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INSIDE

"Science affects the way we think together."

Lewis Thomas

No Place Like Home: Using Seed Zones to Improve Restoration of Native Grasses in the West

"I listened carefully for clues whether the West has accepted cheat [grass] as a necessary evil, to be lived with until kingdom come, or whether it regards cheat as a challenge to rectify its past errors in land-use. I found the hopeless attitude almost universal."

—Aldo Leopold


Brad St. Clair

*Bluebunch wheatgrass (*Pseudoroegneria spicata*) is a native grass, integral to many ecosystems throughout the American West. It is a key species used in restoration efforts after fire.*

IN SUMMARY

Seed zones and seed transfer guidelines describe where plants are most likely to thrive. Scientists with the Forest Service and Agricultural Research Service undertook a 9-year project to build empirical seed zones for bluebunch wheatgrass, a foundational native grass throughout the West. The research will help the Forest Service and Bureau of Land Management accelerate restoration of native grasses and combat invasive species such as cheatgrass.

Scientists documented variation in bluebunch populations, looking particularly at traits important for adaptation to drought and cold. Forest Service scientists also used high-resolution climate data to develop generalized provisional seed zones for a host of important native plant species.

Knowledge of geographic variation in adaptive traits and the development of seed transfer guidelines can help resource managers select plant material that may be expected to adapt well to future climates.

These guidelines are critical to efforts to restore native grasses to the inland Pacific Northwest and Great Basin. Empirical seed zones are helping to support a recently renewed federal commitment to coordinate efforts to prioritize conservation of native plants across land-management agencies.

An effort is underway to beat back invasive species and restore native plants to the rangelands and steppes of the Great Basin and inland Pacific Northwest. Cheatgrass *(Bromus tectorum)*, an exotic invasive grass that has plagued the American West for more than a century, is high on the list of targets.

So named because it tends to lower yields for farmers, cheatgrass likely hitched a ride to North America in shipments of grain seed from Europe in the mid 1880s. Its seeds cling easily to animal hides, enabling cheatgrass to conquer the West along with the swelling herds of livestock. As a prolific seed producer that can germinate in the fall or spring, it easily outcompetes native perennials, producing as many as 10,000 plants per square yard. Once cheatgrass sets seed, it dries into highly flammable kindling that can stretch to the horizon, ready to ignite. Cheatgrass-dominated land burns every 2 to 5 years. In contrast, lands rich in sagebrush and native grasses burn every 11 to 200 years.

A 2013 study in the journal *Global Change Biology* found that cheatgrass fed and sustained 39 of the largest 50 fires of the previous decade in the Great Basin. The study also found that fires that burned across multiple vegetation types were significantly more likely to have started in cheatgrass-dominated landscapes.

These findings lend urgency to the efforts of land-management agencies to restore native grasses and shrubs. However, native species need help if they are to compete and thrive on sites that aren't as hospitable as in the past.

KEY FINDINGS

- Bluebunch wheatgrass populations differed in traits important for adaptation to drought and cold. Populations from arid climates were smaller, with earlier phenology and narrower leaves than those from wetter climates. Later phenology was associated with populations from cold climates.
- Genecological models of relationships between adaptive traits and source climates were used to develop seed zones for guiding population transfers across the inland West.
- These models may also be used to evaluate differences between optimal trait values associated with current and future climates.
- Researchers also developed generalized provisional seed zones for a host of important native species used in restoration by using high-resolution climate data for winter minimum temperature and aridity, variables that are important for adaptation.

GIVING BLUEBUNCH A BOOST

Brad St. Clair, a research geneticist with the U.S. Forest Service Pacific Northwest (PNW) Research Station, is fully engaged in the effort. St. Clair has been exploring the differing abilities of bluebunch wheatgrass (*Pseudoroegneria spicata*) populations to adapt to drought and cold across the plant's vast range, which stretches throughout much of the western United States and as far north as Alaska. Through common garden studies, St. Clair and his colleagues have developed empirically tested seed zones and seed transfer guidelines for bluebunch, a lynchpin native species. Restoration managers are using these guidelines to focus their work and target specific varieties of native grasses to landscapes where they're most likely to flourish now and in the future.

"Bluebunch wheatgrass is a large component of the seeding mixtures used in restoration work after fires," says St. Clair. "That's why it's one of the first species that we chose to look at, with respect to genetic variation."

St. Clair and Vicky Erickson, a geneticist with the Forest Service Pacific Northwest Region, began studying bluebunch in 2005. They collected seed from 114 bluebunch populations scattered across 400,000 square miles of the inland Pacific Northwest and northern Great Basin, a range that demonstrates the hardy nature of the plant. These sites, located across six states, ranged in elevation from 750 to 8,000 feet. Average annual rainfall ranged from 8 to 74 inches and average annual temperatures ranged from 38 to 53 °F.

"Probably the most fun I've had in the last decade is going out and doing these seed collections for these species throughout the Great Basin and Blue Mountains and Columbia Plateau," says St. Clair. "I just love driving around out there and stopping and collecting grass, and then driving to the next place. It's beautiful. I spend a lot of time in front of a computer too, but this sort of fieldwork is not only invigorating but essential. By driving around and visiting all the places in which we collect seed, I also gain a better understanding of the diversity of environments in which bluebunch evolved and grows."

In summer 2006, field crews planted the seeds in three test sites in Washington and Idaho. The next few years were devoted to the somewhat tedious task of conducting a common garden study, the kind that plant scientists, farmers, and even amateur gardeners have been doing for centuries. Common garden studies are done by planting different populations of the same species in the same environmental conditions. Because of genetic variation, the plants won't grow in a uniform manner; they often differ in height, flowering dates, leaf

Brad St. Clair

A forestry technician collects bluebunch wheatgrass seeds in the Blue Mountains of southeastern Washington. The seeds were later used in a common garden study.

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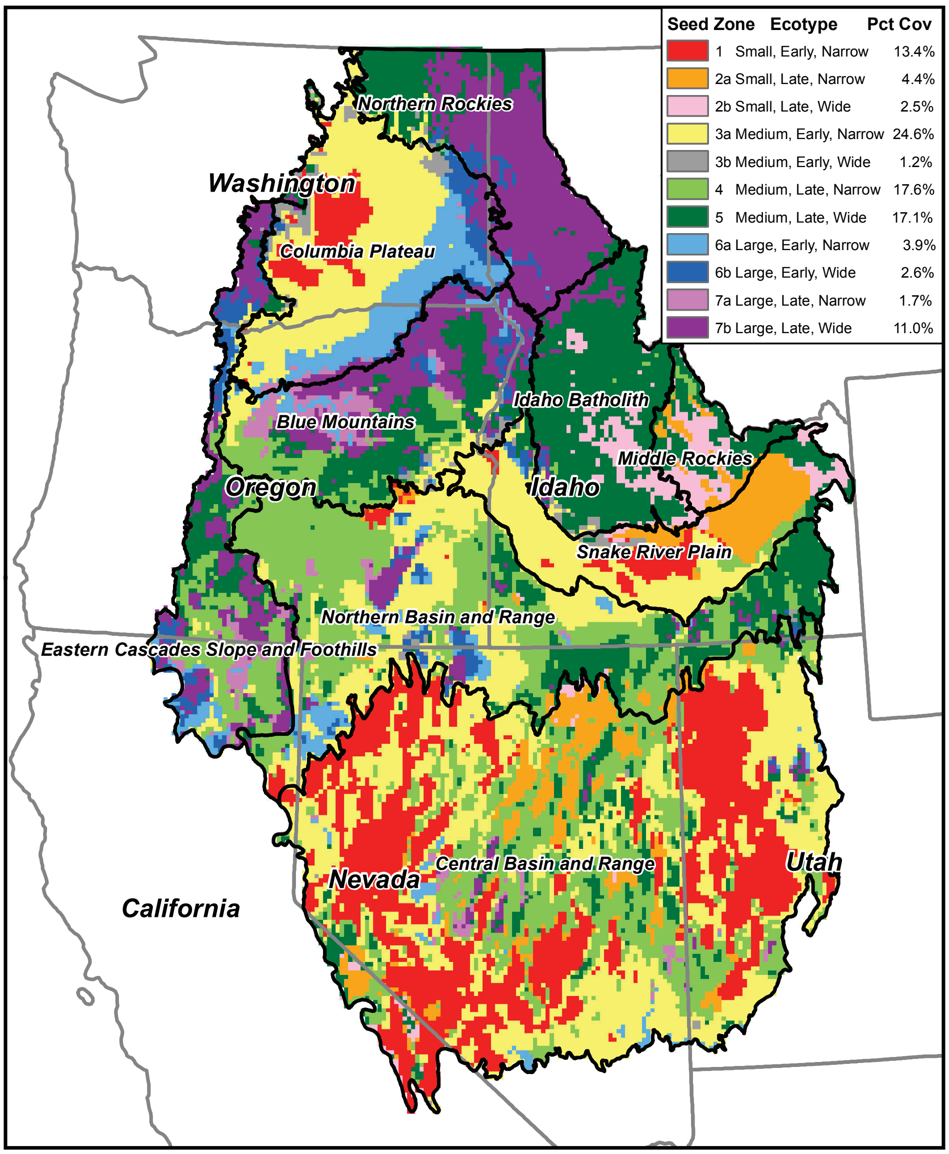
The Lucky Peak Nursery in Idaho was one site in the common garden study. Researchers measured genetic variation in bluebunch wheatgrass grown from different seed sources.

Researchers measured a range of plant characteristics, including leaf width, to determine how populations of bluebunch wheatgrass differed depending on the geographic location of the seed source.



Based on the findings from the common garden study, the scientists developed this map that shows 11 distinct seed zones for bluebunch wheatgrass. Restoration managers can use the map to inform decisions about what seed source to use for best performance in a given location.

widths, and appearance. These variations, created by natural selection within a plant's environment, are grouped together and called ecotypes.

There are various ways to gauge genetic variation in any plant or animal species. St. Clair used what is known as a genecological approach.

"Genecology is the study of genetic variation within species and the relationship to the environments from which they came," he explains. "Basically, it's looking for correlations between traits of plants and the different habitats in which they evolved. If there's consistent correlation, that indicates adaptation as determined by natural selection."

The idea is to first sort through which heritable characteristics contribute most to bluebunch's ability to survive and reproduce in a particular environment and then to plant seed from these plant populations in similar environments during restoration activities.

The scientists collected data on 22 plant traits such as leaf length, width, and color as well as timing of emergence, flowering, and seed set. After analyzing the data, St. Clair and his colleagues found significant variation among bluegrass populations, mostly related to local levels of drought and temperature.

In general, plants from drier climates were smaller, had narrower leaves, and displayed earlier phenology, a basic measure of seasonal phenomena such as when plants first emerge in the spring, flower, and set their seed. The colder the climate, the later these seasonal milestones occurred.

"These characteristics help plants survive and reproduce by avoiding water loss and starting to grow but shutting down earlier before summer drought becomes problematic," says St. Clair.

St. Clair's basic conclusions conform to observations made about many plant species. What is unique, however, is the degree of precision to which he was able to sort the various plants in his study and map variations across the landscape. His findings indicate that bluebunch can be grouped into 11 distinct ecotypes, each corresponding to a specific seed zone.

St. Clair says the bluebunch plants in his study display an average level of variation—not so robust that one ecotype fits all environments, and not so finicky that each microclimate has its own distinct variety. This is good news when it comes to restoration because it means that only a modest number of seed zones are likely needed to cover reseeding work across much of bluebunch's sprawling range.

FOCUSING ON NATIVE PLANTS

The current effort to restore native plant communities stems from the realization that so many of the species that depend on native grasses and shrubs—from butterflies to sage grouse to birds of prey—are increasingly at risk.

"The big issue for restoration was about even using native plants in the first place," says St. Clair. "For a long time, a lot of the agencies would use nonnative species—for example, crested wheatgrass and the like. Eventually people started asking 'Well, is that the right thing to do?'"

Through the mid-2000s, the Forest Service and the Bureau of Land Management (BLM) fought cheatgrass by planting other exotic species from Eurasia. It was a lesser-of-two-evils situation for restoration managers, who needed plants that were better able to compete with cheatgrass, particularly in terms of resistance to fire and grazing, than their native counterparts. The quick fix was modestly successful in stemming the cheatgrass tide, although swapping one introduced species for another missed the mark of more complete restoration by a wide margin.

"In the last 15 years especially, there's been an increasing emphasis on using native species for restoration," St. Clair says. "And once we started using native species, some of us from the forestry side of things took it a step further and started to ask 'Are we using locally adapted material and genetically diverse material?'"

In 2014, the Forest Service, BLM, and other federal agencies renewed a memorandum of understanding (MOU) that agencies will coordinate their native plant restoration and conservation efforts. St. Clair and Erickson are among Forest Service staff contributing to the strategy document that will guide these efforts.

Erickson, who manages a native seedbank for the Pacific Northwest Region, attended the meeting in Washington, D.C., when the details of the MOU were being finalized. She says, "It was just remarkable...never in my career did I think I'd be sitting in a meeting with such high-level officials talking about native seeds."

The Forest Service's evolving focus is a boon to geneticists like St. Clair and Erickson because it's easier in many respects to study grasses rather than trees. Conifers can live for centuries and take decades to set seed. Grasses, on the other hand, are often able to mature and set seed within a single growing season, dramatically shrinking the time it takes to gather and analyze data on genetic variation and adaptation.

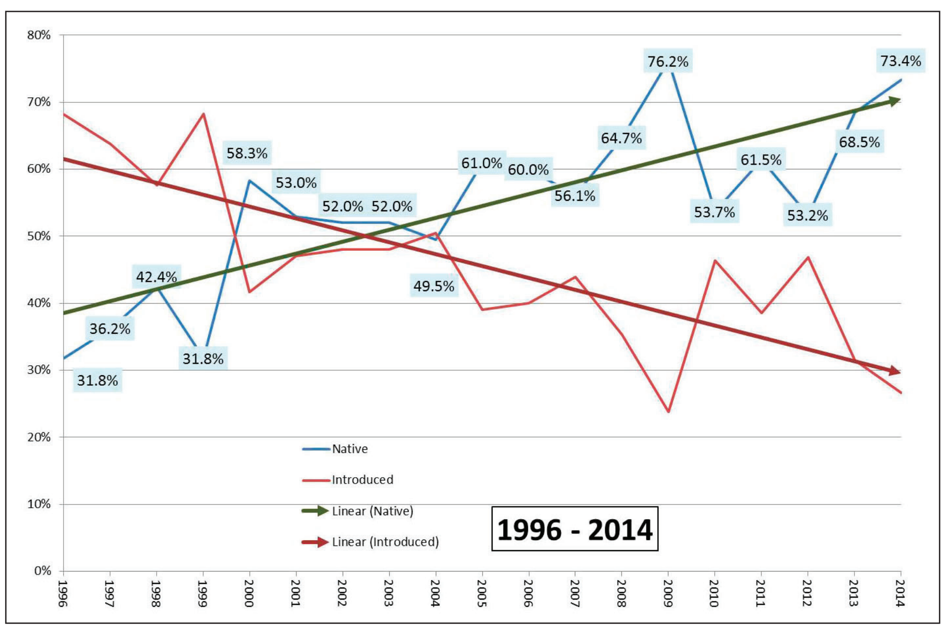
"This research has huge economic implications in the marketplace," adds Erickson.

IN PRACTICE

Paul Krabacher, based in Boise, Idaho, is the national seed coordinator for BLM. Working through the BLM's regional seed warehouse managers, it is his job to ensure that BLM staff have the seed they need for their fieldwork, much of which is rehabilitating landscapes after fires. This turns out to be a lot of seed because the BLM is the largest nonagricultural buyer of seed in the Northern Hemisphere, if not the world. In 2012, Krabacher oversaw procurement of more than 3 million pounds of seed, enough to replant at least several hundred thousand acres.

Krabacher notes that the seed zone concept is new and that private industry supplying seed to the BLM will need at least a few years to begin producing more locally adapted varieties in the quantities the agency needs. But he expects that the use of seed zones will increase, and that this in turn will lead to healthier ecosystems and new economic opportunities for the seed industry. "I can see this as being win-win once this gets underway," he says.

Krabacher rattles off a growing list of native species for which he considers seed zones in making seed purchases: Indian ricegrass, Sandberg bluegrass, globemallow, and bluebunch wheatgrass. In the last big sagebrush buy, 113,000 pounds of seed were selected from six seed transfer zones. The seed wound up being used in 14 counties across five states.



Paul Krabacher

The Forest Service and Bureau of Land Management have a memorandum of understanding to coordinate their native plant restoration efforts. The BLM is the largest buyer of nonagricultural seed in the Northern Hemisphere, and the percentage of native seed it purchases has increased over the past 18 years.

"That one was really successful; we were really able to zero in specifically on the provisional seed transfer zones," Krabacher says, referring to research published by St. Clair and others in 2014 in *Ecological Applications*.

Change always comes slowly, whether in scientific paradigms, government agencies, or the marketplace. For a host of reasons, for now most of the BLM's mixes still include a mix of native and introduced species. Recently, though, he has seen an increase of mixes comprising 100 percent native species pass through the BLM procurement system and into the field.

LAND MANAGEMENT IMPLICATIONS

- Differences among native plant populations that make sense for survival, growth, and reproduction in various source climates indicate that genetic variation across the landscape is adaptive and should be considered during restoration.
- Knowledge of this geographic variation in adaptive traits and the development of seed transfer guidelines can help resource managers select plant material that may be adapted to future climates.
- Generalized provisional seed zones are useful for the many restoration species for which information about adaptation and population variation is lacking. These seed zones may be modified as more is learned about different species.

ANTICIPATING CHANGE

St. Clair and Erickson recently collaborated with Andy Bower, a Forest Service geneticist based at the Olympic National Forest in Washington state, to map provisional seed zones for the continental United States. The study combined high-resolution climate data for winter minimum temperature and aridity, variables important for adaptation in a wide range of species, and well-accepted data on ecoregions, a method researchers use to describe areas containing distinct collections of species, natural communities, and environmental conditions. They produced a map with 64 provisional U.S. seed zones, each unique in terms of both climate and ecology. These provisional seed zones are meant to be generalizable to any species, particularly those lacking genetic studies of adaptive variation.

The scientists then tested their provisional seed zones with actual seed zone data for bluebunch, tapertip onion, and Indian ricegrass. They found that the provisional seed zones closely matched the actual seed zones derived from common garden studies like the one St. Clair did for bluebunch.

"These provisional seed zones can be considered a starting point for guidelines for seed transfer," St. Clair explains. "And both the provisional seed zones and the seed zones derived from genecology studies may be used to study how seed zones and adaptation might change in the future."

For example, St. Clair and Francis Kilkenny, now at the Forest Service's Rocky Mountain Research Station, found that optimal dates of reproduction will be both earlier and later by 2050, depending on the location.

St. Clair and his colleagues have begun the next phase of their research—a reciprocal transplant study that involves planting bluebunch from one seed zone (such as the hot, dry Columbia Plateau) into another (the cooler, wetter Blue Mountains in northeast Oregon and southeast Washington). As St. Clair describes it, this is essentially an effort to confirm their earlier work.

"We want to be able to say with more certainty 'Okay, the one place is one seed zone, the other place is another seed zone, and we should not transfer things between those seed zones because they won't be adapted,'" he says. "And by moving populations between different climates, we can better explore the effects of climate change on adaptation by, in effect, substituting space for time."

This new research should validate his conclusion that, it is in fact, many shades of bluebunch that color the Western landscape. And it will help build still more accurate seed zones and seed transfer guidelines for bringing back more native grasses to the American West.

"I believe a leaf of grass is no less than the journey-work of the stars."

—Walt Whitman

FOR FURTHER READING

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