# SURVEY OF TALL SAGEBRUSH VEGETATION ON STABILIZED SANDS IN THE JACK MORROW HILLS COORDINATED MANAGEMENT AREA, BLM ROCK SPRINGS FIELD OFFICE, WYOMING

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## ABSTRACT

Fifty-six sample plots were used to collect data on plant species composition and vegetation structure in the tall sagebrush vegetation on sand substrates in the Jack Morrow Hills Coordinated Management Area of southwestern Wyoming. These plots were located in undisturbed vegetation, in burned areas, in pipeline corridors, on reclaimed gas well pads, and on active gas well-pads. Undisturbed vegetation consists of a tall shrub layer (often over 2 m tall) strongly dominated by *Artemisia tridentata* ssp. *tridentata*; a shorter shrub layer of *Ericameria nauseosa*, *Chrysothamnus viscidiflorus*, and (often) a few other shrubs; and a herbaceous undergrowth of *Psoralidium lanceolatum*, *Achnatherum hymenoides*, *Hesperostipa comata*, *Machaeranthera canescens*, and other grasses and forbs. Disturbed sites lack the tall sagebrush overstory but often have a shorter shrub layer of *Ericameria* and *Chrysothamnus*. The herbaceous vegetation on burned sites and the pipeline corridor is similar in species composition to the herbaceous undergrowth of undisturbed vegetation but is somewhat more sparse. The herbaceous vegetation on reclaimed and (especially) active well-pads differs more from undisturbed vegetation in species composition and is more sparse.

In addition to reducing the amount of plant canopy cover, disturbance also reduces the amount of litter and wood on the ground surface, and increases the amount of bare ground.

Rates of recovery of the tall shrub overstory were not estimated from the data, and those estimates would seem to be useful in assessments of likely effects of disturbance in the vegetation. The information needed to estimate recovery rates for the sites studied in this project may be relatively easily obtained, and useful data might also be obtained from a few additional burned sites in the area.

Grazing by elk seems to have had little effect on the species composition or the amount of canopy cover in the herbaceous vegetation. Rather, the amount of herbaceous undergrowth appears to depend on the height and density of the shrub overstory.

Exotic plant species are scattered throughout the tall sagebrush vegetation but rarely contribute more than a trace of canopy cover to the vegetation. The exception is the very sparse vegetation on active well-pads.

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Jim Glennon and Lorraine Keith of the BLM's Rock Springs Field Office helped with selection of the study area, provided valuable information about the area, and advised on the selection of sampling locations. Jake Powell and Fred Lindzey, Wyoming Cooperative Fish and Wildlife Research Unit (University of Wyoming), generously provided unpublished information on elk use throughout the study area and advised on methods for estimating intensity of elk use. Data were collected by Cathy Cooper, Sal Madden, Jason Maes, and Brigette (Wilmetti) Maes of the Natural Diversity Database, who dealt well with the challenges that accompany any field work and provided the information on which this report is based. Cathy Cooper also carefully checked the data and entered them into databases for analysis. Al Redder of the Natural Diversity Database advised on statistical analyses. Hollis Marriott identified the plant specimens, and Ron Hartman and Ernie Nelson (curator and manager, respectively) of the Rocky Mountain Herbarium made facilities available for plant identification.

## INTRODUCTION

Stabilized sand dunes in the Killpecker Dune Field of southwestern Wyoming (Figure 1) support unusual tall shrub vegetation dominated by basin big sagebrush, *Artemisia tridentata* ssp. *tridentata*. The major features of this vegetation have been described (Knight 1994, Ahlbrandt 1973) and a limited amount of data have been collected to quantitatively characterize the species composition (Jones and Fertig 1996). That information indicated that these tall sagebrush stands differ substantially in composition and structure from vegetation on stabilized sand elsewhere in Wyoming (Jones 2005).

The tall sagebrush stands on the Killpecker Dunes have long been recognized for the habitat they provide to the herd of elk (*Cervis canadensis*) that inhabit the area (e.g., Henderson 1955). Early concerns that development of petroleum resources in the area might negatively affect the elk and other wildlife in the area (Henderson 1955) have intensified in the past several years, leading the Bureau of Land Management to designate the Jack Morrow Hills Coordinated Management Area that includes much of the tall sagebrush vegetation.

In 2002, the Bureau of Land Management's Rock Springs Field Office and the University of Wyoming's Natural Diversity Database entered into a cooperative agreement for a survey of tall sagebrush vegetation in and around the Killpecker Dunes. Biologists from the Rock Springs Field Office and the Natural Diversity Database developed a project to collect quantitative data for describing species composition and structure of the tall sagebrush vegetation, for examining the effects of various types of disturbance on the vegetation, and for investigating the possibility that grazing by elk was reducing the amount of herbaceous understory. Field work for this project was conducted by Natural Diversity Database staff during two field seasons, August 6 - 16, 2002 and August 21 - 28, 2003. This report describes the methods used in the project and presents the results.

## METHODS

### SELECTION OF SAMPLING LOCATIONS

The first point of this study was to characterize the tall sagebrush vegetation that provides important elk habitat within the Jack Morrow Hills Coordinated Resource Management Area. Biologists from the BLM's Rock Springs Field Office who were familiar with the elk herd outlined the boundaries of the area used by elk, and this constituted the study area. A digital data layer showing the tall sagebrush vegetation within the study area, provided by the Rock Springs Field Office staff, was used to identify the vegetation to be sampled. The portion of the Jack Morrow Hills management area within the Sand Dunes Wilderness Study Area (WSA) was excluded from the study because walking to sampling locations inside the WSA would have taken considerable time and reduced the amount of data collected. The boundaries of the wilderness study area had been digitized from paper maps provided by BLM staff.

A second point of the study was to look for effects of elk grazing on the undergrowth in the tall sagebrush vegetation, so sampling locations were sought to represent a range in intensity of elk grazing. Radio-telemetry data had shown parts of the study area in which elk spent much of their time and areas in which they spent relatively little time (Jacob Powell and Fred Lindzey, UW Cooperative Fishery and Wildlife Research Unit, personal communication), and the study area was divided into heavy elk-use portions and light elk-use portions based on that information.

A third point of the study was to discover the effects of fire and petroleum production on the vegetation. BLM staff provided three digital data layers showing different types of disturbance within the study area: burned areas, two pipeline corridors, and active oil or gas wells. Aerial photographs were used to identify additional active wells and those were added to the digital layer. These three layers were used to choose sampling locations in disturbed areas before the field season. Reclaimed dry-hole sites were identified in the field during the second year of the study and sample locations were selected on them to provide another category of disturbed area.

The digital data layers were combined in a geographic information system (ArcView 3.0, ESRI, Redlands WA, USA) to identify five disturbance categories in the tall sagebrush vegetation of the study area: undisturbed light elk-use, undisturbed heavy elk-use, burned areas, pipeline corridors, and active petroleum wells. (The undisturbed category was later split into two groups, the undisturbed plots on White Mountain vs. all other undisturbed plots, to give six categories.) A set of random points was overlaid on the data layers, and from those random points a set of potential sampling locations was chosen to include the different disturbance categories. The geographic coordinates (UTM North American Datum 1983, Zone 12N) were determined from the geographic information system. Two 2-person field crews used global positioning system receivers (GeoExplorer II, Trimble Navigation Ltd., Sunnyvale CA, USA) to find each potential sampling location in the field. If a location represented the disturbance category to which it had been assigned, the crew collected data there. If not, then the crew moved the location slightly if possible (for example, a location intended to represent a burned area but that actually was in an unburned area could be moved up to ca. 100 meters into the nearest burned area) or abandoned that location and went to the next potential location on the list.

## DATA COLLECTION

The nested vegetation-sampling plots developed by Stohlgren *et al.* (1995) were used to estimate canopy cover of plants at each of the 56 sampling locations. This plot design features a 20 m x 50 m macroplot with 13 sub-plots inside it (Figure 2). The field crew placed the starting corner for the macroplot close to the sampling location, then used the GPS receiver to record the UTM coordinates (NAD83, Zone 12N) of the corner's actual position. The azimuth of the macroplot's long axis was recorded with a sighting compass.

The canopy cover of a plant was defined (following Daubenmire 1959) as the polygon described by a line drawn around the leaf tips of the undisturbed above-ground portion of the plant. Sampling began with the microplots: in each, the percentage of the microplot beneath the canopy of each species was estimated, and was recorded as the mid-point of the appropriate cover range (Table 1). After canopy cover had been estimated in the 10 microplots, the two corner sub-plots were searched for species that had not been recorded in the microplots, and their presence was noted. The center sub-plot was next searched for species that had not been recorded in the microplots or in the corner sub-plots, and finally, the area of the macroplot outside of the microplots and the corner and center sub-plots was searched for new species.

The values for a species from the 10 microplots were averaged to give an estimate of the species's cover for the entire macroplot, and that estimate was converted to the mid-point of the appropriate cover range. For example, suppose that the 10 values for species A (each a mid-point from a microplot) average 7.6, which average falls within the 5% - 15% cover range. The value for species A for the macroplot then is 10, the mid-point of that range. Any species that was not found in a microplot but was found in one of the corner plots, or in the center plot, or in the macroplot was assumed to have a canopy cover of less than 1%, and was assigned a value of 0.05 for the macroplot. This method of estimating canopy cover allows one to say that the canopy cover for a given species in a macroplot falls within a range. It does not yield a precise, point estimate of canopy cover for the species.

The heights above the ground of the upper and lower edges of the shrub canopy were recorded for the largest shrub in each microplot or, where no shrub was present, for the shrub nearest the microplot. These height estimates were averaged to give an average upper and lower shrub height for each macroplot.

The percentage of the ground surface in each microplot covered by each of 12 categories (Table 2) was estimated and an average value for each category was calculated for the macroplot, in the same manner as for the plant canopy cover values from the microplots. The number of elk droppings (elk pellets) in each microplot also was recorded, and those values were averaged to give a single number for each macroplot. That number was converted to density (number of pellets / square meter) as a measure of the intensity of elk use.

Estimates of shrub canopy cover were made with a convex spherical densiometer (Forest Densiometers, Bartlesville OK, USA) at six points around the perimeter of the macroplot (Figure 2). At each point, the observer lay on the ground and held the densiometer within 30 cm of the ground surface, facing toward the center of the plot. The six estimates were then averaged to give a single estimate of percent shrub canopy cover for the macroplot. This estimate is assumed to be more precise than the ocular estimate from the microplots.

The vegetation at the sampling location was briefly described and a photograph was taken of the macroplot. Selected environmental variables were recorded, including type of surface material (residual, colluvial, alluvial, or aeolian), soil texture (based on one hand texture of the top 10 cm of soil, made near the starting corner), slope steepness, and slope aspect.

## DATA ANALYSIS

Similarities among plots in plant species composition were examined with ordination, an analysis approach that arranges entities (in this case, sample plots) along axes of similarity. The results of an ordination analysis are displayed on graphs that place similar plots close together and dissimilar plots far apart. Ordination is particularly useful in revealing gradients of similarity between plots, in contrast to classification, which groups plots together but is less effective at showing the patterns of similarity.

Ordination was performed with nonmetric multidimensional scaling (NMS), a technique that is particularly well-suited for analyzing vegetation data, which usually are not normally distributed and contain a great range in values (McCune and Grace 2002). NMS works by first calculating a matrix of similarity between every pair of plots, then constructing axes and arranging the plots along the axes in a manner that preserves, as much as possible, the pattern of similarity among all of the plots contained in the original matrix. NMS analysis was done with the PC-ORD software package (MjM Software Design, Gleneden Beach OR, USA), version 4.3, using the autopilot mode with medium thoroughness settings (McCune and Mefford 1999). The medium-thoroughness values for the NMS parameters are shown in Table 3. Similarity between plots was calculated with Sorensen's coefficient. The original cover class data were log-transformed before analysis, using the equation:

$$b_{ij} = \log (x_{ij} + d) - c$$

where

$b_{ij}$ = the transformed value for species *j* in plot *i*,
$x_{ij}$ = the original cover-class value for species *j* in plot *i*,
d = a decimal constant = $\log^{-1}$ (c), or the anti-log of c.
c = order-of-magnitude constant = integer value of (log [minimum $x_{ij}$ in the data]),

This logarithmic transformation expresses the data values as orders of magnitude and is especially useful in improving the analysis of data sets when there is great variation between samples (McCune and Grace 2002).

NMS produced, as its optimum result, a two-dimensional ordination of the plot data. Various types of information about the vegetation, such as total cover and relative cover of different plant-growth forms, were displayed on the two-dimensional ordination graph to show patterns of vegetation features.

Standard statistical tests were used to examine differences between undisturbed plots and undisturbed plots for certain vegetation parameters. All of these tests were performed with the Minitab statistical package, release 12.21 (Minitab Inc., State College PA, USA). Details are given below.

## RESULTS AND DISCUSSION

Data were collected at 56 sampling locations representing the different disturbance categories (Figure 3, Table 4). The 6 undisturbed plots on White Mountain, in the western part of the study area, were placed in a different category from the 31 plots in the Killpecker Dunes and on Steamboat Rim because the west-dipping, windward slope of White Mountain was judged to offer substantially different environmental conditions than the rolling stabilized dunes in the dune field and on the lee side of Steamboat Rim.

### FLORA

One-hundred eighteen taxa of vascular plants and 1 moss were documented in the 56 sample plots (Table 5 and Table 6). Eighty-six taxa (72.3%) could be identified to species, 14 taxa (11.8%) could be identified only to genus, and 19 (16%) could not be identified to genus. Only 10 of the taxa (8.4%) were found in at least half of the plots, and 64 taxa (53.8%) were found in only one or two plots (Table 6, Figure 4). Most of the unknown forbs and grasses were found in only one plot, and had they been identified, the number of species in only one plot probably would be smaller.

Forbs were the most common growth-form, accounting for 78 taxa (66% of the vascular taxa). Fourteen of the taxa that could not be identified to genus were forbs. Twenty-one taxa (17.8% of the vascular plants) were grasses, including 4 of the unknown taxa. Shrubs accounted for 14 taxa (11.9% of vascular taxa), and only 5 taxa (4.2% of the vascular taxa) were sub-shrubs. All of the shrubs and sub-shrubs could be identified at least to genus.

Only 11 of the vascular plant taxa (9.2%) are known to be exotic, and those species were limited to just a few plots (as discussed below). Had the unknown taxa been identified to species, the number of exotic taxa in the flora might be larger.

For analysis of the plot data, the list of 119 taxa (vasculars and moss) was reduced to 114 taxa, through the following combinations:

*Agropyron cristatum* includes *A. cristatum* + *A. desertorum*
*Astragalus kentrophyta* includes *A. kentrophyta* + *A. kentrophyta* var. *elatus*
*Chaenactis douglasii* includes *C. douglasii* + *C. douglasii* var. *douglasii*
*Eriogonum cernuum* includes *E. cernuum* + *E. cernuum* var. *cernuum*
*Salsola tragus* includes *S. tragus* + *Salsola* sp.

### VEGETATION

The results of the ordination of all 56 plots and 114 taxa, using transformed data, are displayed on the two-dimensional NMS ordination graph in Figure 5. (Technical details of the results of the NMS ordination are shown in Table 3.) Each of the two axes in the graph expresses similarity between plots in species composition: the closer together two plots are on the graph, the more similar they are in species composition. Various types of information can be displayed on the graph to reveal features of the vegetation.

#### Disturbance and Vegetation Features

Figure 5 suggests some differences among the disturbance categories. All of the disturbed plots (burned plots and those on pipelines, dry-hole sites, and active well-pads) are located in the right half of the graph. The mingling of some undisturbed plots with the disturbed plots indicates overlap in species composition. The different categories of disturbed plots segregate noticeably from one another, with the three plots on active well-pads the least similar to others. All five burned plots, the seven plots on

pipelines, and the four plots on dry-hole sites are located in the right-central part of the graph, mixed with some undisturbed plots.

Most of the 31 undisturbed plots from the Killpecker Dunes and Steamboat Rim are in the center of the graph, but plots from this category mix to some degree with plots on pipelines, burned plots, and plots on dry-hole sites, and with the White Mountain plots. All six undisturbed plots from White Mountain are in the upper-left quadrant of the graph, far from the disturbed plots and mixed with several undisturbed plots from the Killpecker Dunes and Steamboat Rim.

Overlays of various vegetation features on the ordination graph illustrate the nature of the vegetation in the disturbance categories, by showing where different types of plants and different species reached their maximum values.[1] Total plant canopy cover was generally greatest in undisturbed plots, least in plots on active well-pads, and intermediate in burned plots and plots on pipelines and dry-hole sites (Figure 6). Shrub canopy cover shows a similar pattern: the greatest amounts of absolute shrub cover were found in undisturbed plots, intermediate amounts were found in plots along pipelines and on some dry-hole sites, and the smallest amounts were found in burned plots and plots on active well-pads (Figure 7). The pattern for relative shrub canopy cover (that is, the amount of the plant canopy cover in a plot contributed by shrubs) is similar to that for absolute cover (Figure 8).

For forbs, in contrast, the greatest amounts of absolute cover were found in burned plots, plots on pipelines and dry-hole sites, and a few undisturbed plots in the dunes and on Steamboat Rim (Figure 9). Forb cover was minimal in the plots on White Mountain. The pattern of relative forb canopy cover (Figure 10) is nearly opposite that of relative shrub cover: relative forb cover was greatest in plots on active well pads and some burned plots, and the smallest values were in undisturbed plots. For grasses, no obvious difference in absolute cover appears between categories of plots (Figure 11). As with relative forb cover, the plots with the greatest relative grass cover were those with the least relative shrub cover (Figure 12).

The distributions of growth-forms that appear on the ordination diagrams are supported by statistical tests. The numbers of plots in different disturbance categories are so uneven that comparisons of all of the categories with each other cannot be made, but two-sample t-tests comparing all of the undisturbed plots to all of the disturbed plots show that the undisturbed plots had significantly more ($p=0.05$) total plant canopy cover (Table 7) and absolute shrub canopy cover (Table 8). Absolute cover of forbs and grasses, though, was not significantly greater in the undisturbed plots than in the disturbed plots (Table 9 and Table 10).

Differences among disturbance categories are obvious in the amounts of individual species present in the plots. Among shrubs, the most common species, *Chrysothamnus viscidiflorus* ssp. *viscidiflorus*, reached its greatest cover values in undisturbed plots and plots on pipelines and dry-holes sites (Figure 13). Burned plots had intermediate amounts of *Chrysothamnus viscidiflorus* ssp. *viscidiflorus*. For *Ericameria nauseosa*, the second-most common shrub, the greatest cover values were more concentrated in undisturbed plots in the dunes and on Steamboat Rim, plots on dry-hole sites, and a few plots on pipelines, with intermediate values in many undisturbed plots (Figure 14). *Artemisia tridentata* ssp. *tridentata*, the third widespread shrub, occurred in greatest amounts in undisturbed plots and also was present in substantial amounts in plots on pipelines (Figure 15). Burned plots and most plots on dry-hole sites had little or no *Artemisia tridentata* ssp. *tridentata*.

Only three forb species -- *Psoralidium lanceolatum*, *Machaeranthera canescens* ssp. *canescens*, and *Comandra umbellata* -- were present in more than half of the plots (Table 6). Two of those species, *Psoralidium lanceolatum* and *Machaeranthera canescens* ssp. *canescens*, reached maximum cover values in undisturbed plots and disturbed plots, and both were absent from the plots on White Mountain

[1] Note that, on each overlay diagram, symbol sizes reflect only the amount of a particular vegetation feature (such as amount of shrub cover) in each plot relative to the amounts *of that feature* in the other plots. E.g., plot *x* might have the largest symbol on the overlay for shrub canopy cover and on the overlay for forb canopy cover. This indicates that the greatest shrub canopy cover value and the greatest forb canopy cover value were found in plot *x*. It does not indicate that plot *x* had the same amounts of shrub canopy cover and forb canopy cover.

(Figure 16 and Figure 17). The third widespread species, *Comandra umbellata*, reached its maximum cover values in only a few disturbed plots and one pipeline plot (Figure 18).

Among grasses, too, only three species were present in more than half of the plots. *Achnatherum hymenoides*, the most widespread grass, reached its maximum cover values in undisturbed plots (at White Mountain and elsewhere), burned plots, plots on pipelines, and dry-hole sites (Figure 19). *Hesperostipa comata* also had maximum cover values in a variety of plots -- undisturbed (but not at White Mountain), burned, and pipeline (Figure 20). *Elymus lanceolatus* ssp. *lanceolatus* was nearly as widespread as *Hesperostipa comata* but reached its maximum cover values in plots on pipelines and dry-hole sites, and had intermediate values in undisturbed plots (Figure 21). A contrast to these distribution patterns is provided by *Poa secunda*, which was concentrated in the White Mountain plots (Figure 22).

Disturbance seems to have only a modest effect on richness of vascular plant species in small areas of the tall sagebrush vegetation, as measured by the number of species in sample plots (Figure 23). Plots on active well-pads, which are still occasionally disturbed, had few species relative to other categories of plots. Burned plots had slightly more species. Plots on pipelines and dry holes, though, had as many species as did many of the undisturbed plots on the Killpecker Dunes and Steamboat Rim. The pipeline and dry-hole plots probably were disturbed longer ago than were the burned plots and plants have had more time to become established again in the vegetation.

Over larger areas within the tall sagebrush vegetation, disturbance appears to reduce species richness and homogenize species composition from place to place. The 31 undisturbed plots in the Killpecker Dunes and on Steamboat Rim contained (as a group) 96 plant species, and beta diversity (a measure of heterogeneity among samples) was 5.12 (Table 11). (Greig-Smith [1983] notes that beta diversity is a measure of the heterogeneity in composition among samples and is not a characteristic of the vegetation being sampled.) Among the 12 plots in burned areas and on pipelines, only 40 species were documented and the heterogeneity among the plots was only 1.93.

## Species Composition

Overlays show the amount of a species in one plot relative to its amounts in other plots, not to the amounts of other species in the same plot. Consequently, overlays of individual species on ordination diagrams are unsuitable for showing patterns of species composition -- that is, of the relative amounts of all species in different plots. Species composition can be shown, though, by comparing groups of plots on the ordination diagram to tables of species cover.

Figure 24 shows seven groups of plots, and the distribution and abundance of plant species in plots of those groups is shown in Table 12 through Table 18. The largest plot group, D, consists of plots with a shrub stratum dominated by *Artemisia tridentata* ssp. *tridentata* and containing *Chrysothamnus viscidiflorus* ssp. *viscidiflorus* and (usually) *Ericameria nauseosa* (Table 12). *Purshia tridentata* sometimes contributed substantial cover. The herbaceous stratum consisted of *Psoralidium lanceolatum* (the most common species) and smaller amounts of *Achnatherum hymenoides*, *Hesperostipa comata*, *Machaeranthera canescens* ssp. *canescens*, and *Comandra umbellata*. Many additional forbs, and some grasses and shrubs, often were present. The height of the shrub stratum varied widely among the plots of this group (Figure 25). The tallest canopies were found in undisturbed plots (over 200 cm in one plot) and the shortest in pipeline plots, but there was considerable overlap in canopy height between undisturbed plots and disturbed plots (Figure 25).

The plots in group E also had a shrub stratum dominated by *Artemisia tridentata* ssp. *tridentata* in which *Ericameria nauseosa* was common, and undergrowths dominated by *Psoralidium lanceolatum* (Table 13). The shrub stratum in these plots contained far less *Chrysothamnus viscidiflorus* ssp. *viscidiflorus* than in the plots of group D, and often contained a substantial amount of *Purshia tridentata* or *Symphoricarpos oreophilus*. The herbaceous understory in most plots contained little canopy cover other than that of *Psoralidium lanceolatum*. The six undisturbed plots in this group had tall shrub canopies, and the single pipeline plot had short shrubs (Figure 25).

*Artemisia tridentata* ssp. *tridentata* dominated the shrub stratum in the plots of group C as well, and *Chrysothamnus viscidiflorus* ssp. *viscidiflorus* was present in smaller amounts (Table 14). *Tetradymia canescens* was a minor but widespread shrub. *Ericameria nauseosa* was all but absent from these plots. The herbaceous understory was depauperate and no species were consistently common, but *Poa secunda* dominated in three plots. All of the plots in this group were undisturbed and had tall or medium-height shrub strata (Figure 25).

Group B contains four undisturbed plots, three of which had shrub strata dominated by *Artemisia tridentata* ssp. *wyomingensis* and one of which had a shrub stratum dominated by *Artemisia tridentata* ssp. *tridentata* (Table 15). *Chrysothamnus viscidiflorus* ssp. *viscidiflorus* was present. In the three plots with the *Artemisia tridentata* ssp. *wyomingensis* overstories, *Poa secunda* dominated the sparse herbaceous stratum, and few other herbaceous species were consistently present. Shrub overstories were intermediate in height (Figure 25).

Group A contains just two plots, both undisturbed, in which *Artemisia tridentata* ssp. *tridentata* dominated the shrub stratum (Table 16). *Ericameria nauseosa* contributed substantial cover to one plot. The understories were sparse and depauperate, and no species were consistently present. *Elymus trachycaulus* ssp. *trachycaulus* contributed substantial cover to one plot but was absent from the other. Shrub overstories in these plots were intermediate in height (Figure 25).

The two remaining groups of plots have virtually no sagebrush. Group F is composed of plots with shrub strata of *Chrysothamnus viscidiflorus* ssp. *viscidiflorus* and *Ericameria nauseosa*, and understories of *Psoralidium lanceolatum*, *Achnatherum hymenoides*, *Hesperostipa comata*, *Elymus lanceolatus* ssp. *lanceolatus*, and *Machaeranthera canescens* ssp. *canescens* (Table 17). Over half of these plots were disturbed, and consequently the shrub overstories were short (Figure 25). Group G contains the three plots on active well-pads, in which *Ericameria nauseosa* and *Psoralidium lanceolatum* dominated the sparse, short vegetation (Table 18). *Chrysothamnus viscidiflorus* ssp. *viscidiflorus* and *Achnatherum hymenoides* were present in substantial amounts in all three plots. Two exotic plants, *Halogeton glomeratus* and *Salsola sp.*, were present in some plots, and the latter co-dominated one plot.

These plot groups do not differ markedly from one another in richness of vascular plant species (Figure 26). Five of the seven plot groups contain plots with relatively large numbers of species and plots with relatively few species. The exceptions are group A, the two plots of which contained an intermediate number of species; and group G, the plots on active well-pads, which contained few species relative to other plots. All six plots from White Mountain had few species relative to the plots from the Killpecker Dunes and Steamboat Rim (Figure 23).

The types of vegetation documented by the sample plots match well with the vegetation briefly described by Ahlbrandt (1973) from the Killpecker Dunes. Ahlbrandt mentioned shrub vegetation dominated by various rabbitbrushes (including *Chrysothamnus viscidiflorus* and *Ericameria nauseosa* [identified in his description as *Chrysothamnus nauseosus*]) as an intermediate step in the stabilization of the dunes, and tall shrub vegetation dominated by *Artemisia tridentata* on dormant dunes. The former corresponds to plot group F, and the latter to plot groups D and E.

The lack of correspondence between the plot groups defined by species composition and the disturbance categories shows that disturbance does not produce simple changes in species composition. Fire, pipeline construction, and construction of well-pads all remove the shrub overstory and reduce sagebrush in the vegetation or remove it altogether. Because shrubs contribute most canopy cover to the vegetation, total canopy cover also is reduced. Construction of pipelines and well-pads removes the understory vegetation, and the herbaceous vegetation that then develops on these disturbed sites is less dense than the surrounding vegetation. Nevertheless, it contains about the same relative amounts of the common herbaceous species. Fire has less effect on the amount and composition of the herbaceous understory, which persists as herbaceous vegetation after the fire. Following any of these disturbances, *Chrysothamnus viscidiflorus* ssp. *viscidiflorus* and *Ericameria nauseosa* increase in the vegetation faster than does *Artemisia tridentata* ssp. *tridentata*, and the vegetation comes to resemble that described by Ahlbrandt (1973) from recently stabilized dunes. The undisturbed plots in group F apparently illustrate

this vegetation. Following any disturbance, the reductions in sagebrush cover, in total shrub cover, and in height of the vegetation persist for some time.

Exotic Plants

Eleven plant taxa known to be exotic were documented in 20 of the sample plots (Table 19). Thirteen of the plots contained only one exotic taxon, and in only five plots did exotics account for more than 5% of the canopy cover. Four of those five plots were on active well-pads or dry-hole sites. *Descurainia sophia* occurred in the most plots (and most of those were undisturbed). Three of the exotic taxa -- *Agropyron cristatum*, *Agropyron desertorum*, and *Bromus inermis* -- are (or used to be) commonly planted as part of the reclamation of disturbed sites, and almost certainly were originally planted in the study area, although they may have spread from the introduction sites. A fourth grass, *Leymus racemosus*, was growing in rows on a reclaimed dry-hole site and road and no doubt was planted. *Bromus tectorum*, a widespread weed in the western U.S. and a subject of recent concern in Wyoming, was found in only one plot.

Exotic species may be widespread, occurring in 36% of the sample plots, but for the most part they seem to be a minor part of the tall sagebrush vegetation, at least as measured by canopy cover. The exceptions are planted grasses in a few locations, and two undesirable plants, *Halogeton glomeratus* and *Salsola* sp., on well-pads. Gillham's (2001) surveys of the Jack Morrow Hills management area also showed that halogeton and *Salsola* sp. (Russian thistle) are common on well-pads and along roads.

Possible Effects of Elk on the Herbaceous Undergrowth

BLM biologists and others have expressed concern that grazing by elk might be reducing the amount of herbaceous undergrowth in the tall sagebrush vegetation. This possibility was investigated with regression analysis, in which herbaceous canopy cover (the sum of forb cover plus grass cover) in plots was regressed on the estimated density of elk pellets. The assumption was that, if elk grazing is harming the herbaceous undergrowth, then the amount of herbaceous plant cover should be inversely related to the density of elk pellets.

Powell (2003) has shown that, from early May through August, elk in the study area select tall sagebrush vegetation more than expected from its representation on the landscape, and elk avoid areas within 2 km of roads. (Herbaceous plants are active during much of this period and probably are most susceptible to grazing then.) Selection of particular areas by elk and their avoidance of other areas might confound the relationship between herbaceous undergrowth cover and elk use. This possible complication was addressed in two ways. First, all 19 disturbed plots (where the shrub canopy is short or altogether missing) and the 17 undisturbed plots within 2 km of major roads were eliminated from the regression analysis, leaving 19 undisturbed plots in the analysis. Those roads identified by Powell as major roads (Powell 2003, Figure 3) were identified with ArcMap on a digital layer of all roads in the area, and a 2-km wide buffer was placed on each side of them.

Preliminary analysis showed that one of the remaining plots, 02EM05, had an unusually large residual value. This plot had a very dense undergrowth in which *Bromus inermis* ssp. *inermis* (smooth brome) was a sub-dominant species. The presence in large amount of this exotic grass suggested that the undergrowth cover may have been augmented by planting (although no note was made of that in the field), so the plot was dropped from subsequent analyses. Dropping this plot had virtually no effect on the regression coefficients.

Second, the height of the top of the shrub canopy was included with pellet density as a regressor variable in a multiple regression analysis, to account for the effect of shrub height on the relationship between elk use and undergrowth cover.

The multiple linear regression analysis showed no statistically significant ($p=0.05$) linear relationship between the amount of herbaceous canopy and the density of elk pellets (Table 20). Herbaceous canopy cover was inversely related, though, to the height of the shrub canopy. A second

expression of vegetation structure, the density of the shrub canopy (estimated from densiometer measurements) is available for the plots, and linear regression showed that the amount of herbaceous undergrowth was inversely related to this variable as well (Table 21). These results suggest that the amount of herbaceous undergrowth is related to the structure of the shrub overstory but not to the amount of elk use.

Within the area sampled by the vegetation plots, then, it does not appear that elk are causing a decline in the amount of the herbaceous undergrowth of tall sagebrush vegetation. It is possible that elk hide or rest in the tall sagebrush stands but do not graze there, and that they are having an effect in nearby open areas with more herbaceous plants where they do graze.

Relationship to Vegetation on Sand Substrates Elsewhere in Southern Wyoming

Compared to vegetation growing on sand substrates elsewhere (Jones 2005), the tall sagebrush vegetation of the study area appears to be both relatively rich in plant species and heterogeneous in species composition from place to place. The 49 plots outside the dry-hole sites and the active well-pads contained (in total) 105 taxa, and beta diversity was 6.92 (Table 11). In comparison, 11 sample plots in The Sand Hills north of Baggs, an area of well-stabilized dunes, contained 101 plant taxa, and beta diversity was much lower, at 2.16. A set of 16 sample plots placed on areas mapped as Quaternary sand substrates elsewhere in southwestern Wyoming recorded only 85 taxa, and had a beta diversity of 4.11. The tall sagebrush vegetation in the present study area also is unusual in structure: here much of the vegetation has a tall shrub layer dominated by *Artemisia tridentata* ssp. *tridentata*, while the vegetation in The Sand Hills has a shorter shrub layer that is not strongly dominated by any one species and that usually contains *Artemisia cana* ssp. *cana*, *Purshia tridentata*, *Artemisia tridentata* ssp. *tridentata*, *Chrysothamnus viscidiflorus*, and *Ericameria nauseosa* and may also have substantial amounts of other shrubs. On the other areas of sand substrate, the short shrub layer usually is dominated by *Artemisia tridentata* ssp. *wyomingensis*.

## GROUND COVER

Litter and bare soil were by far the most common ground-cover types in the sample plots (Figure 27). All of the undisturbed plots appeared to have more litter and wood on the ground than did all categories of disturbed plots, and less bare soil. Two-sample t-tests (on all undisturbed plots together vs. all disturbed plots together) confirmed this observation: litter cover (Table 22) and wood cover (Table 23) were significantly greater on the undisturbed plots, and bare soil (Table 24) was significantly greater on the disturbed plots. Disturbance, then, not only changes the structure of the vegetation, but also removes ground cover.

## SUMMARY

The information gathered in this project suggests that the primary effects of fires and construction of petroleum well sites and pipelines to date in the tall sagebrush vegetation have been removal of the sagebrush-dominated shrub overstory and thinning of the herbaceous undergrowth. After fire, construction of pipelines, and reclamation of well-pads, rabbitbrushes (*Ericameria nauseosa* and *Chrysothamnus viscidiflorus*) eventually form a shrub layer shorter and more open than the original tall sagebrush shrub layer. Observations by Ahlbrandt (1973) and from this project suggest that a tall sagebrush overstory will, with time, grow back in the disturbed areas. How long this will take, though, is unclear. We have been unable so far to ascertain the dates of the disturbances studied in this project, and so we have been unable to estimate recovery rates. More investigation into dates of abandonment of the dry-hole well sites and the burns that were studied here may be useful. Also, there are other burned areas in tall sagebrush vegetation that were not studied here, and data from those areas may be

useful as well in showing recovery rates. Estimates of recovery rates for the tall shrub layer will be important in predicting the effects of different levels of disturbance in the tall sagebrush vegetation.

The herbaceous undergrowth usually is thinner in disturbed sites than in the undisturbed vegetation, but generally there is little change in species composition. The exception to this pattern is the large contribution of exotic plants to the sparse vegetation on active well-pads (relative to plots in other disturbance categories). These well-pads are still being disturbed, and with their reclamation in the future the exotic plants may decline in abundance. Abandoned and reclaimed dry-hole sites in the study have less cover of exotics, but it is unclear whether those sites disturbed in past years had fewer exotic plants immediately after disturbance than sites disturbed in recent years, or exotics were as common immediately after disturbance on the now-reclaimed sites and have decreased in abundance with reclamation. The results of this study and of Gillham's (2001) surveys suggest that disturbance of more areas in the tall sagebrush vegetation would result in an increased amount of exotic plants.

No evidence was found in this project that grazing by elk has affected the species composition or the amount of cover in the herbaceous undergrowth of the tall sagebrush vegetation. Rather, the amount of herbaceous undergrowth seems to be controlled by the height and density of the shrub overstory. The tall sagebrush vegetation appears to be exhibit the well-known relationship between overstory density and undergrowth density observed in forests.

The tall sagebrush on the Killpecker Dunes has long been recognized as unusual because of the height of the shrub stratum. This vegetation also dffers from shrub vegetation on other sandy areas in the composition of the shrub stratum and of the herbaceous undergrowth.

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# FIGURES

Figure 1. Location of the Study Area Within the BLM's Rock Springs Field Office and Wyoming.

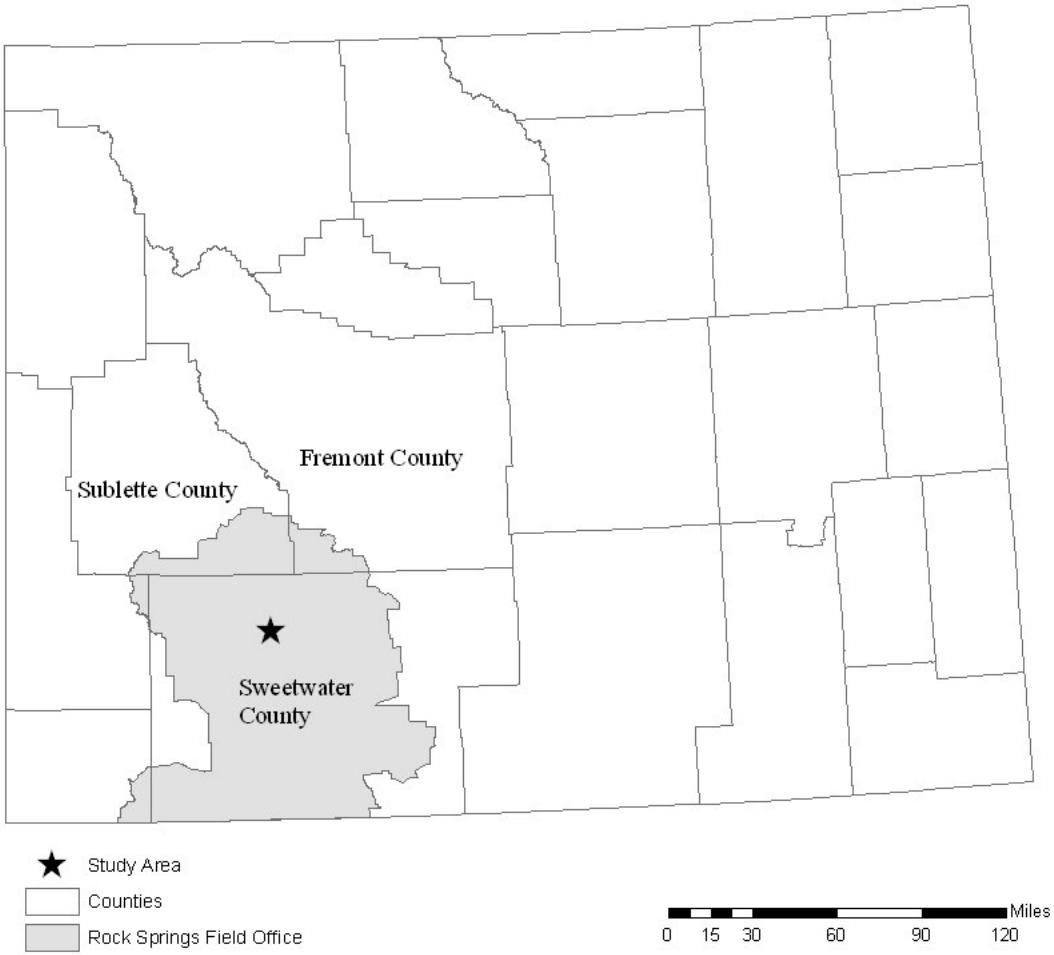


Figure 2. Layout of the nested, modified-Whittaker vegetation sampling plots.

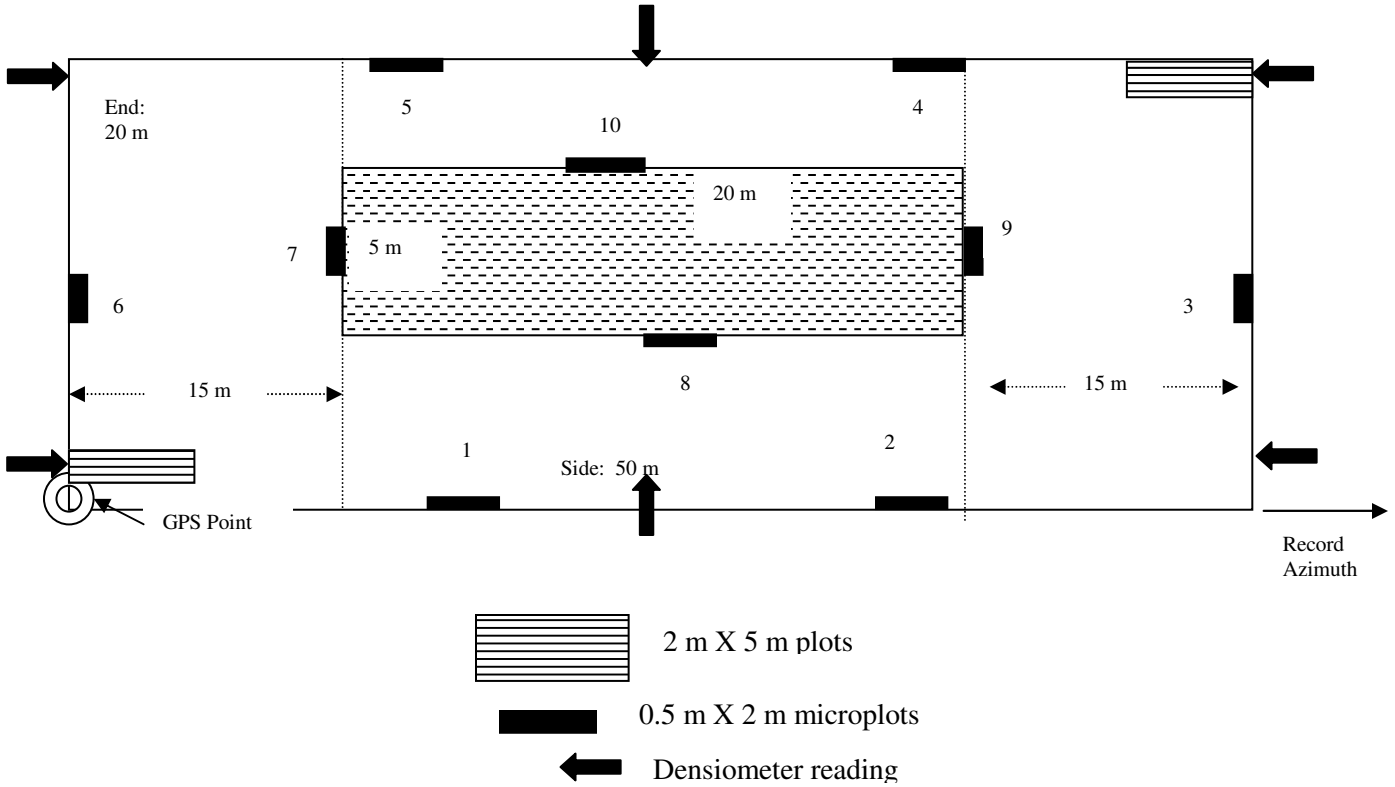


Figure 3. Locations of Sampling Plots.
See Table 4 for information about plots.

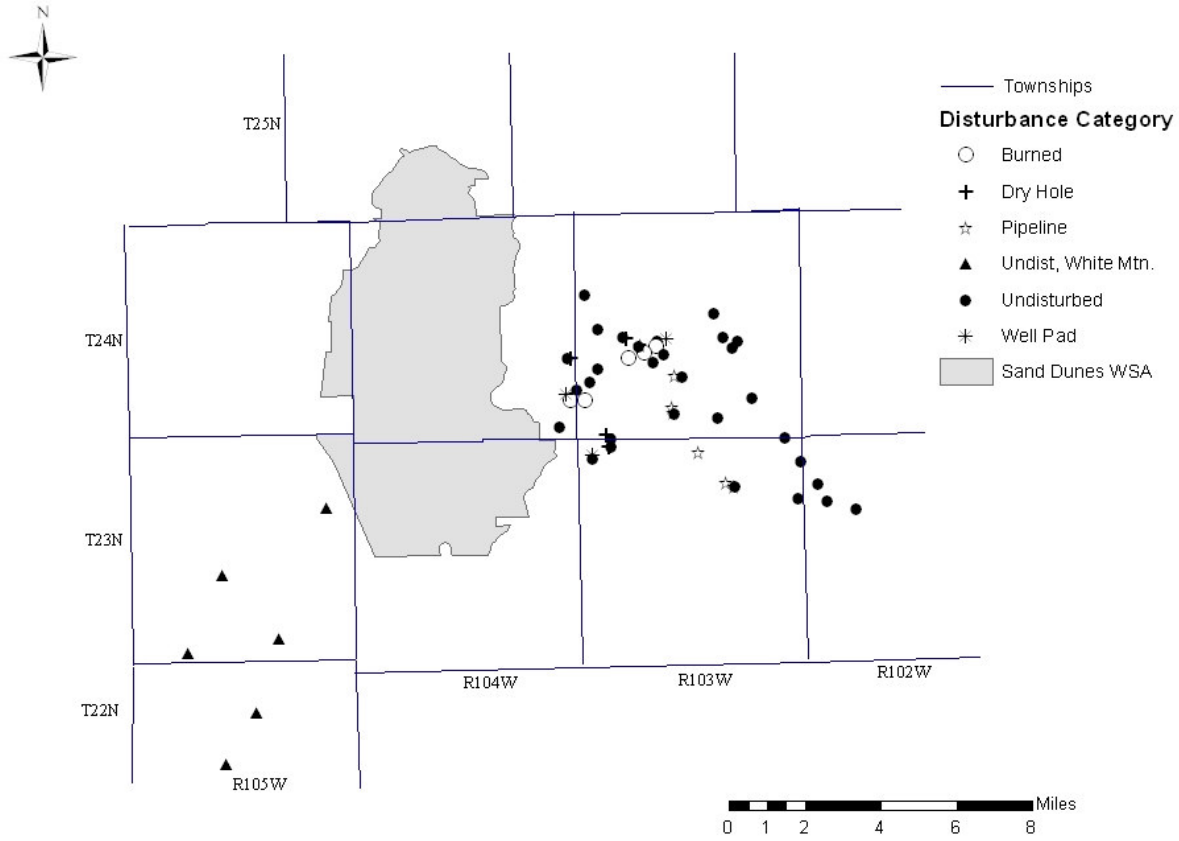


Figure 4. Frequency of occurrence of 119 plant taxa in 56 sample plots.

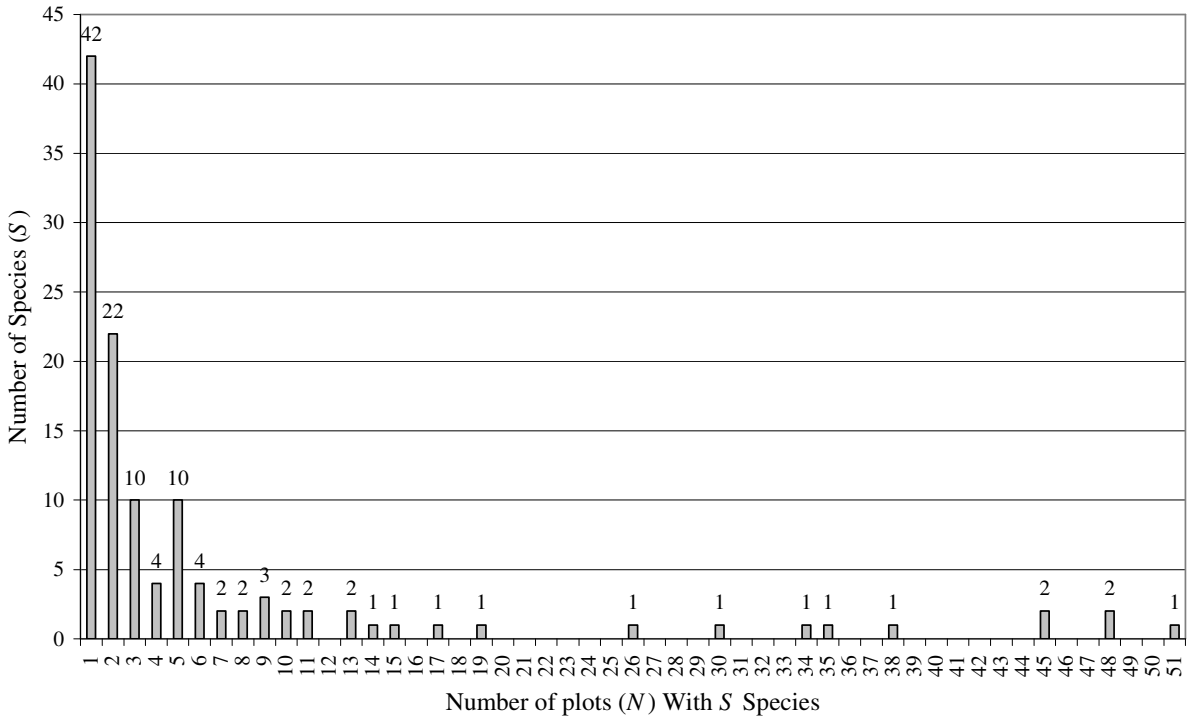
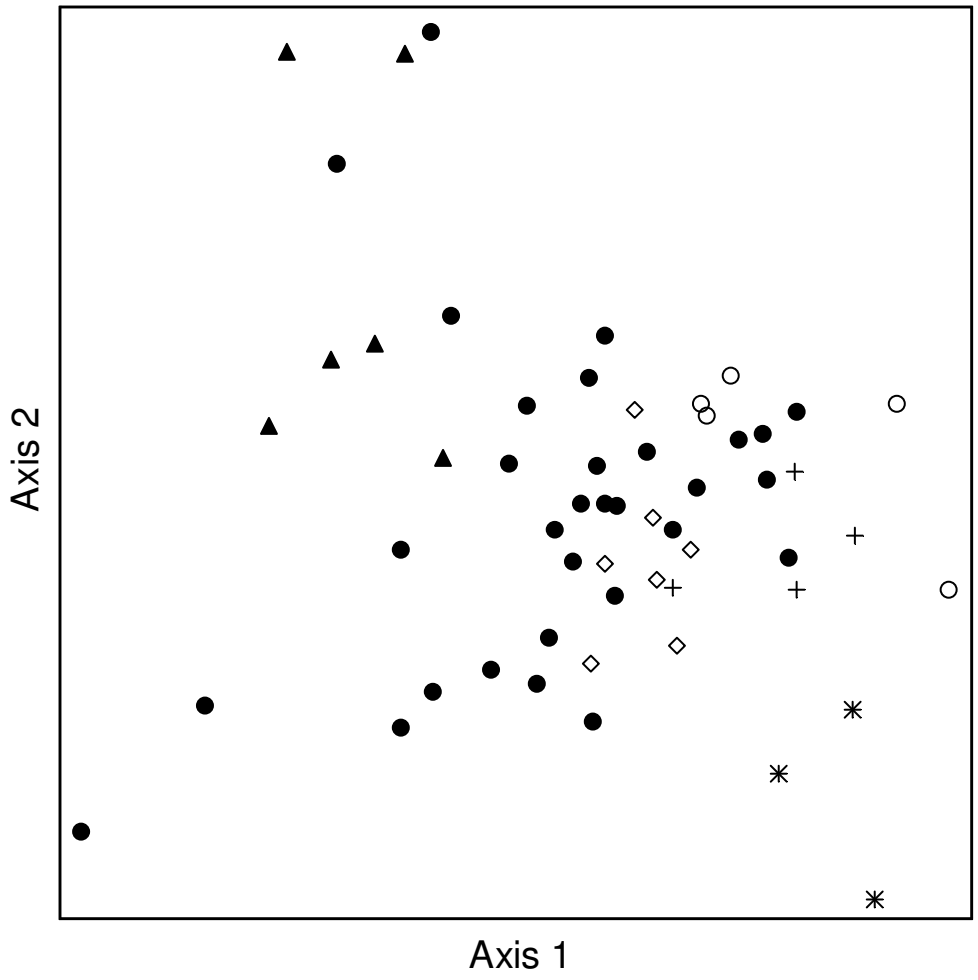


Figure 5. Ordination diagram based on transformed data, showing plots in different disturbance categories.



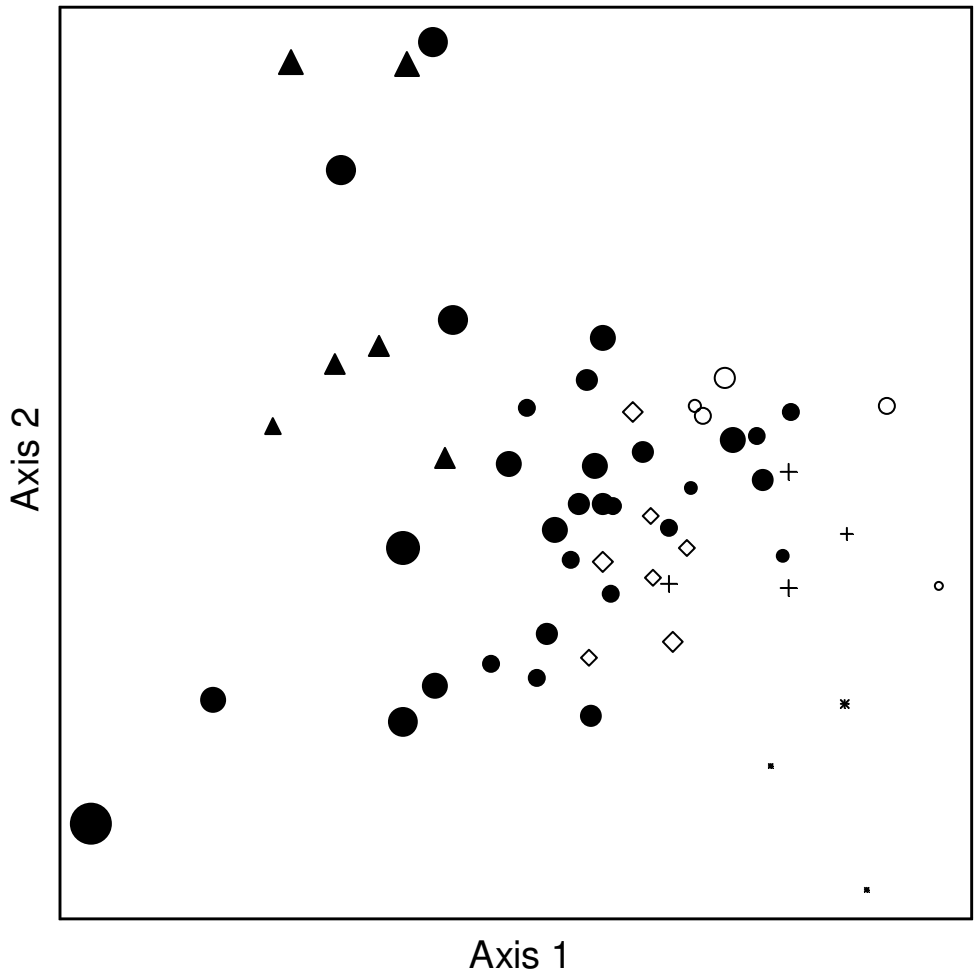

Disturbance Categories:

● Undisturbed, Killpecker Dunes & Steamboat Rim (n=31)

▲ Undisturbed, White Mountain (n=6) ○ Burned (n=5)

◊ Pipeline (n=7) + Dry-hole (n=4) * Well-pad (n=3)

Figure 6. Ordination diagram based on transformed data, showing plant canopy cover in each plot. Symbols indicate different categories of disturbance. Size of symbol represents the amount of plant canopy cover in a plot relative to the other plots.



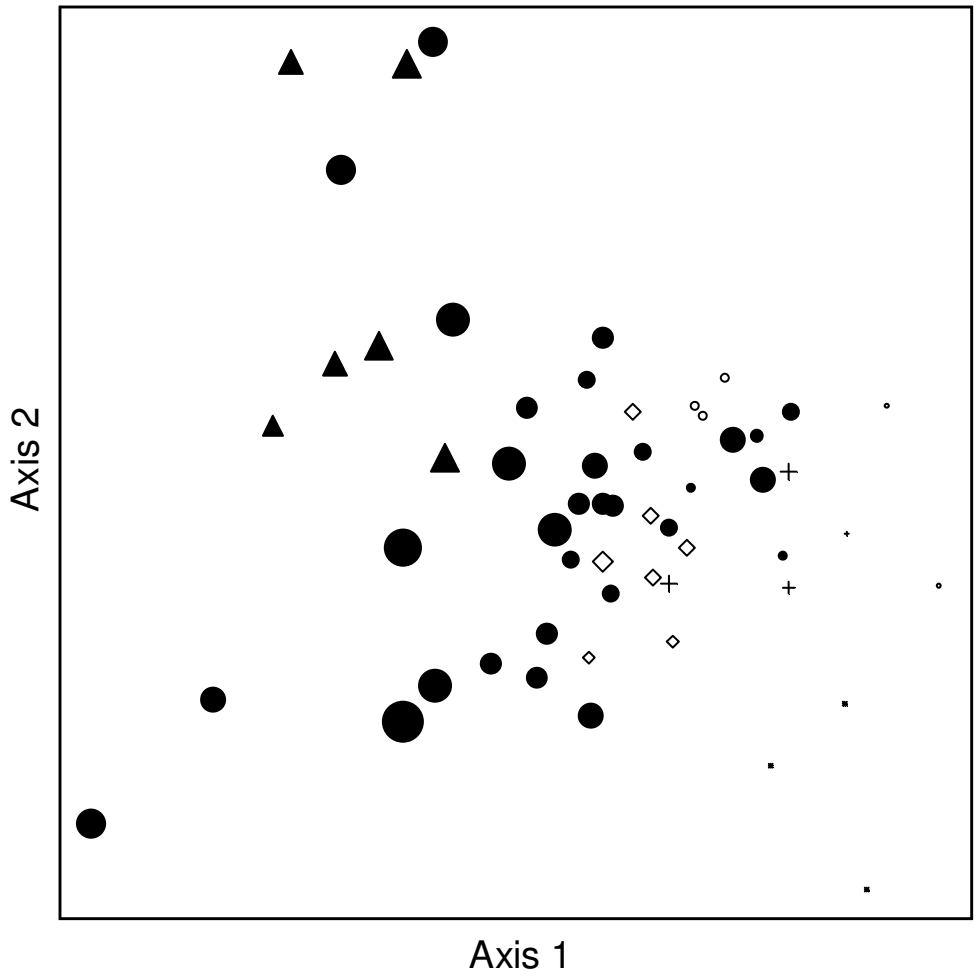

Disturbance Categories:

● Undisturbed, Killpecker Dunes & Steamboat Rim (n=31)

▲ Undisturbed, White Mountain (n=6) ○ Burned (n=5)

◊ Pipeline (n=7) + Dry-hole (n=4) * Well-pad (n=3)

Figure 7. Ordination diagram based on transformed data, showing shrub canopy cover. Symbols indicate different categories of disturbance. Size of symbol represents the amount of shrub canopy cover in a plot relative to the other plots.




Disturbance Categories:

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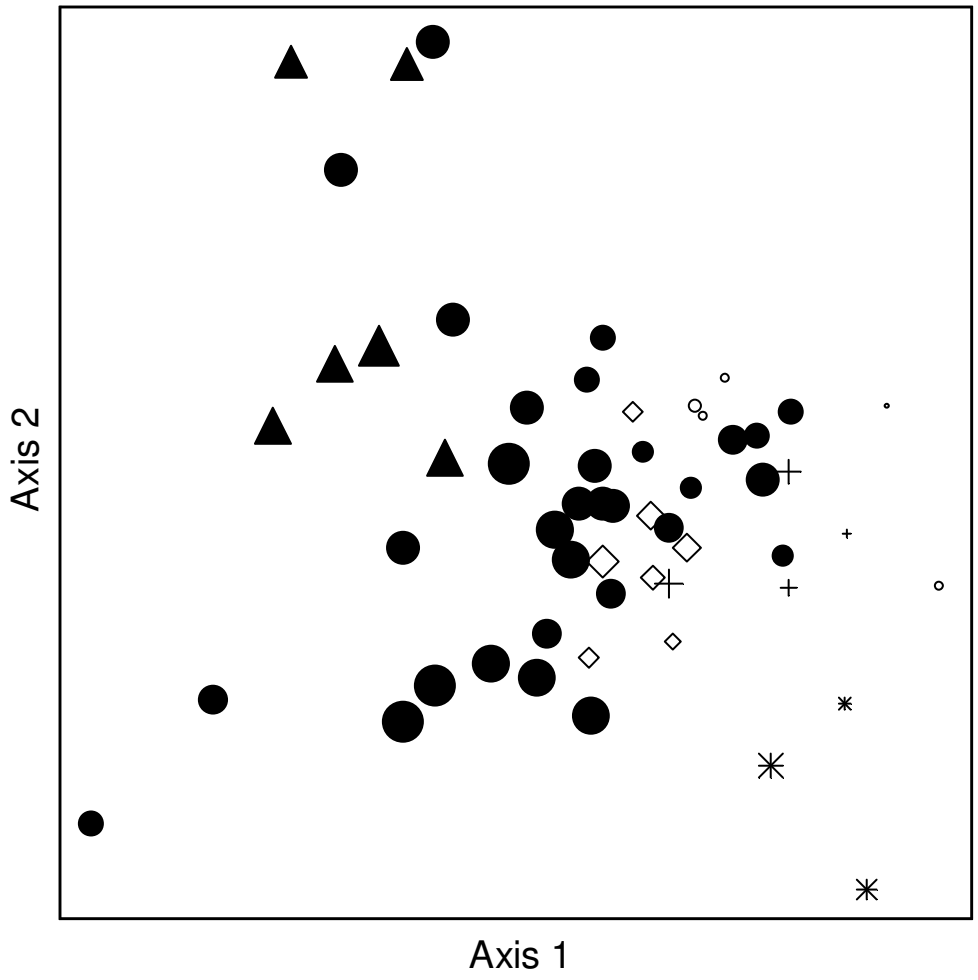
▲ Undisturbed, White Mountain (n=6) ○ Burned (n=5)

◊ Pipeline (n=7) + Dry-hole (n=4) * Well-pad (n=3)

Figure 8. Ordination diagram based on transformed data, showing relative shrub canopy cover. Symbols indicate different categories of disturbance. Size of symbol represents the amount of the canopy cover in each plot contributed by shrubs, relative to that in the other plots.




Disturbance Categories:

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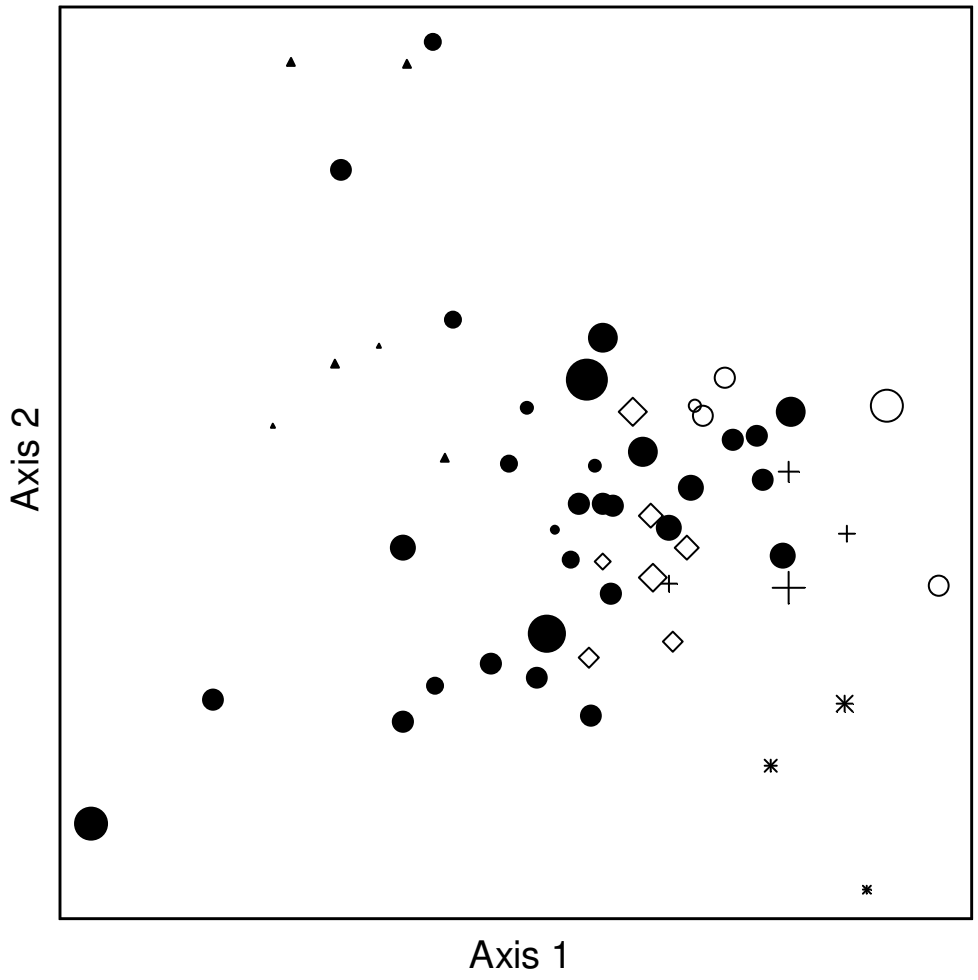
▲ Undisturbed, White Mountain (n=6) ○ Burned (n=5)

◊ Pipeline (n=7) + Dry-hole (n=4) * Well-pad (n=3)

Figure 9. Ordination diagram based on transformed data, showing forb canopy cover. Symbols indicate different categories of disturbance. Size of symbol represents the amount of forb canopy cover in a plot relative to the other plots.




Disturbance Categories:

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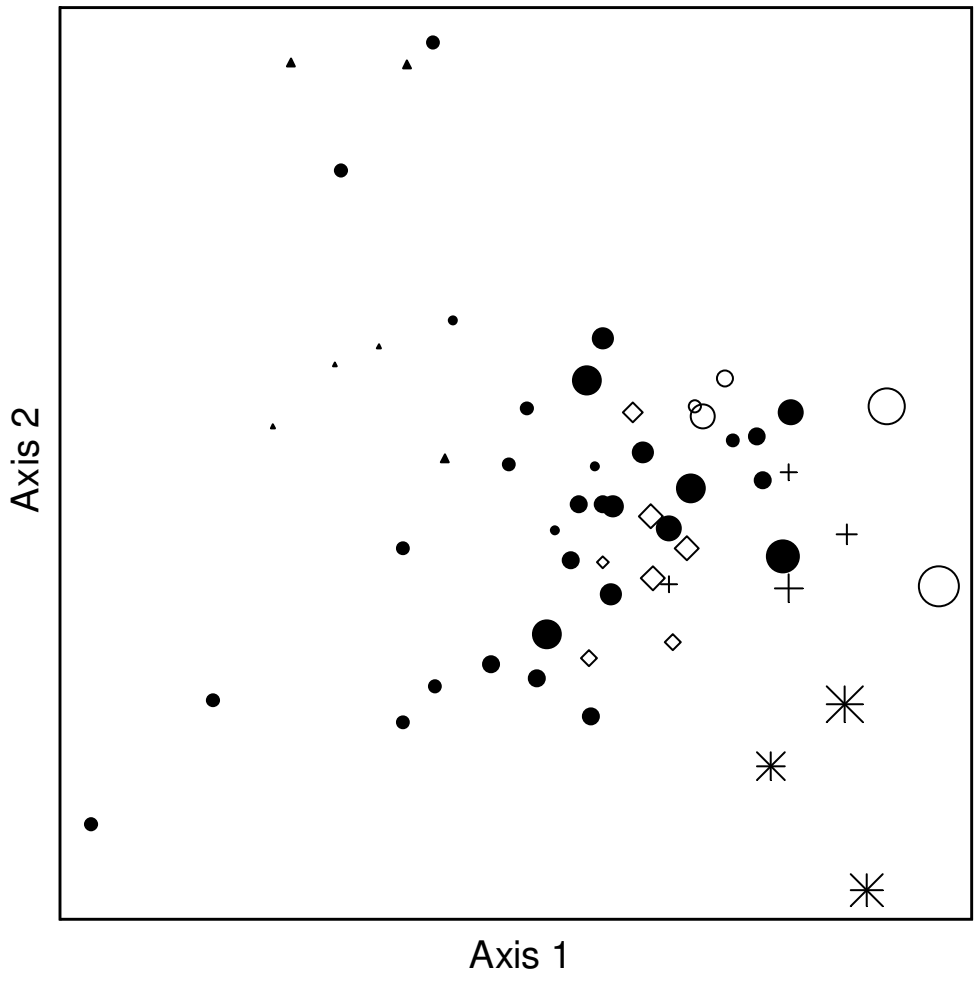
▲ Undisturbed, White Mountain (n=6) ○ Burned (n=5)

◊ Pipeline (n=7) + Dry-hole (n=4) * Well-pad (n=3)

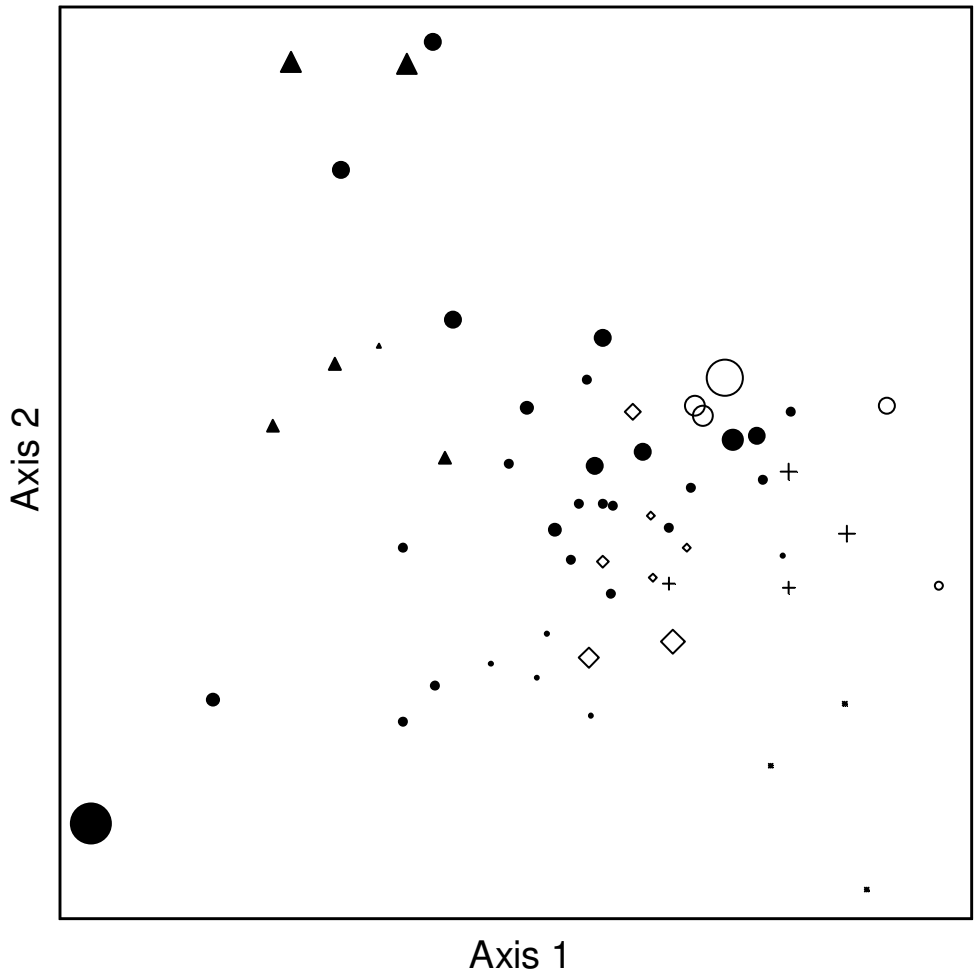
Figure 10. Ordination diagram based on transformed data, showing relative forb canopy cover. Symbols indicate different categories of disturbance. Size of symbol represents the amount of the canopy cover in each plot contributed by shrubs, relative to that in the other plots.




Disturbance Categories:

- ● Undisturbed, Killpecker Dunes & Steamboat Rim (n=31)
- ▲ Undisturbed, White Mountain (n=6)  ○ Burned (n=5)
- ◊ Pipeline (n=7)  + Dry-hole (n=4)  * Well-pad (n=3)

Figure 11. Ordination diagram based on transformed data, showing grass canopy cover. Symbols indicate different categories of disturbance. Size of symbol represents the amount of grass canopy cover in a plot relative to the other plots.




Disturbance Categories:

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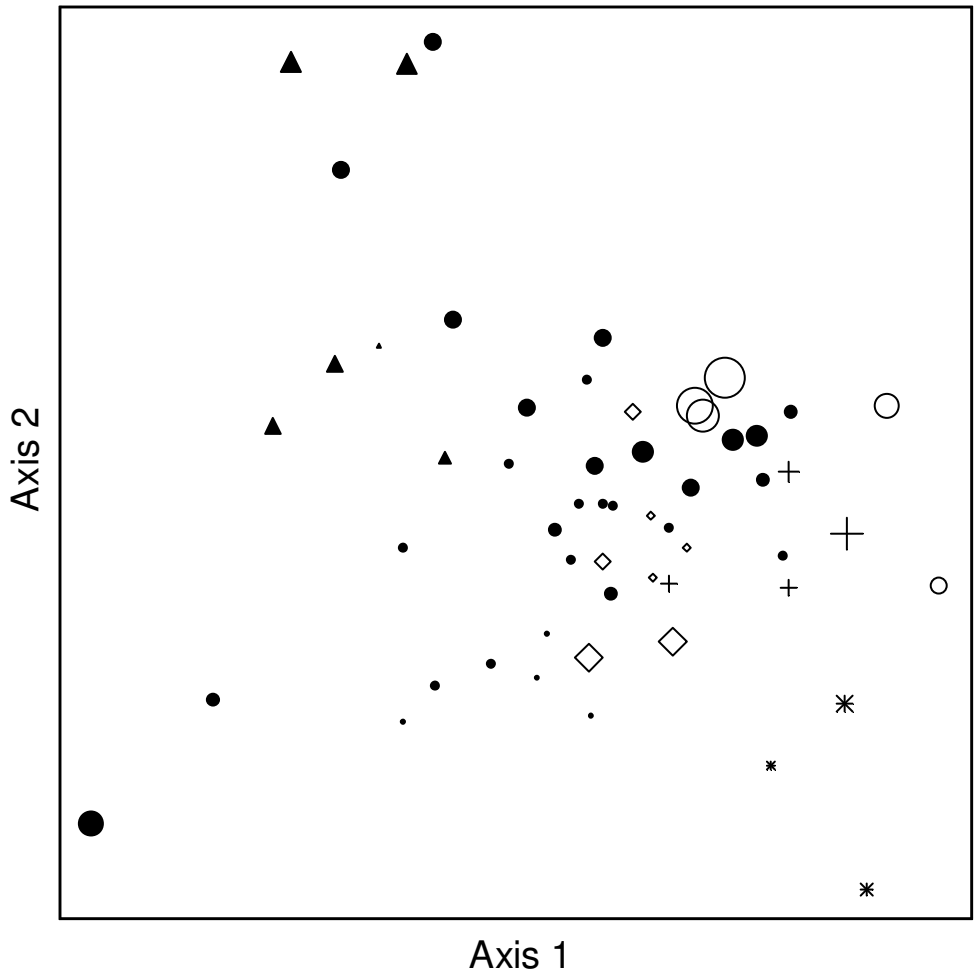
▲ Undisturbed, White Mountain (n=6) ○ Burned (n=5)

◊ Pipeline (n=7) + Dry-hole (n=4) * Well-pad (n=3)

Figure 12. Ordination diagram based on transformed data, showing relative grass canopy cover. Symbols indicate different categories of disturbance. Size of symbol represents the amount of the canopy cover in each plot contributed by shrubs, relative to that in the other plots.



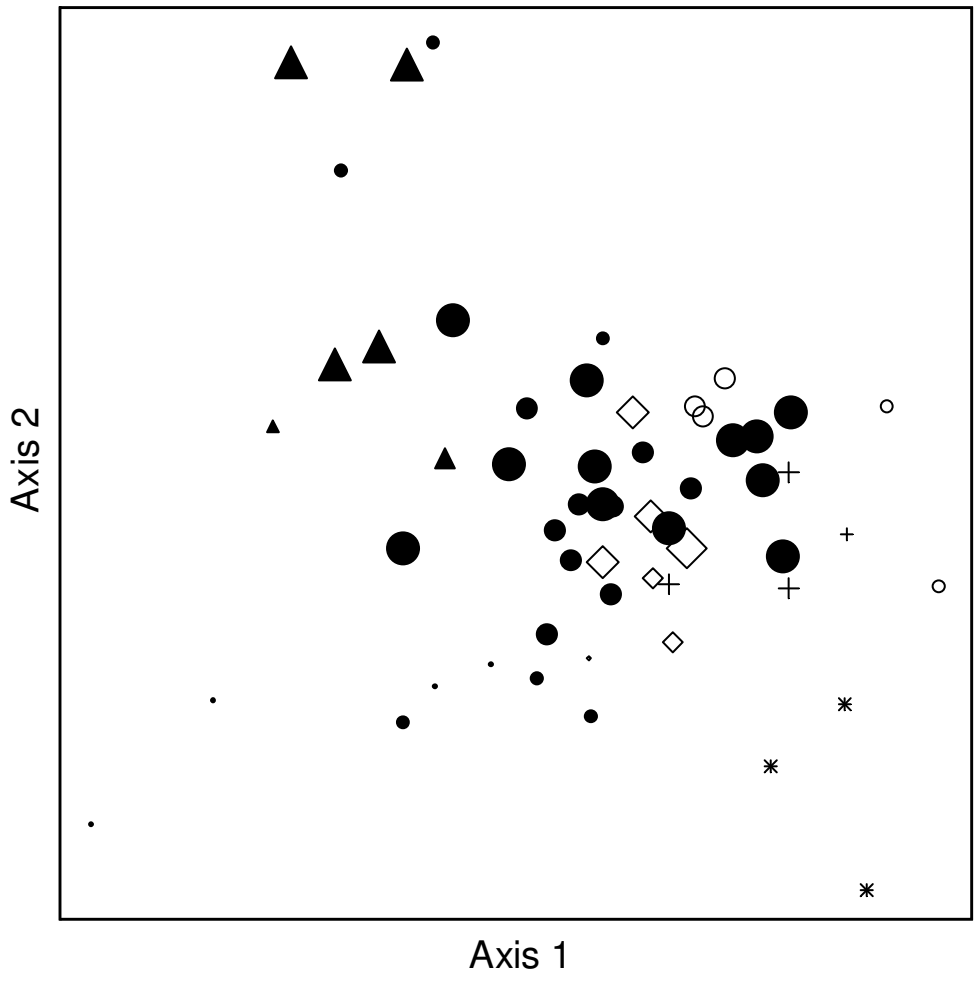

Disturbance Categories:

● Undisturbed, Killpecker Dunes & Steamboat Rim (n=31)

▲ Undisturbed, White Mountain (n=6) ○ Burned (n=5)

◊ Pipeline (n=7) + Dry-hole (n=4) * Well-pad (n=3)

Figure 13. Ordination diagram based on transformed data, showing *Chrysothamnus viscidiflorus* ssp. *viscidiflorus* canopy cover.
Symbols indicate different categories of disturbance. Size of symbol represents the amount of *Chrysothamnus viscidiflorus* ssp. *viscidiflorus* canopy cover in a plot relative to the other plots.

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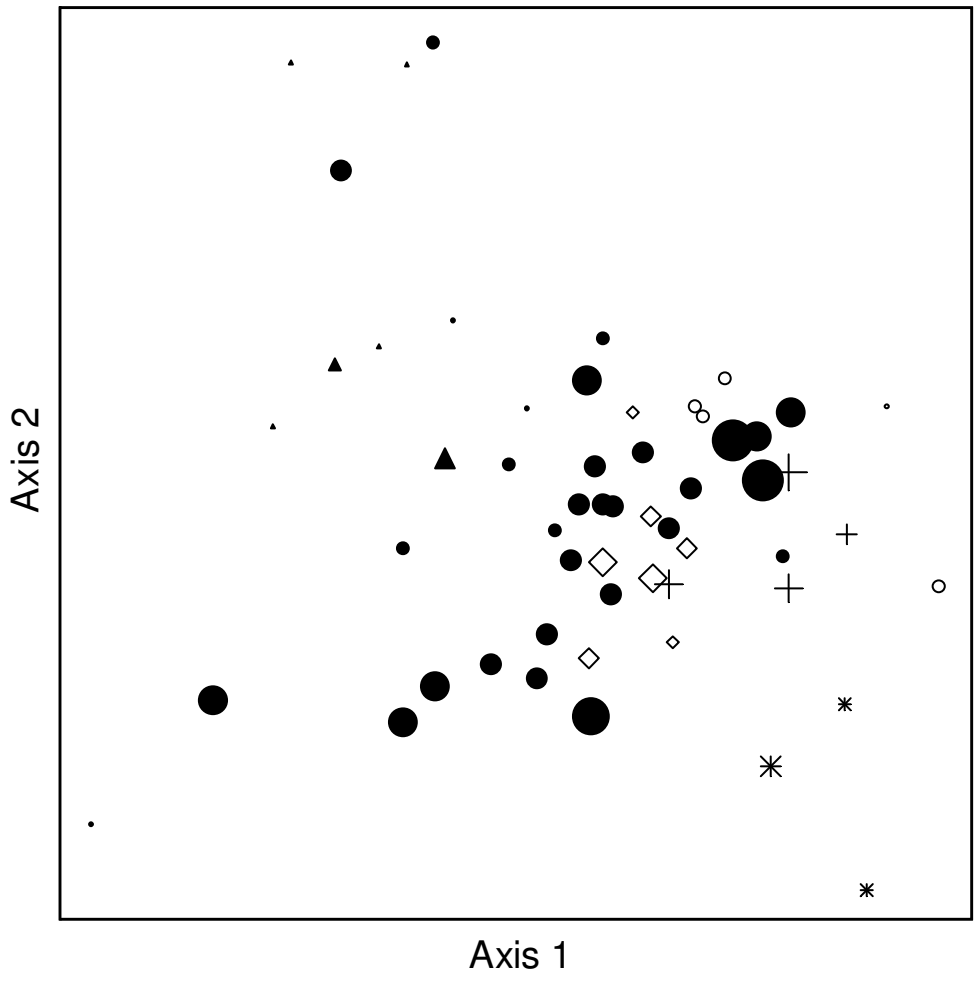
◊ Pipeline (n=7) + Dry-hole (n=4) * Well-pad (n=3)

Figure 14. Ordination diagram based on transformed data, showing *Ericameria nauseosa* forb canopy cover.
Symbols indicate different categories of disturbance. Size of symbol represents the amount of *Ericameria nauseosa* canopy cover in a plot relative to the other plots.



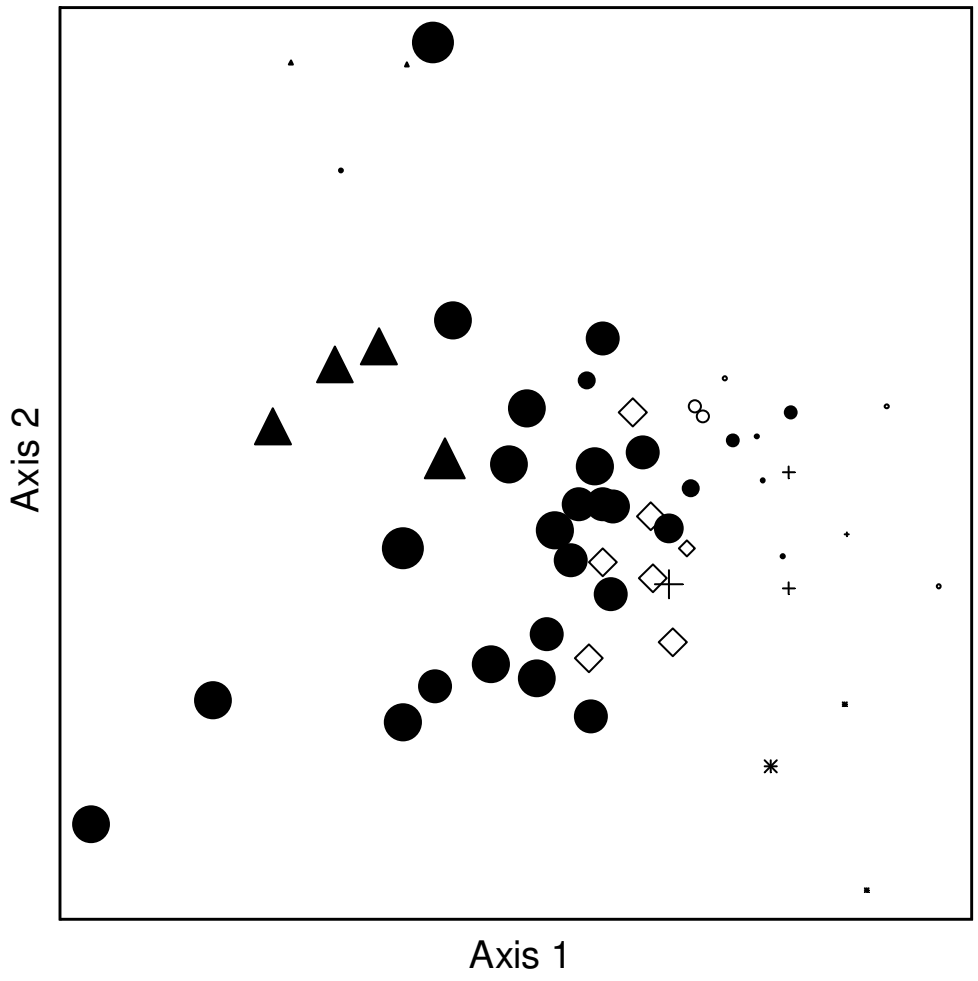

Disturbance Categories:

● Undisturbed, Killpecker Dunes & Steamboat Rim (n=31)

▲ Undisturbed, White Mountain (n=6) ○ Burned (n=5)

◊ Pipeline (n=7) + Dry-hole (n=4) * Well-pad (n=3)

Figure 15. Ordination diagram based on transformed data, showing *Artemisia tridentata* ssp. *tridentata* canopy cover.
Symbols indicate different categories of disturbance. Size of symbol represents the amount of *Artemisia tridentata* ssp. *tridentata* canopy cover in a plot relative to the other plots.



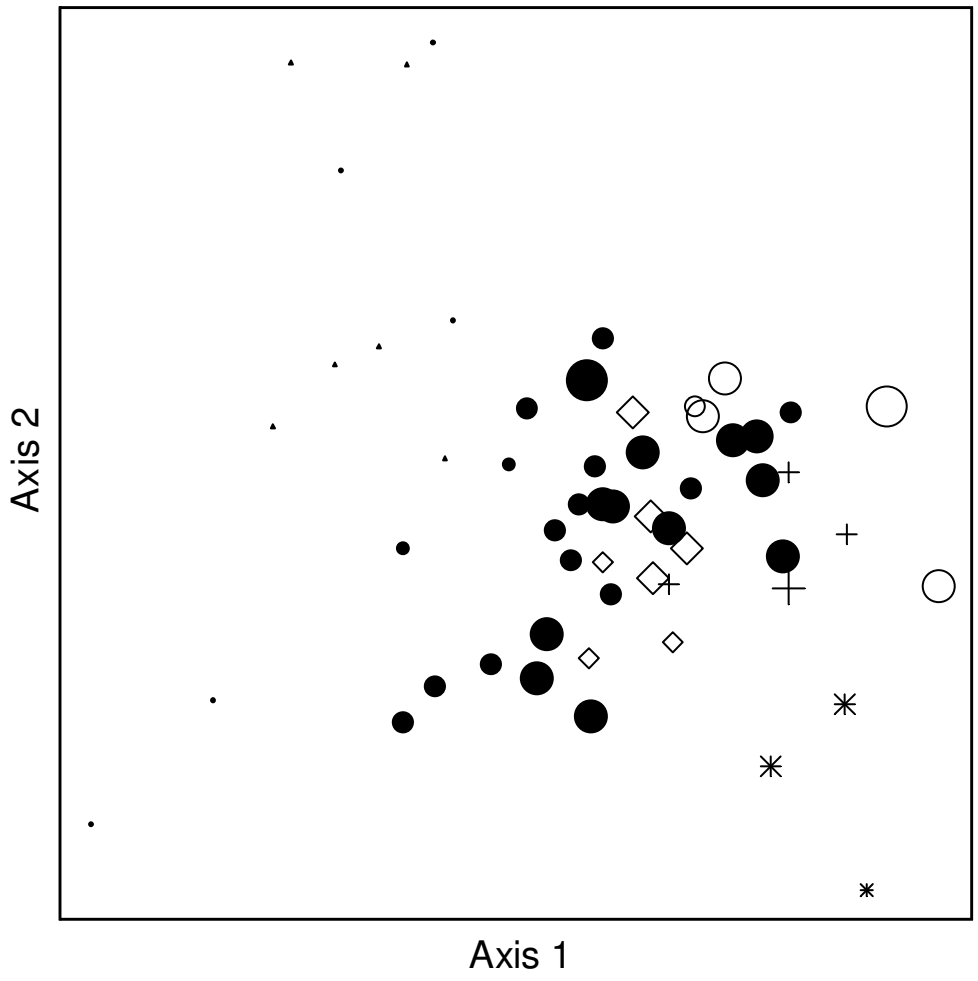

Disturbance Categories:

● Undisturbed, Killpecker Dunes & Steamboat Rim (n=31)

▲ Undisturbed, White Mountain (n=6) ○ Burned (n=5)

◊ Pipeline (n=7) + Dry-hole (n=4) * Well-pad (n=3)

Figure 16. Ordination diagram based on transformed data, showing *Psoralidium lanceolatum* canopy cover.
Symbols indicate different categories of disturbance. Size of symbol represents the amount of *Psoralidium lanceolatum* canopy cover in a plot relative to the other plots.




Disturbance Categories:

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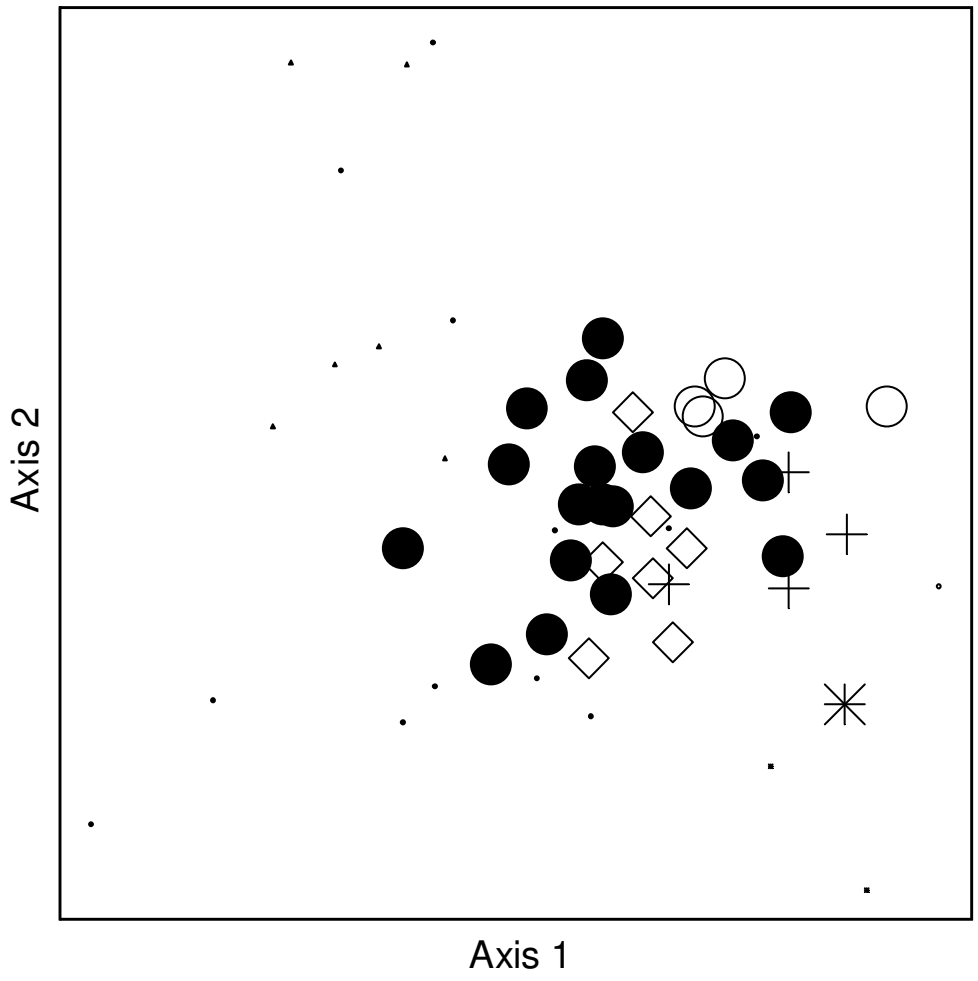
▲ Undisturbed, White Mountain (n=6) ○ Burned (n=5)

◊ Pipeline (n=7) + Dry-hole (n=4) * Well-pad (n=3)

Figure 17. Ordination diagram based on transformed data, showing *Machaeranthera canescens* ssp. *canescens* canopy cover.
Symbols indicate different categories of disturbance. Size of symbol represents the amount of *Machaeranthera canescens* ssp. *canescens* canopy cover in a plot relative to the other plots.



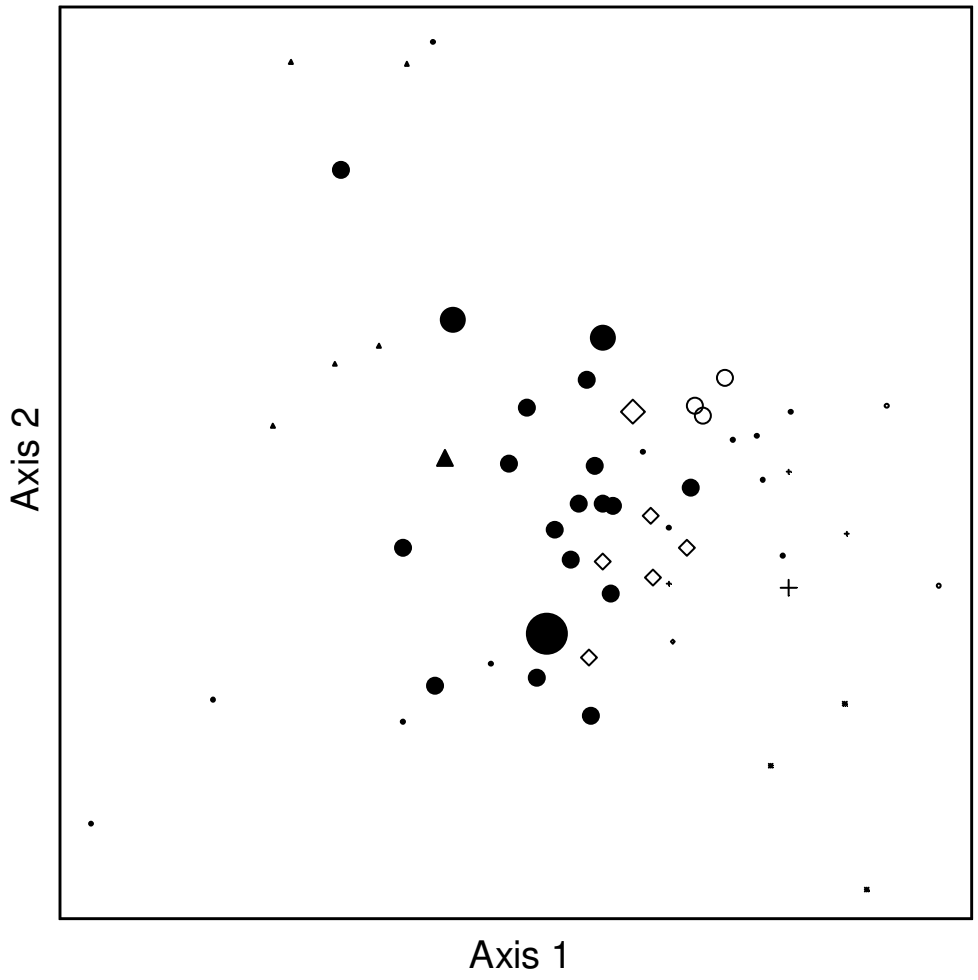

Disturbance Categories:

● Undisturbed, Killpecker Dunes & Steamboat Rim (n=31)

▲ Undisturbed, White Mountain (n=6) ○ Burned (n=5)

◊ Pipeline (n=7) + Dry-hole (n=4) * Well-pad (n=3)

Figure 18. Ordination diagram based on transformed data, showing *Comandra umbellata* canopy cover. Symbols indicate different categories of disturbance. Size of symbol represents the amount of *Comandra umbellata* canopy cover in a plot relative to the other plots.




Disturbance Categories:

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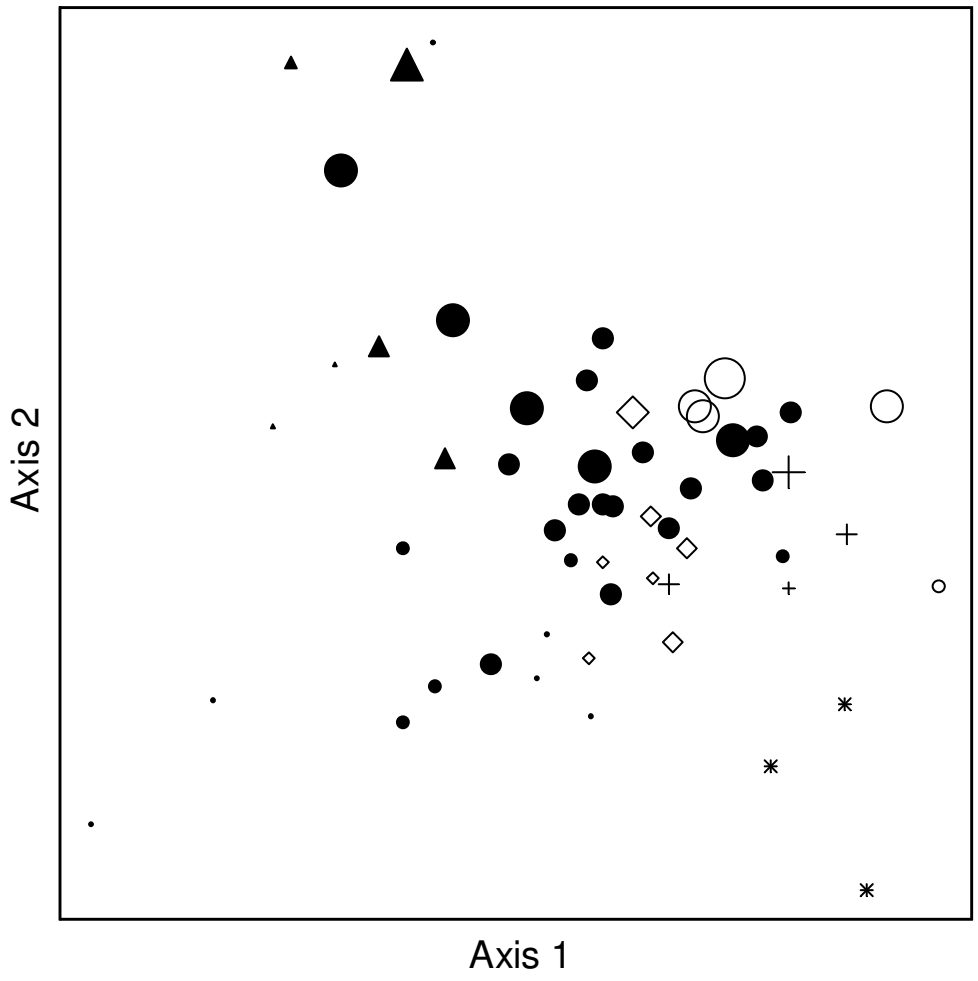
▲ Undisturbed, White Mountain (n=6) ○ Burned (n=5)

◊ Pipeline (n=7) + Dry-hole (n=4) * Well-pad (n=3)

Figure 19. Ordination diagram based on transformed data, showing *Achnatherum hymenoides* canopy cover.
Symbols indicate different categories of disturbance. Size of symbol represents the amount of *Achnatherum hymenoides* canopy cover in a plot relative to the other plots.

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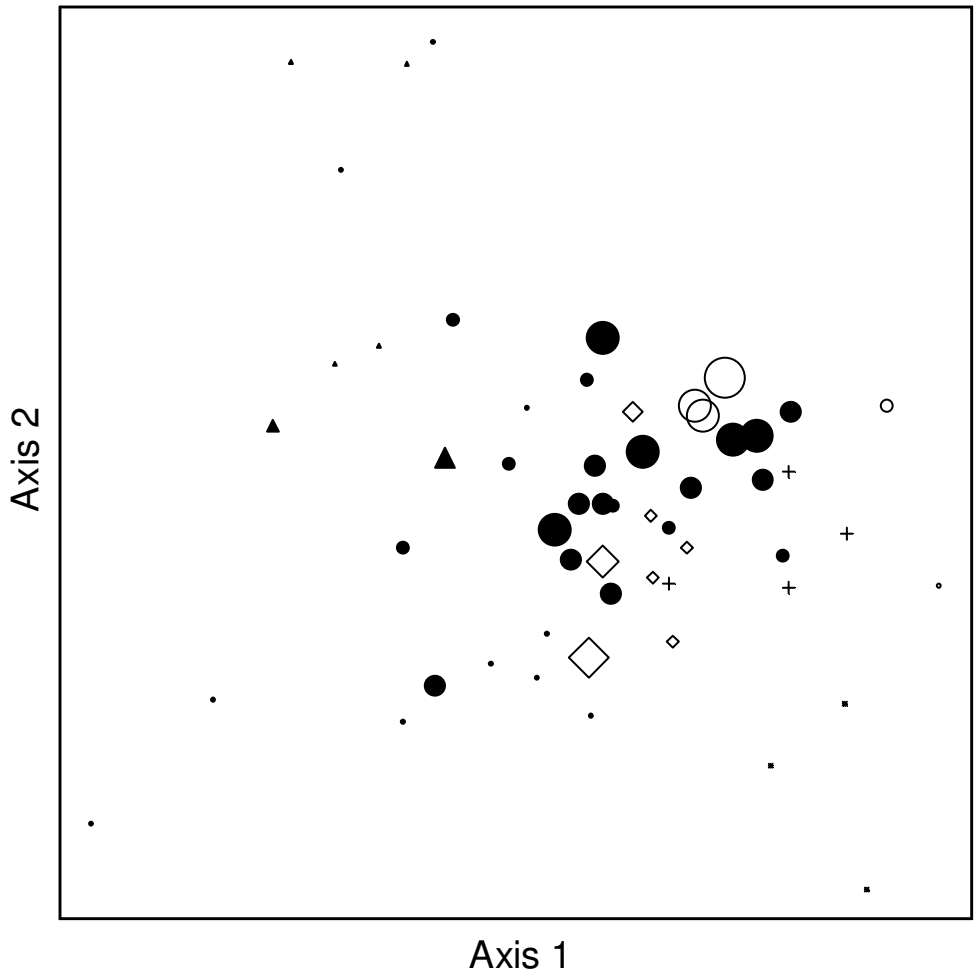
▲ Undisturbed, White Mountain (n=6) ○ Burned (n=5)

◊ Pipeline (n=7) + Dry-hole (n=4) * Well-pad (n=3)

Figure 20. Ordination diagram based on transformed data, showing *Hesperostipa comata* canopy cover. Symbols indicate different categories of disturbance. Size of symbol represents the amount of *Hesperostipa comata* canopy cover in a plot relative to the other plots.




Disturbance Categories:

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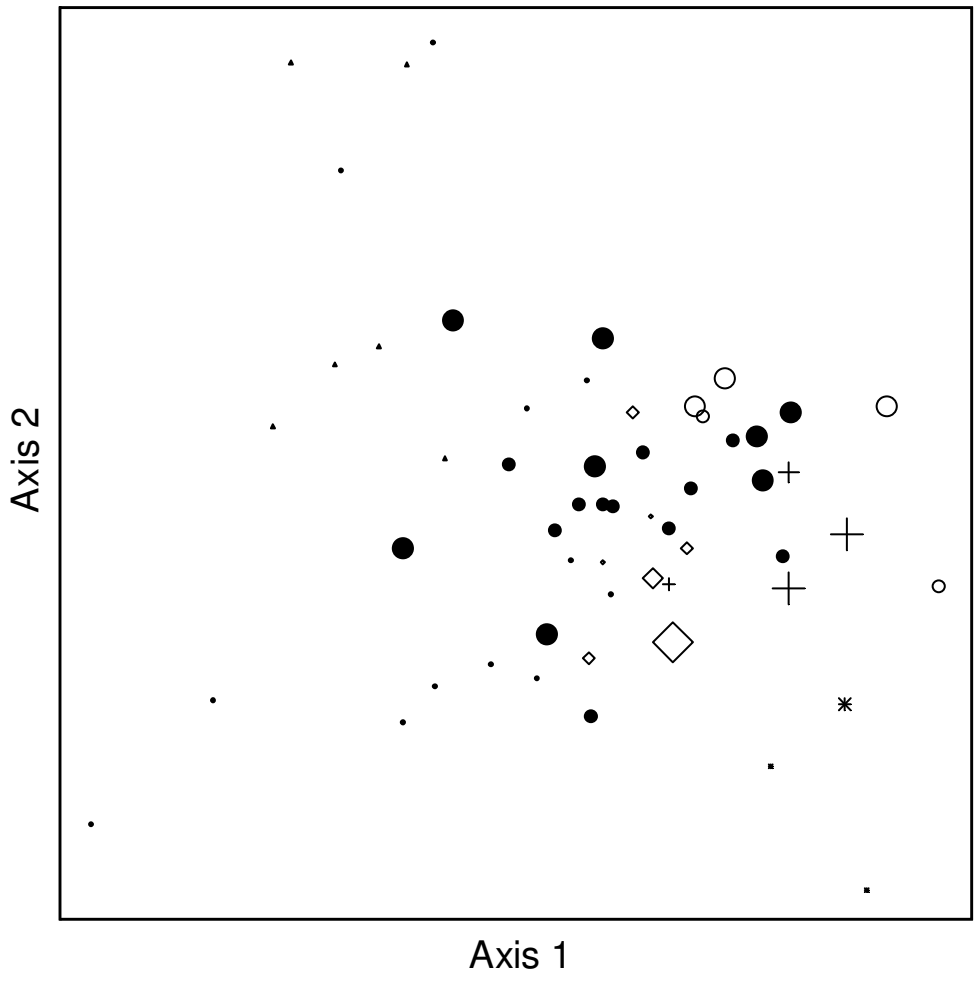
▲ Undisturbed, White Mountain (n=6) ○ Burned (n=5)

◊ Pipeline (n=7) + Dry-hole (n=4) * Well-pad (n=3)

Figure 21. Ordination diagram based on transformed data, showing *Elymus lanceolatus* ssp. *lanceolatus* canopy cover.
Symbols indicate different categories of disturbance. Size of symbol represents the amount of *Elymus lanceolatus* ssp. *lanceolatus* canopy cover in a plot relative to the other plots.




Disturbance Categories:

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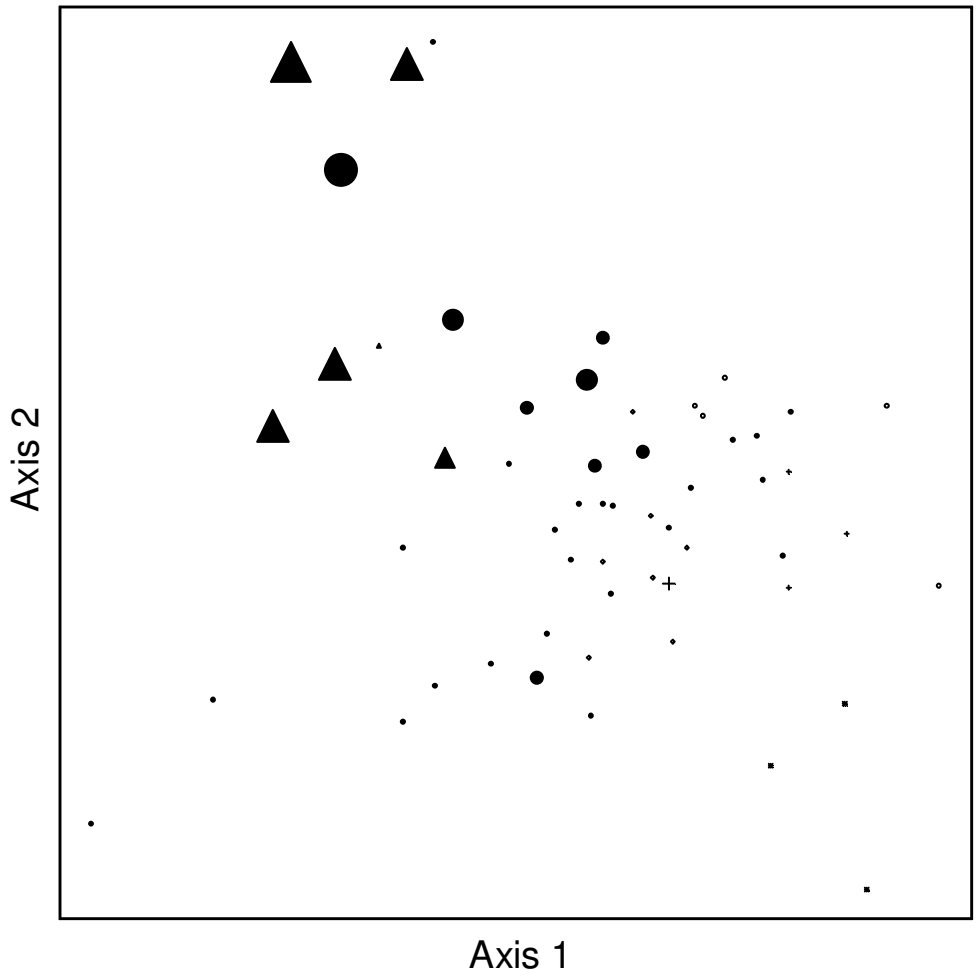
▲ Undisturbed, White Mountain (n=6) ○ Burned (n=5)

◊ Pipeline (n=7) + Dry-hole (n=4) * Well-pad (n=3)

Figure 22. Ordination diagram based on transformed data, showing *Poa secunda* canopy cover. Symbols indicate different categories of disturbance. Size of symbol represents the amount of *Poa secunda* canopy cover in a plot relative to the other plots.




Disturbance Categories:

● Undisturbed, Killpecker Dunes & Steamboat Rim (n=31)

▲ Undisturbed, White Mountain (n=6) ○ Burned (n=5)

◊ Pipeline (n=7) + Dry-hole (n=4) * Well-pad (n=3)

Figure 23. Vascular plant species richness (number of taxa) in plots of different disturbance categories.

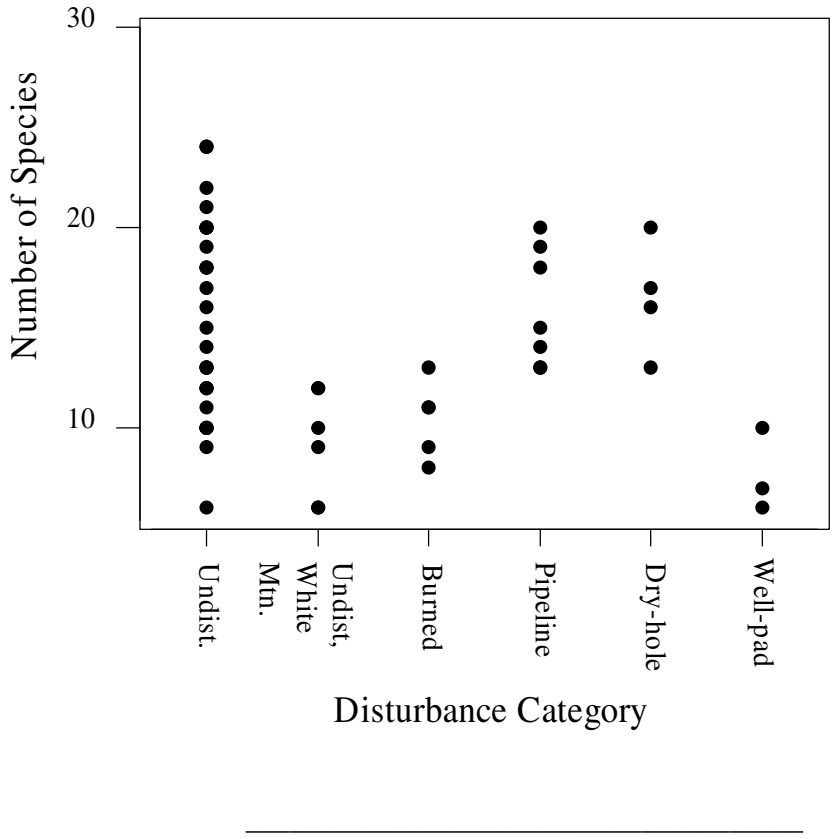
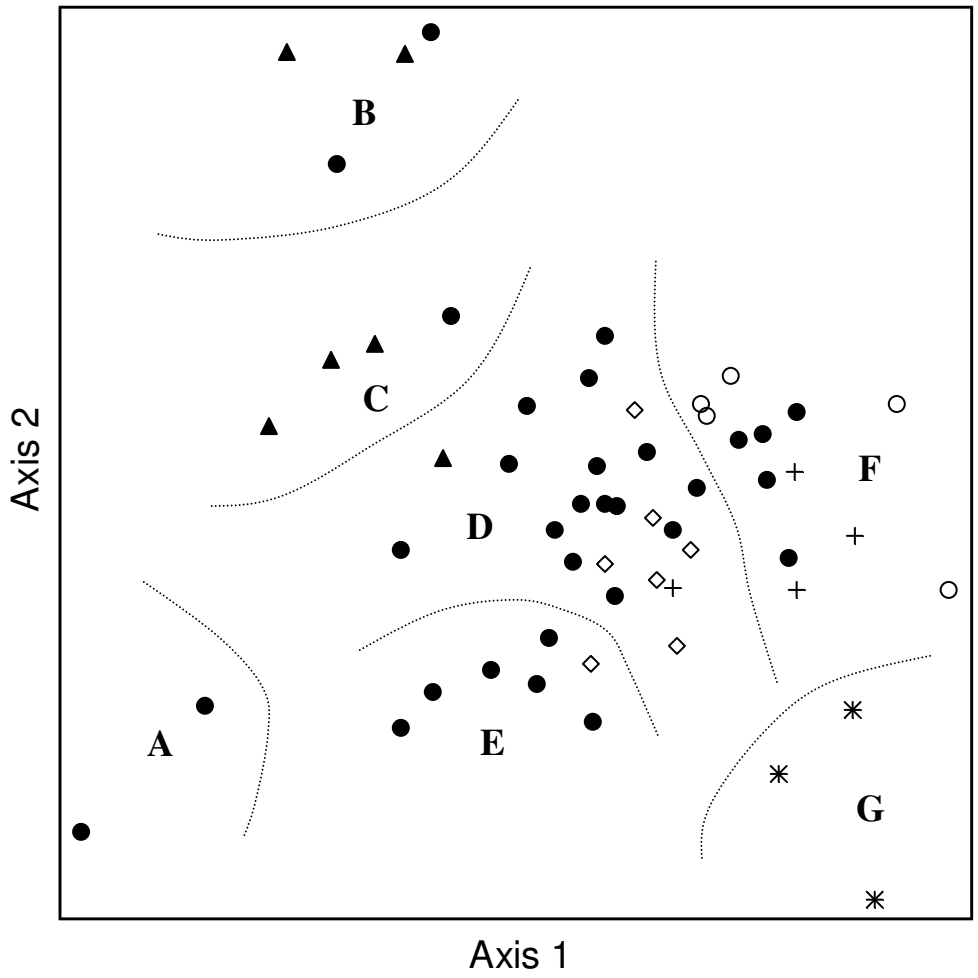


Figure 24. Ordination diagram based on transformed data, showing groups of plots based on species composition.
Symbols indicate different categories of disturbance. Letters identify groups (separated by lines) of plots with similar species composition.



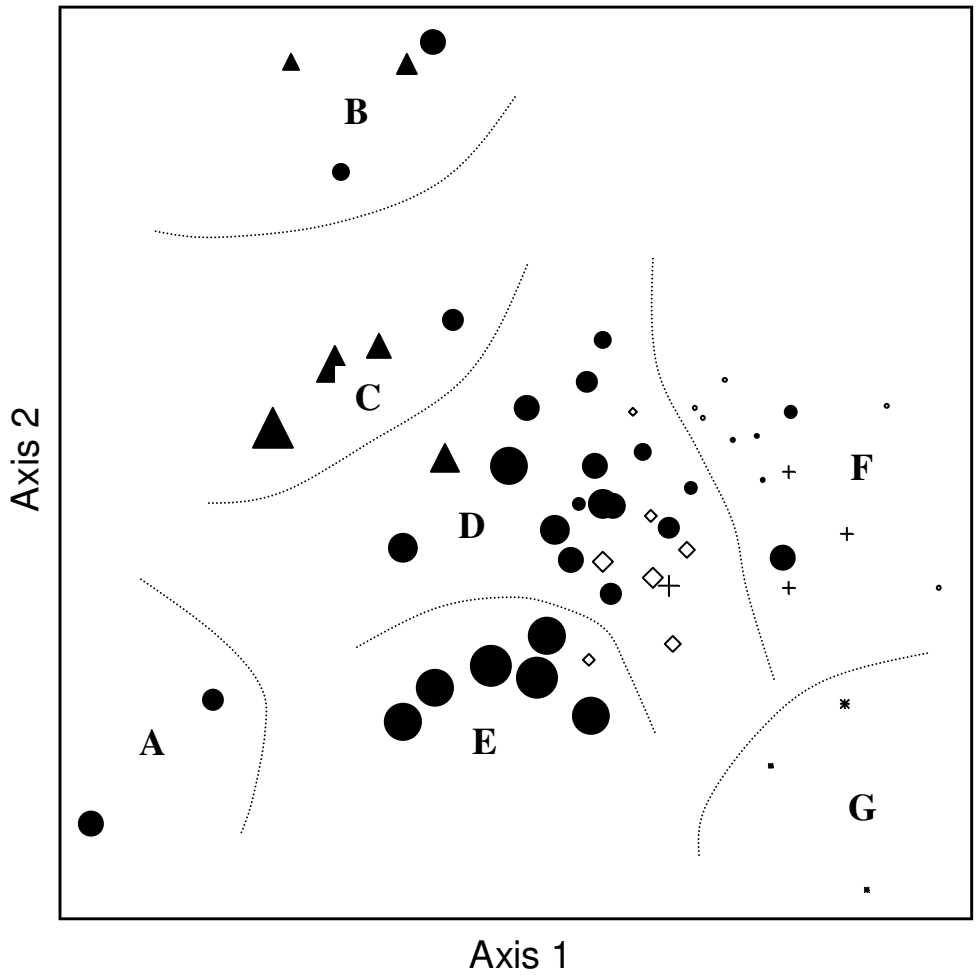

Disturbance Categories:

● Undisturbed, Killpecker Dunes & Steamboat Rim (n=31)

▲ Undisturbed, White Mountain (n=6) ○ Burned (n=5)

◊ Pipeline (n=7) + Dry-hole (n=4) * Well-pad (n=3)

Figure 25. Ordination diagram based on transformed data, showing height of the shrub canopy. Letters identify groups of plots (separated by lines) with similar species composition. Symbols indicate different categories of disturbance. The size of a symbol indicates height of the shrub canopy in a plot relative to other plots: the larger the symbol, the taller the shrub canopy. Smallest symbols indicate plots without shrubs.



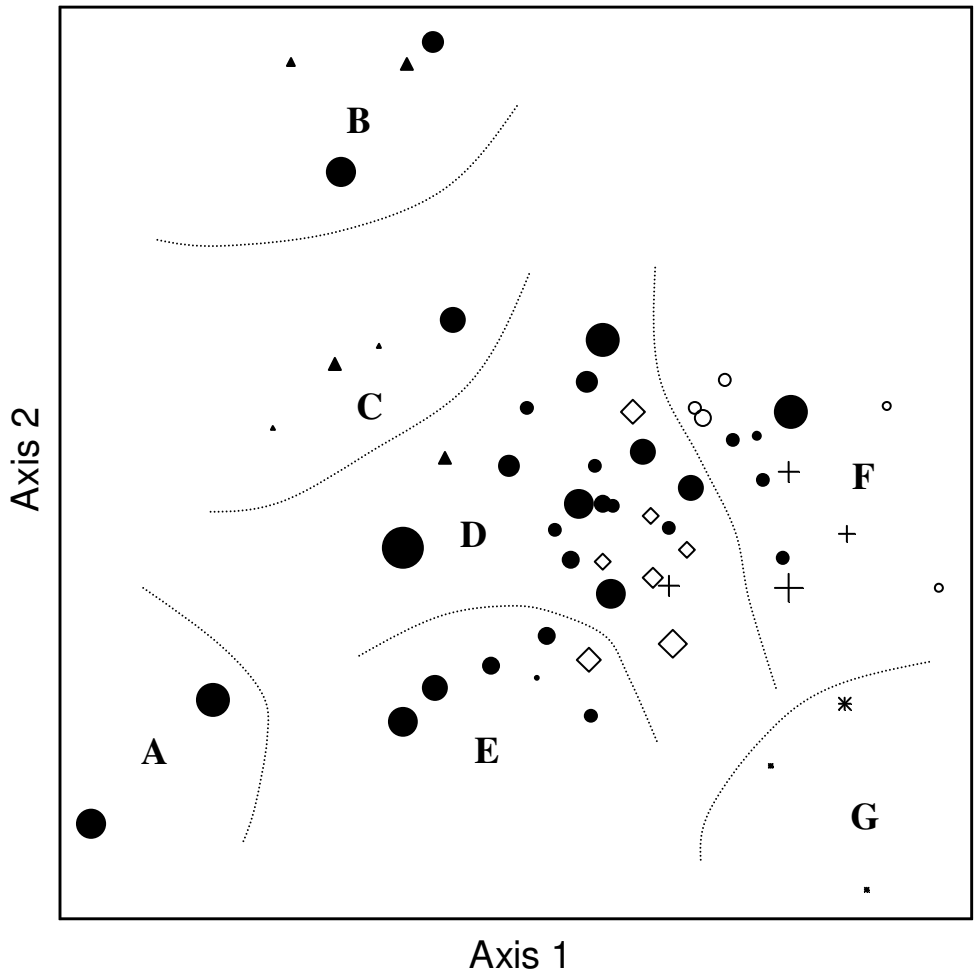

Disturbance Categories:

● Undisturbed, Killpecker Dunes & Steamboat Rim (n=31)

▲ Undisturbed, White Mountain (n=6) ○ Burned (n=5)

◊ Pipeline (n=7) + Dry-hole (n=4) * Well-pad (n=3)

Figure 26. Ordination diagram based on transformed data, showing relative numbers of vascular plant species in plots.
Letters identify groups of plots with similar species composition (separated by lines). Symbols indicate different categories of disturbance. The size of the symbol reflects the number of species in a plot relative to the number in other plots: the larger the symbol, the more species.



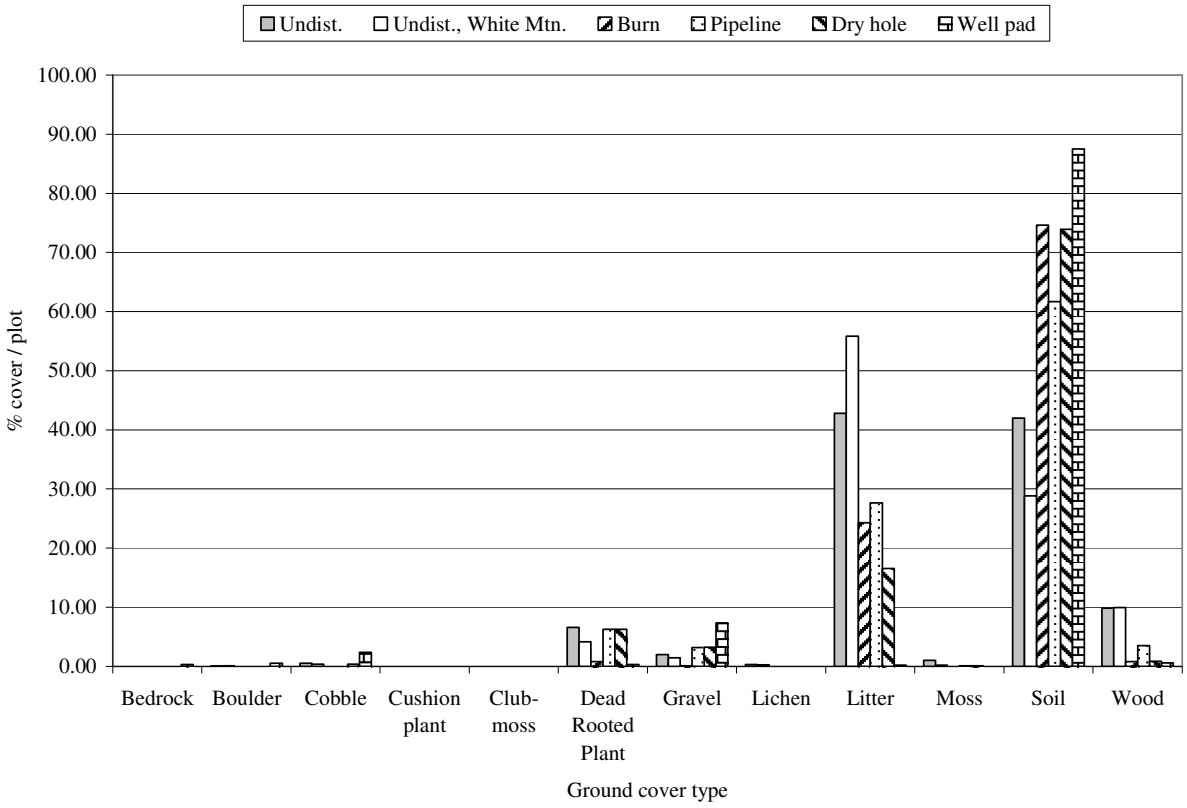

Disturbance Categories:

● Undisturbed, Killpecker Dunes & Steamboat Rim (n=31)

▲ Undisturbed, White Mountain (n=6) ○ Burned (n=5)

◊ Pipeline (n=7) + Dry-hole (n=4) * Well-pad (n=3)

Figure 27. Types of ground cover recorded in the plots, by disturbance category. Bars are average per-plot cover.



# TABLES

Table 1. Ranges and mid-points used in estimating canopy cover in the microplots.

| % cover | >1 | 1-5 | 5-15 | 15-25 | 25-35 | 35-45 | 45-55 | 55-65 | 65-75 | 75-85 | 85-95 | 95-99 | >99 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mid-point (value recorded) | 1 | 3 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 98 | 100 |

Table 2. Categories of ground cover recorded in the microplots.

| Category | Description |
|---|---|
| Bare Soil | Particles < 2 mm across |
| Bedrock | Consolidated rock |
| Boulder | Rocks > 250 mm across |
| Club moss | *Selaginella* sp. |
| Cobble | Rocks 75 mm - 250 mm across |
| Cushion-plant | Living cushion-form plant |
| Dead rooted plant | Dead plant material still rooted in the ground |
| Gravel | Particles 2 mm - 75 mm across |
| Litter | Loose organic matter < 6 mm across |
| Wood | Loose organic matter > 6 mm across |
| Lichen | Fruticose lichens on soil surface |
| Moss | Non-vascular plants other than lichens |

Table 3. Details on the NMS ordination of plot data.

a. Medium thoroughness settings for input parameters

| Parameter | Value |
|---|---|
| Similarity measure | Sorensen on log-transformed data |
| Starting configuration | Random, using time-of-day |
| Starting number of dimensions (axes) | 4 |
| Reduction in dimensionality at each cycle of each run | 1 |
| Maximum number of iterations in each run | 200 |
| Step length between each iteration | 0.2 |
| Instability criterion (standard deviation in stress over preceding 10 iterations) | 0.0001 |
| Number of runs with real data | 15 |
| Number of runs with randomized data for Monte Carlo test | 30 |

b. Results

| Parameter | Value |
|---|---|
| Number of final dimensions | 2 |
| Final stress for 2-d result | 19.96548 |
| Final instability | 0.0001 |
| Instability calculated over N iterations | 55 |
| Proportion of random runs with stress $\leq$ stress from runs with real data (i.e., probability from Monte Carlo test) | 0.0323 |
| Proportion of variance in original distance matrix represented by axis 1 | 0.588 |
| Proportion of variance in original distance matrix represented by axis 2 | 0.211 |

Table 4. Locations and disturbance categories of the 56 sample plots.
UTM coordinates are in NAD83, Zone 12N. See map in Figure 3.

| Plot Name | Disturbance Category | Northing | Easting | Township, Range, Section |
|---|---|---|---|---|
| 02EM04P | Pipeline | 4653228 | 658994 | T24N, R103W, Sec. 33 |
| 02EM05 | Undisturbed | 4651959 | 663821 | T23N, R103W, Sec. 1 |
| 02EM6P | Pipeline | 4654603 | 659073 | T24N, R103W, Sec. 28 |
| 02EM07 | Undisturbed | 4653614 | 662408 | T24N, R103W, Sec. 35 |
| 02EM08 | Undisturbed | 4656037 | 661770 | T24N, R103W, Sec. 23 |
| 02EM09 | Undisturbed | 4655739 | 661584 | T24N, R103W, Sec. 23 |
| 02EM09P | Well Pad | 4656148 | 658737 | T24N, R103W, Sec. 21 |
| 02EM10 | Undisturbed | 4656217 | 661189 | T24N, R103W, Sec. 22 |
| 02EM14 | Burned | 4653529 | 655249 | T24N, R103W, Sec. 30 |
| 02EM14P | Pipeline | 4652997 | 659016 | T24N, R103W, Sec. 33 |
| 02EM18 | Burned | 4655550 | 657789 | T24N, R103W, Sec. 20 |
| 02EM67 | Burned | 4655305 | 657149 | T24N, R103W, Sec. 20 |
| 02EM127 | Burned | 4655838 | 658293 | T24N, R103W, Sec. 21 |
| 02EM192 | Undisturbed | 4655297 | 657145 | T24N, R103W, Sec. 20 |
| 02EM721 | Undisturbed | 4654835 | 655812 | T24N, R103W, Sec. 30 |
| 02EM849 | Undisturbed | 4655455 | 658629 | T24N, R103W, Sec. 21 |
| 02EM1145 | Undisturbed | 4656025 | 658362 | T24N, R103W, Sec. 21 |
| 02EM1185 | Undisturbed | 4654305 | 655476 | T24N, R103W, Sec. 30 |
| 02EM1999 | Undisturbed | 4655148 | 658209 | T24N, R103W, Sec. 28 |
| 02EM2302 | Undisturbed | 4654550 | 659451 | T24N, R103W, Sec. 28 |
| 02EM2470 | Undisturbed | 4657979 | 655294 | T24N, R103W, Sec. 18 |
| 02EM2701 | Undisturbed | 4657242 | 660783 | T24N, R103W, Sec. 15 |
| 02EM3291 | Undisturbed | 4652769 | 660920 | T24N, R103W, Sec. 34 |
| 02EM3519 | Undisturbed | 4656569 | 655835 | T24N, R103W, Sec. 19 |
| 02NT02 | Undisturbed | 4649252 | 665610 | T23N, R102W, Sec. 7 |
| 02NT03 | Undisturbed | 4650956 | 664463 | T23N, R103W, Sec. 1 |
| 02NT3778 | Undisturbed | 4649375 | 664347 | T23N, R103W, Sec. 12 |
| 02OY94 | Burned | 4653498 | 654629 | T24N, R104W, Sec. 25 |
| 02OY193 | Undisturbed | 4653942 | 654908 | T24N, R103W, Sec. 30 |
| 02OY2312 | Undisturbed | 4652376 | 654181 | T24N, R104W, Sec. 36 |
| 02SM01 | Undisturbed | 4648903 | 666822 | T23N, R102W, Sec. 17 |
| 02TM02 | Pipeline | 4651325 | 660117 | T23N, R103W, Sec. 3 |
| 02TM03 | Well Pad | 4651207 | 655617 | T23N, R103W, Sec. 6 |

Table 4 (continued).

| Plot Name | Disturbance Category | Northing | Easting | Township, Range, Section |
|---|---|---|---|---|
| 02TM04 | Undisturbed | 4649950 | 665191 | T23N, R102W, Sec. 7 |
| 02TM05 | Pipeline | 4650044 | 661275 | T23N, R103W, Sec. 10 |
| 02TM29 | Pipeline | 4649848 | 661637 | T23N, R103W, Sec. 11 |
| 02TM1706 | Undisturbed | 4651068 | 655619 | T23N, R103W, Sec. 6 |
| 02TMX | Undisturbed | 4649888 | 661697 | T23N, R103W, Sec. 11 |
| 02WM06 | Undisturbed, White Mtn. | 4640287 | 641300 | T22N, R105W, Sec. 10 |
| 02WM15 | Undisturbed, White Mtn. | 4643406 | 642264 | T23N, R105W, Sec. 34 |
| 02WM16 | Undisturbed, White Mtn. | 4638051 | 640002 | T22N, R105W, Sec. 16 |
| 02WM17 | Undisturbed, White Mtn. | 4642797 | 638396 | T23N, R105W, Sec. 32 |
| 02WP04 | Well Pad | 4653799 | 654511 | T24N, R104W, Sec. 25 |
| 02WR01 | Undisturbed, White Mtn. | 4646114 | 639818 | T23N, R105W, Sec. 21 |
| 02WR13 | Undisturbed, White Mtn. | 4648959 | 644243 | T23N, R105W, Sec. 12 |
| 03TS01 | Pipeline | 4655884 | 657602 | T24N, R103W, Sec. 20 |
| 03TS02 | Undisturbed | 4655823 | 657578 | T24N, R103W, Sec. 20 |
| 03TS03 | Undisturbed | 4655298 | 654545 | T24N, R104W, Sec. 24 |
| 03TS04 | Dry Hole | 4655336 | 654626 | T24N, R104W, Sec. 24 |
| 03TS05 | Dry Hole | 4656178 | 657015 | T24N, R103W, Sec. 20 |
| 03TS06 | Undisturbed | 4656219 | 656886 | T24N, R103W, Sec. 20 |
| 03TS07 | Undisturbed | 4652925 | 659080 | T24N, R103W, Sec. 33 |
| 03TS08 | Dry Hole | 4652048 | 656195 | T24N, R103W, Sec. 31 |
| 03TS09 | Undisturbed | 4651884 | 656376 | T23N, R103W, Sec. 6 |
| 03TS10 | Dry Hole | 4651552 | 656285 | T23N, R103W, Sec. 6 |
| 03TS11 | Undisturbed | 4651567 | 656406 | T23N, R103W, Sec. 6 |

Table 5. One-hundred nineteen plant taxa documented in 56 sample plots, sorted by name. Exotic taxa are shown in italic typeface. Species names are from the PLANTS database (USDA Natural Resources Conservation Service 2002).

| Species Name | NRCS Code | # of plots (n=56) |
|---|---|---|
| achnatherum hymenoides, indian ricegrass | achy | 48 |
| achnatherum sp., ricegrass | achna | 1 |
| *agropyron cristatum, crested wheatgrass* | *agcr* | *5* |
| *agropyron desertorum, desert wheatgrass* | *agde2* | *1* |
| *alyssum desertorum, desert madwort* | *alde* | *2* |
| antennaria, pussytoes | anten | 1 |
| arabis cobrensis, sagebrush rockcress | arco | 9 |
| arenaria hookeri, hooker's sandwort | arho4 | 9 |
| artemisia dracunculus, wormwood | ardr4 | 3 |
| artemisia nova, black sagebrush | arno4 | 1 |
| artemisia tridentata ssp. tridentata, basin big sagebrush | artrt | 45 |
| artemisia tridentata ssp. wyomingensis, wyoming big sagebrush | artrw8 | 5 |
| astragalus geyeri, geyer's milkvetch | asge | 1 |
| astragalus kentrophyta var. elatus, tall spiny milkvetch | askee | 2 |
| astragalus kentrophyta, spiny milkvetch | aske | 5 |
| astragalus megacarpus, great bladdery milkvetch | asme2 | 1 |
| astragalus sp., milkvetch | astra | 1 |
| atriplex sp., saltbush | atrip | 1 |
| balsamorhiza sagittata, arrowleaf balsamroot | basa3 | 1 |
| *bromus inermis* ssp. *inermis, smooth brome* | *brini* | *4* |
| *bromus tectorum, cheatgrass* | *brte* | *1* |
| castilleja linariifolia, wyoming indian paintbrush | cali4 | 2 |
| cercocarpus ledifolius, curlleaf mountain mahogany | cele3 | 7 |
| chaenactis douglasii var. douglasii, douglas's dustymaiden | chdod | 1 |
| chaenactis douglasii, douglas's dustymaiden | chdo | 5 |
| chenopodium atrovirens, pinyon goosefoot | chat | 9 |
| chenopodium pratericola, desert goosefoot | chpr5 | 8 |
| chrysothamnus viscidiflorus ssp. lanceolatus, yellow rabbitbrush | chvil4 | 2 |
| chrysothamnus viscidiflorus ssp. viscidiflorus, yellow rabbitbrush | chviv2 | 51 |
| cirsium, thistle | cirsi | 3 |
| comandra umbellata, bastard toadflax | coum | 30 |
| cordylanthus ramosus, bushy bird's beak | cora5 | 5 |
| corispermum villosum, hairy bugseed | covi5 | 1 |
| crepis acuminata, longleaf hawksbeard | crac2 | 1 |
| cryptantha cana, mountain catseye | crca8 | 1 |
| cryptantha fendleri, sanddune catseye | crfe3 | 7 |
| cryptantha flavoculata, roughseed catseye | crfl6 | 5 |
| cryptantha sericea, silky catseye | crse3 | 2 |
| cryptantha sp., cryptantha | crypt | 13 |
| cryptantha watsonii, watson's catseye | crwa2 | 13 |
| *descurainia sophia, herb sophia* | *deso2* | *5* |
| elymus elymoides, bottlebrush squirreltail | elel5 | 5 |
| elymus lanceolatus ssp. lanceolatus, thickspike wheatgrass | ellal | 34 |
| elymus trachycaulus ssp. trachycaulus, slender wheatgrass | eltrt | 1 |

Table 5 (continued).

| Species Name | NRCS Code | # of plots (n=56) |
|---|---|---|
| ericameria nauseosa, rubber rabbitbrush | erna10 | 48 |
| eriogonum cernuum var. cernuum, nodding buckwheat | ercec | 2 |
| eriogonum cernuum, nodding buckwheat | erce2 | 2 |
| eriogonum microthecum var. laxiflorum, slender buckwheat | ermil2 | 2 |
| eriogonum ovalifolium var. purpureum, cushion buckwheat | erovp2 | 1 |
| eriogonum sp., eriogonum | eriog | 6 |
| eriogonum umbellatum, sulphur wildbuckwheat | erum | 5 |
| erysimum sp., wallflower | erysi | 1 |
| euphorbia brachycera, horned spurge | eubr | 2 |
| festuca idahoensis, idaho fescue | feid | 1 |
| forb unknown em05 (opposite leaf) | forbem05 | 1 |
| forb unknown em07 (dead balsamorhiza) | forbem07 | 1 |
| forb unknown em09 (round fruit) | forbem09 | 1 |
| forb unknown em10 (white stem) | forbem10 | 2 |
| forb unknown em2701 (fat al) | forb2701 | 1 |
| forb unknown em5 (4 leaf forb) | forbem5 | 1 |
| forb unknown sm01 (sow thistle) | forbsm01 | 1 |
| forb unknown tall sage (red green) | forboyem | 3 |
| forb unknown tall sage (skeleton plant) | forboynt | 2 |
| forb unknown tm1706 (hairy green leaf) | forb1706 | 1 |
| forb unknown tmx (forb dry white hair) | forbtmx | 1 |
| forb unknown ts11 (forb pinnate narrow) | forbts11 | 1 |
| forb unknown wp04 (spikey plant) | forbwp04 | 1 |
| forb unknown wr01 (erigodium) | forbwr01 | 1 |
| galium boreale, northern bedstraw | gabo2 | 1 |
| gayophytum ramosissimum, pinyon groundsmoke | gara2 | 1 |
| gilia tenerrima, delicate gilia | gite | 1 |
| grass unknown em07 (long blade grass) | grasem07 | 1 |
| grass unknown sm01 (unidentifiable grass) | grassm01 | 1 |
| grass unknown tm04 (fescue) | grastm04 | 2 |
| grass unknown wr01 (fat grass) | graswr01 | 3 |
| *halogeton glomeratus, halogeton* | *hagl* | *2* |
| helianthella sp., helianthella | helia | 1 |
| helianthella uniflora, oneflower helianthella | heun | 5 |
| hesperostipa comata, needle and thread | heco26 | 38 |
| ipomopsis aggregata, skyrocket gilia | ipag | 3 |
| krascheninnikovia lanata, winterfat | krla2 | 1 |
| lappula redowskii, western stickseed | lare | 3 |
| leptodactylon pungens, granite pricklygilia | lepu | 17 |
| lesquerella ludoviciana, foothill bladderpod | lelu | 6 |
| leucopoa kingii, spike fescue | leki2 | 2 |
| leymus cinereus, basin wildrye | leci4 | 1 |
| *leymus racemosus, volga wildrye* | *lera5* | *2* |
| ligusticum filicinum, fernleaf licorice-root | lifi | 4 |
| lithospermum ruderale, western gromwell | liru4 | 8 |

Table 5 (continued).

| Species Name | NRCS Code | # of plots (n=56) |
|---|---|---|
| lupinus pusillus, rusty lupine | lupu | 1 |
| lupinus sericeus, silky lupine | luse4 | 3 |
| lupinus sp., lupine | lupin | 6 |
| lygodesmia juncea, rush skeletonplant | lyju | 11 |
| machaeranthera canescens ssp. canescens, hoary tansyaster | macac | 35 |
| mahonia repens, oregongrape | mare11 | 2 |
| mentzelia pumila, dwarf mentzelia | mepu3 | 11 |
| moss unknown ts02 | mossts02 | 1 |
| opuntia polyacantha, plains pricklypear | oppo | 10 |
| oxytropis sp., crazyweed | oxytr | 2 |
| paronychia sessiliflora, creeping nailwort | pase | 2 |
| pascopyrum smithii, western wheatgrass | pasm | 2 |
| penstemon arenicola, sand penstemon | pear | 4 |
| penstemon laricifolius, larchleaf beardtongue | pela9 | 1 |
| penstemon sp., penstemon | penst | 1 |
| penstemon strictus, rocky mountain penstemon | pest2 | 3 |
| poa secunda, sandberg bluegrass | pose | 14 |
| psoralidium lanceolatum, lemon scurfpea | psla3 | 45 |
| purshia tridentata, antelope bitterbrush | putr2 | 19 |
| ribes cereum, wax currant | rice | 6 |
| rosa sp., rose | rosa5 | 3 |
| rosa woodsii, woods' rose | rowo | 2 |
| rumex venosus, veiny dock | ruve2 | 15 |
| *salsola tragus, prickly Russian thistle* | *satr12* | *2* |
| *salsola, russian thistle* | *salso* | *3* |
| spartina gracilis, alkali cordgrass | spgr | 1 |
| symphoricarpos oreophilus, whortleleaf snowberry | syor2 | 10 |
| tetradymia canescens, spineless horsebrush | teca2 | 26 |
| tiquilia nuttallii, nuttall's coldenia | tinu2 | 2 |
| *tragopogon dubius, yellow salsify* | *trdu* | *4* |

Table 6. One-hundred nineteen plant taxa documented in 56 sample plots, sorted by number of plots of occurrence.
Species names are from the PLANTS database (USDA Natural Resources Conservation Service 2002). Exotic taxa are shown in italic typeface.

| Species Name | NRCS Code | # of plots (n=56) |
|---|---|---|
| chrysothamnus viscidiflorus ssp. viscidiflorus, yellow rabbitbrush | chviv2 | 51 |
| achnatherum hymenoides, indian ricegrass | achy | 48 |
| ericameria nauseosa, rubber rabbitbrush | erna10 | 48 |
| artemisia tridentata ssp. tridentata, basin big sagebrush | artrt | 45 |
| psoralidium lanceolatum, lemon scurfpea | psla3 | 45 |
| hesperostipa comata, needle and thread | heco26 | 38 |
| machaeranthera canescens ssp. canescens, hoary tansyaster | macac | 35 |
| elymus lanceolatus ssp. lanceolatus, thickspike wheatgrass | ellal | 34 |
| comandra umbellata, bastard toadflax | coum | 30 |
| tetradymia canescens, spineless horsebrush | teca2 | 26 |
| purshia tridentata, antelope bitterbrush | putr2 | 19 |
| leptodactylon pungens, granite pricklygilia | lepu | 17 |
| rumex venosus, veiny dock | ruve2 | 15 |
| poa secunda, sandberg bluegrass | pose | 14 |
| cryptantha sp., cryptantha | crypt | 13 |
| cryptantha watsonii, watson's catseye | crwa2 | 13 |
| lygodesmia juncea, rush skeletonplant | lyju | 11 |
| mentzelia pumila, dwarf mentzelia | mepu3 | 11 |
| opuntia polyacantha, plains pricklypear | oppo | 10 |
| symphoricarpos oreophilus, whortleleaf snowberry | syor2 | 10 |
| arabis cobrensis, sagebrush rockcress | arco | 9 |
| arenaria hookeri, hooker's sandwort | arho4 | 9 |
| chenopodium atrovirens, pinyon goosefoot | chat | 9 |
| chenopodium pratericola, desert goosefoot | chpr5 | 8 |
| lithospermum ruderale, western gromwell | liru4 | 8 |
| cercocarpus ledifolius, curlleaf mountain mahogany | cele3 | 7 |
| cryptantha fendleri, sanddune catseye | crfe3 | 7 |
| eriogonum sp., eriogonum | eriog | 6 |
| lesquerella ludoviciana, foothill bladderpod | lelu | 6 |
| lupinus sp., lupine | lupin | 6 |
| ribes cereum, wax currant | rice | 6 |
| *agropyron cristatum, crested wheatgrass* | *agcr* | 5 |
| artemisia tridentata ssp. wyomingensis, wyoming big sagebrush | artrw8 | 5 |
| astragalus kentrophyta, spiny milkvetch | aske | 5 |
| chaenactis douglasii, douglas's dustymaiden | chdo | 5 |
| cordylanthus ramosus, bushy bird's beak | cora5 | 5 |
| cryptantha flavoculata, roughseed catseye | crfl6 | 5 |
| *descurainia sophia, herb sophia* | *deso2* | 5 |
| elymus elymoides, bottlebrush squirreltail | elel5 | 5 |
| eriogonum umbellatum, sulphur wildbuckwheat | erum | 5 |
| helianthella uniflora, oneflower helianthella | heun | 5 |
| *bromus inermis* ssp. *inermis, smooth brome* | *brini* | 4 |
| ligusticum filicinum, fernleaf licorice-root | lifi | 4 |

Table 6 (continued).

| Species Name | NRCS Code | # of plots (n=56) |
|---|---|---|
| penstemon arenicola, sand penstemon | pear | 4 |
| *tragopogon dubius, yellow salsify* | *trdu* | 4 |
| artemisia dracunculus, wormwood | ardr4 | 3 |
| cirsium, thistle | cirsi | 3 |
| forb unknown tall sage (red green) | forboyem | 3 |
| grass unknown wr01 (fat grass) | graswr01 | 3 |
| ipomopsis aggregata, skyrocket gilia | ipag | 3 |
| lappula redowskii, western stickseed | lare | 3 |
| lupinus sericeus, silky lupine | luse4 | 3 |
| penstemon strictus, rocky mountain penstemon | pest2 | 3 |
| rosa sp., rose | rosa5 | 3 |
| *salsola, russian thistle* | *salso* | 3 |
| *alyssum desertorum, desert madwort* | *alde* | 2 |
| astragalus kentrophyta var. elatus, tall spiny milkvetch | askee | 2 |
| castilleja linariifolia, wyoming indian paintbrush | cali4 | 2 |
| chrysothamnus viscidiflorus ssp. lanceolatus, yellow rabbitbrush | chvil4 | 2 |
| cryptantha sericea, silky catseye | crse3 | 2 |
| eriogonum cernuum var. cernuum, nodding buckwheat | ercec | 2 |
| eriogonum cernuum, nodding buckwheat | erce2 | 2 |
| eriogonum microthecum var. laxiflorum, slender buckwheat | ermil2 | 2 |
| euphorbia brachycera, horned spurge | eubr | 2 |
| forb unknown em10 (white stem) | forbem10 | 2 |
| forb unknown tall sage (skeleton plant) | forboynt | 2 |
| grass unknown tm04 (fescue) | grastm04 | 2 |
| *halogeton glomeratus, halogeton* | *hagl* | 2 |
| leucopoa kingii, spike fescue | leki2 | 2 |
| *leymus racemosus, volga wildrye* | *lera5* | 2 |
| mahonia repens, oregongrape | mare11 | 2 |
| oxytropis sp., crazyweed | oxytr | 2 |
| paronychia sessiliflora, creeping nailwort | pase | 2 |
| pascopyrum smithii, western wheatgrass | pasm | 2 |
| rosa woodsii, woods' rose | rowo | 2 |
| *salsola tragus, prickly Russian thistle* | *satr12* | 2 |
| tiquilia nuttallii, nuttall's coldenia | tinu2 | 2 |
| achnatherum sp., ricegrass | achna | 1 |
| *agropyron desertorum, desert wheatgrass* | *agde2* | 1 |
| antennaria, pussytoes | anten | 1 |
| artemisia nova, black sagebrush | arno4 | 1 |
| astragalus geyeri, geyer's milkvetch | asge | 1 |
| astragalus megacarpus, great bladdery milkvetch | asme2 | 1 |
| astragalus sp., milkvetch | astra | 1 |
| atriplex sp., saltbush | atrip | 1 |
| balsamorhiza sagittata, arrowleaf balsamroot | basa3 | 1 |
| *bromus tectorum, cheatgrass* | *brte* | 1 |
| chaenactis douglasii var. douglasii, douglas's dustymaiden | chdod | 1 |

Table 6 (continued).

| Species Name | NRCS Code | # of plots (n=56) |
|---|---|---|
| corispermum villosum, hairy bugseed | covi5 | 1 |
| crepis acuminata, longleaf hawksbeard | crac2 | 1 |
| cryptantha cana, mountain catseye | crca8 | 1 |
| elymus trachycaulus ssp. trachycaulus, slender wheatgrass | eltrt | 1 |
| eriogonum ovalifolium var. purpureum, cushion buckwheat | erovp2 | 1 |
| erysimum sp., wallflower | erysi | 1 |
| festuca idahoensis, idaho fescue | feid | 1 |
| forb unknown em05 (opposite leaf) | forbem05 | 1 |
| forb unknown em07 (dead balsamorhiza) | forbem07 | 1 |
| forb unknown em09 (round fruit) | forbem09 | 1 |
| forb unknown em2701 (fat al) | forb2701 | 1 |
| forb unknown em5 (4 leaf forb) | forbem5 | 1 |
| forb unknown sm01 (sow thistle) | forbsm01 | 1 |
| forb unknown tm1706 (hairy green leaf) | forb1706 | 1 |
| forb unknown tmx (forb dry white hair) | forbtmx | 1 |
| forb unknown ts11 (forb pinnate narrow) | forbts11 | 1 |
| forb unknown wp04 (spikey plant) | forbwp04 | 1 |
| forb unknown wr01 (erigodium) | forbwr01 | 1 |
| galium boreale, northern bedstraw | gabo2 | 1 |
| gayophytum ramosissimum, pinyon groundsmoke | gara2 | 1 |
| gilia tenerrima, delicate gilia | gite | 1 |
| grass unknown em07 (long blade grass) | grasem07 | 1 |
| grass unknown sm01 (unidentifiable grass) | grassm01 | 1 |
| helianthella sp., helianthella | helia | 1 |
| krascheninnikovia lanata, winterfat | krla2 | 1 |
| leymus cinereus, basin wildrye | leci4 | 1 |
| lupinus pusillus, rusty lupine | lupu | 1 |
| moss unknown ts02 | mossts02 | 1 |
| penstemon laricifolius, larchleaf beardtongue | pela9 | 1 |
| penstemon sp., penstemon | penst | 1 |
| spartina gracilis, alkali cordgrass | spgr | 1 |

Table 7. Two-sample t-test, Total Plant Canopy Cover, Undisturbed Plots vs.Disturbed Plots.

$H_0$: Mean per-plot plant canopy cover in undisturbed plots equals that in disturbed plots.
$H_1$: Mean per-plot plant canopy cover is greater in undisturbed plots than in disturbed plots.

| Category | N | Mean | StDev | SE Mean |
|---|---|---|---|---|
| Undisturbed | 37 | 63.9 | 19.0 | 3.1 |
| Disturbed | 19 | 40.5 | 16.9 | 3.9 |

95% confidence interval for undisturbed mean - disturbed mean: (13.4, 33.5)
T-Test, undisturbed mean = disturbed mean vs undisturbed mean > disturbed mean: T = 4.71 P = 0.0000 DF = 40

Conclusion: Reject $H_0$. Mean per-plot total plant canopy cover is greater in undisturbed plots than in disturbed plots.

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Table 8. Two-sample t-test, Shrub Canopy Cover, Undisturbed Plots vs. Disturbed Plots.

$H_0$: Mean per-plot shrub canopy cover in undisturbed plots equals that in disturbed plots.
$H_1$: Mean per-plot shrub canopy cover is greater in undisturbed plots than in disturbed plots.

| Category | N | Mean | StDev | SE Mean |
|---|---|---|---|---|
| Undisturbed | 37 | 39.4 | 14.0 | 2.3 |
| Disturbed | 19 | 14.1 | 10.4 | 2.4 |

95% confidence interval for undisturbed mean - disturbed mean: (18.7, 32.0)
T-Test, undisturbed mean = disturbed mean vs undisturbed mean > disturbed mean: T = 7.64 P = 0.0000 DF = 46

Conclusion: Reject $H_0$. Mean per-plot shrub canopy cover is greater in undisturbed plots than in disturbed plots.

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Table 9. Two-sample t-test, Forb Canopy Cover, Undisturbed Plots vs. Disturbed Plots.

$H_0$: Mean per-plot forb canopy cover in undisturbed plots equals that in disturbed plots.
$H_1$: Mean per-plot forb canopy cover is greater in undisturbed plots than in disturbed plots.

| Category | N | Mean | StDev | SE Mean |
|---|---|---|---|---|
| Undisturbed | 37 | 11.78 | 6.49 | 1.1 |
| Disturbed | 19 | 12.53 | 5.62 | 1.3 |

95% confidence interval for undisturbed mean - disturbed mean: (-4.1, 2.6)
T-Test, undisturbed mean = disturbed mean vs undisturbed mean > disturbed mean: T = -0.44 P = 0.67
DF = 41

Conclusion: Do Not Reject $H_0$. Mean per-plot forb canopy cover is not greater in undisturbed plots than in disturbed plots.

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Table 10. Two-sample t-test, Grass Canopy Cover, Undisturbed Plots vs. Disturbed Plots.

$H_0$: Mean per-plot grass canopy cover in undisturbed plots equals that in disturbed plots.
$H_1$: Mean per-plot grass canopy cover is greater in undisturbed plots than in disturbed plots.

| Category | N | Mean | StDev | SE Mean |
|---|---|---|---|---|
| Undisturbed | 37 | 11.27 | 9.11 | 1.5 |
| Disturbed | 19 | 13.6 | 10.7 | 2.5 |

95% confidence interval for undisturbed mean - disturbed mean: (-8.2, 3.6)
T-Test, undisturbed mean = disturbed mean vs undisturbed mean > disturbed mean: T = -0.80 P = 0.79
DF = 31

Conclusion: Do Not Reject $H_0$. Mean per-plot grass canopy cover is not greater in undisturbed plots than in disturbed plots.

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Table 11. Beta diversity among plots of different disturbance categories.

Beta diversity = $B_w = (S_c/S)-1$, where Sc = the number of species in all of the plots being considered and B = average number of species per plot (McCune and Grace 2002).

| I. This study: | # of plots | Sc | Bw |
|---|---|---|---|
| a. Category 1: Undisturbed, Killpecker Dunes & Steamboat Rim | 31 | 96 | 5.12 |
| b. Categories 4 & 5: Burned & Pipeline, Killpecker Dunes | 12 | 40 | 1.93 |
| c. Categories 1, 4, 5: Undisturbed, Burned, Pipeline in Killpecker Dunes & Steamboat Rim | 43 | 101 | 5.68 |
| d. Categories 1 - 5: Undisturbed plots in Killpecker Dunes, Steamboat Rim, and White Mtn. plus Burned plots & Pipeline plots | 49 | 105 | 6.92 |
| II. Sand Hills | 11 | 101 | 2.16 |
| III. Sand Substrates in Various Locations | 16 | 85 | 4.11 |

Table 12. Relative plant canopy cover in the plots of group D.
Each cell shows the proportion of the plant canopy cover in a plot contributed by a species. The number of the plots in a group containing the species, and the average relative cover of the species in just those plots, also are shown. Italic type-face indicates exotic species.

| NRCS Code | Species Name | Group D | | Plots | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | # plots (n=23) | Ave | 02EM09 | 02WM06 | 02EM2701 | 02OY2312 | 02EM2302 | 02EM3519 | 02EM1145 | 02EM192 | 02EM721 | 03TS03 |
| | 2. Shrub | | | | | | | | | | | | |
| artrt | artemisia tridentata ssp. tridentata, basin big sagebrush | 23 | 0.31 | 0.41 | 0.63 | 0.44 | 0.45 | 0.41 | 0.58 | 0.34 | 0.42 | 0.50 | 0.41 |
| artrw8 | artemisia tridentata ssp. wyomingensis, wyoming big sagebrush | 2 | 0.05 | - | - | - | - | - | - | - | 0.06 | - | - |
| cele3 | cercocarpus ledifolius, curlleaf mountain mahogany | 2 | 0.02 | - | 0.02 | 0.01 | - | - | - | - | - | - | - |
| chviv2 | chrysothamnus viscidiflorus ssp. viscidiflorus, yellow rabbitbrush | 23 | 0.12 | 0.10 | 0.05 | 0.15 | 0.15 | 0.04 | 0.06 | 0.17 | 0.06 | 0.08 | 0.06 |
| erna10 | ericameria nauseosa, rubber rabbitbrush | 22 | 0.07 | 0.01 | 0.05 | 0.01 | 0.04 | 0.01 | - | 0.05 | 0.06 | 0.08 | 0.06 |
| putr2 | purshia tridentata, antelope bitterbrush | 10 | 0.08 | 0.01 | - | 0.15 | - | 0.27 | - | 0.02 | - | - | - |
| rice | ribes cereum, wax currant | 1 | 0.01 | - | - | 0.01 | - | - | - | - | - | - | - |
| rosa5 | rosa sp., rose | 1 | 0.02 | - | - | - | - | - | - | - | - | - | 0.02 |
| rowo | rosa woodsii, woods' rose | 1 | 0.02 | - | - | - | - | - | - | - | - | - | - |
| syor2 | symphoricarpos oreophilus, whortleleaf snowberry | 1 | 0.01 | 0.01 | - | - | - | - | - | - | - | - | - |
| teca2 | tetradymia canescens, spineless horsebrush | 11 | 0.05 | 0.10 | - | 0.01 | 0.01 | - | - | 0.05 | 0.02 | 0.03 | - |
| | 3. Subshrub | | | | | | | | | | | | |
| ermil2 | eriogonum microthecum var. laxiflorum, slender buckwheat | 1 | 0.01 | 0.01 | - | - | - | - | - | - | - | - | - |
| lepu | leptodactylon pungens, granite pricklygilia | 7 | 0.03 | 0.10 | - | - | - | 0.01 | - | - | - | 0.03 | - |
| oppo | opuntia polyacantha, plains pricklypear | 6 | 0.02 | - | - | - | - | - | 0.02 | - | - | - | - |
| | 5. Grass | | | | | | | | | | | | |
| achy | achnatherum hymenoides, indian ricegrass | 23 | 0.06 | 0.01 | 0.05 | 0.04 | 0.15 | 0.04 | 0.19 | 0.05 | 0.06 | 0.03 | 0.06 |
| *agcr* | *agropyron cristatum, crested wheatgrass* | 4 | 0.02 | - | - | - | - | - | - | - | - | - | - |
| *brini* | *bromus inermis* ssp. *inermis, smooth brome* | 2 | 0.02 | - | - | - | - | - | - | - | - | - | - |
| *brte* | *bromus tectorum, cheatgrass* | 1 | 0.05 | - | 0.05 | - | - | - | - | - | - | - | - |
| elel5 | elymus elymoides, bottlebrush squirreltail | 4 | 0.04 | 0.01 | - | - | - | - | - | - | - | - | 0.02 |
| ellal | elymus lanceolatus ssp. lanceolatus, thickspike wheatgrass | 16 | 0.05 | 0.03 | - | 0.01 | 0.04 | 0.01 | - | 0.02 | 0.02 | - | - |
| grastm04 | grass unknown tm04 (fescue) | 1 | 0.01 | 0.01 | - | - | - | - | - | - | - | - | - |
| heco26 | hesperostipa comata, needle and thread | 22 | 0.06 | 0.01 | 0.05 | 0.01 | 0.04 | 0.14 | - | 0.05 | 0.02 | 0.08 | 0.06 |
| leki2 | leucopoa kingii, spike fescue | 1 | 0.02 | - | - | - | - | - | - | - | - | - | - |
| pose | poa secunda, sandberg bluegrass | 7 | 0.03 | - | 0.05 | - | 0.01 | - | 0.02 | - | - | - | - |
| spgr | spartina gracilis, alkali cordgrass | 1 | 0.02 | - | - | - | - | - | - | - | - | - | 0.02 |

Table 12 (continued).

| NRCS Code | Species Name | Group D # plots (n=23) | Group D Ave | Plots 02EM09 | 02WM06 | 02EM2701 | 02OY2312 | 02EM2302 | 02EM3519 | 02EM1145 | 02EM192 | 02EM721 | 03TS03 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6. Forb | | | | | | | | | | | | |
| *alde* | *alyssum desertorum, desert madwort* | 2 | 0.01 | - | - | - | - | - | - | - | - | - | - |
| arco | arabis cobrensis, sagebrush rockcress | 7 | 0.02 | 0.01 | - | - | - | - | - | 0.02 | - | 0.03 | 0.02 |
| arho4 | arenaria hookeri, hooker's sandwort | 3 | 0.03 | 0.01 | - | - | - | - | 0.02 | - | - | - | - |
| ardr4 | artemisia dracunculus, wormwood | 1 | 0.03 | - | - | - | - | - | - | - | - | - | - |
| aske | astragalus kentrophyta, spiny milkvetch | 3 | 0.02 | - | - | - | - | - | - | - | - | - | - |
| cali4 | castilleja linariifolia, wyoming indian paintbrush | 1 | 0.01 | 0.01 | - | - | - | - | - | - | - | - | - |
| chdo | chaenactis douglasii, douglas's dustymaiden | 3 | 0.02 | - | - | - | - | - | - | - | - | - | - |
| chat | chenopodium atrovirens, pinyon goosefoot | 2 | 0.02 | - | - | - | - | - | - | - | - | - | - |
| chpr5 | chenopodium pratericola, desert goosefoot | 6 | 0.02 | - | - | - | - | - | - | - | - | - | 0.02 |
| cirsi | cirsium, thistle | 1 | 0.01 | 0.01 | - | - | - | - | - | - | - | - | - |
| coum | comandra umbellata, bastard toadflax | 19 | 0.02 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.03 | 0.02 |
| crac2 | crepis acuminata, longleaf hawksbeard | 1 | 0.01 | - | - | - | - | - | - | - | - | - | - |
| crca8 | cryptantha cana, mountain catseye | 1 | 0.02 | - | - | - | - | - | - | - | - | - | - |
| crfe3 | cryptantha fendleri, sanddune catseye | 2 | 0.02 | - | - | - | - | - | - | - | - | - | 0.02 |
| crfl6 | cryptantha flavoculata, roughseed catseye | 4 | 0.03 | - | - | - | - | - | - | - | - | - | - |
| crse3 | cryptantha sericea, silky catseye | 2 | 0.02 | - | - | - | - | - | - | - | - | - | 0.02 |
| crypt | cryptantha sp., cryptantha | 5 | 0.02 | - | - | 0.01 | 0.01 | - | 0.02 | - | - | - | - |
| crwa2 | cryptantha watsonii, watson's catseye | 7 | 0.02 | - | - | - | - | - | - | - | - | 0.03 | 0.02 |
| *deso2* | *descurainia sophia, herb sophia* | 5 | 0.02 | - | - | - | - | - | - | - | - | - | 0.02 |
| erce2 | eriogonum cernuum, nodding buckwheat | 2 | 0.02 | - | - | - | - | - | - | - | - | - | - |
| erovp2 | eriogonum ovalifolium var. purpureum, cushion buckwheat | 1 | 0.01 | - | - | - | - | - | - | - | - | - | - |
| eriog | eriogonum sp., eriogonum | 1 | 0.03 | 0.03 | - | - | - | - | - | - | - | - | - |
| erum | eriogonum umbellatum, sulphur wildbuckwheat | 1 | 0.02 | - | - | - | - | - | - | - | - | - | - |
| eubr | euphorbia brachycera, horned spurge | 2 | 0.02 | - | - | - | - | - | - | - | - | - | - |
| forbem09 | forb unknown em09 (round fruit) | 1 | 0.01 | 0.01 | - | - | - | - | - | - | - | - | - |
| forb2701 | forb unknown em2701 (fat al) | 1 | 0.04 | - | - | 0.04 | - | - | - | - | - | - | - |
| forb1706 | forb unknown tm1706 (hairy green leaf) | 1 | 0.02 | - | - | - | - | - | - | - | - | - | - |
| forbts11 | forb unknown ts11 (forb pinnate narrow) | 1 | 0.03 | - | - | - | - | - | - | - | - | - | - |
| heun | helianthella uniflora, oneflower helianthella | 1 | 0.01 | 0.01 | - | - | - | - | - | - | - | - | - |
| ipag | ipomopsis aggregata, skyrocket gilia | 1 | 0.01 | 0.01 | - | - | - | - | - | - | - | - | - |
| lare | lappula redowskii, western stickseed | 1 | 0.02 | - | - | - | - | - | - | - | - | - | - |

Table 12 (continued).

| NRCS Code | Species Name | Group D # plots (n=23) | Group D Ave | Plots 02EM09 | 02WM06 | 02EM2701 | 02OY2312 | 02EM2302 | 02EM3519 | 02EM1145 | 02EM192 | 02EM721 | 03TS03 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| lelu | lesquerella ludoviciana, foothill bladderpod | 5 | 0.02 | - | - | - | - | - | - | - | - | - | - |
| lifi | ligusticum filicinum, fernleaf licorice-root | 1 | 0.02 | - | 0.02 | - | - | - | - | - | - | - | - |
| liru4 | lithospermum ruderale, western gromwell | 3 | 0.01 | 0.01 | 0.02 | 0.01 | - | - | - | - | - | - | - |
| luse4 | lupinus sericeus, silky lupine | 1 | 0.01 | 0.01 | - | - | - | - | - | - | - | - | - |
| lupin | lupinus sp., lupine | 2 | 0.02 | - | 0.02 | 0.01 | - | - | - | - | - | - | - |
| lyju | lygodesmia juncea, rush skeletonplant | 5 | 0.02 | - | - | - | - | - | - | - | - | - | - |
| macac | machaeranthera canescens ssp. canescens, hoary tansyaster | 20 | 0.02 | 0.01 | - | 0.01 | 0.01 | - | 0.02 | 0.02 | 0.02 | 0.03 | 0.02 |
| mepu3 | mentzelia pumila, dwarf mentzelia | 5 | 0.02 | 0.01 | - | - | - | - | - | 0.02 | - | 0.03 | - |
| pase | paronychia sessiliflora, creeping nailwort | 2 | 0.02 | - | - | - | - | - | - | - | - | - | 0.02 |
| pear | penstemon arenicola, sand penstemon | 3 | 0.02 | - | - | - | - | - | - | - | - | - | - |
| pest2 | penstemon strictus, rocky mountain penstemon | 1 | 0.01 | 0.01 | - | - | - | - | - | - | - | - | - |
| psla3 | psoralidium lanceolatum, lemon scurfpea | 22 | 0.12 | 0.01 | - | 0.01 | 0.04 | 0.04 | 0.06 | 0.17 | 0.21 | 0.08 | 0.06 |
| ruve2 | rumex venosus, veiny dock | 9 | 0.04 | - | - | - | - | - | - | - | - | - | 0.02 |
| *satr12* | *salsola tragus, prickly russian thistle* | 1 | 0.02 | - | - | - | - | - | - | - | - | - | - |
| tinu2 | tiquilia nuttallii, nuttall's coldenia | 2 | 0.02 | - | - | - | - | - | - | - | 0.02 | - | 0.02 |
| *trdu* | *tragopogon dubius, yellow salsify* | 1 | 0.02 | - | - | - | - | - | - | - | - | - | - |

Table 12 (continued).

| NRCS Code | Species Name | Plots | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 03TS06 | 03TS07 | 03TS02 | 02EM14P | 02TM05 | 02TM1706 | 03TS01 | 02EM6P | 02TM29 | 03TS05 | 02EM2470 | 02TM02 | 03TS11 |
| | 2. Shrub | | | | | | | | | | | | | |
| artrt | artemisia tridentata ssp. tridentata, basin big sagebrush | 0.31 | 0.34 | 0.28 | 0.19 | 0.23 | 0.23 | 0.16 | 0.21 | 0.18 | 0.23 | 0.05 | 0.06 | 0.09 |
| artrw8 | artemisia tridentata ssp. wyomingensis, wyoming big sagebrush | - | - | - | - | - | - | - | - | - | - | 0.05 | - | - |
| cele3 | cercocarpus ledifolius, curlleaf mountain mahogany | - | - | - | - | - | - | - | - | - | - | - | - | - |
| chviv2 | chrysothamnus viscidiflorus ssp. viscidiflorus, yellow rabbitbrush | 0.05 | 0.05 | 0.01 | 0.19 | 0.23 | 0.23 | 0.16 | 0.06 | 0.05 | 0.07 | 0.15 | 0.43 | 0.09 |
| erna10 | ericameria nauseosa, rubber rabbitbrush | 0.05 | 0.05 | 0.01 | 0.19 | 0.07 | 0.07 | 0.02 | 0.21 | 0.02 | 0.23 | 0.15 | 0.06 | 0.09 |
| putr2 | purshia tridentata, antelope bitterbrush | - | 0.17 | 0.01 | 0.06 | - | - | 0.02 | 0.02 | 0.05 | - | - | - | - |
| rice | ribes cereum, wax currant | - | - | - | - | - | - | - | - | - | - | - | - | - |
| rosa5 | rosa sp., rose | - | - | - | - | - | - | - | - | - | - | - | - | - |
| rowo | rosa woodsii, woods' rose | - | - | - | - | - | - | - | - | - | 0.02 | - | - | - |
| syor2 | symphoricarpos oreophilus, whortleleaf snowberry | - | - | - | - | - | - | - | - | - | - | - | - | - |
| teca2 | tetradymia canescens, spineless horsebrush | - | 0.02 | 0.14 | - | - | - | 0.05 | - | - | - | 0.05 | - | 0.09 |
| | 3. Subshrub | | | | | | | | | | | | | |
| ermil2 | eriogonum microthecum var. laxiflorum, slender buckwheat | - | - | - | - | - | - | - | - | - | - | - | - | - |
| lepu | leptodactylon pungens, granite pricklygilia | - | 0.02 | - | - | - | - | - | 0.02 | 0.02 | - | 0.02 | - | - |
| oppo | opuntia polyacantha, plains pricklypear | 0.02 | 0.02 | 0.01 | 0.02 | - | - | 0.02 | - | - | - | - | - | - |
| | 5. Grass | | | | | | | | | | | | | |
| achy | achnatherum hymenoides, indian ricegrass | 0.05 | 0.05 | 0.04 | 0.02 | 0.07 | 0.07 | 0.16 | 0.02 | 0.05 | 0.07 | 0.05 | 0.06 | 0.09 |
| *agcr* | *agropyron cristatum, crested wheatgrass* | 0.02 | - | - | - | - | - | 0.03 | - | 0.02 | 0.02 | - | - | - |
| *brini* | *bromus inermis* ssp. *inermis, smooth brome* | - | - | - | 0.02 | - | - | - | - | 0.02 | - | - | - | - |
| *brte* | *bromus tectorum, cheatgrass* | - | - | - | - | - | - | - | - | - | - | - | - | - |
| elel5 | elymus elymoides, bottlebrush squirreltail | 0.05 | - | - | - | - | - | - | - | - | 0.07 | - | - | - |
| ellal | elymus lanceolatus ssp. lanceolatus, thickspike wheatgrass | 0.02 | 0.02 | 0.04 | - | - | 0.02 | 0.02 | 0.06 | 0.36 | 0.02 | - | 0.02 | 0.03 |
| grastm04 | grass unknown tm04 (fescue) | - | - | - | - | - | - | - | - | - | - | - | - | - |
| heco26 | hesperostipa comata, needle and thread | 0.16 | 0.05 | 0.14 | 0.19 | 0.02 | 0.02 | 0.05 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.09 |
| leki2 | leucopoa kingii, spike fescue | - | - | - | - | - | - | - | - | 0.02 | - | - | - | - |
| pose | poa secunda, sandberg bluegrass | 0.02 | - | 0.01 | - | - | - | - | - | - | 0.02 | 0.05 | - | - |
| spgr | spartina gracilis, alkali cordgrass | - | - | - | - | - | - | - | - | - | - | - | - | - |

Table 12 (continued).

| NRCS Code | Species Name | Plots | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 03TS06 | 03TS07 | 03TS02 | 02EM14P | 02TM05 | 02TM1706 | 03TS01 | 02EM6P | 02TM29 | 03TS05 | 02EM2470 | 02TM02 | 03TS11 |
| | 6. Forb | | | | | | | | | | | | | |
| *alde* | *alyssum desertorum, desert madwort* | 0.02 | - | 0.01 | - | - | - | - | - | - | - | - | - | - |
| arco | arabis cobrensis, sagebrush rockcress | 0.02 | - | 0.01 | - | - | - | - | - | - | 0.02 | - | - | - |
| arho4 | arenaria hookeri, hooker's sandwort | - | - | - | - | - | - | - | - | - | - | 0.05 | - | - |
| ardr4 | artemisia dracunculus, wormwood | - | - | - | - | - | - | - | - | - | - | - | - | 0.03 |
| aske | astragalus kentrophyta, spiny milkvetch | - | - | - | - | 0.02 | - | - | - | 0.02 | - | 0.02 | - | - |
| cali4 | castilleja linariifolia, wyoming indian paintbrush | - | - | - | - | - | - | - | - | - | - | - | - | - |
| chdo | chaenactis douglasii, douglas's dustymaiden | - | 0.02 | 0.01 | - | - | - | 0.02 | - | - | - | - | - | - |
| chat | chenopodium atrovirens, pinyon goosefoot | - | - | - | - | - | - | - | 0.02 | - | - | - | 0.02 | - |
| chpr5 | chenopodium pratericola, desert goosefoot | 0.02 | 0.02 | - | - | - | - | 0.02 | - | - | 0.02 | - | - | 0.03 |
| cirsi | cirsium, thistle | - | - | - | - | - | - | - | - | - | - | - | - | - |
| coum | comandra umbellata, bastard toadflax | - | 0.02 | 0.04 | 0.02 | 0.02 | - | 0.05 | 0.02 | - | - | 0.02 | 0.02 | 0.03 |
| crac2 | crepis acuminata, longleaf hawksbeard | - | - | 0.01 | - | - | - | - | - | - | - | - | - | - |
| crca8 | cryptantha cana, mountain catseye | - | - | - | - | - | - | - | - | - | 0.02 | - | - | - |
| crfe3 | cryptantha fendleri, sanddune catseye | - | 0.02 | - | - | - | - | - | - | - | - | - | - | - |
| crfl6 | cryptantha flavoculata, roughseed catseye | - | 0.02 | 0.04 | - | - | - | 0.02 | - | - | - | - | - | 0.03 |
| crse3 | cryptantha sericea, silky catseye | 0.02 | - | - | - | - | - | - | - | - | - | - | - | - |
| crypt | cryptantha sp., cryptantha | - | - | - | - | 0.02 | - | - | - | - | - | 0.02 | - | - |
| crwa2 | cryptantha watsonii, watson's catseye | - | - | 0.01 | 0.02 | - | - | - | 0.02 | 0.02 | - | - | 0.02 | - |
| *deso2* | *descurainia sophia, herb sophia* | 0.02 | 0.02 | 0.01 | - | - | - | 0.02 | - | - | - | - | - | - |
| erce2 | eriogonum cernuum, nodding buckwheat | - | - | - | - | - | - | - | - | 0.02 | - | - | - | 0.03 |
| erovp2 | eriogonum ovalifolium var. purpureum, cushion buckwheat | - | - | 0.01 | - | - | - | - | - | - | - | - | - | - |
| eriog | eriogonum sp., eriogonum | - | - | - | - | - | - | - | - | - | - | - | - | - |
| erum | eriogonum umbellatum, sulphur wildbuckwheat | - | - | - | - | - | - | - | - | - | - | 0.02 | - | - |
| eubr | euphorbia brachycera, horned spurge | - | - | - | - | 0.02 | - | - | - | 0.02 | - | - | - | - |
| forbem09 | forb unknown em09 (round fruit) | - | - | - | - | - | - | - | - | - | - | - | - | - |
| forb2701 | forb unknown em2701 (fat al) | - | - | - | - | - | - | - | - | - | - | - | - | - |
| forb1706 | forb unknown tm1706 (hairy green leaf) | - | - | - | - | - | 0.02 | - | - | - | - | - | - | - |
| forbts11 | forb unknown ts11 (forb pinnate narrow) | - | - | - | - | - | - | - | - | - | - | - | - | 0.03 |
| heun | helianthella uniflora, oneflower helianthella | - | - | - | - | - | - | - | - | - | - | - | - | - |
| ipag | ipomopsis aggregata, skyrocket gilia | - | - | - | - | - | - | - | - | - | - | - | - | - |
| lare | lappula redowskii, western stickseed | 0.02 | - | - | - | - | - | - | - | - | - | - | - | - |

Table 12 (continued).

| NRCS Code | Species Name | Plots | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 03TS06 | 03TS07 | 03TS02 | 02EM14P | 02TM05 | 02TM1706 | 03TS01 | 02EM6P | 02TM29 | 03TS05 | 02EM2470 | 02TM02 | 03TS11 |
| lelu | lesquerella ludoviciana, foothill bladderpod | 0.02 | 0.02 | 0.01 | - | - | - | 0.02 | - | - | - | - | - | 0.03 |
| lifi | ligusticum filicinum, fernleaf licorice-root | - | - | - | - | - | - | - | - | - | - | - | - | - |
| liru4 | lithospermum ruderale, western gromwell | - | - | - | - | - | - | - | - | - | - | - | - | - |
| luse4 | lupinus sericeus, silky lupine | - | - | - | - | - | - | - | - | - | - | - | - | - |
| lupin | lupinus sp., lupine | - | - | - | - | - | - | - | - | - | - | - | - | - |
| lyju | lygodesmia juncea, rush skeletonplant | - | 0.02 | - | - | 0.02 | 0.02 | - | - | 0.02 | - | - | - | 0.03 |
| macac | machaeranthera canescens ssp. canescens, hoary tansyaster | 0.02 | 0.02 | 0.01 | 0.02 | 0.02 | - | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 |
| mepu3 | mentzelia pumila, dwarf mentzelia | - | - | - | 0.02 | - | - | - | - | - | - | - | 0.02 | - |
| pase | paronychia sessiliflora, creeping nailwort | - | - | 0.01 | - | - | - | - | - | - | - | - | - | - |
| pear | penstemon arenicola, sand penstemon | - | - | 0.01 | - | - | - | 0.02 | - | - | 0.02 | - | - | - |
| pest2 | penstemon strictus, rocky mountain penstemon | - | - | - | - | - | - | - | - | - | - | - | - | - |
| psla3 | psoralidium lanceolatum, lemon scurfpea | 0.16 | 0.05 | 0.04 | 0.06 | 0.23 | 0.23 | 0.16 | 0.21 | 0.05 | 0.07 | 0.31 | 0.21 | 0.09 |
| ruve2 | rumex venosus, veiny dock | - | - | - | 0.02 | 0.02 | 0.07 | - | 0.06 | 0.02 | 0.02 | - | 0.02 | 0.09 |
| *satr12* | *salsola tragus, prickly russian thistle* | - | - | - | - | - | - | - | 0.02 | - | - | - | - | - |
| tinu2 | tiquilia nuttallii, nuttall's coldenia | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *trdu* | *tragopogon dubius, yellow salsify* | - | - | - | - | - | - | - | - | 0.02 | - | - | - | - |

Table 13. Relative plant canopy cover in the plots of group E.
Each cell shows proportion of the plant canopy cover in a plot contributed by a species. The number of the plots in a group containing the species, and the average relative cover of the species in just those plots, also are shown. Italic type-face indicates exotic species.

| | | Group E | | Plots | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| NRCS Code | Species Name | # plots (n=7) | Ave | 02EM849 | 02EM08 | 02SM01 | 02NT02 | 02TM04 | 02EM10 | 02EM04P |
| | 2. Shrub | | | | | | | | | |
| artrt | artemisia tridentata ssp. tridentata, basin big sagebrush | 7 | 0.39 | 0.65 | 0.60 | 0.33 | 0.34 | 0.28 | 0.35 | 0.19 |
| chviv2 | chrysothamnus viscidiflorus ssp. viscidiflorus, yellow rabbitbrush | 4 | 0.03 | 0.02 | - | 0.01 | 0.05 | - | 0.02 | - |
| erna10 | ericameria nauseosa, rubber rabbitbrush | 7 | 0.12 | 0.07 | 0.06 | 0.11 | 0.05 | 0.14 | 0.35 | 0.06 |
| putr2 | purshia tridentata, antelope bitterbrush | 4 | 0.09 | - | - | 0.11 | 0.05 | 0.14 | - | 0.06 |
| rice | ribes cereum, wax currant | 2 | 0.03 | - | - | - | 0.02 | 0.04 | - | - |
| syor2 | symphoricarpos oreophilus, whortleleaf snowberry | 4 | 0.10 | - | - | 0.22 | - | 0.14 | 0.02 | 0.02 |
| teca2 | tetradymia canescens, spineless horsebrush | 4 | 0.03 | - | 0.02 | 0.03 | - | 0.04 | - | 0.02 |
| | 3. Subshrub | | | | | | | | | |
| lepu | leptodactylon pungens, granite pricklygilia | 3 | 0.02 | - | 0.02 | - | 0.02 | 0.01 | - | - |
| mare11 | mahonia repens, oregongrape | 1 | 0.01 | - | - | - | - | 0.01 | - | - |
| | 5. Grass | | | | | | | | | |
| achy | achnatherum hymenoides, indian ricegrass | 4 | 0.03 | - | 0.06 | 0.01 | - | 0.01 | - | 0.02 |
| brini | bromus inermis ssp. inermis, smooth brome | 1 | 0.02 | - | - | - | - | - | - | 0.02 |
| ellal | elymus lanceolatus ssp. lanceolatus, thickspike wheatgrass | 3 | 0.03 | - | - | - | 0.05 | - | 0.02 | 0.02 |
| grassm01 | grass unknown sm01 (unidentifiable grass) | 1 | 0.03 | - | - | 0.03 | - | - | - | - |
| grastm04 | grass unknown tm04 (fescue) | 1 | 0.01 | - | - | - | - | 0.01 | - | - |

Table 13 (continued).

| | | Group E | | Plots | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| NRCS Code | Species Name | # plots (n=7) | Ave | 02EM849 | 02EM08 | 02SM01 | 02NT02 | 02TM04 | 02EM10 | 02EM04P |
| heco26 | hesperostipa comata, needle and thread | 2 | 0.21 | - | - | - | - | 0.04 | - | 0.38 |
| leci4 | leymus cinereus, basin wildrye | 1 | 0.01 | - | - | - | - | 0.01 | - | - |
| pose | poa secunda, sandberg bluegrass | 1 | 0.02 | 0.02 | - | - | - | - | - | - |
| | 6. Forb | | | | | | | | | |
| astra | astragalus sp., milkvetch | 1 | 0.02 | - | - | - | - | - | - | 0.02 |
| chdo | chaenactis douglasii, douglas's dustymaiden | 1 | 0.02 | - | - | - | - | - | - | 0.02 |
| chat | chenopodium atrovirens, pinyon goosefoot | 5 | 0.02 | - | 0.02 | 0.01 | - | 0.01 | 0.02 | 0.02 |
| cirsi | cirsium, thistle | 1 | 0.01 | - | - | 0.01 | - | - | - | - |
| coum | comandra umbellata, bastard toadflax | 5 | 0.05 | 0.02 | - | - | 0.17 | 0.01 | 0.02 | 0.02 |
| crwa2 | cryptantha watsonii, watson's catseye | 4 | 0.02 | - | 0.02 | - | 0.02 | 0.01 | 0.02 | - |
| erce2 | eriogonum cernuum, nodding buckwheat | 1 | 0.02 | - | - | - | - | - | - | 0.02 |
| eriog | eriogonum sp., eriogonum | 2 | 0.01 | - | - | 0.01 | - | 0.01 | - | - |
| forbem10 | forb unknown em10 (white stem) | 2 | 0.02 | - | - | - | 0.02 | - | 0.02 | - |
| forbsm01 | forb unknown sm01 (sow thistle) | 1 | 0.01 | - | - | 0.01 | - | - | - | - |
| gara2 | gayophytum ramosissimum, pinyon groundsmoke | 1 | 0.01 | - | - | - | - | 0.01 | - | - |
| heun | helianthella uniflora, oneflower helianthella | 3 | 0.02 | - | 0.02 | 0.01 | 0.02 | - | - | - |
| ipag | ipomopsis aggregata, skyrocket gilia | 1 | 0.01 | - | - | 0.01 | - | - | - | - |
| lifi | ligusticum filicinum, fernleaf licorice-root | 1 | 0.01 | - | - | 0.01 | - | - | - | - |
| liru4 | lithospermum ruderale, western gromwell | 2 | 0.02 | - | 0.02 | 0.01 | - | - | - | - |
| luse4 | lupinus sericeus, silky lupine | 1 | 0.06 | - | 0.06 | - | - | - | - | - |
| lupin | lupinus sp., lupine | 1 | 0.01 | - | - | 0.01 | - | - | - | - |

Table 13 (continued).

| | | Group E | | Plots | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| NRCS Code | Species Name | # plots (n=7) | Ave | 02EM849 | 02EM08 | 02SM01 | 02NT02 | 02TM04 | 02EM10 | 02EM04P |
| lyju | lygodesmia juncea, rush skeletonplant | 1 | 0.01 | - | - | 0.01 | - | - | - | - |
| macac | machaeranthera canescens ssp. canescens, hoary tansyaster | 3 | 0.02 | - | 0.02 | - | 0.02 | - | - | 0.02 |
| mepu3 | mentzelia pumila, dwarf mentzelia | 4 | 0.02 | - | 0.02 | 0.01 | 0.02 | - | - | 0.02 |
| psla3 | psoralidium lanceolatum, lemon scurfpea | 7 | 0.11 | 0.22 | 0.06 | 0.03 | 0.17 | 0.04 | 0.18 | 0.06 |
| ruve2 | rumex venosus, veiny dock | 1 | 0.02 | - | - | - | - | - | - | 0.02 |

Table 14. Relative plant canopy cover in the plots of group C.
Each cell shows proportion of the plant canopy cover in a plot contributed by a species. The number of the plots in a group containing the species, and the average relative cover of the species in just those plots, also are shown. Italic type-face indicates exotic species.

| | | Group C | | Plots | | | |
|---|---|---|---|---|---|---|---|
| NRCS Code | Species Name | # plots (n=4) | Ave | 02NT3778 | 02WM16 | 02WM17 | 02WR13 |
| | 2. Shrub | | | | | | |
| artrt | artemisia tridentata ssp. tridentata, basin big sagebrush | 4 | 0.50 | 0.36 | 0.51 | 0.68 | 0.45 |
| atrip | atriplex sp., saltbush | 1 | 0.05 | - | - | - | 0.05 |
| cele3 | cercocarpus ledifolius, curlleaf mountain mahogany | 2 | 0.03 | 0.04 | 0.02 | - | - |
| chviv2 | chrysothamnus viscidiflorus ssp. viscidiflorus, yellow rabbitbrush | 4 | 0.12 | 0.12 | 0.17 | 0.02 | 0.15 |
| erna10 | ericameria nauseosa, rubber rabbitbrush | 1 | 0.02 | - | 0.02 | - | - |
| putr2 | purshia tridentata, antelope bitterbrush | 1 | 0.12 | 0.12 | - | - | - |
| teca2 | tetradymia canescens, spineless horsebrush | 4 | 0.05 | 0.01 | 0.02 | 0.02 | 0.15 |
| | 3. Subshrub | | | | | | |
| lepu | leptodactylon pungens, granite pricklygilia | 2 | 0.03 | 0.04 | 0.02 | - | - |
| oppo | opuntia polyacantha, plains pricklypear | 2 | 0.08 | 0.01 | - | - | 0.15 |
| | 5. Grass | | | | | | |
| achy | achnatherum hymenoides, indian ricegrass | 2 | 0.08 | 0.12 | - | - | 0.05 |
| elel5 | elymus elymoides, bottlebrush squirreltail | 1 | 0.01 | 0.01 | - | - | - |
| ellal | elymus lanceolatus ssp. lanceolatus, thickspike wheatgrass | 1 | 0.04 | 0.04 | - | - | - |
| graswr01 | grass unknown wr01 (fat grass) | 1 | 0.05 | - | 0.05 | - | - |
| heco26 | hesperostipa comata, needle and thread | 2 | 0.02 | 0.01 | - | 0.02 | - |
| pose | poa secunda, sandberg bluegrass | 3 | 0.14 | 0.04 | 0.17 | 0.23 | - |
| | 6. Forb | | | | | | |
| arho4 | arenaria hookeri, hooker's sandwort | 2 | 0.02 | 0.01 | - | 0.02 | - |
| coum | comandra umbellata, bastard toadflax | 1 | 0.04 | 0.04 | - | - | - |
| cora5 | cordylanthus ramosus, bushy bird's beak | 1 | 0.01 | 0.01 | - | - | - |
| crypt | cryptantha sp., cryptantha | 2 | 0.01 | 0.01 | 0.02 | - | - |
| erum | eriogonum umbellatum, sulphur wildbuckwheat | 2 | 0.01 | 0.01 | 0.02 | - | - |
| forboynt | forb unknown tall sage (skeleton plant) | 1 | 0.01 | 0.01 | - | - | - |

Table 15. Relative plant canopy cover in the plots of group B.
Each cell shows proportion of the plant canopy cover in a plot contributed by a species. The number of the plots in a group containing the species, and the average relative cover of the species in just those plots, also are shown. Italic type-face indicates exotic species.

| | | Group B | | Plots | | | |
|---|---|---|---|---|---|---|---|
| NRCS Code | Species Name | # plots (n=4) | Ave | 02NT03 | 02WM15 | 02EM3291 | 02WR01 |
| | 2. Shrub | | | | | | |
| arno4 | artemisia nova, black sagebrush | 1 | 0.04 | - | - | 0.04 | - |
| artrt | artemisia tridentata ssp. tridentata, basin big sagebrush | 1 | 0.49 | 0.49 | - | - | - |
| artrw8 | artemisia tridentata ssp. wyomingensis, wyoming big sagebrush | 3 | 0.39 | - | 0.42 | 0.36 | 0.39 |
| cele3 | cercocarpus ledifolius, curlleaf mountain mahogany | 3 | 0.02 | - | 0.04 | 0.01 | 0.01 |
| chviv2 | chrysothamnus viscidiflorus ssp. viscidiflorus, yellow rabbitbrush | 4 | 0.07 | 0.01 | 0.14 | 0.01 | 0.13 |
| erna10 | ericameria nauseosa, rubber rabbitbrush | 2 | 0.02 | 0.01 | - | 0.04 | - |
| putr2 | purshia tridentata, antelope bitterbrush | 2 | 0.04 | 0.04 | - | 0.04 | - |
| rice | ribes cereum, wax currant | 1 | 0.01 | 0.01 | - | - | - |
| rosa5 | rosa sp., rose | 1 | 0.04 | 0.04 | - | - | - |
| syor2 | symphoricarpos oreophilus, whortleleaf snowberry | 3 | 0.02 | 0.04 | 0.01 | 0.01 | - |
| teca2 | tetradymia canescens, spineless horsebrush | 2 | 0.12 | - | - | 0.12 | 0.13 |
| | 3. Subshrub | | | | | | |
| krla2 | krascheninnikovia lanata, winterfat | 1 | 0.01 | - | - | - | 0.01 |
| lepu | leptodactylon pungens, granite pricklygilia | 2 | 0.03 | - | 0.04 | 0.01 | - |
| oppo | opuntia polyacantha, plains pricklypear | 1 | 0.01 | - | - | - | 0.01 |
| | 5. Grass | | | | | | |
| achy | achnatherum hymenoides, indian ricegrass | 3 | 0.09 | - | 0.01 | 0.12 | 0.13 |
| feid | festuca idahoensis, idaho fescue | 1 | 0.12 | 0.12 | - | - | - |
| graswr01 | grass unknown wr01 (fat grass) | 2 | 0.07 | 0.12 | - | - | 0.01 |
| pose | poa secunda, sandberg bluegrass | 3 | 0.18 | - | 0.28 | 0.12 | 0.13 |
| | 6. Forb | | | | | | |
| arho4 | arenaria hookeri, hooker's sandwort | 3 | 0.01 | - | 0.01 | 0.01 | 0.01 |
| basa3 | balsamorhiza sagittata, arrowleaf balsamroot | 1 | 0.01 | - | - | 0.01 | - |
| cali4 | castilleja linariifolia, wyoming indian paintbrush | 1 | 0.01 | 0.01 | - | - | - |
| coum | comandra umbellata, bastard toadflax | 1 | 0.01 | - | - | 0.01 | - |
| cora5 | cordylanthus ramosus, bushy bird's beak | 2 | 0.01 | 0.01 | - | 0.01 | - |
| crypt | cryptantha sp., cryptantha | 2 | 0.01 | - | - | 0.01 | 0.01 |
| eriog | eriogonum sp., eriogonum | 1 | 0.01 | 0.01 | - | - | - |
| erum | eriogonum umbellatum, sulphur wildbuckwheat | 2 | 0.03 | - | 0.04 | 0.01 | - |
| forbwr01 | forb unknown wr01 (erigodium) | 1 | 0.01 | - | - | - | 0.01 |
| helia | helianthella sp., helianthella | 1 | 0.04 | 0.04 | - | - | - |
| lifi | ligusticum filicinum, fernleaf licorice-root | 2 | 0.02 | 0.01 | - | 0.04 | - |
| liru4 | lithospermum ruderale, western gromwell | 1 | 0.01 | - | - | 0.01 | - |
| lupin | lupinus sp., lupine | 2 | 0.02 | 0.04 | - | 0.01 | - |

Table 16. Relative plant canopy cover in the plots of group A.
Each cell shows proportion of the plant canopy cover in a plot contributed by a species. The number of the plots in a group containing the species, and the average relative cover of the species in just those plots, also are shown. Italic type-face indicates exotic species.

| NRCS Code | Species Name | Group A | | Plot | |
|---|---|---|---|---|---|
| | | # plots (n=2) | Ave | 02EM05 | 02EM07 |
| | 2. Shrub | | | | |
| artrt | artemisia tridentata ssp. tridentata, basin big sagebrush | 2 | 0.32 | 0.24 | 0.40 |
| erna10 | ericameria nauseosa, rubber rabbitbrush | 1 | 0.13 | - | 0.13 |
| putr2 | purshia tridentata, antelope bitterbrush | 1 | 0.01 | - | 0.01 |
| rice | ribes cereum, wax currant | 2 | 0.02 | 0.02 | 0.01 |
| rosa5 | rosa sp., rose | 1 | 0.08 | 0.08 | - |
| syor2 | symphoricarpos oreophilus, whortleleaf snowberry | 2 | 0.05 | 0.08 | 0.01 |
| teca2 | tetradymia canescens, spineless horsebrush | 1 | 0.01 | - | 0.01 |
| | 3. Subshrub | | | | |
| ermil2 | eriogonum microthecum var. laxiflorum, slender buckwheat | 1 | 0.04 | - | 0.04 |
| lepu | leptodactylon pungens, granite pricklygilia | 2 | 0.02 | 0.01 | 0.04 |
| mare11 | mahonia repens, oregongrape | 1 | 0.01 | 0.01 | - |
| | 5. Grass | | | | |
| achna | achnatherum sp., ricegrass | 1 | 0.13 | - | 0.13 |
| *brini* | *bromus inermis* ssp. *inermis, smooth brome* | 1 | 0.08 | 0.08 | - |
| eltrt | elymus trachycaulus ssp. trachycaulus, slender wheatgrass | 1 | 0.31 | 0.31 | - |
| grasem07 | grass unknown em07 (long blade grass) | 1 | 0.01 | - | 0.01 |
| leki2 | leucopoa kingii, spike fescue | 1 | 0.01 | - | 0.01 |
| | 6. Forb | | | | |
| anten | antennaria, pussytoes | 1 | 0.01 | 0.01 | - |
| arco | arabis cobrensis, sagebrush rockcress | 1 | 0.01 | 0.01 | - |
| arho4 | arenaria hookeri, hooker's sandwort | 1 | 0.01 | - | 0.01 |
| ardr4 | artemisia dracunculus, wormwood | 1 | 0.01 | - | 0.01 |
| aske | astragalus kentrophyta, spiny milkvetch | 1 | 0.01 | 0.01 | - |
| cirsi | cirsium, thistle | 1 | 0.01 | - | 0.01 |
| cora5 | cordylanthus ramosus, bushy bird's beak | 2 | 0.01 | 0.01 | 0.01 |
| eriog | eriogonum sp., eriogonum | 2 | 0.01 | 0.01 | 0.01 |
| erysi | erysimum sp., wallflower | 1 | 0.01 | 0.01 | - |
| forbem05 | forb unknown em05 (opposite leaf) | 1 | 0.01 | 0.01 | - |
| forbem07 | forb unknown em07 (dead balsamorhiza) | 1 | 0.01 | - | 0.01 |
| forbem5 | forb unknown em5 (4 leaf forb) | 1 | 0.08 | 0.08 | - |
| gabo2 | galium boreale, northern bedstraw | 1 | 0.01 | 0.01 | - |
| heun | helianthella uniflora, oneflower helianthella | 1 | 0.01 | 0.01 | - |
| ipag | ipomopsis aggregata, skyrocket gilia | 1 | 0.01 | - | 0.01 |
| liru4 | lithospermum ruderale, western gromwell | 2 | 0.01 | 0.01 | 0.01 |
| luse4 | lupinus sericeus, silky lupine | 1 | 0.01 | 0.01 | - |
| lupin | lupinus sp., lupine | 1 | 0.01 | - | 0.01 |
| mepu3 | mentzelia pumila, dwarf mentzelia | 1 | 0.01 | - | 0.01 |
| pela9 | penstemon laricifolius, larchleaf beardtongue | 1 | 0.01 | - | 0.01 |
| penst | penstemon sp., penstemon | 1 | 0.01 | - | 0.01 |
| pest2 | penstemon strictus, rocky mountain penstemon | 2 | 0.01 | 0.01 | 0.01 |

Table 17. Relative plant canopy cover in the plots of group F.
Each cell shows proportion of the plant canopy cover in a plot contributed by a species. The number of the plots in a group containing the species, and the average relative cover of the species in just those plots, also are shown. Italic type-face indicates exotic species.

| | | Group F | | Plots | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NRCS Code | Species Name | # plots (n=13) | Ave | 02EM1185 | 02EM127 | 02EM14 | 02EM18 | 02EM1999 | 02EM67 | 02OY193 | 02OY94 | 02TMX | 03TS04 | 03TS08 | 03TS09 | 03TS10 |
| | 2. Shrub | | | | | | | | | | | | | | | |
| artrt | artemisia tridentata ssp. tridentata, basin big sagebrush | 6 | 0.02 | - | 0.02 | - | - | 0.01 | 0.03 | - | - | - | 0.02 | - | 0.02 | 0.02 |
| chvil4 | chrysothamnus viscidiflorus ssp. lanceolatus, yellow rabbitbrush | 2 | 0.02 | - | - | - | - | - | - | - | - | - | 0.02 | - | 0.02 | - |
| chviv2 | chrysothamnus viscidiflorus ssp. viscidiflorus, yellow rabbitbrush | 13 | 0.11 | 0.16 | 0.07 | 0.02 | 0.05 | 0.13 | 0.08 | 0.20 | 0.05 | 0.33 | 0.06 | 0.04 | 0.20 | 0.06 |
| erna10 | ericameria nauseosa, rubber rabbitbrush | 12 | 0.18 | 0.48 | 0.02 | - | 0.02 | 0.39 | 0.03 | 0.20 | 0.05 | 0.03 | 0.20 | 0.11 | 0.20 | 0.40 |
| rowo | rosa woodsii, woods' rose | 1 | 0.02 | - | - | - | - | - | - | - | - | - | 0.02 | - | - | - |
| teca2 | tetradymia canescens, spineless horsebrush | 4 | 0.04 | - | 0.02 | - | 0.05 | - | 0.08 | 0.02 | - | - | - | - | - | - |
| | 3. Subshrub | | | | | | | | | | | | | | | |
| lepu | leptodactylon pungens, granite pricklygilia | 1 | 0.02 | 0.02 | - | - | - | - | - | - | - | - | - | - | - | - |
| oppo | opuntia polyacantha, plains pricklypear | 1 | 0.02 | - | 0.02 | - | - | - | - | - | - | - | - | - | - | - |
| | 5. Grass | | | | | | | | | | | | | | | |
| achy | achnatherum hymenoides, indian ricegrass | 13 | 0.14 | 0.05 | 0.24 | 0.24 | 0.31 | 0.13 | 0.27 | 0.06 | 0.05 | 0.03 | 0.02 | 0.11 | 0.06 | 0.20 |
| ellal | elymus lanceolatus ssp. lanceolatus, thickspike wheatgrass | 13 | 0.09 | 0.05 | 0.02 | 0.07 | 0.05 | 0.01 | 0.08 | 0.06 | 0.05 | 0.03 | 0.20 | 0.36 | 0.06 | 0.06 |
| heco26 | hesperostipa comata, needle and thread | 12 | 0.12 | 0.05 | 0.24 | 0.02 | 0.31 | 0.13 | 0.27 | 0.20 | - | 0.03 | 0.02 | 0.04 | 0.06 | 0.02 |
| *lera5* | *leymus racemosus, volga wildrye* | 2 | 0.03 | - | - | - | - | - | - | - | - | - | - | 0.04 | - | 0.02 |
| pasm | pascopyrum smithii, western wheatgrass | 2 | 0.11 | - | - | 0.07 | - | - | - | - | 0.14 | - | - | - | - | - |

Table 17 (continued).

| | | Group F | | Plots | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NRCS Code | Species Name | # plots (n=13) | Ave | 02EM1185 | 02EM127 | 02EM14 | 02EM18 | 02EM1999 | 02EM67 | 02OY193 | 02OY94 | 02TMX | 03TS04 | 03TS08 | 03TS09 | 03TS10 |
| | 6. Forb | | | | | | | | | | | | | | | |
| arco | arabis cobrensis, sagebrush rockcress | 1 | 0.03 | - | - | - | - | - | - | - | - | 0.03 | - | - | - | - |
| ardr4 | artemisia dracunculus, wormwood | 1 | 0.02 | - | - | - | - | - | - | - | - | - | - | - | 0.02 | - |
| asge | astragalus geyeri, geyer's milkvetch | 1 | 0.04 | - | - | - | - | - | - | - | - | - | - | 0.04 | - | - |
| aske | astragalus kentrophyta, spiny milkvetch | 3 | 0.02 | 0.02 | - | - | - | - | - | - | - | - | 0.02 | - | 0.02 | - |
| asme2 | astragalus megacarpus, great bladdery milkvetch | 1 | 0.02 | - | - | - | - | - | - | - | - | - | 0.02 | - | - | - |
| chdo | chaenactis douglasii, douglas's dustymaiden | 2 | 0.02 | - | - | - | - | - | - | - | - | - | - | - | 0.02 | 0.02 |
| chat | chenopodium atrovirens, pinyon goosefoot | 1 | 0.02 | - | - | - | 0.02 | - | - | - | - | - | - | - | - | - |
| chpr5 | chenopodium pratericola, desert goosefoot | 2 | 0.02 | - | - | - | - | - | - | - | - | - | - | - | 0.02 | 0.02 |
| coum | comandra umbellata, bastard toadflax | 4 | 0.02 | - | 0.02 | - | 0.02 | - | 0.03 | - | - | - | 0.02 | - | - | - |
| covi5 | corispermum villosum, hairy bugseed | 1 | 0.04 | - | - | - | - | - | - | - | - | - | - | 0.04 | - | - |
| crfe3 | cryptantha fendleri, sanddune catseye | 5 | 0.02 | - | 0.02 | - | - | 0.01 | - | 0.02 | - | - | - | - | 0.02 | 0.02 |
| crfl6 | cryptantha flavoculata, roughseed catseye | 1 | 0.02 | - | - | - | - | - | - | - | - | - | - | - | 0.02 | - |
| crypt | cryptantha sp., cryptantha | 4 | 0.02 | - | 0.02 | - | 0.02 | 0.01 | 0.03 | - | - | - | - | - | - | - |
| crwa2 | cryptantha watsonii, watson's catseye | 2 | 0.03 | - | - | - | - | - | - | - | - | 0.03 | 0.02 | - | - | - |
| erce2 | eriogonum cernuum, nodding buckwheat | 1 | 0.02 | - | - | - | - | - | - | - | - | - | - | - | 0.02 | - |
| forboyem | forb unknown tall sage (red green) | 3 | 0.06 | 0.02 | - | - | - | - | - | 0.02 | 0.14 | - | - | - | - | - |
| forboynt | forb unknown tall sage (skeleton plant) | 1 | 0.05 | - | - | - | - | - | - | - | 0.05 | - | - | - | - | - |

Table 17 (continued).

| | | Group F | | Plots | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NRCS Code | Species Name | # plots (n=13) | Ave | 02EM1185 | 02EM127 | 02EM14 | 02EM18 | 02EM1999 | 02EM67 | 02OY193 | 02OY94 | 02TMX | 03TS04 | 03TS08 | 03TS09 | 03TS10 |
| forbtmx | forb unknown tmx (forb dry white hair) | 1 | 0.03 | - | - | - | - | - | - | - | - | 0.03 | - | - | - | - |
| gite | gilia tenerrima, delicate gilia | 1 | 0.04 | - | - | - | - | - | - | - | - | - | - | 0.04 | - | - |
| lare | lappula redowskii, western stickseed | 2 | 0.02 | - | - | - | - | - | - | - | - | - | 0.02 | - | 0.02 | - |
| lelu | lesquerella ludoviciana, foothill bladderpod | 1 | 0.02 | - | - | - | - | - | - | - | - | - | - | - | 0.02 | - |
| lupu | lupinus pusillus, rusty lupine | 1 | 0.02 | - | - | - | - | - | - | - | - | - | - | - | 0.02 | - |
| lyju | lygodesmia juncea, rush skeletonplant | 4 | 0.02 | - | - | - | - | 0.01 | - | - | - | - | - | 0.04 | 0.02 | 0.02 |
| macac | machaeranthera canescens ssp. canescens, hoary tansyaster | 11 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.03 | - | - | 0.03 | 0.02 | 0.04 | 0.02 | 0.02 |
| mepu3 | mentzelia pumila, dwarf mentzelia | 1 | 0.03 | - | - | - | - | - | - | - | - | 0.03 | - | - | - | - |
| oxytr | oxytropis sp., crazyweed | 2 | 0.02 | - | - | 0.02 | - | - | - | - | - | - | 0.02 | - | - | - |
| pear | penstemon arenicola, sand penstemon | 1 | 0.02 | - | - | - | - | - | - | - | - | - | 0.02 | - | - | - |
| psla3 | psoralidium lanceolatum, lemon scurfpea | 13 | 0.21 | 0.16 | 0.24 | 0.49 | 0.16 | 0.13 | 0.08 | 0.20 | 0.48 | 0.33 | 0.20 | 0.11 | 0.06 | 0.06 |
| ruve2 | rumex venosus, veiny dock | 5 | 0.03 | - | - | - | - | - | - | - | - | 0.03 | 0.02 | 0.04 | 0.06 | 0.02 |
| *satr12* | *salsola tragus, prickly russian thistle* | 3 | 0.02 | - | - | 0.02 | - | - | - | - | - | - | 0.02 | - | - | 0.02 |
| *trdu* | *tragopogon dubius, yellow salsify* | 3 | 0.02 | - | - | - | - | - | - | - | - | - | 0.02 | - | 0.02 | 0.02 |

Table 18. Relative plant canopy cover in the plots of group G.
Each cell shows proportion of the plant canopy cover in a plot contributed by a species. The number of the plots in a group containing the species, and the average relative cover of the species in just those plots, also are shown. Italic type-face indicates exotic species.

| | | Group G | | Plots | | |
|---|---|---|---|---|---|---|
| NRCS Code | Species Name | # plots (n=3) | Ave | 02EM09P | 02TM03 | 02WP04 |
| | 2. Shrub | | | | | |
| artrt | artemisia tridentata ssp. tridentata, basin big sagebrush | 1 | 0.09 | - | 0.09 | - |
| chviv2 | chrysothamnus viscidiflorus ssp. viscidiflorus, yellow rabbitbrush | 3 | 0.11 | 0.07 | 0.09 | 0.17 |
| erna10 | ericameria nauseosa, rubber rabbitbrush | 3 | 0.17 | 0.07 | 0.27 | 0.17 |
| putr2 | purshia tridentata, antelope bitterbrush | 1 | 0.07 | 0.07 | - | - |
| | 5. Grass | | | | | |
| achy | achnatherum hymenoides, indian ricegrass | 3 | 0.11 | 0.07 | 0.09 | 0.17 |
| *agcr* | *agropyron cristatum, crested wheatgrass* | 1 | 0.07 | 0.07 | - | - |
| ellal | elymus lanceolatus ssp. lanceolatus, thickspike wheatgrass | 1 | 0.07 | 0.07 | - | - |
| | 6. Forb | | | | | |
| chat | chenopodium atrovirens, pinyon goosefoot | 1 | 0.07 | 0.07 | - | - |
| forbwp04 | forb unknown wp04 (spikey plant) | 1 | 0.17 | - | - | 0.17 |
| *hagl* | *halogeton glomeratus, halogeton* | 2 | 0.13 | - | 0.09 | 0.17 |
| lyju | lygodesmia juncea, rush skeletonplant | 1 | 0.09 | - | 0.09 | - |
| macac | machaeranthera canescens ssp. canescens, hoary tansyaster | 1 | 0.07 | 0.07 | - | - |
| psla3 | psoralidium lanceolatum, lemon scurfpea | 3 | 0.22 | 0.21 | 0.27 | 0.17 |
| *satr12* | *salsola tragus, prickly russian thistle* | 1 | 0.21 | 0.21 | - | - |

Table 19. Relative plant canopy cover of 11 exotic plant taxa in the sample plots.
Only the 20 plots with exotic plants are shown. For each taxon, the proportion of the canopy cover it contributes to each plot, and the number of plots in which it occurs, are shown. For plots, the number of exotics present and the proportion of the canopy cover contributed by those exotics, are shown. Bold-face type shows values greater than 5%.

| Plot | Disturbance Category | Plot Total Cover | # of Exotics in Plot | Relative Cover of Exotics in Plot | agropyron cristatum, crested wheatgrass (agcr) | agropyron desertorum, desert wheatgrass (agde2) | bromus inermis ssp. inermis, smooth brome (brini) | bromus tectorum, cheatgrass (brte) | leymus racemosus, volga wildrye (lera5) | alyssum desertorum, desert madwort (alde) | descurainia sophia, herb sophia (deso2) | halogeton glomeratus, halogeton (hagl) | salsola tragus, prickly Russian thistle (satr12) | salsola sp., russian thistle (salso) | tragopogon dubius, yellow salsify (trdu) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 02EM05 | Undisturbed | 127 | 1 | **0.079** | - | - | **0.079** | - | - | - | - | - | - | - | - |
| 03TS02 | Undisturbed | 72 | 2 | 0.028 | - | - | - | - | - | 0.014 | 0.014 | - | - | - | - |
| 03TS03 | Undisturbed | 49 | 1 | 0.020 | - | - | - | - | - | - | 0.020 | - | - | - | - |
| 03TS06 | Undisturbed | 64 | 3 | 0.047 | 0.016 | - | - | - | - | 0.016 | 0.016 | - | - | - | - |
| 03TS07 | Undisturbed | 58 | 1 | 0.017 | - | - | - | - | - | - | 0.017 | - | - | - | - |
| 03TS09 | Undisturbed | 50 | 1 | 0.020 | - | - | - | - | - | - | - | - | - | - | 0.020 |
| 02WM06 | Undisturbed, White Mtn | 63 | 1 | 0.048 | - | - | - | 0.048 | - | - | - | - | - | - | - |
| 02EM14 | Burn | 41 | 1 | 0.024 | - | - | - | - | - | - | - | - | - | 0.024 | - |
| 02EM04P | Pipeline | 52 | 1 | 0.019 | - | - | 0.019 | - | - | - | - | - | - | - | - |
| 02EM14P | Pipeline | 54 | 1 | 0.019 | - | - | 0.019 | - | - | - | - | - | - | - | - |
| 02EM6P | Pipeline | 48 | 1 | 0.021 | - | - | - | - | - | - | - | - | - | 0.021 | - |
| 02TM29 | Pipeline | 56 | 3 | 0.054 | 0.018 | - | 0.018 | - | - | - | - | - | - | - | 0.018 |
| 03TS01 | Pipeline | 62 | 2 | 0.048 | 0.032 | - | - | - | - | - | 0.016 | - | - | - | - |
| 03TS04 | Dry hole | 49 | 2 | 0.041 | - | - | - | - | - | - | - | - | 0.020 | - | 0.020 |
| 03TS05 | Dry hole | 43 | 1 | 0.023 | 0.023 | - | - | - | - | - | - | - | - | - | - |
| 03TS08 | Dry hole | 28 | 1 | 0.036 | - | - | - | - | 0.036 | - | - | - | - | - | - |
| 03TS10 | Dry hole | 50 | 3 | **0.060** | - | - | - | - | 0.020 | - | - | - | 0.020 | - | 0.020 |
| 02EM09P | Well pad | 14 | 2 | **0.286** | - | **0.071** | - | - | - | - | - | - | - | **0.214** | - |
| 02TM03 | Well pad | 11 | 1 | **0.091** | - | - | - | - | - | - | - | **0.091** | - | - | - |
| 02WP04 | Well pad | 6 | 1 | **0.167** | - | - | - | - | - | - | - | **0.167** | - | - | - |
| # of Plots with Taxon | | | | | 4 | 1 | 4 | 1 | 2 | 2 | 5 | 2 | 2 | 3 | 4 |

Table 20. Linear regression of herbaceous canopy cover on density of elk pellets and height of the shrub canopy in 19 undisturbed plots.

$H_o$: The amount of herbaceous canopy cover has no linear relationship to the density of elk pellets or the height of the top of the shrub canopy.
$H_1$: The amount of herbaceous canopy cover is related in a linear manner to the density of elk pellets or the height of the top of the shrub canopy.

*Regression Table:*

| Predictor | Coefficient | Std Deviation | T Value | Probability |
|---|---|---|---|---|
| Constant | 26.590 | 3.764 | 7.06 | 0.000 |
| Height of canopy | 0.146 | 0.080 | 1.83 | 0.088 |
| Pellet density | -0.034 | 0.026 | -1.31 | 0.210 |
| Interaction | -0.0009 | 0.0004 | -2.03 | 0.061 |

S = 4.690, $r^2$ = 56.8%, $r^2$ (adjusted) = 48.2%

*Regression Equation:*

% Herbaceous Cover = 26.6 + 0.146 (elk pellet density) - 0.0344 (canopy height) - 0.000853 (pellet X canopy height interaction)

*Analysis of Variance Table*

| Source | Degrees of Freedom | Sum of Squares | Mean Square | F | Probability |
|---|---|---|---|---|---|
| Regression | 3 | 434.44 | 144.81 | 6.58 | 0.005 |
| Residual Error | 15 | 329.98 | 22.00 | | |
| Total | 18 | 764.42 | | | |

Conclusion: Reject $H_0$. Amount of herbaceous canopy cover is related in a linear manner to the height of the shrub overstory but not to the density of elk pellets.

Table 21. Linear regression of herbaceous canopy cover on density of the shrub canopy in 36 undisturbed plots.

$H_o$: The amount of herbaceous canopy cover has no linear relationship to the density of the shrub overstory.
$H_1$: The amount of herbaceous canopy cover is related in a linear manner to the density of the shrub overstory.

*Regression Table:*

| Predictor | Coefficient | Std Deviation | T Value | Probability |
|---|---|---|---|---|
| Constant | 26.575 | 2.654 | 10.01 | 0.000 |
| Overstory density | -15.818 | 7.597 | -2.08 | 0.045 |

S = 7.471, $r^2$ = 11.3%, $r^2$ (adjusted) = 8.7%

*Regression Equation:*

% Herbaceous Cover = 26.6 - 15.8 (overstory density)

*Analysis of Variance Table*

| Source | Degrees of Freedom | Sum of Squares | Mean Square | F | Probability |
|---|---|---|---|---|---|
| Regression | 1 | 241.99 | 241.99 | 4.34 | 0.045 |
| Residual Error | 34 | 1897.64 | 55.81 | | |
| Total | 35 | 2139.64 | | | |

Conclusion: Reject $H_0$. Amount of herbaceous canopy cover is related in a linear manner to the density of the shrub overstory.

Table 22. Two-sample t-test on litter cover, undisturbed vs. disturbed plots.

$H_0$: Average per-plot percent litter cover is not greater in undisturbed plots than in disturbed plots.
$H_1$: Average per-plot percent litter cover is greater in undisturbed plots than in disturbed plots.

| Disturbance Categories | N | Mean | StDev | SE Mean |
|---|---|---|---|---|
| Undisturbed | 37 | 44.9 | 16.7 | 2.8 |
| Disturbed | 19 | 20.1 | 15.2 | 3.5 |

95% CI for μ (undisturbed) - μ (disturbed): (15.8, 33.8)
T-Test μ (undisturbed) = μ (disturbed) VS. μ (undisturbed) > μ (disturbed): T = 5.58 P = 0.0000 DF = 39
Equal variances not assumed.

Conclusion: Reject $H_0$. Average per-plot percent litter cover is greater in undisturbed plots than in disturbed plots.

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Table 23. Two-sample t-test on wood cover, undisturbed vs. disturbed plots.

$H_0$: Average per-plot percent wood cover is not greater in undisturbed plots than in disturbed plots.
$H_1$: Average per-plot percent wood cover is less in undisturbed plots than in disturbed plots.

| Disturbance Categories | N | Mean | StDev | SE Mean |
|---|---|---|---|---|
| Undisturbed | 37 | 39.9 | 18.5 | 3.0 |
| Disturbed | 19 | 71.7 | 14.4 | 3.3 |

95% CI for μ (undisturbed) - μ (disturbed): (-40.9, -22.8)
T-Test μ (undisturbed) = μ (disturbed) VS. μ (undisturbed) > μ (disturbed): T = -7.10 P = 0.0000 DF = 48
Equal variances not assumed.

Conclusion: Reject $H_0$. Average per-plot percent wood cover is greater in undisturbed plots than in disturbed plots.

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Table 24. Two-sample t-test on bare soil, undisturbed vs. disturbed plots.

$H_0$: Average per-plot percent bare soil is not greater in undisturbed plots than in disturbed plots.
$H_1$: Average per-plot percent bare soil is less in undisturbed plots than in disturbed plots.

| Disturbance Categories | N | Mean | StDev | SE Mean |
|---|---|---|---|---|
| Undisturbed | 37 | 39.9 | 18.5 | 3.0 |
| Disturbed | 19 | 71.7 | 14.4 | 3.3 |

95% CI for μ (undisturbed) - μ (disturbed): (-40.9, -22.8)
T-Test μ (undisturbed) = μ (disturbed) VS. μ (undisturbed) < μ (disturbed): T = -7.10 P = 0.0000 DF = 45
Equal variances not assumed.

Conclusion: Reject $H_0$. Average per-plot percent bare soil is less in undisturbed plots than in disturbed plots.

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## APPENDIX 1. SAMPLING FORMS FROM FROM INDIVIDUAL SAMPLING PLOTS

This appendix contains two pages of informaton for each sample plot. The first page describes the plot's location of the, environment, and vegetation. The second page shows the canopy cover of each plant species in the plot.

This appendix is in a separate file available upon request from the Wyoming Natural Diversity Database.

## APPENDIX 2. PHOTOGRAPHS FROM THE TALL SAGEBRUSH PROJECT SAMPLING PLOTS

The photographs are in a separate digital file, "BLM_Tall_Sage_Appen2_Photos.doc", available upon request from the Wyoming Natural Diversity Database.