



Evaluating Options for Revegetation Following a Catastrophic Fire in a Pinyon-Juniper Community at Grand Canyon / 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 seeds. 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 the relative abundance of cheatgrass and foxtail chess (*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 four 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 with a 6x6 foot metal rake to create shallow surface disturbance. Perennial plant cover, density and species richness were measured, along with annual plant production and species richness, on each of the sixteen plots. These data were averaged over the four sites and statistically evaluated using Analysis of Variance for responses quantified in a random complete block design. This report provides analysis and a summary of information collected a little over one year after the revegetation treatments were applied.

Although one year is a very short period of time in terms of ecological consequences, the vegetation shows the signs of some treatment differences. Seeding, with or without harrowing, changed perennial species composition by establishment of seeded species, but has not increased perennial cover or density compared to untreated burned sites. Instead, successful seeded species appear to have displaced other post-fire perennial species. Harrowing did not change this result, nor did it influence which seeded species thrived in the post-fire environment. Despite an increase from our sampling in the year 2000, perennial cover was still greater on control plots than on any of the burned plots. Regardless of treatment, herbaceous perennials dominated all 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 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, even on the unburned control, suggesting the importance of abiotic factors, such as rainfall, to revegetation. Total exotic annual species did not differ between years or among treatments. Cheatgrass and foxtail chess were themselves unaffected by seeding or harrowing, indicating that these treatments are neutral with regard to exotic annual species infestation. However, the absence of a pattern could also be due to the species' responses to inter-annual climatic variation indicating that more time is required to discern a pattern in response of the vegetation.

Abstract

Land managers have a need for unbiased evaluation of management activities subsequent to catastrophic wildfire. The specific goals of such activities include reducing soil erosion, controlling the invasion of exotic species such as cheatgrass (*Bromus tectorum*) and foxtail chess (*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 the Grand Canyon/Parashant National Monument. Although only one year has passed since treatments were applied, interesting results have started to develop.

Seeding, with or without harrowing, changes perennial species composition by establishment of seeded species, but does not increase over-all perennial cover 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, perennial cover was still below control levels on all burn treatments and herbaceous perennials dominated burned plots.

Annual production increased after burning, but seeding or harrowing had no effect on this pattern. Annual production and species richness also increased between years, even on the unburned control, which indicates the importance of abiotic factors in recovery. Exotic annuals, including cheatgrass and foxtail chess, were unaffected by either seeding or harrowing.

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. In the past these efforts have spanned the continuum from rehabilitation to restoration. Rehabilitation creates an ecosystem that is entirely different from the one present prior to disturbance. Rehabilitation often results in a monoculture that requires continual management, but is useful for human activities such as livestock grazing. At the other end of the spectrum, restoration is often seen as a difficult, if not impossible, goal because it requires transforming an ecosystem to a fully functioning late succession stage with only the preexisting native species (NAS 1974, Allen 1995). Somewhere between these two extremes exists the concept of reclamation. Reclamation implies

a fully functioning ecosystem similar to pre-disturbance but allows for the presence of exotic species as well as lower species diversity (NAS 1974, Allen 1995). Increased habitat disturbance and greater public interest in restoring land have brought many revegetation practices into question. This report responds to the need for quantifying community changes that occur as a result of prescribed management treatments.

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 (Brooks 1998, Brooks and Esque 1999) and Sonoran Desert (McAuliffe 1995, Esque and Schwalbe *In Press*, Esque et al. *In Press*). 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, thus understanding this process is 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 Grand Canyon / 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 soils. 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 describes the development and implementation of the collaborative research project between BLM and USGS, and presents results for the first and second years. The reader will observe some redundancy with the First Annual Report in this report. 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 foxtail chess - *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 the 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. These criteria demand that we develop a rigorous scientific protocol and that each team member understand the importance of maintaining a high level of scientific integrity as we implement treatments, collect and analyze the data, and present results.

General Research/Management Questions

- 1) Which of four treatment combinations (i.e. burned 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 foxtail chess and other alien plant infestations?
- 3) Is post-fire soil erosion reduced as a result of treatments?

Methods

Study Plots. The experimental design consists of 4 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 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 without replication). The UTM coordinates of all sixteen study plots are provided in Appendix I.

Aerial 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, 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, and eight bowls were placed in each burned plot. 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 0.1m² annual plant quadrats per hectare were randomly placed within each treatment plot. The production of annual plants was quantified by clipping aboveground live biomass and sorting by species. Samples were then oven dried at 40° C for three days. Annual species richness was calculated based on all species found within 1m² 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). Five randomly placed permanent perennial plant transects (50m long) were established on each treatment 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 determine 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.

Soil Erosion. Soil erosion monitoring was established on the Bin Tank plot by BLM soil scientist, Robert Smith, and reported elsewhere.

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:

H₀1: Cover of perennial plants is not different among treatments.

H₀2: Diversity of perennial plants is not different among treatments.

H₀3: Production of annual plants is not different among treatments.

H₀4: Diversity of annual plants is not different among treatments.

H₀5: Production of *Bromus* spp. 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. When a significant treatment difference occurred, treatments were compared using Tukey's Studentized Range (HSD) Test at the $\alpha = 0.05$ level. In the future, Repeated Measures Analysis of Variance will be used as additional measurements are made over time.

Results

Aerial Seeding. Seed capture by the seed bowls showed that aerial application of the seed mix varied spatially within the plots. There was also a small overlap of seeding onto the edge of 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 treatments occurred, we captured all of the seed species present in the seed mix except for western wheatgrass (*Agropyron smithii*), which made up only 2.59% of the seeding mixture.

Perennial Plants. There was 25% more perennial plant cover in 2001 than in 2000 averaged across all treatments (Figure 1). This increase was primarily due to increased cover on the burned treatment plots with very little difference on the unburned control plots between years. The unburned control had significantly more perennial plant cover than the three burned

treatments ($P < 0.01$). Perennial cover was not significantly different among these burned treatments. Averaged over all sites, percent perennial cover was 45.56 (3.77 SE) on the unburned control, 11.94 (1.64 SE) on the burned treatment, 9.88 (2.66 SE) on the burned and seeded treatment and 9.30 (1.33 SE) on the burned-seeded-harrowed treatment in 2001.

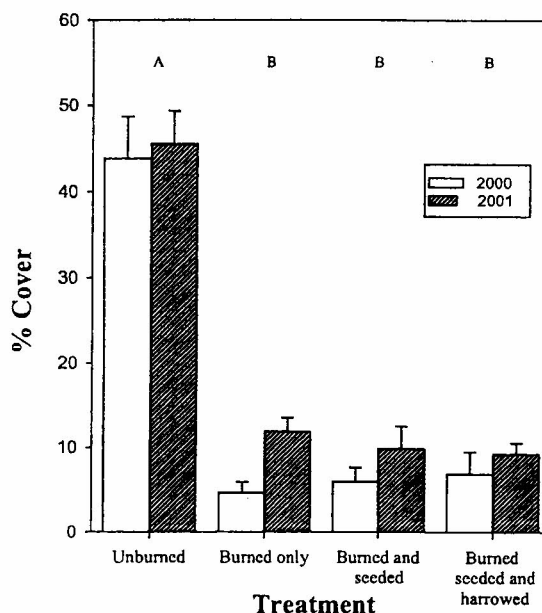


Figure 1. Mean perennial plant cover at Jump Canyon 2000 and 2001. Data were averaged across sites. Error bars represent one standard error above the mean. Significantly different treatments averaged over years are denoted by different letters at $P < 0.01$.

Similar to cover, perennial plant density increased significantly by year (density in 2001 > 2000 at $P < 0.01$, Figure 2), but did not differ significantly between treatments in either year ($P = 0.58$). The 2001 average perennial density in plants per 100m² was 302.55 (105.08 SE) on the unburned control, 424.10 (114.79 SE) on the burned treatment, 293.30 (64.22 SE) on the burned and seeded treatment and 348.75 (57.48 SE) on the burned-seeded-harrowed treatment. Perennial species richness was not significantly different between years ($P = 0.46$, Figure 3), nor was it significantly different between any of the treatments ($P = 0.72$). Average 2001 species richness was 16.25 (3.57 SE) on the unburned control, 17.25 (2.25 SE) on the burned treatment, 16.00 (2.48 SE) on the burned and seeded treatment and 17.00 (1.68 SE) on the burned-seeded-harrowed treatment.

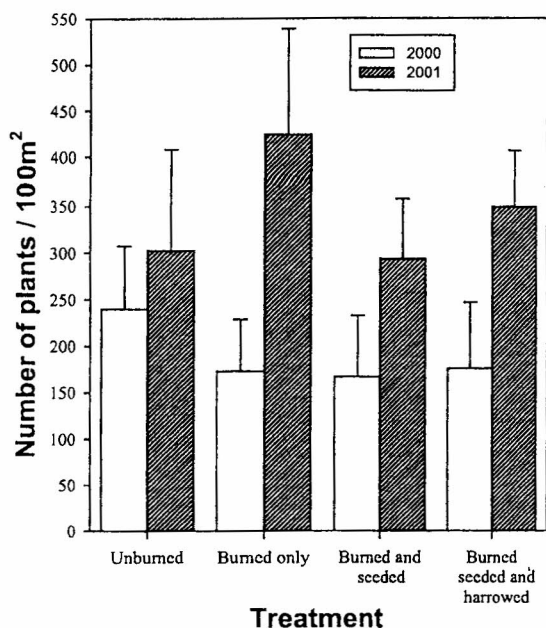


Figure 2. Density of perennial plants at Jump Canyon 2000 and 2001. Data were averaged across sites. Error bars represent one standard error above the mean.

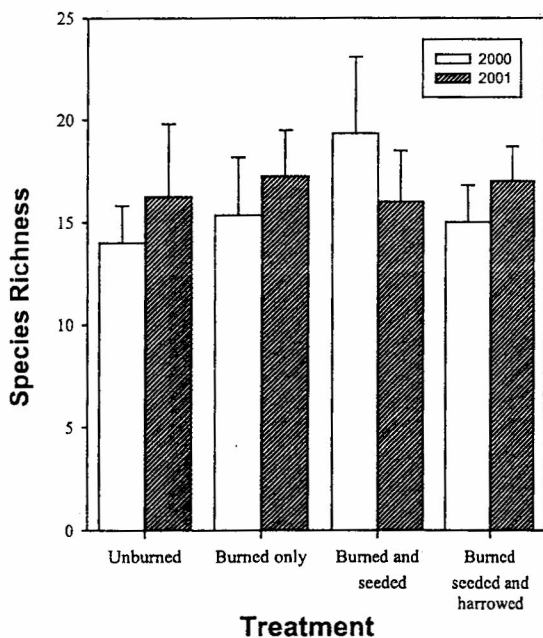


Figure 3. Perennial plant species richness at Jump Canyon 2000 and 2001. Data were averaged across sites. Error bars represent one standard error above the mean.

Out of fifty-eight perennial plant species identified in the study area, only five species were common to all treatment types during both cover and density estimates (Table 1). These five species were big sagebrush, rattlesnake weed (*Chamaesyce albomarginata*), squirreltail (*Elymus elymoides*), snakeweed (*Gutierrezia* sp.) and desert globemallow (*Sphaeralcea ambigua*). Four-wing saltbush (*Atriplex canescens*), cushion buckwheat (*Eriogonum ovalifolium*), mat buckwheat (*Eriogonum umbellatum*), Mammillaria cactus (*Mammillaria* species), Unknown C and Unknown H were found only on unburned plots. Juniper, blackbrush and big sagebrush were only rarely encountered outside of the unburned control, where they provided 88.42% of perennial cover. The Jump Canyon study site is in an area generally described as a Pinyon-Juniper community, although pinyon pines are rare. No pinyons were actually encountered during cover or density measurements.

Burned sites, on the other hand, were dominated by herbaceous perennials such as desert globemallow, perennial grasses and rattlesnake weed. Twenty-two perennial plant species were found solely on one or more of the burned treatments. Five species were found only on the untreated burn – milkvetch (*Astragalus* sp.), rabbitbrush (*Chrysothamnus* sp.), jimson weed (*Datura meteloides*), Unknown 27 and one unidentified composite species. Palmer's penstemon (*Penstemon palmeri*) and wire-lettuce (*Stephanomeria pauciflora*) were unique to the seeded burn, while burned-seeded-harrowed was the only treatment on which sideoats grama (*Bouteloua curtipendula*), fluffgrass (*Eriogonum pulchellum*) and hop-sage (*Grayia spinosa*) occurred.

Annual Plants. Annual plant production was approximately 50 times greater in 2001 than in 2000 averaged across all treatments ($P < 0.01$, Figure 4). The unburned control had significantly less above ground annual production than the three burned treatments in both years ($P < 0.01$). However, annual plant production was not significantly different among the three burned treatments. Average above ground production in grams per square meter was 9.07 (2.66 SE) on the unburned control, 133.60 (37.11 SE) on the burned treatment, 124.39 (50.54 SE) on the seeded burn and 153.33 (39.64 SE) on the seeded and harrowed burn in 2001. Annual species richness was significantly higher in 2001 than 2000 for all treatment types ($P < 0.01$, Figure 5) and significantly lower on the unburned control than on the burned and seeded treatment ($P < 0.01$). Average 2001 annual species richness was 21.00 (3.51 SE) on the unburned control, 21.00 (2.08 SE) on the burned treatment, 23.33 (2.40 SE) on the burned and seeded treatment and 21.33 (2.03 SE) on the burned-seeded-harrowed treatment.

Table 1. Species break-down of perennial cover and density at Jump Canyon in 2001. Data were averaged across sites.

Perennial species	Common Name	Percent of Perennial Cover				Percent of Perennial Density			
		Unburned	Burned	Burned, Seeded,	Harrowed	Unburned	Burned	Burned, Seeded,	Harrowed
Agropyron cristatum	Ephraim wheatgrass	0.00	3.11	10.62	15.86	0.13	3.20	11.47	13.01
Agropyron intermedium	Pubescent wheatgrass	0.00	1.16	7.48	5.97	0.00	1.94	2.74	4.31
Argemone pleiacantha	Bluestem pricklypoppy	0.00	3.98	10.18	6.52	0.13	0.99	2.06	2.22
Aristida purpurea	Purple three-awn	0.00	0.00	0.00	0.00	0.01	0.00	0.08	0.04
Artemisia tridentata	Big sagebrush	24.16	0.48	0.57	0.20	11.21	1.16	0.94	0.31
Astragalus species	Milkvetch	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00
Asteraceae 1	Composite	0.00	0.00	0.00	0.00	0.00	0.04	0.05	0.03
Asteraceae 2	Composite	0.00	0.00	0.00	0.00	0.00	0.06	0.03	0.00
Asteraceae 3	Composite	0.00	0.00	0.00	0.00	0.00	0.15	0.38	0.00
Asteraceae 4	Composite	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.01
Asteraceae 5	Composite	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00
Atriplex canescens	Four-wing saltbush	0.78	0.00	0.00	0.00	0.16	0.00	0.00	0.00
Bouteloua curtipendula	Sideoats grama	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Chamaesyce albomarginata	Rattlesnake weed	0.06	5.83	5.18	12.49	2.62	22.15	15.51	19.39
Chrysothamnus species	Rabbitbrush	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Chamaesyce 2	Spurge	0.00	0.00	0.26	0.00	0.00	0.00	0.89	1.19
Chamaesyce 3	Spurge	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00
Coleogyne ramosissima	Blackbrush	20.16	0.00	0.00	0.00	12.17	0.03	0.28	0.01
Datura meteloides	Jimson weed	0.00	0.36	0.00	0.00	0.00	0.01	0.00	0.00
Elymus elymoides	Squirreltail	2.09	0.59	1.31	0.29	16.77	1.45	1.08	0.49
Ephedra nevadensis	Nevada Ephedra	0.43	2.24	1.43	0.00	0.24	0.48	0.42	0.09
Ephedra viridis	Green Ephedra	0.23	0.07	0.00	1.41	0.25	0.02	0.00	0.01
Eriogonum species	Buckwheat	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00
Eriogonum ovalifolium	Cushion buckwheat	0.29	0.00	0.00	0.00	3.37	0.00	0.00	0.00
Erioneuron pulchellum	Fluffgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Eriogonum umbellatum	Mat buckwheat	0.01	0.00	0.00	0.00	0.29	0.00	0.00	0.00

Table 1 (Continued)

Perennial species	Common Name	Percent of Perennial Cover				Percent of Perennial Density			
		Unburned	Burned	Burned, Seeded,	Burned, Seeded, Harrowed	Unburned	Burned	Burned, Seeded,	Burned, Seeded, Harrowed
Grass 8	--	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Unidentified Perennial Grass	--	0.22	3.61	11.48	10.61	8.14	13.55	36.09	32.87
Grayia spinosa	Hop-sage	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Gutierrezia species	Snakeweed	0.54	9.59	2.51	6.01	3.37	10.87	1.02	0.60
Heliomeris multiflora	Showy goldeneye	0.00	0.12	1.27	0.00	0.10	0.00	2.36	0.00
Juniperus osteosperma	Utah juniper	44.10	0.00	0.00	0.00	3.53	0.00	0.01	0.00
Lycium species	Box thorn	0.00	2.08	0.00	0.00	0.02	0.54	0.00	0.03
Mammalaria species	--	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00
Mirabilis multiflora	Desert four o'clock	0.00	0.00	0.00	0.00	0.00	0.01	0.07	0.00
Nicotiana trigonophylla	Desert tobacco	0.00	8.04	0.27	0.56	0.33	17.52	2.54	4.91
Opuntia acanthocarpa	Buckhorn cholla	0.00	0.10	0.04	0.00	0.00	0.27	0.46	0.00
Opuntia species	Prickly pear	0.00	0.07	0.00	0.00	0.05	0.23	0.28	0.05
Penstemon species	Penstemon	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Penstemon palmeri	Palmer penstemon	0.00	0.00	0.33	0.00	0.00	0.00	0.36	0.00
Phlox stansburyi	Stansbury phlox	0.00	0.10	0.05	0.00	0.76	2.75	1.46	0.39
Pleuraphis rigida	Big galleta grass	0.69	0.26	0.00	0.00	13.50	0.30	0.04	0.01
Purshia mexicana	Cliff rose	3.72	0.00	0.09	0.00	2.04	0.42	0.11	0.07
Quercus turbinella	Shrub live oak	0.55	0.00	0.00	0.00	0.21	0.01	0.00	0.00
Sanguisorba minor	Small burnet	0.00	1.78	3.36	6.27	0.24	2.85	8.80	10.55
Sphaeralcea ambigua	Desert globemallow	0.18	55.62	42.35	33.55	0.26	16.52	10.03	7.82
Sporobolus cryptandrus	Sand dropseed	0.00	0.00	0.00	0.27	0.02	0.01	0.00	0.05
Stephanomeria pauciflora	Wire-lettuce	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
Streptanthus species	Jewelflower	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.05
Unknown 5	--	0.00	0.39	0.00	0.00	0.00	0.31	0.00	0.03
Unknown 9	--	0.00	0.00	0.00	0.00	0.00	0.03	0.04	0.03
Unknown 12	--	0.64	0.00	0.00	0.00	8.87	0.00	0.02	0.02

Table 1 (Continued)

Perennial species	Common Name	Percent of Perennial Cover				Percent of Perennial Density			
		Unburned	Burned	Seeded	Harrowed	Unburned	Burned	Seeded	Harrowed
Unknown 13	--	0.00	0.00	0.00	0.00	10.89	0.00	0.00	0.00
Unknown 22	--	0.00	0.03	0.00	0.00	0.00	1.33	0.05	0.00
Unknown 27	--	0.00	0.20	0.00	0.00	0.00	0.01	0.00	0.00
Unknown A	--	0.00	0.00	0.00	0.00	0.00	0.00	0.03	1.16
Unknown C	--	0.02	0.00	0.00	0.00	0.04	0.00	0.00	0.00
Unknown H	--	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00
Yucca baccata	Banana yucca	0.92	0.00	1.22	0.00	0.04	0.29	0.23	0.15

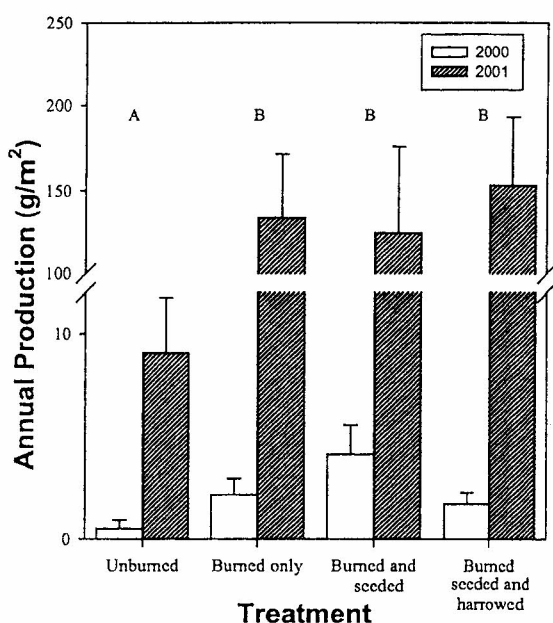


Figure 4. Annual plant production at Jump Canyon 2000 and 2001. Data were averaged across sites. Error bars represent one standard error above the mean. Significantly different treatments averaged over years are denoted by different letters at $P < 0.01$.

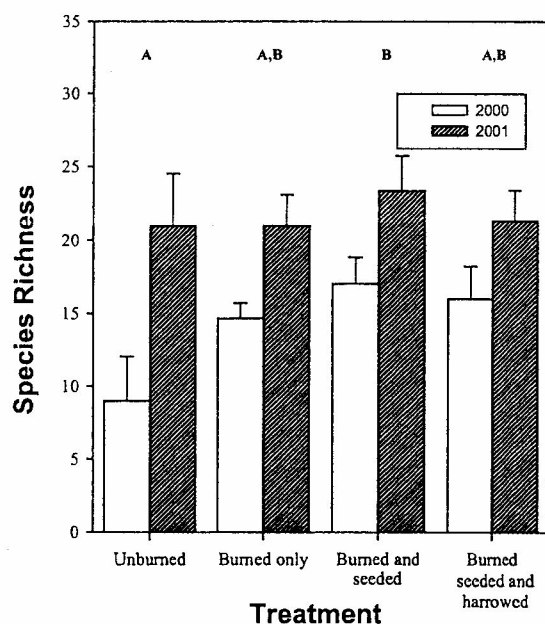


Figure 5. Annual plant species richness at Jump Canyon 2000 and 2001. Data were averaged across sites. Error bars represent one standard error above the mean. Significantly different treatments averaged over years are denoted by different letters at $P < 0.01$.

Thirty-four of forty-nine annual plant species were found on both burned and unburned treatment types (Table 2). Pigweed (*Chenopodium* sp.), yelloweye lupine (*Lupinus flavoculatus*) and cutleaf heliotrope (*Phacelia crenulata*) were only found on the unburned control. Twelve species were found solely on one or more burned treatment. One unidentified composite species was unique to the burned only treatment. On the seeded burn, Thurber's spineflower (*Centrostegia thurberi*) and a different unidentified composite species were unique. The seeded and harrowed burn was the only treatment where Nevada cryptanth (*Cryptantha nevadensis*), African mustard (*Malcolmia africana*) and woolly plantain (*Plantago patagonica*) were found.

Exotic annual species encountered in the plots were foxtail chess (*Bromus madritensis*), cheatgrass (*Bromus tectorum*), pigweed (*Chenopodium* species), filaree (*Erodium cicutarium*), prickly lettuce (*Lactuca serriola*), African mustard (*Malcolmia africana*), yellow sweet clover (*Melilotus officinalis*, seeded), Mediterranean grass (*Schismus barbatus*) and Jim Hill mustard (*Sisymbrium altissimum*). The percentage of annual production contributed by all exotic species was not significantly different between years ($P = 0.84$, Figure 6), or among treatments ($P = 0.12$). A significant year by treatment interaction ($P < 0.01$), however, indicates that while the unburned control had the highest percentage of exotics in 2000 compared to the other treatments, it had the lowest percentage in 2001. The average percentage of production provided by exotic species in 2001 was 14.49 (7.69 SE) on the unburned control, 21.19 (7.38 SE) on the burned treatment, 30.36 (11.31 SE) on the burned and seeded treatment and 48.82 (17.03 SE) on the burned-seeded-harrowed treatment.

The percentage of annual production contributed by only cheatgrass and foxtail chess was significantly greater in 2000 than in 2001 ($P < 0.01$, Figure 7) and significantly different among treatments in 2000 ($P < 0.01$). However, a significant year by treatment interaction ($P < 0.01$) occurred because of the very large proportion of these grasses in 2000 on the unburned control. The average 2001 percentage of cheatgrass and foxtail chess production was 7.01 (4.48 SE) on the unburned control, 2.94 (1.61 SE) on the burned treatment, 4.62 (3.00 SE) on the seeded burn and 12.18 (4.71 SE) on the seeded and harrowed burn.

Table 2. Species break-down of annual production at Jump Canyon, 2001. Data were averaged across sites.

Annual species	Common Name	Percent of Annual Production			
		Unburned	Burned	Burned, Seeded	Burned, Seeded, Harrowed
Allionia species	Windmills	0.04	0.00	0.00	0.00
Asteraceae 2	Composite	0.00	0.00	**	0.00
Asteraceae 4	Composite	0.00	**	0.00	0.00
Astragalus nuttallianus	Milkvetch	0.00	**	**	**
Astragalus 3	Milkvetch	0.00	0.06	**	0.00
Bouteloua aristidoides	Needle grama	0.23	0.19	0.03	**
Bromus madritensis	Foxtail chess	0.62	0.90	0.07	3.29
Bromus species	--	0.98	0.00	0.00	0.00
Bromus tectorum	Cheatgrass	9.92	2.04	4.55	8.89
Centrostegia thurberi	Thurber's spineflower	0.00	0.00	**	0.00
Chenopodium species	Pigweed	**	0.00	0.00	0.00
Chorizanthe watsonii	Watson's spineflower	**	0.00	**	0.00
Cryptantha gracilis	Slender cryptanth	1.49	8.85	9.58	13.86
Cryptantha nevadensis	Nevada cryptanth	0.00	0.00	0.00	**
Cryptantha pterocarya	Winged-nut cryptanth	0.00	**	**	1.40
Cryptantha species	Cryptanth	0.03	0.00	0.00	0.06
Descurania pinnata	Tansy mustard	0.26	0.53	0.66	1.79
Draba cuneifolia	Wedgeleaf draba	23.57	12.14	10.27	12.79
Eriastrum diffusum	Spreading eriastrum	0.08	11.01	6.33	1.49
Eriastrum eremicum	Desert eriastrum	0.19	0.00	0.19	0.00
Eriastrum species	--	0.04	**	0.00	0.13
Eriogonum deflexum	Skeletonweed buckwheat	0.24	0.87	1.12	0.18
Erodium cicutarium	Filaree	4.08	15.57	23.21	25.20
Gilia scopulorum	--	12.57	15.96	16.40	2.12
Gilia species	--	0.77	0.00	1.57	**
Gilia 1	--	**	0.00	**	0.00
Lactuca serriola	Prickly lettuce	**	0.88	1.45	1.98
Layia glandulosa	White layia	**	0.95	0.41	0.35
Lepidium flavum	Pepperweed	0.02	0.18	1.06	**
Linanthus bigelovii	Bigelow linanthus	1.73	1.07	0.29	2.60
Linanthus species	Linanthus	0.00	**	**	0.00
Lupinus brevicaulis	Shortstem lupine	2.92	**	**	0.00
Lupinus flavoculatus	Yelloweye lupine	3.05	0.00	0.00	0.00

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

Table 2 (Continued)

Annual species	Common Name	Percent of Annual Production			
		Unburned	Burned	Burned, Seeded	Burned, Seeded, Harrowed
<i>Lupinus kingii</i>	King lupine	0.68	0.00	0.09	0.01
<i>Lupinus</i> 1	Lupine	5.49	**	0.00	0.00
<i>Malcolmia africana</i>	African mustard	0.00	0.00	0.00	9.04
<i>Melilotus officinalis</i>	Yellow sweetclover	0.00	**	1.14	0.10
<i>Mentzelia albicaulis</i>	Whitestem blazing star	0.27	2.78	1.26	0.61
<i>Microseris linearifolia</i>	--	**	0.00	**	**
<i>Mimulus rubellus</i>	--	0.08	0.01	0.02	0.02
<i>Myosurus cupulatus</i>	Horseshoe mousetail	1.44	0.07	0.003	0.17
<i>Nemacladus rubescens</i>	--	**	0.15	0.00	0.00
<i>Oxytheca perfoliata</i>	--	**	0.00	0.00	0.03
<i>Phacelia crenulata</i>	Cutleaf heliotrope	0.21	0.00	0.00	0.00
<i>Phacelia fremontii</i>	Fremont phacelia	0.54	8.31	3.43	3.65
<i>Phlox gracilis</i>	Little polecat	6.12	3.00	4.62	5.06
<i>Salsola species</i>	Tumbleweed	0.00	1.12	0.00	**
<i>Schismus barbatus</i>	Mediterranean grass	0.54	0.67	0.15	0.04
<i>Silene antirrhina</i>	Catch-fly	**	0.00	0.01	0.00
<i>Sisymbrium altissimum</i>	Jim Hill mustard	0.00	**	2.07	0.28
<i>Syntrichopappus fremontii</i>	--	0.56	1.96	4.96	0.09
<i>Thysanocarpus curvipes</i>	Sand fringe pod	0.00	0.00	**	0.95
Unidentifiable	--	0.02	0.00	0.00	0.30
Unknown 2	--	0.45	0.96	0.57	**
<i>Vulpia octoflora</i>	Sixweeks fescue	12.80	4.08	4.49	3.51

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

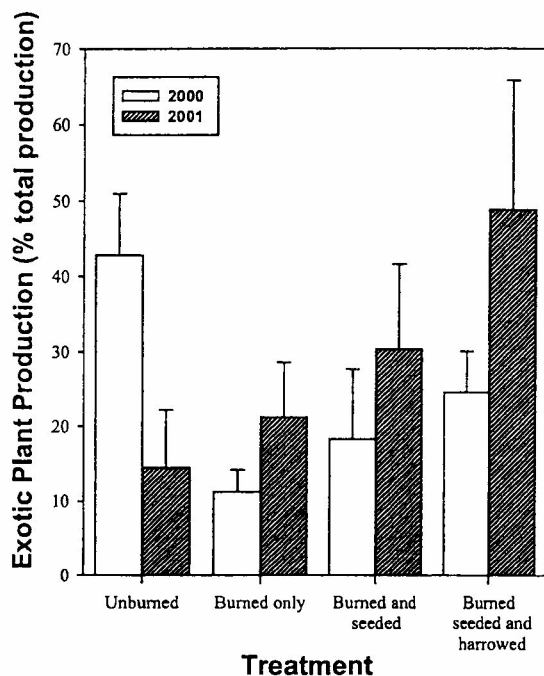


Figure 6. Exotic species production as a percentage of total annual production at Jump Canyon 2000 and 2001. Data were averaged across sites. Error bars represent one standard error above the mean.

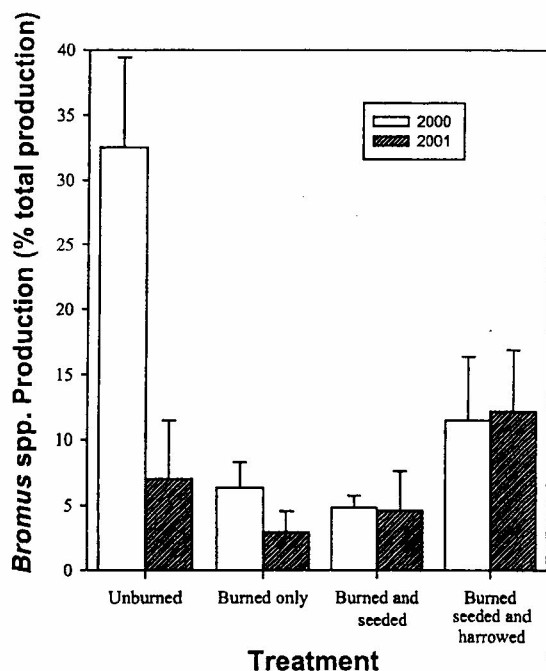


Figure 7. *Bromus* spp. production expressed as a percentage of all annual production at Jump Canyon 2000 and 2001. Data were averaged across sites. Error bars represent one standard error above the mean.

Perennial Seeded Species. A significantly greater percentage of perennial cover was composed of seeded species in 2001 compared to 2000 ($P < 0.01$, Figure 8). 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. The average seeded cover in 2001 was zero on the unburned control, 6.05 (5.68 SE) on the burned treatment, 21.46 (11.87 SE) on the seeded burn and 28.37 (14.51 SE) on the seeded and harrowed burn. In 2000, these average percentages were all zero except 5.00 (5.00 SE) on the burned-seeded-harrowed treatment.

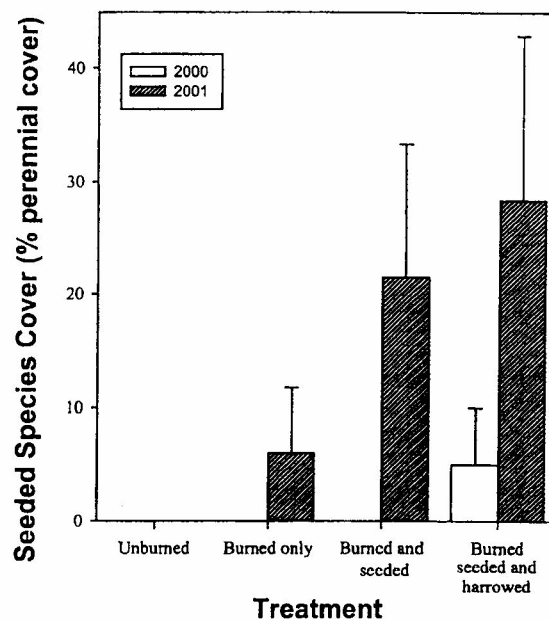


Figure 8. Seeded species cover expressed as a percentage of total perennial cover at Jump Canyon 2000 and 2001. Data were averaged across sites. Error bars represent one standard error above the mean.

A greater density of seeded species also occurred in 2001 than in 2000 averaged over all treatments ($P < 0.01$, Figure 9). 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. In 2001, the average percentage of perennial density provided by seeded species was 0.39 (0.25 SE) on the unburned control, 7.99 (6.10 SE) on the burned treatment, 23.01

(9.07 SE) on the burned and seeded treatment and 27.95 (10.23 SE) for the burned-seeded-harrowed treatment.

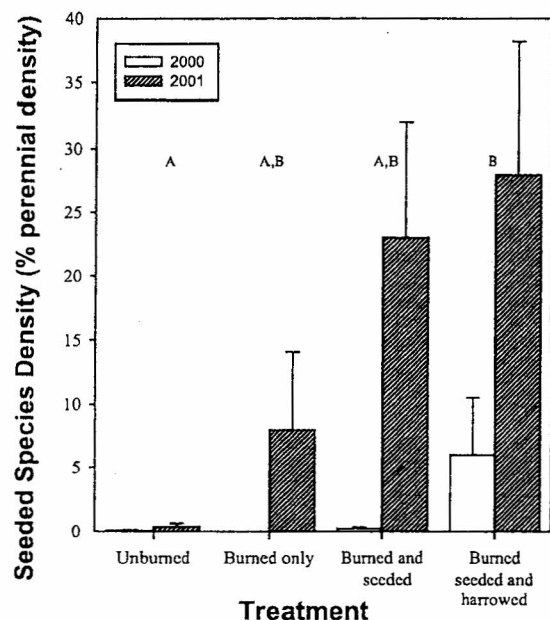


Figure 9. Seeded species density expressed as a percentage of total perennial density at Jump Canyon 2000 and 2001. Data were averaged across sites. Error bars represent one standard error above the mean. Significantly different treatments averaged over years are denoted by different letters at $P < 0.01$.

Not all seeded species established equally well (Table 3). Indian ricegrass, western wheatgrass and Russian wild-rye (*Elymus junceus*), although seeded, were not positively identified on any 2001 cover or density transects. Among the seeded species positively identified, sand dropseed was represented by only five plants. Sideoats grama was positively identified (one plant) on one burned-seeded-harrowed plot.

No seeded species were detected during cover measurements on the unburned control and therefore this treatment is not included in Figure 10. 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 (Figure 11). 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.

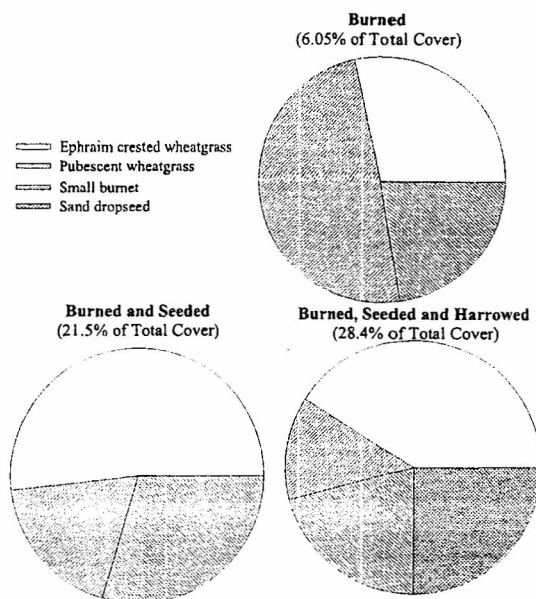


Figure 10. Seeded cover broken down by species at Jump Canyon 2001. Data were averaged across sites.

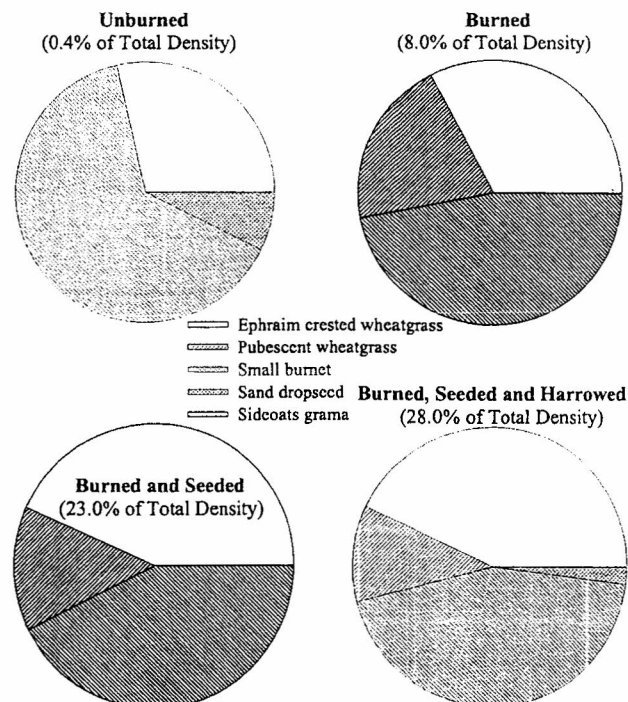


Figure 11. Seeded density broken down by species at Jump Canyon 2001. Data were averaged across sites.

Table 3. Success of seeded plant species at Jump Canyon, 2001. Data were averaged across sites.

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

Discussion

The three numerically 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 only 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, with different plant species dominating the burned sites 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 compared to the untreated burn. 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 in the first year 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 control plots, indicating it was present prior to the fire or because of contamination during aerial application of seeds. Contamination is likely 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 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 and are relatively light compared to the remaining species and therefore may be expected to travel more easily. This species, however, was not found established in any unseeded plots, 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 therefore indicates that these species were also 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 was not detected with the seed bowls, so sparse seed dissemination may explain why this species was not encountered on any plot. Since future recovery efforts on public lands already 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 found 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 increase in annual species richness and production, regardless of treatment, illustrates that variable abiotic factors can have a large impact on recovery.

Exotic annual species contributed from 10 to 50 percent of production on burned and unburned plots, with no change due to seeding or harrowing. Cheatgrass and foxtail chess were present on all plots; regardless of burn condition, with the largest percentage found on the unburned control in 2000. This represents an accumulation of vegetation from previous years, which was incinerated in the burned areas. The accumulation of cheatgrass and foxtail chess likely contributed to the occurrence and intensity of the fire (D'Antonio and Vitousek 1992). Infestation post-fire was unchanged by seeding or harrowing burned plots. Despite this finding, it is important to continue examining these species since 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

Two years is a short period of time in terms of ecological consequences, but just two years after the fire, the vegetation shows some treatment differences. Seeding, with or without harrowing, changes perennial species composition by establishment of seeded species, 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. 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, perennial cover was still below control levels on all burn treatments and herbaceous perennials dominated burned plots.

Annual production increased after burning, but no additional increase or decrease was attributed to seeding or harrowing burned plots. Annual production and species richness also increased between years, even on the unburned control, which indicates the importance of abiotic factors in recovery. Exotic annual species, including cheatgrass and foxtail chess, were unaffected by either seeding or harrowing.

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.

Acknowledgments

Kelly Goward, along with many Student Conservation Association Volunteers, provided long hours of fieldwork to help collect the vegetation data. The BLM Arizona Strip District employees provided invaluable support by implementing experimental treatments. Ken Beckstrom provided general project administration and logistical support. L.D. Walker facilitated ATV transport to the more remote study site. Roger Taylor encouraged the project's development and continuation.

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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 study areas and harrowed prescribed areas
- June 2000
 - Collected annual plant production data
 - Established perennial transects and started to collect perennial plant data
- July 2000
 - Finished collecting perennial plant data
- May 2001
 - Collected annual plant production data
- July 2001
 - Collected perennial plant 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 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 m²). 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 other *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 100m² for all statistical analysis.
- The annual biomasses from all quadrats in one plot were averaged after conversion to g/m² for all statistical 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	Bouteloua curtipendula	2	
Burned only	Sporobolus cryptandrus	3	
Burned only	Total	5	6
Burned and seeded	Achnatherum hymenoides	1	
Burned and seeded	Agropyron cristatum	10	
Burned and seeded	Agropyron intermedium var. trichophorum	3	
Burned and seeded	Bouteloua curtipendula	5	
Burned and seeded	Elymus junceus	1	
Burned and seeded	Melilotus officinalis	1	
Burned and seeded	Sanguisorba minor	1	
Burned and seeded	Sporobolus cryptandrus	12	
Burned and seeded	Total	34	5
Burned, seeded and harrowed	Achnatherum hymenoides	5	
Burned, seeded and harrowed	Agropyron cristatum	12	
Burned, seeded and harrowed	Agropyron intermedium var. trichophorum	14	
Burned, seeded and harrowed	Bouteloua curtipendula	43	
Burned, seeded and harrowed	Elymus junceus	3	
Burned, seeded and harrowed	Melilotus officinalis	1	
Burned, seeded and harrowed	Sporobolus cryptandrus	56	
Burned, seeded and harrowed	Total	134	7

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

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