



# Cheatgrass and Red Brome abundance following post-fire revegetation treatments in a Pinyon- Juniper Community at Parashant National Monument, Arizona

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## Executive Summary

On Memorial Day 1999, a 16,000 acre fire occurred near Hobbie Canyon and Tweeds Point on the Arizona Strip of Mohave County, Arizona. The fire mostly burned a Pinyon-Juniper (*Pinus edulis*, *Juniperus osteosperma*) community. Bureau of Land Management (BLM) developed a plan for revegetating the burned areas, including aerial seeding and harrowing (shallow surface disturbance) to help establish seedlings. US Geological Survey (USGS) designed and implemented a research project to evaluate the costs and benefits of these activities with respect to plant diversity, above ground production, and abundance of cheatgrass and red brome (*Bromus tectorum* and *Bromus madritensis* ssp. *rubens* [formerly *Bromus rubens*], respectively) and other alien plant species.

Four sites were selected within the burn complex to represent key vegetation and/or soil types. At each of these sites, four plots with different revegetation treatments were established (N=16 treatment plots). The four treatments at each site included unburned (control); burned with no additional treatments; burned with commercial seed mix applied; and burned with seed mix applied and harrowed using a 6x6 foot metal rake. Annual plant production and species richness were measured on each of the sixteen plots. These data were statistically evaluated using Analysis of Variance for responses quantified in a random complete block design. In 2000 and 2001, perennial plant cover, density and species richness were also measured. Perennial plant parameters were not measured in 2002 due to extremely poor precipitation during the winter of 2001/2002 and subsequent spring. In 2003, these variables will again be measured to determine the recovery of perennials and establishment of seeded species. This report provides analysis and a summary of information collected two years after revegetation treatments were applied. A brief summary of perennial plant cover, density and species richness is also included based on 2000 and 2001 data. For more detailed analysis of perennial data, please see previous reports.

Although measurements have been made for a short period of time, the vegetation shows the signs of some treatment differences. Seeding, with or without harrowing, changed perennial species composition by establishment of seeded species, but did not increase perennial cover or density compared to untreated burn sites. Indeed, successful seeded species appear to have displaced other post-fire perennial species in seeded burn plots. Harrowing did not influence which seeded species thrived in the post-fire environment. Despite an increase from our sampling in 2000, perennial cover in 2001 was still greater on control plots than on any of the burned plots. Regardless of treatment, herbaceous perennials dominated the burned plots, while unburned areas were dominated by the long-lived woody perennials juniper (*Juniperus osteosperma*), blackbrush (*Coleogyne ramosissima*) and big sagebrush (*Artemisia tridentata*).

Production and species richness of annual plants increased after burning, but no additional increase or decrease was attributed to seeding or harrowing burned plots. Annual production and species richness increased in 2001 over the values in 2000 and then decreased again in 2002, even on the unburned control, emphasizing the importance of abiotic factors, such as rainfall, to revegetation. Exotic annual species production, likewise, was higher in 2001 than in 2000 or 2002. The combined production of all exotics was higher on all burned plots, but unaffected by any of the treatments applied. Burning alone and seeding burned areas were not found to increase cheatgrass and red brome production, but harrowing was, possibly by bringing buried seed to the surface.

## Abstract

Land managers have a need for unbiased evaluation of management activities subsequent to wildfire. The specific goals of such activities include reducing soil erosion, controlling the invasion of exotic species such as cheatgrass (*Bromus tectorum*) and red brome (*Bromus madritensis* ssp. *rubens*), and establishing a diverse and productive plant community for livestock and wildlife. We assessed the effects of non-intervention, seeding, and seeding with harrowing at four sites of burned Pinyon-Juniper habitat in Parashant National Monument. Although only two years have passed since treatments were applied, interesting results have started to develop.

Seeding changes perennial species composition by establishment of seeded species, but does not increase over-all perennial cover or density compared to the untreated burn. Harrowing does not change this result, nor does it influence which seeded species thrive in the post-fire environment. Despite an increase from 2000 measurements, 2001 perennial cover was still below control levels on all burn treatments and herbaceous perennials dominated burned plots.

Annual production and species richness increased after burning, and seeding or harrowing had no effect on this pattern. Annual production and species richness fluctuated between years, even on the unburned control, which indicates the importance of abiotic factors in recovery. Exotic annuals overall showed this same trend, and were unaffected by seeding or harrowing. Cheatgrass and red brome, in contrast, were increased by harrowing in combination with burning and seeding.

## Introduction

**Background.** The Bureau of Land Management (BLM) is charged with stewardship of public lands by protecting natural resources, which includes implementing treatments to reach management goals and responding to anthropogenic or natural disturbances. Increased habitat disturbance and greater public interest in restoring land have brought many revegetation practices into question. This report responds to the need to quantify community changes that occur as a result of prescribed management treatments following wildfire.

One of the most widespread disturbances in natural communities in the southwestern United States is wildfire. During the past 100 years invasive Mediterranean grasses have encroached onto private and public lands infesting most of the Great Basin (Mack 1981, Mack and Pyke 1983, Whisenant 1990,

Young et al. 1987), Mojave Desert (Duck et al. 1995, Brooks 1998, Brooks and Esque 2002) and Sonoran Desert (McAuliffe 1995, Esque and Schwalbe 2002, Esque et al. 2002). These grasses promote wildfires via a positive feedback process known in other systems as the grass-fire cycle: flammable invasive grasses ignite fires, native vegetation is injured or killed, and invasive grasses continue to reestablish and promote future wildfires (D'Antonio and Vitousek, 1992). The grass-fire cycle can threaten ecosystem processes, biodiversity, recreational use and economic development, making an understanding of this process a high priority for land managers (Billings, 1992). In an effort to stabilize soil and reestablish vegetation following wildfires, BLM applies a variety of management prescriptions including, but not limited to, aerial seeding, mechanical sowing of seed mixtures, herbicides or no intervention. In this report we refer to combinations of these activities as experimental treatments.

**Project History.** In May of 1999 approximately 16,000 acres of Pinyon-Juniper community burned near Jump Canyon and Tweeds Point, Mohave County, Arizona. BLM planned to apply a standard mixture of seed from an airplane and then disturb the soil surface by "chaining" to establish seedlings. The cost of this operation was considerable, and the Washington Office of BLM suggested that a research component be included in the project. The Arizona Strip District of BLM contacted the USGS for technical consultation about a research component in October of 1999. During the interim the site was included in a new administrative jurisdiction as the Parashant National Monument. This new designation opened further public discussions about management activities. As a result, the area was not chained, but a lightweight harrow was dragged over the area with an ATV to facilitate the mixing of seeds and soil. During August of 1999, a violent summer rainstorm caused noticeable erosion to some of the burned area. USGS developed an experimental design to address key management questions, and BLM implemented the experimental treatments for this collaborative research project.

This annual report presents results from 2000, 2001 and 2002 for the project. The reader will observe some redundancy with the first and second annual reports. We considered it beneficial to provide all relevant materials, each year, in successive reports such that each report has sufficient information to stand alone.

**Project Goals.** The primary BLM objective is to implement and evaluate management activities subsequent to a catastrophic wildfire with the specific goals of reducing soil erosion, controlling the invasion

of brome grasses (cheatgrass - *Bromus tectorum* and red brome - *Bromus madritensis* ssp. *rubens*) and establishing a diverse and productive plant community for livestock and wildlife. Accurate quantification and analysis of management prescriptions following this and future wildfires will assist BLM in weighing the costs and benefits of revegetation activities in Pinyon-Juniper communities on public lands. The mission of the USGS is to provide scientific expertise for the evaluation and improved management of public lands. The data collected for research and monitoring must be replicated and reproducible for robust statistical analysis and provide levels of confidence under different treatments.

### General Research/Management Questions

- 1) Which of four treatment combinations (i.e. burning only, burning and seeding, burning and seeding and harrowing, or no manipulations [control]) provides the greatest benefit to production and species richness after fire in a Pinyon-Juniper community?
- 2) Do treatments increase or decrease cheatgrass and/or red brome and other alien plant infestations?
- 3) Is post-fire soil erosion reduced as a result of treatments? Soil erosion monitoring was established at the Bin Tank site by BLM soil scientist, Robert Smith, and reported elsewhere.

## Methods

**Study Plots.** The experimental design consists of 4 pre-selected blocks: One block each in a rocky substrate (named the Ancient Flake site), a rocky substrate with moderately well developed soil (named the Walk-In site), a deep loamy soil (named the Hobbie Canyon site) and a gravelly soil (named the Bin Tank site). Four treatment combinations were randomly assigned to plots within each block: 1) unburned (control); 2) burned with no manipulation; 3) burned with commercial seed mix applied; 4) burned with commercial seed mix applied followed by harrowing with a 6 X 6 foot metal rake designed to disturb the soil surface and mix in the seed. Seed was distributed onto two of the four blocks aerially and on the other two blocks from an ATV. Three of the blocks have 2.25 hectare plots while the Hobbie Canyon site has 1.00 hectare plots, due to geographical restrictions. The total number of treatment plots is 16 (4 blocks x 4 treatment plots). The UTM coordinates of all sixteen study plots are provided in Appendix I.

**Seeding.** A commercial seed mixture of nine species (Appendix II) was applied to the appropriate plots either by ATV or airplane. To serve as an experimental control for the success of aerial seeding, eight six-inch plastic bowls were systematically arrayed on each burned plot at the Ancient Flake and Walk-In

sites. The inside bottom of each bowl was covered with two-sided adhesive tape to catch seeds. One bowl was placed ~10m in from the middle of each plot edge. One bowl was also placed at forty-five degrees 5m from each corner of the plot. All bowls were picked up as soon as possible after seeding in order to minimize exposure to any other disturbance. The seeds in each bowl were identified and counted to assess the experimental application of seed.

**Vegetation.** Annual vegetation from plots was extrapolated to a per hectare basis rather than a per plot basis to accommodate inclusion of the smaller plots at the Hobbie Canyon site. Eleven 0.1m<sup>2</sup> annual plant quadrats per hectare were randomly placed within each treatment plot. Production was quantified by clipping aboveground live biomass and sorting by species. Samples were then oven dried at 40° C for three days and massed. Annual species richness was calculated based on all species found within 1m<sup>2</sup> quadrats placed around the biomass quadrats. The Hobbie Canyon site was not used in species richness analysis because richness is an area dependant factor (Elzinga et al. 1998). Because the Hobbie Canyon plots are smaller than those at the other sites, a smaller area was sampled and the species richness data are not comparable.

Five randomly placed permanent perennial plant transects (50m long) were established on each plot shortly after the treatments were applied. Line intercept was used to determine cover of grasses, shrubs and perennial forbs by species. Belt transects (2m wide and 50m long) were established to measure density and diversity of perennial plant species. Field vouchers of all annual and perennial plant species were collected and recorded. Occasionally some species were differentiated, but not identifiable due to senescence. In such cases, species were collected for future identification and assigned interim names (e.g. Unknown 1, Unknown 2, etc.). Appendix III provides a more detailed description of field collection techniques and Appendix IV lists the UTM coordinates of perennial plant transects.

**Research Design.** The study design is a single factor (management prescription) Analysis of Variance set in a randomized complete block design without replication. Site is the blocking factor, and within each block are the four treatment levels. We tested the following hypotheses:

H<sub>01</sub>: Production of annual plants is not different among treatments.

H<sub>02</sub>: Diversity of annual plants is not different among treatments.

H<sub>03</sub>: Production of all exotic annual species is not different among treatments.

$H_{04}$ : Production of *Bromus* spp. is not different among treatments.

$H_{05}$ : Cover and density of perennial plants are not different among treatments.

$H_{06}$ : Diversity of perennial plants is not different among treatments.

**Analysis.** The hypotheses were tested using Analysis of Variance (SAS version 7.0, Cary, NC) for responses quantified in a block design. Data were log-transformed when necessary to meet the assumptions of equal variance. When a significant treatment difference occurred, treatments were compared using Tukey's Studentized Range (HSD) Test at the  $\alpha=0.05$  level.

## Results

**Annual Plants.** Annual plant production was approximately 50 times greater in 2001 than in 2000 or 2002 averaged across all treatments ( $P<0.01$ , Figure 1). The unburned control had significantly less above ground annual production than the three burned treatments in all years ( $P<0.01$ ). However, annual plant production was not significantly different among the three burned treatments.

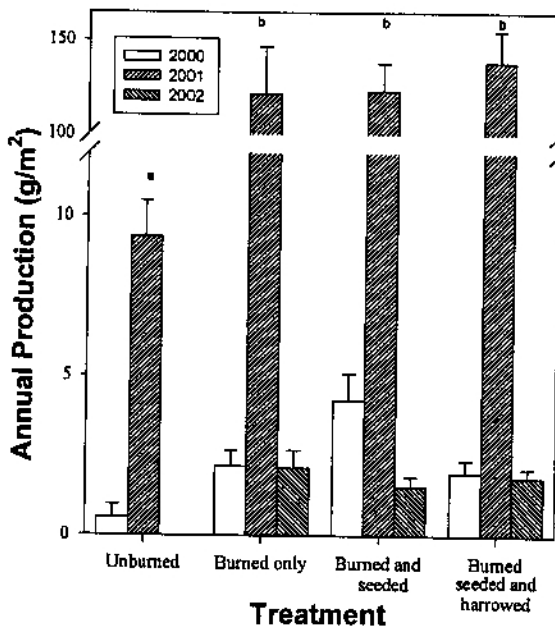


Figure 1. Mean annual plant production at Jump Canyon 2000, 2001 and 2002. Error bars represent one standard error above the mean. Significantly different treatments averaged over years are denoted by different letters.

Annual species richness was significantly higher in 2001 than 2000 or 2002 and significantly higher in 2000 than 2002 for all treatment types ( $P<0.01$ , Figure 2). Averaged over years, species richness was lower on the unburned plots than on any of the burned treatments

( $P<0.01$ ), but not statistically different on the burned treatments. Table 1 details the annual plant species found in each treatment plot during 2002.

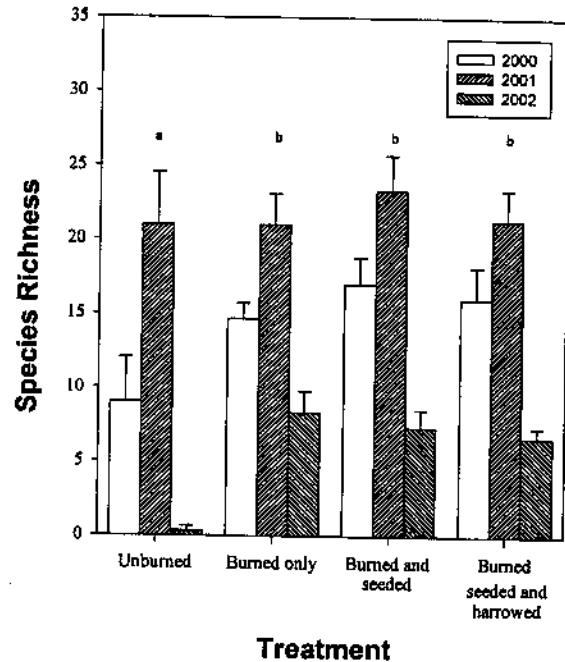


Figure 2. Mean annual plant species richness at Jump Canyon 2000, 2001 and 2002. Error bars represent one standard error above the mean. Significantly different treatments averaged over years are denoted by different letters.

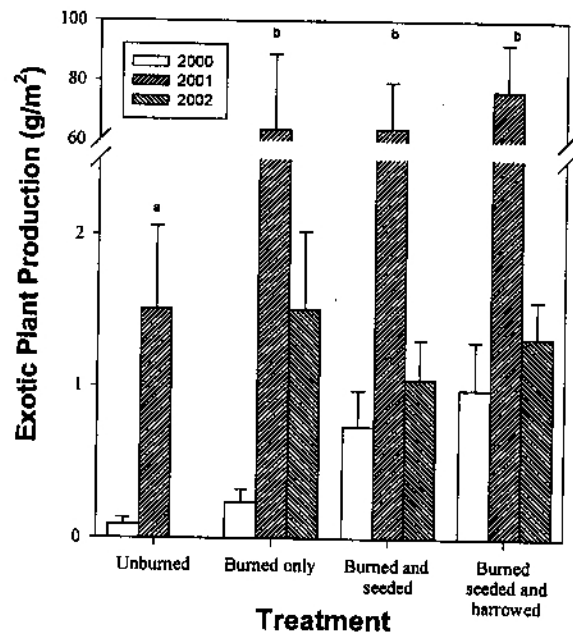


Figure 3. Mean exotic annual species production at Jump Canyon 2000, 2001 and 2002. Error bars represent one standard error above the mean. Significantly different treatments averaged over years are denoted by different letters.

Table 1. Species break-down of annual production at Jump Canyon, 2002.

Data are averaged across sites.

| Annual species                | Common Name        | Average Annual Biomass Production (g/m <sup>2</sup> ) |        |                |                          |
|-------------------------------|--------------------|-------------------------------------------------------|--------|----------------|--------------------------|
|                               |                    | Unburned                                              | Burned | Burned, Seeded | Burned, Seeded, Harrowed |
| <i>Astragalus</i> species     | Milkvetch          | 0.001081                                              | **     | 0.023105882    | 0                        |
| <i>Bromus madritensis</i>     | Red brome          | 0                                                     | 0.087  | 0.044258824    | 0.176942529              |
| <i>Bromus tectorum</i>        | Cheatgrass         | 0                                                     | 0.1072 | 0.069423529    | 0.144494253              |
| <i>Bromus</i> species         | --                 | 0                                                     | 1.1101 | 0.174235294    | 0.563218391              |
| <i>Cryptantha</i> species     | Cryptanth          | 0                                                     | 0.0547 | 0.003929412    | 0.118931034              |
| <i>Eriogonum nidularium</i>   | Wild buckwheat     | 0                                                     | 0.0218 | 0.059458824    | 0.018873563              |
| <i>Eriogonum</i> species      | Wild buckwheat     | 0                                                     | **     | **             | **                       |
| <i>Eriophyllum lanosum</i>    | Woolly sunflower   | 0                                                     | 0.1232 | 0.037976471    | 0                        |
| <i>Eriophyllum wallacei</i>   | Woolly sunflower   | 0                                                     | 0.063  | 0.019435294    | **                       |
| <i>Eriophyllum</i> species    | Woolly sunflower   | 0                                                     | 0.0202 | 0.008341176    | 0                        |
| <i>Erodium cicutarium</i>     | Filaree            | 0                                                     | 0.2059 | 0.759891765    | 0.438827586              |
| <i>Langloisia setosissima</i> | Bristly langloisia | 0                                                     | 0.0075 | **             | **                       |
| <i>Linanthus</i> species      | --                 | 0                                                     | 0      | 0              | **                       |
| <i>Mentzelia</i> species      | Blazing star       | 0                                                     | 0.2172 | 0.067788235    | 0.111701149              |
| <i>Phlox</i> species          | Phlox              | 0                                                     | 0      | 0              | **                       |
| <i>Salsola</i> species        | Tumbleweed         | 0                                                     | 0      | 0.002223529    | 0                        |
| unknown 2                     | --                 | 0                                                     | 0.065  | 0.055058824    | 0.206724138              |
| unknown 5                     | --                 | 0                                                     | 0      | **             | 0                        |
| unknown 6                     | --                 | 0                                                     | **     | 0              | 0                        |
| <i>Vulpia octoflora</i>       | Sixweeks fescue    | 0                                                     | 0.0357 | 0              | 0.033482759              |

\*\* Although this species was not plucked as production, it was found in the frequency quads.

Exotic annual species encountered in the plots were red brome (*Bromus madritensis*), cheatgrass (*Bromus tectorum*) and filaree (*Erodium cicutarium*). Production of exotic annuals was significantly higher in 2001 than in 2000 or 2002 and on all burned plots compared to the control ( $P < 0.01$ , Figure 3). Averaged across years, exotic production was not significantly different among any of the burn treatments.

Similarly, production of cheatgrass and red brome was significantly greater in 2001 than in 2000 or 2002 ( $P < 0.01$ , Figure 4). Averaged over years, the unburned control had less *Bromus* spp. production than the seeded and harrowed burn ( $P = 0.02$ ), while none of the other treatments were found different.

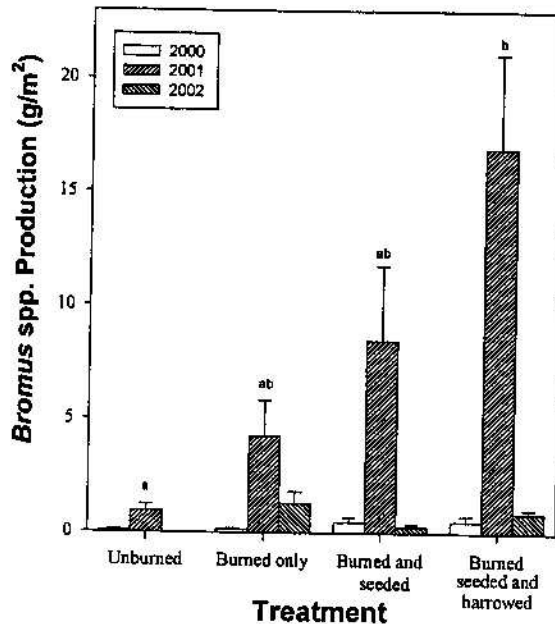


Figure 4. Mean *Bromus* spp. production at Jump Canyon 2000, 2001 and 2002. Error bars represent one standard error above the mean. Significantly different treatments averaged over years are denoted by different letters.

**Aerial Seeding.** Seed capture by the seed bowls showed that aerial application of the seed mix varied spatially within the plots. There was a small overlap of seeding onto the unseeded plots, but this overlap was minimal (Appendix V). Out of nine species, only sideoats grama (*Bouteloua curtipendula*) and sand dropseed (*Sporobolus cryptandrus*) seeds were found in bowls placed on the unseeded plots. Where aerial seeding occurred, we captured all of the seed species present in the seed mix except for western wheatgrass (*Agropyron smithii*).

**Perennial Plants.** There was 25% more perennial plant cover in 2001 than in 2000 averaged across all treatments ( $P < 0.01$ , Figure 5). This increase was primarily due to increased cover on the burned treatment plots with very little change on the unburned

control plots between years. The unburned control had approximately four and a half times more perennial plant cover than the three burned treatments ( $P < 0.01$ ). Perennial cover was not significantly different among these burned treatments.

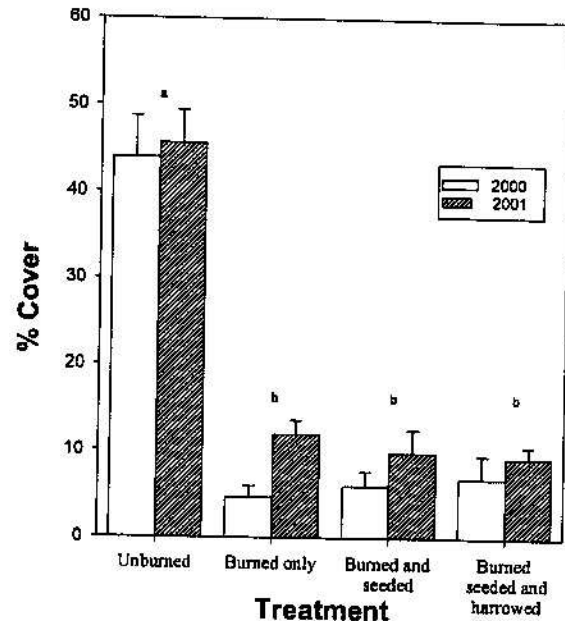


Figure 5. Mean perennial plant cover at Jump Canyon 2000 and 2001. Error bars represent one standard error above the mean. Significantly different treatments averaged over years are denoted by different letters.

Similar to cover, perennial plant density increased significantly from 2000 to 2001 ( $P < 0.01$ ; see previous reports for data), but did not differ significantly between treatments in either year ( $P = 0.58$ ). Perennial species richness was not significantly different between years ( $P = 0.46$ , see previous reports for data), nor was it significantly different between any of the treatments ( $P = 0.72$ ).

**Perennial Seeded Species.** A significantly greater percentage of perennial cover was composed of seeded species in 2001 compared to 2000 ( $P < 0.01$ , Figure 6). Treatments also differed significantly ( $P = 0.05$ ), but means comparisons could not discern individual treatment differences. Ephraim crested wheatgrass (*Agropyron cristatum*), pubescent wheatgrass (*Agropyron intermedium*), small burnet (*Sanguisorba minor*), and sand dropseed (*Sporobolus cryptandrus*) were the seeded species encountered on cover transects.

A greater density of seeded species also occurred in 2001 than in 2000 averaged over all treatments ( $P < 0.01$ , Figure 7). The unburned control had a significantly lower density of seeded species than the burned-seeded-harrowed treatment ( $P = 0.01$ ). The seeded species encountered during density measurements were Ephraim crested wheatgrass, pubescent wheatgrass, sideoats grama (*Bouteloua curtipendula*), small burnet and sand dropseed.

Table 2. Success of seeded plant species at Jump Canyon, 2001.

Success was measured as mean percent of seeded cover or mean percent of seeded density.

| Species                    | Percent of Seed Mix | Percent of Seeded Perennial Cover |        |                |                          |
|----------------------------|---------------------|-----------------------------------|--------|----------------|--------------------------|
|                            |                     | Unburned                          | Burned | Burned, Seeded | Burned, Seeded, Harrowed |
| Indian ricegrass           | 3.32                | 0.00                              | 0.00   | 0.00           | 0.00                     |
| Ephraim crested wheatgrass | 9.43                | 0.00                              | 28.46  | 51.81          | 40.98                    |
| Pubescent wheatgrass       | 4.71                | 0.00                              | 48.88  | 18.73          | 13.15                    |
| Western wheatgrass         | 2.59                | 0.00                              | 0.00   | 0.00           | 0.00                     |
| Sideoats grama             | 9.01                | 0.00                              | 0.00   | 0.00           | 0.00                     |
| Russian wild-rye           | 4.13                | 0.00                              | 0.00   | 0.00           | 0.00                     |
| Yellow sweet clover        | 3.06                | 0.00                              | 0.00   | 0.00           | 0.00                     |
| Small burnet               | 1.30                | 0.00                              | 22.66  | 29.47          | 20.87                    |
| Sand dropseed              | 62.45               | 0.00                              | 0.00   | 0.00           | 25.00                    |

| Species                    | Percent of Seed Mix | Percent of Seeded Perennial Density |        |                |                          |
|----------------------------|---------------------|-------------------------------------|--------|----------------|--------------------------|
|                            |                     | Unburned                            | Burned | Burned, Seeded | Burned, Seeded, Harrowed |
| Indian ricegrass           | 3.32                | 0.00                                | 0.00   | 0.00           | 0.00                     |
| Ephraim crested wheatgrass | 9.43                | 28.65                               | 32.74  | 43.33          | 43.03                    |
| Pubescent wheatgrass       | 4.71                | 0.00                                | 20.36  | 14.09          | 11.09                    |
| Western wheatgrass         | 2.59                | 0.00                                | 0.00   | 0.00           | 0.00                     |
| Sideoats grama             | 9.01                | 0.00                                | 0.00   | 0.00           | 0.08                     |
| Russian wild-rye           | 4.13                | 0.00                                | 0.00   | 0.00           | 0.00                     |
| Yellow sweet clover        | 3.06                | 0.00                                | 0.00   | 0.00           | 0.00                     |
| Small burnet               | 1.30                | 64.05                               | 46.73  | 42.59          | 43.84                    |
| Sand dropseed              | 62.45               | 7.30                                | 0.17   | 0.00           | 1.96                     |

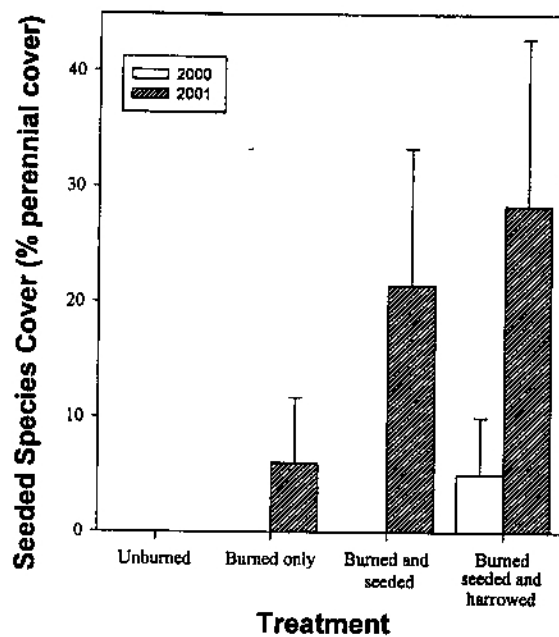


Figure 6. Mean seeded species cover expressed as a percentage of total perennial cover at Jump Canyon 2000 and 2001. Error bars represent one standard error above the mean.

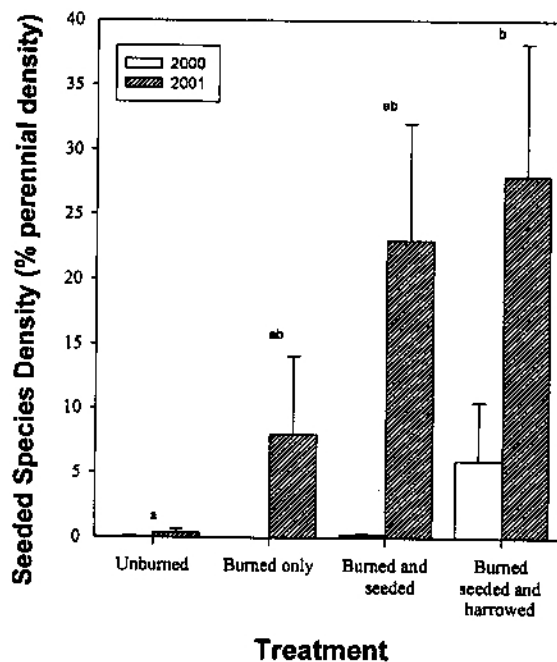


Figure 7. Mean seeded species density expressed as a percentage of total perennial density at Jump Canyon 2000 and 2001. Error bars represent one standard error above the mean. Significantly different treatments averaged over years are denoted by different letters.

Not all seeded species established equally well (Table 2). Indian ricegrass, western wheatgrass and Russian wild-rye (*Elymus junceus*), although seeded,

were not positively identified on any 2001 cover or density transects. Of the seeded species providing cover on burned plots, over half was supplied by Ephraim crested wheatgrass and pubescent wheatgrass, regardless of treatment. Ephraim crested wheatgrass was most successful on the two seeded treatments, while pubescent wheatgrass provided nearly 50% of seeded cover on the burned only treatment. These same two grass species contributed over half the seeded density on all three burn treatments, with small burnet also making a sizable density contribution to all treatments and even to the unburned control. In addition to the identified seeded species, there were many encounters with perennial grasses that could not be identified to species due to small size. Some of these unidentified grasses may well be seeded species.

## Discussion

The three dominant perennials in the Jump Canyon area – blackbrush, big sagebrush and Utah juniper – display slow post-fire re-establishment. Callison et al. (1985) documented no blackbrush recovery even 37 years after a fire, so the absence of this species two years after any burn is not unexpected. Big sagebrush is not thought to re-sprout on a population level after fire but needs a seed source for re-establishment, either in the seed bank or from unburned areas nearby (Barney and Frischknecht 1974). Considering the size and intensity of the Jump Canyon fire, it comes as no surprise to find very minimal re-establishment of sagebrush over all burn treatments. Juniper also shows little sign of recovery two years post fire, which is hardly unexpected for a large tree species. These same trends are observed throughout the Great Basin Desert. An increase from 2000 to 2001 in perennial plant density and cover over all treatments shows that revegetation is occurring, although different plant species dominate the burned areas than formerly inhabited the sites.

Although seeded perennials accounted for a large percentage of cover and density on both seeding treatments, their success did not result in an increase of either perennial cover or density. The rate of perennial revegetation is not increased two years after fire by either seeding or seeding and harrowing burned areas under these climatic conditions, which suggests biotic or abiotic limitations to this process. Seeding can, however, drastically alter species composition, at least shortly after treatment. Harrowing did not increase or decrease the success of seeded species, either individually or collectively, compared to seeding alone.

Although sand dropseed outnumbered other seeded species on the harrowed plots, this result was represented by only three plants. Considering the number of grass seedlings that could not be identified, sand dropseed did not demonstrate a very large

advantage over other species. Sand dropseed was also rarely found (two plants) in unburned plots, indicating it was present prior to the fire or because of contamination during aerial application of seeds. Contamination is possible since this species made up 62.45% of the seed mixture and was captured by seed bowls in unseeded burned plots. Sand dropseed has very small, light seeds that would be expected to travel readily (Burrows 1986). It is also possible that sand dropseed was already established in the area as a native and/or distributed during previous revegetation treatments. Further investigation of revegetation history in the area would be beneficial for determining the likelihood of these scenarios.

Bowls in the unseeded plots also captured sideoats grama seeds, which made up 9.01% of the seed mix. The seeds of this species are second-lightest in the seeding mixture and therefore may be expected to travel more easily than most others (Appendix II). Sideoats grama was not found established in any unseeded plots, however, so the extent of seeding contamination was probably minimal. The presence of sand dropseed, Ephraim crested wheatgrass, small burnet and Indian ricegrass (found in 2000) in unburned plots indicates that these species were likely established in the Jump Canyon area prior to the 1999 fire either as natives or from previous revegetation efforts.

The native grass species in the seed mix (Indian ricegrass, western wheatgrass, sideoats grama and sand dropseed) have had little measurable establishment success thus far, regardless of treatment. Western wheatgrass made up only 2.59% of the seed mixture and has heavy seeds compared to most of the other species, but was not detected with the seed bowls. With seeds unlikely to drift far, sparse seed dissemination may explain why this species was not encountered on any plot. Since recovery efforts on public lands are already beginning to focus on native plant species, it would be useful to compare seed mixture combinations ranging from current range mixtures to all native mixtures.

There are anecdotal and published reports of wildflower blooms after fire in desert areas (Loftin 1987). Similarly, we observed much higher annual plant production on all burned treatments compared to the unburned control. The revegetation treatments had no detectable effect on this increase in production. This suggests chemical changes in the soil (e.g. nitrogen flux) or reduction in competition from perennials as probable causes for the increase, although these were not monitored as a part of this study. The large inter-annual fluctuation in annual species richness and production, regardless of treatment, illustrates that variable abiotic factors have a large impact on recovery.

Overall, exotic annual species displayed the same production trends as did all annuals, with no change due to seeding or harrowing. Cheatgrass and red brome displayed the same annual pattern but a different treatment response than the other species. The seeded and harrowed burn had greater *Bromus* spp. production than the unburned control. In light of this finding, it is important to continue examining these species because exotic annuals such as cheatgrass have been shown to change the composition of native communities as well as affecting long-term rates and patterns of succession (Allen and Knight 1984).

## Conclusions

Three years is a short period of time in terms of ecological consequences. In spite of the short time period, the vegetation shows some treatment differences. Seeding, with or without harrowing, changed perennial species composition by establishment of species in the seed mixture, but it has not increased over-all perennial cover compared to the untreated burn. Instead, successful seeded species appear to replace other perennial species after fire. Despite an increase from 2000 measurements, 2001 perennial cover was still below control levels on all burn treatments and herbaceous perennials dominated burned plots.

Annual production and species richness increased after burning, but no additional change could be attributed to seeding or harrowing burned plots. Annual production and species richness fluctuated greatly between years, even on the unburned control, which indicates the importance of abiotic factors in recovery. Exotic annual species, although increased by burning, were unaffected by either seeding or harrowing. Cheatgrass and red brome, on the other hand, were increased by seeding and harrowing burned plots. Although two of the three years measured so far have had low precipitation, and therefore low *Bromus* germination, this suggests that soil disturbances following fire may encourage cheatgrass and red brome.

Soil erosion, which was visually evident on several of the burned plots, is an important factor in future revegetation activities and should be incorporated with this vegetation data. Further research should also focus on the seeding success of native plant species and their effect on perennial community composition.

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# Appendix I. UTM locations of Jump Canyon fire rehab study plots.

## Ancient Flake Site

Juniper (*Juniperus osteosperma*) on a rocky substrate.

| Treatment                   | Corner | Easting | Northing | Elevation | Error |
|-----------------------------|--------|---------|----------|-----------|-------|
| Unburned                    | NE     | 255611  | 4057440  | 1434      | 5.3   |
| Unburned                    | NW     | 255532  | 4057512  | 1433      | 4.9   |
| Unburned                    | SE     | 255589  | 4027311  | 1432      | 7.4   |
| Unburned                    | SW     | 255469  | 4057374  | 1437      | 5.1   |
| Burned only                 | NE     | 255729  | 4056670  | 1449      | 4.3   |
| Burned only                 | NW     | 255584  | 4056701  | 1457      | 4.3   |
| Burned only                 | SE     | 255702  | 4056522  | 1459      | 4.3   |
| Burned only                 | SW     | 255597  | 4056552  | 1469      | 7.4   |
| Burned and seeded           | NE     | 255543  | 4056679  | 1464      | 8.4   |
| Burned and seeded           | NW     | 255546  | 4056525  | 1470      | 5.4   |
| Burned and seeded           | NW     | 255393  | 4056663  | 1468      | 7.6   |
| Burned and seeded           | SW     | 255387  | 4056513  | 1468      | 7.7   |
| Burned, seeded and harrowed | NE     | 255711  | 4056435  | 1451      | 5.6   |
| Burned, seeded and harrowed | NW     | 255567  | 4056468  | 1472      | 5.4   |
| Burned, seeded and harrowed | SE     | 255722  | 4056287  | 1451      | 5.2   |
| Burned, seeded and harrowed | SW     | 255579  | 4056323  | 1466      | 4.8   |

## Bin Tank Site

Blackbrush (*Coleogyne ramosissima*) with a gravelly soil

| Treatment                   | Corner | Easting | Northing | Elevation | Error |
|-----------------------------|--------|---------|----------|-----------|-------|
| Unburned                    | NE     | 260107  | 4055055  | 1462      | 6.6   |
| Unburned                    | NW     | 259964  | 4055097  | 1455      | 5     |
| Unburned                    | SE     | 260043  | 4054914  | 1444      | 4     |
| Unburned                    | SW     | 259900  | 4054961  | 1432      | 8.1   |
| Burned only                 | NE     | 260432  | 4054847  | 1470      | 5.5   |
| Burned only                 | NW     | 260301  | 4054772  | 1462      | 5     |
| Burned only                 | SE     | 260511  | 4054718  | 1481      | 5.7   |
| Burned only                 | SW     | 260362  | 4054634  | 1450      | 4.9   |
| Burned and seeded           | NE     | 260275  | 4054962  | 1457      | 6.8   |
| Burned and seeded           | NW     | 260146  | 4054884  | 1450      | 7.3   |
| Burned and seeded           | SE     | 260354  | 4054833  | 1462      | 6.1   |
| Burned and seeded           | SW     | 260217  | 4054773  | 1447      | 7.3   |
| Burned, seeded and harrowed | NE     | 260603  | 4054578  | 1476      | 5.9   |
| Burned, seeded and harrowed | NW     | 260466  | 4054515  | 1454      | 5     |
| Burned, seeded and harrowed | SE     | 260675  | 4054444  | 1480      | 4.9   |
| Burned, seeded and harrowed | SW     | 260555  | 4054369  | 1463      | 7.8   |

## Appendix I (Continued)

## Hobble Canyon Site

Big sagebrush (*Artemisia tridentata*) with a deep loamy soil

| Treatment                   | Corner | Easting | Northing | Elevation | Error |
|-----------------------------|--------|---------|----------|-----------|-------|
| Unburned                    | NE     | 259176  | 4057311  | 1338      | 5.1   |
| Unburned                    | NW     | 259077  | 4057291  | 1340      | 5     |
| Unburned                    | SE     | 259199  | 4057211  | 1343      | 5.3   |
| Unburned                    | SW     | 259100  | 4057192  | 1343      | 5.1   |
| Burned only                 | NE     | 258946  | 4057676  | 1330      | 4.8   |
| Burned only                 | NW     | 258861  | 4057666  | 1326      | 4.9   |
| Burned only                 | SE     | 258977  | 4057573  | 1334      | 5.7   |
| Burned only                 | SW     | 258878  | 4057562  | 1334      | 4.9   |
| Burned and seeded           | NE     | 258331  | 4058735  | 1311      | 3.9   |
| Burned and seeded           | NW     | 258261  | 4058658  | 1305      | 4.5   |
| Burned and seeded           | SE     | 258406  | 4058663  | 1311      | 4.4   |
| Burned and seeded           | SW     | 258328  | 4058590  |           | 5.7   |
| Burned, seeded and harrowed | NE     | 258532  | 4058433  | 1318      | 6.4   |
| Burned, seeded and harrowed | NW     | 258448  | 4058376  | 1325      | 6.3   |
| Burned, seeded and harrowed | SE     | 258592  | 4058363  | 1434      | 21    |
| Burned, seeded and harrowed | SW     | 258512  | 4058302  | 1434      | 31    |

## Walk-In Site

Juniper (*Juniperus osteosperma*) with a moderately well developed soil

| Treatment                   | Corner | Easting | Northing | Elevation | Error |
|-----------------------------|--------|---------|----------|-----------|-------|
| Unburned                    | NE     | 262838  | 4057053  | 1624      | 7.2   |
| Unburned                    | NW     | 262710  | 4056983  | 1610      | 14    |
| Unburned                    | SE     | 262924  | 4056942  | 1609      | 5.1   |
| Unburned                    | SW     | 262789  | 4056868  |           | 7.4   |
| Burned only                 | NE     | 262279  | 4056039  | 1614      | 7.9   |
| Burned only                 | NW     | 262124  | 4056045  | 1632      | 9.9   |
| Burned only                 | SE     | 262283  | 4055891  | 1633      | 5.3   |
| Burned only                 | SW     | 262134  | 4055878  | 1632      | 4.6   |
| Burned and seeded           | NE     | 262280  | 4055815  | 1630      | 5.3   |
| Burned and seeded           | NW     | 262131  | 4055823  | 1626      | 5.6   |
| Burned and seeded           | SE     | 262287  | 4055663  | 1644      | 5.8   |
| Burned and seeded           | SW     | 262139  | 4055694  | 1637      | 5.5   |
| Burned, seeded and harrowed | NE     | 262464  | 4055803  | 1621      | 6.1   |
| Burned, seeded and harrowed | NW     | 262319  | 4055813  | 1619      | 7.3   |
| Burned, seeded and harrowed | SE     | 262454  | 4055655  | 1644      | 5.2   |
| Burned, seeded and harrowed | SW     | 262307  | 4055631  | 1642      | 30    |

## Appendix II. List of seeded species.

| Scientific name                                       | Common name                | Annual or Perennial | Native or Exotic | Percent of Seed Mix |
|-------------------------------------------------------|----------------------------|---------------------|------------------|---------------------|
| <i>Achnatherum hymenoides</i>                         | Indian ricegrass           | Perennial           | Native           | 3.32                |
| <i>Agropyron cristatum</i>                            | Ephraim crested wheatgrass | Perennial           | Exotic           | 9.43                |
| <i>Agropyron intermedium</i> var. <i>trichophorum</i> | Pubescent wheatgrass       | Perennial           | Exotic           | 4.71                |
| <i>Agropyron smithii</i>                              | Western wheatgrass         | Perennial           | Native           | 2.59                |
| <i>Bouteloua curtipendula</i>                         | Sideoats grama             | Perennial           | Native           | 9.01                |
| <i>Elymus junceus</i>                                 | Russian wild-rye           | Perennial           | Exotic           | 4.13                |
| <i>Melilotus officinalis</i>                          | Yellow sweet clover        | Annual              | Exotic           | 3.06                |
| <i>Sanguisorba minor</i>                              | Small burnet               | Perennial           | Exotic           | 1.30                |
| <i>Sporobolus cryptandrus</i>                         | Sand dropseed              | Perennial           | Native           | 62.45               |

## Appendix III. Detailed notes on field methods

### Field Schedule

- February 2000
  - Selected and marked study plots and buffer zones
- March 2000
  - Established sticky plates and seed bowls to determine spread of seeds
  - Aerially seeded and harrowed prescribed study areas
- June 2000
  - Collected annual plant production data
  - Established perennial transects and started to collect perennial plant data (finished in July)
- May 2001
  - Collected annual plant production data
- July 2001
  - Collected perennial plant data
- April 2002
  - Collected annual plant production data

### Perennial Transects

- Transects were located within the study plots by adding random numbers to the UTM coordinates of the southwest plot corner. This location became the south end of the transect.
- Each end was marked with a 1.5' re-bar. An aluminum tag with the transect number was attached to the south re-bar.
- Intercept data was collected starting from the south end.
- Different plant species sometimes overlapped inflating total cover.
- The transect line was used as the western edge of the belt transects.
- Species richness was determined by counting the number of species that occurred in the belt transects. When an unidentifiable species could be a species that was already tallied it was not tallied separately (i.e. the blanket category of perennial grass was not tallied if any other perennial grass species was listed separately).
- Only live vegetation was measured
- Individuals were included in the density data if more than 50% of the root crown fell within the belt transect.
- When individual plants were not clearly discernible (i.e. perennial grasses), the number of individuals was approximated by counting the number of clumps. Clumps were considered separate when less than 50% of their canopies overlapped and if their roots did not come from the same area of the ground.

### Annual Vegetation

- Only live vegetation was collected.
- Biomass samples were oven dried at 49°C (120°F) for three days.
- Species richness was determined by counting the number of species that occurred in the frequency quadrats (1 m<sup>2</sup>). When an unidentifiable species could be a species that was already tallied it was not tallied separately (i.e. *Bromus* spp. was not tallied if any *Bromus* species was listed separately).

### Statistical Analysis

- The perennial plant cover data from each transect within one study plot was summed and averaged over transects to get percent cover for all statistical analysis.
- The perennial plant density data from each transect within one study plot was summed and averaged over the transects to get number of individual per 100m<sup>2</sup> for all statistical analysis.
- The annual biomasses from all quadrats in one plot were averaged after conversion to g/m<sup>2</sup> for all analysis.
- Transformations (i.e. log to the base ten) were used on the data when necessary to account for unequal variances.

# Appendix IV- A. UTM locations of perennial plant transects.

Azimuth is the bearing from the south stake to the north stake including a 13 degree east magnetic declination

## Ancient Flake Site

| Treatment                   | Transect # | Azimuth | South stake UTM |          |       | North Stake UTM |          |       |
|-----------------------------|------------|---------|-----------------|----------|-------|-----------------|----------|-------|
|                             |            |         | Easting         | Northing | error | Easting         | Northing | error |
| Unburned                    | 76         |         | 255496          | 4057320  |       | 255517          | 4057367  | 4.5   |
| Unburned                    | 77         |         | 255543          | 4057273  |       | 255543          | 4057320  | 6.3   |
| Unburned                    | 78         | 355     | 255523          | 4057330  |       | 255518          | 4057379  | 5.3   |
| Unburned                    | 79         |         | 255488          | 4057319  |       | 255477          | 4057360  | 6.1   |
| Unburned                    | 80         |         | 255532          | 4057274  |       | 255543          | 4057325  | 5     |
| Burned only                 | 66         |         | 255642          | 4056640  |       | 255642          | 4056689  | 9     |
| Burned only                 | 67         |         | 255602          | 4056610  |       | 255593          | 4056658  | 5.8   |
| Burned only                 | 68         |         | 255692          | 4056609  |       | 255699          | 4056654  | 8.6   |
| Burned only                 | 69         |         | 255630          | 4056555  |       | 255634          | 4056605  | 4.8   |
| Burned only                 | 70         |         | 255717          | 4056597  |       | 255725          | 4056645  | 6.5   |
| Burned and seeded           | 71         |         | 255450          | 4056514  |       | 255451          | 4056572  | 7.1   |
| Burned and seeded           | 72         |         | 255477          | 4056600  |       | 255475          | 4056653  | 5     |
| Burned and seeded           | 73         |         | 255406          | 4056563  |       | 255409          | 4056612  | 6.7   |
| Burned and seeded           | 74         |         | 255398          | 4056517  |       | 255404          | 4056566  | 7.9   |
| Burned and seeded           | 75         |         | 255482          | 4056572  |       | 255485          | 4056622  | 6.7   |
| Burned, seeded and harrowed | 61         |         | 255631          | 4056378  |       | 255637          | 4056435  | 5     |
| Burned, seeded and harrowed | 62         |         | 255580          | 4056364  |       | 255587          | 4056412  | 3.3   |
| Burned, seeded and harrowed | 63         |         | 255720          | 4056403  |       | 255720          | 4056454  | 6.4   |
| Burned, seeded and harrowed | 64         |         | 255679          | 4056380  |       | 255681          | 4056431  | 4.1   |
| Burned, seeded and harrowed | 65         |         | 255699          | 4056391  |       | 255698          | 4056443  | 4.5   |

## Appendix IV- B.

## Bin Tank Site

| Treatment                   | Transect # | Azimuth | South stake UTM |          |       | North Stake UTM |          |       |
|-----------------------------|------------|---------|-----------------|----------|-------|-----------------|----------|-------|
|                             |            |         | Easting         | Northing | error | Easting         | Northing | error |
| Unburned                    | 41         | 17      | 259971          | 4054971  |       | 259987          | 4055023  | 5.3   |
| Unburned                    | 42         | 17      | 260009          | 4055000  |       | 260024          | 4055048  | 6.8   |
| Unburned                    | 43         | 17      | 260048          | 4055032  |       | 260059          | 4055080  | 5.8   |
| Unburned                    | 44         | 17      | 260004          | 4055034  |       | 260021          | 4055080  | 7     |
| Unburned                    | 45         | 17      | 259936          | 4054963  |       | 259946          | 4055011  | 4.8   |
| Burned only                 | 51         | 329     | 260412          | 4054674  |       | 260386          | 4054716  | 5.1   |
| Burned only                 | 52         | 329     | 260500          | 4054667  |       | 260478          | 4054708  | 4.3   |
| Burned only                 | 53         | 329     | 260500          | 4054646  |       | 260475          | 4054689  | 4.1   |
| Burned only                 | 54         | 329     | 260399          | 4054703  |       | 260371          | 4054744  | 7.2   |
| Burned only                 | 55         | 329     | 260432          | 4054678  |       | 260406          | 4054723  | 4.7   |
| Burned and seeded           | 56         | 325     | 260333          | 4054855  | 6.1   | 260302          | 4054894  | 3.9   |
| Burned and seeded           | 57         | 325     | 260337          | 4054831  |       | 260306          | 4054874  | 3.4   |
| Burned and seeded           | 58         | 325     | 260275          | 4054858  | 3.5   | 260242          | 4054895  | 11    |
| Burned and seeded           | 59         | 325     | 260295          | 4054782  |       | 260265          | 4054823  | 5.8   |
| Burned and seeded           | 60         | 325     | 260273          | 4054799  |       | 260244          | 4054839  | 7     |
| Burned, seeded and harrowed | 46         | 59      | 260561          | 4054451  |       | 260604          | 4054475  | 5     |
| Burned, seeded and harrowed | 47         | 59      | 260539          | 4054464  |       | 260579          | 4054495  | 7     |
| Burned, seeded and harrowed | 48         | 59      | 260566          | 4054387  |       | 260607          | 4054409  | 5.5   |
| Burned, seeded and harrowed | 49         | 59      | 260518          | 4054446  |       | 260562          | 4054470  | 7.6   |
| Burned, seeded and harrowed | 50         | 59      | 260505          | 4054461  |       | 260547          | 4054488  | 6.6   |

## Appendix IV - C

## Hobble Canyon Site

| Treatment                   | Transect # | Azimuth | South stake UTM |          |       | North Stake UTM |          |       |
|-----------------------------|------------|---------|-----------------|----------|-------|-----------------|----------|-------|
|                             |            |         | Easting         | Northing | error | Easting         | Northing | error |
| Unburned                    | 1          |         | 259130          | 4057208  |       |                 |          |       |
| Unburned                    | 2          |         | 259138          | 4057201  |       |                 |          |       |
| Unburned                    | 3          |         | 259109          | 4057242  |       |                 |          |       |
| Unburned                    | 4          |         | 259159          | 4057236  |       | 259166          | 4057286  | 6.7   |
| Unburned                    | 5          |         | 259181          | 4057233  |       | 259183          | 4057282  | 6.6   |
| Burned only                 | 6          | 344     | 258950          | 4057572  |       |                 |          |       |
| Burned only                 | 7          | 344     | 258975          | 4057595  |       |                 |          |       |
| Burned only                 | 8          | 344     | 258921          | 4057589  |       |                 |          |       |
| Burned only                 | 9          | 344     | 258938          | 4057570  |       |                 |          |       |
| Burned only                 | 10         | 344     | 258961          | 4057615  |       |                 |          |       |
| Burned and seeded           | 16         |         | 258367          | 4058636  |       | 258328          | 4058667  | 4.9   |
| Burned and seeded           | 17         |         | 258380          | 4058665  |       | 258354          | 4058701  | 4.9   |
| Burned and seeded           | 18         |         | 258350          | 4058615  |       | 258316          | 4058640  | 7.1   |
| Burned and seeded           | 19         |         | 258364          | 4058620  |       | 258328          | 4058654  | 6.4   |
| Burned and seeded           | 20         |         | 258371          | 4058655  |       | 258332          | 4058689  | 6.1   |
| Burned, seeded and harrowed | 11         |         | 258559          | 4058383  |       | 258532          | 4058422  | 5.5   |
| Burned, seeded and harrowed | 12         |         | 258531          | 4058377  |       | 258503          | 4058417  | 5.5   |
| Burned, seeded and harrowed | 13         |         | 258522          | 4058349  |       | 258493          | 4058388  | 5.5   |
| Burned, seeded and harrowed | 14         |         | 258571          | 4058356  |       | 258537          | 4058403  | 7.1   |
| Burned, seeded and harrowed | 15         |         | 258501          | 4058350  |       | 258471          | 4058392  | 8.7   |

## Appendix IV - D

## Walk-In Site

| Treatment                   | Transect # | Azimuth | South stake UTM |          |       | North Stake UTM |          |       |
|-----------------------------|------------|---------|-----------------|----------|-------|-----------------|----------|-------|
|                             |            |         | Easting         | Northing | error | Easting         | Northing | error |
| Unburned                    | 36         |         | 262819          | 4056906  |       | 262785          | 405694   | 5.9   |
| Unburned                    | 37         |         | 262825          | 4056921  |       | 262789          | 4056953  | 5.9   |
| Unburned                    | 38         | 300     | 262842          | 4056880  |       | 262802          | 4056900  | 8.5   |
| Unburned                    | 39         | 295     | 262853          | 4056889  |       | 262812          | 4056919  | 4.8   |
| Unburned                    | 40         | 310     | 262808          | 4056888  |       | 262775          | 4056925  | 5.9   |
| Burned only                 | 31         |         | 262235          | 4055893  |       |                 |          |       |
| Burned only                 | 32         |         | 262199          | 4055939  |       |                 |          |       |
| Burned only                 | 33         |         | 262179          | 4055878  |       |                 |          |       |
| Burned only                 | 34         |         | 262244          | 4055936  |       |                 |          |       |
| Burned only                 | 35         |         | 262151          | 4055920  |       |                 |          |       |
| Burned and seeded           | 26         |         | 262268          | 4055694  |       |                 |          |       |
| Burned and seeded           | 27         |         | 262180          | 4055780  |       |                 |          |       |
| Burned and seeded           | 28         |         | 262279          | 4055753  |       |                 |          |       |
| Burned and seeded           | 29         |         | 262223          | 4055765  |       |                 |          |       |
| Burned and seeded           | 30         |         | 262236          | 4055685  |       |                 |          |       |
| Burned, seeded and harrowed | 21         |         | 262399          | 4055671  |       |                 |          |       |
| Burned, seeded and harrowed | 22         |         | 262321          | 4055669  |       |                 |          | 6.1   |
| Burned, seeded and harrowed | 23         |         | 262368          | 4055721  |       |                 |          |       |
| Burned, seeded and harrowed | 24         |         | 262349          | 4055701  |       |                 |          |       |
| Burned, seeded and harrowed | 25         |         | 262393          | 4055637  |       |                 |          |       |

## Appendix V- A. Aerial distribution of seed at Ancient Flake site.

| Treatment                          | Seed Type                                             | # of Seeds | # of Bowls |
|------------------------------------|-------------------------------------------------------|------------|------------|
| Burned only                        | <i>Bouteloua curtipendula</i>                         | 2          |            |
| Burned only                        | <i>Sporobolus cryptandrus</i>                         | 3          |            |
| <b>Burned only</b>                 | <b>Total</b>                                          | <b>5</b>   | <b>6</b>   |
| Burned and seeded                  | <i>Achnatherum hymenoides</i>                         | 1          |            |
| Burned and seeded                  | <i>Agropyron cristatum</i>                            | 10         |            |
| Burned and seeded                  | <i>Agropyron intermedium</i> var. <i>trichophorum</i> | 3          |            |
| Burned and seeded                  | <i>Bouteloua curtipendula</i>                         | 5          |            |
| Burned and seeded                  | <i>Elymus junceus</i>                                 | 1          |            |
| Burned and seeded                  | <i>Melilotus officinalis</i>                          | 1          |            |
| Burned and seeded                  | <i>Sanguisorba minor</i>                              | 1          |            |
| Burned and seeded                  | <i>Sporobolus cryptandrus</i>                         | 12         |            |
| <b>Burned and seeded</b>           | <b>Total</b>                                          | <b>34</b>  | <b>5</b>   |
| Burned, seeded and harrowed        | <i>Achnatherum hymenoides</i>                         | 5          |            |
| Burned, seeded and harrowed        | <i>Agropyron cristatum</i>                            | 12         |            |
| Burned, seeded and harrowed        | <i>Agropyron intermedium</i> var. <i>trichophorum</i> | 14         |            |
| Burned, seeded and harrowed        | <i>Bouteloua curtipendula</i>                         | 43         |            |
| Burned, seeded and harrowed        | <i>Elymus junceus</i>                                 | 3          |            |
| Burned, seeded and harrowed        | <i>Melilotus officinalis</i>                          | 1          |            |
| Burned, seeded and harrowed        | <i>Sporobolus cryptandrus</i>                         | 56         |            |
| <b>Burned, seeded and harrowed</b> | <b>Total</b>                                          | <b>134</b> | <b>7</b>   |

## Appendix V- B. Aerial distribution of seed at Walk-in site.

| Treatment                          | Seed Type                                             | Total # of Seeds | # of Bowls |
|------------------------------------|-------------------------------------------------------|------------------|------------|
| Burned only                        | <i>Bouteloua curtipendula</i>                         | 5                |            |
| <b>Burned only</b>                 | <b>Total</b>                                          | <b>5</b>         | <b>8</b>   |
| Burned and seeded                  | <i>Achnatherum hymenoides</i>                         | 5                |            |
| Burned and seeded                  | <i>Agropyron cristatum</i>                            | 23               |            |
| Burned and seeded                  | <i>Agropyron intermedium</i> var. <i>trichophorum</i> | 6                |            |
| Burned and seeded                  | <i>Bouteloua curtipendula</i>                         | 29               |            |
| Burned and seeded                  | <i>Elymus junceus</i>                                 | 4                |            |
| Burned and seeded                  | <i>Melilotus officinalis</i>                          | 3                |            |
| Burned and seeded                  | <i>Sporobolus cryptandrus</i>                         | 69               |            |
| <b>Burned and seeded</b>           | <b>Total</b>                                          | <b>139</b>       | <b>8</b>   |
| Burned, seeded and harrowed        | <i>Achnatherum hymenoides</i>                         | 2                |            |
| Burned, seeded and harrowed        | <i>Agropyron cristatum</i>                            | 24               |            |
| Burned, seeded and harrowed        | <i>Agropyron intermedium</i> var. <i>trichophorum</i> | 12               |            |
| Burned, seeded and harrowed        | <i>Bouteloua curtipendula</i>                         | 52               |            |
| Burned, seeded and harrowed        | <i>Elymus junceus</i>                                 | 5                |            |
| Burned, seeded and harrowed        | <i>Melilotus officinalis</i>                          | 5                |            |
| Burned, seeded and harrowed        | <i>Sanguisorba minor</i>                              | 2                |            |
| Burned, seeded and harrowed        | <i>Sporobolus cryptandrus</i>                         | 103              |            |
| <b>Burned, seeded and harrowed</b> | <b>Total</b>                                          | <b>205</b>       | <b>8</b>   |