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# Field-Based Evaluation of Two Herbaceous Plant Community Sampling Methods for Long-Term Monitoring in Northern Great Plains National Parks

By Amy J. Symstad, Cody L. Wienk, and Andy Thorstenson

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# Field-Based Evaluation of Two Herbaceous Plant Community Composition Sampling Methods for Long-Term Monitoring in Northern Great Plains National Parks

By Amy J. Symstad[1], Cody L. Wienk[2], and Andy Thorstenson[2]

## Introduction

The Northern Great Plains Inventory & Monitoring (I&M) Network (Network) of the National Park Service (NPS) consists of 13 NPS units in North Dakota, South Dakota, Nebraska, and eastern Wyoming. The Network is in the planning phase of a long-term program to monitor the health of park ecosystems. Plant community composition is one of the "Vital Signs", or indicators, that will be monitored as part of this program for three main reasons. First, plant community composition is information-rich; a single sampling protocol can provide information on the diversity of native and non-native species, the abundance of individual dominant species, and the abundance of groups of plants. Second, plant community composition is of specific management concern. The abundance and diversity of exotic plants, both absolute and relative to native species, is one of the greatest management concerns in almost all Network parks (Symstad 2004). Finally, plant community composition reflects the effects of a variety of current or anticipated stressors on ecosystem health in the Network parks including invasive exotic plants, large ungulate grazing, lack of fire in a fire-adapted system, chemical exotic plant control, nitrogen deposition, increased atmospheric carbon dioxide concentrations, and climate change.

Before the Network begins its Vital Signs monitoring, a detailed plan describing specific protocols used for each of the Vital Signs must go through rigorous development and review. The pilot study on which we report here is one of the components of this protocol development. The goal of the work we report on here was to determine a specific method to use for monitoring plant community composition of the herb layer (< 2 m tall).

### Vegetation in Northern Great Plains Parks

The herb-layer vegetation in the Network parks in which plant community composition will be monitored is largely graminoid-dominated, even in areas characterized as shrublands by the National Vegetation Classification System. One exception to this generalization is the vegetation of black-tailed prairie dog (*Cynomys ludovicianus*) towns, where forb cover is often greater than graminoid cover. In all vegetation types, however, graminoids constitute a major portion of the cover. Because of the generally dry conditions in this region (average annual precipitation is

[1] U.S. Geological Survey, Northern Prairie Wildlife Research Center, Black Hills Station
[2] National Park Service, Northern Great Plains Fire Management Office, Wind Cave National Park

around 38 cm in most parks, but up to 51 cm in the Black Hills parks), herb-layer vegetation is rarely over 1 m tall and is often much shorter (<15 cm), particularly in areas where black-tailed prairie dogs occur. Total herb-layer cover ranges considerably, with values generally being lowest in badlands and under dense pine forest canopy (35-75%) and highest in riparian zones (80-200%). In most cases, just one or two species will comprise 50% of the total cover, and the median species cover for a typical site (0.1 ha) is less than 1%. These characteristics influence the type of sampling that is appropriate for long-term monitoring in these parks.

## Potential Methods for Sampling Plant Community Composition

In 1959, Daubenmire lamented the lack of standardization of methods used in vegetation sampling and analysis (Daubenmire 1959). Not much has changed in the intervening years, despite the fact that many investigators have adopted Daubenmire's described methodology. The main reason for this is because the most appropriate method for measuring the relative abundance of species in a plant community depends on the objective of the project for which the measurements are done, as well as on the type of vegetation being measured. The advantages and disadvantages of each method must be weighed carefully when deciding on which method will be used. This is especially important when designing a long-term monitoring program because there is a great cost, in terms of continuity of data, to changing methods midstream. Also, in contrast to measuring plant community composition between experimental treatments, where large differences are often expected between the experimental treatments, long-term monitoring must be sensitive to relatively subtle changes over time – time in which the people doing the measurements will change. Thus, a method must have high repeatability among observers. In addition, the method must be efficient enough that a useful amount of data can be collected in a reasonable time, allowing for adequate sample sizes. Finally, because the data provided by this monitoring will be used by park staff to make resource management decisions, the data must be relevant to those decisions and relatively easy to comprehend. Using these guidelines, we evaluated the advantages and disadvantages of the four main ways of measuring the abundance of all species within a plant community. This evaluation was influenced by a desire to have the resulting methodology compatible with other long-term vegetation monitoring programs.

The four main methods of measuring the abundance of all species in a plant community are clipping and sorting biomass, counting stems, calculating frequency of occurrence, and estimating cover. We eliminated the first three of these methods from consideration for this program after weighing the advantages and disadvantages of all four methods.

The first method, clipping and sorting of biomass, is a preferred method for sampling plant community composition in some circumstances because it reflects the size and abundance of individual species. It also represents, to some degree, the amount of energy captured by individual species and the plant community as a whole, which is relevant to fire behavior and ecosystem processes such as nutrient cycling and support of other trophic levels. However, this method requires a lot of time to sort clipped samples in the field, and repeated clipping of the same area could affect the values of the variables being monitored. The method also produces a large number of samples that require considerable post-field processing (drying and weighing) before any data are secured. These issues, as well as logistical problems in transporting a large number of samples to sites with adequate drying facilities, make this method untenable for the Network's long-term monitoring program. However, total standing and dead biomass of herbaceous vegetation data may be important for some park resource managers because of their relevance to fire fuel loads and capacity for supporting large ungulates. If we determine, through further discussions with park resource managers, that total herbaceous plant biomass is of sufficient importance, we will develop

a protocol specific to this measurement in the future, possibly by developing biomass-stature relationships.

The second method, counting stems to measure stem density, has the advantage over other methods of directly measuring population size. However, stem density does not necessarily represent the influence that a species or group of species has on other individuals (i.e., competition) or ecosystem processes (e.g., nutrient cycling, energy transfer to other trophic levels) because individuals and species differ considerably in their size. In addition, difficulties in determining what constitutes an individual stem, particularly when dealing with rhizomatous species and a large number of species, makes it likely that counts would be inconsistent among observers. Finally, this is probably the most time-consuming method of measuring plant abundance, and the time spent counting the stems is also time spent trampling the vegetation being sampled. Thus, we eliminated stem density as a possible method for measuring plant community composition.

The third measurement, frequency, has the reputation of being relatively repeatable among observers (Helm and Mead 2004) and can be one of the fastest methods of measuring plant species abundance. It is also relatively conservative, or invariable, with respect to variations in precipitation, an important consideration for the Great Plains, where precipitation varies considerably from year to year. However, in comparison to the other three measurement techniques, plant frequency is complicated by the relationship between the size of the sampling area used and the measurement obtained (Critchley and Poulton 1998). Larger sample areas yield higher frequencies. An optimal sample area for determining differences in frequency is one which yields frequencies between 30 and 70% (Elzinga et al. 1998), and this optimal area will vary among species because of differences in their abundance. Frequency of dominant species is thus measured using smaller sample areas than frequency of rare species. This complication can be somewhat overcome by using nested frequency sampling, in which a variety of sample areas are used at each location. However, the analysis of the data from this type of sampling can also be complicated. In addition, like stem density, frequency does not represent differences in plant species' size. Finally, as a measure of plant abundance, interpreting changes in frequency for management purposes is not as intuitive as with other measures of plant abundance. For these reasons, we eliminated frequency as the primary method of measuring plant abundance for the Network's long-term monitoring program.

The remaining method for measuring plant abundance is to measure cover, and there are two types of cover that can be measured and many different ways to measure them. Basal cover measures the ground-level area occupied by a plant, whereas canopy cover measures the area occupied by a plant above ground level. Canopy cover of herb-layer vegetation may vary considerably within seasons as plants grow and senesce, as well as among seasons due to variations in precipitation and herbivory. Basal cover is generally much more consistent than canopy cover within and among seasons, but only for certain types of plants (bunchgrasses, tussocks and trees). For other types (sod-forming or rhizomatous grasses, single stemmed forbs, etc.), basal cover is quite variable and difficult to measure. Because so many of the species and so much of the cover in the vegetation that the Network will work in are comprised of this latter category of species, we focused our measurements of individual species on canopy cover. However, we did estimate total basal cover (see below).

The three primary methods for measuring cover are line-intercept, point-intercept, and ocular estimates. The line-intercept method is most useful in vegetation with distinct individuals and dense canopy covers; it is not useful for diffuse species, such as rhizomatous grasses (Bonham 1989, Elzinga et al. 1998). Because these species are often dominant in the vegetation that will be monitored for this program, we did not consider using this as our primary method. However, it may be incorporated into the protocol for measuring the abundance of shrubs. The two remaining

methods for measuring cover both have significant advantages and disadvantages. Ocular cover estimates have a reputation for being unrepeatable among observers, though many feel that this can be overcome by adequate training (Elzinga et al. 1998). Ocular estimates capture a larger area, and therefore more species, in each sample compared to point-intercept methods. The point-intercept method is accepted by many as being more repeatable among observers than ocular estimates, but recent tests comparing the two have shown this is not necessarily true (Kercher et al. 2003, Helm and Mead 2004). Also, this method may be more efficient than ocular cover estimates in that less time is needed to adequately capture species composition. In the context of this study, the point-intercept method has the advantage that this is the primary method of the Northern Great Plains Fire Effects monitoring program, which has been monitoring plant community composition in many of the Network's 13 parks since 1997 and with which the Network is planning to integrate its monitoring.

### Study Objectives

Because there is no clear advantage of one of these methods over the other, and to ensure that the optimal method for the vegetation types occurring in Network parks is chosen for long-term monitoring, we conducted a comparison of the two in a variety of vegetation types over the geographic spectrum encompassed by the Network. This comparison focused on herbaceous and small (< 2 m tall) shrub vegetation. (Further work will determine whether methods for measuring larger woody vegetation currently used by the Fire Effects program are adequate.) For this comparison, our specific objectives were:

Across a variety of broad vegetation categories (riparian herbaceous wetland, grassland, prairie dog town, badlands sparse vegetation, ponderosa pine forest/woodland, shrubland, riparian forest, and woody draw),

1. compare point-intercept and ocular estimates of herbaceous and small shrub cover between two observer teams for repeatability;
2. determine the number of subsamples (quadrats in the ocular estimate method or points in the point-intercept method) necessary to adequately measure a small number of important plant community parameters at a site (e.g., native species cover, exotic species cover, and native species richness) using these two methods; and,
3. compare the efficiency of ocular and point-intercept methods of estimating plant cover.

## Methods

### Study Areas

We conducted this study at five NPS units in the Network: Agate Fossil Beds National Monument (AGFO) in northwestern Nebraska, Devils Tower National Monument (DETO) in northeastern Wyoming, Fort Laramie National Historic Site (FOLA) in southeastern Wyoming, Theodore Roosevelt National Park (THRO) in west-central North Dakota, and Wind Cave National Park (WICA) in southwestern South Dakota (Figure 1). We chose these parks because they represent the range of conditions in geography, ecology, and vegetation that occur within the Network.

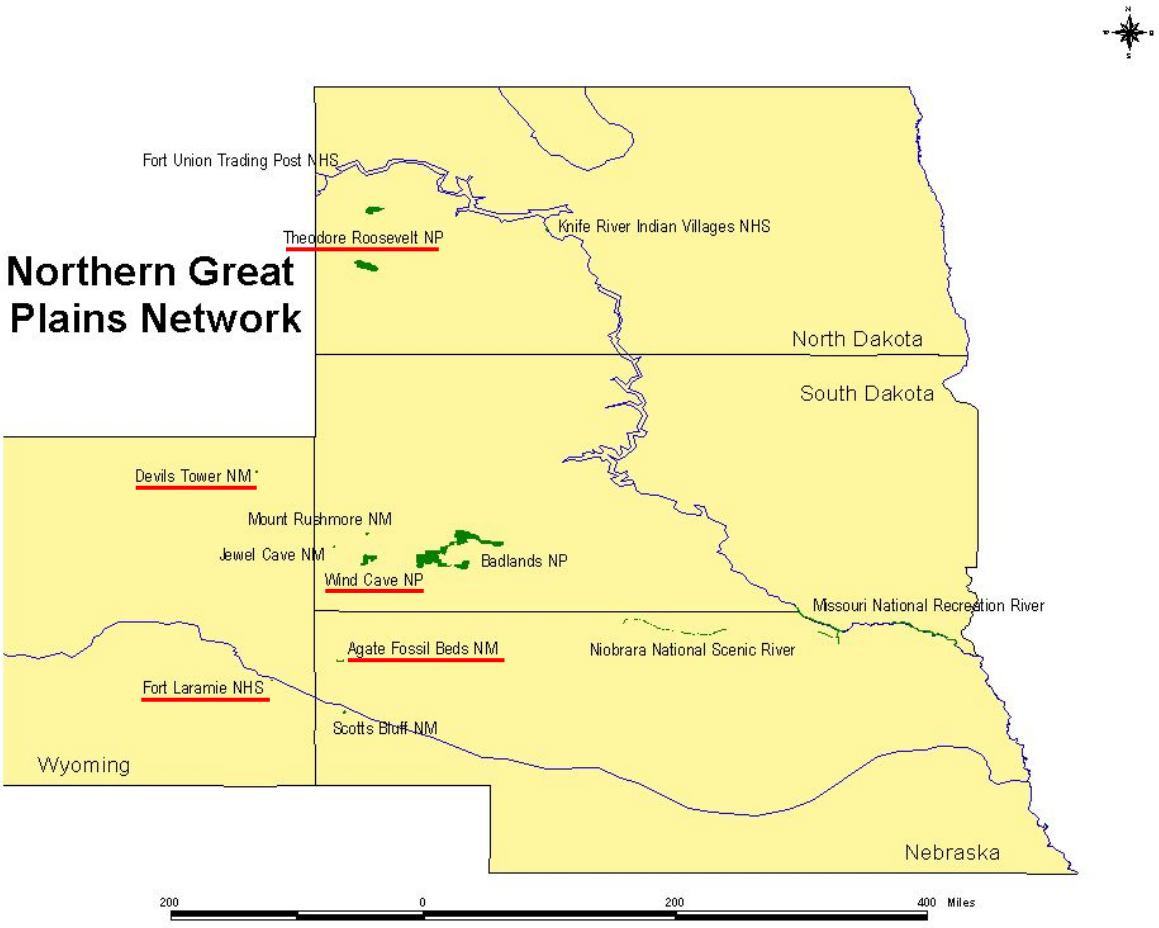


**Figure 1.** Locations of NPS units in the Northern Great Plains I&M Network. The parks used in this study are underlined in red.

## Sample Sites

Because the sampling design for the long-term monitoring has not yet been determined, we could not use sites that will definitely be used in the long term. In addition, differing goals between this pilot study and the long-term monitoring require different sampling designs. Whereas the long-term monitoring sample design must enable us to make inferences across a whole park from the samples, in this study we were determining which sampling method was preferable across the variety of vegetation types that occur in the Network. Thus, for this study we based our sampling design on vegetation classifications. We allocated the total number of samples across vegetation types according to the vegetation's approximate abundance in the Network (Table 1). We chose specific sample sites within each park using a variety of methods based on the size of the park and whether previously existing sample sites meeting our criteria were available. Maps of the final sample sites and plot GPS coordinates for each park are in Appendix A.

**Table 1.** Number of sample locations in each vegetation type for each park.

[Abbreviations for vegetation types used in other tables and figures are in parentheses. Numbers in parentheses indicate the number of sites within each park-vegetation type combination that were double sampled for examining repeatability.]

| Vegetation Type | AGFO | DETO | FOLA | THRO | WICA | Total |
|---|---|---|---|---|---|---|
| Riparian herbaceous wetland (HERBRIP) | 5 (2) | | | | | 5 (2) |
| Grassland (GRASS) | 6 (1) | | 6 (0) | | 4 (0) | 16 (1) |
| Prairie dog town (DOG) | | 1 (0) | | | 2 (1) | 3 (1) |
| Ponderosa pine forest/woodland (PIPO) | | 3 (1) | | | 4 (2) | 7 (3) |
| Shrubland (SHRUB) | | | | 4 (1) | 1 (1) | 5 (2) |
| Woody draw[a] | | | | | 1 (0) | 1 (0) |
| Riparian forest (FORRIP) | | 1 (1) | 1 (0) | 1 (0) | | 3 (1) |
| Badlands/Sparse (BAD) | | | 1 (0)[b] | 5 (1) | | 6 (1) |
| **Total** | 11 (3) | 5 (2) | 8 (0) | 10 (2) | 12 (4) | 46 (11) |

[a]characterized as riparian forest in analyses; [b]cobble river terrace

At AGFO, we sampled two broad vegetation types – upland native prairie and herbaceous riparian vegetation. For prairie sampling sites we simply used six plots previously established by the NPS Prairie Cluster Prototype Long-term Ecological Monitoring program (DeBacker et al. 2004). For herbaceous riparian vegetation (for which no previous sites existed), we randomly selected eight sites within the three herbaceous mapped vegetation classes occurring along the Niobrara River (Aerial Information Systems 1998a). We eliminated three of these sites because they had inappropriate vegetation or because they fell on private land.

At DETO, we randomly selected sites in three broad vegetation types (prairie dog town, ponderosa pine forest/woodland, and riparian forest) based on mapped vegetation classes (Salas and Pucherelli 1998), with the restriction that sites must be more than 20 m from a developed trail, more than 100 m from a road, and with a slope of less than 35% (based on digital elevation models). Our initial pool of sampling sites contained many more points than our desired number because we knew that some sites would be discarded after field checking. Thus, we randomly selected sites for initial field checking. If we rejected a site in the field (for wrong vegetation, too steep of slope, etc.), we field checked the next site on the random list in the desired vegetation type, then repeated this process until we had reached the desired number of sites (Table 1). We used this method for four of the five sites; the fifth site was a plot previously established by the Fire Effects monitoring program using a method identical to that for the other four sites.

At FOLA, we used a GIS to overlay a coarse grid, with random orientation and start, over a map of the park's vegetation classifications (Aerial Information Systems 1998b). Intersections of the lines on the grid constituted the pool of potential sampling sites. The grid size was chosen to yield the approximate number of sites we anticipated being able to monitor over the long term at this park[3]. From this sampling pool of 39 sites, we eliminated those less than 20 m from a

[3] This number is extremely approximate and probably little better than a wild guess. A grid was used because, prior to this study, we were planning on using a systematic sampling design within each park. After further investigation into various sampling designs, we are now leaning towards using a Generalized Random Tessellation Stratified (GRTS) design.

developed trail or less than 100 m from a road. From the remainder, we randomly chose eight sites in three broad vegetation types (riparian, disturbed upland, and native prairie) following our desired allocation shown in Table 1. If, upon field visitation, we determined that a randomly chosen site was unsuitable (i.e., was too close to a road because of mapping errors or was not in the vegetation type expected), we used the next nearest grid point in the appropriate vegetation type.

At THRO, a large park, we restricted our sampling to two focus areas in the South Unit to reduce the amount of time spent traveling to sample sites. In the Burning Coal Vein focus area, which we defined as south of Scenic Loop Drive and within 1.6 km of the road to the Coal Vein trailhead, we sampled badlands sparse vegetation. In the Jones Creek focus area, which we defined as within 1.6 km of the intersection of Jones Creek and Scenic Loop Drive, we sampled shrubland vegetation and riparian forest vegetation. For both of these focus areas, we used the same method of randomly choosing sites based on mapped vegetation classes (Von Loh et al. 2000) and field checking described for DETO, with one exception. In the Jones Creek area, we used one shrubland site previously established by the Fire Effects program.

We also limited the geographic scope of areas for sampling at WICA to reduce travel time. At this park, we limited sampling sites to be within 1.2 km of a road and used mapped vegetation classes (Cogan et al. 1999) to allocate sample sites within this area. We restricted sites in grassland, ponderosa pine, and prairie dog town vegetation to those falling on a grid (with random orientation and start) overlaid on the park[4]. We also distributed grassland and prairie dog town sites evenly between the eastern and western halves of the park because soil types, and therefore vegetation, differ between these two areas. Ponderosa pine sites all occurred in the western half of the park because this vegetation is rare in the eastern half. We did not restrict the woody draw and shrubland sites to the overlaid grid because of the rarity of these vegetation types (no sites on the grid fell in these vegetation types). Instead, we randomly selected sites from the appropriate vegetation types. We used the same iterative method of field checking the pool of sample sites described for DETO within these vegetation types, except two ponderosa pine sites were plots previously established by the Fire Effects program.

## Sampling

Once a sample site was selected, we established a single 20 m x 50 m plot at that site and collected data. Prior to any data collection, we wrote Preliminary Operating Procedures (POPs) for establishing and marking plots, sampling plant cover via the two methods (ocular and point-intercept), compiling a plot species list, and dealing with unknown specimens (Appendix B). Field crews followed these POPs, with some minor modifications, throughout the study. The general procedure we used for each plot follows:

4. The plot was established and marked following POP 1. Care was taken to avoid trampling of vegetation during this process.
5. We designated a sampling team from the field staff available, ensuring that the team always included at least one person with substantial knowledge of the plant species expected and, if possible, a person skilled in using a taxonomic key to identify unknown species (often the same individual). The composition of the teams was not held constant across plots because we knew this would not be the case in the long-term monitoring due to staff abailability varying through a given field season.
6. Sub-teams of two people (rarely one person) were formed. Each of the two 50-m transects that comprised a plot's edge was sampled twice, once by a sub-team using POP 2 (ocular method)

[4] Again, this was in an attempt to increase the chances that the sites would be used in future long-term monitoring.

and once by a sub-team using POP 3 (point-intercept method). For 21 of the 46 plots, the same sub-team used both methods on the same transect. In these cases, the sub-team members randomly chose which method (ocular or point-intercept) was used first on the transect. For the remainder of the plots, the ocular and point-intercept methods were completed by two different sub-teams on the same transect.

7. One person on the team was responsible for compiling a plot species list following POP 4, but all team members contributed to this task.
8. All sampling was done on the same day or on consecutive days to reduce differences due to vegetation growth between samples.

Eleven plots were double-sampled to compare the repeatability of measurements between observers for the two cover estimate methods (Table 1). When a plot was designated for double sampling, the first team to sample the plot left plot markers in place but removed all tapes. A second team relocated and sampled the plot following POPs 2 and 3. If any member of the first team was on the second team, care was taken to ensure that those members did not sample the same transect both times. The second team did not discuss the plot with the first team prior to the second team's finishing their sampling of that plot. Most double-sampling was completed within 36 hours of the original sample, although two second samples occurred 6 days after the original sample.

## Data Analysis

We concentrated our analyses on six community-level and three species-level response variables. The community-level variables were total canopy cover, graminoid canopy cover, broadleaf (forb + shrub) canopy cover, percentage of canopy cover that is non-native, bare soil ground cover, and number of species for which canopy cover was measured (species richness). The species-level variables were the cover of the first- and second-most abundant species in a plot, as representatives of dominant species, and the cover of the species with the median cover level in that plot, as a representative of the majority of species.

Except for analyses specifically focusing on repeatability, we used only the values obtained in the first sampling of a double-sampled plot.

We could not use our data to evaluate the accuracy of cover estimates or species richness measures by the two sampling methods because the true values were unknown. However, we did compare the values obtained for the six community-level response variables between the two methods using correlation analyses and paired t-tests. Preliminary analyses showed that our results were not affected by whether the same or different sub-teams completed the two sampling methods in an individual plot; in an ANOVA in which sampling method, a dichotomous variable denoting whether teams were the same or different, and the interaction of these two variables were factors, there was no significant effect ($P > 0.15$) of either the "teams same" variable alone or its interaction with sampling method for any of the community-level response variables. Thus, in our analyses comparing values between the two sampling methods, we used all plots in one analysis.

For comparing repeatability among observers for the two methods, we used correlations and paired t-tests for the nine response variables at the plot level. Thus, the sample size for these analyses was 11. For the species-level variables, the species used for an individual plot were based on their abundance measured by the first team. We also compared repeatability of plot-level composition by calculating the quantitative Sorenson (Bray-Curtis) and Morisita-Horn similarity indices between the two samples of each method for each plot. The quantitative Sorenson index is more sensitive to species richness, whereas the Morisita-Horn index is more sensitive to the

abundance of the most abundant species (Magurran 1988). We compared the difference in similarity between the two sampling methods using a paired t-test, where each plot was a sample.

Compositional similarity indices are sensitive to species pseudoturnover, in which one team records a species that the other does not. Species pseudoturnover is defined as

$$(A + B)/(S_A + S_B) \text{ X } 100,$$

where A and B are the number of exclusive species found by Team A and Team B, respectively, and $S_A$ and $S_B$ are the total number of species found by Team A and Team B, respectively (Nilsson and Nilsson 1985). We calculated species pseudoturnover for each sampling method in each double-sampled plot, then used a paired t-test to test for differences in species pseudoturnover between sampling methods.

We used the coefficient of variation (CV = 100 x sample standard deviation/sample mean) as a standardized measure of within-plot variability of the six community-level response variables. We used a mixed model (SAS Institute Inc. 2004) to evaluate the effects of sampling method, response variable, and vegetation type on natural-log-transformed CV values. Transformation was necessary to fit the normal-distribution assumption of the mixed model. We used post-hoc tests on differences between least-squares means to evaluate differences between factors with significant effects in the mixed model.

To determine the number of subsamples within a plot necessary to adequately measure the nine response variables for that site, we used the Power procedure (one-sample confidence interval option) in SAS (SAS Institute Inc. 2004). Subsamples in the ocular method were individual 0.5-$m^2$ frames, whereas subsamples in the point-intercept method were 10 consecutive points. Thus, we had 20 subsamples at each plot for both methods, from which we calculated the standard deviation of three of the six community response variables and all three species-level response variables described above. In addition, initial analyses showed that the ocular method detected more species than did the point-intercept method. Thus, we were interested in the precision with which the ocular method measured the cover of the species missed by the point-intercept method. To do this, we calculated the standard deviation of the ocular cover of species with 1% and 5% cover (values representing two separate thresholds for species detection) in each plot, using the species with the cover closest to these target values when the exact values did not occur. When more than one species with an individual target value occurred in a plot, we used the average of the standard deviations for these species.

We used the standard deviations described above as one of the parameters in the Power procedure to calculate the number of subsamples necessary to obtain 20% precision about the mean, where precision is defined as one-half the width of the specified confidence interval for the mean. We varied two other parameters, $\alpha$ and $\beta$, in these calculations to provide a range of subsample size-statistical power possibilities. $\alpha$ is the probability of committing a type I error (saying the true mean is within a given confidence interval when it actually is not), and $\beta$ is the probability of committing a type II error (saying the true mean is *not* within a given confidence interval when it actually is), with the power being the conditional probability that the desired precision is achieved, given that the interval includes the true mean. In addition, because the resulting subsample numbers were often unrealistically high, we obtained *absolute* (i.e., 20% cover instead of 20 % of the mean cover) precision levels attainable with 20 subsamples for each response variable. Finally, we constructed species-subsample number curves (Colwell 2005) for the plots with highest and lowest plot species richness in each vegetation type to determine the approximate return in greater species capture for each subsample added.

We compared the efficiency of the two methods in two ways. First, we calculated the amount of time spent sampling each plot with each sampling method. Second, we used a t-test to compare the percentage of species captured by each method. This percentage was the number of species encountered in the cover estimate procedure divided by the total number of species found in the entire plot via POP 4. We also used linear regression to investigate the relationship between time for completion of each method or species capture and plot species richness or total canopy cover.

We used SAS version 9.1 for Windows (SAS Institute Inc. 2004) for all statistical analyses.

# Results

We encountered 402 species during our sampling. Species encountered at each park are listed in Appendix C. To put our results in context with other vegetation sampling protocol development efforts in the NPS, we provide summary information on the vegetation types we sampled in Table 2. Graminoids (grasses, sedges, and rushes) are by far the most abundant life form in all but the prairie dog town and badlands/sparse vegetation types. Species richness per 1000-$m^2$ plot ranged from 21 to 92, with the median species cover being quite low. Species rank-abundance curves (Figure 2) for each plot, in which the cover of each species in a plot is plotted against its rank (species of lowest cover has rank 1), further illustrate the tendency for most species to have low cover and for vegetation to be heavily dominated by just a few species in most vegetation types. For example, of the 1606 species-plot occurrences, less than 4% had greater than 20% cover.

**Table 2.** Mean and range (in parentheses) of variables descriptive of vegetation in each vegetation type sampled in this study.

[Cover values are those measured by the ocular method, and plot species richness is from the whole plot (1000 $m^2$) species list.]

| Vegetation Type | Graminoid Cover (%) | Forb Cover (%) | Shrub Cover (%) | Total Cover (%) | Non-native Cover (% of Total Cover) | Plot Species Richness | Cover of an individual species (%) | Median Species Cover (%) |
|---|---|---|---|---|---|---|---|---|
| Badlands/Sparse | 28 (16 - 36) | 10 (2 - 19) | 15 (4 - 33) | 54 (36 - 70) | 3 (0 - 14) | 67 (40 - 88) | 1.28 (0.02 – 23) | 0.30 |
| Prairie dog town | 34 (6 - 55) | 75 (16 - 120) | 5 (0 - 15) | 104 (71 - 126) | 15 (0 - 32) | 50 (45 - 56) | 2.92 (0.02 – 39) | 0.31 |
| Riparian forest | 107 (80 - 136) | 30 (2 - 57) | 14 (0 - 46) | 154 (83 - 201) | 64 (31 - 86) | 49 (25 - 78) | 4.84 (0.02 – 82) | 0.85 |
| Grassland | 78 (40 - 115) | 17 (2 - 31) | 9 (0 - 53) | 104 (58 - 192) | 22 (0 - 82) | 58 (29 - 92) | 2.88 (0.02 – 76) | 0.44 |
| Riparian herbaceous wetland | 107 (79 - 141) | 39 (14 - 55) | 1 (0 - 6) | 147 (134 - 159) | 22 (7 - 37) | 31 (21 - 42) | 7.36 (0.02 – 90) | 1.39 |
| Ponderosa pine forest/woodland | 57 (20 - 79) | 4 (2 - 7) | 11 (1 - 43) | 79 (32 - 125) | 19 (1 - 50) | 55 (38 - 69) | 2.18 (0.02 – 64) | 0.30 |
| Shrubland | 78 (29 - 121) | 14 (8 - 21) | 41 (30 - 54) | 133 (75 - 160) | 31 (4 - 55) | 62 (41 - 85) | 3.35 (0.02 – 87) | 0.40 |

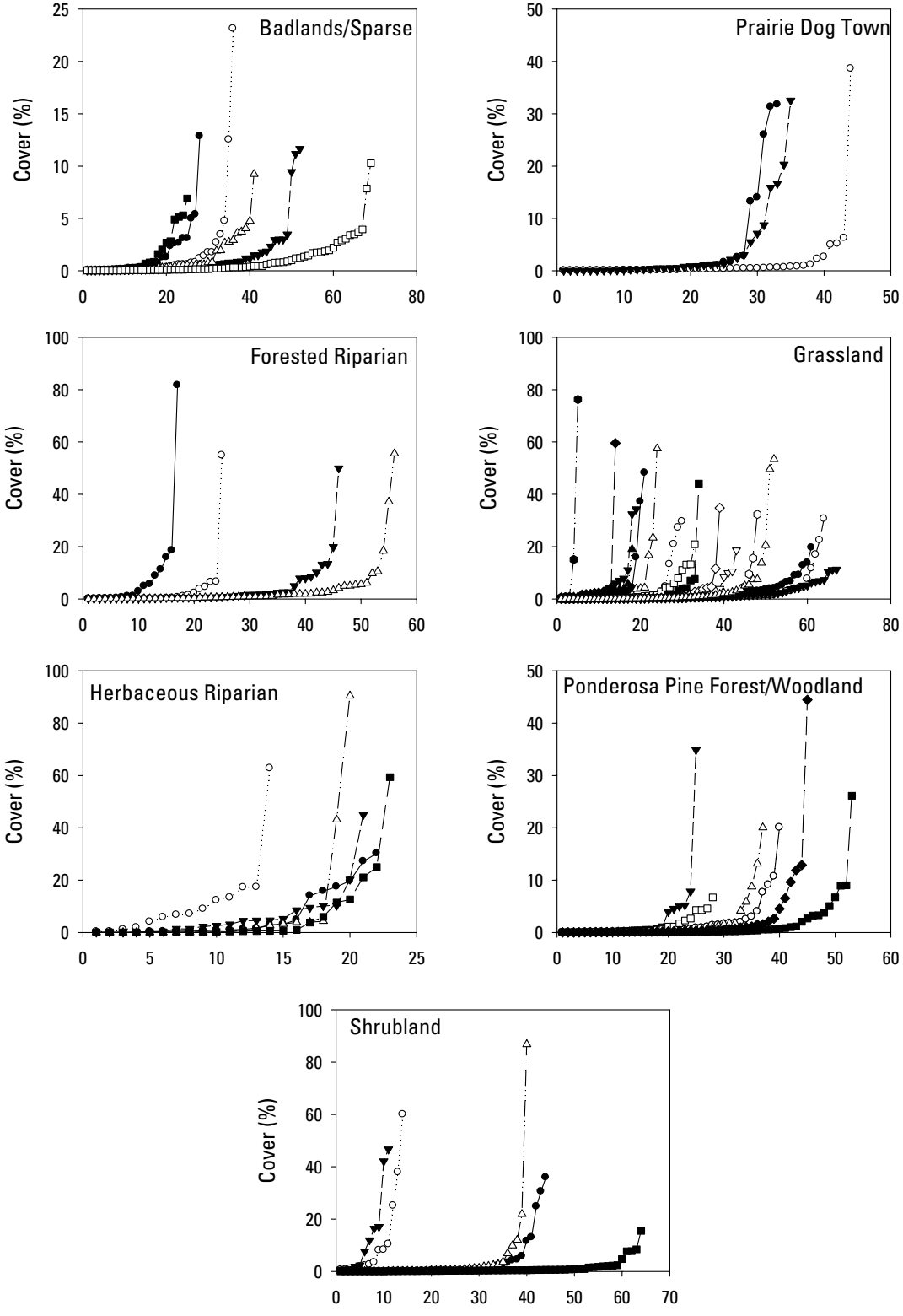


**Figure 2.** Rank (x-axis)-abundance (y-axis) curves for the 46 plots sampled, by vegetation type. Each line-symbol combination within a graph represents a single plot.

## Between-Method Comparison of Values Obtained

The two sampling methods gave significantly different values for five of the six community-level response variables (paired *t*-tests were significant; Table 3). The point-intercept method yielded substantially higher values for graminoid and total canopy cover, whereas the ocular method yielded substantially higher values for species richness. Differences in values of broadleaf cover and bare soil cover were much less substantial, though still statistically significant, with the point-intercept method producing higher values for both. The difference between proportional non-native cover values was not significant.

**Table 3.** Paired t-test and correlation results for point-intercept vs. ocular sampling methods for six community response variables.

["PI-Ocular Mean" is the mean difference between the ocular and point-intercept value of the variable, with the standard error shown in parentheses beneath. df = 45 for all tests.]

| | Paired *t*-test for PI-Ocular Mean = 0 | | | Correlation between PI value and Ocular value | |
|---|---|---|---|---|---|
| **Response Variable** | **PI-Ocular Mean** | ***t*** | ***P*** | $r^2$ | ***P*** |
| Total canopy cover | 32.46 (3.28) | 9.90 | <0.001 | 0.84 | <0.001 |
| Graminoid canopy cover | 28.97 (2.94) | 9.87 | <0.001 | 0.78 | <0.001 |
| Broadleaf canopy cover | 3.23 (1.09) | 2.98 | 0.005 | 0.96 | <0.001 |
| % cover non-native | 1.35 (0.81) | 1.68 | 0.100 | 0.96 | <0.001 |
| Bare soil ground cover | 4.71 (1.34) | 3.51 | 0.001 | 0.85 | <0.001 |
| Species richness | -14.09 (1.34) | -10.48 | <0.001 | 0.63 | <0.001 |

Although values of the response variables generally differed between the two methods, there were strong correlations between them (Table 3). The tightness of this relationship was greatest for broadleaf cover and the percentage of cover that's non-native and smallest for species richness (Table 3). Visual inspection of plots of the point-intercept value *vs.* the ocular value for each response variable (Figure 3) suggests that the relationship between values from the two methods for four of the community variables deviated from a strict 1:1 fit. Total canopy and graminoid cover were consistently higher than a 1:1 line. Bare soil cover tended to be higher than the 1:1 line, though less consistently than for total canopy and graminoid cover. Species richness was consistently below the 1:1 line, with the deviation being greater at higher levels of species richness.

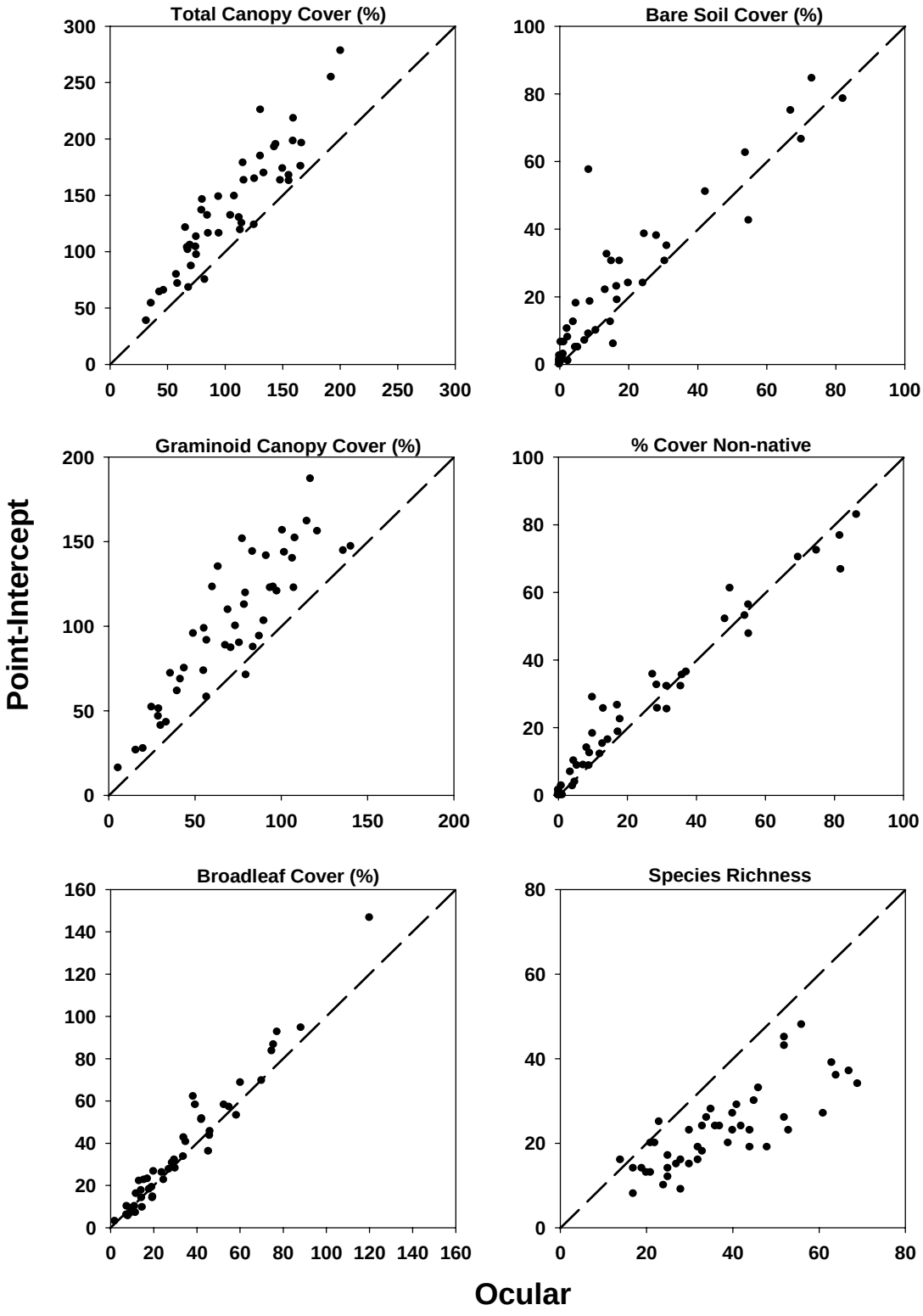


**Figure 3.** Relationship between community-level response variable values obtained by the two sampling methods. Dashed lines are y=x.

**Table 4.** Comparison of repeatability for two methods of vegetation sampling based on correlation coefficients and paired t-tests.

[For individual methods, t-test results show difference in values between sampling teams, with standard error (SE) in parentheses. For method comparison, the difference shown is the mean difference (SE in parentheses) between methods in between-team differences.]

| | Ocular | | | | | Point-Intercept | | | | | Method Comparison | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Response Variable | $r^2$ | \|Team A – Team B\| | *t* | df | *P* | $r^2$ | \|Team A – Team B\| | *t* | df | *P* | PI – Ocular | *t* | df | *P* |
| Total canopy cover | 0.97* | 5.32 (2.23) | 2.39 | 10 | 0.038 | 0.93* | 11.18 (1.66) | 6.74 | 10 | <0.001 | 5.86 (2.38) | 2.46 | 10 | 0.034 |
| Graminoid canopy cover | 0.99* | 4.49 (1.69) | 2.66 | 10 | 0.024 | 0.97* | 6.73 (1.46) | 4.60 | 10 | 0.001 | 2.24 (2.14) | 1.05 | 10 | 0.320 |
| Broadleaf canopy cover | 0.99* | 2.05 (0.48) | 4.31 | 10 | 0.002 | 0.99* | 3.45 (0.83) | 4.15 | 10 | 0.002 | 1.41 (1.00) | 1.41 | 10 | 0.190 |
| % cover non-native | 0.99* | 1.99 (0.61) | 3.25 | 10 | 0.009 | 0.98* | 2.37 (0.68) | 3.51 | 10 | 0.006 | 0.38 (0.63) | 0.60 | 10 | 0.563 |
| Bare soil ground cover | 0.96* | 3.17 (1.28) | 2.47 | 10 | 0.033 | 0.96* | 4.00 (0.95) | 4.20 | 10 | 0.002 | 0.83 (1.05) | 0.80 | 10 | 0.444 |
| Species richness | 0.93* | 2.55 (0.74) | 3.43 | 10 | 0.006 | 0.71* | 4.00 (0.81) | 4.96 | 10 | <0.001 | 1.46 (1.05) | 1.39 | 10 | 0.196 |
| Most abundant species cover | 0.96* | 4.96 (1.00) | 4.96 | 10 | <0.001 | 0.98* | 3.77 (0.83) | 4.56 | 10 | 0.001 | -1.19 (1.67) | -0.71 | 10 | 0.493 |
| Second-most abundant species cover | 0.72* | 4.09 (1.67) | 2.45 | 10 | 0.034 | 0.70* | 5.09 (1.38) | 3.69 | 10 | 0.004 | 1.00 (0.79) | 1.27 | 10 | 0.233 |
| Median cover species cover | 0.73* | 0.19 (0.05) | 3.86 | 10 | 0.003 | 0.28† | 1.14 (0.21) | 5.31 | 10 | <0.001 | 0.95 (0.23) | 4.17 | 10 | 0.002 |

*$P$ • 0.001; †P =0.095

## Repeatability

For most community-level variables, correlation between the two teams was high for both methods ($r^2 \geq 0.93$) and regressions were highly significant (Table 4). Only for species richness did correlations between the two teams for the two methods differ substantially (ocular $r^2 = 0.93$ vs. point-intercept $r^2 = 0.71$). However, for both methods there were significant differences between the two teams' values for all community-level response variables (Table 4). These differences were similar between methods for all community-level response variables except total canopy cover. For this variable, the point-intercept method had significantly greater discrepancies between teams than the ocular method did.

Values of species-level response variables also differed significantly between sample teams for both methods (Table 4). These differences were similar between methods for the cover of the two most abundant species, but for the cover of median species, the point-intercept method had significantly greater discrepancies between teams. For cover of the most abundant individual species, correlation between samples for both methods was similar to that for the community-level variables ($r^2 \geq 0.96$). For cover of the second most abundant species and median species, however, correlation was considerably lower, especially for the point-intercept method for the median species, for which there was no significant correlation between the two teams' values (Table 4).

Compositional similarity tended to be slightly greater for the ocular method than for the point-intercept method when measured either with the quantitative Sorenson or the Morisita-Horn similarity index (Table 5). Species pseudoturnover was substantial in most plots that were double-sampled, ranging from 6% to 57%, and it was significantly higher with the point-intercept method (Table 5). Species pseudoturnover did not vary with total species richness for either method (Point-Intercept: $r^2 = 0.003$, $F_{1,9} = 0.03$, $P = 0.874$; Ocular: $r^2 = 0.015$, $F_{1,9} = 0.14$, $P = 0.716$). Twenty percent of the species detected by one team but not the other had greater than 1% cover, but this did not differ significantly between sampling methods (difference = 6.75 ± 5.91, $t = 1.14$, df = 10, $P = 0.280$).

**Table 5.** Similarity indices and species turnover between first and second sampling for each method and double-sampled plot.

[Mean and standard error of differences between methods (ocular – point-intercept) and results of paired t-test between the two sampling methods, are shown at the bottom of the table.]

| | | | Quantitative Sorenson Similarity | | Morisita-Horn Similarity | | Species Pseudoturnover | |
|---|---|---|---|---|---|---|---|---|
| Plot | Park | Vegetation Type | Ocular | Point-Intercept | Ocular | Point-Intercept | Ocular | Point-Intercept |
| APR05 | AGFO | HERBRIP | 0.861 | 0.844 | 0.989 | 0.976 | 33.3 | 57.1 |
| APR06 | AGFO | HERBRIP | 0.811 | 0.847 | 0.932 | 0.941 | 25.5 | 29.7 |
| DPCM02 | DETO | FORRIP | 0.920 | 0.903 | 0.993 | 0.981 | 5.9 | 16.7 |
| DPCM03 | DETO | PIPO | 0.877 | 0.856 | 0.978 | 0.973 | 17.5 | 19.1 |
| LTEM04 | AGFO | GRASS | 0.903 | 0.822 | 0.991 | 0.990 | 20.5 | 20.0 |
| TPCM03 | THRO | BAD | 0.721 | 0.661 | 0.875 | 0.854 | 16.7 | 30.9 |
| TPCM06 | THRO | SHRUB | 0.946 | 0.911 | 0.997 | 0.985 | 19.0 | 17.6 |
| WPCM02 | WICA | DOG | 0.903 | 0.892 | 0.984 | 0.985 | 15.9 | 25.9 |
| WPCM09 | WICA | SHRUB | 0.797 | 0.778 | 0.942 | 0.939 | 19.3 | 30.7 |

Table 5, continued.

| Plot | Park | Vegetation Type | Quantitative Sorenson Similarity: Ocular | Quantitative Sorenson Similarity: Point-Intercept | Morisita-Horn Similarity: Ocular | Morisita-Horn Similarity: Point-Intercept | Species Pseudoturnover: Ocular | Species Pseudoturnover: Point-Intercept |
|---|---|---|---|---|---|---|---|---|
| WPCM12 | WICA | PIPO | 0.763 | 0.751 | 0.826 | 0.812 | 27.3 | 18.5 |
| WPCM13 | WICA | PIPO | 0.827 | 0.836 | 0.961 | 0.970 | 20.5 | 33.3 |
| | | mean difference | 0.021 | | 0.006 | | -7.12 | |
| | | SE difference | 0.009 | | 0.003 | | 2.73 | |
| | | df | 10 | | 10 | | 10 | |
| | | *t* | 2.21 | | 1.84 | | -2.60 | |
| | | *P* | 0.052 | | 0.095 | | 0.026 | |

## Number of Subsamples

Sampling method, vegetation type, and response variable, as well as the interaction between response variable and vegetation type, significantly affected log-transformed CV values (Table 6). Overall, the ocular method had a significantly higher log-transformed CV (least-squares mean ± SE = 4.39 ± 0.05) than the point-intercept method (4.29 ± 0.05). The log-transformed CV of median species cover did not differ ($P > 0.05$) among vegetation types. For the other five response variables, the only consistent patterns in log-transformed CV among vegetation types were that the Badlands/Sparse vegetation type always had the highest log-transformed CV, and the Ponderosa Pine Forest/Woodland type had generally high log-transformed CV compared to the others (Figure 4). Although this analysis does not translate directly into differences in the precision attainable with each method in each vegetation type, its results do help explain some of the differences shown below. It should be noted that the variability in sample sizes among vegetation types may have weakened our ability to detect differences among the vegetation types in the log-transformed CV of the response variables.

**Table 6.** Results of mixed model analysis for effects of sampling method, vegetation type, response variable, and their interactions on log-transformed coefficient of variation.

| Effect | Numerator DF | Denominator DF | *F* | *P* |
|---|---|---|---|---|
| Method | 1 | 422 | 6.07 | 0.014 |
| Vegetation type | 6 | 39 | 7.90 | < 0.001 |
| Response variable | 5 | 422 | 286.33 | < 0.001 |
| Method x Vegetation type | 6 | 422 | 0.62 | 0.717 |
| Method x Response variable | 5 | 422 | 1.14 | 0.340 |
| Vegetation type x Response variable | 30 | 422 | 3.59 | < 0.001 |
| Method x Vegetation type x Response variable | 30 | 422 | 0.29 | 1.000 |

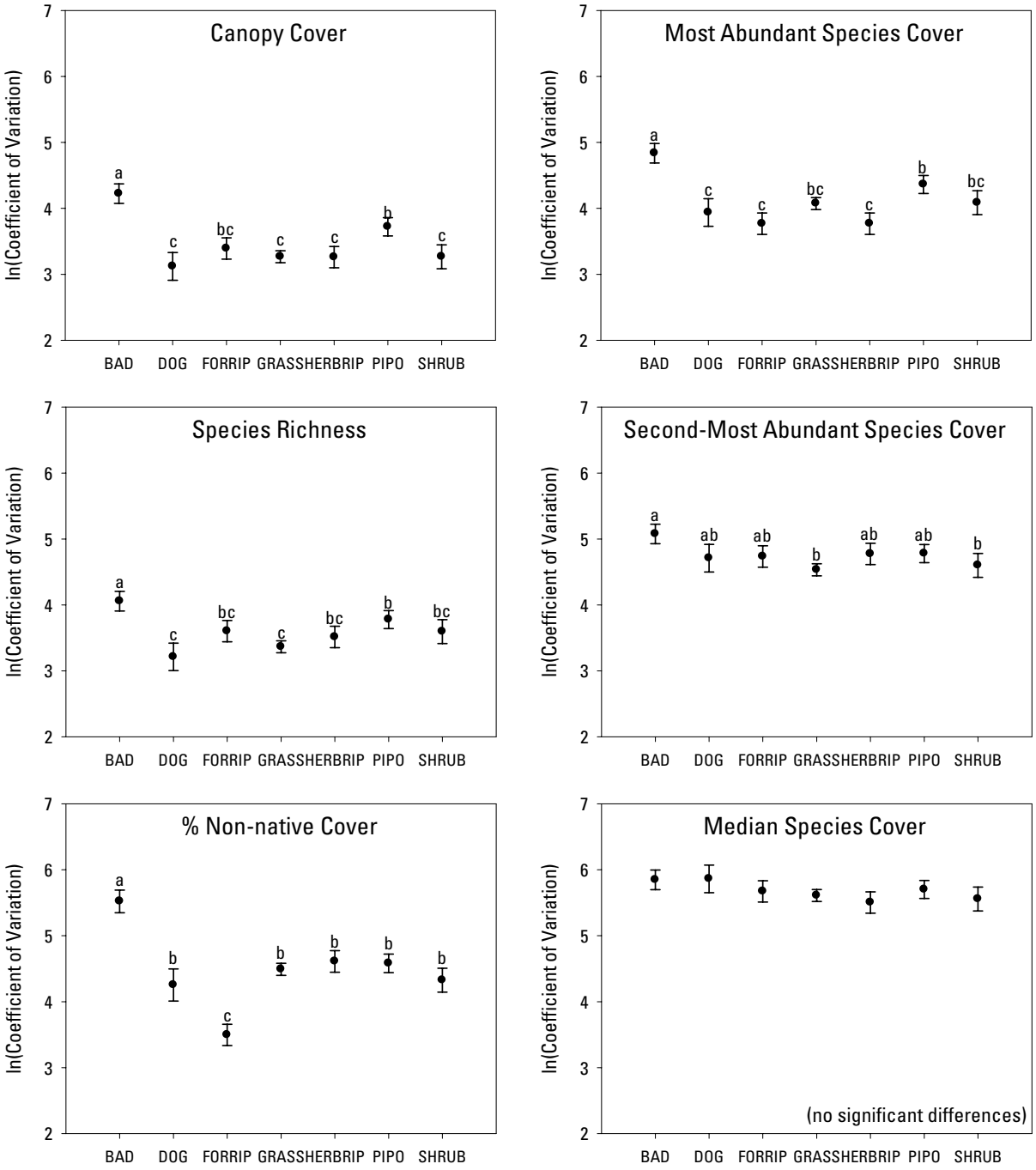


**Figure 4.** Least squares means and standard errors for log-transformed coefficients of variation among subsamples within plots for six response variables, by vegetation type. Different letters above symbols within a graph indicate significant ($P < 0.05$) differences between vegetation types. Vegetation type abbreviations follow those in Table 1.

For most vegetation types, sampling 20 subsamples with either method was more than adequate to obtain 20% precision around the mean in the estimate of total canopy cover with 95%

confidence and 90% power (Tables 7 and 8). For the ponderosa vegetation type, sampling 20 subsamples was adequate to obtain 20% precision around the mean with slightly lower confidence (90%). However, because of low overall cover of vegetation in the badlands/sparse vegetation type, as well as the high variability among subsamples, 20 subsamples only attained absolute precision of 17-30% cover, which is approximately 30-40% of the mean.

Twenty percent precision around the mean for the percent of total canopy cover that is non-native was attainable with 20 subsamples with either method only for the vegetation type with the highest value for this variable – forested riparian vegetation. Approximately doubling the number of subsamples in either method would attain this precision with either method for the average plot, but even this intense of sampling would not provide this precision in most vegetation types (Tables 7 and 8). The precision obtainable with 20 subsamples ranged from 2% non-native cover in those vegetation types with the least non-native vegetation (badlands/sparse and prairie dog town) to 12% for those with higher non-native cover. Overall, the point-intercept method required slightly fewer subsamples than the ocular method to obtain 20% precision around the mean for this response variable, but this was not the case for all vegetation types. This may be due to the differences in growth form (graminoid vs. forb) of the non-natives that occurred in each vegetation type.

Sampling 20 subsamples was adequate or close to adequate for obtaining 20% precision around the mean (95% confidence and 90% power) for species richness for five of the seven vegetation types with the point-intercept method and four of the vegetation types with the ocular method (Tables 7 and 8). As with total canopy cover, the badlands/sparse and ponderosa pine forest vegetation types required more subsamples to attain this precision for species richness because of their relatively high CVs. In general, the point-intercept method provided greater absolute precision (0.8 species) than the ocular method (2 species) with 20 subsamples, but the point-intercept method also recorded fewer species (Table 8 vs. Table 7).

Twenty percent precision around the mean (95% confidence and 90% power) for cover of the most abundant species was not obtainable with either method for any vegetation type (Tables 7 and 8). The number of subsamples required to attain this precision for this response variable was consistently lower for the point-intercept method than for the ocular method across vegetation types, except for the prairie dog town type, in which subsample number was approximately equal between the two methods. The point-intercept method could obtain absolute precision of 9-15% for most abundant species cover across vegetation types (Table 8), whereas the ocular method's absolute precision ranged from 8 to 19% cover (Table 7).

The number of subsamples required to attain 20% precision around the mean for the cover of the second-most abundant species or a species with median cover was very high or astronomical, respectively, for either method (Tables 7 and 8). For second-most abundant species cover, 20 subsamples attained a precision of 7-19% absolute cover, depending on vegetation type, with either sampling method. For the point-intercept method, this is 39 to 86% of the mean and for the ocular method this is 48 to 102% of the mean. For cover of the median species, the ocular method produced a precision of 0.4 to 2 % cover, depending on vegetation type, with 20 subsamples. This is 121 to 308% of the mean. The point-intercept method produced a precision of 3 to 6% absolute cover, depending on vegetation type, with 20 subsamples. This is 106 to 226% of the mean.

**Tables 7 & 8.** Means, standard deviations, coefficients of variation (CV), sample size needed for 20% precision around mean, and absolute precision attainable with 20 subsamples for the ocular (Table 7) and point-intercept (Table 8) methods for six response variables.

[$\alpha$ and $\beta$ are the probability of type 1 and type 2 errors, respectively.]

| Table 7 | | | | | | ----N for 20% precision---- | | | | Prec. w/ 20 subs | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Vegetation Type** | Mean | Mean SD | Min SD | Max SD | Mean CV | α=0.1 β=0.2 | α=0.1 β=0.1 | α=0.05 β=0.1 | 20% of Mean | α=0.1 β≤0.1 | α=0.05 β≤0.1 |
| *Total Canopy Cover* | | | | | | | | | | | |
| BAD | 53.69 | 36.47 | 22.03 | 50.11 | 68.97 | 40 | 43 | 58 | 10.74 | 17 | 21 |
| DOG | 108.28 | 20.88 | 17.21 | 27.96 | 20.02 | 6 | 7 | 9 | 21.66 | 10 | 12 |
| FORRIP | 154.36 | 45.94 | 26.46 | 65.01 | 29.86 | 11 | 12 | 16 | 30.87 | 22 | 26 |
| GRASS | 103.54 | 27.93 | 14.66 | 43.34 | 27.41 | 9 | 11 | 14 | 20.71 | 14 | 16 |
| HERBRIP | 147.31 | 42.57 | 35.82 | 48.02 | 28.86 | 10 | 12 | 15 | 29.46 | 20 | 24 |
| PIPO | 79.26 | 32.98 | 16.99 | 44.14 | 46.01 | 18 | 20 | 26 | 15.85 | 19 | 20 |
| SHRUB | 135.06 | 36.88 | 30.06 | 44.68 | 31.54 | 11 | 12 | 14 | 27.01 | 18 | 21 |
| Overall | 105.58 | 33.35 | 14.66 | 65.01 | 35.90 | 12 | 13 | 17 | 21.12 | 16 | 19 |
| *Percent Cover Non-native* | | | | | | | | | | | |
| BAD | 2.74 | 3.91 | 0.32 | 18.77 | 269.03 | 152 | 159 | 221 | 0.55 | 2 | 3 |
| DOG | 14.89 | 9.49 | 0.00 | 18.59 | 67.20 | 35 | 39 | 52 | 2.98 | 5 | 6 |
| FORRIP | 63.52 | 20.35 | 10.70 | 27.38 | 36.06 | 12 | 13 | 18 | 12.70 | 10 | 12 |
| GRASS | 22.22 | 11.21 | 0.23 | 30.63 | 138.81 | 24 | 26 | 35 | 4.44 | 6 | 7 |
| HERBRIP | 21.51 | 19.83 | 13.98 | 28.18 | 118.77 | 68 | 73 | 100 | 4.30 | 10 | 12 |
| PIPO | 17.99 | 15.80 | 1.90 | 28.47 | 140.98 | 63 | 67 | 92 | 3.60 | 8 | 9 |
| SHRUB | 17.24 | 16.64 | 7.98 | 32.88 | 98.82 | 27 | 30 | 40 | 6.12 | 8 | 10 |
| Overall | 22.54 | 13.25 | 0.00 | 32.88 | 136.16 | 28 | 31 | 42 | 4.74 | 7 | 6 |
| *Species Richness* | | | | | | | | | | | |
| BAD | 6.58 | 3.66 | 2.06 | 6.21 | 56.23 | 28 | 31 | 41 | 1.32 | 2 | 3 |
| DOG | 11.92 | 2.64 | 2.18 | 2.99 | 22.86 | 4 | 5 | 11 | 2.38 | 2 | 2 |
| FORRIP | 7.37 | 2.64 | 1.73 | 3.27 | 41.18 | 14 | 16 | 21 | 1.47 | 2 | 2 |
| GRASS | 10.10 | 2.82 | 1.60 | 4.37 | 29.21 | 10 | 11 | 14 | 2.02 | 2 | 2 |
| HERBRIP | 6.06 | 1.94 | 1.67 | 2.26 | 32.14 | 12 | 13 | 18 | 1.21 | 1 | 2 |
| PIPO | 7.16 | 3.17 | 2.08 | 4.87 | 45.47 | 19 | 22 | 29 | 1.43 | 2 | 2 |
| SHRUB | 8.45 | 3.45 | 2.41 | 4.23 | 40.69 | 13 | 15 | 25 | 1.69 | 2 | 2 |
| Overall | 8.43 | 2.91 | 1.60 | 6.21 | 37.41 | 17 | 19 | 20 | 1.69 | 2 | 2 |
| *Most Abundant Species Cover* | | | | | | | | | | | |
| BAD | 12.34 | 16.29 | 8.97 | 28.45 | 141.81 | 132 | 139 | 192 | 2.47 | 8 | 10 |
| DOG | 34.30 | 18.01 | 10.16 | 22.85 | 54.23 | 26 | 28 | 38 | 6.86 | 9 | 11 |
| FORRIP | 60.40 | 30.71 | 19.41 | 38.22 | 53.88 | 24 | 27 | 36 | 12.08 | 15 | 18 |
| GRASS | 36.87 | 23.58 | 10.95 | 33.71 | 76.53 | 36 | 39 | 53 | 7.37 | 11 | 14 |
| HERBRIP | 57.55 | 32.08 | 10.66 | 41.33 | 68.64 | 28 | 31 | 42 | 11.51 | 15 | 19 |
| PIPO | 30.95 | 24.72 | 11.13 | 37.59 | 95.78 | 53 | 57 | 77 | 6.19 | 12 | 14 |
| SHRUB | 46.23 | 31.97 | 21.42 | 41.10 | 97.84 | 41 | 44 | 60 | 9.25 | 15 | 18 |
| Overall | 38.22 | 24.87 | 8.97 | 41.33 | 85.05 | 37 | 40 | 54 | 7.64 | 12 | 14 |
| *Second Abundant Species Cover* | | | | | | | | | | | |
| BAD | 7.83 | 13.85 | 8.97 | 24.96 | 187.75 | 230 | 238 | 332 | 1.57 | 7 | 8 |
| DOG | 19.29 | 20.40 | 10.16 | 22.41 | 151.03 | 88 | 93 | 128 | 3.86 | 10 | 12 |
| FORRIP | 23.99 | 25.09 | 19.41 | 33.01 | 121.48 | 86 | 91 | 125 | 4.80 | 12 | 15 |
| GRASS | 18.82 | 18.42 | 10.95 | 40.44 | 109.51 | 76 | 81 | 112 | 3.76 | 9 | 11 |
| HERBRIP | 26.57 | 31.55 | 10.66 | 41.36 | 123.83 | 109 | 115 | 159 | 5.31 | 15 | 18 |
| PIPO | 14.41 | 15.45 | 11.13 | 23.74 | 149.32 | 90 | 95 | 132 | 2.88 | 8 | 9 |
| SHRUB | 25.75 | 25.94 | 21.42 | 44.74 | 103.61 | 80 | 85 | 117 | 5.15 | 13 | 15 |
| Overall | 18.75 | 20.31 | 8.97 | 44.74 | 130.83 | 92 | 97 | 134 | 3.75 | 10 | 12 |
| *Median Species Cover* | | | | | | | | | | | |
| BAD | 0.33 | 1.26 | 0.79 | 1.79 | 383.52 | 914 | 932 | 1311 | 0.07 | 0.6 | 0.8 |
| DOG | 0.36 | 1.16 | 0.90 | 1.46 | 347.68 | 777 | 794 | 1116 | 0.07 | 0.6 | 0.7 |
| FORRIP | 0.65 | 2.16 | 0.21 | 4.92 | 310.17 | 781 | 798 | 1121 | 0.13 | 2 | 2 |
| GRASS | 0.42 | 1.33 | 0.26 | 5.22 | 320.64 | 782 | 799 | 1123 | 0.08 | 0.7 | 0.8 |
| HERBRIP | 2.45 | 6.71 | 0.53 | 20.94 | 262.71 | 536 | 550 | 771 | 0.49 | 4 | 4 |
| PIPO | 0.30 | 0.99 | 0.46 | 1.79 | 337.79 | 771 | 787 | 1106 | 0.06 | 0.5 | 0.6 |
| SHRUB | 0.33 | 0.81 | 0.34 | 1.23 | 236.95 | 387 | 398 | 557 | 0.07 | 0.4 | 0.5 |
| Overall | 0.62 | 1.89 | 0.21 | 20.94 | 318.51 | 704 | 720 | 1011 | 0.12 | 0.9 | 2 |

| Table 8 | | | | | | ----N for 20% precision---- | | | | Prec. w/ 20 subs | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Vegetation Type | Mean | Mean SD | Min SD | Max SD | Mean CV | α=0.1 β=0.2 | α=0.1 β=0.1 | α=0.05 β=0.1 | 20% of Mean | α=0.1 β≤0.1 | α=0.05 β≤0.1 |
| *Total Canopy Cover* | | | | | | | | | | | |
| BAD | 77.33 | 52.45 | 37.19 | 63.77 | 69.36 | 40 | 43 | 58 | 15.47 | 25 | 30 |
| DOG | 139.33 | 36.04 | 30.17 | 46.51 | 26.96 | 9 | 10 | 13 | 27.87 | 17 | 21 |
| FORRIP | 178.50 | 49.65 | 40.32 | 59.77 | 31.70 | 10 | 11 | 14 | 35.70 | 24 | 28 |
| GRASS | 144.38 | 37.38 | 19.22 | 53.46 | 27.09 | 9 | 10 | 13 | 28.88 | 18 | 22 |
| HERBRIP | 180.80 | 43.23 | 27.31 | 49.47 | 23.98 | 8 | 9 | 12 | 36.16 | 21 | 25 |
| PIPO | 107.29 | 40.93 | 25.81 | 61.25 | 43.30 | 13 | 15 | 23 | 21.46 | 20 | 24 |
| SHRUB | 162.88 | 39.93 | 25.98 | 53.44 | 24.75 | 9 | 10 | 12 | 32.58 | 19 | 23 |
| Overall | 138.93 | 41.99 | 19.22 | 63.77 | 35.02 | 9 | 10 | 16 | 27.79 | 20 | 24 |
| *Percent Cover Non-native* | | | | | | | | | | | |
| BAD | 2.69 | 4.36 | 0.00 | 447.21 | 278.30 | 194 | 202 | 281 | 0.54 | 3 | 3 |
| DOG | 12.77 | 8.73 | 0.00 | 74.55 | 70.01 | 40 | 43 | 59 | 2.55 | 5 | 5 |
| FORRIP | 63.79 | 20.48 | 14.95 | 48.63 | 34.39 | 12 | 13 | 18 | 12.76 | 10 | 12 |
| GRASS | 23.06 | 12.80 | 0.00 | 244.44 | 109.20 | 28 | 31 | 41 | 4.61 | 6 | 8 |
| HERBRIP | 21.39 | 16.77 | 12.37 | 179.86 | 101.29 | 51 | 55 | 75 | 4.28 | 8 | 10 |
| PIPO | 24.09 | 15.53 | 0.00 | 159.91 | 84.95 | 36 | 39 | 53 | 4.82 | 8 | 9 |
| SHRUB | 29.54 | 13.51 | 6.22 | 241.27 | 107.76 | 20 | 23 | 30 | 5.91 | 7 | 8 |
| Overall | 24.70 | 13.18 | 0.00 | 447.21 | 105.80 | 26 | 29 | 39 | 4.94 | 7 | 8 |
| *Species Richness* | | | | | | | | | | | |
| BAD | 4.19 | 2.58 | 1.63 | 3.18 | 62.44 | 33 | 36 | 49 | 0.84 | 2 | 2 |
| DOG | 5.47 | 1.56 | 1.10 | 2.16 | 28.57 | 10 | 11 | 15 | 1.09 | 0.8 | 0.9 |
| FORRIP | 5.48 | 1.76 | 1.33 | 2.18 | 36.87 | 12 | 13 | 18 | 1.10 | 0.9 | 1 |
| GRASS | 5.59 | 1.65 | 0.92 | 2.68 | 30.51 | 11 | 12 | 16 | 1.12 | 0.8 | 1 |
| HERBRIP | 4.57 | 1.63 | 0.97 | 2.15 | 35.80 | 14 | 16 | 21 | 0.91 | 0.8 | 1 |
| PIPO | 4.14 | 1.77 | 0.86 | 2.39 | 44.44 | 18 | 20 | 27 | 0.83 | 0.9 | 1 |
| SHRUB | 5.64 | 1.87 | 1.48 | 2.28 | 33.55 | 13 | 14 | 18 | 1.13 | 0.9 | 2 |
| Overall | 5.06 | 1.81 | 0.86 | 3.18 | 38.20 | 14 | 16 | 21 | 1.01 | 0.9 | 2 |
| *Most Abundant Species Cover* | | | | | | | | | | | |
| BAD | 16.58 | 18.95 | 13.99 | 29.64 | 122.74 | 101 | 107 | 147 | 3.32 | 9 | 11 |
| DOG | 39.17 | 20.96 | 16.03 | 27.70 | 54.47 | 26 | 29 | 39 | 7.83 | 10 | 12 |
| FORRIP | 67.00 | 25.44 | 12.09 | 33.48 | 42.72 | 15 | 17 | 23 | 13.40 | 12 | 15 |
| GRASS | 49.94 | 24.73 | 9.40 | 35.73 | 56.49 | 23 | 26 | 34 | 9.99 | 12 | 14 |
| HERBRIP | 68.80 | 26.41 | 7.59 | 42.83 | 45.43 | 16 | 17 | 23 | 13.76 | 11 | 13 |
| PIPO | 37.71 | 23.87 | 12.57 | 30.86 | 73.44 | 35 | 38 | 52 | 7.54 | 12 | 14 |
| SHRUB | 48.38 | 22.43 | 5.71 | 42.98 | 67.22 | 21 | 23 | 31 | 9.68 | 11 | 13 |
| Overall | 46.79 | 23.66 | 5.71 | 42.98 | 65.81 | 24 | 26 | 36 | 9.36 | 12 | 14 |
| *Second Abundant Species Cover* | | | | | | | | | | | |
| BAD | 9.33 | 13.52 | 8.65 | 19.03 | 158.24 | 157 | 165 | 239 | 1.87 | 7 | 8 |
| DOG | 24.33 | 23.11 | 14.32 | 30.00 | 98.24 | 72 | 77 | 105 | 4.87 | 11 | 13 |
| FORRIP | 23.30 | 25.03 | 17.74 | 28.00 | 115.02 | 90 | 96 | 132 | 4.66 | 12 | 15 |
| GRASS | 25.53 | 21.30 | 10.89 | 37.76 | 88.78 | 57 | 61 | 84 | 5.11 | 10 | 12 |
| HERBRIP | 29.50 | 33.32 | 30.50 | 36.29 | 115.19 | 99 | 105 | 145 | 5.90 | 16 | 19 |
| PIPO | 21.14 | 19.60 | 11.42 | 29.20 | 118.90 | 69 | 73 | 101 | 4.23 | 10 | 12 |
| SHRUB | 30.75 | 29.15 | 16.94 | 40.31 | 96.62 | 72 | 76 | 105 | 6.15 | 14 | 17 |
| Overall | 23.32 | 22.54 | 8.65 | 40.31 | 109.45 | 75 | 79 | 109 | 4.66 | 11 | 13 |
| *Median Species Cover* | | | | | | | | | | | |
| BAD | 1.58 | 4.55 | 2.24 | 8.01 | 338.45 | 577 | 591 | 829 | 0.32 | 3 | 3 |
| DOG | 1.33 | 4.75 | 4.47 | 4.89 | 366.56 | 874 | 891 | 1253 | 0.27 | 3 | 3 |
| FORRIP | 2.00 | 5.66 | 3.08 | 9.33 | 297.19 | 571 | 585 | 821 | 0.40 | 3 | 4 |
| GRASS | 2.16 | 4.86 | 3.08 | 10.46 | 245.61 | 370 | 381 | 533 | 0.43 | 3 | 3 |
| HERBRIP | 4.70 | 9.02 | 4.89 | 18.32 | 244.61 | 270 | 279 | 390 | 0.94 | 5 | 6 |
| PIPO | 1.86 | 4.74 | 3.08 | 8.13 | 276.26 | 471 | 484 | 678 | 0.37 | 3 | 3 |
| SHRUB | 1.25 | 3.27 | 2.24 | 4.10 | 301.11 | 490 | 503 | 706 | 0.25 | 2 | 2 |
| Overall | 2.16 | 5.19 | 2.24 | 18.32 | 280.59 | 420 | 432 | 604 | 0.43 | 3 | 3 |

The shape of species-subsample curves suggest that adding more subsamples in the point-intercept method would yield fewer additional species than would adding more subsamples in the ocular method (Figure 5a, b). For only two of the 14 plots for which we constructed species-subsample curves did the point-intercept method add species at a greater rate than did the ocular method, and this was only at higher subsample numbers (Figure 5c). Only with the ocular method, and for only for two plots, did 20 subsamples reach the point where adding more subsamples would add no more species (Table 9). For the most diverse plots of each vegetation type, the average (over vegetation types) twentieth subsample added 0.53 and 0.78 species with the point-intercept and ocular methods, respectively. For the least diverse plots of each vegetation type, the average (over vegetation types) twentieth subsample added 0.19 and 0.30 species with the point-intercept and ocular methods, respectively.

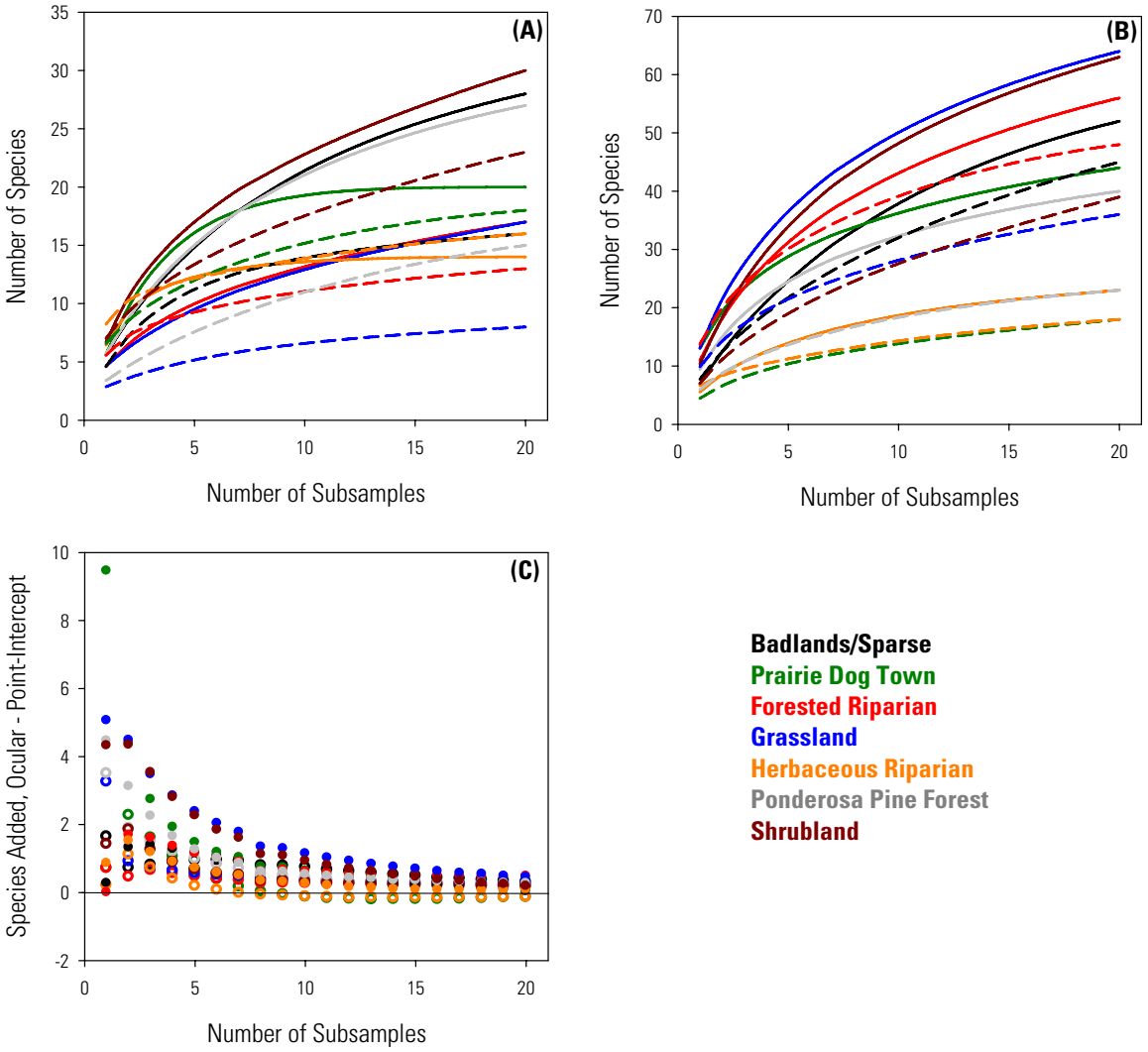


**Figure 5.** Species-sample number curves for plots with *(A)* the lowest and *(B)* the highest species richness from each vegetation type. Solid lines are for the ocular method, dashed lines for the point-intercept method. *(C)* Difference between ocular and point-intercept methods in the number of species added with an additional subsample. Open symbols are for plots with high species richness, closed symbols for plots with low species richness.

**Table 9.** Rate of species added with each subsample for the ocular and point-intercept sampling methods, based on species-subsample curves from EstimateS (Colwell 2005) for the most and least species-rich plots from each vegetation type.

[Rate of species added was calculated as the cumulative number of species in subsample *i* minus the cumulative number of species in subsample *i*-1.]

| | Badlands/Sparse | | Prairie Dog Town | | Forested Riparian | | Grassland | | Herbaceous Riparian | | Ponderosa Pine | | Shrubland | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | Ocular | Point | Ocular | Point | Ocular | Point | Ocular | Point | Ocular | Point | Ocular | Point | Ocular | Point |
| *Highest Species Richness* | | | | | | | | | | | | | | |
| 1 | 6.95 | 6.68 | 13.02 | 3.56 | 10.95 | 10.95 | 13.06 | 8.00 | 5.55 | 4.69 | 9.40 | 4.94 | 10.36 | 6.04 |
| 2 | 5.47 | 4.15 | 6.28 | 1.88 | 7.14 | 5.45 | 8.33 | 3.85 | 3.01 | 1.49 | 5.54 | 2.42 | 7.93 | 3.59 |
| 3 | 4.59 | 3.20 | 4.12 | 1.38 | 5.35 | 3.75 | 6.15 | 2.68 | 2.19 | 1.01 | 4.01 | 1.76 | 6.27 | 2.74 |
| 4 | 4.00 | 2.72 | 3.01 | 1.09 | 4.25 | 2.89 | 4.90 | 2.06 | 1.73 | 0.83 | 3.07 | 1.42 | 5.11 | 2.31 |
| 5 | 3.57 | 2.40 | 2.37 | 0.90 | 3.53 | 2.38 | 4.08 | 1.70 | 1.44 | 0.72 | 2.47 | 1.21 | 4.28 | 2.02 |
| 6 | 3.24 | 2.16 | 1.95 | 0.77 | 3.03 | 2.02 | 3.49 | 1.46 | 1.23 | 0.65 | 2.05 | 1.04 | 3.66 | 1.82 |
| 7 | 2.97 | 1.97 | 1.70 | 0.67 | 2.68 | 1.78 | 3.07 | 1.30 | 1.09 | 0.59 | 1.79 | 0.93 | 3.25 | 1.65 |
| 8 | 2.49 | 1.81 | 1.36 | 0.61 | 2.20 | 1.58 | 2.51 | 1.17 | 0.89 | 0.55 | 1.44 | 0.83 | 2.64 | 1.52 |
| 9 | 2.40 | 1.68 | 1.28 | 0.55 | 2.08 | 1.42 | 2.36 | 1.07 | 0.82 | 0.51 | 1.34 | 0.74 | 2.48 | 1.40 |
| 10 | 2.20 | 1.57 | 1.15 | 0.51 | 1.89 | 1.28 | 2.12 | 0.98 | 0.73 | 0.47 | 1.20 | 0.67 | 2.23 | 1.30 |
| 11 | 2.00 | 1.48 | 1.05 | 0.46 | 1.74 | 1.17 | 1.93 | 0.91 | 0.65 | 0.45 | 1.09 | 0.61 | 2.02 | 1.22 |
| 12 | 1.84 | 1.39 | 0.96 | 0.44 | 1.60 | 1.07 | 1.77 | 0.85 | 0.57 | 0.42 | 0.98 | 0.55 | 1.85 | 1.15 |
| 13 | 1.69 | 1.31 | 0.89 | 0.41 | 1.49 | 0.97 | 1.63 | 0.80 | 0.52 | 0.39 | 0.91 | 0.50 | 1.71 | 1.09 |
| 14 | 1.55 | 1.24 | 0.82 | 0.39 | 1.39 | 0.89 | 1.50 | 0.75 | 0.46 | 0.36 | 0.82 | 0.46 | 1.58 | 1.06 |
| 15 | 1.43 | 1.18 | 0.77 | 0.37 | 1.30 | 0.82 | 1.40 | 0.71 | 0.42 | 0.34 | 0.77 | 0.42 | 1.48 | 1.02 |
| 16 | 1.31 | 1.12 | 0.72 | 0.36 | 1.21 | 0.74 | 1.29 | 0.67 | 0.39 | 0.31 | 0.71 | 0.39 | 1.37 | 0.99 |
| 17 | 1.21 | 1.06 | 0.68 | 0.34 | 1.14 | 0.66 | 1.21 | 0.64 | 0.36 | 0.29 | 0.66 | 0.35 | 1.30 | 0.96 |
| 18 | 1.11 | 1.01 | 0.65 | 0.33 | 1.07 | 0.60 | 1.14 | 0.60 | 0.33 | 0.27 | 0.62 | 0.33 | 1.22 | 0.94 |
| 19 | 1.03 | 0.96 | 0.62 | 0.33 | 1.01 | 0.54 | 1.06 | 0.58 | 0.32 | 0.25 | 0.58 | 0.30 | 1.16 | 0.92 |
| 20 | 0.95 | 0.92 | 0.60 | 0.32 | 0.95 | 0.47 | 1.00 | 0.55 | 0.30 | 0.23 | 0.55 | 0.28 | 1.10 | 0.91 |
| *Lowest Species Richness* | | | | | | | | | | | | | | |
| 1 | 5.60 | 3.96 | 5.66 | 4.94 | 4.60 | 3.89 | 4.65 | 1.40 | 6.45 | 6.24 | 5.70 | 2.20 | 6.70 | 5.28 |
| 2 | 2.97 | 2.25 | 3.99 | 1.72 | 1.89 | 1.43 | 1.56 | 0.65 | 2.81 | 1.70 | 3.00 | 1.11 | 3.82 | 1.97 |
| 3 | 2.37 | 1.56 | 2.86 | 1.25 | 1.44 | 0.79 | 1.26 | 0.54 | 1.51 | 0.78 | 2.47 | 0.97 | 2.70 | 1.44 |
| 4 | 2.06 | 1.15 | 2.07 | 1.01 | 1.12 | 0.56 | 1.09 | 0.45 | 0.91 | 0.51 | 2.07 | 0.87 | 2.08 | 1.19 |
| 5 | 1.83 | 0.89 | 1.50 | 0.85 | 0.93 | 0.46 | 0.95 | 0.39 | 0.60 | 0.41 | 1.77 | 0.78 | 1.70 | 1.02 |
| 6 | 1.64 | 0.69 | 1.10 | 0.72 | 0.80 | 0.40 | 0.84 | 0.33 | 0.43 | 0.36 | 1.54 | 0.71 | 1.46 | 0.90 |
| 7 | 1.48 | 0.56 | 0.80 | 0.63 | 0.71 | 0.35 | 0.77 | 0.29 | 0.31 | 0.33 | 1.36 | 0.65 | 1.31 | 0.80 |
| 8 | 1.24 | 0.45 | 0.57 | 0.55 | 0.59 | 0.32 | 0.64 | 0.25 | 0.24 | 0.31 | 1.13 | 0.61 | 1.06 | 0.73 |
| 9 | 1.16 | 0.38 | 0.43 | 0.49 | 0.56 | 0.28 | 0.61 | 0.22 | 0.18 | 0.28 | 1.06 | 0.56 | 1.03 | 0.68 |
| 10 | 1.06 | 0.32 | 0.31 | 0.44 | 0.52 | 0.25 | 0.55 | 0.19 | 0.15 | 0.27 | 0.95 | 0.53 | 0.95 | 0.63 |
| 11 | 0.95 | 0.28 | 0.23 | 0.40 | 0.49 | 0.23 | 0.52 | 0.18 | 0.11 | 0.25 | 0.86 | 0.49 | 0.88 | 0.60 |
| 12 | 0.86 | 0.24 | 0.16 | 0.35 | 0.46 | 0.21 | 0.47 | 0.16 | 0.08 | 0.24 | 0.78 | 0.46 | 0.83 | 0.57 |
| 13 | 0.79 | 0.22 | 0.11 | 0.32 | 0.43 | 0.20 | 0.45 | 0.15 | 0.07 | 0.22 | 0.71 | 0.43 | 0.79 | 0.53 |
| 14 | 0.72 | 0.20 | 0.08 | 0.28 | 0.41 | 0.19 | 0.42 | 0.13 | 0.05 | 0.21 | 0.65 | 0.40 | 0.75 | 0.52 |
| 15 | 0.66 | 0.17 | 0.06 | 0.26 | 0.38 | 0.17 | 0.40 | 0.12 | 0.04 | 0.19 | 0.60 | 0.37 | 0.72 | 0.50 |
| 16 | 0.60 | 0.17 | 0.03 | 0.23 | 0.37 | 0.16 | 0.38 | 0.11 | 0.02 | 0.18 | 0.55 | 0.34 | 0.69 | 0.47 |
| 17 | 0.56 | 0.15 | 0.02 | 0.21 | 0.35 | 0.15 | 0.37 | 0.10 | 0.02 | 0.17 | 0.50 | 0.32 | 0.67 | 0.46 |
| 18 | 0.52 | 0.15 | 0.01 | 0.18 | 0.33 | 0.15 | 0.36 | 0.10 | 0.01 | 0.16 | 0.47 | 0.29 | 0.64 | 0.44 |
| 19 | 0.48 | 0.14 | 0.01 | 0.16 | 0.32 | 0.14 | 0.36 | 0.10 | 0.01 | 0.15 | 0.43 | 0.27 | 0.62 | 0.42 |
| 20 | 0.45 | 0.14 | 0.00 | 0.14 | 0.30 | 0.14 | 0.35 | 0.09 | 0.00 | 0.14 | 0.40 | 0.24 | 0.60 | 0.41 |

## Efficiency

Sampling time for the point-intercept method was significantly lower than for the ocular method ($t = 9.50$, $P < 0.001$). On average, it took 2.1 hours (SE = 0.22 hr) longer for a two-person team to complete the sampling of two transects with the ocular method than with the point-intercept method. The difference in sampling time between the methods increased with plot species richness ($r^2 = 0.26$, $P < 0.001$), but not with total canopy cover ($r^2 = 0.03$, $P = 0.291$). This was due to the fact that ocular sampling time increased significantly with plot species richness ($r^2 = 0.34$, $P < 0.001$; Figure 6a) and total canopy cover ($r^2 = 0.11$, $P = 0.025$; Figure 6b), but point-intercept sampling time did not increase with plot species richness ($r^2 = 0.02$, $P = 0.344$; Figure 6A) and only slightly with increasing total canopy cover ($r^2 = 0.09$, $P = 0.059$; Figure 6B).

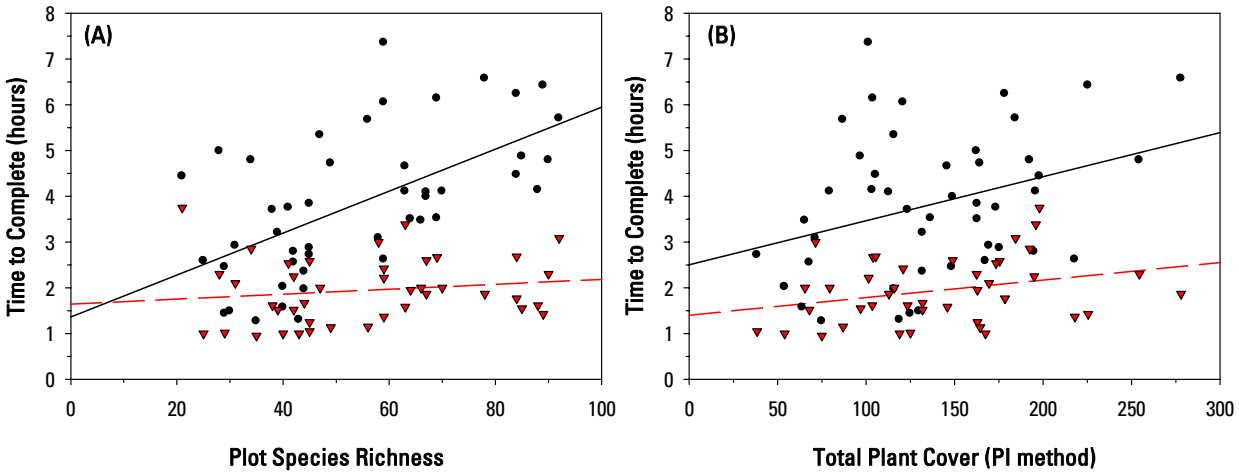


**Figure 6.** Relationship between time to complete each sampling method (ocular = black circles and solid line; point-intercept = red triangles and dashed line) and *(A)* plot species richness or *(B)* total plant cover as measured by the point-intercept method.

The two methods also differed significantly in the number of species they captured as a percentage of the number of species recorded in the plot walk-through ($t = 13.37$, df = 45, $P < 0.001$). On average, the point-intercept method captured only 44% of the species recorded in the plot walk-through, whereas the ocular method captured 68% of a plot's species. Capture rates did not vary by plot species richness or total canopy cover; correlations between capture rate and either of these variables were not significant ($P > 0.10$). Despite the lower number of species captured by the point-intercept method, this method was still more efficient than the ocular method in terms of the number of species captured per hour (difference = 3.05 ± 0.89 SE; $t = 3.43$, df = 45, $P = 0.001$).

The low species-capture rate of the point-intercept method compared to the ocular method is somewhat troubling because the rare species are often of management concern, either as newly occurring exotic species or as species more sensitive to adverse environmental conditions (e.g., over-grazing). Therefore, we investigated in more detail the difference between the two methods in their detection and precision of estimating the cover of these less abundant species. In the entire study, there were 1,749 species-plot combinations. The point-intercept method failed to capture 702 of these that the ocular method did; the average cover of these missed species (as measured by the ocular method) was 0.25%. The ocular method failed to capture 141 species-plot combinations; the average cover of these missed species (as measured by the point-intercept method) was 0.84%. Figure 7 shows the distribution, by cover, of all of these missed species-plot combinations. All of

them had cover of less than 10%, and the vast majority of them from either method had cover of less than 0.5%. Based on these results, we calculated the precision with which the ocular method estimated the cover of species with 1% and 5% cover (Table 10). The number of subsamples required to attain 20% precision (0.2 or 1 % absolute cover) is extremely high; the precision obtainable with 20 subsamples is 100-500% of the cover value, depending on vegetation type and confidence level (Table 10).

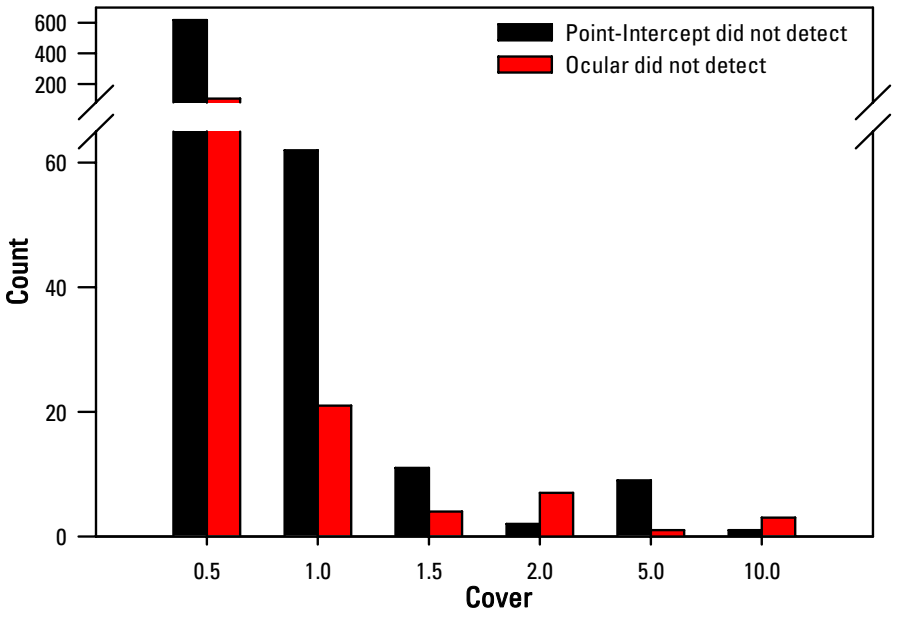


**Figure 7.** Number of times a method (point-intercept = black bars; ocular = red bars) did not detect a species that the other method did, for all 46 plots.

**Table 10.** Standard deviations (mean, minimum, and maximum) of species with 1 and 5% cover from ocular sampling method by vegetation type.

[Sample size needed for 20% precision around these values, and precision attainable with 20 subsamples with the ocular method for species with the mean standard deviation in each vegetation type are shown. α and β are the probability of type 1 and type 2 errors, respectively.]

| | | | | --N for 20% precision-- | | | | Absolute precision w/ 20 subsamples | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | Min | Max | α=0.1 | α=0.1 | α=0.05 | 20% of | α=0.1 | α=0.05 |
| **Vegetation Type** | SD | SD | SD | β=0.2 | β=0.1 | β=0.1 | Mean | β≤0.1 | β≤0.1 |
| *Species Cover = 1* | | | | | | | | | |
| BAD | 2.79 | 1.69 | 4.02 | 556 | 570 | 799 | 0.2 | 2 | 2 |
| DOG | 2.16 | 1.57 | 2.61 | 339 | 349 | 488 | 0.2 | 2 | 2 |
| FORRIP | 3.76 | 2.66 | 4.70 | 995 | 1014 | 1426 | 0.2 | 2 | 5 |
| GRASS | 2.32 | 0.67 | 3.80 | 389 | 400 | 349 | 0.2 | 2 | 2 |
| HERBRIP | 3.01 | 2.43 | 3.84 | 644 | 659 | 926 | 0.2 | 2 | 2 |
| PIPO | 2.56 | 1.93 | 4.02 | 470 | 483 | 677 | 0.2 | 2 | 2 |
| SHRUB | 2.47 | 1.34 | 4.02 | 439 | 451 | 632 | 0.2 | 2 | 2 |
| Overall | 2.65 | 0.67 | 4.70 | 503 | 516 | 723 | 0.2 | 2 | 2 |

Table 10, continued.

| Vegetation Type | Mean SD | Min SD | Max SD | --N for 20% precision-- α=0.1 β=0.2 | α=0.1 β=0.1 | α=0.05 β=0.1 | 20% of Mean | Absolute precision w/ 20 subsamples α=0.1 β≤0.1 | α=0.05 β≤0.1 |
|---|---|---|---|---|---|---|---|---|---|
| *Species Cover = 5* | | | | | | | | | |
| BAD | 13.52 | 5.66 | 21.24 | 523 | 536 | 752 | 1.0 | 10 | 10 |
| DOG | 5.50 | 3.07 | 8.17 | 94 | 100 | 138 | 1.0 | 5 | 5 |
| FORRIP | 15.78 | 5.27 | 22.14 | 706 | 722 | 1015 | 1.0 | 10 | 10 |
| GRASS | 7.31 | 4.19 | 11.65 | 161 | 168 | 233 | 1.0 | 5 | 5 |
| HERBRIP | 14.82 | 6.81 | 21.67 | 625 | 640 | 898 | 1.0 | 10 | 10 |
| PIPO | 12.66 | 8.33 | 19.65 | 460 | 473 | 663 | 1.0 | 10 | 10 |
| SHRUB | 9.67 | 7.03 | 13.70 | 274 | 283 | 396 | 1.0 | 5 | 10 |
| Overall | 10.83 | 3.07 | 22.14 | 340 | 351 | 491 | 1.0 | 10 | 10 |

# Discussion

To summarize the results:

1. The two sampling methods yielded different values for many response variables, particularly graminoid cover and species richness. However, the values from the two methods were highly correlated.
2. Using our protocols, both methods were highly repeatable for most community-level response variables (species richness with the point-intercept method being the exception) and cover of the most abundant species. Cover of less abundant species was less repeatable, and not repeatable at all for the median species with the point-intercept method.
3. The number of subsamples necessary to achieve 20% precision around the mean (an arbitrarily chosen level of precision), or, conversely, the precision obtainable with a given number of subsamples, varied considerably depending on the type of vegetation and on the response variable of interest. Neither method had considerably greater precision than the other, although overall the variability among subplots was less with the point-intercept method than with the ocular method.
4. The point-intercept method was significantly faster than the ocular method, and the time it required to complete was more consistent across variations in plot species richness and canopy cover.
5. The ocular method captured significantly more (approximately half again as many) species than the point-intercept method did. However, the point-intercept method was more efficient in terms of species capture per hour. Also, the vast majority of species missed by the point-intercept method had a cover of less than 0.5%.

All of these factors and more will need to be considered in making the final decision as to which method, and the exact form of that method (e.g., number of subsamples) will be used for the Network's long-term plant community monitoring. To make the best decision, these results must be taken in their proper context. To that end, we interpret our results and their implications for long-term monitoring.

## Comparison of Values Obtained by Each Method

The difference in values obtained for most of the community-level response variables between the two methods is not surprising. Our results are consistent with those of two other recent studies. Kercher et al. (2003) compared cover values obtained from a line-intercept method to those from ocular cover class estimates in herbaceous wetlands, and Miller et al. (2006) compared cover values of point-intercept and ocular methods very similar to ours in a variety of ecological sites in National Park Service units on the Colorado Plateau. Both of these studies found that cover values were consistently lower when measured by the ocular method than when measured with an intercept method. Miller et al. (2006) attributed much of this difference between methods to the greater cover values obtained for graminoids with the point-intercept method than the ocular method, which is also consistent with our results.

The implications of this difference in values for the two methods are three-fold. First, it implies that data from the two methods should not be compared unless one is converted to the other. The relatively high correlation coefficients between the two methods that we found for most response variables suggest that such a conversion could be quite reliable, with species richness being the exception. However, the relationships we obtained in this study may not be equally applicable across all types of vegetation. Thus, if data were to be compared between sampling methods, we advise that the methods should be carefully calibrated in the vegetation type in which the comparison will be done. This is particularly relevant to the two parks in the Network that have vegetation monitoring plots established as part of the prototype Long-Term Ecological Monitoring program. If the monitoring method used in these plots were switched from the current ocular method to the point-intercept method, the two methods should be used in all plots for a few years to obtain a clear calibration.

The second implication is that, when quantitative objectives are set for management purposes, these objectives should take into account the method by which those objectives will be measured. For example, in our study the ocular method yielded consistently lower graminoid cover values than the point-intercept method. Because some of the most abundant non-native species in Network parks are grasses (e.g., smooth brome, annual brome species, crested wheatgrass), it could be easier to reach a target of, say, 20% cover for one of these species if the measurement is done using the ocular method rather than the point-intercept method.

Finally, it is not clear which method more accurately represents the true cover of vegetation. Because the point-intercept method assumes an infinitesimally small point, but actual points used in sampling have a diameter, the point-intercept method inevitably over-estimates cover compared to the true value (Winkworth 1955). Because we used Daubenmire's (1959) polygon method, the cover values we obtained with the ocular method were also inevitably over-estimates of true cover, which would be the amount of vertical light intercepted by leaf tissue. One could conceivably evaluate the accuracy of these two methods with model vegetation, but that is beyond the scope of this project. Not knowing the accuracy of either method is not necessarily a problem for long-term monitoring, however, as long as the sampling method is consistently applied across space and through time and interpretation of the information – in setting management goals and evaluating management actions, for example – takes into account the peculiarities of the sampling method used.

## Repeatability among Observers

The high repeatability for both methods for most response variables is encouraging. Although the differences between the two teams were significant for every response variable with both methods, the differences were in most cases a relatively small proportion of the values

recorded. For example, the difference in total canopy cover between the two teams was 4.6% of the cover for the ocular method and 9.2% of the cover for the point-intercept method. In comparison, these differences are smaller than the level of precision that we obtained for these variables (Tables 7 and 8).

The ocular method seemed to have greater repeatability than the point-intercept method for total canopy cover, the cover of the second most abundant species and the cover of the median species. The greater difference between teams for total canopy cover for the point-intercept method could simply be due to the fact that the point-intercept method produced greater values of total canopy cover overall. Similarly, the ocular method's much lower difference in values between teams for median species cover is due to the fact that the cover of the median species was much lower in the ocular method (Table 7 vs. Table 8). However, the very low repeatability of the median species cover with the point-intercept method suggests that this method is not very good for estimating the cover of low-abundance species. We will discuss this topic in more detail in a later section.

We were somewhat surprised at the high repeatability of the ocular method, but our results are consistent with Miller et al. (2006), who found no significant difference in repeatability between ocular and point-intercept methods. On reflection, we think we can attribute the high repeatability of the ocular method to two factors. First, we believe we were able to be much more consistent in our estimates of graminoid cover by following the Daubenmire method of estimating the cover of an individual plant based on a polygon encompassing the plant's outer-most points than we would have if we had tried to estimate the amount of light intercepted by the foliage of a plant, a method used by some in ocular cover estimates. Second, having two people working together on each frame made it necessary for those two observers to agree on a number. This most likely moderated the tendencies of some individuals to estimate high or low compared to others (Klimeš 2003).

Despite the high repeatability of the ocular method that we found in this study, we are somewhat skeptical that this high rate could be sustained over time, particularly in the case where there is a large turnover in crew members. To illustrate, during our training at the beginning of the season, the first estimates of the cover of an individual grass species in a frame ranged from 2% to 30%. Although the individuals with the extremely low values were eventually convinced that they were underestimating the cover, it is possible that a crew in one year could all be low estimators compared to crews in other years. Thus, if the ocular method is the one chosen for long-term monitoring, we recommend that a training manual consisting of photographs of real vegetation in a sample frame and cover values assigned to each species visible in that frame be produced and used in training each year. We would recommend this even if there was little turnover between years. In addition, we would recommend establishing a standard deviation among crew members that must be attained on training plots before the crew begins sampling real plots to assure consistent levels of within-crew variability.

Repeatability of both methods could probably be improved beyond our rate if two issues are addressed. First is the issue of "tape creep". One plot in badlands vegetation at THRO (TPCM03) had particularly low compositional similarity between sampling teams (Table 5). Comparison of the data from the two teams and field notes suggest that this was primarily due to variation in the placement of the transects from one sample team to the next, in this case because of rough terrain (Figure 8a). Two other plots with relatively low similarity between teams, WPCM09 and WPCM12 (Table 5), were also on rough terrain and/or had dense woody vegetation near ground level that may have made accurate re-placement of the transects difficult (Figure 8b, c). No matter which method is used for the long-term monitoring, we highly recommend that a larger number of markers be used to designate the location of transects.


**Figure 8.** Photos of plots showing variability in terrain and obstructions to transect tapes. *(A)* TPCM03, *(B)* WPCM09, *(C)* WPCM12.

The second, and more difficult, issue is species identification, which surely caused species pseudoturnover. There were definite cases of different identification of an individual species between teams – *Schizachne purparescens* versus *Danthonia spicata* or *Alyssum desertorum* versus *Lepidium densiflorum*, for example. Also, there were many cases that suggest that one team was able to identify a species whereas the other could not. For at least two of the plots, one team had many more unknown species than did the other team. Finally, there seem to be instances in which one team was more discriminating in species identification than was the other team, in that the number of species recorded by one team but not the other was highly uneven between teams. More training of individuals on recording teams and careful attention to always having at least one team member highly skilled in plant identification on each plot may reduce this problem of repeatability, but there will always be variability in experience and skill levels of observers. One method to increase the likelihood that species will be identified the same way from year to year is to have a cumulative list of a plot's previous years' species in the field when sampling is done. We recommend that previous years' quantitative data *not* be available, however, in order to avoid influencing team members' observations.

## Precision and Number of Subsamples

The ocular method's slightly higher variability among subsamples within a plot compared to the point-intercept method's made the estimates of the response variables slightly more precise with the latter. Although it is difficult to attribute this difference to any one factor, it is possible that a large part of it was caused simply by the larger overall cover values obtained with the point-intercept method and the larger number of species captured by the ocular method. Whatever the cause of this slight difference, it did not substantially affect the precision obtainable by the two methods, as we tested them. Both provided precision of 20% around the mean on the estimates for just two of the key

community-level response variables (total canopy cover and species richness), and none of the species-level response variables. Neither method proved very good at obtaining precise measurements of cover for individual species other than the most abundant one. Also, 20 subsamples did not provide very precise estimates for any of the response variables in the most variable vegetation type, the Badlands/Sparse type.

In addition to increasing precision, adding subsamples would, in most cases, increase the number of species quantitatively sampled by either method. Species-sample number curves show that this increase would be greater for the ocular method, but the number of additional species captured by adding more subsamples would not be substantial for either method.

The most straight-forward means for adding subsamples would be to decrease the distance between subsamples – frames or points in the ocular and point-intercept methods, respectively. Subsamples could instead be added to the interior of the plot. Floyd and Anderson (1987) found that sampling more lines generally increased precision more than adding samples to a line. Whether this would hold true with our arrangement of lines is unclear because of the potential for encountering greater variability in the interior of the plot. Adding subsamples by adding lines in the interior may also capture additional species, but field comparisons would be necessary to test this.

With either method, adding more subsamples would require more sampling time at an individual plot. Since a plot contributes just one sample – not the number of subsamples – to the long-term monitoring design, the time added in increasing the precision of that one estimate must be weighed against the time that could be spent sampling another plot instead. Also, the precision estimates we generated here are useful for understanding the precision of estimates for the status of a response variable within a plot at any given time. They do not indicate the precision of the sampling methods for measuring trends over time; measurements of year-to-year variability are necessary for making these precision estimates. When such data are available, the precision estimates provided here may be used for optimizing the number of subsamples within a plot and the number of plots to meet status and trends monitoring objectives.

## Efficiency

The greatest difference between the two sampling methods as we executed them was the efficiency, both in terms of the time to complete the sampling and in the number of species captured by the method. The point-intercept method was clearly more efficient, and more predictable, in terms of time, whereas the ocular method was clearly better at capturing more species quantitatively. However, those species captured by the ocular method but missed by the point-intercept method all had relatively low abundance. As shown and discussed above, the precision on the estimate of their abundance is quite low. Thus, we believe that the greater species capture of the ocular method does not make up for the greater amount of time that it takes to complete.

The amount of time needed to complete the ocular method could be reduced by using cover classes instead of estimating cover to the nearest 1%. In this case, the standard practice for data analysis is to use the mid-point of the cover class as the datum for a species. Analyses then treat the data as continuous. This practice has been questioned, however, because plant abundances generally are not distributed evenly around the midpoint of a cover class, and using analytical methods designed for continuous data for ordinal data is not legitimate (Podani 2006). It is for these reasons that we did not use cover classes in this study and we do not think they should be used for long-term monitoring.

The difference in completion time between the two methods is substantial enough to significantly impact the number of plots that could be sampled in a given field season. The average amount of time to complete the ocular method was 3.8 hours (for two people), whereas it was exactly half that (1.9 hours for two people) for the point-intercept method. Thus, a team of four people (the usual sample team size) could complete the ocular and point-intercept sampling in 1.9 and 0.95 hours, respectively. If plot set-up, tear-down, and compiling the plot-wide species list required an additional 1.5 hours, the total time for the ocular and point-intercept methods would be 3.4 and 2.4 hours, respectively. In a 10-hour day, completing three plots with the point-intercept method would be

doable, whereas it would be impossible with the ocular method since considerable travel time to plots is often involved.

Travel time to plots must be considered in the final decision of which method will be used. In many of the parks in this Network, travel time is insubstantial compared to the amount of time spent sampling a site. However, at the three largest parks, the amount of time it takes to reach a sampling site could easily be greater than the amount of time necessary to do the sampling. Consequently, the argument could be made that the benefit of obtaining more or better information at a distant site outweighs the cost of extra time at a site to obtain that information. The question in our case, then, is whether the information obtained by the ocular method is truly more or better than that obtained with the point-intercept method. We address this further in the Conclusions and Recommendations section below.

### Impacts of Sampling on Vegetation

Although we did not quantitatively measure the impacts of the two sampling methods on the areas sampled, we did make some observations that are relevant to deciding which method to use for long-term sampling. With the point-intercept method, the person recording the data generally sits or stands at least a couple of meters from the transect, usually on the outside of the plot. The person doing the measurements walks along the transect, generally standing or kneeling (if necessary to identify a species) at any given point for a short amount of time (3 to 60 seconds). The area walked on in the course of this sampling is thus a fairly continuous line of short-duration impact. With the ocular method, since both team members are making the observations, both stand or kneel close to the frame that is being sampled, usually one on each side. The amount of time spent at an ocular frame ranged from 0 to 78 minutes, with the mean and median being 12 and 10 minutes, respectively. Thus, the area impacted with this method was longer duration, but more spatially concentrated, than with the point-intercept method. In most cases, the area trampled by sampling was not visible after a few days, but in areas with sparse cover and/or steep terrain, or in the wet vegetation of the Herbaceous Riparian areas at AGFO, trampling was still visible at least a week after the initial sampling.

## Conclusions and Recommendations

Based on our results, there is no clear-cut advantage of using one method over the other. However, we recommend the point-intercept method for long-term plant community composition monitoring in the Northern Great Plains Network for the following reasons. First, it is faster, probably has less physical impact on the vegetation, and is as repeatable as the ocular method. Second, the Fire Effects program has been using this method in eight of the 12 parks in which plant community composition will be monitored; in some parks, this monitoring began in 1998. On the other hand, a variation on the ocular method has been used in only two parks in the Network, since 1997.

Although others have also recommended the point-intercept method over the ocular method for its greater efficiency (e.g., Floyd and Anderson 1987), some have argued that the large number of species that are missed by this method make it undesirable (Stohlgren et al. 1998). Our results suggest that the precision on the cover estimates for the species that are missed by the point-intercept method is quite low anyway. However, we are concerned about missing these low-abundance species. Consequently, we recommend the following modifications to the protocols we followed in this pilot study to increase the amount and quality of information collected on these low-abundance species:

1. Sample more transects in each plot. Adding five evenly spaced, 20-m transects perpendicular to the two 50-m transects (Figure 9) would hopefully capture a greater number of species because the coverage of the plot's area would be more complete. The endpoints of these additional transects would be permanently marked to reduce tape creep on the 50 m transects. The distribution of points along these transects (i.e., whether the number of points for the whole plot would be greater than the 200 we used in this study or if the 200 points would be re-distributed among all transects) will depend on whether a larger number of subsamples is desired. If the number of points is kept

the same, we anticipate that this rearrangement of points would substantially increase neither the sampling time nor the amount of trampling of the plot, since the amount of time spent at an individual point would not be significantly greater than that spent in the plot-wide species search. However, we will test these assumptions on a small number of plots before incorporating this change into the protocol.

2. For all species on the plot-wide species list, assign an abundance-dominance or cover class based on their abundance in the whole plot. The Braun-Blanquet (Mueller-Dombois and Ellenberg 1974) and modified Daubenmire scales (Table 11) are two examples of scales that could be used. These ordinal data could be analyzed using ordinal methods, or they could simply be used as background information for interpreting trends in the more quantitative data collected with the point-intercept method. Because of its slightly greater resolution of the lower cover classes (the end of the scale we are most interested in for this part of the protocol), we recommend the Braun-Blanquet scale.

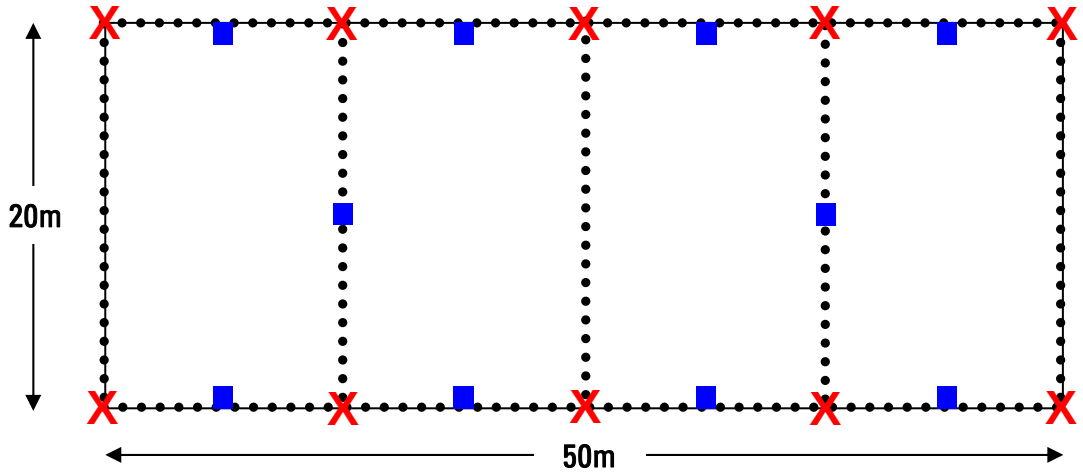


**Figure 9.** Suggested modification of transect layout for point-intercept sampling. Red "X" indicates permanent marker. Black dots are approximate locations of points, spaced at 1-m intervals. Blue boxes are 1-$m^2$ species-occurrence subplots.

**Table 11.** Potential cover class scales to use for recording abundance of species in 1000 $m^2$ plot.

| Braun-Blanquet | | modified Daubenmire | |
|---|---|---|---|
| **Class** | **Cover-Abundance** | **Class** | **Cover** |
| r | one individual – insignificant cover | 1 | <1% |
| + | few individuals – insignificant cover | 2 | 1-5% |
| 1 | scattered individuals – 1-5% cover | 3 | 6-25% |
| 2 | 6-25% cover | 4 | 26-50% |
| 3 | 26-50% cover | 5 | 51-75% |
| 4 | 51-75% cover | 6 | 76-95% |
| 5 | 76-100% cover | 7 | 96-100% |

A substantial modification to address this issue that would take more time but could have substantial benefits would be to measure species occurrence in subplots (e.g., 1 $m^2$) within the 0.1 ha plot. An example of a potential arrangement of such plots is shown by the blue squares in Figure 9. One benefit of adding this type of sampling is greater comparability of species richness values to those in most published literature, as well as to those obtained by the Heartland I&M Network and potentially other I&M Networks that will be sampling grassland vegetation. In addition, data from

these plots could be used for measuring frequency of occurrence or investigating spatial dispersion patterns of species within the plots. Finally, by forcing the search of small subplots for individual species, it is less likely that species will be missed for the whole-plot species list. The amount of time spent on a modification like this, as well as the extra trampling of the vegetation that would occur, would have to be tested in the field and weighed against the benefits of obtaining this information. For example, Figure 9 shows 10 subplots in a 0.1 ha plot. Although this number is not enough to yield 20% precision of the estimate of species richness for any but the grassland and prairie dog town vegetation types (Table 7), preliminary analyses of data from Scotts Bluff National Monument and AGFO suggest that it would be enough to detect a change of 1.5 species at a single site. More data from different vegetation types and more thorough analyses are needed before a decision as to whether the extra time spent on this effort would be beneficial.

Additional modifications that could resolve some issues encountered during the course of this study include:

1. Follow an established classification of ground cover. Examples include those used by the Natural Resource Conservation Service for rangeland sampling. This will eliminate dissatisfaction expressed by crew members with our definition of "rock" as anything larger than a dime, vs. "soil" as anything the size of a dime or smaller.
2. For woody species, record both live and dead material attached to a live plant in the herbaceous layer, but distinguish between live and dead material. This will be consistent with current Fire Effects monitoring protocols (USDI National Park Service 2003) and will provide useful information in the case of shrub die-back.

Other issues that need to be resolved to complete the protocol for plant community sampling include:

1. Whether biomass and/or structure of herb-layer vegetation (< 2 m height) will be measured. As we explained in the Introduction, we would not consider measuring biomass by individual species because of the logistical problems. However, because of the relevance of standing biomass to both fire behavior and forage availability, some or all parks may want information on the total standing biomass in the herb layer. Structure, measured as height or height/density (Robel et al. 1970, Benkobi et al. 2000) is of particular relevance to grassland nesting birds and could, with calibration, be used as a surrogate for standing biomass.
2. Shape and distribution of subplots for sampling woody vegetation greater than 2 m tall (trees, poles, and saplings).
3. The amount of heterogeneity allowable within a plot, and whether we should maintain the practice of aligning the long edge of a plot parallel to the topographic contours. By following this rule, the expectation is that heterogeneity within the plot will be decreased, although the validity of this assumption is not clear at the scale of a 20 m x 50 m plot (Keeley and Fotheringham 2006). In addition, this does not necessarily provide a representative sample of the park as a whole. This issue is particularly relevant in areas where there are steep topographic and vegetation gradients in small areas, such as in woody draws or along streams.
4. The spatial and temporal sampling distribution of plots within and across parks.

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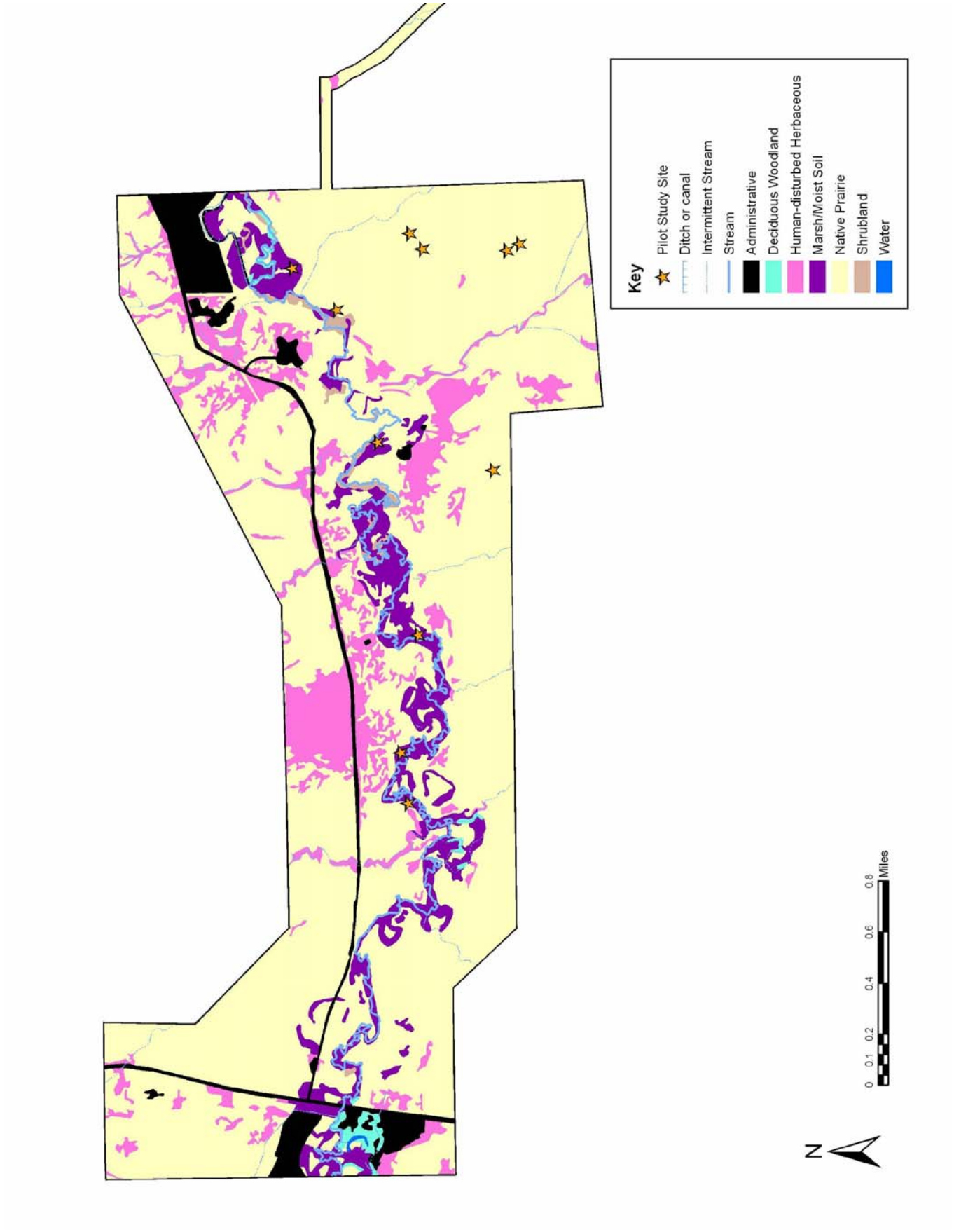
# Appendix A

# Maps and GPS Coordinates of Plots Used in Methods Comparison Study

Notes: All GPS coordinates are in UTM units following the NAD 83 projection, Zone 13T. Maps show broad vegetation categories based on vegetation mapping from the National Vegetation Classification System. Specific sources of vegetation maps are described in the Methods section of the main text under “Sample Sites.”

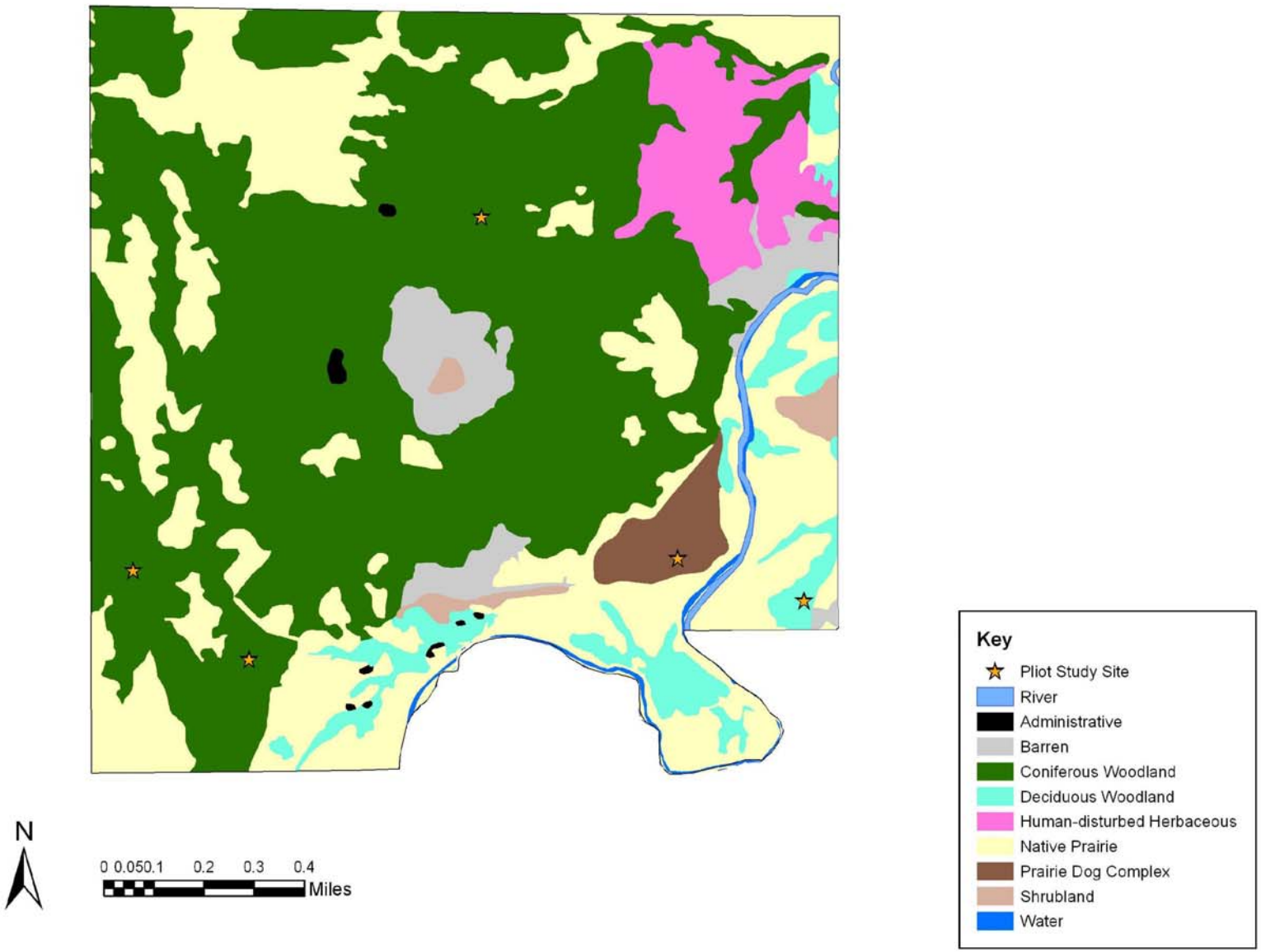
## Agate Fossil Beds National Monument (AGFO)

| Plot | Vegetation Type | Corner | Northing | Easting |
|---|---|---|---|---|
| APR02 | Herbaceous riparian | A0 | 4697797.56 | 604714.65 |
| | | A50 | 4697751.30 | 604689.30 |
| | | B0 | 4697808.00 | 604695.95 |
| | | B50 | 4697762.94 | 604670.58 |
| APR03 | Herbaceous riparian | A0 | 4697262.29 | 603619.51 |
| | | A50 | 4697303.54 | 603588.89 |
| | | B0 | 4697274.44 | 603635.23 |
| | | B50 | 4697315.10 | 603605.05 |
| APR04 | Herbaceous riparian | A0 | 4697003.73 | 602407.59 |
| | | A50 | 4697053.15 | 602405.54 |
| | | B0 | 4697002.20 | 602425.71 |
| | | B50 | 4697053.42 | 602424.52 |
| APR05 | Herbaceous riparian | A0 | 4697113.25 | 601666.13 |
| | | A50 | 4697121.47 | 601617.01 |
| | | B0 | 4697093.53 | 601662.45 |
| | | B50 | 4697101.73 | 601612.00 |
| APR06 | Herbaceous riparian | A0 | 4697066.92 | 601348.09 |
| | | A50 | 4697105.51 | 601379.75 |
| | | B0 | 4697054.64 | 601364.16 |
| | | B50 | 4697093.22 | 601394.94 |
| LTEM03 | Grassland | A0 | 4696978.49 | 604837.81 |
| | | A50 | 4696934.17 | 604859.32 |
| | | B0 | 4696987.33 | 604855.82 |
| | | B50 | 4696942.34 | 604877.31 |
| LTEM04 | Grassland | A0 | 4696446.57 | 604828.22 |
| | | A50 | 4696414.14 | 604865.99 |
| | | B0 | 4696461.85 | 604840.97 |
| | | B50 | 4696428.81 | 604879.07 |
| LTEM05 | Grassland | A0 | 4696367.29 | 604868.98 |
| | | A50 | 4696339.51 | 604910.28 |
| | | B0 | 4696359.37 | 604863.74 |
| | | B50 | 4696332.05 | 604905.15 |
| LTEM07 | Grassland | A0 | 4697056.82 | 604936.26 |
| | | A50 | 4697009.11 | 604949.95 |
| | | B0 | 4697051.14 | 604917.24 |
| | | B50 | 4697003.53 | 604930.91 |
| LTEM08 | Grassland | A0 | 4697519.44 | 604452.38 |
| | | A50 | 4697472.23 | 604436.04 |
| | | B0 | 4697527.40 | 604434.12 |
| | | B50 | 4697480.35 | 604417.79 |
| LTEM11 | Grassland | A0 | 4696571.18 | 603477.59 |
| | | A50 | 4696533.17 | 603444.89 |
| | | B0 | 4696584.30 | 603461.92 |
| | | B50 | 4696545.62 | 603429.95 |


Key
Pilot Study Site
Ditch or canal
Intermittent Stream
Stream
Administrative
Deciduous Woodland
Human-disturbed Herbaceous
Marsh/Moist Soil
Native Prairie
Shrubland
Water
0 0.1 0.2 0.4 0.6 0.8
Miles
N

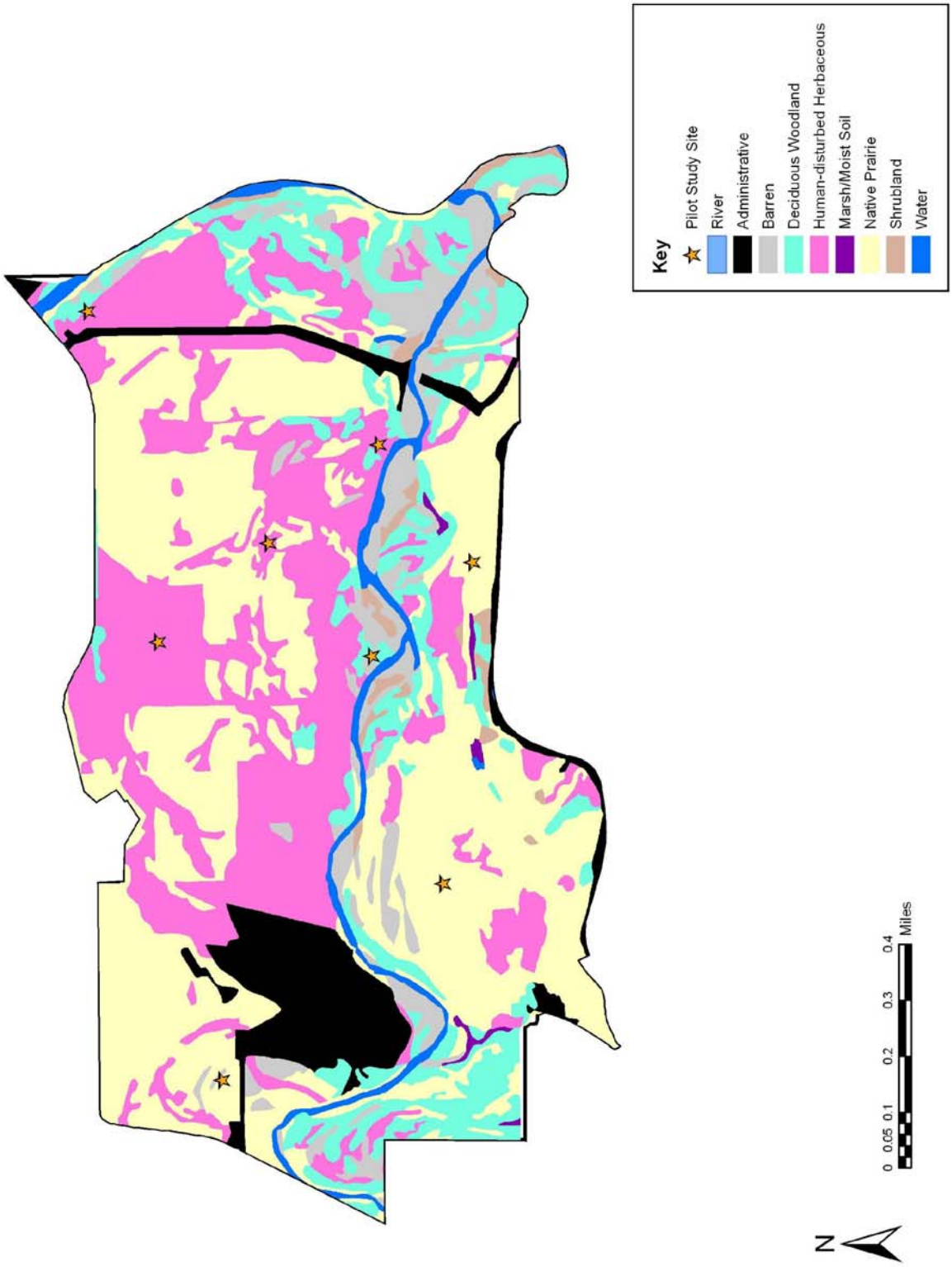
## Devils Tower National Monument (DETO)

| Plot | Vegetation Type | Corner | Northing | Easting |
|---|---|---|---|---|
| DPCM01 | Prairie dog town | A0 | 4936909.50 | 523297.31 |
| | | A50 | 4936945.28 | 523332.40 |
| | | B0 | 4936895.24 | 523312.59 |
| | | B50 | 4936930.51 | 523347.24 |
| DPCM02 | Forested riparian | A0 | 4936773.75 | 523703.78 |
| | | A50 | 4936742.20 | 523665.82 |
| | | B0 | 4936790.23 | 523690.53 |
| | | B50 | 4936757.72 | 523652.98 |
| DPCM03 | Pine woodland | A0 | 4936585.83 | 521923.11 |
| | | A50 | 4936567.82 | 521967.06 |
| | | B0 | 4936599.84 | 521929.72 |
| | | B50 | 4936585.42 | 521976.28 |
| DPCM04 | Pine woodland | A0 | 4936871.55 | 521550.77 |
| | | A50 | 4936907.75 | 521506.79 |
| | | B0 | 4936891.26 | 521565.18 |
| | | B50 | 4936921.52 | 521525.05 |
| DPCM05 | Pine woodland | A0 | 4938004.57 | 522668.91 |
| | | A50 | 4938052.21 | 522662.35 |
| | | B0 | 4938011.19 | 522687.62 |
| | | B50 | 4938058.84 | 522682.34 |


N
0 0.050.1 0.2 0.3 0.4
Miles
Key
Pliot Study Site
River
Administrative
Barren
Coniferous Woodland
Deciduous Woodland
Human-disturbed Herbaceous
Native Prairie
Prairie Dog Complex
Shrubland
Water

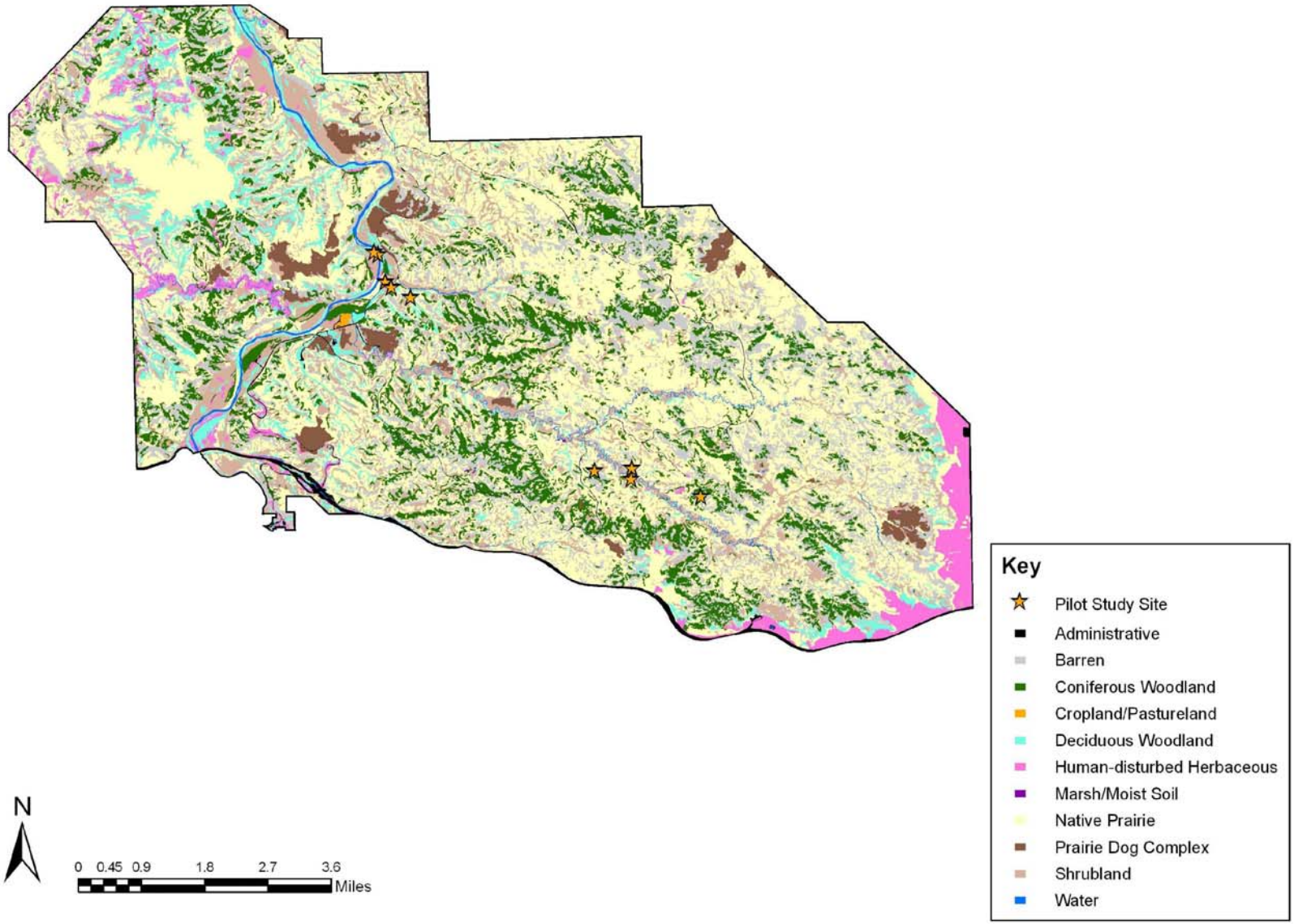
## Fort Laramie National Historic Site (FOLA)

| Plot | Vegetation Type | Corner | Northing | Easting |
|---|---|---|---|---|
| FP01 | Forested riparian | A0 | 4673108.24 | 538504.55 |
| | | A50 | 4673148.29 | 538475.61 |
| | | B0 | 4673120.36 | 538517.85 |
| | | B50 | 4673158.74 | 538492.03 |
| FP04 | Grassland | A0 | 4672906.24 | 537554.98 |
| | | A50 | 4672894.82 | 537507.08 |
| | | B0 | 4672886.38 | 537507.08 |
| | | B50 | 4672873.68 | 537511.85 |
| FP07 | Grassland | A0 | 4672722 | 536298 |
| | | A50 | missing | missing |
| | | B0 | missing | missing |
| | | B50 | missing | missing |
| FP11 | Grassland | A0 | 4672589.49 | 537838.82 |
| | | A50 | 4672592.31 | 537788.25 |
| | | B0 | 4672568.58 | 537835.91 |
| | | B50 | 4672572.82 | 537785.89 |
| FP16 | Sparse vegetation | A0 | 4672292.32 | 537514.23 |
| | | A50 | 4672323.8 | 537472.59 |
| | | B0 | 4672275.42 | 537496.43 |
| | | B50 | 4672309.41 | 537459.20 |
| FP18 | Grassland | A0 | 4672272.88 | 538121.66 |
| | | A50 | 4672259.30 | 538174.53 |
| | | B0 | 4672288.78 | 538125.58 |
| | | B50 | 4672277.90 | 538174.68 |
| FP21 | Grassland | A0 | 4672087.77 | 536862.30 |
| | | A50 | 4672087.97 | 536909.61 |
| | | B0 | 4672105.87 | 536858.68 |
| | | B50 | 4672117.01 | 536907.18 |
| FP24 | Grassland | A0 | 4672004.22 | 537783.92 |
| | | A50 | 4672003.36 | 537833.48 |
| | | B0 | 4672022.63 | 537784.50 |
| | | B50 | 4672023.23 | 537835.40 |


Key
Pilot Study Site
River
Administrative
Barren
Deciduous Woodland
Human-disturbed Herbaceous
Marsh/Moist Soil
Native Prairie
Shrubland
Water
0 0.05 0.1 0.2 0.3 0.4
Miles
N

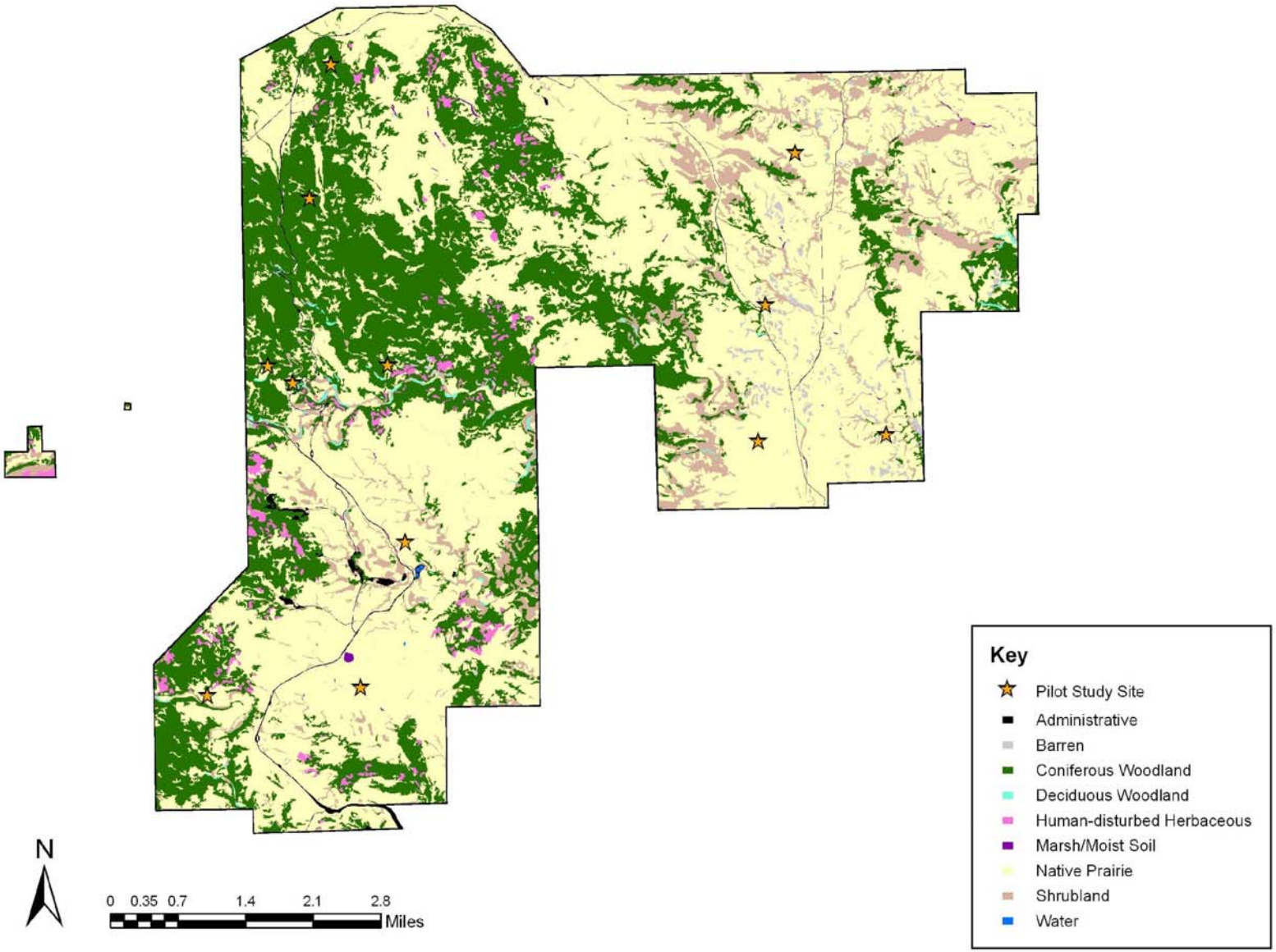
## Theodore Roosevelt National Park (THRO)

| Plot | Vegetation Type | Corner | Northing | Easting |
|---|---|---|---|---|
| TPCM01 | Badlands/Sparse | A0 | 5198413 | 620406 |
| | | A50 | 5198457 | 620433 |
| | | B0 | 5198406 | 620426 |
| | | B50 | 5198448 | 620450 |
| TPCM02 | Badlands/Sparse | A0 | 5198410 | 620405 |
| | | A50 | 5198402 | 620357 |
| | | B0 | 5198390 | 620411 |
| | | B50 | 5198383 | 620361 |
| TPCM03 | Badlands/Sparse | A0 | 5198163 | 620386 |
| | | A50 | 5198128 | 620419 |
| | | B0 | 5198148 | 620373 |
| | | B50 | 5198112 | 620408 |
| TPCM04 | Badlands/Sparse | A0 | 5197763 | 621985 |
| | | A50 | 5197804 | 621959 |
| | | B0 | 5197762 | 621978 |
| | | B50 | 5197802 | 621950 |
| TPCM06 | Shrubland | A0 | 5202319 | 615330 |
| | | A50 | 5202314 | 615381 |
| | | B0 | 5202339 | 615333 |
| | | B50 | 5202332 | 615382 |
| TPCM07 | Shrubland | A0 | 5202671 | 614754 |
| | | A50 | 5202685 | 614803 |
| | | B0 | 5202687 | 614751 |
| | | B50 | 5202704 | 614796 |
| TPCM08 | Shrubland | A0 | 5202548 | 614889 |
| | | A50 | 5202512 | 614922 |
| | | B0 | 5202561 | 614903 |
| | | B50 | 5202526 | 614938 |
| TPCM09 | Shrubland | A0 | 5203299 | 614593 |
| | | A50 | 5203337 | 614564 |
| | | B0 | 5203311 | 614608 |
| | | B50 | 5203349 | 614579 |
| TPCM10 | Forested riparian | A0 | 5203356 | 614494 |
| | | A50 | 5203350 | 614544 |
| | | B0 | 5203375 | 614497 |
| | | B50 | 5203370 | 614546 |
| TPCM11 | Badlands/Sparse | A0 | 5198355 | 619550 |
| | | A50 | 5198362 | 619501 |
| | | B0 | 5198377 | 619552 |
| | | B50 | 5198380 | 619502 |


Key
Pilot Study Site
Administrative
Barren
Coniferous Woodland
Cropland/Pastureland
Deciduous Woodland
Human-disturbed Herbaceous
Marsh/Moist Soil
Native Prairie
Prairie Dog Complex
Shrubland
Water
N
0 0.45 0.9 1.8 2.7 3.6
Miles

Wind Cave National Park (WICA)

| Plot | Vegetation Type | Corner | Northing | Easting |
|---|---|---|---|---|
| WPCM01 | Prairie dog town | A0 | 4821763.64 | 622949.14 |
| | | A50 | 4821723.68 | 622979.79 |
| | | B0 | 4821776.44 | 622964.52 |
| | | B50 | 4821735.86 | 622994.31 |
| WPCM02 | Prairie dog town | A0 | 4825866.38 | 629569.93 |
| | | A50 | 4825860.63 | 629519.34 |
| | | B0 | 4825845.58 | 629573.36 |
| | | B50 | 4825840.44 | 629523.19 |
| WPCM03 | Grassland | A0 | 4830670.72 | 630181.62 |
| | | A50 | 4830623.31 | 630195.54 |
| | | B0 | 4830677.06 | 630200.99 |
| | | B50 | 4830629.04 | 630214.48 |
| WPCM04 | Grassland | A0 | 4824182.01 | 623689.34 |
| | | A50 | 4824138.63 | 623663.70 |
| | | B0 | 4824193.61 | 623672.22 |
| | | B50 | 4824150.24 | 623647.02 |
| WPCM05 | Grassland | A0 | 4825977.02 | 631701.87 |
| | | A50 | 4826008.44 | 631662.69 |
| | | B0 | 4825992.77 | 631714.56 |
| | | B50 | 4826023.58 | 631674.96 |
| WPCM06 | Pine woodland | A0 | 4829911.24 | 622098.86 |
| | | A50 | 4829943.97 | 622063.62 |
| | | B0 | 4829911.55 | 622115.75 |
| | | B50 | 4829947.86 | 622080.44 |
| WPCM07 | Pine woodland | A0 | 4827121.90 | 621401.09 |
| | | A50 | 4827092.57 | 621360.90 |
| | | B0 | 4827106.11 | 621417.84 |
| | | B50 | 4827080.30 | 621374.55 |
| WPCM09 | Shrubland | A0 | 4828137.13 | 629691.97 |
| | | A50 | 4828159.57 | 629650.39 |
| | | B0 | 4828152.79 | 629700.33 |
| | | B50 | 4828177.01 | 629658.28 |
| WPCM10 | Forested riparian | A0 | 4826830.31 | 621819.66 |
| | | A50 | 4826829.36 | 621767.26 |
| | | B0 | missing | missing |
| | | B50 | 4826823.39 | 621865.28 |
| WPCM11 | Grassland | A0 | 4821630.89 | 620390.52 |
| | | A50 | 4821642.55 | 620342.62 |
| | | B0 | 4821612 | 620386 |
| | | B50 | 4821622.79 | 620337.33 |
| WPCM12 | Pine woodland | A0 | 4827132.69 | 623396.69 |
| | | A50 | 4827184.52 | 623395.31 |
| | | B0 | 4827125.20 | 623378.20 |
| | | B50 | 4827174.09 | 623379.47 |
| WPCM13 | Pine woodland | A0 | 4832137.17 | 622454.39 |
| | | A50 | 4832168.29 | 622493.65 |
| | | B0 | 4832157.27 | 622445.37 |
| | | B50 | 4832184.76 | 622482.09 |


N
0 0.35 0.7 1.4 2.1 2.8
Miles
Key
Pilot Study Site
Administrative
Barren
Coniferous Woodland
Deciduous Woodland
Human-disturbed Herbaceous
Marsh/Moist Soil
Native Prairie
Shrubland
Water

# Appendix B

# Preliminary Operating Procedures Followed for Field Sampling in Methods Comparison Study

# Preliminary Operating Procedure (POP) 1: Establishing and Marking Permanent Sample Plots

Version 1.1 (March 2006)

Description: This POP gives step-by-step instructions for establishing and marking sample plots. It provides instructions for marking transect ends and the correct procedure for labeling rebar tags.

## I. Equipment List

- Park map showing site location
- GPS unit (1)
- Clinometer (1)
- Compass (1)
- Digital camera
- Pliers
- Corner markers: 7" galvanized pole barn nails (4) and 1-3/8" outer-diameter galvanized washers (4) OR 24" rebar with one end bent over (4)
- Hammer
- Labeled tags
- Wire
- 50-m tapes marked for point-intercept (2)
- 30-m tapes (2)
- Data Form 1

## II. Procedures

1. Sample sites are located within each park using varying criteria for each park. The plot establishment team goes to the designated site using a hand-held GPS receiver in which previously designated coordinates, in the UTM NAD83 projection, are stored. This point serves as the A0 corner of the plot.
2. The primary sampling unit is a 50 m x 20 m rectangular plot with the 50-m transects running parallel to topographic contours. The upslope (A) transect is laid out first. At the site GPS coordinates one plot marker is sunk into the ground (nail through a washer) so that approximately 5 cm of the marker is above the ground level. This is designated corner A0. An azimuth that runs parallel to the contours is determined. Since two possible directions (one 180° from the other) are possible with this instruction, a coin is flipped to choose which direction will be used. If the area is flat, an azimuth is chosen randomly. A 50-m tape is then run out 50 m along this azimuth and a second marker into the ground; this is corner A50. An azimuth perpendicular to and heading down slope from the first transect line is determined using the 3-4-5 rule of legs and hypotenuse of a right triangle and the appropriate tapes. If the area is flat, a coin is flipped to determine which direction is "down slope." The endpoint of the second transect (corner B50 on transect B) is established 20 m from A50 on this azimuth, with the third corner marker being driven into the ground here. The final corner (B0) is established by running a second 50-m tape parallel to and 20 m from transect A and driving the fourth marker into the ground at this point. Squareness of all corners and distances are checked to ensure that the plot is a 20 m x 50 m rectangle. The area of the rectangle for the plot is based on slope distance (the area on the ground) rather than on horizontal distance, as this is the truest representation of the area on the ground. **Note** that all plot markers should protrude approximately 5 cm from the ground surface – this low profile reduces the chance of vandalism to the markers, excessive interest in the plot by people or wildlife, and injury to human or non-human passers-by.
3. Once all four corner markers are established, brass tags labeled with plot information as shown in Figure B1.1 are attached to each marker with wire.
4. Three photos are taken at the sampling plot. The "Overview" photo is taken from a point in the vicinity of the plot so that it captures as much of the plot as possible (with tapes in place) in the greater landscape context. The location of the "Transect A" photo is 10 m outside the plot from the A0 corner on the line extending Transect A. The photo is directed towards the A50 corner, along the transect. The "Transect B" photo is located and directed similarly, except that it is taken 10 m outside the plot from the B50 corner, looking towards the B0 corner. Photo numbers for each photo are recorded on Data Form 1.
5. Relocation data for each transect are collected. GPS coordinates for all four corners of the plots are taken using real-time differential correction for the GPS, which yields approximately 1-m accuracy. Metadata are recorded on Data Form 1 "Plot Location and Description Sheet for Plant Community Monitoring" (see section III for detailed instructions on Data Form 1).

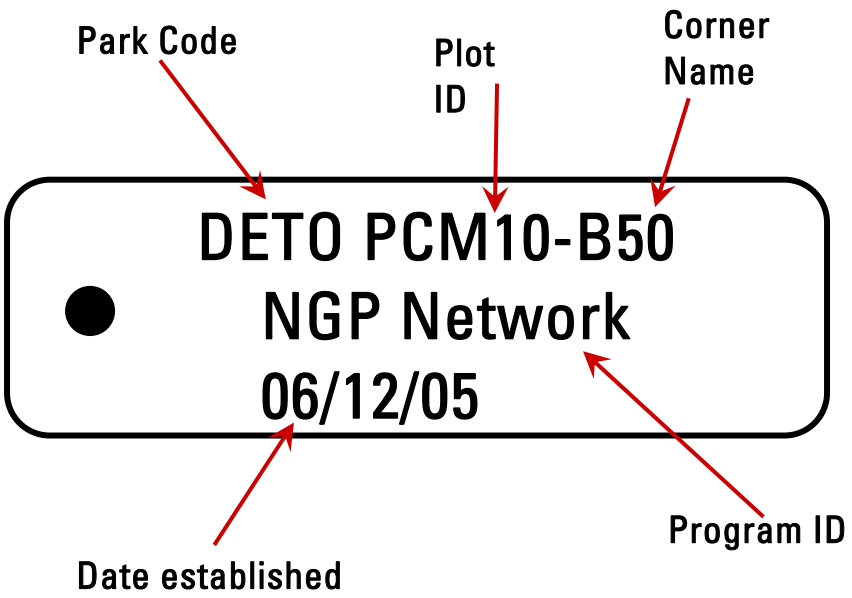



**Figure B1.1.** Example tag for plot corner markers. Format shown is for tags on the A0 corner; A50, B0, and B50 tags have only the tag (corner) name and establishment date.

## III. Collecting and Recording Data

When a plot is initially established, Data Form 1 "Plot Location and Description Sheet for Plant Community Monitoring" is filled out by the field crew involved in the plot installation. The intent of the survey is to prompt the field crew to leave a description that others can follow to re-locate the plot and to assist in characterizing the structure and composition of the site. Notes about the plots should also be noted on this datasheet, including information about disturbance that appears to have occurred.

**Park:** A unique 4 digit code (example: AGFO Agate Fossil Beds National Monument)

**Park Unit:** Management unit or other descriptive location name (example: Carnegie Hill Unit)

**Plot ID:** A unique sample unit identification (example: DPCM10, where D stands for Devils Tower NM and PCM stands for "Plant Community Monitoring")

**Establishment date:** Include month / day / year (mm/dd/yyyy)

**Established by:** Provide the unique initials (example: AJS, Amy J. Symstad) or full names of the people that established the plot.

**UTM Zone:** UTM zone for UTM coordinates

**UTM N and UTM E:** UTM northerly and easterly coordinates, respectively, for each of the four corners of the plot.
**NOTE: All GPS work is done using the UTM NAD83 projection!!!!**

**Description of route to the plot:** Describe the location of the plot and a reasonable route to get there using permanent landmarks as reference points. Ideally, a crew that has never been to this site would

be able to find the plot using this description without the aid of a GPS unit. Useful information in this description includes a safe parking spot and routes that do NOT work because of hazardous terrain, water crossing, etc.

**Azimuth of transects (from 0 – 50 m):** Recorded to the nearest one degree. Make sure the declination on your compass is correct for your location, so that all compass directions are true.

**Monumenting:** Describe the type of corner markers used (nails, rebar, etc.), since this may vary among parks.

**Other monumenting notes:** If possible, describe the exact location of one or more plot corners with respect to landmarks such as trees (e.g., list species, dbh, height, location with respect to corner), large rocks, or streams in close vicinity to the corner.

**Slope angle (%):** Use the clinometer to measure slope sighting from Transect A to Transect B. Sight slope angle at both transect ends. Specifically, for the A0 to B0 reading, stand at the A0 plot corner. Look through the clinometer with your right eye while sighting an object at your eye's height (e.g., another team member holding a card at your eye's height) located at the B0 plot corner with your left eye. Do the same for the A50 to B50 reading. Record each reading in percent (not degrees!), which is usually the right-hand column of numbers in the clinometer. It is important to remember that percent slope changes more quickly than degrees slope, e.g., 45 degrees slope = 100 percent slope.

**Slope aspect (deg):** Dominant aspect readings are taken at two points in the plot, at the beginning and end of transect A (A0 and A50). Slope aspect can be obtained by determining the main direction that water would flow from the observed point. Slope aspect is measured to the nearest degree.

**Terrain shape:** Describe or sketch, using transect ends for reference.

**Topographic position:** Circle the overall topographic position of the plot using the provided NVCS terminology and definitions. Categories include:
Level – no slope

Lower-slope – gently inclined surface at the base of a slope, commonly gentle and almost linear in surface profile

Mid-slope – intermediate slope position

Upper-slope (high slope, shoulder slope) – the uppermost inclined surface at the top of a slope, typically convex in profile

Crest (interfluve, summit, ridge) – linear top of a ridge, hill or mountain; the elevated area between two drainage-ways that sheds water

Ledge (terrace) – nearly level shelf interrupting a steep slope or cliff face

Depression – bottom surface of a basin

Streambed – bed of single or braided watercourse, typically barren and formed of modern alluvium

**Hydrologic regime:** Circle the overall hydrology of the plot using the provided descriptive modifiers from NVCS. Categories include:
Permanently flooded – water covers the surface at all times of the year in all years

Semi-permanently flooded – surface water persists throughout the growing season in most years; land surface is generally saturated when the water level drops below the surface

Seasonally/temporarily flooded – surface water is present for extended periods during the growing season, but is absent by the end of the growing season in most years; the water table is normally very variable

Intermittently flooded – surface water is present during times of increased precipitation, but generally dry

Seep – intermittent, seasonal, or permanent flow of water from a subterranean source that is generally confined to a relatively discrete area

Upland – the plot cannot be characterized as a wetland as it either sheds or absorbs water quickly; the water table is almost always well below the soil surface

**Surface water:** This is the distance to standing water. Categories to choose from are: (1) in plot; (2) <50 m away; and (3) >50 m away.

**Vegetation type:** Circle corresponding description, sample categories include:
Upland Prairie – prairie with well drained soils

Riparian Woodland – open stands of trees with crowns not usually touching, generally forming 25-60% cover, located in riparian area

Rocky site – prairie area with large amount of exposed rock

**Notes about plot:** Describe anything noteworthy, including recent disturbances (bison wallow, fire, windthrow, etc.)

**Photos:** List photo numbers and file names, as well as a description of where the "Overview" photo was taken from so that it can be taken from the same location in the future.

# Preliminary Operating Procedure (POP) 2: Ocular Cover Estimates of Herbaceous and Shrub Species

Version 1.1 (March 2006)

Description: This POP gives step-by-step instructions for obtaining ocular cover estimates of herbaceous and shrub species in 0.5-$m^2$ quadrats along 50-m transects. Detailed instructions are provided for locating the quadrats along transects. This POP describes the procedure for filling in Data Form 2 "Ocular Cover Estimate Data Sheet" and Data Form 6 "Unknown Specimen Data Sheet".

## I. Equipment List

- Clip boards (2)
- Data Form 2 (4 pages – 2 for Transect A and 2 for Transect B)
- Pencils, extra pencil lead, and erasers
- 0.5-$m^2$ sampling frames (2)
- 2% cover cards (4)
- 50-m tapes (2)
- 30-m tapes (2)
- Plant press
- Unknown specimen forms
- Field guides and identification keys/books as needed
- Species code list for appropriate park
- Write-In-Rain blank data sheets (to avoid confusion with regular paper, keep labeled)
- Metal detector for finding plot corners

## II. Procedures

### Site and Quadrat Setup

#### Laying out Transects

Each plot includes two 50-m transects (A and B), which form two edges of the plot. The ends of the transects are marked with stakes labeled with metal tags containing pertinent plot and transect information. Once all four corners of the plot have been located, a 50-m tape is laid along each 50-m edge and a 30-m tape is laid along each 20-m edge of the site. The origin (0m end) of the 50-m tape is hooked over the "0" corner marker for its transect. Tapes are stretched as tautly as possible to avoid curvature in the line. Curvature in the line makes re-locating quadrats inconsistent. All members of the sampling team assist in locating corner markers and setting up transect lines. **All are cautious to avoid trampling vegetation in the plot, especially on the transects and 1 m into the plot from the transects.** All transects have a "start" (0 m) end and a "finish" (50 m) end, which are indicated by the tags on the rebar. It is absolutely crucial to begin at the starting end and to know which transect line you are sampling. These two factors relate directly to the location of each quadrat along the length of the transect.

#### Sampling teams

The entire team at the plot is divided into sub-teams. One sub-team consisting of two people is assigned to each transect line. The sub-team is responsible for the following: (1) collecting all of the required data; (2) collecting and describing any unknown plants encountered and relaying the information to the team leader before leaving the site; and (3) ensuring that all equipment, including sampling poles, meter tape, data sheets and clip boards, makes it to the next site. The person designated as recorder for a sub-team is responsible for recording all data, **including times.**

#### Laying out the 0.5-m2 quadrats

Herbaceous and shrub species cover data are collected in ten 0.5-$m^2$ quadrats located along each transect, spaced 5 m apart (Figure B2.1). Along transect A, quadrats are anchored at 1 m , 6 m, 11 m, 16 m, … 46 m. Along transect B, quadrats are anchored at 3 m, 8 m, 13 m, 18 m, … 48 m. The quadrats extend 1 m beyond the anchor (towards the 50 m end of the transect and 0.5 m *into* the 1000-$m^2$ site. Quadrat frames are laid as close to the ground surface as possible, with the inside edge of the frame flush with the edge of the tape that is inside the 1000-$m^2$ site.

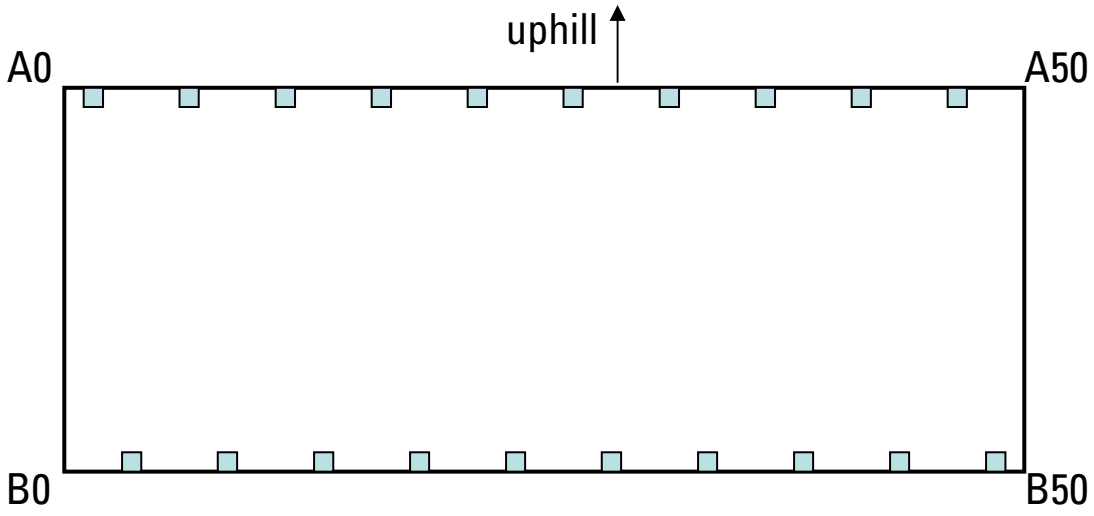



**Figure B2.1.** 1000 $m^2$ sampling plot (open rectangle), with rebar labels indicating corners, and 0.5 $m^2$ cover estimate quadrats.

In summary:
1. Transect tapes must be pulled as tautly as possible between the two transect ends.
2. Consult plot records and transect tags to ensure that the "A" and "B" transect lines (recorded on the tags around the rebar as "A" and "B") are not reversed.
3. Always start the tape at the beginning of the transect (recorded on the tags around the corner marker as "0" for "0 m").

## III. Collecting and Recording Data

Fill in the blanks in the heading of Data Form 2 following the instructions below:

**Park Code:** A unique 4-digit code (example: AGFO Agate Fossil Beds National Monument)

**Park Unit:** Management unit or other descriptive location name (example: Carnegie Hill Unit)

**Plot ID:** A unique sample unit identification (example: PCM10, where PCM stands for "Plant Community Monitoring")

**Observers:** The unique initials of the first, middle, and last name, or full name, of each person in the team collecting data. If initials of two or more persons are the same, use full names.

**Date:** Include month / day / year (mm/dd/yyyy)

Each data sheet has 10 tables (5 on each side), one for each of the quadrats on the transect. Each of the tables is labeled with the quadrat identifier, which indicates the transect (A or B) and the distance from the origin of the transect at which the quadrat is anchored.

For each quadrat:

1. Place the cover frame in the appropriate location (see "Laying out the 0.5-$m^2$ quadrats" above). For start time, record the time that the sample frame is set on the ground in the appropriate table on the data form.
2. Search thoroughly for all plant species whose foliage polygon (see # 3 below) or stem overlaps or is wholly inside the frame; record their species codes in the appropriate table. Include all species that had growth in the current year. Species codes follow NRCS naming conventions; refer to the list of codes for species in the park you're in. If a species cannot be identified, assign it an unknown code according to the directions in the "Unknown Specimens" section below.
3. A foliage polygon for an individual plant is the area within a polygon connecting the outermost points of the live leaves (do *not* include inflorescences) of an individual plant. Figure B2.2 shows some examples of foliage polygons.
4. Using the 2% cards and the marks on the side of the frame to calibrate yourself, estimate, to the nearest 1%, the percentage of the area within the frame covered by each species using the individuals' foliage polygons. Overlap of plants of the same species is ignored. Record this in the appropriate row and column for that quadrat. For species with cover under 1%, record their cover as "0.5". For stems of plants whose foliage polygon does not intersect the quadrat, or whose foliage is more than 2 m above the quadrat, **estimate their cover based on their basal area**. Record their cover only as the area within the frame. See Figure B2.2. Base percent cover estimates on the current year's growth by including living, damaged, and dead material from the current year. Do not adjust the percent for the time of year during which the visit was made (i.e., for immature or wilted plants). Sparse plants can be difficult to assess, but follow the polygon rule unless it is obvious that the plant(s) have been trampled or otherwise recently disturbed and would naturally stand more upright.
5. Do not count foliage or branches intercepted for woody plants over 2 m tall. (This is because they will be sampled using other procedures better suited to large woody vegetation.) If the trunk of a standing live woody plant that is over 2 m tall lies either wholly or partially within the frame, record its species code followed by "trunk". Standing dead tree trunks in the quadrat are accounted for in the "Ground Cover" estimate.
6. After recording the cover for all species, the reader should look away from the quadrat for a few seconds, then look down at the quadrat again and estimate *total* plant cover. Meanwhile, the recorder sums the values from the individual species to obtain total plant cover. Compare these two values, and adjust cover estimates of individual species as (or if) necessary to make the two values agree. Total plant cover can be any value equal to or greater than zero. Values over 100% can occur when there are multiple layers of vegetation.
7. Move to the bottom of the table for the quadrat. Estimate, to the nearest 1%, the percentage of the ground within the frame covered by each of the cover types listed (veg, bare soil, bare rock, litter, and woody debris). Record these values in the appropriate rows. For veg, imagine mowing the quadrat so that all that is left is 2 cm of stubble. The percentage of the area of the frame covered by this stubble (stems of plants) is the cover of veg. "Rock" is defined as stone larger than a dime (1.8 mm diameter). The sum of these five values must be 100%. Do not spend more than 1 minute doing the estimates for ground cover.
8. In the "end time" row of the table, record the time at which all data collection for the quadrat is complete.

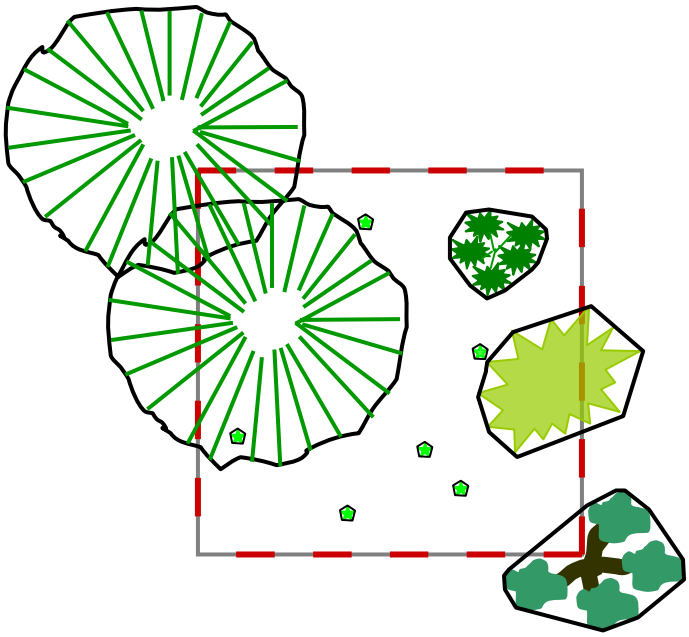


**Figure B2.2.** Foliage polygons, indicated in black lines, for different types of plants. Despite the different colors, all shapes are intended to be leaves, not flowers. The quadrat frame is indicated in gray, with red dashes each being 10 cm in length. Cover of the species as represented here would be: A, 36%; B, 5%; C, 2%; D, 0.5% (i.e., <1%); and E, 7%.

## Unknown Specimens

Sometimes species determinations of individual plants encountered in sampling are difficult or uncertain. When this situation occurs, the area surrounding the quadrat should be searched, looking particularly for a specimen of the unknown that is in flower or fruit, or perhaps is a specimen from last year with its flowering stalk still intact. These may assist in correctly identifying the species in the quadrat. Most of these plants are not entirely "unknown" species. Rather, they are of a species that is known but sometimes difficult to distinguish from another given the timing of sampling. For example, small *Bouteloua curtipendula* plants may be confused with *Bouteloua gracilis*. Both of these species are common and often confidently identified during our various sampling procedures. If the evidence does not favor one species over another enough, then the next broader taxonomic grouping can be recorded. In the above example, "*Bouteloua* spp." could be recorded. This name would be sufficient until species-level identification is available, e.g., during a subsequent sampling the plant is found in the same location in flower, seed, or fruit, aiding correct identification.

Plants not immediately identified in the quadrat are recorded on the data sheet with an unknown specimen code distinguishing it from other unknowns in that plot and other plots in the park. A sample of that species is then collected. Because of the long-term nature of the monitoring, collecting outside the plot is preferred. If a specimen does not occur outside the plot, a portion of the plant from inside the site can be collected, but at no time should the roots be dug up or the entire plant be collected from inside the site. Collecting the roots and/or the entire above-ground portion of the plant may affect future sampling events. If a camera is available, a photodocument could be taken.

For each unknown specimen, there is a corresponding Unknown Specimen Data Sheet (Form 6). The more detailed a definition of each characteristic, the greater the possibility of a future identification. Use the following procedure when filling out the Unknown Record sheet:

**Park:** A four letter alpha code unique to a particular park (example: AGFO – Agate Fossil Beds National Monument in Nebraska)

**Plot and Quadrat/Point:** Unique plot ID, and if applicable, quadrat number (m distance along transect) or point-intercept point (including transect letter). Indicate whether number refers to quadrat or point number. Note that point number is *not* the same as the distance of the point from the transect anchor. Examples:
PCM5-B38 (quad) = monitoring site 5, transect B, quadrat 38
PCM5-B38 (point) = monitoring site 5, transect B, point # 38

**Date:** Include month (mm) / day (dd) / year (yy)

**Unknown Code:** A unique code referring to the plant's form (e.g., grass, sedge, succulent), taxon (genus, family), or some other distinguishing characteristic.

**Plant type and General Description:** Circle the appropriate category and provide a detailed description of the overall appearance

**Most Salient Feature:** The feature that identifies this plant from all others; a unique characteristic

**Leaf Characteristics:** Describe the leaf type, leaf margin, leaf surface, petiole, etc.

**Stem Characteristics:** Describe the shape, pubescence, markings, and color of the stem, as well as the bud characteristics.

**Flower Characteristics:** Describe the floral formula, location (axillary or terminal), habit (indeterminate or determinate), pubescence, and color.

**General and Microhabitat Characteristics:** List other species located in the general vicinity, selecting the more conservative species in the area. Describe the microhabitat in which it was found.

**Collected:** Circle yes or no, whether a specimen was collected.

**Best Guess:** Preliminary guess about species in field.

**Confirmed to be:** After consultation of reference books and/or herbarium, the species determined.

# Preliminary Operating Procedure (POP) 3: Point-Intercept Cover Estimates of Herbaceous and Shrub Species

Version 1.1 (March 2006)

Description: This POP gives step-by-step instructions for obtaining cover estimates of herbaceous and shrub species using the point-intercept method along 50 m transects. The POP describes the procedure for filling in Form 3 "Point-Intercept Data Sheet" and Data Form 6 "Unknown Specimen Data Sheet".

## I. Equipment List

- Clip boards (2)
- Form 3 Point-intercept data sheets (2 sheets for each plot, 1 per transect)
- Pencils, extra pencil lead, and erasers
- Sampling poles = ¼ inch diameter collapsible tent poles (2)
- 50-m tapes (2)
- 30-m tapes (2)
- Plant press
- Unknown specimens forms
- Field guides and identification keys/books as needed
- Species code list for appropriate park
- Write-In-Rain blank data sheets (to avoid confusion with regular paper, keep labeled)

## II. Procedures

### Plot Setup

#### Laying out Transects

Each monitoring plot includes two 50-m transects (A and B), which form the edges of the sampling plots. The ends of the transects are marked with stakes labeled with metal tags containing pertinent plot and transect information. Once all four corners of the sampling plot have been located, a 50-m tape is laid along each 50-m edge and a 30-m tape is laid along each 20-m edge of the plot. The origin (0 m end) of the 50-m tape is hooked over the "0" corner marker for its transect. Tapes are stretched as tautly as possible to avoid curvature in the line. Curvature in the line makes data collection from year to year inconsistent. All members of the sampling team assist in locating corner markers and setting up transect lines. **All are cautious to avoid trampling vegetation in the plot, especially on the transects and 1 m on either side of the transects.**

All transects have a "start" (0 m) end and a "finish" (50 m) end, which are indicated by the tags on the corner marker. It is absolutely crucial to begin at the starting end and to know which transect line you are sampling.

#### Sampling teams

One sampling team, each consisting of a reader and a recorder, is assigned to a transect line. The sampling team is responsible for the following: (1) collecting all of the required data; (2) collecting and describing any unknown plants encountered and relaying the information to the team leader before leaving the site; and (3) ensuring that all equipment, including sampling poles, meter tape, data sheets and clip boards, makes it to the next site. The recorder is responsible for recording all data, **including start and finish times.**

In summary:

1. Transect tapes must be pulled as tautly as possible between the two transect ends.
2. Consult plot records and transect tags to ensure that the "A" and "B" transect lines (recorded on the tags around the rebar as "A" and "B") are not reversed.
3. Always start the tape at the beginning of the transect (recorded on the tag on the corner marker as "0" for "0 m").

## III. Collecting and Recording Data

Fill in the information on the top of the first page of the data sheet according to the following directions.

**Park Code:** A unique 4-digit code (example: AGFO Agate Fossil Beds National Monument)

**Park Unit:** Management unit or other descriptive location name (example: Carnegie Hill Unit)

**Plot ID:** A unique sample unit identification (example: DPCM10, where D stands for Devils Tower National Monument and PCM stands for "Plant Community Monitoring")

**Transect Line:** Circle A or B as appropriate. Check against the corner marker you are standing next to!

**Date:** Include month / day / year (mm/dd/yyyy)

**Start Time:** Time that data collection begins.

**Reader/Recorder:** The unique initials of the first, middle, and last name of each person in the team collecting data. If initials of two or more persons are the same, use full names. Reader is the person plunking the pole, recorder is the person recording the data.

Procedure:
Start at 30 cm from the 0 end of the transect. At each of the 100 evenly spaced, marked points (as indicated on the data sheet), gently drop the pole (rigid plumb-bob) to the ground. The pole should be *plumb* to the ground, which on a slope will *not* be perpendicular to the ground. Record the code for each species that touches the pole, starting with the upper-most hit and working down, on the data sheet in the appropriate row. Species codes follow NRCS naming conventions; refer to the list of codes for species in the park you're in. Count each species only once at each point-intercept even if the pole touches it more than once. If the pole fails to intercept any vegetation, put a dash "—" in the first column for that row and move to the final column labeled "Ground".

If a species cannot be identified, record its presence with a unique "unknown" code (see section below on unidentifiable specimens) instead of a species code.

Do not count foliage or branches intercepted for trees or shrubs over 2 m tall, but count all herbaceous vegetation no matter its height. (This is because tall woody species will be sampled using other procedures.) If the pole intersects the bole of a tree that is over 2 m tall, record "2BOLE" if the tree is alive or "2SDED" if the tree is dead.

For the column labeled "Ground" at each of the marked points, record the substrate (SOIL, ROCK, LIT, or WOOD) or species code of what the pole touches where it intersects the ground. A species code should be recorded only if the pole touches the base of the plant, as the goal of this measurement is to record basal cover of plants vs. substrate cover. "ROCK" is defined as larger than a dime (1.8 mm diameter).

After the last hit is recorded, write down the time in the appropriate place at the top page of the data sheet.

## Unknown Specimens

Sometimes species determinations of individual plants encountered in sampling are difficult or uncertain. When this situation occurs, the area surrounding the point should be searched, looking particularly for a specimen of the unknown that is in flower or fruit, or perhaps is a specimen from last year with its flowering stalk still intact. These may assist in correctly identifying the species at the point. Most of these plants are not entirely "unknown" species. Rather, they are of a species that is known but sometimes difficult to distinguish from another given the timing of sampling. For example, small *Bouteloua curtipendula* plants may be confused with *Bouteloua gracilis*. Both of these species are common and often confidently identified during our various sampling procedures. If the evidence does not favor one species over another enough, then the next broader taxonomic grouping can be recorded. In the above example, "*Bouteloua* spp." could be recorded. This name would be sufficient until species-level identification is available, e.g., during a subsequent sampling the plant is found in the same location in flower, seed, or fruit, aiding correct identification.
Plants not immediately identified in the plot are recorded on the data sheet with an unknown specimen code distinguishing it from other unknowns in that plot and other plots in the park. A sample of that species is then collected. Because of the long-term nature of the monitoring, collecting outside the plot is preferred. If a specimen does not occur outside the plot, a portion of the plant from inside the plot can be collected, but at no time should the roots be dug up or the entire plant be collected from inside the plot. Collecting the roots and/or the entire above-ground portion of the plant may affect future sampling events. If a camera is available, a photodocument could be taken.

For each unknown specimen, there is a corresponding Unknown Specimen Data Sheet (Form 6). The more detailed a definition of each characteristic, the greater the possibility of a future identification. Use the following procedure when filling out the Unknown Record sheet:

**Park:** A four letter alpha code unique to a particular park (example: AGFO – Agate Fossil Beds National Monument in Nebraska)

**Plot and Quadrat/Point:** Unique plot ID, and if applicable, quadrat number (m distance along transect) or point-intercept point (including transect letter). Indicate whether number refers to quadrat or point number. Note that point number is *not* the same as the distance of the point from the transect anchor. Examples:
PCM5-B38 (quad) = monitoring site 5, transect B, quadrat 38
PCM5-B38 (point) = monitoring site 5, transect B, point # 38

**Date:** Include month (mm) / day (dd) / year (yy)

**Unknown Code:** A unique code referring to the plant's form (e.g., grass, sedge, succulent), taxon (genus, family), or some other distinguishing characteristic.

**Plant type and General Description:** Circle the appropriate category and provide a detailed description of the overall appearance

**Most Salient Feature:** The feature that identifies this plant from all others; a unique characteristic

**Leaf Characteristics:** Describe the leaf type, leaf margin, leaf surface, petiole, etc.

**Stem Characteristics:** Describe the shape, pubescence, markings, and color of the stem, as well as the bud characteristics.

**Flower Characteristics:** Describe the floral formula, location (axillary or terminal), habit (indeterminate or determinate), pubescence, and color.

**General and Microhabitat Characteristics:** List other species located in the general vicinity, selecting the more conservative species in the area. Describe the microhabitat in which it was found.

**Collected:** Circle yes or no, whether a specimen was collected.

**Best Guess:** Preliminary guess about species in field.

**Confirmed to be:** After consultation of reference books and/or herbarium, the species determined.

# Preliminary Operating Procedure (POP) 4: Compiling a Plot Species List

Version 1.1 (March 2006)

Description: This POP gives instructions for recording all species encountered within a 1000 $m^2$ plot. The POP describes the procedures for filling in Form 4 "Plot Species List Data Sheet" and Data Form 6 "Unknown Specimen Data Sheet".

## I. Equipment List

- Clip boards
- Plot Species List Data Sheet (Form 4)
- Pencils, extra pencil lead, and erasers
- Field guides and identification keys/books as needed
- Hand lenses

## II. Procedures

This POP assumes that a sampling plot has already been set up, with tapes indicating the borders of the plot already in place.

Fill in the information on the top of Form 4 according to the following directions.
**Park Code:** A unique 4 digit code (example: AGFO Agate Fossil Beds National Monument)

**Park Unit:** Management unit or other descriptive location name (example: Carnegie Hill Unit)

**Plot ID:** A unique sample unit identification (example: DPCM10, where D stands for Devils Tower National Monument and PCM stands for "Plant Community Monitoring")

**Date:** Include month / day / year (mm/dd/yyyy)

**Start Time:** Record the time that searching for species within the plot begins. Usually this is immediately after the tapes have been laid out for the plot.

**Finish Time:** Record the time that searching for species ends. Usually this is immediately before the tapes are rolled up and the team departs from the plot.

**Observers:** The unique initials of the first, middle, and last name of each person in the team collecting data. If initials of two or more persons are the same, include some other distinguishing initial or full name.

One team member is responsible for recording species on Form 4 for the entire duration of the plot sampling. All team members are responsible for reporting species encountered at any time while working in the plot to this recorder.

An initial search of the plot for all vascular plants species whose canopy overlaps or whose stem is rooted within the plot is done after the plot tapes are established. The whole team works together on this, with more experienced members pointing out new species and their distinguishing characteristics to less experienced members as necessary. In addition, special note is made of species within the plot that can be confused with others. The recorder records species' codes and full names on Form 4. The team assists in

assessing the phenological stage of each species, following the definitions of these stages on page 2 of Form 4. The stage that the majority of individuals of a species in the plot are in at the time of sampling is the one recorded on the form. The team should work in a methodical manner from one end of the plot to the other, making sure all areas are covered, with one exception. Team members should avoid walking within 1 m of the 50-m tapes to avoid trampling vegetation that will be sampled using other techniques.

After this initial search, plant cover sampling begins. If any new species are encountered during this sampling, the team member that encounters the new species ensures that the Form 4 recorder records this species on the list.

After all data collection in a plot is complete, one person takes responsibility to ensure that species occurring on cover data sheets are recorded on the plot species list and that species codes are consistent across all data sheets from a plot. This is ideally done immediately after the plot is completed, but it should be done no more than three days after the plot is sampled so that questions that arise can be answered with information that is fresh in the sampling teams' memory.

Directions for dealing with unidentifiable specimens are detailed below.

## Unknown Specimens

Sometimes species determinations of individual plants encountered in sampling are difficult or uncertain. When this situation occurs, the area surrounding the quadrat should be searched, looking particularly for a specimen of the unknown that is in flower or fruit, or perhaps is a specimen from last year with its flowering stalk still intact. These may assist in correctly identifying the species in the quadrat. Most of these plants are not entirely "unknown" species. Rather, they are of a species that is known but sometimes difficult to distinguish from another given the timing of sampling. For example, small *Bouteloua curtipendula* plants may be confused with *Bouteloua gracilis*. Both of these species are common and often confidently identified during our various sampling procedures. If the evidence does not favor one species over another enough, then the next broader taxonomic grouping can be recorded. In the above example, "*Bouteloua* spp." could be recorded. This name would be sufficient until species-level identification is available, e.g., during a subsequent sampling the plant is found in the same location in flower, seed, or fruit, aiding correct identification.

Plants not immediately identified in the quadrat are recorded on the data sheet with an unknown specimen code distinguishing it from other unknowns in that plot and other plots in the park. A sample of that species is then collected. Because of the long-term nature of the monitoring, collecting outside the plot is preferred. If a specimen does not occur outside the plot, a portion of the plant from inside the site can be collected, but at no time should the roots be dug up or the entire plant be collected from inside the site. Collecting the roots and/or the entire above-ground portion of the plant may affect future sampling events. If a camera is available, a photodocument could be taken.

For each unknown specimen, there is a corresponding Unknown Specimen Data Sheet (Form 6). The more detailed a definition of each characteristic, the greater the possibility of a future identification. Use the following procedure when filling out the Unknown Record sheet:

**Park:** A four letter alpha code unique to a particular park (example: AGFO – Agate Fossil Beds National Monument in Nebraska)

**Plot and Quadrat/Point:** Unique plot ID, and if applicable, quadrat number (m distance along transect) or point-intercept point (including transect letter). Indicate whether number refers to quadrat or point number. Note that point number is *not* the same as the distance of the point from the transect anchor. Examples:

PCM5-B38 (quad) = monitoring site 5, transect B, quadrat 38

PCM5-B38 (point) = monitoring site 5, transect B, point # 38

**Date:** Include month (mm) / day (dd) / year (yy)

**Unknown Code:** A unique code referring to the plant's form (e.g., grass, sedge, succulent), taxon (genus, family), or some other distinguishing characteristic.

**Plant type and General Description:** Circle the appropriate category and provide a detailed description of the overall appearance

**Most Salient Feature:** The feature that identifies this plant from all others; a unique characteristic

**Leaf Characteristics:** Describe the leaf type, leaf margin, leaf surface, petiole, etc.

**Stem Characteristics:** Describe the shape, pubescence, markings, and color of the stem, as well as the bud characteristics.

**Flower Characteristics:** Describe the floral formula, location (axillary or terminal), habit (indeterminate or determinate), pubescence, and color.

**General and Microhabitat Characteristics:** List other species located in the general vicinity, selecting the more conservative species in the area. Describe the microhabitat in which it was found.

**Collected:** Circle yes or no, whether a specimen was collected.

**Best Guess:** Preliminary guess about species in field.

**Confirmed to be:** After consultation of reference books and/or herbarium, the species determined.

# Appendix C

# Plant Species Encountered During Field Sampling for Methods Comparison Study

Nomenclature follows the Integrated Taxonomic Information System (*www.itis.usda.gov*). Variety and subspecies names match those on lists provided by the NGPN Inventory & Monitoring program to the methods comparison field crew prior to field sampling.

## Agate Fossil Beds National Monument (AGFO)

| Family | Scientific Name | Common Name(s) | Origin | Code |
|---|---|---|---|---|
| Agavaceae | *Yucca glauca* | Great Plains yucca, small soapweed, soapweed yucca, Spanish bayonet, yucca, beargrass | native | YUGL |
| Anacardiaceae | *Rhus trilobata* var. *trilobata* | skunkbush sumac | native | RHTR |
| Apiaceae | *Cicuta maculata* var. *angustifolia* | water hemlock | native | CIMA2 |
| | *Lomatium orientale* | oriental desert-parsley | native | LOOR |
| | *Musineon tenuifolium* | slender wildparsley | native | MUTE3 |
| | *Pastinaca sativa* | wild parsnip | non-native | PASA2 |
| Asclepiadaceae | *Asclepias incarnata* ssp. *incarnata* | swamp milkweed | native | ASINI |
| | *Asclepias speciosa* | showy milkweed | native | ASSP |
| | *Asclepias viridiflora* | green antelopehorn milkweed, green comet milkweed, green milkweed | native | ASVI |
| Asteraceae | *Ambrosia trifida* | blood ragweed, giant ragweed, great ragweed, horseweed, perennial ragweed (great), tall ragweed | native | AMTR |
| | *Antennaria microphylla* | littleleaf pussytoes, Rocky Mountain pussytoes, small leaf everlasting, smallleaf pussytoes | native | ANMI3 |
| | *Artemisia frigida* | fringed sagebrush, fringed sagewort, prairie sagewort | native | ARFR4 |
| | *Bidens cernua* | bur marigold, nodding beggartick, nodding bur marigold, nodding burmarigold, sticktight | native | UFR2 |
| | *Cirsium arvense* | Californian thistle, Canada thistle, Canadian thistle, creeping thistle, field thistle | non-native | CIAR4 |
| | *Cirsium canescens* | Platte thistle, prairie thistle | native | CICA11 |
| | *Cirsium flodmanii* | Flodman thistle, Flodman's thistle | native | CIFL |
| | *Conyza canadensis* | Canada horseweed, Canadian horseweed, horseweed, horseweed fleabane, mares tail | native | COCA5 |
| | *Erigeron bellidiastrum* | western fleabane | native | ERBE2 |
| | *Gutierrezia sarothrae* | broom snakeweed, broomweed, perennial snakeweed, stinkweed, turpentine weed, yellow top | native | GUSA2 |
| | *Helianthus annuus* | annual sunflower, common sunflower, sunflower, wild sunflower | native | HEAN3 |
| | *Helianthus maximiliani* | Maximilian sunflower | native | HEMA2 |
| | *Helianthus petiolaris* | prairie sunflower | native | HEPE |
| | *Heterotheca villosa* | hairy false goldaster, hairy false goldenaster, hairy goldaster, hairy goldenaster | native | HEVI4 |
| | *Hymenopappus filifolius* var. *polycephalus* | manyhead hymenopappus | native | HYFI |
| | *Lactuca serriola* | China lettuce, prickly lettuce, wild lettuce | non-native | LASE |
| | *Lactuca tatarica* var. *pulchella* | blue lettuce, blue wild lettuce, chicory lettuce, Russian blue lettuce | native | LATA |
| | *Liatris punctata* | dotted blazing star, dotted gayfeather | native | LIPU |

## Agate Fossil Beds National Monument (AGFO)

| Family | Scientific Name | Common Name(s) | Origin | Code |
|---|---|---|---|---|
| | *Lygodesmia juncea* | rush skeletonplant, rush skeletonweed, skeletonplant, skeletonweed | native | LYJU |
| | *Machaeranthera pinnatifida* var. *pinnatifida* | lacy tansyaster | native | MAPI |
| | *Oligoneuron album* | prairie goldenrod | native | OLAL2 |
| | *Senecio integerrimus* | lambstongue groundsel, lambstongue ragwort | native | SEIN2 |
| | *Senecio riddellii* | riddell groundsel, Riddell's ragwort, sand groundsel | native | SERI2 |
| | *Solidago canadensis* var. *gilvocanescens* | Canada goldenrod, common goldenrod | native | SOCA6 |
| | *Solidago gigantea* | giant goldenrod | native | SOGI |
| | *Sonchus arvensis* ssp. *uliginosus* | sowthistle | non-native | SOAR2 |
| | *Symphyotrichum ericoides* var. *stricticaule* | white heath aster | native | SYER |
| | *Symphyotrichum lanceolatum* var. *hesperium* | white panicle aster | native | SYLA6 |
| | *Taraxacum officinale* | blowball, common dandelion, dandelion, faceclock | non-native | TAOF |
| | *Tetraneuris acaulis var. acaulis* | stemless hymenoxys, stemless four-nerve daisy | native | TEAC |
| | *Townsendia grandiflora* | largeflower Townsend daisy | native | TOGR |
| | *Tragopogon dubius* | goatsbeard, meadow goat's-beard, salsify, Western goat's beard, western salsify, wild oysterplant, yellow goat's beard, yellow salsify | non-native | TRDU |
| Boraginaceae | *Cryptantha cana* | mountain cryptantha | native | CRCA8 |
| | *Cryptantha celosioides* | buttecandle, minerscandle | native | CRCE |
| | *Cryptantha minima* | small cryptantha | native | CRMI5 |
| | *Lappula occidentalis* var. *occidentalis* | western stickseed | native | LAOC3 |
| | *Lithospermum incisum* | fringed gromwell, fringed puccoon, narrowleaf gromwell, narrowleaf pucoon | native | LIIN2 |
| Brassicaceae | *Alyssum desertorum* | desert alyssum, desert madwort | non-native | ALDE |
| | *Arabis holboellii* var. *collinsii* | Holboell's rockcress | native | ARHO2 |
| | *Camelina microcarpa* | false flax, littlepod false flax, littleseed falseflax, small fruited falseflax, smallseed falseflax | non-native | CAMI2 |
| | *Descurainia pinnata* var. *intermedia* | green tansymustard, pinnate tansymustard, tansymustard, western tansymustard | native | DEPI |
| | *Descurainia sophia* | flaxweed tansymustard, flixweed, flixweed tansymustard, herb sophia | non-native | DESO2 |
| | *Draba reptans* | Carolina draba, Carolina whitlowgrass, creeping draba | native | DRRE2 |
| | *Erysimum capitatum* var. *capitatum* | plains wallflower, prairie rocket, sanddune wallflower, western wallflower | native | ERCA14 |
| | *Lepidium densiflorum* | common pepperweed, miners pepperweed, peppergrass, prairie pepperweed | native | LEDE |
| | *Lesquerella alpina* var. *alpina* | alpine bladderpod | native | LEAL |

## Agate Fossil Beds National Monument (AGFO)

| Family | Scientific Name | Common Name(s) | Origin | Code |
|---|---|---|---|---|
| | *Lesquerella ludoviciana* | foothill bladderpod, Louisiana bladderpod, silver bladderpod | native | LELU |
| | *Sisymbrium altissimum* | Jim Hill mustard, tall tumblemustard, tumble mustard, tumbleweed mustard | non-native | SIAL2 |
| Cactaceae | *Escobaria vivipara* var. *vivipara* | pink pincushioncactus, spinystar, spinystar cactus | native | ESVI2 |
| | *Opuntia fragilis* | brittle cactus, brittle pricklypear, fragile cactus, jumping cactus, little pricklypear | native | OPFR |
| | *Opuntia macrorhiza* var. *macrorhiza* | twistspine pricklypear, bigroot pricklypear | native | OPMA2 |
| | *Opuntia polyacantha* var. *polyacantha* | Plains pricklypear | native | OPPO |
| Capparaceae | *Cleome serrulata* | bee spiderflower, Rocky Mountain beeplant | native | CLSE |
| Caprifoliaceae | *Symphoricarpos occidentalis* | western snowberry, wolfberry | native | SYOC |
| Caryophyllaceae | *Arenaria hookeri* | Hooker's sandwort | native | ARHO4 |
| | *Paronychia depressa* | spreading nailwort | native | PADE4 |
| | *Silene drummondii* var. *drummondii* | Drummond's catchfly | native | SIDR |
| Chenopodiaceae | *Atriplex subspicata* | spreading orach | native | ATSU2 |
| | *Chenopodium pratericola* | desert goosefoot | native | CHPR5 |
| | *Kochia scoparia* | fireweed, kochia, Mexican burningbush, Mexican fireweed, mock cypress, Summer cypress | non-native | KOSC |
| Commelinaceae | *Tradescantia occidentalis* | prairie spiderwort, spiderwort, western spiderwort | native | TROC |
| Cyperaceae | *Carex filifolia* | threadleaf sedge | native | CAFI |
| | *Carex hallii* | deer sedge | native | CAHA3 |
| | *Carex pellita* | wooly sedge | native | CAPE42 |
| | *Carex praegracilis* | slim sedge | native | CAPR5 |
| Equisetaceae | *Equisetum laevigatum* | horsetail, smooth horsetail, smooth scouringrush | native | EQLA |
| Euphorbiaceae | *Euphorbia brachycera* | horned spurge, Rocky Mountain spurge | native | EUBR |
| Fabaceae | *Astragalus ceramicus* var. *filifolius* | painted milkvetch | native | ASCE |
| | *Astragalus crassicarpus* var. *crassicarpus* | ground-plum, groundplum milkvetch | native | ASCR2 |
| | *Astragalus gracilis* | slender milkvetch | native | ASGR3 |
| | *Astragalus laxmannii* var. *robustior* | Laxmann's milkvetch, prairie milkvetch | native | ASLA27 |
| | *Astragalus missouriensis* | Missouri milkvetch | native | ASMI10 |
| | *Astragalus sericoleucus* | silky milkvetch | native | ASSE5 |
| | *Astragalus spatulatus* | tufted milkvetch | native | ASSP6 |
| | *Dalea candida* var. *oligophylla* | white prairieclover | native | DACA7 |
| | *Dalea purpurea* | Purple prairieclover, violet dalea, violet prairie clover | native | DAPU5 |
| | *Glycyrrhiza lepidota* | American licorice, licorice, wild licorice | native | GLLE3 |
| | *Lathyrus polymorphus* ssp. *incanus* | manystem peavine | native | LAPO2 |
| | *Lupinus argenteus* | silvery lupine | native | LUAR3 |
| | *Lupinus plattensis* | Platte lupine | native | LUPL |
| | *Lupinus pusillus* | small lupine, rusty lupine | native | LUPU |

## Agate Fossil Beds National Monument (AGFO)

| Family | Scientific Name | Common Name(s) | Origin | Code |
|---|---|---|---|---|
| | *Melilotus officinalis* | yellow sweet-clover, yellow sweetclover | non-native | MEOF |
| | *Oxytropis lambertii* | Lambert crazyweed, Lambert loco, Lambert locoweed, purple locoweed, stemless loco | native | OXLA3 |
| | *Oxytropis sericea* | locoweed, silky crazyweed, silvery oxytrope, white crazyweed, white locoweed, white pointloco | native | OXSE |
| | *Pediomelum esculentum* | breadroot scurfpea, Indian breadroot, large Indian breadroot | native | PEES |
| | *Psoralidium lanceolatum* | dune scurfpea, lemon scurfpea, wild lemonweed | native | PSLA3 |
| | *Psoralidium tenuiflorum* | slimflower scurfpea | native | PSTE5 |
| | *Thermopsis rhombifolia* | goldenpea, prairie thermopsis | native | THRH |
| Grossulariaceae | *Ribes aureum* var. *villosum* | golden currant | native | RIAU |
| Hydrophyllaceae | *Ellisia nyctelea* | Aunt Lucy, ellisia, false babyblueeyes, waterpod | native | ELNY |
| | *Phacelia hastata* var. *hastata* | silverleaf phacelia | native | PHHA |
| Iridaceae | *Iris pseudacorus* | yellow flag | non-native | IRPS |
| Juncaceae | *Juncus balticus* | Baltic rush | native | JUBA |
| Lamiaceae | *Hedeoma drummondii* | Drummond's false pennyroyal, Drummond's pennyroyal | native | HEDR |
| | *Lycopus asper* | rough water-horehound | native | LYAS |
| | *Mentha arvensis* | wild mint | non-native | MEAR4 |
| | *Nepeta cataria* | catnip | non-native | NECA2 |
| Liliaceae | *Allium textile* | prairie onion, textile onion, wild onion | native | ALTE |
| | *Leucocrinum montanum* | common starlily, star-lily | native | LEMO4 |
| | *Zigadenus venenosus* var. *gramineus* | meadow deathcamas | native | ZIVE |
| | *Linum puberulum* | Plains flax | native | LIPU4 |
| Linaceae | *Linum rigidum* var. *rigidum* | orange flax, stiff flax, stiffstem flax | native | LIRI |
| Loasaceae | *Mentzelia nuda* | stickleaf mentzelia, bractless blazingstar | native | MENU |
| Onagraceae | *Calylophus serrulatus* | halfshrub calylophus, halfshrub sundrop, serrateleaf eveningprimrose, yellow sundrops | native | CASE12 |
| | *Gaura coccinea* | scarlet beeblossom, scarlet gaura, Scarlet guara | native | GACO5 |
| | *Gaura mollis* | James velvetweed | native | GAMO5 |
| | *Oenothera albicaulis* | halfshrub sundrop, white-stem evening-primrose, whitest evening-primrose | native | OEAL |
| | *Oenothera latifolia* | mountain evening-primrose | native | OELA2 |
| Orobanchaceae | *Orobanche fasciculata* | clustered broomrape, purple broomrape, tufted broomrape | native | ORFA |
| Plantaginaceae | *Plantago patagonica* | woolly Indianwheat, woolly plantain | native | PLPA2 |
| Poaceae | *Achnatherum hymenoides* | Indian ricegrass | native | ACHY |
| | *Agropyron cristatum* | crested wheatgrass | non-native | AGCR1 |
| | *Agrostis stolonifera* | creeping bentgrass | native | AGST2 |

## Agate Fossil Beds National Monument (AGFO)

| Family | Scientific Name | Common Name(s) | Origin | Code |
|---|---|---|---|---|
| | *Andropogon hallii* | sand bluestem | native | ANHA |
| | *Aristida purpurea* | Purple three-awn | native | ARPU9 |
| | *Bouteloua curtipendula* | sideoats grama | native | BOCU |
| | *Bouteloua gracilis* | blue grama | native | BOGR2 |
| | *Bromus inermis* | awnless brome, smooth brome | non-native | BRIN2 |
| | *Bromus japonicus* | Japanese brome, Japanese chess | non-native | BRJA |
| | *Bromus tectorum* | cheat grass, cheatgrass, downy brome, early chess, military grass, wild oats | non-native | BRTE |
| | *Calamagrostis stricta* ssp. *inexpansa* | slimstem reedgrass | native | CAST36 |
| | *Calamovilfa longifolia* | prairie sandreed | native | CALO |
| | *Distichlis spicata* | seashore saltgrass | native | DISP |
| | *Elymus elymoides* ssp. *brevifolius* | squirreltail | native | ELEL5 |
| | *Elymus trachycaulus* ssp. *trachycaulus* | slender wheatgrass | native | ELTR7 |
| | *Hesperostipa comata* ssp. *comata* | needleandthread | native | HECO26 |
| | *Koeleria macrantha* | junegrass, prairie Junegrass | native | KOMA |
| | *Muhlenbergia asperifolia* | scratchgrass | native | MUAS |
| | *Muhlenbergia pungens* | sandhill muhly | native | MUPU2 |
| | *Pascopyrum smithii* | pubescent wheatgrass, western wheatgrass | native | PASM |
| | *Poa pratensis* | Kentucky bluegrass | non-native | POPR |
| | *Poa secunda* | big bluegrass, Sandberg bluegrass | native | POSE |
| | *Schizachyrium scoparium* | little bluestem | native | SCSC |
| | *Sporobolus cryptandrus* | sand dropseed | native | SPCR |
| | *Vulpia octoflora* | eight-flower six-weeks grass, pullout grass, sixweeks fescue, sixweeks grass | native | VUOC |
| Polemoniaceae | *Phlox andicola* | prairie phlox | native | PHAN4 |
| | *Phlox hoodii ssp. hoodii* | Hood's phlox, spiny phlox | native | PHHO |
| Polygonaceae | *Eriogonum annuum* | annual buckwheat, annual eriogonum, annual wild buckwheat, umbrella plant, wild buckwheat | native | ERAN4 |
| | *Eriogonum flavum* | alpine golden buckwheat, yellow eriogonum | native | ERFL4 |
| | *Polygonum amphibium* var. *stipulaceum* | water smartweed | native | UFR5 |
| | *Rumex crispus* | curly dock, narrowleaf dock, sour dock, yellow dock | non-native | RUCR |
| | *Rumex venosus* | veiny dock | native | RUVE2 |
| Santalaceae | *Comandra umbellata* ssp. *pallida* | bastard toadflax | native | COUM |
| Scrophulariaceae | *Castilleja sessiliflora* | downy paintedcup, Great Plains Indian paintbrush, Indianpaintbrush | native | CASE5 |
| | *Penstemon angustifolius* var. *angustifolius* | broad-beard beardtongue, broadbeard beardtongue, narrowleaf penstemon | native | PEAN4 |
| | *Penstemon eriantherus* var. *eriantherus* | fuzzytongue penstemon | native | PEER |
| Solanaceae | *Physalis virginiana* | Virginia groundcherry | native | PHVI5 |

## Agate Fossil Beds National Monument (AGFO)

| Family | Scientific Name | Common Name(s) | Origin | Code |
|---|---|---|---|---|
| Urticaceae | *Parietaria pensylvanica* | Pennsylvania pellitory | native | PAPE5 |
| | *Urtica dioica* ssp. *gracilis* | tall nettle, stinging nettle | native | URDI |
| Verbenaceae | *Verbena hastata* | blue verbena, blue vervain, Simpler's-joy, swamp verbena | native | VEHA2 |
| Violaceae | *Viola nuttallii* | Nuttall violet, Nuttall's violet, yellow prairie violet | native | VINU2 |

## Devils Tower National Monument (DETO)

| Family | Scientific Name | Common Name(s) | Origin | Code |
|---|---|---|---|---|
| Anacardiaceae | *Rhus trilobata* var. *trilobata* | skunkbush sumac | native | RHAR4 |
| Apiaceae | *Perideridia gairdneri* ssp. *borealis* | common yampah | native | PEGA3 |
| Apocynaceae | *Apocynum androsaemifolium* | spreading dogbane | native | APAN2 |
| Asclepiadaceae | *Asclepias pumila* | plains milkweed | native | ASPU |
| | *Asclepias verticillata* | whorled milkweed | native | ASVE |
| Asteraceae | *Achillea millefolium* var. *occidentalis* | western yarrow | native | ACMI2 |
| | *Ambrosia psilostachya* | perennial ragweed, western ragweed | native | AMPS |
| | *Antennaria neglecta* | field pussytoes | native | ANNE |
| | *Antennaria parvifolia* | little-leaf pussytoes, Rocky Mountain pussytoes, small leaf pussytoes, smalleaf pussytoes | native | ANPA4 |
| | *Artemisia frigida* | fringed sagebrush, fringed sagewort, prairie sagewort | native | ARFR4 |
| | *Artemisia ludoviciana* ssp. *ludoviciana* | cudweed sagewort, gray sagewort, Louisiana sagewort, Louisiana wormwood, mugwort wormwood, prairie sage, white sagebrush | native | ARLU |
| | *Conyza canadensis* | Canada horseweed, Canadian horseweed, horseweed, horseweed fleabane, mares tail, marestail | native | COCA5 |
| | *Gutierrezia sarothrae* | broom snakeweed, broomweed, perennial snakeweed, stinkweed, turpentine weed, yellow top | native | GUSA2 |
| | *Hieracium canadense* var. *canadense* | yellow hawkweed | native | HICA3 |
| | *Liatris punctata* | dotted blazing star, dotted gayfeather | native | LIPU |
| | *Machaeranthera pinnatifida* var. *pinnatifida* | lacy tansyaster | native | MAPI |
| | *Oligoneuron album* | prairie goldenrod | native | OLAL2 |
| | *Ratibida columnifera* | prairie coneflower, redspike Mexican hat, upright prairie coneflower | native | RACO3 |
| | *Solidago missouriensis* | Missouri goldenrod, prairie goldenrod | native | SOMI2 |
| | *Solidago mollis* | ashy goldenrod, soft goldenrod, velvety goldenrod, woolly goldenrod | native | SOMO |
| | *Solidago nemoralis* var. *longipetiolata* | dyersweed goldenrod, gray goldenrod | native | SONE |
| | *Symphyotrichum ericoides* | white heath aster | native | SYER |
| | *Symphyotrichum laeve* var. *laeve* | smooth blue aster, geyer's aster | native | SYLA3 |
| | *Symphyotrichum oblongifolium* | aromatic aster | native | SYOB |
| | *Taraxacum officinale* | blowball, common dandelion, dandelion, faceclock | non-native | TAOF |
| | *Tetraneuris acaulis* var. *acaulis* | stemless hymenoxys, stemless four-nerve daisy | native | TEAC |
| | *Tragopogon dubius* | common salsify, goatsbeard, meadow goat's-beard, salsify, Western goat's beard, western salsify, wild oysterplant, yellow goat's beard, yellow salsify | non-native | TRDU |
| Berberidaceae | *Mahonia repens* | trunkee barberry | native | MARE11 |
| Boraginaceae | *Cynoglossum officinale* | common houndstongue, gypsyflower, houndstongue | non-native | CYOF |

## Devils Tower National Monument (DETO)

| Family | Scientific Name | Common Name(s) | Origin | Code |
|---|---|---|---|---|
| | *Lappula occidentalis* var. *occidentalis* | western stickseed | native | LAOC3 |
| | *Lithospermum incisum* | fringed gromwell, fringed puccoon, narrowleaf gromwell, narrowleaf pucoon, narrowleaf stoneseed | native | LIIN2 |
| Brassicaceae | *Descurainia pinnata* | green tansymustard, pinnate tansy mustard, pinnate tansymustard, tansymustard, western tansymustard | native | DEPI |
| | *Sisymbrium altissimum* | Jim Hill mustard, tall hedge-mustard, tall mustard, tall tumblemustard, tumble mustard, tumbleweed mustard | non-native | SIAL2 |
| Campanulaceae | *Campanula rotundifolia* | bluebell, bluebell bellflower, roundleaf harebell | native | CARO2 |
| | *Triodanis perfoliata* | clasping bellwort, clasping Venus' looking-glass, common Venus' lookingglass, roundleaved triodanis, Venus lookingglass | native | TRPE4 |
| Caprifoliaceae | *Symphoricarpos occidentalis* | western snowberry, wolfberry | native | SYOC |
| Caryophyllaceae | *Cerastium arvense* | starry chickweed | native | CEAR4 |
| Chenopodiaceae | *Chenopodium album* | common lambsquarters, lambsquarters, lambsquarters goosefoot, white goosefoot | unknown | CHAL7 |
| | *Chenopodium pratericola* | desert goosefoot | native | CHPR5 |
| Cupressaceae | *Juniperus communis v*ar. *depressa* | dwarf juniper | native | JUCO6 |
| | *Juniperus scopulorum* | Rocky Mountain juniper | native | JUSC2 |
| Cyperaceae | *Carex alopecoidea* | foxtail sedge | native | CAAL8 |
| | *Carex brevior* | shortbeak sedge | native | CABR10 |
| | *Carex duriuscula* | needleleaf sedge, spike-rush sedge | native | CADU6 |
| | *Carex inops ssp. heliophila* | sun sedge | native | CAIN9 |
| | *Carex sprengelii* | long-beak sedge, Sprengel sedge, Sprengel's sedge | native | CASP7 |
| Euphorbiaceae | *Euphorbia esula* var. *uralensis* | leafy spurge, spurge, wolf's milk | non-native | EUES |
| Fabaceae | *Astragalus crassicarpus* var. *paysonii* | groundplum milkvetch | native | ASCR2 |
| | *Astragalus missouriensis* | Missouri milkvetch | native | ASMI10 |
| | *Lotus unifoliolatus* | American bird's foot trefoil | native | LOUN |
| | *Medicago lupulina* | black medic, black medic clover, black medick, hop clover, hop medic, nonesuch, yellow trefoil | non-native | MELU |
| | *Melilotus officinalis* | yellow sweet-clover, yellow sweetclover | non-native | MEOF |
| | *Oxytropis sericea* | locoweed, silky crazyweed, silvery oxytrope, white crazyweed, white locoweed, white pointloco | native | OXSE |
| | *Pediomelum argophyllum* | silverleaf Indian breadroot, silverleaf scurfpea | native | PEAR6 |
| | *Pediomelum esculentum* | breadroot scurfpea, Indian breadroot, large Indian breadroot | native | PEES |
| | *Thermopsis rhombifolia* | goldenpea, prairie thermopsis | native | THRH |
| | *Vicia americana* | american vetch | native | VIAM |

## Devils Tower National Monument (DETO)

| Family | Scientific Name | Common Name(s) | Origin | Code |
|---|---|---|---|---|
| Fagaceae | *Quercus macrocarpa* | bur oak | native | QUMA2 |
| Grossulariaceae | *Ribes oxyacanthoides* ssp. *setosum* | Canadian gooseberry, inland gooseberry, redshoot gooseberries | native | RIOX |
| Juncaceae | *Juncus compressus* | roundfruit rush | non-native | JUCO |
| Lamiaceae | *Hedeoma hispida* | false pennyroyal, rough false pennyroyal, rough pennyroyal | native | HEHI |
| | *Monarda fistulosa* var. *menthifolia* | mintleaf beebalm, Oswego-tea, wild bergamot, wildbergamot beebalm, wildbergamot horsemint | native | MOFI |
| Liliaceae | *Zigadenus venenosus* var. *gramineus* | meadow deathcamas | native | ZIVE |
| Linaceae | *Linum lewisii* | blue flax, Lewis blue flax, Lewis flax, prairie flax | native | LILE3 |
| Malvaceae | *Sphaeralcea coccinea* | scarlet globemallow, copper mallow, orange globemallow, red falsemallow | native | SPCO |
| Nyctaginaceae | *Mirabilis linearis* | linearleaf four-o'clock, narrow-leaf four-o'clock, narrowleaf four o clock, narrowleaf four o'clock, narrowleaf four-o'clock | native | MILI3 |
| Oleaceae | *Fraxinus pennsylvanica* | green ash | native | FRPE |
| Oxalidaceae | *Oxalis stricta* | common yellow oxalis, sheep sorrel, sourgrass, toad sorrel, upright yellow woodsorrel, yellow woodsorrel | native | OXST |
| Pinaceae | *Pinus ponderosa* | ponderosa pine, rock pine, western yellow pine | native | PIPO |
| Plantaginaceae | *Plantago patagonica* | woolly Indianwheat, woolly plantain | native | PLPA2 |
| Poaceae | *Achnatherum nelsonii* ssp. *nelsonii* | Columbian needlegrass | native | ACNE9 |
| | *Agrostis scabra* | ticklegrass | native | AGSC5 |
| | *Andropogon gerardii* | big bluestem, bluejoint, turkeyfoot | native | ANGE |
| | *Aristida purpurea* var. *longiseta* | threeawn | native | ARPU9 |
| | *Bouteloua curtipendula* | sideoats grama | native | BOCU |
| | *Bromus anomalus* | nodding brome, nodding bromegrass | native | BRAN |
| | *Bromus inermis* var. *inermis* | awnless brome, smooth brome | non-native | BRIN2 |
| | *Bromus japonicus* | Japanese brome, Japanese chess | non-native | BRJA |
| | *Bromus tectorum* | cheat grass, cheatgrass, downy brome, early chess, military grass, wild oats | non-native | BRTE |
| | *Buchloe dactyloides* | buffalograss | native | BUDA |
| | *Calamagrostis montanensis* | plains reedgrass | native | CAMO |
| | *Calamovilfa longifolia* | prairie sandreed | native | CALO |
| | *Danthonia spicata* | poverty danthonia, poverty oatgrass, poverty wild oat grass | native | DASP2 |
| | *Elymus canadensis* var. *canadensis* | Canada wildrye | native | ELCA4 |
| | *Elymus glaucus* | blue wild rye, blue wildrye | native | ELGL |
| | *Elymus trachycaulus* | slender wheatgrass | native | ELTR7 |

## Devils Tower National Monument (DETO)

| Family | Scientific Name | Common Name(s) | Origin | Code |
|---|---|---|---|---|
| | *Festuca ovina* | sheep fescue | non-native | FEOV |
| | *Hesperostipa comata* ssp. *comata* | needleandthread | native | HECO26 |
| | *Hesperostipa spartea* | porcupinegrass | native | HESP11 |
| | *Koeleria macrantha* | junegrass, prairie Junegrass | native | KOMA |
| | *Muhlenbergia racemosa* | green muhly, marsh muhly | native | MURA |
| | *Nassella viridula* | green needlegrass | native | NAVI4 |
| | *Pascopyrum smithii* | pubescent wheatgrass, western wheatgrass | native | PASM |
| | *Phleum pratense* | common timothy, timothy | non-native | PHPR3 |
| | *Piptatherum micranthum* | little-seed mountain-rice grass, littleseed ricegrass | native | PIMI7 |
| | *Poa nemoralis* var. *interior* | inland bluegrass | native | PONE |
| | *Poa pratensis* | Kentucky bluegrass | non-native | POPR |
| | *Schedonnardus paniculatus* | tumblegrass | native | SCPA |
| | *Schizachyrium scoparium* var. *scoparium* | little bluestem | native | SCSC |
| | *Vulpia octoflora* var. *octoflora* | eight-flower six-weeks grass, pullout grass, sixweeks fescue, sixweeks grass | native | VUOC |
| Polemoniaceae | *Collomia linearis* | narrowleaf mountaintrumpet, slenderleaf collomia, tiny trumpet | native | COLI2 |
| | *Linanthus septentrionalis* | northern linanthus | native | LISE |
| | *Phlox alyssifolia* | alyssumleaf phlox, phlox | native | PHAL3 |
| Polygonaceae | *Polygonum aviculare* | prostrate knotweed, yard knotweed | non-native | POAV |
| Primulaceae | *Androsace occidentalis* | western rock-jasmine | native | ANOC2 |
| Ranunculaceae | *Anemone cylindrica* | cottonweed | native | ANCY |
| | *Ceratocephala testiculata* | curve-seed-butterwort | non-native | CETE5 |
| | *Myosurus minimus* | tiny mousetail | native | MYMI2 |
| | *Pulsatilla patens* ssp. *multifida* | Pasque flower | native | PUPA5 |
| Rosaceae | *Prunus virginiana* var. *melanocarpa* | chokecherry, common chokecherry, Virginia chokecherry | native | PRVI |
| Rubiaceae | *Galium boreale* | northern bedstraw | native | GABO2 |
| Salicaceae | *Populus deltoides* ssp. *monilifera* | Plains cottonwood | native | PODE3 |
| Scrophulariaceae | *Collinsia parviflora* | small-flower blue-eyed mary | native | COPA3 |
| | *Penstemon gracilis* | lilac penstemon, slender penstemon | native | PEGR5 |
| | *Penstemon grandiflorus* | large beardtongue, largeflowered penstemon | native | PEGR7 |
| | *Verbascum thapsus* | big taper, common mullein, flannel mullein, great mullein, mullein, velvet plant, woolly mullein | non-native | VETH |
| Solanaceae | *Solanum triflorum* | cut-leaf nightshade | native | SOTR |
| Verbenaceae | *Verbena bracteata* | bigbract verbena, bracted vervain, carpet vervain, prostrate verbena, prostrate vervain | native | VEBR |
| Violaceae | *Viola adunca* | blue violet, hook violet, hookedspur violet | native | VIAD |

## Fort Laramie National Historic Site (FOLA)

| Family | Scientific Name | Common Name(s) | Origin | Code |
|---|---|---|---|---|
| Anacardiaceae | *Toxicodendron rydbergii* | poison ivy, western poison ivy | native | TORY |
| Asclepiadaceae | *Asclepias speciosa* | showy milkweed | native | ASSP |
| | *Asclepias viridiflora* | green milkweed | native | ASVI |
| Asteraceae | *Ambrosia psilostachya* | perennial ragweed, western ragweed | native | AMPS |
| | *Artemisia campestris* | wormwood sagewort | native | ARCA12 |
| | *Artemisia dracunculus* | false tarragon, green sagewort, silky wormwood, tarragon, wormwood | native | ARDR4 |
| | *Artemisia filifolia* | sand sagebrush | native | ARFI2 |
| | *Artemisia frigida* | fringed sagebrush, fringed sagewort, prairie sagewort | native | ARFR4 |
| | *Artemisia ludoviciana* | cudweed sagewort, gray sagewort, Louisiana sagewort, Louisiana wormwood, prairie sage, white sagebrush | native | ARLU |
| | *Conyza canadensis* | Canada horseweed, Canadian horseweed, horseweed, horseweed fleabane, mares tail, marestail | native | COCA5 |
| | *Ericameria nauseosa* | rubber rabbitbrush | native | ERNA10 |
| | *Erigeron divergens* | spreading fleabane | native | ERDI4 |
| | *Grindelia squarrosa* | curlycup gumweed, curlytop gumweed, gumweed, rosinweed, tarweed | native | GRSQ |
| | *Heterotheca villosa* | hairy false goldaster, hairy false goldenaster, hairy goldaster, hairy goldenaster | native | HEVI4 |
| | *Lactuca serriola* | China lettuce, prickly lettuce, wild lettuce | non-native | LASE |
| | *Lactuca tatarica* | blue lettuce, blue wild lettuce, chicory lettuce, Russian blue lettuce | native | LATA |
| | *Liatris punctata* | dotted blazing star, dotted gayfeather | native | LIPU |
| | *Logfia arvensis* | field cottonrose | non-native | LOAR5 |
| | *Lygodesmia juncea* | rush skeleton-plant, rush skeletonplant, rush skeletonweed, skeletonplant, skeletonweed | native | LYJU |
| | *Machaeranthera tanacetifolia* | tansyleaf tansyaster | native | MATA2 |
| | *Scorzonera laciniata* | cutleaf vipergrass | non-native | SCLA6 |
| | *Senecio riddellii* | Riddell's grounsel, Riddell's ragwort | native | SERI2 |
| | *Symphyotrichum ericoides* | white heath aster | native | SYER |
| | *Taraxacum officinale* | blowball, common dandelion, dandelion, faceclock | non-native | TAOF |
| | *Thelesperma megapotamicum* | Hopitea, greenthread | native | THME |
| | *Tragopogon dubius* | common salsify, goatsbeard, meadow goat's-beard, salsify, Western goat's beard, western salsify, wild oysterplant, yellow goat's beard, yellow salsify | non-native | TRDU |
| Boraginaceae | *Cryptantha cinerea* var. *jamesii* | James' cryptantha | native | CRCIJ |

## Fort Laramie National Historic Site (FOLA)

| Family | Scientific Name | Common Name(s) | Origin | Code |
|---|---|---|---|---|
| | *Cryptantha minima* | small cryptantha | native | CRMI5 |
| | *Lappula occidentalis* | western stickseed | native | LAOC3 |
| | *Lithospermum incisum* | fringed gromwell, fringed puccoon, narrowleaf gromwell, narrowleaf pucoon, narrowleaf stoneseed | native | LIIN2 |
| | *Lithospermum ruderale* | western stoneseed | native | LIRU4 |
| Brassicaceae | *Alyssum desertorum* | desert alyssum, desert madwort | non-native | ALDE |
| | *Camelina microcarpa* | false flax, littlepod falseflax, littleseed falseflax, small fruited falseflax, smallseed falseflax | non-native | CAMI2 |
| | *Descurainia pinnata* | green tansymustard, pinnate tansymustard, tansymustard, western tansymustard | native | DEPI |
| | *Descurainia sophia* | flaxweed tansymustard, flixweed, flixweed tansymustard, herb sophia, herb-sophia | non-native | DESO2 |
| | *Lepidium densiflorum* | common pepperweed, greenflower pepperweed, miner's pepperwort, peppergrass, prairie pepperweed | native | LEDE |
| | *Sisymbrium altissimum* | Jim Hill mustard, tall hedge-mustard, tall mustard, tall tumblemustard, tumble mustard, tumbleweed mustard | non-native | SIAL2 |
| Cactaceae | *Escobaria vivipara* | pink pincushioncactus, spinystar, spinystar cactus | native | ESVI2 |
| | *Opuntia fragilis* | brittle cactus, brittle pricklypear, fragile cactus, jumping cactus, little pricklypear | native | OPFR |
| | *Opuntia macrorhiza* | twistspine pricklypear, bigroot pricklypear | native | OPMA2 |
| | *Opuntia polyacantha* | Plains pricklypear | native | OPPO |
| Caprifoliaceae | *Symphoricarpos occidentalis* | western snowberry, wolfberry | native | SYOC |
| Chenopodiaceae | *Kochia scoparia* | fireweed, kochia, Mexican burningbush, Mexican fireweed, Mexican-fireweed, mock cypress, Summer cypress | non-native | KOSC |
| | *Salsola collina* | spineless Russian thistle | non-native | SACO8 |
| Commelinaceae | *Tradescantia occidentalis* | prairie spiderwort, spiderwort, western spiderwort | native | TROC |
| Convolvulaceae | *Ipomoea leptophylla* | bush morningglory | native | IPLE |
| Cyperaceae | *Carex duriuscula* | needleleaf sedge, spike-rush sedge | native | CADU6 |
| Euphorbiaceae | *Chamaesyce glyptosperma* | ribseed sandmat, ridgeseed spurge | native | CHGL13 |
| Fabaceae | *Glycyrrhiza lepidota* | American licorice, licorice, wild licorice | native | GLLE3 |
| | *Lupinus pusillus* | small lupine, rusty lupine | native | LUPU |
| | *Medicago sativa* | alfalfa | non-native | MESA |
| | *Psoralidium tenuiflorum* | slimflower scurfpea | native | PSTE5 |
| Geraniaceae | *Erodium cicutarium* | redstem stork's bill | non-native | ERCI6 |
| Lamiaceae | *Melilotus officinalis* | yellow sweet-clover, yellow sweetclover | non-native | MEOF |
| Loasaceae | *Mentzelia nuda* | stickleaf mentzelia, bractless blazingstar | native | MENU |

## Fort Laramie National Historic Site (FOLA)

| Family | Scientific Name | Common Name(s) | Origin | Code |
|---|---|---|---|---|
| Malvaceae | *Sphaeralcea coccinea* | scarlet globemallow, copper mallow, orange globemallow, red falsemallow | native | SPCO |
| Nyctaginaceae | *Mirabilis hirsuta* | hairy four o'clock | native | MIHI |
| | *Mirabilis linearis* | linearleaf four-o'clock, narrowleaf four-o'clock | native | MILI3 |
| Onagraceae | *Gaura coccinea* | scarlet beeblossom, scarlet gaura | native | GACO5 |
| | *Gaura mollis* | James velvetweed | native | GAMO5 |
| | *Oenothera albicaulis* | halfshrub sundrop, white-stem evening-primrose, whitest evening-primrose | native | OEAL |
| Papaveraceae | *Argemone polyanthemos* | prickly poppy | native | ARPO2 |
| Plantaginaceae | *Plantago patagonica* | woolly Indianwheat, woolly plantain, woolly plantian | native | PLPA2 |
| Poaceae | *Achnatherum hymenoides* | Indian ricegrass | native | ACHY |
| | *Agropyron cristatum* | crested wheatgrass | non-native | AGCR1 |
| | *Aristida purpurea* | purple three-awn | native | ARPU9 |
| | *Bouteloua gracilis* | blue grama | native | BOGR2 |
| | *Bromus inermis* | awnless brome, smooth brome | non-native | BRIN2 |
| | *Bromus japonicus* | Japanese brome, Japanese chess | non-native | BRJA |
| | *Bromus tectorum* | cheat grass, cheatgrass, downy brome, early chess, military grass, wild oats | non-native | BRTE |
| | *Calamovilfa longifolia* | prairie sandreed | native | CALO |
| | *Distichlis spicata* | seashore saltgrass | native | DISP |
| | *Elymus elymoides* | squirreltail | native | ELEL5 |
| | *Elymus repens* | quackgrass | non-native | ELRE4 |
| | *Hesperostipa comata* | needleandthread | native | HECO26 |
| | *Hordeum pusillum* | little barley | native | HOPU |
| | *Nassella viridula* | green needlegrass | native | NAVI4 |
| | *Pascopyrum smithii* | pubescent wheatgrass, western wheatgrass | native | PASM |
| | *Poa pratensis* | Kentucky bluegrass | non-native | POPR |
| | *Sporobolus cryptandrus* | sand dropseed | native | SPCR |
| | *Vulpia octoflora* | eight-flower six-weeks grass, pullout grass, sixweeks fescue, sixweeks grass | native | VUOC |
| Polygonaceae | *Eriogonum annuum* | annual buckwheat, annual eriogonum, annual wild buckwheat, umbrella plant, wild buckwheat | native | ERAN4 |
| Salicaceae | *Populus angustifolia* | narrowleaf cottonwood | native | POAN3 |
| | *Populus deltoides* ssp. *monilifera* | Plains cottonwood | native | PODEM |
| Scrophulariaceae | *Penstemon albidus* | white penstemon | native | PEAL2 |
| | *Penstemon angustifolius* | broad-beard beardtongue, narrowleaf penstemon | native | PEAN4 |
| Solanaceae | *Physalis hispida* | prairie groundcherry | native | PHHI8 |

## Fort Laramie National Historic Site (FOLA)

| Family | Scientific Name | Common Name(s) | Origin | Code |
|---|---|---|---|---|
| | *Physalis longifolia* | common groundcherry, longleaf groundcherry | native | PHLO4 |
| Verbenaceae | *Phyla cuneifolia* | wedgeleaf | native | PHCU3 |

## Theodore Roosevelt National Park (THRO)

| Family | Scientific Name | Common Name(s) | Origin | Code |
|---|---|---|---|---|
| Amaranthaceae | *Amaranthus retroflexus* | redroot pigweed, rough pigweed | non-native | AMARA |
| Anacardiaceae | *Rhus trilobata* | skunkbush sumac | native | RHTR |
| | *Toxicodendron rydbergii* | poison ivy, western poison ivy, western poison-ivy | native | TORY |
| Apiaceae | *Lomatium foeniculaceum* | biscuitroot, carrot-leaf desert-parsley, desert biscuitroot | native | LOFO |
| Apocynaceae | *Apocynum androsaemifolium* | bitterroot, flytrap dogbane, spreading dogbane | native | APAN2 |
| Asclepiadaceae | *Asclepias speciosa* | showy milkweed | native | ASSP |
| | *Asclepias viridiflora* | green antelopehorn milkweed, green comet milkweed, green milkweed | native | ASVI |
| Asteraceae | *Achillea millefolium* | common yarrow | native | ACMI2 |
| | *Ambrosia psilostachya* | perennial ragweed, western ragweed | native | AMPS |
| | *Anaphalis margaritacea* | western pearly everlasting | native | ANMA |
| | *Antennaria microphylla* | pink pussytoes, littleleaf pussytoes | native | ANMI3 |
| | *Antennaria parvifolia* | Rocky Mountain pussytoes, smalleaf pussytoes | native | ANPA4 |
| | *Artemisia campestris* ssp. *caudata* | field sagewort | native | ARCA12 |
| | *Artemisia cana* | silver sagebrush | native | ARCA13 |
| | *Artemisia dracunculus* | false tarragon, green sagewort, silky wormwood, tarragon, wormwood | native | ARDR4 |
| | *Artemisia frigida* | fringed sagebrush, fringed sagewort, prairie sagewort | native | ARFR4 |
| | *Artemisia longifolia* | longleaf wormwood | native | ARLO7 |
| | *Artemisia ludoviciana* | cudweed sagewort, gray sagewort, Louisiana sagewort, Louisiana wormwood, mugwort wormwood, prairie sage, white sagebrush | native | ARLU |
| | *Artemisia tridentata* | big sagebush | native | ARTR2 |
| | *Cirsium arvense* | Californian thistle, Canada thistle, Canadian thistle, creeping thistle, field thistle | non-native | CIAR4 |
| | *Cirsium flodmanii* | Flodman thistle, Flodman's thistle | native | CIFL |
| | *Conyza canadensis* | Canada horseweed, Canadian horseweed, horseweed, horseweed fleabane, mares tail, marestail | native | COCA5 |
| | *Dyssodia papposa* | dogbane dyssodia, dogweed, fetid dogweed, fetid marigold, prairie dogweed | native | DYPA |
| | *Echinacea angustifolia* | blacksamson, blacksamson echinacea | native | ECAN2 |
| | *Ericameria nauseosa* var. *nauseosa* | rubber rabbitbrush | native | ERNA10 |
| | *Grindelia squarrosa* | curlycup gumweed, curlytop gumweed, gumweed, rosinweed, tarweed | native | GRSQ |
| | *Gutierrezia sarothrae* | broom snakeweed, broomweed, perennial snakeweed, stinkweed, turpentine weed, yellow top | native | GUSA2 |
| | *Helianthus annuus* | annual sunflower, common sunflower, sunflower, wild sunflower | native | HEAN3 |

## Theodore Roosevelt National Park (THRO)

| Family | Scientific Name | Common Name(s) | Origin | Code |
|---|---|---|---|---|
| | *Helianthus maximiliani* | Maximilian sunflower | native | HEMA2 |
| | *Helianthus pauciflorus* | stiff sunflower | native | HEPA19 |
| | *Helianthus petiolaris* | prairie sunflower | native | HEPE |
| | *Heterotheca villosa* | hairy false goldaster, hairy false goldenaster, hairy goldaster, hairy goldenaster | native | HEVI4 |
| | *Hymenopappus filifolius* | cutleaf, fine-leaf woollywhite, fineleaf hymenopappus | native | HYFI |
| | *Hymenoxys richardsonii* | pingue rubberweed | native | HYRI |
| | *Lactuca serriola* | China lettuce, prickly lettuce, wild lettuce | non-native | LASE |
| | *Lactuca tatarica* var. *pulchella* | blue lettuce, blue wild lettuce, chicory lettuce, Russian blue lettuce | native | LATA |
| | *Liatris punctata* | dotted blazing star, dotted gayfeather | native | LIPU |
| | *Machaeranthera canescens* | hoary tansyaster | native | MACA2 |
| | *Oligoneuron album* | prairie goldenrod | native | OLAL2 |
| | *Packera cana* | wooly groundsel | native | PACA15 |
| | *Packera plattensis* | prairie groundsel | native | PAPL12 |
| | *Ratibida columnifera* | prairie coneflower, redspike Mexican hat, upright prairie coneflower | native | RACO3 |
| | *Solidago canadensis* | Canada goldenrod, common goldenrod | native | SOCA6 |
| | *Solidago gigantea* | giant goldenrod | native | SOGI |
| | *Solidago missouriensis* | Missouri goldenrod, prairie goldenrod | native | SOMI2 |
| | *Solidago nemoralis* | dyersweed goldenrod, gray goldenrod | native | SONE |
| | *Symphyotrichum ericoides* | white heath aster | native | SYER |
| | *Symphyotrichum laeve* | smooth blue aster, geyer's aster | native | SYLA3 |
| | *Symphyotrichum lanceolatum* | white panicle aster | native | SYLA6 |
| | *Symphyotrichum oblongifolium* | aromatic aster | native | SYOB |
| | *Taraxacum officinale* | blowball, common dandelion, dandelion, faceclock | non-native | TAOF |
| | *Tetraneuris acaulis* | stemless hymenoxys, stemless four-nerve daisy | native | TEAC |
| | *Tragopogon dubius* | common salsify, goatsbeard, meadow goat's-beard, salsify, Western goat's beard, western salsify, wild oysterplant, yellow goat's beard, yellow salsify | non-native | TRDU |
| | *Xanthium strumarium* | rough cocklebur | native | XAST |
| Boraginaceae | *Cryptantha celosioides* | buttecandle, minerscandle | native | CRCE |
| | *Cynoglossum officinale* | common houndstongue, gypsy-flower, gypsyflower, hound's tongue, houndstongue | non-native | CYOF |
| | *Lappula occidentalis* | flatspine stickseed | native | LAOC3 |
| | *Lithospermum incisum* | fringed gromwell, fringed puccoon, narrowleaf gromwell, narrowleaf pucoon, narrowleaf stoneseed | native | LIIN2 |

## Theodore Roosevelt National Park (THRO)

| Family | Scientific Name | Common Name(s) | Origin | Code |
|---|---|---|---|---|
| Brassicaceae | *Alyssum desertorum* | desert alyssum, desert madwort | native | ALDE |
| | *Camelina microcarpa* | false flax, littlepod falseflax, littleseed falseflax, small fruited falseflax, smallseed falseflax | non-native | CAMI2 |
| | *Descurainia pinnata* | green tansymustard, pinnate tansy mustard, pinnate tansymustard, tansymustard, western tansymustard | native | DEPI |
| | *Descurainia sophia* | flaxweed tansymustard, flixweed, flixweed tansymustard, herb sophia, herb-sophia | non-native | DESO2 |
| | *Erysimum capitatum* | plains wallflower, prairie rocket, sanddune wallflower, western wallflower | native | ERCA14 |
| | *Erysimum inconspicuum* | smallflower wallflower | native | ERIN7 |
| | *Lepidium densiflorum* | common pepperweed, greenflower pepperweed, miner's pepperwort, peppergrass, prairie pepperweed | native | LEDE |
| | *Lesquerella alpina* | alpine bladderpod | native | LEAL |
| | *Lesquerella ludoviciana* | foothill bladderpod, Louisiana bladderpod, silver bladderpod | native | LELU |
| | *Thlaspi arvense* | fanweed, field pennycress, Frenchweed, pennycress, stinkweed | non-native | THAR5 |
| Cactaceae | *Opuntia macrorhiza* | twistspine pricklypear, bigroot pricklypear | native | OPMA2 |
| | *Opuntia polyacantha* | Plains pricklypear | native | OPPO |
| Campanulaceae | *Campanula rotundifolia* | bluebell, bluebell bellflower, roundleaf harebell | native | CARO2 |
| Caprifoliaceae | *Symphoricarpos occidentalis* | western snowberry, wolfberry | native | SYOC |
| Caryophyllaceae | *Cerastium arvense* | starry chickweed | non-native | CEAR |
| | *Silene antirrhina* | catchfly, sleepy campion, sleepy catchfly, sleepy silene | native | SIAN2 |
| Chenopodiaceae | *Atriplex canescens* | fourwing saltbush | native | ATCA2 |
| | *Atriplex confertifolia* | spiny saltbush | native | ATCO |
| | *Atriplex nuttallii* | Nuttall's saltbush | native | ATNU2 |
| | *Chenopodium album* | common lambsquarters, lambsquarters, lambsquarters goosefoot, white goosefoot | native | CHAL7 |
| | *Chenopodium pratericola* | desert goosefoot | native | CHPR5 |
| | *Chenopodium simplex* | giant-seed goosefoot, mapleleaf goosefoot | native | CHSI2 |
| | *Endolepis dioica* | Suckley's endolepis | native | ENDI |
| | *Krascheninnikovia lanata* | winterfat | native | KRLA2 |
| | *Salsola kali* | tumbleweed | non-native | SAKA |
| | *Sarcobatus vermiculatus* | black greasewood, greasewood | native | SAVE4 |
| | *Suaeda moquinii* | Torrey seepweed | native | SUMO |
| Cupressaceae | *Juniperus communis* | common juniper, dwarf juniper | native | JUCO6 |

## Theodore Roosevelt National Park (THRO)

| Family | Scientific Name | Common Name(s) | Origin | Code |
|---|---|---|---|---|
| | *Juniperus horizontalis* | creeping juniper | native | JUHO2 |
| | *Juniperus scopulorum* | Rocky Mountain juniper | native | JUSC2 |
| Cyperaceae | *Carex brevior* | shortbeak sedge | native | CABR10 |
| | *Carex duriuscula* | needleleaf sedge, spike-rush sedge | native | CADU6 |
| | *Carex filifolia* | threadleaf sedge | native | CAFI |
| | *Carex inops* ssp. *heliophila* | sun sedge | native | CAIN9 |
| Euphorbiaceae | *Chamaesyce glyptosperma* | ribseed sandmat, ridgeseed spurge | native | CHGL13 |
| | *Euphorbia brachycera* | horned spurge, Rocky Mountain spurge | native | EUBR |
| | *Euphorbia esula* | leafy spurge, spurge, wolf's milk, wolf's-milk | non-native | EUES |
| | *Euphorbia spathulata* | roughpod spurge, warty spurge | native | EUSP |
| Fabaceae | *Astragalus agrestis* | cock's-head, field milkvetch, purple milkvetch | native | ASAG2 |
| | *Astragalus crassicarpus* | ground-plum, groundplum milkvetch | native | ASCR2 |
| | *Astragalus gilviflorus* | plains milkvetch | native | ASGI5 |
| | *Astragalus laxmannii* var. *robustior* | Laxmann's milkvetch, prairie milkvetch | native | ASLA27 |
| | *Astragalus missouriensis* | Missouri milkvetch | native | ASMI10 |
| | *Astragalus purshii* | woollypod milkvetch | native | ASPU9 |
| | *Dalea candida* | white prairieclover | native | DACA7 |
| | *Dalea purpurea* | Purple prairieclover, violet dalea, violet prairie clover | native | DAPU5 |
| | *Glycyrrhiza lepidota* | American licorice, licorice, wild licorice | native | GLLE3 |
| | *Hedysarum boreale* | sweetvetch | native | HEBO |
| | *Lotus unifoliolatus* | American bird's-foot trefoil | native | LOUNU |
| | *Medicago lupulina* | black medic, black medic clover, black medick, hop clover, hop medic, nonesuch, yellow trefoil | non-native | MELU |
| | *Melilotus officinalis* | yellow sweet-clover, yellow sweetclover | non-native | MEOF |
| | *Oxytropis lambertii* | Lambert crazyweed, Lambert locoweed, purple loco, purple locoweed, stemless loco, whitepoint locoweed | native | OXLA3 |
| | *Oxytropis sericea* | locoweed, silky crazyweed, silvery oxytrope, white crazyweed, white locoweed, white pointloco | native | OXSE |
| | *Pediomelum esculentum* | breadroot scurfpea, Indian breadroot, large Indian breadroot | native | PEES |
| | *Thermopsis rhombifolia* | goldenpea, prairie thermopsis | native | THRH |
| | *Vicia americana* | American deervetch, American vetch | native | VIAM |
| Grossulariaceae | *Ribes aureum* | golden currant | native | RIAU |
| | *Ribes oxyacanthoides* | Canadian gooseberry | native | RIOX |
| Lamiaceae | *Hedeoma drummondii* | Drummond's false pennyroyal, Drummond's falsepennyroyal | native | HEDR |
| | *Hedeoma hispida* | rough false pennyroyal | native | HEHI |

## Theodore Roosevelt National Park (THRO)

| Family | Scientific Name | Common Name(s) | Origin | Code |
|---|---|---|---|---|
| | *Monarda fistulosa* | mintleaf beebalm, Oswego-tea, wild bergamot, wildbergamot beebalm, wildbergamot horsemint | native | MOFI |
| Liliaceae | *Allium textile* | prairie onion, textile onion, wild onion | native | ALTE |
| | *Maianthemum stellatum* | starry false lily of the valley | native | MAST4 |
| Linaceae | *Linum lewisii* | blue flax, Lewis blue flax, Lewis flax, prairie flax | native | LILE3 |
| | *Linum rigidum* | orange flax, stiff flax, stiffstem flax | native | LIRI |
| Malvaceae | *Sphaeralcea coccinea* | copper mallow, orange globemallow, red falsemallow, scarlet globemallow | native | SPCO |
| Nyctaginaceae | *Mirabilis hirsuta* | hairy four o'clock | native | MIHI |
| | *Mirabilis linearis* | linearleaf four-o'clock, narrowleaf four-o'clock | native | MILI3 |
| Oleaceae | *Fraxinus pennsylvanica* | green ash | native | FRPE |
| Onagraceae | *Gaura coccinea* | scarlet beeblossom, scarlet gaura | native | GACO5 |
| | *Oenethera biennis* | common evening-primrose | native | OEBI |
| | *Oenothera caespitosa* | tufted evening-primrose | native | OECA10 |
| Plantaginaceae | *Plantago patagonica* | woolly Indianwheat, woolly plantain | native | PLPA2 |
| Poaceae | *Achnatherum hymenoides* | Indian ricegrass | native | ACHY |
| | *Andropogon gerardii* | big bluestem, bluejoint, turkeyfoot | native | ANGE |
| | *Bouteloua curtipendula* | sideoats grama | native | BOCU |
| | *Bouteloua gracilis* | blue grama | native | BOGR2 |
| | *Bromus inermis* | awnless brome, smooth brome | non-native | BRIN2 |
| | *Bromus japonicus* | Japanese brome, Japanese chess | non-native | BRJA |
| | *Bromus pubescens* | hairy woodland brome | native | BRPU |
| | *Bromus tectorum* | cheat grass, cheatgrass, downy brome, early chess, military grass, wild oats | non-native | BRTE |
| | *Calamovilfa longifolia* | prairie sandreed | native | CALO |
| | *Danthonia spicata* | poverty danthonia, poverty oatgrass, poverty wild oat grass | native | DASP2 |
| | *Distichlis spicata* | seashore saltgrass | native | DISP |
| | *Elymus canadensis* | Canada wildrye | native | ELCA4 |
| | *Elymus elymoides* | squirreltail | native | ELEL5 |
| | *Elymus repens* | quackgrass | non-native | ELRE4 |
| | *Elymus trachycaulus* | slender wheatgrass | native | ELTR7 |
| | *Hesperostipa comata* ssp. *comata* | needleandthread | native | HECO26 |
| | *Koeleria macrantha* | junegrass, prairie Junegrass | native | KOMA |
| | *Muhlenbergia cuspidata* | plains muhly | native | MUCU3 |
| | *Muhlenbergia racemosa* | green muhly, marsh muhly | native | MURA |
| | *Nassella viridula* | green needlegrass | native | NAVI4 |
| | *Pascopyrum smithii* | pubescent wheatgrass, western wheatgrass | native | PASM |

## Theodore Roosevelt National Park (THRO)

| Family | Scientific Name | Common Name(s) | Origin | Code |
|---|---|---|---|---|
| | *Piptatherum micranthum* | little-seed mountain-rice grass, littleseed ricegrass | native | PIMI7 |
| | *Poa arida* | Plains bluegrass | native | POAR3 |
| | *Poa compressa* | Canada bluegrass, flat-stem blue grass | non-native | POCO |
| | *Poa pratensis* | Kentucky bluegrass | non-native | POPR |
| | *Schedonnardus paniculatus* | tumblegrass | non-native | SCPA |
| | *Schizachyrium scoparium* | little bluestem | native | SCSC |
| | *Sporobolus airoides* | alkali-sacaton | native | SPAI |
| | *Sporobolus cryptandrus* | sand dropseed | native | SPCR |
| | *Thinopyrum intermedium* | intermediate wheatgrass | non-native | THIN6 |
| | *Vulpia octoflora* | eight-flower six-weeks grass, pullout grass, sixweeks fescue, sixweeks grass | native | VUOC |
| Polemoniaceae | *Collomia linearis* | narrow-leaf mountain-trumpet, slenderleaf collomia, tiny trumpet | native | COLI2 |
| | *Phlox hoodii* | Hood's phlox, spiny phlox | native | PHHO |
| Polygalaceae | *Polygala alba* | white milkwort | native | POAL4 |
| | *Polygala verticillata* | whorled milkwort | native | POVE |
| Polygonaceae | *Eriogonum flavum* | alpine golden buckwheat, yellow eriogonum | native | ERFL4 |
| | *Eriogonum pauciflorum* | fewflower buckwheat, manybranch eriogonum | native | ERPA9 |
| | *Polygonum convolvulus* | black bindweed, black-bindweed, climbing buckwheat, climbing knotweed, cornbind, dullseed cornbind, pink smartweed, wild buckwheat | non-native | POCO10 |
| Ranunculaceae | *Clematis ligusticifolia* | virgin'sbower, virgins bower, western white clematis | native | CLLI2 |
| | *Pulsatilla patens* | cutleaf anemone | native | PUPA5 |
| | *Thalictrum dasycarpum* | purple meadow-rue, purple meadowrue | native | THDA |
| Rosaceae | *Agrimonia striata* | woodland grooveburr | native | AGST |
| | *Dasiphora floribunda* | shrubby cinquefoil | native | DAFL3 |
| | *Geum triflorum* | old man's whiskers, prairie smoke | native | GETR |
| | *Prunus pumila* var. *besseyi* | Great Lakes sand cherry, western sandcherry | native | PRPU3 |
| | *Prunus virginiana* | chokecherry, common chokecherry, Virginia chokecherry | native | PRVI |
| | *Rosa woodsii* | Wood's rose, woods rose, Woods' rose | native | ROWO |
| Rubiaceae | *Galium aparine* | bedstraw, catchweed bedstraw, cleavers, cleaverwort, goose grass, scarthgrass, sticky-willy, white hedge | native | GAAP2 |
| | *Galium boreale* | northern bedstraw | native | GABO2 |
| Salicaceae | *Populus deltoides* ssp. *monilifera* | Plains cottonwood | native | PODE3 |
| Santalaceae | *Comandra umbellate* | bastard toadflax | native | COUM |
| Scrophulariaceae | *Orthocarpus luteus* | golden-tongue owl-clover, yellow owl's-clover, yellow owlclover | native | ORLU2 |

## Theodore Roosevelt National Park (THRO)

| Family | Scientific Name | Common Name(s) | Origin | Code |
|---|---|---|---|---|
| | *Penstemon angustifolius* | broad-beard beardtongue, broadbeard beardtongue, narrowleaf penstemon | native | PEAN4 |
| Solanaceae | *Physalis virginiana* | lanceleaf groundcherry, Virginia groundcherry | native | PHVI5 |
| Urticaceae | *Parietaria pensylvanica* | Pennsylvania pellitory | native | PAPE5 |
| Violaceae | *Viola canadensis* var. *rugulosa* | Canadian white violet | native | VICA4 |
| | *Viola nuttallii* | Nuttall violet, Nuttall's violet, yellow prairie violet | native | VINU2 |
| | *Viola pedatifida* | crow-foot violet, prairie violet | native | VIPE2 |
| Vitaceae | *Parthenocissus vitacea* | thicket creeper, Virginia creeper, woodbine | native | PAVI5 |

## Wind Cave National Park (WICA)

| Family | Scientific Name | Common Name(s) | Origin | Code |
|---|---|---|---|---|
| Aceraceae | *Acer negundo* var. *interius* | western boxelder | native | ACNE2 |
| Agavaceae | *Yucca glauca* | beargrass, Great Plains yucca, small soapweed, soapweed yucca, Spanish bayonet, yucca | native | YUGL |
| Amaranthaceae | *Amaranthus blitoides* | mat amaranth, prostrate pigweed | native | AMBL |
| | *Amaranthus retroflexus* | redroot pigweed, rough pigweed | non-native | AMRE |
| Anacardiaceae | *Rhus trilobata* | skunkbush sumac | native | RHTR |
| | *Toxicodendron rydbergii* | poison ivy, western poison ivy | native | TORY |
| Apiaceae | *Lomatium foeniculaceum* | biscuitroot, carrot-leaf desert-parsley, desert biscuitroot | native | LOFO |
| | *Musineon tenuifolium* | slender wildparsley | native | MUTE3 |
| Apocynaceae | *Apocynum cannabinum* | prairie dogbane | native | APCA |
| Asclepiadaceae | *Asclepias ovalifolia* | milkweed, oval-leaf milkweed | native | ASOV |
| | *Asclepias pumila* | plains milkweed | native | ASPU |
| | *Asclepias speciosa* | showy milkweed | native | ASSP |
| | *Asclepias viridiflora* | green antelopehorn milkweed, green comet milkweed, green milkweed | native | ASVI |
| Asteraceae | *Achillea millefolium* var. *occidentalis* | western yarrow | native | ACMI2 |
| | *Antennaria neglecta* | field pussytoes | native | ANNE |
| | *Antennaria parvifolia* | little-leaf pussytoes, Rocky Mountain pussytoes, small leaf pussytoes, smallleaf pussytoes | native | ANPA4 |
| | *Artemisia campestris* | wormwood sagewort | native | ARCA12 |
| | *Artemisia dracunculus* | false tarragon, green sagewort, silky wormwood, tarragon, wormwood | native | ARDR4 |
| | *Artemisia frigida* | fringed sagebrush, fringed sagewort, prairie sagewort | native | ARFR4 |
| | *Artemisia ludoviciana* ssp. *ludoviciana* | cudweed sagewort, gray sagewort, Louisiana sagewort, Louisiana wormwood, mugwort wormwood, prairie sage, white sagebrush | native | ARLU |
| | *Brickellia eupatorioides* var. *eupatorioides* | false boneset | native | BREU |
| | *Cirsium arvense* | Californian thistle, Canada thistle, Canadian thistle, creeping thistle, field thistle | non-native | CIAR4 |
| | *Cirsium flodmanii* | Flodman thistle, Flodman's thistle | native | CIFL |
| | *Cirsium undulatum* | gray thistle, wavy-leaf thistle, wavyleaf thistle | native | CIUN |
| | *Cirsium vulgare* | bull thistle, common thistle, spear thistle | non-native | CIVU |
| | *Conyza canadensis* | Canada horseweed, Canadian horseweed, horseweed, horseweed fleabane, mares tail, marestail | native | COCA5 |
| | *Dyssodia papposa* | dogbane dyssodia, dogweed, fetid dogweed, fetid marigold, prairie dogweed | native | DYPA |

## Wind Cave National Park (WICA)

| Family | Scientific Name | Common Name(s) | Origin | Code |
|---|---|---|---|---|
| | *Echinacea angustifolia* | blacksamson, blacksamson echinacea | native | ECAN2 |
| | *Erigeron canus* | hoary fleabane | native | ERCA4 |
| | *Erigeron subtrinervis* | threeveined fleabane | native | ERSU2 |
| | *Eupatorium maculatum* var. *bruneri* | spotted joe-pye-weed | native | EUMA6 |
| | *Gutierrezia sarothrae* | broom snakeweed, broomweed, perennial snakeweed, stinkweed, turpentine weed, yellow top | native | GUSA2 |
| | *Helianthus annuus* | annual sunflower, common sunflower, sunflower, wild sunflower | native | HEAN3 |
| | *Helianthus maximiliani* | Maximilian sunflower | native | HEMA2 |
| | *Helianthus pauciflorus* ssp. *pauciflorus* | stiff sunflower | native | HEPA19 |
| | *Heterotheca villosa* | hairy false goldaster, hairy false goldenaster, hairy goldaster, hairy goldenaster | native | HEVI4 |
| | *Hymenopappus filifolius* var. *polycephalus* | manyhead hymenopappus | native | HYFI |
| | *Lactuca canadensis* | wild lettuce | native | LACA |
| | *Lactuca serriola* | China lettuce, prickly lettuce, wild lettuce | non-native | LASE |
| | *Liatris punctata* | dotted blazing star, dotted gayfeather | native | LIPU |
| | *Lygodesmia juncea* | rush skeletonplant, rush skeletonweed, skeletonplant, skeletonweed | native | LYJU |
| | *Machaeranthera pinnatifida* var. *pinnatifida* | lacy tansyaster | native | MAPI |
| | *Oligoneuron album* | prairie goldenrod | native | OLAL2 |
| | *Oligoneuron rigidum* | stiff goldenrod | native | SORI |
| | *Oligoneuron rigidum* var. *rigidum* | stiff goldenrod | native | OLRI |
| | *Packera cana* | wooly groundsel | native | SECA |
| | *Packera tridenticulata* | threetooth ragwort | native | SETR |
| | *Ratibida columnifera* | prairie coneflower, redspike Mexican hat, upright prairie coneflower | native | RACO3 |
| | *Rudbeckia hirta* | blackeyed Susan | native | RUHI2 |
| | *Senecio integerrimus* var. *integerrimus* | lambstongue groundsel, lambstongue ragwort | native | SEIN2 |
| | *Solidago canadensis* | Canada goldenrod, common goldenrod | native | SOCA6 |
| | *Solidago gigantea* | giant goldenrod | native | SOGI |
| | *Solidago missouriensis* | Missouri goldenrod, prairie goldenrod | native | SOMI2 |
| | *Solidago mollis* | ashy goldenrod, soft goldenrod, velvety goldenrod, woolly goldenrod | native | SOMO |
| | *Solidago nemoralis* | dyersweed goldenrod, gray goldenrod | native | SONE |
| | *Solidago speciosa* | noble goldenrod, showy goldenrod | native | SOSP2 |
| | *Symphyotrichum ericoides* | white heath aster | native | SYER |
| | *Symphyotrichum laeve* | smooth blue aster, geyer's aster | native | SYLA3 |
| | *Symphyotrichum lanceolatum* var. *hesperium* | white panicle aster | native | SYLA6 |
| | *Symphyotrichum oblongifolium* | aromatic aster | native | SYOB |

## Wind Cave National Park (WICA)

| Family | Scientific Name | Common Name(s) | Origin | Code |
|---|---|---|---|---|
| | *Taraxacum officinale* | blowball, common dandelion, dandelion, faceclock | non-native | TAOF |
| | *Tetraneuris acaulis* | stemless hymenoxys, stemless four-nerve daisy | native | TEAC |
| | *Townsendia exscapa* | stemless Townsend daisy, stemless townsend-daisy, stemless townsendia | native | TOEX2 |
| | *Tragopogon dubius* | common salsify, goatsbeard, meadow goat's-beard, salsify, Western goat's beard, western salsify, wild oysterplant, yellow goat's beard, yellow salsify | non-native | TRDU |
| Boraginaceae | *Cryptantha celosioides* | buttecandle, minerscandle | native | CRCE |
| | *Cryptantha fendleri* | sanddune cryptantha | native | CRFE |
| | *Cynoglossum officinale* | common houndstongue, gypsy-flower, gypsyflower, hound's tongue, houndstongue | non-native | CYOF |
| | *Hackelia floribunda* | manyflower stickseed | native | HAFL2 |
| | *Lappula occidentalis* var. *occidentalis* | western stickseed | native | LAOC3 |
| | *Lithospermum incisum* | fringed gromwell, fringed puccoon, narrowleaf gromwell, narrowleaf pucoon, narrowleaf stoneseed | native | LIIN2 |
| | *Mertensia lanceolata* | lanceleaf bluebells, prairie bluebells | native | MELA3 |
| | *Onosmodium molle* | false gromwell, smooth onosmodium, soft-hair marbleseed, softhair marbleseed | native | ONMO |
| Brassicaceae | *Alyssum desertorum* | desert alyssum, desert madwort | non-native | ALDE |
| | *Arabis glabra* | tower rockcress | native | ARGL |
| | *Arabis hirsuta* var. *pycnocarpa* | creamflower rockcress, hairy rockcress | native | ARHI |
| | *Camelina microcarpa* | false flax, littlepod falseflax, littleseed falseflax, small fruited falseflax, smallseed falseflax | non-native | CAMI2 |
| | *Descurainia pinnata* | green tansymustard, pinnate tansymustard, tansymustard, western tansymustard | native | DEPI |
| | *Draba reptans* | Carolina draba, Carolina whitlowgrass, creeping draba | native | DRRE2 |
| | *Erysimum capitatum* | plains wallflower, prairie rocket, sanddune wallflower, western wallflower | native | ERCA14 |
| | *Lepidium densiflorum* | common pepperweed, greenflower pepperweed, miner's pepperwort, miners pepperweed, peppergrass, prairie pepperweed | native | LEDE |
| | *Lesquerella ludoviciana* | foothill bladderpod, Louisiana bladderpod, silver bladderpod | native | LELU |
| | *Sisymbrium altissimum* | Jim Hill mustard, tall tumblemustard, tumble mustard, tumblemustard, tumbleweed mustard | non-native | SIAL2 |
| Cactaceae | *Escobaria missouriensis* var. *missouriensis* | Missouri foxtail cactus | native | ESMI3 |
| | *Escobaria vivipara* var. *vivipara* | pink pincushioncactus, spinystar, spinystar cactus | native | ESVI2 |

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| Family | Scientific Name | Common Name(s) | Origin | Code |
|---|---|---|---|---|
| | *Opuntia fragilis* | brittle cactus, brittle pricklypear, fragile cactus, jumping cactus, little pricklypear | native | OPFR |
| | *Opuntia macrorhiza* | twistspine pricklypear, bigroot pricklypear | native | OPMA2 |
| | *Opuntia polyacantha* | Plains pricklypear | native | OPPO |
| Campanulaceae | *Campanula rotundifolia* | bluebell, bluebell bellflower, roundleaf harebell | native | CARO2 |
| | *Triodanis perfoliata* | clasping bellwort, clasping Venus' looking-glass, common Venus' lookingglass, roundleaved triodanis, Venus lookingglass | native | TRPE4 |
| Capparaceae | *Polanisia dodecandra* ssp. *trachysperma* | western clammyweed | native | PODO3 |
| Caprifoliaceae | *Symphoricarpos occidentalis* | western snowberry, wolfberry | native | SYOC |
| | *Viburnum lentago* | nanny-berry | native | VILE |
| Caryophyllaceae | *Cerastium arvense* | field chickweed, field mouse-ear chickweed, starry chickweed | native | CEAR4 |
| | *Paronychia depressa* | spreading nailwort | native | PADE4 |
| | *Silene antirrhina* | catchfly, sleepy campion, sleepy catchfly, sleepy silene | native | SIAN2 |
| | *Silene latifolia ssp. alba* | bladder campion, bladder-campion, evening lychnis, white campion, white cockle | non-native | SILA21 |
| Chenopodiaceae | *Chenopodium pratericola* | desert goosefoot | native | CHPR5 |
| | *Salsola kali* | tumbleweed | non-native | SAKA |
| Commeliniaceae | *Tradescantia occidentalis* | prairie spiderwort, spiderwort, western spiderwort | native | TROC |
| Convolvulaceae | *Evolvulus nuttallianus* | silver wild morning-glory | native | EVNU |
| Cupressaceae | *Juniperus communis* | common juniper, dwarf juniper | native | JUCO6 |
| | *Juniperus horizontalis* | creeping juniper | native | JUHO2 |
| | *Juniperus scopulorum* | Rocky Mountain juniper | native | JUSC2 |
| Cyperaceae | *Carex backii* | back sedge, Back's sedge | native | CABA3 |
| | *Carex brevior* | brevior sedge, fescue sedge, shortbeak sedge | native | CABR10 |
| | *Carex duriuscula* | needleleaf sedge, spike-rush sedge | native | CADU |
| | *Carex filifolia* | threadleaf sedge | native | CAFI |
| | *Carex hystericina* | porcupine sedge | native | CAHY4 |
| | *Carex inops* ssp. *heliophila* | sun sedge | native | CAIN9 |
| | *Carex praegracilis* | slim sedge | native | CAPR5 |
| | *Carex sprengelii* | long-beak sedge, Sprengel sedge, Sprengel's sedge | native | CASP7 |
| Equisetaceae | *Equisetum hyemale* | western scouringrush | native | EQHY |
| Euphorbiaceae | *Chamaesyce glyptosperma* | ribseed sandmat, ridgeseed spurge | native | CHGL13 |
| | *Chamaesyce serpyllifolia* ssp. *serpyllifolia* | thymleaf spurge | native | CHSE6 |
| | *Euphorbia brachycera* | horned spurge, Rocky Mountain spurge | native | EUBR |

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|---|---|---|---|---|
| | *Euphorbia marginata* | smoke-on-the-prairie, snow-on-the-mountain, variegated spurge, whitemargined spurge | native | EUMA8 |
| | *Euphorbia spathulata* | roughpod spurge, warty spurge | native | EUSP |
| Fabaceae | *Amorpha canescens* | leadplant, leadplant amorpha | native | AMCA6 |
| | *Astragalus agrestis* | cock's-head, field milkvetch, purple milkvetch | native | ASAG2 |
| | *Astragalus crassicarpus* | ground-plum, groundplum milkvetch | native | ASCR2 |
| | *Astragalus gilviflorus* var. *gilviflorus* | Plains milkvetch | native | ASGI5 |
| | *Astragalus gracilis* | slender milkvetch | native | ASGR3 |
| | *Astragalus laxmannii* | Laxmann's milkvetch, prairie milkvetch | native | ASLA27 |
| | *Dalea candida* var. *oligophylla* | white prairieclover | native | DACA7 |
| | *Dalea purpurea* | Purple prairieclover, violet dalea, violet prairie clover, violet prairie-clover | native | DAPU5 |
| | *Lathyrus polymorphus* | manystem peavine | native | LAPO2 |
| | *Medicago lupulina* | black medic, black medic clover, black medick, hop clover, hop medic, nonesuch, yellow trefoil | non-native | MELU |
| | *Melilotus alba* | white sweetclover | non-native | MEAL12 |
| | *Melilotus officinalis* | yellow sweet-clover, yellow sweetclover | non-native | MEOF |
| | *Oxytropis campestris* | field locoweed | native | OXCA4 |
| | *Oxytropis lambertii* | Lambert crazyweed, Lambert locoweed, purple loco, purple locoweed, stemless loco, whitepoint locoweed | native | OXLA3 |
| | *Oxytropis sericea* | locoweed, silky crazyweed, silvery oxytrope, white crazyweed, white locoweed, white pointloco | native | OXSE |
| | *Pediomelum argophyllum* | silverleaf Indian breadroot, silverleaf scurfpea | native | PEAR6 |
| | *Pediomelum esculentum* | breadroot scurfpea, Indian breadroot, large Indian breadroot | native | PEES |
| | *Psoralidium tenuiflorum* | slimflower scurfpea | native | PSTE5 |
| | *Thermopsis rhombifolia* | goldenpea, prairie thermopsis | native | THRH |
| | *Vicia americana* | American deervetch, American vetch | native | VIAM |
| Grossulariaceae | *Ribes aureum* var. *villosum* | golden currant | native | RIAU |
| | *Ribes cereum* | wax currant | native | RICE |
| | *Ribes oxyacanthoides* | Canadian gooseberry | native | RIOX |
| Hydrophyllaceae | *Ellisia nyctelea* | Aunt Lucy, ellisia, false babyblueeyes, waterpod | native | ELNY |
| Iridaceae | *Sisyrinchium montanum* | strict blue-eyed grass | native | SIMO2 |
| Lamiaceae | *Hedeoma drummondii* | Drummond's false pennyroyal, Drummond's pennyroyal | native | HEDR |
| | *Hedeoma hispida* | rough false pennyroyal | native | HEHI |
| | *Leonurus cardiaca* | common motherwort, motherwort | non-native | LECA2 |
| | *Marrubium vulgare* | horehound, white horehound | non-native | MAVU |
| | *Mentha arvensis* | wild mint | non-native | MEAR4 |

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| Family | Scientific Name | Common Name(s) | Origin | Code |
|---|---|---|---|---|
| | *Monarda fistulosa* var. *menthifolia* | mintleaf beebalm, Oswego-tea, wild bergamot, wildbergamot beebalm, wildbergamot horsemint | native | MOFI |
| | *Salvia reflexa* | blue sage, lambsleaf sage, lanceleaf sage, Rocky Mountain sage, sage mint | native | SARE3 |
| Liliaceae | *Allium cernuum* | nodding onion | native | ALCE2 |
| | *Allium textile* | prairie onion, textile onion, wild onion | native | ALTE |
| | *Asparagus officinalis* | asparagus, garden asparagus | non-native | ASOF |
| | *Calochortus nuttallii* | sego-lily | native | CANU3 |
| | *Lilium philadelphicum* | wood lily | native | LIPH |
| | *Maianthemum racemosum* ssp. *racemosum* | false Solomons-seal, feathery false lily of the vally, feathery false Solomons-seal | native | MARA7 |
| | *Maianthemum stellatum* | starry false lily of the valley | native | MAST4 |
| | *Polygonatum biflorum* | Solomon's seal | native | POBI2 |
| | *Zigadenus elegans* | mountain deathcamas | native | ZIEL2 |
| | *Zigadenus venenosus* var. *gramineus* | meadow deathcamas | native | ZIVE |
| Linaceae | *Leucocrinum montanum* | common starlily, star-lily | native | LEMO4 |
| | *Linum lewisii* | blue flax, Lewis blue flax, Lewis flax, prairie flax | native | LILE3 |
| Linaceae | *Linum rigidum* | orange flax, stiff flax, stiffstem flax | native | LIRI |
| Malvaceae | *Sphaeralcea coccinea* | copper mallow, orange globemallow, red falsemallow, scarlet globemallow | native | SPCO |
| Nyctaginaceae | *Mirabilis linearis* | linearleaf four-o'clock, narrowleaf four-o'clock | native | MILI3 |
| Onagraceae | *Calylophus serrulatus* | halfshrub calylophus, halfshrub sundrop, serrateleaf eveningprimrose, yellow sundrops | native | CASE12 |
| | *Gaura coccinea* | scarlet beeblossom, scarlet gaura, Scarlet guara | native | GACO5 |
| | *Oenothera coronopifolia* | crownleaf evening primrose, crownleaf evening-primrose | native | OECO2 |
| Oxalidaceae | *Oxalis stricta* | common yellow oxalis, sheep sorrel, sourgrass, toad sorrel, upright yellow woodsorrel, yellow woodsorrel | native | OXST |
| Papaveraceae | *Argemone polyanthemos* | prickly poppy | native | ARPO2 |
| Pinaceae | *Pinus ponderosa* | ponderosa pine, rock pine, western yellow pine | native | PIPO |
| Plantaginaceae | *Plantago patagonica* | woolly Indianwheat, woolly plantain | native | PLPA2 |
| Poaceae | *Achnatherum hymenoides* | Indian ricegrass | native | ACHY |
| | *Andropogon gerardii* | big bluestem, bluejoint, turkeyfoot | native | ANGE |
| | *Aristida purpurea* | purple three-awn | native | ARPU9 |
| | *Bouteloua curtipendula* | sideoats grama | native | BOCU |
| | *Bouteloua gracilis* | blue grama | native | BOGR2 |

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| Family | Scientific Name | Common Name(s) | Origin | Code |
|---|---|---|---|---|
| | *Bouteloua hirsuta* | hairy grama | native | BOHI2 |
| | *Bromus japonicus* | Japanese brome, Japanese chess | non-native | BRJA |
| | *Bromus tectorum* | cheat grass, cheatgrass, downy brome, early chess, military grass, wild oats | non-native | BRTE |
| | *Buchloe dactyloides* | buffalograss | native | BUDA |
| | *Calamovilfa longifolia* | prairie sandreed | native | CALO |
| | *Danthonia spicata* | poverty danthonia, poverty oatgrass, poverty wild oat grass | native | DASP2 |
| | *Dichanthelium oligosanthes* | Heller's rosette grass, Scribner panic, Scribner's rosette grass, Scribners panicum | native | DIOL |
| | *Dichanthelium wilcoxianum* | fall rosette grass | native | DIWI5 |
| | *Elymus canadensis* | Canada wildrye | native | ELCA4 |
| | *Elymus elymoides* ssp. *brevifolius* | squirreltail | native | ELEL5 |
| | *Elymus trachycaulus* | slender wheatgrass | native | ELTR7 |
| | *Elymus virginicus* | Virginia wild rye | native | ELVI3 |
| | *Festuca ovina* | sheep fescue | non-native | FEOV |
| | *Hesperostipa comata* ssp. *comata* | needleandthread | native | HECO26 |
| | *Hesperostipa spartea* | porcupinegrass | native | HESP11 |
| | *Koeleria macrantha* | junegrass, prairie Junegrass | native | KOMA |
| | *Muhlenbergia cuspidata* | plains muhly | native | MUCU3 |
| | *Muhlenbergia racemosa* | green muhly, marsh muhly | native | MURA |
| | *Nassella viridula* | green needlegrass | native | NAVI4 |
| | *Pascopyrum smithii* | pubescent wheatgrass, western wheatgrass | native | PASM |
| | *Piptatherum micranthum* | little-seed mountain-rice grass, littleseed ricegrass | native | PIMI7 |
| | *Poa compressa* | Canada bluegrass, flat-stem blue grass | native | POCO |
| | *Poa pratensis* | Kentucky bluegrass | non-native | POPR |
| | *Schedonnardus paniculatus* | tumblegrass | native | SCPA |
| | *Schizachne purpurascens* | false melic grass | native | SCPU |
| | *Schizachyrium scoparium* var. *scoparium* | little bluestem | native | SCSC |
| | *Sporobolus cryptandrus* | sand dropseed | native | SPCR |
| | *Sporobolus heterolepis* | prairie dropseed | native | SPHE |
| | *Thinopyrum intermedium* | intermediate wheatgrass | non-native | THIN6 |
| | *Vulpia octoflora* var. *octoflora* | eight-flower six-weeks grass, pullout grass, sixweeks fescue, sixweeks grass | native | VUOC |
| Polemoniaceae | *Collomia linearis* | narrowleaf mountaintrumpet, slenderleaf collomia, tiny trumpet | native | COLI2 |
| | *Phlox alyssifolia* | alyssumleaf phlox, phlox | native | PHAL3 |
| | *Phlox andicola* | prairie phlox | native | PHAN4 |
| | *Phlox hoodii* | Hood's phlox, spiny phlox | native | PHHO |

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|---|---|---|---|---|
| Polygalaceae | *Polygala alba* | white milkwort | native | POAL4 |
| | *Eriogonum flavum* | alpine golden buckwheat, yellow eriogonum | native | ERFL4 |
| | *Eriogonum pauciflorum* | fewflower buckwheat, manybranch eriogonum | native | ERPA9 |
| | *Polygonum aviculare* | prostrate knotweed, yard knotweed | non-native | POAV |
| | *Polygonum convolvulus* | black bindweed, climbing buckwheat, climbing knotweed, cornbind, dullseed cornbind, pink smartweed, wild buckwheat | non-native | POCO10 |
| | *Rumex aquaticus* | western dock | native | RUOC |
| Primulaceae | *Dodecatheon pulchellum* | darkthroat shootingstar, Southern shootingstar | native | DOPU |
| | *Lysimachia ciliata* | fringed yellow-loosestrife | native | LYCI |
| Ranunculaceae | *Anemone cylindrica* | candle anemone, cottonweed | native | ANCY |
| | *Pulsatilla patens* ssp. *multifida* | Pasque flower | native | PUPA5 |
| | *Thalictrum dasycarpum* | purple meadow-rue, purple meadowrue | native | THDA |
| Rosaceae | *Agrimonia striata* | woodland grooveburr | native | AGST |
| | *Amelanchier alnifolia* | juneberry, pacific serviceberry, Saskatoon serviceberry, western serviceberry, western shadbush | native | AMAL2 |
| | *Cercocarpus montanus* | true mountain mahagony | native | CEMO2 |
| | *Potentilla concinna* | red cinquefoil | native | POCO13 |
| | *Potentilla glandulosa* | sticky cinquefoil | native | POGL |
| | *Potentilla hippiana* | horse cinquefoil, woolly cinquefoil | native | POHI6 |
| | *Potentilla pensylvanica* | prairie cinquefoil | native | POPE8 |
| | *Prunus americana* | American plum | native | PRAM |
| | *Prunus pumila* var. *besseyi* | Great Lakes sand cherry, western sandcherry | native | PRPU3 |
| | *Prunus virginiana* var. *melanocarpa* | chokecherry, common chokecherry, Virginia chokecherry | native | PRVI |
| | *Rosa woodsii* | Wood's rose, woods rose, Woods' rose | native | ROWO |
| | *Rubus idaeus ssp. strigosus* | red raspberry | native | RUID |
| Rubiaceae | *Galium aparine* | bedstraw, catchweed bedstraw, cleavers, cleaverwort, goose grass, scarthgrass, sticky-willy, white hedge | native | GAAP2 |
| | *Galium boreale* | northern bedstraw | native | GABO2 |
| Santalaceae | *Comandra umbellata* ssp. *pallida* | bastard toadflax | native | COUM |
| Saxifragaceae | *Heuchera richardsonii* | alumroot, Richardson's alumroot | native | HERI |
| Scrophulariaceae | *Besseya wyomingensis* | Wyoming besseya, Wyoming kittentail | native | BEWY |
| | *Castilleja sessiliflora* | downy paintedcup, Great Plains Indian paintbrush, Indianpaintbrush | native | CASE5 |
| | *Penstemon albidus* | white penstemon | native | PEAL2 |
| | *Penstemon gracilis* | lilac penstemon, slender penstemon | native | PEGR5 |

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|---|---|---|---|---|
| | *Verbascum thapsus* | big taper, common mullein, great mullein, mullein, velvet dock, velvet plant, woolly mullein | non-native | VETH |
| Smilacaceae | *Smilax lasioneura* | Blue Ridge carrionflower | native | SMLA3 |
| Solanaceae | *Physalis heterophylla* | clammy groundcherry | native | PHHE5 |
| | *Physalis longifolia* | common groundcherry, long-leaf ground-cherry, longleaf groundcherry | native | PHLO4 |
| | *Physalis virginiana* | lanceleaf groundcherry, Virginia groundcherry | native | PHVI5 |
| | *Solanum triflorum* | cut-leaf nightshade | native | SOTR |
| Urticaceae | *Parietaria pensylvanica* | Pennsylvania pellitory | native | PAPE5 |
| | *Urtica dioica ssp. gracilis* | tall nettle, stinging nettle | native | URDI |
| Verbenaceae | *Glandularia bipinnatifida* var. *bipinnatifida* | dakota verbena | native | GLBI2 |
| | *Verbena bracteata* | bigbract verbena, bracted vervain, carpet vervain, prostrate verbena, prostrate vervain | native | VEBR |
| | *Verbena hastata* | blue verbena, blue vervain, Simpler's-joy, swamp verbena | native | VEHA2 |
| | *Verbena stricta* | hoary verbena, hoary vervain, tall vervain, wooly verbena | native | VEST |
| Violaceae | *Viola adunca* | blue violet, hook violet, hookedspur violet | native | VIAD |
| | *Viola nuttallii* | Nuttall violet, Nuttall's violet, yellow prairie violet | native | VINU2 |
| | *Viola pedatifida* | crow-foot violet, prairie violet | native | VIPE2 |
| Vitaceae | *Parthenocissus vitacea* | thicket creeper, Virginia creeper, woodbine | native | PAVI5 |
| | *Vitis riparia* | river-bank grape | native | VIRI |