



## **Evaluation of treatment type and grass species for restoring Artemisia-dominated rangelands in the Great Basin of North America**

Thacker, E<sup>1</sup>; Bryan, R<sup>2</sup>; Clifford, A<sup>3</sup>

<sup>1</sup> Utah State University, Logan NU, USA; <sup>2</sup> Western-enviro Vernal, UT, USA <sup>3</sup>Cirus Ecological Solutions Logan, UT, USA

**Key words:** sagebrush; restoration; grasses; rangeland; wildfire

### **Abstract**

Decades of research and management activities have focused on restoring Artemisia-dominated rangelands. Future climate projections suggest that drought and wildfire may become more frequent; therefore, being able to restore rangelands following these events is critical for the future maintenance of ecological services. We initiated two studies, one focusing on assessing treatment types (chaining, drill seeding, and aerial seeding) for post-fire restoration, and in a separate study, we evaluated 52 grass species that were opportunistically exposed to drought and fire over seven years to determine which groups of species are resilient to these drivers. The treatment analysis relied on the Rangeland Analysis Platform tool to evaluate how burned areas responded to treatment by examining the cover estimates of functional groups before and after treatment. The functional groups varied significantly in their responses to different treatments. Overall, we discovered mild successes in perennial grass and forb establishment. Conversely, postfire invasive annual forbs and grasses were more dependent on pretreatment conditions than treatment type. We also concluded that restoration success may depend more on pretreatment conditions than treatment type. Our results also demonstrate that a wide array of plant materials can establish, persist, and resist cheatgrass (*B. tectorum*) invasion through drought and fire and that species selection for restoration should be based on their possession of functional traits that can meet management objectives. Thus, in the future, managers attempting rangeland restoration must carefully consider pretreatment conditions and select species for restoration based on functional traits that ensure the resilience of rangelands.

### **Introduction**

Rangelands in the Great Basin of Western North America are subjected to frequent drought and wildfire at sporadic intervals. Sagebrush rangelands are being invaded by invasive annual grasses such as *Bromus tectorum*, which alter ecological processes and fire regimes (Mack 1981; Bradley et al. 2018; Young & Clements 2009; Davies 2011). Land managers are tasked with trying to restore these altered rangelands. Therefore, we first determined the outcomes of post-fire rehabilitation efforts across Northwestern Utah; to do this, we wanted to understand if post-fire treatments decreased annual forb and grass cover while increasing perennial grass and forbs; and shrubs. As range managers look forward to the future, they must

grapple with the effects of climate change in altered ecosystems while maintaining ecological services provided by rangelands, such as livestock grazing, wildlife habitat, biodiversity, and carbon sequestration. Therefore, rangeland managers must choose the proper restoration species to rehabilitate degraded ecosystems, which is an essential part of the restoration process (Asay et al. 2003; Booth and Jones 2001). Land managers and restoration practitioners face difficult decisions when deciding which perennial grasses to plant for restoration. However, little research has been done on the ability of individual species and varieties of perennial grass species to survive and regenerate after fire and drought stress. Our study sought to shed light on which species and varieties are most effective at coping with wildfire, drought, and cheatgrass.

## Methods

The fire restoration study examines the post-fire treatment of fires from 1999-2019. Treatment scenario groups were used to lump similar treatments into like categories. Treatment scenario groups describe the different combinations of treatment that occurred in the study area. For example, a treatment scenario is an area that received a single aerial seeding and chaining event following a wildfire.

We used the Rangeland Analysis Platform (RAP; Allred et al. 2021) to quantify vegetation before the wildfire (3 years) and every subsequent year after the wildfire post-wildfire mitigation. We used functional when analyzing vegetation cover. The groups included annual forbs and grasses, perennial forbs and grasses, and shrubs (Bryan 2022). We performed an effect size analysis to compare treatment outcomes across treatment types across time to determine changes in vegetation post-wildfire management.

When evaluating restoration species to determine which species and varieties best persist through drought, wildfire, and cheatgrass invasion, we examined the responses of 52 species and varieties. The plant materials used in this study are listed in Table 1. The study was conducted on an agricultural research farm operated by the Utah Division of Wildlife Resources' Great Basin Research Center in Ephraim, UT, USA. Seedling establishment was quantified by estimating frequency in June 2016 using a frequency grid (Vogel and Masters 2001). In the fall of 2020, an experimental burn on the research plots unintentionally burned the entire site. Persistence was measured in June 2021, and we collected the frequency of cheatgrass, annual grasses, and weeds. Our study assessed the ability of the various species and varieties to establish, persist, and resist cheatgrass invasion through drought and fire. To determine which species or variety resisted invasion and persisted through drought and grazing, we used a dimensional scaling (NMS) analysis to cluster the species that performed the best (Clifford 2022).

## Results

The overall effect of the functional groups on treatments showed modest increases in annual grasses and forbs 0.31 (0.14,0.48), and perennial grass and forbs had a slightly more significant effect 0.46 (0.37,0.054). At the same time, shrubs declined -0.17 (-0.27,0.06) due to wildfires even after post-fire management (Bryan 2022). The method of postfire (aerial seeding, drill seeding, and chaining) mitigation showed little consistency in our analysis.

The NMS ordination of the responses of the 52 varieties of restoration grasses showed that varieties were clustered into four discrete groups using a hierarchical cluster analysis, accounting for 59.4% of the information (Table 1.). Pairwise comparisons for the interactions showed that group 2 had a significantly higher frequency of restoration species and lower frequency of cheatgrass than all other groups for all years studied (Table 1; Clifford 2022).

## Discussion

The outcomes from the different post-fire restoration methods used in West Box Elder County are variable. Our analysis did not prove that one treatment method was superior in all cases. Mild successes in perennial establishment occurred across all treatment types. Annual cover increased and appeared to depend more on pretreatment levels than treatment type. The results also indicate that the needed recovery time after fire may be longer than 15 years, especially when evaluating shrub response to post-fire treatments. The analysis reemphasized that annual, perennial, and shrub responses to treatments are highly variable and depend on many factors besides the treatment method. Factors influencing treatment success include the site's pretreatment abiotic and biotic conditions, including plant composition, soil type, health, aspect, and elevation (Boyd et al. 2012, Knutson 2014, Miller 2012). Considering these factors and acknowledging variations in treatment outcomes emphasizes the importance of avoiding extrapolating results from one successful treatment to other potential treatments. The success or failures of a handful of individual projects should not become the basis for future management decisions. Instead, examining several occurrences of a particular treatment can provide a more complete picture of the range of expected outcomes. Our research can be used to inform managers better when developing strategies for future treatments, especially when considering the treatment type that should be used and the various abiotic and biotic conditions of the proposed restoration sites. Planning restoration methods to suit individual projects best will require high levels of collaboration between stakeholders to decide where and how best treatment practices should occur.

We attempted to determine which varieties of restoration grasses could establish, persist, and resist cheatgrass over seven years, including multiple years of below-average precipitation and a fire that burned all treatments in 2020. Climate projections show increasing temperatures and periods of drought throughout the Great Basin in the future (Snyder et al. 2019). Similarly, the continued spread and dominance of cheatgrass will increase wildfire across the Great Basin (DiTomaso et al. 2010). Therefore, finding species and varieties that can establish and persist through drought and fire is critical for maintaining intact stands of perennial grasses and resisting invasion by cheatgrass. Our results suggest that the varieties found in group 2 possess some functional traits that enable them to establish, persist, and resist cheatgrass through drought and fire. Given the diversity in species found in group 2 and the variation across varieties of the same species, we recommend that restoration seed selection be based on the functional traits that allow varieties to establish, persist, and resist cheatgrass through drought and fire.

In the future, range managers must maintain rangeland integrity and function. Our study shows that our best efforts can return rangelands to the pre-disturbance condition. If the rangelands have already lost some function before the disturbance, it becomes the new ceiling for ecological conditions. Future rehabilitation will require careful study of the disturbed sites, and cautious evaluation of the plant species chosen for restoration efforts focused on plant functional traits rather than classifications. Rehabilitating rangelands needs to be more of an adaptive process rather than a recipe to ensure we maintain rangeland integrity,

Table 1. List of species sorted by NMS group designation from the hierarchical cluster analysis. Species abbreviations include bluebunch wheatgrass (BBWG), bluegrass (BG), basin wildrye (BWR), crested wheatgrass (CWG), intermediate wheatgrass (IWG), fine fescue (FF), slender wheatgrass (SLWG), Snake River wheatgrass (SRWG) and thickspike wheatgrass (TSWG).

Group			
1	2	3	4
BBWG, Boardman	BBWG, Anatone	BG, Mountain Home	FF, R1574
BBWG, P-7	BBWG, Columbia	BG, Opportunity	Junegrass, KomaL
BBWG, P-33	BBWG, Goldar	BWR, Magnar	Salina Wildrye, KBJ_4x
BBWG, Wahluke	BBWG, P-45	FF, Boreal	Sideoats Grama, Vaughn
BBWG, Whitmar	BWR, Continental	TSWG, Bannock II	SLWG, First Strike
BG, Canbar	BWR, Int. Tetra		SLWG, Pryor
BG, High Plains	BWR, L_57X		SLWG, SanLuis
BG, UP_Sandburg	BWR, L_66X		
BWR, L_72X	BWR, Trailhead		
FF, Covar	BWR, Trailhead II		
FF, Durar	CWG, HxB28		
FF, R4S22	CWG, Hycrest		
Salina Wildrye, 9053601	CWG, Hycrest II		
SRWG, E_64X	IWG, AI		
TSWG, Bannock	IWG, Luna		
	IWG, Oahe		
	IWG, Rush		
	Salina Wildrye, LS_4		
	Siberian Wheatgrass, Stabilizer		
	Siberian Wheatgrass, Vavilov II		
	SRWG, Discovery		
	SRWG, dryland		
	SRWG, Secar		
	SRWG, Secar78		
	TSWG, Critana		

### Acknowledgements

We want to thank the Utah Watershed Restoration program for funding and access to their treatment data. We would also like to thank the USDA Forage and Range Research Lab for allowing us access to plots established several years before our study. We also greatly appreciate the collaborative efforts of the Utah Department of Natural Resources Great Basin Restoration Center for help with access to plots and historical data for both projects. Lastly, we thank the Utah State University Public Land Initiative for funding both projects. This paper contains an adaption from Rayce Bryan and Adam Clifford's theses.

## References

- Allred, Brady W. et al. 2021. "Improving Landsat Predictions of Rangeland Fractional Cover with Multitask Learning and Uncertainty." *Methods in Ecology and Evolution* 12(5): 841–49.
- Asay, K.H., N.J. Chatterton, K.B. Jensen, T.A. Jones, B.L. Waldron, W.H. Horton, 2003. Breeding improved grasses for semiarid rangelands. *Arid Land Research and Management* 17, 469–478.
- Bradley, B.A., Curtis, C.A., Fusco, E.J., Abatzoglou, J.T., Balch, J.K., Dadashi, S., Tuanmu, M.-N., 2018. Cheatgrass (*Bromus tectorum*) distribution in the intermountain Western United States and its relationship to fire frequency, seasonality, and ignitions. *Biological Invasions* 20, 1493–1506
- Bryan, R. 2022. Assessing Post-Fire Revegetation Efforts in Box Elder County, Utah, Using the Rangeland Analysis Platform. MS Thesis, Utah State University, Logan, UT, USA
- Booth, D.T., Jones, T.A., 2001. Plants for Ecological Restoration: a foundation and a philosophy for the future. *Native Plants Journal* 2, 12-20.
- Boyd, Chad, and Kirk Davies. 2012. "Spatial Variability in Cost and Success of Revegetation in a Wyoming Big Sagebrush Community." *Environmental management* 50: 441–50.
- Clifford, A. 2022. An Evaluation of Stress Tolerance in Restoration Plant Species in Response to Fire, Drought, and Invasive Plants Through the Lens of Functional Traits. MS Thesis, Utah State University Logan, UT, USA
- Davies, K.W., 2011. Plant community diversity and native plant abundance decline with increasing abundance of an exotic annual grass. *Oecologia* 167, 481–491.
- DiTomaso, J. M., Masters, R. A., Peterson, V. F., 2010. Rangeland invasive plant management. *Rangelands* 32, 43–47.
- Knutson, Kevin C. et al. 2014. "Long-Term Effects of Seeding after Wildfire on Vegetation in Great Basin Shrubland Ecosystems." *Journal of Applied Ecology* 51(5): 1414–24.
- Mack, R.N., 1981. Invasion of *Bromus tectorum* L. into Western North America: An ecological chronicle. *Agro-Ecosystems* 7, 145–165.
- Snyder, K.A., Evers, L., Chambers, J.C., Dunham, J., Bradford, J.B., Loik, M.E., 2019. Effects of Changing Climate on the Hydrological Cycle in Cold Desert Ecosystems of the Great Basin and Columbia Plateau. *Rangeland Ecology & Management* 72, 1–12.
- Young, J.A., Clements, C.D., 2009. Cheatgrass: fire and forage on the range. University of Nevada Press, Reno, 348 pages.
- Vogel, K.P., Masters, R.A., 2001. Frequency grid—a simple tool for measuring grassland establishment. *Journal of Range Management* 54, 653-655.