PROGRESS REPORT: IMPLEMENTATION OF PILOT NATIVE VEGETATION RESTORATION EFFORTS IN THE GARDINER BASIN, YELLOWSTONE NATIONAL PARK, 2008-2014

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NATIVE SEED COLLECTION & PROPAGATION, EXCLOSURE CONSTRUCTION, WEED CONTROL, SITE PREPARATION, MONITORING OF SOIL PROCESSES & NATIVE SEEDING TRIALS, DRILLING OF NATIVE SEED, AND WORK PLAN FOR 2014

This report details a pilot effort from 2008 to 2014 to implement native vegetation restoration on 4 non-native weed-dominated sites totaling 50 acres in the Gardiner Basin of Yellowstone National Park (Figure A). Remediation was based on specific, prescriptive recommendations following an invited workshop (19-21 April 2005) of agency and academic restoration specialists (Interagency Workshop Steering Committee 2005a). The sites represent areas that were initially settled in the 1870s (including the townsite of Cinnabar, MT), converted from native vegetation for agricultural purposes, acquired by the park in the 1930s, abandoned from agricultural use and planted to non-native crested wheatgrass (*Agropyron cristatum*) by the 1950s, and further degrading to varying degrees to support a plant community dominated by non-native Eurasian annual weeds (mostly desert alyssum [*Alyssum desertorum*] and annual wheatgrass [*Eremopyrum triticeum*]).

The prescription for native vegetation restoration is a dryland approach that emphasizes: 1) maximizing weed control using chemical, mechanical, and cultural techniques; 2) site preparation using a barley/winter wheat cover crop to hold and decompact soil, provide competition with weeds, stimulate soil biota, and increase soil organic material; 3) fencing to exclude ungulate use during site preparation through native seed planting/germination/establishment; and 4) drill seeding native seed at a rate of 16-22 lbs per acre. The stated objective for this pilot project was to "**restore a mosaic of native plant communities that provides wildlife habitat and forage**". A secondary restoration objective identified for the sites was to: **restore functioning water, soil, and energy cycles; soil properties; and a sustainable native shrub-grassland plant association similar to the site potential** (Interagency Workshop Steering Committee 2005b)**.**

Prior to implementing project work, the preparation of funding proposals, descriptive soils analyses, NEPA and NHPA Section 110 and Section 106 compliance were completed. In 2007 and 2008, the University of Montana, Department of Anthropology, completed cultural resource surveys at a cost of $42,000 independent from costs associated with project implementation (MacDonald 2007, 2008). Secured funding and a budget breakdown of costs associated with the project are summarized in Appendices D and E.

Activities associated with project implementation in the field can be divided into the categories: native seed collection and propagation, exclosure construction, weed control, site preparation, monitoring, native seeding trials, and drill seeding of native seed at the recommended rate. Each activity is described below.

- Figure A: Location and name of fenced exclosures used in the pilot native vegetation restoration project in the Gardiner Basin and referenced throughout this report.

Native Seed Collection and Propagation

Local efforts to collect native seed were undertaken beginning in 2008 by NPS Maintenance and Vegetation personnel, including contracts with the Montana Conservation Corps (MCC) to provide additional manpower under NPS supervision. In 2009, the Bureau of Land Management completed an Environmental Assessment allowing NPS to manually and mechanically collect native seed (bluebunch wheatgrass, Sandberg's bluegrass, prairie junegrass, and needle and thread) during a five year period (2009-2013) at their Carbella Day Use Recreation Site west of Highway 89 (USDOI-BLM 2009). The collected seed (bluebunch wheatgrass, Sandberg's bluegrass, and needle-and-thread grass) was used as source for growing out sufficient seed to accommodate the restoration process.

A contract was initiated in 2008, and a 1-acre field was planted by 2010, with the Upper Colorado Environmental Plant Center (Meeker, CO) for 5 years (FY2010-FY2015) of bluebunch wheatgrass seed production. Funds were obligated in the amount of $10,000 per year (total obligation = $50,000). A total of 62.35 lbs of pure live seed had been produced in the 2011 and 2012 growing seasons, and this seed was incorporated into the native seed planting of 30 acres in 2013 (see section on native drill seeding).

An Interagency Agreement with the USDA-NRCS Bridger (MT) Plant Materials Center was initiated in 2008 through 2011 for growing native bluebunch wheatgrass seed on 0.5 acres and needle-and-thread hay on 0.3 acres. Funds totaling $27,700 were obligated for the effort. The agreement was modified in 2011 to extend the original contract for an addition 2 years (FY2012 and FY2013) at a total cost of $20,000 ($10,000 for each of 2 years). A second modification to the agreement occurred in FY2012 when: 1) the 0.3 acres of needle-and-thread grass was contaminated with green needlegrass from an adjacent seed plot at the Bridger Plant Materials Center; 2) the park quickly exhausted all available space in which to store large hay bales of needle-and-thread grass; 3) dispersing hay bales of needle-and-thread into the field could not be accomplished with a drill seeder, and would most likely need to be manually spread; 4) the original 0.5-acre planting of bluebunch wheatgrass began to decrease in productivity, likely exceeding its peak capacity for seed production; and 5) other fields became available at the Bridger PMC, allowing for an increase or change in species/amounts of seed produced. Consequently, the 2012 modification to the existing agreement called for: 1) replacing the .3 acres of needle-and-thread grass with a new planting of bluebunch wheatgrass; 2) replacing the original 0.5 acres of bluebunch wheatgrass with 0.5 acres of Sandberg's bluegrass; and 3) adding a new 1-acre field and new species—slender wheatgrass—to the mix (locally-collected starter seed was provided by the Division of Maintenance). This second modification was for FY2013 only, and added an additional $18,750 to the 1.8 acres being grown out at the Bridger PMC. Because the original 2008 Interagency Agreement had reached its 5-yr lifespan in FY2013, a new Interagency Agreement was needed if native seed growing operation were to continue. Consequently a new Interagency Agreement was initiated in FY2013 for continued growing operations through FY2015, and called for increasing Sandberg's bluegrass seed production on 1.0 acres (up from 0.5 acres) while maintaining 1 acre of slender wheatgrass and .3 acres of bluebunch wheatgrass (2.3 acres total seed production). The operating costs for FY2014 through FY2015 were estimated at $20,157 annually (total cost = $40,314). Costs associated with native seed growing operations at the Bridger PMC since 2008 have totaled $106,764 and through 2013 has produced 84.57 lbs pure live seed of bluebunch wheatgrass, 313.03 lbs slender wheatgrass, 62.02 lbs green needlegrass, ~17 lbs Sandberg's bluegrass, and 12.8 lbs of needle-and-thread grass.

A similar Interagency Agreement was also initiated with the USDA-NRCS Aberdeen (ID) Plant Materials Center in 2008, and called for establishing seed fields of 1 acre each for western wheatgrass, Sandberg's bluegrass, and needle-and-thread grass (hay). Funds totaling $64,530 were obligated for planting/production beginning in FY2009 through FY2011. The original contract was first modified in 2009, and called for changing 1 acre of western wheatgrass to 1 acre of bluebunch wheatgrass (because of insufficient western wheatgrass seed) and extending growing operations 1 additional year through

FY2012. An additional $24,867 was obligated to the growing effort. In 2012, a second modification to the original agreement called for I additional year of seed production through 2013 for 1 acre each of bluebunch wheatgrass and Sandberg's bluegrass, discontinue production of needle-and-thread grass (because of the reasons cited above), and install 2 new fields of 2.5 acres each of bluebunch wheatgrass and Sandberg's bluegrass. An additional $50,090 was obligated for this modification for 2013 only. Because the 5-year lifespan of the agreement expired in 2013, a new Interagency Agreement was initiated to continue with seed production of 2.5 acres each bluebunch wheatgrass and Sandberg's bluegrass for FY2014 and FY2015. The new agreement obligated an additional $100,952 through FY2015. Seed growing expenditures for the Aberdeen PMC total $240,259. Total seed produced through 2012 are 16 large bales of needle-and-thread grass, 159.38 lbs pure live seed of bluebunch wheatgrass, and 190.39 lbs Sandberg's bluegrass. Seed produced through 2015 should result in sufficient amounts to accommodate the pilot project as well as provide additional seed if partial reseeding is necessary or needed for new growing operations.

The total cost for seed growing operations among the 3 facilities for 2008-2015 is $397,023.

Exclosure Construction:

Recommendations from the Restoration Workshop participants were nearly unanimous for the need to fence project sites to exclude ungulate use so as to benefit site preparation activities and otherwise "protect the investment" of native seed germination and early establishment following native seed planting. The exclosures were projected to have a minimum lifespan of 8-10 years. The exclosure design should consist of solid bracing and supports (preferably steel) and be constructed with galvanized woven wire to withstand bison scratching/rubbing, be at least 6 feet (preferably 8 ft) tall to preclude elk and deer from jumping over, and reach to within 4 inches of the ground surface to prevent antelope from going under.

In 2008, the first contract was awarded to Hottel Fencing Co. (Hereford, AZ) specifying 4,850 linear feet of fencing surrounding the 23-acre Cinnabar site following the construction recommendations of the workshop participants. Exclosure construction began 22 September 2008 and was completed by 27 October 2008 at a total cost of $48,330 ($9.96 per linear ft). A second contract was awarded in the fall of 2009 to Schaefer Fencing Co. (Drewsey, OR) specifying 8,765 linear feet of fencing for 3 separate exclosures (7, 9, and 11 acres, respectively) using similar materials. Construction was completed by November 2009 at a total cost of $115,440 ($13.17 per linear ft). All exclosures were lined with de-commissioned 3-inch fire hose at waist height so as to provide a visual marker and prevent ungulates from running into the structure.

Total cost associated with exclosure construction was $163,770. It is recommended that the exclosure fencing be left in place at least through the summer of 2017 to afford protection through the germination and establishment period.

Weed Control

Throughout the life of the project, maximal effort to control weeds by chemical, mechanical, and cultural methods were employed (See Appendix B). Treatments consisted of herbicide applications, hand pulling, burning, harrowing, and the planting of a cover crop (See Site Preparation section). Herbicide applications consisted of a broad-based generalist herbicide (Roundup) mostly targeting crested wheatgrass and annual wheatgrass, a broadleaf (non-grass) herbicide (Express) approved for use in barley and winter wheat targeting alyssum, and a pre-emergent herbicide (Plateau) targeting incidental patches of cheatgrass. Herbicide treatments included one, and in some cases a second, broadcast application with a boom sprayer over the whole unit as well as incidental spot treatment using a backpack sprayer. The sites were somewhat different in that the Cinnabar and Stevens Creek sites contained more annual weeds whereas the Reese Creek sites contained higher densities of the perennial crested wheatgrass.

Herbicide application in the 23-acre Cinnabar exclosure began in May 2009 with a broadcast application of either Roundup alone or a Roundup/Express mixture targeting created wheatgrass and alyssum control, respectively. Spot treatments with Roundup continued from 2010 through 2013, sometimes targeting annual wheatgrass. Montana Conservation Corps (MCC) crews also contributed to hand pulling annual wheatgrass in the summer of 2012.

During October 2011, a 100 ft x 100 ft section of the Cinnabar exclosure was burned so as to remove cover crop stubble and prepare the site for native seeding trials (see Native Seeding Trials section). Fire intensities were not uniform, but alyssum densities were significantly reduced more than an order of magnitude the following spring in areas blackened by the burn. Recognizing this tremendous loss of alyssum seed density, an attempt was made to burn the whole 23-acre parcel in October of 2012. Again because of spotty burn intensities, an attempt was made to complete the burn in March of 2013 prior to weed seed germination. In all attempts, burning proved spotty and fire could not carry unless consistent wind speeds >10 mph occurred. A final attempt to harrow emerging seedlings in the Cinnabar exclosure occurred in April 2013 during early weed seed germination and prior to planting a barley cover crop (see Site Preparation section).

Herbicide application at the 7-acre Stevens Creek site began with a broadcast treatment using Roundup in June 2009, prior to erecting the fenced exclosure later in October 2009 (see Appendix B). Spot treatment with Roundup continued from 2010-2013, and included a spot treatment in early 2012 with Express targeting alyssum in the established barley field as well as a 2010 summer mechanical control of annual wheatgrass using MCC crews. In April of 2013 a mechanical harrowing treatment was applied to early-germinating annual weeds prior to planting a barley cover crop (see Site Preparation section).

A 4-acre broadcast spray using Roundup and targeting crested wheatgrass occurred in the Reese Creek North site in June 2009, prior to erecting the fenced exclosure later in October 2009 (see Appendix B). In May of 2010, both the 9- and 11-acre exclosure sites of Reese Creek North and South were broadcast-sprayed with Roundup. Spot treatments continued through 2012, and included both Roundup and Plateau spot treatments targeting incidental populations of cheatgrass. MCC crews also contributed to hand-pulling/grubbing crested wheatgrass. As in the Cinnabar exclosure, a 100 ft x 100 ft area was prescribe burned in October 2011 to remove stubble and prepare the area for native seeding trials (see Native Seeding Trials section). During April 2013, a second broadcast spray with Roundup occurred in both exclosure sites for crested wheatgrass prior to planting a barley cover crop (see Site Preparation section). A final planting of barley is planned for spring 2014 prior to native seed drilling in October 2014.

Site Preparation:

In adhering to a systems approach to restoration, the workshop participants were unanimous in recognizing that restoration success was dependent upon site remediation and preparation. To that end, it was recommended that a cover crop—such as “Otis” barley or other sterile cereal crop—be planted to build soil organic material, increase soil holding moisture capacity, stimulate soil microbial activity, percolate and aerate the upper soil profile down through the rooting zone, and otherwise provide competition with weeds. Initial soil testing and characterization at the Cinnabar exclosure revealed the lack of an impermeable layer at 4-6 inches below the soil surface, negating the recommendation to mechanically fracture (e.g., rip) the soil to a depth of 1 ft to promote soil infiltration. Site preparation using a cover crop was recommended for 2-3 years or until an acceptable level of weed reduction occurs.

Cover crop plantings were undertaken to ensure no area were barren during the growing season because of chemical weed control, lack of germination, seed predation by birds and small mammals, etc. The emphasis was on the functional and competitive use of a cover crop rather than an agricultural approach to maximizing productivity. Recommended and actual cover crop seeding rate of 50 lbs per acre was used in all plantings.

The 23-acre Cinnabar site was initially drill-seeded with barley in May of 2009, and again with winter wheat in September of 2009 (See Appendix C). Fourteen of 23 acres were reseeded with barley in May of 2010 because of overwinter mortality. The full 23 acres were again seeded with winter wheat in the fall of 2011, and with barley in May of 2013. The site was drill-seeded with a native seed grass mix in October of 2013 (see sections on Native Seed Collection/Propagation and Drill Seeding of Native Seed).

It is worth noting that native seed drilling in the 23-acre Cinnabar site was initially planned for the fall of 2011. Record snowmelt conditions during March of 2011, however, resulted in the site being a “muddy, shallow lake” (the adjacent county road was closed for 4 days because it was underwater and impassible). Consequently, copious amounts of weed seed were collected in the wash and redistributed from outside the treatment site, and weed seed monitoring data revealed weed seed densitiy returned to pre-treatment levels. This unanticipated trend with weed seed density delayed native seed planting for another 2 years until weed seed density could be brought under control.

The 7-acre Stevens Creek site was initially seeded with winter wheat in September 2009 (See Appendix C). Spring barley was planted on 4.75 acres in June of 2010 where the winter wheat planting failed to establish. The entire site was again planted to winter wheat in September of 2010. Other cover crop plantings at the site included a partial planting of barley in May 2011 following chemical control of annual wheatgrass, seeding the entire site with winter wheat in September 2011, and seeding the entire site with barley in May of 2013.

Both the 9- and 11-acre Reese Creek exclosure sites were initially seeded with winter wheat in September 2010, and with barley in May of 2013 (see Appendix C). The sites will again be seeded with barley in May of 2014 prior to native grass seeding in October 2014 (see Section on Drill Seeding of Native Seed).

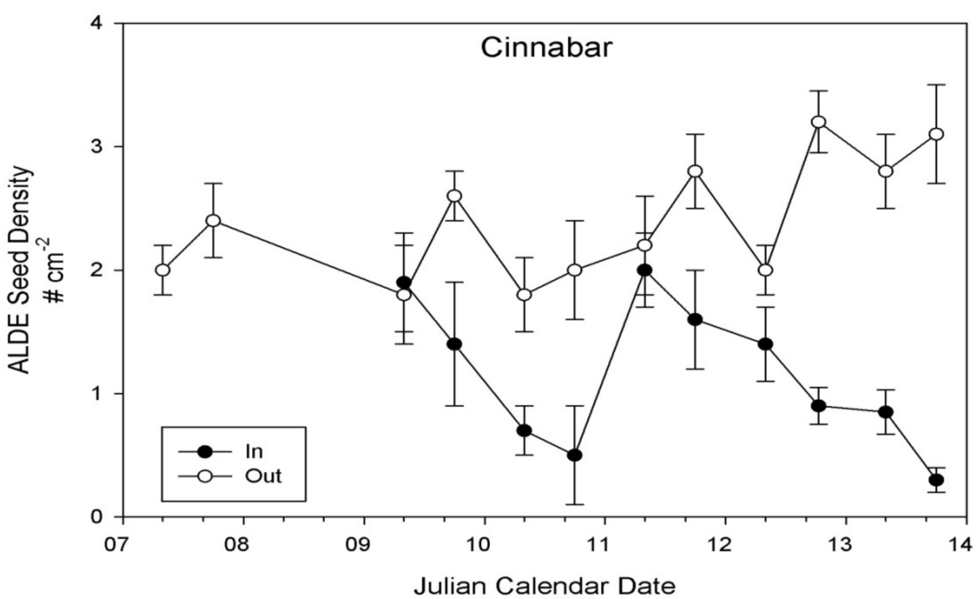
<u>Monitoring:</u>

Monitoring at the restoration sites has focused on describing baseline conditions related to plant-soil feedbacks, ecosystem processes of respiration and nitrogen transformations, and soil microbial community diversity as influenced by former agricultural practices and the current vegetation pattern. Addressing these conditions will allow for understanding the ecological consequences of management actions to control undesirable vegetation and preparation of the site for native seed planting, and ultimately, the success or failure of vegetation restoration efforts.

Hellquist et al. (2011) measured 3 CO_2 exchange parameters (net ecosystem productivity, ecosystem respiration, and soil respiration) in paired native vs. exotic sites in the Gardiner Basin. CO_2 flux varied among individual sites, but when pooled across sites, native plant communities showed greater net ecosystem productivity (net CO_2 flux into plant biomass) and soil respiration (CO_2 flux from plant roots and soil organisms into the atmosphere). No differences were observed in ecosystem respiration (CO_2 flux from plants and soil into the atmosphere). Net ecosystem productivity was generally low in low plant biomass-dry sites dominated by either native or exotic plants, but along stream banks where soil moisture was higher, net ecosystem productivity was 2-3 times greater in high plant biomass-wet sites dominated by native plant species compared to exotics. Likewise, low plant biomass-dry sites dominated by either native or exotic plants experienced low soil respiration rates, but soil respiration rates in high biomass-wet sites was 4 times greater in native vs. exotic sites.

Soil organic matter (available carbon), and its influences on nutrient availability and soil fertility via nitrogen cycling, is affected by both the quality and quantity of plants growing on a given site. Soil microbial communities respond and interact with carbon and nitrogen stores, and reflect overall soil quality. In addressing soil microbial community diversity at sites dominated by native vs. exotic sites in the Gardiner Basin, Hamilton and Hellquist (2012) found that microbial community diversity was highest in soils beneath native plant communities (26 ± 3 genetic markers), lower in soils colonized by the exotic perennial grasses crested wheatgrass and quackgrass (18 ± 4 markers), and lowest in soils dominated by the exotic annual mustard *Alyssum* (12 ± 5 markers). In comparing the effects of weed control and cover crop plantings inside and outside of the Cinnabar exclosure, Hamilton and Hellquist (2012) found that soil microbial community diversity increased inside the exclosure along with increases in soil organic matter. After only 1 season of a barley cover crop in the Cinnabar exclosure site, soil organic matter increased by 22% inside compared to outside the exclosure. After 2 growing seasons with a cover crop, soil organic matter was variable but increased to as high as 40%, representing a significant 67% increase in the top 6 inches of the soil from pre-treatment levels (YNP data, two-sample t-test, $p < .0001$). Commensurate increases in soil microbial diversity inside the Cinnabar exclosure were approaching soil community diversity measured in a nearby native remnant native plant community. Soil microbial community diversity remained consistently low in adjacent exotic-dominated sites outside of the exclosure.

Further investigation by Hamilton and Hellquist (2012) explored the seed bank dynamics of the dominant exotic *Alyssum desertorum* inside and outside the Cinnabar exclosure. Chemical weed control and competition with planted cover crops after 2 years of treatment significantly ($p < .05$) reduced *Alyssum* seed densities by a factor of 4 inside vs. outside the exclosure. Flooding at the site during the extreme snowmelt spring of 2011, however, redistributed the seed bank from outside to inside the exclosure, resulting in a resurgent flush of *Alyssum* and increasing the seed bank to pre-treatment levels. Continued weed control through burning and cover crop plantings served to again reduce the *Alyssum* seed bank by 25% through 2012. At the end of the 2013 growing season, the *Alyssum* seed bank had been reduced by 90% inside the exclosure compared to outside. Although highly variable, reported seed densities averaged 0.3 per cm^2 inside the exclosure and $3.2/cm^2$ outside (Figure B).



- Figure B: Average density of *Alyssum* seed derived from 12 sample quadrats with 3 replicates each, inside and outside of the Cinnabar exclosure (Hamilton, unpublished data). Julian calendar coincides with years 2007-2014.

The overall implication of these monitoring activities shows: 1) the established exotic vegetation communities are negatively affecting soil quality through decreases in soil organic matter, soil moisture holding capacity, net ecosystem productivity, soil respiration rates, and soil community diversity. These potential "legacy effects" must be overcome to increase the likelihood of successful native vegetation restoration. 2) Management actions (weed control and cover crop plantings) are reducing the exotic *Alyssum* seed bank while increasing soil organic matter, soil moisture holding capacity, net ecosystem productivity, soil respiration, nitrogen mineralization, and soil microbial community diversity. Thus, management actions on the restoration sites are acting to increase the likelihood of successful native vegetation restoration.

The collaborators plan to continue with these monitoring activities of ecological function through the planting, germination, and establishment of native vegetation.

Native Seeding Trials:

See Appendix A for a 4-part investigation into exotic and/or native plant dynamics in test trials within the Gardiner Basin restoration sites. The progress report was compiled and submitted by collaborators Susan Winslow, Jim Jacobs, and Joe Scianna of the NRCS Montana Plant Materials Center.

Drill Seeding of Native Seed:

The first phase of native seed planting was undertaken in the fall of 2013. Beginning 24 October 2013, the 7-acre Steven Creek exclosure and 23-acre Cinnabar exclosure were drill-seeded with a native mix collected and propagated specifically for the project. In each site, a seed mix containing 50% bluebunch wheatgrass, 30% Sandberg bluegrass, 15% slender wheatgrass, and 5% green needlegrass was drilled in 12-inch rows at a depth of ¼- to ½-inch below the surface at a rate of 18.18 lbs/acre. Rice hulls (3.5 lbs/acre) were added to the seed mix to facilitate uniform distribution of different-sized seed at an accurate seeding rate (St. John et al. 2012). Additionally, five acres of barren, exposed, N-facing hillslopes in the Reese Creek N and S exclosure were broadcast with 11-14 lbs/acre of Sandberg bluegrass seed and mulched with 12 bales of the needle and thread hay. Remaining seed, including mixes use to calibrate the seeder and 4 bales of needle and thread hay, were drill-seeded/mulched around the perimeter of the Cinnabar exclosure and roadside perimeter of the Stevens Creek exclosure. In late November 2013, about 2 lbs of seed containing sagebrush, rabbitbrush, greasewood, and basin wild rye was hand-collected locally and widely broadcast throughout the 2 sites.

Work Plan for 2014:

Final Implementation of the pilot project is scheduled for October 2014, culminating with the drill-seeding of native seed in the Reese Creek N (9 acres) and S (11 acres) exclosures. Activities planned for 2014 include: 1) Spot treating with Roundup any early-germinating annual weeds in the Cinnabar and Stevens Creek exclosures prior to emergence of the planted native seed to enhance native seed germination and survival.

2) Chemically-treating resurgent crested wheatgrass in the Reese Creek exclosures, if necessary, depending on spring germination/greenup. It is anticipated that spot-spraying in 2014 may be a necessary follow-up to broadcast spraying conducted in 2013. Even though crested wheatgrass cover was reduced >95% as a result of the 2013 broadcast treatment, uncertainty remains regarding the prolific crested wheatgrass seed bank and/or persistence of the perennial root mass that can contribute to crested wheatgrass resurgence. Such resilience of crested wheatgrass has proven to be problematic in other native vegetation restoration efforts (Hulet et al. 2010).

3) Drill-seeding a spring 2014 barley cover crop in the Reese Creek exclosures to continue with site preparation prior to native seed planting and competition with exotic plant species.

4) Continue with native seed production and the monitoring of soil properties, soil biota, ecosystem processes, and native seeding trials already underway. Continued collaboration with university and NRCS personnel will be required.

5) Initiate new monitoring plots to quantify the germination and early establishment of native seeding efforts in the Cinnabar and Stevens Creek exclosures, the mulched native seeding in the Reese Creek exclosures, and the mulched outed perimeter of the Cinnabar exclosure. Given the likely variability in both native and exotic plant dynamics, monitoring will involve the establishment of both permanent and random plots to quantify plant frequency and cover.

6) Complete the pilot effort by drill-seeding "native" grasses into the remaining flat areas of the 20-acre Reese creek exclosures. Discussion about introducing an experimental design into this final phase limits options/factors to seeding rates, seed sources, and the use of exclosures/site remediation. Other options considered but rejected include the use of irrigation and/or nitrogen fertilization. The complexities surrounding water rights and the park's stated objective of using its water from Reese Creek to remain in the channel to the benefit of spawning cutthroat trout preclude irrigation as an experimental factor; fertilizing to supposedly enhance native plant performance has a higher probability, expressed by experienced university and NRCS collaborators, of benefitting undesirable non-natives rather than the planted native seedlings (also see Perry et al. 2010).

The resulting experimental design will use seed rate, seed source, and site/remediation as main factors to test as main factors in a randomized block design for the 2014 "native" seed plantings. The native seeding rate (18 lbs/acre) use in the 2013 planting is consistent with NRCS recommendations for "Critical Area Planting", and could be doubled (36 lbs/acre) as suggested from results of the native seeding trials. Furthermore, locally-collected and propagated native species could be compared to a similar mix of commercially-available "native" species planted at both the recommended and doubled seeding rate. Additionally, weed control and cover crop plantings within the exclosures allows for the opportunity to assess the contribution of such "site remediation" efforts compared to native seed plantings outside the exclosures where no site remediation has taken place.

Consequently, native seed planting in the Reese Creek sites during fall of 2014 will involve: 1) Planting the Reese Creek N exclosure (9 acres) with the same seed mix and at the same seeding rate (18 lbs/acre) as the 2013 planting in the Cinnabar and Stevens Creek exclosures. This will allow for YEAR x SITE comparisons with the previous and current seeding efforts.

2) Plant the Reese Creek S exclosure (11 acres) with: a) 2 acres of double the NRCS-recommended seeding rate to 36 lbs/acre with local seed; b) 2 acres of double the NRCS-recommended seeding rate to 36 lbs/acre using a paired (by species) commercially-available seed mix; c) 2 acres of the NRCS-recommended seeding rate (18 lbs/acre) using the paired, commercially-available seed; and d) the remaining area of the Reese Creek S exclosure (2-3 acres when considering the hillslopes were mulched with needle and thread hay) with the NRCS-recommended seeding rate (18 lbs/acre) using locally-collected/grown seed mix.

3) Plant *outside* of the Reese Creek exclosures, in the adjacent 56-acre field dominated by annual weeds, 2-acres each of the NRCS-recommended rate (18 lbs/acre) using the local seed mix, commercial seed mix, double the local seed mix, and double the commercial seed mix. The annual weed-dominated field (with *Alyssum*, annual wheatgrass, yellow mustard, and Russian thistle) would be preferable to a field dominated by crested wheatgrass given the futile efforts of converting crested wheatgrass without site preparation efforts (see Hulet et al. 2010 and previous efforts in the basin). Therefore, a total of 8 additional acres outside of the Reese Creek exclosures would be planted during the fall of 2014, bringing the total area to be planted with "native" seed to ~28 acres in the fall of 2014.

Both permanent and random plots will be replicated by treatment in a factorial design to test for differences and interaction in the following main effects on plant frequency and density:

> $H0_1$: There is no difference in YEAR (2013 vs 2014) or SITE among the 3 exclosure sites (Reese Creek N, Cinnabar, Stevens Creek) planted with the NRCS-recommended native seeding rate of 18 lbs/acre.
>
> $H0_2$: There is no difference in germination/establishment among "native" seed mixes (local vs. commercial) used for planting.
>
> $H0_3$: There is no difference in germination/establishment among "native" seeding rates (18 lbs/acre vs. 36 lbs/acre) used for planting.
>
> $H0_4$: There is no effect of site remediation (inside vs. outside the exclosures) on germination/establishment of "native" seed mixes and rates used for planting.

It is recognized the above design is dependent on sufficient seed that is either grown out or purchased commercially. In the event seed becomes a limiting factor, the proposed 2-acre treatments can be scaled back to 1 acre in size.

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<u>APPENDIX A:</u> PROGRESS REPORT OF THE NRCS MONTANA PLANT MATERIALS CENTER INTO MONITORING RESULTS OF EXOTIC AND NATIVE PLANT DYNAMICS IN THE GARDINER BASIN VEGETATION RESTORATION TRIALS.

The 2012 and 2013 Study Results in the Gardiner Basin of Yellowstone National Park

1. **Establishment of Eight Native Grasses With and Without Seed Agglomeration Treatments.**
2. **The Use of Seed Hay Mulch to Establish Needle and Thread and Bluebunch Wheatgrass.**
3. **The Effect of Controlled Burning on Desert Alyssum.**
4. **Comparing the Establishment and Growth of Grass Species Collected in Yellowstone National Park to Those Selected by the USDA Natural Resources Conservation Service's Plant Materials Program.**

Cooperators: Yellowstone National Park; USDA ARS-Burns, OR; Washington and Lee University-Lexington, VA; and the USDA NRCS Plant Materials Centers in Bridger, Montana, and Aberdeen, Idaho.

Introduction: Yellowstone National Park (YNP) manages 700 acres of the Gardiner Basin as wildlife habitat and the area has historically been used heavily by large ungulate wildlife species for winter range. Vegetative cover of a large proportion of these acres is dominated by desert alyssum (*Alyssum desertorum*), a small annual non-native forb. There is little information on the biology and management of desert alyssum, but it does not meet the YNP objectives supporting a diversity of wildlife species and it provides little cover to protect against soil erosion. Previous attempts by YNP to restore native plants to the Gardiner Basin have failed. In 2008, the park enclosed 22 acres at Cinnabar and 20 acres at Reese Creek with wildlife fence in order to restrict grazing, chemically control desert alyssum, and allow planting of annual grain cover crops to prevent soil erosion, improve soil biota, and provide competition with desert alyssum emerging from the soil seed bank. Soil analyses from cropped versus un-cropped areas are being conducted to determine how invasive species alter soil microbial populations in the context of revegetation practices across a grazed landscape characterized by exotic plant communities (Hamilton and Hellquist, 2012). In 2011, the Bridger Plant Material Center initiated testing the establishment and survival of eight native grass species for restoration to permanent, desirable vegetation.

Site Descriptions: <u>Cinnabar (Old Agriculture Field H)</u> GPS coordinates (degree decimal) are North latitude 45.0520499718016 and West longitude -110.762292712783 at elevation 5,213 feet. The soil is described as deep, well-drained, and heavily impacted by irrigated agriculture. The surface texture is loam with 34% sand, 46% silt, and 20% clay. The results of soil laboratory tests on surface (0 to 4 inches) and subsurface (4 to 13 inches) characteristics include, respectively: pH 8.1-8.3, 1.2-2.4% exchangeable sodium, 0.6% soluble salts based on millimhos per centimeter (mmhos/cm), and 1.96-1.40% organic matter. In addition, the exchangeable acidity test results, based on millequivalents of hydrogen per 100 grams of dry soil (meq/100g), are: carbon exchange capacity 25-29.3, sodium 0.3-0.7, potassium 1.1-0.3, calcium 17.7-21.2, and magnesium 7.7-9.0.

<u>Reese Creek (Old Agriculture Field L</u>) GPS coordinates (degree decimal) are North latitude 45.0637101497144 and West longitude -110.772507594123 at elevation 5,188 feet. The soils are deep, well-drained, and heavily impacted by irrigated agriculture. The surface texture is silty clay loam with 7% sand, 54% silt, and 39% clay. The results of soil laboratory tests on surface (0 to 3.5 inches) and subsurface (3.5 to 9 inches) characteristics include, respectively: pH 8.1, 30.7-27.6% exchangeable sodium, 0.7-1.4% soluble salts based on millimhos per centimeter (mmhos/cm), and 8.3 to 2.5% organic matter. In addition, the exchangeable acidity test results, based on millequivalents of hydrogen per 100 grams of dry soil (meq/100g), are: carbon exchange capacity 30.7-27.6, sodium 0.2-0.4, potassium 5.9-1.8, calcium 21.1-23.3, and magnesium 6.8-6.2.

Study 1—Compares eight native grass species with and without seed agglomeration treatments in replicated plots as a method to improve establishment. Seed agglomeration bundles six seeds into a single pellet. Studies in the Great Basin have shown it enhanced seedling emergence through soil crusts

(Madsen et al., 2012). We hypothesize establishment and persistence will be affected by species seeded and agglomeration will improve establishment regardless of the species.

- **Species Seeded:** The selection of YNP grasses was based on native plant communities in the Gardiner Basin, as well as seed availability, and included Indian ricegrass *Achnatherum hymenoides* ACHY, slender wheatgrass *Elymus trachycaulus* ELTR, needle and thread *Hesperostipa 12pprox* HECO, prairie Junegrass *Koeleria macrantha* KOMA, basin wildrye *Leymus cinereus,* green needlegrass *Nassella viridula* NAVI, Sandberg bluegrass *Poa secunda* POSE*,* and bluebunch wheatgrass *Pseudoroegneria spicata* PSSP.

- **Agglomeration Treatment:** The seed coating agglomeration treatment was performed at the Eastern Oregon Agricultural Research Center (EOARC) in Burns, Oregon, using a RP14DB® rotary seed coater by BraceWorks Automation and Electric (Lloydminster, Saskatchewan). Materials used in the coating process included the adhesive binder, Celvol-205® applied at 0.025 g/cm^3 of seed, and the powder filler material, diatomaceous earth (Perma-Guard, Inc., Albuquerque, New Mexico), applied at 0.38 g/cm^3 of seed. A detailed description of the application rates used to form the agglomerated seeds is described by Madsen et.al. (2012).

- **Method:** Study 1 was planted in the Reese Creek exclosure on October 17 and in the Cinnabar exclosure on October 18, 2011, as a Randomized Complete Block Design with four replications of two factorially arranged treatments (8 species seeded and with and without seed coat agglomeration). Each of the previously-mentioned eight entries was seeded in 4 rows with 16 inches between the rows, at a length of 20 feet. Seeds were planted at a rate of 25 pure-live-seeds per foot to an approximate depth of ¼ to ½ inch using a Kincaid Precision Cone Seeder.

- **Evaluations:** In 2012, density and frequency of occurrence by species were sampled in April using the frequency grid method (Vogel and Masters, 2001). At the end of July in each treatment plot, seeded grass densities were counted in 20 cm by 50 cm frames, heights were measured, and growth stage was noted (Moore et. Al 1991). In early July 2013, densities and frequencies of occurrence of seeded grass species were sampled within each treatment plot using the frequency grid method (Vogel and Masters, 2001), height was measured, and growth stage was noted (Moore et al., 1991).

- **Analysis:** Species with no establishment were not included in the analysis. Density, frequency, and height data were analyzed using a factorial analysis of variance model (ANOVA). Because sampling method was different between years, years were analyzed separately. Where variances were not normal, data were either square root, or sin- transformed to meet assumptions of ANOVA, non-transformed data are presented. The 2012 ANOVA model included site, species, seed agglomeration treatment and all interactions. Because of site differences in 2013, sites were analyzed separately. The 2013 ANOVA model for each site included species, seed agglomeration treatment and their interaction. Tukey's means separations ($\alpha=0.05$) were used to determine differences among means for main effects and interactions when f-test p-values were ≤ 0.1.

- **Results:** Density measures the level of establishment. In 2012, averaged over all species that established and both treatments (site main effect), density was greater (p=0.0153) at Cinnabar (0.9 $plant/ft^2$) than Reese Creek (0.5 $plant/ft^2$). Averaged over both sites and agglomeration treatments (species main effect p=0.0006), ELTR (1.03 plants/ft2) and PSSP (0.92 $plant/ft^2$) had greater densities than POSE (0.17 $plants/ft^2$ or HECO (0.62 $plant/ft^2$). Species densities averaged over the two seed agglomeration treatments were not different between sites with the exception of HECO, which had greater densities at Cinnabar (1.2 $plants/ft^2$) than Reese Creek (0.1 $plant/ft^2$, site by species interaction p=0.0818). Averaged over all species, density was greater at Cinnabar for non-treated seed (1.1 $plants/ft^2$) than for agglomerated seed (0.5 $plant/ft^2$). The analysis supports recommendations to use non-agglomerated seed, and to seed ELTR, PSSP, and HECO at Cinnabar, and to seed ELTR and PSSP at Reese Creek. The densities of PSSP and POSE in 2013 at Reese Creek support seeding these species at this site. At Cinnabar, densities of ELTR, HECO and PSSP decreased, and at Reese Creek densities of POSE and PSSP increased from 2012 to 2013. There is no statistical test of significance for changing seedling densities and may have resulted from different sampling methods rather than plants dying or establishing after the first growing season. Soil at the Cinnabar site has higher sand content (34%) than at the Reese Creek site (7%) and therefore, seedlings may have less available soil moisture at the Cinnabar than Reese Creek—plants at Cinnabar may be more exposed to desiccation stress than at Reese Creek.

- The mean densities by species, treatment, year, and site are listed in Table 1. A density of 1.0 plants/ft^2 is considered by the NRCS as adequate to protect the soil against soil erosion.

Table 1. The mean (n=4) densities (plants/ft^2) by species for the seed agglomeration treatments (with and without) in 2012 and 2013 at Cinnabar and Reese Creek.

	Cinnabar				Reese Creek			
	2012		2013		2012		2013	
Species	No Treat.	Treat.	No Treat.	Treat.	No Treat.	Treat.	No Treat.	Treat.
ELTR	1.8	1.3	0.01	0.01	2.5	1.1	0	0
HECO	3.6	0.5	0.32	0.18	0	0.1	0	0
POSE	0	0	0.36	0.21	0.3	0.2	5.3	4.6
PSSP	2.7	1.1	0.68	0.41	0.5	1.1	2.0	2.9
ACHY	0	0	0	0	0	0	0	0
KOMA	0	0	0	0	0	0	0	0
LECI4	0	0	0	0	0	0	0	0
NAVI	0	0	0	0	0	0	0	0

- Frequency of occurrence is a measure of how evenly the stand establishes. Averaged over all species that established and the two agglomeration treatments, frequencies were greater (site main effect p=0.0009) at Cinnabar (2%) than Reese Creek (1%). Averaged over both of the sites and agglomeration treatments, frequency of POSE (3%) and PSSP (3%) were greater (species main effect p<0.0001) than HECO (1%) and ELTR (<1%), and HECO frequency was greater than ELTR. Seed agglomeration did not affect frequency. There were differences in species frequencies between sites (species by site interaction p<0.0001). Averaged over both agglomeration treatments, both PSSP (4% and 2%) and POSE (2% and <1%) had greater frequency at Cinnabar than Reese creek, respectively. None of the species established at near the target of 100% frequency. Doubling the seeding rate from 25 to 50 seeds per square foot is recommended to improve frequency of establishment.

- The frequencies for each species for 2013 ranged from 0% to 17% are reported in Table 2.

Table 2. The mean (n=4) frequency of occurrence (percentage) of seeded grass species for the seed agglomeration treatments (with and without) in 2013 at the Cinnabar and Reese Creek sites.

	Cinnabar		Reese Creek	
Species	No Treat.	Treat.	No Treat.	Treat.
ELTR	<1	<1	0	0
HECO	8	5	0	0
POSE	9	5	13	12
PSSP	17	10	5	7
ACHY	0	0	0	0
KOMA	0	0	0	0
LECI	0	0	0	0
NAVI	0	0	0	0

- The seed agglomeration treatment did not affect plant height (p>0.01). In 2012, averaged over all seed agglomeration treatments, ELTR (4.5 cm) and PSSP (3.6 cm) were taller than HECO (2.0 cm) and POSE (1.7 cm) at Cinnabar, as well as at Reese Creek (ELTR = 3.5 cm, PSSP = 3.0 cm, HECO = 2.7 cm, and POSE = 2.1 cm). In 2013 at Cinnabar, HECO (23.9 cm) and PSSP (23.6 cm) were taller than ELTR (8.4 cm), but POSE (14.9 cm) was not different than any of the other species tested. In 2013 at Reese Creek, PSSP (23.6 cm) was taller than POSE (14.9 cm), but there were no differences among POSE, ELTR (8.4 cm), or HECO (23.9 cm).

- Height differences among species (p<0.01) are reported in Table 3.

Table 3. The mean (n=4) heights (cm) by species for the seed agglomeration treatments (with and without) in 2012 and 2013 at Cinnabar and Reese Creek.

	Cinnabar				Reese Creek			
	2012		2013		2012		2013	
Species	No Treat.	Treat.	No Treat.	Treat.	No Treat.	Treat.	No Treat.	Treat.
ELTR	16.5	28.7	5.8	11.0	11.3	13.0	0	0
HECO	4.0	4.3	26.8	21.0	7.0	7.5	0	0
POSE	4.5	2.3	16.3	13.5	4.3	4.3	7.8	7.0
PSSP	13.3	12.8	28.3	19.0	10.3	9.0	13.5	12.5
ACHY[†]	2.5	0	0	0	6.4	6.4	0	0
KOMA[†]	0	0.3	0	0	4.1	3.6	0	0
LECI[†]	6.9	6.4	16.3	0	5.3	8.9	0	0
NAVI[†]	3.1	2.5	0	0	1.3	4.3	0	0

[†] Not included in the analysis but measured as present out of the sampled area and in the seeded plot.

- After 2 years of growth, most of the seeded entries at Cinnabar remained in a primary stage of vegetative leaf development with plants in the non-agglomerated treatment slightly more advanced than those in the agglomerated treatment (Table 4). Plants in the non-agglomerated treatment of HECO reached an early stage of reproductive maturity. Plants of POSE and PSSP in both of the treatments at Reese Creek reached secondary stages of plant growth with stem elongation and palpable nodes. Height and phenology results suggest HECO, POSE, and PSSP will persist at Cinnabar, and POSE and PSSP will persist at Reese Creek. The phenology data suggest the conditions at Cinnabar may be less favorable for plant development than at Reese Creek. The Cinnabar site may be more exposed to wind desiccation than the Reese Creek site.

Table 4. The average plant growth stage† by species for the seed agglomeration treatments (with and without) in 2012 and 2013 at Cinnabar and Reese Creek.

	Cinnabar				Reese Creek			
	2012		2013		2012		2013	
Species	No Treat.	Treat.	No Treat.	Treat.	No Treat.	Treat.	No Treat.	Treat.
ELTR	V1	V1	Vn	Vn	E2	E2	none	none
HECO	V0	V1	R1	Vn	V2	V1	none	none
POSE	V0	V0-V1	V2	V1	Vn	Vn	En	En
PSSP	V1-V2	V0	Vn	Vn	Vn	Vn	E2	E2
ACHY	V0	V0	V2‡	none	V1	Vn	none	none
KOMA	V0	V0	none	none	V1	V2	none	none
LECI	V1	V0-V1	V2	V1‡	V2	V2	none	none
NAVI	V0-V1	V0	none	none	V1	V2	none	none

† In order from least to more advanced plant growth: V0 Emergence of first leaf; V1 first leaf collared; V2 second leaf collared; Vn >three leaves collared; E2 second node palpable/visible; En >three nodes palpable/visible; R1 Inflorescence emerged, first spikelet visible.
‡ Plants measured as present out of the sampled area and in the seeded plot.

- **Summary:** The results of Study 1 support our hypothesis that species establishment would vary by site. At Cinnabar, PSSP, HECO, and ELTR had better establishment than the other species tested and are recommended for this site. At Reese Creek, PSSP, POSE, and ELTR had better establishment than the other species tested and are recommended for this site. The results support rejecting the hypothesis that the seed agglomeration treatment improves establishment regardless of species, and we do not recommend this treatment.

Study 2—Observe PSSP establishment after broadcast seeding and covering with a mulch of HECO hay that was harvested with the seed. We expect to observe PSSP and HECO establishment under the mulch treatment.

- **Methods:** At the Reese Creek site, PSSP seed was broadcast at a rate of 50 pure-live-seed per square foot in a 10 ft. by 40 ft. area and covered with a 3-inch mulch layer of HECO seed hay. An adjacent 10 ft. by 40 ft. area was similarly mulched with the HECO seed hay without broadcast seeding PSSP. At the Cinnabar site, PSSP seed was broadcast at a rate of 25 pure-live-seed per square foot in a 20 ft. by 40 ft. area and covered with a 1-inch mulch layer of HECO seed hay. An adjacent 20 ft. by 40 ft. area was similarly mulched with the HECO seed hay without broadcast seeding PSSP. The mulched seed hay was “crimped” into the top inch of the soil surface at both sites, using the double-disk openers on the cone seeder. The study was not replicated.

- **Evaluations:** In late July 2012, PSSP and HECO plants were counted from 10 randomly located 20 cm by 50 cm frames in the seed hay mulch plots (with and without bluebunch wheatgrass) at both sites.

- **Analysis:** No analysis was done. Observations are reported.

- **Results:** In 2012, in the HECO seed-hay mulch plots, there were averages of 65 HECO plants/m^2 at Cinnabar, and 97 HECO plants/m^2 at Reese Creek (Table 5). No plants of PSSP were found at either site. In 2013, no counts were conducted due to the thick layer of mulch and the difficulty in confidently distinguishing seedlings by species. We expected the mulch to facilitate bluebunch wheatgrass establishment by reducing the desiccating effects of solar soil heating and wind, and poor soil water holding capacity. The results do not support facilitation of PSSP, but support using HECO hay seed mulch as a seeding method for this grass.

Table 5. The average (n=10) densities (plants/m^2) by species for the needle and thread seed hay mulch treatment in 2012 and 2013 at Cinnabar and Reese Creek.

	Cinnabar		Reese Creek	
	2012	2013	2012	2013
HECO	65	NA	97	NA
PSSP	0	NA	0	NA

- **Summary:** Study 2 showed that using HECO seed hay was an effective way to seed this species, but it did not facilitate the establishment of bluebunch wheatgrass. A less thick mat of mulch may have a different result.

Study 3—Determine the effect of prescribed burning on desert alyssum density. We hypothesize alyssum densities will be reduced by burning.

- **Methods:** In October 2011, YNP used a prescribed burn within the 100 ft x 100 ft test area inside the two exclosures to reduce litter prior to drill-seeding the native seed trial plots. During evaluation of the test plots, it was observed that desert alyssum densities were lower in the burned area than in the test plots not burned. The third study determined the difference in desert alyssum between the burn and not-burned areas in the exclosures.

- **Evaluations:** In late July 2012 and early July 2013, desert alyssum plants were counted within twenty 20 cm by 50 cm frames randomly located on the prescribed burn area and on the adjacent not-burned area. At Reese Creek, crested wheatgrass was observed reestablishing within the exclosure and its percentage canopy cover was estimated from 20 randomly located 20 cm by 50 cm frames in the burned plots and in unburned adjacent areas at Reese Creek.

- **Analysis:** The effect of prescribed burn on alyssum was tested using a split-plot in time ANOVA model with burn treatment as the whole plot, year as the sub-plot, and the interaction of burn by year. Tukey's means separations (α=0.05) were used to determine differences among means for main effects and interactions when f-test p-values were ≤0.1.

- **Results**—Averaged over both treatments and years, seedling densities were greater at Cinnabar (548 plants/m^2) than Reese creek (215 plants/m^2). At Cinnabar, averaged over burn treatment [Burn and No Burn (Year main effect p<0.0001)], density increased from 24 plants/m^2 in 2012 to

85 plants/m^2 in 2013. When averaged over both years (burn main effect $p<0.0001$), density was greater where there was no burn (800 plants/m^2) as compared to where it was burned (300 plants/m^2). At Reese Creek, density was greatest in 2012 where there was no burn (610 plants/m^2), then decreased to 220 plants/m^2 in 2013, which was still greater than in the burn treatment in both 2012 (6 plants/m^2) and 2013 (31 plants/m^2). These results support fall prescribed burning as a management to reduce desert alyssum density, most likely by killing seeds on the soil or in intact pods on plants. The analysis indicates the reduced seedling density will persist for at least 2 years. At Cinnabar, litter from the annual grain cover crop was more even than at Reese Creek and carried a more consistent and hotter fire. At Reese Creek, it is suspected the steep decline in desert alyssum in the No Burn treatment is the result of glyphosate application in spring of 2013 to control a resurging crested wheatgrass population (see below).

- Desert alyssum seedling densities in the No Burn (perennial grass study plots) and Burn (cereal grain cover crop) treatments at Cinnabar and Reese Creek in 2012 and 2013 are listed in Table 6.

Table 6. The mean (n=20) densities (plants/m^2) of desert alyssum in the No Burn and Burn treatments at Cinnabar and Reese Creek in 2012 and 2013.

	Cinnabar		Reese Creek	
	2012	2013	2012	2013
No Burn	490	1110	610	6
Burn	5	590	220	30

- At Reese Creek in 2013, there was an estimated 20% canopy cover/m^2 of crested wheatgrass in the Burn treatment (cereal grain cover crop) in which no chemical control took place. No crested wheatgrass plants were found in the No Burn treatment (perennial grass study plots) where chemical control took place in spring of 2013. Crested wheatgrass was becoming a significant component of the plant community in 2012 despite earlier control efforts. Crested wheatgrass was planted by the National Park Service in the 1950s as a restoration/forage crop, but it was partially replaced during the turn of the 21st century by desert alyssum probably as a result of long-term drought conditions and heavy grazing pressure. Its resurgence at Reese Creek is likely the result of excluding large ungulate grazers, the reduction of desert alyssum by glyphosate application, and persistence in the seed bank. Prescribed burning may have also temporarily increased available soil nitrogen thereby improving conditions for crested wheatgrass establishment.

- **Summary:** Study 3 supports fall prescribed burning as an effective management tool to reduce dessert alyssum density, at least during the establishment year of a seeding. The resurgence of crested wheatgrass in the Reese Creek exclosure suggests this species is still a part of the plant community and may increase after establishment of the seeded permanent native plant community.

Study 4—The goal of the study is to determine if differences exist in establishment and growth of park-collected versus commercial or non-park materials. A secondary objective is to use the functional performance results of this study to evaluate the appropriateness of using non-Park plant materials to more cost-effectively revegetate vast areas in the Gardiner Basin.

- **Methods:** The Bridger PMC assembled, weighed and packaged all seed, then organized the packets in the correct planting order for both test sites (Table 1). At the Cinnabar site, the study area was burned in October 2011 and lightly harrowed a few days prior to planting. At the Bridger site, the study area had been maintained in fallow condition for many years.

- The study was installed at Cinnabar and the Bridger PMC on April 26 and April 29, 2013, respectively. The drill-seeded plots were installed with the Bridger PMC's push-type, single-row cone seeder. The two study areas were planted in a Randomized Complete Block Design consisting of two entries of five species with four replications (Appendix Figure 1). Each entry was seeded in two rows with 1 foot between rows, at a length of 12 feet. Seeds were planted at a rate of 50 pure-live-seeds per foot to an approximate depth of ¼ to ½ inch. A 2-inch by 8-inch weed barrier pin was used to mark the top and bottom of the first row in each plot. Long-term evaluations will include emergence (frequency grid count per square foot), growth (height, biomass), and reproduction (seeds and viability). Genetic sampling and analysis will be done by Washington and Lee University.

- **Evaluations**: In 2013, due to slow germination and small seedling size, plant establishment was rated from 1 to 5, with 5 best. Plots with 1 to 12 seedlings were rated as 1, while plots with greater than 100 seedlings were rated as 5.

- **Analysis:** No analysis was done. Observations are reported.

- **Results:** There were 40 seeded plots installed at the two sites, each with an approximate dimension of 20 feet by 48 feet (0.022 acre). Ocular estimates of stand establishment were determined for seeded grasses at Cinnabar and the Bridger PMC on July 2 and July 9, 2013, as shown in Figure 1.

- At Cinnabar, the average performance rating was highest for YNP bluebunch wheatgrass, followed by 'Pryor' slender wheatgrass, 'Lodorm' green needlegrass, and 'Rimrock' Indian ricegrass. There were no seedlings of YNP green needlegrass or Indian ricegrass. Very few desert alyssum plants were present in the Cinnabar study area, which was burned in September 2011.

- At the Bridger PMC, the average performance rating was highest for Pryor slender wheatgrass, followed by YNP slender wheatgrass, Lodorm green needlegrass, YNP bluebunch wheatgrass, and both entries of Indian ricegrass. An evaluation of reproductive capability was conducted on August 13, with only Pryor slender wheatgrass developing fully emerged spikelets (without peduncle fully elongated) in two of the four replications.

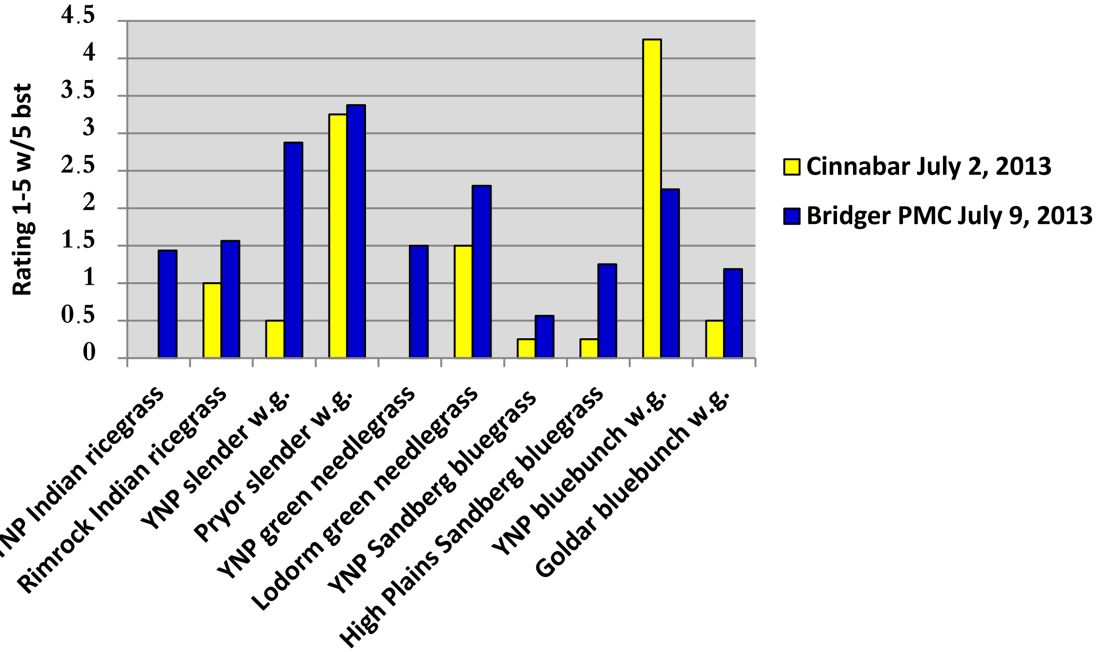

Figure 1. Performance Ratings of YNP and NRCS Plant Materials Grasses.

Additional Information:

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Table 1. Comparative Evaluation Planting. The YNP and PMP native grass seed lot specifics and seeding rates as planted at the Cinnabar Site and the Bridger PMC on April 26 and April 29, 2013, respectively.

Species	Accession	Source	Lot Number	Purity	Germ.	PLS[†]	Number Seeds/gr.	Number Seeds/ft.	Number Seeds/row	Bulk wt./row	Bulk wt./plot
				%	*%*	*%*				*gr*	*gr*
Indian ricegrass	9081862	YNP	SWC-07-YNP-64	0.8873	0.68	0.6034	594	50	600	1.68	3.35
Indian ricegrass	Rimrock	BPMC	SFD-04-FLD20	0.9987	0.99	0.9887	341	50	600	1.78	3.55
Slender wheatgrass[‡]	9081526	YNP	SWC-12-YNP-64	0.9809	0.98	0.9543	254	50	600	2.47	4.95
Slender wheatgrass	Pryor	BPMC	SFD-10-FLD18	0.9958	0.95	0.9460	214	50	600	2.97	5.94
Green needlegrass	9081773	YNP	SCO-05-YNP-43	0.9920	0.94	0.9325	377	50	600	1.71	3.42
Green needlegrass	Lodorm	NDPMC	SFD-06-MINOT-XN	0.9998	0.95	0.9498	370	50	600	1.71	3.41
Sandberg bluegrass	9087868	YNP	SCO-10-YNP-IDPMC	0.9702	0.75	0.7277	2,093	50	600	0.39	0.79
Sandberg bluegrass	High Plains	BPMC	SFD-06-FLD13	0.9852	0.92	0.9064	2,037	50	600	0.32	0.65
Bluebunch wheatgrass	9087860	YNP	SCO-11-YNP-148A	0.9650	0.93	0.8975	348	50	600	1.92	3.84
Bluebunch wheatgrass	Goldar	IDPMC	SCO-01-29	0.9845	0.85	0.8368	306	50	600	2.34	4.68

[†] Pure-Live-Seed.
[‡] Average of 13 lots.

APPENDIX B: SUMMARY OF WEED CONTROL EFFORTS ON PROJECT VEGETATION RESTORTATION SITES IN THE GARDINER BASIN.

Weed Control Treatments for Gardiner Basin Restoration Project		
Cinnabar Enclosure	**Stephens Creek Enclosure**	**Reese Creek Enclosure(s)**
May 2009 Treated 12 acres with Express herbicide only and 10 acres with Express & Roundup mixed	June 2009 Treated Stephens Creek enclosure with Roundup	June 2009 Treated 4-acre section with Roundup targeting crested wheatgrass
May 2010 Treated 21pprox.. 3-acre middle section of enclosure for annual wheatgrass	May 2010 Treated 21pprox.. 2-acre southern strip of enclosure for annual wheatgrass July 2010 Hand-pulled 25-20 gallon bags of annual wheatgrass with MCC crew	May 2010 Treated entire Reese Creek enclosures with Roundup July 2010 Spot treated Reese Creek enclosures with Roundup for crested wheatgrass September 2010 Partially retreated Reese Creek enclosures with Roundup for crested wheatgrass
Spring/Summer 2011 Broadcast sprayed 21pprox.. 4-acre section with Roundup for annual wheatgrass Spot treated with Roundup for crested wheatgrass October 2011 Prescribe burn a 100 ft x 100 ft parcel to prep site for native seeding trials	Spring/Summer 2011 Broadcast sprayed areas of enclosure with Roundup for annual wheatgrass Spot treated with Roundup for crested wheatgrass	Spring/Summer 2011 Spot treated with Roundup for crested wheatgrass October 2011 Spot treated with Plateau and surfactant perimeters of enclosures for cheat grass October 2011 Prescribe burn a 100 ft x 100 ft parcel to prep site for native seeding trials
April 2012 Spot treated with Roundup for annual wheatgrass May 2012 Spot treated with Roundup for crested wheatgrass August 2012 Hand-pulled 10-15 gallon size bags of crested wheatgrass with MCC crew October 2012 prescribed burn 23-acre parcel	April 2012 Broadcast sprayed over winter wheat areas of enclosure for broadleaf alyssum with Express XP (a broadleaf herbicide) May 2012 Spot treated with Roundup for crested wheatgrass	April 2012 Spot treated with Roundup for cheat grass June 2012 Spot treated with Roundup for crested wheatgrass August 2012 Hand-pulled 10-15 gallon size bags of crested wheatgrass with MCC crew
March 2013 complete prescribed burn of 23-acre parcel April 2013 Harrowed areas of enclosure for annual wheatgrass and alyssum May 2013 Broadcast sprayed with Roundup areas of enclosure for annual wheatgrass at a rate of 1 quart per acre	April 2013 Harrowed areas of enclosure for annual wheatgrass May 2013 Broadcast sprayed with Roundup areas of enclosure for annual wheatgrass at a rate of 1 quart per acre May 2013 Spot treated with Roundup for crested wheatgrass	April 2013 Broadcast sprayed entire enclosures with Roundup at a rate of 3 quarts per acre May 2013 Spot treated with Roundup for crested wheatgrass

<u>APPENDIX C:</u> SUMMARY TABLES OF PLANTING EFFORTS ON VEGETATION RESTORATION SITES IN THE GARDINER BASIN.

Cover Crop and Native Plant Seeding for Gardiner Basin Restoration Project		
Cinnabar Enclosure	**Stephens Creek Enclosure**	**Reese Creek Enclosure(s)**
May 2009 Seeded entire enclosure in spring barley September 2009 Seeded entire enclosure in winter wheat	September 2009 Seeded entire enclosure in winter wheat	
May 2010 Partially-seeded 22pprox.. 14 acres of spring barley (the other 8 acres had productive winter wheat growing from September 2009 seeding) September 2010 Seeded entire enclosure with winter wheat	June 2010 Partially-seeded 4.75 acres of spring barley (the 2.25 acres had productive winter wheat growing from September 2009 seeding) September 2010 Seeded entire enclosure with winter wheat	September 2010 Seeded entire Reese Creek enclosure(s) in winter wheat
May 2011 Partially-seeded enclosure with spring barley after spraying areas of enclosure for annual wheatgrass September 2011 Seeded entire enclosure in winter wheat	May 2011 Partially-seeded enclosure in spring barley after spraying areas of enclosure for annual wheatgrass September 2011 Seeded entire enclosure in winter wheat	May 2011 Seeded spring barley in winter wheat rows and bare spots after spot-spraying for crested wheatgrass September 2011 Seeded entire enclosure(s) with winter wheat
May 2013 Seeded entire enclosure with spring barley	May 2013 Seeded entire enclosure with spring barley	May 2013 Seeded entire enclosures with spring barley
October 2013 Drill-seeded entire enclosure with native seed mix formula and a 30’ buffer around 3 sides of enclosure with native test seed mix left-over from calibrating the seeder November 2013 Broadcasted areas of enclosure with a shrub mix collected from the local area	October 2013 Drill-seeded entire enclosure with native seed mix formula November 2013 Broadcasted areas of enclosure with a shrub mix collected from the local area	November 2013 Broadcast-seeded banks of enclosure(s) with native needle-and-thread grass bales and Sanbergs bluegrass native seed at a rate of 22pprox.. 14 pounds per acre

APPENDIX D: Secured funding, allocated by fiscal year, for the pilot vegetation restoration project in the Gardiner Basin.

FY08 - $215,000	FY12 - $112,944
FY09 - $240,500	FY13 - $128,300
FY10 - $49,000	FY14 - $132,285
FY11 - $112,500	FY15 - $22,930 (1ST QTR ONLY)

TOTAL 8 YRS = $1,013,459 (/50 ACRES = $20,269/ACRE)

Appendix E: Actual and projected (P) costs associated with the pilot vegetation restoration project in the Gardiner Basin, fiscal years 2008-2015.

NRCS SEED PRODUCTION:	$397,023 (39%)*
SALARIES/CROSS CHARGES P:	$342,733 (34%)
FENCE CONTRACTS:	$163,770 (16%)**
EQUIPMENT P:	$69,888 (7%)
HERBICIDES/DYE P:	$19,165 (2%)
COVER CROPS/SEED P:	$17,846 (2%)
SOIL SAMPLES P:	$3,034 (< 1 %)
	$1,013,459

* ~$10,000 per acre per year

** $9.96 and $13.17 per linear foot