Restoration of community Structure and Composition in Cheatgrass Dominated Rangelands

Roger Rosentreter
208-373-3824
rrosentr@id.blm.gov
Bureau of Land Management
1387 S. Vinnell Way
Boise, Idaho 83709

Abstract

Restoration in cheatgrass (*Bromus tectorum*) dominated rangelands is a tremendous challenge. It requires the control of both the existing cheatgrass litter and its seed-bank, as well as the establishment of plants that can compete with future cheatgrass flushes. Perennial plants that are seeded must be capable of utilizing the entire soil profile, provide competitive growth over a long phenological period, and provide tight nutrient cycling, especially of nitrogen and phosphorus. Restoration efforts must include management actions that limit the reintroduction of exotic annual plants and prevent soil surface trampling or disturbance by livestock and off-highway vehicles. Maintenance of a patchy vegetative structure of the plant community appears necessary to retain native species. The perennial bunchgrasses form clumps with an open, low-growing vegetation in the interspaces that typically includes biological soil crusts. The crust component contributes to the maintenance of the community and helps exclude exotic annuals from the site.

Keywords

rehabilitation, sagebrush, native plants, rangelands, microbiotic crusts, herbicide.

Introduction

The extent of the cheatgrass (*Bromus tectorum*) problem has been discussed in depth by Billings (1990). Briefly, cheatgrass is an annual grass native to eastern Europe. It grows densely and becomes dry in early June, creating a fire hazard and a fuel ladder to other plants. In the arid portions of the Intermountain West, cheatgrass has advanced from scattered plants to nearly pure stands over vast areas. Its success is due to its competitive ability with the native plants and the dense, fine fuel it produces, which subsequently leads to an increased frequency of wildfire. Cheatgrass is very competitive and difficult to displace without extensive treatments (Pellant and Hall 1994).

This landscape conversion is a major problem for many plant and animal species that are dependent on the sagebrush steppe (Connelly and Braun 1997). For example, Connelly and Braun (1997) recommend protection and rehabilitation of sagebrush rangelands in each state and province to halt the decline of sage grouse. Sage grouse symbolize the sagebrush steppe and its decline concerns many hunters, biologists and ranchers. This species has declined so precipitously that it is now being reviewed for listing by the U.S. Fish and Wildlife Service (USFWS). Several rare plant species have also been displaced by exotic annuals such as cheatgrass (Rosentreter 1994).

The Bureau of Land Management's emergency fire rehabilitation program was established to expedite the seeding of rangelands following major wildland fires. The Intermountain greenstripping program has arisen to accommodate wildfire rehabilitation efforts as well as the enhancement of remnant habitats and basic research on fire resistant vegetation. Through these programs, much knowledge has been gained and millions of acres have been treated, with varying degrees of success.

Methods

This is a synthesis paper based on field experience and data from a variety of land treatments. Research from several master's theses has also been drawn upon. This paper will attempt to review restoration efforts from the native plant perspective, though most rehabilitation in the sagebrush steppe has historically made use of introduced species. Also incorporated is species specific information gathered from grey literature and work in progress by several graduate students. Vascular plant nomenclature follows Hitchcock and Cronquist (1973), except for Artemisia, which follows Winward (1980).

Discussion

Many land treatments, though guided by differing management objectives, can still be instructive to the restoration ecologist. Examples of such treatments or studies and their contribution to restoration ecology are summarized in Table 1. Unfortunately, results from many of these treatments have not been published or they are compiled in progress reports withholding conclusions until some future completion date (Monsen and Shaw a & b 1998, Pellant et al. 1998, Peters and Bunting 1998).

One overall goal in restoration is that the restored plant community will resist conversion back to a community dominated by exotic, non-desireable species such as cheatgrass. The restored community should be resilient to disturbance such as wildfire (Kaltenecker 1997). It has been observed that com-

Table 1. Revegetation treatments that demonstrate one or more restoration action, with results to date. BLM= Bureau of Land Management, TNC= The Nature Conservancy.

Project	Geographic Area	Restoration Action	Results to Date
Lawrence Grasslands (TNC)	Columbia Plateau central Oregon	herbicide vs- fire to control annual grasses	herbicide caused less damage to the existing plant community than fire did
Kuna Butte (BLM)	Great Basin Kuna, ID	rangeland drill seed native & exotic grasses & rest	established perennial bunch-grass & biological crusts
1992 Study	Great Basin Elko, NV	herbicide & fire mechanical	herbicide controlled cheatgrass the best
Long Gulch (BLM)	Snake River grasslands in N. Idaho	rest from livestock grazing	*Stipa* returned from seedbank & cheatgrass decreased until fire caused cheat to return & dominate
World Center Birds of Prey	Great Basin S. of Boise, ID	mowing	perennial grasses slowly increased in cover
Orchard Test Plots	Great Basin Mt. Home, ID	test plots with many native spp.	hundreds of different native and exotic accessions planted
Eighth St. Fire Rehab.	Great Basin N. of Boise, ID	ripping, chaining, rangeland drill seeding	ripping damaged existing native plants, minimal tillage provided suitable seedbed

munities dominated by both perennial bunchgrasses and biological soil crusts are resistant to cheatgrass invasion after fire (Table 1; Kaltenecker 1997). It appears that the two components are synergistic in their exclusion of cheatgrass (Rosentreter 1994), possibly a result of the patchy physical structure they create (Rosentreter 1986). The variable height and low density of plants in this community creates gaps comparable to those found in forests. Under these conditions, optimal growth is possible, even in areas with limited moisture. If a wildfire does occur, it will be less intense than in a community with continuous fuels.

Evaluating Existing Conditions

Before planning a restoration project in cheatgrass dominated or other degraded habitats, a thorough evaluation of existing conditions on site and in adjacent native sites must be made. Species composition and spatial distribution within the community must be carefully considered. Lack of knowledge of on-site or nearby sources of invasive weeds such as rush skeletonweed (*Chondrilla juncea*) and yellowstar thistle (*Centaurea solstitialis*), or resprouting natives such as rabbitbrush (*Chrysothamnus* spp.) or snakeweed (*Gutierrezia sarothrae*), can create conditions that are equally difficult to control. This is especially important if fire is a component of the proposed treatment.

Current management of a site is also an important consideration prior to determining restoration needs. For example, if sufficient perennials remain, a change in management in lieu of a physical land treatment might bring about adequate improvement. Such management changes might include: 1) rest from grazing, 2) a livestock season of use change to winter or early spring, or 3) closure to off-highway vehicles (OHVs). However, in many cases, significant recovery will not be made simply through the implementation of a management change (Billings 1990, Monsen and Shaw 1998, Peters and Bunting 1998). There are numerous examples where even after fifty years of complete rest from grazing, cheatgrass still dominates (Billings 1990, Peters and Bunting 1998). In sites like these, mechanical treatments such as herbicide, prescribed fire, or mowing/burning of the cheatgrass seedbank prior to seeding might also be necessary to facilitate recovery. The ecological mechanisms behind these management changes and mechanical treatments and how they promote recovery are discussed below.

Rest from livestock grazing allows perennials to build reserves and eliminates trampling disturbance. It is critical for the establishment of perennial grasses which, when young, are readily eaten and can be pulled completely from the ground. Rest for one or two seasons in the form of a rest rotation grazing system has shown improvement in perennial cover compared to grazing a site every year. Rest from livestock grazing also limits the potential introduction of additional non-native seeds. Even the introduction of new genetic material of pre-existing exotic species can be damaging to a plant community's health. New genetic material increases the exotic species' genetic diversity and potentially its phenotypic plasticity and vigor.

Many low elevation pastures that are grazed in the winter have shown improved perennial cover compared to adjacent spring/fall grazed pastures. A change in season of use to winter is typically preferred for low elevation sites that are susceptible to cheatgrass invasion. While spring and fall grazing sounds reasonable, conditions can be extremely wet or dry and soil surface conditions are negatively affected by trampling, destroying soil structure microtopography and biological soil crusts. When some soil moisture is present or when the ground is frozen, these features are less affected by trampling. Spring/fall pasture use dates should be more narrowly defined and the pastures grazed for shorter periods of time, and only when soil moisture is present. During some years fall rains are early and grazing these sites is reasonable, but in other years the fall rains are late. It is during these years when excessive surface trampling creates ideal conditions for exotic plants to invade. This is especially true for winter annuals such as cheatgrass.

Closure to OHVs might be necessary not only to eliminate the direct damage to native perennial plants, but also as a means of limiting the introduction of exotic weedy plants or diversification of their gene pool. Weed seeds can be present in the mud and soil dried on the undercarriage of the OHV and on the trailers that transport them. When an OHV arrives at a new location the dried mud and weed seed are slowly released. These seeds fall into disturbed soil along an OHV trail, optimal sites for germination and establishment because of the lack of vegetative competition. I have found large areas free of exotics that first become infested along an OHV trail. Some exotics such as cheatgrass often stay along the trails for many years as they adapt to local climatic and soil conditions (Novak et al. 1993). Eventually they migrate into the adjacent plant communities, especially during wet years when conditions promote high germination and high plant density.

Herbicides that control annual species can be used to decrease the growth and seed set of cheatgrass. Several sites have shown remarkable control of cheatgrass where the herbicide Oust was used (Pellant et al. 1999). Fall application of this herbicide can control cheatgrass for two growing seasons. If the site retained some perennial vegetation it will be released and its vigor improved. Sites treated with herbicide must be rested from grazing to allow the remnant perennials to set seed. These sites can also be seeded the following fall if there is insufficient regrowth of the remnant perennials. In Oregon, treatments using the herbicide "Roundup" were compared to the use of prescribed fire for controlling cheatgrass at The Nature Conservancy's Lawrence Grasslands Preserve. The herbicide caused less damage to the existing biological soil crusts than did fire (Ponzetti et al. 1998; Table 1).

One could use prescribed fire to attempt to control cheatgrass (Table 1). This is an option when the site lacks remnant perennial cover, but it can also create less than desireable conditions. Fire controls cheatgrass best when the seed heads are still purple and seeds have not yet been dispersed. This means that the burn must occur in late spring or early summer. Many perennial plants can be damaged by fire at this time of year since they still contain a fair amount of moisture. Less desirable species such as rabbitbrush and snakeweed that sprout vegetatively after fire could potentially dominate the site. In addition, the conditions created by fire are optimal for cheatgrass growth and the site could become even more densely colonized by cheatgrass within two years. Cheatgrass and other invasive species alter disturbance regimes and thereby permanently change the ecosystems that they invade.

Mowing is another possible method to attempt to control cheatgrass (Table 1). Mowing should be done prior to seed maturation and can include removal of the clippings and their maturing cheatgrass seeds. Collins et al. (1998) found that mowing in a Great Plains native grassland enhanced species diversity. In mixed cheatgrass-perennial grasslands, mowing before seed dispersal places most of the cheatgrass seed on top of the stems rather then beneath the litter, the usual dispersal location. Cheatgrass seed prefers to germinate under a layer of litter rather than on the soil surface, on top of litter, or on top of biological crusts (Larsen 1995). Mowing spatially concentrates the clippings to the site where the cheatgrass grew that season. It also limits cheatgrass dispersal locally, giving native seeds an opportunity to germinate and establish while precluding the cheat from smothering them. Mowing seems to enhance or at least maintain the patchiness (heterogeneity) or physical structure of the site. In contrast, cheatgrass litter and seeds spread with the wind and fill in open spaces, decreasing site patchiness.

In summary, field evaluation of the existing site is often one of the weak points in many restoration plans. Small zones of remnant perennial vegetation within or adjacent to a restoration project might need to be excluded from treatment, since they can serve as centers of dispersal of desireable species not included in the treatment. Organisms such as forbs, mosses, lichens, and mycorrhizal fungi are typically not included in restoration plans, but they might prove to be critical for the reestablishment of a diverse and functional plant community.

Major Restoration, or, Starting Over At a Site

If a site lacks a good component of remnant perennials, it will need more drastic efforts. The tremendous difficulty with the rehabilitation of cheatgrass dominated areas is the high density of cheatgrass litter and large seed bank reserves. There are several ecological conditions that prevail on sites dominated by cheatgrass (Table 2.) If a site is in need of major restoration, many of the management actions discussed above should also be included in the restoration plan. Although basic restoration procedures need to be employed at this type of site

Table 2. Ecological conditions that result from cheatgrass and other exotic annual grass domination on a site.

	Cheatgrass Domination	
Ecological Factor	Before	After
Species diversity	high	low
Life forms	shrub, perennial grass, forbs, biological crusts	annual grass
Community structure	heterogenous	homogeneous
Nitrogen fixation	produced by crusts and recycled	no on site production, lost from the site
Fire hazard	low	high
Fire frequency potential	low	high
Biological activity	some biological activity year round	shortened to the life cycle of the annual grass

(Plummer 1969), it will also require greater than average efforts to control the competing annual weeds, especially cheatgrass. Site preparation is critical, however, in some treatments it has been too extreme (Table 1). This can actually damage existing native plants and favor weed invasion (Monsen and Memmott 1998). Seed selection for most cheatgrass sites is difficult due to the limited moisture regime. The success of slow-growing seeded species is dependant on a lack of competition with seeded species that are fast-growing. This means that the seeding equipment must have some method of partitioning seeds during planting. Ultimately this will produce a seeding with clusters or rows of slow-growing species surrounded by those that establish more rapidly.

Seed mixtures should include a variety of species which will resist reinvasion by cheatgrass or other exotics. This requires the use of perennial plants that utilize the entire soil profile, provide competitive growth over a long phenological period, and provide tight nutrient cycling, especially of nitrogen and phosphorus. Table 3 lists examples of suitable native species for a formerly cheatgrass dominated rangeland site, relative to their rooting depth. Because cheatgrass is a winter annual and can germinate in the late fall or winter, maintaining shallow rooted perennials such as Sandberg bluegrass (*Poa sandbergii*) which also grows during this time, along with mintenance of a healthy biological soil crust, is critical to facilitate cheatgrass displacement.

Planting a diverse mixture of species is difficult in a one time treatment such as a drill seeding. It is best to plant in multiple treatments, however this is both uneconomical and difficult because of the agency's funding mechanism. Following wildfire, the BLM has a limited time during which it can expend Emergency Fire Rehabilitation funds. Drill seeding is typically done only once, with shrub seeds aerially broadcast in the winter over snow (Rosentreter and Jorgensen 1986). Rehabilitation on some sites is a multi-step procedure which might include: 1) fall herbicide application to control cheatgrass, 2) drill seeding of grass species the following fall, 3) aerial seeding of shrubs during the second winter, 4) a minimum of two years of rest from livestock grazing after the seeding, and 5) closing the area to OHVs.

Research Needs and Limitations to Restoration

One of the primary limitations to rangeland restoration is the lack of suitable, available, and economical native seed sources. Many native species have been tested and their superior accessions have been identified (Monsen et al. 1998; Table 1), however much work remains to be done. Suitable species must be capable of rapid establishment and growth, lack complex secondary dormancy characteristics, and be compatible with standard seeding equipment use in large scale restoration efforts. Such characteristics are necessary to facilitate competition with cheatgrass. The commercial production of native species is necessary if they are to be widely used by land management agencies in the future. Most rangeland sites are currently seeded to exotic grasses which have large seeds, more predictable establishment rates, and are much less expensive.Until native seed is used more in restoration, our understanding will remain low and the

Table 3. Soil profile rooting depth of species recommended for seeding in a low elevation Great Basin steppe community.

Rooting Depth:	Common Name
Deep	
Artemisia tridentata ssp. *wyomingensis*	sagebrush
Chrysothamnus nauseosus ssp. *albicaulis*	rabbitbrush
Atriplex canescens	four-wing saltbush
Moderate	
Stipa thurberiana	Thurber's needle grass
Agopyron spicatum	bluebunch wheatgrass
Oryzopsis hymenoides	Indian ricegrasss
Sitanion hystrix	squirrel-tail grass
Sphaeralcea grossulariifolia	globemallow
Shallow	
Sporobolus cryptandrus	sand drop seed
Poa sandbergii	Sandberg bluegrass
Achillea millefolium	western yarrow
L*inum lewisii*	blue flax

Table 4. Ecological attributes to measure progress toward the restoration of a mature native steppe community.

Ecological Attribute	Restored Steppe Community	Not Restored
canopy	multi-layered	single
spatial distribution	heterogeneity	homogeneity
soil surface roughness	rough	flat
biological soil crusts	high cover	low cover
compositional diversity	high	low
structural diversity	high	low
nutrient retentive	yes	no
mixed bunchgrass age classes	yes	no
complex soil food webs	yes	no
mycorrhizal fungi	present	absent or low
associated bird species	several	few

price of the seed will remain high.

The concept of "seed reserves" has been recommended for areas dominated by a native species from which locally adapted seed could be collected when needed. These sites would be managed solely for the production of seed. They would not be grazed and could be developed on public or private lands in partnership with commercial seed companies. To my knowledge, seed reserves have recieved little support though the concept appears valid.

Measuring Successful Restoration

There are several ecological attributes useful for measuring the success of restoration efforts in native steppe communities (Table 4). I feel it is important to emphasize community composition and physical structure when evaluating restoration projects. A diverse species composition and good representation by each life form or ecological guild (functional groups of species) is critical. Ecological guilds, which I group as shrubs, perennial grasses (moderate and shallow rooted), forbs, biological soil crusts, and mycorrhizal fungi, can be used as indicators of ecosystem function and health. Ehrenfeld and Toth (1997) measured the success of ecological restoration as a self-sustaining system. They focus on ecological function and stress that the establishment of appropriate plant populations does not necessarily result in the restoration of ecosystem processes. Ecological functions are much more difficult to measure than species composition, but their point needs to be considered.

Net primary production is another factor often used as a measure of success in revegetation projects. For rangelands, I believe that other vegetative parameters are better indicators of the long term stability of the system (Table 4). Physical structure, sustainability, fire resiliency, competitive growth over a long phenological period, and species diversity are more important than mere net primary production (Table 2). Comparing vegetative structure and species composition by guilds with a near by reference area will assist in the evaluation of successful restoration efforts. Restoration is a goal for degraded rangelands but it may still be beyond our reach at the present time.

Acknowledgments

I would like to thank the many scientists, field biologists, and range conservationists that provided data from restoration and fire rehabilitation projects they have been involved with. In particular, I would like to thank Dr. Steve Monsen, Mike Pellant, Julie Kaltenecker, and Ann DeBolt for comments and discussions related to this topic.

Literature Cited

Billings, W.D. 1990. *Bromus tectorum*, a biotic cause of ecosystem impoverishment in the Great Basin. In The Earth in Transition: Patterns and Processes of Biotic Impoverishment, pp. 300-322, G.M. Woodwell, ed. Cambridge University Press, New York. 530 pp.

Collins, S.L., A.K. Knapp, J.M. Briggs, J.M. Blair, and E.M. Steinauer. 1998. Modulation of diversity by grazing and mowing in native tallgrass prairie. Science 280:745-747.

Connelly J.W., and C.E. Braun. 1997. Long-term changes in sage grouse *Centrocercus urophasianus* populations in western North America. Wildlife Biology 3:29-234.

Ehrenfeld, J.G., and L.A. Toth. 1997. Restoration ecology and the ecosystem perspective. Restoration Ecology 5:307-317.

Hitchcock, C.L., and A. Cronquist. 1973. Flora of the Pacific Northwest. University of Washington Press, Seattle, WA. 730 pp.

Kaltenecker J.H. 1997. The recovery of microbiotic crusts following post-fire rehabilitation on rangelands of the western Snake River Plain. MS Thesis, Boise State University, Boise. 99 pp.

Larsen, K.D. 1995. Effects of microbiotic crusts on the germination and establishment of three range grasses. MS Thesis, Boise State University, Boise. 86 pp.

Monsen, S.B., and K.L. Memmott. 1998. Comparison of site preparation practices and re-establishment of native plants on the Boise 8 th street fire. Progress report to the Bureau of Land Management, Boise, Idaho.

Monsen, S.B., D.G. Naillon, and S.G. Kitchen. 1998. Comparing 53 native collections of bluebunch wheatgrass and Snake River wheatgrass in two common garden experiments at Nephi, Utah and Orchard, Idaho. Progress report to the Bureau of Land Management, Boise, Idaho.

Monsen, S.B., and N.L. Shaw. 1998. Effectiveness of Oust herbicide (sulfometuron methyl) to control exotic annual grasses and evaluate the effects of the chemical on native and seeded species. Progress report to the Bureau of Land Management, Boise, Idaho.

Monsen, S.B., and N.L. Shaw. 1998. Persistence of cheatgrass amid bunchgrass shrub-steppe communities. Progress report to the Bureau of Land Management, Boise, Idaho.

Novak, S.J., R.N. Mack, and P.S. Soltis. 1993. Genetic variation in *Bromus tectorum* (Poaceae): introduction dynamics in North America. Canadian Journal of Botany 71:1441-1448.

Pellant, M., and C. Hall. 1994. Distribution of two exotic grasses on intermountain rangelands: status in 1992. In: S.B. Monsen, and S.G. Kitchen, compilers. Proceedings: Ecology and Management of Annual Rangelands. Gen. Tech. Report INT-GTR-313, Ogden, Utah.

Pellant, M., J. Kaltenecker, and S. Jirik. 1999. Use of Oust herbicide to control cheatgrass in the northern Great Basin. In: S.B. Monsen, R. Stevens, R.J. Tausch, R. Miller, S. Goodrich, compilers. Proceedings: Ecology and Management of Pinyon-Juniper Communities Within the Interior West. Gen. Tech. Report RMRS-GTR-000 (in press), Ogden, Utah.

Peters, E.F., and S.C. Bunting. 1998. 50+ years of change on abandoned farmland in southern Idaho. Progress report to the Bureau of Land Management, Boise, Idaho.

Piemeisel, R.L. 1951. Causes affecting change and rate of change in a vegetation of annuals in Idaho. Ecology 32:53-72.

Plummer, P.A, D.R. Christensen, and S.B. Monsen. 1963. Restoring Big-Game Range in Utah. Publication No. 69-3, Utah Division of Fish and Game, Ephraim, Utah. 183 pp.

Ponzetti, J., B. Youtie, D. Salzer, and T. Kimes. 1998. The effects of fire and herbicides on microbiotic crust dynamics in high desert ecosystems. Report submitted to the U.S. Geological Survey, Corvallis, Oregon. 89 pp.

Rosentreter, R. 1986. Compositional patterns within a rabbitbrush (*Chrysothamnus*) community of the Idaho Snake River Plain. Pages 273-277 In: McArthur, E.D., Welch, B.L., comps. Proceedings of the Symposium: Biology of Artemisia and Chrysothamnus. Gen. Tech. Report INT-200, Ogden, UT.

Rosentreter, R., and R. Jorgensen. 1986. Restoring winter game ranges in Southern Idaho. U.S. Dept. of Interior, Idaho Bureau of Land Management Tech. Bulletin #86-3. 26 p.

Rosentreter, R. 1994. Displacement of rare plants by exotic grasses. In: S.B. Monsen, and S.G. Kitchen, compilers. Proceedings: Ecology and Management of Annual Rangelands. Gen. Tech. Report INT-GTR-313, Ogden, Utah.

Winward, A.H. 1980. Taxonomy and ecology of sagebrush in Oregon. Station Bulletin #642, Oregon State University, Corvallis. 15 pp.