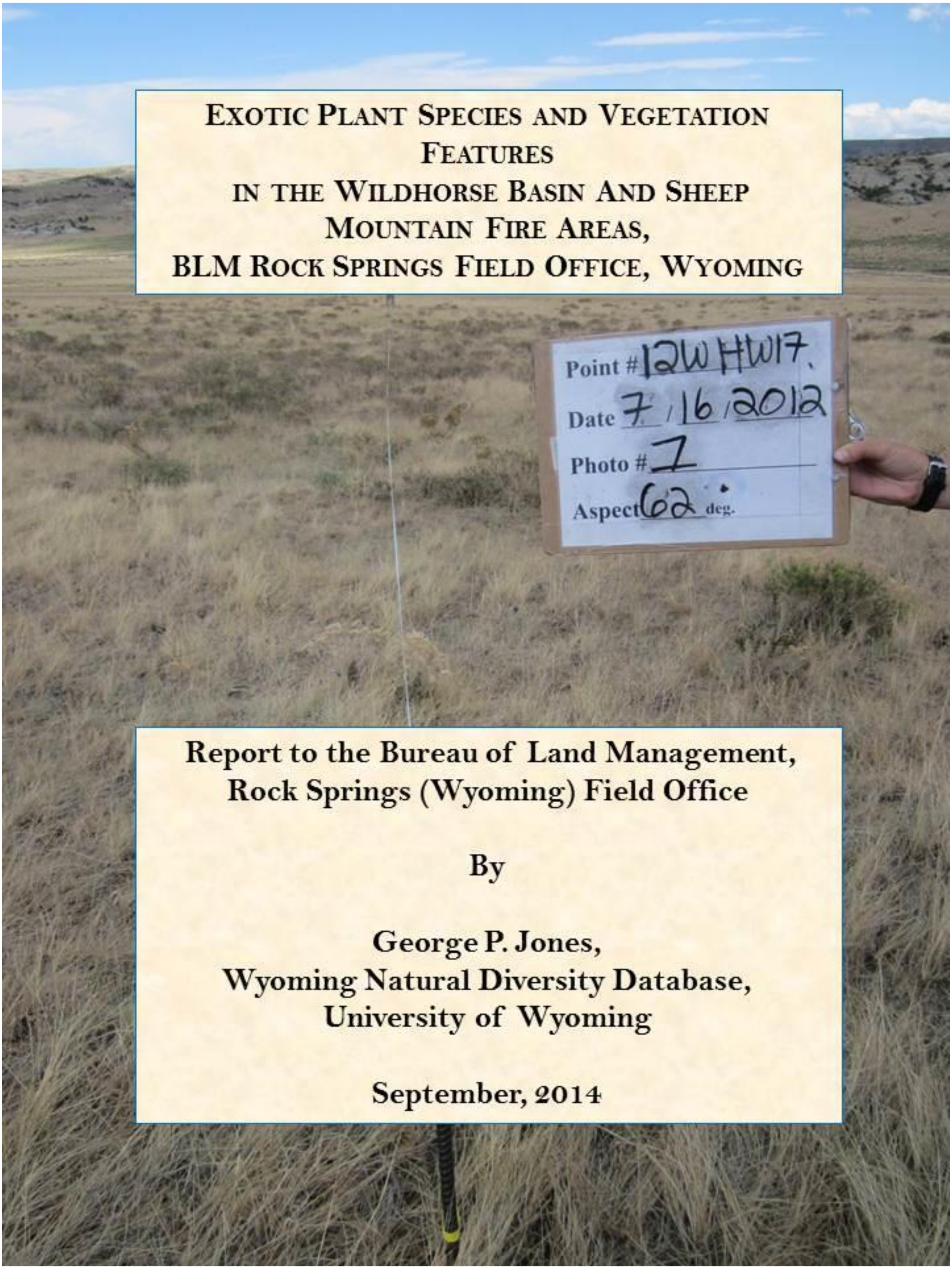
EXOTIC PLANT SPECIES AND VEGETATION FEATURES IN THE WILDHORSE BASIN AND SHEEP MOUNTAIN FIRE AREAS, BLM ROCK SPRINGS FIELD OFFICE, WYOMING



Report to the Bureau of Land Management, Rock Springs (Wyoming) Field Office

By

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September, 2014

ABSTRACT

The Wildhorse Basin and Sheep Mountain wildfires burned in sagebrush steppe and juniper woodland of southwestern Wyoming in 2000. Data were collected in these burned areas and in nearby unburned areas in 2001 and in 2012 to examine (1) differences in the distribution and abundance of exotic plant species and the composition of the vegetation, and changes in these differences over time; and (2) differences in the shrub layer in burned vs. unburned areas 12 years post-fire.

Exotic plants accounted for 10% of the taxa identified during the study. Exotics were widespread at the beginning of the study, in both the burned and unburned areas, and were about equally abundant in burned samples and unburned samples. Exotics increased in abundance through the course of the study in both burned and unburned samples, but the magnitude of the increase was greater in the burned samples, and by the end of the study, exotics were unambiguously more abundant in the burned areas than the unburned. Cheatgrass (*Bromus tectorum*) was far and away the most widespread and common of the exotic species.

Species richness was no different in the burned samples than the unburned samples at the beginning or the end of the study, and it declined slightly in both types of plots. Perennial plants accounted for 76% of the plant taxa and annuals for 21%. In 2001, perennials were slightly more common in the unburned samples and annuals in the unburned samples, but these differences disappeared by 2012. Forbs were the most common growth-form (accounting for 73% of taxa) and they were equally common in the burned and unburned samples. Graminoids and shrubs contributed approximately equally to the flora (13% and 12% of taxa, respectively). Graminoids were equally common in the burned samples and the unburned samples. Shrubs, though, were more common in the unburned samples at the beginning and at the end of the study.

Burned and unburned areas differed markedly in the dominant plant species in the vegetation. In the unburned samples, species that dominated more than a handful of plots at the beginning and end of the study were big sagebrush, (*Artemisia tridentata*), black sagebrush (*A. nova*), bluebunch wheatgrass (*Pseudoroegneria spicata*), Sandberg bluegrass (*Poa secunda*), mock goldenweed (*Stenotus* sp.), and Utah juniper (*Juniperus osteosperma*). The group of common dominants in the burned areas shared only one species, bluebunch wheatgrass, with the unburned areas. The other dominants in the burned areas throughout the study were cheatgrass, thickspike wheatgrass (*Elymus lanceolatus*), western wheatgrass (*Pascopyrum smithii*), greasewood (*Sarcobatus vermiculatus*), and Utah snowberry (*Symphoricarpos oreophilus* ssp. *utahensis*). These are the species that remained dominants throughout the study, but additional species were dominants either early or late in the study; and in both the burned vegetation and the unburned vegetation, the list of dominant species changed by approximately 50% from 2001 to 2012.

Vegetation structure, too, differed between burned areas and unburned areas. Percent canopy cover of all shrubs was substantially greater in the unburned plots, due primarily to the greater cover of big sagebrush in the unburned plots. Density of shrubs, though, was hardly different between burned and unburned samples. Shrub size, expressed either as height or canopy volume, also did not differ between burned and unburned areas, although individual species did differ: big sagebrush plants were slightly larger and black sagebrush were substantially larger in the unburned plots, while Douglas rabbitbrush (*Chrysothamnus viscidiflorus*) plants were slightly larger in the burned areas. Lastly, burned areas supported shrubs with more vigorous canopies.

While data are unavailable for analyzing changes in these features of shrub canopy structure over the course of the study, the differences between burned and unburned areas must have changed between 2001 and 2012. In 2001, a year after the fires, big sagebrush and black sagebrush (neither of which sprout) very likely were all but absent from much of the burned areas, while

Douglas rabbitbrush and Utah snowberry (both sprouters) may have been apparent already. For several years, density of the sagebrushes likely was substantially less on the burned plots, and individuals of all species were substantially smaller. Hence the burned and unburned areas almost certainly started out with very different vegetation structure, and the differences have diminished with time.

This report should be cited as:

Jones, George P. 2014. Exotic Plant Species and Vegetation Features in the Wildhorse Basin and Sheep Mountain Fire Areas, BLM Rock Springs Field Office, Wyoming. Unpublished Report to the Bureau of Land Management, Rock Springs (Wyoming) Field Office from the Wyoming Natural Diversity Database, University of Wyoming.

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PART I. INTRODUCTION AND METHODS

INTRODUCTION

This report presents information about exotic plants and vegetation features in and around the areas burned in 2000 in the Wildhorse Basin and Sheep Mountain wildfires, in southwestern Wyoming (Figure 1). The information was collected on public lands of the Bureau of Land Management's Rock Springs Field Office. Most of the land burned by these fires was vegetated with sagebrush steppe or shrubland or with juniper woodland. Smaller areas supported conifer or aspen woodland.

In the winter of 2000-2001, the BLM and the University of Wyoming signed a cooperative agreement for biologists from the university's Wyoming Natural Diversity Database (WYNDD) to conduct vegetation sampling in the area. BLM and WYNDD biologists selected sampling points for collection of data using either transects of quadrats (referred to as "weed transects") or macroplots. Most of the points were located in burned areas but a few were placed in unburned areas (Table 1). WYNDD field crews collected data at the sampling points in 2001, 2002, and 2012. The information in this report comes from analyses mainly of the 2001 data and 2012 data.

Detailed information about exotic plant species in the study area is presented in section II of this report. Section III focuses on species composition and structure of the vegetation. Section IV summarizes the detailed information presented in the earlier sections. In each section, the primary emphasis is on change from 2001 to 2012 in the various features measured, and how those features changed in burned areas vs. unburned areas.

Figure 1. Location of the study area in Wyoming and in the Rock Springs Field Office, and locations of sampling points. The gray area in the inset map is the Rock Springs Field Office.

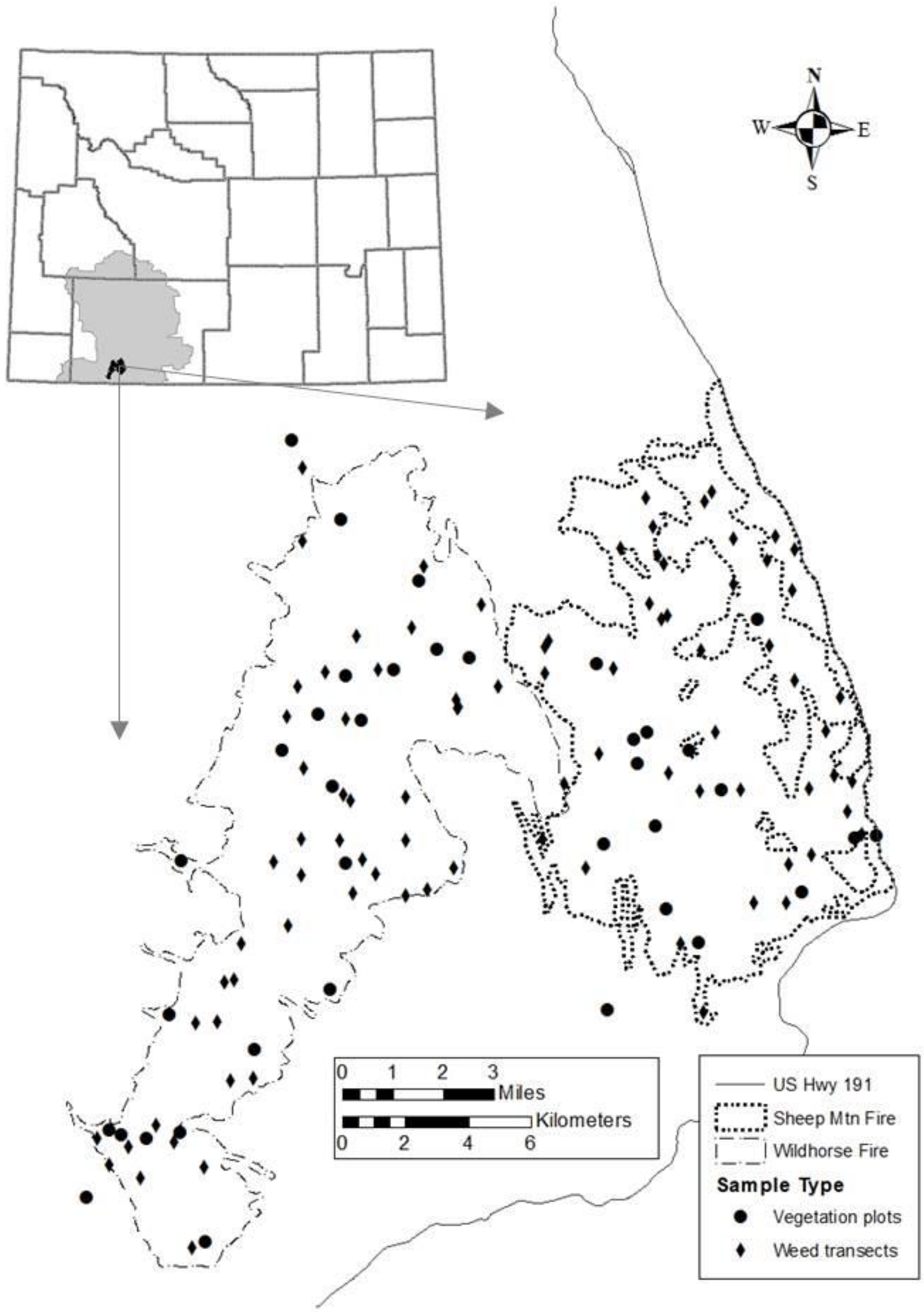


Table 1. Numbers of burned and unburned weed transects and vegetation plots sampled in each year.

		2001	2002	2012
Weed Transects	Burned	70	70	69
	Unburned	21	21	21
	All	91	91	90
Vegetation Plots	Burned	32	32	32
	Unburned	11	10	9
	All	43	42	41

METHODS

Selection of Sampling Points

Potential sampling points were selected before the 2001 field season. The BLM provided a digital file of the boundaries of the Wildhorse Basin and Sheep Mountain fires. This file was overlaid in a GIS project on a landcover layer from the 1996 Wyoming Gap Analysis Project (Merrill *et al.* 1996) and points were selected subjectively to represent different landscape positions in both burned and unburned areas, mainly in the juniper woodland, mountain big sagebrush, and Wyoming big sagebrush cover-types. The points for weed transects were selected separately from the points for vegetation macroplots. The UTM coordinates for each point were obtained from the GIS project.

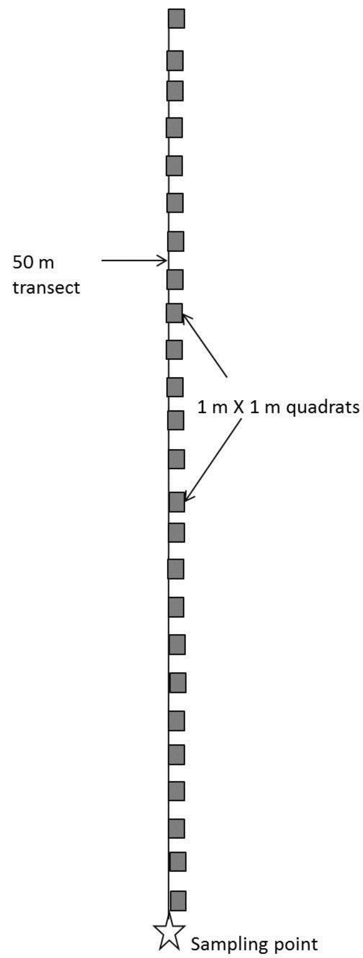
During the 2001 field season, the field crews used GPS receivers and topographic maps to navigate to each potential sampling point. Each point was marked in the field with an aluminum tag wired to a piece of re-bar hammered into the ground, and the location of the re-bar was determined with a GPS receiver. In 2002 and 2012, crew members again used a GPS receiver to navigate to each sampling point, and attempted to find the marker. One vegetation plot sampling point was not relocated (and therefore not sampled) in 2002, and two vegetation sampling points and one weed transect sampling point could not be relocated in 2012. Table 1 shows the numbers of weed transects and vegetation plots sampled in each year.

Field Sampling

Weed Transects

At each of these 91 sampling points, the crews established a 50-meter long transect by stretching a surveyor's rope from the point marker up the slope (Figure 2). The direction of the transect, from the starting point, was measured with a compass. Slope aspect and steepness, landscape position, bedrock type, and texture of surface soil were recorded. Notes were made about obvious soil features, the degree to which the vegetation along the transect resembled that in the surrounding area, and signs of disturbance to the vegetation or soil. Photographs were taken in 2012 of many of the transects.

Figure 2. Arrangement of quadrats along weed transects.



Twenty-five quadrats, each 1-meter by 1-meter, were temporarily marked out along the right-hand side of the surveyor's rope (looking from the starting point), with 1 meter between successive quadrats; the first quadrat extended from the 2-meter point to the 3-meter point on the rope, the second quadrat from the 4-meter point to the 5-meter point, and so on. Each quadrat was examined for the presence of plants from a list of exotic species. If a species was present, a value was recorded that represented its abundance (by broad abundance class) in the quadrat (Table 2). In 2001 and 2002, three abundance classes were used in recording the data. In 2012, four abundance classes were used, to allow better discrimination of abundance of common species. Unfortunately, the classes used in 2012 cannot be collapsed to those used in earlier years, so the data cannot be used to examine changes in the percentage of quadrats occupied by a species through the study period. Specimens were collected of plants that the crew could not positively identify to species in the field.

Table 2. Abundance classes used on weed transects, all years.

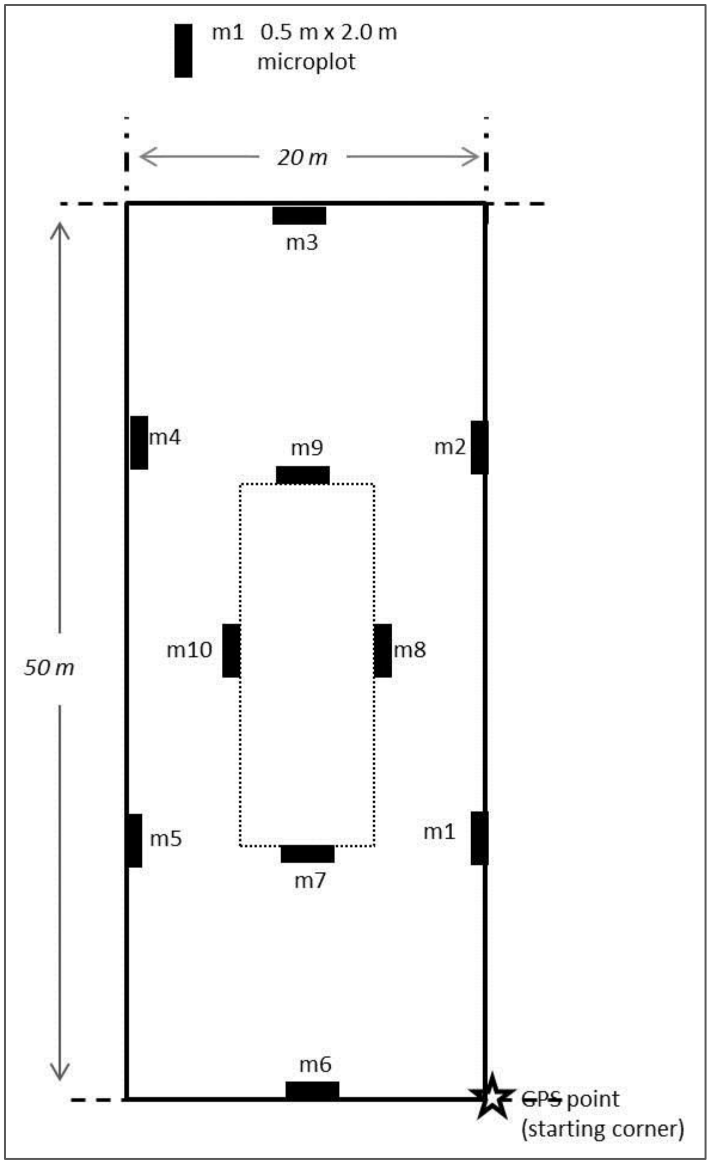
	Class	# stems or rosettes
2001 & 2002	1	≤10
	2	11 - 25
	3	> 25
2012	1	≤10
	2	11-50
	3	51-100
	4	>100

Vegetation Plots

At each of these 43 points, the crew marked out a 20 meter x 50 meter macroplot, starting at the corner with the re-bar point marker. The compass bearing of the long axis was measured from that point. Aspect, slope steepness, landscape position, bedrock type, and texture of surface soil were recorded, and notes were made about obvious soil features, the degree to which the macroplot represented the vegetation of the surrounding area, and signs of disturbance to the vegetation or soil.

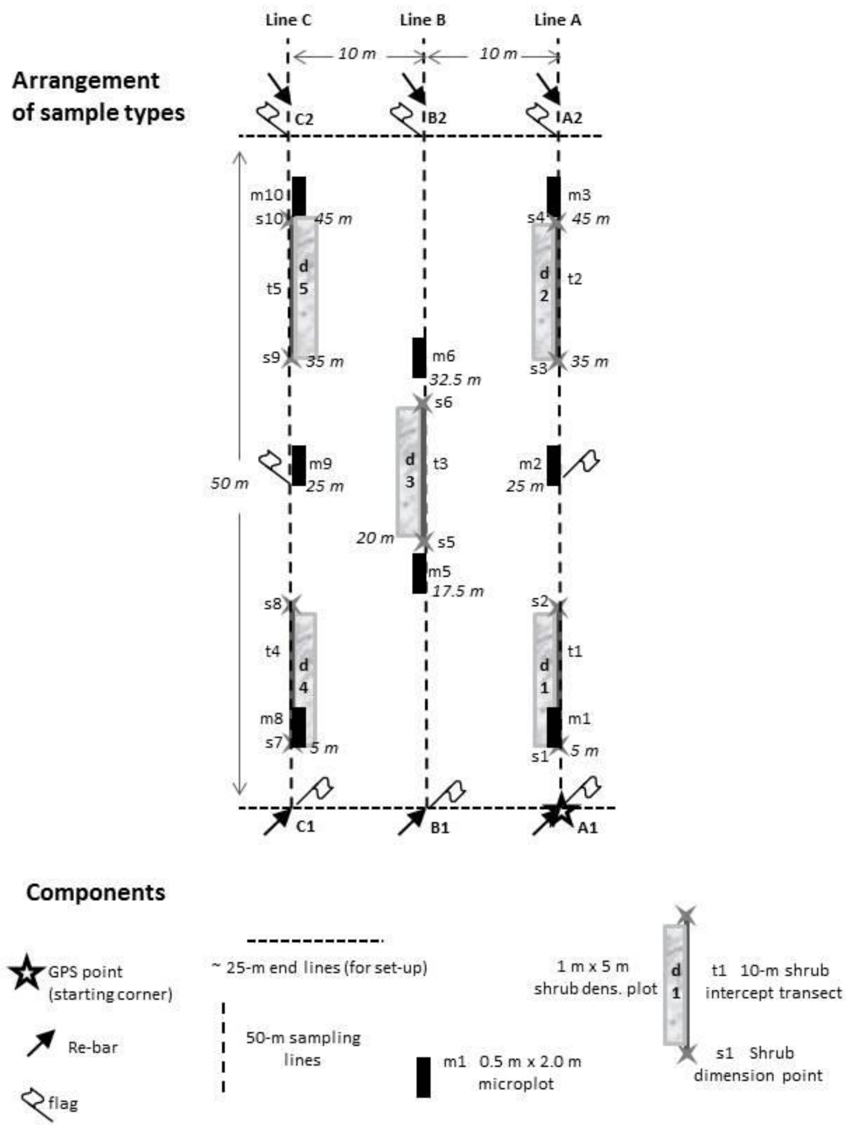
Nested within the macroplot were 0.5 meter x 2.0 meter microplots. In 2001 and 2002, the perimeter of the macroplot was marked by surveyor's ropes, and 10 microplots were located around the perimeter and in the interior of the macroplot (Figure 3). The design of the macroplots was changed slightly for 2012, to speed up sampling: the corners of the macroplot were marked with flags and three 50-meter long sampling lines were laid out parallel to the long axis of the macroplot (Figure 4). Eight microplots were located along the three sampling lines. The data analyses included only 8 of the microplots from 2001, so that comparisons can be made between years.

Figure 3. Diagram of the vegetation plots used in 2001 and 2002



Data from microplots 4 and 7 were excluded from the data analyses. See text.

Figure 4. Diagram of the vegetation sample plots used in 2012.



In each microplot, the percent canopy cover of each plant species was estimated by cover-class (Table 3). The same cover-classes were used in 2001 and 2002 but, in an attempt to speed up sampling, slightly different cover classes were used in 2012. Canopy-cover was treated using the approach of Daubenmire (1959): the data collector imagined a polygon drawn around the outer parts of the canopy of each plant of a given species, and imagined all of those polygons as a single area; the percentage of the microplot beneath that area then was recorded as the percent canopy cover for that species in the microplot. Percent cover of types of ground cover was estimated in the same way. After the microplots were sampled, the macroplot was searched for plant species not recorded in the microplots. For each species, the percent canopy cover for the macroplot was calculated by averaging the midpoints of the cover classes recorded from the microplots. Each of the species that were found only in the macroplot (but not in the microplots) was assigned a canopy cover value of < 1%. The same procedure was used for calculating percent cover values for the different types of ground cover.

Table 3. Cover-classes used to estimate plant canopy cover and ground cover in the vegetation plots, all years.

<table>
<tr><th colspan="3">2001 & 2002</th><th colspan="3">2012</th></tr>
<tr><th>Category</th><th>% Range</th><th>Midpoint</th><th>Category</th><th>% Range</th><th>Midpoint</th></tr>
<tr><td>1</td><td><1%</td><td>0.5</td><td>1</td><td><1%</td><td>0.5</td></tr>
<tr><td>3</td><td>1-5%</td><td>3</td><td>3</td><td>1-5%</td><td>3</td></tr>
<tr><td>10</td><td>5.1-15%</td><td>10</td><td>10</td><td>5.1-15%</td><td>10</td></tr>
<tr><td>20</td><td>15.1-25%</td><td>20</td><td>20</td><td>15.1-25%</td><td>20</td></tr>
<tr><td>30</td><td>25.1-35%</td><td>30</td><td rowspan="2">37.5</td><td rowspan="2">25.1-50%</td><td rowspan="2">37.5</td></tr>
<tr><td>40</td><td>35.1-45%</td><td>40</td></tr>
<tr><td>50</td><td>45.1-55%</td><td>50</td><td rowspan="3">62.5</td><td rowspan="3">50.1-75%</td><td rowspan="3">62.5</td></tr>
<tr><td>60</td><td>55.1-65%</td><td>60</td></tr>
<tr><td>70</td><td>65.1-75%</td><td>70</td></tr>
<tr><td>80</td><td>75.1-85%</td><td>80</td><td rowspan="2">85</td><td rowspan="2">75.1-95%</td><td rowspan="2">85</td></tr>
<tr><td>90</td><td>85.1-95%</td><td>90</td></tr>
<tr><td>98</td><td>95.1-99%</td><td>97</td><td rowspan="2">97.5</td><td rowspan="2">>95%</td><td rowspan="2">97.5</td></tr>
<tr><td>100</td><td>100%</td><td>100</td></tr>
</table>

In 2012, additional data were collected on the shrubs in each vegetation plot. Percent canopy cover was sampled with the line-intercept method. Five canopy intercept lines, each 10 meters long, were marked out along the sampling lines (Figure 4). For each each intersection of a line with a shrub canopy, the length of the intersection was recorded (gaps $\geq$ 10 cm were not included), as were the species name and its condition as alive (any living leaves) or dead. Overlapping canopies of 2 shrubs of the same species were treated as a single intercept, but overlapping canopies of 2 shrubs of different species were recorded as two intercepts. For each species, a single estimate of the percent canopy cover in the plot was calculated by adding the lengths of all the intercepts and dividing by the total length of the 5 intercept lines.

Shrub density was estimated by counting individual shrubs rooted in one of five 1 meter x 5 meter shrub-density plots (Figure 4). For each shrub, its species name and condition as either alive or dead were recorded. The estimate of the density of each species in a macroplot was calculated by summing the counts from the 5 shrub-density plots and dividing by the area of the density plots.

Shrub dimensions and vigor were recorded on 40 shrubs in each plot. Ten shrub-dimension points were located throughout the plot (Figure 4), and 4 shrubs (the nearest in each of 4 quadrants) were sampled at each point. Three dimensions were measured: height of vegetative canopy (excluding inflorescences), canopy length (longest horizontal dimension of canopy), and canopy width (perpendicular to the length). The percentage of the canopy that was alive was estimated. For each species, the average dimensions and vigor were calculated for all of the burned shrubs as a group and all of the unburned shrubs as a group, by averaging the values from all of the individuals of that species in either the burned plots or unburned plots.

Data Analysis

<u>Data Sets and Analyses Used</u>

The sampling design produced three data sets that were analyzed separately. First, the weed transects and the vegetation plots yielded data on the presence and abundance of exotic plant species on individual transects and in individual plots. Second, the vegetation plots yielded data on the presence and abundance of all plant species (natives as well as exotics); these data were analyzed for individual species, and also for plant groups (defined by life-form and life-span). Third, the canopy-intercept lines, shrub-density plots, and shrub-dimension points yielded data from which were calculated several measures of the shrub stratum in each plot, and also measures of shrub size and vigor for all of the shrubs in the burned plots vs. all of the shrubs in the unburned plots (i.e., not on a plot-by-plot basis).

In the analyses of these data sets about different vegetation features, three questions were of interest: (1) Does the feature (e.g., presence of a given species) differ between burned samples and unburned samples? (2) How did this feature change over the course of the study, from 2001 to 2012? (3) Was the change in the feature over the course of the study different in the burned samples than the unburned? All three questions were asked about the first and second data sets. Because the third data set, about shrub canopy, dimensions, and vigor, was collected only in 2012, changes from 2001 to 2012 could not be analyzed.

The following statistical tests were applied to different data sets:

(1) Chi-squared goodness of fit test with Yates correction for continuity (Zar 2010). This test was used to compare the numbers of burned samples with or without exotic species to the numbers of unburned samples with or without exotic species, and also to compare those numbers from 2001 to the numbers from 2012. These tests were performed by hand calculation. The hypotheses in these tests were: *Null hypothesis,* H_0*:* The numbers of samples in group 1 with and without exotics are the same as the numbers in group 2; *Alternate hypothesis,* H_A*:* The numbers of samples with and without exotics in group 1 are different from the numbers in group 2.

(2) The Mann-Whitney U-Test, 2-tailed, using the W statistic in Minitab Version 16.2.4.0 (Minitab, Inc.), was used in several analyses. (a) Comparisons were made of burned vs. unburned weed transects for the number of exotic species present per transect; and for burned vs. unburned vegetation plots for the number of all plant species present, shrub density, and percent shrub canopy cover. In these tests, values were per-transect or per-plot values of numbers of species, or of

density, or of percent canopy cover. (b) This test was also used to compare shrub height, volume, and vigor, for shrubs from burned vegetation plots vs. shrubs from unburned plots. In these tests, the values were for individual shrubs, not averages for plots.

Each of these tests used these hypotheses: *Null hypothesis, H_0:* The distribution of values (numbers of species, shrub density, shrub size) from burned samples (or shrubs) is the same as the distribution of values from unburned samples (or shrubs); *Alternate hypothesis, H_A:* The distribution of values from burned samples (or shrubs) is different than the distribution of values from unburned samples (or shrubs).

This non-parametric test of ranks was used because, in every case, the data values being tested were markedly non-normally distributed, so parametric tests were unsuitable. The Mann-Whitney test does not test for differences in means or medians of the groups being compared (Zar 2021). Rather, it compares the distribution of the ranks of values in the first group with the distribution in the second group, and calculates the probability that the values in the first group and the values in the second group come from the same population (the null hypothesis) or from different populations (the alternate hypothesis). When data from the two groups have closely similar variances, then a significant result from the Mann-Whitney test means that the groups' medians are different; but when their variances are substantially different, then a significant result means that the two groups may differ in their variances or their medians, or both. Because, in almost every case, the variance in the data from the burned samples was very different than the variance in the data from the unburned samples, these Mann-Whitney tests could only show that the distribution of values in the burned samples differed in some way from the distribution in the unburned samples; the two groups may have had different medians, or one may just have been more variable than the other.

(3) T-test (1-sample, 2-tailed) in Minitab Version 16.2.4.0 (Minitab, Inc.). T-tests were used to analyze change from 2001 to 2012 in numbers of plant taxa per sample. The data values were the difference, for each sample, between the 2001 value and the 2012 value. Hypotheses were: *Null hypothesis, H_0*: Change in the values for each sample from 2001 to 2012 = 0; *Alternate hypothesis, H_A*: Change in values for each sample from 2001 to 2012 ≠ 0

Exotic Plant Species

The weed transects and the vegetation plots provide two independent but complementary data sets about the distribution and abundance of exotic plants in the study area.

Exotics on Weed Transects

Two parameters were calculated for selected exotic plant species on each transect: presence (in at least one quadrat along the transect) and abundance (the percentage of the 25 quadrats on the transect in which the species was recorded). Presence and abundance were calculated for individual species and also for the exotics as a group. Both presence and abundance on the transects were examined for differences between burned and unburned samples, and for change over the life of the project.

The following analyses were done on the weed transect data:

(1) Difference in number of transects with or without exotic species, burned vs. unburned transects, and change over time (2001 vs. 2012), using the chi-squared goodness of fit test. The data were were numbers of transects with exotics or without exotics.

(2) Difference in number of exotic species per transect, burned vs. unburned transects. This analysis used the Mann-Whitney U-test. The data were the numbers of exotic plant species per transect.

(3) Change in number of exotic species per transect, 2001 to 2012. Data values were the difference, for each transect, between the number of exotic species in 2001 and the number in 2012. This analysis used the T-test.

(4) Differences in percentages of quadrats with exotic species per transect. Data were the percentage of the 25 quadrats on a transect in which exotic species were recorded. The test was a Mann-Whitney U-test.

(5) Change in percentages of quadrats with exotic species per transect. The data values were the difference, for each transect, between the percentage of quadrats with exotic species in 2001 and the percentage in 2012. The test was a T-test.

Exotics in Vegetation Plots

The same two parameters, presence and abundance, were calculated for every exotic plant species in each vegetation plot. Every exotic plant species, not just the exotics on the list used for the weed transects, was recorded in the plots. Abundance in a vegetation plot is expressed as the percentage (or proportion) of the 8 microplots in which the species was recorded. This proportion of microplots was used as the measure of abundance, rather than percent canopy cover, because the cover-classes used in 2001 and 2002 could not collapsed into the broader cover-classes used in 2012, and so the calculations of percent cover based on the cover classes could not be compared among years. As with the weed transects, both presence and abundance were examined for differences between burned and unburned plots and for change over time. The series of analyses paralleled those done on the weed transect data:

(1) Difference in proportions of vegetation plots with or without exotic species, burned vs. unburned plots, and change over time (2001 vs. 2012). The test was the chi-squared goodness-of-fit test, and the data were numbers of vegetation plots with exotics or without exotics.

(2) Differences in numbers of exotic species per vegetation plot, burned vs. unburned plots. The test was the Mann-Whitney U test. The data were the number of exotic species per vegetation plot.

(3) Change in number of exotic species per vegetation plot, 2001 to 2012. The data values were the difference, for each vegetation plot, between the number of exotic species in 2001 and the number in 2012. These data were tested with a T-test.

(4) Differences in proportions of microplots with exotic species per vegetation plot, burned vs. unburned plots. Data were the proportion of the 8 microplots in a vegetation plot in which exotic species were recorded. The test was a Mann-Whitney U-test.

(5) Change in proportions of microplots with exotic species per vegetation plot. The data values were the difference, for each vegetation plot, between the proportion of microplots with exotic species in 2001 and the proportion in 2012. The test was a T-test.

<u>Composition of the Vegetation</u>

Numbers of plant taxa were calculated for each vegetation plot. These calculations include the number of all taxa, and the numbers of taxa in plant groups based on growth-form (forbs, graminoids, and shrubs), on life-span (annual or perennial), and on origin (native or introduced). Analyses were:

(1) Difference in number of taxa present, burned vs. unburned plots. The data values were numbers of species per plot. Tests were Mann-Whitney U-tests.

(2) Change in number of taxa present, 2001 to 2012. The data values were the difference, for each vegetation plot, between the number of taxa present in 2001 and the number present in 2012. These analyses used T-tests.

Vegetation plot data also were analyzed to show the most common plant species in burned vs. unburned plots, as explained in section III.

Shrub Stratum

Shrub Canopy Cover and Density

The data were the per-vegetation-plot estimates of percent live-shrub canopy cover and live-shrub density (shrubs / square meter). Tests were Mann-Whitney U-tests of burned plots vs. unburned plots.

Shrub Size

Data were shrub height and shrub canopy volume (canopy height X canopy length X canopy width). Data values were for individual shrubs, not averages for vegetation plots. Tests were Mann-Whitney U-tests on shrubs in burned plots vs. shrubs in unburned plots.

Shrub Vigor

Data were percent of the canopy alive, by 10% classes, for individual shrubs. The test was chi-squared goodness-of-fit, on shrubs from burned plots vs. shrubs from unburned plots.

PART II. EXOTIC PLANT SPECIES

These are the results of the analyses of data about exotic plant species, both from the weed transects and from the vegetation plots. The methods used to collect and analyze these data are described in the preceding section.

EXOTICS ON WEED TRANSECTS

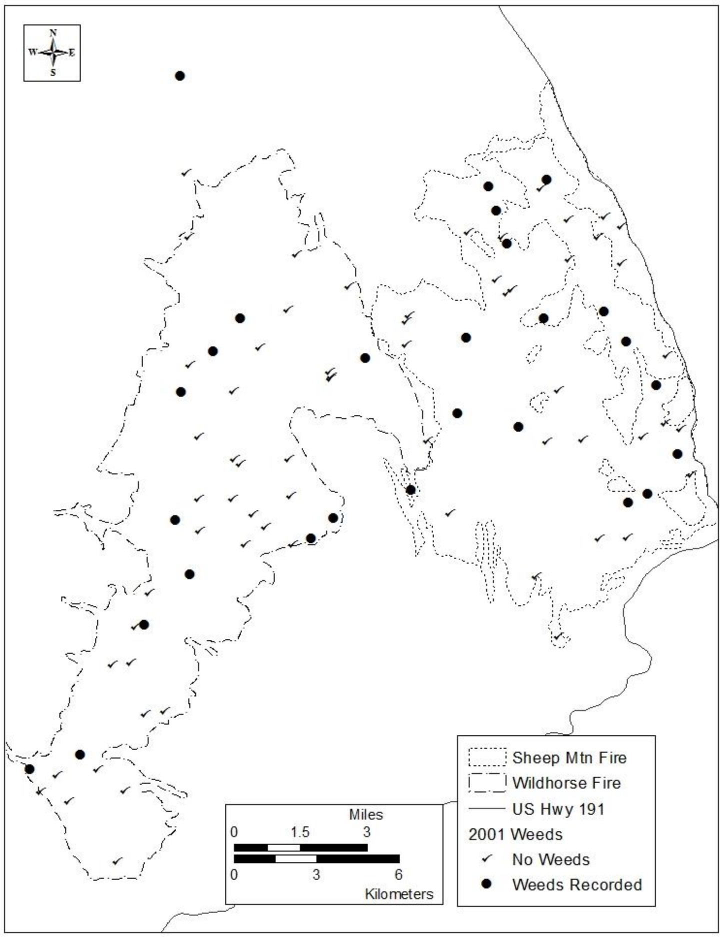
Exotics As a Group on Transects

Three measures give a picture of the distribution and abundance of exotic plant species on the weed transects. The first, the number and distribution of transects on which exotic species were recorded gives an idea of how widespread were the exotic plants in general. Transects with weeds were well distributed throughout the study area (Figure 5). In 2001, exotic plant species were recorded on 29% of the burned transects and 33% of the unburned transects (Table 4). The occurrence of exotic species increased markedly by 2012, especially on the burned transects: 86% of the burned transects, and 52% of the unburned transects, had exotic species in 2012. Chi-squared goodness-of-fit tests (Table 5) showed that the 2001 difference between burned and unburned transects was not statistically significant ($0.75 < p < 0.90$), but by 2012, a statistically-significant difference had developed between the burned and unburned transects ($0.001 < p < 0.005$). Obviously, if more burned transects had exotics in 2012 than in 2001, there was a significant increase in the number of burned transects with exotics. The question remains if the change in the number of unburned transects was significant. A chi-squared test of this difference (Table 6) shows that it was not statistically significant ($0.25 < p < 0.50$). So the 2012 difference between burned and unburned transects developed solely because the number of burned transects with exotics increased significantly.

A second measure of the abundance of exotic plants in the study area is the number of species recorded on each transect. In 2001, the number of species per transect was essentially the same for burned transects (mean = 0.31 species/transect) as for unburned (mean = 0.48 species/transect) (Figure 6). A Mann-Whitney U-test showed no statistically significant difference ($p = 0.5541$) between burned and unburned transects in 2001 (Table 7). From 2001 to 2012, the number of exotic species per transect increased for both burned and unburned transects (Figure 7), and t-tests on the 2001-to-2012 changes showed that they were statistically significant for both types of transects ($p = 0.000$ for burned transects, $p = 0.010$ for unburned transects) (Table 8). The increases on the burned transects were enough greater than the increases on the unburned transects that, by 2012, the burned transects had significantly more exotic species per transect (mean = 1.27 species/transect) than did the unburned transects (mean = 0.71) species/transect) ($p = 0.0163$; Table 7).

Figure 5. Transects with and without exotic plant species, 2001 and 2012.

a. 2001



b. 2012

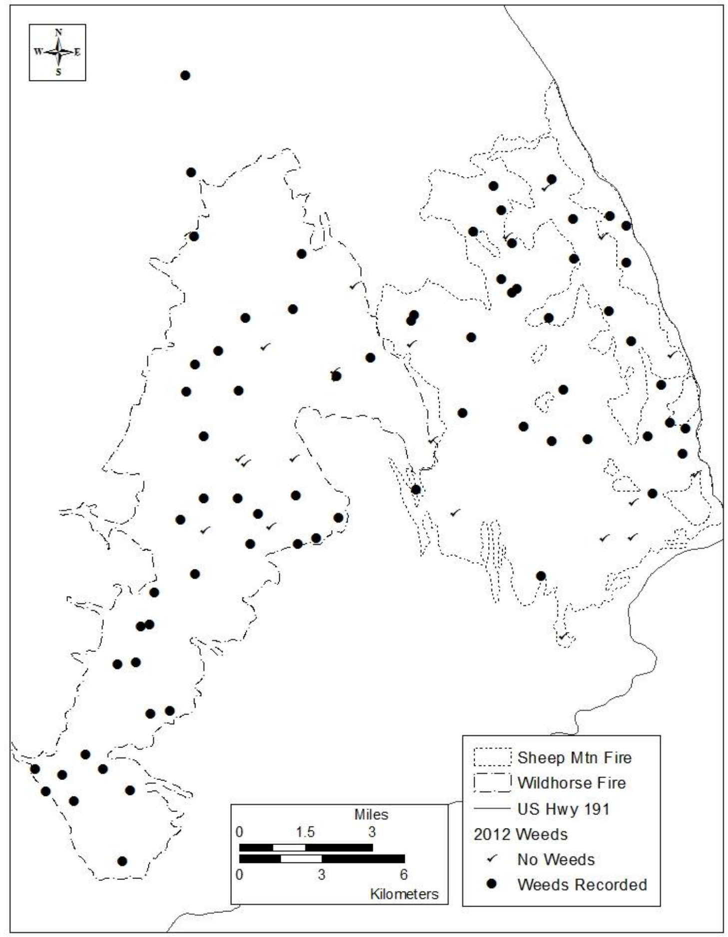


Table 4. Numbers and percentages of weed transects with exotic plants, each year.

	Year	Weeds Recorded on Transect?		# Transects
		No	Yes	
Burned Transects	2001	50 (71%)	20 (29%)	70
	2002	39 (56%)	31 (44%)	70
	2012	10(14%)	59 (86%	69
Unburned Transects	2001	14 (67%)	7 (33%)	21
	2002	17 (81%)	4 (19%)	21
	2012	10 (48%)	11 (52%)	21

Table 5. Chi-squared goodness-of-fit tests, difference in number of burned vs. unburned transects with exotics, 2001 vs. 2012

H_O: The proportions of transects with or without exotic species are the same for burned transects as for unburned transects. **H_A**: The proportions of transects with or without exotic species are different for burned transects than for unburned transects.

In tables, numbers in normal type-face are observed numbers of transects, and numbers in italic type-face are expected numbers of transects.

a. 2001

Type of Transect	No Exotics	Exotics Present	Number of Transects
Burned	50 / *49.23*	20 / *20.77*	70
Unburned	14 / *14.77*	7 / *6.231*	21
Both	64	27	91

Chi-squared (Yates) = 0.022. Degrees of freedom = 1. $0.75 < p < 0.90$. **Do not reject H_O:** The proportions of transects with or without exotics are the same for burned and unburned transects.

b. 2012

Type of Transect	No Exotics	Exotics Present	Number of Transects
Burned	10 / *15.33*	59/ *53.67*	69
Unburned	10 / *4.67*	11/ *16.33*	21
Both	20	70	90

Chi-squared (Yates) = 8.395. Degrees of freedom = 1. $0.001 < p < 0.005$. **Reject H_O:** The proportions of burned transects with or without exotics are different from the proportions of unburned transects.

Table 6. Chi-squared test, change from 2001 to 2012 in the number of unburned transects with exotics.

H_O: The proportions of unburned transects with or without exotic species are the same in 2001 as in 2012. **H_A**: The proportions of unburned transects with or without exotic species in 2001 are different from the proportions in 2012.

Numbers in normal type-face are observed numbers of transects, and numbers in italic type-face are expected numbers of transects.

Year	No Exotics	Exotics Present	Number of Transects
2001	14 / *12*	7 / *9*	21
2012	10 / *12*	11 / *9*	21
Both	24	18	42

Chi-squared (Yates) = 0.875. Degrees of freedom = 1. $0.25 < p < 0.50$. **Do not reject H_O**: The proportions of burned transects with or without exotics in 2001 are the same as the proportions in 2012.

Figure 6. Numbers of exotic plant species per weed transect, burned vs. unburned transects, 2001 vs. 2012. Crosses represent individual transects; solid circles are medians; stars are outliers.

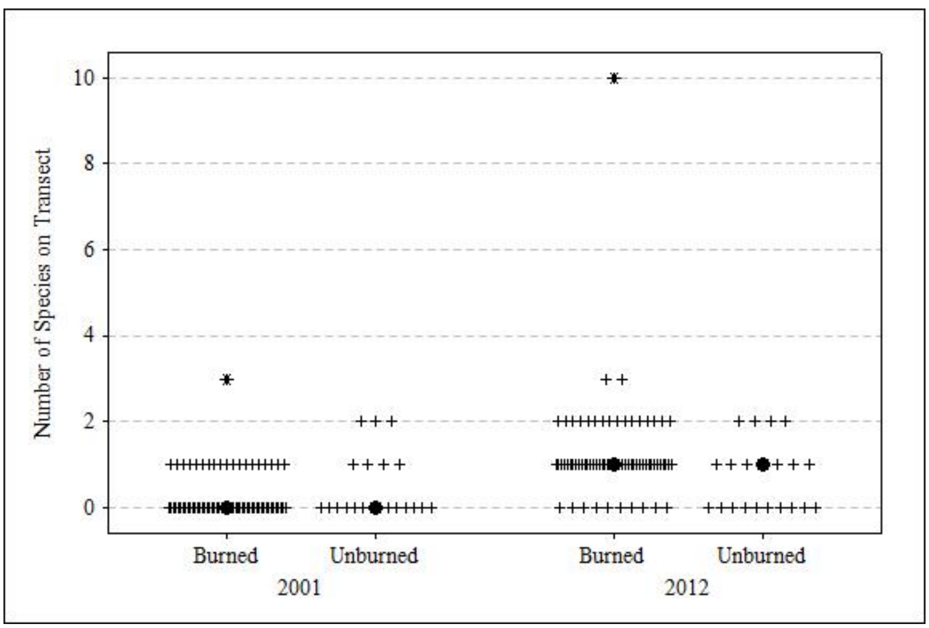


Table 7. Mann-Whitney U tests, number of exotic plant species per transect, burned vs. unburned transects, 2001 vs. 2012.

H_O: The distribution of number of plant species per transect is the same for burned transects as for unburned transects.
H_A: The distribution of number of plant species per transect is not the same for burned transects as for unburned transects.

a. 2001

Transect Type	N	Mean	Median	Variance	Skewness	Kurtosis
Burned	70	0.3143	0.0	0.3056	2.11	6.47
Unburned	21	0.476	0.0	0.457	1.36	0.76

W = 3169.5, p = 0.5541. **Do no reject H_O:** The distribution of number of species per transect is the same for burned transects as for unburned transects.

b. 2012

Transect Type	N	Mean	Median	Variance	Skewness	Kurtosis
Burned	70	1.271	1.0	0.4889	0.30	0.19
Unburned	21	0.714	1.0	0.614	0.58	-1.08

W = 3370.0, p =0.0163. **Reject H_O:** The distribution of number of species per transect differs between burned and unburned transects.

Figure 7. Change, 2001 to 2012, in the number of exotic species on each transect, burned vs. unburned transects. Crosses represent individual transects; solid circles are means.

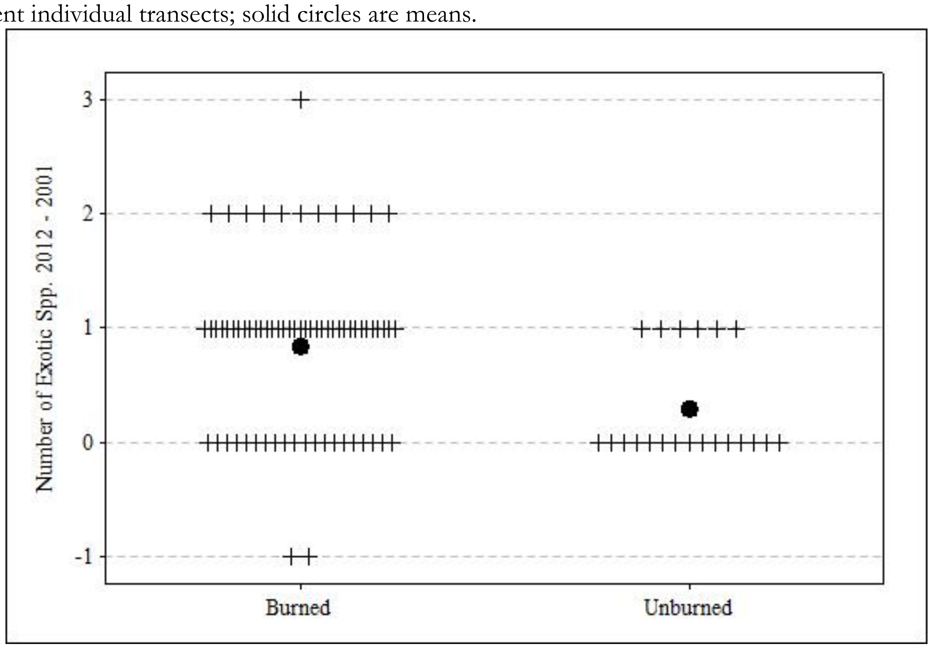


Table 8. T-tests, change from 2001 to 2012 in number of exotic species per transect, burned vs. unburned transects.

H_O: Mean change in number of species = 0. **H_A**: Mean change in number of species ≠ 0

a. Burned transects

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
(Number of species 2012) - (Number of species 2001)	69	0.8406	0.7788	0.0938	(0.6535, 1.0277)	8.97	0.000

Reject H_O: Mean change in number of species 2012 - 2001, is not zero -- the number of species per transect changed

b. Unburned transects

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
(Number of species 2012) - (Number of species 2001)	21	0.286	0.463	0.101	(0.075, 0.496)	2.83	0.010

Reject H_O: Mean change in number of species 2012 - 2001 is not zero -- the number of species per transect changed

A third measure of weed abundance is the frequency of exotic species in the quadrats along each transect (that is, how many of the quadrats along each transect contained exotic species). These frequencies are an index of how common the exotic plants are in the local area of a transect: the more common a weed, the more quadrats it likely will occupy. Figure 8 shows, for each transect, the percentage of quadrats occupied by at least one exotic plant species. These frequencies showed the same pattern as did the numbers of exotic species on transects: they differed very little, if at all, between burned and unburned transects in 2001 (although the means were quite different: 9.60% of quadrats on burned transects, 17.90% on unburned transect), but in 2012, frequencies were higher on many of the burned transects than on the unburned transects (as was the mean: 34.80% of quadrats on burned transects, 19.24% on unburned transects). Mann-Whitney tests for differences (Table 9) confirmed this pattern: there was no significant difference in 2001 (p = 0.4516); but in 2012, the burned transects differed significantly (p = 0.0086) from unburned transects. The difference in 2012 developed because the percentages of quadrats with at least one exotic species on burned transects increased from 2001 to 2012, but the percentages on unburned transects did not (Figure 9). T-tests on the changes show that the increase on the burned transects was statistically significant (p = 0.000), but the increase on the unburned transects probably was not (p = 0.732) (Table 10).

Figure 8. Percentage of quadrats on each transect with at least 1 exotic plant species, burned vs. unburned transects, 2001 vs. 2012.
Crosses represent individual transects; solid circles are medians; stars are outliers.

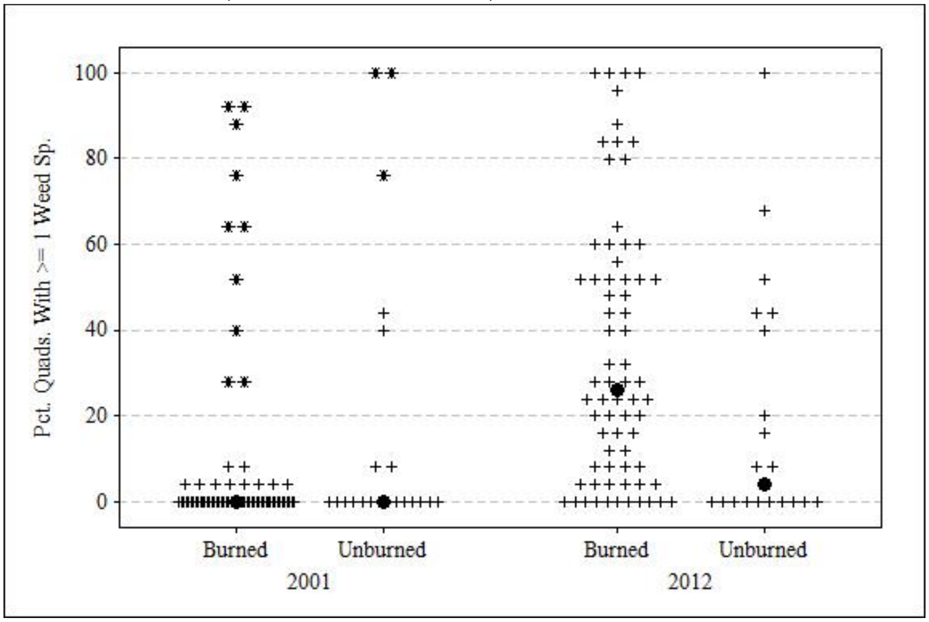


Table 9. Mann-Whitney U tests, percentage of quadrats per transect occupied by at least one exotic species, burned vs. unburned transects, 2001 vs. 2012.

H_O: The distribution of the percentages of quadrats with exotic species on burned transects is the same as the distribution on unburned transects. **H_A:** The distribution of the percentages of quadrates with exotics species on burned transects is different from the distribution on unburned transects

a. 2001

Transect Type	N	Mean	Median	Variance	Skewness	Kurtosis
Burned	70	9.60	0.000	555.32	2.61	5.67
Unburned	21	17.90	0.000	963.74	0.67	-0.65

W = 3155, p = 0.4516. **Do no reject H_O**: the distributions of percentages of quadrats per transect with exotic species are not different between burned and unburned transects.

b. 2012

Transect Type	N	Mean	Median	Variance	Skewness	Kurtosis
Burned	69	34.80	28.00	1135.39	1.80	1.96
Unburned	21	19.24	4.00	791.39	1.59	2.07

W = 3413.5, p =0.0086. **Reject H_O:** the distributions of percentages of quadrats per transect with exotic species are different between burned and unburned transects.

Figure 9. Change, 2001 to 2012, in the percentage of quadrats with at least 1 exotic species per transect, burned vs. unburned transects.
Crosses represent individual transects; solid circles are means; stars are outliers.

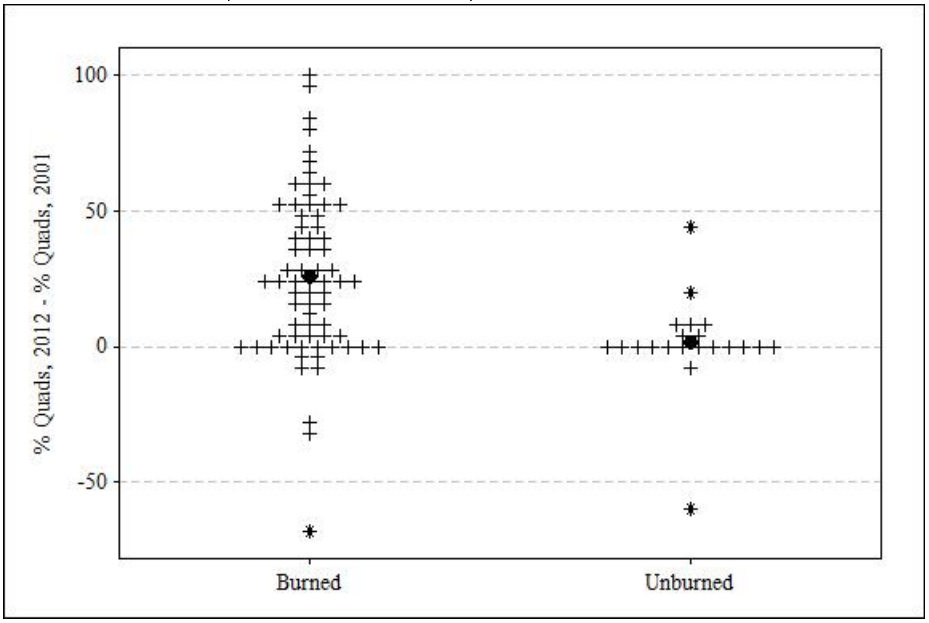


Table 10. T-tests, change from 2001 to 2012 in percentage of quadrats with at least one exotic species per transect, burned vs. unburned transects.

H$_O$: Mean change in percentage of quadrats = 0. **H$_A$**: Mean change in percentage of quadrats ≠ 0.

a. Burned transects

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
(% quadrats in 2012) - (% quadrats in 2001)	69	16.12	30.26	3.64	(18.30, 32.83)	7.02	0.000

Reject H$_O$: Mean change in percentage of quadrats is not zero

b. Unburned transects

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
(% quadrats in 2012) - (% quadrats in 2001)	21	1.33	17.59	3.84	(-6.67, 9.34)	0.35	0.732

Do Not Reject H$_O$: Mean change in percentage of quadrats is zero

Individual Exotic Species on Transects

Ten species of exotic plants were documented on the weed transects during the study (Table 11), three of them perennials, three biennials, and four annuals. Half of the species were recorded in all three of the sampling years, one species was recorded in just two years, and four species were recorded in only one year.

Cheatgrass (*Bromus tectorum*) was by far the most common species, occurring on 20% of the transects in 2001 and almost 66% in 2012. By 2012, it was found throughout both burned areas, except for the southern tip of the Sheep Mountain Fire area (Figure 10). In 2001, cheatgrass was recorded on approximately equal percentages of burned (20%) and unburned transects (19%) (Table 11), and not surprisingly, the difference was not statistically significant ($0.75 < p < 0.90$; Table 12). In 2012, though, the species was recorded on a much larger percentage of burned transects (almost 74%) than unburned (38%) (Table 11), and the difference was statistically significant ($0.005 < p < 0.01$; Table 12). The difference between burned and unburned transects in 2012 developed solely because the proportion of burned transects with cheatgrass increased significantly ($p < 0.0001$); the proportion of unburned transects with cheatgrass did not change from 2001 to 2012 ($0.25 < p < 0.50$) (Table 13).

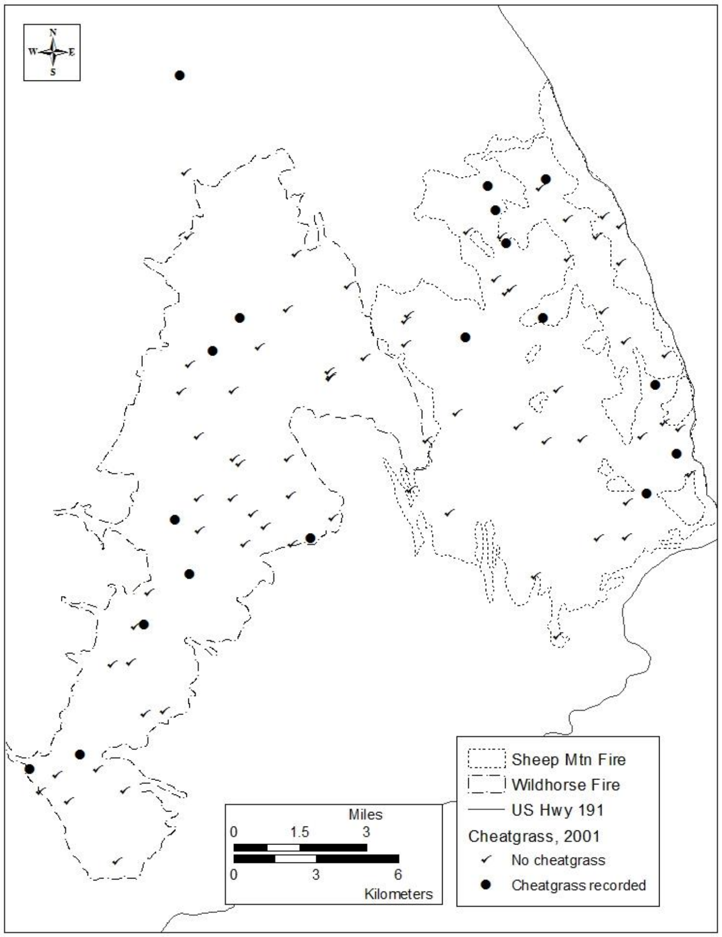
Table 11. Occurrence of exotic plant species on weed transects in each year.

trans and % trans are the number and percentage, respectively, of transects on which the species was recorded. % quad/trans. is the percentage of quadrats in which the species was recorded, averaged for just the transects on which the species was recorded. Values are rounded to tenths.

Species	Transect Type	2001 # trans	2001 % trans	2001 % quad / trans.	2002 # trans	2002 % trans	2002 % quad / trans.	2012 # trans	2012 % trans	2012 % quad / trans.
Alyssum spp. (annual)	Burned	-	-	-	-	-	-	5	7.2	3.3
	Unburned	-	-	-	-	-	-	-	-	-
	All	-	-	-	-	-	-	5	5.6	2.5
Bromus tectorum (annual)	Burned	14	20.0	7.8	11	15.7	3.6	51	73.9	33.3
	Unburned	4	19.0	4.8	1	4.8	3.8	8	38.1	11.1
	All	18	19.8	7.1	12	13.2	3.7	59	65.6	28.1
Carduus nutans (biennial)	Burned	-	-	-	1	1.4	0.1	1	1.4	0.2
	Unburned	1	4.8	0.2	-	-	-	-	-	-
	All	1	1.1	0.1	1	1.1	0.1	1	1.1	0.1
Ceratocephala testiculata (annual)	Burned	-	-	-	-	-	-	6	8.7	1
	Unburned	-	-	-	-	-	-	1	4.8	0.2
	All	-	-	-	-	-	-	7	7.8	0.8
Cirsium arvense (perennial)	Burned	3	4.3	1.7	4	5.7	1.3	3	4.3	0.6
	Unburned	2	9.5	5	3	14.3	6.7	2	9.5	2.9
	All	5	5.5	2.4	7	7.7	2.5	5	5.6	1.2
Cirsium vulgare (biennial)	Burned	-	-	-	-	-	-	-	-	-
	Unburned	1	4.8	0.1	-	-	-	-	-	-
	All	1	1.1	0.1	-	-	-	-	-	-
Elymus repens (perennial)	Burned	2	2.9	0.3	-	-	-	-	-	-
	Unburned	-	-	-	-	-	-	-	-	-
	All	2	2.2	0.3	-	-	-	-	-	-
Halogeton glomeratus (annual)	Burned	1	1.4	0.1	7	10.0	2.6	11	15.9	1.5
	Unburned	-	-	-	-	-	-	2	9.5	0.4
	All	1	1.1	0.1	7	7.7	2	13	14.4	1.2
Hyoscyamus niger (biennial)	Burned	2	2.9	0.6	2	2.9	0.5	-	-	-
	Unburned	-	-	-	-	-	-	-	-	-
	All	2	2.2	0.4	2	2.2	0.4	-	-	-
Sonchus arvensis (perennial)	Burned	-	-	-	13	18.6	3.7	3	4.3	0.3
	Unburned	2	9.5	8.4	-	-	-	2	9.5	8.0
	All	2	2.2	1.9	13	14.3	2.8	5	5.6	2.1

Figure 10. Transects with and without *Bromus tectorum*, 2001 and 2012.

a. 2001



b. 2012

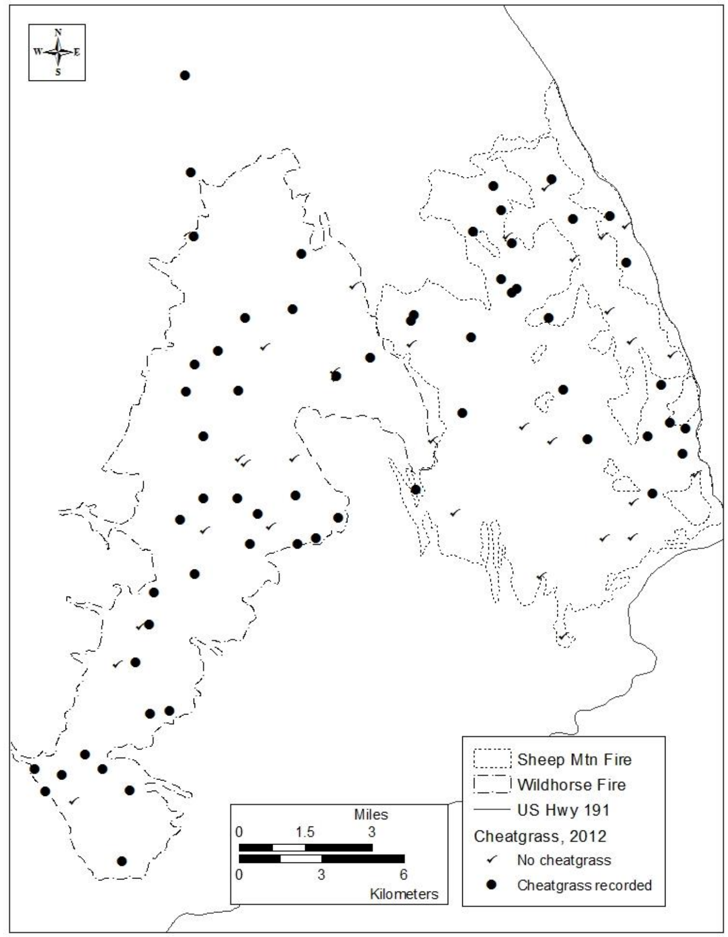


Table 12. Chi-squared goodness of fit test, difference in number of burned vs. unburned transects with *Bromus tectorum*, 2001 vs. 2012.

H_O: The proportions of transects with or without *Bromus tectorum* are the same for burned transects as for unburned transects. **H_A:** The proportions of transects with or without *Bromus tectorum* are different for burned transects than for unburned transects.

In tables, numbers in normal type-face are observed numbers of transects, and numbers in italic type-face are expected numbers of transects.

a. 2001

Type of Transect	No cheatgrass	Cheatgrass Present	Number of Transects
Burned	56 / *56.15*	14 / *13.85*	70
Unburned	17 / *16.85*	4 / *4.15*	21
Both	73	18	91

Chi-squared (Yates) = 0.047. Degrees of freedom = 1. $0.75 < p < 0.90$. **Do not reject H_O:** The proportions of transects with or without exotics are the same for burned and unburned transects.

b. 2012

Type of Transect	No Cheatgrass	Cheatgrass Present	Number of Transects
Burned	18 / *23.77*	51 / *45.23*	69
Unburned	13 / *7.23*	8 / *13.77*	21
Both	31	59	90

Chi-squared (Yates) = 7.629. Degrees of freedom = 1. $0.005 < p < 0.01$. **Reject H_O:** The proportions of burned transects with or without exotics are different from the proportions of unburned transects.

Table 13. Chi-squared tests, change from 2001 to 2012 in the proportions of burned vs. unburned transects with *Bromus tectorum*.

H_O: The proportions of transects with or without *Bromus tectorum* in 2001 are the same as the proportions in 2012. **H_A**: The proportions of transects with or without *Bromus tectorum* in 2001 are different from the proportions in 2012.

In tables, numbers in normal type-face are observed numbers of transects, and numbers in italic type-face are expected numbers of transects.

a. Burned transects

Year	No cheatgrass	Cheatgrass Present	Number of Transects
2001	56 / *37.27*	14 / *32.73*	70
2012	18 / *36.73*	51 / *32.27*	69
Both years	74	65	139

Chi-squared (Yates) = 34.433. Degrees of freedom = 1. $p < 0.0001$. **Reject H_O:** The proportions of burned transects with *Bromus tectorum* in 2001 are not the same as the proportions in 2012.

b. Unburned transects

Year	No Cheatgrass	Cheatgrass Present	Number of Transects
2001	17 / *15*	4 / *6*	21
2012	13 / *15*	8 / *6*	21
Both years	30	12	42

Chi-squared (Yates) = 1.05. Degrees of freedom = 1. $0.25 < p < 0.50$. **Do not reject H_O**: The proportions of unburned transects in 2001 with or without *Bromus tectorum* are not different from the proportions in 2012.

The occurrence of cheatgrass in quadrats along the transects shows the same pattern (Figure 11): the percentages of quadrats occupied per burned or unburned transect differed only slightly in 2001 (mean = 7.77% of quadrats on burned transects, mean = 4.76% on unburned transects; Table 14) and not significantly (p = 0.8216); but in 2012, the percentage of quadrats per burned transect (mean = 33.33% of quadrats) was significantly higher than on unburned transects (mean = 11.05% of quadrats) (p = 0.0018). The percentage of quadrats per transect with cheatgrass increased significantly from 2001 to 2012 on both burned transects (p = 0.0000; Table 15) and unburned transects (p = 0.0037), and the magnitude of the increase was significantly greater (p = 0.0046) on the burned transects than the unburned transects (Figure 12, Table 16).

Figure 11. Percentage of quadrats with *Bromus tectorum* per transect, burned vs. unburned transects, 2001 vs. 2012. Crosses represent individual transects; solid circles are medians; stars are outliers.

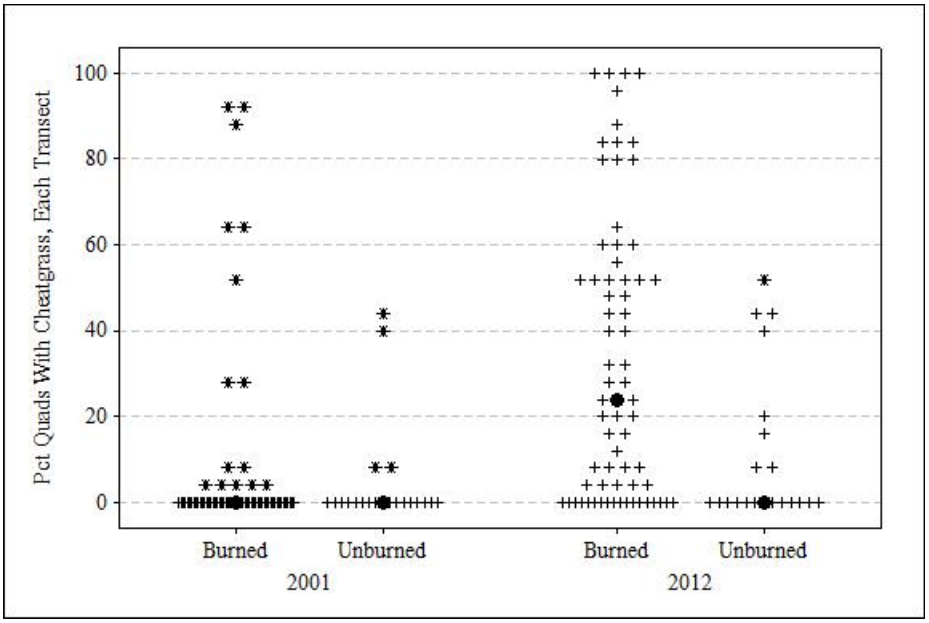


Table 14. Mann-Whitney U-tests, frequency of occurrence of *Bromus tectorum* in quadrats on individual transects, burned vs. unburned transects, 2001 vs. 2012.

H_O: The distribution of the percentage of quadrats with *Bromus tectorum* per transect is the same for burned transects as for unburned transects. **H_A:** The distribution of the percentage of quadrats with *Bromus tectorum* per transect is different for buned transects than for unburned transects

a. 2001

Transect Type	N	Mean	Median	Variance	Skewness	Kurtosis
Burned	70	7.77	0.000	479.95	3.04	8.29
Unburned	21	4.76	0.000	159.39	2.81	6.92

W = 3237.5, p = 0.8216. **Do no reject H_O:** the distribution of percentage of quadrats with *Bromus tectorum* per transect is the same for burned transects as for unburned transects

b. 2012

Transect Type	N	Mean	Median	Variance	Skewness	Kurtosis
Burned	69	33.33	24.00	1090.20	0.65	-0.85
Unburned	21	11.05	0.00	319.85	1.43	0.50

W = 3460.5, p =0.0018. **Reject H_O:** the distribution of the percentage of quadrats with *Bromus tectorum* per transect is different for burned transects than for unburned transects

Table 15. T-tests, change from 2001 to 2012 in frequency of *Bromus tectorum* in quadrats on individual transects, burned vs. unburned transects.

H$_O$: Change in percentage of quadrats per transect with *Bromus tectorum* = 0. **H$_A$:** Change in percentage of quadrats per transect with *Bromus tectorum* ≠ 0

a. Burned transects

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
(% quadrats in 2012) - (% quadrats in 2001)	69	25.45	28.05	3.38	(18.71, 32.19)	7.54	0.000

Reject H$_O$: Change in percent quadrats per transect with *Bromus tectorum* is not zero

b. Unburned transects

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
(% quadrats in 2012) - (% quadrats in 2001)	21	6.29	12.87	2.81	(0.43, 12.51)	2.24	0.037

Reject H$_O$: Change in percent quadrats per transect with *Bromus tectorum* is not zero

Figure 12. Change, 2001 to 2012, in the percentage of quadrats with *Bromus tectorum* per transect, burned vs. unburned transects.
Crosses represent individual transects; solid circles are means; stars are outliers.

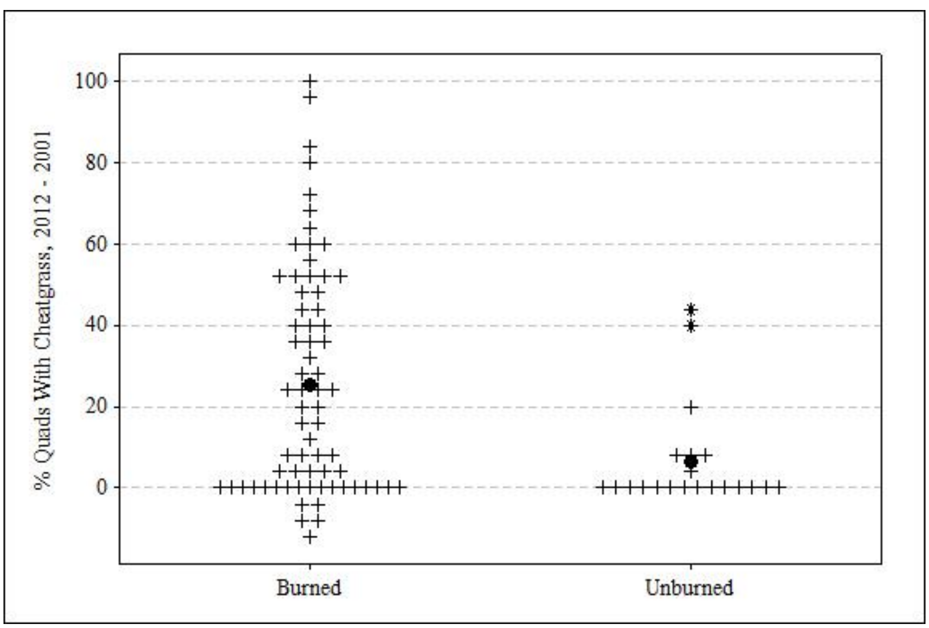


Table 16. Mann-Whitney U-test, magnitude of change from 2001 to 2012 in percentage of quadrats with *Bromus tectorum* per transect, burned vs. unburned transects.

H_O: The distribution of changes per transect is the same for burned transects as for unburned transects. **H_A**: The distribution of changes per transect is different for burned transects than for unburned transects

Transect Type	N	Median	Variance	Skewness	Kurtosis
Burned	69	20.000	786.81	0.77	-0.29
Unburned	21	0.000	165.71	2.36	4.79

W = 3431.0, p =0.0046. **Reject H_O**: the distribution of changes per burned transects is different from the distribution per unburned transect

No other individual exotic species were recorded on enough transects to test for significant differences in their occurrence on burned versus unburned transects or for significant changes in their occurrence from 2001 to 2012, but less-formal examinations can be done of their distributions and abundance. Halogeton (or saltlover, *Halogeton glomeratus*) was recorded on weed transects in all three years and showed a substantial change in number of transects from 2001 (1 transect) to 2012 (13 transects) (Table 11). In 2001 and 2002, this annual species was found only on burned transects, and in 2012 it was recorded on a higher percentage of the burned transects than the unburned. Average percent frequency of halogeton in the quadrats was low even in 2012 (mean on burned transects = 1.5% of quadrats, mean on unburned transects = 0.4%; Table 11), but the species was found in over 10% of the quadrats on each of four burned transects in 2012 (Figure 13). Halogeton apparently is more restricted than cheatgrass in its distribution in the study area, with documentation mainly on transects at the southern end of the Wildhorse Basin Fire area and the northern end of the Sheep Mountain Fire area (Figure 14).

Figure 13. Percentage of quadrats with *Halogeton glomeratus* per transect, burned vs. unburned transects, 2001 vs. 2012. Crosses represent individual transects; solid circles are medians; stars are outliers.

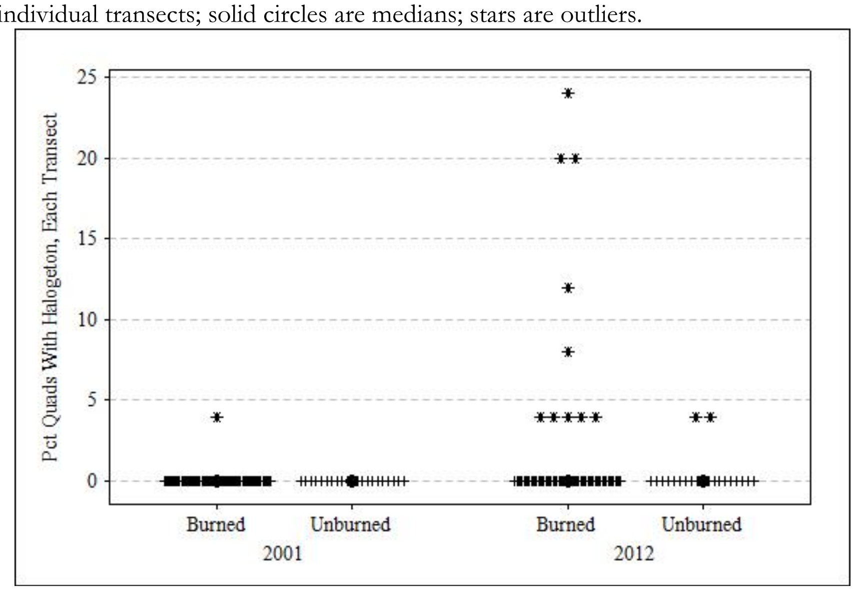
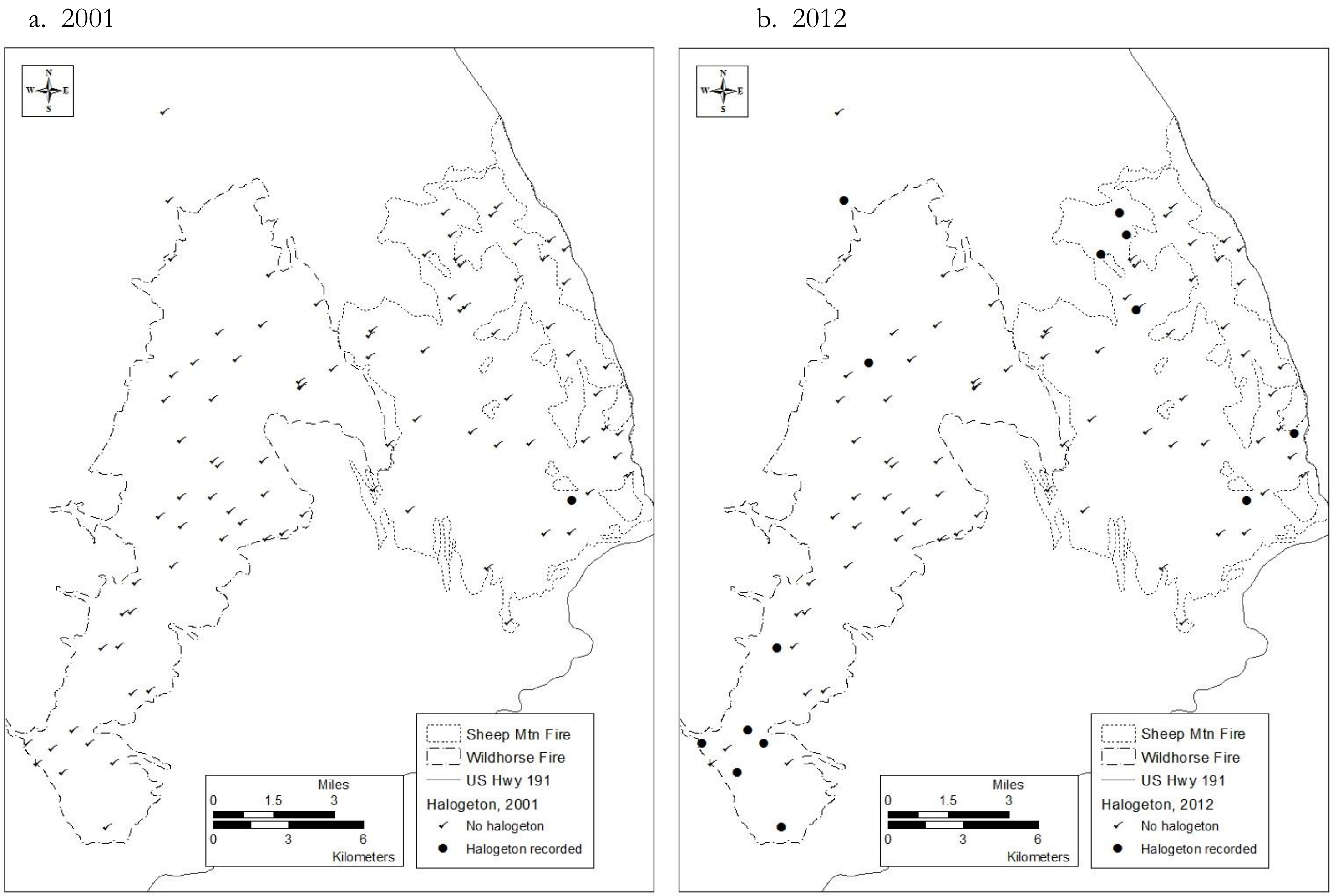


Figure 14. Transects with and without *Halogeton glomeratus*, 2001 and 2012.



Two perennial forb species, Canada thistle (*Cirsium arvense*) and perennial sowthistle (*Sonchus arvensis*), were recorded in all three years, but on so few transects that analysis of their frequencies is pointless (Table 11). Canada thistle was recorded on the same total numbers of transects, and the same numbers of burned transects and unburned transects, in 2001 and 2012 (although on a slightly different set of transects in 2001 than in 2012). In 2002, Canada thistle was recorded on 2 more transects than it was in the other two years. For perennial sowthistle, in contrast, the number of transects on which it was recorded increased between 2001 and 2012, albeit only slightly. This species was recorded on just 2 unburned transects in 2001, and in 2012 on the same 2 unburned transects as well as 3 burned transects. Oddly, sowthistle was recorded on 13 transects (all of them burned) in 2002.

Musk thistle (or nodding plumeless thistle, *Carduus nutans*) is the fifth plant species recorded in all years, on just one transect in each year.

Three species of exotic plants were recorded on the transects in the first year or two of sampling, but not at the end of the project in 2012 (Table 11). Black henbane (*Hyoscyamus niger*) was found on 2 burned transects in both 2001 and 2002, with one of the transects the same in both years. Bull thistle (*Cirsium vulgare*), a biennial forb, and quackgrass (*Elymus repens*), a perennial grass, each was found just in 2001.

Two annual forb taxa were recorded only in 2012. Madwort (*Alyssum* spp.) is common in sagebrush steppe in southern Wyoming, and it was recorded on 5 transects, all of them burned, in the eastern half of the Sheep Mountain Fire area and north of the Wildhorse Basin Fire area (Figure 15). It occurred in a high percentage of the quadrats on some of the transects (Figure 16), but its average percentage of quadrats of occurrence on transects was low (3.3%; Table 11). Bur buttercup (*Ceratocephala testiculata*) also was recorded mainly from the Sheep Mountain Fire area, but was found on 2 transects in the Wildhorse Basin Fire area as well (Figure 17). The species was found on 6 burned transects and only 1 unburned transect. As with madwort, bur buttercup occurred, on average, in a very low percentage of quadrats/transect (mean = 1% of quadrats on burned transects, 0.2% on unburned transects; Table 11), but it was found in a fairly high percentage of quadrats on some individual transects (Figure 18).

Figure 15. Transects with and without *Alyssum* spp. in 2012.

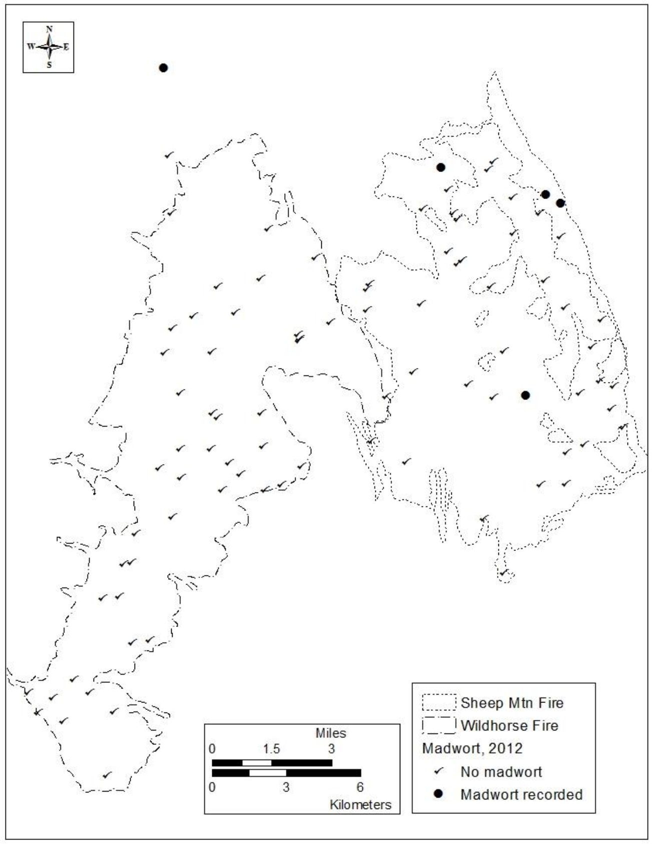


Figure 16. Percentage of quadrats with *Alyssum* spp. per transect, burned vs. unburned transects, 2001 and 2012. Crosses represent individual transects; solid circles are medians; stars are outliers.

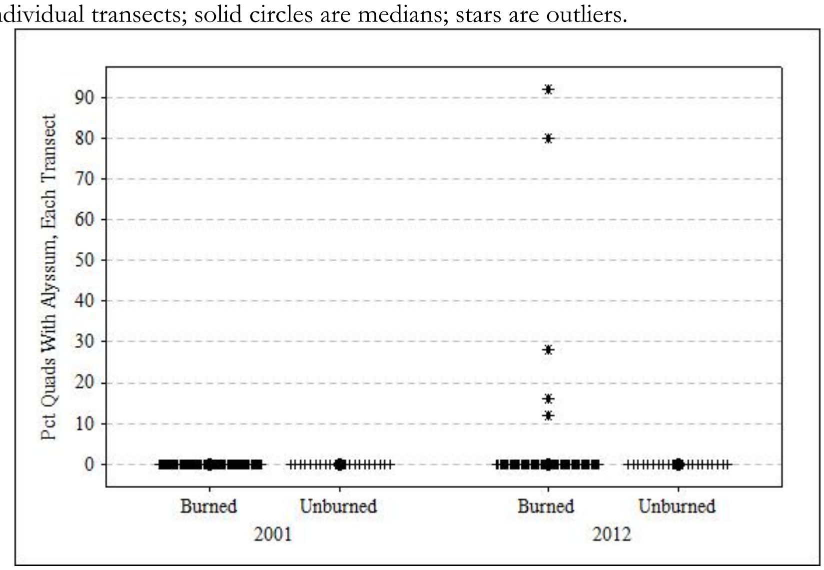


Figure 17. Transects with and without *Ceratocephala testiculata*, 2012.

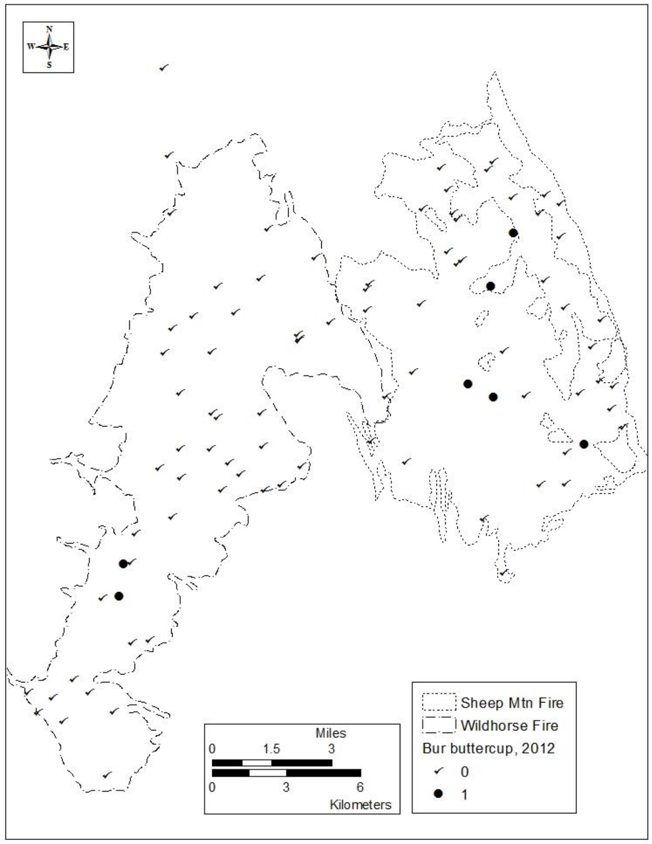
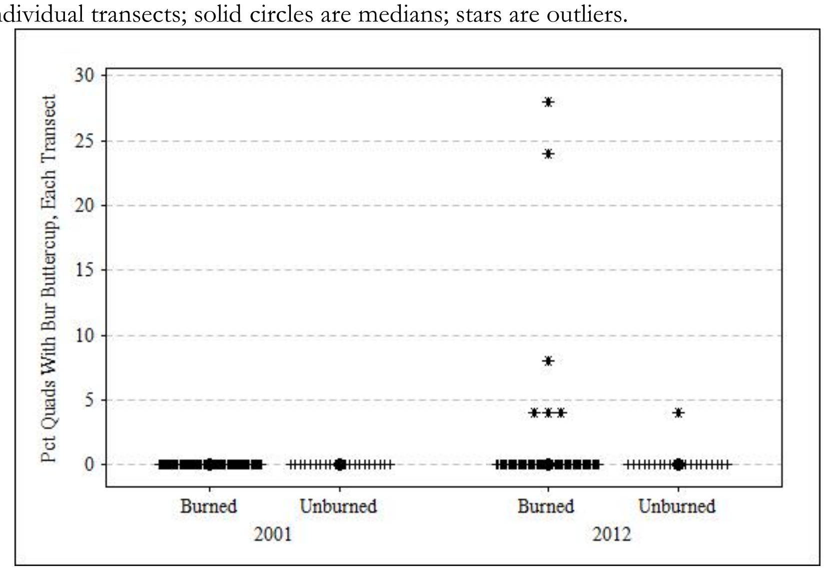


Figure 18. Percentage of quadrats with *Ceratocephala testiculata* per transect, burned vs. unburned transects, 2001 vs. 2012. Crosses represent individual transects; solid circles are medians; stars are outliers.



Exotics on Transects -- Summary

The data from the weed transects shows that at least 10 exotic plant species occurred in the study area and, even in 2001, many were distributed widely throughout the area. Exotics spread to more transects by 2012, and the data suggest that they also increased in abundance. This increase is shown by the greater number of transects with at least one exotic species in 2012, the greater number of exotic species per transect in 2012, and the greater percentage of quadrats with exotics per transect in 2012. All three of these measures of weed abundance clearly increased on the burned transects. On the unburned transects, only the number of species per transect clearly increased; data about the number of transects with exotics and the percentage of quadrats with exotics per transect show no significant increase. The burned transects differed little from the unburned transects in all 3 measures in 2001, but by 2012, the burned transects clearly had more exotics according to all 3 measures. The data suggest, then, that exotics increased in distribution and abundance from 2001 to 2012, due largely to increases on the burned transects.

The pattern of occurrence of the exotics as a group appears to be created by that of cheatgrass (*Bromus tectorum*), the most widespread and by far the most common of the exotics. Most other exotic species recorded in more than a scattering of transects (*Halogeton glomeratus*, *Ceratocephala testiculata*, *Alyssum* spp.) likewise were more common on burned transects than unburned.

EXOTICS IN VEGETATION PLOTS

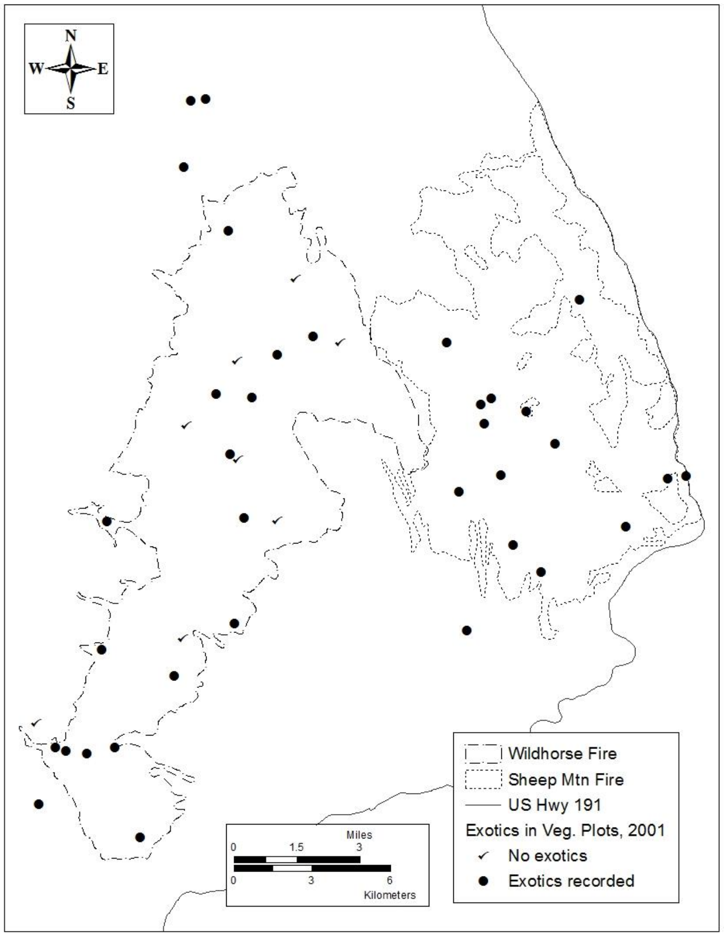
Vegetation plots were sampled at 32 burned points and up to 11 unburned points in each year (Table 17). Fewer unburned plots were sampled in 2002 and 2012 because some sampling points could not be relocated. The sampling points were spread throughout both of the burned areas (Figure 19).

Table 17. Numbers and percentages of vegetation plots with or without exotic plant species, all 3 years.

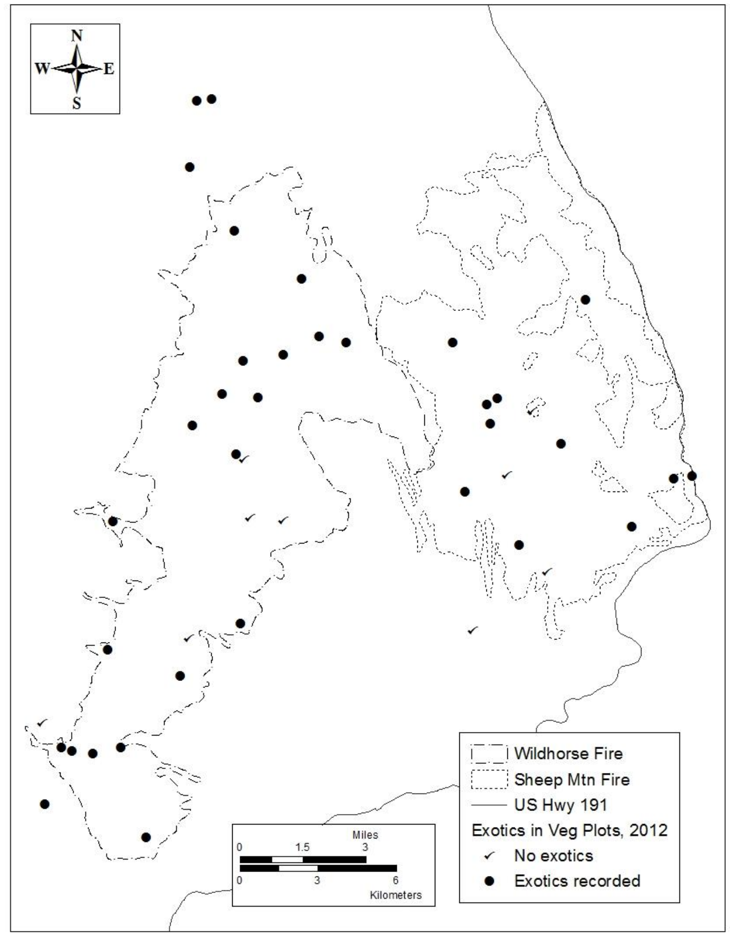
		Weeds Recorded in Plot?		
	Year	No	Yes	# Plots
Burned Plots	2001	2 (6%)	30 (94%)	32
	2002	10 (31%)	22 (69%)	32
	2012	3 (9%)	29 (91%)	32
Unburned Plots	2001	6 (55%)	5 (45%)	11
	2002	7 (70%)	3 (30%)	10
	2012	4 (44%)	5 (56%)	9

Figure 19. Locations of vegetation plots with and without exotic plant species, 2001 and 2012

a. 2001



b. 2012



Exotics As a Group in Vegetation Plots

From the beginning to the end of the project, exotic plants were found in vegetation plots throughout the study area. In 2001 and 2012, exotics were recorded in over 90% of the burned plots and in 45% (2001) or 56% (2012) of the unburned plots (Table 17), and these plots were distributed throughout the study area (Figure 19). In both 2001 and 2012, the proportion of burned plots with exotic species was significantly larger than the proportion of unburned plots ($0.001 < p < 0.005$ for 2001; $0.025 < p < 0.05$ for 2012; Table 18).

The number of exotic species per vegetation plot provides an indication of the abundance of those plants in the study area. In all three years of sampling, the number of species per plot was greater in burned plots than unburned plots (Figure 20). Mann-Whitney U-tests showed that the difference between burned plots and unburned plots in numbers of exotic species was statistically significant, in 2001 ($p = 0.0013$) and in 2012 ($p = 0.0030$) (Table 19). The number of exotic species recorded per vegetation plot remained essentially constant from year to year, in both burned plots and unburned plots (Figure 21). T-tests of the 2001-to-2012 differences (Table 20) confirm that there was no significant change in the burned plots ($p=0.689$) or the unburned plots ($p=1.000$).

Table 18. Chi-squared goodness-of-fit tests, proportions of burned vs. unburned plots with and without exotics, 2001 vs. 2012

H_O: The proportions of plots with or without exotic species are the same for burned plots as for unburned plots. **H_A:** The proportions of plots with or without exotic species are different for burned plots than for unburned plots.

In tables, numbers in normal type-face are observed numbers of plots, and numbers in italic type-face are expected numbers of plots.

a. 2001

Type of Plot	No Exotics	Exotics Present	Number of Plots
Burned	2 / *5.95*	30 / *26.05*	32
Unburned	6 / *2.05*	5 / *8.95*	11
Both	8	35	43

Chi-squared (Yates) = 9.621. Degrees of freedom = 1. $0.001 < p < 0.005$. **Reject H_O:** The proportions of plots with or without exotics are not the same for burned as for unburned plots.

b. 2012

Type of Plot	No Exotics	Exotics Present	Number of Plots
Burned	3 / *5.46*	29 / *26.54*	32
Unburned	4 / *1.54*	5 / *7.46*	9
Both	7	34	41

Chi-squared (Yates) = 3.876. Degrees of freedom = 1. $0.025 < p < 0.05$. **Reject H_O:** The proportions of plots with or without exotics are not the same for burned plots as for unburned plots.

Figure 20. Number of exotic plant species in each vegetation plot, burned vs. unburned plots, 2001 vs. 2012. Crosses represent individual transects; solid circles are medians; stars are outliers.

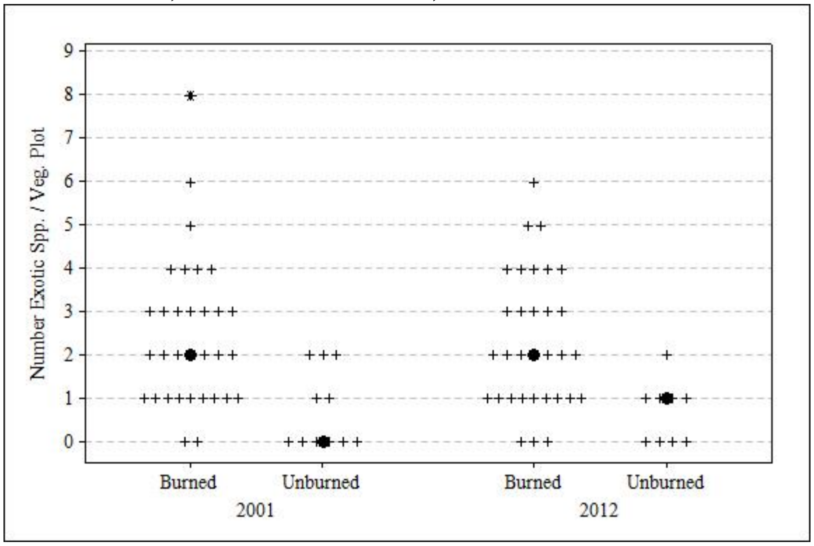


Table 19. Mann-Whitney U tests, number of exotic species per vegetation plot, burned vs. unburned plots, 2001 vs. 2012.

H_O: The distribution of the number of species per plot is the same for burned plots as for unburned plots. **H_A:** The distribution of the number of species per plot is different for burned plots than for unburned plots

a. 2001

Plot Type	N	Mean	Median	Variance	Skewness	Kurtosis
Burned	32	2.469	2.000	3.031	1.21	2.11
Unburned	11	0.727	0.0	0.818	0.65	-1.55

W = 817.5, p =0.0013. **Reject H_O:** the distribution of the number of species per plot is different for burned plots than for unburned plots.

b. 2012

Plot Type	N	Mean	Median	Variance	Skewness	Kurtosis
Burned	32	2.313	2.000	2.480	0.50	-0.49
Unburned	9	0.667	1.000	0.500	0.61	-0.29

W = 764.5, p =0.0030. **Reject H_O:** the distribution of the number of species per plot is different for burned plots than for unburned plots.

Figure 21. Change, 2001 to 2012, in the numbers of exotic plant species in each vegetation plot, burned vs. unburned plots.
Each cross represents change on an individual vegetation plot. Solid circles are means.

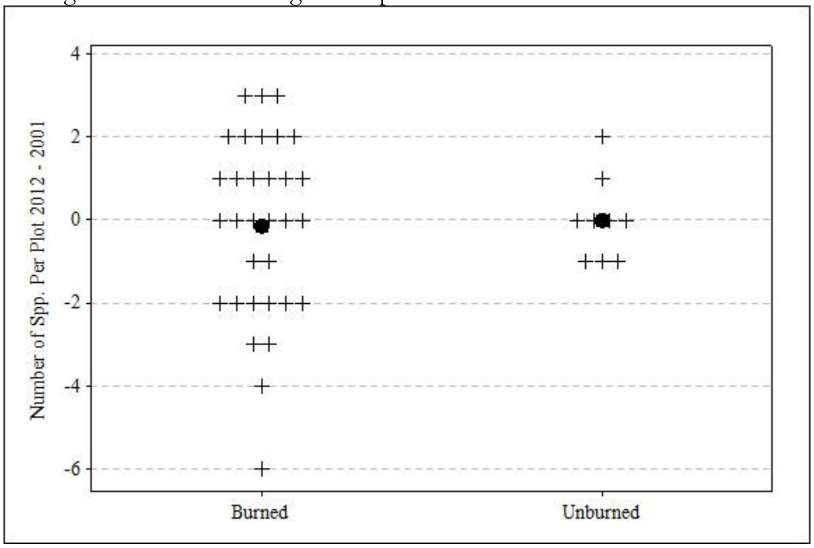


Table 20. T-tests, change from 2001 to 2012 in number of exotic plant species per vegetation plot, burned vs. unburned plots.

H_O: Mean change in number of species = 0. **H_A**: Mean change in number of species ≠ 0

a. Burned plots

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
(Number of species 2012) - (Number of species 2001)	32	-0.156	2.187	0.387	(-0.945, 0.632)	-0.40	0.689

Do Not Reject H_O: Mean change in number of species 2012 - 2001, is zero -- the number of species per plot did not change

b. Unburned plots

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
(Number of species 2012) - (Number of species 2001)	9	0.000	1.000	0.333	(-0.769, 0.769)	0.00	1.000

Do Not Reject H_O: Mean change in number of species 2012 - 2001, is zero -- the number of species per plot did not change

A second indicator of the abundance of exotic plants in the study area is provided by the number of microplots in which the exotic species were recorded per vegetation plot. The sum, for a vegetation plot, of the number of microplots that each exotic species occupied is a measure of how abundant the exotics were within the area of the vegetation plot. The more exotic species in a vegetation plot and the more of the microplots in which each species was found, the larger this sum. Figure 22 shows these sums for each of the vegetation plots. Although the sums in burned plots overlapped those of unburned plots, the data indicate that burned plots had larger values (in 2001, burned plots mean = 3.181, unburned plots mean = 0.418; in 2012, burned plots mean = 5.375, unburned plots mean = 0.667; Table 21). Mann-Whitney U-tests confirm this impression (Table 21): the sums of microplots were significantly different between burned plots and unburned plots in 2001 (p=0.0015) and in 2012 (p = 0.0005). Figure 22 suggests that the abundance of exotics increased between 2001 and 2012 on the burned plots but not the unburned plots. The changes are illustrated more clearly in Figure 23, which shows the change in sums of microplots for each of the vegetation plots. These changes were tested statistically with t-tests (Table 22), which showed a significant increase (p=0.0014) in the burned plots but not (p=0.671) in the unburned plots.

Figure 22. Sum, for all exotic species, of the number of occupied microplots per plot, burned vs. unburned plots, 2001 vs. 2012.
Crosses represent individual transects; solid circles are medians; stars are outliers.

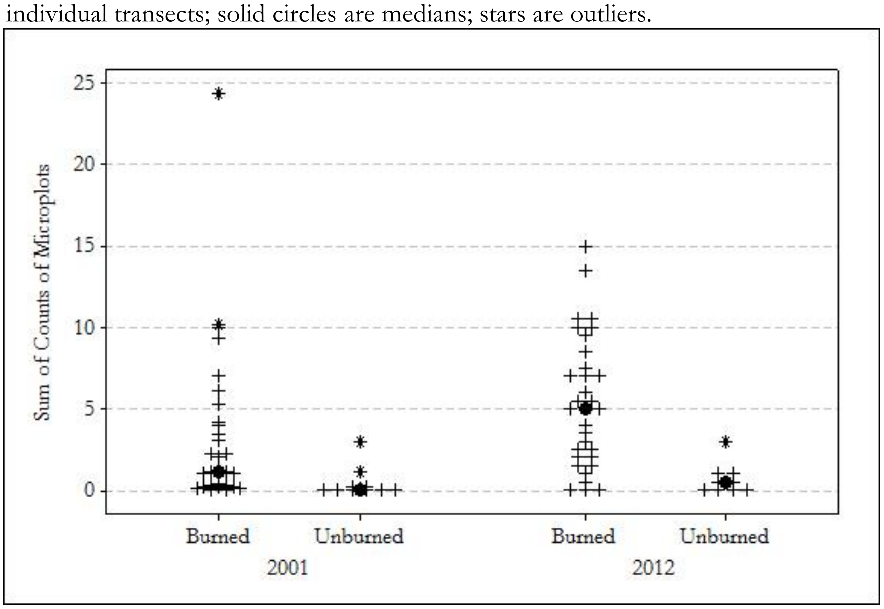


Table 21. Mann-Whitney U tests, sum for all exotic species, of the number of occupied microplots per vegetation plot, burned vs. unburned plots, 2001 vs. 2012.

H_O: The distribution of sums, for all exotic species, of the number of occupied microplots is the same for burned plots as for unburned plots. **H_A:** The distribution of sums, for all exotic species, of the number of occupied microplots is different for burned plots than for unburned plots.

a. 2001

Plot Type	N	Mean	Median	Variance	Skewness	Kurtosis
Burned	32	3.181	1.100	24.264	2.92	10.66
Unburned	11	0.418	0.000	0.838	2.72	7.55

W = 818.0, p =0.0015. **Reject H_O**: The distribution of the sums of number of occupied microplots is different for burned plots than for unburned plots.

b. 2012

Plot Type	N	Mean	Median	Variance	Skewness	Kurtosis
Burned	32	5.375	5.000	16.258	0.57	-0.35
Unburned	9	0.667	0.500	0.938	2.05	4.71

W = 782.5, p =0.0005. **Reject H_O:** The distribution of the sums of number of occupied microplots is different for burned plots than for unburned plots.

Figure 23. Change, 2001 to 2012, in the sum, for all exotic species, of the number of occupied microplots per vegetation plot, burned vs. unburned plots.
Each cross represents change in an individual vegetation plot. Solid circles are means.

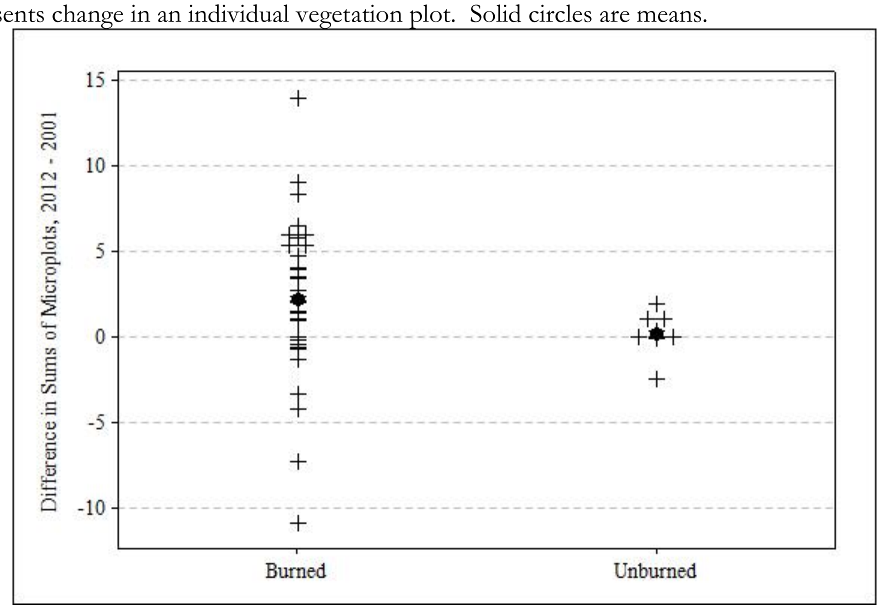


Table 22. T-test of changes, 2001 to 2012, in the sum, for all exotic species, of the number of occupied microplots per vegetation plot, burned vs. unburned plots.

H_O: Mean change = 0. **H_A:** Mean change ≠ 0

a. Burned plots

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
(Sum of microplots 2012) - (Sum of microplots 2001)	32	2.194	4.749	0.839	(0.482, 3.906)	2.61	0.014

Reject H_O: Mean change in sums of numbers of occupied microplots per vegetation plot is not zero.

b. Unburned plots

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
(Sum of microplots 2012) - (Sum of microplots 2001)	9	0.178	1.208	0.403	(-0.751, 1.106)	0.44	0.671

Do not reject H_O: Mean change in sums of numbers of occupied microplots per vegetation plot is zero.

In summary, data from the vegetation sample plots suggest that exotic plants were widely distributed throughout the study area, apparently more widely in the burned areas than the unburned. There is no evidence from the vegetation plots that the distribution of exotics changed over the course of the study. Exotics seem to have been more abundant in the burned areas than the unburned, judging from larger values, for burned plots, of both the number of exotic species per vegetation plot and the number of microplots per plot in which the exotics were documented. The data suggest that the number of exotic species present in the study area did not change. But exotic species apparently became somewhat denser in the burned areas, although not in the unburned areas, between 2001 and 2012.

Individual Exotics in Vegetation Plots

Twenty-four species of exotic plants were documented in the vegetation sampling plots during the study (Table 23). Seven of those species are perennials, two are biennials, and 15 are annuals. Nearly half of the species (11 of them) were recorded in only one year, five species were recorded in two years, and the remaining eight species were recorded in all three years. Only five species were documented in unburned vegetation plots.

Table 23. Occurrence of exotic plant species in vegetation plots, all 3 years.

Species	Plot Type	2001 # plots	2001 % plots	2002 # plots	2002 % plots	2012 # plots	2012 % plots
Agropyron cristatum (perennial)	Burned	2	6.25%	1	3.13%	2	6.25%
	Unburned	2	18.18%	1	10.00%	1	11.11%
	Both	4	9.30%	2	4.76%	3	7.32%
Alyssum desertorum (annual)	Burned	1	3.13%				
	Unburned						
	Both	1	2.33%				
*Bromus tectorum** (annual)	Burned	18	56.25%	17	53.13%	24	75.00%
	Unburned	2	18.18%	2	20.00%	4	44.44%
	Both	20	46.51%	19	45.24%	28	68.29%
Cardaria chalepensis (perennial)	Burned					1	3.13%
	Unburned						
	Both					1	2.44%
Carduus nutans (biennial)	Burned					4	12.50%
	Unburned						
	Both					4	9.76%
Centaurea repens (perennial)	Burned			1	3.13%		
	Unburned						
	Both			1	2.38%		
*Ceratocephala testiculata** (annual)	Burned	3	9.38%			5	15.63%
	Unburned						
	Both	3	6.98%			5	12.20%
Chorispora tenella (annual)	Burned	1	3.13%			1	3.13%
	Unburned						
	Both	1	2.33%			1	2.44%
Cirsium arvense (perennial)	Burned	1	3.13%			2	6.25%
	Unburned					1	11.11%
	Both	1	2.33%			3	7.32%
*Descurainia sophia** (annual)	Burned	8	25.00%	3	9.38%	7	21.88%
	Unburned						
	Both	8	18.60%	3	7.14%	7	17.07%
*Halogeton glomeratus** (annual)	Burned	7	21.88%	12	37.50%	7	21.88%
	Unburned						
	Both	7	16.28%	12	28.57%	7	17.07%
Hyoscyamus niger (biennial)	Burned	3	9.38%	2	6.25%	1	3.13%
	Unburned						
	Both	3	6.98%	2	4.76%	1	2.44%

Table 23 (continued).

Species	Plot Type	2001		2002		2012	
		# plots	% plots	# plots	% plots	# plots	% plots
Kochia scoparia (annual)	Burned			1	3.13%		
	Unburned						
	Both			1	2.38%		
Lactuca serriola (annual)	Burned	1	3.13%	2	6.25%	3	9.38%
	Unburned						
	Both	1	2.33%	2	4.76%	3	7.32%
Lappula squarrosa (annual)	Burned	1	3.13%				
	Unburned						
	Both	1	2.33%				
Lepidium perfoliatum (annual)	Burned	1	3.13%			1	3.13%
	Unburned						
	Both	1	2.33%			1	2.44%
Malcolmia africana (annual)	Burned	5	15.63%				
	Unburned						
	Both	5	11.63%				
Poa pratensis (perennial)	Burned	4	12.50%				
	Unburned	1	9.09%				
	Both	5	11.63%				
Polygonum aviculare (annual)	Burned	1	3.13%				
	Unburned						
	Both	1	2.33%				
Salsola tragus (annual)	Burned			4	12.50%	1	3.13%
	Unburned						
	Both			4	9.52%	1	2.44%
Taraxacum laevigatum (perennial)	Burned	1	3.13%				
	Unburned						
	Both	1	2.33%				
*Taraxacum officinale** (perennial)	Burned	6	18.75%	4	12.50%	3	9.38%
	Unburned						
	Both	6	13.95%	4	9.52%	3	7.32%
Thlaspi arvense (annual)	Burned	5	15.63%				
	Unburned						
	Both	5	11.63%				
*Tragopogon dubius** (annual)	Burned	10	31.25%	3	9.38%	12	37.50%
	Unburned	3	27.27%				
	Both	13	30.23%	3	7.14%	12	29.27%

*species examined in detail

Only cheatgrass (*Bromus tectorum*) was encountered in enough plots to warrant examining its distribution and abundance in detail. Cheatgrass was recorded in plots widely scattered throughout the study area in 2001 and in 2012 (Figure 24). In 2001, cheatgrass was recorded on almost half of the plots; by 2012, it was recorded on well over half (Table 23). In both 2001 and 2012, there was no significant difference between burned and unburned plots in the proportions of plots with and without cheatgrass (Table 24); that is, cheatgrass was no more likely to occur on the burned plots than the unburned plots. Although the number of burned plots and the number of unburned plots with cheatgrass each increased modestly from 2001 to 2012, neither increase was statistically significant (Table 25).

In contrast, cheatgrass was recorded in more microplots per burned plot than unburned plot in both 2001 and 2012 (Figure 25), and the difference was statistically significant in each year (Table 26). As both Figure 25 and Figure 26 suggest, the number of microplots per vegetation plot with cheatgrass increased from 2001 to 2012 in the burned plots but not in the unburned plots (Table 27).

Herb sophia (*Descurainia sophia*) and halogeton (or salt lover, *Halogeton glomeratus*) were each recorded in a substantial number of burned plots, but in no unburned plots, in 2001 and in 2012 (Table 23). Neither was documented in more plots in 2012 than in 2001. And the numbers of microplots per plot in which they were recorded remained essentially constant from the beginning to the end of the project (Figure 27, Figure 28). Yellow salsify (*Tragopogon dubius*) exhibited a very similar pattern (Figure 29), although it was recorded in a few unburned plots in 2001 (Table 23). Other exotic species generally were found in few plots or were recorded in only one or two years.

Figure 24. Locations of vegetation plots with *Bromus tectorum*, 2001 and 2012.

a. 2001 b. 2012

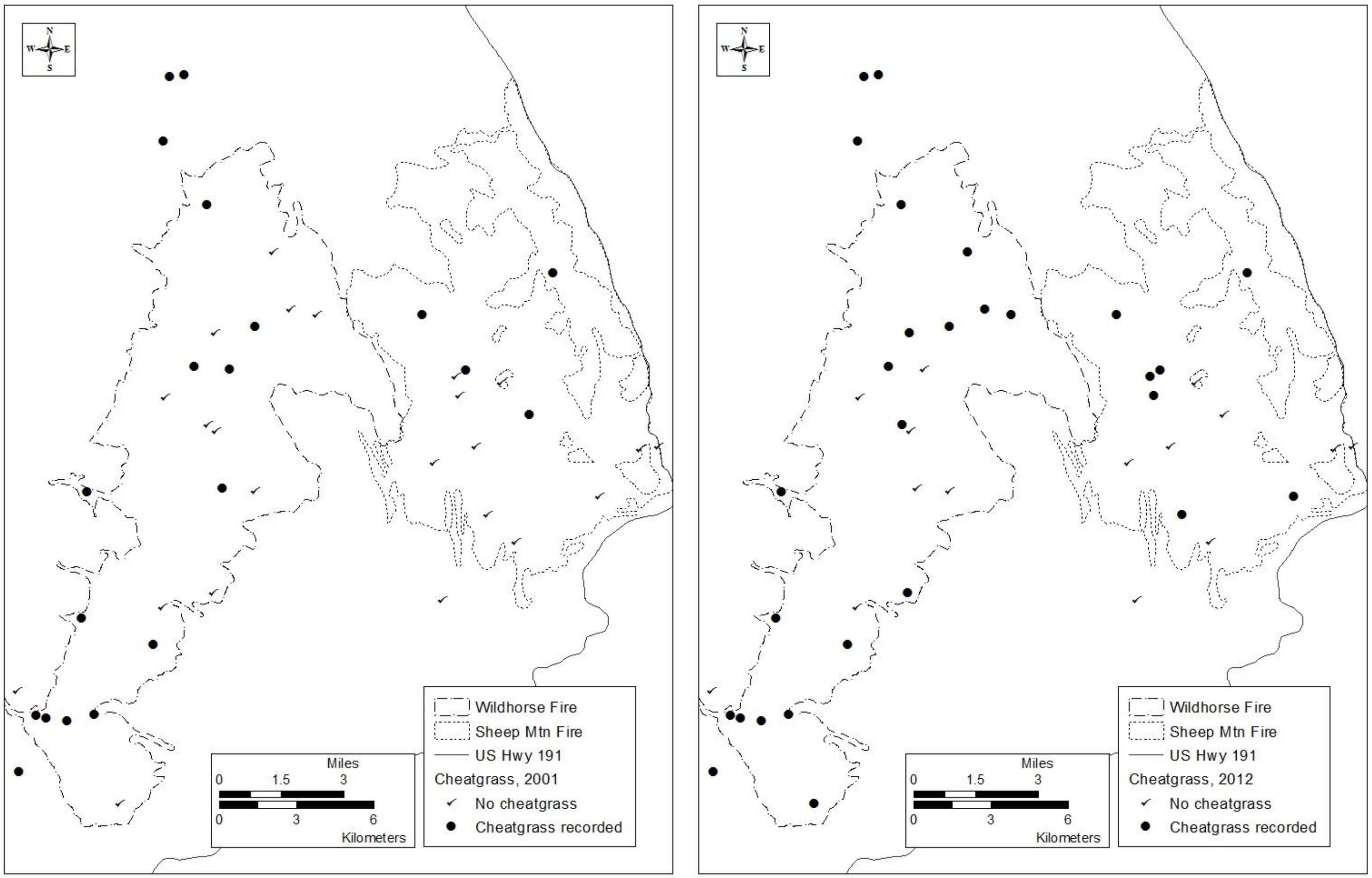


Table 24. Chi-squared goodness-of-fit tests, proportions of burned vs. unburned plots with and without *Bromus tectorum*, 2001 vs. 2012

H_O: The proportions of plots with or without *Bromus tectorum* are the same for burned plots as for unburned plots. **H_A**: The proportions of plots with or without *Bromus tectorum* are different for burned plots than for unburned plots.

In tables, numbers in normal type-face are observed numbers of plots, and numbers in italic type-face are expected numbers of plots.

a. 2001

Type of Plot	No Cheatgrass	Cheatgrass Present	Number of Plots
Burned	14 / *14.88*	18 / *17.12*	32
Unburned	9 / *5.12*	2 / *5.88*	11
Both	23	20	43

Chi-squared (Yates) = 3.361. Degrees of freedom = 1. $0.05 < p < 0.1$. **Do not reject H_O:** The proportions of plots with or without *Bromus tectorum* are the same for burned as for unburned plots.

b. 2012

Type of Plot	No Cheatgrass	Cheatgrass Present	Number of Plots
Burned	8 / *10.15*	24 / *21.85*	32
Unburned	5 / *2.85*	4 / *6.15*	9
Both	13	28	41

Chi-squared (Yates) = 1.782. Degrees of freedom = 1. $0.1 < p < 0.25$. **Do not reject H_O:** The proportions of plots with or without *Bromus tectorum* are the same for burned as for unburned plots.

Table 25. Chi-squared tests for differences, 2001 to 2012, in the proportions of burned vs. unburned vegetation plots with *Bromus tectorum*

H_O: The proportions of plots with or without cheatgrass in 2001 are the same as the proportions in 2012. **H_A:** The proportions of plots with or without cheatgrass in 2001 are different from the proportions in 2012.

In tables, numbers in normal type-face are observed numbers of plots, and numbers in italic type-face are expected numbers of plots.

a. Burned plots

Year	No cheatgrass	Cheatgrass Present	Number of Plots
2001	14 / *11*	18 / *21*	32
2012	8 / *11*	24 / *21*	32
Both years	22	42	64

Chi-squared (Yates) = 1.732. Degrees of freedom = 1. $0.1 < p < 0.25$. **Do not reject H_O:** The proportions of burned plots with and without *Bromus tectorum* in 2001 are the same as the proportions in 2012.

b. Unburned plots

Year	No Cheatgrass	Cheatgrass Present	Number of Plots
2001	9 / *7.7*	2 / *3.3*	11
2012	5 / *6.3*	4 / *2.7*	9
Both years	14	6	20

Chi-squared (Yates) = 0.615. Degrees of freedom = 1. $0.25 < p < 0.50$. **Do not reject H_O:** The proportions of unburned plots with and without *Bromus tectorum* in 2001 are the same as the proportions in 2012.

Figure 25. Number of microplots with *Bromus tectorum* per vegetation plot, burned vs. unburned plots, 2001 vs. 2012. Crosses represent individual transects; solid circles are medians; stars are outliers.

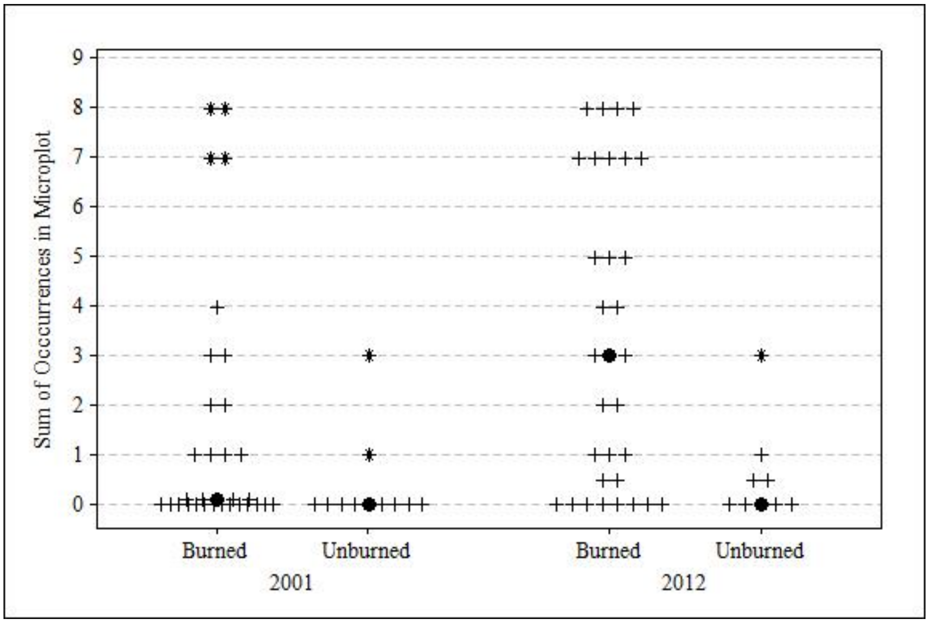


Table 26. Mann-Whitney U-tests, number of microplots with *Bromus tectorum* per vegetation plot, burned vs. unburned plots, 2001 vs. 2012
H_O: The distribution of number of microplots with *Bromus tectorum* per plot is the same for burned plots as for unburned plots. **H_A:** The distribution of number of microplots per plot with *Bromus tectorum* is different for burned plots than for unburned plots.

a. 2001

Plot Type	N	Median	Variance	Skewness	Kurtosis
Burned	32	0.500	6.244	1.78	1.98
Unburned	11	0.000	0.855	2.81	8.04

W = 770.0, p = 0.0471. **Reject H_O:** the distribution of number of microplots per plot is different for burned plots than unburned plots.

b. 2012

Plot Type	N	Median	Variance	Skewness	Kurtosis
Burned	32	3.000	9.314	0.33	-1.50
Unburned	9	0.000	0.965	2.34	5.84

W = 750.0, p =0.0128. **Reject H_O**: the distribution of number of microplots per plot is different for burned plots than unburned plots.

Figure 26. Change, 2001 to 2012, in the number of microplots with *Bromus tectorum* per vegetation plot, burned vs. unburned plots.
Crosses represent individual vegetation plots. Circles are means.

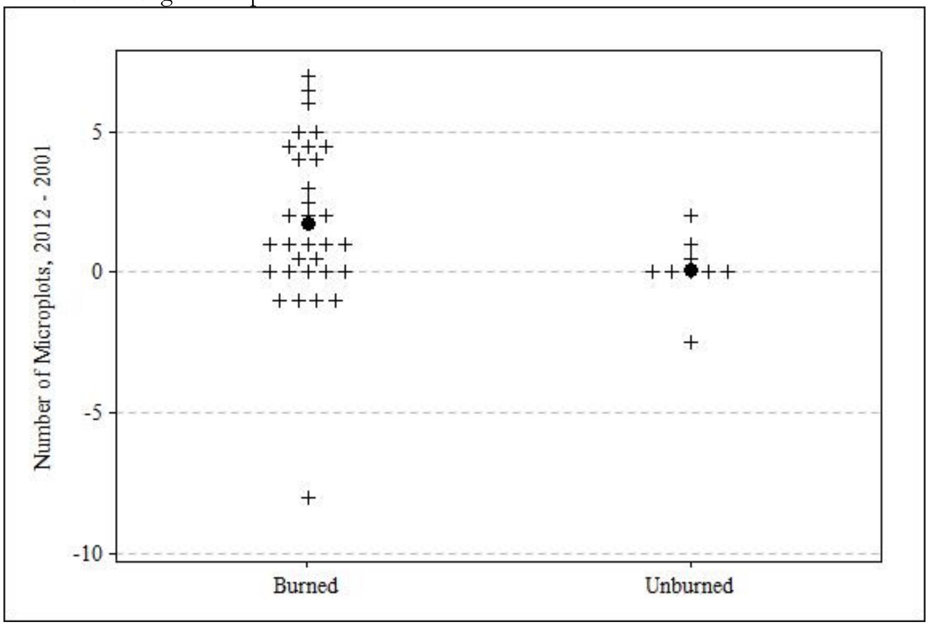


Table 27. T-tests, change from 2001 to 2012 in numbers of microplots with *Bromus tectorum* per vegetation plot, burned vs. unburned vegetation plots.

H_O: Change from 2001 to 2012 in number of microplots per plot with *Bromus tectorum* = 0. **H_A:** Change from 2001 to 2012 in number of microplots with *Bromus tectorum* ≠ 0

a. Burned plots

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
(# microplots in 2012) - (# microplots in 2001)	32	1.766	2.957	0.523	(0.700, 2.832)	3.38	0.002

Reject H_O: Change from 2001 to 2012 in number of microplots per plot with *Bromus tectorum* is not zero

b. Unburned plots

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
(# microplots in 2012) - (# microplots in 2001)	9	0.111	1.193	0.398	(-0.806, 1.028)	0.28	0.787

Do not reject H_O: Change from 2001 to 2012 in number of microplots per plot with *Bromus tectorum* is zero

Figure 27. Number of microplots with *Descurainia sophia* per vegetation, burned vs. unburned plots, 2001 vs. 2012.
Crosses represent individual transects; solid circles are medians; stars are outliers.

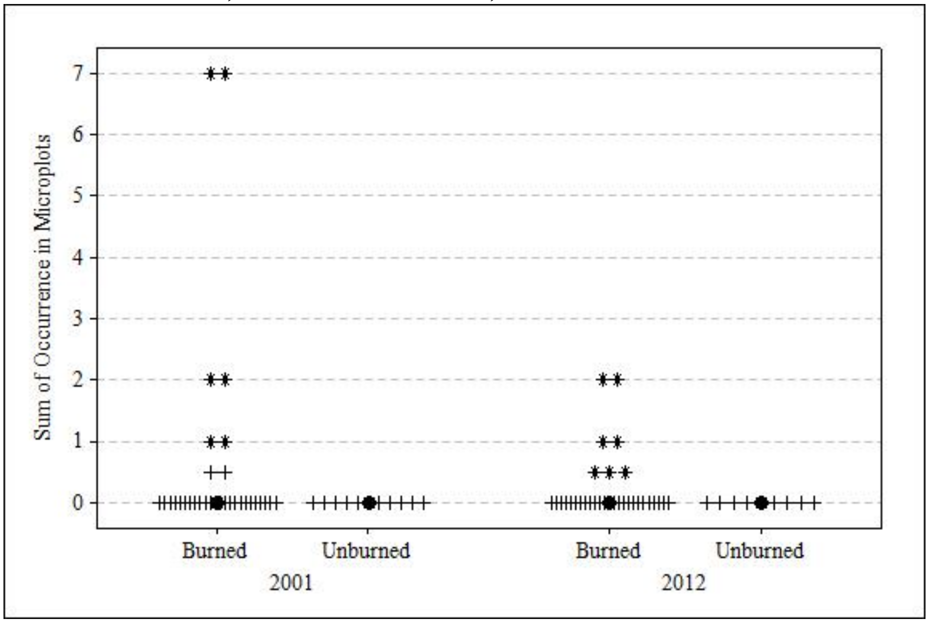


Figure 28. Numbers of microplots with *Halageton glomeratus* per vegetation plot, burned vs. unburned plots, 2001 vs. 2012.
Crosses represent individual transects; solid circles are medians; stars are outliers.

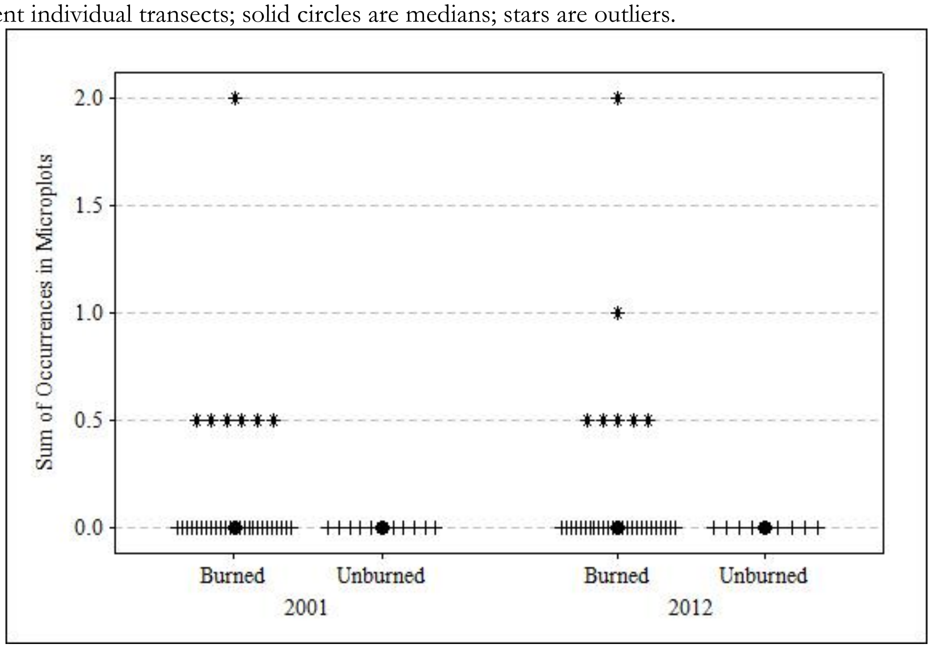
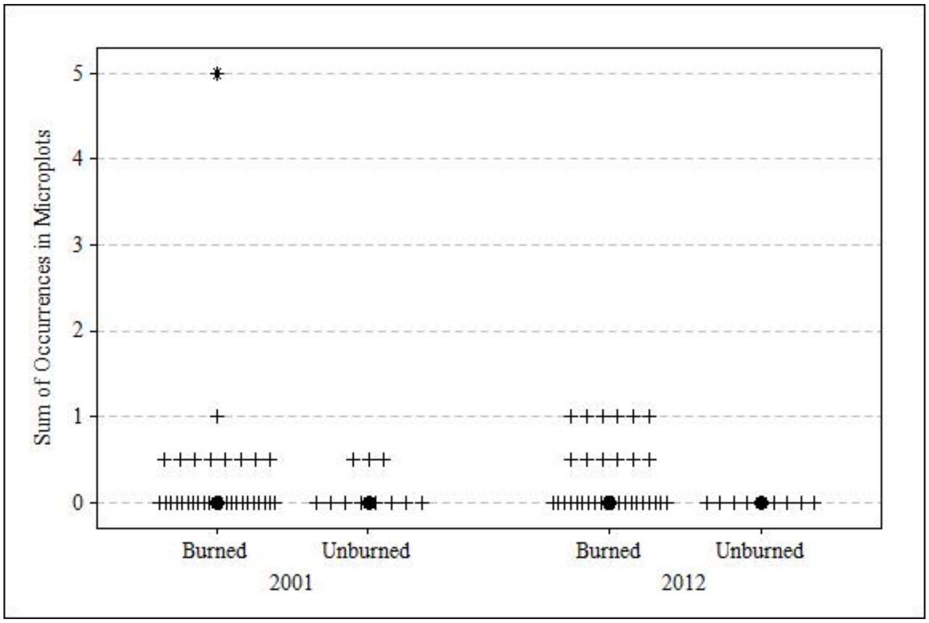


Figure 29. Number of microplots with *Tragopogon dubius* per vegetation plot, burned vs. unburned plots, 2001 vs. 2012. Crosses represent individual transects; solid circles are medians; stars are outliers.



Exotics in Vegetation Plots -- Summary

Data from the vegetation sampling plots suggest that exotic plant species were distributed widely throughout the study area, and more widely in burned areas than unburned. Their distributions changed very little or not at all over the course of the study. The abundance of exotic plants seems to have increased in the burned areas from 2001 to 2012. The changes in abundance of exotic plants in general appear to be a result of the changes in cheatgrass. Other exotic species were uncommon enough that they only slightly modified the pattern set by cheatgrass.

EXOTIC PLANTS IN THE STUDY AREA: SUMMARY

Twenty-seven species of exotic plants were documented on the weed transects and in the vegetation plots combined during three years of sampling (Table 28). Ten species were recorded on the weed transects and 23 were recorded on the vegetation plots. Seven species were recorded in both methods of sampling. These numbers should not be interpreted to suggest that the vegetation plots are the better type of sample for documenting the presence of exotic plants because only a sub-set of the exotics were recorded on the transects, while every plant species found in the vegetation plots was recorded.

Table 28. Exotic plant species recorded on weed transects and in vegetation plots, all three years.

Numbers in cells are percentages of transects or plots, rounded to the nearest whole number. The number of transects and plots sampled in each year is shown at the top of each column. Species in bold type-face are those found in both transects and plots.

Species	2001		2002		2012	
	% trans (n=91)	% plots (n=43)	%trans (n=91)	% plots (n=42)	%trans (n=91)	% plots (n=41)
Agropyron cristatum		9		5		7
Alyssum desertorum		2			6	
Bromus tectorum	20	47	13	45	66	68
Cardaria chalepensis						2
Carduus nutans	1		1		1	10
Centaurea repens				2		
Ceratocephala testiculata		7			8	12
Chorispora tenella		2				2
Cirsium arvense	5	2	8		6	7
Cirsium vulgare	1					
Descurainia sophia		19		7		17
Elymus repens	2					
Halogeton glomeratus	1	16	8	29	14	17
Hyoscyamus niger	2	7	2	5		2
Kochia scoparia				2		
Lactuca serriola		2		5		7
Lappula squarrosa		2				
Lepidium perfoliatum		2				2
Malcolmia africana		12				
Poa pratensis		12				
Polygonum aviculare		2				
Salsola tragus				10		2
Sonchus arvensis	2		14		6	
Taraxacum laevigatum		2				
Taraxacum officinale		14		10		7
Thlaspi arvense		12				
Tragopogon dubius		30		7		29

Exotic plants as a group were widespread throughout the study area at the beginning of the study, in 2001. This is clear from the number of samples (both weed transects and vegetation plots) in which exotics were recorded and the distributions of those samples throughout the study area. The three measures of exotic species abundance calculated from the transect data -- the proportion of transects with exotic species, the number of exotic species per transect, and the percentages of quadrats per transect with exotic species -- indicate a significant difference between burned areas and unburned areas in the abundance of exotic species. The vegetation plot data also suggest that exotic plants were more common in the burned areas, as measured by the proportion of plots with exotics, the number of exotic species per plot, and the proportion of microplots with exotics per plot.

The transect data show that exotic plants increased in abundance in the burned areas (as measured by proportion of transects occupied, number of species per transect, and percent of quadrates per transect with exotic species). The abundance of exotics in unburned areas increased less (only the number of species per transect clearly increased). Consequently, by 2012, exotics had become more common in burned areas than unburned. The vegetation plot data suggest a more modest increase in abundance of exotic species over the course of the study: the number of exotic species per plot did not increase in either the burned plots or the unburned plots, and the frequency of occurrence of exotics in microplots increased only in the burned plots.[1]

Taken together, the data suggest that exotic plants were more common in the burned parts of the study area than the unburned parts by the end of the study in 2012.

Only cheatgrass was common enough that its patterns of distribution and abundance could be examined in detail. Overall, cheatgrass seems to have been no more common in burned areas than unburned in 2001 (as measured by proportions of transects or vegetation plots occupied), although it may have been more abundant locally in burned areas (as measured by the number of microplots occupied per vegetation plot). The abundance of cheatgrass by several measures increased from 2001 to 2012, and by the end of the study, the species was more common in burned areas than unburned. The data for other exotic species individually suggest that most were more common in burned areas than unburned areas. The patterns of distribution and abundance of exotic plants, then, seem to have been determined largely by cheatgrass, and modified slightly by other species.

PART III. VEGETATION STRUCTURE AND COMPOSITION

These are the results from analyses of the data about the composition and structure of the vegetation, collected in the vegetation plots. The methods used to collect and analyze these data are described in part I of this report.

The analyses reported in this section looked at the contribution of individual plant species, as well as groups of species identified by growth-form (shrubs, graminoids, and forbs), life-span (annuals and perennials), and origin (native vs. introduced to Wyoming). They used the estimates of percent canopy cover for all species. Also reported here are the analyses on the detailed shrub data from the canopy-intercept lines, density plots, and dimension and vigor points, collected only in 2012.

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[1] This discrepancy between the transect data and the plot data might be a result of inconsistent recording of plant species on the transects; that is, some species may have been recorded in 2012 that had been present but not recorded in 2001. For example, *Alyssum desertorum* and *Ceratocephala testiculata* were recorded on transects in 2012 but not in 2001, even though they were present in plots in 2001. But most of the species recorded on weed transects were recorded in more than one year, so the increase in the number of transects likely indicates spreading of some exotics to more transects.

The PLANTS database of the USDA Natural Resources Conservation Service (USDA, NRCS 2013) is the source of information about life-span and origin.

COMPOSITION BY PLANT GROUPS AND BY TAXA

During the three years of sampling, we recorded 206 plant taxa that we were able to identify to species and 43 additional taxa that we were able to identify to genus (Table 29). We recorded an additional 278 names for plants that we were unable to identify to genus or species, and we refer to these as "unknown plants", although we were able to place 69 of them into a plant family (Appendix I). Of the 527 names that we recorded on the data sheets, then, we identified 39% to species, 8% to genus, and 13% to family, and 40% of the names that we recorded went unidentified.

An explanation of these numbers is in order. Our practice was to write down a field name for each taxon that we recognized in every plot and, for each of these apparent taxa that we could not confidently assign to a species, collect a specimen for later identification. In some cases, if we thought that we had seen a particular taxon earlier, then we did not collect an additional specimen. With this practice, we hoped to later assign a species name to each field name. Unfortunately, in many cases, we were able to collect only vegetative specimens that we could neither identify to species later nor confidently relate to another identified specimen. Additionally, a few specimens were lost. The result is that a large number of field names remain unassigned to a species.

When we compiled the list of field names after the third year, we made sure that each field name was unique to an apparent taxon, a plot, and a year. For example, "Asteraceae Unknown 1222-01" is an unknown composite collected in 2012 in plot 22, and "Asteraceae Unknown 1218-1" is an unknown composite collected in 2012 in plot 18. We followed this practice because it tells us something about the richness of species of different growth forms in each plot, and it allows us to estimate cover by growth-form. Unfortunately, it also very likely inflates the number of apparent plant taxa, because different field names may represent the same taxon, but we cannot tell that; those two unknown composites may be the same species, and they may be individuals of, say, *Packera cana*, which we identified from yet a different plot. Hence, rather than representing 3 different taxa, the 3 names may represent a single taxon.

So, we did not find 527 distinct plant taxa in the vegetation plots. Rather, when we added up the list of field names we'd recorded from each of the plots in all years, and identified the species represented by as many of those names we could, we had 527 different names.

Table 29. Plants identified to species or to genus.

"Short Scientific Name" is used in other tables in this report. "#Years" is the number of years in which the taxon was recorded; 92 taxa recorded in all 3 years are shaded. "Com.Dom.?" indicates common dominant taxa (those that contribute ≥ 10% of the canopy cover in ≥ 10% of plots in 2001 or 2012) in burned (b) or unburned (u) plots. Information in other columns is from the PLANTS database (USDA, NRCS 2013). "Acc Or Syn?" indicates the complete scientific name recognized as the accepted name for the taxon (Acc) or as a synonym (Syn). Life-span: P = perennial, A = Annual, U = Unknown. Origin: N = native, I = introduced, U = unknown.

Short Scientific Name	Complete Scientific Name, PLANTS	Common Name, PLANTS	Acc Or Syn?	Growth-form	Life-span	Origin	#Years	Com. Dom?
Abies lasiocarpa	Abies lasiocarpa (Hook.) Nutt.	subalpine fir	Acc	Tree	P	N	2	
Acer glabrum	Acer glabrum Torr.	Rocky Mountain maple	Acc	Shrub	P	N	1	
Achillea millefolium	Achillea millefolium L.	common yarrow	Acc	Forb	P	N	3	
Achnatherum hymenoides	Achnatherum hymenoides (Roem. & Schult.) Barkworth	Indian ricegrass	Acc	Gram	P	N	3	b,u
Achnatherum nelsonii	Achnatherum nelsonii (Scribn.) Barkworth	Columbia needlegrass	Acc	Gram	P	N	3	
Agoseris aurantiaca	Agoseris aurantiaca (Hook.) Greene	orange agoseris	Acc	Forb	P	N	1	
Agoseris glauca	Agoseris glauca (Pursh) Raf.	pale agoseris	Acc	Forb	P	N	3	
Agoseris sp.	Agoseris Raf.	agoseris	Acc	Forb	P	N	2	
Agropyron cristatum	Agropyron cristatum (L.) Gaertn.	crested wheatgrass	Acc	Gram	P	I	3	
Agrostis scabra	Agrostis scabra Willd.	rough bentgrass	Acc	Gram	P	N	1	
Allium textile	Allium textile A. Nelson & J.F. Macbr.	textile onion	Acc	Forb	P	N	1	
Alyssum desertorum	Alyssum desertorum Stapf	desert madwort	Acc	Forb	A	I	1	
Amelanchier alnifolia	Amelanchier alnifolia (Nutt.) Nutt. ex M. Roem.	Saskatoon serviceberry	Acc	Shrub	P	N	3	
Antennaria microphylla	Antennaria microphylla Rydb.	littleleaf pussytoes	Acc	Forb	P	N	3	
Antennaria rosea	Antennaria rosea Greene	rosy pussytoes	Acc	Forb	P	N	1	
Arabis pendulocarpa	Arabis holboellii Hornem. var. pendulocarpa (A. Nelson) Rollins	Dropseed rockcress	Syn	Forb	P	N	3	
Arabis sp.	Arabis L.	rockcress	Acc	Forb	P	U	3	
Arnica cordifolia	Arnica cordifolia Hook.	heartleaf arnica	Acc	Forb	P	N	1	
Artemisia frigida	Artemisia frigida Willd.	prairie sagewort	Acc	Shrub	P	N	3	
Artemisia ludoviciana	Artemisia ludoviciana Nutt.	white sagebrush	Acc	Forb	P	N	3	
Artemisia nova	Artemisia nova A. Nelson	black sagebrush	Acc	Shrub	P	N	3	u

Table 29 (continued).

Short Scientific Name	Complete Scientific Name, PLANTS	Common Name, PLANTS	Acc Or Syn?	Growth-form	Life-span	Origin	#Years	Com. Dom.?
Artemisia sp.	Artemisia L.	sagebrush	Acc	?	U	N	1	
Artemisia tridentata	Artemisia tridentata Nutt.	big sagebrush	Acc	Shrub	P	N	3	u
Aster sp.	Symphyotrichum Nees?	Aster	Acc	Forb	P	N	1	
Astragalus agrestis	Astragalus agrestis Douglas ex G. Don	purple milkvetch	Acc	Forb	P	N	2	
Astragalus convallarius	Astragalus convallarius Greene	lesser rushy milkvetch	Acc	Forb	P	N	3	b
Astragalus jejunus	Astragalus jejunus S. Watson	starveling milkvetch	Acc	Forb	P	N	1	
Astragalus megacarpus	Astragalus megacarpus (Nutt.) A. Gray	great bladdery milkvetch	Acc	Forb	P	N	1	
Astragalus miser	Astragalus miser Douglas ex Hook.	timber milkvetch	Acc	Forb	P	N	3	
Astragalus oreganus	Astragalus oreganus Nutt.	Oregon milkvetch	Acc	Forb	P	N	1	
Astragalus purshii	Astragalus purshii Douglas ex Hook.	woollypod milkvetch	Acc	Forb	P	N	2	
Astragalus sp.	Astragalus L.	milkvetch	Acc	Forb	P	N	2	
Astragalus spatulatus	Astragalus spatulatus Sheldon	tufted milkvetch	Acc	Forb	P	N	2	
Astragalus tenellus	Astragalus tenellus Pursh	looseflower milkvetch	Acc	Forb	P	N	1	
Astragalus utahensis	Astragalus utahensis (Torr.) Torr. & A. Gray	Utah milkvetch	Acc	Forb	P	N	1	
Atriplex canescens	Atriplex canescens (Pursh) Nutt.	fourwing saltbush	Acc	Shrub	P	N	1	
Atriplex confertifolia	Atriplex confertifolia (Torr. & Frém.) S. Watson	shadscale saltbush	Acc	Shrub	P	N	3	b
Atriplex gardneri	Atriplex gardneri (Moq.) D. Dietr.	Gardner's saltbush	Acc	Shrub	P	N	1	
Balsamorhiza sagittata	Balsamorhiza sagittata (Pursh) Nutt.	arrowleaf balsamroot	Acc	Forb	P	N	3	
Bromus carinatus	Bromus marginatus Nees ex Steud.	mountain brome	Acc	Gram	P	N	2	
Bromus tectorum	Bromus tectorum L.	cheatgrass	Acc	Gram	A	I	3	b
Calochortus nuttallii	Calochortus nuttallii Torr. & A. Gray	sego lily	Acc	Forb	P	N	2	
Camissonia scapoidea	Camissonia scapoidea (Nutt. ex Torr. & A. Gray) P.H. Raven	Paiute suncup	Acc	Forb	A	N	1	
Cardaria chalepensis	Cardaria chalepensis (L.) Hand.-Maz.	lenspod whitetop	Acc	Shrub	P	I	1	
Carduus nutans	Carduus nutans L.	nodding plumeless thistle	Acc	Forb	P	I	1	
Carex geyeri	Carex geyeri Boott	Geyer's sedge	Acc	Gram	P	N	2	
Carex petasata	Carex petasata Dewey	Liddon sedge	Acc	Gram	P	N	1	
Carex rossii	Carex rossii Boott	Ross' sedge	Acc	Gram	P	N	1	
Carex sp.	Carex L.	sedge	Acc	Gram	P	N	2	
Carex bunch sp.	Carex L.	sedge	Acc	Gram	P	N	1	
Carex rhizomatous sp.	Carex L.	sedge	Acc	Gram	P	N	1	
Castilleja angustifolia	Castilleja angustifolia (Nutt.) G. Don	northwestern Indian paintbrush	Acc	Forb	P	N	2	

Table 29 (continued).

Short Scientific Name	Complete Scientific Name, PLANTS	Common Name, PLANTS	Acc Or Syn?	Growth-form	Life-span	Origin	#Years	Com. Dom.?
Castilleja flava	Castilleja flava S. Watson	yellow Indian paintbrush	Acc	Forb	P	N	2	
Castilleja linariifolia	Castilleja linariifolia Benth.	Wyoming Indian paintbrush	Acc	Forb	P	N	1	
Castilleja sp.	Castilleja Mutis ex L. f.	Indian paintbrush	Acc	Forb	P	N	3	
Caulanthus crassicaulis	Caulanthus crassicaulis (Torr.) S. Watson	thickstem wild cabbage	Acc	Forb	P	N	2	
Centaurea repens	Acroptilon repens (L.) DC.	Hardheads (Russian knapweed)	Syn	Forb	P	I	1	
Ceratocephala testiculata	Ceratocephala testiculata (Crantz) Roth	curveseed butterwort	Acc	Forb	A	I	2	
Cercocarpus montanus	Cercocarpus montanus Raf.	alderleaf mountain mahogany	Acc	Shrub	P	N	3	
Chaenactis douglasii	Chaenactis douglasii (Hook.) Hook. & Arn.	Douglas' dustymaiden	Acc	Forb	P	N	3	
Chaenactis sp.	Chaenactis DC.	pincushion	Acc	Forb	P	N	2	
Chenopodium atrovirens	Chenopodium atrovirens Rydb.	pinyon goosefoot	Acc	Forb	A	N	3	
Chenopodium desiccatum	Chenopodium desiccatum A. Nelson	aridland goosefoot	Acc	Forb	A	N	2	
Chenopodium fremontii	Chenopodium fremontii S. Watson	Fremont's goosefoot	Acc	Forb	A	N	1	
Chenopodium leptophyllum	Chenopodium leptophyllum (Moq.) Nutt. ex S. Watson	narrowleaf goosefoot	Acc	Forb	A	N	1	
Chenopodium rubrum	Chenopodium rubrum L.	red goosefoot	Acc	Forb	A	N	2	
Chenopodium sp.	Chenopodium L.	goosefoot	Acc	Forb	A	U	2	
Chorispora tenella	Chorispora tenella (Pall.) DC.	crossflower	Acc	Forb	A	I	2	
Chrysothamnus linifolius	Chrysothamnus linifolius Greene	spearleaf rabbitbrush	Acc	Shrub	P	N	3	
Chrysothamnus viscidiflorus	Chrysothamnus viscidiflorus (Hook.) Nutt.	yellow rabbitbrush	Acc	Shrub	P	N	3	b,u
Cirsium arvense	Cirsium arvense (L.) Scop.	Canada thistle	Acc	Forb	P	I	2	
Cirsium ownbeyi	Cirsium ownbeyi S.L. Welsh	Ownbey's thistle	Acc	Forb	P	N	2	
Collinsia parviflora	Collinsia parviflora Lindl.	maiden blue eyed Mary	Acc	Forb	A	N	1	
Collomia linearis	Collomia linearis Nutt.	tiny trumpet	Acc	Forb	A	N	1	
Comandra umbellata	Comandra umbellata (L.) Nutt.	bastard toadflax	Acc	Forb	P	N	3	
Cordylanthus ramosus	Cordylanthus ramosus Nutt. ex Benth.	bushy bird's beak	Acc	Forb	A	N	3	u
Corydalis aurea	Corydalis aurea Willd.	scrambled eggs	Acc	Forb	A	N	1	
Crepis acuminata	Crepis acuminata Nutt.	tapertip hawksbeard	Acc	Forb	P	N	3	
Crepis atribarba	Crepis atribarba A. Heller	slender hawksbeard	Acc	Forb	P	N	1	
Crepis intermedia	Crepis intermedia A. Gray	limestone hawksbeard	Acc	Forb	P	N	2	
Crepis modocensis	Crepis modocensis Greene	Modoc hawksbeard	Acc	Forb	P	N	2	
Crepis runcinata	Crepis runcinata (James) Torr. & A. Gray	fiddleleaf hawksbeard	Acc	Forb	P	N	3	
Crepis sp.	Crepis L.	hawksbeard	Acc	Forb	P	N	3	
Cryptantha flava	Cryptantha flava (A. Nelson) Payson	Brenda's yellow cryptantha	Acc	Forb	P	N	1	
Cryptantha flavoculata	Cryptantha flavoculata (A. Nelson) Payson	roughseed cryptantha	Acc	Forb	P	N	3	

Table 29 (continued).

Short Scientific Name	Complete Scientific Name, PLANTS	Common Name, PLANTS	Acc Or Syn?	Growth-form	Life-span	Origin	#Years	Com. Dom.?
Cryptantha kelseyana	Cryptantha kelseyana Greene	Kelsey's cryptantha	Acc	Forb	A	N	2	
Cryptantha sericea	Cryptantha sericea (A. Gray) Payson	silky cryptantha	Acc	Forb	P	N	3	
Cryptantha sp.	Cryptantha Lehm. ex G. Don	cryptantha	Acc	Forb	U	N	3	
Cryptantha torreyana	Cryptantha torreyana (A. Gray) Greene	Torrey's cryptantha	Acc	Forb	A	N	1	
Cryptantha watsonii	Cryptantha watsonii (A. Gray) Greene	Watson's cryptantha	Acc	Forb	A	N	1	
Cymopterus longipes	Cymopterus longipes S. Watson	longstalk springparsley	Acc	Forb	P	N	1	
Cymopterus sp.	Cymopterus Raf.	springparsley	Acc	Forb	P	N	2	
Cymopterus terebinthinus	Pteryxia terebinthina (Hook.) J.M. Coult. & Rose var. albiflora (Torr. & A. Gray) Mathias	turpentine wavewing	Syn	Forb	P	N	3	u
Delphinium occidentale	Delphinium ×occidentale (S. Watson) S. Watson (pro sp.) [barbeyi × glaucum]	(Larkspur)	Syn	Forb	P	N	2	
Delphinium sp.	Delphinium L.	larkspur	Acc	Forb	P	N	1	
Descurainia incana	Descurainia incana (Bernh. ex Fisch. & C.A. Mey.) Dorn	mountain tansymustard	Acc	Forb	P	N	2	
Descurainia pinnata	Descurainia pinnata (Walter) Britton	western tansymustard	Acc	Forb	P	N	1	
Descurainia sophia	Descurainia sophia (L.) Webb ex Prantl	herb sophia	Acc	Forb	A	I	3	
Descurainia sp.	Descurainia Webb & Bethel.	tansymustard	Acc	Forb	A	U	3	b
Draba juniperina	Draba oligosperma Hook.	Fewseed draba	Syn	Forb	P	N	2	
Dracocephalum parviflorum	Dracocephalum parviflorum Nutt.	American dragonhead	Acc	Forb	P	N	1	
Elymus elymoides	Elymus elymoides (Raf.) Swezey	squirreltail	Acc	Gram	P	N	3	
Elymus lanceolatus*	Elymus lanceolatus (Scribn. & J.G. Sm.) Gould	thickspike wheatgrass	Acc	Gram	P	N	3	b
Elymus lanceolatus ssp. lanceolatus*	Elymus lanceolatus (Scribn. & J.G. Sm.) Gould ssp. lanceolatus	thickspike wheatgrass	Acc	Gram	P	N	*	
Elymus lanceolatus var. riparius*	Elymus lanceolatus (Scribn. & J.G. Sm.) Gould ssp. lanceolatus	thickspike wheatgrass	Syn	Gram	P	N	*	
Elymus sp.	Elymus L.	wildrye	Acc	Gram	P	N	1	
Elymus trachycaulus	Elymus trachycaulus (Link) Gould ex Shinners	slender wheatgrass	Acc	Gram	P	N	1	
Epilobium brachycarpum	Epilobium brachycarpum C. Presl	tall annual willowherb	Acc	Forb	A	N	2	
Eremogone congesta	Arenaria congesta Nutt. var. congesta	Ballhead sandwort	Syn	Forb	P	N	3	
Eremogone hookeri	Arenaria hookeri Nutt. ssp. hookeri	Hooker's sandwort	Syn	Forb	P	N	3	
Eremogone sp.	Arenaria L.	sandwort	-	Forb	P	N	3	
Ericameria nauseosa	Ericameria nauseosa (Pall. ex Pursh) G.L. Nesom & Baird	rubber rabbitbrush	Acc	Shrub	P	N	3	u
Erigeron corymbosus	Erigeron corymbosus Nutt.	longleaf fleabane	Acc	Forb	P	N	1	
Erigeron eatonii	Erigeron eatonii A. Gray	Eaton's fleabane	Acc	Forb	P	N	2	

Table 29 (continued).

Short Scientific Name	Complete Scientific Name, PLANTS	Common Name, PLANTS	Acc Or Syn?	Growth-form	Life-span	Origin	#Years	Com. Dom.?
Erigeron ochroleucus	Erigeron ochroleucus Nutt.	buff fleabane	Acc	Forb	P	N	2	
Erigeron pumilus	Erigeron pumilus Nutt.	shaggy fleabane	Acc	Forb	P	N	3	
Erigeron sp.	Erigeron L.	fleabane	Acc	Forb	P	N	2	
Erigeron speciosus	Erigeron speciosus (Lindl.) DC.	aspen fleabane	Acc	Forb	P	N	3	
Eriogonum brevicaule	Eriogonum brevicaule Nutt.	shortstem buckwheat	Acc	Forb	P	N	3	
Eriogonum cernuum	Eriogonum cernuum Nutt.	nodding buckwheat	Acc	Forb	A	N	1	
Eriogonum hookeri	Eriogonum hookeri S. Watson	Hooker's buckwheat	Acc	Forb	A	N	1	
Eriogonum microthecum	Eriogonum microthecum Nutt.	slender buckwheat	Acc	Shrub	P	N	3	u
Eriogonum ovalifolium	Eriogonum ovalifolium Nutt.	cushion buckwheat	Acc	Forb	P	N	2	
Eriogonum sp.	Eriogonum Michx.	buckwheat	Acc	Forb	U	N	3	
Eriogonum umbellatum	Eriogonum umbellatum Torr.	sulphur-flower buckwheat	Acc	Forb	P	N	3	
Erysimum inconspicuum	Erysimum inconspicuum (S. Watson) MacMill.	shy wallflower	Acc	Forb	P	N	1	
Frasera speciosa	Frasera speciosa Douglas ex Griseb.	elkweed	Acc	Forb	P	N	2	
Gayophytum ramosissimum	Gayophytum ramosissimum Torr. & A. Gray	pinyon groundsmoke	Acc	Forb	A	N	2	
Geranium viscosissimum	Geranium viscosissimum Fisch. & C.A. Mey. ex C.A. Mey.	sticky purple geranium	Acc	Forb	A	N	3	
Gilia sp.	Gilia Ruiz & Pav.	gilia	Acc	Forb	A	N	2	
Gilia tweedyi	Gilia tweedyi Rydb.	Tweedy's gilia	Acc	Forb	A	N	1	
Halogeton glomeratus	Halogeton glomeratus (M. Bieb.) C.A. Mey.	saltlover	Acc	Forb	A	I	3	
Haplopappus sp.	Unknown	Unknown	?	Forb	P	N	1	
Hesperostipa comata	Hesperostipa comata (Trin. & Rupr.) Barkworth	needle and thread	Acc	Gram	P	N	3	
Heuchera parvifolia	Heuchera parvifolia Nutt. ex Torr. & A. Gray	littleleaf alumroot	Acc	Forb	P	N	1	
Hyoscyamus niger	Hyoscyamus niger L.	black henbane	Acc	Forb	A	I	3	
Ipomopsis aggregata	Ipomopsis aggregata (Pursh) V.E. Grant	scarlet gilia	Acc	Forb	P	N	3	
Ipomopsis congesta	Ipomopsis congesta (Hook.) V.E. Grant	ballhead ipomopsis	Acc	Forb	P	N	2	
Ipomopsis sp.	Ipomopsis Michx.	ipomopsis	Acc	Forb	P	N	2	
Juniperus communis	Juniperus communis L.	common juniper	Acc	Shrub	P	N	2	
Juniperus osteosperma	Juniperus osteosperma (Torr.) Little	Utah juniper	Acc	Tree	P	N	3	u
Kochia scoparia	Bassia scoparia (L.) A.J. Scott	Burningbush (kochia, summer cypress)	Syn	Forb	A	I	1	
Kochia sp.	Bassia All.	(Summer cypress)	Syn	Forb	A	U	1	
Koeleria macrantha	Koeleria macrantha (Ledeb.) Schult.	prairie Junegrass	Acc	Gram	P	N	3	
Krascheninnikovia lanata	Krascheninnikovia lanata (Pursh) A. Meeuse & Smit	winterfat	Acc	Shrub	P	N	3	

Table 29 (continued).

Short Scientific Name	Complete Scientific Name, PLANTS	Common Name, PLANTS	Acc Or Syn?	Growth-form	Life-span	Origin	#Years	Com. Dom.?
Lactuca serriola	Lactuca serriola L.	prickly lettuce	Acc	Forb	A	I	3	
Lappula occidentalis	Lappula occidentalis (S. Watson) Greene	flatspine stickseed	Acc	Forb	A	N	1	
Lappula redowskii	Lappula occidentalis (S. Watson) Greene var. occidentalis	(Stickseed)	Syn	Forb	A	N	2	
Lappula sp.	Lappula Moench	stickseed	Acc	Forb	A	U	2	
Lappula squarrosa	Lappula squarrosa (Retz.) Dumort.	European stickseed	Acc	Forb	A	I	1	
Lepidium perfoliatum	Lepidium perfoliatum L.	clasping pepperweed	Acc	Forb	A	I	2	
Leucopoa kingii	Leucopoa kingii (S. Watson) W.A. Weber	spike fescue	Acc	Gram	P	N	2	
Leymus cinereus	Leymus cinereus (Scribn. & Merr.) A. Love	basin wildrye	Acc	Gram	P	N	3	
Linanthus caespitosus	Linanthus caespitosus (Nutt.) J.M. Porter & L.A. Johnson	mat prickly phlox	Acc	Forb	P	N	2	
Linanthus pungens	Linanthus pungens (Torr.) J.M. Porter & L.A. Johnson	granite prickly phlox	Acc	Forb	P	N	3	
Linanthus sp.	Linanthus Benth.	linanthus	Acc	Forb	P	N	3	
Linum lewisii	Linum lewisii Pursh	Lewis flax	Acc	Forb	P	N	3	
Lithospermum ruderale	Lithospermum ruderale Douglas ex Lehm.	western stoneseed	Acc	Forb	P	N	3	
Lomatium triternatum	Lomatium triternatum (Pursh) J.M. Coult. & Rose	nineleaf biscuitroot	Acc	Forb	P	N	1	
Lupinus argenteus	Lupinus argenteus Pursh	silvery lupine	Acc	Forb	P	N	2	
Lupinus sericeus	Lupinus sericeus Pursh	silky lupine	Acc	Forb	P	N	2	
Lupinus sp.	Lupinus L.	lupine	Acc	Forb	P	N	3	
Machaeranthera canescens	Machaeranthera canescens (Pursh) A. Gray	hoary tansyaster	Acc	Forb	P	N	3	
Machaeranthera grindelioides	Machaeranthera grindelioides (Nutt.) Shinners	rayless tansyaster	Acc	Forb	P	N	3	
Machaeranthera sp.	Machaeranthera Nees	tansyaster	Acc	Forb	U	N	2	
Mahonia repens	Mahonia repens (Lindl.) G. Don	creeping barberry	Acc	Shrub	P	N	3	
Malacothrix torreyi	Malacothrix torreyi A. Gray	Torrey's desertdandelion	Acc	Forb	A	N	1	
Malcolmia africana	Malcolmia africana (L.) W.T. Aiton	African mustard	Acc	Forb	A	I	1	
Melica sp.	Melica L.	melicgrass	Acc	Gram	P	N	1	
Mentzelia dispersa	Mentzelia dispersa S. Watson	bushy blazingstar	Acc	Forb	A	N	1	
Mentzelia montana	Mentzelia montana (Davidson) Davidson	variegated-bract blazingstar	Acc	Forb	A	N	2	
Mentzelia pumila	Mentzelia pumila Nutt. ex Torr. & A. Gray	dwarf mentzelia	Acc	Forb	A	N	2	
Mentzelia sp.	Mentzelia L.	blazingstar	Acc	Forb	A	N	2	
Mertensia lanceolata	Mertensia lanceolata (Pursh) DC.	prairie bluebells	Acc	Forb	P	N	2	
Mertensia oblongifolia	Mertensia oblongifolia (Nutt.) G. Don	oblongleaf bluebells	Acc	Forb	A	N	2	

Table 29 (continued).

Short Scientific Name	Complete Scientific Name, PLANTS	Common Name, PLANTS	Acc Or Syn?	Growth-form	Life-span	Origin	#Years	Com. Dom.?
Mertensia sp.	Mertensia Roth	bluebells	Acc	Forb	P	N	3	
Mertensia spp.	Mertensia Roth	bluebells	Acc	Forb	P	N	3	
Mertensia viridis	Mertensia oblongifolia (Nutt.) G. Don	oblongleaf bluebells	Syn	Forb	A	N	2	
Microseris nutans	Microseris nutans (Hook.) Sch. Bip.	nodding microseris	Acc	Forb	A	N	1	
Nicotiana attenuata	Nicotiana attenuata Torr. ex S. Watson	coyote tobacco	Acc	Forb	A	N	1	
Opuntia polyacantha	Opuntia polyacantha Haw.	plains pricklypear	Acc	Shrub	P	N	3	
Osmorhiza chilensis	Osmorhiza berteroi DC.	Sweetcicely	Syn	Forb	P	N	2	
Oxytropis lagopus	Oxytropis lagopus Nutt.	haresfoot locoweed	Acc	Forb	P	N	1	
Packera cana	Packera cana (Hook.) W.A. Weber & A. Love	woolly groundsel	Acc	Forb	P	N	3	
Packera multilobata	Packera multilobata (Torr. & A. Gray ex A. Gray) W.A. Weber & A. Love	lobeleaf groundsel	Acc	Forb	A	N	3	
Packera sp.	Packera A. Love & D. Love	ragwort	Acc	Forb	P	N	3	
Pascopyrum smithii	Pascopyrum smithii (Rydb.) A. Love	western wheatgrass	Acc	Gram	P	N	3	b
Paxistima myrsinites	Paxistima myrsinites (Pursh) Raf.	Oregon boxleaf	Acc	Shrub	P	N	1	
Pediocactus simpsonii	Pediocactus simpsonii (Engelm.) Britton & Rose	mountain ball cactus	Acc	Shrub	P	N	3	
Penstemon humilis	Penstemon humilis Nutt. ex A. Gray	low beardtongue	Acc	Forb	P	N	2	
Penstemon sp.	Penstemon Schmidel	beardtongue	Acc	Forb	P	N	3	
Penstemon strictus	Penstemon strictus Benth.	Rocky Mountain penstemon	Acc	Forb	P	N	1	
Penstemon subglaber	Penstemon subglaber Rydb.	smooth penstemon	Acc	Forb	P	N	2	
Petradoria pumila	Petradoria pumila (Nutt.) Greene	rock goldenrod	Acc	Forb	P	N	2	
Phacelia sericea	Phacelia sericea (Graham) A. Gray	silky phacelia	Acc	Forb	P	N	1	
Phlox andicola	Phlox andicola E.E. Nelson	prairie phlox	Acc	Forb	P	N	1	
Phlox hoodii	Phlox hoodii Richardson	spiny phlox	Acc	Forb	P	N	3	
Phlox multiflora	Phlox multiflora A. Nelson	flowery phlox	Acc	Forb	P	N	2	
Phlox sp.	Phlox L.	phlox	Acc	Forb	P	N	2	
Physaria acutifolia	Physaria acutifolia Rydb.	sharpleaf twinpod	Acc	Forb	P	N	3	
Physaria sp.	Physaria (Nutt. ex Torr. & A. Gray) A. Gray	twinpod	Acc	Forb	P	N	1	
Physocarpus malvaceus	Physocarpus malvaceus (Greene) Kuntze	mallow ninebark	Acc	Shrub	P	N	1	
Poa arida	Poa arida Vasey	plains bluegrass	Acc	Gram	P	N	1	
Poa cusickii	Poa cusickii Vasey	Cusick's bluegrass	Acc	Gram	P	N	1	
Poa fendleriana	Poa fendleriana (Steud.) Vasey	muttongrass	Acc	Gram	P	N	2	
Poa interior	Poa nemoralis L. ssp. interior (Rydb.) W.A. Weber	Inland bluegrass	Syn	Gram	P	N	2	
Poa pratensis	Poa pratensis L.	Kentucky bluegrass	Acc	Gram	P	I	1	

Table 29 (continued).

Short Scientific Name	Complete Scientific Name, PLANTS	Common Name, PLANTS	Acc Or Syn?	Growth-form	Life-span	Origin	#Years	Com. Dom.?
Poa secunda	Poa secunda J. Presl	Sandberg bluegrass	Acc	Gram	P	N	3	b,u
Poa sp.	Poa L.	bluegrass	Acc	Gram	U	U	2	
Polygonum aviculare	Polygonum aviculare L.	prostrate knotweed	Acc	Forb	A	I	1	
Polygonum sawatchense	Polygonum douglasii Greene ssp. johnstonii (Munz) J.C. Hickman	(Knotweed)	Syn	Forb	A	U	1	
Populus tremuloides	Populus tremuloides Michx.	quaking aspen	Acc	Tree	P	N	3	
Potentilla concinna	Potentilla concinna Richardson	elegant cinquefoil	Acc	Forb	P	N	2	
Potentilla gracilis	Potentilla gracilis Douglas ex Hook.	slender cinquefoil	Acc	Forb	P	N	2	
Pseudoroegneria spicata	Pseudoroegneria spicata (Pursh) A. Love	bluebunch wheatgrass	Acc	Gram	P	N	3	b,u
Pseudostellaria jamesiana	Pseudostellaria jamesiana (Torr.) W.A. Weber & R.L. Hartm.	tuber starwort	Acc	Forb	P	N	1	
Pseudotsuga menziesii	Pseudotsuga menziesii (Mirb.) Franco	Douglas-fir	Acc	Tree	P	N	2	u
Purshia tridentata	Purshia tridentata (Pursh) DC.	antelope bitterbrush	Acc	Shrub	P	N	3	
Ribes cereum	Ribes cereum Douglas	wax currant	Acc	Shrub	P	N	3	
Ribes oxyacanthoides	Ribes oxyacanthoides L.	Canadian gooseberry	Acc	Shrub	P	N	1	
Rosa sp.	Rosa L.	rose	Acc	Shrub	P	N	1	
Rosa woodsii	Rosa woodsii Lindl.	Woods' rose	Acc	Shrub	P	N	2	
Salsola tragus	Salsola tragus L.	prickly Russian thistle	Acc	Forb	A	I	2	
Sarcobatus vermiculatus	Sarcobatus vermiculatus (Hook.) Torr.	greasewood	Acc	Shrub	P	N	3	b
Schoenocrambe linifolia	Schoenocrambe linifolia (Nutt.) Greene	flaxleaf plainsmustard	Acc	Forb	P	N	2	
Senecio sp.	Senecio L.	ragwort	Acc	Forb	P	N	1	
Sphaeralcea coccinea	Sphaeralcea coccinea (Nutt.) Rydb.	scarlet globemallow	Acc	Forb	P	N	3	
Stanleya pinnata	Stanleya pinnata (Pursh) Britton	desert princesplume	Acc	Forb	P	N	1	
Stanleya viridiflora	Stanleya viridiflora Nutt.	green princesplume	Acc	Forb	P	N	2	
Stenotus acaulis	Stenotus acaulis (Nutt.) Nutt.	stemless mock goldenweed	Acc	Forb	P	N	3	
Stenotus armerioides	Stenotus armerioides Nutt.	thrift mock goldenweed	Acc	Forb	P	N	3	
Stenotus sp.	Stenotus Nutt.	mock goldenweed	Acc	Forb	P	N	3	u
Stephanomeria runcinata	Stephanomeria runcinata Nutt.	desert wirelettuce	Acc	Forb	P	N	3	
Suaeda sp.	Suaeda Forssk. ex J.F. Gmel.	seepweed	Acc	Forb	U	N	2	
Symphoricarpos oreophilus	Symphoricarpos oreophilus A. Gray	mountain snowberry	Acc	Shrub	P	N	3	b
Symphyotrichum ascendens	Symphyotrichum ascendens (Lindl.) G.L. Nesom	western aster	Acc	Forb	P	N	1	
Taraxacum laevigatum	Taraxacum laevigatum (Willd.) DC.	rock dandelion	Acc	Forb	P	I	1	
Taraxacum officinale	Taraxacum officinale F.H. Wigg.	common dandelion	Acc	Forb	P	I	3	
Taraxacum sp.	Taraxacum F.H. Wigg.	dandelion	Acc	Forb	P	U	2	

Table 29 (continued).

Short Scientific Name	Complete Scientific Name, PLANTS	Common Name, PLANTS	Acc Or Syn?	Growth-form	Life-span	Origin	#Years	Com. Dom.?
Tetradymia canescens	Tetradymia canescens DC.	spineless horsebrush	Acc	Shrub	P	N	3	
Thalictrum sp.	Thalictrum L.	meadow-rue	Acc	Forb	P	N	1	
Thlaspi arvense	Thlaspi arvense L.	field pennycress	Acc	Forb	A	I	1	
Townsendia hookeri	Townsendia hookeri Beaman	Hooker's Townsend daisy	Acc	Forb	P	N	1	
Townsendia sp.	Townsendia Hook.	Townsend daisy	Acc	Forb	P	N	1	
Tragopogon dubius	Tragopogon dubius Scop.	yellow salsify	Acc	Forb	A	I	3	
Trifolium gymnocarpon	Trifolium gymnocarpon Nutt.	hollyleaf clover	Acc	Forb	P	N	3	
Viola adunca	Viola adunca Sm.	hookedspur violet	Acc	Forb	P	N	1	
Viola vallicola	Viola vallicola A. Nelson	sagebrush violet	Acc	Forb	P	N	1	
Zigadenus venenosus	Zigadenus venenosus S. Watson	meadow deathcamas	Acc	Forb	P	N	1	

* *Elymus lanceolatus* ssp. *lanceolatus* and *E. l.* spp. *riparius* were counted as *Elymus lanceolatus* before the number of years of occurrence were calculated, so there are only 248 taxa for which the numbers of years are shown.

Growth-form, Life-span, and Origin Of Plants In the Flora

When data from the individual plots are aggregated, they show what plant growth-forms, life-spans, and source of origin are most common in the flora. Among the 249 plants identified at least to genus (Table 29), 73% are forbs (183 taxa), 13% are graminoids (32 taxa), 12% are shrubs (29 taxa), 2% are trees (4 taxa), and only 1 taxon is of unknown growth-form. Perennials (190 taxa) account for 76% of these identified taxa, 21% are annuals (53 taxa), and 2% are of unknown life-span (6 taxa). Eighty-seven percent (217 taxa) are native to Wyoming, 10% are introduced (24 taxa), and 3% are of unknown origin (8 taxa). The taxa of unknown life-span or origin are genera that include both annual species and perennial species, or both native species and introduced species.

Growth-form, Life-span, and Origin Of Plants In Different Plots and Years

Analysis of plant groups and taxa on a plot-by-plot basis (rather than in the entire flora) can show differences between burned and unburned plots, and changes over the life of the study. Taxonomic richness (that is, the number of plant taxa present) per vegetation plot ranged from 13 taxa to 55 taxa in 2001, and from 6 taxa to 43 taxa in 2012 (Figure 30). Unburned plots had higher average per-plot numbers of species in 2001 (29.6 for unburned plots, 27.3 for unburned plots) and in 2012 (24.7 for unburned plots, 22.4 for burned plots). In neither year was there a significant difference (at $p = 0.05$) between burned plots and unburned plots (Table 30). In both the burned plots and the unburned plots, the number of taxa present generally declined from 2001 to 2012 (Figure 31), and in both types of plots, the decline was significant ($p < 0.05$) (Table 31).

Figure 30. Numbers of plant species per vegetation plot, burned vs. unburned plots, 2001 vs. 2012. Crosses represent individual vegetation plots. Circles are medians, used in the statistical test.

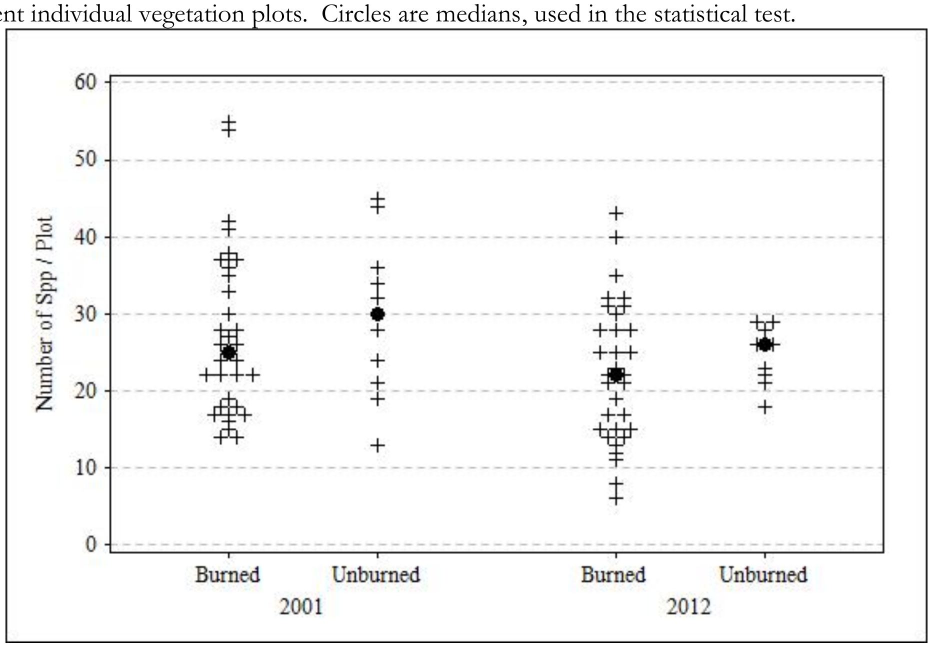

Table 30. Mann-Whitney U tests, number of plant species per vegetation plot, burned vs. unburned plots, 2001 vs. 2012.
H_O: Distribution of number of species per burned plot = distribution of number of species per unburned plot. **H_A**: Distributions of number of species per burned plot ≠ distribution of number of species per unburned plot

a. 2001

Plot Type	N	Median	Variance	Skewness	Kurtosis
Burned	32	25.00	119.12	0.96	0.49
Unburned	11	30.00	100.65	0.04	-0.61

W = 674.5, p = 0.4190. **Do no reject H_O:** the distributions of number of species per vegetation plot are the same for burned plots and unburned plots.

b. 2012

Plot Type	N	Median	Variance	Skewness	Kurtosis
Burned	32	22.00	83.22	0.29	-0.45
Unburned	9	26.00	15.00	-0.46	-0.94

W = 644.0, p = 0.3857. **Do no reject H_O:** the distributions of number of species per vegetation plot are the same for burned plots and unburned plots.

Figure 31. Change, 2001 to 2012, in number of plant species in individual vegetation plots, burned vs. unburned plots. Crosses represent individual vegetation plots. Circles are means.

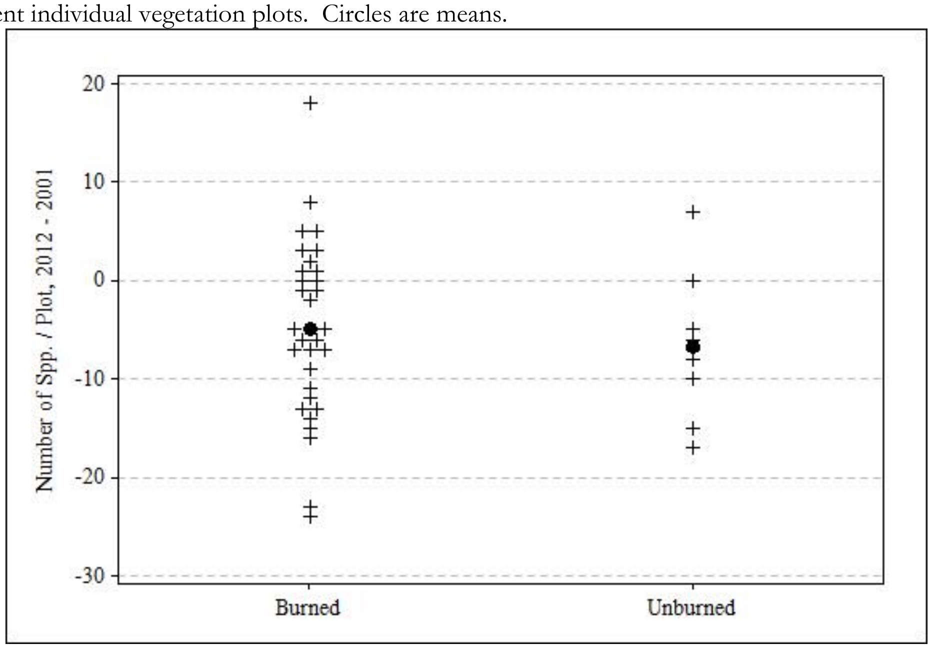

Table 31. T-tests, change from 2001 to 2012 in number of plant species per vegetation plot, burned vs. unburned plots. **H_O:** Mean change in number of species = 0. **H_A**: Mean change in number of species ≠ 0

a. Burned plots

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
(Number of species 2012) - (Number of species 2001)	32	-4.88	8.92	1.58	(-8.09, -1.66)	-3.09	0.004

Reject H_O: Mean change in number of species, 2012 - 2001, is not zero

b. Unburned plots

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
(Number of species 2012) - (Number of species 2001)	9	-6.78	7.28	2.43	(-12.37, -1.18)	-2.79	0.023

Reject H_O: Mean change in number of species, 2012 - 2001 is not zero

The great majority of plant taxa in the plots in each year were perennials (Figure 32). In 2001, the unburned plots had a higher average number of perennials (25.0/plot) than did the burned plots (18.8/plot), although the two groups overlapped (Figure 33). The Mann-Whitney test suggests that the difference, although slight, probably was significant (Table 32). In 2012, the difference between the burned plots and unburned plots had narrowed (Figure 33), with the burned plots having essentially the same average number of perennials (18.5/plot) as in 2001 and the unburned plots having, on average, slightly fewer (22.3/plot). The Mann-Whitney test showed no significant difference between the burned vs. unburned plots (Table 32). Examination of the 2001-to-2012 changes in individual plots (Figure 34) confirms that the number of perennials per burned plot did not change, and a T-test on the data shows (as expected) no significant difference (Table 33). The disappearance by 2012 of the burned vs. unburned difference that appeared to exist in 2001 must have resulted from the decline in the per-plot number of perennials in the unburned plots. Most of the unburned plots did show a decline in the number of perennial taxa (Figure 34), but a T-test shows that the difference probably was not statistically significant (Table 33). This contradiction between the results of the two statistical tests probably results from the very small number of unburned transects. Because the T-test generally is more powerful than the Mann-Whitney test, the sensible conclusion is that the number of perennials per plot generally did not change from 2001 to 2012 in either the burned or the unburned plots, and the two types of plots did not actually differ in the per-plot number of perennial taxa in 2001.

Figure 32. Proportions of perennial species, annual species, and species of unknown lifespan in the vegetation plots, 2001 vs. 2012.

Bars are means for burned and unburned plots combined; error bars are standard errors of the means. Annuals include species that may be either annuals or biennials; perennials include species that may be either biennials or perennials; unknowns are taxa that were not identified to species and for which lifespan was not determined.

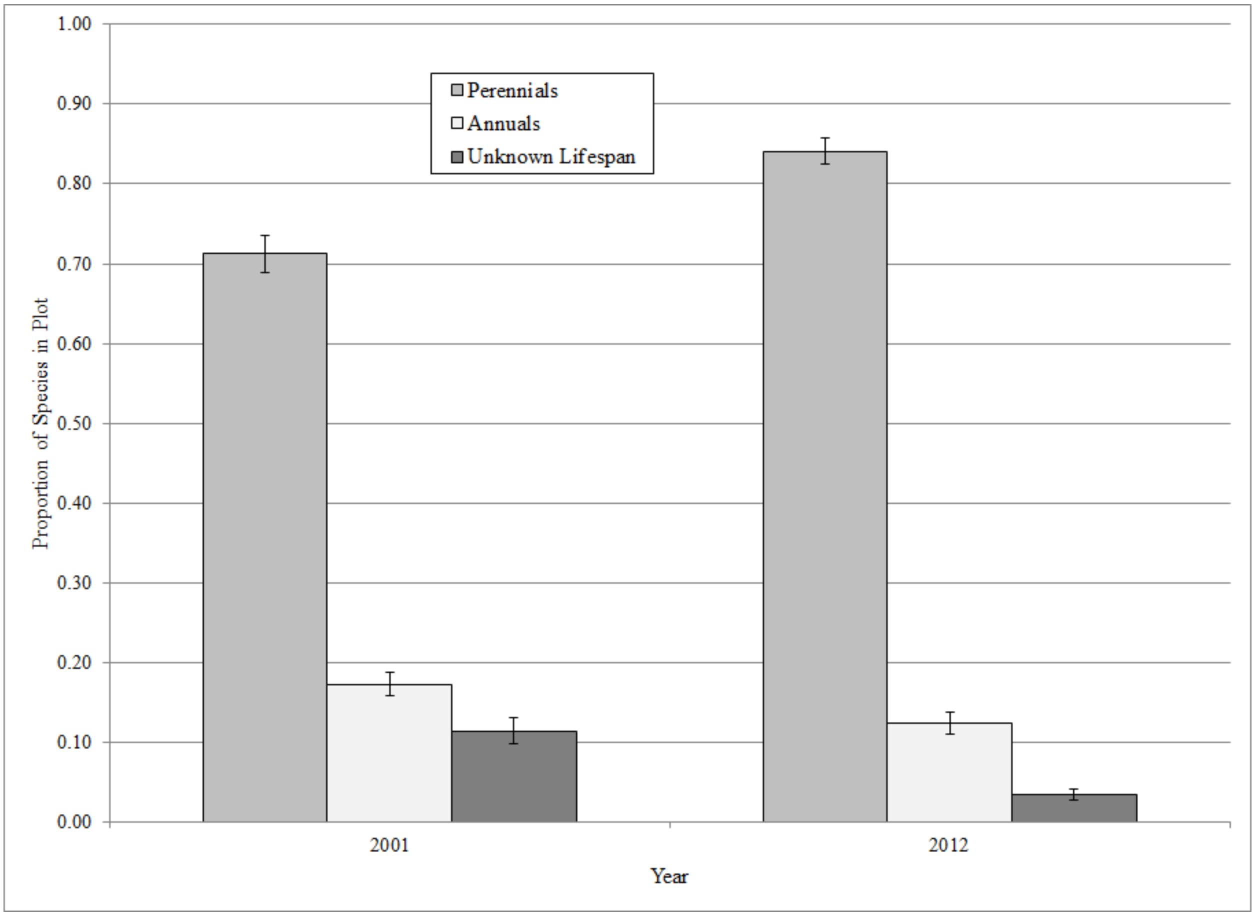

Figure 33. Number of perennial plant taxa per vegetation plot, burned vs. unburned plots, 2001 vs. 2012. Crosses represent individual vegetation plots. Circles are medians.

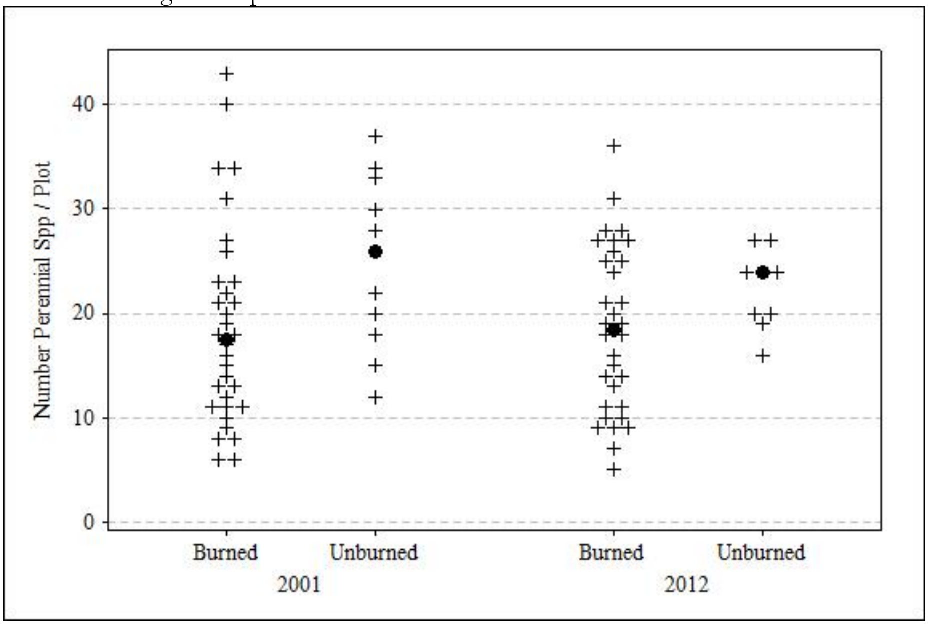

Table 32. Mann-Whitney U tests, number of perennial plant taxa per vegetation plot, burned vs. unburned plots, 2001 vs. 2012.

H_O: The distribution of number of perennial species per vegetation plot in burned plots is the same as the distribution in burned plots. **H_A**: The distribution of number of perennial species per vegetation plot in burned plots is different than the distribution in unburned plots

a. 2001

Plot Type	N	Median	Variance	Skewness	Kurtosis
Burned	32	17.50	93.61	0.89	0.26
Unburned	11	26.00	67.60	-0.13	-1.21

W = 631.5, p = 0.0449. **Reject H_O**: the distribution of the number of perennial species per plot in burned plots is different than the distribution in unburned plots.

b. 2012

Plot Type	N	Median	Variance	Skewness	Kurtosis
Burned	32	18.50	63.81	0.19	-0.90
Unburned	9	24.00	14.25	-0.30	-0.93

W = 631.0, p = 0.211. **Do not reject H_O:** the distribution of the number of perennial species per plot in burned plots is the same as the distribution in unburned plots.

Figure 34. Change, 2001 to 2012, in number of perennial plant taxa in each vegetation plot, burned vs. unburned plots. Crosses represent individual vegetation plots. Circles are means.

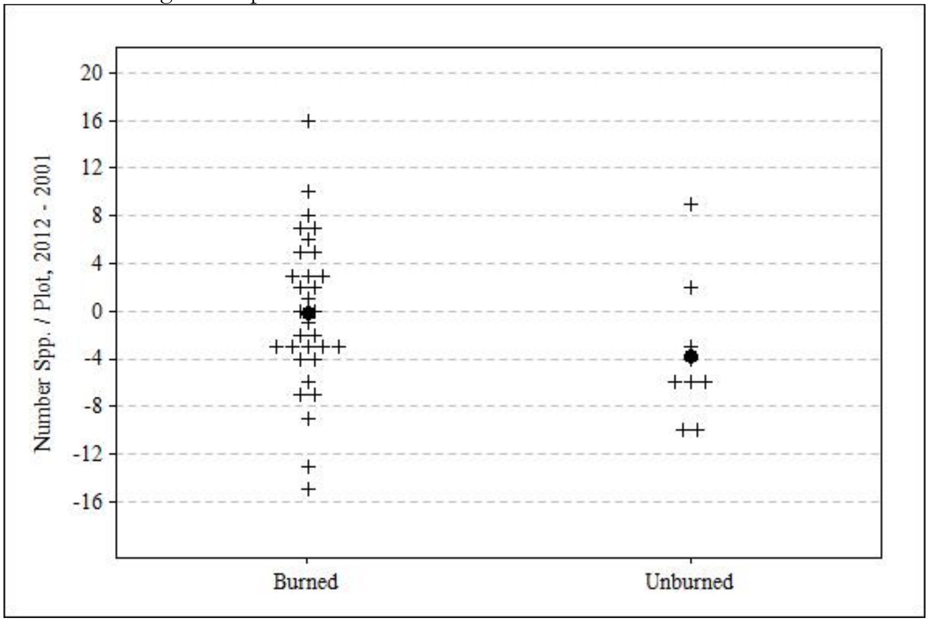

Table 33. T-tests, change from 2001 to 2012 in number of perennial plant taxa in each vegetation plot, burned vs. unburned plots.

H_O: Mean change in number of perennial species = 0. **H_A:** Mean change in number of perennial species ≠ 0

a. Burned plots

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
(Number of species 2012) - (Number of species 2001)	32	-0.22	6.56	1.16	(-2.58, 2.15)	-0.19	0.852

Do not reject H_O: Mean change in number of perennial species 2012 - 2001, is zero.

b. Unburned plots

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
(Number of species 2012) - (Number of species 2001)	9	-3.78	6.02	2.01	(-8.40, 0.85)	-1.88	0.096

Do not reject H_O: Mean change in number of perennial species 2012 - 2001 is zero.

Annual taxa showed the opposite pattern from perennials (Figure 35). Burned plots had greater per-plot average numbers of annuals in both 2001 (5.3 species for burned, 2.5 species for unburned) and 2012 (2.9 species for burned plots, 1.7 species for unburned). Burned plots had significantly (at p = 0.05) more annual taxa than unburned plots in 2001, but there was no significant difference in 2012 (Table 34). The difference between burned and unburned plots disappeared by 2012 because, although the number of annual taxa per plot declined significantly in both burned plots and unburned plots (Figure 36, Table 35), the decline was greater in the burned plots than the unburned.

Figure 35. Number of annual plant taxa per vegetation plot, burned vs. unburned plots, 2001 vs. 2012. Crosses represent individual vegetation plots. Circles are medians.

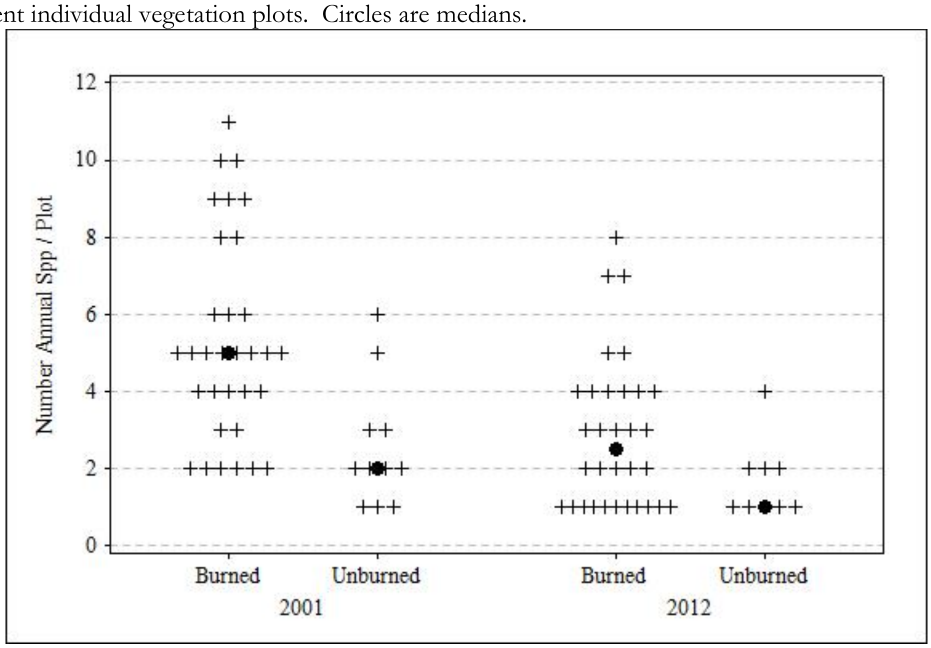

Table 34. Mann-Whitney U tests, number of annual plant taxa per vegetation plot, burned vs. unburned plots, 2001 vs. 2012.
H_O: The distribution of number of annual species per plot is the same in burned plots as in unburned plots. **H_A:** The distribution of number of annual species per plot in burned plots is different than the distribution in unburned plots.

a. 2001

Plot Type	N	Median	Variance	Skewness	Kurtosis
Burned	32	5.00	7.060	0.60	-0.59
Unburned	11	2.00	2.673	1.24	0.87

W = 814.5, p = 0.0019. **Reject H_O:** the distribution of the number of annual species per plot is different in burned plots than in unburned plots.

b. 2012

Plot Type	N	Median	Variance	Skewness	Kurtosis
Burned	32	22.00	3.855	1.03	0.53
Unburned	9	26.00	1.000	1.82	3.64

W = 724.0, p = 0.0920. **Do not reject H_O:** the distribution of number of annual species per plot is the same in burned plots as in unburned plots.

Figure 36. Change, 2001 to 2012, in number of annual plant taxa in individual vegetation plots, burned vs. unburned plots.
Crosses represent individual vegetation plots. Circles are means.

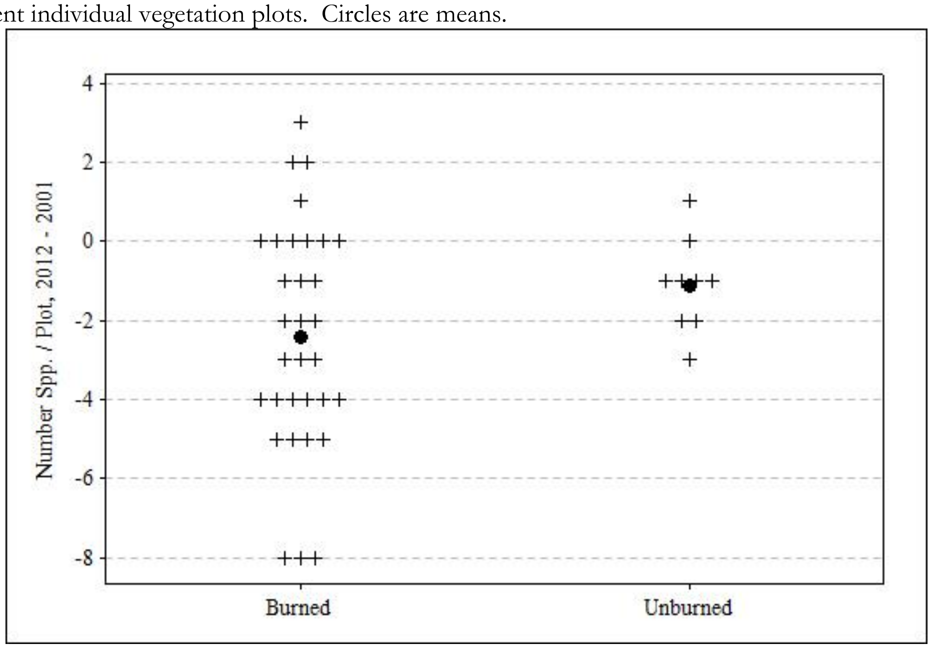

Table 35. T-tests, change from 2001 to 2012 in number of annual plant taxa per vegetation plot, burned vs. unburned plots.
H_O: Mean change in number of annual species = 0. **H_A:** Mean change in number of annual species ≠ 0

a. Burned plots

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
(Number of species 2012) - (Number of species 2001)	32	-2.438	2.884	0.510	(-3.477, -1.398)	-4.78	0.000

Reject H_O: Mean change in number of annual species 2012 - 2001, is not zero

b. Unburned plots

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
(Number of species 2012) - (Number of species 2001)	9	-1.111	1.167	0.389	(-2.08, -0.214)	-2.86	0.021

Reject H_O: Mean change in number of annual taxa 2012 - 2001 is not zero

Forbs were, on average, the most numerous life-form in the vegetation plots in each year; shrubs (including partially woody, sub-shrubs) and graminoids contributed approximately equal numbers of taxa (Figure 37). In 2001 and in 2012, there was no statistically significant difference between burned and unburned plots in the number of forb taxa (Figure 38, Table 36). For both the burned plots and the unburned plots, the numbers of forb taxa declined significantly (p = 0.05) from 2001 to 2012 (Figure 39, Table 37). The per-plot average for burned plots declined from 17.1 to 10.3 forb taxa/plot; and for unburned plots, from 16.4 to 11.4 taxa/plot.

Figure 37. Numbers of forb, graminoid, and shrub taxa in vegetation plots, 2001 vs. 2012.
Bars are means for burned and unburned plots combined; error bars are standard errors of the means. Shrubs includes partially woody species (sub-shrubs).

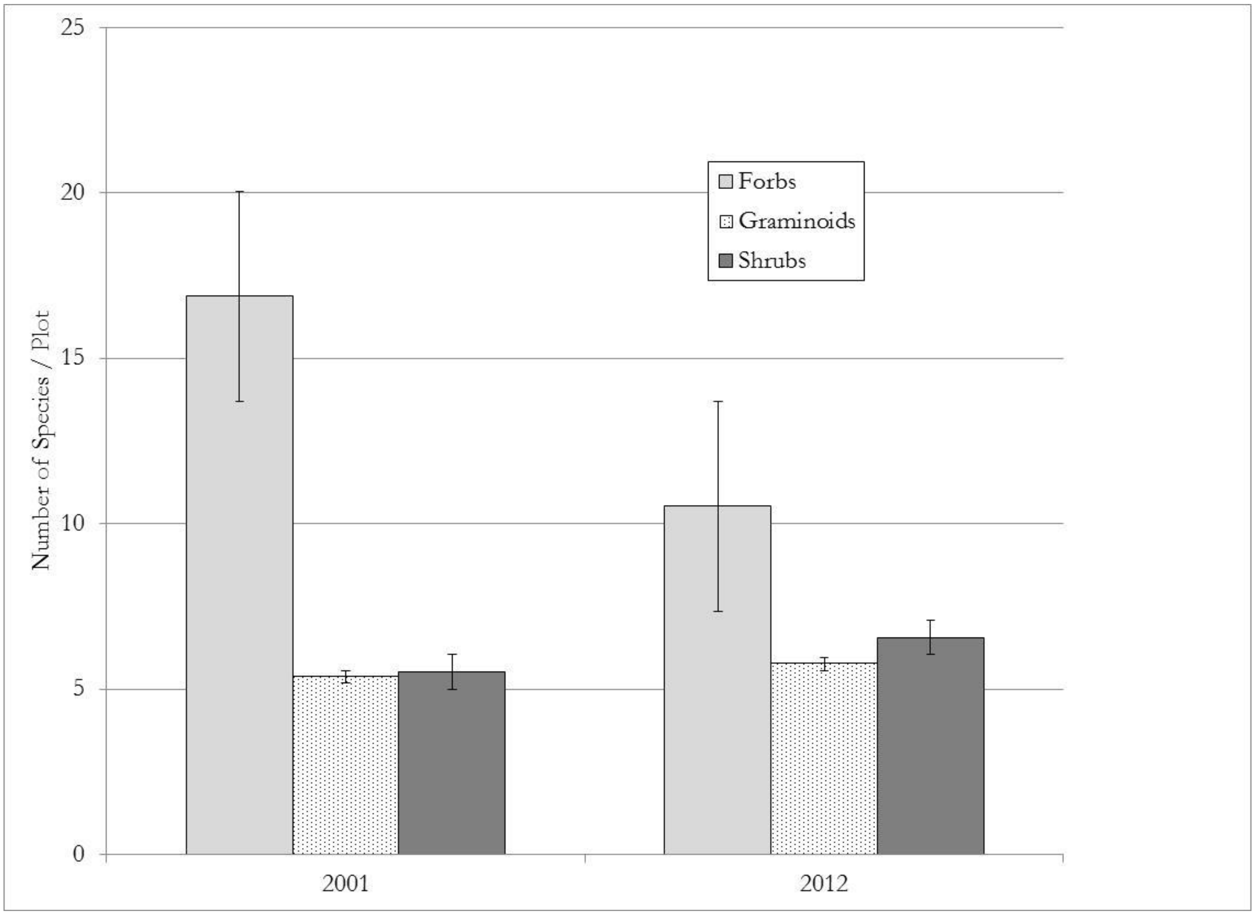

Figure 38. Number of forb taxa per vegetation plot, burned vs. unburned plots, 2001 vs. 2012. Crosses represent individual vegetation plots. Circles are medians, used in statistical test.

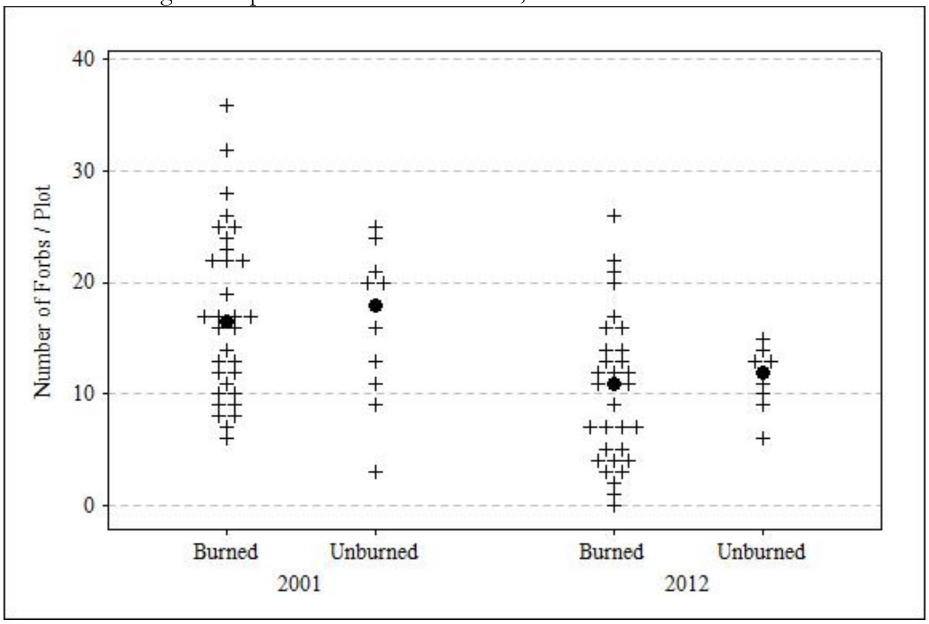

Table 36. Mann-Whitney U tests, number of forb taxa per vegetation plot, burned vs. unburned plots.
H_O: The distribution of the number of forb taxa per vegetation plot in burned plots = the distribution in unburned plots. **H_A:** The distribution of the number of forb taxa per vegetation plot in burned plots ≠ the distribution in unburned plots.

a. 2001

Plot Type	N	Median	Variance	Skewness	Kurtosis
Burned	32	16.50	58.64	0.60	-0.26
Unburned	11	18.00	45.65	-0.67	-0.16

W = 704.0, p = 1.000. **Do not reject H_O**: the distribution of the number of forb taxa per plot in burned plots is the same as the distribution in unburned plots.

b. 2012

Plot Type	N	Median	Variance	Skewness	Kurtosis
Burned	32	11.00	43.31	0.49	-0.34
Unburned	9	12.00	7.778	-0.81	0.45

W = 647.5, p = 0.4487. **Do not eject H_O**: the distribution of the number of forb taxa per plot in burned plots is the same as the distribution in unburned plots.

Figure 39. Change, 2001 to 2012, in number of forb taxa in individual vegetation plots, burned vs. unburned plots. Crosses represent individual vegetation plots. Circles are means.

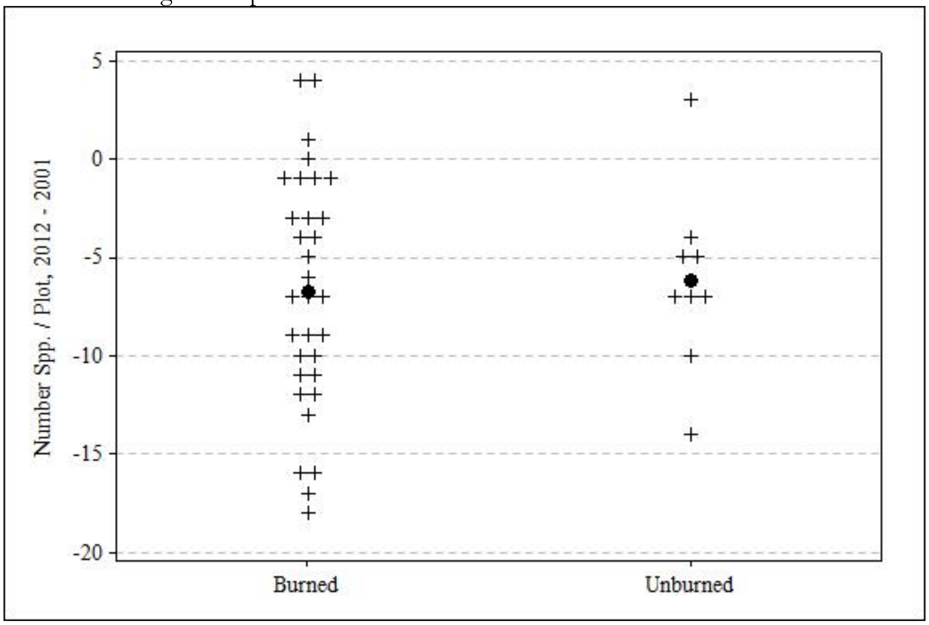

Table 37. T-tests, change from 2001 to 2012, in number of forb taxa in individual vegetation plots, burned vs. unburned plots.

H$_O$: Mean change in number of forb taxa = 0. **H$_A$**: Mean change in number of forb taxa ≠ 0

a. Burned plots

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
(Number of species 2012) - (Number of species 2001)	32	-6.78	5.96	1.05	(-8.93, -4.63)	-6.44	0.000

Reject H$_O$: Mean change in number of forb taxa per plot is not zero.

b. Unburned plots

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
(Number of species 2012) - (Number of species 2001)	9	-6.22	4.60	1.53	(-9.76, -2.68)	-4.05	0.004

Reject H$_O$: Mean change in number of forb taxa per plot is not zero.

The average number of graminoid taxa per plot also did not differ between burned plots and unburned plots in 2001 (5.2 graminoids per burned plot, 5.9 graminoids per unburned plot) or 2012 (6.0 graminoids per burned plot, 4.9 graminoids per unburned plot) (Figure 40, Table 38). In contrast to the forbs, the average number of graminoids per plot did not change from 2001 to 2012 in either the burned or the unburned plots (Figure 41, Table 39).

Figure 40. Number of graminoid taxa per vegetation plot, burned vs. unburned plots, 2001 vs. 2012. Crosses represent individual vegetation plots. Circles are medians.

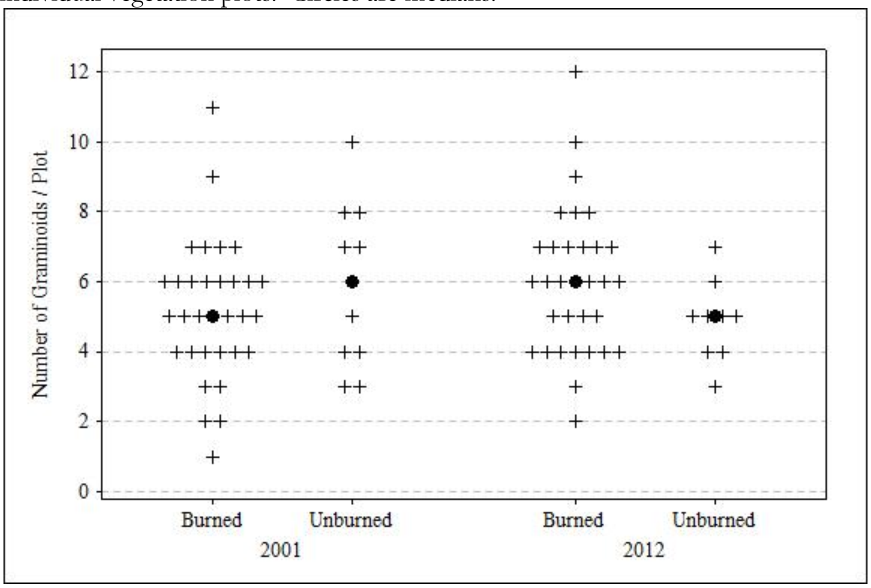

Table 38. Mann-Whitney U tests, number of graminoid taxa per vegetation plot, burned vs. unburned plots, 2001 vs. 2012.
H_O: The distribution of the number of graminoid taxa per plot in burned plots **=** the distribution in unburned plots.
H_A: The distribution of the number of graminoid taxa per plot in burned plots **≠** the distribution in unburned plots

a. 2001

Plot Type	N	Median	Variance	Skewness	Kurtosis
Burned	32	5.000	3.964	0.48	1.60
Unburned	11	6.000	5.291	0.26	-0.95

W = 672.5, p = 0.3821. **Do not reject H_O:** the distribution of the number of graminoid taxa per plot is not different in burned plots than in unburned plots.

b. 2012

Plot Type	N	Median	Variance	Skewness	Kurtosis
Burned	32	6.000	4.387	0.70	1.04
Unburned	9	5.000	1.361	0.27	0.54

W = 720.0, p = 0.1287. **Do not eject H_O**: the distribution of the number of graminoid taxa per plot is not different in burned plots than in unburned plots.

Figure 41. Change , 2001 to 2012, in number of graminoid taxa in individual vegetation plots, burned vs. unburned plots.
Crosses represent individual vegetation plots. Circles are means.

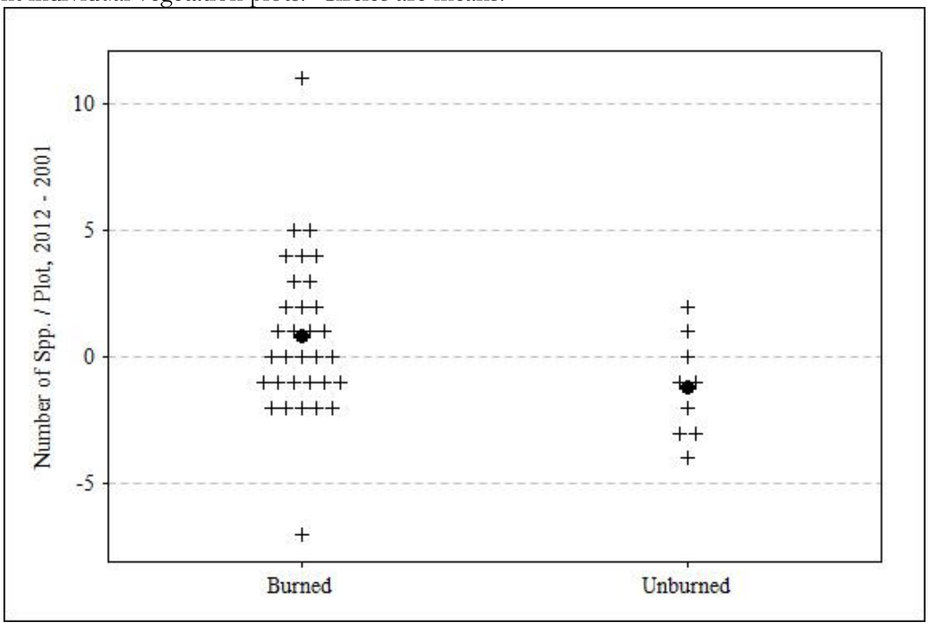

Table 39. T-tests, change from 2001 to 2012 in number of graminoid taxa per vegetation plot, burned vs. unburned plots.

H_O: Mean change in number of graminoid taxa = 0. **H_A**: Mean change in number of graminoid taxa ≠ 0

a. Burned plots

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
(Number of species 2012) - (Number of species 2001)	32	0.813	3.146	0.556	(-0.322, 1.947)	1.46	0.154

Do not reject H_O: Mean change in number of graminoid taxa per burned plot is zero.

b. Unburned plots

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
(Number of species 2012) - (Number of species 2001)	9	-1.222	1.986	0.622	(-2.749, 0.304)	-1.85	0.102

Do not reject H_O: Mean change in number of graminoid taxa per burned plot is zero.

Unburned plots had a higher average number of shrub taxa than did burned plots in 2001 (7.2 per unburned plot, 4.9 per burned plot) and in 2012 (8.3 per unburned plot, 6.1 per burned plot) (Figure 42, Table 40). From 2001 to 2012, the average number of shrub taxa per plot increased significantly ($p = 0.05$) in the burned plots, but not in the unburned plots (Figure 43, Table 41).

Figure 42. Number of shrub species per vegetation plot, burned vs. unburned plots, 2001 vs. 2012. Crosses represent individual vegetation plots. Circles are medians.

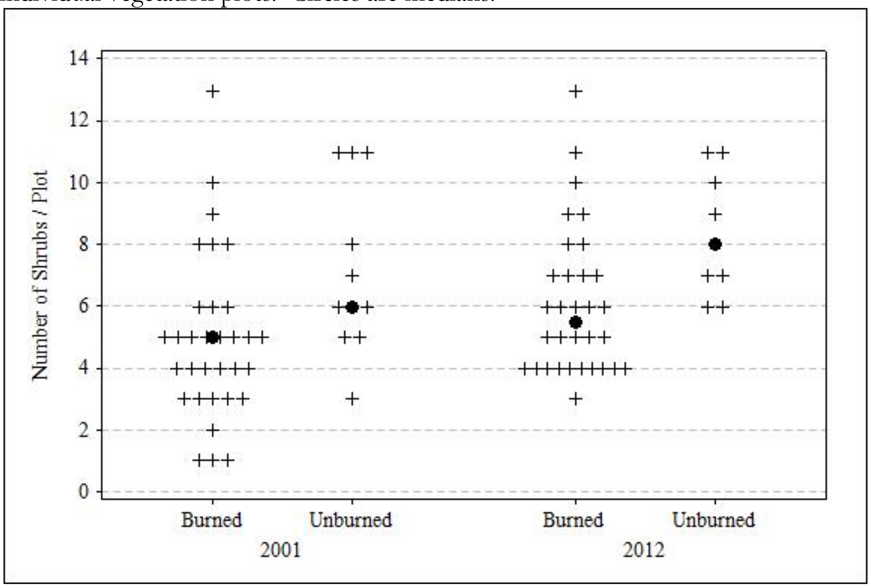

Table 40. Mann-Whitney U tests, number of shrub species per vegetation plot, burned vs. unburned plots, 2001 vs. 2012.
H_O: The distribution of the number of shrub species per plot in burned plots = the distribution in unburned plots. **H_A:** The distribution of the number of shrub species per plot in burned plots ≠ the distribution unburned plots

a. 2001

Plot Type	N	Median	Variance	Skewness	Kurtosis
Burned	32	5.000	7.028	1.04	1.67
Unburned	11	6.000	7.564	0.40	-0.98

W = 615.5, $p = 0.0133$. **Reject H_O:** the distribution of the number of shrub species per plot is different in burned plots than in unburned plots.

b. 2012

Plot Type	N	Median	Variance	Skewness	Kurtosis
Burned	32	5.500	5.609	1.20	1.17
Unburned	9	8.000	4.000	0.25	-1.65

W = 588.5, $p = 0.0081$. **Reject H_O:** the distribution of the number of shrub species per plot is different in burned plots than in unburned plots.

Figure 43. Change, 2001 to 2012, in number of shrub species in individual vegetation plots, burned vs. unburned plots. Crosses represent individual vegetation plots. Circles are means.

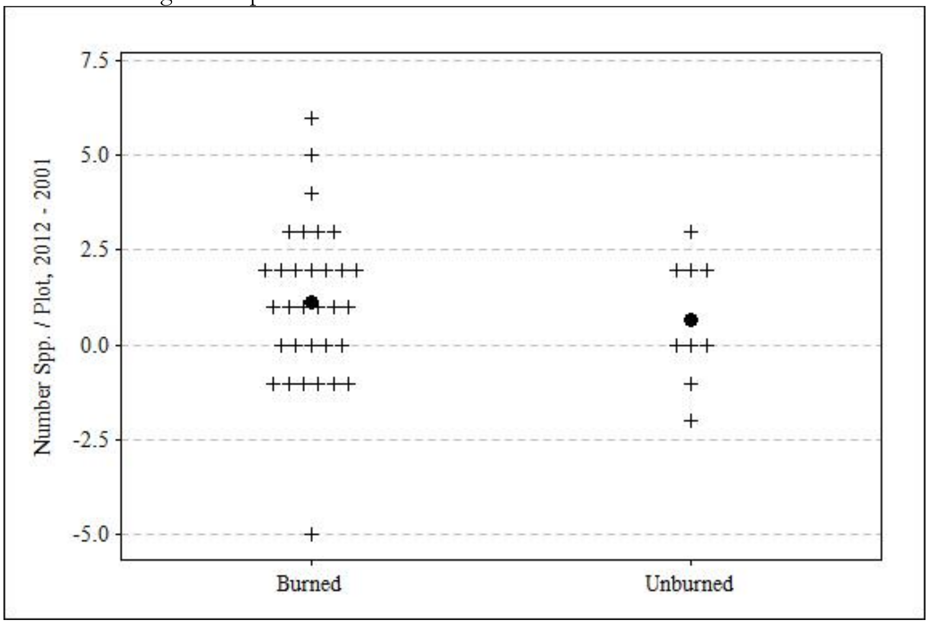

Table 41. T-tests, change from 2001 to 2012 in number of shrub species per vegetation plot, burned vs. unburned plots.

H_O: Mean change in number of shrub species per plot = 0. **H_A:** Mean change in number of shrub species per plot ≠ 0

a. Burned plots

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
(Number of species 2012) - (Number of species 2001)	32	1.125	2.106	0.372	(0.366, 1.884)	3.02	0.005

Reject H_O: Mean change in number of shrub species per burned plot is not zero

b. Unburned plots

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
(Number of species 2012) - (Number of species 2001)	9	0.667	1.658	0.553	(-0.608, 1.941)	1.21	0.262

Do not reject H_O: Mean change in number of shrub species per unburned plot is zero

In summary, the data suggest only modest change in plant species richness. The burned and unburned plots did not differ in the number of species per plot at the beginning of the study or at the end, but the number of species per plot declined slightly from beginning to end. The great majority of plant species were perennials, and it appears that the unburned plots had essentially the same number of perennials per plot as did burned plots. For annual taxa, the unburned plots had slightly fewer taxa per plot (on average) than did the burned plots in 2001, but the difference disappeared by the end of the study. The average number of annual taxa per plot declined in both burned and unburned plots over the course of the study.

Forbs were the most common life-form in the vegetation. There was no difference between burned and unburned plots in the average number of forb taxa per plot at either the beginning or the end of the study. Over the course of the study, both burned and unburned plots showed a slight decline in the average number of forb taxa per plot. For graminoids, too, there was no difference between burned and unburned plots in average number of taxa per plot, either at the beginning or the end of the study; and the average number of graminoid taxa per plot remained unchanged over the course of the study. In contrast, unburned plots had, on average, more shrub species than did burned plots at the beginning and at the end of the study. The greatest difference between burned plots and unburned plots, then, was in the average number of shrub species per plot.

Common Species Based on Occurrence

The common taxa among the 249 that were identified to genus or to genus and species can be judged by how many vegetation plots they were recorded in, and by the number of years in which they were recorded. Ninety-four genera and species, 38% of the taxa identified to genus or species, were found in at least 10% of the vegetation plots in at least one year (Table 42). The composition by growth-form of this group of common species is similar to that of the entire flora: 68% are forbs, 16% are graminoids, 15% are shrubs, and one species, *Juniperus osteosperma*, is a tree. The composition by life-span also is similar to that of the entire flora: 17% are annuals, 79% are perennials, and 4% are of unknown lifespan. Nine of these common species (10% of the group) are exotics: *Bromus tectorum*, *Ceratocephala testiculata*, *Descurainia sophia*, *Halogeton glomeratus*, *Malcolmia africana*, *Poa pratensis*, *Taraxacum officinale*, *Thlaspi arvense*, and *Tragopogon dubius*.

Only 92 taxa (37% of the identified taxa) were recorded in all three years of sampling (Table 29); 71 taxa (29% percent of the identified taxa) were recorded in 2 years; and 84 taxa (34% or the identified taxa) were recorded in only a single year. Unsurprisingly, the percentage of annuals is lowest among the taxa found in all 3 years (11%) and highest among those found in only one year (24%). Eight of the taxa found in all 3 years were introduced : *Agropyron cristatum*, *Bromus tectorum*, *Descurainia sophia*, *Halogeton glomeratus*, *Hyoscyamus niger*, *Lactuca serriola*, *Taraxacum officinale*, and *Tragopogon dubius*.

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Table 42. Ninety-four plant taxa found in at least 10% of vegetation sample plots in at least one year.

"Burned", Unburn", and "All" columns show the proportions of burned plots, unburned plots, and all plots in which each species was recorded, in each year. "n" is the number of plots of that type in that year. "Rank" is based on the proportion of occurrence in all plots ("All") for that year; larger ranks indicate higher proportions; ties are common; "max" is the maximum rank for that year. "AveRank" is the average of the 3 annual ranks, rounded to the nearest integer. Species are sorted first by AveRank (maximum to minimum) and then alphabetically. Nine introduced species are shown in italic typeface. Empty cells mean 0 values.

			2001				2002				2012			
Species		AveRank (max=24)	Burned (n=32	Unburned (n=11)	All (n=43	Rank (max=28)	Burned (n=32)	Unburned (n=10)	All (n=42)	Rank (max-21	Burned (n=32)	Unburned (n=9)	All (n=41)	Rank (max=25)
Chrysothamnus viscidiflorus	Shrub	24	0.84	0.82	0.84	27	0.88	0.80	0.86	21	0.88	0.89	0.88	24
Poa secunda	Gram	24	0.88	1.09	0.93	28	0.56	0.40	0.52	18	0.91	1.00	0.93	25
Achnatherum hymenoides	Gram	22	0.59	0.82	0.65	25	0.75	0.70	0.74	20	0.66	0.67	0.66	21
Artemisia tridentata	Shrub	21	0.38	1.00	0.53	21	0.56	0.90	0.64	19	0.81	1.00	0.85	23
Pseudoroegneria spicata	Gram	21	0.66	0.82	0.70	26	0.53	0.20	0.45	16	0.56	0.56	0.56	20
Bromus tectorum	*Gram*	19	*0.56*	*0.18*	*0.47*	*19*	*0.53*	*0.20*	*0.45*	*16*	*0.75*	*0.44*	*0.68*	*22*
Symphoricarpos oreophilus	Shrub	19	0.59	0.36	0.53	21	0.53	0.40	0.50	17	0.53	0.44	0.51	19
Astragalus convallarius	Forb	17	0.59	0.55	0.58	23	0.34	0.60	0.40	14	0.44	0.11	0.37	14
Phlox hoodii	Forb	17	0.53	0.64	0.56	22	0.19	0.20	0.19	8	0.59	0.89	0.66	21
Atriplex confertifolia	Shrub	16	0.44	0.55	0.47	19	0.47	0.30	0.43	15	0.38	0.56	0.41	15
Eriogonum microthecum	Shrub	16	0.31	0.27	0.30	13	0.38	0.60	0.43	15	0.56	0.56	0.56	20
Elymus elymoides	Gram	14	0.56	0.55	0.56	22	0.41	0.10	0.33	12	0.28		0.22	9
Koeleria macrantha	Gram	14	0.34	0.64	0.42	17	0.19		0.14	6	0.41	0.78	0.49	18
Elymus lanceolatus	Gram	13	0.41	0.18	0.35	15	0.44	0.10	0.36	13	0.31		0.24	10
Tetradymia canescens	Shrub	13	0.34	0.27	0.33	14	0.28	0.30	0.29	11	0.38	0.22	0.34	13
Pascopyrum smithii	Gram	12	0.25	0.64	0.35	15	0.06		0.05	2	0.53	0.67	0.56	20
Sarcobatus vermiculatus	Shrub	12	0.28	0.18	0.26	12	0.38	0.30	0.36	13	0.34	0.11	0.29	12
Juniperus osteosperma	Tree	12	0.34	0.73	0.44	18	0.09	0.60	0.21	9	0.09	0.67	0.22	9
Trifolium gymnocarpon	Forb	12	0.47	0.55	0.49	20	0.03	0.30	0.10	4	0.25	0.33	0.27	11

Table 42 (continued).

Species		AveRank (max=24)	2001 Burned (n=32	2001 Unburned (n=11)	2001 All (n=43	2001 Rank (max=28)	2002 Burned (n=32)	2002 Unburned (n=10)	2002 All (n=42)	2002 Rank (max-21	2012 Burned (n=32)	2012 Unburned (n=9)	2012 All (n=41)	2012 Rank (max=25)
Stenotus sp.	Forb	11	0.13	0.36	0.19	8	0.13	0.70	0.26	10	0.31	0.89	0.44	16
Packera cana	Forb	10	0.16	0.27	0.19	8	0.09	0.10	0.10	4	0.41	0.67	0.46	17
Krascheninnikovia lanata	Shrub	9	0.16	0.36	0.21	9	0.19	0.10	0.17	7	0.25	0.44	0.29	12
Tragopogon dubius	*Forb*	*9*	*0.31*	*0.27*	*0.30*	*13*	*0.09*		*0.07*	*3*	*0.38*		*0.29*	*12*
Crepis sp.	Forb	9	0.38	0.36	0.37	16	0.09		0.07	3	0.22	0.11	0.20	8
Descurainia sp.	Forb	9	0.66	0.45	0.60	24	0.03		0.02	1	0.03	0.11	0.05	2
Mertensia lanceolata	Forb	9	0.25	0.27	0.26	12				0	0.41	0.44	0.41	15
Cercocarpus montanus	Shrub	9	0.13	0.27	0.16	7	0.19	0.20	0.19	8	0.25	0.33	0.27	11
Eremogone hookeri	Forb	9	0.06	0.45	0.16	7	0.44	0.30	0.40	14	0.09	0.22	0.12	5
Cordylanthus ramosus	Forb	8	0.41	0.64	0.47	19		0.10	0.02	1	0.06	0.33	0.12	5
Halogeton glomeratus	*Forb*	*8*	*0.22*		*0.16*	*7*	*0.38*		*0.29*	*11*	*0.22*		*0.17*	*7*
Ipomopsis aggregata	Forb	8	0.38	0.18	0.33	14	0.09		0.07	3	0.19	0.11	0.17	7
Astragalus miser	Forb	7	0.19	0.18	0.19	8	0.13	0.10	0.12	5	0.25	0.11	0.22	9
Artemisia nova	Shrub	7	0.03	0.55	0.16	7		0.30	0.07	3	0.09	0.89	0.27	11
Astragalus purshii	Forb	7	0.19	0.36	0.23	11				0	0.22	0.33	0.24	10
Chenopodium atrovirens	Forb	7	0.41		0.30	13	0.16		0.12	5	0.06		0.05	2
Cryptantha sericea	Forb	7	0.09	0.27	0.14	6	0.19		0.14	6	0.16	0.33	0.20	8
Cryptantha sp.	Forb	7	0.16	0.09	0.14	6	0.22	0.40	0.26	10	0.13		0.10	4
Cymopterus terebinthinus	Forb	7	0.19	0.18	0.19	8	0.06	0.30	0.12	5	0.16	0.22	0.17	7
Ericameria nauseosa	Shrub	7	0.13	0.09	0.12	5	0.13	0.20	0.14	6	0.22	0.22	0.22	9
Penstemon humilis	Forb	7	0.28	0.18	0.26	12				0	0.16	0.33	0.20	8
Antennaria microphylla	Forb	6	0.09	0.27	0.14	6	0.06		0.05	2	0.31	0.11	0.27	11
Linanthus pungens	Forb	6	0.06	0.09	0.07	3	0.19	0.30	0.21	9	0.16	0.22	0.17	7
Machaeranthera canescens	Forb	6	0.13	0.27	0.16	7	0.13		0.10	4	0.19	0.22	0.20	8
Penstemon sp.	Forb	6	0.25	0.18	0.23	11	0.06		0.05	2	0.19		0.15	6
Lithospermum ruderale	Forb	6	0.22	0.18	0.21	9		0.20	0.05	2	0.19	0.11	0.17	7

Table 42 (continued).

Species		AveRank (max=24)	2001 Burned (n=32	2001 Unburned (n=11)	2001 All (n=43	2001 Rank (max=28)	2002 Burned (n=32)	2002 Unburned (n=10)	2002 All (n=42)	2002 Rank (max-21	2012 Burned (n=32)	2012 Unburned (n=9)	2012 All (n=41)	2012 Rank (max=25)
Cryptantha flavoculata	Forb	6		0.27	0.07	3		0.10	0.02	1	0.25	0.67	0.34	13
Leymus cinereus	Gram	6	0.16		0.12	5	0.06		0.05	2	0.31		0.24	10
Castilleja flava	Forb	5	0.34	0.27	0.33	14				0	0.03	0.11	0.05	2
Eriogonum sp.	Forb	5	0.06	0.45	0.16	7	0.09	0.40	0.17	7	0.03	0.11	0.05	2
Eriogonum umbellatum	Forb	5	0.09	0.18	0.12	5	0.06		0.05	2	0.22	0.22	0.22	9
Hesperostipa comata	Gram	5	0.13	0.27	0.16	7	0.16		0.12	5	0.09	0.11	0.10	4
Mertensia sp.	Forb	5	0.22	0.18	0.21	9	0.06		0.05	2	0.09	0.22	0.12	5
Physaria acutifolia	Forb	5	0.03	0.09	0.05	2	0.28	0.20	0.26	10	0.06	0.22	0.10	4
Amelanchier alnifolia	Shrub	5	0.25	0.09	0.21	10		0.10	0.02	1	0.13	0.00	0.10	4
Descurainia sophia	Forb	5	0.13		0.09	4	0.09		0.07	3	0.22		0.17	7
Arabis sp.	Forb	4	0.06	0.27	0.12	5	0.13		0.10	4	0.06	0.22	0.10	4
Balsamorhiza sagittata	Forb	4	0.13		0.09	4	0.13	0.10	0.12	5	0.13		0.10	4
Leucopoa kingii	Gram	4	0.09	0.09	0.09	4				0	0.28		0.22	9
Phlox multiflora	Forb	4	0.09		0.07	3				0	0.22	0.22	0.22	9
Lupinus sp.	Forb	4	0.16		0.12	5	0.06		0.05	2	0.13		0.10	4
Packera sp.	Forb	4	0.22	0.09	0.19	8				0	0.09		0.07	3
Taraxacum officinale	Forb	4	0.19		0.14	6	0.06		0.05	2	0.09		0.07	3
Artemisia frigida	Shrub	3	0.03		0.02	1	0.06	0.10	0.07	3	0.16	0.11	0.15	6
Chaenactis douglasii	Forb	3	0.22	0.09	0.19	8	0.03		0.02	1	0.03		0.02	1
Comandra umbellata	Forb	3	0.09	0.09	0.09	4	0.03	0.00	0.02	1	0.13	0.11	0.12	5
Erigeron sp.	Forb	3	0.09	0.09	0.09	4		0.10	0.02	1	0.09	0.22	0.12	5
Gilia sp.	Forb	3	0.06	0.09	0.07	3				0	0.06	0.56	0.17	7
Lappula redowskii	Forb	3	0.22	0.09	0.19	8	0.06		0.05	2				0
Poa fendleriana	Gram	3		0.09	0.02	1				0	0.22	0.22	0.22	9
Purshia tridentata	Shrub	3	0.13	0.18	0.14	6	0.03	0.10	0.05	2	0.03	0.11	0.05	2
Chenopodium sp.	Forb	3	0.19		0.14	6	0.06		0.05	2	0.03		0.02	1

Table 42 (continued)

Species		AveRank (max=24)	2001 Burned (n=32	2001 Unburned (n=11)	2001 All (n=43	2001 Rank (max=28)	2002 Burned (n=32)	2002 Unburned (n=10)	2002 All (n=42)	2002 Rank (max-21	2012 Burned (n=32)	2012 Unburned (n=9)	2012 All (n=41)	2012 Rank (max=25)
Eremogone sp.	Forb	3	0.09	0.27	0.14	6	0.03	0.20	0.07	3				0
Arabis pendulocarpa	Forb	3	0.03	0.36	0.12	5		0.20	0.05	2		0.11	0.02	1
Calochortus nuttallii	Forb	3	0.16	0.09	0.14	6				0	0.03	0.11	0.05	2
Castilleja sp.	Forb	3	0.03	0.36	0.12	5	0.03	0.10	0.05	2	0.03		0.02	1
Ceratocephala testiculata	Forb	3	0.09		0.07	3				0	0.16		0.12	5
Crepis acuminata	Forb	3	0.13	0.09	0.12	5	0.03		0.02	1	0.06		0.05	2
Machaeranthera sp.	Forb	3			0.00	0	0.06	0.10	0.07	3	0.09	0.22	0.12	5
Schoenocrambe linifolia	Forb	3	0.16	0.09	0.14	6	0.06		0.05	2				0
Astragalus sp.	Forb	2	0.16		0.12	5				0	0.06		0.05	2
Erigeron eatonii	Forb	2	0.13	0.27	0.16	7				0				0
Ipomopsis congesta	Forb	2		0.18	0.05	2				0	0.06	0.33	0.12	5
Petradoria pumila	Forb	2	0.03	0.09	0.05	2	0.09	0.20	0.12	5				0
Poa cusickii	Gram	2			0.00	0				0	0.16	0.22	0.17	7
Cymopterus sp.	Forb	2	0.09	0.18	0.12	5				0	0.03		0.02	1
Linanthus caespitosus	Forb	2			0.00	0		0.10	0.02	1	0.03	0.44	0.12	5
Mentzelia dispersa	Forb	2	0.19		0.14	6				0				0
Poa sp.	Gram	2	0.03		0.02	1				0	0.16		0.12	5
Chenopodium leptophyllum	Forb	2	0.16		0.12	5				0				0
Collinsia parviflora	Forb	2	0.09	0.18	0.12	5				0				0
Malcolmia africana	Forb	2	0.16		0.12	5				0				0
Penstemon strictus	Forb	2			0.00	0				0	0.13	0.11	0.12	5
Poa pratensis	Gram	2	0.13	0.09	0.12	5				0				0
Thlaspi arvense	Forb	2	0.16		0.12	5				0				0

Dominant Taxa

Dominance was calculated for taxa on a plot-by-plot basis: a dominant taxon in a plot was one that contributed at least 10% of the canopy cover in the plot. This relative canopy -cover was calculated as follows:

Rel. Canopy-Cover of Taxon X in Plot Y = Ave. of mid-points of canopy-cover ranges of Taxon X in 8 microplots of Plot Y / Sum of averages for all taxa in Plot Y

When unburned and burned plots are considered together, 55 of the 249 taxa identified at least to genus (22%) dominated in at least one plot in at least one year. In addition, 12 of the unidentified forbs or graminoids also were dominant taxa in at least a single plot in at least one year. The number of taxa that dominated repeatedly was small: only 13 taxa (all of them identified at least to genus) contributed 10% or more relative canopy cover to at least 10% of the plots in at least one year. These 13 taxa are identified in Table 29 as common dominant taxa.

In 2001, 7 taxa were common dominants in the unburned plots (that is, contributed $\geq$10% of the canopy cover in at least 10% of the plots) (Table 43). This group consists of 1 tree (*Juniperus osteosperma*), 2 non-sprouting shrubs (*Artemisia nova* and *A. tridentata*), 2 perennial grasses (*Pseudoroegneria spicata* and *Poa secunda*), 1 annual forb (*Cordylanthus ramosus*), and 1 perennial forb (*Stenotus* sp.). The burned plots in 2001 had a group of 10 common dominants, only two of which (*Poa secunda* and *Pseudoroegneria spicata*) were also common dominants in the unburned plots. The other 8 consisted of two additional perennial grasses (*Elymus lanceolatus* and *Pascopyrum smithii*, both of which grow from stout rhizomes); the annual, exotic grass *Bromus tectorum*; three sprouting shrubs, *Chrysothamnus viscidiflorus*, *Sarcobatus vermiculatus*, and *Symphoricarpos oreophilus*; one perennial forb, *Astragalus convallarius*, which usually has a root-crown well underground (Dorn 2001); and one annual forb, *Descurainia* sp.

In 2012, the common dominants in the unburned plots had changed somewhat (Table 43). This group of 10 species included 6 that had been common dominants in 2001: *Artemisia nova*, *A. tridentata*, *Juniperus osteosperma*, *Poa secunda*, *Pseudoroegneria spicata*, and *Stenotus* sp.. The four new species were two sprouting shrubs, *Chrysothamnus viscidiflorus* and *Ericameria nauseosa*; the small shrub *Eriogonum microthecum*; and the perennial forb, *Cymopterus terebinthinus*. In the burned plots in 2012, the common dominants consisted of 9 species, 7 of which had also been common dominants in 2001: the grasses *Bromus tectorum*, *Elymus lanceolatus*, *Pascopyrum smithii*, and *Pseudoroegneria spicata*; and all 3 of the sprouting shrubs, *Chrysothamnus viscidiflorus*, *Sarcobatus vermiculatus*, and *Symphoricarpos oreophilus*. The two new common dominants were the perennial grass, *Achnatherum hymenoides*, and the non-sprouting shrub, *Atriplex confertifolia*.

Only three species were common dominants in both the burned plots and unburned plots: the sprouting shrub *Chrysothamnus viscidiflorus*, and the perennial grasses *Poa secunda* and *Pseudoroegneria spicata* (Table 43).

Table 43. Common dominant species, burned plots and unburned plots, 2001 and 2012.
"Dom" means a species that contributed ≥ 10% of the canopy cover in ≥ 10% of the plot in that group and year.

	2001		2012	
Species	Burned	Unburned	Burned	Unburned
Achnatherum hymenoides			x	
Artemisia nova		x		x
Artemisia tridentata		x		x
Astragalus convallarius	x			
Atriplex confertifolia			x	
Bromus tectorum	x		x	
Chrysothamnus viscidiflorus	x		x	x
Cordylanthus ramosus		x		
Cymopterus terebinthinus				x
Descurainia sp.	x			
Elymus lanceolatus	x		x	
Ericameria nauseosa				x
Eriogonum microthecum				x
Hesperostipa comata				
Juniperus osteosperma		x		x
Pascopyrum smithii	x		x	
Poa secunda	x	x		x
Pseudoroegneria spicata	x	x	x	x
Sarcobatus vermiculatus	x		x	
Stenotus sp.		x		x
Symphoricarpos oreophilus	x		x	
Number of Plots	32	11	32	9

In summary, the data on species composition show a substantial difference between burned plots and unburned plots in terms of the plant species that commonly contribute much of the canopy cover. In 2001, 14 species were common dominants in the burned plots and the unburned plots combined, and only 2 of those species were common dominants in both groups. The situation was virtually the same in 2012: of the 17 species of common dominants in the burned and unburned plots combined, only 2 were common dominants in both groups. Within the burned plots and the unburned plots, there was approximately a 50% change in the common dominant species. Twelve species were common dominants in the burned plots either in 2001 or 2012, and only 7 of those were common dominants in both years Similarly, in the unburned plots, 11 species were common dominants in either 2001 or 2012, and only 6 of those were common dominants in both years.

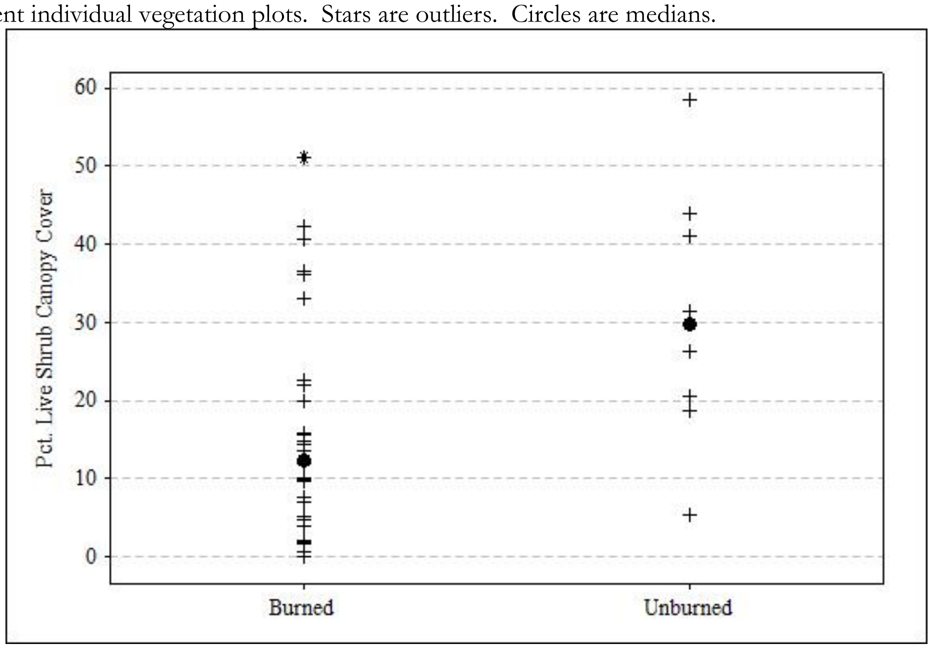
SHRUB CANOPY STRUCTURE

Data on shrub canopy cover, density, size, and vigor were collected only in 2012, so all of the analyses using them examine only the differences between burned plots and unburned plots.

Shrub Canopy Cover and Density

Density and percent canopy cover are treated as properties of plots, and the analyses of these properties use the per-plot averages. Average percent canopy cover of live shrubs in unburned plots (30.6%) was almost twice that in burned plots (15.9%). The distribution of values in the burned plots overlapped that in the unburned plots (Figure 44), but the unburned plots generally had greater cover values, and the difference between them was statistically significant (Table 44). Average shrub density also was greater (slightly so) in the unburned plots (2.97 shrubs/m^2) than the burned plots (2.34 shrubs/m^2), but the distributions of shrub density in the two groups of plots overlapped a great deal (Figure 45)[2], and there appears to be no difference in shrub density between burned and unburned plots (Table 45).

Figure 44. Percent canopy cover of live shrubs, all species, burned vs. unburned plots, 2012. Crosses represent individual vegetation plots. Stars are outliers. Circles are medians.



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[2] Plots WH06 and WH30 were excluded from the calculations of density of all shrubs. Both had very high densities of *Mahonia repens*, which occurred only in those plots. These two plots were burned conifer-aspen plots, with no unburned equivalents, and so are treated as outliers.

Table 44. Mann-Whitney U test , percent live shrub canopy cover, all species, burned vs. unburned plots.

H_O: The distribution of percent shrub canopy cover per plot in burned plots = the distribution in unburned plots. **H_A:** The distribution of percent shrub canopy cover per plot in burned plots ≠ the distribution in unburned plots

Plot Type	N	Median	Variance	Skewness	Kurtosis
Burned	32	12.30	180.46	1.10	0.46
Unburned	9	29.72	254.69	0.26	0.25

W = 591.0, p = 0.0112. **Reject H_O**: the distribution of percent live shrub canopy cover per plot is different in burned plots than in unburned plots.

Figure 45. Density of live shrubs, all species, burned vs. unburned plots, 2012.
Plots WH06 & WH30 excluded; see footnote 2. Crosses show individual plots. Circles are medians.

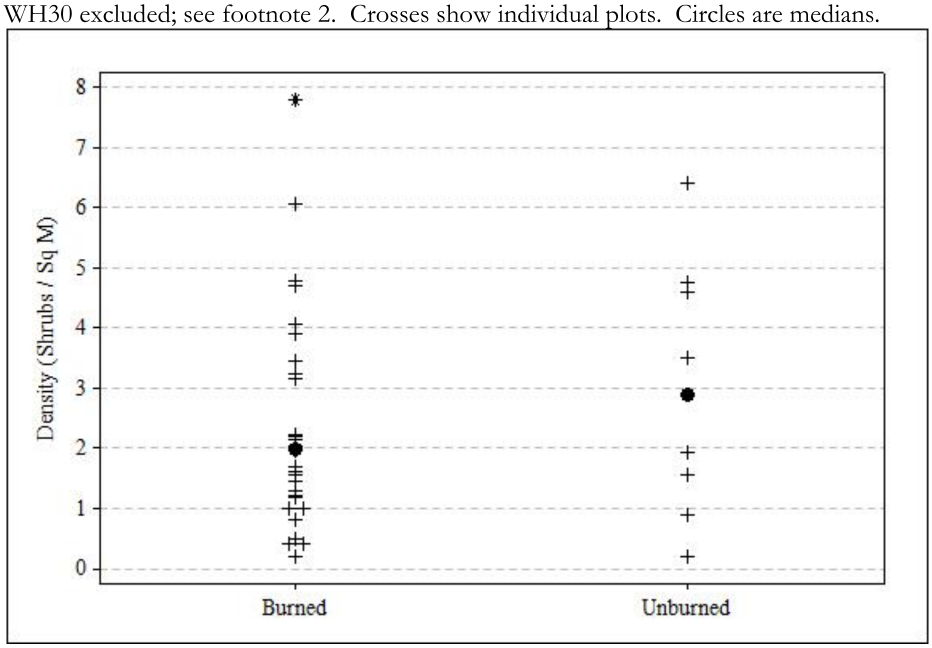

Table 45. Mann-Whitney U test, density of live shrubs, burned vs. unburned plots
Plots WH06 and WH30 are excluded; see footnote 2.

H_O: The distribution of shrub density per plot in burned plots = the distribution in unburned plots. **H_A:** The distribution of shrub density per plot in burned plots ≠ the distribution in unburned plots

Plot Type	N	Median	Variance	Skewness	Kurtosis
Burned	30	1.975	3.160	1.37	1.96
Unburned	9	2.900	4.139	0.32	-0.80

W = 577.0, p = 0.4531. **Do not reject H_O:** the distribution of live shrub density per plot is the same in burned plots as in unburned plots.

Unburned vs. burned comparisons of percent canopy cover and density are difficult to make for individual shrub species because most were recorded in few plots (Table 46). Three species (*Artemisia tridentata*, *Chrysothamnus viscidiflorus*, and *Eriogonum microthecum*) occurred in enough plots, though, that comparisons were made for them individually.

Table 46. Numbers (and percentages) of unburned plots and burned plots in which live canopy of each species of shrub was recorded on the line-intercept transects.

	Unburned plots, n=9	Burned plots, n=32
Amelanchier alnifolia	0	3 (9)
Artemisia nova	7 (78)	1 (3)
*Artemisia tridentata**	8 (89)	14 (44)
Atriplex confertifolia	1 (11)	7 (22)
Atriplex gardneri	0	2 (6)
Cercocarpus montanus	1 (11)	4 (13)
*Chrysothamnus viscidiflorus**	5 (56)	24 (75)
*Eriogonum microthecum**	4 (44)	8 (25)
Ericameria nauseosa	1 (11)	1 (3)
Juniperus osteosperma	4 (44)	1 (3)
Krascheninnikovia lanata	1 (11)	1 (3)
Mahonia repens	0	3 (9)
Rosa sp.	0	1 (3)
Sarcobatus vermiculatus	0	9 (28)
Symphoricarpos oreophilus	1 (11)	15 (47)
Tetradymia canescens	0	5 (16)

*Quantitative comparisons were made for these 3 species

Average canopy cover of *A. tridentata* was markedly greater in the unburned plots than the burned plots (Figure 46), and this difference in cover was statistically significant (Table 47). In contrast, average cover of *C. viscidiflorus* differed little between burned plots (average = 4.45%) and unburned plots (2.17%) (Figure 47). Although the greatest amounts of canopy cover of *C. viscidiflorus* were found in the burned plots, the species did not have significantly more cover in them than it did in the unburned plots (Table 48). Cover of *E. microthecum* showed hardly any difference between burned plots and unburned plots (Figure 48, Table 49).

Figure 46. Percent canopy cover of live *Artemisia tridentata,* burned vs. unburned plots, 2012. Crosses represent individual vegetation plots. Stars are outliers. Circles are medians.

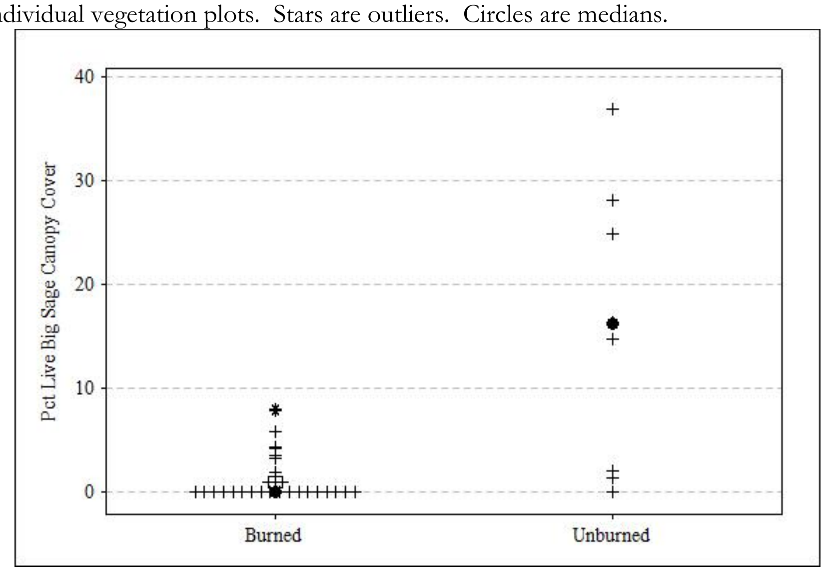

Table 47. Mann-Whitney U test, percent live canopy cover of *Artemisia tridentata*, burned vs. unburned plots, 2012.

H_O: The distribution of percent shrub canopy cover per plot in burned plots = as the distribution in unburned plots.
H_A: Distribution of percent shrub canopy cover per plot in burned plots ≠ the distribution in unburned plots

Plot Type	N	Median	Variance	Skewness	Kurtosis
Burned	32	0.00	5.590	1.64	1.75
Unburned	9	16.18	165.88	0.24	-0.96

W = 569.0, p = 0.0007. **Reject H_O:** the distribution of live *A. tridentata* canopy cover in burned plots is different from the distribution in unburned plots.

Figure 47. Percent canopy cover of live *Chrysothamnus viscidiflorus,* burned vs. unburned plots, 2012. Crosses represent individual vegetation plots. Stars are outliers. Circles are medians.

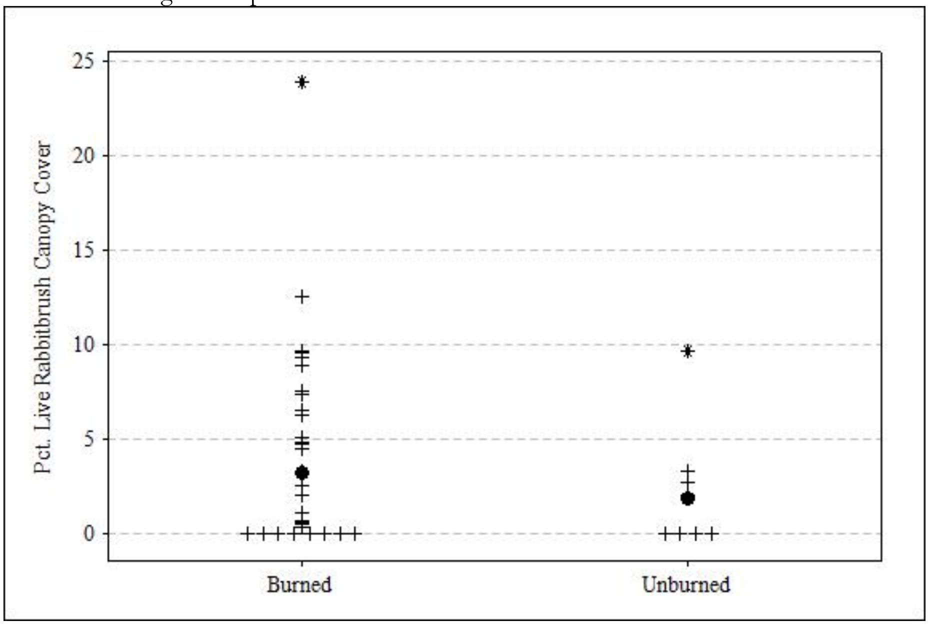

Table 48. Mann-Whitney U test, percent live canopy cover of *Chrysothamnus viscidiflorus*, burned vs. unburned plots, 2012.

H_O: The distribution of percent canopy cover per plot in burned plots = the distribution in unburned plots. **H_A**: The distribution of percent canopy cover per plot in burned plots ≠ the distribution in unburned plots

Plot Type	N	Median	Variance	Skewness	Kurtosis
Burned	32	3.240	26.332	1.88	5.31
Unburned	9	1.840	9.54	2.06	4.85

W = 712.5, p = 0.2077. **Do not reject H_O**: the distribution of live *C. viscidiflorus* canopy cover per plot in burned plots = the distribution in unburned plots.

Figure 48. Percent canopy cover of live *Eriogonum microthecum,* burned vs. unburned plots, 2012. Crosses represent individual vegetation plots. Stars are outliers. Circles are medians.

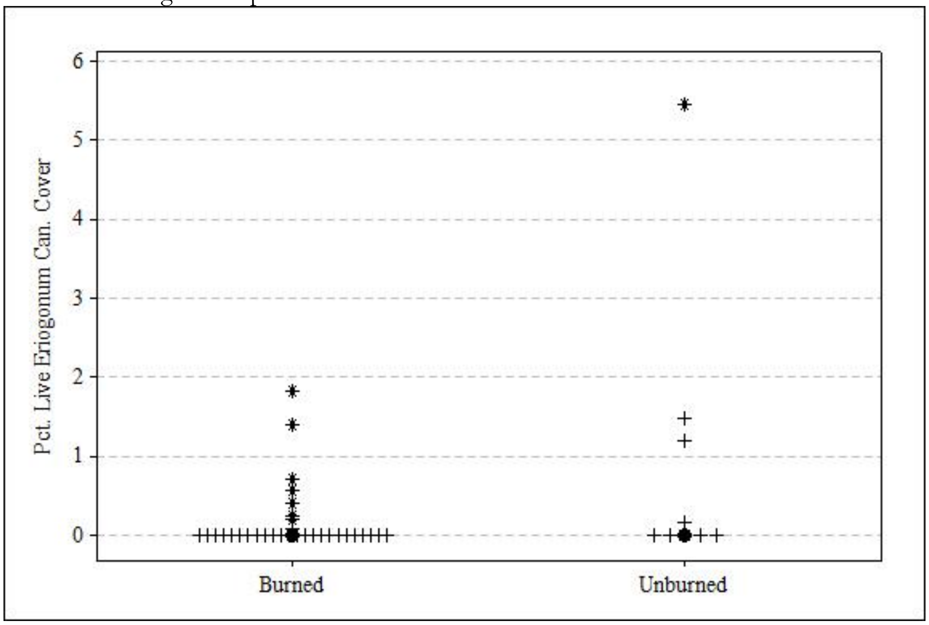

Table 49. Mann-Whitney U test, percent live canopy cover of *Eriogonum microthecum*, burned vs. unburned plots, 2012.

H_O: The distribution of percent canopy cover per plot in burned plots = the distribution in unburned plots. **H_A**: The distribution of percent canopy cover per plot in burned plots ≠ the distribution in unburned plots

Plot Type	N	Median	Variance	Skewness	Kurtosis
Burned	32	0.000	0.1751	3.04	9.27
Unburned	9	0.000	3.204	2.47	6.42

W = 638.0, p = 0.2914. **Do not reject H_O:** the distribution of live *E. microthecum* canopy cover per plot in burned plots = the distribution in unburned plots.

Unburned plots had greater densities of *Artemisia tridentata* than did burned plots (Figure 49), and the difference was statistically significant (Table 50). *Eriogonum microthecum* also generally had greater average density in unburned plots than burned plots (Figure 50), but the distribution of densities in unburned plots overlapped that in burned plots and there was no significant difference between the plot-groups (Table 51). For *Chrysothamnus viscidiflorus*, in contrast, average density was higher in the burned plots than the unburned plots, although the distribution of densities in burned plots overlapped that in the unburned plots (Figure 51), and there was no statistically significant difference between burned and unburned plots in *C. viscidiflorus* density (Table 52).

In summary, percent canopy cover of all shrubs was substantially greater in the unburned plots, but the data suggest no difference in density of all shrubs between the unburned plots and the burned plots. *Artemisia tridentata* apparently causes the difference in canopy cover between burned and unburned plots, as its cover was markedly greater in the unburned plots. *A. tridentata* shrubs also were somewhat denser in the unburned plots, but this difference seems to have been overwhelmed by the other shrub species. In contrast, *Chrysothamnus viscidiflorus* appeared to contribute slightly more canopy cover and to be slightly denser in the burned plots, but the data indicate no significant difference for this species. The only other species tested, *Eriogonum microthecum*, differed hardly at all in canopy cover or density between burned and unburned plots.

Figure 49. Density of live *Artemisia tridentata*, burned vs. unburned plots, 2012.
Crosses show individual plots, stars are outlier plots, circles are medians. Plots WH06 and WH30 are excluded; see footnote 2.

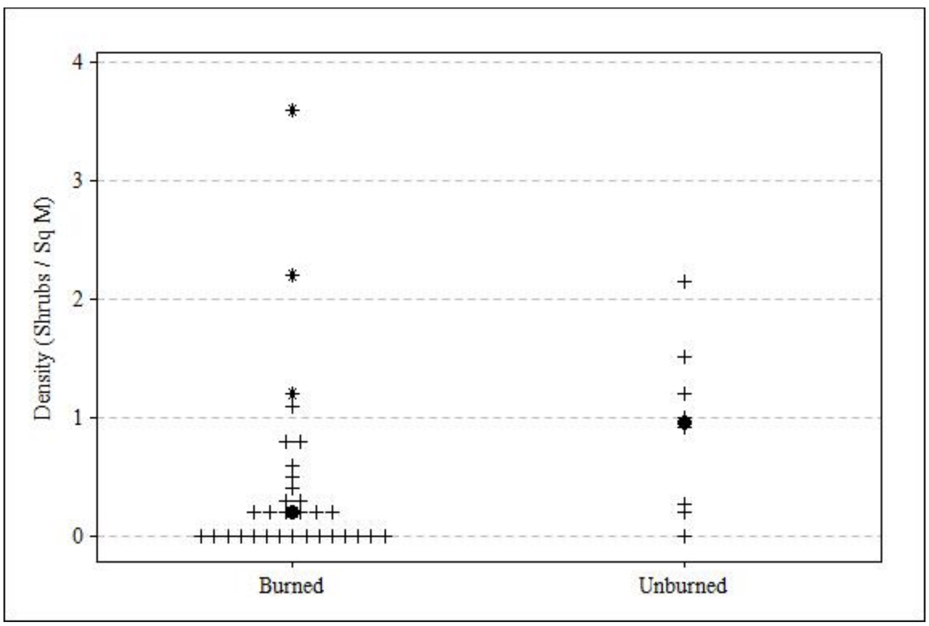

Table 50. Mann-Whitney U test, density of *Artemisia tridentata*, burned vs. unburned plots, 2012
Plots WH06 and WH30 are excluded; see footnote 2.
H_O: The distribution of density per plot in burned plots = the distribution in unburned plots. **H_A:** The distribution of density per plot in burned plots ≠ the distribution in unburned plots

Plot Type	N	Median	Variance	Skewness	Kurtosis
Burned	32	0.200	0.569	3.07	10.65
Unburned	9	0.960	0.469	0.37	-0.17

W = 596.0, p = 0.0174. **Reject H_O:** the distribution of *A. tridentata* density per plot in burned plots ≠ the distribution in. unburned plots.

Figure 50. Density of live *Eriogonum microthecum*, burned vs. unburned plots, 2012.
Crosses show individual plots. Stars are outlier plots. Circles are medians. Plots WH06 and WH30 are excluded; see footnote 2.

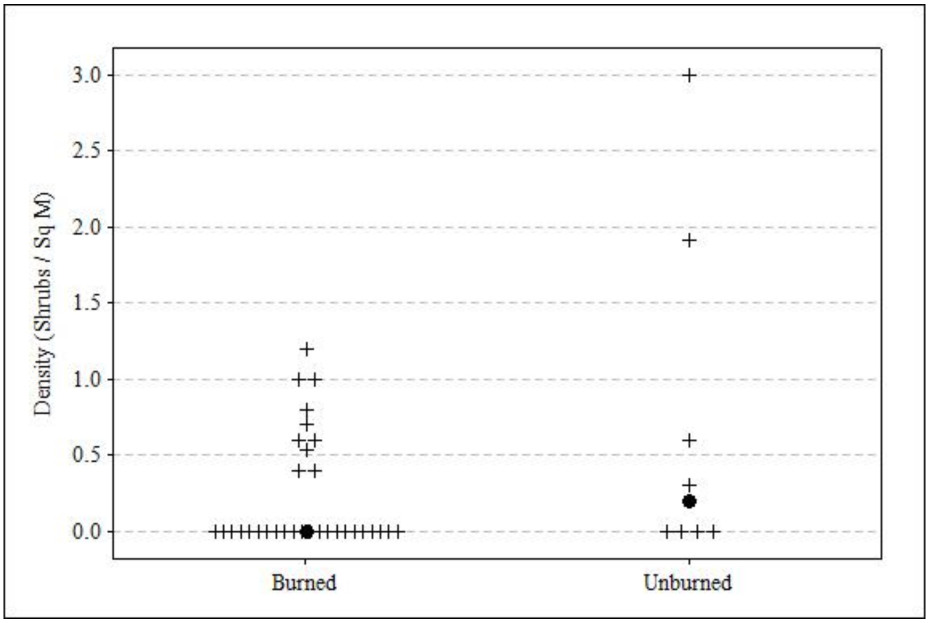

Table 51. Mann-Whitney U test, density of *Eriogonum microthecum*, burned vs. unburned plots, 2012.
Plots WH06 and WH30 are excluded; see footnote 2.

H_O: The distribution of density per plot in burned plots = the distribution in unburned plots. **H_A:** The distribution of density per plot in burned plots ≠ the distribution in unburned plots

Plot Type	N	Median	Variance	Skewness	Kurtosis
Burned	32	0.000	0.1374	1.38	0.59
Unburned	9	0.200	1.144	1.74	2.15

W = 638, p = 0.2914. **Do not reject H_O:** the distribution of *E. microthecum* density per plot does not differ between burned plots and unburned plots.

Figure 51. Density of live *Chrysothamnus viscidiflorus*, burned vs. unburned plots, 2012.
Crosses show individual plots. Stars are outlier plots. Circles are medians. Plots WH06 and WH30 are excluded; see footnote 2.

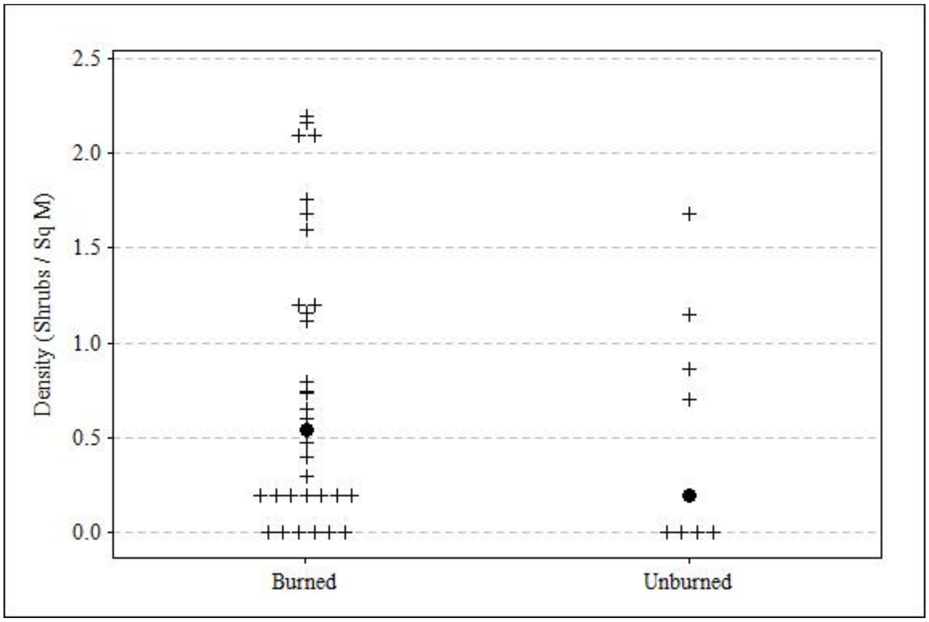

Table 52. Mann-Whitney U test, density of *Chrysothamnus viscidiflorus*, burned vs. unburned plots, 2012.
Plots WH06 and WH30 are excluded; see footnote 2.

H_O: The distribution of density per plot in burned plots = the distribution in unburned plots. **H_A:** The distribution of density per plot in burned plots ≠ the distribution in unburned plots

Plot Type	N	Median	Variance	Skewness	Kurtosis
Burned	32	0.540	0.548	0.77	-0.75
Unburned	9	0.2000	0.385	0.91	-0.35

W = 707.0, p = 0.2772. **Do not reject H_O:** the distribution of *C. viscidiflorus* density per plot does not differ between burned plots and unburned plots.

Shrub Size

Canopy height and volume were treated as properties of individual shrubs, not of the vegetation plots. These data were analyzed for differences between all shrubs in the unburned plots as one group, and all shrubs in the burned plots as a second group.

Shrub height differed little between burned and unburned plots. The average height of all shrubs in burned plots (35.87 cm) appears to have been slightly taller than in unburned plots (32.81

cm), but the distributions of average heights overlapped (Figure 52) and were not significantly different (Table 53).

Figure 52. Heights of shrubs of all species, burned vs. unburned plots, 2012.
Boxes show 25th to 75th percentiles of heights; vertical lines show ranges (excluding outliers); horizontal lines are medians; stars are outliers.

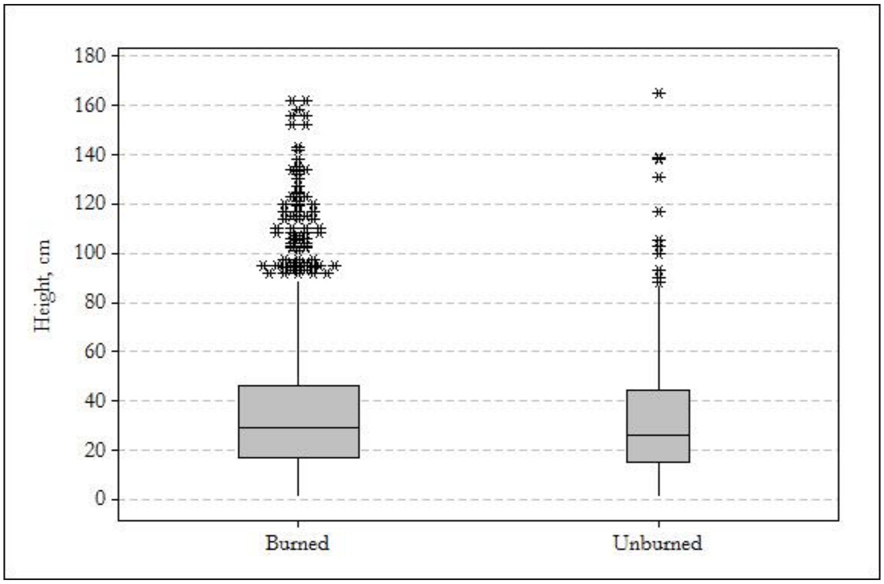

Table 53. Mann-Whitney U test, heights of all shrubs, unburned vs. burned plots, 2012

H_O: The distribution of shrub heights in burned plots = the distribution in unburned plots. **H_A:** The distribution of shrubs height in burned plots ≠ the distribution in unburned plots

Plot Type	N	Median	Variance	Skewness	Kurtosis
Burned	1272	29.000	746.223	1.68	3.31
Unburned	344	26.000	570.36	1.83	5.19

W = 1,039,741.5 p = 0.1401. **Do not reject H_O**: the distribution of shrub heights in unburned plots is not different from the distribution in burned plots.

Heights of shrubs of several individual species, though, were different between burned and unburned plots, albeit generally slightly. For *Artemisia tridentata*, average height in the unburned plots was approximately 5 cm taller than in the burned plots (40.67 cm vs. 36.81 cm), and most of the shrubs (from the 25th to 75th percentiles of heights) in the unburned plots were taller than most shrubs in the burned plots (Figure 53); this difference in distributions was statistically significant (Table 54).

Figure 53. Height of *Artemisia tridentata*, burned vs. unburned plots, 2012.
Boxes show 25th to 75th percentiles of heights; vertical lines show ranges (excluding outliers); horizontal lines are medians; stars are outliers.

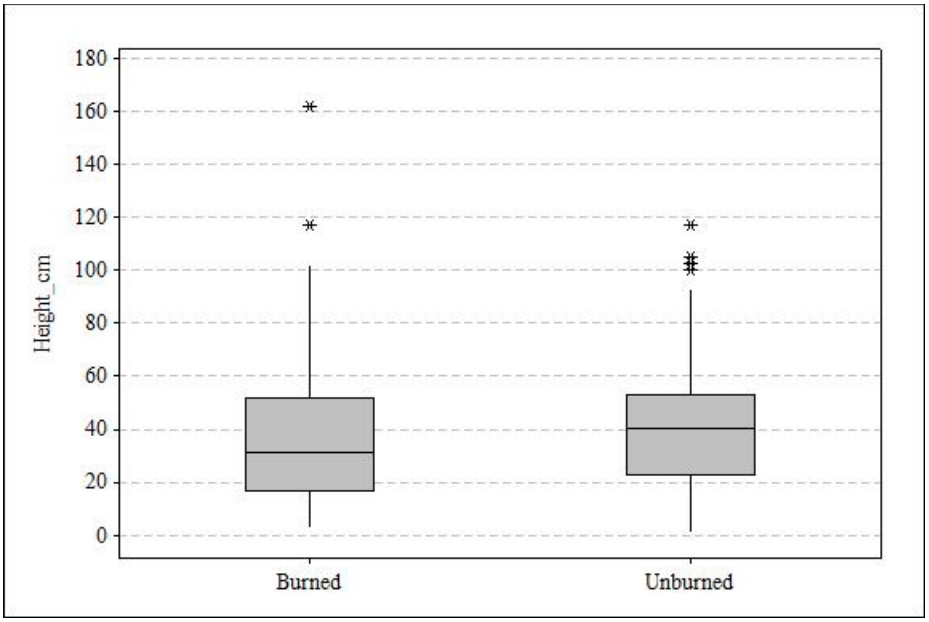

Table 54. Mann-Whitney U test, heights of *Artemisia tridentata* shrubs, burned vs. unburned plots, 2012.

H_O: The distribution of shrub heights in unburned plots = the distribution in burned plots. **H_A:** The distribution of shrub heights in unburned plots ≠ distribution in burned plots

Plot Type	N	Median	Variance	Skewness	Kurtosis
Burned	149	40.500	694.14	1.31	2.79
Unburned	166	31.00	485.71	0.68	0.71

W = 21761.5, p = 0.0274. **Reject H_O:** The distribution of *A. tridentata* heights in burned plots is different than the distribution in burned plots.

The difference for *Artemisia nova* was greater: average height of *A. nova* shrubs in unburned plots (20.92 cm) was over twice that in burned plots (9.18 cm), and the difference in averages reflects a distinct difference in the distributions of heights (Figure 54), with heights of *A. nova* in unburned plots significantly greater than in burned plots (Table 55).

Figure 54. Height of *Artemisia nova*, burned vs. unburned plots, 2012.
Boxes show 25th to 75th percentiles of heights; vertical lines show ranges (excl. outliers); horizontal lines are medians; stars are outliers.

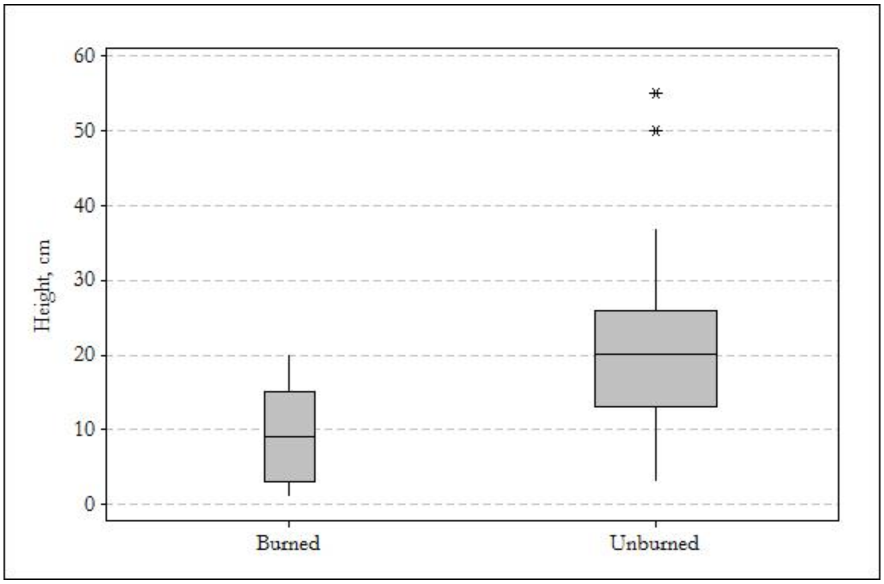

Table 55. Mann-Whitney U test, heights of *Artemisia nova* shrubs, burned vs. unburned plots, 2012.

H_O: The distribution of shrub heights in unburned plots = the distribution in burned plots. **H_A:** The distribution of shrub heights in unburned plots ≠ distribution in burned plots

Plot Type	N	Median	Variance	Skewness	Kurtosis
Burned	11	9.000	37.96	0.24	-0.98
Unburned	64	20.000	95.06	1.01	1.82

W = 174.5, p = 0.0003. **Reject H_O:** The distribution of *A. nova* heights in burned plots is different than the distribution in burned plots.

In contrast, for *Chrysothamnus viscidiflorus*, which sprouts after fire, average height was slightly greater in the burned plots than the unburned plots, and most of the shrubs (from the 25th to 75th percentiles) were slightly taller in the burned plots than the unburned plots (Figure 55); this difference, too, was statistically significant (Table 56).

Figure 55. Height of *Chrysothamnus viscidiflorus*, unburned vs. burned plots, 2012.
Boxes show 25th to 75th percentiles of heights; vertical lines show ranges (excl. outliers); horizontal lines are medians; stars are outliers.

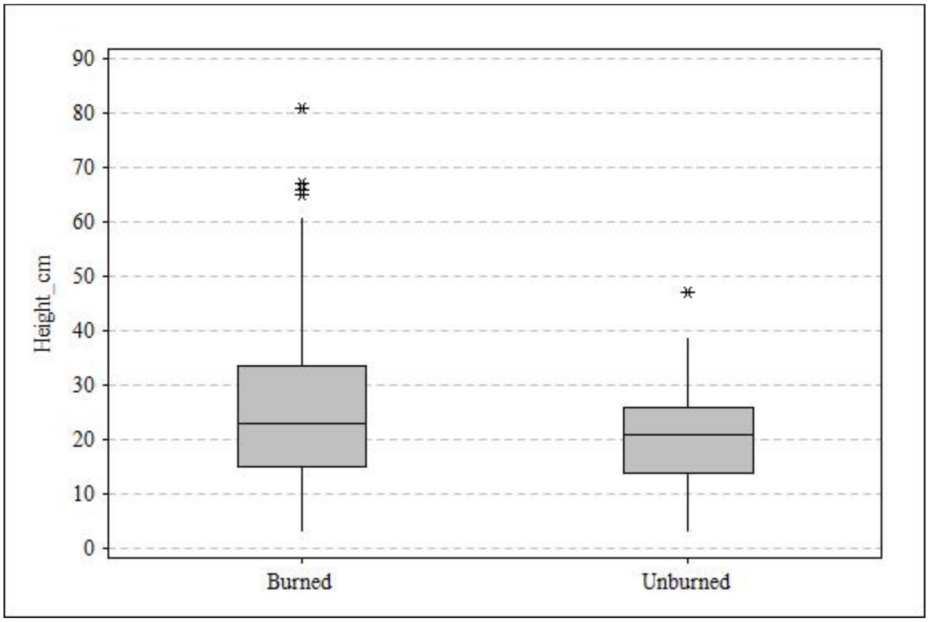

Table 56. Mann-Whitney U test, height of *Chrysothamnus viscidiflorus* shrubs, burned vs. unburned plots, 2012.

H_O: The distribution of shrub heights in unburned plots = the distribution in burned plots. **H_A:** The distribution of shrub heights in unburned plots ≠ distribution in burned plots.

Plot Type	N	Median	Variance	Skewness	Kurtosis
Burned	493	23.000	183.608	0.69	0.20
Unburned	44	21.000	86.11	0.75	0.57

W = 134822, p = 0.0254. **Reject H_O**: The distribution of *C. viscidiflorus* heights in burned plots is different than the distribution in burned plots.

Four additional shrubs species -- *Atriplex confertifolia*, *Cercocarpus montanus*, *Ericameria nauseosa*, and *Eriogonum microthecum* -- were represented by enough individuals that tests seemed justified for differences in their heights between burned plots and unburned plots, but for none did the Mann-Whitney U test show a statistically significant difference. The 11 remaining species were not tested because they were recorded only in burned plots, or in very small numbers in both types of plots.

Shrub canopy volume, predictably, showed much the same pattern of differences between burned and unburned plots as did canopy height. The average canopy volume for all shrubs in unburned plots was approximately 40% greater than the average volume in the burned plots, but the large difference in averages obscured the great overlap in distributions of volumes (Figure 56), and canopy volumes did not differ significantly between unburned plots and burned plots (Table 57).

Figure 56. Canopy volume of shrubs of all species, burned vs. unburned plots, 2012.
Boxes show 25th to 75th percentiles; vertical lines show ranges (excl. outliers); horizontal lines are medians. Each group contains many outliers with very large values, not shown.

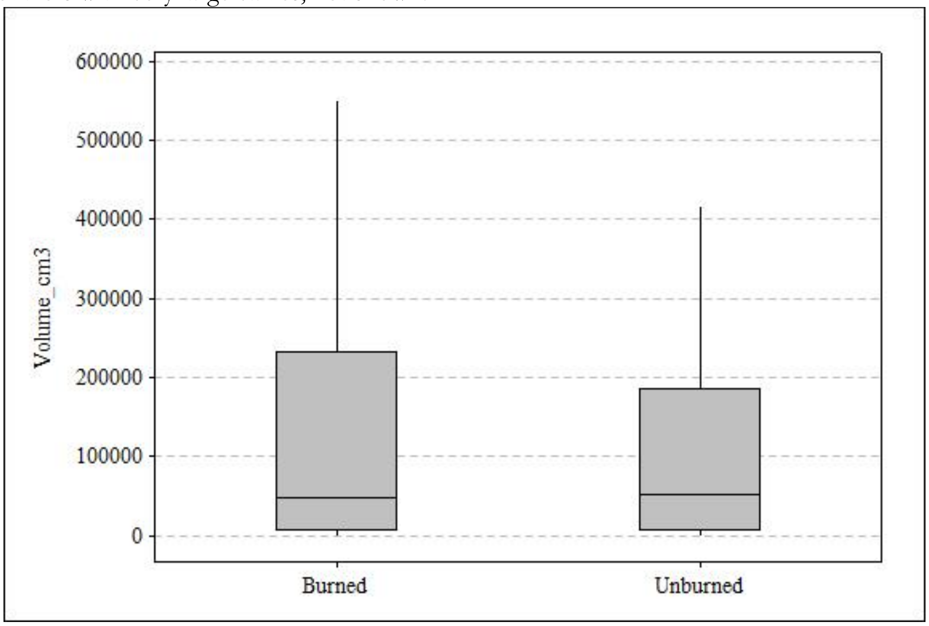

Table 57. Mann-Whitney U test, canopy volume of all shrubs, burned vs. unburned plots, 2012

H_O: The distribution of volumes in burned plots = the distribution in unburned plots. **H_A:** The distribution of volumes in burned plots ≠ the distribution in unburned plots

Plot Type	N	Median	Variance	Skewness	Kurtosis
Burned	1272	47676	4.2×10^{11}	4.31	22.61
Unburned	344	51531	3.56×10^{11}	7.71	70.97

W = 1,032,611.5, p = 0.5845. **Do not reject H_O:** the distribution of shrub volumes in burned plots is the same as the distribution in unburned plots.

For *Artemisia tridentata*, mean canopy volume was slightly greater in the burned plots than the unburned plots, but this difference in means obscured the larger volume of most shrubs in the unburned plots (Figure 57), and *A. tridentata* volume in fact appears to be significantly greater in the unburned plots (Table 58).

Figure 57. Canopy volume of *Artemisia tridentata*, burned vs. unburned plots, 2012.
Boxes show 25th to 75th percentiles; vertical lines show ranges (excl. outliers); horizontal lines are medians. Each group contains many outliers with very large values, not shown.

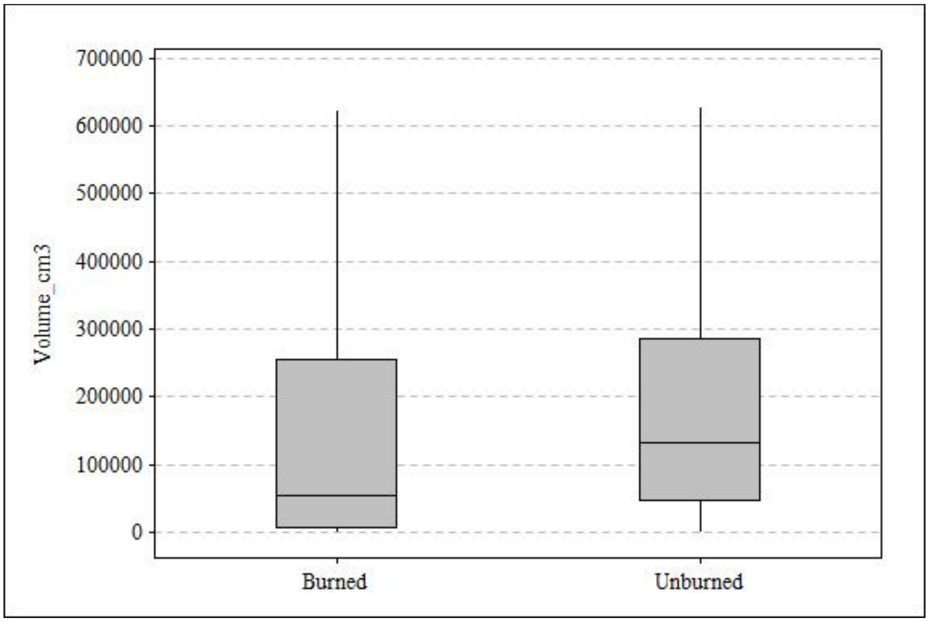

Table 58. Mann-Whitney U test, canopy volume of *Artemisia tridentata* shrubs, burned vs. unburned plots, 2012

H_O: The distribution of volumes in burned plots = the distribution in unburned plots. **H_A:** The distribution of volumes in burned plots ≠ the distribution in unburned plots

Plot Type	N	Median	Variance	Skewness	Kurtosis
Burned	149	53,900	2.09×10^{11}	3.24	12.57
Unburned	166	132,981	1.38×10^{11}	4.14	21.54

W = 21,244, p = 0.0044. **Reject H_O:** The distribution of canopy volumes of *A. tridentata* in burned plots is different than the distribution in unburned plots.

For *Artemisia nova*, canopy volumes of most shrubs, as well as average canopy volume, are substantially greater among shrubs in the unburned plots than the burned plots (Figure 58), and the difference is statistically significant (Table 59).

Figure 58. Canopy volume of *Artemisia nova*, burned vs. unburned plots, 2012.
Boxes show 25th to 75th percentiles of volumes; vertical lines show ranges (excl. outliers); horizontal lines are medians; stars are outliers.

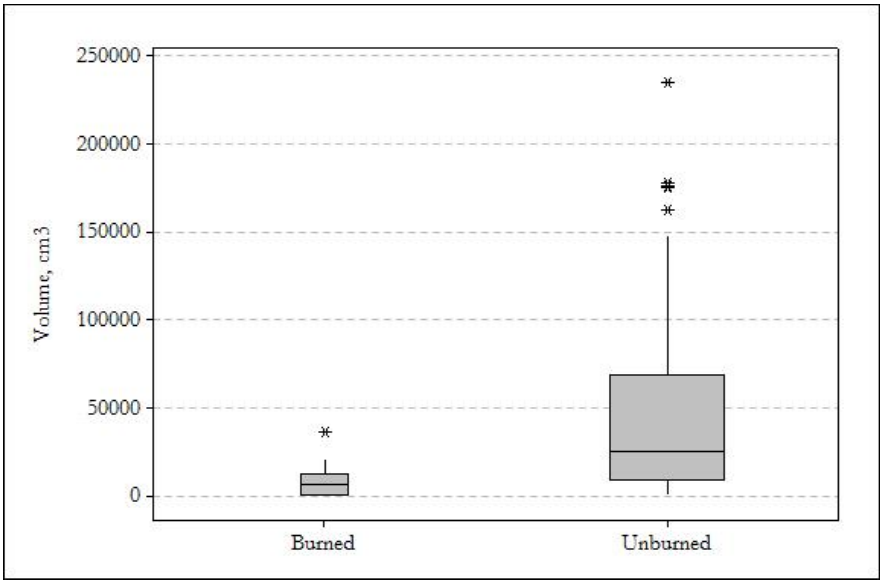

Table 59. Mann-Whitney U test, canopy volume of *Artemisia nova* shrubs, burned vs. unburned plots, 2012.

H_O: The distribution of volumes in burned plots = the distribution in unburned plots. **H_A:** The distribution of volumes in burned plots ≠ the distribution in unburned plots

Plot Type	N	Median	Variance	Skewness	Kurtosis
Burned	11	6720	$1.19x10^8$	1.76	3.19
Unburned	64	25438	$2.87x10^9$	1.61	2.17

W = 204.5, p = 0.0014. **Reject H_O:** The distribution of canopy volumes of *A. nova* in burned plots is different than the distribution in unburned plots.

As with shrub height, *Chrysothamnus viscidiflorus* shrubs in the burned plots had greater canopy volume than those in the unburned plots (Figure 59), and the difference was statistically significant (Table 60).

Figure 59. Canopy volume of *Chrysothamnus viscidiflorus*, burned vs. unburned plots, 2012.
Boxes show 25th to 75th percentiles of volumes; vertical lines show ranges (excl. outliers); horizontal lines are medians; stars are outliers.

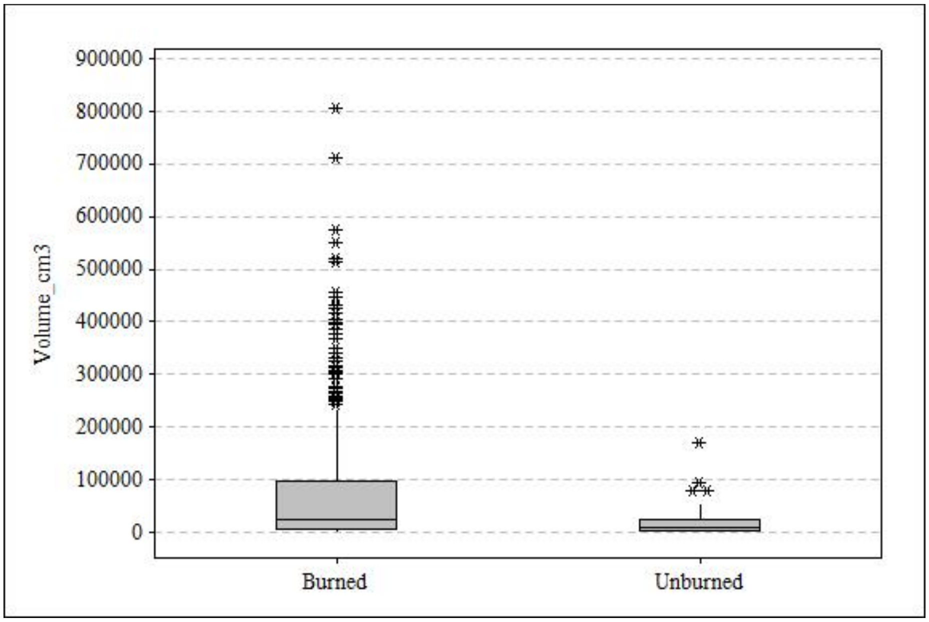

Table 60. Mann-Whitney U test, canopy volume of *Chrysothamnus viscidiflorus* shrubs, burned vs. unburned plots, 2012

H_O: The distribution of volumes in burned plots = the distribution in unburned plots. **H_A:** The distribution of volumes in burned plots ≠ the distribution in unburned plots

Plot Type	N	Median	Variance	Skewness	Kurtosis
Burned	493	25024	1.31×10^{10}	2.59	8.14
Unburned	44	9635	1.04×10^{9}	2.96	10.60

W = 135777.5, p = 0.0014. **Reject H_O:** The distribution of canopy volumes of *C. viscidiflorus* in burned plots is different than the distribution in unburned plots.

A fourth species, the sub-shrub *Eriogonum microthecum*, also had larger canopy volumes in the burned plots than unburned plots (Figure 60), with a statistically significant difference (Table 61). Tests on *Atriplex confertifolia*, *Cercocarpus montanus*, and *Ericameria nauseosa* showed no significant differences, and the remaining shrubs were not tested because of insufficient numbers of individuals in one or both of the groups of plots.

Figure 60. Canopy volume of *Eriogonum microthecum*, burned vs. unburned plots, 2012.
Boxes show 25th to 75th percentiles of volumes; vertical lines show ranges (excl. outliers); horizontal lines are medians; stars are outliers.

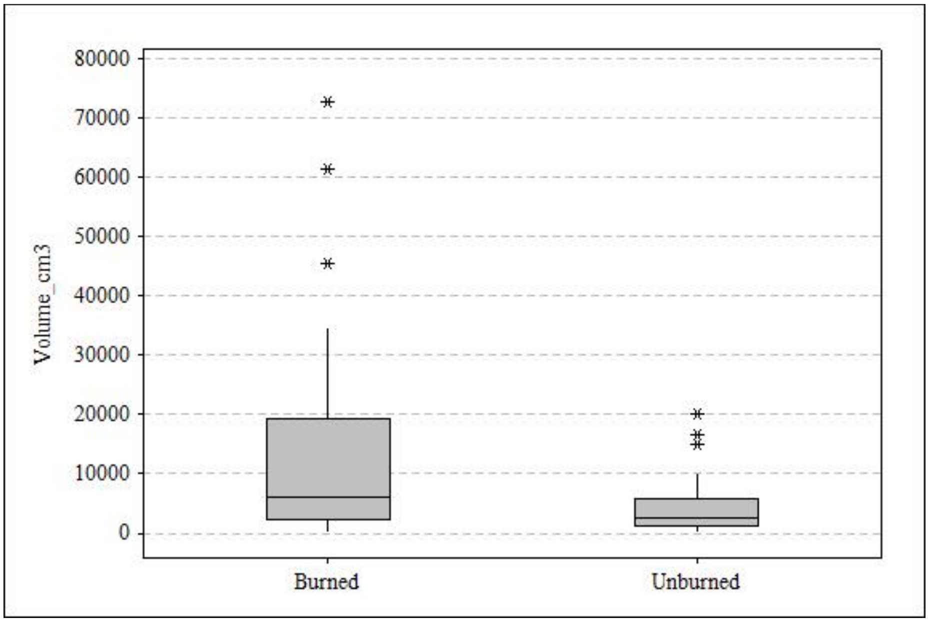

Table 61. Mann-Whitney U test, canopy volume of *Eriogonum microthecum* shrubs, burned vs. unburned plots, 2012.

H_O: The distribution of volumes in burned plots = the distribution in unburned plots. **H_A:** The distribution of volumes in burned plots ≠ the distribution in unburned plots

Plot Type	N	Median	Variance	Skewness	Kurtosis
Burned	37	6048	2.87×10^8	2.12	4.53
Unburned	30	2603	2.58×10^7	1.78	2.63

W = 1457.0, p = 0.023. **Reject H_O:** The distribution of canopy volumes of *E. microthecum* in burned plots is different than the distribution in unburned plots.

In summary, the data suggest that the sizes of all shrubs as a group, expressed by canopy height or by canopy volume, did not differ between burned and unburned plots. Individual species did show differences, though. *Artemisia tridentata* shrubs were slightly taller and had slightly larger canopies in the unburned plots. *A. nova* plants were substantially taller and had substantially larger canopies in the unburned plots, but this species was not common enough to create a difference when all shrubs were considered together. Both of the *Artemisia* spp. are easily killed by fire and must re-establish from seed. *Eriogonum microthecum* plants had larger canopies, but were not taller, in the burned plots. Only one of the species tested, *Chrysothamnus viscidiflorus* (which sprouts after fire), was taller and had larger canopies in the burned plots, but the differences were modest.

Shrub Vigor

Shrub vigor, or percent live canopy, also was treated as a property of individual shrubs, and the analysis used the data from individual shrubs rather than means for plots.

Figure 61 shows the proportions of shrubs of all species, from burned plots vs. unburned plots, in each of ten-percent live-canopy classes. Burned shrubs are present in higher proportions in the most vigorous class (91-100% of the canopy alive) and in lower proportions in the least vigorous classes than are unburned shrubs. A chi-squared test of the distributions of burned and unburned shrubs among the live-canopy classes (Table 62) indicates that the two are statistically different; more burned shrubs have very vigorous canopies (>90% alive) and fewer have mostly-dead canopies ($\leq$ 30% live) than do the unburned shrubs.

Figure 61. Proportions of shrubs of all species in percent-live-canopy classes, burned plots vs. unburned plots, 2012. The values on the X-axis are the upper limits of canopy classes; e.g., 10 on the X-axis represents shrubs with 0-10% live canopy.

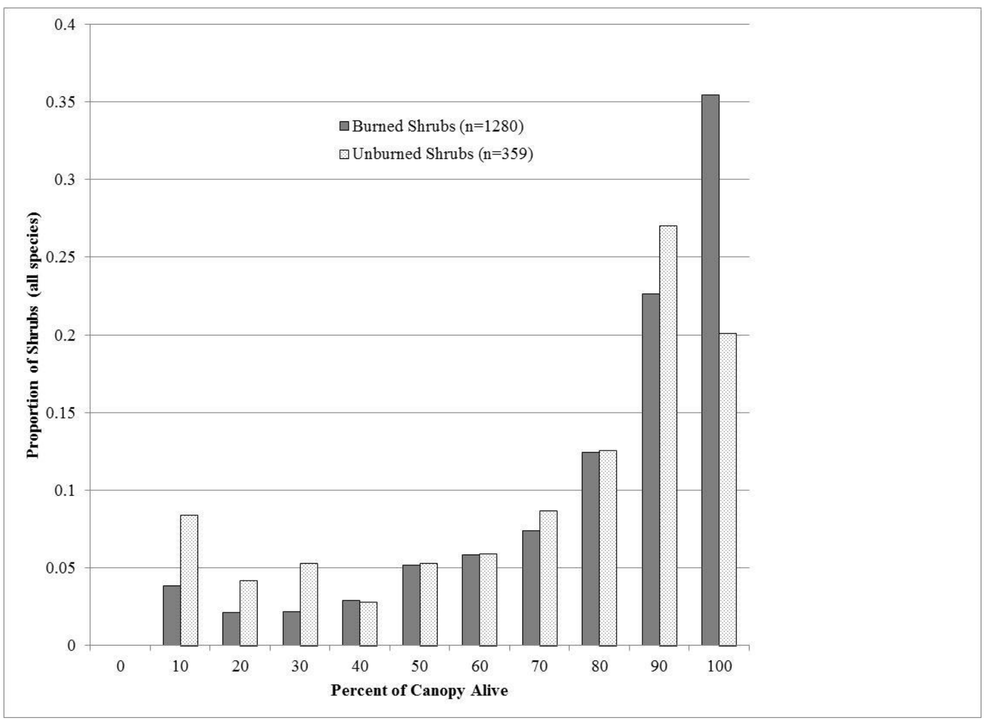

Table 62. Chi-squared test, distribution of shrubs of all species in percent-live-canopy classes, burned vs. unburned shrubs, 2012.

Column headings in tables are upper ends of percent live-canopy classes. **H_O**: The distribution of burned shrubs among live-canopy classes is the same as that of unburned shrubs. **H_A:** The distribution of burned shrubs among live-canopy classes is different from that of unburned shrubs.

live-can. class >>		10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	Totals
Burned	Obs	49	27	28	37	66	75	95	159	290	454	1280
	Exp	61.70	32.80	36.71	36.71	66.38	74.97	98.40	159.32	302.23	410.79	1280
Unburned	Obs	30	15	19	10	19	21	31	45	97	72	359
	Exp	17.30	9.20	10.29	10.29	18.62	21.03	27.60	44.68	84.77	115.21	359
Totals		79	42	47	47	85	96	126	204	387	526	1639

Chi-squared (Yates) = 46.06. Degrees of freedom = 9. $p < 0.0001$. **Reject H_O:** The distribution of burned shrubs among live-canopy classes is not the same as the distribution of unburned shrubs.

The distributions of burned and unburned *Artemisia tridentata* show the same pattern as those of all shrubs, but more strongly: the burned shrubs are more heavily represented in the most-vigorous class and more lightly represented in the least-vigorous classes, and the opposite is true of the unburned *A. tridentata* (Figure 62). The chi-squared test shows that burned *A. tridentata* and unburned *A. tridentata* differ significantly in their distributions among the live-canopy classes (Table 63). A higher proportion of burned than unburned *A. tridentata* have very vigorous canopies, and a lower proportion of burned *A. tridentata* have mostly-dead canopies.

Figure 62. Proportions of *Artemisia tridentata* shrubs in percent-live-canopy classes, burned vs. unburned plots, 2012. The values on the X-axis are the upper limits of canopy classes; e.g., 10 on the X-axis represents shrubs with 0-10% live canopy.

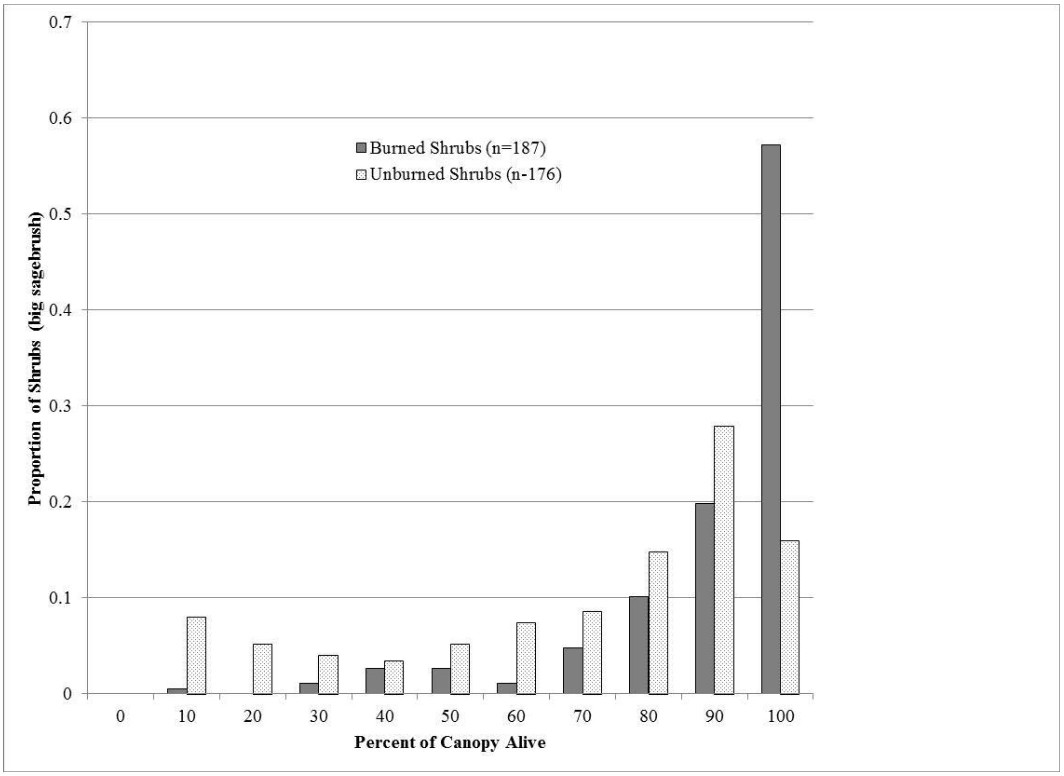

Table 63. Chi-squared test, distribution of live *Artemisia tridentata* in percent-canopy-cover classes, burned vs. unburned shrubs, 2012.

Column headings in tables are upper ends of percent live-canopy classes. **H_O**: The distribution of burned shrubs among live-canopy classes is the same as that of unburned shrubs. **H_A:** The distribution of burned shrubs among live-canopy classes is different from that of unburned shrubs.

live-can. class >>		10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	Totals
Burned	Obs	1	0	2	5	5	2	9	19	37	107	187
	Exp	7.73	4.64	4.64	5.67	7.21	7.73	12.36	23.18	44.30	69.55	187
Unburned	Obs	14	9	7	6	9	13	15	26	49	28	176
	Exp	7.27	4.36	4.36	5.33	6.79	7.27	11.64	21.82	41.70	65.45	176
Totals		15	9	9	11	14	15	24	45	86	135	363

Chi-squared (Yates) = 73.37. Degrees of freedom = 9. $p < 0.0001$. **Reject H_O:** The distribution of *Artemisia tridentata* burned shrubs among live-canopy classes is not the same as the distribution of unburned shrubs.

Chrysothamnus viscidiflorus, the only other species with sufficient numbers of burned and unburned shrubs to warrant a statistical test, shows a marked difference in distribution of burned shrubs vs. unburned shrubs among canopy-vigor classes (Figure 63). Higher proportions of burned shrubs than unburned shrubs are found in all but one of the canopy classes with more than 40% live canopy, and higher proportions of unburned than burned shrubs are found in the three least-vigorous classes. (Note that nearly 10 times as many burned shrubs were sampled as unburned). As might be expected, the chi-squared test showed a statistically significant difference in the distributions among the percent live-canopy classes (Table 64).

Figure 63. Proportions of *Chrysothamnus viscidiflorus* shrubs in percent live-canopy classes, burned vs. unburned plots, 2012.
The values on the X-axis are the upper limits of canopy classes; e.g., 10 on the X-axis represents shrubs with 0-10% live canopy.

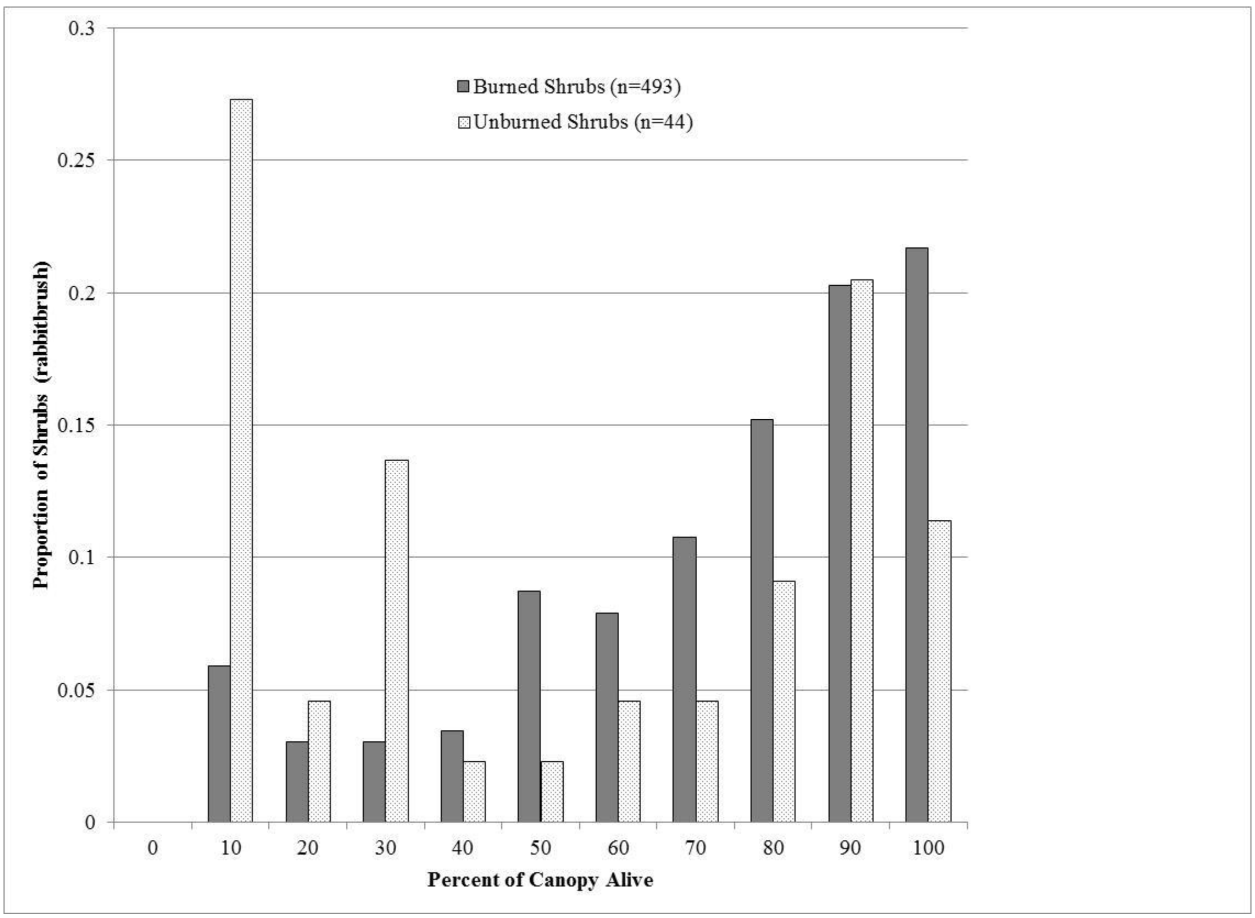

Table 64. Chi-squared test, distribution of live *Chrysothamnus viscidiflorus* in percent-canopy-cover classes, burned vs. unburned shrubs, 2012.

Column headings are upper ends of percent live-canopy classes. **H_O**: The distribution of burned shrubs among live-canopy classes is the same as that of unburned shrubs. **H_A:** The distribution of burned shrubs among live-canopy classes is different from that of unburned shrubs.

live-can. class >>		10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	Totals
Burned	Obs	29	15	15	17	43	39	53	75	100	107	493
	Exp	37.64	15.61	19.28	16.53	40.39	37.64	50.49	72.53	100.07	102.82	493
Unburned	Obs	12	2	6	1	1	2	2	4	9	5	44
	Exp	3.36	1.39	1.72	1.47	3.61	3.36	4.51	6.47	8.93	9.18	44
Totals		41	17	21	18	44	41	55	79	109	112	537

Chi-squared (Yates) = 35.37. Degrees of freedom = 9. $p < 0.0001$. **Reject H_O:** The distribution of *Chrysothamnus viscidiflorus* burned shrubs among live-canopy classes is different from that of unburned shrubs.

IN SUMMARY, these analyses indicate that even among the non-sprouting shrubs, larger proportions of individuals in the burned plots have very vigorous canopies, and smaller proportions have mostly-dead canopies, compared to the individuals in the unburned plots.

SHRUB CANOPY STRUCTURE: SUMMARY

Unburned plots have more canopy cover of all shrubs, apparently mainly because *A. tridentata* cover was much greater in the unburned plots; cover of the other shrub species was not greatly different between burned and unburned plots. Burned plots and unburned plots had about the same densities of all shrub species, although *A. tridentata* was slightly more dense in the unburned plots. Shrubs of all species were about the same size on burned plots as on unburned plots, although individual species showed differences: unburned plots had slightly larger *Artemisia tridentata* shrubs and substantially larger *A. nova* (this species was uncommon enough that it had little effect on the shrubs as a whole), while burned plots had larger individuals of the sprouting *Chrysothamnus viscidiflorus*. Finally, canopy vigor was greater among all shrub species on the burned plots than the unburned plots, with a larger proportion of shrubs on the burned plots in the most-vigorous canopy classes and larger proportions on the unburned plots in the less-vigorous classes.

IV. BURNED VS. UNBURNED FLORA AND VEGETATION: SUMMARY

The data set from this study should be well suited for examining differences in flora and vegetation between burned and unburned areas, and changes in those differences over the course of the study. Conclusions about the long-term changes must be made with caution, though, because differences between measurements made at the beginning of the study and those made at the end might reflect annual vagaries in establishment and growth of plants (especially annuals) and differences between observers as well as changes over 12 years. The conclusions that follow are offered with that caveat in mind.

Exotics plants were widespread at the beginning of the study, in both the burned and unburned areas. The data suggest that there was little, if any, difference between burned and unburned areas in how widely the exotics were distributed and how abundant they were, although the analyses of abundance are somewhat unclear. Exotic species increased in abundance through the course of the study, both in terms of the number of exotic species documented in individual samples and in the number of sub-samples per sample in which exotics were documented; it appears that species of exotics had spread to more locations within the study area by 2012 and that some species, at least, grew in greater density locally. The increases in exotic species were greater in the burned areas than the unburned, so that by the end of the study, exotics were unambiguously more abundant in the burned areas than the unburned.

Cheatgrass (*Bromus tectorum*) was far and away the most widespread and common of the exotic species, and the changes observed in the exotics as a group were driven by changes in cheatgrass, with relatively minor effects by the other species. Other exotic species that were present at more than a handful of sample sites were halogeton (*Halogeton glomeratus*), Canada thistle (*Cirsium arvense*), perennial sowthistle (*Sonchus arvensis*), and herb sophia (*Descurainia sophia*). Although only cheatgrass was encountered in enough samples to warrant detailed analysis, the other exotics species appeared to also be more abundant in the burned areas than the unburned areas by the end of the project.

Burned and unburned areas appeared to differ not only in the abundance of exotics species, they also differed markedly in the dominant plant species in the vegetation (that is, the species that contributed a substantial proportion of the canopy cover). In the unburned samples (and, presumably, in the unburned vegetation as a whole), species that dominated more than a handful of plots at the beginning and end of the study were big sagebrush, (*Artemisia tridentata*), black sagebrush (*A. nova*), bluebunch wheatgrass (*Pseudoroegneria spicata*), Sandberg bluegrass (*Poa secunda*), mock goldenweed (*Stenotus* sp.), and Utah juniper (*Juniperus osteosperma*). (Note that these species were not consistently present together, and they are not dominants in a single community-type.) The group of common dominants in the burned areas shared only one species, bluebunch wheatgrass, with the unburned areas. The other dominants in the burned areas throughout the study were cheatgrass, thickspike wheatgrass (*Elymus lanceolatus*), western wheatgrass (*Pascopyrum smithii*), greasewood (*Sarcobatus vermiculatus*), and Utah snowberry (*Symphoricarpos oreophilus* ssp. *utahensis*). These are the species that remained dominants throughout the study, but additional species were dominants either early or late in the study, and in both the burned vegetation and the unburned vegetation, the list of dominant species changed by approximately 50% from 2001 to 2012.

Vegetation structure, too, differed between burned areas and unburned areas. Percent canopy cover of all shrubs was substantially greater in the unburned plots, due primarily to the greater cover of big sagebrush in the unburned plots. Density of shrubs, though, was hardly different between burned and unburned vegetation. Big sagebrush was slightly more dense in the unburned plots, but this small difference was overwhelmed by the other shrubs species (which occurred either in so few burned plots or unburned plots that differences in their densities could not be analyzed individually). Shrub size, expressed either as height or canopy volume of shrubs as a group, also did not differ between burned and unburned areas, although individual species did differ: big sagebrush plants were slightly larger and black sagebrush were substantially larger in the unburned plots, while Douglas rabbitbrush (*Chrysothamnus viscidiflorus*) plants were slightly larger in the burned areas. Lastly, burned areas supported shrubs with more vigorous canopies.

While data are unavailable for analyzing changes in the these aspects of shrub canopy structure over the course of the study, the differences between burned and unburned areas must have changed between 2001 and 2012. In 2001, a year after the fires, big sagebrush and black sagebrush (neither of which sprout) very likely were all but absent from much of the burned areas, while Douglas rabbitbrush and Utah snowberry (both sprouters) may have been apparent already. For several years, density of the sagebrushes likely was substantially less on the burned plots, and individuals of all species were substantially smaller. Hence the burned and unburned areas almost certainly started out with very different vegetation structure, and those differences have diminished with time.

V. REFERENCES

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These three appendixes may be found in separate documents:

Appendix I. List of Unidentified Plants

Appendix II. Tables of Occurrences of Exotic Species on Weed Transects and in Vegetation Plots in Each Year

Appendix III. Details About the Distribution and Abundance of Each Exotic Species on Weed Transects and in Vegetation Plots