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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

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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.

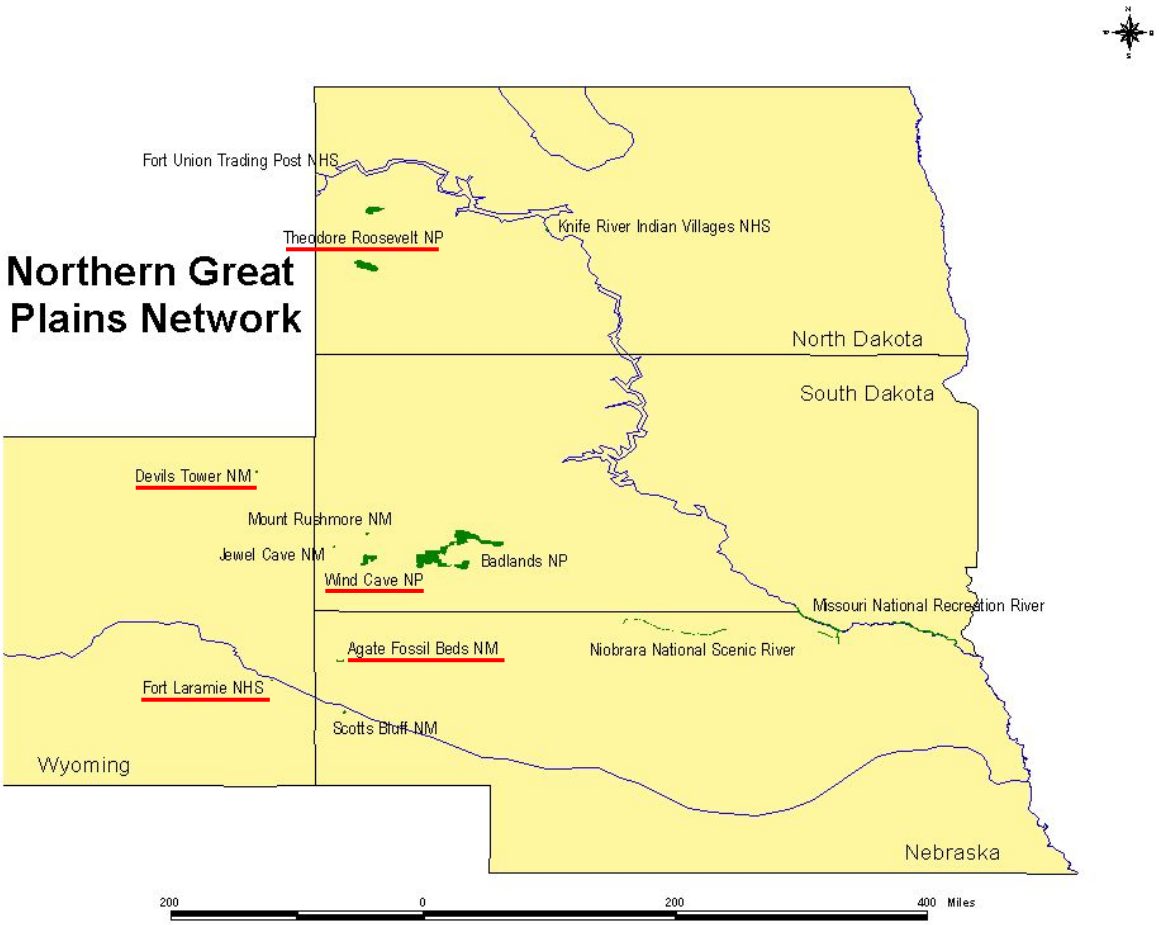

Figure 1. Locations of NPS units in the Northern Great Plains I&M Network. The parks used in this study are underlined in red.

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, α and β, in these calculations to provide a range of subsample size-statistical power possibilities. α 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 β 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

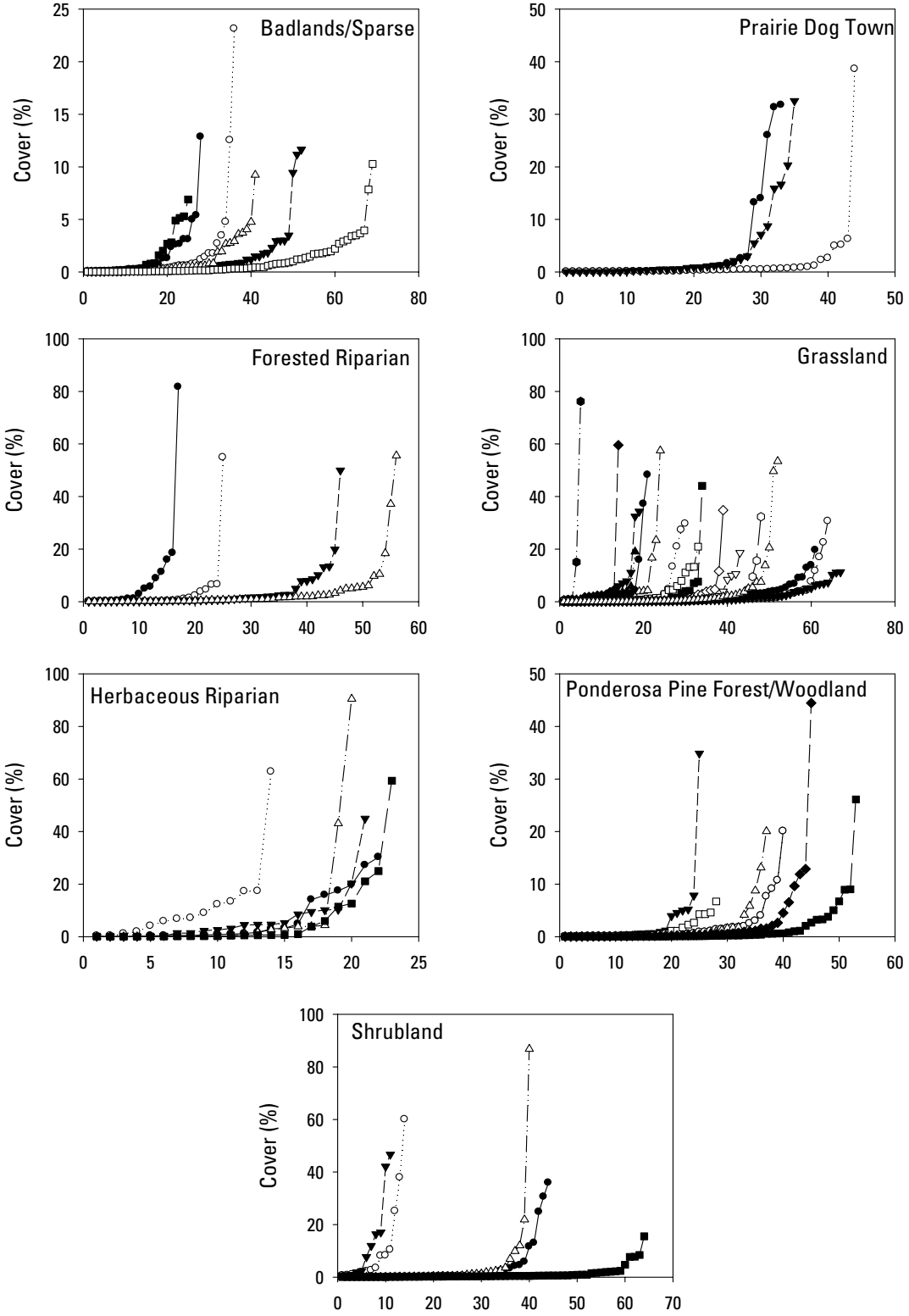

Figure 2. Rank (x-axis)-abundance (y-axis) curves for the 46 plots sampled, by vegetation type. Each line-symbol combination within a graph represents a single plot.

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.

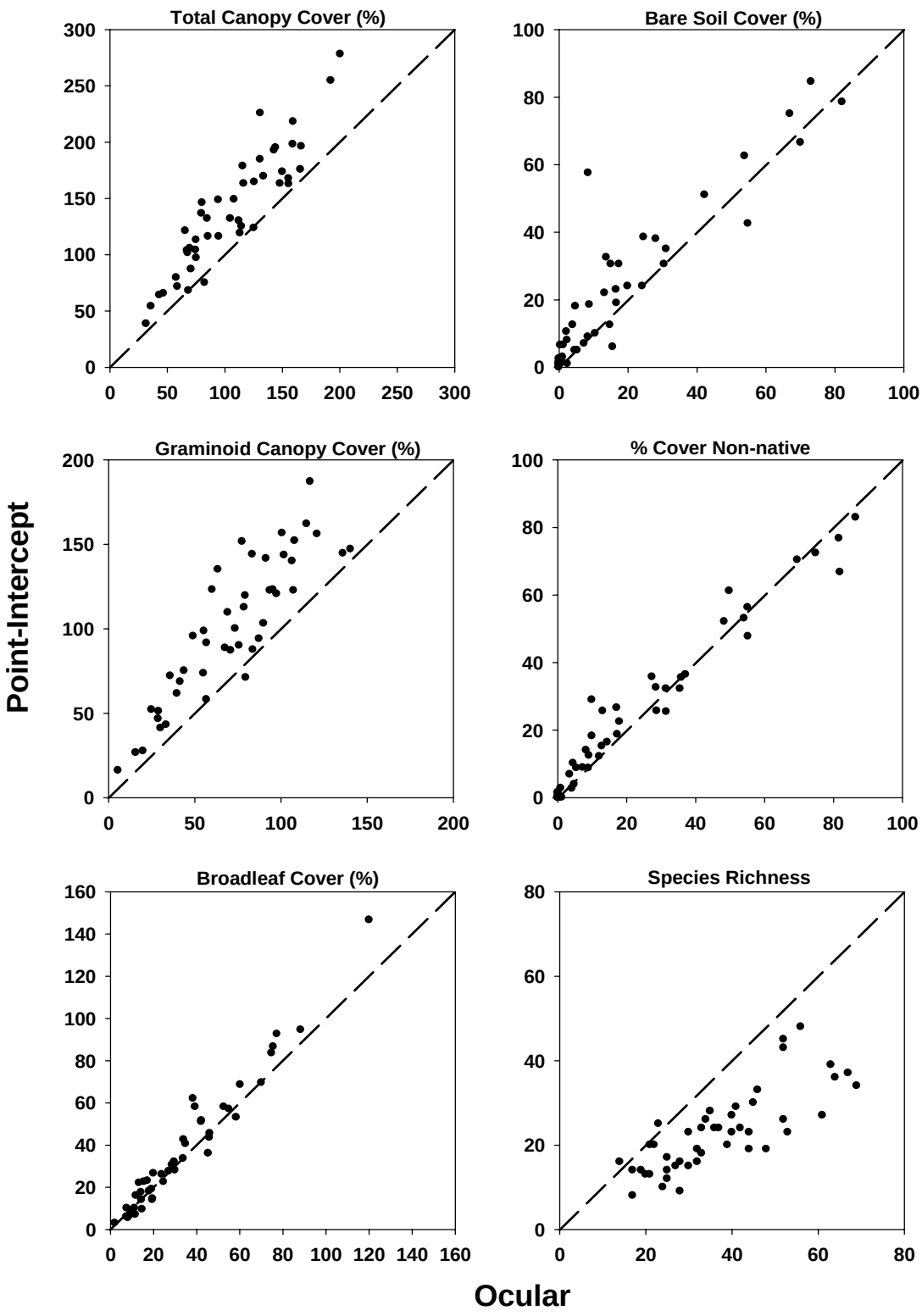

Figure 3. Relationship between community-level response variable values obtained by the two sampling methods. Dashed lines are y=x.

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

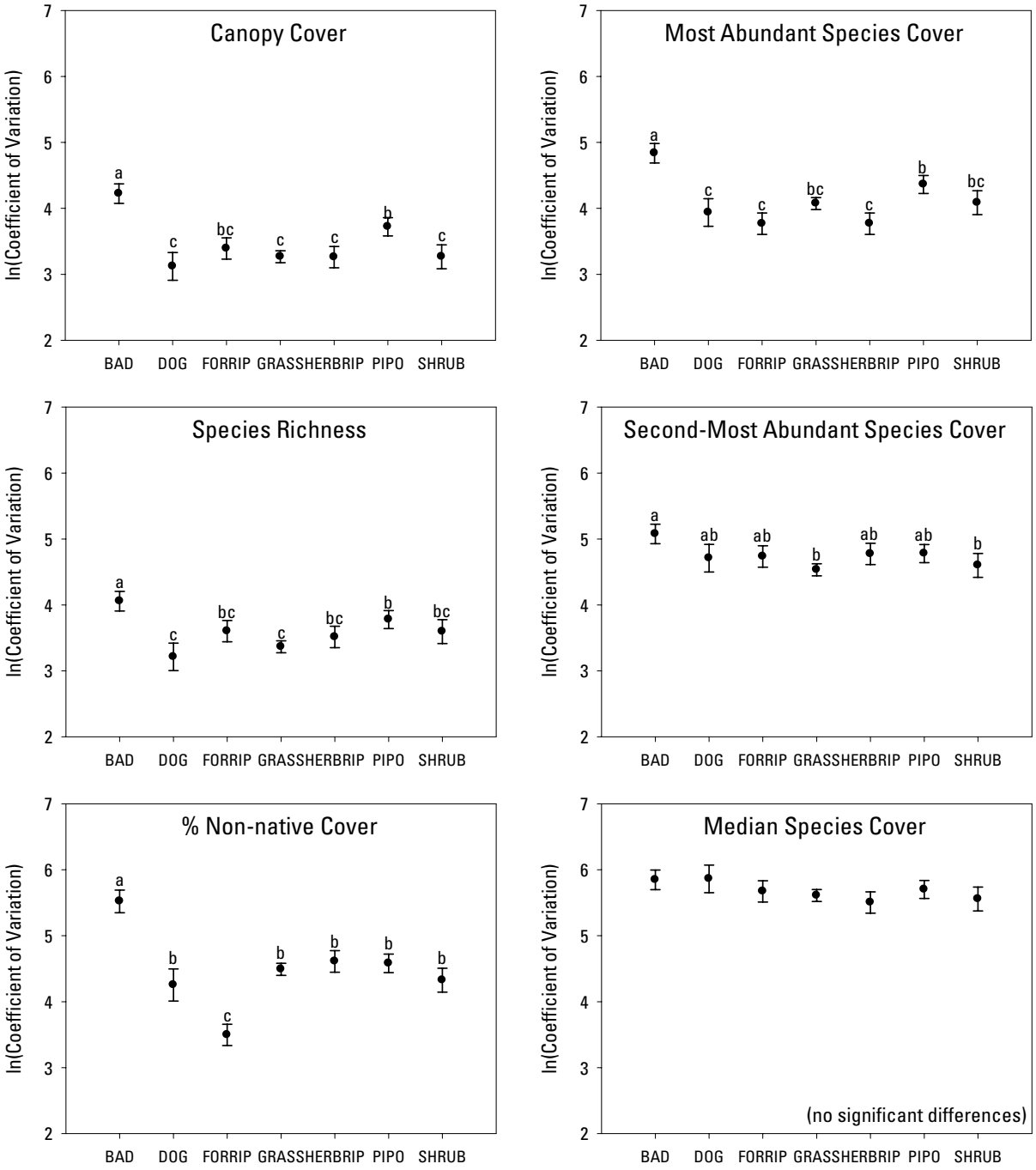

Figure 4. Least squares means and standard errors for log-transformed coefficients of variation among subsamples within plots for six response variables, by vegetation type. Different letters above symbols within a graph indicate significant ($P < 0.05$) differences between vegetation types. Vegetation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

[α and β 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.

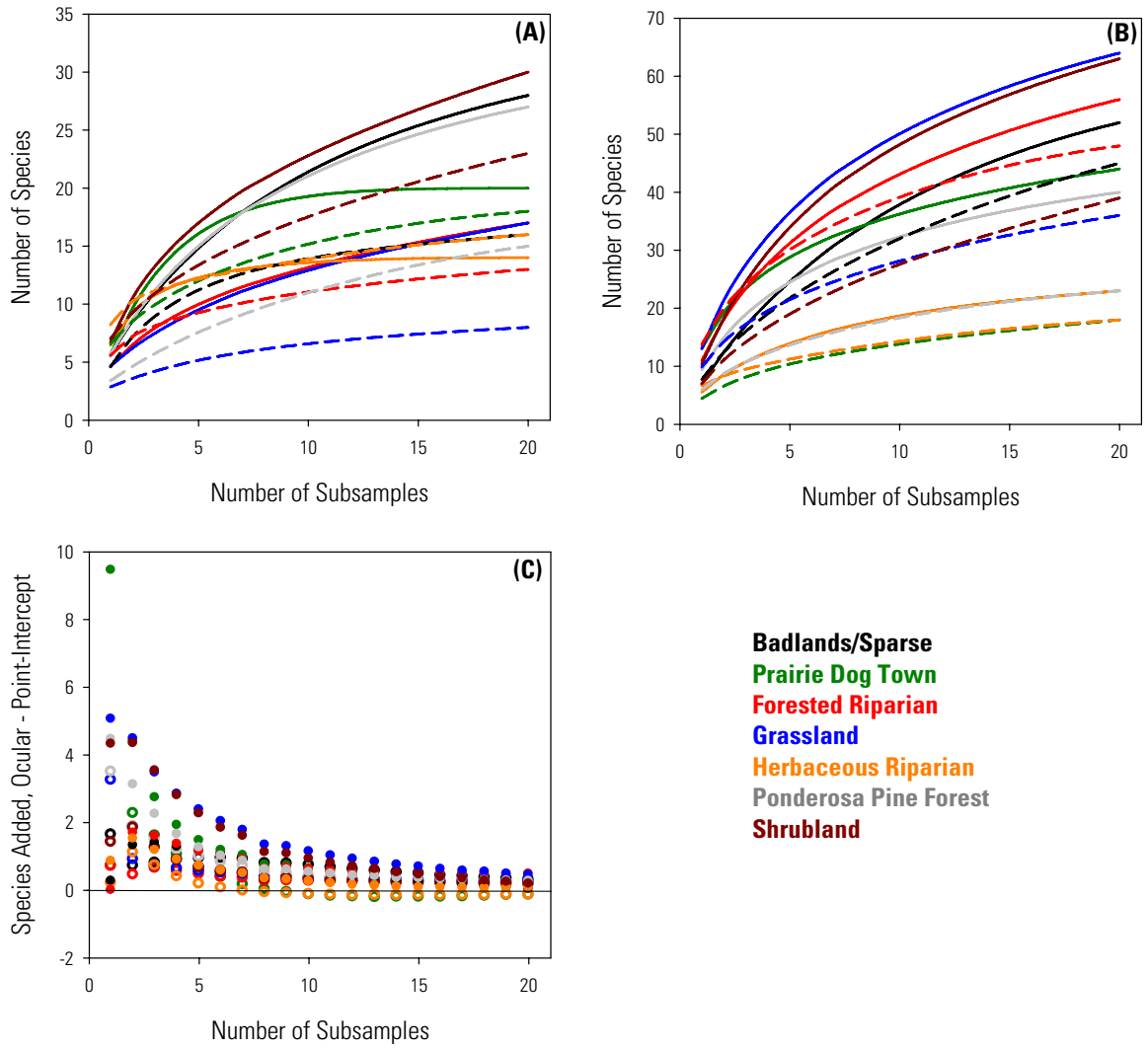

Figure 5. Species-sample number curves for plots with *(A)* the lowest and *(B)* the highest species richness from each vegetation type. Solid lines are for the ocular method, dashed lines for the point-intercept method. *(C)* Difference between ocular and point-intercept methods in the number of species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

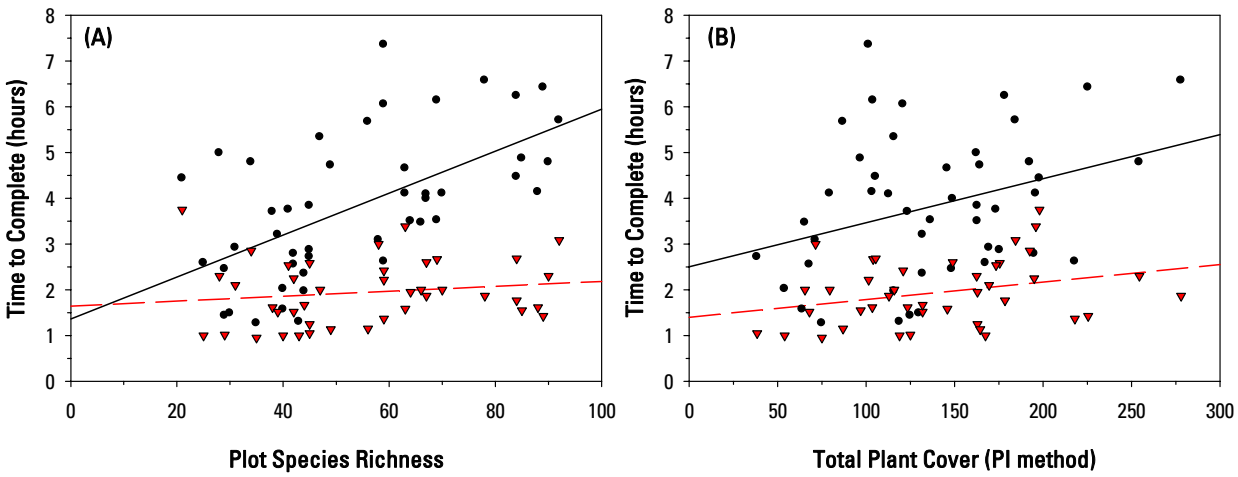

Figure 6. Relationship between time to complete each sampling method (ocular = black circles and solid line; point-intercept = red triangles and dashed line) and *(A)* plot species richness or *(B)* total plant cover as measured by the point-intercept method.

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).

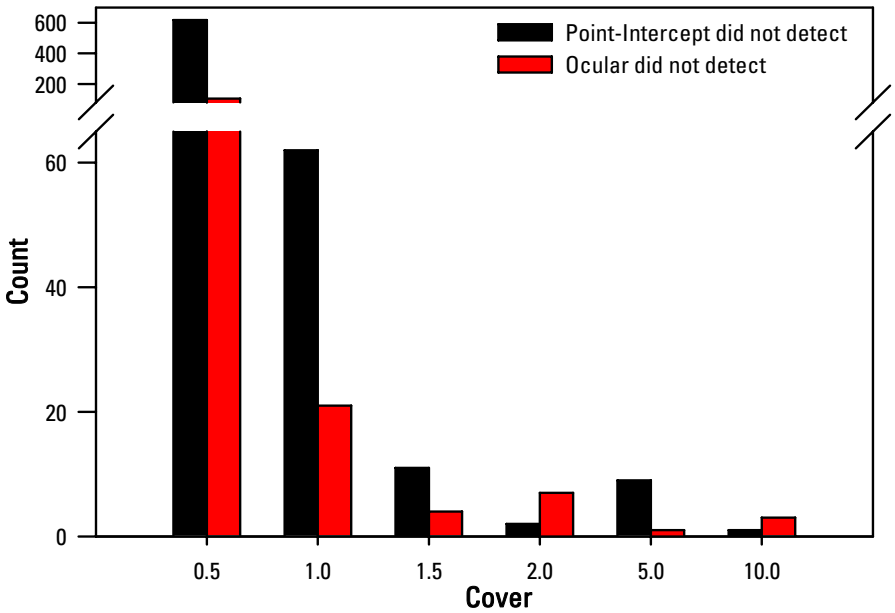

Figure 7. Number of times a method (point-intercept = black bars; ocular = red bars) did not detect a species that the other method did, for all 46 plots.

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	
Vegetation Type	Mean SD	Min SD	Max SD	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
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.

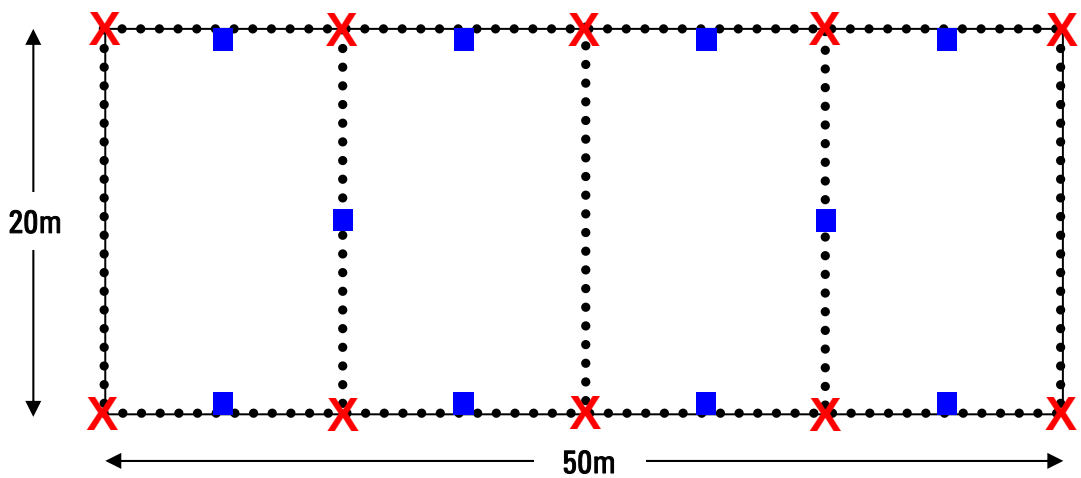

Figure 9. Suggested modification of transect layout for point-intercept sampling. Red "X" indicates permanent marker. Black dots are approximate locations of points, spaced at 1-m intervals. Blue boxes are 1-m^2 species-occurrence subplots.

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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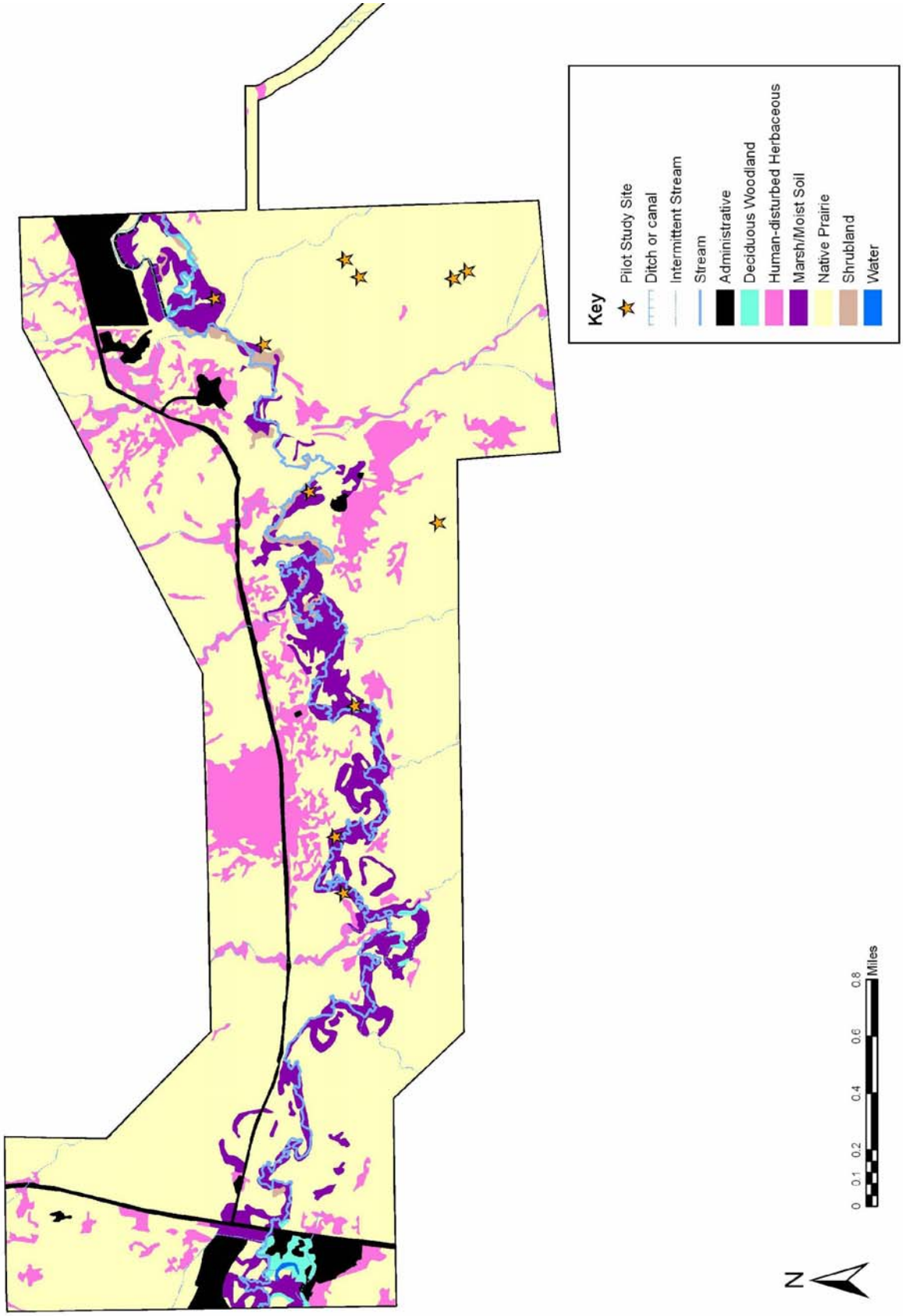
Appendix A

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."

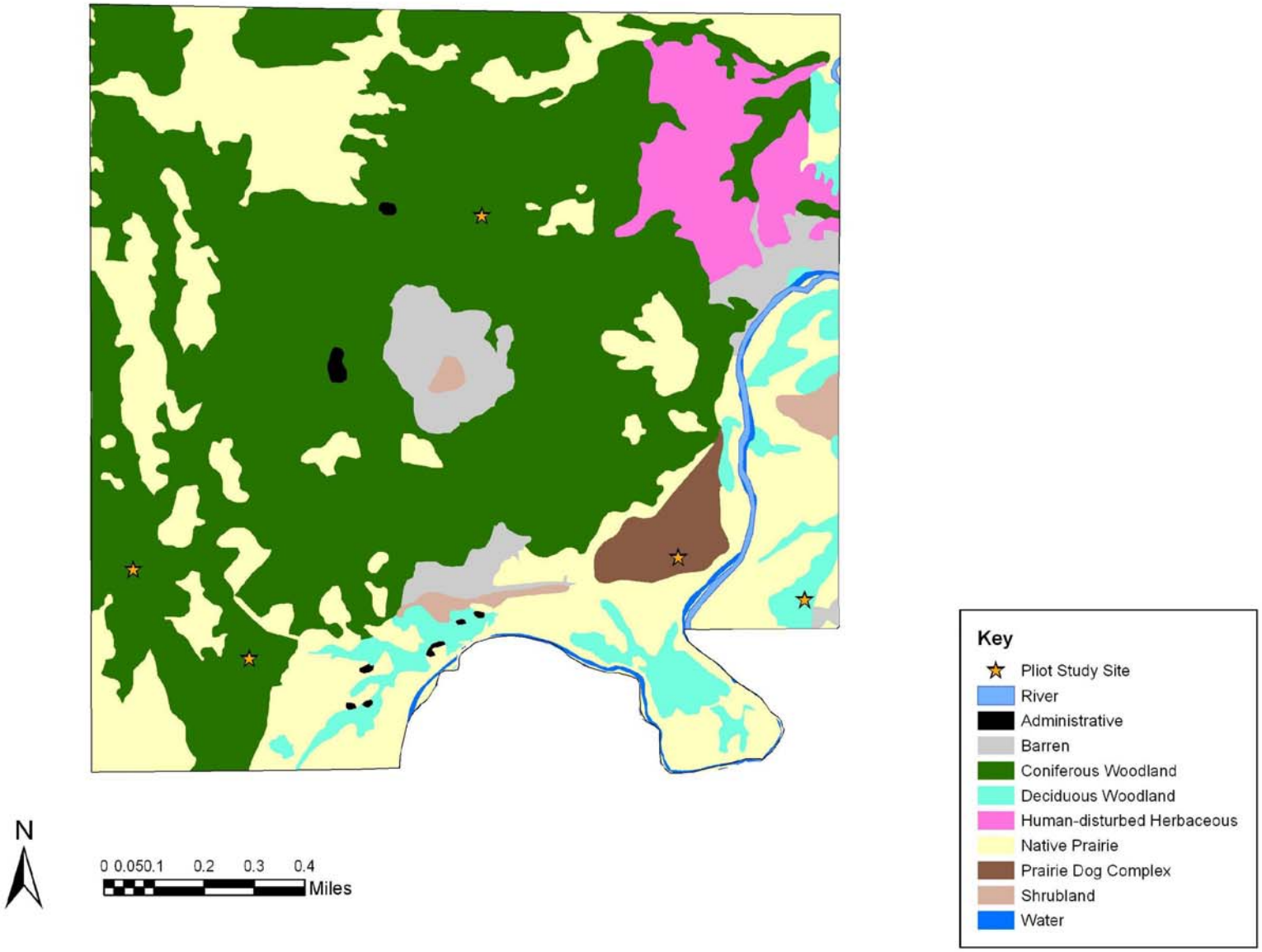
Agate Fossil Beds National Monument (AGFO)

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

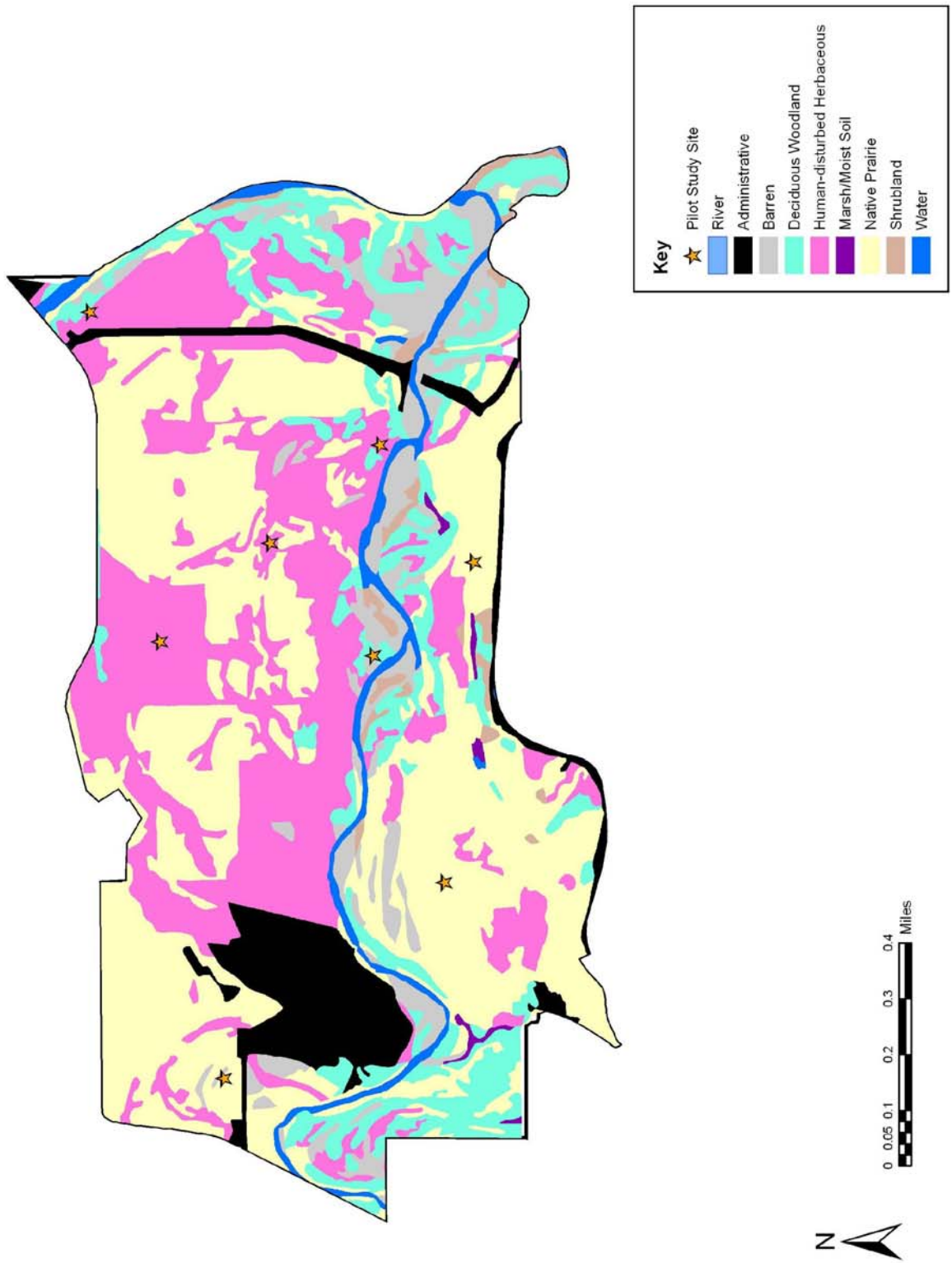
Devils Tower National Monument (DETO)

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

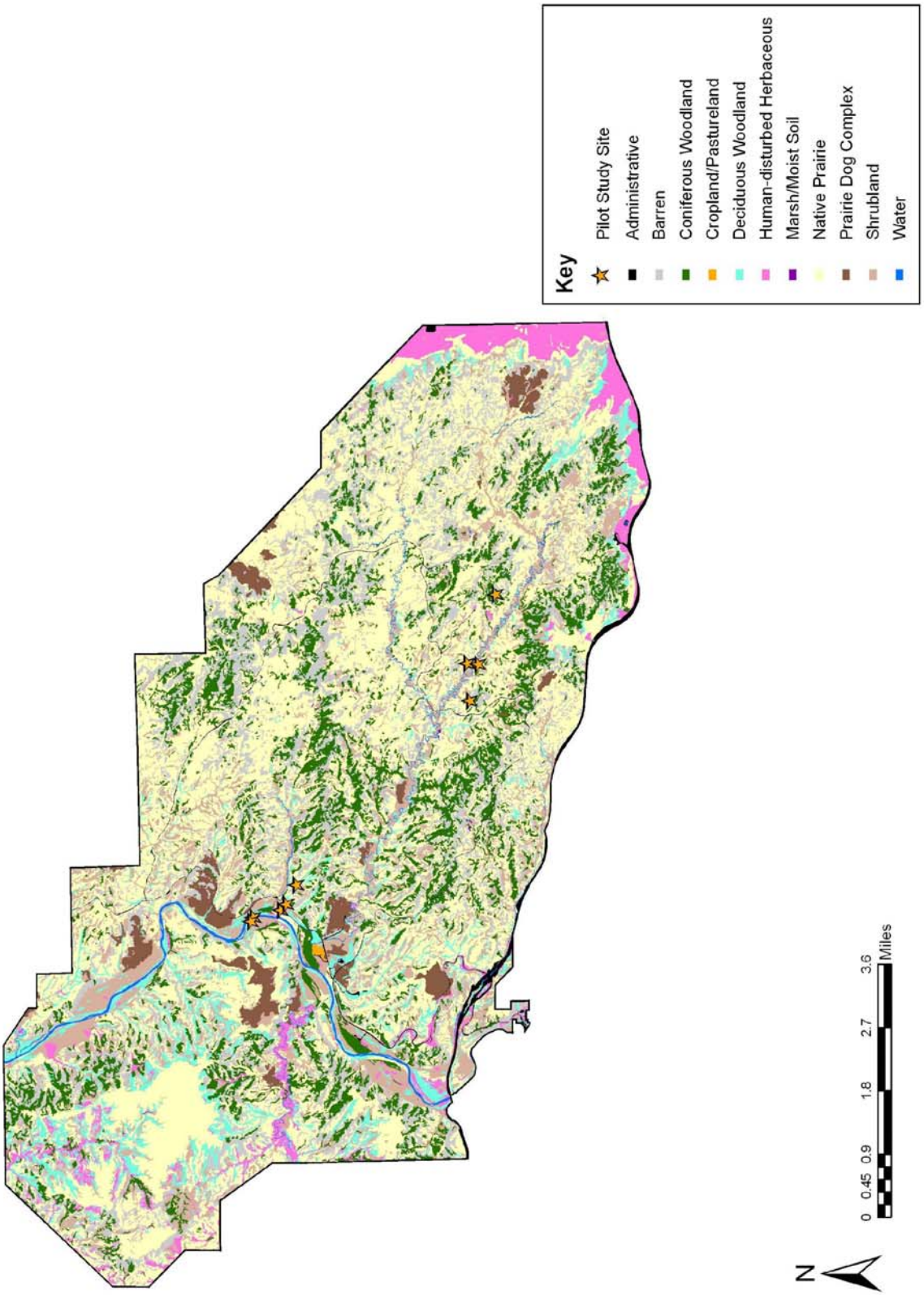
Fort Laramie National Historic Site (FOLA)

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

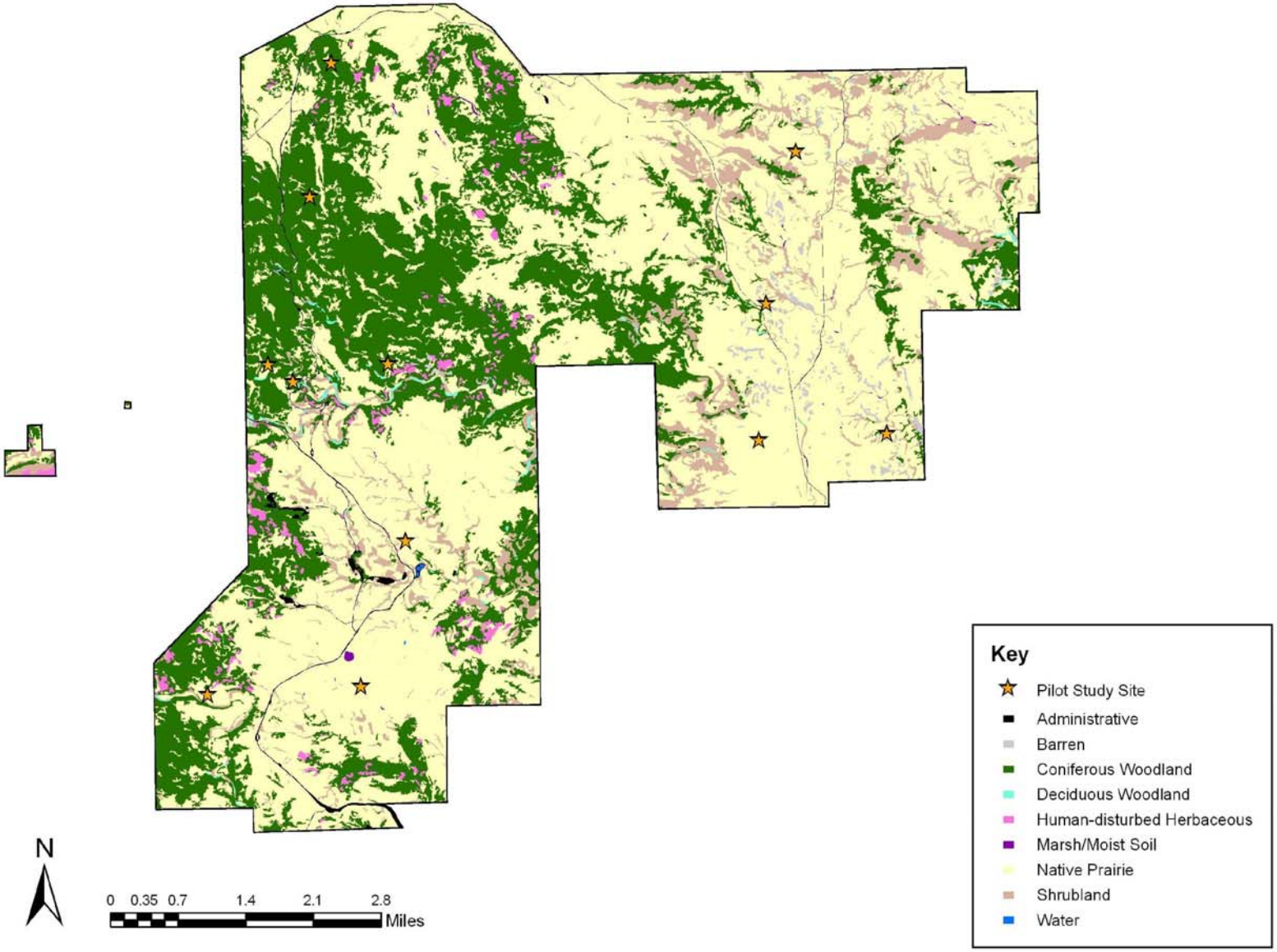
Theodore Roosevelt National Park (THRO)

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
0 0.45 0.9 1.8 2.7 3.6
Miles
N

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


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

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).

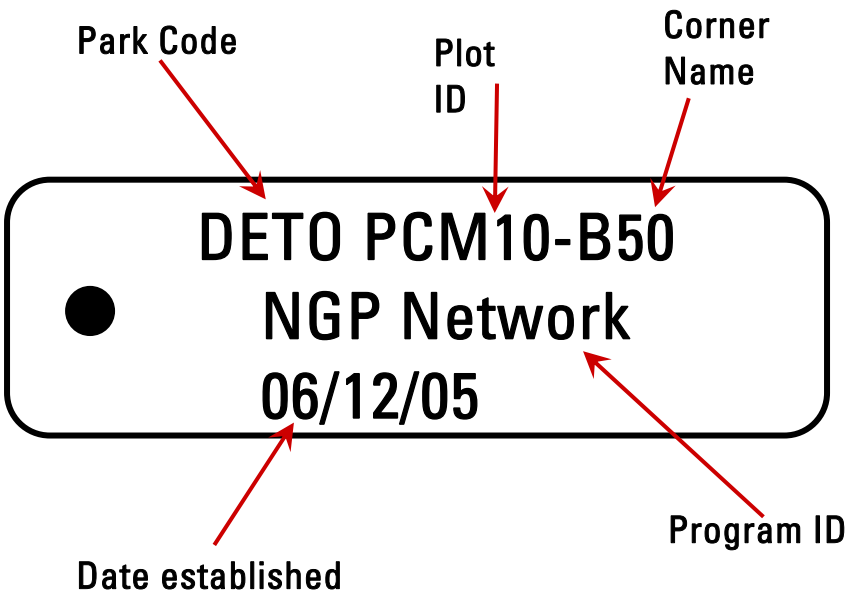


Figure B1.1. Example tag for plot corner markers. Format shown is for tags on the A0 corner; A50, B0, and B50 tags have only the tag (corner) name and establishment date.

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.

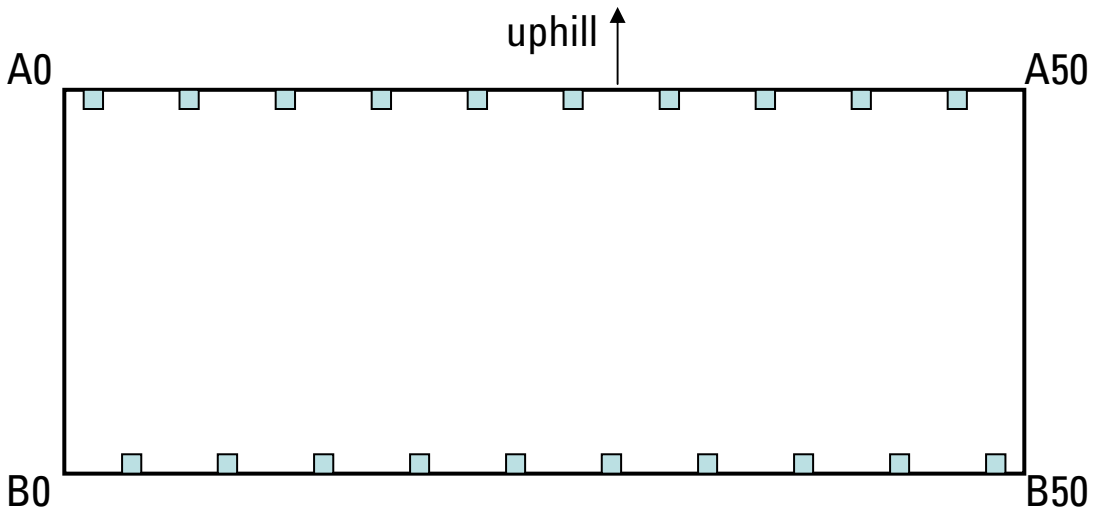


Figure B2.1. 1000 m^2 sampling plot (open rectangle), with rebar labels indicating corners, and 0.5 m^2 cover estimate quadrats.

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.

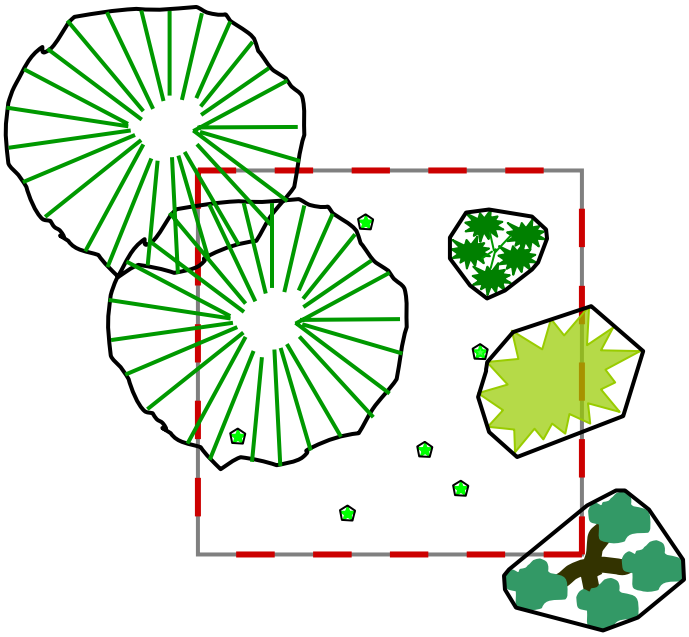


Figure B2.2. Foliage polygons, indicated in black lines, for different types of plants. Despite the different colors, all shapes are intended to be leaves, not flowers. The quadrat frame is indicated in gray, with red dashes each being 10 cm in length. Cover of the species as represented here would be: 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* var. *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

Wind Cave National Park (WICA)

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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	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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	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