VEGETATION ON SAND SUBSTRATES IN THE BLM RAWLINS AND ROCK SPRINGS FIELD OFFICES, WYOMING

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and

the University of Wyoming,
Wyoming Natural Diversity Database

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ABSTRACT

Sand substrates provide an uncommon type of environment for plants in southwestern Wyoming. The "Quaternary sand" map unit from the Wyoming bedrock geology map was used to select sampling points in this environment, and nested sample plots were used to record presence and estimate canopy cover of the vascular plant species growing at those points. Throughout southwestern Wyoming, *Hesperostipa comata* (needle and thread) and *Achnatherum hymenoides* (indian ricegrass) are common on sand substrates and often dominate the herbaceous stratum, and *Chrysothamnus viscidiflorus* ssp. *viscidiflorus* (yellow rabbitbrush) is common and sometimes dominant in the shrub layer. The vegetation in the Sand Hills north of Baggs differs from vegetation on sand substrates elsewhere in the presence of a number of plant species, and in the dominance by *Artemisia cana* ssp. *cana* (basin big sagebrush), *Purshia tridentata* (antelope bitterbrush), and *Symphoricarpos oreophilus* (whortleleaf snowberry) in the shrub stratum and by *Muhlenbergia pungens* (sandhill muhly) in the herbaceous stratum. The Sand Hills vegetation is denser than vegetation elsewhere, and richer in species. Fires in that area have reduced the cover of shrubs, but not of other plants.

Outside the Sand Hills, the vegetation on sand substrates is less dense and contains little or no *Artemisia cana* ssp. *cana* or *Purshia tridentata*. *Artemisia tridentata* spp. *wyomingensis* (Wyoming big sagebrush) dominates the shrub stratum in many places, and a number of other shrubs, especially *Sarcobatus vermiculatus* (greasewood) often are present. The vegetation is more variable in the species present and poorer in species than in the Sand Hills.

Few exotic plant species were encountered in the plots, and those species were minor components of the vegetation. Thirty-one percent of the 158 plant taxa encountered in the plots could not be identified to species, though, and if the identity of these taxa were known, exotic species might constitute a higher proportion of the flora. They still would be minor constitutents of the vegetation.

Classification of the plot data suggest that three recognizable plant community-types might be named from sand substrates: an *Artemisia cana - Purshia tridentata* / *Hesperostipa comata* plant community-type in the Sand Hills, an *Artemisia tridentata* ssp. *wyomingensis* / *Hesperostipa comata* plant community-type from outside the Sand Hills, and a *Chrysothamnus viscidiflorus* ssp. *viscidiflorus* / *Hesperostipa comata* plant community-type in the Sand Hills and elsewhere. Many of the plots, though, are classified into clusters so variable in their dominant species that naming plant community-types from them is unjustified. None of these putative plant community-types suggested by the plot data bear any close relationship to vegetation types in the national vegetation classification.

INTRODUCTION

In April 2002, the Bureau of Land Management's Wyoming State Office, Rawlins Field Office, and Rock Springs Field Office entered into a cooperative agreement with the University of Wyoming's Natural Diversity Database (WYNDD) for the study of vegetation growing on sand substrates on BLM-managed lands in south-central and southwestern Wyoming. The project was conducted for two reasons. The first was to document the degree of recovery of vegetation in the Sand Hills northeast of Baggs (Figure 1), where three fires have burned since 1968. BLM biologists and managers want to know how quickly the vegetation recovers after disturbance in this important mule deer habitat (Frank Blomquist, Rawlins BLM, personal communication). By comparing vegetation in sample plots in all three fires and in unburned areas, we hoped to estimate roughly how long recovery takes.

The second reason for the project was to characterize the species composition and the structure of the vegetation growing in this type of habitat, which is uncommon in Wyoming by either of two measures. According to the Wyoming Gap Analysis Project's land cover map, active dunes and vegetated dunes together constitute only 0.23% of Wyoming's land surface (Merrill *et al.* 1996, Table 2.2). And only 2.3% of the state's surface is mapped as Quaternary sand (calculated from an Albers conformal conic projection of the bedrock geology map of Wyoming [U.S. Geological Survey 1994]). In semi-arid climates, these sandy substrates provide a relatively large water supply to those species that can tolerate the unstable substrate, compared to the finer-textured sediments that often form the regional bedrock (e.g., Knight 1994, pp. 120-123; Walter 1985, pp. 248 - 251).

This characterization of sand-substrate vegetation was accomplished by collection of canopy cover data from study points throughout the public lands administered by the two field offices (Figure 1). The Killpecker Dunes in north-central Sweetwater County, the largest occurrence of sand substrate in the study area, were excluded from this project because they are the subject of other BLM - WYNDD cooperative projects (Jones in prep[a], [b], [c]).

The results from the Sand Hills, a specific locale for sand-substrate vegetation, are reported first in this document. The results from all of the sample locations, which give a broader picture of sand-substrate vegetation in southern Wyoming and provide a context for the vegetation of the Sand Hills, are reported second.

VEGETATION OF THE SAND HILLS NORTH OF BAGGS

METHODS

Selection of Sampling Locations

The public lands within the Sand Hills Area of Critical Environmental Concern (ACEC) (Bureau of Land Management 1990) constituted the study area (Figure 2). BLM Rawlins Field Office biologists provided a paper map at 1:24,000 scale showing the boundaries of areas burned in the ACEC in 1968, 1990, and 1993. This map was used by WYNDD biologists to digitize the boundaries on-screen in ArcView 3.2 (ESRI, Redlands CA, USA), against a background of the digital raster graphic (i.e., digital topographic map) and the black-and-white digital orthophotoquad quarters (i.e., digital aerial photographs). The boundaries of the 1990 and 1993 fires were easily discerned on the aerial photographs, but the boundary of the 1968 fire was faint and very difficult to discern in some areas.

A layer of random points was superimposed on the map of the study area, and a subset of those points was selected to serve as potential sampling locations. The UTM coordinates for each of those locations were recorded, which allowed WYNDD field crew members to find the locations in the field using a global positioning system (GPS) receiver (GeoExplorer 2, Trimble Navigation Ltd., Sunnyvale CA, USA). Reconnaissance showed, in the judgement of WYNDD biologists, that the vegetation was homogeneous in appearance and species composition within a given burned area. The vegetation also

appeared to vary little in structure and species composition throughout most of the unburned area, except that the vegetation at higher elevation in the eastern part of the study area contained more shrub species. With this high degree of homogeneity in mind, the WYNDD biologists selected eleven of the potential locations for sampling, four in unburned vegetation and 7 in burned areas. Those eleven locations, all on sand substrate, were selected randomly from the larger set of potential locations to illustrate, in the judgement of the WYNDD field crew, the variation in vegetation within each of the burned areas and within the unburned area.

In several cases, readings from the GPS units were unavailable, so the field crew used the 7.5-minute topographic map to navigate as near as possible to the sampling location. One of the locations near the southern boundary of the 1993 fire was moved by the field crew because inaccuracies in the digital data layers had caused its placement within the burned area, and it was intended as a sample of unburned vegetation.

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 11 sampling locations. This plot design features a 20 m x 50 m macroplot with 13 sub-plots inside it (Figure 3). 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 (NAD27, Zone 13) of the corner's actual location. The azimuth of the macroplot's long axis was recorded with a sighting compass.

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). 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. 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. With this procedure, canopy cover was recorded only for the plants in the microplots. Presence alone was recorded for species in the larger sub-plots and in the macroplot.

The values for a species from the 10 microplots were then 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 value from a microplot) average 7.6, which average falls within the 5% - 15% cover range. The value for species A for the macroplot 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 vegetation at the sampling location was briefly described and a photograph was taken of the macroplot. The percentage of the ground surface in each microplot covered by each of nine categories of material (Table 2) was estimated and an average value for each calculated for the macroplot, as for the canopy cover values from the microplots. 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.

RESULTS

Canopy Cover

Four plots were sampled in the unburned vegetation, two in the area burned by the 1968 fire, two in the 1990 fire area, and three in the 1993 fire area (Table 2). Due to the small sample sizes, canopy cover estimates were pooled for all of the burned plots for analyses, and the pooled cover value for the burned plots was compared to cover in the unburned plots. Shrub cover appeared to be greater in the unburned plots, but cover of sub-shrubs (species such as plains pricklypear, winterfat, granite pricklygilia, and cushion buckwheat), graminoids, and forbs appeared to be the same in the burned as the unburned plots (Figure 4). Cover of all plants taken together appeared to be slightly greater in the unburned than in the burned plots.

Analysis of variance showed that both fire and plant growth-form had a statistically significant effect on canopy cover (Table 3). Differences in shrub canopy cover and total plant canopy cover were tested for significance with two-sample t-tests. Shrub canopy cover was significantly greater ($p < 0.05$) in unburned than in burned plots (Table 4), but total plant cover was not ($p > 0.05$) (Table 5).

That the data analysis shows less shrub cover in burned than in unburned areas comes as no surprise, given the differences in their appearances. The more interesting result is that the fires in the Sand Hills apparently had no lasting effect on the amounts of sub-shrubs, graminoids, forbs, and total canopy cover.

Although the data could not be tested for statistical differences between fire years, shrub canopy cover appears to be greater on the plots burned in 1968 than on plots burned in 1990 (Figure 5). Total plant canopy cover, though, does not appear to vary between burns. More sampling in each of the burned areas might reveal significant differences in canopy cover.

Species Composition

One-hundred-one vascular plant species were documented in the 11 sample plots (Tables 6 and 7). Fifty-four of those species were noted in only one or two plots, and only five species were found in all 11 plots (Figure 6). Seventeen species (7% of the total) were forbs that could not be identified to genus or species.

Exotic species, although widespread, apparently are a minor part of the vegetation. Only six introduced plants were identified to species, and only two of those occurred in at least half of the plots (desert madwort [*Alyssum desertorum*] in 9 plots, and herb sophia [*Descurainia sophia*] in 6) (Table 6). The 17 unidentified taxa may include some exotics. Cheatgrass (*Bromus tectorum*), an exotic recently of particular concern in Wyoming, was documented in only two plots. Ten of the 11 plots had at least one exotic species (Table 8), but those species accounted for less than 10% of the canopy cover in any plot (Table 9). Exotic species accounted for no higher proportion of the plant species present in burned plots than in unburned plots (Table 10a), but they did contribute a slightly (but significantly) higher proportion of the canopy cover on the burned plots than on the unburned plots -- 4.7% of cover on the burned plots and 1.7% on the unburned plots (Table 10b).

The relationships among the sample plots in terms of their overall species composition are impossible to examine with standard statistical approaches, but identifying these relationships is a requirement for answering questions such as these: Do the burned plots contain different groups of plant species than the unburned plots? Do certain sample plots, either with the same fire history or with different fire histories, share groups of plant species? What are those groups?

These questions can be studied with analytical procedures known as “ordination”. A variety of ordination techniques are available that use different methods for calculating the similarity (or its complement, dissimilarity) between plots, but every ordination technique tries to summarize the multi-dimensional relationship between plots and express it in a few dimensions. Ordination complements

classification; the latter seeks to place plots or stands into groups and to show the differences between those groups, while the former seeks to show gradients in similarity or difference.

The results from ordination usually are displayed in graphs, where plots with similar species composition lie close to one another and dissimilar plots are far apart. Each axis in the graph expresses some of the information about the relationships between all of the plots. Every ordination procedure tries to reduce the number of dimensions (or axes in a graph) required to adequately show the similarity or dissimilarity between points. In the present case, the relationship between the 11 sample plots would require 10 dimensions for its full expression, but this multi-dimensional arrangement would be impossible to understand. Ordination of the sample plots reduces the 11 dimensions to several dimensions in which the plots can be graphed, and the relationships more clearly seen.

Non-metric multidimensional scaling (NMS) is an ordination technique well suited to analysis of plant community data such as these Sand Hills sample plots, where each plot contains at least a score of species and the abundance values for species do not meet the assumptions of standard statistical analysis (McCune and Grace 2002). NMS works by initially constructing a matrix of the dissimilarity values between each pair of plots, then calculating an increasing number of axes along which the plots are arranged, with the score for a plot on each axis representing some amount of information from the matrix of dissimilarity values. The axis scores can never contain all of the information in the dissimilarity matrix, and NMS repeatedly re-calculates the scores for each plot on each axis, each time adjusting the scores slightly so that they better represent the information in the matrix. The analysis proceeds until some maximum number of axes has been constructed and the difference between the axis scores and the dissimilarity matrix can no longer be significantly reduced. Usually, there is some number of axes *n* beyond which no improvement in the result is realized, and scores for all plots on these *n* axes are chosen as the best result of the initial analysis. Those scores are then used in the final NMS analysis, which repeatedly re-calculates the plot scores along the *n* axes and compares them to the original dissimlarity matrix, until the difference between them can not be significantly reduced.

For the NMS analysis of the Sand Hills plot data, the cover values for each species in each plot were converted to presence/absence data: each species was noted simply as being present or absent in each plot. The data were converted in this manner to answer the question, "How do the plots with different fire histories resemble each other in terms of the plant species they contain?" The analysis of canopy cover by life form had already shown that the unburned plots contained more shrub cover than did the burned plots, and that difference likely would have partially obscured the picture of relationships in species composition. So, the cover data were converted to presence/absence to remove the effect of differences in amounts of species.

The presence/absence data still reflected the large differences between the species in the number of plots in which each was recorded (Table 6), a situation that gives the common species greater influence than the rare species in the analysis. Therefore, the data were further transformed, by dividing the value for each species in each plot by the total number of plots for that species. This transformation (known as "relativizing by species total"; McCune and Grace 2002) makes common species and rare species more nearly equal in their influence on the analysis. The NMS ordination was then performed on the presence/absence data relativized by species total.

An initial NMS ordination indicated that a two-dimensional solution gave the best representation of the information in the dissimilarity matrix (because stress declined greatly from one dimension to two, but much less in going from two dimensions to three: Table 11) and the final, two-dimensional NMS ordination represents most of the information present in the original matrix of dissimilarities between pairs of plots (Table 12). The plots appear to form three groups on the axes from this ordination (Figure 7), one group consisting of the three plots burned in 1993 plus one plot (02SH07) burned in 1990, a second group consisting of the four unburned plots, and a third group made up of the two plots burned in 1968 and one of the plots (02SH06) burned in 1993. This graph suggests that the unburned plots strongly resemble each other in plant species composition, as do the plots burned in 1993. The two plots burned in 1968 also resemble each other, but the two plots burned in the 1990 fire are quite different from one another and resemble either the 1993 fire plots or the 1968 fire plots.

The likelihood of a statistically-significant difference between these possible groups was tested with Multi-response Permutation Procedures (MRPP), a non-parametric tool that looks for differences between groups (McCune and Grace 2002). The MRPP analysis on all three groups indicated that, in fact, these groups of plots do not differ from one another in overall species composition (Table 13).

Classification of vegetation by the plant species that contribute most of the canopy cover (that is, by dominance) is a common practice and is being applied to vegetation across the United States (Grossman *et al.* 1998). According to this approach, the vegetation in the Sand Hills is largely a shrubland or shrub-steppe with a shrub component composed mainly of plains silver sagebrush (*Artemisia cana*, ssp. *cana*), antelope bitterbrush (*Purshia tridentata*), yellow rabbitbrush (*Chrysothamnus viscidiflorus* ssp. *viscidiflorus*), and spineless horsebrush (*Tetradymia canescens*) (Table 14). Silver sagebrush and antelope bitterbrush dominate in most of the vegetation, but the other shrubs dominate in places. Vegetation dominated by whortleleaf snowberry (*Symphoricarpos oreophilus*) or basin big sagebrush (*Artemisia tridentata* ssp. *tridentata*) also is present. In the herbaceous component, needle and thread (*Hesperostipa comata*) is common and Indian ricegrass (*Achnatherum hymenoides*) and sandhill muhly (*Muhlenbergia pungens*) are widespread but contribute less cover.

The other main section of this report compares the Sand Hills vegetation to that on sand subtrates elsewhere in southwestern Wyoming.

Summary

The reduction in shrub cover caused by fire in the shrub-steppe vegetation of the Sand Hills has lasted for 35 years. This finding might be worrisome should substantial areas of the vegetation be disturbed at one time in the future. The rate of recovery of shrub cover cannot be estimated from the limited data set presented here. Overall species composition does not appear to differ between plots burned in different years, or between the burned plots and the unburned plots. So far, exotic plants are minor contributors to the vegetation in the Sand Hills.

VEGETATION ON SAND SUBSTRATES THROUGHOUT THE STUDY AREA

METHODS

Selection of Sampling Locations

Two representations of sand substrate habitats are available for Wyoming. The first is the land cover layer produced by the Wyoming Gap Analysis Program, or "GAP" (Merrill *et al.* 1996), which shows active dunes and vegetated dunes as two of the state's general landcover types. This layer is intended for use at scales of 1:100,000 or larger, and the minimum mapping unit for upland cover-types (including the two types of dunes) is 100 ha. The second representation, the bedrock geology map of Wyoming (U.S. Geological Survey 1994), shows Quaternary sand as a map unit. This is an indirect representation of the vegetation type of interest, but perhaps a better representation of the physical habitat provided by sand substrates. This geology layer is intended for use at a 1:500,000 scale.

WYNDD biologists had concluded, based on work with both of these data layers in and near the Killpecker Sand Dunes northeast of Rock Springs, that the bedrock geology layer is the better of the two for selecting sampling locations. Two environments are common in that area: fine-textured, sedimentary bedrock with vegetation composed largely of saltbush, greasewood, rhizomatous wheatgrass, and bottlebrush squirreltail; and sandy substrates with vegetation composed largely of basin big sagebrush, rabbitbrush, needle-and-thread, Indian ricegrass, and lemon scurfpea. Those two types of environment were delineated on aerial photographs and sampling locations were selected subjectively in each. The sampling locations were visited, UTM coordinates were recorded with a GPS receiver, and

vegetation and soils information were collected. Each sampling location was then mapped in a geographic information system on the GAP landcover layer and on the bedrock geology layer. None of the sampling locations that were mapped on the GAP active or vegetated dunes cover-types or on the Quaternary sand geologic had the indicators characteristic of the fine-textured bedrock. Thus both layers were useful in eliminating areas *not* on sand substrates. But some of the sampling locations with indicators of the sand substrate were not on the GAP active or vegetated dunes cover-types but were on the Quaternary sand geologic unit. Consequently, we concluded that the bedrock geology map allows us to identify areas of sand substrate that are missed by the GAP layer.

Potential sampling sites on this project were selected with the ArcView geographic information system software, version 3.2 (ESRI, Redlands CA, USA). A shape file of the boundaries of the BLM's Rawlins and Rock Springs Field Office lands was used to define the project area. That shape file was used to clip the public lands in the project area from a state-wide land ownership layer, producing a second shape file. A third shape file of Quaternary sand in the project area was clipped from the state-wide geology layer, and the intersection of the Quaternary sands with the public lands served as the area within which the sampling locations would lie. Several thousand random points were laid over the area of Quaternary sand on public lands, a subset of those points was randomly selected as the potential sampling sites, and the UTM coordinates (NAD 1927) of those potential sampling sites were recorded.

A two-person sampling crew used a geographic positioning system receiver (GeoExplorer 2, Trimble Navigation Ltd., Sunnyvale CA, USA) to locate each of the potential sampling sites in the field. If that site was obviously highly disturbed or not obviously on sand substrate, then a different location nearby was chosen subjectively as the sampling site.

Data Collection

Data were collected at the sampling sites throughout the larger project area in the same manner as was used in the Sand Hills: canopy cover of each vascular plant species, and amount of ground-cover types, were estimated in nested sample plots, selected environmental variables were recorded, the location of the sample plot was documented with a GPS receiver, and a photograph was taken. See page 2 of this report for details.

Data Analysis

Several types of quantitative analysis were used in an attempt to group the plots into plant community-types based first on the species present in each plot, then on the amounts of the more common species in each plot. All data manipulations and analyses were performed with the PC-ORD software package, version 4.27 (MjM Software Design, Gleneden Beach OR).

Sample plots were classified into groups with cluster analysis, a procedure that combines individual plots into groups, and small groups into larger groups, until all of the plots are combined into one large group. In cluster analysis, the similarity in species composition between each pair of plots is calculated (in this case, using Sorensen's coefficient) and then is converted to a measure of dissimilarity, or distance, between stands. The plot-to-plot distances are stored in a matrix, and the combining of plots starts with the closest plots and proceeds to the most distant plots. When plots are combined into a group, the distance from the centroid of the group to each remaining plot or to the centroid of every other group is calculated. Both of the classifications performed here used flexible-beta linkage (beta = -0.25) to combine plots and groups.

A classification resulting from cluster analysis typically is displayed in a dendrogram that shows how the plots are combined into groups, and how those groups are combined with one another (e.g., Figures 9 and 12). The final form of the classification depends on where the branches of the dendrogram are cut. Cutting the dendrogram close to its beginning gives a classification with many, usually small and relatively homogeneous, groups. If the dendrogram is cut too close to the beginning, the resulting classification does a poor job of summarizing the wealth of information present in the data.

Cutting the dendrogram farther out toward its end produces a classification with few, but larger and more heterogeneous, groups. A classification with a few large groups can be difficult to interpret because a large group often contains such disparate plots.

The goal in cutting the classification dendrogram is to produce a classification with enough groups that the variability in the original plot data can be summarized and explained, without having such large groups that the ecological differences between them is obscured. PC-ORD provides two scales to illustrate the effect of combining plots and groups (McCune and Mefford 1999, McCune and Grace 2002). Combining plots into a group results in the loss of some of the original information about how dissimilar the plots are from one another, and when all the plots are in one group, all of that information has been lost. PC-ORD shows the amount of information remaining in the data at each step, as a percentage of the information on stand-to-stand distances that was present in the original data matrix. A second scale on the dendrogram, the objective function, shows the amount of variability among the plots within the groups, calculated as the sum of squares of the distance between each plot and the group centroid. This variability increases as plots are added to groups, because the closest (that is, most similar) plots are combined first, and the most distant (that is, most dissimilar) plots and groups are combined later. In terms of these scales, the goal of cutting the classification dendrogram is to have a classification with the smallest number of groups and that retains a large amount of the information present in the original data set.

PC-ORD provides a second tool, Multiple Response Permutation Procedures (MRPP), that helps in indicating where the classification dendrogram might best be cut. MRPP is a non-parametric approach for determining whether a statistically-significant difference exists between groups (McCune and Grace 2002). In MRPP, the distance (dissimilarity) between each pair of plots in a group is calculated, the average distance between the plots in each group being compared is calculated, and those average distances are summed into a weighted-average, within-group dissimilarity (a parameter known as "delta"). The probability of obtaining a delta value this large by chance is assessed by comparing it to a Pearson type III distribution. MRPP also calculates a measure of within-group homogeneity (the parameter "A") that is independent of sample size. Both delta and A are used to judge whether the groups differ significantly. MRPP can be used to determine whether groups on the classification dendrogram differ statistically from one another.

A third tool available for helping one decide where to cut the dendrogram, and thus how many groups the classification will contain, is indicator species analysis (ISA), which identifies the species that can be used to distinguish between groups. ISA starts by calculating, for each species in each group, the proportional abundance (that is, the degree of concentration of the species in the group) and the frequency (the proportion of plots in the group that contain the species). The abundance and frequency values are then combined into an indicator value for each species in each group. For each species, the indicator values for each group are compared, and the largest is saved as the final, observed indicator value for the species. Indicator values range from 0 to 100. A value of 100 for species *i* in group *j* indicates that species *i* is found only in the plots of group *j* and is found in all of those plots.

The statistical significance of each observed indicator value can be judged through a Monte Carlo test, in which the plots are randomly assigned to groups and species indicator values are calculated for those groups. This random reassignment of plots is repeated 1000 times, and the distribution of possible indicator values for a species from the Monte Carlo test allows one to calculate the probability of obtaining an indicator value as large as the one observed in the real data. ISA can help in decisions about where the classification dendrogram ought to be cut because the number of statistically-significant indicator species for all of the groups can be calculated for any point in the dendrogram. Also, at each level in the dendrogram, the average probability of the indicator values for the groups can be calculated. The dendrogram can be cut where the groups have either a large number of significant indicator species, or a low average probability of indicator values. Once the dendrogram has been cut and the final number of groups decided upon, ISA can show which species are responsible for separating the groups from one another.

All three tools -- the amount of information remaining in the data set, MRPP, and ISA -- influenced the decision on where to cut the classification dendrogram in this study.

RESULTS

Data were collected at 27 sampling locations throughout the project area, 11 of them in the Rawlins Field Office area (all in the Sand Hills north of Baggs) and 16 in the Rock Springs or Kemmerer Field Office areas (Figure 1). Despite the attempt to place all sampling locations on sandy substrates, the soil texture or the substrate type recorded for some of the plots suggests that they were on sedimentary substrates (Table 15).

One-hundred fifty-eight vascular plant taxa were documented in the 27 sample plots, of which 18 taxa (11%) could be identified only to genus and 32 taxa (20%) could not be identified even to genus (Table 16). Of these 32 unknowns, 27 were forbs and 5 were grasses. No taxon was found in all 27 plots, and only 10 taxa, 6% of the total, were found in at least half (13) of the plots (Figure 8). The most common taxa were divided mainly between shrub and graminoid growth-forms: four were shrubs (*Chrysothamnus viscidiflorus* spp. *viscidiflorus*, yellow rabbitbrush; *Ericameria nauseosa*, rubber rabbitbrush; *Artemisia tridentata* spp. *wyomingensis*, Wyoming big sagebrush; *Tetradymia canescens*, spineless horsebrush), three were grasses (*Achnatherum hymenoides*, Indian ricegrass; *Hesperostipa comata*, needle and thread; *Elymus lanceolatus* spp. *lanceolatus*, thickspike wheatgrass), one was a sub-shrub (*Opuntia polyacantha*, plains pricklypear), and one was a forb (*Chenopodium* sp., goosefoot, identified only to genus). *Chenopodium* sp. may well have included several species, and had it been identified to species, the most common species might have included no forbs.

Only nine species (6% of the total documented) were known to be exotic, although some of the unidentified plants also could have been exotic. Thirteen of the plots had no exotic species in them, and the largest number of exotic species in a plot was three (Table 17). Exotic plants accounted for a maximum of 8.5% of the canopy cover in a plot (02SH06, Table 18). Cheatgrass (*Bromus tectorum*), a plant of recent and serious concern among land managers and biologists in Wyoming, was present in only 2 plots.

Identification of Community-Types Based on Presence of Species

The simple presence of various species in the sample plots was used to answer the question, "Can the sample plots be classified into groups that indicate repeated combinations of vascular plant species?" Classification based on presence/absence data produces plant community-types that differ from one another in their species composition; minor species are considered as important biologically as are common species. This approach contrasts with classification using abundance data, which produces plant community-types that differ in vegetation structure as well as in species composition; abundant species are considered more important than are rare species.

The quantitative, canopy-cover data for all 158 plant species in the 27 sample plots were transformed to presence/absence data, and a cluster analysis classification was performed on the transformed data.

The classification on presence of species produced two large groups of plots that remained separate until the final step of the classification (Figure 9). Group 2-17 consists of the 11 plots from the Sand Hills, and group 2-1 of the remaining 16 plots from other locations. An MRPP test showed that these two groups are significantly different (statistically) from each other (Table 19). Indicator species analysis on the two groups showed that group 2-1 of plots from outside the Sand Hills has only *Artemisia tridentata* ssp. *wyomingensis* (Wyoming big sagebrush) and *Sarcobatus vermiculatus* (greasewood) as significant indicator species (Table 20). The former is found in 15 of the 16 plots, and the latter in 12. The group of Sand Hills plots (group 2-17), in contrast, contains 13 statistically-significant indicator species, of which *Purshia tridentata* (antelope bitterbrush) is a perfect indicator, being found in all of the Sand Hills plots and in none of the other plots. Five more species -- *Artemisia*

cana spp. *cana* (basin silver sagebrush), *Chenopodium* sp. (goosefoot), *Alyssum desertorum* (desert madwort), *Cryptantha watsonii* (Watson's catseye), and *Vulpia octoflora* (sixweeks fescue) -- have high indicator values. The remaining seven species, found in roughly half of the Sand Hills plot, have low value as indicators.

The Sand Hills plots, then, differ in species composition from the other plots, and the presence of antelope bitterbrush, basin silver sagebrush, goosefoot, desert madwort, Watson's catseye, and sixweeks fescue is a good indicator of the Sand Hills vegetation. The absence of those species, and the presence of Wyoming big sagebrush or greasewood, in contrast, indicate vegetation different from that in the Sand Hills.

The classification dendrogram was cut at a point with five plot groups, in an attempt to elucidate the variation in species composition within the two large plot groups, 2-1 and 2-17 (Figure 9). The five groups still contained over a third of the information present in the original matrix of plot-to-plot dissimilarity values. Graphs of the number of significant ($p < 0.01$) indicator species versus number of groups and of the average probability versus number of groups (Figure 10) suggested that the dendrogram might be cut at the four-group, the five-group, or the six-group levels. MRPP showed that groups 5-1 and 5-3, which are separate at the 5-group level but combined at the 4-group level (Figure 9) differ significantly in species composition (Table 19), so the 4-group level was rejected as the point at which to cut the dendrogram. Cutting at the 6-group level would have split group 5-3 into two groups, but MRPP analysis showed that those two groups do not differ significantly from each other (Table 19). Hence the 5-group level was selected as the cutting point, to separate statistically-significant groups but not groups that apparently do not differ significantly from each other.

Although the analysis found statistically-significant indicator species for all five plot groups (Figure 11), only a few of those species appear to have practical value in distinguishing groups from one another. The Sand Hills plots are in two groups (Figure 9). Group 5-24, composed of four of the Sand Hills plots, has 10 species with indicator values of at least 75, including three perfect indicators: *Comandra umbellata* ssp. *pallida* (common toadflax), *Rosa woodsii* (Wood's rose), and *Symphoricarpos oreophilus* (whortleleaf snowberry) (Table 21). Group 5-17, comprising the other seven sample plots from the Sand Hills, has four statistically-significant indicator species, but only one (*Vulpia octoflora*, six-weeks fescue) with a high indicator value. The other three indicators for that group -- *Artemisia cana* spp. *cana* (basin silver sagebrush), *Purshia tridentata* (antelope bitterbrush), and *Chenopodium* sp. (goosefoot) -- were indicators for the entire set of Sand Hills plots (group 2-17) in the previous analysis, and have indicator values for group 5-17 equal to, or nearly equal to, their values for group 5-24 (Table 21). The Sand Hills plots, then, which as a group are indicated by the presence of antelope bitterbrush, basin silver sagebrush, or goosefoot, can be sub-divided into two groups, one of which is indicated by the presence of common toadflax, Wood's rose, or whortleleaf snowberry, and the other by the presence of sixweeks fescue.

Sample plots from outside the Sand Hills were classified into three groups but there appears to be no set of species whose presence can be used to reliably distinguish between them. Group 5-2, consisting of just three plots, was the only group in which *Sphaeralcea coccinea* (scarlet globemallow) was found. *Kochia americana* (greenmolly) and *Atriplex* sp. (saltbush) also had their highest indicator values in that group, but the former was present in half of the plots of group 5-3 as well, and the latter was present in about a third of the plots of both groups 5-1 and 5-3 (Table 21). Three indicator species were identified for group 5-3, but two of them -- *Astragalus convallarius* (timber milkvetch) and *Grayia spinosa* (spiny hopsage) -- were found in only four of the seven plots, and the third -- *Chrysothamnus viscidiflorus* (yellow rabbitbrush) -- was present in many plots of other groups as well (Table 21). For group 5-1, two indicator species were identified, but *Achnatherum hymenoides* (indian ricegrass) is the most common species encountered in the study and has indicator values for three of the other groups as great as its value for this group (Table 21), and *Krascheninnikovia lanata* (winterfat) is present in only four of this group's six plots (Table 21).

In summary, the presence of a group of plant species in nearly all of the 27 sample plots (Table 22, species group 1) argues against the existence of distinct plant community-types based on the

presence of groups of plant species. Chief among these widespread species are *Achnatherum hymenoides* (indian ricegrass), *Chrysothamnus viscidiflorus* ssp. *viscidiflorus* (yellow rabbitbrush), *Opuntia polyacantha* (plains pricklypear), *Hesperostipa comata* (needle and thread), and *Ericameria nauseosa* (rubber rabbitbrush). A number of additional species are widespread but occur with lower frequency (Table 22, species group 9). The vegetation in the Sand Hills differs from the vegetation elsewhere by the presence of some two-score species, especially *Purshia tridentata* (antelope bitterbrush), *Artemisia cana* ssp. *cana* (basin silver sagebrush), and *Chenopodium* sp. (goosefoot) (Table 22, species group 6). That group of species is missing outside the Sand Hills, where the vegetation usually contains *Artemisia tridentata* ssp. *wyomingensis* (Wyoming big sagebrush) and *Sarcobatus vermiculatus* (greasewood). In the Sand Hills, the presence of another group of species (Table 22, species group 8) sets one group of plots (group 5-24) off from the other group (5-17). This group of species includes *Artemisia tridentata* ssp. *tridentata* (basin big sagebrush), *Rosa woodsii* (Wood's rose), *Symphoricarpos oreophilus* (whortleleaf snowberry), and a variety of forbs. Outside the Sand Hills, the vegetation is more heterogeneous in terms of species composition, and no readily identifiable groups of species distinguish one community-type from another.

Identification of Community-Types Based on the Amounts of Plant Species

The plant community-types in a vegetation classification based on some measure of abundance (such as canopy cover) differ from one another in the amounts of each species that they contain, not just in the species present in the vegetation; typically, they are repeated combinations of certain amounts of some species. With abundance data, abundant species typically are given greater weight than are rare species. This approach is widely used in the U.S. and is the basis for the national vegetation classification being developed by the Ecological Society of America's Vegetation Panel (Jennings *et al.* 2003).

Rare species often obscure the relationships that we look for when we classify vegetation. Those species can be ignored as long as identifying patterns of species richness is not the point of the classification (McCune and Mefford 2002). Hence the 88 species that occurred in only one or two sample plots in this study were ignored in the classification based on canopy cover data, leaving 70 species in the analysis. The canopy cover data for the remaining species were then changed from absolute cover (the mean canopy-cover class for each species in each plot) to relative cover (the proportion of a plot's cover contributed by each species). This "relativization by plot total" (McCune and Grace 2002) focusses the analysis on the proportions of species in each plot and decreases the influence of differences between plots in the amounts of vegetation present.

This cluster analysis classification based on relative canopy cover resembles that based on species presence in that the Sand Hills plots remained separate from all but two of the plots from elsewhere (02SQ01 and 02QS03) until the final step in the classification (Figure 12). Two additional plots from elsewhere were grouped with the Sand Hills plots. The dendrogram for this classification was cut at the six-group level (as suggested by the graph of the number of statistically-significant indicator species and of the average probability for indicator species at various levels in the classification [Figure 13]), resulting in two groups (6-24 and 6-17) composed entirely of Sand Hills plots and one group (6-13) containing Sand Hills plots and some plots from elsewhere.

The five plots in group 6-17 are relatively densely vegetated, and have a shrub stratum dominated or co-dominated by *Artemisia cana* spp. *cana* (basin silver sagebrush) (Table 24). *Purshia tridentata* (antelope bitterbrush) contributes a substantial amount of cover to the shrub stratum and *Hesperostipa comata* (needle and thread) and *Muhlenbergia pungens* (sandhill muhly) are common in the herbaceous stratum. *Chrysothamnus viscidiflorus* ssp. *viscidiflorus* (yellow rabbitbrush), *Opuntia polyacantha* (plains pricklypear), *Achnatherum hymenoides* (indian ricegrass), *Chenopodium* sp. (goosefoot), and *Cryptantha watsonii* (Watson's catseye) occur regularly but contribute relatively little cover. Plots 02SH01 and 02SH03 were located in the area burned by the 1993 fire in the Sand Hills but still had enough silver sagebrush cover at the time of sampling nine years later to be grouped with

unburned plots. Indicator species analysis identified basin silver sagebrush, *Descurainia sophia* (herb sophia, an exotic forb), and *Gayophytum ramosissimum* (muchbranched groundsmoke) as the indicator species for this group (Table 23, Figure 14). Note, though, that *Descurainia* and *Gayophytum* contribute only small amounts of canopy cover to the vegetation. It is their frequency and abundance in the plots of this group relative to other groups that cause them to be identified as indicator species.

The second group of plots from the Sand Hills (6-24) also contains well-vegetated plots with shrub strata, but they are heterogeneous in species composition (Table 25). *Symphoricarpos oreophilus* (whortleleaf snowberry) dominated the shrub stratum in two of the four and was present in the other two. *Artemisia tridentata* spp. *tridentata* (basin big sagebrush) dominated another. Several additional shrubs -- *Purshia tridentata*, *Chrysothamnus viscidiflorus* spp. *viscidiflorus*, *Ericameria nauseosa* (rubber rabbitbrush), and *Rosa woodsii* (Wood's rose) -- usually are present in small amounts but may co-dominate. *Amelanchier* sp. (serviceberry) and *Artemisia cana* ssp. *cana* often are present but contribute little canopy cover. *Prunus virginiana* (chokecherry) may be common. In the undergrowth, *Hesperostipa comata* contributes substantial cover, and a number of graminoids and forbs are present in small amounts, especially *Achnatherum hymenoides*, *Chenopodium* sp., *Comandra umbellata* ssp. *pallida* (common toadflax), *Eriogonum umbellatum* (sulphur buckwheat), *Erysimum capitatum* spp. *capitatum*, and *Machaeranthera canescens* (hoary aster). Indicator species analysis identified ten statistically-significant species in this group (Table 23, Figure 14), nine of which are strong indicators beacuse they are absent from or rare in other groups. None of them are consistently dominant.

Group 6-13 includes the remaining two Sand Hills plots (Figure 12). These four plots of this group, including two from the area of the Sand Hills burned in the 1990 fire, were moderately vegetated (Table 26). Three of the plots had a shrub stratum dominated by *Chrysothamnus viscidiflorus* ssp. *viscidiflorus* above an undergrowth dominated or co-dominated by *Achnatherum hymenoides* or *Muhlenbergia pungens*. *Danthonia intermedia* (timber oatgrass), *Elymus lanceolatus* spp. *lanceolatus* (thickspike wheatgrass), and *Alyssum desertorum* (desert madwort) contributed substantial cover in one plot, and *Hesperostipa comata* was present in small amounts in all plots. The fourth plot in this group had a shrub stratum dominated by *Tetradymia canescens* (spineless horsebrush) and an undergrowth co-dominated by *Hesperostipa comata*, *Koeleria macrantha* (prairie junegrass), and *Elymus lanceolatus* spp. *lanceolatus*. *Artemisia cana* spp. *cana* and *Purshia tridentata* were present in some plots but contributed little cover. Only two weak indicator species, *Chaenactis douglasii* var. *douglasii* (Douglas's dustymaiden) and *Cryptantha flava* (Brenda's yellow cyptantha) were identified for this group (Table 23, Figure 14).

The remaining 14 plots from outside the Sand Hills were clustered into three groups. Group 6-1 contains six moderately vegetated plots with a shrub stratum strongly dominated by *Artemisia tridentata* ssp. *wyomingensis* (Wyoming big sagebrush) (Table 27). *Chrysothamnus viscidiflorus* ssp. *viscidiflorus* and *Sarcobatus vermiculatus* (greasewood) usually are present in the shrub stratum but contribute little cover. The undergrowth usually is dominated by *Achnatherum hymenoides* or *Hesperostipa comata*, and *Opuntia polyacantha* and *Krascheninnikovia lanata* usually are present in small amounts. The dominant grasses in one stand could not be identified to species. *Artemisia tridentata* ssp. *wyomingensis* and *Krascheninnikovia lanata* are the indicator species for this group (Figure 14), the former due to its strong dominance and the latter to its occurrence only in the plots of this group (Table 23).

Group 6-5 contains four plots, also moderately vegetated and with a shrub stratum in which *Artemisia tridentata* ssp. *wyomingensis* contributes a substantial amount of the cover (Table 28). In these plots, though, sagebrush shares dominance with several other shrub species, especially *Chrysothamnus viscidiflorus* ssp. *viscidiflorus*. *Grayia spinosa* (spiny hopsage) is present but usually contributes little cover relative to the other shrubs. *Achnatherum hymenoides*, *Elymus elymoides* (bottlebrush squirreltail), *Hesperostipa comata*, and *Opuntia polyacantha* are present in the undergrowth, which is dominated or co-dominated by *Achnatherum* and *Hesperostipa* in most plots. Four species were identified as indicators for this group (Table 23), of which the strongest was *Grayia spinosa* because it occurred in all of the plots of this group and only in those plots.

The final cluster from the classification (6-2) consists of four plots with sparse vegetation to which graminoids and forbs contribute more canopy cover than do shrubs (Table 29). *Elymus lanceolatus* ssp. *lanceolatus* (thickspike wheatgrass) and *Kochia americana* (greenmolly) dominated or co-dominated the vegetation in three of the plots, and (along with *Artemisia tridentata* ssp. *tridentata* and a number of other species) contributed substantial cover in the fourth. *Atriplex* sp. (saltbush) and *Opuntia polyacantha* were present in all plots. Of the three indicator species (Figure 14), only *Atriplex* sp. had a high indicator value for the group (Table 23).

In summary, classification based on relative amounts of the common plant species produces three plot clusters that might be considered reasonably coherent plant community-types. In the Sand Hills, an *Artemisia cana* spp. *cana - Purshia tridentata/Hesperostipa comata* community-type is suggested by plot cluster 6-17. Plot group 6-13 contains three plots suggesting a *Chrysothamnus viscidiflorus* ssp. *viscidiflorus/Achnatherum hymenoides - Muhlenbergia pungens* community-type. And the plots in group 6-1 suggest an *Artemisia tridentata* ssp. *wyomingensis/Achnatherum hymenoides* community-type. The other three plot clusters appear to be so heterogeneous in species composition that identifying them as possible plant community-types is difficult to justify.

DISCUSSION

The plot data show that vegetation on areas in southern Wyoming mapped as Quaternary sand (U.S. Geological Survey 1994) is highly variable: only four of 158 vascular plant species -- *Achnatherum hymenoides* (indian ricegrass), *Hesperostipa comata* (needle and thread), *Chrysothamnus viscidiflorus* ssp. *viscidiflorus* (yellow rabbitbrush), and *Opuntia polyacantha* (plains pricklypear) -- were found in at least 75% of the 27 plots sampled (Table 22, "All" column). When either the plant species present or the relative amounts of common species are considered, the vegetation in the Sand Hills north of Baggs differs from that in the other areas studied. The Sand Hills contain a large number of species not noted elsewhere, and much of the vegetation is dominated by *Artemisia cana* ssp. *cana*, *Purshia tridentata*, and *Symphoricarpos oreophilus* in the shrub overstory, and by *Achnatherum hymenoides*, *Hesperostipa comata*, and *Muhlenbergia pungens* (sandhills muhly) in the undergrowth. The Sand Hills vegetation is denser than vegetation elsewhere (Figure 15), and the mixed-shrub vegetation represented by plot group 6-24 is richer in species (Figure 16). Plot groups 6-17 and 6-24 have low diversity in species composition (measured as beta diversity, β_w; McCune and Grace 2002) relative to most other plot groups (Figure 17), suggesting that the vegetation in the Sand Hills varies less from place to place in the species it contains. (Beta diversity is a function of the set of sample plots, and the plot groups from the Sand Hills no doubt have low values in part because they lie within a limited geographic area.)

Chadwick and Dalke (1965) reported vegetation with *Purshia tridentata* as a dominant species on stabilized sand deposits in southern Idaho. *Stipa comata* (syn. *Hesperostipa comata*) and *Chrysothamnus viscidiflorus* were common in that vegetation, and many of the same species (or other species in the same genus) were found in Idaho as were noted in the Sand Hills. *Artemisia cana* ssp. *cana*, though, was absent from the Idaho vegetation. The major shrubs there, in addition to *P. tridentata*, were *Prunus virginiana* and *Artemisia tridentata* (subspecies not identified), both of which seem to be common locally in the Sand Hills.

Outside of the Sand Hills, the vegetation on sand substrates is sparser (Figure 15) and species richness, measured as the number of species encountered in areas the size of the sample plots, is lower (Figure 16). *Achnatherum hymenoides* and *Hesperostipa comata* dominate in many places, but overall their influence is smaller than in the Sand Hills. *Artemisia cana* and *Purshia tridentata* are all but absent from the vegetation, and the shrub stratum is most commonly dominated by *Artemisia tridentata* ssp. *wyomingensis* (Wyoming big sagebrush). *Sarcobatus vermiculatus* (greasewood) is common, and a number of additional shrubs usually are present. The high beta diversity values for three of the four groups composed entirely (groups 6-1 and 6-2) or partly (group 6-13) of plots outside the Sand Hills

suggest that the vegetation represented by these plots is less uniform in species composition, due in part (no doubt) to the broad geographic area over which the plots were located.

The *Artemisia tridentata* ssp. *wyomingensis* / *Achnatherum hymenoides* vegetation represented by plot group 6-1 and the *A. tridentata* ssp. *wyomingensis* - *Chrysothamnus viscidiflorus* ssp. *viscidiflorus* vegetation represented by group 6-5 both closely resemble the vegetation growing on loamy sand and sandy loam soils near the Killpecker Dunes (Jones in prep. a & b). Those areas, too, are mapped as Quaternary sand (U.S. Geological Survey 1994). Plot group 6-2, in contrast, is more similar to the vegetation on sedimentary substrates around the Killpecker Dunes, where *Atriplex* sp. and *Elymus elymoides* are common. Although the plots of group 6-2 were located on Quaternary sand substrate according to the geological layer used in this project (U.S. Geological Survey 1994), they may well have lain on small areas of sedimentary substrate within the Quaternary sand map units, or where the Quaternary sand is so thin that the vegetation is influenced by the underlying bedrock. However, there is no obvious relationship between membership in this plot group and substrate type (Table 15) to suggest that the vegetation in these plots is influenced by fine-textured bedrock.

The large number of plants that could not be identified to species (31% of the taxa documented from the plots) may well have influenced the classification based on species presence. Each unknown plant was given a unique name, which results in its appearing in only one plot. In cluster analysis, plots that share few species are unlikely to be clustered together. Most of the unknowns, though, likely belong to species that were identified in other plots, and consequently are shared by at least two plots. The exotic species probably have less influence on the classification based on canopy cover because in very few plots did an unknown species contribute more than a trace of the cover.

Conclusions about the rarity of exotic plant species in vegetation of sand substrates might also be different if the unknown species could be identified. The rarity of exotics suggested by the plot data is both surprising and encouraging, given the recent concern about the increase in distribution and abundance of exotic plants. If a substantial number of the unknown plants are exotics, then exotics are more widespread than the data now suggest, although they still contribute only a minor amount of canopy cover.

As a national classification of vegetation types for the U.S. is built from data sets such as the one collected on this project (Jennings *et al.* 2003), the plot groups identified from the classification based on canopy cover can be put into a broader context. At present, the detailed levels of the national vegetation classification consist of a list plant alliances and plant associations, some of which have not been described (Nature 2003). Table 30 shows the relationship of the plot groups from the classification on canopy cover to the national classification. Only plot group 6-1 seems to resemble a plant association on the NatureServe list. The *Artemisia tridentata* ssp. *wyomingensis* / *Hesperostipa comata* association (element code CEGL001046) has been described from sandy soils in Washington, Oregon, and Idaho, but apparently *Hesperostipa comata* regularly dominates in that association and *Achnatherum hymenoides* is less common. The opposite is the case in the plots from this group. The national classification also includes an *Artemisia tridentata* ssp. *wyomingensis* / *Achnatherum hymenoides* association (element code CEGL001051) named from Oregon, but no description is provided and its relationship to plot group 6-1 is unclear. This plot group can be placed into the *Artemisia tridentata* ssp. *wyomingensis* Shrubland Alliance, a broader classification category that includes plant associations sharing the same dominant species in the overstory.

The plots in group 6-5 also can be placed into the *Artemisia tridentata* ssp. *wyomingensis* Shrubland Alliance, but it is unclear to which association they might belong. The plots in group 6-24 are being placed into the *Artemisia tridentata* ssp. *tridentata* Shrubland Alliance because basin big sagebrush is present (and sometimes common) in them. The four plots in group 6-13 are being placed, tentatively, into the *Chrysothamnus viscidiflorus* Shrub Herbaceous Alliance. The four plots in group 6-2 may belong to the *Elymus lanceolatus* Herbaceous Alliance. And the five Sand Hills Plots in group 6-17, in which *Artemisia cana* ssp. *cana* usually co-dominates the canopy, are being placed into the *Artemisia cana* Shrubland Alliance, with uncertainty.

The placement of these plots into groups from the national classification will be done with more certainty as more information is gathered on the vegetation of North America, and the groups in the national classification are better described.

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Figure 1. Sampling locations in southern Wyoming.

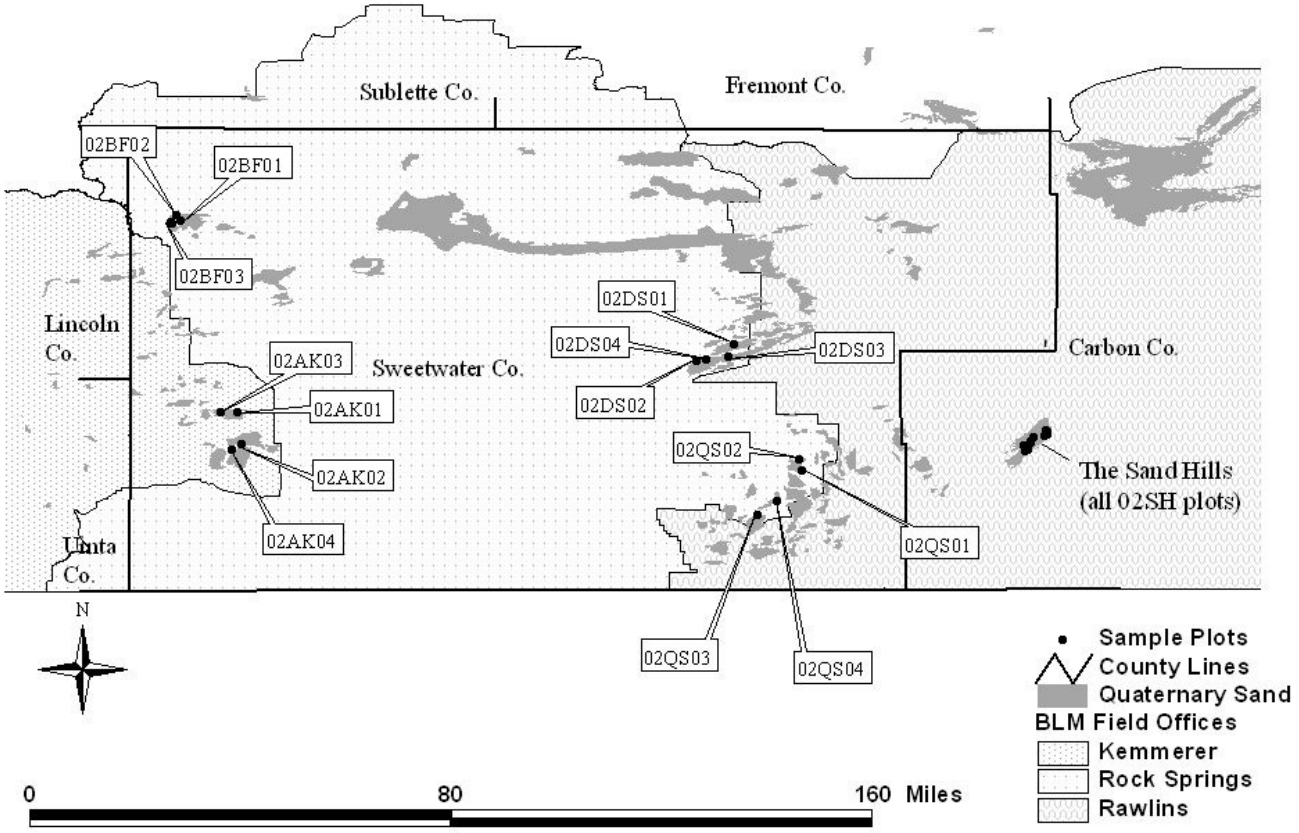

Figure 2. Public land in the Sand Hills study area, showing the outer boundaries of the three fires and the locations of 2002 vegetation sampling plots.
The dark line shows the part of the study area mapped as Quaternary Sand (U.S. Geological Survey 1994). The unburned area includes only the public land within the ACEC.

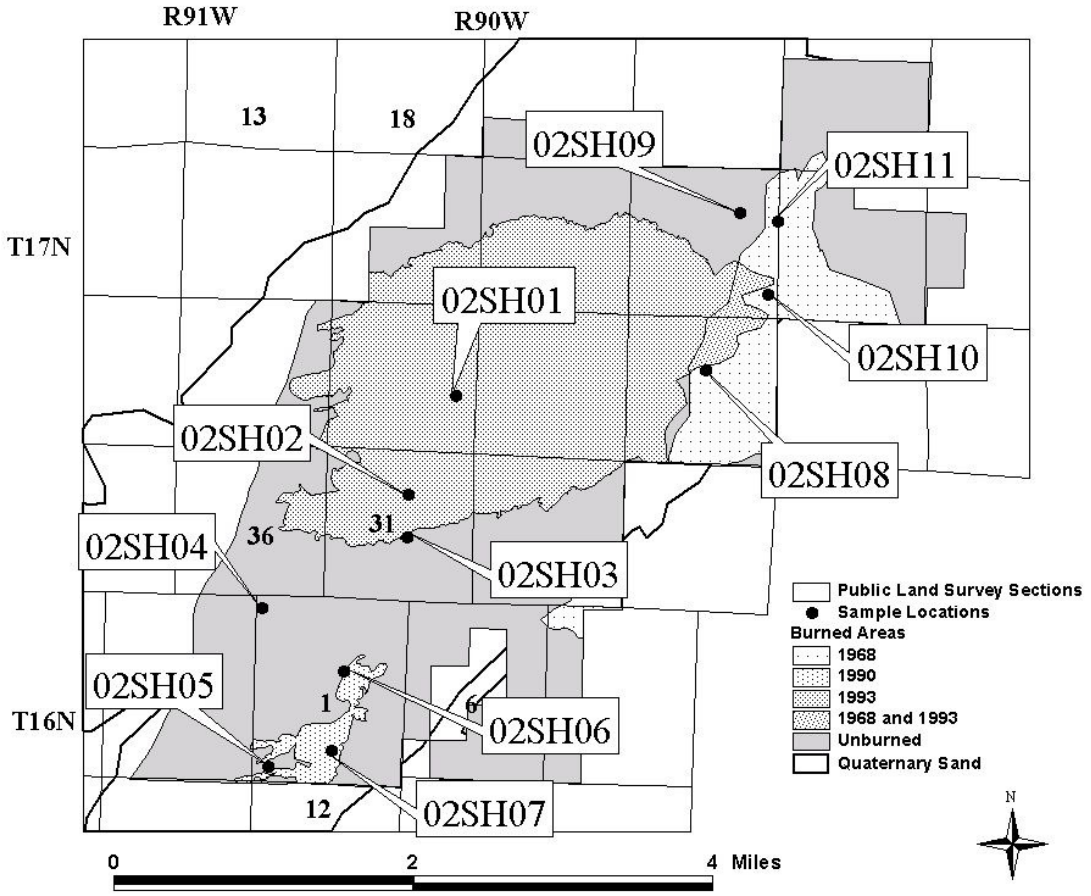

Figure 3. Layout of the nested vegetation sampling plots.

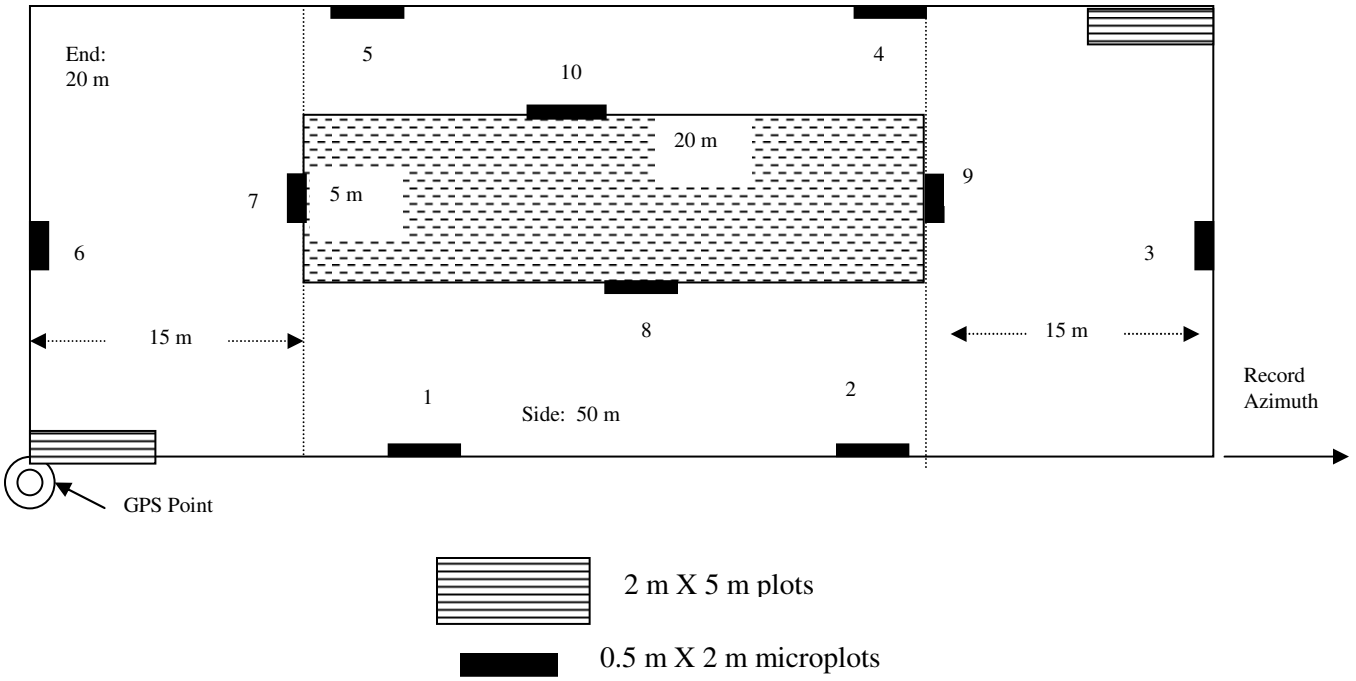

Figure 4. Canopy cover of plant growth-forms in Sand Hills burned and unburned plots.
Plots from the 1968, 1990, and 1993 burned areas were combined. Canopy cover is expressed as cover class, as explained in the text.

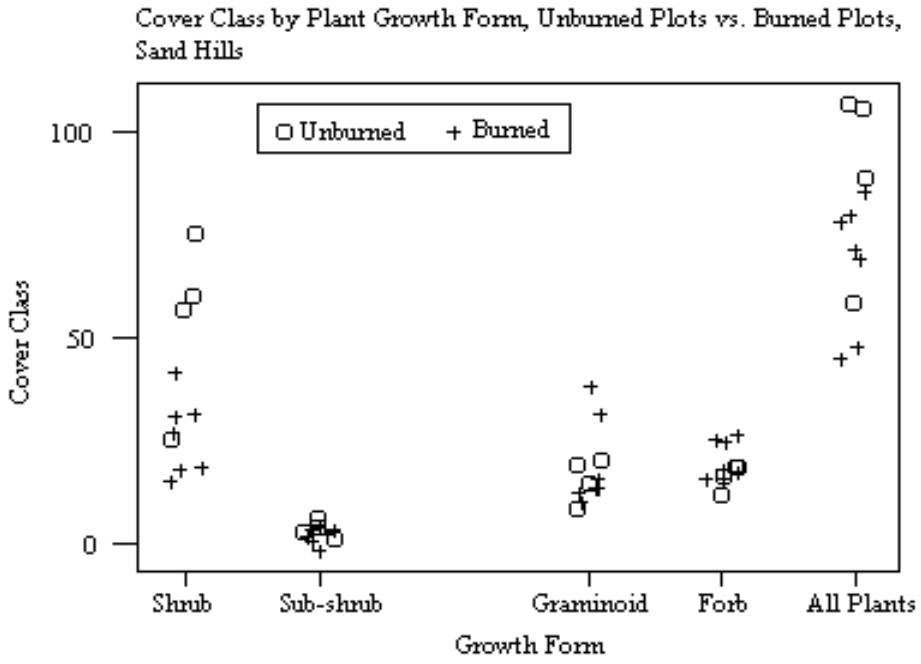

Figure 5. Canopy cover of shrubs and all plants in the Sand Hills plots with different fire histories.

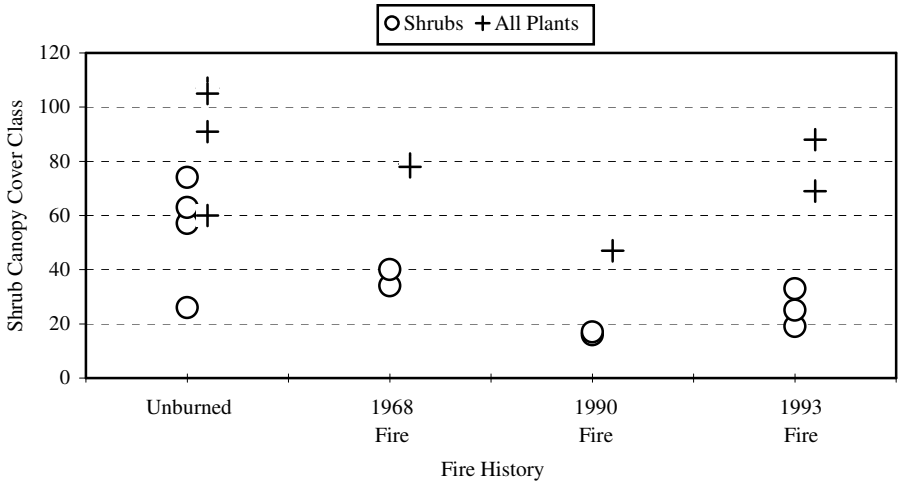

Figure 6. Frequency of occurrence of 101 vascular plant species in the 11 sample plots in the Sand Hills.

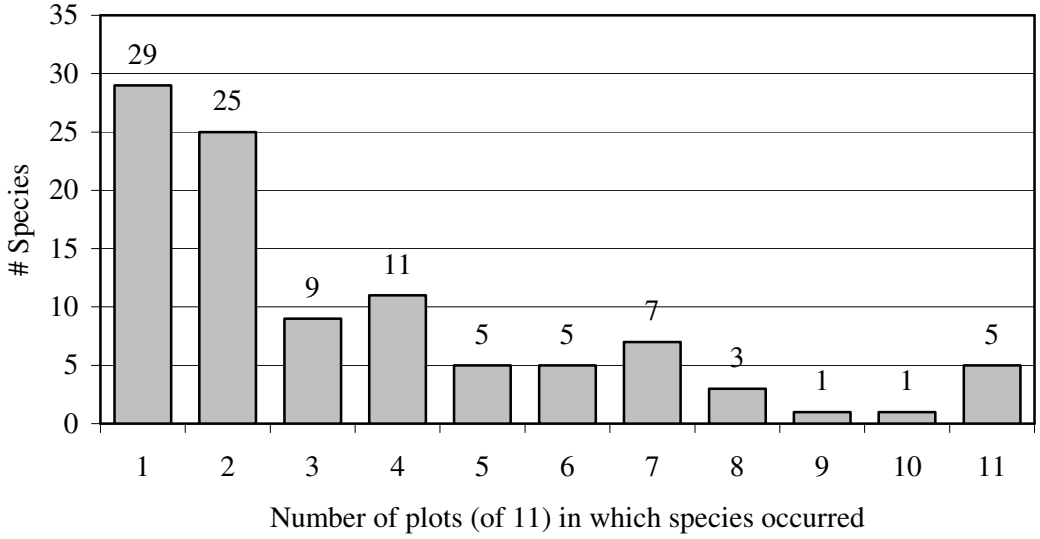

Figure 7. Two-dimensional NMS ordination of the Sand Hills sample plots.
"Fire" refers to fire history: 0 = unburned, 68 = burned in 1968, 90 = burned in 1990, 93 = burned in 1993.

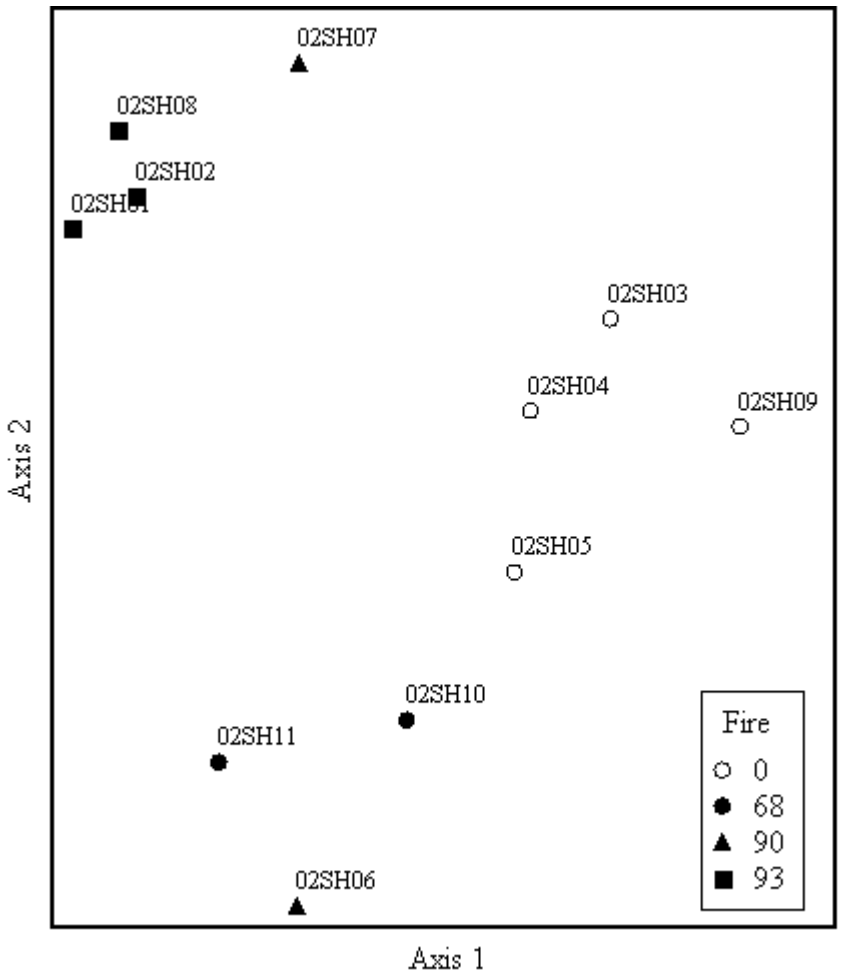

Figure 8. Frequency of occurrence of 158 vascular plant taxa in all 27 sample plots.

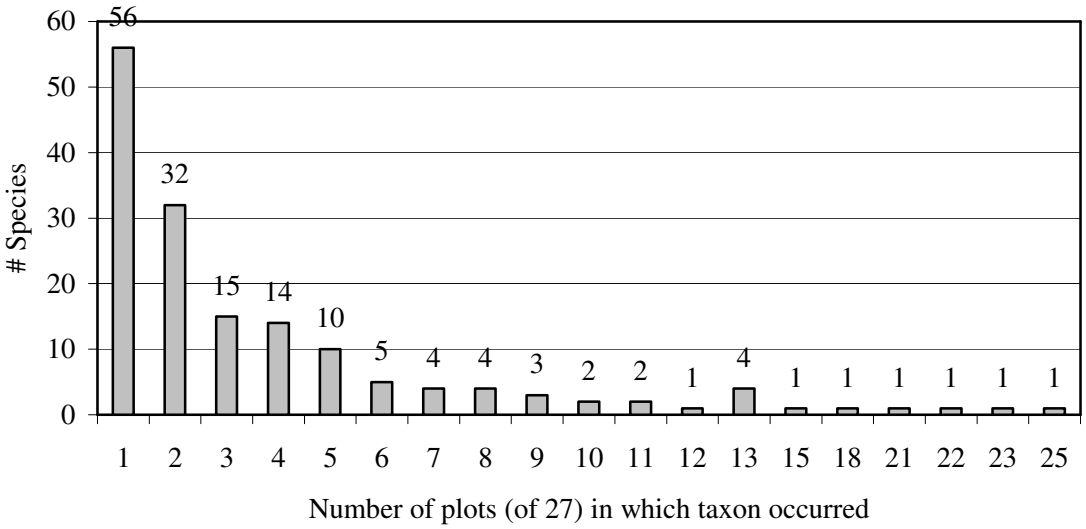

Figure 9. Cluster analysis classification of all 27 sample plots, based on presence of species. Group numbers are shown on the dendrogram branches. Diagonal lines indicate groups that were tested for differences in species composition with Multiple Response Permutation Procedures (Table 19).

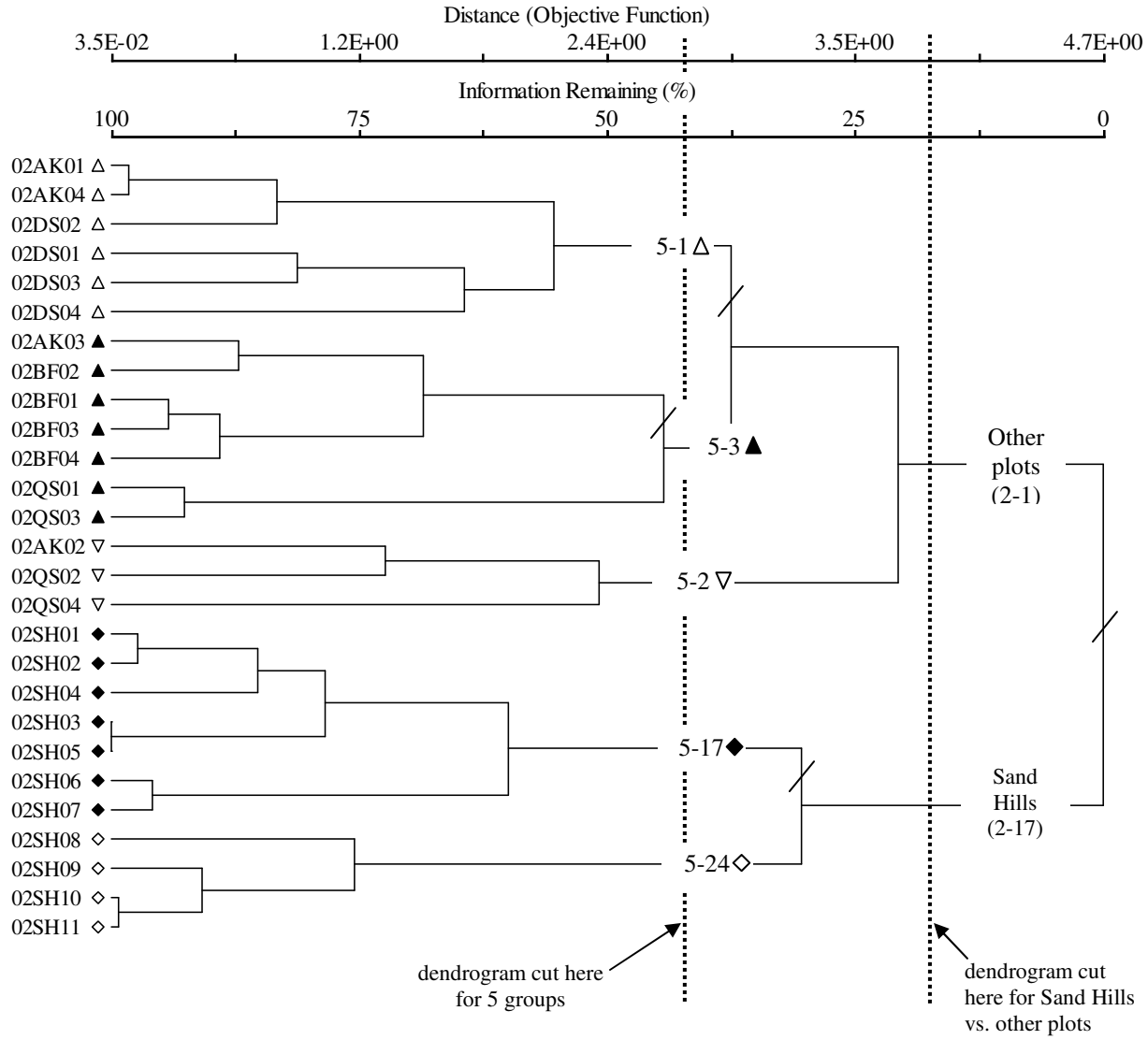

Figure 10. Number of significant indicator species and average probability of indicator values at various levels in the classification of plots based on species presence.
(Significance at $p < 0.01$)

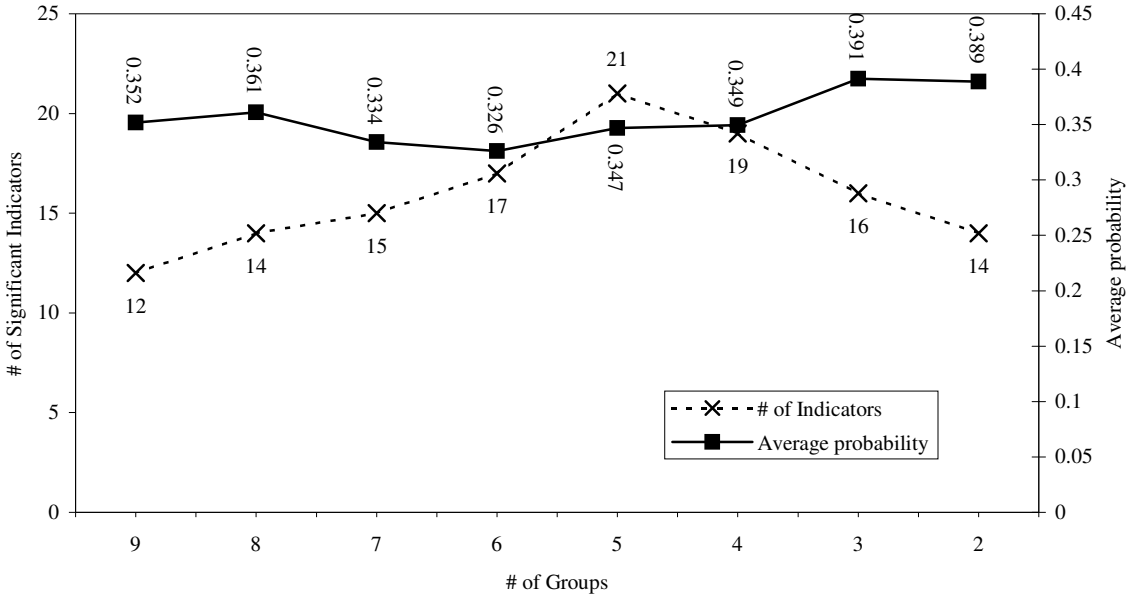

Figure 11. Statistically-significant indicator species for the five groups from the cluster analysis classification based on species presence.
(See Figure 9). Numbers are indicator values. Strong indicators (IV $\geq$ 75) are shown in boldface type.

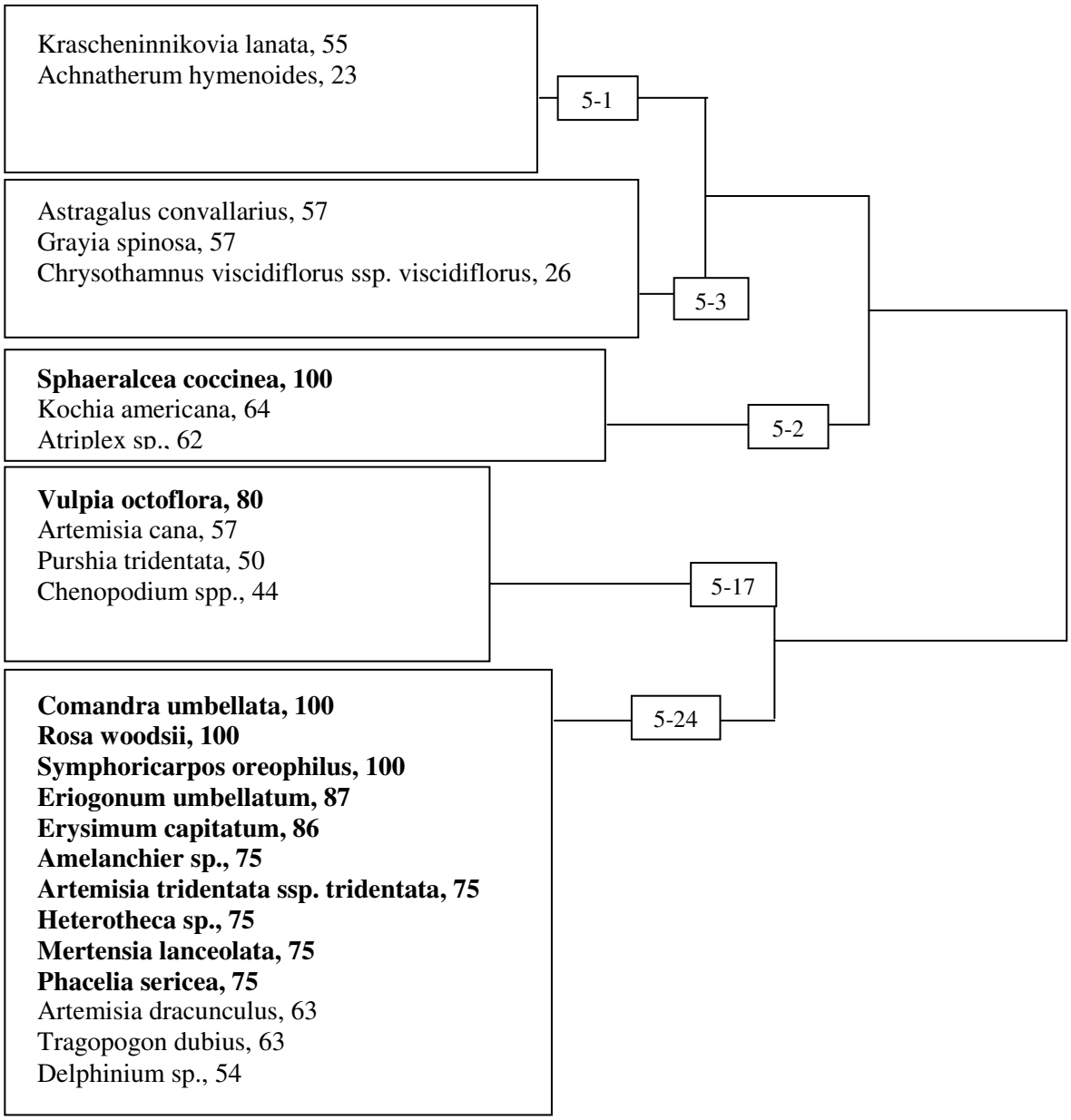

Figure 12. Cluster analysis classification of all 27 sample plots, based on canopy cover of 102 species. Group numbers are shown on the dendrogram branches.

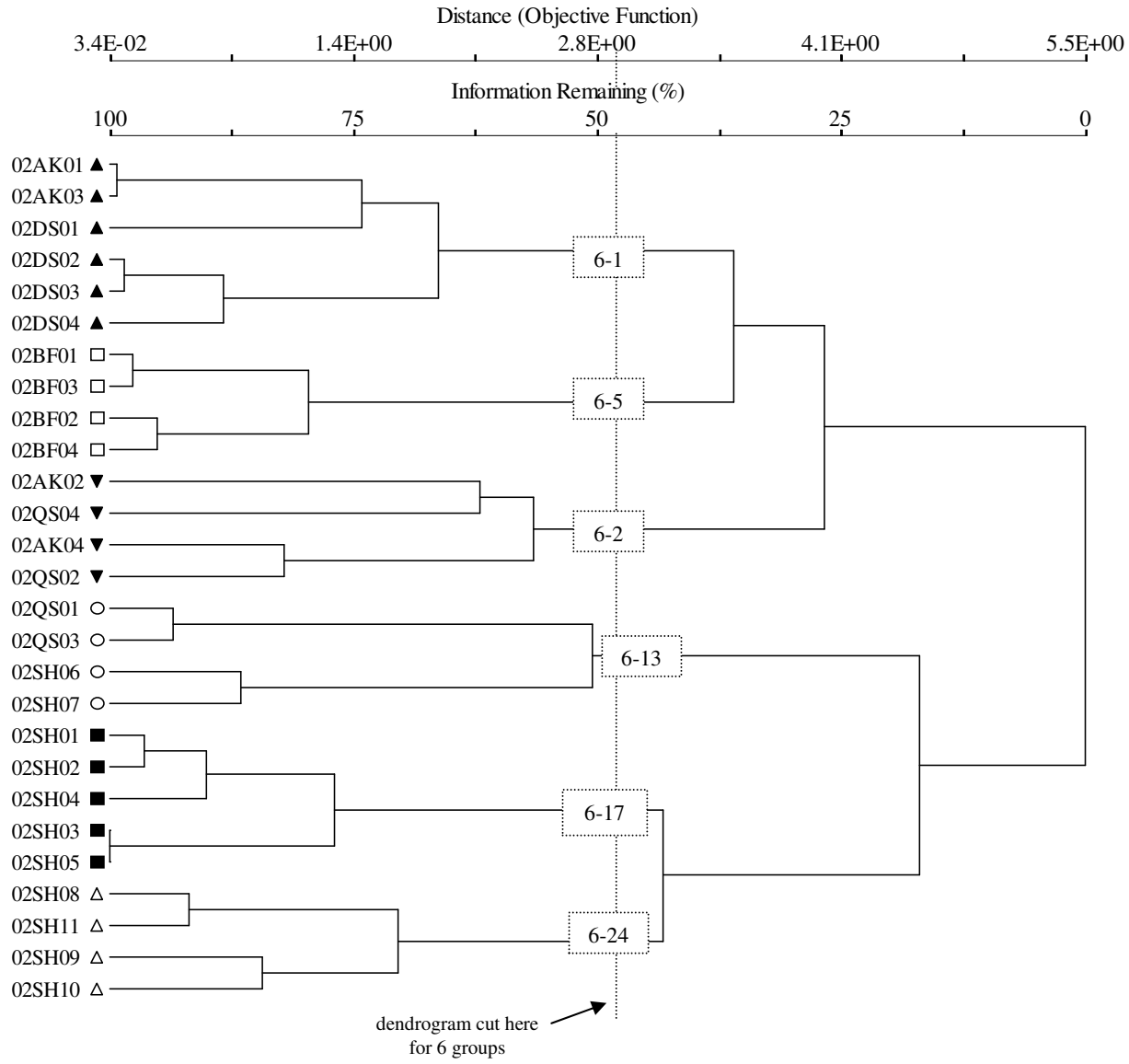

Figure 13. Number of significant indicator species and average probability of indicator values at various levels in the classification of plots based on canopy cover.
(Significance at $p < 0.01$)

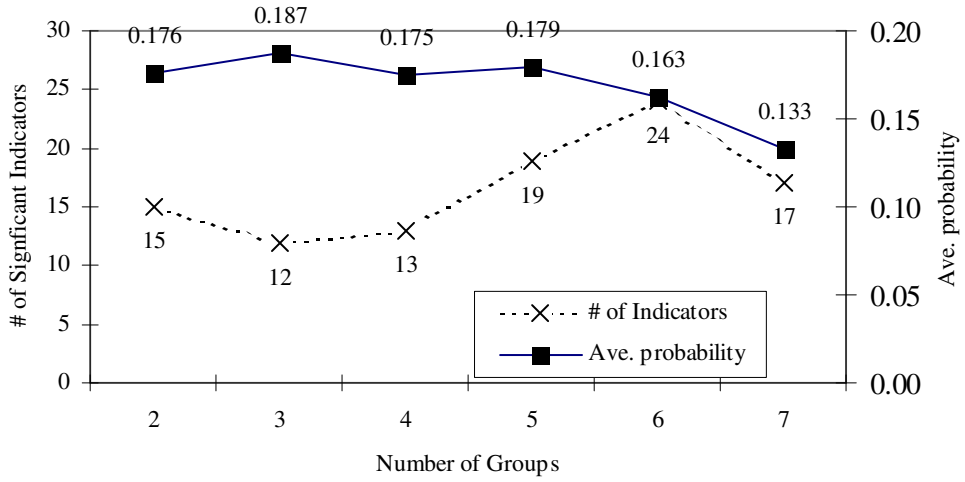

Figure 14. Indicator species for the six groups from the cluster analysis classification based on relative canopy cover.
See Figure 12. Numbers are indicator values.

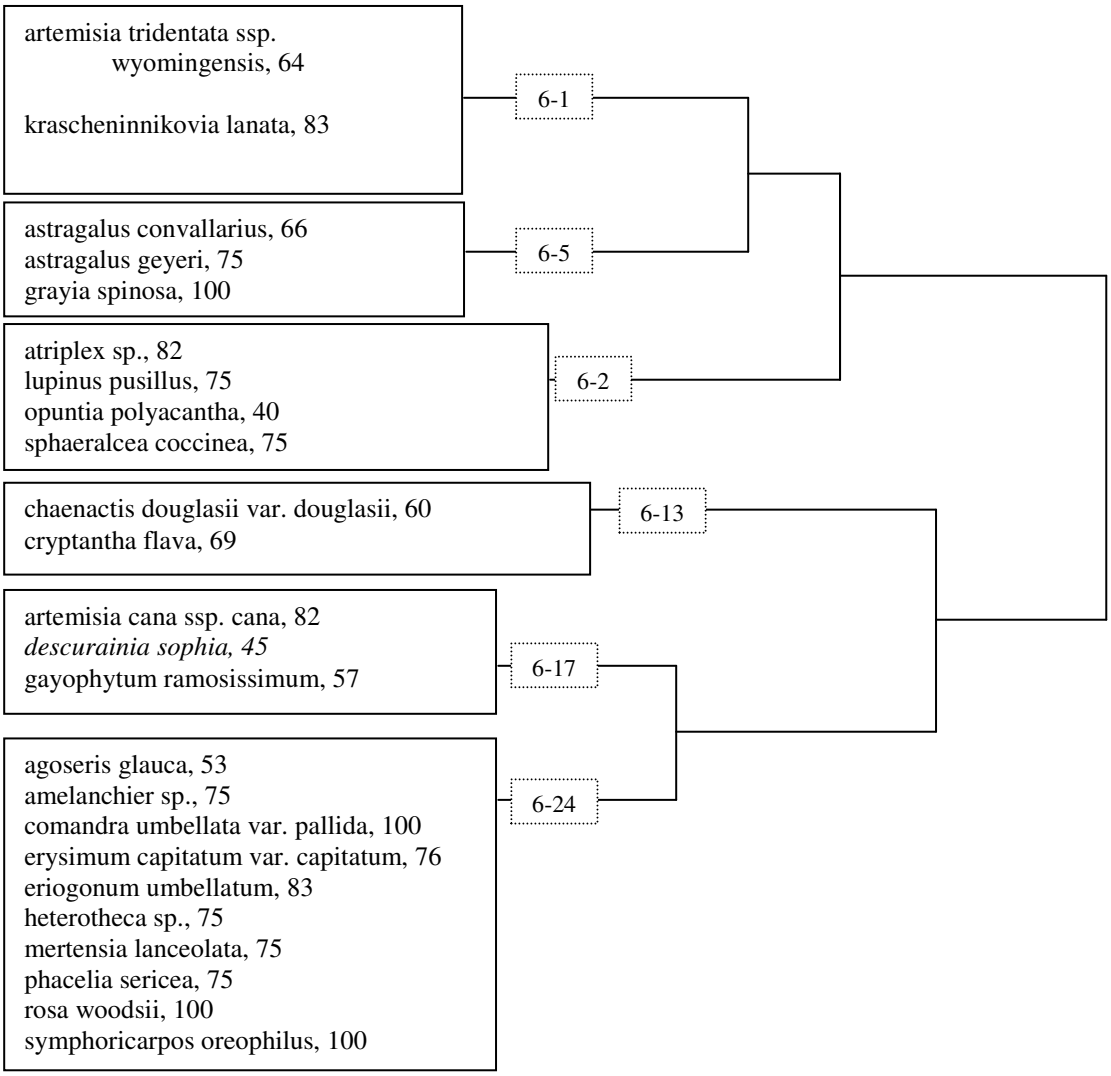

Figure 15. Average total plant canopy cover (in percent) in the six plot groups from cluster analysis classification based on relative canopy cover.

Bars show 95% confidence intervals around the means.

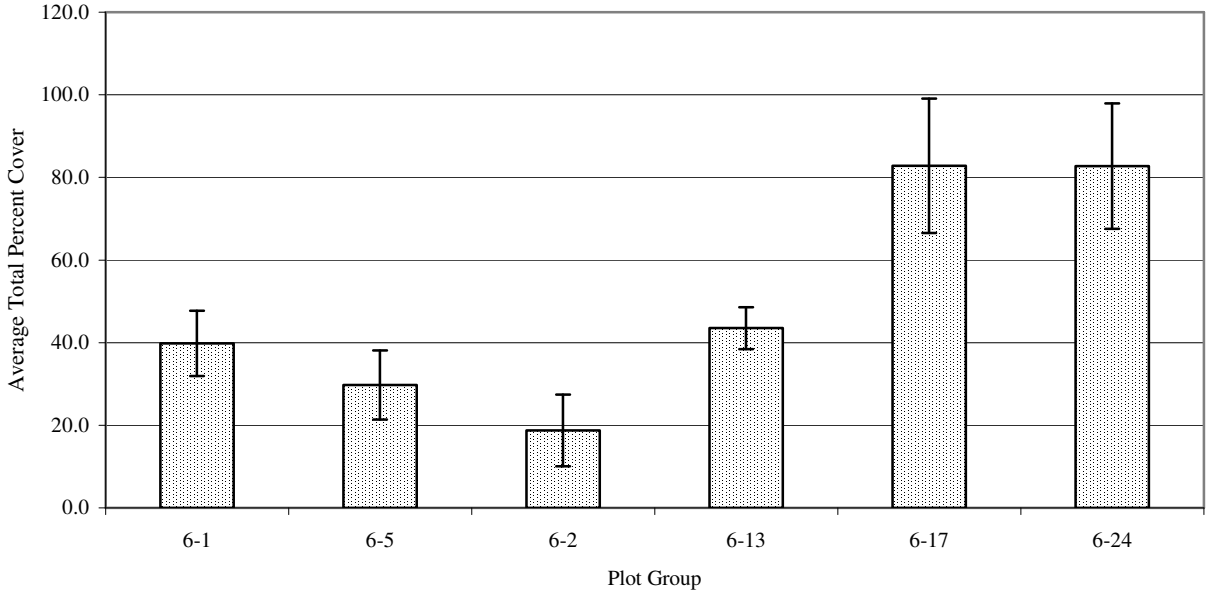

Figure 16. Mean number of species per plot in the six plot groups from cluster analysis classification based on relative canopy cover.

Bars show 95% confidence intervals around the means.

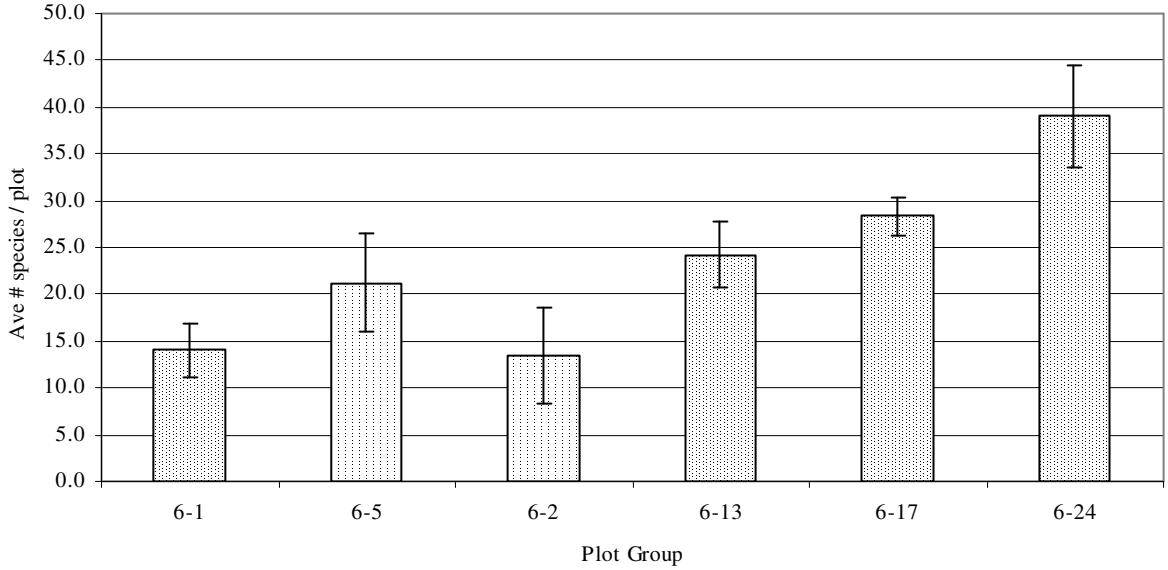

Figure 17. Beta diversity (β_w) in the six plot groups from cluster analysis classification based on relative canopy cover.

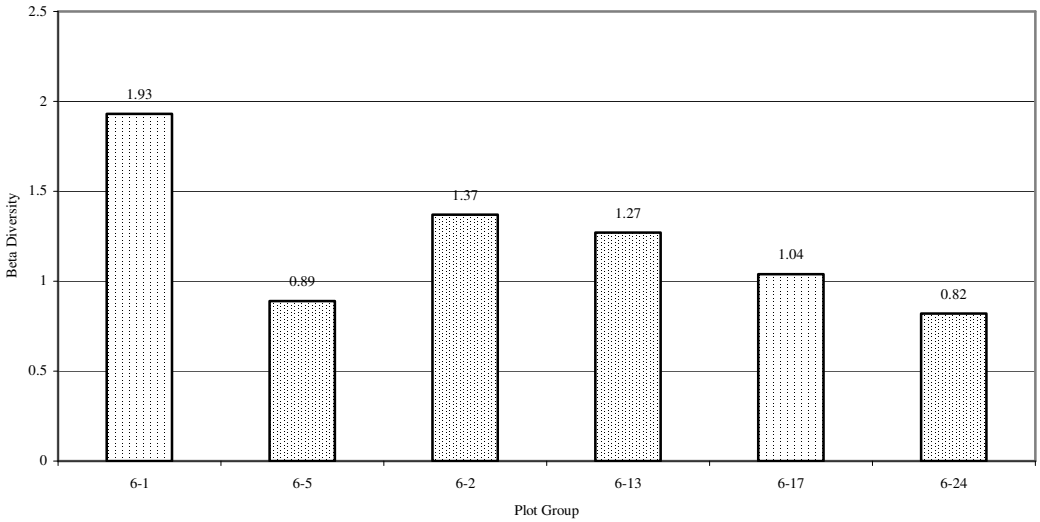

Table 1. Canopy cover ranges and mid-points.

% 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. Locations of 2002 Sampling Locations in the Sand Hills. Locations are shown on Figure 2.

		Public Land Survey Location				UTM Coordinates (NAD27, Zone 13N)		
Fire	Plot	Township North	Range East	Sec.	1/4 sec.	m E	m N	Elevation (ft.)
Unburned	02SH03	17	90	31	SW	284920	4586595	6980
Unburned	02SH04	16	91	1	NW	283355	4585832	6940
Unburned	02SH05	16	91	1	SW	283427	4584133	6880
Unburned	02SH09	17	90	21	NE	288498	4590078	7531
1968	02SH10	17	90	21	SE	288790	4589199	7700
1968	02SH11	17	90	22	NW	288900	4589986	7780
1990	02SH06	16	91	1	NE	284242	4585152	6880
1990	02SH07	16	91	1	SE	284102	4584300	6840
1993	02SH01	17	90	30	SE	285446	4588122	7115
1993	02SH02	17	90	31	NW	284925	4587051	7040
1993	02SH08	17	90	29	SE	288126	4588385	7250

Table 3. Results of analysis of variance in canopy cover in Sand Hills plots due to plant growth form and fire.

Plots in the 1968, 1990, and 1993 burned areas were combined. Canopy cover was expressed by cover class. Analysis of variance was performed with the general linear model, Minitab Statistical Software (Minitab, Inc.), Release 12 (Feb. 1998)

Factor	levels	d.f.	Adjusted sum of squares	F	Prob-ability
Fire (fixed)	2	1	1041	6.42	0.015
Growth Form (fixed)	5	4	35164	54.2	0.000
Error		49	7948	16.2	
Total		54			

Table 4. Results of two-sample t-test for differences between Sand Hills burned and unburned plots in shrub canopy cover.

Plots in the 1968, 1990, and 1993 burned areas were combined. Canopy cover was expressed by cover class. H_o: Unburned mean = burned mean. H_1: Unburned mean > burned mean. T-test was performed with Minitab Statistical Software (Minitab, Inc.), Release 12 (Feb. 1998)

Plot groups	N	Mean	Std Dev	SE Mean
Unburned	4	55.0	20.6	10
Burned	7	26.29	9.48	3.6
Test Result	d.f.	t	Prob.	
	3	2.64	0.039	

Table 5. Results of two-sample t-test for differences between Sand Hills burned and unburned plots in canopy cover of all plants.

Plots in the 1968, 1990, and 1993 burned areas were combined. Canopy cover was expressed by cover class. H_o: Unburned mean = burned mean. H_1: Unburned mean > burned mean.. T-test was performed with Minitab Statistical Software (Minitab, Inc.), Release 12 (Feb. 1998)

Plot groups	N	Mean	Std Dev	SE Mean
Unburned	4	90.7	21.7	11
Burned	7	68.1	15.8	6.0
Test Result	d.f.	t	Prob.	
	4	1.82	0.071	

Table 6. Frequency of occurrence of 101 vascular plants in the Sand Hills sampling plots, in order of frequency.

N = 11 plots.

Species	NRCS Code	On This Many Plots	Growth-form	Origin
achnatherum hymenoides, indian ricegrass	achy	11	5. Graminoid	Native
chenopodium sp., goosefoot	cheno	11	6. Forb	Native
chrysothamnus viscidiflorus ssp. viscidiflorus, yellow rabbitbrush	chviv2	11	2. Shrub	Native
hesperostipa comata, needle and thread	heco26	11	5. Graminoid	Native
purshia tridentata, antelope bitterbrush	putr2	11	2. Shrub	Native
artemisia cana ssp. cana, plains silver sagebrush	arcac5	10	2. Shrub	Native
alyssum desertorum, desert madwort	*alde*	*9*	*6. Forb*	*Introduced*
cryptantha watsonii, watson's catseye	crwa2	8	6. Forb	Native
elymus lanceolatus ssp. lanceolatus, thickspike wheatgrass	ellal	8	5. Graminoid	Native
vulpia octoflora, sixweeks fescue	vuoc	8	5. Graminoid	Native
ericameria nauseosa, rubber rabbitbrush	erna10	7	2. Shrub	Native
leptodactylon pungens, granite pricklygilia	lepu	7	3. Subshrub	Native
machaeranthera canescens, hoary aster	maca2	7	6. Forb	Native
muhlenbergia pungens, sandhill muhly	mupu2	7	5. Graminoid	Native
opuntia polyacantha, plains pricklypear	oppo	7	3. Subshrub	Native
poa secunda, sandberg bluegrass	pose	7	5. Graminoid	Native
tetradymia canescens, spineless horsebrush	teca2	7	2. Shrub	Native
carex sp., sedge	carex	6	5. Graminoid	Native
descurainia sophia, herb sophia	*deso2*	*6*	*6. Forb*	*Introduced*
gayophytum ramosissimum, muchbranched groundsmoke	gara2	6	6. Forb	Native
koeleria macrantha, prairie junegrass	koma	6	5. Graminoid	Native
lesquerella, bladderpod	lesqu	6	6. Forb	Native
agoseris glauca, pale agoseris	aggl	5	6. Forb	Native
cryptantha sp., cryptantha	crypt	5	6. Forb	Native
delphinium sp., larkspur	delph	5	6. Forb	Native
eriogonum umbellatum, sulphur wildbuckwheat	erum	5	6. Forb	Native
oenothera pallida, pale eveningprimrose	oepa	5	6. Forb	Native
artemisia tridentata ssp. tridentata, basin big sagebrush	artrt	4	2. Shrub	Native
collinsia parviflora, smallflower blue eyed mary	copa3	4	6. Forb	Native

Table 6 (continued).

Species	NRCS Code	On This Many Plots	Growth-form	Origin
comandra umbellata ssp. pallida, common toadflax	coump2	4	6. Forb	Native
eriogonum sp., eriogonum	eriog	4	6. Forb	Native
erysimum capitatum var. capitatum, sanddune wallflower	ercac	4	6. Forb	Native
heterotheca villosa, hairy goldenaster	hevi4	4	6. Forb	Native
lappula occidentalis var. occidentalis, flatspine stickseed	laoco	4	6. Forb	Native
lupinus argenteus, silvery lupine	luar3	4	6. Forb	Native
rosa woodsii, woods' rose	rowo	4	2. Shrub	Native
symphoricarpos oreophilus, whortleleaf snowberry	syor2	4	2. Shrub	Native
tragopogon dubius, yellow salsify	*trdu*	*4*	*6. Forb*	*Introduced*
amelanchier, serviceberry	amela	3	2. Shrub	Native
artemisia dracunculus, wormwood	ardr4	3	3. Subshrub	Native
cryptantha cinerea, james' catseye	crci3	3	6. Forb	Native
heterotheca sp., telegraphplant	heter8	3	6. Forb	Native
lesquerella ludoviciana, foothill bladderpod	lelu	3	6. Forb	Native
lupinus sp., lupine	lupin	3	6. Forb	Native
mertensia lanceolata, lanceleaf bluebells	mela3	3	6. Forb	Native
phacelia sericea, silky phacelia	phse	3	6. Forb	Native
rumex venosus, veiny dock	ruve2	3	6. Forb	Native
arabis holboellii, holboell's rockcress	arho2	2	6. Forb	Native
bromus tectorum, cheatgrass	*brte*	*2*	*5. Graminoid*	*Introduced*
chaenactis douglasii var. douglasii, douglas's dustymaiden	chdod	2	6. Forb	Native
crepis acuminata, longleaf hawksbeard	crac2	2	6. Forb	Native
cryptantha affinis, quill cryptantha	craf	2	6. Forb	Native
cryptantha circumscissa, cushion catseye	crci2	2	6. Forb	Native
cryptantha flava, brenda's yellow catseye	crfl5	2	6. Forb	Native
cymopterus acaulis, plains springparsley	cyac	2	6. Forb	Native
cymopterus sp., cymopterus	cymop2	2	6. Forb	Native
descurainia sp., tansymustard	descu	2	6. Forb	Unknown
eriogonum ovalifolium, cushion buckwheat	erov	2	3. Subshrub	Native
juncus balticus var. montanus	jubam	2	5. Graminoid	Native

Table 6 (continued).

Species	NRCS Code	On This Many Plots	Growth-form	Origin
lithospermum incisum, narrowleaf gromwell	liin2	2	6. Forb	Native
lithospermum ruderale, western gromwell	liru4	2	6. Forb	Native
lomatium simplex, narrowleaf lomatium	losi2	2	6. Forb	Native
lygodesmia juncea, rush skeletonplant	lyju	2	6. Forb	Native
mahonia repens, oregongrape	mare11	2	3. Subshrub	Native
mentzelia dispersa, bushy blazingstar	medi	2	6. Forb	Native
penstemon strictus, rocky mountain penstemon	pest2	2	6. Forb	Native
poa fendleriana, muttongrass	pofe	2	5. Graminoid	Native
poa pratensis, kentucky bluegrass	*popr*	*2*	*5. Graminoid*	*Introduced*
polygonum douglasii, douglas' knotweed	podo4	2	6. Forb	Native
polygonum sawatchense, knotweed	posa17	2	6. Forb	Native
polygonum sp., knotweed	polyg4	2	6. Forb	Unknown
prunus virginiana, common chokecherry	prvi	2	2. Shrub	Native
alyssum alyssoides, pale madwort	*alal3*	*1*	*6. Forb*	*Introduced*
bromus sp., brome	bromu	1	5. Graminoid	Unknown
camissonia parvula, lewis river suncup	capa39	1	6. Forb	Native
cryptantha torreyana, torrey's cryptantha	crto4	1	6. Forb	Native
danthonia intermedia, timber oatgrass	dain	1	5. Graminoid	Native
delphinium nuttallianum, nuttall's larkspur	denu2	1	6. Forb	Native
elymus sp., wildrye	elymu	1	5. Graminoid	Native
forb unknown 23 ("pasque flower" 02sh08)	forbsv23	1	6. Forb	Unknown
forb unknown sv 16 ("whorled lvs white stem" 02sh05)	forbsv16	1	6. Forb	Unknown
forb unknown sv11 ("broadleaf" 02sh02)	forbsv11	1	6. Forb	Unknown
forb unknown sv12 ("oblanc green lf forb" 02sh03)	forbsv12	1	6. Forb	Unknown
forb unknown sv13 ("primrose w/ leathery achenes" 02sh04)	forbsv13	1	6. Forb	Unknown
forb unknown sv14 ("asteraceae" 02sh04)	forbsv14	1	6. Forb	Unknown
forb unknown sv15 ("bright green slick leaves" 02sh05)	forbsv15	1	6. Forb	Unknown
forb unknown sv17 ("low lobed apiaceae" 02sh05)	forbsv17	1	6. Forb	Unknown

Table 6 (continued).

Species	NRCS Code	On This Many Plots	Growth-form	Origin
forb unknown sv18 ("big stipule, bright green" 02sh07)	forbsv18	1	6. Forb	Unknown
forb unknown sv19 ("dwarf small white herb" 02sh07)	forbsv19	1	6. Forb	Unknown
forb unknown sv20 ("one leaf" 02sh08)	forbsv20	1	6. Forb	Unknown
forb unknown sv21 ("long horn" 02sh08)	forbsv21	1	6. Forb	Unknown
forb unknown sv22 ("white sticky normal" 02sh08)	forbsv22	1	6. Forb	Unknown
forb unknown sv24 ("white fuzzy herb" 02sh09)	forbsv24	1	6. Forb	Unknown
forb unknown sv25 ("not evening prim (ast)" 02sh10)	forbsv25	1	6. Forb	Unknown
forb unknown sv26 ("small hairy herb" 02sh11)	forbsv26	1	6. Forb	Unknown
forb unknown sv27 ("wide toothed plant" 02sh11)	forbsv27	1	6. Forb	Unknown
leucopoa kingii, spike fescue	leki2	1	5. Graminoid	Native
lupinus sericeus, silky lupine	luse4	1	6. Forb	Native
mentzelia albicaulis, whitestem blazingstar	meal6	1	6. Forb	Native
thermopsis, thermopsis	therm	1	6. Forb	Native
trifolium gymnocarpon, hollyleaf clover	trgy	1	6. Forb	Native

Table 7. Frequency of occurrence of 101 vascular plants in the Sand Hills sampling plots, in order of species names.

N = 11 plots.

Species	NRCS Code	On This Many Plots	Growth-form	Origin
achnatherum hymenoides, indian ricegrass	achy	11	5. Graminoid	Native
agoseris glauca, pale agoseris	aggl	5	6. Forb	Native
alyssum alyssoides, pale madwort	*alal3*	*1*	*6. Forb*	*Introduced*
alyssum desertorum, desert madwort	*alde*	*9*	*6. Forb*	*Introduced*
amelanchier, serviceberry	amela	3	2. Shrub	Native
arabis holboellii, holboell's rockcress	arho2	2	6. Forb	Native
artemisia cana ssp. cana, plains silver sagebrush	arcac5	10	2. Shrub	Native
artemisia dracunculus, wormwood	ardr4	3	3. Subshrub	Native
artemisia tridentata ssp. tridentata, basin big sagebrush	artrt	4	2. Shrub	Native
bromus sp., brome	bromu	1	5. Graminoid	Unknown
bromus tectorum, cheatgrass	*brte*	*2*	*5. Graminoid*	*Introduced*
camissonia parvula, lewis river suncup	capa39	1	6. Forb	Native
carex sp., sedge	carex	6	5. Graminoid	Native
chaenactis douglasii var. douglasii, Douglas's dustymaiden	chdod	2	6. Forb	Native
chenopodium sp., goosefoot	cheno	11	6. Forb	Native
chrysothamnus viscidiflorus ssp. viscidiflorus, yellow rabbitbrush	chviv2	11	2. Shrub	Native
collinsia parviflora, smallflower blue eyed mary	copa3	4	6. Forb	Native
comandra umbellata ssp. pallida, common toadflax	coump2	4	6. Forb	Native
crepis acuminata, longleaf hawksbeard	crac2	2	6. Forb	Native
cryptantha affinis, quill cryptantha	craf	2	6. Forb	Native
cryptantha cinerea, james' catseye	crci3	3	6. Forb	Native
cryptantha circumscissa, cushion catseye	crci2	2	6. Forb	Native
cryptantha flava, brenda's yellow catseye	crfl5	2	6. Forb	Native
cryptantha sp., cryptantha	crypt	5	6. Forb	Native
cryptantha torreyana, torrey's cryptantha	crto4	1	6. Forb	Native
cryptantha watsonii, watson's catseye	crwa2	8	6. Forb	Native
cymopterus acaulis, plains springparsley	cyac	2	6. Forb	Native
cymopterus sp., cymopterus	cymop2	2	6. Forb	Native
danthonia intermedia, timber oatgrass	dain	1	5. Graminoid	Native
delphinium nuttallianum, nuttal's larkspur	denu2	1	6. Forb	Native

Table 7 (continued).

Species	NRCS Code	On This Many Plots	Growth-form	Origin
delphinium sp., larkspur	delph	5	6. Forb	Native
descurainia sophia, herb sophia	*deso2*	*6*	*6. Forb*	*Introduced*
descurainia sp., tansymustard	descu	2	6. Forb	Unknown
elymus lanceolatus ssp. lanceolatus, thickspike wheatgrass	ellal	8	5. Graminoid	Native
elymus sp., wildrye	elymu	1	5. Graminoid	Native
ericameria nauseosa, rubber rabbitbrush	erna10	7	2. Shrub	Native
eriogonum ovalifolium, cushion buckwheat	erov	2	3. Subshrub	Native
eriogonum sp., eriogonum	eriog	4	6. Forb	Native
eriogonum umbellatum, sulphur wildbuckwheat	erum	5	6. Forb	Native
erysimum capitatum var. capitatum, sanddune wallflower	ercac	4	6. Forb	Native
forb unknown 23 ("pasque flower" 02sh08)	forbsv23	1	6. Forb	Unknown
forb unknown sv 16 ("whorled lvs white stem" 02sh05)	forbsv16	1	6. Forb	Unknown
forb unknown sv11 ("broadleaf" 02sh02)	forbsv11	1	6. Forb	Unknown
forb unknown sv12 ("oblanc green lf forb" 02sh03)	forbsv12	1	6. Forb	Unknown
forb unknown sv13 ("primrose w/ leathery achenes" 02sh04)	forbsv13	1	6. Forb	Unknown
forb unknown sv14 ("asteraceae" 02sh04)	forbsv14	1	6. Forb	Unknown
forb unknown sv15 ("bright green slick leaves" 02sh05)	forbsv15	1	6. Forb	Unknown
forb unknown sv17 ("low lobed apiaceae" 02sh05)	forbsv17	1	6. Forb	Unknown
forb unknown sv18 ("big stipule, bright green" 02sh07)	forbsv18	1	6. Forb	Unknown
forb unknown sv19 ("dwarf small white herb" 02sh07)	forbsv19	1	6. Forb	Unknown
forb unknown sv20 ("one leaf" 02sh08)	forbsv20	1	6. Forb	Unknown
forb unknown sv21 ("long horn" 02sh08)	forbsv21	1	6. Forb	Unknown
forb unknown sv22 ("white sticky normal" 02sh08)	forbsv22	1	6. Forb	Unknown
forb unknown sv24 ("white fuzzy herb" 02sh09)	forbsv24	1	6. Forb	Unknown
forb unknown sv25 ("not evening prim (ast)" 02sh10)	forbsv25	1	6. Forb	Unknown
forb unknown sv26 ("small hairy herb" 02sh11)	forbsv26	1	6. Forb	Unknown

Table 7 (continued).

Species	NRCS Code	On This Many Plots	Growth-form	Origin
forb unknown sv27 ("wide toothed plant" 02sh11)	forbsv27	1	6. Forb	Unknown
gayophytum ramosissimum, muchbranched groundsmoke	gara2	6	6. Forb	Native
hesperostipa comata, needle and thread	heco26	11	5. Graminoid	Native
heterotheca sp., telegraphplant	heter8	3	6. Forb	Native
heterotheca villosa, hairy goldenaster	hevi4	4	6. Forb	Native
juncus balticus var. montanus	jubam	2	5. Graminoid	Native
koeleria macrantha, prairie junegrass	koma	6	5. Graminoid	Native
lappula occidentalis var. occidentalis, flatspine stickseed	laoco	4	6. Forb	Native
leptodactylon pungens, granite pricklygilia	lepu	7	3. Subshrub	Native
lesquerella ludoviciana, foothill bladderpod	lelu	3	6. Forb	Native
lesquerella, bladderpod	lesqu	6	6. Forb	Native
leucopoa kingii, spike fescue	leki2	1	5. Graminoid	Native
lithospermum incisum, narrowleaf gromwell	liin2	2	6. Forb	Native
lithospermum ruderale, western gromwell	liru4	2	6. Forb	Native
lomatium simplex, narrowleaf lomatium	losi2	2	6. Forb	Native
lupinus argenteus, silvery lupine	luar3	4	6. Forb	Native
lupinus sericeus, silky lupine	luse4	1	6. Forb	Native
lupinus sp., lupine	lupin	3	6. Forb	Native
lygodesmia juncea, rush skeletonplant	lyju	2	6. Forb	Native
machaeranthera canescens, hoary aster	maca2	7	6. Forb	Native
mahonia repens, oregongrape	mare11	2	3. Subshrub	Native
mentzelia albicaulis, whitestem blazingstar	meal6	1	6. Forb	Native
mentzelia dispersa, bushy blazingstar	medi	2	6. Forb	Native
mertensia lanceolata, lanceleaf bluebells	mela3	3	6. Forb	Native
muhlenbergia pungens, sandhill muhly	mupu2	7	5. Graminoid	Native
oenothera pallida, pale eveningprimrose	oepa	5	6. Forb	Native
opuntia polyacantha, plains pricklypear	oppo	7	3. Subshrub	Native
penstemon strictus, rocky mountain penstemon	pest2	2	6. Forb	Native
phacelia sericea, silky phacelia	phse	3	6. Forb	Native
poa fendleriana, muttongrass	pofe	2	5. Graminoid	Native
poa pratensis, kentucky bluegrass	*popr*	*2*	*5. Graminoid*	*Introduced*
poa secunda, sandberg bluegrass	pose	7	5. Graminoid	Native

Table 7 (continued).

Species	NRCS Code	On This Many Plots	Growth-form	Origin
polygonum douglasii, douglas' knotweed	podo4	2	6. Forb	Native
polygonum sawatchense, knotweed	posa17	2	6. Forb	Native
polygonum sp., knotweed	polyg4	2	6. Forb	Unknown
prunus virginiana, common chokecherry	prvi	2	2. Shrub	Native
purshia tridentata, antelope bitterbrush	putr2	11	2. Shrub	Native
rosa woodsii, woods' rose	rowo	4	2. Shrub	Native
rumex venosus, veiny dock	ruve2	3	6. Forb	Native
symphoricarpos oreophilus, whortleleaf snowberry	syor2	4	2. Shrub	Native
tetradymia canescens, spineless horsebrush	teca2	7	2. Shrub	Native
thermopsis, thermopsis	therm	1	6. Forb	Native
tragopogon dubius, yellow salsify	*trdu*	*4*	*6. Forb*	*Introduced*
trifolium gymnocarpon, hollyleaf clover	trgy	1	6. Forb	Native
vulpia octoflora, sixweeks fescue	vuoc	8	5. Graminoid	Native

Table 8. Numbers of native species, exotic species, and species of unknown origin in unburned and burned sample plots in the Sand Hills.

Plot	Total # Spp	Native	Exotic	Origin Unknown
02SH01	30	27	3	
02SH02	30	26	3	1
02SH03	27	24	2	1
02SH04	25	20	2	3
02SH05	30	25	2	3
02SH06	26	23	2	1
02SH07	28	24	1	3
02SH08	46	38	3	5
02SH09	34	32	0	2
02SH10	41	37	3	1
02SH11	35	30	3	2

Table 9. Canopy cover of native species, exotic species, and species of unknown origin in unburned and burned sample plots in the Sand Hills.

PlotName	Total Cover	Native	Exotic	Unknown Origin
02SH01	88	85	3	
02SH02	69	63	5	1
02SH03	107	104	2	1
02SH04	60	55	2	3
02SH05	91	86	2	3
02SH06	47	42	4	1
02SH07	47	43	1	3
02SH08	69	61	3	5
02SH09	105	103	0	2
02SH10	79	75	3	1
02SH11	78	73	3	2

Table 10. Exotic species in unburned vs. burned sample plots in the Sand Hills.

a. Number of Species

	Introduced Species	Native Species	Total # Spp.
Burned Plots	18	205	223
Unburned Plots	6	101	107
Total	24	306	330

H_0: Ratio (# Introduced Spp **:** # Native Spp) on Unburned Plots **=** Ratio (# Introduced Spp **:** # Native Spp) on Burned Plots

H_A: Ratio (# Introduced Spp **:** # Native Spp) on Unburned Plots **≠** Ratio (# Introduced Spp **:** # Native Spp) on Burned Plots

Observed $\chi^2 = 0.65$

$\chi^2_{1, 0.1}$ (two-sided test) = 3.84

Conclusion: No difference was observed between unburned plots and burned plots in the proportion of introduced plant species present.

b. Canopy Cover

	Introduced Species	Native Species	Total Cover
Burned Plots	22	442	464
Unburned Plots	6	347	353
Total	28	789	817

Canopy cover values are the sums of the cover class codes (Table 1) for all species in the plots.

H_0: Ratio (Cover of Introduced Spp **:** Cover of Native Spp) on Unburned Plots **=** Ratio (Cover of Introduced Spp **:** Cover Native Spp) on Burned Plots

H_A: Ratio (Cover Introduced Spp **:** Cover Native Spp) on Unburned Plots **≠** Ratio (Cover Introduced Spp **:** Cover Native Spp) on Burned Plots

Observed $\chi^2 = 5.6$

$\chi^2_{1, 0.1}$ (two-sided test) = 3.84

Conclusion: Introduced species contribute a greater proportion of the canopy cover on the burned plots than on the unburned plots.

Table 11. Stress in initial NMS ordination of the Sand Hills sample plots using real data and randomized data in a Monte Carlo test.
Stress measures the degree to which the plot-to-plot relationships shown on the ordination axes depart from the plot-to-plot relationships in the original dissimilarity matrix.

	Stress in real data			Stress in randomized data			
	40 runs			Monte Carlo rest, 50 runs			
Axes	Min.	Mean	Max.	Min.	Mean	Max.	p*
1	22.176	39.753	52.134	26.149	43.738	52.223	0.0196
2	7.950	11.457	25.777	13.710	20.241	26.409	0.0196
3	4.807	5.582	16.729	6.286	10.766	15.449	0.0196
4	3.074	3.616	8.515	2.696	5.964	14.804	0.0392
5	1.705	2.198	5.680	0.010	2.786	5.856	0.2353
6	0.005	0.533	1.268	0.003	0.949	2.735	0.0392

*p = proportion of randomized runs with stress ≤ observed stress
i.e., p = (1 + no. permutations ≤ observed)/(1 + no. permutations)

Ordinationa was performed with PC-ORD Version 4.0 autopilot mode set for slow and thorough analysis (McCune and Mefford 1999), using Sorensen distance measure on presence/absence data relativized by species totals. Parameters: 6 axes (default value), 400 iterations (default value), random starting coordinates, 1 reduction in dimensionality at each cycle, step length (rate of movement toward minimum stress) = 0.20, time of day used for random number seeds, 40 runs with real data, 50 runs with randomized data, stability criterion (standard deviations in stress over last 15 iterations) = 0.000010

Table 12. Proportion of variance represented by the 2 axes in the final NMS ordination of Sand Hills plots.

Proportion of variance is calculated as the r^2 between the plot-to-plot distance in the dissimilarity matrix and the plot-to-plot distance on the ordination axis for each pair of plots.

	Incremental r^2	cumulative r^2
axis 1	0.240	0.240
axis 2	0.614	0.854

Parameters for NMS ordination: 2 axes (per recommendation from the initial ordination), starting coordinates from 2-dimensional solution in initial ordination, no reduction in dimensionality at each cycle, step length (rate of movement toward minimum stress) = 0.20, 1 run with real data, 0 runs with randomized data, stability criterion (standard deviations in stress over last 250 iterations) = 0.0050.
Result: 250 iterations, final stress = 7.95007, final instability = 0.00613

Table 13. Results from MRPP analysis of differences in the three plot groups produced by the final NMS ordination of Sand Hills plots.

Comparison	Observed Delta	Expected Delta	T	p	A
3 groups*	0.52249770	0.50	0.42500206	0.62920049	-0.04499541

Delta = weighted average distance between plots within a group
$= \sum_{\text{all groups}} (n_i / \sum n_i)$(ave. within group distance between plots)

T = (observed delta - expected delta) / (standard deviation of expected delta)
p = probability of delta this small or smaller
A = chance-corrected within-group agreement = 1 - (observed delta / expected delta).
A = 1 when all items are identical within groups (delta=0), A = 0 when heterogeneity within groups equals expectation by chance, A < 0 with more heterogeneity within groups than expected by chance

Analysis was performed with PC-ORD Version 4.0. Weighting option: C(I) = n(I)/sum(n(I)); Distance measure = Sorensen; distance matrix rank transformed.

* Groups were identified from the two-dimensional, final NMS ordination (Figure 7).
Group 1 = 02SH01, 02SH02, 02SH07, 02SH08
Group 2 = 02SH03, 02SH04, 02SH05, 02SH09
Group 3 = 02SH06, 02SH10, 02SH11

Table 14. Relative canopy cover of the plant species contributing the most canopy cover to the Sand Hills sample plots.
Relative canopy cover of species *i* in plot *j* = (cover species *i*) / (cover of all species in plot *j*). These are the species that, when canopy cover is summed plot-by-plot, contribute ≥ 50% of the cover in each plot.

Plot	Fire History*	Relative Shrub Cover	Relative Graminoid Cover	Plant Species																		
				artemisia cana ssp. cana, plains silver sagebrush	purshia tridentata, antelope bitterbrush	hesperostipa comata, needle and thread	chrysothamnus viscidiflorus ssp. viscidiflorus, yellow rabbitbrush	symphoricarpos oreophilus, whortleleaf snowberry	achnatherum hymenoides, indian ricegrass	*alyssum desertorum, desert madwort*	elymus lanceolatus ssp. lanceolatus, thickspike wheatgrass	muhlenbergia pungens, sandhill muhly	tetradymia canescens, spineless horsebrush	ericameria nauseosa, rubber rabbitbrush	poa secunda, sandberg bluegrass	carex sp., sedge	koeleria macrantha, prairie junegrass	artemisia tridentata ssp. tridentata, basin big sagebrush	rosa woodsii, woods' rose	comandra umbellata ssp. pallida, common toadflax	heterotheca sp., telegraphplant	prunus virginiana, common chokecherry	crepis acuminata, longleaf hawksbeard
02SH01	93	0.38	0.41	0.341	0.011	0.114	0.011	0	0.011	0	0.011	0.114	0.011	0	0.011	0.114	0	0	0	0	0	0
02SH02	93	0.28	0.42	0.145	0.043	0.145	0.043	0	0.014	0.043	0.014	0.145	0.043	0	0.014	0.043	0.014	0	0	0	0	0
02SH05	0	0.63	0.11	0.333	0.222	0.033	0.033	0	0.011	0.011	0.033	0.011	0.033	0.011	0	0	0.011	0	0	0	0	0
02SH03	0	0.69	0.13	0.280	0.280	0.009	0.093	0	0.009	0.009	0.009	0.093	0.009	0.028	0	0	0	0	0	0	0	0
02SH04	0	0.43	0.30	0.167	0.167	0.167	0.050	0	0.017	0.017	0	0.017	0	0.050	0.017	0.050	0	0	0	0	0	0
02SH10	68	0.43	0.19	0.038	0.253	0.127	0.038	0.013	0.013	0.013	0	0	0.013	0.013	0.013	0.013	0.013	0.038	0.013	0.038	0.013	0	0
02SH07	90	0.36	0.26	0.064	0.064	0.064	0.021	0	0.021	0.021	0.064	0	0.213	0	0.021	0	0.064	0	0	0	0	0	0
02SH06	90	0.34	0.26	0.064	0.064	0.021	0.213	0	0.064	0.064	0.064	0	0	0	0	0	0.021	0	0	0	0	0	0
02SH09	0	0.60	0.17	0.029	0.095	0.095	0.029	0.029	0.010	0	0.010	0.029	0.010	0.010	0.010	0	0	0.381	0.010	0.010	0	0	0.029
02SH08	93	0.36	0.20	0.014	0.043	0.043	0.043	0.145	0.014	0.014	0	0.014	0	0.043	0.043	0.014	0.014	0.014	0.043	0.014	0.043	0.014	0.014
02SH11	68	0.51	0.18	0	0.013	0.128	0.038	0.256	0.013	0.013	0.013	0	0	0.013	0	0.013	0	0.013	0.038	0.013	0.013	0.128	0
Species Relative Importance Value**				1.057	1.114	1.086	1.056	0.474	1.018	0.841	0.755	0.697	0.684	0.660	0.655	0.587	0.568	0.475	0.390	0.382	0.296	0.253	0.203

* Fire History: 0 = unburned, 68 = burned in 1968, 90 = burned in 1990, 93 = burned in 1993
** Relative importance value for species *i* = (mean relative cover of species *i*) + (# plots with species *i* / 11 plots)

Table 15. Soil texture, substrate type, and topographic position for all 27 sampling plots.

Plot	Soil Texture[1]	Substrate Type	Topographic Position
02AK01	Sandy Loam	Aeolian	Terrace
02AK02	Sandy Loam	Aeolian	Terrace
02AK03	Sandy Loam	Aeolian	Toeslope
02AK04	Loamy Sand	Aeolian	Terrace
02BF01	Loamy Sand	Aeolian	Terrace
02BF02	Sandy Loam	Residual[2]	Interfluve
02BF03	Sandy Loam	Residual[2]	Terrace
02BF04	Sandy Loam	Aeolian	Basin Floor
02DS01	Sandy Loam	Alluvial[2]	Footslope
02DS02	Sandy Loam	Residual	Shoulder
02DS03	Silty Clay[2]	Alluvial	Terrace
02DS04	Sandy Loam	Residual[2]	Interfluve
02QS01	Sandy Loam	Alluvial	Footslope
02QS02	Sandy Loam	Residual[2]	Toeslope
02QS03	Loamy Sand	Aeolian	Toeslope
02QS04	Sandy Loam	Residual[2]	Basin Floor
02SH01	Loamy Sand	Aeolian	Toeslope
02SH02	Loamy Sand	Aeolian	Footslope
02SH03	Loamy Sand	Aeolian	Backslope
02SH04	Loamy Sand	Aeolian	Footslope
02SH05	Loamy Sand	Aeolian	Footslope
02SH06	Loamy Sand	Aeolian	Toeslope
02SH07	Loamy Sand	Aeolian	Footslope
02SH08	Loamy Sand	Aeolian	Backslope
02SH09	Sandy Loam	Aeolian	Footslope
02SH10	Loamy Sand	Aeolian	Backslope
02SH11	Loamy Sand	Aeolian	Backslope

1. Soil texture is based on one hand-texture of the surface 10 cm of soil.
2. May indicate substrate other than Quaternary sand.

Table 16. Frequency of occurrence of 158 vascular plants in all 27 sampling plots, in order of species names.

Species	NRCS Code	Frequency	Growth-form	Origin
achnatherum hymenoides, indian ricegrass	achy	25	5. Graminoid	Native
agoseris glauca, pale agoseris	aggl	5	6. Forb	Native
agropyron desertorum, desert wheatgrass	*agde2*	*2*	*5. Graminoid*	*Introduced*
alyssum alyssoides, pale madwort	*alal3*	*1*	*6. Forb*	*Introduced*
alyssum desertorum, desert madwort	*alde*	*9*	*6. Forb*	*Introduced*
amelanchier, serviceberry	amela	3	2. Shrub	Native
arabis cobrensis, sagebrush rockcress	arco	1	6. Forb	Native
arabis holboellii, holboell's rockcress	arho2	5	6. Forb	Native
artemisia cana ssp. cana, plains silver sagebrush	arcac5	10	2. Shrub	Native
artemisia dracunculus, wormwood	ardr4	4	3. Subshrub	Native
artemisia frigida, fringed sagewort	arfr4	3	3. Subshrub	Native
artemisia tridentata ssp. tridentata, basin big sagebrush	artrt	5	2. Shrub	Native
artemisia tridentata ssp. wyomingensis, wyoming big sagebrush	artrw	15	2. Shrub	Native
astragalus convallarius, timber milkvetch	asco12	4	6. Forb	Native
astragalus geyeri, geyer's milkvetch	asge	3	6. Forb	Native
astragalus sp., milkvetch	astra	1	6. Forb	Native
astragalus spatulatus, tufted milkvetch	assp6	1	6. Forb	Native
atriplex confertifolia, shadscale saltbush	atco	2	2. Shrub	Native
atriplex gardneri, gardner's saltbush	atga	2	3. Subshrub	Native
atriplex sp., saltbush	atrip	7	2. Shrub	Native
bromus sp., brome	bromu	1	5. Graminoid	Unknown
bromus tectorum, cheatgrass	*brte*	*2*	*5. Graminoid*	*Introduced*
camissonia parvula, lewis river suncup	capa39	1	6. Forb	Native
carex sp., sedge	carex	6	5. Graminoid	Native
chaenactis douglasii var. douglasii, Douglas's dustymaiden	chdod	6	6. Forb	Native
chenopodium sp., goosefoot	cheno	13	6. Forb	Native
chrysothamnus viscidiflorus ssp. viscidiflorus, yellow rabbitbrush	chviv2	23	2. Shrub	Native
cleome lutea, yellow spiderflower	cllu2	2	6. Forb	Native
collinsia parviflora, smallflower blue eyed mary	copa3	4	6. Forb	Native
comandra umbellata ssp. pallida, common toadflax	coump2	4	6. Forb	Native
crepis acuminata, longleaf hawksbeard	crac2	2	6. Forb	Native
cryptantha affinis, quill cryptantha	craf	2	6. Forb	Native
cryptantha caespitosa, tufted catseye	crca7	1	6. Forb	Native
cryptantha cinerea, james' catseye	crci3	3	6. Forb	Native
cryptantha circumscissa, cushion catseye	crci2	2	6. Forb	Native
cryptantha flava, brenda's yellow catseye	crfl5	4	6. Forb	Native

Table 16 (continued).

Species	NRCS Code	On This Many Plots	Growth-form	Origin
cryptantha kelseyana, kelsey's catseye	crke	1	6. Forb	Native
cryptantha sp., cryptantha	crypt	7	6. Forb	Native
cryptantha torreyana, torrey's cryptantha	crto4	1	6. Forb	Native
cryptantha watsonii, watson's catseye	crwa2	8	6. Forb	Native
cymopterus acaulis, plains springparsley	cyac	2	6. Forb	Native
cymopterus sp., cymopterus	cymop2	2	6. Forb	Native
danthonia intermedia, timber oatgrass	dain	2	5. Graminoid	Native
delphinium nuttallianum, nuttal's larkspur	denu2	1	6. Forb	Native
delphinium sp., larkspur	delph	5	6. Forb	Native
descurainia sophia, herb sophia	*deso2*	*6*	*6. Forb*	*Introduced*
descurainia sp., tansymustard	descu	3	6. Forb	Unknown
distichlis spicata, inland saltgrass	disp	1	5. Graminoid	Native
elymus elymoides, bottlebrush squirreltail	elel5	7	5. Graminoid	Native
elymus lanceolatus ssp. lanceolatus, thickspike wheatgrass	ellal	13	5. Graminoid	Native
elymus smithii, western wheatgrass	elsm3	4	5. Graminoid	Native
elymus sp., wildrye	elymu	5	5. Graminoid	Native
ericameria nauseosa, rubber rabbitbrush	erna10	18	2. Shrub	Native
erigeron compositus, cutleaf daisy	erco4	1	6. Forb	Native
eriogonum cernuum, nodding buckwheat	erce2	2	6. Forb	Native
eriogonum ovalifolium, cushion buckwheat	erov	9	3. Subshrub	Native
eriogonum sp., eriogonum	eriog	5	6. Forb	Native
eriogonum umbellatum, sulphur wildbuckwheat	erum	5	6. Forb	Native
erysimum capitatum var. capitatum, sanddune wallflower	ercac	5	6. Forb	Native
erysimum sp., wallflower	erysi	1	6. Forb	Native
forb unknown 23 ("pasque flower" 02sh08)	forbsv23	1	6. Forb	Unknown
forb unknown sv 16 ("whorled lvs white stem" 02sh05)	forbsv16	1	6. Forb	Unknown
forb unknown sv 8 ("mean needle forb")	forbsv8	1	6. Forb	Unknown
forb unknown sv 9 ("pitch green forb" 02qs02)	forbsv9	1	6. Forb	Unknown
forb unknown sv1 ("dead furry")	forbak01-1	1	6. Forb	Unknown
forb unknown sv1 ("menzelia")	forbsv1	1	6. Forb	Unknown
forb unknown sv10 ("phlox a" 02qs02)	forbsv10	2	6. Forb	Unknown
forb unknown sv11 ("broadleaf" 02sh02)	forbsv11	1	6. Forb	Unknown
forb unknown sv12 ("oblanc green lf forb" 02sh03)	forbsv12	1	6. Forb	Unknown
forb unknown sv13 ("primrose w/ leathery achenes" 02sh04)	forbsv13	1	6. Forb	Unknown
forb unknown sv14 ("asteraceae" 02sh04)	forbsv14	1	6. Forb	Unknown

Table 16 (continued).

Species	NRCS Code	On This Many Plots	Growth-form	Origin
forb unknown sv15 ("bright green slick leaves" 02sh05)	forbsv15	1	6. Forb	Unknown
forb unknown sv17 ("low lobed apiaceae" 02sh05)	forbsv17	1	6. Forb	Unknown
forb unknown sv18 ("big stipule, bright green" 02sh07)	forbsv18	1	6. Forb	Unknown
forb unknown sv19 ("dwarf small white herb" 02sh07)	forbsv19	1	6. Forb	Unknown
forb unknown sv2 ("velvet ovate")	forbsv2	1	6. Forb	Unknown
forb unknown sv20 ("one leaf" 02sh08)	forbsv20	1	6. Forb	Unknown
forb unknown sv21 ("long horn" 02sh08)	forbsv21	1	6. Forb	Unknown
forb unknown sv22 ("white sticky normal" 02sh08)	forbsv22	1	6. Forb	Unknown
forb unknown sv24 ("white fuzzy herb" 02sh09)	forbsv24	1	6. Forb	Unknown
forb unknown sv25 ("not evening prim (ast)" 02sh10)	forbsv25	1	6. Forb	Unknown
forb unknown sv26 ("small hairy herb" 02sh11)	forbsv26	1	6. Forb	Unknown
forb unknown sv27 ("wide toothed plant" 02sh11)	forbsv27	1	6. Forb	Unknown
forb unknown sv3 ("toothed")	forbsv3	1	6. Forb	Unknown
forb unknown sv5 ("hawaiin forb"}	forbsv5	1	6. Forb	Unknown
forb unknown sv6 (green spike forb0	forbsv6	1	6. Forb	Unknown
forb unknown sv7 ("hookers sand wort"}	forbsv7	1	6. Forb	Unknown
gayophytum ramosissimum, muchbranched groundsmoke	gara2	6	6. Forb	Native
gilia leptomeria, sand gilia	gile3	2	6. Forb	Native
grass unknown sv1 ("clump grass")	grassv1	2	5. Graminoid	Unknown
grass unknown sv2 ("curlend grass")	grassv2	3	5. Graminoid	Unknown
grass unknown sv3 (orsopsis)	grassv3	1	5. Graminoid	Unknown
grass unknown sv4 (silky awn)	grassv4	1	5. Graminoid	Unknown
grass unknown sv5 ("sandberg bluegrass" 02qs02)	grassv5	1	5. Graminoid	Unknown
grayia spinosa, spiny hopsage	grsp	4	2. Shrub	Native
halogeton glomeratus, halogeton	*hagl*	*2*	*6. Forb*	*Introduced*
hesperostipa comata, needle and thread	heco26	21	5. Graminoid	Native
heterotheca sp., telegraphplant	heter8	3	6. Forb	Native
heterotheca villosa, hairy goldenaster	hevi4	4	6. Forb	Native
hymenopappus filifolius, fineleaf hymenopappus	hyfi	1	6. Forb	Native
juncus balticus var. montanus, mountain rush	jubam	2	5. Graminoid	Native
kochia americana, greenmolly	koam	7	6. Forb	Native

Table 16 (continued).

Species	NRCS Code	On This Many Plots	Growth-form	Origin
koeleria macrantha, prairie junegrass	koma	6	5. Graminoid	Native
krascheninnikovia lanata, winterfat	krla2	5	3. Subshrub	Native
lappula occidentalis var. occidentalis, flatspine stickseed	laoco	4	6. Forb	Native
leptodactylon pungens, granite pricklygilia	lepu	10	3. Subshrub	Native
lesquerella ludoviciana, foothill bladderpod	lelu	3	6. Forb	Native
lesquerella sp., bladderpod	lesqu	8	6. Forb	Native
leucopoa kingii, spike fescue	leki2	1	5. Graminoid	Native
lithospermum incisum, narrowleaf gromwell	liin2	2	6. Forb	Native
lithospermum ruderale, western gromwell	liru4	2	6. Forb	Native
lomatium simplex, narrowleaf lomatium	losi2	2	6. Forb	Native
lupinus argenteus, silvery lupine	luar3	4	6. Forb	Native
lupinus pusillus, rusty lupine	lupu	3	6. Forb	Native
lupinus sericeus, silky lupine	luse4	1	6. Forb	Native
lupinus sp., lupine	lupin	3	6. Forb	Native
lygodesmia juncea, rush skeletonplant	lyju	3	6. Forb	Native
machaeranthera canescens, hoary aster	maca2	13	6. Forb	Native
mahonia repens, oregongrape	mare11	2	3. Subshrub	Native
malacothrix torreyi, torrey's desertdandelion	mato2	1	6. Forb	Native
mentzelia albicaulis, whitestem blazingstar	meal6	1	6. Forb	Native
mentzelia dispersa, bushy blazingstar	medi	2	6. Forb	Native
mertensia lanceolata, lanceleaf bluebells	mela3	3	6. Forb	Native
monolepis nuttalliana, nuttall's povertyweed	monu	1	6. Forb	Native
muhlenbergia pungens, sandhill muhly	mupu2	9	5. Graminoid	Native
nama densum, leafy nama	nade2	1	6. Forb	Native
oenothera pallida, pale eveningprimrose	oepa	8	6. Forb	Native
opuntia polyacantha, plains pricklypear	oppo	22	3. Subshrub	Native
oxytropis sp., crazyweed	oxytr	1	6. Forb	Native
penstemon sp., penstemon	penst	1	6. Forb	Native
penstemon strictus, rocky mountain penstemon	pest2	2	6. Forb	Native
phacelia ivesiana, ives' phacelia	phiv	1	6. Forb	Native
phacelia sericea, silky phacelia	phse	3	6. Forb	Native
phlox hoodii, hoods phlox	phho	2	6. Forb	Native
phlox muscoides, musk phlox	phmu4	2	6. Forb	Native
poa fendleriana, muttongrass	pofe	2	5. Graminoid	Native
poa pratensis, kentucky bluegrass	*popr*	*2*	*5. Graminoid*	*Introduced*
poa secunda, sandberg bluegrass	pose	11	5. Graminoid	Native
polygonum douglasii, douglas' knotweed	podo4	2	6. Forb	Native
polygonum sawatchense, knotweed	posa17	2	6. Forb	Native
polygonum sp., knotweed	polyg4	2	6. Forb	Unknown

Table 16 (continued).

Species	NRCS Code	On This Many Plots	Growth-form	Origin
prunus virginiana, common chokecherry	prvi	2	2. Shrub	Native
psoralidium lanceolatum, lemon scurfpea	psla3	3	6. Forb	Native
purshia tridentata, antelope bitterbrush	putr2	11	2. Shrub	Native
rosa woodsii, woods' rose	rowo	4	2. Shrub	Native
rumex venosus, veiny dock	ruve2	5	6. Forb	Native
salsola tragus, prickly Russian thistle	*satr12*	*2*	*6. Forb*	*Introduced*
sarcobatus vermiculatus, greasewood	save4	12	2. Shrub	Native
schoenocrambe linifolia, flaxleaf plainsmustard	scli	4	6. Forb	Native
sphaeralcea coccinea, scarlet globemallow	spco	3	6. Forb	Native
sporobolus cryptandrus, sand dropseed	spcr	1	5. Graminoid	Native
symphoricarpos oreophilus, whortleleaf snowberry	syor2	4	2. Shrub	Native
tetradymia canescens, spineless horsebrush	teca2	13	2. Shrub	Native
thermopsis, thermopsis	therm	1	6. Forb	Native
tiquilia nuttallii, nuttall's coldenia	tinu2	1	6. Forb	Native
tragopogon dubius, yellow salsify	*trdu*	*4*	*6. Forb*	*Introduced*
trifolium gymnocarpon, hollyleaf clover	trgy	1	6. Forb	Native
vulpia octoflora, sixweeks fescue	vuoc	8	5. Graminoid	Native

Table 17. Numbers of native taxa, exotic taxa, and taxa of unknown origin in all 27 sample plots.

Plot	Total # Spp.	Native	Exotic	Origin Unknown
02AK01	10	9	0	1
02AK02	13	11	0	2
02AK03	16	16	0	0
02AK04	10	10	0	0
02BF01	28	24	1	3
02BF02	15	14	0	1
02BF03	21	20	0	1
02BF04	21	19	2	0
02DS01	20	20	0	0
02DS02	13	11	1	1
02DS03	12	10	0	2
02DS04	13	10	0	3
02QS01	23	23	0	0
02QS02	21	16	0	5
02QS03	20	20	0	0
02QS04	10	7	2	1
02SH01	30	27	3	0
02SH02	30	26	3	1
02SH03	27	24	2	1
02SH04	25	20	2	3
02SH05	30	25	2	3
02SH06	26	23	2	1
02SH07	28	24	1	3
02SH08	47	38	3	5
02SH09	34	32	0	2
02SH10	41	37	3	1
02SH11	35	30	3	2

Table 18. Canopy cover of native taxa, exotic taxa, and taxa of unknown origin in all 27 sample plots.

Plot	Total Cover	Native	Exotic	Origin Unknown
02AK01	38	37	0	1
02AK02	15	13	0	2
02AK03	38	38	0	0
02AK04	14	14	0	0
02BF01	42	38	1	3
02BF02	23	22	0	1
02BF03	29	28	0	1
02BF04	25	23	2	0
02DS01	40	40	0	0
02DS02	58	56	1	1
02DS03	37	35	0	2
02DS04	28	23	0	5
02QS01	36	36	0	0
02QS02	32	27	0	5
02QS03	44	44	0	0
02QS04	14	11	2	1
02SH01	88	85	3	0
02SH02	69	63	5	1
02SH03	107	104	2	1
02SH04	60	55	2	3
02SH05	91	86	2	3
02SH06	47	42	4	1
02SH07	47	43	1	3
02SH08	69	61	3	5
02SH09	105	103	0	2
02SH10	79	75	3	1
02SH11	78	73	3	2

Table 19. Results from MRPP analysis of differences between groups of plots in the 5-group cluster analysis classification of all 27 sample plots, based on presence of species.

Comparison of Groups*	Observed Delta	Expected Delta	T	p	A
2-1 vs 2-17	0.294	0.50	-15.12	0.00000004	0.41
5-17 vs 5-24	0.311	0.50	-5.25	0.00064	0.378
5-1 vs 5-3	0.3998	0.50	-3.618	0.0026	0.20
Within 5-3	0.333	0.50	-2.703	0.0158	0.334

Delta = weighted average distance between plots within a group
$= \Sigma_{\text{all groups}} (n_i / \Sigma n_i)$(ave. within group distance between plots)

T = (observed delta - expected delta) / (standard deviation of expected delta)
p = probability of delta this small or smaller
A = chance-corrected within-group agreement = 1 - (observed delta / expected delta).
A = 1 when all items are identical within groups (delta=0), A = 0 when heterogeneity within groups equals expectation by chance, A < 0 with more heterogeneity within groups than expected by chance

Analysis was performed with PC-ORD Version 4.27. Weighting option: C(I) = n(I)/sum(n(I)); Distance measure = Sorensen; distance matrix rank transformed.

* Groups were identified from cluster analysis using presence/absence data (Figure 9).
Group 2-1 = 16 plots from outside the Sand Hills
Group 2-17 = 11 plots from the Sand Hills
Group 5-17 = 7 Sand Hills plots, 02SH01 - 02SH07
Group 5-24 = 4 Sand Hills plots, 02SH08 - 02SH11
Group 5-1 = plots 02AK01, 02AK04, 02DS01, 02DS02, 02DS03, 02DS04 (n=6)
Group 5-3 plots 02AK03, 02BF01, 02BF02, 02BF03, 02BF04, 02QS01, 02QS03 (n=7)
Groups within 5-3: (02AK03, 02BF01, 02BF02, 02BF03, 02BF04) vs. (02QS01, 02QS03)

Table 20. Statistically-significant indicator species for the Sand Hills sample plots (group 2-17) vs. all other sample plots (group 2-1), based on presence of species.
Significance is $p < 0.01$. Maximum indicator values are in bold typeface. Exotic species are shown in italic typeface.

Indicator for group	Species	Abundance[1] in Group		Frequency[2] in Group (n)		Indicator Value[3]		
		2-1	2-17	2-1 (16)	2-17 (11)	2-1	2-17	p[4]
2-1	artemisia tridentata ssp. wyomingensis, Wyoming big sagebrush	100	0	94	0	**94**	0	0.001
	sarcobatus vermiculatus, greasewood	100	0	75	0	**75**	0	0.001
2-17	purshia tridentata, antelope bitterbrush	0	100	0	100	0	**100**	0.001
	artemisia cana ssp. cana, plains silver sagebrush	0	100	0	91	0	**91**	0.001
	chenopodium sp., goosefoot	11	89	13	100	1	**89**	0.001
	alyssum desertorum, desert madwort	0	100	0	82	0	**82**	0.001
	cryptantha watsonii, watson's catseye	0	100	0	73	0	**73**	0.001
	vulpia octoflora, sixweeks fescue	0	100	0	73	0	**73**	0.001
	carex sp., sedge	0	100	0	55	0	**55**	0.002
	descurainia sophia, herb sophia	0	100	0	55	0	**55**	0.002
	gayophytum ramosissimum, muchbranched groundsmoke	0	100	0	55	0	**55**	0.002
	koeleria macrantha, prairie junegrass	0	100	0	55	0	**55**	0.002
	delphinium sp., larkspur	0	100	0	45	0	**45**	0.006
	agoseris glauca, pale agoseris	0	100	0	45	0	**45**	0.008
	eriogonum umbellatum, sulphur buckwheat	0	100	0	45	0	**45**	0.008

1. Relative abundance of species *i* in group *j* = [(frequency of species *i* in plots of group *j*) / (sum of frequencies of species *i* in plots of each group)]
2. Frequency of species *i* in group *j* = 100[(number of plots of group *j* with species *i*) / (number of plots in group *j*)]
3. Indicator value of species *i* in group *j* = 100[(relative abundance of species *i* in group *j*) X (frequency of species *i* in group *j*)]. A perfect indicator (i.e., a species whose presence indicates a particular group without error) has an IV = 100.
4. Probability of obtaining a maximum indicator value this large or larger in 1000 runs of a Monte Carlo test of data.

Table 21. Statistically-significant indicator species for the five groups of sample plots based on presence of species.
Species with indicator values ≥ 75 are shown in upper-case type.
Significance is $p < 0.01$.

Indicators for Group	Species	Abundance[1] in Group:					Frequency[2] in Group: (# of plots in group)					Indicator Value[3] for Group:					Maximum		
		5-1	5-3	5-2	5-17	5-24	5-1 (6)	5-3 (7)	5-2 (3)	5-17 (7)	5-24 (4)	5-1	5-3	5-2	5-17	5-24	Group	IV	p[4]
5-1	kraschenninnikovia lanata, winterfat	82	18	0	0	0	67	14	0	0	0	55	3	0	0	0	1	54.9	0.006
	achnatherum hymenoides, indian ricegrass	23	23	8	23	23	100	100	33	100	100	23	23	3	23	23	1	23.1	0.007
5-3	astragalus convallarius, timber milkvetch	0	100	0	0	0	0	57	0	0	0	0	57	0	0	0	3	57.1	0.007
	grayia spinosa, spiny hopsage	0	100	0	0	0	0	57	0	0	0	0	57	0	0	0	3	57.1	0.005
	chrysothamnus viscidiflorus ssp. viscidiflorus, yellow rabbitbrush	22	26	0	26	26	83	100	0	100	100	18	26	0	26	26	3	26.1	0.004
5-2	SPHAERALCEA COCCINEA, SCARLET GLOBEMALLOW	0	0	100	0	0	0	0	100	0	0	0	0	100	0	0	2	100	0.001
	kochia americana, greenmolly	0	36	64	0	0	0	57	100	0	0	0	21	64	0	0	2	63.6	0.005
	atriplex sp., saltbush	21	18	62	0	0	33	29	100	0	0	7	5	62	0	0	2	61.8	0.006
5-17	VULPIA OCTOFLORA, SIXWEEKS FESCUE	0	0	0	80	20	0	0	0	100	25	0	0	0	80	5	17	80	0.001
	artemisia cana ssp. cana, plains silver sagebrush	0	0	0	57	43	0	0	0	100	75	0	0	0	57	32	17	57.1	0.001
	purshia tridentata, antelope bitterbrush	0	0	0	50	50	0	0	0	100	100	0	0	0	50	50	17	50	0.003
	chenopodium sp., goosefoot	0	13	0	44	44	0	29	0	100	100	0	4	0	44	44	17	43.8	0.008
5-24	COMANDRA UMBELLATA SSP. PALLIDA, COMMON TOADFLAX	0	0	0	0	100	0	0	0	0	100	0	0	0	0	100	24	100	0.002
	ROSA WOODSII, WOODS' ROSE	0	0	0	0	100	0	0	0	0	100	0	0	0	0	100	24	100	0.002
	SYMPHORICARPOS OREOPHILUS, WHORTLELEAF SNOWBERRY	0	0	0	0	100	0	0	0	0	100	0	0	0	0	100	24	100	0.002
	ERIOGONUM UMBELLATUM, SULPHUR WILDBUCKWHEAT	0	13	0	13	87	0	0	0	14	100	0	0	0	2	87	24	87.5	0.001
	ERYSIMUM CAPITATUM VAR. CAPITATUM, SANDDUNE WALLFLOWER	14	0	0	0	86	17	0	0	0	100	2	0	0	0	86	24	85.7	0.002
	AMELANCHIER, SERVICEBERRY	0	0	0	0	100	0	0	0	0	75	0	0	0	0	75	24	75	0.003
	ARTEMISIA TRIDENTATA SSP. TRIDENTATA, BASIN BIG SAGEBRUSH	0	0	25	0	75	0	0	33	0	100	0	0	8	0	75	24	75	0.005
	HETEROTHECA SP., TELEGRAPHPLANT	0	0	0	0	100	0	0	0	0	75	0	0	0	0	75	24	75	0.003
	MERTENSIA LANCEOLATA, LANCELEAF BLUEBELLS	0	0	0	0	100	0	0	0	0	75	0	0	0	0	75	24	75	0.003
	PHACELIA SERICEA, SILKY PHACELIA	0	0	0	0	100	0	0	0	0	75	0	0	0	0	75	24	75	0.003
	artemisia dracunculus, wormwood	0	16	0	0	84	0	14	0	0	75	0	2	0	0	63	24	63	0.004
	tragopogon dubius, yellow salsify	0	0	0	16	84	0	0	0	14	75	0	0	0	2	63	24	63	0.008
	delphinium sp., larkspur	0	0	0	28	72	0	0	0	29	75	0	0	0	8	54	24	54.3	0.01

1. Relative abundance of species *i* in group *j* = [(frequency of species *i* in plots of group *j*) / (sum of frequencies of species *i* in plots of each group)]
2. Frequency of species *i* in group *j* = 100[(number of plots of group *j* with species *i*) / (number of plots in group *j*)]
3. Indicator value of species *i* in group *j* = 100[(relative abundance of species *i* in group *j*) X (frequency of species *i* in group *j*)]. A perfect indicator (i.e., a species whose presence indicates a particular group without error) has an IV = 100.
4. Probability of obtaining an indicator value this large or larger in 1000 runs of a Monte Carlo test of data.

Table 22. Frequency of all 158 vascular plant species in each of the five plot groups based on presence of species and in all 27 plots together.
Statistically-significant indicator species for each of the five groups are shown in bold typeface. Exotic species are in italic typeface.

group spp.	Species (n=158)	Frequency in Plot Group (n)					
		5-1	5-3	5-2	5-17	5-24	All
		(6)	(7)	(3)	(7)	(4)	(27)
1	**achnatherum hymenoides, indian ricegrass**	**6**	7	1	7	4	25
	chrysothamnus viscidiflorus ssp. viscidiflorus, yellow rabbitbrush	5	**7**		7	4	23
	opuntia polyacantha, plains pricklypear	6	6	3	5	2	22
	hesperostipa comata, needle and thread	2	7	1	7	4	21
	ericameria nauseosa, rubber rabbitbrush	3	6	2	3	4	18
	elymus lanceolatus ssp. lanceolatus, thickspike wheatgrass	3		2	6	2	13
	machaeranthera canescens, hoary aster	2	3	1	3	4	13
	tetradymia canescens, spineless horsebrush	2	4		5	2	13
2	artemisia tridentata ssp. wyomingensis, wyoming big sagebrush	6	7	2			15
	sarcobatus vermiculatus, greasewood	5	5	2			12
	elymus elymoides, bottlebrush squirreltail	2	4	1			7
	elymus smithii, western wheatgrass	2	1	1			4
	artemisia frigida, fringed sagewort		2	1			3
	psoralidium lanceolatum, lemon scurfpea	1	2				3
	phlox hoodii, hoods phlox	1	1				2
	halogeton glomeratus, halogeton		*1*	*1*			*2*
	agropyron desertorum, desert wheatgrass	*1*		*1*			*2*
	grass unknown sv1 ("clump grass")	1		1			2
	grass unknown sv2 ("curlend grass")	1		2			3
3	**krascheninnikovia lanata, winterfat**	**4**	1				5
	phlox muscoides, musk phlox	2					2
	astragalus sp., milkvetch	1					1
	astragalus spatulatus, tufted milkvetch	1					1
	forb unknown sv1 ("dead furry")	1					1
	forb unknown sv6 (green spike forb0	1					1
	forb unknown sv7 ("hookers sand wort"}	1					1
	grass unknown sv3 (orsopsis)	1					1
	grass unknown sv4 (silky awn)	1					1
	oxytropis sp., crazyweed	1					1
	penstemon sp., penstemon	1					1
	astragalus convallarius, timber milkvetch		**4**				4
	grayia spinosa, spiny hopsage		**4**				4
4	schoenocrambe linifolia, flaxleaf plainsmustard		4				4
	astragalus geyeri, geyer's milkvetch		3				3
	lupinus pusillus, rusty lupine		3				3
	atriplex confertifolia, shadscale saltbush		2				2
	atriplex gardneri, gardner's saltbush		2				2
	cleome lutea, yellow spiderflower		2				2
	eriogonum cernuum, nodding buckwheat		2				2
	gilia leptomeria, sand gilia		2				2
	salsola tragus, prickly Russian thistle		*2*				*2*
	arabis cobrensis, sagebrush rockcress		1				1
	cryptantha kelseyana, kelsey's catseye		1				1
	erigeron compositus, cutleaf daisy		1				1
	erysimum sp., wallflower		1				1
	forb unknown sv1 ("menzelia")		1				1

Table 22 (continued).

Spp. group	Species (n=158)	Frequency in Plot Group (n)					
		5-1	5-3	5-2	5-17	5-24	All
		(6)	(7)	(3)	(7)	(4)	(27)
4 cont.	forb unknown sv2 ("velvet ovate")		1				1
	forb unknown sv3 ("toothed")		1				1
	forb unknown sv5 ("hawaiin forb"}		1				1
	hymenopappus filifolius, fineleaf hymenopappus		1				1
	malacothrix torreyi, torrey's desertdandelion		1				1
	nama densum, leafy nama		1				1
	phacelia ivesiana, ives' phacelia		1				1
	tiquilia nuttallii, nuttall's coldenia		1				1
5	**kochia americana, greenmolly**		4	**3**			7
	sphaeralcea coccinea, scarlet globemallow			**3**			3
	atriplex sp., saltbush	2	2	**3**			7
	forb unknown sv10 ("phlox a" 02qs02)			2			2
	cryptantha caespitosa, tufted catseye			1			1
	distichlis spicata, inland saltgrass			1			1
	forb unknown sv 8 ("mean needle forb")			1			1
	forb unknown sv 9 ("pitch green forb" 02qs02)			1			1
	monolepis nuttalliana, nuttall's povertyweed			1			1
	sporobolus cryptandrus, sand dropseed			1			1
	grass unknown sv5 ("sandberg bluegrass" 02qs02)			1			1
6	**chenopodium sp., goosefoot**		2		**7**	4	13
	purshia tridentata, antelope bitterbrush				**7**	4	11
	artemisia cana, silver sagebrush				**7**	3	10
	alyssum desertorum, desert madwort				*6*	*3*	*9*
	cryptantha watsonii, watson's catseye				5	3	8
	carex sp., sedge				3	3	6
	descurainia sophia, herb sophia				*4*	*2*	*6*
	gayophytum ramosissimum, muchbranched groundsmoke				4	2	6
	koeleria macrantha, prairie junegrass				4	2	6
	agoseris glauca, pale agoseris				2	3	5
	collinsia parviflora, smallflower blue eyed mary				3	1	4
	lappula occidentalis var. occidentalis, flatspine stickseed				2	2	4
	lupinus argenteus, silvery lupine				2	2	4
	cryptantha cinerea, james' catseye				2	1	3
	lesquerella ludoviciana, foothill bladderpod				2	1	3
	lupinus sp., lupine				1	2	3
	cymopterus acaulis, plains springparsley				1	1	2
	juncus balticus var. montanus				1	1	2
	lithospermum incisum, narrowleaf gromwell				1	1	2
	penstemon strictus, rocky mountain penstemon				1	1	2
	poa pratensis, kentucky bluegrass				*1*	*1*	*2*
	polygonum sp., knotweed				1	1	2
7	**vulpia octoflora, sixweeks fescue**				**7**	1	8
	heterotheca villosa, hairy goldenaster				4		4
	bromus tectorum, cheatgrass				*2*		*2*
	cryptantha affinis, quill cryptantha				2		2
	cryptantha circumscissa, cushion catseye				2		2
	cymopterus sp., cymopterus				2		2
	mentzelia dispersa, bushy blazingstar				2		2
	alyssum alyssoides, pale madwort				*1*		*1*
	camissonia parvula, lewis river suncup				1		1
	cryptantha torreyana, torrey's cryptantha				1		1

Table 22 (continued).

Spp. group	Species (n=158)	Frequency in Plot Group (n) 5-1 (6)	5-3 (7)	5-2 (3)	5-17 (7)	5-24 (4)	All (27)
7 cont.	forb unknown sv 16 ("whorled lvs white stem" 02sh05)				1		1
	forb unknown sv11 ("broadleaf" 02sh02)				1		1
	forb unknown sv12 ("oblanc green lf forb" 02sh03)				1		1
	forb unknown sv13 ("primrose w/ leathery achenes" 02sh04)				1		1
	forb unknown sv14 ("asteraceae" 02sh04)				1		1
	forb unknown sv15 ("bright green slick leaves" 02sh05)				1		1
	forb unknown sv17 ("low lobed apiaceae" 02sh05)				1		1
	forb unknown sv18 ("big stipule, bright green" 02sh07)				1		1
	forb unknown sv19 ("dwarf small white herb" 02sh07)				1		1
	lupinus sericeus, silky lupine				1		1
	thermopsis, thermopsis				1		1
	trifolium gymnocarpon, hollyleaf clover				1		1
	leptodactylon pungens, granite pricklygilia	1	2		6	1	10
8	**artemisia tridentata ssp. tridentata, basin big sagebrush**			1		**4**	5
	comandra umbellata ssp. pallida, common toadflax					**4**	4
	eriogonum umbellatum, sulphur wildbuckwheat				1	**4**	5
	erysimum capitatum var. capitatum, sanddune wallflower	1				**4**	5
	rosa woodsii, woods' rose					**4**	4
	symphoricarpos oreophilus, whortleleaf snowberry					**4**	4
	amelanchier, serviceberry					**3**	3
	artemisia dracunculus, wormwood		1			**3**	4
	delphinium sp., larkspur				2	**3**	5
	heterotheca sp., telegraphplant					**3**	3
	mertensia lanceolata, lanceleaf bluebells					**3**	3
	phacelia sericea, silky phacelia					**3**	3
	tragopogon dubius, yellow salsify				*1*	***3***	*4*
	crepis acuminata, longleaf hawksbeard					2	2
	lithospermum ruderale, western gromwell					2	2
	lomatium simplex, narrowleaf lomatium					2	2
	mahonia repens, oregongrape					2	2
	poa fendleriana, muttongrass					2	2
	polygonum douglasii, douglas' knotweed					2	2
	prunus virginiana, common chokecherry					2	2
	bromus sp., brome					1	1
	delphinium nuttallianum, nuttal's larkspur					1	1
	forb unknown 23 ("pasque flower" 02sh08)					1	1
	forb unknown sv20 ("one leaf" 02sh08)					1	1
	forb unknown sv21 ("long horn" 02sh08)					1	1
	forb unknown sv22 ("white sticky normal" 02sh08)					1	1
	forb unknown sv24 ("white fuzzy herb" 02sh09)					1	1
	forb unknown sv25 ("not evening prim (ast)" 02sh10)					1	1
	forb unknown sv26 ("small hairy herb" 02sh11)					1	1
	forb unknown sv27 ("wide toothed plant" 02sh11)					1	1
	leucopoa kingii, spike fescue					1	1
	mentzelia albicaulis, whitestem blazingstar					1	1

Table 22 (continued).

Spp. group	Species (n=158)	Frequency in Plot Group (n)					
		5-1	5-3	5-2	5-17	5-24	All
		(6)	(7)	(3)	(7)	(4)	(27)
9	descurainia sp., tansymustard		1		2		3
	lygodesmia juncea, rush skeletonplant		1		2		3
	danthonia intermedia, timber oatgrass		1		1		2
	polygonum sawatchense, knotweed				2		2
	eriogonum sp., eriogonum		1		4		5
	cryptantha flava, brenda's yellow catseye		2		2		4
	chaenactis douglasii var. douglasii, douglas's dustymaiden		4		2		6
	poa secunda, sandberg bluegrass	3	1		4	3	11
	eriogonum ovalifolium, cushion buckwheat	4	2	1	2		9
	muhlenbergia pungens, sandhill muhly		2		5	2	9
	lesquerella, bladderpod		1	1	3	3	8
	oenothera pallida, pale eveningprimrose		3		4	1	8
	cryptantha sp., cryptantha	1		1	5		7
	rumex venosus, veiny dock		2		2	1	5
	arabis holboellii, holboell's rockcress	1	2			2	5
	elymus sp., wildrye	1	3			1	5

Table 23. Statistically-significant indicator species in each of the six groups from the cluster analysis classification of all 27 plots based on canopy cover.
Exotic species are shown in italic typeface.

Indicator for Group	Group / Species / n	Abundance in Group						Frequency in Group						Indicator Value in Group						
		6-1	6-5	6-2	6-13	6-17	6-24	6-1	6-5	6-2	6-13	6-17	6-24	6-1	6-5	6-2	6-13	6-17	6-24	p
	n	6	4	4	4	5	4	6	4	4	4	5	4	6	4	4	4	5	4	
6-1	artemisia tridentata ssp. wyomingensis, Wyoming big sagebrush	64	20	14	2	0	0	100	100	75	50	0	0	64	20	10	1	0	0	0.001
	krascheninnikovia lanata, winterfat	100	0	0	0	0	0	83	0	0	0	0	0	83	0	0	0	0	0	0.002
6-5	astragalus geyeri, Geyer's milkvetch	12	88	0	0	0	0	17	75	0	0	0	0	2	66	0	0	0	0	0.005
	astragalus convallarius, timber milkvetch	0	100	0	0	0	0	0	75	0	0	0	0	0	75	0	0	0	0	0.006
	grayia spinosa, spiny hopsage	0	100	0	0	0	0	0	100	0	0	0	0	0	100	0	0	0	0	0.001
	lupinus pusillus, rusty lupine	0	100	0	0	0	0	0	75	0	0	0	0	0	75	0	0	0	0	0.006
6-2	atriplex sp., saltbush	5	8	82	4	0	0	17	25	100	25	0	0	1	2	82	1	0	0	0.001
	opuntia polyacantha, plains pricklypear	16	24	40	4	13	4	100	100	100	25	100	50	16	24	40	1	13	2	0.002
	sphaeralcea coccinea, scarlet globemallow	0	0	100	0	0	0	0	0	75	0	0	0	0	0	75	0	0	0	0.005
6-13	chaenactis douglasii var. douglasii, Douglas's dustymaiden	0	40	0	60	0	0	0	50	0	100	0	0	0	20	0	60	0	0	0.004
	cryptantha flava, Brenda's yellow cryptantha	0	0	0	91	9	0	0	0	0	75	20	0	0	0	0	68	2	0	0.005
6-17	artemisia cana spp. cana, basin silver sagebrush	0	0	0	11	82	7	0	0	0	50	100	75	0	0	0	6	82	5	0.001
	descurainia sophia, herb sophia	*0*	*0*	*0*	*0*	*57*	*43*	*0*	*0*	*0*	*0*	*80*	*50*	*0*	*0*	*0*	*0*	*45*	*22*	*0.01*
	gayophytum ramosissimum, muchbranched groundsmoke	0	0	0	0	71	29	0	0	0	0	80	50	0	0	0	0	57	15	0.006

Table 23 (continued).

Indicator for Group	Group / Species / n	Abundance in Group						Frequency in Group						Indicator Value in Group						
		6-1	6-5	6-2	6-13	6-17	6-24	6-1	6-5	6-2	6-13	6-17	6-24	6-1	6-5	6-2	6-13	6-17	6-24	p
	Species / n	6	4	4	4	5	4	6	4	4	4	5	4	6	4	4	4	5	4	
6-24	agoseris glauca, pale agoseris	0	0	0	0	30	70	0	0	0	0	40	75	0	0	0	0	12	53	0.007
	amelanchier sp., serviceberry	0	0	0	0	0	100	0	0	0	0	0	75	0	0	0	0	0	75	0.006
	erysimum capitatum var. capitatum, sanddune wallflower	24	0	0	0	0	76	17	0	0	0	0	100	4	0	0	0	0	76	0.002
	eriogonum umbellatum, sulphur buckwheat	0	0	0	0	17	83	0	0	0	0	20	100	0	0	0	0	3	83	0.001
	comandra umbellata ssp. pallida, common toadflax	0	0	0	0	0	100	0	0	0	0	0	100	0	0	0	0	0	100	0.002
	heterotheca sp., telegraphplant	0	0	0	0	0	100	0	0	0	0	0	75	0	0	0	0	0	75	0.004
	mertensia lanceolata, lanceleaf bluebells	0	0	0	0	0	100	0	0	0	0	0	75	0	0	0	0	0	75	0.006
	phacelia sericea, silky phacelia	0	0	0	0	0	100	0	0	0	0	0	75	0	0	0	0	0	75	0.008
	rosa woodsii, Wood's rose	0	0	0	0	0	100	0	0	0	0	0	100	0	0	0	0	0	100	0.002
	symphoricarpos oreophilus, whortleleaf snowberry	0	0	0	0	0	100	0	0	0	0	0	100	0	0	0	0	0	100	0.002

1. Relative abundance of species *i* in group *j* = [(frequency of species *i* in plots of group *j*) / (sum of frequencies of species *i* in plots of each group)]
2. Frequency of species *i* in group *j* = 100[(number of plots of group *j* with species *i*) / (number of plots in group *j*)]
3. Indicator value of species *i* in group *j* = 100[(relative abundance of species *i* in group *j*) X (frequency of species *i* in group *j*)]. A perfect indicator (i.e., a species whose presence indicates a particular group without error) has an IV = 100.
4. Probability of obtaining an indicator value this large or larger in 1000 runs of a Monte Carlo test of data.

Table 24. Plot table for group 6-17 from the cluster analysis classification of all 27 plots based on canopy cover.
Table shows total canopy cover of all plants per plot and, for each species, relative canopy cover, number of plots of occurrence, and average cover in plots of occurrence.

Plot	# of Plots	Ave. Cover	02SH01	02SH02	02SH04	02SH03	02SH05
Total % Cover			88	69	60	107	90
Species							
2. Shrub							
artemisia cana, silver sagebrush	5	0.25	0.34	0.14	0.17	0.28	0.33
chrysothamnus viscidiflorus ssp. viscidiflorus, yellow rabbitbrush	5	0.05	0.01	0.04	0.05	0.09	0.03
ericameria nauseosa, rubber rabbitbrush	3	0.03	0	0	0.05	0.03	0.01
purshia tridentata, antelope bitterbrush	5	0.14	0.01	0.04	0.17	0.28	0.22
tetradymia canescens, spineless horsebrush	4	0.02	0.01	0.04	0	0.01	0.03
3. Subshrub							
eriogonum ovalifolium, cushion buckwheat	1	0.01	0	0	0	0	0.01
leptodactylon pungens, granite pricklygilia	4	0.03	0.01	0	0.05	0.01	0.03
opuntia polyacantha, plains pricklypear	5	0.02	0.01	0.04	0.02	0.03	0.01
5. Graminoid							
achnatherum hymenoides, indian ricegrass	5	0.01	0.01	0.01	0.02	0.01	0.01
bromus tectorum, cheatgrass	2	0.02	0	0.01	0.02	0	0
carex sp., sedge	3	0.07	0.11	0.04	0.05	0	0
elymus lanceolatus ssp. lanceolatus, thickspike wheatgrass	4	0.02	0.01	0.01	0	0.01	0.03
hesperostipa comata, needle and thread	5	0.09	0.11	0.14	0.17	0.01	0.03
juncus balticus var. montanus	1	0.01	0.01	0	0	0	0
koeleria macrantha, prairie junegrass	2	0.01	0	0.01	0	0	0.01
muhlenbergia pungens, sandhill muhly	5	0.08	0.11	0.14	0.02	0.09	0.01
poa pratensis, kentucky bluegrass	1	0.01	0.01	0	0	0	0
poa secunda, sandberg bluegrass	3	0.01	0.01	0.01	0.02	0	0
vulpia octoflora, sixweeks fescue	5	0.01	0.01	0.01	0.02	0.01	0.01
6. Forb							
agoseris glauca, pale agoseris	2	0.01	0	0	0	0.01	0.01
alyssum alyssoides, pale madwort	1	0.01	0.01	0	0	0	0
alyssum desertorum, desert madwort	4	0.02	0	0.04	0.02	0.01	0.01
camissonia parvula, lewis river suncup	1	0.01	0.01	0	0	0	0
chenopodium sp., goosefoot	5	0.02	0.01	0.01	0.02	0.01	0.03
collinsia parviflora, smallflower blue eyed mary	3	0.01	0.01	0.01	0.02	0	0
cryptantha affinis, quill cryptantha	2	0.01	0.01	0	0	0.01	0
cryptantha cinerea, james' catseye	1	0.01	0	0	0	0	0.01
cryptantha circumscissa, cushion catseye	1	0.01	0	0	0	0	0.01
cryptantha flava, brenda's yellow catseye	1	0.01	0	0	0	0.01	0
cryptantha sp., cryptantha	3	0.01	0	0.01	0.02	0	0.01

Table 24 (continued).

Plot	# of Plots	Ave. Cover	02SH01	02SH02	02SH04	02SH03	02SH05
Total % Cover			88	69	60	107	90
Species							
cryptantha watsonii, watson's catseye	5	0.01	0.01	0.01	0.02	0.01	0.01
cymopterus acaulis, plains springparsley	1	0.01	0	0.01	0	0	0
cymopterus sp., cymopterus	1	0.01	0	0	0	0	0.01
delphinium sp., larkspur	2	0.01	0.01	0.01	0	0	0
descurainia sophia, herb sophia	*4*	*0.01*	*0.01*	*0.01*	*0*	*0.01*	*0.01*
eriogonum sp., eriogonum	2	0.01	0	0	0	0.01	0.01
eriogonum umbellatum, sulphur wildbuckwheat	1	0.01	0	0.01	0	0	0
forb unknown sv 16 ("whorled lvs white stem" 02sh05)	1	0.01	0	0	0	0	0.01
forb unknown sv11 ("broadleaf" 02sh02)	1	0.01	0	0.01	0	0	0
forb unknown sv12 ("oblanc green lf forb" 02sh03)	1	0.01	0	0	0	0.01	0
forb unknown sv13 ("primrose w/ leathery achenes" 02sh04)	1	0.02	0	0	0.02	0	0
forb unknown sv14 ("asteraceae" 02sh04)	1	0.02	0	0	0.02	0	0
forb unknown sv15 ("bright green slick leaves" 02sh05)	1	0.01	0	0	0	0	0.01
forb unknown sv17 ("low lobed apiaceae" 02sh05)	1	0.01	0	0	0	0	0.01
gayophytum ramosissimum, pinyon groundsmoke	4	0.02	0.03	0.01	0.02	0.01	0
heterotheca villosa, hairy goldenaster	2	0.01	0	0	0	0.01	0.01
lappula occidentalis var. occidentalis, flatspine stickseed	1	0.01	0	0.01	0	0	0
lesquerella ludoviciana, foothill bladderpod	1	0.01	0	0.01	0	0	0
lesquerella, bladderpod	2	0.01	0	0	0	0.01	0.01
lupinus argenteus, silvery lupine	2	0.01	0.01	0	0.02	0	0
lygodesmia juncea, rush skeletonplant	2	0.01	0.01	0.01	0	0	0
machaeranthera canescens, hoary aster	1	0.01	0.01	0	0	0	0
mentzelia dispersa, bushy blazingstar	2	0.01	0	0	0.02	0.01	0
oenothera pallida, pale eveningprimrose	4	0.01	0.01	0.01	0	0.01	0.01
polygonum sawatchense, knotweed	2	0.01	0.01	0.01	0	0	0
polygonum sp., knotweed	1	0.02	0	0	0.02	0	0
rumex venosus, veiny dock	2	0.01	0.01	0	0	0.01	0
trifolium gymnocarpon, hollyleaf clover	1	0.02	0	0	0.02	0	0

Table 25. Plot table for group 6-24 from the cluster analysis classification of all 27 plots based on canopy cover.
Table shows total canopy cover of all plants per plot and, for each species, relative canopy cover, number of plots of occurrence, and average cover in plots of occurrence.

Plot			02SH08	02SH09	02SH10	02SH11
Total & Cover			69	105	79	78
Species	Fre-quency	Ave. Cover				
2. Shrub						
amelanchier, serviceberry	3	0.01	0	0.01	0.01	0.01
artemisia cana, silver sagebrush	3	0.03	0.01	0.03	0.04	0
artemisia tridentata ssp. tridentata, basin big sagebrush	4	0.11	0.01	0.38	0.04	0.01
chrysothamnus viscidiflorus ssp. viscidiflorus, yellow rabbitbrush	4	0.04	0.04	0.03	0.04	0.04
ericameria nauseosa, rubber rabbitbrush	4	0.02	0.04	0.01	0.01	0.01
prunus virginiana, common chokecherry	2	0.07	0.01	0	0	0.13
purshia tridentata, antelope bitterbrush	4	0.10	0.04	0.10	0.25	0.01
rosa woodsii, woods' rose	4	0.03	0.04	0.01	0.01	0.04
symphoricarpos oreophilus, whortleleaf snowberry	4	0.11	0.14	0.03	0.01	0.26
tetradymia canescens, spineless horsebrush	2	0.01	0	0.01	0.01	0
3. Subshrub						
artemisia dracunculus, wormwood	3	0.01	0.01	0	0.01	0.01
leptodactylon pungens, granite pricklygilia	1	0.01	0.01	0	0	0
mahonia repens, oregongrape	2	0.03	0	0.03	0.04	0
opuntia polyacantha, plains pricklypear	2	0.01	0.01	0.01	0	0
5. Graminoid						
achnatherum hymenoides, indian ricegrass	4	0.01	0.01	0.01	0.01	0.01
bromus sp., brome	1	0.01	0	0.01	0	0
carex sp., sedge	3	0.01	0.01	0	0.01	0.01
elymus lanceolatus ssp. lanceolatus, thickspike wheatgrass	2	0.01	0	0.01	0	0.01
elymus sp., wildrye	1	0.01	0	0	0.01	0
hesperostipa comata, needle and thread	4	0.10	0.04	0.10	0.13	0.13
juncus balticus var. montanus	1	0.01	0.01	0	0	0
koeleria macrantha, prairie junegrass	2	0.01	0.01	0	0.01	0
leucopoa kingii, spike fescue	1	0.01	0.01	0	0	0
muhlenbergia pungens, sandhill muhly	2	0.02	0.01	0.03	0	0
poa fendleriana, muttongrass	2	0.01	0	0.01	0	0.01
poa pratensis, kentucky bluegrass	1	0.01	0.01	0	0	0
poa secunda, sandberg bluegrass	3	0.02	0.04	0.01	0.01	0
vulpia octoflora, sixweeks fescue	1	0.01	0.01	0	0	0

Table 25 (continued).

Plot			02SH08	02SH11	02SH09	02SH10
Total % Cover			69	78	105	79
Species	Fre-quency	Ave. Cover				
6. Forb						
agoseris glauca, pale agoseris	3	0.01	0	0.01	0.01	0.01
alyssum desertorum, desert madwort	3	0.01	0.01	0.01	0	0.01
arabis holboellii, holboell's rockcress	2	0.01	0	0	0.01	0.01
chenopodium sp., goosefoot	4	0.01	0.01	0.01	0.01	0.01
collinsia parviflora, smallflower blue eyed mary	1	0.01	0.01	0	0	0
comandra umbellata ssp. pallida, common toadflax	4	0.02	0.01	0.01	0.01	0.04
crepis acuminata, longleaf hawksbeard	2	0.02	0.01	0	0.03	0
cryptantha cinerea, james' catseye	1	0.01	0.01	0	0	0
cryptantha watsonii, watson's catseye	3	0.01	0.01	0.01	0	0.01
cymopterus acaulis, plains springparsley	1	0.01	0.01	0	0	0
delphinium nuttallianum, nuttal's larkspur	1	0.01	0.01	0	0	0
delphinium sp., larkspur	3	0.01	0	0.01	0.01	0.01
descurainia sophia, herb sophia	2	0.01	0	0.01	0	0.01
eriogonum umbellatum, sulphur wildbuckwheat	4	0.01	0.01	0.01	0.01	0.01
erysimum capitatum var. capitatum, sanddune wallflower	4	0.01	0.01	0.01	0.01	0.01
forb unknown 23 ("pasque flower" 02sh08)	1	0.01	0.01	0	0	0
forb unknown sv20 ("one leaf" 02sh08)	1	0.01	0.01	0	0	0
forb unknown sv21 ("long horn" 02sh08)	1	0.01	0.01	0	0	0
forb unknown sv22 ("white sticky normal" 02sh08)	1	0.01	0.01	0	0	0
forb unknown sv24 ("white fuzzy herb" 02sh09)	1	0.01	0	0	0.01	0
forb unknown sv25 ("not evening prim (ast)" 02sh10)	1	0.01	0	0	0	0.01
forb unknown sv26 ("small hairy herb" 02sh11)	1	0.01	0	0.01	0	0
forb unknown sv27 ("wide toothed plant" 02sh11)	1	0.01	0	0.01	0	0
gayophytum ramosissimum, pinyon groundsmoke	2	0.01	0	0.01	0.01	0
heterotheca sp., telegraphplant	3	0.02	0.04	0.01	0	0.01
lappula occidentalis var. occidentalis, flatspine stickseed	2	0.01	0	0.01	0	0.01
lesquerella ludoviciana, foothill bladderpod	1	0.01	0.01	0	0	0
lesquerella, bladderpod	3	0.01	0	0.01	0.01	0.01
lithospermum incisum, narrowleaf gromwell	1	0.01	0	0	0.01	0
lithospermum ruderale, western gromwell	2	0.01	0.01	0	0	0.01
lomatium simplex, narrowleaf lomatium	2	0.01	0.01	0	0	0.01
lupinus argenteus, silvery lupine	2	0.01	0	0.01	0	0.01
lupinus sp., lupine	2	0.01	0.01	0	0.01	0
machaeranthera canescens, hoary aster	4	0.01	0.01	0.01	0.01	0.01
mentzelia albicaulis, whitestem blazingstar	1	0.01	0	0.01	0	0
mertensia lanceolata, lanceleaf bluebells	3	0.03	0	0.04	0.03	0.01

Table 25 (continued).

Plot			02SH08	02SH11	02SH09	02SH10
Total % Cover			69	78	105	79
Species	Fre-quency	Ave. Cover				
oenothera pallida, pale eveningprimrose	1	0.01	0	0	0	0.01
penstemon strictus, rocky mountain penstemon	1	0.01	0	0	0	0.01
phacelia sericea, silky phacelia	3	0.01	0.01	0	0.01	0.01
polygonum douglasii, douglas' knotweed	2	0.01	0	0.01	0	0.01
polygonum sp., knotweed	1	0.01	0.01	0	0	0
rumex venosus, veiny dock	1	0.01	0.01	0	0	0
tragopogon dubius, yellow salsify	3	0.01	0.01	0.01	0	0.01

Table 26. Plot table for group 6-13 from the cluster analysis classification of all 27 plots based on canopy cover.
Table shows total canopy cover of all plants per plot and, for each species, relative canopy cover, number of plots of occurrence, and average cover in plots of occurrence.

Plot			02QS01	02QS03	02SH06	02SH07
Total % Cover			36	44	47	47
Species	# of Plots	Ave. Cover				
2. Shrub						
artemisia cana, silver sagebrush	2	0.06	0	0	0.06	0.06
artemisia tridentata ssp. wyomingensis, wyoming big sagebrush	2	0.03	0.03	0.02	0	0
atriplex sp., saltbush	1	0.03	0.03	0	0	0
chrysothamnus viscidiflorus ssp. viscidiflorus, yellow rabbitbrush	4	0.18	0.28	0.23	0.21	0.02
ericameria nauseosa, rubber rabbitbrush	2	0.05	0.03	0.07	0	0
purshia tridentata, antelope bitterbrush	2	0.06	0	0	0.06	0.06
sarcobatus vermiculatus, greasewood	1	0.03	0.03	0	0	0
tetradymia canescens, spineless horsebrush	2	0.12	0.03	0	0	0.21
3. Subshrub						
artemisia dracunculus, wormwood	1	0.07	0	0.07	0	0
artemisia frigida, fringed sagewort	2	0.03	0.03	0.02	0	0
eriogonum ovalifolium, cushion buckwheat	3	0.02	0.03	0.02	0	0.02
leptodactylon pungens, granite pricklygilia	3	0.02	0	0.02	0.02	0.02
opuntia polyacantha, plains pricklypear	1	0.03	0.03	0	0	0
5. Graminoid						
achnatherum hymenoides, indian ricegrass	4	0.06	0.08	0.07	0.06	0.02
danthonia intermedia, timber oatgrass	2	0.07	0.08	0	0.06	0
elymus lanceolatus ssp. lanceolatus, thickspike wheatgrass	2	0.06	0	0	0.06	0.06
elymus sp., wildrye	1	0.02	0	0.02	0	0
hesperostipa comata, needle and thread	4	0.03	0.03	0.02	0.02	0.06
koeleria macrantha, prairie junegrass	2	0.04	0	0	0.02	0.06
muhlenbergia pungens, sandhill muhly	2	0.13	0.03	0.23	0	0
poa secunda, sandberg bluegrass	2	0.02	0.03	0	0	0.02
vulpia octoflora, sixweeks fescue	2	0.02	0	0	0.02	0.02
6. Forb						
alyssum desertorum, desert madwort	*2*	*0.04*	*0*	*0*	*0.06*	*0.02*
arabis cobrensis, sagebrush rockcress	1	0.03	0.03	0	0	0
chaenactis douglasii var. douglasii	4	0.02	0.03	0.02	0.02	0.02
chenopodium sp., goosefoot	2	0.02	0	0	0.02	0.02
cryptantha cinerea, james' catseye	1	0.02	0	0	0	0.02
cryptantha circumscissa, cushion catseye	1	0.02	0	0	0.02	0
cryptantha flava, brenda's yellow catseye	3	0.02	0.03	0.02	0.02	0
cryptantha sp., cryptantha	2	0.02	0	0	0.02	0.02
cryptantha torreyana, torrey's cryptantha	1	0.02	0	0	0.02	0

Table 26 (continued).

Plot			02QS01	02QS03	02SH06	02SH07
Total % Cover			36	44	47	47
Species	# of Plots	Ave. Cover				
cymopterus sp., cymopterus	1	0.02	0	0	0	0.02
descurainia sp., tansymustard	2	0.02	0	0	0.02	0.02
eriogonum sp., eriogonum	2	0.02	0	0	0.02	0.02
forb unknown sv18 ("big stipule, bright green" 02sh07)	1	0.02	0	0	0	0.02
forb unknown sv19 ("dwarf small white herb" 02sh07)	1	0.02	0	0	0	0.02
heterotheca villosa, hairy goldenaster	2	0.02	0	0	0.02	0.02
hymenopappus filifolius, fineleaf hymenopappus	1	0.03	0.03	0	0	0
kochia americana, greenmolly	1	0.03	0.03	0	0	0
lappula occidentalis var. occidentalis, flatspine stickseed	1	0.02	0	0	0.02	0
lesquerella ludoviciana, foothill bladderpod	1	0.02	0	0	0.02	0
lesquerella, bladderpod	2	0.02	0.03	0	0	0.02
lithospermum incisum, narrowleaf gromwell	1	0.02	0	0	0.02	0
lupinus sericeus, silky lupine	1	0.02	0	0	0	0.02
lupinus sp., lupine	1	0.02	0	0	0.02	0
lygodesmia juncea, rush skeletonplant	1	0.02	0	0.02	0	0
machaeranthera canescens, hoary aster	4	0.02	0.03	0.02	0.02	0.02
malacothrix torreyi, torrey's desertdandelion	1	0.02	0	0.02	0	0
oenothera pallida, pale eveningprimrose	2	0.03	0.03	0.02	0	0
penstemon strictus, rocky mountain penstemon	1	0.02	0	0	0	0.02
psoralidium lanceolatum, lemon scurfpea	2	0.03	0.03	0.02	0	0
schoenocrambe linifolia, flaxleaf plainsmustard	1	0.02	0	0.02	0	0
thermopsis, thermopsis	1	0.02	0	0	0	0.02
tiquilia nuttallii, nuttall's coldenia	1	0.02	0	0.02	0	0
tragopogon dubius, yellow salsify	1	0.02	0	0	0.02	0

Table 27. Plot table for group 6-1 from the cluster analysis classification of all 27 plots based on canopy cover.
Table shows total canopy cover of all plants per plot and, for each species, relative canopy cover, number of plots of occurrence, and average cover in plots of occurrence.

Plot			02AK01	02AK03	02DS01	02DS02	02DS03	02DS04
Total % Cover	# of plots	Ave. Cover	38	38	40	58	37	28
Species								
2. Shrub								
artemisia tridentata ssp. wyomingensis, wyoming big sagebrush	6	0.39	0.26	0.26	0.25	0.69	0.54	0.36
atriplex sp., saltbush	1	0.05	0	0	0	0.05	0	0
chrysothamnus viscidiflorus ssp. viscidiflorus, yellow rabbitbrush	5	0.05	0.03	0.08	0.03	0.02	0	0.11
ericameria nauseosa, rubber rabbitbrush	4	0.03	0.03	0.03	0.03	0	0	0.04
sarcobatus vermiculatus, greasewood	5	0.02	0.03	0.03	0.03	0.02	0.03	0
tetradymia canescens, spineless horsebrush	3	0.03	0.03	0.03	0.03	0	0	0
3. Subshrub								
eriogonum ovalifolium, cushion buckwheat	4	0.03	0	0	0.03	0.02	0.03	0.04
krascheninnikovia lanata, winterfat	5	0.04	0	0.03	0.03	0.02	0.08	0.04
leptodactylon pungens, granite pricklygilia	1	0.03	0	0	0.03	0	0	0
opuntia polyacantha, plains pricklypear	6	0.03	0.03	0.03	0.03	0.02	0.03	0.04
5. Graminoid								
achnatherum hymenoides, indian ricegrass	6	0.09	0.03	0.08	0.25	0.05	0.08	0.04
agropyron desertorum, desert wheatgrass	*1*	*0.02*	*0*	*0*	*0*	*0.02*	*0*	*0*
elymus elymoides, bottlebrush squirreltail	1	0.08	0	0	0	0	0.08	0
elymus lanceolatus ssp. lanceolatus, thickspike wheatgrass	2	0.04	0.03	0	0	0.05	0	0
elymus smithii, western wheatgrass	2	0.03	0	0	0.03	0	0.03	0
elymus sp., wildrye	1	0.11	0	0	0	0	0	0.11
grass unknown sv1 ("clump grass")	1	0.11	0	0	0	0	0	0.11
grass unknown sv2 ("curlend grass")	1	0.04	0	0	0	0	0	0.04
grass unknown sv3 (orsopsis)	1	0.03	0	0	0	0	0.03	0
grass unknown sv4 (silky awn)	1	0.03	0	0	0	0	0.03	0
hesperostipa comata, needle and thread	2	0.39	0.53	0.26	0	0	0	0
poa secunda, sandberg bluegrass	2	0.05	0	0	0.08	0.02	0	0

Table 27 (continued).

Plot			02AK01	02AK03	02DS01	02DS02	02DS03	02DS04
Total % Cover	# of plots	Ave. Cover	38	38	40	58	37	28
Species								
6. Forb								
arabis holboellii, holboell's rockcress	1	0.03	0	0	0.03	0	0	0
astragalus convallarius, timber milkvetch	1	0.03	0	0.03	0	0	0	0
astragalus sp., milkvetch	1	0.04	0	0	0	0	0	0.04
astragalus spatulatus, tufted milkvetch	1	0.03	0	0	0.03	0	0	0
cryptantha sp., cryptantha	1	0.02	0	0	0	0.02	0	0
eriogonum cernuum, nodding buckwheat	1	0.03	0	0.03	0	0	0	0
eriogonum sp., eriogonum	1	0.03	0	0.03	0	0	0	0
erysimum capitatum var. capitatum, sanddune wallflower	1	0.03	0	0	0.03	0	0	0
erysimum sp., wallflower	1	0.03	0	0.03	0	0	0	0
forb unknown sv1 ("dead furry")	1	0.03	0.03	0	0	0	0	0
forb unknown sv6 (green spike forb0	1	0.02	0	0	0	0.02	0	0
forb unknown sv7 ("hookers sand wort"}	1	0.04	0	0	0	0	0	0.04
machaeranthera canescens, hoary aster	3	0.03	0	0.03	0.03	0	0.03	0
oxytropis sp., crazyweed	1	0.03	0	0	0.03	0	0	0
penstemon sp., penstemon	1	0.03	0	0	0.03	0	0	0
phlox hoodii, hoods phlox	2	0.03	0	0.03	0	0	0	0.04
phlox muscoides, musk phlox	2	0.03	0	0	0.03	0	0.03	0
psoralidium lanceolatum, lemon scurfpea	1	0.03	0	0	0.03	0	0	0
schoenocrambe linifolia, flaxleaf plainsmustard	1	0.03	0	0.03	0	0	0	0

Table 28. Plot table for group 6-5 from the cluster analysis classification of all 27 plots based on canopy cover.
Table shows total canopy cover of all plants per plot and, for each species, relative canopy cover, number of plots of occurrence, and average cover in plots of occurrence.

Plot			02BF01	02BF03	02BF02	02BF04
Total % Cover	# of plots	Ave. Cover	42	29	23	25
Species						
2. Shrub						
artemisia tridentata ssp. wyomingensis, wyoming big sagebrush	4	0.11	0.07	0.10	0.13	0.12
atriplex confertifolia, shadscale saltbush	2	0.04	0	0.03	0.04	0
atriplex sp., saltbush	1	0.04	0	0	0	0.04
chrysothamnus viscidiflorus ssp. viscidiflorus, yellow rabbitbrush	4	0.09	0.07	0.10	0.13	0.04
ericameria nauseosa, rubber rabbitbrush	3	0.03	0.02	0.03	0.04	0
grayia spinosa, spiny hopsage	4	0.05	0.07	0.03	0.04	0.04
sarcobatus vermiculatus, greasewood	3	0.05	0.07	0	0.04	0.04
tetradymia canescens, spineless horsebrush	2	0.05	0.07	0.03	0	0
3. Subshrub						
atriplex gardneri, gardner's saltbush	2	0.08	0	0.03	0	0.12
leptodactylon pungens, granite pricklygilia	1	0.03	0	0.03	0	0
opuntia polyacantha, plains pricklypear	4	0.04	0.02	0.03	0.04	0.04
5. Graminoid						
achnatherum hymenoides, indian ricegrass	4	0.06	0.07	0.10	0.04	0.04
elymus elymoides, bottlebrush squirreltail	4	0.04	0.02	0.03	0.04	0.04
elymus smithii, western wheatgrass	1	0.13	0	0	0.13	0
elymus sp., wildrye	2	0.03	0.02	0	0	0.04
hesperostipa comata, needle and thread	4	0.05	0.02	0.10	0.04	0.04
6. Forb						
arabis holboellii, holboell's rockcress	2	0.03	0.02	0.03	0	0
astragalus convallarius, timber milkvetch	3	0.04	0	0.03	0.04	0.04
astragalus geyeri, geyer's milkvetch	3	0.03	0.02	0.03	0	0.04
chaenactis douglasii var. douglasii	2	0.03	0.02	0.03	0	0
chenopodium sp., goosefoot	2	0.03	0.02	0	0	0.04
cleome lutea, yellow spiderflower	2	0.06	0.07	0	0	0.04
cryptantha kelseyana, kelsey's catseye	1	0.02	0.02	0	0	0
descurainia sp., tansymustard	1	0.03	0	0.03	0	0
erigeron compositus, cutleaf daisy	1	0.04	0	0	0	0.04
eriogonum cernuum, nodding buckwheat	1	0.04	0	0	0.04	0
forb unknown sv1 ("menzelia")	1	0.02	0.02	0	0	0
forb unknown sv2 ("velvet ovate")	1	0.02	0.02	0	0	0
forb unknown sv3 ("toothed")	1	0.02	0.02	0	0	0
forb unknown sv5 ("hawaiin forb"}	1	0.04	0	0	0.04	0
gilia leptomeria, sand gilia	2	0.03	0.02	0	0	0.04

Table 28 (continued).

Plot			02BF01	02BF03	02BF02	02BF04
Total % Cover	# of plots	Ave. Cover	42	29	23	25
Species						
halogeton glomeratus, halogeton	*1*	*0.04*	*0*	*0*	*0*	*0.04*
kochia americana, greenmolly	3	0.07	0	0.03	0.13	0.04
lupinus pusillus, rusty lupine	3	0.03	0.02	0.03	0	0.04
nama densum, leafy nama	1	0.02	0.02	0	0	0
oenothera pallida, pale eveningprimrose	1	0.02	0.02	0	0	0
phacelia ivesiana, ives' phacelia	1	0.02	0.02	0	0	0
rumex venosus, veiny dock	2	0.03	0.02	0.03	0	0
salsola tragus, prickly Russian thistle	*2*	*0.03*	*0.02*	*0*	*0*	*0.04*
schoenocrambe linifolia, flaxleaf plainsmustard	2	0.03	0.02	0.03	0	0

Table 29. Plot table for group 6-2 from the cluster analysis classification of all 27 plots based on canopy cover.
Table shows total canopy cover of all plants per plot and, for each species, relative canopy cover, number of plots of occurrence, and average cover in plots of occurrence.

Plot			02AK02	02QS04	02AK04	02QS02
Total % Cover	# of plots	Ave. Cover	15	14	14	32
Species						
2. Shrub						
artemisia tridentata ssp. tridentata, basin big sagebrush	1	0.20	0.20	0	0	0
artemisia tridentata ssp. wyomingensis, wyoming big sagebrush	3	0.11	0	0.07	0.21	0.03
atriplex sp., saltbush	4	0.11	0.07	0.21	0.07	0.09
chrysothamnus viscidiflorus ssp. viscidiflorus, yellow rabbitbrush	1	0.07	0	0	0.07	0
ericameria nauseosa, rubber rabbitbrush	2	0.05	0.07	0	0	0.03
sarcobatus vermiculatus, greasewood	3	0.06	0.07	0	0.07	0.03
3. Subshrub						
artemisia frigida, fringed sagewort	1	0.03	0	0	0	0.03
eriogonum ovalifolium, cushion buckwheat	1	0.03	0	0	0	0.03
opuntia polyacantha, plains pricklypear	4	0.06	0.07	0.07	0.07	0.03
5. Graminoid						
achnatherum hymenoides, indian ricegrass	2	0.05	0	0	0.07	0.03
agropyron desertorum, desert wheatgrass	1	0.07	0	0.07	0	0
distichlis spicata, inland saltgrass	1	0.07	0.07	0	0	0
elymus elymoides, bottlebrush squirreltail	2	0.05	0	0	0.07	0.03
elymus lanceolatus ssp. lanceolatus, thickspike wheatgrass	3	0.20	0.07	0	0.21	0.31
elymus smithii, western wheatgrass	1	0.07	0.07	0	0	0
grass unknown sv1 ("clump grass")	1	0.07	0.07	0	0	0
grass unknown sv2 ("curlend grass")	2	0.05	0.07	0	0	0.03
grass unknown sv5 ("sandberg bluegrass" 02qs02)	1	0.03	0	0	0	0.03
hesperostipa comata, needle and thread	2	0.05	0	0	0.07	0.03
poa secunda, sandberg bluegrass	1	0.07	0	0	0.07	0
sporobolus cryptandrus, sand dropseed	1	0.07	0	0.07	0	0
6. Forb						
cryptantha caespitosa, tufted catseye	1	0.03	0	0	0	0.03
cryptantha sp., cryptantha	1	0.03	0	0	0	0.03
forb unknown sv 8 ("mean needle forb")	1	0.03	0	0	0	0.03
forb unknown sv 9 ("pitch green forb" 02qs02)	1	0.03	0	0	0	0.03
forb unknown sv10 ("phlox a" 02qs02)	2	0.05	0	0.07	0	0.03
halogeton glomeratus, halogeton	1	0.07	0	0.07	0	0
kochia americana, greenmolly	3	0.10	0.07	0.21	0	0.03
lesquerella, bladderpod	1	0.03	0	0	0	0.03
machaeranthera canescens, hoary aster	1	0.07	0.07	0	0	0
monolepis nuttalliana, nuttall's povertyweed	1	0.07	0	0.07	0	0
sphaeralcea coccinea, scarlet globemallow	3	0.06	0.07	0.07	0	0.03

Table 30. Relationship of the plot groups from the classification of all 27 plots based on canopy cover to units in the national vegetation classification
(NatureServe 2003).

Plot Group		Related National Classification Units
6-1	Moderately dense vegetation. *Artemisia tridentata* ssp. *wyomingensis* dominates the shrub stratum; *Achnatherum hymenoides* and *Hesperostipa comata* dominate the herbaceous undergrowth. (Table 27)	Plant alliance: *Artemisia tridentata* ssp. *wyomingensis* Shrubland Alliance. Plant association: Unknown.
6-5	Moderately dense vegetation. *Artemisia tridentata* ssp. *wyomingensis* co-dominates the shrub stratum with various other shrubs; *Achnatherum hymenoides*, *Elymus elymoides*, *Hesperostipa comata*, *Opuntia polyacantha* are present in the undergrowth, *Achnatherum* and *Hesperostipa* dominate in most plots. (Table 28)	Plant alliance: *Artemisia tridentata* ssp. *wyomingensis* Shrubland Alliance. Plant association: Unknown.
6-2	Sparse vegetation. Mix of plots in which *Artemisia tridentata* spp. *tridentata*, *Elymus lanceolatus* ssp. *lanceolatus*, and *Kochia americana* may dominate or co-dominate; *Atriplex* sp. (saltbush) and *Opuntia polyacantha* are present. (Table 29)	Plant Alliance: *Elymus lanceolatus* Herbaceous Alliance? Plant Association: Unknown
6-13	Moderately dense vegetation. *Chrysothamnus viscidiflorus* ssp. *viscidiflorus* or by *Tetradymia canescens* dominate the shrub stratum; *Achnatherum hymenoides*, *Muhlenbergia pungens*. *Danthonia intermedia*, *Elymus lanceolatus* spp. *lanceolatus*, *Alyssum desertorum* may contribute substantial cover and *Hesperostipa comata* is present. (Table 26)	Plant Alliance: *Chrysothamnus viscidiflorus* Shrub Herbaceous Alliance (some plots)? Plant Association: Unknown
6-17	Dense vegetation. *Artemisia cana* spp. *cana* and *Purshia tridentata* usually co-dominate the shrub stratum and *Chrysothamnus viscidiflorus* ssp. *viscidiflorus* is present; *Hesperostipa comata*, *Opuntia polyacantha*, *Achnatherum hymenoides*, *Chenopodium* sp., *Cryptantha watsonii* occur regularly in the herbaceous stratum, where *Hesperostipa* comata and *Muhlenbergia pungens* often dominate. (Table 24)	Plant Alliance: *Artemisia cana* Shrubland Alliance? Plant Association: Unknown
6-24	Dense vegetation. *Symphoricarpos oreophilus, Artemisia tridentata* spp. *tridentata*, *Purshia tridentata*, *Chrysothamnus viscidiflorus* spp. *viscidiflorus*, *Ericameria nauseosa*, *Rosa woodsii*, and *Prunus virginiana* may contribute substantial cover to the shrub stratum, and *Amelanchier* sp. and *Artemisia cana* ssp. *cana* often are present; *Hesperostipa comata* contributes substantial cover to the herbaceous stratum and a number of graminoids and forbs are present in small amounts, especially *Achnatherum hymenoides*, *Chenopodium* sp., *Comandra umbellata* ssp. *pallida*, *Eriogonum umbellatum*, *Erysimum capitatum* spp. *capitatum*, *Machaeranthera canescens.* (Table 25)	Plant Alliance: *Artemisia tridentata* ssp. *tridentata* Shrubland Alliance? Plant Association: Unknown

APPENDIX 1. SUMMARIES OF INFORMATION FROM VEGETATION SAMPLING PLOTS

The plot summaries are in a separate digital file, "BLM_SandVeg_Appen1_PlotSummaries.doc"

APPENDIX 2. PHOTOGRAPHS FROM THE SAND VEGETATION PROJECT SAMPLING PLOTS

The photographs are in a separate digital file, "BLM_SandVeg_Appen2_Photos.doc"