The Effects of a Fall verses Spring Prescribed burn on the Control of Cheatgrass and Japanese Brome at Rabbit Mountain Open Space, Boulder County, Colorado U.S.A.

PROJECT REPORT – DECEMBER 29, 2003
BOULDER COUNTY PARKS AND OPEN SPACE
SMALL GRANTS PROGRAM 2003

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ABSTRACT

In the spring of 2003, Denver Botanic Gardens (DBG) and Boulder County Parks and Open Space (BCPOS) initiated a two-year project to study the effects of spring and fall prescribed burns as a tool to control the invasion of cheatgrass (*Anisantha tectorum*) and Japanese brome (*Bromus japonicus*) at Rabbit Mountain Open Space, a nearly 3000 acre park in north Boulder County. Cheatgrass and Japanese brome are the dominant invasive species of concern for this study, although several additional state-listed noxious weeds were documented during the 2003 sampling. Cheatgrass is a winter annual, maturing before its native grass counterparts in early spring and out competing these species for water and space. Cheatgrass can alter the natural fire cycle by modifying the frequency, seasonality, and severity of natural and prescribed fires. These blazes may be disproportionately detrimental to natives and potentially beneficial to cheatgrass, although the prescribed burns may provide opportunities for native plants to out compete the exotics. Using ocular point-cover estimates, density measurements, and soil sampling; we intend to document the changes in species diversity and cover following spring and fall prescribed burns. Applied experiments such as this provide valuable information to promote effective methods of invasive species control and the conservation of existing natural areas. The fall 2003 burn could not occur and therefore this project will be reviewed in conjunction with BCPOS to determine options for the continuation of the experimental restoration of Rabbit Mountain.

INTRODUCTION

Much debate surrounds the success of using fire to control cheatgrass (*Anisantha tectorum*). Many variables factor into this debate and effective management practices must be sensitive to specific sites and circumstances, including previous management practices, intensity of the invasion by exotics, and abiotic factors such as precipitation, climate, and/or soils. A disturbance to a native population causes the initial invasion of adventives species such as *Anisantha tectorum* and *Bromus japonicus*. Removal of the disturbance will allow the natives to rebound but will not result in displacement of the non-native species. (Keeley, 2001) Controlled burns are often used as an effective, non-chemical method to control targeted adventive species. However, the timing of the controlled burn can have a detrimental effect on native species and can increase the fecundity of invasive species. Optimal timing of the burn can decrease the production of cheatgrass, at least in the short-run (Young, 1978). Frequency of fires can also affect the spread and dominance of cheatgrass as well as the amount of nitrogen in the soil. This research project will determine if differences occur in the frequency and density of cheatgrass, based on spring versus fall prescribed burns. Soil samples will also be analyzed to determine the affect of fire on the soil nutrient composition. The fall 2003 prescribed burn could not occur due to a fire ban by the Sheriff's department. This unexpected change in the timing of the experiment will require BCPOS and DBG to determine a new plan and timeline for the Rabbit Mountain project. Options have been discussed with Claire DeLeo and will be outlined in detail in a 2004 proposal.

Spring fires occur at a time when the burn will destroy cheatgrass before it is able to release seeds, but will not harm the natives which have yet to begin sprouting. Overall, cheatgrass populations show an initial decline after these burns, but studies have shown that individual plants surviving these burns are more fecund and robust (Young, 1978). Fall burns have a similar effect of reducing the following generation, but in the absence of reseeding, recovery to pre-burn conditions occurs after three to four years (Nature Conservancy, 1999). The soil seed bank obviously plays an important role in the life cycle and establishment of cheatgrass, although this project does not study the seed bank or the effect of prescribed burns on the survivorship of dormant seeds in the soil.

Many organisms have evolved mechanisms to alter their environment to one more favorable to their needs. This process of niche construction allows invasive grass species to increase the frequency and intensity of the fire regime (Keeley, 2001). Cheatgrass, like many non-native species, completes its life cycle early in the growing season. This allows it to monopolize early soil moisture and then senesce when natives are beginning their growing season. Dry cheatgrass is extremely flammable and can shorten the fire cycle dramatically by increasing the chance of ignition and the rate of spread of wildfires (Young, 1995). Wildfires release an abundance of nutrients, including nitrogen from the volatized biomass. Cheatgrass is favored in nutrient rich soils while natives and late seral species are more tolerant of lower nitrogen levels (Pyke, 2002). Therefore, the study of nutrient cycling and biogeochemistry following prescribed burns is an important aspect of the study. By examining the results of different prescribed burns (spring versus fall), Denver Botanic Gardens will be able to make management recommendations directed towards controlling the spread and dominance of this invasive and damaging species.

METHODS

Study Site – Upon acceptance of Denver Botanic Gardens' proposal in January of 2003, Claire DeLeo (BCPOS) and DBG staff began surveying BCPOS properties that match the requirements of the project. A large southwest-facing hillside at Rabbit Mountain Open Space was chosen as the study site for both the spring and fall prescribed burns. The hillside is dominated by cheatgrass and Japanese brome, although many native forbs and graminoids are present. The study site is located due south of the intersection of Eagle Wind Trail and Indian Mesa Trail and is bisected by a loop portion of the Eagle trail. The approximate elevational range is 5600 to 5750 feet.

Prescribed Fires - All prescribed burns were conducted by BCPOS staff following submission of a BCPOS burn request form. The spring burn occurred on March 10, 2003, and included the northern portion of the study area. Baseline point-cover data was collected in five transects during February 2003, prior to the spring prescribed burn. The fall burn occurred on September 24, 2003 and represents the southern portion of the hillside. Following each burn DBG staff used a Trimble Geoexplorer 2 global positioning system (GPS) to digitally map the areas burned.

Sampling Methods – A central point of origin was selected in the spring burn site and another in the fall burn site. The starting point of each 25 meter transect was determined from these points of origin by a randomly chosen compass bearing (degrees) and distance (meters). From this starting point, another randomly chosen bearing was used for the orientation of the transect. Cover of all plant material, rock, standing dead, litter and bare soil was measured on both the left and right side of the transect every half meter. Standing dead refers to last year's growth while litter is any loose plant material. We used the ocular point-cover devise to determine the first "hit" of each data point. This type of cover measurement is useful for assessing graminoids and undesirable species based upon the biology of the plants and ease of implementation (Elzinga, 1998). Point-cover measurements allow all species, native and non-native, to be monitored. Additionally, point-cover measurements are generally stable regardless of the timing of data collection, i.e. spring versus late summer (Elzinga, 1998). At half-meter intervals, the point-cover was noted on both sides of the transect. Subjectivity was diminished by using the ocular point-cover device borrowed from Boulder County Parks and Open Space. The plant species or item found at the junction of the cross hairs was considered the "hit" for that point-cover data point. All but two transects contained 100 data points. The percent cover was taken out of 99 data points for transect 14 and 101 data points for transect 6.

Ten plots were selected within each transect by a stratified random sampling method for the determination of cheatgrass and Japanese brome density. Five transects were monitored for density during the summer of 2003. At each plot a 25cm X 100cm frame was used to count the number of individual cheatgrass (*Anisantha tectorum*) and Japanese brome (*Bromus japonicus*) plants, therefore determining density (number of plants per area). A random stratified method was used to place a 1.0m x 0.25m density plot every 5 meters on the left and right side of the transect. To avoid over counting, the left and bottom side (when oriented towards the end of the transect) were included in the count while the right and top sides were excluded. Blades were included if their basal growth fell within the plot. Density data is useful for measuring the abundance of a plant species in an area.

In addition to the spring burn (Site 1) and the fall burn (Site 2), the control site (areas unburned within Site 1 and 2) will be used as a reference to examine the general trend of cheatgrass abundance due to current climate and precipitation. Point-cover and density will provide information concerning the vegetation change within each site following the treatments.

All transects were tested for soil nutrients including nitrate and nitrogen (NO_3-N), phosphorus (P), potassium (K), zinc (Zn), iron (Fe), magnesium (Mn), copper (Cu) as well as pH, electrical conductivity (EC mmhos/cm), lime, organic matter (%OM) and texture within the burned and unburned areas. A soil auger was used to remove soil cores (approximately 20cm deep) every 5 meters from each transect plot. All samples from a transect were combined and air-dried in a cool environment. Two pints of soil from each transect was removed and sent to the Soil, Water and Plant Testing Laboratory at Colorado State University. The results from these samples will aid in examining the soil nutrient changes due to burning.

RESULTS

The percent cover of each species found within our study sites was determined by taking 100 data points in each transect. The results are represented in Tables 2-4. In February much of the biomass was standing dead material followed by other abiotic features (rock, bare soil, etc.). *Anisantha tectorum* germinates in the fall, over winters as a seedling and then flowers in the spring and was therefore more abundant than many of the native perennials and annuals. Only two other adventive species, *Erodium cicutarium* and *Alyssum parviflorum,* were found in the baseline point-cover transects during the spring sampling. Along with cheatgrass, these adventive species account for 8.4% of the total cover. Standing dead material, litter, bare soil and rock make up 84.4% while the 7 native species only make up 5% of the total cover.

In the summer of 2003, twenty-one 25-meter transects were analyzed within Site 1 and Site 2. Tables 3 and 4 summarize the top percent cover points. Each table represents over 80% cover of each site. *Anisantha tectorum* and *Bromus japonicus* were uniformly distributed among both sites making up 25.61% of Site 1 and 25.93% Site 2, although Japanese brome was more prevalent than cheatgrass in Site 1. Figures 1 and 2 illustrate the percent cover of the most abundant native and adventive species between the two sites respectively. Both sites contained bare soil, rock, standing dead material and litter. Site 1 contained 26 different native species, 7 adventive and 10 unknowns. These are listed in Table 1. Insufficient material existed for the identification of the unknown species. Site 2 contained 32 native species, 8 adventive and 8 unknowns.

Density was only recorded in Site 1 in 5 transects. Table 5 summarizes the density data. On average there was more cheatgrass (mean of 486.4 plants) than Japanese brome (mean of 363 plants) but the amount of cheatgrass was more varied from transect to transect than Japanese brome, illustrated by a standard deviation of 374.7 for cheatgrass and 139.4 for Japanese brome.

Soil results from the Soil, Water and Plant Testing Laboratory at Colorado State University are summarized in table 6. The majority of the nutrient levels and factors are fairly consistent between the two sites. There is an average pH of 5.9 across both sites. Site 1 has an average of 3.5% organic material while Site 2 contains an average of 3.2% organic material. However, the data shows that the nitrogen levels are significantly different from Site 1 to Site 2. The two-tailed T-test in Figure 3 illustrates this difference with a significant P value of 0.0028. Nitrogen may be a significant factor in the ability of the native grasses and forbs to compete with cheatgrass and Japanese brome. The averages of the remaining soil characteristics between the two sites are shown in Figure 4. The electrical conductivity is significantly different between the two sites. Electrical conductivity measures the amount of salt in the soil as well as the amount of sand, clay and organic matter (Ehsani and Sullivan, 2002). Site 1 had a slightly larger average value for electrical conductivity.

DISCUSSION

Baseline data was collected in the spring and summer of 2003 will be used to compare the effects of a spring and a fall burn on the control of *Anisantha tectorum*. This winter annual increases the fire cycle creating conditions that favor the establishment and growth of exotics (Giessow, 1996). Our preliminary data has shown that cheatgrass is more abundant than the natives in this Boulder County Open space and is a problem for habitat management.

Since both treatment sites contain a number of native species, there should be an adequate seed bank of natives that could thrive in the absence or reduction of competition from cheatgrass and Japanese brome. In the first year after a fire, soil nitrogen will increase and then be leached away in following years. High levels of nitrogen deposition have been shown to favor growth of non-native grass species (Giessow, 1996). It is the initial increase in available soil nitrogen and the removal of competition that posses the threat of further invasion of noxious annuals such as *Anisantha tectorum* instead of the desired control effect. It becomes very important that native populations can become established immediately after a controlled burn. Growth of root-sprouting perennials and robust perennial forbs is stimulated following a fire, which can mean a year of vigorous growth for native species. However, this depends on the reduction of competition from the adventive species. Reduction of weed seeds in the soil depends on the intensity of the fire and fires may not burn at a uniform intensity. As can be seen in Figure 1, Site 2 contains significantly more nitrate and nitrogen deposits in the soil than Site 1. However, the point-cover percentage of cheatgrass and Japanese brome is nearly identical between sites. The effects of the fall and spring burns will be tested in a second year of comparing soil conditions and point-cover analysis of the sites.

The goal is to analyze the short to medium-term (one to four years) effects of prescribed fires on the control of *Anisantha tectorum* and *Bromus japonicus*. In order to understand the efficacy of a spring verses a fall burn on removing these non-native, invasive grasses; the effect on soil and native species needs to be studied as these conditions change from year to year. The goal of this multi-year project is to document the affects of seasonal prescribed burns on the vegetation composition and develop management practices that provide the best results for the conservation of natural ecosystems.

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Figure 1 - Abundant Native Species of Rabbit Mountain

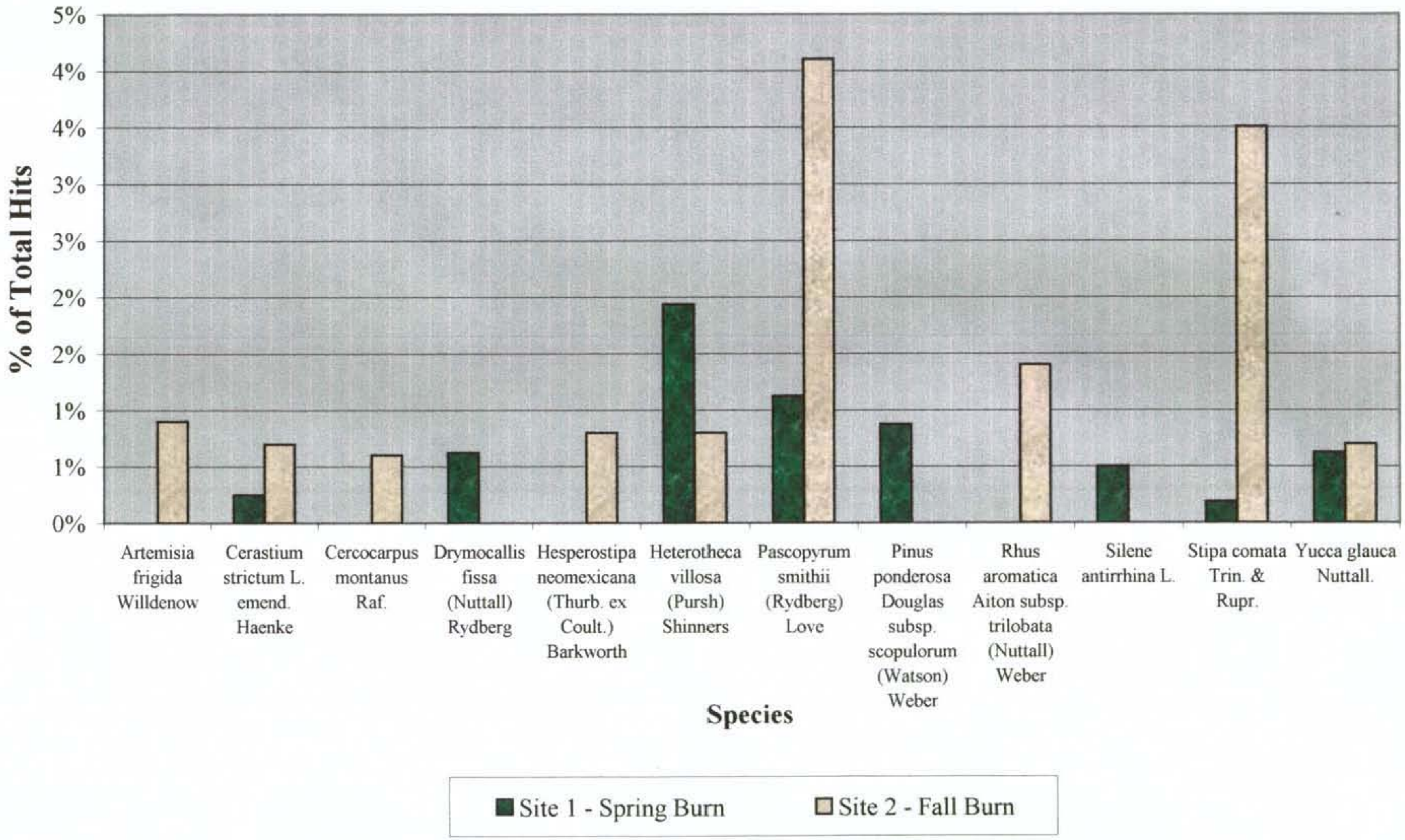

Figure 2 - Abundant Adventive Species of Rabbit Mountain

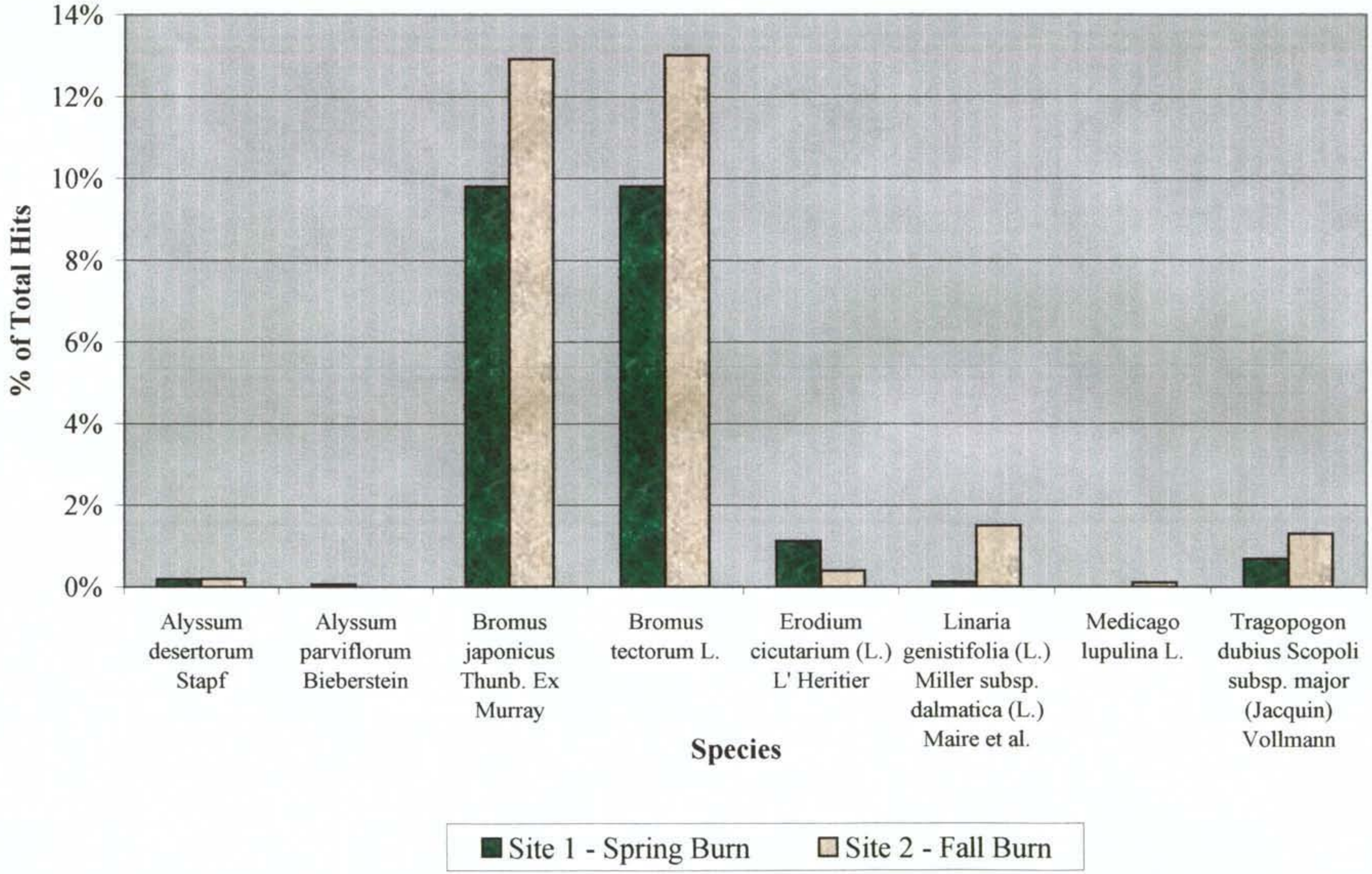

Figure 3: Nitrate and Nitrogen Depostits

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	7.191666667	9.42
Variance	1.586287879	3.237333333
Observations	12	10
Pooled Variance	2.329258333	
Hypothesized Mean Difference	0	
df	20	
t Stat	-3.40997041	
P(T<=t) one-tail	0.00138838	
t Critical one-tail	1.724718004	
P(T<=t) two-tail	0.002776761	
t Critical two-tail	2.085962478	

Electrical Conductivity mmhos/cm

t-Test: Two-Sample Assuming Equal Variances

	Site 1	*Site 2*
Mean	0.516666667	0.36
Variance	0.028787879	0.007111111
Observations	12	10
Pooled Variance	0.019033333	
Hypothesized Mean Difference	0	
df	20	
t Stat	2.652152295	
P(T<=t) one-tail	0.007647269	
t Critical one-tail	1.724718004	
P(T<=t) two-tail	0.015294538	
t Critical two-tail	2.085962478	

Figure 4 - Soil Analysis

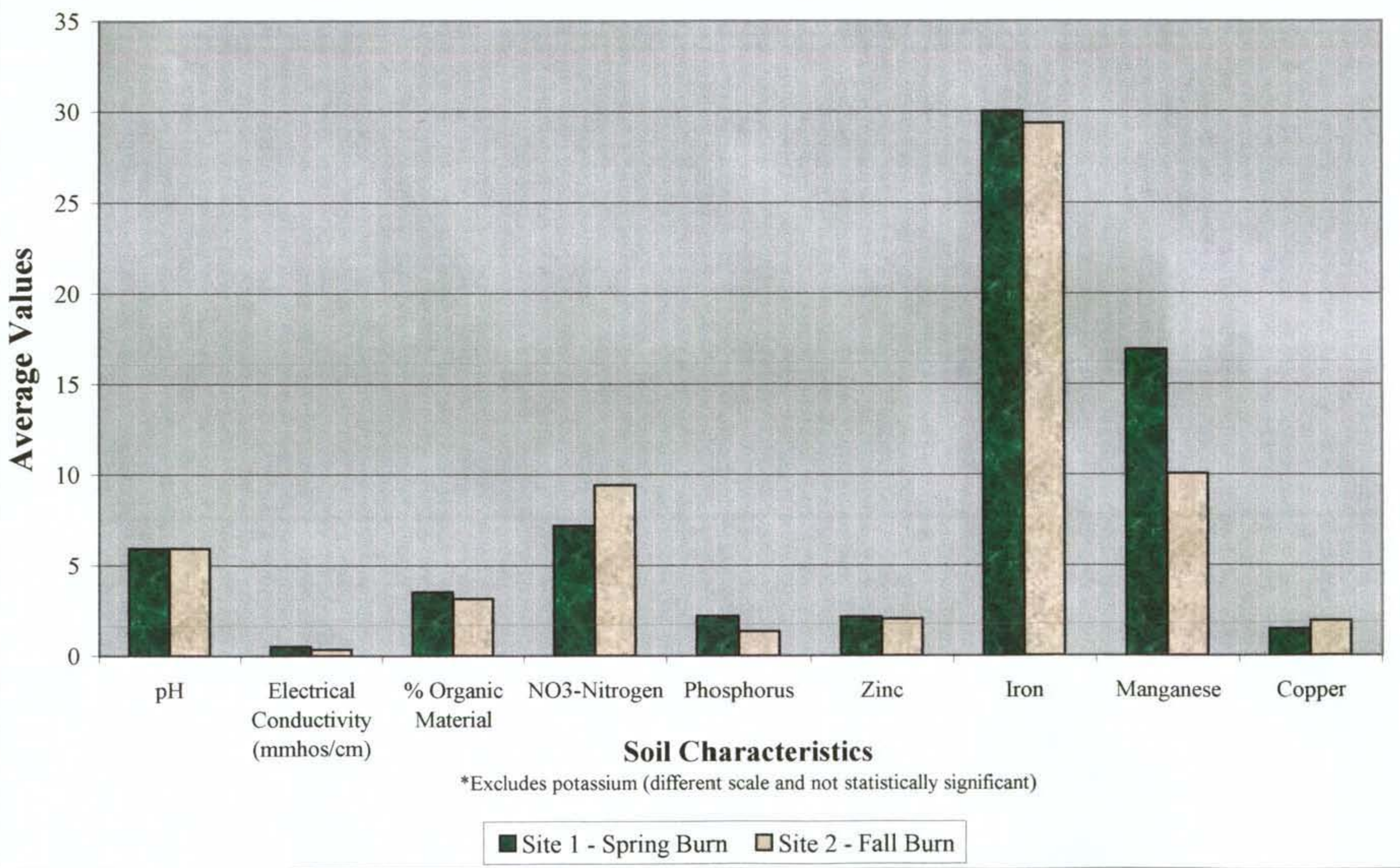

Table 1: Species included in point-cover sampling of Rabbit Mountain Open Space 2003
Species listed alphabetical order by family then scientific name

Family Name	Species	Status	Common Name
Agavaceae			
	Yucca glauca Nuttall.	native	Spanish Bayonet
Alsinaceae			
	Cerastium strictum L. emend. Haenke	native	Mouse Ear
Anacardiaceae			
	Rhus aromatica Aiton subsp. trilobata (Nuttall) Weber	native	Skunkbrush
Asclepiadaceae			
	Asclepias pumila (Gray) Vail	native	Plains Milkweed
Asteraceae			
	Erigeron compositus Pursh	native	Fleabane
	Tragopogon dubius Scopoli subsp. major (Jacquin) Vollmann	adventive	Salsify
	Artemisia frigida Willdenow	native	Silver Sage
	Artemisia ludoviciana Nuttall	native	Sagewort
	Aster porteri Gray	native	Aster
	Heterotheca villosa (Pursh) Shinners	native	Golden Aster
	Liatris punctata Hooker	native	Gayfeather
	Zinnia grandiflora Nuttall.	native	Rocky Mountain Zinnia
	Ratibida columnifera (Nutt.) Woot. & Standl.	native	upright prairie coneflower
Boraginaceae			
	Lappula redowskii (Hornemann) Greene	native	Stickseed

Family Name	Species	Status	Common Name
Brassicaceae			
	Lesquerella montana (Gray) Watson	native	Bladderpod
	Alyssum parviflorum Bieberstein	adventive	Wild Alyssum
	Alyssum desertorum Stapf	adventive	Desert Madwort
	Descurainia pinnata (Walt.) Britt.	native	Western Tansymustard
Cactaceae			
	Opuntia polyacantha Haw.	native	Plains pricklypear
	Echinocereus reichenbachii (Terscheck) Haage var. perbellus (Britton & Rose) Benson	native	Hedgehog Cactus
	Echinocereus viridiflorus Englemann	native	Hen-and-chickens
Euphorbiaceae			
	Tithymalus peplus (L.) Hill	adventive	Petty Spurge
	Tragia ramosa Torr.	native	Branched Noseburn
Fabaceae			
	Medicago lupulina L.	adventive	Black Medic
	Psoraldidium tenuiflorum (Pursh) Rydberg	native	Slimflower scurfpea
	Dalea candida Michx. ex Willd.	native	White Prairie Clover
Geraniaceae			
	Geranium caespitosum James subsp. caespitosum (Rydberg) Weber	native	Wild Geranium
	Erodium cicutarium (L.) L' Heritier	adventive	Crane's Bill
Grossulariaceae			
	Ribes cereum Douglas	native	Currant
Liliaceae			
	Leucocrinum montanum Nutt. ex Gray	native	Sand Lily
Linaceae			
	Linum lewisii Pursh	native	Flax

Family Name	Species	Status	Common Name
Pinaceae			
	Pinus ponderosa Douglas subsp. scopulorum (Watson) Weber	native	Ponderosa Pine
Poaceae			
	Poa compressa L.	native	Canada Bluegrass
	Elymus lanceolatus (Scribner & Smith) Gould	native	Wild Rye
	Koeleria macrantha (Ledebour) Schultes	native	June Grass
	Pascopyrum smithii (Rydberg) Love	native	Western Wheatgrass
	Anisantha tectorum (L.) Nevski	adventive	Cheatgrass
	Stipa comata Trin. & Rupr.	native	Needle and Thread
	Bromus japonicus Thunb. Ex Murray	adventive	Japanese brome
	Andropogon gerardii Vitman.	native	Big Bluestem
	Schizachyrium scoparium (Michaux) Nash	native	Little Bluestem
	Bromus ciliatus L.	native	Fringed Brome
	Hesperostipa neomexicana (Thurb. ex Coult.) Barkworth	native	New Mexico feathergrass
Polygonaceae			
	Pterogonum alatum (Torrey) Gross	native	Winged Buckwheat
	Eriogonum umbellatum Torrey	native	Sulphur flower
Rosaceae			
	Drymocallis fissa (Nuttall) Rydberg	native	Bigflower cinquefoil
	Rosa woodsii Lindley	native	Rose
	Cercocarpus montanus Raf.	native	Mountain Mohogany
Scrophulariaceae			
	Linaria genistifolia (L.) Miller subsp. dalmatica (L.) Maire et al.	adventive	Toadflax

Table 2 Spring sampling of point-cover before the spring burn treatment.(Site 1 prior to spring burn, sampled Feb-March 2003, Five transects)

Species	Status	Total Of Number of Hits	Percent
Dead		211	42.20%
Rock		114	22.80%
Bare Soil		50	10.00%
Litter		47	9.40%
Anisantha tectorum (L.) Nevski	adventive	32	6.40%
Pinus ponderosa Douglas subsp. *scopulorum* (Watson) Weber	native	11	2.20%
Unknown		11	2.20%
Erodium cicutarium (L.) L' Heritier	adventive	9	1.80%
Heterotheca villosa (Pursh) Shinners	native	4	0.80%
Yucca glauca Nuttall.	native	4	0.80%
Elymus lanceolatus (Scribner & Smith) Gould	native	2	0.40%
Pascopyrum smithii (Rydberg) Love	native	2	0.40%
Alyssum parviflorum Bieberstein	adventive	1	0.20%
Ribes cereum Douglas	native	1	0.20%
Leucocrinum montanum Nutt. ex Gray	native	1	0.20%

Table 3: Summer sampling after the spring burn treatment. This table contains the top ten point-cover percentages and represents 87% of the total density. (Site 1 post spring burn, summer sampling, Eleven transects)

Scientific Name	Status	Total Of Number of Hits	Percent
Rock		240	21.25%
Litter		161	14.62%
Bromus japonicus Thunb. Ex Murray	adventive	157	14.26%
Bare Soil		156	14.17%
Anisantha tectorum (L.) Nevski	adventive	125	11.35%
Dead		51	4.63%
Heterotheca villosa (Pursh) Shinners	native	27	2.45%
Elymus lanceolatus (Scribner & Smith) Gould	native	21	1.91%
Trail bare soil		12	1.09%
Pascopyrum smithii (Rydberg) Love	native	12	1.09%

Table 4: Summer sampling before the fall burn treatment. This table contains the top ten point-cover percentages and represents 83% of the total density. (Site 2 prior to fall burn, summer sampling, Ten transects)

Scientific Name	Status	Total Of Number of Hits	Percent
Litter		248	24.825%
Anisantha tectorum (L.) Nevski	adventive	130	13.013%
Bromus japonicus Thunb. Ex Murray	adventive	129	12.913%
Rock		103	10.310%
Bare Soil		68	6.807%
Stipa comata Trin. & Rupr.	native	56	5.606%
Pascopyrum smithii (Rydberg) Love	native	41	4.104%
Dead		25	2.503%
Linaria genistifolia (L.) Miller subsp. *dalmatica* (L.) Maire et al.	adventive	15	1.502%
Andropogon gerardii Vitman.	native	14	1.401%

Table 5: Density of *Anisantha tectorum* and *Bromus japonicus* (Site 1 post spring burn, summer sampling, Five transects sampled with five random 0.25m^2 plots per transect)

Transect #	Total of *Anisantha tectorum per 1.25m^2*	Total of *Bromus japonicus per 1.25m^2*
1	96	322
2	105	198
5	906	293
6	549	555
7	776	447

Mean per plot (0.25m^2)	97.28	72.6
Mean per transect (5 x 0.25m^2 plots)	486.4	363
Standard deviation	374.7429786	139.3969153

Table 6: Soil Analysis (composite sample for each of 22 transects), analyzed by CSU soil testing lab

Transect	Treatment	pH	EC mmhos/cm	Lime Estimate	%OM	NO3-N	P	K	Zn	Fe	Mn	Cu	Texture Estimate
1	Spring Burn	6.1	0.5	Low	3.4	6.5	1.6	222	2.1	25.5	15.8	0.98	Loam
2	Spring Burn	5.1	0.4	Low	5.2	5.3	3.0	271	2.3	49.8	22.7	0.66	Loam
3	Spring Burn	6.3	1.0	Low	4.0	7.0	5.5	260	3.1	33.8	20.7	1.18	Loam
5	Spring Burn	6.0	0.5	Low	2.7	8.6	2.1	187	1.9	27.3	13.3	1.49	Loam
6	Spring Burn	6.0	0.5	Low	2.8	4.9	1.8	152	1.7	21.0	11.5	0.93	Loam
7	Spring Burn	6.3	0.4	Low	3.6	6.5	2.3	248	2.1	20.9	13.3	3.57	Loam
8	Spring Burn	5.9	0.5	Low	3.8	8.9	3.8	186	3.0	34.5	21.6	2.32	Loam
9	Spring Burn	6.0	0.6	Low	3.8	7.5	1.2	261	1.9	27.3	15.4	1.30	Loam
10	Spring Burn	6.0	0.4	Low	3.0	7.5	1.6	208	2.1	26.7	13.5	1.13	Loam
11	Spring Burn	6.0	0.6	Low	3.0	8.7	1.6	196	1.9	31.5	23.1	0.71	Loam
12	Spring Burn	5.8	0.4	Low	3.2	7.7	0.8	169	1.8	29.8	14.3	0.92	Loam
13	Spring Burn	5.7	0.4	Low	3.7	7.2	1.0	185	2.0	32.2	17.9	2.53	Loam
14	Fall Burn	5.9	0.3	Low	3.1	8.9	1.0	220	2.0	31.8	12.5	1.07	Loam
15	Fall Burn	5.7	0.2	Low	3.4	11.6	0.8	208	1.9	29.4	11.5	1.34	Loam
16	Fall Burn	5.8	0.4	Low	2.9	9.0	1.7	204	1.5	32.8	11.4	0.81	Loam
17	Fall Burn	6.0	0.4	Low	2.8	8.3	1.5	228	1.8	27.7	11.4	2.16	Loam
18	Fall Burn	6.1	0.5	Low	3.5	10.7	1.9	236	2.6	34.0	9.5	1.89	Loam
19	Fall Burn	5.8	0.3	Low	3.2	7.2	0.8	178	2.0	27.2	10.2	2.17	Loam
20	Fall Burn	6.0	0.3	Low	2.9	6.9	0.7	196	1.7	23.9	5.5	2.94	Loam
21	Fall Burn	5.9	0.4	Low	3.2	12.5	1.3	226	2.3	33.6	8.8	2.15	Loam
22	Fall Burn	5.9	0.4	Low	2.3	9.2	2.5	231	2.0	27.2	8.6	2.21	Loam
23	Fall Burn	6.1	0.4	Low	4.3	9.9	1.4	270	2.5	26.2	11.2	2.60	Loam