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Sagebrush Steppe Restoration Final Report

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Introduction

Greater sage-grouse (*Centrocercus urophasianus*), a sagebrush steppe obligate species, have experienced a long-term decline in numbers and distribution. The species is now absent from almost half of its original range. The reasons for these declines differ across their range but ultimately it is related to a loss or degradation of suitable habitat (Knick and Connelly 2011).

Rangewide, an estimated 75% of the sagebrush steppe has been lost or substantially modified. Nearly all of the remaining 25%, albeit considered "intact," is altered to some degree which has made it less diverse and less productive than in pre-European settlement times (West 2000). The maintenance and enhancement of remaining intact habitats and the restoration of some of the lost habitat is needed to arrest the decline in sage-grouse and facilitate survival of the 350 other wildlife species dependent on sagebrush steppe (Paige and Ritter 1999, Sands et al. 2000, Suring et al. 2005).

Habitat restoration is both an art and a science. The science portion is an understanding of the ecological requirements of individual plant species and community dynamics. The art portion relates to undertaking restoration actions based on the available science and technology to restore sagebrush steppe under highly variable conditions. Technically speaking, true restoration (i.e., restoring the original diverse plant community) is not within our grasp and will likely never be for both biological and fiscal reasons. Restoration in the sense of providing a plant community that functions similarly to the native community and supports dependent and associated wildlife is achievable and is being done successfully with increasing frequency.

This report documents a cooperative effort among The Idaho Chapter of The Nature Conservancy (TNC), Idaho Department Fish and Game (IDFG), and the Bureau of Land Management (BLM) from 2005-2011 to advance both the art and science of sagebrush steppe restoration. The overarching goal of this effort was to improve our ability to reestablish big sagebrush steppe communities that are resistant to weed invasion, resilient to disturbance, and provide productive habitat for greater sage-grouse and other sagebrush steppe associated wildlife. Major funding for this effort was provided by the BLM and the Idaho Governor's Office of Species Conservation.

Restoration Projects Undertaken (2005 – 2011)

To improve the art and science of sagebrush steppe restoration, a number of projects were undertaken during the course of this effort to test innovative restoration methods and to seek answers to unresolved restoration issues. Unfortunately, habitat restoration, especially for upland sagebrush steppe, yields results slowly. Although the projects implemented during this 6-year effort offer some important findings, some are still in their early stages and will require further follow-up monitoring. We conducted or assisted with (in the case of the Upper Pahsimeroi Project) the following projects:

1. Tilden Flat Dixie Harrow Sagebrush Steppe Restoration Project (treated 2005).
2. Bird Dog Farm Big Sagebrush Steppe Restoration Project (treated 2005).
3. Reassessment of the Welch Wyoming Big Sagebrush (*Artemisia tridentata wyomingensis*) Shrub Plot (plot established in 1987, follow up assessment in 2005 and 2010).
4. Upper Pahsimeroi Wyoming Big Sagebrush Mechanical Shrub Crushing/Seeding Restoration Project (treated in 2003, monitoring in 2005 and 2007, and summary report completed 2009).
5. Old Farm Wyoming Big Sagebrush Steppe Rangeland Disk-Plow/Seeding Restoration Project (treated 2006).
6. Thousand Springs Ranch Xeric Big Sagebrush (*A. t. xericensis*) Steppe Restoration Project (treated 2007; treated 2009).
7. Murphy Complex Fire, Idaho Department of Lands (IDL) Big Sagebrush Steppe Restoration Project (seeding 2007).
8. Bear Den Butte, IDL Big Sagebrush Steppe Restoration Project (seeding 2008).
9. Lava Lake Ranch Mountain Big Sagebrush (*A. t. vaseyana*) Steppe Restoration Project (treated 2008).
10. Camas National Wildlife Refuge, Kent Christopher Basin Big Sagebrush (*A. t. tridentata*) Steppe Restoration Demonstration Project (treated 2009).
11. Tilden Flat Wyoming Big Sagebrush Seedling Planting Project (planted 2010).
12. Weiser River Ranches Xeric Big Sagebrush Steppe Restoration Project (treated 2010).
13. Fish Creek Mountain Big Sagebrush Shrub Crushing/Seeding Project (treated 2011).
14. Blair Fire, IDL Wyoming Big Sagebrush Aerial Seeding Project (seeded 2011).

Recently, the Washington Department of Wildlife completed a shrub steppe and grassland habitat restoration manual (Benson et al. 2011). In addition to being an extremely practical restoration manual, it provides a framework for consistently documenting the important elements of restoration projects. We adopted this format and data from each of the projects listed above has been entered into this framework. The documentation reports for these 14 projects are included here in Appendix I and electronically filed in IDFG's Headquarters on the K Drive (K:/Wildlife/Sage-Grouse Statewide/HIP/Shrub Steppe/Shrub Steppe Restoration Projects).

This report summarizes the results and lessons learned from these 14 projects. Appendix I provides details on each project.

Restoration Principles

The principles of restoration were articulated decades ago by Perry Plummer (Plummer et al. 1968), a pioneer in wildland restoration. These principles are as important today as they were then and are:

1. The proposed change to the plant community is ecologically attainable.
2. The terrain and soil must support the desired change.
3. Precipitation must be adequate to assure establishment and survival.
4. Competition must be controlled.
5. Plant adapted species, subspecies, and varieties.
6. A multi-species seed mixture should be planted.
7. Sufficient seed of acceptable purity and viability should be planted.
8. Seed must be planted on a well prepared seedbed and covered properly.
9. Plant during the season most conducive for establishment.
10. Newly seeded areas must be managed properly.

Often one or more of these principles is violated in restoration efforts, nearly assuring less than satisfactory results. The reasons why these principles are violated vary greatly but most are the result of poor planning and not providing adequate lead times to ensure that actions are done at the appropriate time. For anyone actively involved in restoration efforts, repeated reference to this list prior to undertaking any project is strongly advised.

Types of Restoration Situations Addressed

We found it useful to classify the restoration projects into specific types that address the various situations encountered on the ground. Five types of sagebrush steppe restoration situations were addressed and the projects that were associated with these categories are listed below:

1. Big sagebrush largely absent, herbaceous layer largely intact.
    a. Murphy Complex Fire Rehabilitation, Owyhee County
    b. Tilden Flat Sagebrush Seedling Project, Bingham County
    c. Welch Shrub Plot, Elmore County
    d. Blair Fire Rehabilitation Project, Gooding County
2. Big sagebrush largely absent, herbaceous layer largely native but depauperate (i.e., lacking or depleted in the variety and abundance of certain native plant species that should be present).
    a. Murphy Complex Fire Rehabilitation Project, Owyhee County
    b. Tilden Flat Dixie Harrow Project, Bingham County
    c. Bear Den Butte Restoration Project, Minidoka County
3. Big sagebrush largely absent, herbaceous layer dominated by non-native annuals.
    a. Old Farm Restoration Project, Bingham County
    b. Bird Dog Farm Restoration Project, Lincoln County
    c. Weiser River Ranches Restoration Project, Washington County
4. Big sagebrush largely absent, herbaceous layer dominated by non-native perennial grasses.

    a. Lava Lake Ranch Restoration Project, Blaine County
    b. Thousand Springs Ranch Restoration Project, Washington County
    c. Camas National Wildlife Refuge Restoration Project, Jefferson County
5. Big sagebrush present, herbaceous layer largely native but depauperate.
    a. Upper Pahsimeroi Shrub Crushing/Seeding Project, Custer County
    b. Fish Creek Shrub Crushing/Seeding Project, Blaine County

Type 1 - Big sagebrush largely absent, herbaceous layer largely intact

This situation is most often encountered after a fire. The fire may have just occurred or it can be many years post-burn in places where there has been little natural re-colonization of the site by big sagebrush. Natural re-colonization by the fire-sensitive big sagebrush is quite variable depending on a number of factors, including subspecies, availability of seed in the seedbank, and weather. If few or no seeds are present in the seedbank - a common situation on Wyoming big sagebrush sites after fire - natural recovery can take many decades (Welch 2005). The current situation with frequent major fires in the Snake River Plain is presenting a major management challenge to maintaining sage-grouse and other sagebrush steppe associated wildlife.

Two options are available for facilitating recovery of big sagebrush on these sites: seeding or planting seedlings. The former is relatively inexpensive ($8 to $15/acre) and can be accomplished over large areas but success has been sporadic. The latter is very expensive ($150 to $300/acre) and not practical over large areas but is usually less prone to failure. A lower cost and somewhat more practical seedling approach involves planting seedlings in patches on the landscape by planting patches of sufficient size and density to support most shrub steppe species. Configuring the patches and providing elongated patches where the long axis is orientated perpendicular to the prevailing winds, the 'mother plants' in the patch can facilitate re-colonization of the interspaces within and between patches. The down-side of this approach is that the interval for full re-occupancy of sagebrush and associated wildlife will take longer than full density planting over the entire area and this is still impractical on a large scale.

We experimented with patch planting of sagebrush seedlings on Tilden Flat, located about 20 miles northwest of Blackfoot, Idaho. Wyoming big sagebrush seedlings were planted in 2- to 10-acre elongated blocks in April 2010 using a tree planter at an average density of 160 plants/acre. Initial mortality during a mid-June 2010 examination was very low (4%). Most plants had gone through some transplant shock as evidenced by the presence of dead leaves on some branches but most of these plants had recovered and were putting out vigorous new growth. However, follow-up monitoring one year later revealed that substantial mortality had occurred and only 31% of plants remained alive. We do not have a good explanation for the loss. Precipitation in 2010 was above average and the summer was cooler than average, a situation favorable to seedling survival. We did not note any disease and although we documented some browsing, it was not a major mortality factor. It did appear that most of the mortality occurred in the spring of 2011 based on leaves still attached to the stems on a high percentage of the plants classified as dead.

Idaho BLM, in response to major losses of big sagebrush habitat from many very large wildfires in recent decades, is regularly conducting aerial broadcast big sagebrush seedings after wildfires. They have been either applying the seed uniformly over suitable sites in the burned areas or in strips covering 50% of area. The strips are usually flown perpendicular to the prevailing winds in an effort to improve downwind re-colonization of the unseeded strips. The more successful strip seedings become readily evident from aerial photography after the shrubs become sufficiently large (Figure 1 and Figure 2).

Since 2007, BLM, IDFG, and IDL have cooperated to aerially seed sagebrush across land ownership boundaries. The Murphy Complex, Bear Den Butte, and Blair fires are examples of such projects.

Climate, and especially spring precipitation, is a major factor affecting establishment and survival for both big sagebrush seedings and seedling plantings. This situation is more problematic in the lower precipitation zones because on a year-to-year basis, a lower percentage of years are conducive to establishment and survival (Monsen et al. 2004). Nevertheless, many previous failures at seeding may be due to seed source. Some early efforts at reseeding did not consider the subspecies of big sagebrush and, even when they did, it is likely that some seed providers may have labeled and sold seed as a certain subspecies based on request even though the seed was from another subspecies. The institution of the Source-Identified Seed Program has alleviated this problem to a large degree.

Many botanists and plant ecologists have promoted using sagebrush seed from local sources. However, little data are available to substantiate this concept. Work conducted by Welch (1992) to find an accession of Wyoming big sagebrush that was adaptable over an extensive region as well as being both palatable and nutritious for wintering mule deer (*Odocoilieus hemionus*) and sage-grouse inadvertently has confirmed the importance of using local seed sources. In 2010, we re-visited Welch's (1992) shrub plot located near Glenns Ferry, Idaho. Re-inventory of the 13 different accessions found that 100% of the plants from the local accession were still surviving in 2010 (23 years since planting) while the best survivorship of the other 12 accessions, including one from relatively close location (Arco, Idaho), was only about 50% (Figure 3). In addition, the local source plants were more vigorous than plants from other accessions as evidenced by plant size and seed production. These results provide strong evidence that Wyoming big sagebrush has differentiated into many site-specific adapted germplasm although as a species it occurs over a large expanse of the Western range. Obtaining seed from local areas is likely to further improve success of future restoration efforts for either seeding or planting seedlings.

Type 2 - Big sagebrush largely absent, herbaceous layer largely native but depauperate

The herbaceous vegetation in this situation is most often dominated by Sandberg bluegrass (*Poa secunda*) and to lesser extent bottlebrush squirreltail (*Elymus elymoides*). The larger native grasses, including bluebunch wheatgrass (*Pseudoroegneria spicata*), Idaho fescue (*Festuca idahoensis*), Thurber's needlegrass (*Achnatherum thurberianum*), Indian ricegrass (*Achnatherum hymenoides*), needle and thread (*Hesperostipa comata*), and Basin wildrye (*Leymus cinereus*), that, in total, should make up a significant proportion of the cover are either absent or at very low density. Often there is an element of non-native annual grasses present in these areas and mechanical disturbance increases the risk of their expansion.

After a fire in plant communities dominated by sagebrush and other shrubs, there is a one-year window to affect a vegetation composition change without having to conduct competition control treatments prior to seeding. If fire occurs in a previously sagebrush-dominated community now dominated by grass, fire alone is inadequate to control competition. Other treatments will be needed to change the composition.

At a herbaceous-dominated site on Tilden Flat, located about 20 miles northwest of Blackfoot, Idaho, we experimented with two different mechanical treatments to control herbaceous competition – Dixie harrow or a light disk – prior to seeding a multi-species mix, including Wyoming big sagebrush, bluebunch wheatgrass, Siberian wheatgrass, and alfalfa. The area had burned in 1997 and virtually no big sagebrush had re-colonized the site. The community was dominated by Sandberg bluegrass. We conducted a two-pass treatment with the Dixie harrow and a single pass treatment with the disk. Seed was broadcast ahead of the treatments. Unfortunately, two successive years of drought followed our effort, resulting in poor establishment of most seeded species. Nevertheless, big sagebrush did establish adequately at 709 plants/acre for the Dixie harrow and at 350 plants/acre with the disk treatment; alfalfa was the second most abundant seeded species at 98 plants/acre and 139 plants/acre, respectively. Establishment of bluebunch wheatgrass and Siberian wheatgrass was very poor. The Dixie Harrow treatment was more successful at controlling the Sandberg bluegrass competition than the light disking treatment, and cheatgrass (*Bromus tectorum*), although present in the pre-treatment composition (11% cover), did not increase with either treatment.

Type 3 - Big sagebrush largely absent, herbaceous layer dominated by non-native annuals

This community tends to be dominated by cheatgrass, medusa wildrye (*Taeniatherum caput-medusae*), or both. In higher moisture zones, the biennial bulbous bluegrass (*Poa bulbosa*) may dominate. Frequent burning of these sites results in a dominance of non-native annual forbs such as tumblemustard (*Sisymbrium altissimum*), Russian thistle (*Salsola kali*), and prickly lettuce *(Lactuca serriola*). These are challenging sites to restore. Considerable time, money, and luck (i.e., adequate precipitation) are needed to successfully convert these types back to big sagebrush steppe.

We established a test project on Weiser River Ranches, located approximately 10 miles east of Weiser, Idaho. This 300-acre site, on a bench about 100 feet above the Weiser River, was previously farmed but was abandoned about 10 years ago. It was dominated by medusa wildrye, cheatgrass, and tumblemustard. In the summer of 2010, a combination of mechanical and chemical treatments were begun to control competing vegetation, deplete the seedbank of undesirable species, and prepare the seedbed for planting. The sequence followed was:

- spring 2010 graze with cattle to reduce weedy species seed production
- late spring 2010 heavy disking
- early summer 2010 heavy disking
- midsummer 2010 light disking
- late summer 2010 spot spraying
- early fall 2010 light disking, cultipacking, and 6 oz/acre application of Plateau

- spring 2011 light disking to kill bulbous bluegrass
- late fall 2011 surface cultivation, Brillion seeding of herbaceous mix and broadcast big sagebrush seeding
- spring 2012 planting of bitterbrush seedlings

No results are available at this time. Approximately 3-5 growing seasons will likely be necessary before treatment results can be determined.

Type 4 - Big sagebrush largely absent, herbaceous layer dominated by non-native perennial grasses

In this situation, the herbaceous vegetation is either dominated by crested wheatgrass (*Agropyron cristatum*), intermediate wheatgrass (*Thinopyrum intermedium*), or smooth brome (*Bromus inermis*). These are highly stable communities unless heavily and repeatedly grazed. Big sagebrush will reinvade these sites if grazed heavily and often, but undesirable vegetation (e.g., noxious weeds, bulbous bluegrass) usually will also invade. Converting any of these situations back to sagebrush steppe is difficult and especially so for smooth brome and intermediate wheatgrass stands. To date, treatments including moldboard plowing provide proven control for smooth brome and intermediate wheatgrass stands (Jerry Benson, pers. comm.). In support of this, at Camas National Wildlife Refuge we experienced that twice over heavy disking treatments and a glyphosate application on a smooth brome stand provided inadequate competition control (Appendix I).

For converting or diversifying crested wheatgrass stands, mechanical and chemical treatments can be used. Working in Eastern Washington, Benson et al. (2011) has developed a proven prescription that involves a 15-month seedbed preparation process of summer mow, fall heavy spring tine harrow, mid-spring glyphosate spray at 96 oz/acre, late-spring spray at 24 oz/acre, and fall spray at 16 oz/acre to adequately control existing plants and prepare for seeding.

The Thousand Springs Ranch, located about 15 miles north of Weiser, has extensive mature stands of smooth brome and intermediate wheatgrass where some desirable native forbs have reinvaded the stands. In an experimental effort to convert these nonnative grass-dominated communities back to sagebrush steppe, we experimented with a single, late-spring treatment of a grass specific herbicide, Fusilade, applied at 20 oz/acre. Unfortunately, the treatment did not result in an adequate kill on either grass species. The chemical caused a browning of the leaves and prevented the plants from going to seed that year but little if any mortality occurred. In retrospect and in light of work done by Benson et al. (2011), we could have possibly improved the kill had we mowed the site prior to chemical application, increased the rate to the label maximum of 24 oz/acre, and applied two successive treatments. Based on new knowledge provided by Benson et al. (2011) on crested wheatgrass, there is merit in experimenting with the following seedbed preparation prescription – summer mow, fall heavy spring tine harrow, mid-spring Fusilade application at 24 oz/acre, late-spring Fusilade application at 24 oz/acre, fall harrow and cultipack, and fall seed.

At the same location in a subsequent follow-up experiment on the same smooth brome stand, two glyphosate treatments were applied, one in early summer at 64 oz/acre and the other in midsummer at 32 oz/acre. The chemical application was delayed as long as possible to allow native forbs to enter dormancy while the grasses were still actively growing. The area was seeded with a mix of native perennial grasses, native and nonnative forbs, and big sagebrush. Although insufficient time has passed for a full assessment, it appears that the treatments were not able to obtain an adequate kill on the smooth brome to establish all the desired species. However, big sagebrush and Western yarrow were in abundance on the treated area after the first growing season. Based on the Benson et al. (2011) approach, our glyphosate application rates were not aggressive enough and we did not mow pre-treatment as they prescribe. Additional seedbed preparation experiments are warranted to determine if a chemical approach can be used that will achieve adequate kill on the grass but saves desirable forbs.

In 2010, we initiated a more aggressive competition control on a smooth brome field on an adjacent area at Thousand Springs Ranch which appears promising. The following treatments were applied over the course of one year: fall moldboard plowing; spring disk, spring harrow, spray, summer fallow, fall harrow and cultipack. A diverse multi-species seeding of grasses, forbs and big sagebrush were seeded into a firm seedbed in November using a grain drill for large-seeded species and a broadcast/cultipack treatment for small-seeded species. First growing season density measurements indicate that seeded perennial grasses, western yarrow, and big sagebrush seedlings were very abundant. Big sagebrush may actually be too abundant. The representation of the other forbs in the mix was acceptable but below expectations. An unseasonable, hard frost (24 F degrees, May 8, 2011) may have killed many of the forb seedlings. Additional follow-up monitoring is needed on this project.

Type 5 - Big sagebrush present, herbaceous layer largely native but depauperate

West (2000) estimated that 25% of the remaining sagebrush steppe is in this condition. Although these sites still retain sagebrush cover, the depauperate understory provides little cover, especially for ground-nesting birds including sage-grouse. Finding a method to improve the understory without removing all the sagebrush, as fire usually does, offers an opportunity to increase the quality of sagebrush steppe wildlife habitat. Mechanical shrub crushing appears to be a promising tool. This method has been employed by the Deseret Ranch in northern Utah since the 1990s. They report good results but lack needed quantitative documentation. Yeo (2009), on the other hand, recently reported on a highly replicated experimental project in the Upper Pahsimeroi Valley in central Idaho. The primary objective of this restoration effort was to determine if shrub crushing and seeding was a useful approach for revitalizing and restoring bluebunch wheatgrass and other native large bunchgrasses to the understory of a depauperate stand of Wyoming big sagebrush. The average pre-treatment cover of bluebunch wheatgrass was 2% canopy cover.

The project addressed several questions and concerns: Does bluebunch wheatgrass and other native grasses and forbs respond positively to mechanical brush crushing? Does brush crushing retain sufficient sagebrush to allow rapid recovery of big sagebrush? Does brush crushing disturbance destroy biotic crusts and result in the invasion of noxious weeds or cheatgrass? Results after four growing seasons indicated that treated plots without seeding had no statistical increase in bluebunch wheatgrass cover

but squirreltail cover increased four-fold and needle and thread increased by 3-fold. In treated and seeded plots, bluebunch wheatgrass increased 12-fold, increasing from 2% to 24% cover.

Average big sagebrush cover was reduced from 20-22% to 6-8% after treatment but recovered to 10-13% after four growing seasons. The trajectory indicated that sagebrush would be between 15-25% cover about 7-10 years post-treatment. This is a much quicker return to a desired sagebrush cover than would occur after a fire.

Cheatgrass remained rare across the project area even within the double pass crush treatment and drill seeding where soil disturbance was greatest, places likely to be most susceptible to invasion. The increased bare soil as a result of treatment quickly declined to below pre-treatment levels and biological crust recovered rapidly.

Key Lessons Learned

1. Restoration of the original biological diversity (richness and abundance) of degraded sagebrush steppe is currently unachievable and likely always will be from a biological, technological, and fiscal perspective. Nevertheless, the restoration of a community which functions and mimics healthy sagebrush steppe both structurally and compositionally, and supports native shrub steppe wildlife, is often achievable. It is being accomplished on a regular basis by BLM as a part of fire rehabilitation efforts. Others, including IDFG habitat biologists, Pheasants Forever biologists, university researchers, restoration businesses like Intermountain Aquatics and Conservation Seeding & Restoration, and some private landowners (most notably, Lava Lake Land & Livestock) are actively engaged and accomplishing shrub steppe restoration.
2. The restoration or revitalization of sagebrush steppe is achievable providing Plummer et al.'s (1968) restoration principles are followed. Other considerations aside, it is absolutely critical that competition is controlled prior to seeding. Competition can come from both existing plants, annual or perennial, and the seedbank. Even native species, like Sandberg bluegrass, can limit the establishment of seeded species. In addition to controlling competition, planting seed at the proper depth is a critical step in successful restoration. This is especially true for native grasses. Broadcast seeding large-seeded native grasses without some type of coverage treatment is risky. On the other hand, we have experienced very good establishment with broadcast seeding followed by some type of cultipacker treatment (e.g., Brillion seeder and roller harrow).
3. Because of the inherent variability in weather from year-to-year, there will always be times when conditions for establishment are poor, resulting in restoration failures. Adequate precipitation during the spring seedling establishment period plays a more important role in restoration success than whether or not the annual precipitation is above or below normal. The risk of failure is greater in the drier sagebrush steppe sites (i.e., below the 10-inch precipitation zone) not because of the total annual average precipitation but rather because of the increased precipitation variability from year-to-year, especially during the critical establishment period. Planning and conducting restoration efforts during La Niña episodes appears to increase the probability of receiving adequate spring precipitation and seeding success. Conversely, conducting seedings during El Niño episodes increases the probability of seeding failure.

4. For herbaceous plants, poor seed germination due to drought in the first spring following planting may not result in project failure. If seed germination and establishment conditions are conducive during the second spring, successful establishment may occur. However, two years of successive drought conditions will likely result in restoration failure.
5. For big sagebrush, poor seedling establishment in the first spring due to drought will likely lead to project failure because sagebrush seed does not survive long in the environment. Re-seeding the following fall/winter is warranted in these situations.
6. Presently there is insufficient availability and quantity of some native grasses and several key native forb species. For grasses, we see a large need for increased supplies of Thurber's needlegrass. Thurber's needlegrass competes strongly against cheatgrass and is a very valuable species for restoration efforts in the drier Wyoming big sagebrush sites (9-11 inch ppt. zone). For forbs, increased supplies of arrowleaf balsamroot (*Balsamorhiza sagittata*), hawksbeard (*Crepis* spp.), and fleabane daisies (*Erigeron* spp.) are needed to restore community diversity and provide valuable food and cover species for wildlife.
7. The species mentioned in item 6, if available, are usually exorbitantly priced. These prices will remain high until there are increased supplies. More supplies will come in response to an increased demand for the seed. For example, in just the last 10 years the availability of bluebunch wheatgrass and big sagebrush seed has dramatically increased and prices have fallen significantly as use of these species has expanded. We were purchasing bluebunch wheatgrass seed in 2005 for $8.00/pound; for the last several years it has been available for $4/pound. Likewise, big sagebrush seed was $50/pound pure live seed (PLS) in 2005-6 and it has dropped to $30/pound in 2010 and 2011.
8. Sainfoin (*Onobrychis viciaefolia*), a non-native legume, appears to be a very desirable forb to include in sagebrush steppe seeding mixtures where annual precipitation is 11 inches or greater. This species is commonly used in food plots in the East and Midwest because of preference and nutrition for deer. Our observations here in Idaho would indicate that it is also very attractive to elk and sage-grouse. Jeff Klausmann (pers. comm.) of Intermountain Aquatics has observed high rates of use by Columbian sharp-tailed grouse on a sainfoin food plot in eastern Idaho. We suspect this species will also be very attractive to pronghorn as well as other herbivores.
9. Very aggressive seedbed treatment prescriptions are necessary to convert or diversify mature intermediate wheatgrass and smooth brome stands. Although preliminary results from some less aggressive experiments (e.g., Thousand Springs Ranch in West-Central Idaho, Paul Falkner and Josh Rydalch, IDFG, and Jeff Klausmann, Intermountain Aquatics) are promising, currently the only sure prescription to convert intermediate wheatgrass or smooth brome stands back to sagebrush steppe is by using multiple mechanical and chemical farming practices, starting with a moldboard plowing. Less aggressive treatment prescriptions are available to diversify crested wheatgrass stands, however.
10. Some researchers and practitioners recommend using only a few species in restoration seedings. Our work, as well as our observations of the work of others, has convinced us that you can establish a diverse community of shrubs, grasses, and forbs from a single seeding treatment. For example, we see no need to limit a seeding to two to three grasses, two forbs, and one shrub. You can create a community as diverse as the limitation of seed availability and cost

provide. However, each species seed coverage requirements must be met and seeding rates for each species need to be balanced to avoid over-seeding some species and under-seeding others. All too often grasses are seeded at a high rate (6 or more lbs/acre) which creates too much competition for the shrubs and forbs.

11. When noxious weeds are a potential threat for habitat conversion projects (i.e., converting crested wheatgrass, intermediate wheatgrass, smooth brome, or annual-infested sites back to sagebrush steppe), a two-stage seeding approach should be adopted (Benson et al. 2011). This approach is as follows: control competition and prepare seedbed; seed only grasses in the first fall; chemically treat undesirable broadleaf plants the next growing season; and seed forbs and shrubs the second fall. Benson et al. (2011) have successfully demonstrated this approach by converting and diversifying crested wheatgrass stands back to big sagebrush steppe.
12. In Idaho we have been experiencing increased fire frequency and size of burns over the last 30-years with the largest sagebrush steppe fire ever recorded occurring in 2007 (Murphy Complex). As a result, big sagebrush is being removed much faster than it is being replaced through natural re-colonization. This is particularly true for Wyoming big sagebrush. In response to this, the BLM has been actively involved in efforts to restore big sagebrush in many areas using aerial broadcast either in strips (Figure 1 and Figure 2) or uniformly over the burned area. There has been considerable criticism of this approach because of the sporadic success with previous aerial broadcast seedings. However, our observations would indicate that success rates of aerial broadcast seeding have improved substantially in recent years. We attribute this to the Source Identified Seed Program that has resulted in use of seed that is more likely to be adapted to the seeding sites.
13. There are strong differences in opinion among both technical and lay people interested in sagebrush steppe regarding approaches to big sagebrush restoration. Some want to let natural re-colonization be the primary mechanism; some want to only plant seedling sagebrush plants; and some want to seed big sagebrush. In our view, allowing natural re-colonization is an unacceptable course of action, especially in Wyoming big sagebrush habitats. The current rate of loss of big sagebrush habitat and its associated wildlife is too great to not intervene. We also see a limited role for planting seedlings because it is expensive and you cannot accomplish enough acres to overcome the current rate of loss. We strongly believe that seeding is the only viable approach to reverse the losses. Based on our experience, broadcast seeding big sagebrush establishment is significantly enhanced where some practice either presses the seed in contact with the soil or covers it very shallowly.
14. Broadcast seeding of big sagebrush without a seed cover practice requires increased rates of application to obtain adequate stand establishment. We recommend application rates of between 0.2-0.3 lbs PLS/acre for broadcast treatments. Alternatively, we have found that broadcast treatment with any practice that either presses big sagebrush seed in contact with the soil or provides a light covering of soil improves establishment dramatically. We have found that a rubber tire roller packer causes little surface disturbance and improves seed soil contact (Figure 4). Using these practices, seed application rates need to be lowered to 0.05-0.1 lbs PLS/acre to ensure that the resulting stand is not overly dense and to reduce inter- and intra-specific competition among seedlings.

15. Broadcast seeding of sagebrush on snow has been a frequently recommended practice. Our experience indicates that this practice is unnecessary and may actually reduce success in some instances. We have had repeated success seeding in the fall on bare ground and prior to winter snow accumulation. Our only effort of seeding on snow failed (Thousand Springs Ranch Project). Seeding on hardened snow may actually result in much of the seed being blown off site. It is our view that seeding can be accomplished during the fall, winter, or early spring. Seedling establishment is mostly dependent on soil contact and adequate moisture. Lucky Peak Nursery produces hundreds of thousands of big sagebrush seedlings annually. They plant seed in May, irrigate, and produce robust seedlings by September.
16. A 23-year post-establishment re-examination of survival and vigor of 13 accessions Wyoming big sagebrush shrub accession plot (Welch et al. 1992) revealed that only the local source was thriving (Figure 3). We conclude that Wyoming big sagebrush has differentiated into many germplasm with narrow environmental tolerances and it is therefore very important to use local seed sources.
17. Based on our experience, fall is the best time to seed. Although there is a risk of losing some forbs to early spring emergence followed by a hard frost, this is balanced by the difficulty of finding a suitable window of time for planting in the spring which allows equipment to operate but is not too late to take advantage of optimum soil moisture. Fall seeding also provides for those species that need cold and/or moisture stratification to overcome dormancy and germinate at the optimum time.
18. Establishing a desired community made up of a certain percentage cover for each species is more of an art than a science. Certainly, a seeding prescription (species and seeding rates) is needed with a clear objective in mind, but the climate variables of precipitation and temperature as well as inter- and intra-specific competition and other factors will ultimately affect what actually establishes and survives. Moreover, the initial compositional cover is likely to change over time based on climate, herbivory, and other biological and physical stresses.

Restoration Seed Mixes and Seeding Rates

Restoration seed mixes need to be tailored to the ecological site, the remaining desirable plants occurring on the restoration area, and the goals of the project. Our work took place in highly modified plant communities and our objectives were focused on restoring sage-grouse and/or Columbian sharp-tailed grouse habitat. Some example restoration seed mixes and rates we used are provided below. A complete list of mixtures and rates are provided for each project in Appendix I.

Table 1. Seed mix for Loamy, 8-12”ppt. Wyoming Big Sagebrush/Bluebunch Wheatgrass Ecological Site, Tilden Flat, Blackfoot, Idaho. Management Objective - diversify site and restore sagebrush cover. (2005 seed prices)

Species and Ecotype	Scientific Name	lbs/ac	Cost/lb	Total Cost/ac
Grasses				
Bluebunch wheatgrass (Anatone) (N)	*Pseudoroegneria spicata*	3.0	$6.00	$18.00
Big bluegrass (Sherman) (N)	*Poa ampla*	0.25	$3.75	$0.94
Basin wildrye (Trailhead) (N)	*Leymus cinereus*	0.5	$2.15	$1.08

Siberian wheatgrass (Vavilov) (I)	*Agropyron fragile*	1.5	$0.59	$0.89
Tall wheatgrass (Alkar) (I)	*Thinopyrum ponticum*	0.25	$1.65	$0.41
Forbs				
Arrowleaf balsamroot (N)	*Balsamorhiza sagittata*	0.5	$33.00	$8.25
Small burnett (Delar) (I)	*Linum lewisii*	0.5	$1.00	$0.50
Sainfoin (Eski) (I)	*Onobrychis viciaefolia*	1.0	$1.55	$1.55
Alfalfa (Ladak) (I)	*Medicago sativa*	1.0	$3.00	$3.00
Shrubs				
Wyoming big sagebrush	*Artemisia tridentata wyomingensis*	0.1	$50.00	$5.00
N = native; I = introduced		8.6		$39.62

Table 2. Seed mix for a Loamy 12-16" ppt. Xeric Big Sagebrush/Bluebunch Wheatgrass Ecological Site, Weiser River Ranches, Weiser, Idaho. Management Objective - Convert cheatgrass/medusa vegetation back to diverse sagebrush steppe. (2011 seed prices)

Species and Ecotype	Scientific Name	lbs/ac	Cost/lb	Total Cost/ac
Grasses				
Bluebunch wheatgrass (Anatone) (N)	*Pseudoroegneria spicata*	4.0	$4.00	$16.00
Big bluegrass (Sherman) (N)	*Poa ampla*	0.5	$3.00	$1.50
Squirreltail (Toe Jam Creek) (N)	*Elymus elymoides*	0.25	$17.50	$4.38
Sandberg's bluegrass (N)	*Poa secunda*	0.1	$3.00	$0.30
Basin wildrye (Trailhead) (N)	*Leymus cinereus*	0.75	$6.50	$4.88
Forbs				
Arrowleaf balsamroot (N)	*Balsamorhiza sagittata*	0.5	$18.00	$9.00
Western yarrow (N)	*Achillea millifolium occidentalis*	0.1	$20.00	$2.00
Silky lupine (N)	*Lupinus arbustus*	0.5	$45.00	$22.50
Desert parsley (N)	*Lomatium dissectum*	0.25	$70.00	$17.50
Munro's globemallow (N)	*Sphaeralcea munroana*	0.2	$50.00	$10.00
Blue flax (Maple Grove (N)	*Linum lewisii*	0.5	$17.00	$8.50
Sainfoin (Eski) (I)	*Onobrychis viciaefolia*	3.0	$1.40	$4.20
Alfalfa (Ladak) (I)	*Medicago sativa*	1.0	$3.00	$3.00
Shrubs				
Xeric big sagebrush	*Artemisia tridentata xericensis*	0.1	$30.00	$30.00
N = native; I = introduced		11.75		$133.76

Restoration Costs

Restoration costs are highly variable depending on the type of restoration, objectives, and approaches. Consequently it is useful to break the costs by the individual elements involved in restoration. The estimated costs shown below are either based on documented cost for our projects or NRCS rates:

1. Project management – $20 to $40/acre
2. Controlling competition (equipment, labor, and materials)
    a. Restoration after big sagebrush fire – $0/acre to $40/acre (If the fire is hot enough it will provide adequate competition control for the first growing season post fire)
    b. Dixie harrow – Single pass – $35 to $60/acre
    c. Aerator (shrub crushing) – Single pass – $25 to $50/acre

    d. Conversion of smooth brome or intermediate wheatgrass stands – $70 to $100/acre (involves multiple mechanical and chemical treatments; mechanical $60 to $80/acre; chemical $10 to $20/acre)
    e. Diversification of crested wheatgrass stands – $50 to $80/acre
    f. Conversion of cheatgrass/medusa site – $130 to $175/acre (involves multiple chemical and mechanical treatments; mechanical $90 to $110/acre; chemical $40 to $65/acre)
3. Seed mix – Needs to be tailored to the ecological site, to the plants needed to restore or diversify the existing desirable vegetation, and the project objectives. See example costs per acre in the previous section of this report. The range would normally be $50/acre to $150/acre.
4. Seeding methods (equipment and labor)
    a. Drill seeding – $11/acre
    b. Ground broadcast and cover – $12/acre
    c. Aerial broadcast – $3 to $10/acre (depends on pounds applied per acre)
5. Planting big sagebrush or bitterbrush seedlings
    a. Plants – $0.45 to $0.65/plant for bareroot stock; $0.75 to $1.50/plant for container stock
    b. Planting – $0.30 to $1.50/per plant depending on whether planting is done with a mechanical tree planter or hand planting
6. Post-seeding weed control – $0 to $30/acre (equipment, labor, and materials)

Recommendations

Policy Recommendations

1. IDFG should continue to collaborate with land management agencies (BLM, Forest Service, Department of Energy, and IDL) on identifying priority sagebrush steppe restoration areas, improving restoration science, and conducting restoration actions to benefit sage-grouse and other sagebrush steppe wildlife.
2. IDFG and BLM should continue to promote, cooperate, and invest in restoration science to provide cost-effective methods for restoring sagebrush steppe. This should be a high priority in light of need to reverse the loss and degradation of sagebrush steppe habitat for declining obligate species such as sage-grouse and pygmy rabbits.
3. Establish a cooperative agreement among BLM, IDL, and IDFG to coordinate and collaborate on fire rehabilitation and other restoration actions to institutionalize coordination and implementation of restoration actions.
4. BLM should, as a standard practice, invite an IDFG representative to be a member of the BLM's fire rehabilitation team for all fires involving crucial wildlife habitat.

Management Recommendations

1. For Wyoming big sagebrush, insist on using seed sources collected from nearby stands.

2. Continue the documentation of restoration research and restoration actions to ensure that results and lessons learned are disseminated.
3. Monitoring studies that enable pre- and post-treatment analysis have been established for nearly all the projects undertaken. However, a number of the projects only have initial results. Additional work should be undertaken to re-read transects, analyze data, update project documentation, and disseminate the lessons learned for the following projects:
    a. Old Farm Wyoming Big Sagebrush Steppe Disk-Plow Restoration Project (last monitored in 2009) – needs one additional monitoring effort; recommend 2012.
    b. Tilden Flat Wyoming Big Sagebrush Steppe Dixie Harrow Restoration Project (last monitored in 2008) – needs one additional monitoring; recommend 2012.
    c. Tilden Flat Wyoming Big Sagebrush Seedling Project (last monitored in 2011, only one growing season post-planting) – needs at least one additional monitoring effort; recommend 2012.
    d. Thousand Springs Ranch Xeric Big Sagebrush Steppe Restoration Project (last monitored in 2011, only one growing season post seeding) – needs at least two additional monitoring efforts; recommend 2012 and 2014.
    e. Weiser River Ranches Xeric Big Sagebrush Steppe Restoration (pre-treatment data only) – recommend follow-up monitoring at least in 2012, 2014, and 2016.
    f. Lava Lake Ranch Mountain Big Sagebrush Aerator Project (pre-treatment data only) – recommend follow-up monitoring in 2012, 2014, and 2016.

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Figure 1. 2011 aerial view of aerial broadcast big sagebrush strip seeding conducted by BLM about 1985 near Crater Rings, Mountain Home, Idaho. Note the re-colonization of big sagebrush between the strips. Note also the lack of big sagebrush outside of the seeded area, 25 years later.

Figure 2. 2011 aerial view of Bacon Pond big sagebrush strip seeding project conducted by BLM in 2002.

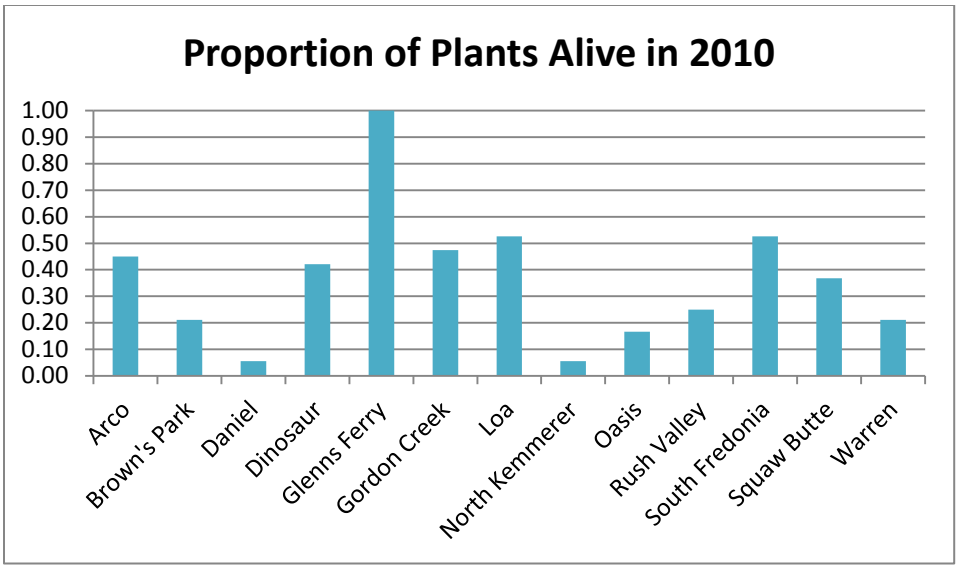

Figure 3. Survival of 13 different accessions of Wyoming big sagebrush 23 years after planting, Welch Sagebrush Plot, Glenns Ferry, Idaho, 2010 (see Appendix I, Welch Project Documentation Report for additional information).

Figure 4. Rubber tire roller packer. A very effective tool to increase broadcast big sagebrush seed contact with the soil and improve establishment.