Colorado Division of Parks and Wildlife
January 2013 – August 2016

WILDLIFE RESEARCH REPORT

RESTORING ENERGY FIELDS FOR WILDLIFE

DANIELLE B. JOHNSTON

All information in this report is preliminary and subject to further evaluation. Information MAY NOT BE PUBLISHED OR QUOTED without permission of the author. Manipulation of these data beyond that contained in this report is discouraged.

EXTENDED ABSTRACT

Healthy sagebrush-steppe areas of western Colorado are characterized by a diverse mixture of shrubs, forbs, and grasses. Restoring such habitats following oil and gas disturbances is often difficult because of the variety of impacted precipitation zones and the threat of weed invasion. An area of particular concern is the Piceance Basin gas field because of its value to mule deer (*Odocoileus hemionus*), greater sage-grouse (*Centrocercus urophasianus*), and other wildlife. In 2008, 2009, and 2012, a series of six experiments was implemented on simulated well pads and pipelines covering the wide range of precipitation and ecological conditions represented in the Piceance Basin gas field.

The experiments conducted at lower elevations emphasize weed control, particularly that of cheatgrass (*Bromus tectorum*), which presents a serious obstacle to effective reclamation (Knapp 1996, Chambers et al. 2007, Reisner et al. 2013). The four lower elevation experiments are the Pipeline experiment (implemented at six sites ranging from 1561 to 2216 m in elevation), the Competition and Competition 2 Experiments (implemented at two sites of elevations 2004 and 2216 m), and the Gulley experiment (implemented at four sites ranging from 1561 to 2084 m in elevation). The remaining two experiments, conducted at high or middle elevations, emphasized maximizing plant diversity. The Mountain Top experiment was implemented at the four highest elevation sites, ranging from 2342 to 2676 m. The Strategy Choice experiment was implemented at four moderate elevation sites ranging from 1662 to 2216 m.

Sites were prepared in 2008 by simulating pipeline disturbances and well pad disturbances. These two disturbance types differ in the length of time topsoil is stored, an important variable for restoration. The Pipeline Experiment was implemented in 2008, three weeks after the disturbances. All other experiments were implemented on well pad disturbances. These experiments were implemented in 2009 immediately after the well pads were reclaimed, except for the Competition 2 Experiment, which was implemented in 2012. Results and analysis for at least 3 post-treatment years for all experiments is now available, either within this report or via the included links to publications.

Although the complexity of elevation, soil type, and prior land use history make finding general recommendations for improving restoration for wildlife challenging, a general theme did emerge over the seven years these six experiments have been studied. This general theme is the importance of controlling weed seed propagule pressure. Propagule pressure is the number of weed seeds per area per unit of time. Even the experiments that were not explicitly designed to address propagule pressure ultimately provided lessons about its importance, and what we can do about controlling it. This corroborates research in other ecosystems which has demonstrated that controlling propagule pressure is more important than

other factors managers might try to influence, such species diversity, herbivory, or abiotic conditions (Von Holle and Simberloff 2005, Eschtruth and Battles 2009).

In the Pipeline Experiment, we learned that in limited circumstances, pipeline disturbances can reduce cheatgrass density compared to unimpacted areas (Johnston 2015). When combined with Plateau ® (ammonium salt of imazapic) herbicide, enough cheatgrass control can be achieved to allow establishment of big sagebrush (*Artemisia tridentata*). While Plateau is a useful herbicide, using it alone is sometimes ineffective because applying it at high enough rates to get sufficient cheatgrass control results in unacceptable injury to desirable plants (Owen et al. 2011). By causing cheatgrass seeds to be buried too deeply to germinate, ground disturbances can work additively with herbicides to reduce cheatgrass propagule pressure. The timing of the disturbance is important. We quantified the seasonality of cheatgrass propagule pressure using seed traps (Appendix 1). Most cheatgrass seeds arrive between May and June, but seeds continued to arrive until September. The disturbances in the Pipeline Experiment occurred in September, which maximized burial of seeds from the prior growing season. A disturbance earlier in the growing season may not be as helpful for limiting cheatgrass.

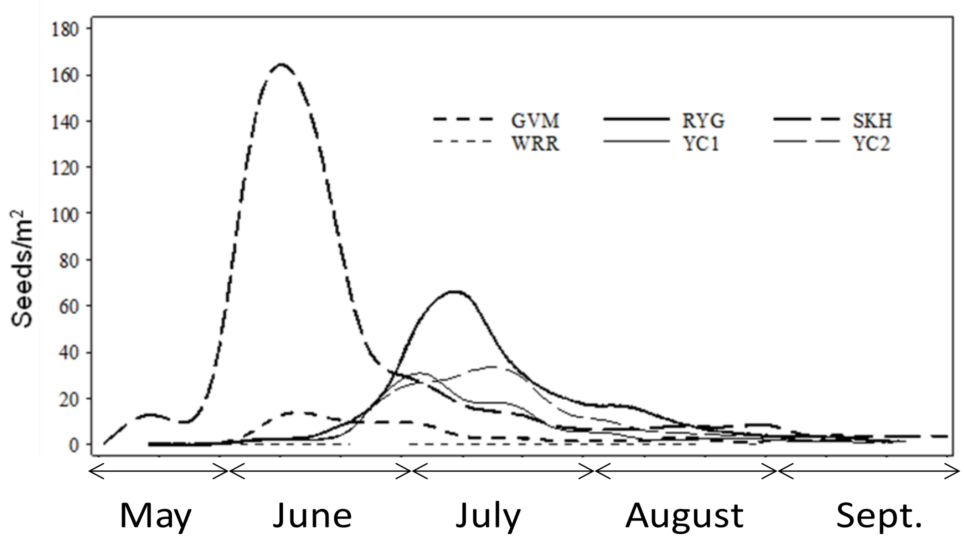

Figure 1. Propagule pressure of cheatgrass seeds between May and September in undisturbed locations near 6 sites: GVM, RYG, SKH, WRR, YC1, and YC2, which varied in elevation from 1561-2216 m (5120-7268 ft.) and cheatgrass cover from 0% to 70%. Data are averages over 3 years, 2009-11

In the Competition and Competition 2 Experiments, cheatgrass propagule pressure was intentionally controlled in order to look for other factors that may limit cheatgrass during restoration. These experiments had mixed results. We focused on abiotic manipulations which might exploit cheatgrass's weaknesses: lower competitive ability under higher, more stable soil moisture (Chambers et al. 2007, Bradley 2009), and inability to germinate through compacted soils (Thill et al. 1979, Beckstead and Augspurger 2004). In the Competition Experiment, the treatments were super-absorbent polymer (SAP) application (to increase water retention), a soil binding agent designed to increase water infiltration (DirtGlue ®), and compaction with a heavy roller. Rolling was not helpful. SAP increased initial perennial grass density and reduced subsequent cheatgrass cover at one of two sites, and the binding agent increased perennial grass density and reduced cheatgrass cover at one of two sites. Because the binding agent application was more expensive, the Competition 2 Experiment focused on SAP. In Competition 2, SAP had beneficial effects at one site (increasing perennial grass cover and reducing cheatgrass), but detrimental effects at the other site, causing a five-fold increase in cheatgrass. The limitations on cheatgrass germination and the nature of competitive interactions between cheatgrass and desirable perennial plants appears to be a complex interaction of site conditions, treatment timing, and treatment choice. Right now, clear management recommendations on how to use SAP or binding agent are not available, although this may be improved through further study.

The Gulley Experiment focused on identifying which sources of propagule pressure are important to control: the seed bank, new seeds entering from the surrounding landscape, or both. The treatments were application of Plateau herbicide at 140 g ai/ha (8 oz/ac) just prior to seeding, fallowing for one year with the broad-spectrum pre-emergent herbicide Pendulum™ (pendamethilin, BASF Corporation), and surrounding plots with seed dispersal barriers of aluminum window screen. The barriers had slight effects which were entirely positive: lower annual forb cover at some sites where Russian thistle (*Salsola tragus*) was dominant, and higher perennial grass and forb cover. The herbicide treatments were a lesson in the dangers of over application. The pendamethilin treatment was especially detrimental. Both herbicides in combination so suppressed perennial vegetation that by four years post-treatment, there was a trend for higher cheatgrass cover where both had been applied, in spite of both herbicides effectively controlling cheatgrass in the initial years of the experiment. The barriers did not reduce cheatgrass cover, possibly because cheatgrass seeds passed under the barriers or blew over them. The Mountain Top and Strategy Choice Experiments examined a treatment that had more success at reducing cheatgrass cover.

The Mountain Top Experiment was initially designed to address how to maximize plant diversity in restoration. This is critical because restored areas are often dominated by grasses, even after decades of recovery. Unexpectedly, this experiment also demonstrated that high elevation sites in Piceance are vulnerable to cheatgrass invasion, and revealed a useful technique for combating that invasion. The treatments were: seeding (17.8 kg/ha PLS native species including 60% grass or no seed), soil surface (roughened with 50 cm-deep holes or flat), and brush mulch replacement (0.024 m^3/m^2 or no brush). Unseeded plots were initially dominated by annual forbs, while seeded plots were dominated by perennial grasses. After five years, unseeded plot annual forb cover had declined to 10%, perennial grass cover had increased to 24% (about two-thirds of that of seeded plots), and perennial forb cover was 6.8% (about one-third that of seeded plots). Cover of shrubs (mostly big sagebrush, *Artemisia tridentata*) in unseeded plots was 26% (almost double that of seeded plots), highlighting the degree to which competition by seeded species can slow the recovery of sagebrush. Brush mulch benefitted shrubs, perennial grasses, and perennial forbs, and also slightly reduced annual forbs. Contrary to expectations, the rough soil surface did not have any large effects on cover of perennial grasses, forbs, or shrubs, but it did have an effect on cheatgrass. By five years post-treatment, cheatgrass had become established in unseeded plots at two sites, especially Scandard. At Scandard, the rough surface reduced unseeded plot cheatgrass cover from 13% to 3% (Figure MountainTop 5). We hypothesize that cheatgrass seeds become entrapped in the bottom of holes, limiting their spatial distribution, and forcing them to compete under wetter conditions under which they are less competitive.

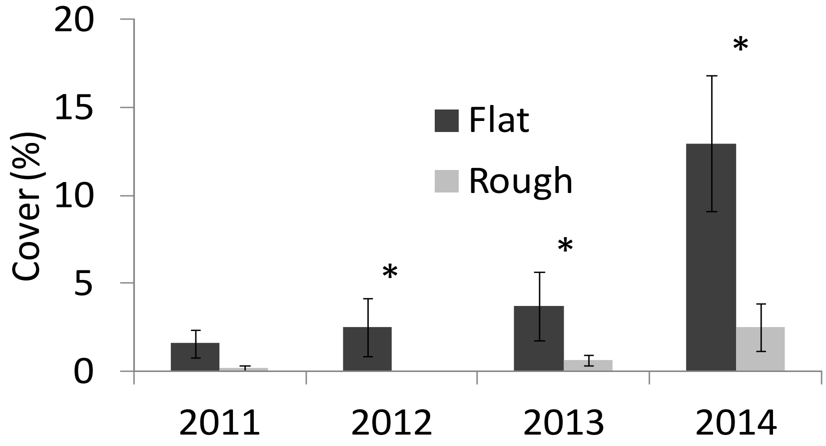

Figure 2. Percent cover of annual grass (*Bromus tectorum*) in response to a rough versus flat soil surface in unseeded plots at Scandard Ridge 2- 5 years post-disturbance. Error bars are SE. Stars denote significant differences at $\alpha = 0.05$.

The Strategy Choice Experiment also included a rough vs. flat soil surface treatment, although in this experiment the rough surface was always applied with brush (and broadcast seeded), while the flat surface was always applied with straw mulch (and primarily drill-seeded). The Strategy Choice Experiment was conducted at middle elevations where the threat of weed invasion was moderate or ambiguous, in order to find optimal strategies in uncertain circumstances. The other treatments included Plateau (8 oz/ac vs. none) and a seed mix treatment. There were two seed mixes compared: one that had about equal numbers of forb, shrub, and grass seeds, and one that was about 75% forbs, 17% shrubs, and only 8% grass. Cheatgrass established at two of the four sites, one each with high (GVM) and low (MTN) cheatgrass propagule pressure. The Plateau treatment successfully controlled cheatgrass, but caused an increase in annual forbs, and had either neutral or negative effects on perennials. At GVM, the rough surface augmented the effect of Plateau, reducing cheatgrass biomass six-fold. At MTN, the rough surface reduced cheatgrass biomass 10-fold in the absence of Plateau and reduced weedy annual forbs 100-fold in the presence of Plateau. Across sites, there was no difference in cheatgrass due to seed mix, and forb and shrub biomass were higher with the high-forb mix.

Looking across the Mountain Top and Strategy Choice experiments, the rough surface helped control cheatgrass at three of four sites where cheatgrass became established. The one site where it had no effect, the Sprague site in Mountain Top, had only sparse and patchy cheatgrass. As an extension of this project, we implemented a rough surface treatment along with a light (4 oz/ac) Plateau application to 7 acres at Horsethief SWA, and successfully turned a cheatgrass near-monoculture into a diverse stand of grasses, forbs, and shrubs (Johnston 2014). Weedy species, almost by definition, produce large numbers of rapidly dispersing seeds to quickly exploit any open or disturbed areas. From prior research we know that holes entrap many kinds of seeds (Chambers 2000), and that cheatgrass seeds disperse 10 to 50-fold farther over bare soils than in intact ecosystems (Kelrick 1991, Johnston 2011, Monty et al. 2013). Our research supports the conclusion that landscapes which permit rapid seed dispersal foster weeds; landscapes which slow seed dispersal favor less weedy species.

Altered seed dispersal is one reason why cheatgrass responds so well to fire. Even though a fire may kill 97% of cheatgrass seeds (Humphrey and Schupp 2001), fire also removes vegetation, which allows cheatgrass seeds to travel farther (Monty et al. 2013). The few surviving seeds grow in the absence of competition, which enables them to produce 40 times more seed than they might have within a dense stand (Hulbert 1955). These seeds disperse readily over the burned surface, producing a second generation of plants which are also relatively free from competition. By two years after the fire, cheatgrass is fully recovered from the 97% reduction (Humphrey and Schupp 2001). A rough soil surface can entrap seeds near the parent plant, preventing the growth of isolated, highly productive cheatgrass plants. This may slow the cheatgrass recovery cycle enough for perennial plants to establish. A rough soil surface is a practical tool managers can use to limit cheatgrass and other weedy invasives after disturbances including fire and development.

The two experiments which addressed seeding practices demonstrate the costs of including too much grass seed in seed mixes: forb and shrub growth is delayed. Including at least a little grass in seed mixes is probably wise, as research has shown that the best competitors for invasive species are native species of the same functional group (i.e. grasses compete best with grass, and forbs with forbs) (Fargione et al. 2003). Even so, the high-forb seed mix performed well at the GVM site, which had high cheatgrass propagule pressure. The recent investments made by CPW through the Uncompagre Project to make additional forb species available at low cost are critical, and additional resources should be devoted to this task.

Results of Plateau application in this series of experiments are mixed, generating beneficial results in one experiment (Pipeline), mixed results in another experiment (Gulley), and largely detrimental results a third experiment (Strategy Choice). Successful use of this herbicide requires accurately applying a light rate, focusing on areas with cheatgrass cover prior to disturbance, and combining Plateau with other measures to reduce cheatgrass propagule pressure, such as a rough soil surface or a well-timed ground disturbance.

Restoring oil and gas disturbances to fully functional, diverse wildlife habitat in northwestern Colorado is possible. Making use of a higher proportion of forbs and shrubs in seed mixes, considering the timing of weed seed dispersal, combining herbicides with other factors to reduce weed propagule pressure, and seeding over a rough soil surface are strategies which can be used over a wide range of elevations and ecological conditions to the benefit of wildlife.

Literature Cited

Beckstead, J., and C. K. Augspurger. 2004. An experimental test of resistance to cheatgrass invasion: limiting resources at different life stages. Biological Invasions **6**:417-432.

Chambers, J. C. 2000. Seed movements and seedling fates in disturbed sagebrush steppe ecosystems: implications for restoration. Ecological Applications **10**:1400-1413.

Chambers, J. C., B. A. Roundy, R. R. Blank, S. E. Meyer, and A. Whittaker. 2007. What makes Great Basin sagebrush ecosystems invasible by *Bromus tectorum*? Ecological Monographs **77**:117-145.

Eschtruth, A. K., and J. J. Battles. 2009. Assessing the relative importance of disturbance, herbivory, diversity, and propagule pressure in exotic plant invasion. Ecological Monographs **79**:265-280.

Fargione, J., C. S. Brown, and D. Tilman. 2003. Community assembly and invasion: An experimental test of neutral versus niche processes. Proceedings of the National Academy of Sciences of the United States of America **100**:8916-8920.

Hulbert, L. C. 1955. Ecological studies of *Bromus tectorum* and other annual bromegrasses. Ecological Monographs **25**:181-213.

Humphrey, L. D., and E. W. Schupp. 2001. Seed banks of Bromus tectorum-dominated communities in the Great Basin. Western North American Naturalist **61**:85-92.

Johnston, D. B. 2011. Movement of weed seeds in reclamation areas. Restoration Ecology **19**:446-449.

Johnston, D. B. 2014. Rangeland restoration with super-absorbent polymer and potholed surface at Horsetheif State Wildlife Area: Colorado Division of Parks and Wildlife Avian Research Program annual progress report http://cpw.state.co.us/Documents/Research/Habitat/2014-Annual-Reoprt-Rangeland-Restoration.pdf.

Johnston, D. B. 2015. Downy brome (Bromus tectorum) control for pipeline restoration. Invasive Plant Science and Management **8**:181-192.

Johnston, D. B., and P. L. Chapman. 2014. Rough surface and high-forb seed mix promote ecological restoration of simulated well pads. Invasive Plant Science and Management **7**:408-424.

Kelrick, M. 1991. Factors affecting seeds in a sagebrush-steppe ecosystem and implications for the dispersion of an annual plant species, cheatgrass (*Bromus tectorum* L.). Utah State University, Logan, UT.

Monty, A., C. S. Brown, and D. B. Johnston. 2013. Fire promotes downy brome (*B. tectorum*) seed dispersal. Biological Invasions **15**:1113-1123.

Owen, S. M., C. H. Sieg, and C. A. Gehring. 2011. Rehabilitating Downy Brome (Bromus tectorum)-Invaded Shrublands Using Imazapic and Seeding with Native Shrubs. Invasive Plant Science and Management **4**:223-233.

Reisner, M. D., J. B. Grace, D. A. Pyke, and P. S. Doescher. 2013. Conditions favouring Bromus tectorum dominance of endangered sagebrush steppe ecosystems. Journal of Applied Ecology **50**:1039-1049.

Thill, D. C., R. D. Schirman, and A. P. Appleby. 1979. Influence of soil-moisture, temperature, and compaction on the germination and emergence of downy brome (*Bromus tectorum*). Weed Science **27**:625-630.

Von Holle, B., and D. Simberloff. 2005. Ecological resistance to biological invasion overwhelmed by propagule pressure. Ecology **86**:3212-3218.