Original Research

Forbs and Greater Sage-grouse Habitat Restoration Efforts: Suggestions for Improving Commercial Seed Availability and Restoration Practices

By Michael F. Curran, Taylor M. Crow, Kristina M. Hufford, and Peter D. Stahl

On the Ground:

- Greater sage-grouse are the species of concern in the largest conservation effort in US history and have populations spanning 11 western states. Restoration of sage-grouse habitat will assist these conservation efforts.
- It is known that forbs are critical to sage-grouse diets, but only isolated studies have measured forbs in the diet at a species- or genera-specific level and little is known about sage-grouse preference to forbs.
- Research has shown that local seed sources promote successful reestablishment of vegetation communities, although commercial seed sources for forb species used in sage-grouse diet often are lacking.
- We make suggestions for selecting forb species and improving seed sources for sage-grouse conservation.

Keywords: sage-grouse conservation, seed source availability, restoration ecology, sage-grouse diet, sage-grouse habitat restoration, Native Seed Network.

Rangelands 37(6):211–216
doi: 10.1016/j.rala.2015.10.007

The greater sage-grouse (*Centrocercus urophasianus*, hereafter: sage-grouse) is a species of concern in 11 western United States. Conservation efforts to protect the bird species and the sagebrush ecosystem on which it depends are considered to be the largest in US history, and are responsible for the US Fish and Wildlife Service's "not warranted" listing decision under the Endangered Species Act announced in September 2015. These efforts may be used as a model to protect and evaluate threatened and endangered species in the future. Ecosystem and habitat restoration should not be considered synonymous with conservation, but restoration programs will be necessary to assist conservation efforts. The aim of this study was to identify forb genera or species that are part of the sage-grouse diet, describe commercial availability of seeds of these genera or species, and make recommendations for future restoration projects and improvement of forb seed availability.

The Need for Restoration of Greater Sage-grouse Habitat

In September 2015, the sage-grouse received a not warranted listing decision after review under the Endangered Species Act.[1] The decision to keep the sage-grouse off the endangered species list was, at least in part, a result of "unprecedented" conservation efforts.[1] Before the 2015 not warranted listing decision, the sage-grouse was designated as "warranted but precluded" from listing due to a decline in abundance of the species, habitat fragmentation and degradation, altered fire cycles, invasive species, and natural resource development.[2] The purpose of the Endangered Species Act is "to conserve endangered and threatened species and the ecosystems on which they depend as key components of America's heritage."[3] The sage-grouse has received national attention and often is referred to as an umbrella species for the sagebrush steppe ecosystems in the arid and semiarid western United States.[2] The US Forest Service and the Bureau of Land Management (BLM) have agreed on land-use plans to address threats to the sage-grouse and conserve key habitat, which spans 165 million acres across 11 western United States.[4] Part of their plan is to improve habitat condition, which may involve land reclamation efforts with the goal of habitat or ecosystem restoration.[4] Therefore, identifying forbs in the sage-grouse diet and increasing forb supply for

Figure 1. This photo is taken on the edge of a natural gas well pad that was reseeded with native forb species in the Pinedale Anticline. Photo courtesy of Michael Curran.

reclamation projects is critical to assist with conservation of sage-grouse and the sagebrush ecosystem. (See Figs. 1– 4.)

The September 2015 not warranted listing decision for the sage-grouse calls for a reevaluation of the species and its habitat in 2020[1]. To keep the sage-grouse off the endangered species list, conservation efforts will need to continue for the foreseeable future. Land reclamation and habitat restoration programs will be a critical component of these conservation efforts. Land reclamation often is performed through active seeding or reseeding of degraded areas with the goal of establishing desired or previously existing plant communities and may ultimately lead to habitat or ecosystem restoration.[5] Vegetation provides ecosystem services such as soil stability, wildlife habitat, carbon capture, and hydrologic function. In the case of the sage-grouse, vegetative community composition and structure are critical factors for habitat selection, and these factors for which sage-grouse select should be considered in habitat restoration projects.[6,7] It is well documented that sage-grouse rely solely or primarily on sagebrush (*Artemisia* spp.) as a food source during winter months.[8] While nesting and brooding, however, native forb species are critical for female sage-grouse to provide nutrition to chicks and benefit egg health.[9] Both insects and native forb species are critical and dominant components of sage-grouse chick diets after hatching during summer months, with forbs playing a progressively more dominant role throughout the season.[7] Studies have suggested adult sage-grouse switch their diet from sagebrush to forbs during summer months if forbs are available.[10] For these reasons, restoring forb species to degraded lands will be critical for future sage-grouse conservation efforts. Forbs that act as food sources to the sage-grouse and also attract insects important to sage-grouse may be especially critical.

What Forbs Are Sage-grouse Eating?

An increasing body of literature describing sage-grouse habitat has been compiled by the BLM.[i] These studies have been conducted to improve knowledge of structural habitat requirements for sage-grouse, seasonal use of sagebrush habitats, effects of fire on sage-grouse habitat, and sage-grouse mating behaviors.[6,11] To our knowledge, relatively few scientific studies have been conducted to determine specific components of sage-grouse diets, especially in regard to forbs. We selected four papers from the scientific literature that studied species- or genera-specific forbs in sage-grouse diet.[9,12–14] These studies are confined to particular locations and none are conducted over a long period of time. Therefore, the knowledge of forbs and their role in sage-grouse diet may be limited because of climate and soil conditions or other environmental variables at study sites. More recent studies have demonstrated that forbs play a role in sage-grouse diets, but the techniques used (e.g., stable isotope analysis) fail to allow forbs to be identified to the species- or genera-specific level. All studies included in this article physically measured crop content of sage-grouse in their analysis, which allows for more specific forb information. These authors also highlight gaps in knowledge that are critical to address in future studies. A summary of forbs relevant for sage-grouse identified by these authors is included in Table S1 (available online at [http://dx.doi.org/10.1016/j.rala.2015.10.007]).

Three studies examined forbs in the diets of sage-grouse chicks and one examined forbs in the diets of sage-grouse hens

[i] BLM Library Greater Sage-grouse Literature citations available at http://www.blm.gov/wo/st/en/info/blm-library/research/subject-guides/greater_sage-grouse_subj_guide/gsg_lit.html.

Figure 2. A natural gas pad being constructed in the Pinedale Anticline natural gas field. Active restoration of this pad will be required after construction is complete. Photo courtesy of Michael Curran.

before brooding and hatching. The sage-grouse chick studies were conducted in Idaho, Montana, and Oregon; the sage-grouse hen study was conducted in Oregon. We identified 29 genera of forbs associated with sage-grouse diet. A review of species and genera found in our reading on the US Department of Agriculture's Plants Database[ii] suggested forbs found in sage-grouse diets included a mix of native and introduced species. These species represented a range of annual, perennial, and biennial forbs. What remains to be determined, however, is whether forbs preferred by sage-grouse differ among geographic regions due to forb distributions or dietary preferences.

Forb Reestablishment as Part of the Habitat Restoration Process

Although we know the forbs identified in the studies we surveyed represent likely food sources for sage-grouse, longer term studies coordinated across larger geographic areas will reveal additional species important in the sage-grouse diet. As available information improves, we may be able to develop species-specific seed mixes to restore sage-grouse habitat. Different industries and government agencies often have varying standards to measure and define successful land reclamation or restoration projects associated with land disturbance. For instance, analysis of the Wyoming Reclamation and Restoration Center Oil and Natural Gas Reclamation Database revealed inconsistencies in reclamation success criteria among BLM field offices in the state of Wyoming at the time of analysis in 2013, with only two BLM field offices requiring forbs in their reclamation assessment of lands disturbed by oil or natural gas development.[15] Oil and natural gas development in the western states is a critical driver of economy, but also plays a role in fragmenting sage-grouse and wildlife habitat, requiring land reclamation and habitat restoration efforts. The Wyoming BLM Reclamation Policy[iii] continues to work toward ensuring uniform application of reclamation activities using the best available information in developing reclamation plans, as well as using locally sourced native seed when feasible. As conservation efforts for the sage-grouse continue, we recommend adding native forbs in seed mixes for reclamation of private, state, and federal lands, particularly near sage-grouse core areas. In addition to adding forbs to seed mixes, scientific studies should continue to address issues aimed at learning best seeding techniques and soil-handling properties to improve germination success and understanding environmental conditions most suitable for specific forbs to continuously improve seed selection for individual restoration projects.

Finally, the geographic and genetic origin of seeds are critical for the restoration of sustainable native plant communities. Studies have shown that plants often are adapted to the environmental conditions in which they grow, and the source of seeds for reclamation and restoration can affect seed germination and survival at restoration sites.[16,17] However, there are few guidelines to describe the distance over which plant material can be safely transferred. The US Forest Service provides seed transfer guidelines for a limited number of species.[iv] Seed transfer zones, however, are delineated for only one species noted in sage-grouse diets, the tapertip onion (*Allium acuminatum*[18]). Alternative resources to guide selection of seed sources are available, and include generalized provisional seed zones[19] and level III and IV ecoregions.[20] The Native Seed Network[v] also provides a platform to identify commercially available seed sources in a given ecoregion, and the BLM Seeds of Success Program[vi] can be contacted for the availability of local native species.

Few studies test how forb species respond to land reclamation efforts (e.g., Seabloom and colleagues[21]). As sage-grouse conservation efforts continue, more studies are needed to determine the methods for successful re-establishment of native forbs important in sage-grouse diets. Although sage-grouse have been shown to eat introduced forb species, there is no evidence to suggest introduced species are overall beneficial to sage-grouse. Studies conducted to compare other

[ii] USDA PLANTS Database is available at http://plants.usda.gov/.

[iii] Wyoming BLM Reclamation Policy is available at http://www.blm.gov/wy/st/en/programs/reclamation.html.

[iv] The Seed Zone Mapper is a Mapping and Planning Tool for Plant Material Development, Gene Conservation and Native Plant Restoration available at http://www.fs.fed.us/wwetac/threat_map/SeedZones_Intro.html.

[v] More information on the Native Seed Network is available at http://www.nativeseednetwork.org.

[vi] More information on the BLM Seeds of Success program is available at (http://www.blm.gov/wo/st/en/prog/more/fish__wildlife_and/plants/seeds_of_success.htm.

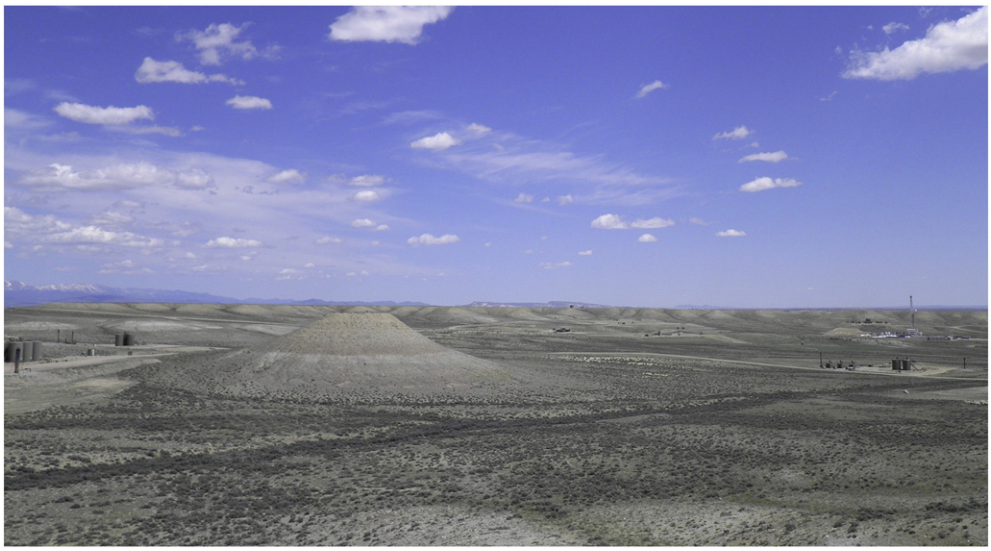

Figure 3. Looking out over the Jonah Infill natural gas field. More than 5,000 acres are being actively reclaimed throughout this field. Photo courtesy of Michael Curran.

rangeland bird species have shown higher success in rangeland birds nesting in native plant communities compared with introduced plant communities, likely because introduced species cannot host insects needed in bird diets to the same extent as native species.[22,23] New research will be particularly beneficial if it addresses different types of land disturbance as individual species may have different potentials to germinate and survive depending on disturbance. For example, a drastically disturbed soil environment associated with a natural gas well pad or surface coal mine may have different restoration potential than a large area invaded by cheatgrass or affected by fire. Environmental factors such as climate, elevation, slope, aspect, and soils likely influence forb reestablishment, and knowledge of forb requirements across large geographic areas can improve reclamation and restoration outcomes.

Commercial Availability of Native Forb Seeds for Sage-grouse Conservation

We searched the Native Seed Network website to determine whether seeds are commercially available for each species of forb identified as a component of sage-grouse diet. Our findings suggest 15 of 29 (51.7%) forbs found in sage-grouse diet are commercially available. (see Table S1 available online at [http://dx.doi.org/10.1016/j.rala.2015.10.007]). Of the species of forbs that were found to be native in rangelands, 8 of 15 (53%) were commercially available as native species within a genera. Of the remaining genera identified in sage-grouse diets, 4 are introduced species, whereas 10 occur as both native and introduced species in western rangelands. We were unable to determine whether sage-grouse were eating native or introduced species for the latter 10. Our literature review highlights the need to increase commercial availability of seeds of native forbs important in the sage-grouse diet. Although introduced forbs may be eaten by sage-grouse, we do not endorse seeding nonnative species. Introduced species often have unintended effects not only on sage-grouse, but also native pollinators and wildlife. For example, nonnative species may displace native pollinators, increase fire frequency, and ultimately lead to high costs of weed control.

It is important to note the origin of available commercial varieties often is limited to one or few original accessions. Seven of 25 (28%) native or possibly native species in the sage-grouse diet from this search were found to be commercially available in the same state where the study occurred. If the seeds from species in our study re-establish more successfully when sourced locally, it may be critical to increase the number of seed sources derived from different sites of origin to both reduce reclamation costs and increase revegetation success.

Conclusions

Other studies have addressed the need to improve the availability of native plant materials throughout the western United States, but they rarely focus on forb species associated with sage-grouse diet (e.g., Shaw and colleagues[24]). Our research suggests that 51.7% of forb species currently identified in sage-grouse diets are commercially available as native seeds, and those that are available are only available in limited supply. Findings from this review may assist the development of seed mixes targeted for sage-grouse habitat restoration and conservation. Previous research supports sourcing seeds from local areas may improve revegetation success.[25] We therefore recommend improved availability of commercial varieties that represent multiple sites of origin across each species' range. However, when native species are increased in an agricultural setting for commercial sale,

Figure 4. An adult sage-grouse browses in a field of grasses and forbs. Photo courtesy of Alan Krakaue.

selection of agronomic traits is likely. Therefore, breeders and commercial suppliers should exercise caution to avoid loss of genetic diversity and the selection of traits maladapted to the semi-arid and arid ecosystems in which these species grow. The best means to do this is to commercially increase wild accessions (e.g., preselected varieties) rather than develop cultivars. Although there may be opportunities to harvest locally adapted seeds at small scales, this often if only practical for restoration and conservation efforts representing a few acres.

Future research is needed to improve our knowledge of forbs important for sage-grouse diet. Valuable research would include delineation of seed transfer zones and seed sourcing guidelines, studies of forbs in land reclamation and ecosystem restoration programs, and sage-grouse response to restoration of different combinations of grasses, shrubs, and forbs. Efforts also should continue to increase native seed availability and improve native plant material availability. As efforts of scientists, practitioners, economists, and policymakers continue to focus on sage-grouse conservation, it would be beneficial for the four groups to work together to improve our overall knowledge of the importance of forbs to sage-grouse, our ability to successfully reestablish native forbs from seed, and—by doing so—improve the overall conservation of the sage-grouse and the vast ecosystem on which it depends.

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.rala.2015.10.007.

Acknowledgments

The authors acknowledge Kurt Smith (PhD student, Program in Ecology, University of Wyoming) for his efforts providing expertise on sage-grouse diet, suggesting literature, and undertaking a courtesy edit. We acknowledge other researchers at University of Wyoming affiliated with the Wyoming Reclamation and Restoration Center, including Dr. Jeffrey L. Beck, for providing basic knowledge in regard to sage-grouse literature. We also acknowledge Dr. Gail Patricelli and Alan Krakauer from University of California–Davis for providing us with pictures of sage-grouse.

References

1. United States Fish and Wildlife Service, 2015. Endangered and Threatened Wildlife and Plants; 12-Month Finding on a Petition to List Greater Sage-grouse (*Centrocercus urophasianus*) as an Endangered or Threatened Species. Available at https://www.federalregister.gov/articles/2015/10/02/2015-24292/endangered-and-threatened-wildlife-and-plants-12-month-finding-on-a-petition-to-list-greater 2015 Accessed 5 October 2015.
2. Gamo, S., J.D. Carlisle, J.L. Beck, J.A.C. Bernard, and M.E. Herget. 2013. Greater sage-grouse in Wyoming: an umbrella species for sagebrush-dependent wildlife. The Wildlife Professional. *Wildl Soc* 7(1):56-59.
3. United States Fish and Wildlife Service, 1973. Endangered Species Act of 1973. Available at: http://www.fws.gov/laws/lawsdigest/ESACT.html 1973 Accessed 5 October 2015.
4. Bureau of Land Management, 2015. Sage-grouse and sagebrush conservation. Available at: http://www.blm.gov/wo/st/en/prog/more/sage_grouse_home2.3.html 2015 Accessed 5 October 2015.
5. Society for Ecological Restoration International, 2004. Primer on Ecological Restoration, Version 2. Available at: http://www.ser.org/resources/resources-detail-view/ser-international-primer-on-ecological-restoration 2004 Accessed 5 October 2015.
6. Hagen, C.A., J.W. Connelly, and M.A. Schroeder. 2007. A metaanalysis of greater sage-grouse Centrocercus urophasianus nesting and brood-rearing habitats. *Wildl Biol* 13:42-50.
7. Kirol, C.P., J.L. Beck, J.B. Dinkins, and M.R. Conover. 2012. Microhabitat selection for nesting and brood-rearing by the great sage-grouse in Xeric big sagebrush. *Condor* 114:75-89.
8. Smith, K.T., C.P. Kirol, J.L. Beck, and F.C. Blomquist. 2014. Prioritizing winter habitat quality for greater sage-grouse in a landscape influenced by energy development. *Ecosphere* 5(2) Article 15.

9. Barnett, J.K., and J.A. Crawford. 1994. Pre-laying nutrition of sage grouse hens in Oregon. *J Range Manag* 47:114-116.
10. Braun, C.E., T. Britt, and R.O. Wallestad. 1977. Guidelines for maintenance of sage grouse habitat. *Wildl Soc Bull* 5:99-106.
11. Connelly, J.W., M.A. Schroeder, A.R. Sands, and C.E. Braun. 2000. Guidelines to manage sage grouse populations and their habitats. *Wildl Soc Bull* 28:967-985.
12. Drut, M.S., W.H. Pyle, and J.A. Crawford. 1994. Diets and food selection of sage grouse chicks in Oregon. *J Range Manag* 47:90-93.
13. Peterson, J.G. 1970. The food habits and summer distribution of juvenile sage grouse in central Montana. *J Wildl Manag* 34:147-155.
14. Klebenow, D.A., and G.M. Gray. 1968. Food habits of juvenile sage grouse. *J Range Manag* 21:80-83.
15. Curran, M.F., B.J. Wolff, and P.D. Stahl. 2013. Approaching oil and gas pad reclamation with data management: a framework for the future. *J Am Soc Min Reclamation* 2:58-67.
16. Hufford, K.M., and S.J. Mazer. 2003. Plant ecotypes: genetic differentiation in the age of ecological restoration. *Trends Ecol Evol* 18:147-155.
17. Johnson, G.R., F.C. Sorenson, J.B.St. Clair, and R.C. Cronn. 2004. Pacific northwest forest tree seed zones: a template for native plants? *Native Plants J* 5:131-140.
18. Johnson, R.C., B.C. Hellier, and K.W. Vance-Borland. 2013. Genecology and seed zones for tapertip onion the US Great Basin. *Botany* 91:686-694.
19. Bower, A.D., J.B.St. Clair, and V. Erickson. 2014. Generalized provisional seed zones for native plants. *Ecol Appl* 24:913-919.
20. Miller, S.A., A. Bartow, M. Gisler, K. Ward, A.S. Young, and T.N. Kaye. 2011. Can an ecoregion serve as a seed transfer zone? Evidence from a common garden study with five native species. *Restor Ecol* 19:268-276.
21. Seabloom, E.W., E.T. Borer, V.L. Boucher, R.S. Burton, K.L. Cottingham, L. Goldwasser, W.K. Gram, B.E. Kendall, and F. Micheli. 2003. Competition, seed limitation, disturbance, and reestablishment of California native forbs. *Ecol Appl* 13(3):575-592.
22. Flanders, A.A., W.P. Kuvlesky, D.C. Ruthven, R.E. Zaiglm, R.L. Bingham, T.E. Fulbright, F. Hernández, and L.A. Brennan. 2006. Effects of invasive exotic grasses on south Texas rangeland breeding birds. *Auk* 123:171-182.
23. Lloyd, J.D., and T.E. Martin. 2005. Reproductive success of chestnut-collared longspurs in native and exotic grassland. *Condor* 107:363-374.
24. Shaw, N., M. Pellant, M. Fisk, and E. Denney. 2012. A collaborative program to provide native plant materials for the Great Basin. *Rangelands* 34:11-16.
25. Gustafson, D.J., D.J. Gibson, and D.L. Nickrent. 2005. Using local seeds in prairie restoration—data support the paradigm. *Native Plants J* 6:25-28.

Authors are Graduate Student, University of Wyoming, Program in Ecology/Department of Ecosystem Science and Management, 1000 E. University Avenue, Department 3354, Laramie, WY 82071 (Curran; mcurran2@uwyo.edu); Graduate Student, University of Wyoming, Department of Ecosystem Science and Management, 1000 E. University Avenue, Department 3354, Laramie, WY 82071 (Crow); Assistant Professor of Ecosystem Science and Management, University of Wyoming, Department of Ecosystem Science and Management, 1000 E. University Avenue, Department 3354, Laramie, WY 82071 (Hufford); and Professor Soil Ecology, University of Wyoming, Department of Ecosystem Science and Management and Director, Wyoming Reclamation and Restoration Center, University of Wyoming, 1000 E. University Avenue Department 3354, Laramie, WY 82071 (Stahl). *Publication funding provided by the Wyoming Reclamation and Restoration Center.*