

The Role of Soil Seed Banks in Sagebrush Restoration

Degraded sagebrush rangelands in the Great Basin are at risk of conversion to cheatgrass-dominated systems, and many have already been overtaken by this invasive species. Yet restoration activities are often carried out without understanding how the soil seed bank may influence success or the potential impacts of restoration activities on the seed bank. The soil seed bank refers to the natural storage of seeds, often dormant, within the soil. The seed bank can affect vegetation recovery by serving as a source of new recruits, which may be desirable if the seed bank is dominated by native perennials, or it could be undesirable if there are high densities of exotic weed seeds. Seed longevity and persistence in soil seed banks varies depending on the species and the environmental conditions. Understanding the role of the seed bank in restoration and the potential impacts of management activities on seed stores may be especially important for restoring sagebrush systems threatened by cheatgrass invasion where disturbance and seedling establishment can be unpredictable.

Several studies have been conducted in collaboration with the primary SageSTEP research to examine the role of seed banks in restoration activities. Here we will highlight two of these studies and their implications for land management.



Soil seed bank contents can affect vegetation recovery following disturbance, and restoration activities can affect the contents of the seed bank. Both should be considered in management decisions.

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Study #1: The relationship between the seed bank and aboveground vegetation in the context of sagebrush restoration

Kristen Pekas and Dr. Gene Schupp of Utah State University conducted a study at the SageSTEP Onaqui study site in Tooele County, Utah, looking at the relationship between soil seed banks and aboveground vegetation in areas threatened by cheatgrass invasion. They also examined the impacts of prescribed fire, a common management activity, on the seed bank. Data were used to address the following questions:

- What is the relationship between seed bank and the aboveground vegetation?
- Does prescribed burning affect seed bank species composition and abundances?
- Does cheatgrass abundance influence seed bank composition?

Line-point intercept data was used to quantify the presence and relative abundance of species aboveground, and seed bank samples were collected along transects before and after prescribed fire from control and burned plots. Data were collected from phase 1 and phase 3 subplots defined by percentage of perennial bunchgrass cover. Subplots with greater than 19% perennial bunchgrass cover were considered phase 1 communities, those with 10–19% bunchgrass cover were considered phase 2, and those with less than 10% perennial bunchgrass cover were considered phase 3 communities. Seed banks were evaluated by direct germination in a greenhouse.

Researchers found that the seed bank and aboveground vegetation shared 19 of 71 species. Relative abundances of these shared species were similar except that desert madwort (*Alyssum desertorum*) and bur buttercup (*Ceratocephala testiculata*) had significantly higher quantities in the seed bank compared with aboveground abundance, and sagebrush (*Artemisia tridentata*) was significantly more abundant aboveground than in the seed bank. Species that were found either only in the seed bank or only in the aboveground vegetation were all at low abundances.

Although prescribed burning did not alter species composition, it did affect the abundance of some species in the seed bank. Fire reduced the abundance of cheatgrass seeds, especially beneath shrubs. Fire also reduced the densities of bur buttercup and Sandberg bluegrass (*Poa secunda*) seeds. While Sandberg bluegrass seed densities remained low one year following the burn, it appears that bur buttercup densities can recover quickly.

The seed bank was highly variable in density and composition. Surprisingly, the abundance of cheatgrass seeds was not related to phase. Although phase 1 and phase 3 seed banks were similar overall, phase 1 communities were slightly more diverse and had significantly higher densities of seeds, especially of seeds of perennial grasses, than did phase 3 communities.

This study indicates that understanding the role of seed banks in restoration of sagebrush communities can aid management decisions. Where possible, identifying percentage of perennial bunchgrass cover and taking the time to determine seed bank contents in a project area could improve project success rates and save time and money in the long run. Additionally, managers should consider potential impacts of management activities on seed stores. Depending on the species present prior to treatment and management objectives, prescribed burning may or may not have desirable impacts on seeds available for reestablishment later on versus other management options. For more information about this study visit: http://www.sagestep.org/collaborative_projects/projects/usu_seed_pool.html

Study #2: Seed longevity of sagebrush subspecies related to burial depth

Upekala Wijayratne of Oregon State University and Dr. David Pyke of the U.S. Geological Survey conducted a study to evaluate the longevity and persistence of sagebrush (*Artemisia tridentata*) seeds in relation to seed burial depth and environmental conditions. Data were collected and analyzed to answer the following questions:

The soil seed bank can affect vegetation recovery by serving as a source of new recruits, which may be desirable if the seed bank is dominated by native perennials, or it could be undesirable if there are high densities of exotic weed seeds.

- How long can sagebrush seeds remain viable in soil?
- Does seed longevity depend on its depth in the seed bank?
- Does seed longevity change with environmental conditions?

To capture variability across the Great Basin, data were collected from six study sites in Oregon, Idaho, Utah and Nevada for two subspecies: Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) and mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*). A seed burial experiment evaluated the effects of seed depth (3 cm below soil surface, at the soil surface beneath 2 cm of sagebrush leaf litter, and above the soil and litter) and collection time (late spring after normal germination, autumn around time of seed dispersal and one year after placement, after germination during second field season, and autumn at seed dispersal two years after placement) on seed longevity. Soil cores of 3 cm depth were used to sample the natural seed bank, and greenhouse germination was used to determine whether seeds persisted from one season to the next.

This is the first study to experimentally document that sagebrush can form a transient seed bank and that seed longevity is greatly enhanced by burial of seeds in the soil. Researchers found that the proportion of viable buried seeds was fairly constant for both subspecies throughout the 2-year study period. Seeds on the surface and under litter decreased in viability over time, but how quickly this happened varied by site. After 24 months, seeds buried at least 3 cm below the soil surface retained 30-40% viability whereas viability of seeds on the surface and under litter declined to 0 and < 11%, respectively. The density of naturally dispersed seeds in the seed bank was highly heterogeneous both spatially and temporally, and seed attrition varied significantly by region.

Sagebrush steppe restoration often involves aerial seeding, which leaves many seeds on the surface and can lead to poor shrub establishment. Results of this study indicate that providing a soil surface disturbance or mulch that promotes burial of some sagebrush seeds may increase restoration success by providing a seed reservoir as a hedge against establishment failure in the initial year of seeding. This may also prevent some seeds from being incinerated during wildfires. For more information about this study visit: http://www.sagestep.org/collaborative_projects/projects/wijayratne_seeds.html

Conclusion

Soil seed banks are an important component of natural systems. Natural seed stores—or the lack thereof—are likely to impact restoration efforts, whether positively or negatively, and should be considered in land management decisions. An increased understanding of seed banks can improve management decisions and save time and resources when implementing restoration measures. Information on these and other seed bank studies related to the SageSTEP project can be found at: http://www.sagestep.org/collaborative_projects.html.



SageSTEP: From Short-term Research to Long-term Monitoring

by Jim McIver, Ecologist and SageSTEP Project Coordinator, Oregon State University

SageSTEP was designed to provide information to land managers that would help them deal with significant changes that have occurred in sagebrush steppe lands over the past 150 years. The widespread invasion of cheatgrass and the encroachment of pinyon-juniper woodlands have shifted a high proportion of the sagebrush steppe land base to conditions that are generally less desirable than those thought to have occurred prior to settlement in the 1800's. Land managers



have recognized this for years, and in the encroached woodlands at least, have been actively trying to reverse the process with the use of prescribed fire and mechanical tree-removal practices.

SageSTEP is designed to help managers better understand the consequences of treating invaded and encroached stands, with a particular focus on ecosystem recovery under different initial conditions of invasion. For example, is there a threshold in tree dominance above which treatment is likely to produce conditions that are even less desirable than those we started with? By taking our measurements across tree dominance and cheatgrass invasion gradients, we hope to tease out any thresholds that may exist, and thus give managers some idea of what might happen when they light the match for a prescribed burn, or when they try to emulate fire with mechanical practices.

For the past six years, we have been focused on sociopolitical and economic work, on implementing treatments at all of our sites, and on measuring both hydrological and ecological response to treatment. Since all sites were successfully treated in the late summer and fall of 2006, 2007, and 2008, we now have between 3 and 5 years of post-treatment data to capture the short-term story of treatment response. We have learned a lot about these systems, and SageSTEP has generated a considerable amount of information related to restoration of tree-encroached or weed-invaded sagebrush steppe lands. Yet much still remains to be accomplished before a solid short-term story can be told that features all aspects of the study. We anticipate that in about two years, we will have

completed the task of understanding and publishing what happened shortly after treatment at 19 SageSTEP sites.

Yet the short-term story will not be enough. From the beginning of the study, SageSTEP scientists and managers knew that we would have to continue measuring response to treatments for at least ten years after treatment. This is because many of the important components of the system will not stabilize until many years after treatment, due primarily to processes that operate at longer time scales. In his article on woodlands, Miller (Issue 14) discussed one such example of a 'time turnaround', in which grasses growing in the cut and fell mechanical treatment were smothered initially by felled trees, allowing cheatgrass to dominate. In just a few years however, the native grass squirreltail has gradually replaced cheatgrass at these same sites. Similar kinds of responses to wildfire over time have been noted repeatedly by Mike Zielinski (Issue 9) of the BLM Winnemucca District, whose observations suggest that at least ten years after treatment is necessary to fully understand vegetation response. For erosion and runoff, Pierson (Issue 14) notes that previous work on Steens Mountain in Oregon has demonstrated that it may take 10–20 years after treatment for a full hydrological story to be told.

For these reasons, we have obtained generous support to monitor SageSTEP sites for most critical variables for an additional five years, which will take us to between 8 and 10 years post-treatment. In particular, both the National Interagency Fire Center and the BLM Rangeland Program have committed support that would allow us to measure critical variables through the 2016 season. While monitoring will occur at a reduced frequency, we believe that we will be able to capture the main events that occur throughout this intermediate time period. Certainly, if we believe SageSTEP sites have not stabilized even after that period of time, we will search for funding to push measurement out further into the future. As the study progresses through time, we will also have a higher probability of detecting climate change events, as they will eventually manifest themselves in measurable changes in flora and fauna. Whatever ends up happening in the distant future, count on SageSTEP being around with our familiar products for at least the next five years, as some of the most interesting stories unfold.

Piñon and Juniper Tree Mastication Effects in the Great Basin and Colorado Plateau

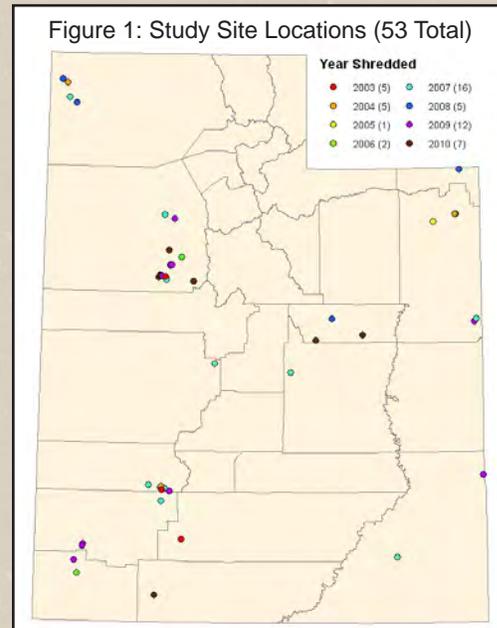
Bruce Roundy, Jordan Bybee, April Hulet, and Leann Crook

The wealth of time and resources invested in SageSTEP have resulted in multiple spin-off projects that will provide additional information about sagebrush systems without duplicating time and resource-intensive treatment implementation and baseline data collection. One such study is being conducted by Bruce Roundy and colleagues from Brigham Young University to evaluate the effectiveness of tree mastication treatments. Sagebrush plant communities invaded by piñon and juniper (PJ) are losing understory vegetation and increasing in woody fuel loads as tree canopies increase in size. Some land managers are masticating or shredding trees to reduce fuel size and better control fire. They prefer PJ mastication over other tree reduction methods for several reasons: PJ mastication involves less risk than prescribed fire, is often seen as less hydrologically or ecologically disruptive than chaining, reduces fuel structure and fire spread better than cutting, and can be used as a thinning or clearcutting tool. PJ mastication can also be implemented during most seasons as long as the soil is not too wet. Short-term soil compaction may occur, but the mulch residue produced has been found to increase infiltration in interspaces (Cline et. al. 2010).

In order to provide land managers with a better understanding of the ecological effects and treatment effectiveness of mastication, the Joint Fire Science Program funded a three-year research project (2011-2013) of Bruce Roundy and colleagues at Brigham Young University. Their retrospective study covers masticated PJ woodlands that have been treated over the last eight years across the Great Basin and Colorado Plateau (fig. 1).

Sites include PJ woodlands found on BLM and USFS lands that have often been seeded pre-mastication by the Utah Division of Wildlife Resources. A follow-up assessment of the SageSTEP Utah woodland plots is also included in the study.

The focus of this study is to determine the effects of mastication and fire after mastication on woody fuels, vegetation, and soils (fig. 2). Researchers hypothesize that masticated tree residue will decrease over time in



relation to the amount of initial biomass and incidence of summer precipitation, and that masticated stands dominated by piñon will decompose faster than those dominated by juniper. Understory vegetation response after

mastication and after burning of masticated areas will most likely depend on residual vegetation at the time of mastication.

Because this is a retrospective study, researchers utilized NAIP imagery (National Agricultural Imagery Program, 1-m pixel resolution) and Feature Extraction (object-based image analysis software; ENVI 4.5) to pair untreated and masticated areas on the same ecological sites with similar initial tree cover. Once tree cover was extracted for each site, individual subplots were randomly selected and paired that represented multiple PJ invasion gradients (fig. 3).



Figure 2. Photos above show a phase 3 PJ woodland site contrasted with a phase 3 PJ woodland site that was masticated in 2007. The study focus is to determine effects of mastication on: 1) fuel structure, potential fire behavior, the amount of fuel biomass loss over time; 2) understory vegetation responses; and 3) soil carbon and nitrogen.

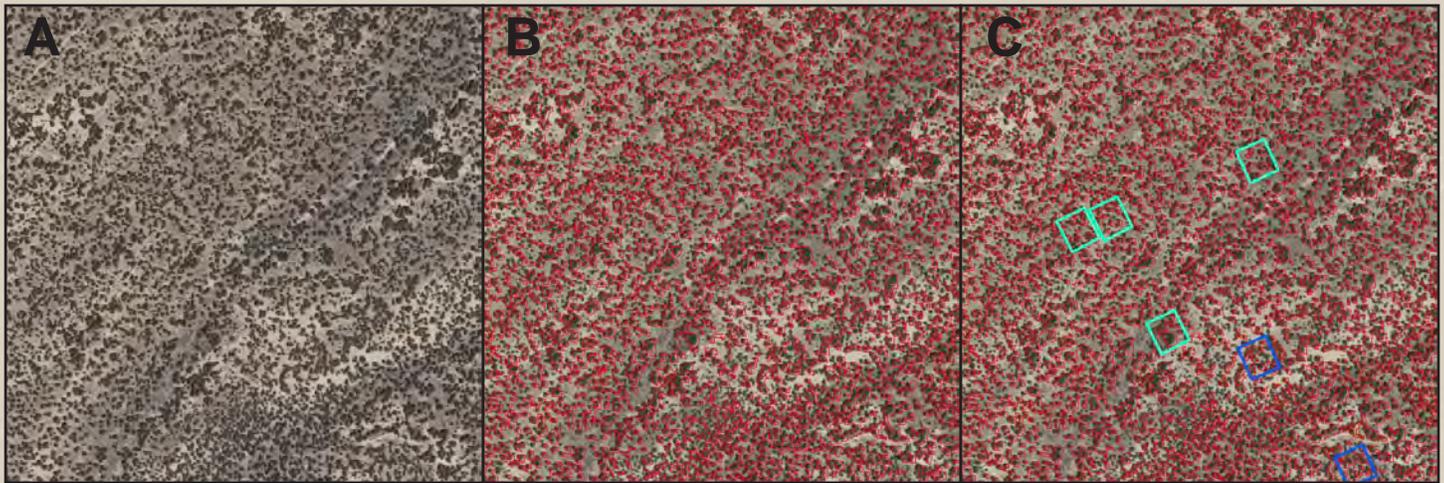


Figure 3. NAIP imagery is used to pair untreated and masticated areas based on initial tree cover and ecological site. (A) NAIP imagery (1-m pixel resolution). (B) Classified trees using Feature Extraction software (ENVI 4.5). (C) Paired subplots with similar tree cover calculated using ArcGIS.



Figure 4. (A) Phase 3 PJ woodland treated in 2004; perennial grass cover generally increased in treated subplots compared to untreated subplots. (B) Phase 2 PJ woodland treated in 2006; shrub recruitment was higher in treated subplots, particularly in phase 1 and 2 where sagebrush was present. (C) Phase 3 PJ woodland treated in 2007; annual weeds (primarily cheatgrass) increased in treated subplots however, where residual perennial species were present, weeds were minimal.

In addition to site and subplot selection, NAIP imagery is being used to determine pre-treatment tree cover and biomass for masticated subplots. All trees rooted within the untreated subplot are measured (tree height, crown base height, longest crown diameter, and the perpendicular diameter) and biomass is calculated using Tausch's (2009) equations. Regression equations are then developed for the untreated subplots using tree cover estimates derived from imagery and ground-measured biomass. This equation is applied to masticated subplots to determine pre-treatment tree biomass. Similar techniques have been used to estimate tree biomass from tree cover derived from imagery using SageSTEP data ($r^2=0.94$, $n=64$ subplots; Hulet et al. in preparation).

Vegetation and fuel data were collected during the summer of 2011 at 25 sites; data collection will occur at the remaining sites in 2012. Preliminary results suggests that perennial grass and shrub cover increased in masticated subplots most likely due to an increase in available resources (fig. 4A and 4B). Weed invasion was minimal on most

subplots; however, a slight increase was observed where cheatgrass was present prior to treatment (fig. 4C).

Results from this study will be presented at scientific and professional meetings in conjunction with publications in rangeland focused journals starting winter 2012. For additional information about this research, contact bruce_roundy@byu.edu, jordanbybee@gmail.com, or april.hulet@gmail.com.

References:

- Cline, N. L., B. A. Roundy, F. B. Pierson, P. Kormos, and C. J. Williams. 2010. Hydrologic response to mechanical shredding in a juniper woodland. *Rangeland Ecology and Management* 63: 467-466.
- Hulet, A., B. A. Roundy, S. L. Petersen, and S. Bunting. 2012. Application and research utilizing remote sensing technologies for rangeland fuels management. In preparation.
- Tausch, R. J. 2009. A structurally based analytic model for estimation of biomass and fuel loads of woodland trees. *Natural Resource Modeling* 22: 463-488.

SageSTEP Special Session at AFE Interior West Fire Ecology Conference

The Association for Fire Ecology (AFE) will be hosting the Interior West Fire Ecology Conference at the Snowbird Resort this November. Participants will learn more about fire ecology with a focus on the Great Basin, Columbia Basin, Northern Rockies, and Cascade-Sierras. The theme of the meeting is *Challenges and Opportunities in a Changing World*. SageSTEP researchers will be presenting a special session at the meeting focusing on the short-term impacts of fuels treatments at our study sites. Come and hear what we've learned from the past five years of data collection and analysis!



SageSTEP Special Session, November 16, 2011, 8am-noon

Introduction

James McIver, Ecologist and SageSTEP Project Coordinator, Oregon State University

Stress in fire-prone sagebrush steppe and resistance to cheatgrass invasion

Dave Pyke, Plant Ecologist, US Geological Survey

Short-term vegetation response to piñon and juniper removal in sagebrush-steppe, Rick Miller, Plant Community Ecologist, Oregon State University

Effects of fire and fuel treatments on soil water availability in sagebrush communities, Bruce Roundy, Plant Ecologist, Brigham Young University

Characterizing Pinyon-Juniper Woodlands Post Fuel-Reduction Treatments Using High-Resolution Imagery, April Hulet, Ph.D. Candidate, Brigham Young University

Germination prediction from soil moisture and temperature in the Great Basin Nathan Cline, Ph.D. Candidate, Brigham Young University

Runoff and erosion responses on burned and unburned sagebrush steppe and wooded shrublands in the Great Basin, USA

Fred Pierson, Research Hydrologist, USDA Agricultural Research Service

Mechanically shredding Utah juniper and soil environment characteristics Kert Young, Ph.D. Candidate, Brigham Young University

Short-term response by bird communities to pinyon-juniper removal by prescribed fire, Steven T. Knick, Wildlife Biologist, US Geological Survey

Butterfly response to sagebrush steppe fire and fire surrogate treatments: unintended consequences?

James McIver, Ecologist and SageSTEP Project Coordinator, Oregon State University

Measuring the Economic Value of Fuel Treatments on Great Basin Rangelands Kim Rollins, Resource Economist, University of Nevada-Reno

Summary

James McIver, Ecologist and SageSTEP Project Coordinator, Oregon State University

For more information about the conference and to register, visit <http://humboldt.edu/iwfire/index.html>.

Upcoming Events

Restoring the West Conference 2011 Sustaining Forests, Woodlands and Communities Through Biomass Use

October 18-19, 2011

Logan, Utah

www.restoringthewest.org

Great Basin Consortium First Annual Conference

November 7-9, 2011

Reno, Nevada

<http://environment.unr.edu/consortium/>

Association for Fire Ecology Interior West Fire Ecology Conference Challenges and Opportunities in a Changing World

November 14-17, 2011

Snowbird Resort, Utah

<http://humboldt.edu/iwfire/>

Society for Range Management 65th Annual Meeting Lessons from the Past, Strategies for the Future

January 29-February 3, 2012

Spokane, Washington

<http://www.rangelands.org/spokane2012/>

SageSTEP is a collaborative effort among the following organizations:

- Brigham Young University
- Bureau of Land Management
- Bureau of Reclamation
- Joint Fire Science Program
- National Interagency Fire Center
- Oregon State University
- The Nature Conservancy
- University of Idaho
- University of Nevada, Reno
- US Geological Survey
- US Fish & Wildlife Service
- USDA Forest Service
- USDA Agricultural Research Service
- Utah State University

Funded by:



For more information visit our website:

www.sagestep.org

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