., Davis, A.S., Landis, T.D. 2011. Conducting seedling stock type trials: a new approach to an old question. *Journal of Forestry* 109:293-299. <http://www.treearch.fs.fed.us/pubs/38391>





The seed pathogen 'black fingers of death' on killed cheatgrass seeds, showing the fingerlike black fruiting structures (stromata).

Photo: Susan Meyer
USDA Forest Service.

A new look at the race for survival: Cheatgrass biocontrol with "black fingers of death"

By Dr. Susan Meyer

The seed pathogen 'black fingers of death' is being considered as a tool for biocontrol of the invasive winter annual cheatgrass (*Bromus tectorum* L.) in the context of restoration seeding in the Great Basin. The interaction between this pathogen and its target seeds has been called a 'race for survival'. Seeds often escape mortality through rapid germination, so we proposed that fast-growing strains of the pathogen would be most effective for biocontrol. We later learned that slow-growing strains were actually better than fast ones at killing germinating cheatgrass seeds. We then proposed that these slow growers might be spending their energy making energy-costly toxins to stop the seeds in their tracks. We have recently confirmed this idea with the help of colleagues who are expert in secondary products chemistry, who have identified and quantified the toxins produced

by our pathogen. Slower-growing strains produced significantly more of the powerful toxin cytochalasin B, a compound that can stop cell division and that probably serves to slow or stop cheatgrass seed germination, providing a longer window for pathogen success. This discovery provides us with a useful selection tool for choosing the best pathogen strains for cheatgrass biocontrol.

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

Beckstead, J.; Meyer, S.E.; Molder, C.J.; Smith, C. 2007. A race for survival: Can *Bromus tectorum* seeds escape *Pyrenophora semeniperda*-caused mortality by germinating quickly? *Annals of Botany* 99: 907-914. <http://www.treeseearch.fs.fed.us/pubs/39164>

Meyer, S.E.; Stewart, T.E.; Clement, S. 2010. The quick and the deadly: Growth versus virulence in a seed bank pathogen. *New Phytologist* 187: 207-216. <http://www.treeseearch.fs.fed.us/pubs/40316>

Masi, M.; Evidente, A.; Meyer, S.; Nicholson, J.; Munoz, A.. 2014. Effect of strain and cultural conditions on the production of cytochalasin B by the potential mycoherbicide *Pyrenophora semeniperda* (Pleosporaceae, Pleosporales). *Biocontrol Science and Technology* 24: 53-64. <http://www.treeseearch.fs.fed.us/pubs/45557>

Masi, M.; Meyer, S.; Clement, S.; Andolfi, A.; Cimmino, A.; Evidente, A. 2014. Spirostaphylotrichin W, a spirocyclic gamma-lactam isolated from liquid culture of *Pyrenophora semeniperda*, a potential mycoherbicide for cheatgrass (*Bromus tectorum*) biocontrol. *Tetrahedron* 70: 1497-1501. <http://www.treeseearch.fs.fed.us/pubs/45556>



Mecinus heydenii: An unexpected appetite for hybrid toadflax

By Dr. Sharlene Sing



Mecinus heydenii emerging from hybrid toadflax.

Photo: Sharlene Sing, USDA Forest Service

Invasive weeds targeted for classical biological control are not always single species, but can be hybrids of two species, or even species complexes (hybrids of multiple exotic species). Hybrid weeds and species complexes in the native range are not always present, evident or genetically similar to the

invaders targeted for biocontrol in North America, which significantly complicates successful matching of agents with targets.

The frequent detection of additional infestations following the initial confirmation of naturally occurring hybridization of yellow (*Linaria vulgaris*) and Dalmatian (*L. dalmatica*) toadflax indicates that it is a fairly widespread phenomenon in the western United States. Although a number of agents have already been approved for release against these two weeds, the growing dominance of hybrid toadflax suggests that none are exerting population level control.

Experiments conducted in spring-summer 2014 with a candidate agent for yellow toadflax, the stem mining weevil *Mecinus heydenii*, showed differential levels of host acceptance and suitability for a range of parental (yellow and Dalmatian toadflax) and hybrid toadflax genotypes. Weevils placed on yellow toadflax (the so-called 'natural' host) produced a high number of adult progeny, but with a very high level of

larval mortality. Hybrid plants with yellow toadflax as the maternal parent generated nearly as many live adult offspring as yellow toadflax hosts, with nearly no larval mortality. Hybrid plants with a Dalmatian toadflax maternal parent produced very few progeny. Field collected and verified hybrid plants from three disjunct locations yielded wildly variable results: Site 1 plants produced many adult progeny with low larval mortality; plants from Site 2 produced very few live adults with very high larval mortality; and plants from Site 3 appeared to be unsuitable, with no progeny produced.



Photo: Sharlene Sing, USDA Forest Service.

Infested plants in Montana State University quarantine greenhouse.



The role of climate in species adaptation, restoration and management

Vulnerability to climate change: an assessment of an important restoration species

By Dr. Francis Kilkenny

Successful plant conservation and restoration efforts will require that land managers have an understanding of climate change impacts on plant populations. Techniques that evaluate traits that allow plants to tolerate environmental conditions, such as aridity, can be effective in assessing population vulnerabilities to climate change, by identifying geographical regions where climates will shift beyond a plant's tolerance limits.

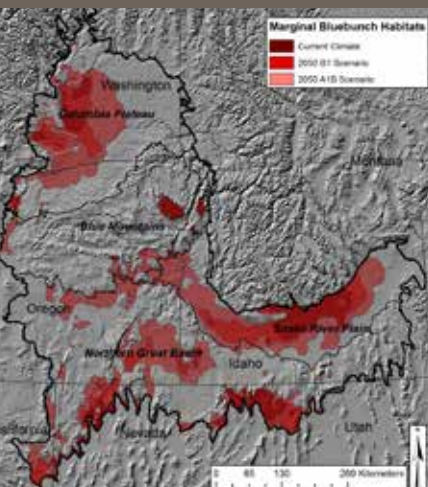
RMRS researchers developed a climate change vulnerability assessment for bluebunch wheatgrass (*Pseudoroegneria spicata*), a keystone species in bunchgrass and sagebrush ecosystems in the Intermountain West, and the most widely used native plant species in post-fire restoration. Vulnerability to climate change was modeled using data from a common garden study on variation in climate related traits (St. Clair et al. 2013) under high and low carbon emission scenarios for 2050 (Kilkenny 2015).

Bluebunch wheatgrass populations in the Intermountain West will become increasingly vulnerable to decline and loss as climates continue to shift away from current norms, and populations in the Snake River Plain and the Columbia Plateau ecoregions will be particularly at risk (Figure). The geographic extent of bluebunch vulnerability will depend on the amount of human-based carbon emissions. These findings will help managers plan future conservation and restoration efforts for bluebunch wheatgrass.

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

Kilkenny, F. F. 2015. Genecological approaches to predicting the effects of climate change on plant populations. *Natural Areas Journal* 35: 152-164. <http://www.bioone.org/doi/abs/10.3375/043.035.0110>

St.Clair, J. B., Kilkenny, F.F., Johnson, R.C., Shaw, N.L., G. Weaver. 2013. Genetic variation in adaptive traits and seed transfer zones for *Pseudoroegneria spicata* (bluebunch wheatgrass) in the northwestern United States. *Evolutionary Applications* 6: 933-948. <http://www.treesearch.fs.fed.us/pubs/44356>



Map of predicted marginal habitats of bluebunch wheatgrass for the current climate (1961–1990 norms, shown in dark red) and two predicted climate models for 2050 (Kilkenny 2015).



Bluebunch wheatgrass garden.

Photo: Nancy L. Shaw,
USDA Forest Service



“Understanding these changes are complex and require the integration of multiple research disciplines including genetics, climate modeling and biogeography.”

– Dr. Bryce Richardson
RMRS Research Geneticist,
Provo, UT

Research to guide restoration in changing climates

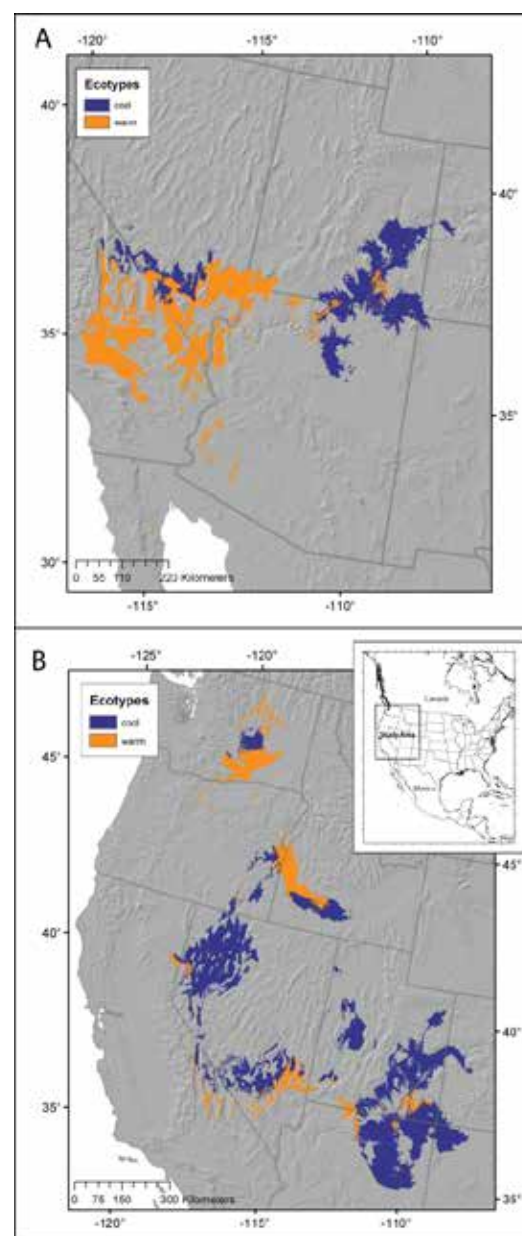
By Dr. Bryce Richardson

The distribution of plant species and populations will likely be reshaped as climate changes. Understanding these changes are complex and require the integration of multiple research disciplines including genetics, climate modeling and biogeography. However, the products of this research provide the foundation for current ecological restoration and insight into planning for future decades. In the intermountain West, shrub species play critical roles in desert and semi-desert ecosystem function. Healthy functioning shrub ecosystems support a diverse array of flora and fauna. This research focuses on blackbrush (*Coleogyne ramosissima*), a widespread shrub that straddles the ecotone between the Mojave Desert and Great Basin ecosystems. An assessment of growth, physiology and survival of wide-ranging populations illustrate the adaptive genetic variation in this species. The relationship between climate and genetic patterns can be mapped with respect to the species distribution for either contemporary or future climates (Figure). These results suggest that 1) blackbrush populations are primarily adapted to winter temperatures, 2) the species is predicted to expand into the Great Basin by mid-century, 3) cold-adapted population will be most suited for the expand regions and 4) human-mediated dispersal of seed will be need to keep pace with climate change.

Warm (orange) and cool (blue) temperature-adapted ecotypes of blackbrush within the predicted climate niche of the species for A) contemporary climate and B) mid-century projections based on general circulation models and composite carbon emission scenarios. (Richardson et al. 2014)

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

Richardson, B.A., Kitchen, S.G., Pendleton, R.L., Pendleton, B.K., Germino, M.J., Rehfeldt, G.E., Meyer, S.E. 2014. Adaptive responses reveal contemporary and future ecotypes in a desert shrub. *Ecological Applications* 24:413-427. <http://www.treesearch.fs.fed.us/pubs/45555>





This view of vegetative recovery five years after fire on a Colorado Plateau site includes scattered mountain big sagebrush plants that grew from seeds that survived the fire. These plants are just large enough to begin producing seeds. Plant density on this site is sufficient to support a prediction of full sagebrush recovery in 25-35 years after the fire.

Photo: Stanley Kitchen,
USDA Forest Service

Rio Grande bosque.

Photo: Mary Ann Donovan,
USDA Forest Service

Climate regulates mountain big sagebrush recovery after fire

By Dr. Stanley Kitchen

Big sagebrush (*Artemisia tridentata*) plants are easily killed by fire, thus post-fire recovery must be from seeds that either survive fire or are spread from unburned areas, and recovery rate is dependent upon how fast new sagebrush plants are able to establish after fire. In recent studies, natural recovery of mountain big sagebrush (*A. t. vaseyana*)” was investigated for 36 fires in the Great Basin and Colorado Plateau ecoregions. Time-since-fire varied from 1 to 36 years. Sagebrush recovery rate was highly variable with full recovery (when compared to paired unburned areas) estimated to take from 25 to 75+ years. Recovery rate was most influenced by the amount of winter-spring precipitation the year after fire suggesting the importance of sufficient soil moisture for seedling growth and establishment during the first growing season. Results also suggest that the opportunity for initial post-fire regeneration of mountain big sagebrush is short-lived due to a short-lived soil seed bank, and if missed, the time needed for big sagebrush recovery may be extended by several decades. Thus, conditions that result in short fire-free intervals or more frequent drought are likely to be less compatible with big sagebrush dominance, increasing risk for wildlife species dependent on this habitat type.

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

Nelson, Z.J., Weisberg, P.J., Kitchen, S.G. 2014. Influence of climate and environment on post-fire recovery of mountain big sagebrush. *International Journal of Wildland Fire* 23: 131-142. <http://www.treearch.fs.fed.us/pubs/45787>

Climate change vulnerability of riparian associated wildlife

By Dr. Megan Friggens

The interaction of fire, climate change, and invasive species is predicted to have extreme effects for ecosystems in the interior western United States. Wildlife species that rely on riparian habitats are likely to be particularly hard hit. Climate will drive changes to river flows through modified precipitation regimes and higher temperatures. These changes will, in turn, increase the risk of severe fires within riparian woodland habitats, affecting species composition, function and structure. The potential for severe changes due to climate and fire threatens our capacity to develop successful strategies to manage for the species, habitats, and natural resources of our western water ecosystems.

Resource managers need tools that identify the likely future of riparian habitats under various climate and fire scenarios, not only to focus limited resources on the most critical needs for wildlife species, but to find opportunities for promoting natural regeneration of riparian woodland and wetland habitats.

RMRS scientists have developed a coupled modeling approach that combines species





Focal area and sub-basins of climate change vulnerability study of riparian wildlife.

Credit: Megan Friggens, USDA Forest Service

distribution modeling, fire behavior models, and vulnerability assessments to generate spatially explicit estimates of species' vulnerability to the interactive effects of climate change and fire. Building upon a risk matrix method developed by the USDA Forest Service Northern Research Station and vulnerability assessment tools developed by RMRS, we are quantifying the effects of fire and climate change on native and nonnative species residing within New Mexico riparian, wetland, and associated upland habitats. All species are predicted to experience a change in distribution of suitable habitat over time and express varying capacities to deal with those changes. Research results point to management strategies that focus on preserving biodiversity hotspots and implementing fire treatments for high importance/high risk areas.

This project has developed a framework for integrating habitat models with vulnerability assessments that can be applied to other species and geographic area. Analysis data provide managers with the information to identify potential intervention points or the location of critical habitats for protection or preservation to better support species' conservation under climate change.

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

Friggens, M., Loehman, R., Holsinger, L., and D. Finch. 2014. Vulnerability of riparian obligate species to the interactive effect of fire, climate and hydrological change. Final Report for Interagency Agreement #13-IA-11221632-006. USDA Forest Service, Rocky Mountain Research Station. 213p. <http://www.fs.fed.us/rm/grassland-shrubland-desert/docs/projects/vulnerable-obligate-species/final-report.pdf>

Climate change impacts on future carbon stores and management of warm deserts

By Dr. Paulette Ford

Climate change is a pressing environmental issue that requires measuring the exchange of greenhouse gases between terrestrial systems and the atmosphere. Reductions in atmospheric CO₂ concentration through enhanced terrestrial carbon storage may help slow or reverse the rate of global climate change. As a result, Federal land management agencies such as the US Forest Service are now beginning to implement management policies to increase carbon storage. Throughout the southwestern U.S. climate models project increased aridity and seasonal shifts in precipitation, along with more extreme precipitation events. Information regarding how these elements of climate change might affect the balance between CO₂ uptake and loss is lacking in forms available to land managers on semiarid rangelands.

Our studies focus on key components of carbon exchange including, photosynthesis, soil respiration and plant productivity across the warm deserts of North America to determine if common trends exist that can be utilized in management. Management practices can influence carbon sequestration in this region. Since desertification is projected to increase in the future, management strategies that increase carbon sequestration or decrease carbon loss are especially important. Xeric rangelands tend to be in carbon balance or are small carbon sources, whereas more mesic rangelands function primarily as carbon sinks. When warm desert rangelands do function as carbon sinks, it is for relatively





Above Top: Chihuahuan Desert.

Photo: Sevilleta Long-Term Ecosystem Research Program

Above Center: Mojave Desert.

Photo: Ken Cole, U.S. Geological Survey

Above Bottom: Sonoran Desert.

Photo: U.S. Fish and Wildlife Service

short periods following adequate rainfall. This requires managers to thoughtfully consider management practices that do not impede sequestration during critical times. We supply information on the USDA Forest Service Climate Change Scorecard which addresses carbon sequestration and provides fundamental questions for managers to address when reporting on their accomplishments towards developing land management strategies in the context of climate change.

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

Thomey, M.L., Ford, P.L., Reeves, M.C., Finch, D.M., Litvak, M.E., Collins, S.L. 2014. Climate change impacts on future carbon stores and management of warm deserts of the United States. *Rangelands* 36:16-24. <http://www.treeseearch.fs.fed.us/pubs/45552>

Thomey, M.L., Ford, P.L., Reeves, M.C., Finch, D.M., Litvak, M.E., Collins, S.L. 2014. Review of climate change impacts on future carbon stores and management of warm deserts of the United States. Gen. Tech. Rep. RMRS-GTR-316. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station. <http://www.treeseearch.fs.fed.us/pubs/45315>



Photo: Justin Runyon, USDA Forest Service

Floral scents are captured by enclosing flowers in clear plastic cups and pulling air out of the cups through an odor trap. Drought changed the smell of all four species studied and reduced pollinator visitation to three of the four plant species.



Photo: Casey Delphia, USDA Forest Service

A metallic green bee (*Agapostemon* sp.) visits flowers of hairy false goldenaster (*Heterotheca villosa*). Drought stress altered the smell of hairy golden aster flowers which could affect attraction of pollinators

Drought stress changes floral scent and reduces pollinator visitation

By Dr. Justin Runyon

Plant-pollinator interactions are essential to the health of natural ecosystems and much of the human diet depends on animal pollination. However, many pollinators are in decline and are being threatened by environmental change. We explored how drought, an important component of climate change, affected floral odors and pollinator visitation in four plant species in Montana.

Drought stress reduced pollinator visitation to three of the four plant species and altered floral scent in all four plant species studied. For example, drought-stressed bluebells (*Campanula rotundifolia*) lacked certain floral odors and received only one-quarter of the pollinator visits when compared to well-watered plants. Drought also negatively affected pollinator visitation to hairy golden aster (*Heterotheca villosa*) and silverleaf phacelia (*Phacelia hastata*). These findings suggest that some plants and pollinators will be negatively affected if the frequency and severity of droughts increase due to climate change. Knowledge about how drought will affect pollination and which plants are most likely to be affected is needed to successfully manage and restore native ecosystems.



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Reproductive strategies of cacti in the driest desert in the world

By Steven Warren

By definition, deserts are areas of minimal precipitation. Organisms have evolved a variety of mechanisms or strategies to cope with aridity. We have studied different organisms in the driest desert in the world, and have discovered a variety of unique adaptations.

The Atacama Desert of northern Chile is the driest place on earth. The northern reaches of the desert receive an average of 2 mm or less of precipitation annually. Some parts of the desert have never recorded rainfall. Previous work by the Rocky Mountain Research Station found living cyanobacteria present in the soil in all places in the Atacama except the hyper-arid center. Some coastal areas benefit from frequent fog banks that roll in from the Pacific Ocean. Many organisms have evolved the capacity to extract moisture directly from the moist air. During one of our last visits to the desert, observations were made of several cactus species that successfully occupy the coastal region. Other scientists have observed some cacti of the genus *Copiapoa* in the Atacama that lean conspicuously to the north. This is presumably in response to the fact that they occur south of the Tropic of Capricorn. Hence, the sun is always in the north. By leaning to the north, they align their apical meristem and reproductive tissues to capture maximum sunlight.

Dr. Steve Warren recently observed that species of the cactus genus *Eulychnia* do not lean to the north. Rather, their fruiting structures grow predominantly on stems on the north side of the multi-stemmed plants,

and on the north side of those stems. With a Chilean colleague from the Universidad de La Serena, he collected data from a large number of individuals of two species in the genus. The data confirm the observation. During the next year, they plan to collect fruits, and test the viability of their seeds. They hypothesize that fruits with northern exposure will have a greater number of seeds and greater viability of those seeds compared to fruits with exposure in other directions.



Photo: Steve Warren, USDA Forest Service.



Photo: Steve Warren, USDA Forest Service.

Top: Collaborators of Dr. Warren: Dr. Lorgio Aguilera (right) and his graduate student (left) in front of an *Eulychnia acida* plant in the Atacama Desert.

Bottom: Flower of *Eulychnia breviflora*.

