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Upwardly Mobile in the Western U.S. Desert: Blackbrush Shrublands Respond to a Changing Climate



Blackbrush shrublands occupy about three million acres of land in the western United States and they provide critical habitat for animals such as desert rodents, birds, and bighorn sheep. This blackbrush community is in Bullfrog, Utah, on the Colorado Plateau. (Photo by Burton Pendleton)

Standing in the Mojave Desert under the broad sweep of the sky, with the seemingly infinite expanse of shrublands stretching out to meet the horizon, you can experience perfect stillness in a landscape that seems eternal. But with the passage of time, change is the rule in most ecosystems, and this desert is no exception. A time-lapse series of this spot would show the boundaries of the different plant communities marching up and down in elevation and latitude, with major shifts in species as the climate has warmed and cooled in the recent geologic past. And while it may not be obvious,

the shrubland you are standing in is probably “on the move.”

The ecology of one desert shrubland, dominated by blackbrush (*Coleogyne ramosissima*), has been the subject of decades of work by U.S. Forest Service Rocky Mountain Research Station (RMRS) researchers Susan Meyer, Bryce Richardson, Rosemary Pendleton, Burton Pendleton, and Stanley Kitchen. Blackbrush shrublands occupy about three million acres of land that includes some of the most scenic, iconic landscapes of the Southwest, and they provide critical habitat for animals such as desert rodents,

SUMMARY

Blackbrush (*Coleogyne ramosissima*) is a desert shrubland species that is currently dominant on over three million acres of the transition zone between the cold desert of the Great Basin and the warm desert of the southwestern United States. Western landscapes are projected to experience unprecedented changes as the climate warms, and researchers at the Rocky Mountain Research Station have been studying the response of this species to assess whether it can move upward in elevation and latitude. Blackbrush was found to have two distinct populations (in the warmer Mojave Desert and the cooler Colorado Plateau), which should give the species greater flexibility in responding to climate change and managers the opportunity to work with locally adapted seeds and plants. There are many barriers to successful dispersal, germination, and establishment of blackbrush under current climate conditions, and any of these may limit the potential of the species to make relatively rapid geographic shifts. Researchers have documented poor seedling survival over the past decade in the warmer Mojave ecoregion, but moving into wetter and cooler areas may not be possible for blackbrush based on current land use and the speed with which the species would have to shift its range. Scientists and managers will need to work together to foster the survival of this important species by identifying priority areas for conservation/restoration, identifying climate-adapted seed sources, and possibly assisting with its long-term migration.

birds, and bighorn sheep. One important and unique aspect of this community is its position between two major climatic zones—blackbrush shrublands occupy the transition area between the cold-desert sagebrush and pinyon-juniper communities of the Great Basin and the warm-desert creosote bush communities of the southwestern United States. According to Research Botanist Stanley Kitchen, this position between major climatic zones is significant because “blackbrush is a species that could give us early warning that a reshuffling of the deck, ecologically speaking, is already in progress, and also a chance to see how it proceeds.”

As a result of climate change, desert shrublands across the West are projected to experience large changes at an unprecedented rate in the coming years. Scientists predict that by the end of the century, the climate will be incompatible with plant communities in many western U.S. landscapes. Speculation is possible, but in reality, what will follow this “sea of change” is unknown. Novel communities are likely to emerge from the reassembling of species in response to changing temperature and precipitation

patterns. These novel communities will reflect differential patterns in mortality and geographic shifts among species. “On the lower ecotone, there are areas where we might have a small fire and blackbrush juveniles don’t recruit into that area because of new climate conditions,” says Research Ecologist Burt Pendleton, “but the blackbrush surrounding the area are still intact.”

The success of native species will depend on their ability to both colonize new areas successfully and hold their ground against the invasive species that are already displacing them from their current range. “Not only will blackbrush plants need to recruit into new territory, they must also contend with the relatively new threat from invasive grasses and the accompanying fire cycle,” says Research Ecologist Rosemary Pendleton. Blackbrush is likely to be pushed onto a precipice, and its survival will depend both on how it responds to these challenges and how well scientists and managers can join forces on its management. To this end, the RMRS research team has uncovered many of the life history secrets of this desert shrub,

and it so happens that blackbrush has a lot to teach us about challenges that our desert shrublands may face in the future and how we might intervene to preserve and foster the resilience of these fragile ecosystems.

DIGGING INTO BLACKBRUSH’S PAST

Deserts—which cover about one-quarter of the earth’s surface—are under assault from many fronts, including urbanization, energy development, invasive weeds, and climate change. Susan Meyer, the lead scientist on this project, says, “The desert is a tough place for people to live sustainably. It is important to study deserts because resource management in these fragile ecosystems is much more difficult and fraught with risk than management of wetter and more resilient ecosystems.” If we want to understand and better manage desert resources, it is helpful to take the long view of these systems. Essentially, to understand the present and have some hope of making predictions about the future in these areas, we need to know what was happening in the recent geologic past under different climate regimes.

How can we learn where these shrubs were historically, and how they have moved around over time? In the arid climates of the western U.S., a widely used tool is the analysis of the materials collected and stored by packrats at their nesting sites. These “middens” date back as far as 40,000 years and the information they contain can help document plant distributions during the end of the last Ice Age—a time when the climate was wetter and cooler. Fossilized blackbrush remains found in middens from this colder time period show that this species used to occur farther south than its current location. The climate has warmed and dried since the end of the last Ice Age, and blackbrush has responded by moving upward both in elevation and latitude to cooler climates. In light of this



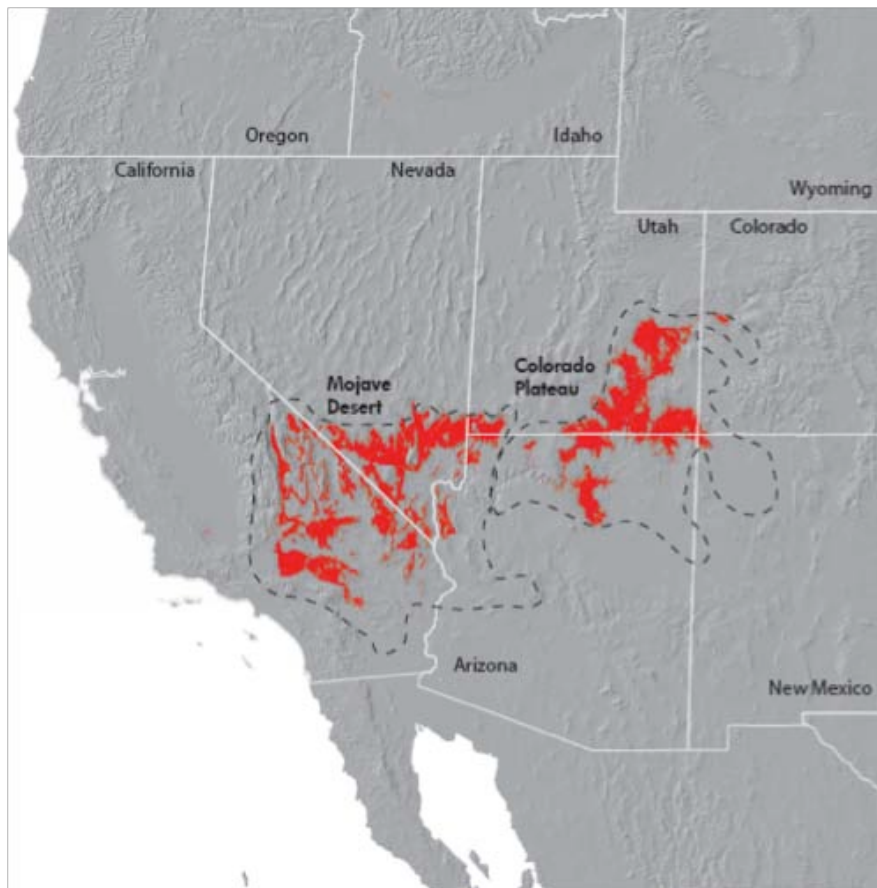
Blackbrush shrublands occupy the transition area between the cold-desert sagebrush and pinyon-juniper communities of the Great Basin and the warm-desert creosote bush communities of the southwestern United States. This Mojave Desert blackbrush community is near the Mojave National Preserve, California. (Photo by Rosemary Pendleton)

“Not only will blackbrush plants need to recruit into new territory, they must also contend with the relatively new threat from invasive grasses and the accompanying fire cycle,” says Research Ecologist Rosemary Pendleton.

past movement, one important question that RMRS researchers have asked is: where will blackbrush be able to persist in our rapidly changing climate? Answering this has required a greater understanding of the ecology, genetics, and physiology of this plant, and coupling this information with modeling of future climate scenarios.

BE GERMINATING OR BE LUNCH

When you consider the hurdles that blackbrush must overcome to become established in the field, it is surprising that there is any around at all. First, successful establishment is weather-dependent, requiring two wetter-than-average years in a row—one to produce a decent seed crop and another for the seedlings to survive the following summer. Also, blackbrush has a close association with the kangaroo rat, which plays a dual role of champion and adversary. The seeds are a much-coveted food source of the kangaroo rat. Accordingly, the rats perform a most important service to the plant—seed dispersal—by burying the seeds in shallow holes all over the soil surface



Blackbrush was found to have two genetically distinct populations: one in the warmer Mojave Desert and the other in the cooler Colorado Plateau (the approximate distribution of the species within these areas shown in red).



Blackbrush spreads only by seed, and kangaroo rats are the main dispersers through their collecting and burying activities. Blackbrush seeds are an important food source for these rodents. (Photo by Susan Meyer)

called “scatterhoards.” The rats do not carry the seeds far, however—according to Susan Meyer, “They will only disperse the seeds on the order of a few hundred meters”—and whether and how the kangaroo rat will shift geographies as a result of climate change remains to be seen. In most years, the kangaroo rats will consume all the blackbrush seeds that are produced, and so the shrub has evolved a strategy of “masting,” or swamping the seed predators with food in some years in order to have some left over that might germinate. Once buried, the seeds germinate quickly and so do not form a long-lived bank of seeds in the soil for coming up in subsequent years. Susan explained, “In order to keep from germinating, you have to be protected

“The desert is a tough place for people to live sustainably. It is important to study deserts because resource management in these fragile ecosystems is much more difficult and fraught with risk than management of wetter and more resilient ecosystems,” says Research Ecologist Susan Meyer.



This higher elevation blackbrush community is showing mass flowering in Browse, Utah. Fossilized blackbrush remains found in ancient packrat middens show that this species used to occur farther south than its current location when the climate was wetter and cooler during the end of the last Ice Age. (Photo by Burton Pendleton)

by a dormancy period. Blackbrush seeds don't have that. They are dormant when first dispersed, but then they lose that dormancy the first year.” There is no real advantage to the seeds in lying dormant in the ground when they are likely to be found and consumed by rodents. By germinating quickly once buried, the plant has a better chance of survival—it's “grow or be lunch” in this community.

Germinating quickly certainly does not guarantee the long-term success of any shrubs that make it through the gauntlet. Young blackbrush seedlings have low odds of surviving—rats will likely eat the seed caches, or summer drought in the desert will destroy them. Simply put, “The tolerance of mature plants and seedlings is very different. So, while the mature plants may remain in place, recruitment of new individuals is the sticking point,” says Burt. In addition, the invasive annual grasses that are



Blackbrush is a masting species, and successful establishment is weather-dependent, requiring two wetter-than-average years in a row—one to produce a decent seed crop and another for the seedlings to survive the following summer. (Photo by Susan Meyer)

becoming so prevalent and problematic in blackbrush habitat (particularly red brome in the Mojave and cheatgrass on the Colorado Plateau) present previously unknown competition for space and resources to these seedlings. These grasses also fuel historically anomalous large and continuous fires from which blackbrush is very slow to recover, if it can at all. The adult shrubs do not readily resprout after an intense fire, and the desert rodents, lacking the cover provided by shrubs, do not move the blackbrush seeds into large burned areas. With all of these barriers to successful germination and establishment of blackbrush in place, seeds rarely mature into full-grown shrubs. And in a changing climate, it is easy to see how the tricky moisture requirements for the seeds, combined with a warming trend, could push the plant up to and beyond its limit in some regions.

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Blackbrush was planted out into an experimental plot at the Desert Experimental Range in Utah, outside of the plant's current range. Specimens from the Mojave had a low rate of survival during the winter of 2010/11, while those from the Colorado Plateau were better able to tolerate the cold temperatures. (Photo by Stan Kitchen)

DIVERSITY MAY BE THE KEY TO SURVIVAL

Blackbrush is in a large plant family that includes rose, apple, and cherry (Rosaceae), but it is the sole member of its genus. This means that it has no close relatives and thus botanists assumed it to be a “relict” species with low genetic diversity. As Susan explained, “Blackbrush is probably quite an ancient plant that has survived through many long-term cycles of climate change.” Genetic diversity in a population is one important measure of its resilience to change. Higher diversity confers a greater likelihood that there

will be certain individuals that can thrive and reproduce under new circumstances. Before the scientists looked into the genetic diversity of this species, “There was a dogma about this plant that it was genetically uniform across the range,” she says. But when Susan and Bryce looked at the genetic structure of blackbrush, they found no support for the assumptions about the shrub’s genetic uniformity.

In fact, they found two distinct metapopulations in the two ecoregions studied, each with considerable genetic diversity among sub-populations. Of the

two metapopulations, one exists in the warmer Mojave Desert and the other in the cooler Colorado Plateau. Further studies by the research team found measureable differences in the ecology of the seeds in these two sub-groups, which may help to explain at least some of the genetic variation. For example, in the Mojave Desert, which is the southern and more low-lying environment, seeds were found to have a shorter chilling requirement and higher optimum chilling temperature than those from the Colorado Plateau, where it regularly snows. The scientists took this finding a step further by challenging shrubs both from the warmer Mojave and the cooler Colorado Plateau populations to grow head-to-head in two different “common garden” experiments. Common garden experiments can provide information on blackbrush survival and growth under novel climatic conditions. Plants representing each metapopulation were planted in both the Desert Experimental Range in Utah and the Los Lunas Garden in New Mexico. The Desert Experimental Range happens to be just outside the northern edge of the species’ current range in the Colorado Plateau; the Los Lunas site is just south of Albuquerque and provides an example of another set of conditions, including higher-elevation, that is outside the normal range. According to Susan, “For these sites we asked, is this the kind of place where blackbrush can survive in 50 years?” In the Desert Experimental site, Susan explains, “We had a cold winter and most of the Mojave Desert plants died but almost none of the Colorado Plateau plants died. It was pretty dramatic.” Meanwhile, the Los Lunas site did not experience the same die-off despite a cold winter. On a local scale and in the shorter term, this type of adaptive genetic variation helps the plants to be finely tuned to their environments—for

KEY FINDINGS

- Blackbrush is a mast-fruiting shrub species, with five years or more between synchronized abundant seed production. A successful seed crop requires two above-average years of precipitation. The seeds, dispersed by the kangaroo rat, do not form a persistent seed bank due to a short dormancy period coupled with high seed predation levels. Successful establishment is a rare event, and seedlings are prone to herbivory.
- Genetic studies have revealed a high level of diversity, and the existence of two genetically distinct populations of blackbrush – one centered in the warmer Mojave Desert and the other in the cooler Colorado Plateau.
- Seeds from the Mojave showed plant adaptation to a warmer climate, with a shorter chilling duration and higher temperature required to break seed dormancy. Seedlings from the Mojave showed a markedly reduced tolerance to cold (compared to seedlings from the Colorado Plateau) in a common garden experiment.
- Historical shifts in the geographic range of blackbrush have been documented and climate models predict further movement based on climate change, particularly in the Mojave. Current recruitment levels in the Mojave are low, even in wetter years, and blackbrush is predicted to move into higher latitudes and elevations where its range may be limited by agriculture, urbanization, and saline soils.

example, to germinate and grow during the conditions that would be optimal in each of these different environments. On a broader geographic and time scale, this genetic variation is of great use to a species that must colonize new areas and potentially adapt in order to persist in a changing climate.

NO COUNTRY FOR OLD SHRUBS

If blackbrush has moved around in the past in response to climate change, the question is, where is it headed now? Armed with information on this plant's past movements and also its genetic and physiological variation, the RMRS scientists have begun piecing together a speculative scenario for this shrub community based on future climate projections. In the higher, cooler Colorado Plateau, climate models predict that blackbrush can be accommodated at higher elevations compared to the current distributions. But, if the climate continues on a long-term warming trend, these predictions suggest that major changes are afoot for this species in the warmer Mojave Desert.

The researchers have looked at the survival of typical, Mojave-adapted blackbrush seedlings in the Mojave by marking the plants when they first germinated and then following their fate for 10 years. And as it turns out, the seedlings did poorly in this ecoregion. According to Susan Meyer, "Blackbrush seedlings don't recruit very well in the Mojave even in good years." With the entire Mojave predicted by climate models to become warmer in the coming years, blackbrush will have to be able to move to areas that are currently cooler and moister to be successful. In fact, preliminary results from the climate models do predict that blackbrush will move northward in the Mojave, but it is probable that its success will be limited by the relatively high proportion of farmed, urban, and saline soils in this area. In addition, "Other desert shrubs may have a competitive advantage because of different dispersal strategies and a higher tolerance for drought," says Rosemary Pendleton. With poor seedling survival and limited options for movement in the Mojave, the future potential range of

blackbrush appears diminished in that ecoregion.

Blackbrush management and restoration can be fine-tuned by coupling information on seed and plant genetic responses with modeling of future climate. According to Research Geneticist Bryce Richardson, "Land managers will be able to make more informed decisions on which populations and regions of blackbrush are of greatest importance to conservation based upon predicted resiliency under climate change and preserving genetic diversity." The adaptive genetic variation that is seen between blackbrush populations in the Mojave and the Colorado Plateau is likely to be present in other desert shrubs to varying degrees, and can be tested through common garden experiments—as described earlier—where plants from different regions are grown across a range of conditions and their genetic responses are measured. These responses, along with modeling of future climate change, can be used to predict the shifting boundaries of populations of shrub species under changing conditions.

Susan Meyer summarizes the problem thusly: "You see maps of where blackbrush is supposed to be in 50 years, and I wonder how the heck it is supposed to get to these places..."

MANAGEMENT IMPLICATIONS

Susan Meyer from the RMRS Shrub Sciences Laboratory in Provo has decades of experience with desert shrubland restoration. The following are some of her specific recommendations for land managers:

- Document the conditions (for example, weather patterns or microsite differences) when there is successful germination and growth of shrubs in the field, since it is not always clear what it takes for plants to become established. Target these field conditions for restoration efforts.
- Find out which seeds you can stockpile. If you know it will live a long time in storage (e.g., blackbrush seeds remain viable in dry storage for up to 15 years despite the fact that they germinate quickly in the field), collect it when it is available so that you have it when you need it. Don't wait for a crisis. With some species, seeding in groups (caches) seems to improve survival. It may also be necessary to protect emerging seedlings from rodent predation.
- Field observations and timing of seeding/planting are critically important for the restoration of blackbrush and other desert shrub species. For example, the Mojave is really dry, so even if you do everything right, seeding is likely to fail most years. If you could work with climate modelers to predict which year was likely to be a good [wetter] one before putting the seeds in the ground, it would increase the odds of successful germination and be a more cost-effective management approach.
- The source of seed or plants must be appropriate to the area that is being planted. For example, blackbrush seeds from the Mojave, with their different chilling requirements and lack of cold tolerance, would not be expected to do well in the colder parts of the Colorado Plateau.

Predicting, and possibly influencing, the trajectory of blackbrush shrublands in coming years will take additional effort. This species may have undergone broad geographic shifts in the past, but whether it can now “pack up and move” remains to be seen given the accelerated rate of change the climate is currently undergoing. Susan summarizes the problem thusly: “You see maps of where blackbrush is supposed to be in 50 years, and I wonder how the heck it is supposed to get to these places. Scientists and managers will need to work together to facilitate long-distance migration and successful seedling recruitment of adapted ecotypes, if establishing blackbrush in new areas of adaptation becomes a priority.” A current scientist-manager collaboration on the Grand Canyon-Parashant National Monument in northern Arizona involving blackbrush

and rehabilitation of burned areas is a good example of cooperative efforts aimed at protecting and restoring blackbrush habitat.

We suspect that climate change is proceeding much more quickly than in the past. It is unknown whether

blackbrush can respond to this rapid change when (1) successful establishment is a relatively rare event, (2) the rodent dispersers do not move the seeds very far or very fast, and (3) blackbrush must deal with invasive annual grasses and the uncharacteristic high-frequency fire regimes that they foster. It seems that, if blackbrush is indeed on the move in our current climate regime (and evidence suggests that it is), it may need help to get where it's going, or even just to maintain itself in areas where it can persist in a warmer climate. Further collaboration between scientists and managers will be key in any effort to proactively move or otherwise foster the survival of blackbrush, and the species that depend on it, in response to projected climate change.

FURTHER READING

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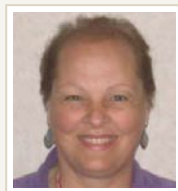
SCIENTIST PROFILES



SUSAN MEYER is a Research Ecologist with the Rocky Mountain Research Station's Shrub Sciences Laboratory in Provo, UT. She received her M.S. in Biological Science from the University of Nevada and her Ph.D. in Botany from Claremont Graduate School. Her work has focused primarily on the regeneration biology of native Intermountain shrubs, forbs, and grasses, as well as invasive annual grasses, in the context of the ecological restoration of shrublands.



BRYCE RICHARDSON is a Research Geneticist with the Rocky Mountain Research Station's Shrub Sciences Laboratory in Provo, UT. He received his M.S. in Forest Resources from University of Idaho and his Ph.D. in Plant Pathology from Washington State University. His research is directed toward investigating adaptive genetic variation and utilizing next-generation sequencing approaches to elucidate genetic relationships in big sagebrush (*Artemisia tridentata*) and blackbrush (*Coleogyne ramosissima*).



ROSEMARY PENDLETON is a Research Ecologist with the Rocky Mountain Research Station's Albuquerque Forestry Sciences Laboratory in Albuquerque, NM. She received her M.S. in Range Science from Brigham Young University and her Ph.D. in Biological Sciences from Wayne State University. Her current research focuses on community dynamics at the grassland/shrubland ecotone.



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STANLEY KITCHEN is a Research Botanist with the Rocky Mountain Research Station's Shrub Sciences Laboratory in Provo, UT. He received his M.S. in Horticulture from Brigham Young University in Provo, UT. He manages the Desert Experimental Range (DER) and conducts collaborative research on the impacts of disturbance on the composition, structure, and stability of shrublands, woodlands, and forests of the Great Basin.

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